Sukkur Barrage Project 1919 Appendices to Report on Proposed Barrage on the Indus at Sukkur Sind

Vol. II

(1920)

Government Document

SUKKUR BARRAGE PROJECT
1919.

VOLUME II.

APPENDICES

TO

REPORT

ON

PROPOSED BARRAGE ON THE INDUS AT SUKKUR, SIND

BOMBAY:
PRINTED AT THE TIMES PRESS
1920.

SUKKUR BARRAGE PROJECT, 1919.

List of Appendices.

APPENDIX A.

Brief History of the Sind Triple Canal Project.

The project for taking a Canal from Rohri to Hyderabad had been twice abandoned, once in 1872, and again in 1892, when in 1904 Dr. Summers brought it forward for the third time.

In December 1904, he asked Government for permission to make a survey for a canal from Rohri, across Khairpur territory, to feed Dad, and after pointing out its immense advantages, said: "The continuous increase of irrigation in the Punjab will eventually force a weir upon us, but the canal now suggested would answer for many years to come, and when a weir becomes necessary it can be made to combine with this canal and one on the Right Bank, etc." Vol. 6, R. C. Project, 1909, pages 180-181.

In October 1905, he obtained permission to extend the survey so as to take in the Central Hyderabad Canals and the lift land of Fuleli. The canal would tail to the Dhoro Puran, below the Jamrao tract. Do. 181-183

Early in 1906, Mr. J. Benton, Inspector-General of Irrigation, visited Sind to enquire into the possibility of perennial canals, and in his note dated the 15th August 1906 suggested what investigations were to be made for a weir and canal with off-take at Rohri. Do. 200-201.

The Government of India, in forwarding this note (in the letter No. 1735, dated the 11th November 1906), suggested to the Bombay Government that the increasing cold weather withdrawals in the Punjab, would very likely diminish the supplies entering the inundation canals in Sind, pointed out the unsatisfactory condition of Sind, as regards low percentage of irrigation to culturable area, and high proportion of lift to flow; and its favourable condition as regards proximity to the seaport of Karachi, and suggested that the eventual requirements of Sind would probably be met by canals taking off from weirs constructed at—. Do. 192-199.

1. Mithan Kote.
2. Sukkur or Sehwan.
3. Kotri or Jherruk.

For the present, however, the second system only need be considered.

In the meantime Dr. Summers had already sent up his rough proposals for the Rohri Canal as under:—

Culturable area commanded			2,500,000 acres.
Annual irrigation 55 per cent. of above:—			
Viz., Kharif	825,000		
Rabi	550,000		
		1,375,000	

Gathered from Mr. Hill's note with proposals, pages 187 to 190 of Vol. 6.

Proposed rate of assessment per acre ..	Rs. 3·33	
Duties, Kharif	68 ..	
„ Rabi	110 ..	
Kharif discharge	12,134 cusecs.	
Bed level at R. L. 172.		F. S. L. at 186.
Bed width, 200 feet.		Bed slope 1 in 10,000.
Cost, 386 lakhs.		Return 6·14 per cent.

File 88 A (1906).

For the head of the canal he made alternative proposals :—(1) between the railway bridge and Sateanjo Than (just below railway) and (2) at the same site as the Nara mouth; and recommended the former because it avoids crossing the railway and the other difficulties presented by hills and the Rohri town. He submitted an estimate of Rs. 1,76,889 for making a detailed survey and drawing up detailed plans and estimates. In forwarding his proposals he said that the Rohri Canal can be made without a weir, and the extra cost of excavating the canal 10 feet deeper than would be necessary with one, would be paid off in a very few years by the interest saved by postponing the weir; and the risk of financial failure is avoided.

The Chief Engineer for Irrigation (Mr. A. Hill) commenting on the proposal states :—

Vol. 6, page 188, para. 3. 1. That the assessment rate would probably be higher than Rs. 5·5 which is the Punjab rate, as Sind is more favourably situated.

Do. 4. 2. More than 55 per cent. of culturable area may be irrigated as abundant water is available. This percentage has been reached and exceeded in some places in Sind.

Do. 6. 3. With a weir, canal can be made to run full in Rabi, the proportion of Kharif to Rabi should be inversely as their duties, *viz.*, 854,000, and 580,000 respectively, and a canal with 8,000 cusecs discharge would suffice.

Do. para 10. 4. The Satean Head is unsuitable because (*a*) the river here has a velocity of 15 feet per second; the water on entering the canal would have its velocity checked to 3½ feet, and the upper reaches of the canal would rapidly silt up. (*b*) It would not have the benefit of the weir. (*c*) With a head at Nara Mouth, whatever measures would be adopted for keeping the mouth clear, would be common to both.

5. The bed level is too low. In Kharif water is high enough and such a low bed is not wanted, for Rabi a weir will be wanted and the low-level canal will then be a nuisance. The low bed would be from 10 to 7 feet below the subsoil water level in the first 11 miles and would add to the cost and difficulty of excavation. A suitable bed level for the Right Bank Canal is 180, and that of the Nara is 177. The bed level for the Rohri Canal should, therefore, be between 177 and 180. (Vol. 6, page 190, para. 11.)

Do. para. 11. 6. The Rohri Canal is part of the larger scheme comprising a weir with Right Bank and Sukkur Canal on one side, and the Eastern Nara and Rohri Canal on the other, and should be designed accordingly.

Do. para. 12. 7. The saving of a few years interest of cost of weir would be small compared with the loss of revenue occasioned by putting back the full development of Sind.

8. Head of canal must not be liable to be blocked by silt and for this reason the weir is necessary.

9. Without a weir there would be no confidence in the constancy of supply and without confidence irrigation will not develop.

The Bombay Government when submitting the above proposals to the Government of India (letter No. W.I.-2635 of 24th October 1906) also submitted a rough plan and estimate for Sukkur weir amounting to about 150 lakhs prepared by Mr. Sprott, Superintending Engineer and Secretary, Indus River Commission, and included an estimate of Rs. 17,667 for further surveys and investigation for weir. Vol. 6, pages 184-187.

In January 1907, Mr. Benton again visited Sind and has done annually ever since. In his note dated the 29th January 1907 he states that :— Do. pages 202-206.

1. In order to exhibit proposals in their true financial aspects, the triple scheme and weir should be considered as a whole to command about 7,988,000 acres of culturable land. Do. pages 202-2015, paras. 3 & 4.

2. A large part of the area under Eastern Nara is not served by any canal, and a weir and extra supply is required to extend irrigation. Do. page 203, para. 5.

3. On the Right Bank the contour map shows that the existing canals are all about at right angles to the direction they should occupy and money should not be expended in improving them, and that there is enormous waste in the excessive number of long parallel water courses. The system has, however, to be served from the Sukkur weir. Do. para. 8.

4. The average cold weather supply at Sukkur is about 39,000 cusecs. The Punjab is already withdrawing 15,000 cusecs in cold weather, and the future requirements for the North-Western Frontier, Punjab, Sind and Baluchistan is 48,000 cusecs. Deficiency is 48,000—39,000—9,000 cusecs. Probably in the Right Bank Canal, and below Kotri, the tracts being rice lands, Rabi will not develop, and a reduction of 4,000 cusecs may be possible. The remaining deficiency about 5,000 cusecs may possibly be made good by seepage and percolation from the Punjab. Vol. 6, page 204, paras. 17 to 25.

5. These figures show (1) that Rabi must be limited to the minimum, *i.e.*, Kharif to Rabi as 1 to 1 ; (2) that the river then just suffices to meet requirements; and (3) that the river will be nearly dry below Sukkur, which is an answerable argument against constructing an inundation canal. Do. para. 25.

6. In the absence of accurate figures, the culturable area to be 80 per cent. of gross area. Annual irrigation to be 60 per cent. of culturable (Kharif 30 and Rabi 30) 48 per cent. of the gross area. Duty at the head of distributaries in North of India has been found to be 100 for Kharif and 200 for Rabi. In Sind, the rain fall being negligible, it may be assumed as 85 and 170, respectively, etc. Do. paras. 57-59.

The Bombay Government in Government Resolution No. W.I.-472 of 19th February 1907, ordered the preparation of plans and estimates for the three projects, the Right Bank Canal by the Superintending Engineer, Indus Right Bank, the weir and Rohri Canal by Dr. Summers, and the Eastern Nara by the Superintending Engineer, Indus Left Bank Dr. Summers had been made Superintending Engineer on special duty for this purpose in Government Resolution No. E. 63, dated the 11th January 1907. Vol. 6, page 209, para. 2 of G. R.

In December 1907, Mr. Benton issued two other inspection notes (not available) on which the Bombay Government note with satisfaction that he has modified his views about it being waste of money to improve the existing canals on the Right Vol. 6, page 209, para. 3 of G. R.

Bank. He now states that perhaps more of these canals could be turned to useful account, and that canals which have yielded good results in the past, should not be hastily abandoned.

Vol. 6, page 220.

Do. 221.

In September 1908, Dr. Summers addressed the Joint Secretary to Government, recommending that the culturable area should be taken at 75 per cent. of the gross area, as from figures given by the Colonization officer, this percentage is obtained, for Dad and Nasrat the percentage comes to 69·7 per cent. Mr. Hill replied that the percentage of the culturable to gross area does not matter, provided the area irrigated is taken at 50 per cent. of gross area. There is no such thing as unculturable land when water is available, even bare sheet rock being cultivated by earth being carted on to them, and he would support Summers even if 60 per cent. is taken.

Do. pages 210-15, para. 15.

Do. page 210, para. 2.

Mr. Benton's note of 17th December 1908, among other matters, remarks that in order to have full advantage of the barrage the Nara should be widened to 220 feet with Kharif F. S. L. at 191·42, the same level as that for the Rohri and Right Bank Canals. Mr. Hill in commenting on this, states that, as the Nara is capable of discharging all the supply required, there is no need for the extra expense and widening is not proposed.

Vol. 6, page 229.

Government Resolution No. W.I.-446, dated the 19th February 1909, required that Revenue Officers should estimate from data supplied by the Engineers :—

I. The extent of the commanded area which would be culturable.

II. Portions which would be likely to become "Kalar".

III. Percentage of culturable area that would be cultivated in Kharif and Rabi.

IV. The rate that could be assessed.

V. Population required for full development of cultivation.

VI. If population insufficient, the extent and rate of colonization possible.

Vol. 6, pages 230 to 238.

Do. 240-242.

Dr. Summers in supplying the data to the Collector of Hyderabad, guaranteed water for 705,000 acres Kharif and 470,000 Rabi, without a barrage in the first instance, *viz.*, 30 and 20 per cent. of the culturable area, and suggested that the assessment rates be 3·5 for the first five years and then increased to Rs. 4. The Collector of Hyderabad, Mr. Pratt, after taking actual facts into consideration was of opinion that all the culturable land would be taken up and the cultivation reach the figures given by Dr. Summers within a short period, say three or four years, and that the average initial rate of Rs. 4 may be expected, and even a higher one later on. He, however, lays great stress on having an assured Rabi supply.

Do. 238-239.

Do. page 246

In Government Resolution No. W.I.-1539 and 1559, dated 19th and 22nd June 1909, Government states that the assumption that the Rohri Canal will give assured Rabi supply without barrage is not accepted, and is probably erroneous. The action of the Superintending Engineer in asking for revenue estimates without barrage is opposed to Government instructions, as it does not afford information for estimating the value of the three canals as a whole. The return from this canal must take account of its share of its cost of barrage. On this Mr. Gebbie, then in charge of the Rohri Project, again referred the matter to the Collector stating that with barrage, the Rabi area would be equal to the Kharif, *viz.*, 705,000 acres and enquiring in how many years this cultivation would be reached, also whether the initial rate could not be raised to a higher figure than that given by Mr. Pratt. Mr Sale, then Collector, replied that the increased area of Rabi would be cultivated within 8 years of opening of canal, but he cannot agree to increase the assessment rate to over Rs. 4 anticipated by Mr. Pratt, who was somewhat sanguine in giving that figure as the initial rate.

Dr. Summers in April 1909, also suggested that, as most of the unoccupied land would have its value greatly increased by the opening of the canal, a part of it should be sold as it would be of great assistance to the Project. Government Resolution No. W.I.-1516 of 17th June 1909 circulated this letter of Dr. Summers for report on the best way for obtaining credit to the works from this increased value. Mr. Sale, Collector of Hyderabad, on 5th November 1909, reported that the present value of unoccupied land ranged from nothing to Rs. 5. An assured supply to these would raise the value to Rs. 9. The only way to obtain credit to works is to postpone its outright sale till the works are ready, provided the project is sanctioned in the immediate future. Vol. 6, pages 227 to 228.

Dr. Summers in October 1909, replying to Government Resolutions Nos. 153 and 1559 regretted that Government consider him to have acted in opposition to instructions and in giving reasons for Rohri Canal without barrage, showed that the culturable area is not more than 75 per-cent. of gross area. Even with the high assessment rate of Rs. 4, the scheme with barrage is not productive. Judging from Bukkur gauge levels, the Rohri Canal without barrage can be made with a sure supply. He had always intended to submit the project according to Government instructions, but thinks that an alternative project for making canal should first be considered. If the first section of canal up to Dad is found unsatisfactory, the barrage could be completed before the Canal was ready. Do. pages 247-8.

Mr. Hill in No. D.-428, dated the 1st November 1909, replied that the alternative proposals may be prepared and submitted, provided the general project is in no way delayed. Do. page 249.

Early in January 1910, Dr. Summers submitted the project according to Government instructions. (This is the Rohri Canal Project, 1909). The Right Bank Canal and the Eastern Nara projects were also submitted about the same time. The results of these are as under :—

Particulars.	Vol. 6. Rohri Canal.	Vol. 8. Right Bank Canal.	Vol. 7. Eastern Nara.
Gross area commanded ..	3,086,793 page 16.	2,009,868 page 8.	1,114,763 page 2.
Culturable area	....	....	891,811 page 2.
Percentage of irrigation—			
Kharif .. .. Rabi	25 25 } of gross area. page 18, para. 30.	30 30 } of gross area. page 6.	30 30 } of culturable area page 2.
Annual irrigation	1,543,396 } page 22.	1,205,920	535,086
Duties { Kharif	85	page 8, 70 mix.	60 mixed.
Duties { Rabi	170	page 10, 150 ,,	170
Assessment rate	page73 4·0	page 30, 4·72	4·0 page 2.
Working expenses	page 72. 1	page 227 1·125	1·00 page 2.
Net increased revenue ..	27,74,833 page 64.	21,25,196	10,77,259 page 2.
Cost of project direct and indirect.	47,776,411 page 67.	46,757,882 page 106.	14,536,813 page 2.
Return of project on direct and indirect	5·80 page 64.	4·55 page 106.	7·40 page 2.

In the above cost of projects the share of barrage is not included, though the amount of Rabi cultivation is dependent on the barrage. Dr. Summers in forwarding the project, shows that the complete triple project (including the cost of barrage which he takes at 324 lakhs) prepared on data not considered safe by local officers, gives a return of 4·25 per cent. exclusive of interest on outlay during construction. This shows that the triple project is unremunerative and he is convinced that it can be made remunerative by constructing Rohri Canal first. The barrage, which is necessary for the Right Bank Canal and the Eastern Nara can be made later, and about 15 to 20 lakhs per annum could be saved in interest and maintenance of barrage.

Vol. 6 page XIV. Do. page III. Do. IV.

As there is a four feet fall at the 30th mile, the bed can be lowered as far as this, to make the Rabi supply in the canal independent of the river level. The extra cost of lowering it by a 2½ feet would be 20 lakhs and by 4 feet, 35 lakhs, the former only about a year's interest and upkeep of barrage. The return would be 4·90 and 4·76, respectively. Without lowering the bed, the canal would get a sufficient supply for the first 2 sections; and even for the whole canal while Rabi is developing, say for 15 years from commencement of work, for which period the barrage could be postponed.

Vol. 6 page V and XIV. Do. page VI.

In his report Dr. Summers also states that he has no fear of the Rabi supply in the river failing, it being kept up from the great underground reservoir, tens of thousands of square miles in area. This immense reservoir is yearly replenished by snow and rain, and its level must rise with increase of irrigation in the Punjab.

Do. page 19.

In the case of Right Bank Canal, Mr. Karpur's financial statements show that 10 years after completion the total interest charges exceed the total net revenue by 65 lakhs, and that the work is therefore unproductive.

Vol. 3, pages 1 & 3.

On receipt of these projects, the Chief Engineer for Irrigation on 12th February 1910, addressed all the Collectors in Sind, sending them statements of probable cultivation and revenue expected and asking their opinion for incorporation with the projects. In these statements, the total cultivation is taken half the gross area. The assessment rate is rice Rs. 5, cotton Rs. 4, other Kharif Rs. 3, Rabi Rs. 4. The duties are: Rice 50, other Kharif 80, Rabi 100.

The programme of the work will be :—

1st year	Barrage and Eastern Nara improvements to begin simultaneously.
6th year	Barrage completed. Supply channel and Khairpur canals begin.
7th year	Rohri Canal and Shahdadpur and Ratodero Branches of the Right Bank Canal begin.
14th year	Eastern Nara and Shahdadpur and Ratodero Branches completed.
19th year	Rohri Canal completed.
21st year	Remaining portion of Right Bank Canal begins.
36th year	Right Bank Canal completed.

Vo. 3, page 17. Page 18. Do. 20.

The total cost of scheme in lakhs of rupees is :—

Barrage	181
Eastern Nara	130
Rohri Canal	462
Shadadpur Ratodero Branches	100
Right Bank Canal remaining portion ..	361
Total ..	1,234

The Eastern Nara having an extensive system of canals would show increase of cultivation if barrage alone is constructed. Cultivation on Sukkur Canal would also increase. Barrage and Eastern Nara should therefore be started first. The southern part of the Right Bank Canal is well supplied at present. The cost of this Right Bank Canal Project is greater than any other, and the supply required is still under contention. It should therefore not be undertaken until the last. Vol. 3, page 9.

The Collectors sent their replies two to three months later and gave their own figures of cultivation and rates of assessment which differed more or less from those of the Chief Engineer. Vol. 3.

Mr. Benton during his visit in 1910 confined himself mainly to the technical part of the design of headworks, and to the programme of work (*vide* his note dated the 5th March 1910). As an alternative to Mr. Hill's programme, he suggested that the proposal to start with the barrage and Rohri Canal should also be considered, and financial statements for this should be prepared for comparison with those prepared by the Chief Engineer in his letter to the Collectors. His reasons were :— Vol. 12, Appendix I to XI. Do. para. 15.

I. The Eastern Nara tract has a high spring level, a sparse population, is unhealthy, and in many parts does not admit of intense irrigation. The reverse is the case with the Rohri Canal tract.

II. The Khairpur State will find a programme which gives priority to its canals more acceptable, especially as increased supplies into the Nara will lower the river level opposite their mouths.

III. It is more desirable to advance the irrigation of cotton in a dry, healthy, well populated tract than in one which is just the reverse.

IV. Stone for barrage can be obtained from the excavation of the supply channel.

V. Constructional, financial and administrative reasons appear to favour this programme.

VI. Additional revenue from Eastern Nara can be obtained from barrage alone without expenditure on its canals. Vol. 12, Appendix para. 16.

Dr. Summer's proposal of deferring the barrage should also receive sympathetic consideration. The saving of interest and maintenance charges on barrage (54 lakhs in 6 years) is certainly an advantage, but there must be assurances that the canal will work successfully, otherwise an inefficient canal will be left on our hands during the 6 or 8 years which will be required for the construction of the weir. Constructional, financial and administrative reasons favour this programme, and the questions to be considered are :— Do. paras. 17 to 20.

I. Will the level in the river give the requisite supply without barrage during Kharif and Rabi ? In considering this the river level should be taken 1·5 above that required in order to force water over probable small deposits of silt in the supply channels. From gauge readings in the past it can be seen whether the river level will meet requirements for the first, second and third sections. If the Do. paras. 43 & 44.

shortage is small in amount, it will not be adequate ground for condemning the proposal.

II. Will the lowering of the river level caused by the fresh withdrawal for Rohri Canal be such as to affect the Nara and Khairpur Canals, or will it be negligible? Large scale discharge diagrams for lower levels will show what diminution will occur.

III. Will the head portion of supply channel and Rohri Canal silt? Mr. Hill is of opinion that without barrage it would silt, there being no undersluices, and instanced the Nara channel. To verify this the hydraulic particulars of the Nara channel should be investigated, *viz.*, in what years cross floods below 12th caused silting in Nara, Vol. 12, paras. 43, 46 and 47. and what was the hydraulic slope of the Nara prior to 1906 when it was not affected by silt due to the cross floods. Silting from running low depths in Rohri Canal and supply channel should also be considered separately. The calculated velocities in Rohri Canal for depths of 6 feet of water and above are greater than their critical velocities, and show that it would be safe to open the canal with this depth and upwards. Similar calculations to be made for the supply channel for the hydraulic slope available between the head and tail of the channel.

Para. 21. IV. The supply channel will probably be completed in two or three years and can be operated at once. If it does not silt, the weir can be put off for some years, but if it silts the weir can be started at once, and the two or three years' delay will not be of material importance.

Para. 5 (i). Regarding widening of Nara, Mr. Benton states that the Chief Engineer's explanation does not appear to establish the adequacy of the present size of channel and would suggest that the provision for widening should not be struck off from the estimate.

Regarding the Right Bank Canal, since it has been found to be unpromising the Chief Engineer's proposal for enlarging the present Sukkur Canal to serve the upper fourth of the tract (Shadadpur and Ratodero Branches) should be accepted, but nothing should be done that would prevent its future extension to serve the whole tract.

Vol. 12, paras. 22 to 26. Regarding the proportions of Kharif to Rabi, the latest information about seepage, and available supply, bears out the soundness of having equal areas of Kharif and Rabi. The Sukkur barrage system should use up only its own share (about 12,000 cusecs) of the cold weather supply, after leaving for the Mithankote system, the share due to it.

Vol. 2, pages 83 to 95. On the 25th, 26th and 27th February 1910, a conference was held at the Government House, Karachi, by the Commissioner, of all the Collectors of Sind, and the Engineers concerned in the projects, to discuss duties, crops, etc. Messrs. Benton and Hill were also present. Another conference was convened by the Commissioner, Do. 98 to 120. of the Collectors from 12th to 23rd April 1910, to discuss the revenue figures and rates in detail. The results of these conferences have been embodied in the Commissioner's report on the revenue prospects of the combined Sind Irrigational Projects.

In this Report the Commissioner points out that the procedure adopted has been to bring the revenue estimates into conformity with the exigencies of a canal system of predetermined design, and to devise such a distribution of the available land as to bring in a maximum revenue on a specified water supply. It is an inversion of the correct procedure, which should have been based on an induction from ascertained facts and conditions of land, and has consequently caused great inconvenience. In the short time at his disposal he has collected as much information as was possible, and though the result is not as satisfactory as desired, the main statistical results may be accepted as trustworthy. He has estimated the future revenue with great care and arrives at the following returns which the various projects will pay in their 20th year :— Vol. 2, pages 1 to 2.

—	Without share of barrage.	With share of barrage.	Share of cost of barrage.
			Rs.
Rohri Canal	6·76	5·33	125 lakhs.
Eastern Nara improvements	5·37	3·95	100 ,,
Shahdadpur and Ratodero Branches ..	5·56 with rice duty 30. 6·33 with rice duty 40.	4·25 5·05	25 ,,
Right Bank whole ..	5·19	4·51	70 lakhs.

Do. pages 6 & 7.

The Rohri Canal bearing the whole cost of barrage with interest during construction will pay 4·18 per cent. as under :—

	Lahks. Rs.	
Estimated cost of canal ..	.. 469	
Interest during construction	.. 40	509
Estimated cost of barrage	.. 219	
Interest during construction	.. 31	250
Total		759 lakhs.
Estimated net revenue from canal ..		31·69 lakhs.

Return $\frac{31\cdot69 \times 100}{759} = 4\cdot18$ per cent.

If the estimated net revenue for Eastern Nara including Jamrao 7·53 lakhs is added, the return comes to :—

$$\frac{(31\cdot69+7\cdot33) \times 100}{759} = 5\cdot17 \text{ per cent.}$$

The figures of cultivation and revenue arrived at by the Commissioner are given in the statements attached to his report.

In view of the inadequate return of the Eastern Nara improvements, he unhesitatingly recommends its indefinite postponement. The Right Bank Canal is not suited to the requirements of the country, and should also be indefinitely postponed. Vol. 2, page 8

Vol. 2, page 9 He is also given to understand that the barrage is an ultimate necessity as a measure of protection. The construction of the barrage alone will give increased revenue of 7½ lakhs from Eastern Nara and about 2 lakhs from Sukkur Canal. The Rohri Canal gives a return of 6·76 per cent. and is the greatest irrigational want of the Province. Both these works must, therefore, be undertaken. If Rohri Canal can do without barrage, it should be immediately commenced, or if barrage is required to ensure its success, it should be started simultaneously with the canal.

He also recommends an estimate to be made to enlarge Sukkur Canal, and extend it to feed Ghar and Western Nara to assure their Kharif supply, and provide Rabi water for waste lands at their tails. It would be a very paying scheme.

Vol. 1, page 2, para. 6. On receipt of the Commissioner's report, Mr. Hill, Chief Engineer, forwarded the projects to Government on 8th July 1910. He supports the Commissioner that the barrage and Rohri Canal should be constructed first, and the Eastern Nara when required. The best project for the Right Bank Canal has not been prepared and will be designed hereafter.

The estimates recommended for sanction are :—

Do. page 1.

	Rs.
Barrage	2,19,34,767
Rohri Canal	4,49,75,768
Eastern Nara	1,16,64,436

Do. para. 4. Do. page 55, para. 27. He shows that the increased revenue due to barrage from the Jamrao portion of Nara without improvements has been underestimated by Commissioner by about one lakh. The return from Nara would therefore be 8½ lakhs which, added to two lakhs from Sukkur Canal, would amount to 10½ lakhs. This has been taken in preparing the financial statements for barrage.

Vol. 1, page 2, para. 8. The barrage is absolutely essential. No improvements are practicable in agriculture without it. The present irrigation is being injured by withdrawals in the Punjab and the prospects of future withdrawals are causing great anxiety.

In the note attached to the above letter he states that Rohri Canal without barrage is impracticable. (I) According to Dr. Summers the Rabi supply will fall to 4,270 cusecs. Loss by absorption would be 2,488, leaving 1,782 for irrigation, which is insufficient for only 178,200 acres. The cotton alone is 397,760, and there would therefore be no Rabi. This small quantity distributed over 2 millions
Vol. 1, page 60, para. 38. acres of culturable land, will be lost in waste. Kharif revenue only can be depended
Do. para. 39. on, which will give a return of about 2 per cent. The first two sections of the canal
Do. page 40. are at present well irrigated and the increased revenue here will not be great. (II) The canal would be an inundation one, and any breach in upper reaches would
Do. page 41. result in loss of water to all the area below. (III) The canal cannot even reckon on the above supply on account of silt banks in the Indus like at the mouths of Nara
Do. page 67, para. 48. and Sukkur Canal. (IV) The canal at head would also silt, and its clearance would be difficult and costly, the bed being below subsoil water level with very high rocky sides where suction dredging would be impracticable. The closure for silt clearance would result in water famine and dislocation of the domestic life of the population. (V) If the barrage and the Khairpur feeder be constructed first water can be sent down the Khairpur Canals during the working season for labour for excavating main canal. As the main canal proceeds water can be admitted into Dad and Nasrat Canals and so on. Without barrage, work will have to be done in a waterless country, with the result that (*a*) the time of construction will be lengthened, probably by three years, (*b*) the cost will increase by at least 10 per

cent. as there will be no fresh fodder, labour will want more wages, cattle will die, bricks will have to be made where water is to be found and carried to site, (c) the works will get a bad name, and the cost of the remainder will materially increase. (VI) Khairpur would object to an inundation canal passing through their State, as it would be of no advantage to them and only a nuisance. Do. page 70, para. 54.

Regarding widening of Nara he states that the Kharif requirements of Nara are not 13,500 but 9,850. The Executive Engineer brought this up to 13,500 to make up for loss on the way. There is, however, no loss owing to rock barrier at Sukkur diverting the subsoil flow from river into the Nara. When in charge of Jamrao he had personal observations for 5 years on discharges at Nara Head and at Jamrao Head. The results are: For discharges under 10,000 cusecs there is no loss. For smaller discharges of about 1,000, there is a gain. For discharges over 10,000 cusecs there is a loss, and the loss is very considerable owing to spill over its banks, into large lakes which again restore it when water goes down. Observations show that a little over 10,000 cusecs are obtained in Nara, when Bukkur reads 10 feet, and during the inundation the period when Bukkur reads less than 10 is unusual. The widening therefore is not proposed. Vol. 1, page 64, para. 47.

In September 1910 Dr. Summers submitted his alternative project for construction of first two sections of Rohri Canal before the barrage. This project is called the Rohri Canal Project, 1910. The estimated amount is as under:— Vol. 12 forwarding letter paras. 1 & 2.

	Rs.
Rohri Canal	4,48,12,861
Barrage	3,00,00,000
Widening Nara	40,00,000
Total ..	7,88,12,861

The net return is as under:—

Rohri Canal	31,68,000
Eastern Nara including Jamrao .	7,53,364
Sukkur Canal	1,20,000
Total ..	40,42,354
Deduct—Maintenance—	
Barrage	2,50,000
Net profit	37,92,354

The revenue for Rohri Canal and Nara is as estimated by the Commissioner. That for Sukkur Canal is arrived at as under:—

	Rs.	Rs.
Gross increase estimated by Commissioner ..		2,00,000
Deduct—One-tenth land share	20,000	
Working expenses at 0·6 per acre	60,000	
		80,000
The return is thus 4·8 per cent.		1,20,000

Vol. 12 forwarding letter para. 6.

The barrage estimate prepared by Mr. Beale in accordance with the instructions of Mr. Benton and Mr. Hill is Rs. 215 lakhs, but Mr. Beale dissociated himself from parts of the estimate and placed the lowest safe figures at 280 lakhs. Dr. Summers therefore takes a round figure of 300 lakhs.

Vol. 12, see pages 22 to 25, duties pages 26 to 38.

In his report Dr. Summers discusses duties in great detail, gives statements to show the large seepage into the river between Dera Ghazi Khan and Sukkur, and between Sukkur and Kotri, and gives the comparative statements asked for by Mr. Benton in his note dated the 5th March 1910

Vol. II, para. 5.

Do. para. 4.

Do. para. 15.

Do. para. 30.

Mr. Hill in his comments on this 1910 project, has criticised it very freely. He states that no allowance has been made by Dr. Summers for diminution of supply in the canal during Rabi on account of silt, though Mr. Benton had suggested that 1·5 feet of silt be assumed at head, when calculating supply available in the canal. Even assuming no silt, Rabi supply will fail in many years. Rabi being insecure, the assessment rates cannot be raised, and the increased net revenue will not exceed Rs. 9,40,000. The duty 140, which may be possible for a volume of water when restricted to a suitable area, is insufficient when the same volume is scattered over a large area. Dr. Summers has taken the average supply as the available supply, but this average is not obtained in 50 per cent. of the years when the crops will wither and die.

File No. XXV 1910-12.

The Bombay Government in submitting the projects for sanction (in December 1910) to the Government of India, recommends only the barrage costing Rs. 2,15,55,775 and the Rohri Canal at Rs. 4,38,72,843. The Right Bank Canal and the Eastern Nara are not proposed to be considered at present. The Governor in Council further remarks :—

Letter No. W.I 8.-2573 of 5th December 1910. Para. 4.

The barrage estimate has been prepared under instructions by Mr. Beale, who expresses anxiety on the provision made for foundation and for pumping, and on the adequacy of the waterway; and the Governor in Council would welcome full critical examination and further investigation on these points. The effects of inadequate waterway would be serious causing the river to deflect to the west with disastrous consequences, and the Bombay Government would willingly seek the advice of an expert American Engineer.

Para. 5.

Paras. 7 & 10.

The Rohri Canal Project has been prepared by Dr. Summers with ability and foresight. He has also submitted an alternative proposal for constructing canal before the barrage, but does not recommend it for the reasons given in the Chief Engineer's note. As a measure of ordinary prudence, the barrage should form an essential part of the scheme.

Paras. 14 to 17.

The Commissioner in Sind has prepared the revenue estimates with great care and extreme caution, and may be confidently accepted, though the Governor is of opinion that ultimately the revenue expected by the Commissioner will be exceeded.

The Governor in Council feels diffident in accepting the estimate of the barrage for reasons given above. Mr. Beale has pointed out that other large works have given excesses as under :—

Para. 21.

—	In million pounds.		Excess.
	Estimate.	Actual.	
Forth Bridge	1·6	2·55	60 per cent.
Manchester Ship Canal	7·3	10·85	50 ,,
Aswan Dam	1·5	3·0	100 ,,

It would be safe to assume that the cost of the barrage will not exceed double the estimate. The joint cost will therefore be :—

	Rs.
Barrage (216 ×2)	432 lakhs.
Rohri Canal	439 „
Total ..	871 „

The financial forecast for this would show that the net revenue in the 12th year after completion will exceed 33·84 lakhs which is the simple interest at 4 per cent. on the total cost. Page 23.

Lastly the Governor considers it very important that means should early be devised for feeding the Ghar and Western Nara from the barrage, not only because the project would be remunerative, but because at low-water periods the barrage would possibly deprive these canals of some of their supply.

The Government of India submitted the whole scheme to the Secretary of State for India in their despatch No. 30-P.W., dated 24th October 1912.

Owing to the complicated nature of the whole scheme, the Secretary of State for India appointed a Committee in London, consisting of Colonel J. W. Ottly, Messrs. L. Jacob, W. L. Cameron and A. L. Webb, to report on the projects, *viz.*, for a barrage and Rohri canal costing Rs. 7,81,70,727. Their report was issued in December 1913, and the conclusions arrived at were :—

(*a*) *That the project is not necessary as a protective measure.*—There is no evidence of Sind having suffered in the past, owing to the withdrawals in the Punjab or that it will suffer in the future. In the inundation season, the withdrawals certainly had no prejudicial effect on Sind, as may be seen by comparing average gauge readings for the two periods 1848-1877 and 1878-1910, and from the number of days the river read above 12 or 13 feet in the two periods. In the cold season the supply in the river may have been affected, but Sind canals never had a cold weather supply, and have, therefore, not been adversely affected. The future effect may be minimised by considering Sind an inundation canal country. Report of S. B. Committee, 1918, paras. 4 to 13.

(*b*) *The project is not productive.*—The forecasts show that, excluding enhanced land revenue, the returns are :—4·28, 3·47, or 4·17 per cent. according as the period of constructions extends to 13, 15 or 16 years. With enhanced land revenue, the returns are somewhat more favourable, but no just claim can be made to this credit. The 15-year programme is unproductive, and in the other two cases the profit is so small that the estimates must be extraordinarily accurate to make the scheme profitable. The estimate for barrage is admittedly incomplete, the design not well thought of, and on many items there are great differences of opinion. The estimate is likely to be greatly exceeded. The feeder to Ghar and Western Nara should also be included in the project, since these two canals will be adversely affected by the barrage, and if this means additional expense without additional revenue, it is all the more necessary to include it, if only to exhibit the true financial aspect of the complete scheme. Paras. 14 to 20.

Constructing the Rohri Canal without a barrage would mean that this canal would be a source of supply to an enormous area at present irrigated by a number of small canals. The latter would never fail simultaneously and the failure of one would be unimportant, but the failure of the Rohri Canal could mean disaster to the whole area. Besides without barrage, perennial Paras. 21 to 28.

supply is not assured, and it would be necessary according to the Commissioner to revise the figures for Kharif and rabi, and the canal would have to be larger, say of 18,000 cusecs to meet increased Kharif requirements.

Para. 32. The only hope would possibly be in a canal followed by a barrage, after the first and second section of the former have been completed, but without carefully prepared forecasts of revenue and expenditure, the Committee cannot give it the necessary critical examination.

Para. 33. Though the scheme is unproductive and premature, the Committee yet recommends a complete scheme to be prepared and kept in readiness. Sind has not suffered in the past but may be affected in future, and in that case
Para. 38. remedial measures though unproductive may be justified. The effect of the Punjab withdrawals should be carefully watched.

Paras. 34 to 37. The Committee also suggests that an alternative site for barrage below gorge founded on sand should be investigated and shows the advantages likely to accrue.

The London Committee's report was received by the Bombay Government in March 1914, and in September 1915, the latter again addressed the Government of India regarding the projects. They said that in unfavourable conditions of the river, the Punjab withdrawals might have appreciable effect in lowering the water-level at Sukkur during the critical months of June and September though it is not possible to trace directly what the effect actually is. Yet there is good reason to say, Sind ought to be protected by the construction of a barrage. The present conditions of cultivation and irrigation are not suitable and Sind is calling loudly for improvements and benefits which Punjab and the United Provinces have long been enjoying. To regard Sind as an inundation country pure and simple would be adopting a policy of stagnation. It is probable that higher rates of assessment than that proposed by the Commissioner will be obtainable in the future.

No. W. I 1055 of 1915, dated 23rd September 1915.

The scheme now to be put forward differs from the former in these two points :—

(1) The Right Bank canal to be included.

(2) The barrage is to be located below the gorge, instead of above, as suggested by the London Committee.

The rough cost of the barrage, Right and Left Bank Canals would be 1,120 lakhs, and the ultimate revenue 635 lakhs. The net revenue is likely to cover the accumulated interest nearly by the 10th year after completion. The return would be about 5·7 per cent.

On these grounds the approval of the Government of India is requested for the preparation of detailed plans and estimates.

Rohri Canal with or without Barrage.

One of the main arguments of Mr. Hill for giving priority in the programme of works to the barrage and Nara improvements, was that with the barrage in operation the construction of the Rohri Canal would be greatly facilitated. The Khairpur feeders would first be constructed, and water admitted in the State canals in the dry season, which would provide the water as well as fresh fodder and vegetables for the men and animals at work on the main canal. Bricks could be made at site of works instead of being made where water is available, and carted to the site. When the main canal is finished through Khairpur, the British canals could be given perennial supply and the same facilities would be available for work lower down. Without such facilities, the Rohri Canal would cost about 10 per cent. more and the time of construction would be lengthened by probably at least three years.

Since however it has been generally admitted, that the Rohri Canal is the greatest irrigational want of the province at present, it is the almost the universal opinion, that this canal should be started first, and the question now arises whether—

I. The Rohri Canal should be constructed with or without barrage.

II. If with barrage, whether the two works should be started simultaneously, or the barrage made to follow the Rohri Canal later on.

Circumstances have changed since the subject was last discussed, as the barrage site is below gorge and the supply channel is done away with.

1. Rohri Canal with or without barrage.

The advantages of Rohri Canal without barrage are—

I. That perennial supply can be given without barrage. The bed will have to be about 4 feet lower than with barrage up to the first fall in mile 30 to give sufficient supply to 25 per cent. Rabi. The extra cost of this would be Rs. 25 lakhs against about 250 lakhs of the barrage.

2. The interest about 10 lakhs, and maintenance charges about 2 lakhs of the barrage, *i.e.*, 12 lakhs per annum would be saved.

The disadvantages are :—

1. The barrage is required for the Right Bank Canal and the Eastern Nara, and the Rohri Canal may as well take advantage of it and keep the bed higher and save 25 lakhs.
2. The first few miles of the canal will silt like Nara and the supply consequently be reduced. Dr. Summers maintains that the canal will not silt. Silting in Nara is due to Ghotki floods. By means of the rising silt, only the upper layer of the river water will be allowed to enter the canal, which contains the finer silt, and this fine silt will be carried down the canal as its velocity will be above the critical velocity.
3. Sand banks will form in the river opposite the canal mouth, and affect the Rabi supply, as happens opposite to Nara.

The river below gorge at barrage site is permanent and does not swing about as at Nara and other places. The sand banks, if any, will only be small in extent and can be soon dredged away.

4. The area under Rabi cannot be increased to be equal to Kharif, and the canal has to be made larger for Kharif.

   Rabi is not a favourite crop, and will not develop until pressure of population is felt. Dr. Summers in his 1910 Project provides 24·7 per cent. of Rabi including bersim (17·7 per cent. rabi and 7 bersim). With canal 4 feet deeper sufficient water for this area will be available.

5. Without barrage the water supply cannot be assured, and without assured supply cultivation will not develop.

   Dr. Summers maintains that the supply will be assured.

6. The withdrawals in the Punjab will reduce the cold weather supply in the river to bare requirements, and will affect the supply in the canal.

II. Rohri Canal with barrage constructed simultaneously or deferred.

Whether the barrage be constructed simultaneously with the Rohri Canal or deferred will depend mainly on the financial forecast. The financial statement prepared by Mr. Hill takes the cost of barrage at 216 lakhs. While the cost gathered from London Committee's report is 283 lakhs. Dr. Summers assumes the cost of 300 lakhs, but his comparisons are between Rohri Canal *followed* by barrage, and barrage *followed* by Rohri Canal which does not suit our purpose. Besides he adds 40 lakhs to the total cost for widening the Nara which Mr. Hill maintains as unnecessary.

In preparing the attached statements, the widening of Nara is omitted, and the cost is assumed as under :—

Barrage	.. 282 lakhs.
Rohri Canal (Dr. Summers' 1910 Project)	.. 448 ,,
Total	.. 730 lakhs.

With barrage alone, the Commissioner estimates an increased revenue of 7½ lakhs from Eastern Nara and about 2 lakhs from Sukkur Canal. Mr. Hill shows (Volume I, page 55, para. 27) that the Commissioner has underestimated the former figure by 1 lakh and takes the total revenue from barrage alone at 10 lakhs. This figure has been taken in the financial statement. For Rohri Canal simultaneously with barrage, the revenue figures are the same as those adopted by Dr. Summers in his 1910 Project, which has been based on the Commissioner's report, *viz.*, Rs. 31,68,990, when fully developed. For Rohri Canal followed by barrage, the revenue from Rohri Canal will not develop as rapidly as above unless the bed is lowered by 4 feet. In the financial statement for this programme 25 lakhs has, therefore, been added to the cost of Rohri Canal for lowering the bed.

The two statements show that at the end of the 30th year, the Rohri Canal followed by barrage is slightly more favourable than the two works started simultaneously, but as 25 lakhs has been added to the capital cost, the ultimate return is less favourable. If the 25 lakhs is not added for lowering the bed, the development of irrigation will be delayed, and the prospects will be about the same.

It has the following further disadvantages :—

1. Khairpur State will not get a perennial supply for so long as the barrage is delayed.

2. Work on the main canal in the Khairpur State will consequently be carried out under difficulties of want of water.

Bed Level of Rohri Canal with or without Barrage.

The crest of the barrage gates being at R. L. 192·0, and allowing 0·5 feet as margin below top of gates and 0·5 for loss of head through regulator, the F. S. L. in the canal would be at R. L. 191. The designed depth of full supply being 13 feet, the bed level will be at R. L. 191-13=178·0.

Without barrage, the bed level has to be fixed with reference to the available cold weather level in the river. The minimum reading at Bukkur gauge is—2·4 but this is very rare. If 1·0 is taken as the available level, it will be obtained in about 9 years out of 10. This level will be 184·44—1=183·44. The fall in river level between Bukkur and barrage being nearly 1·5 feet, the level available at the barrage site will be 182·0 in the river and 181·5 in the canal.

The required Rabi discharge according to Dr. Summers' 1910 project, which is based on the figures given in the Commissioner's report, is 5,650 cusecs, which can be had when the depth in the canal is 7·5 feet. The bed level should therefore be 181·5—7·5=174·0, *i.e.*, 4 feet lower than with Barrage.

The extra cost of lowering the bed four feet would roughly be—

	Rs.
Excavation, 217,000,000 cubic feet at Rs. 9 per 1,000 .	19,53,000
Excavation in wet soil, 58,860,000 cubic feet at additional rate of Rs. 3	1,67,000
Add—For lowering regulator	2,50,000
Total ..	23,70,000

With contingencies say 25 lakhs.

In October 1915, Mr. A. A. Musto, Executive Engineer, was put on special duty under the Chief Engineer in Sind to take up the revision of the Sukkur Barrage Project, and on 1st September 1916, he opened the newly sanctioned temporary Sukkur Barrage Project District.

On the 2nd May 1916 Mr. Musto submitted under his No. 43 to the Chief Engineer in Sind a preliminary report and rough outlines for the revised project for the Sukkur Barrage and Triple Canals. The principal changes proposed in this project as compared with the 1909 projects, were as follows :—

1. The site of the Barrage was shifted to a point about 3½ miles below the original site, *i.e.*, below, instead of above, the Sukkur Rohri gorges.
2. The design of the foundations of the barrage was entirely changed, it being now designed to be built on the sandy bed of the river, like the Punjab weirs and the Esna and Grand Barrages in Egypt, instead of being founded on rock as in the case of the 1909 projects.
3. It was proposed to raise the height of the barrage gates by 2 feet as compared with the 1909 project, *i.e.*, gates were to be 18 feet high instead of 16 feet.
4. It was proposed to substitute a masonry superstructure for a steel superstructure proposed in the 1909 project.
5. The heads of the Right Bank Canal, the Rohri Canal and the Khairpur feeders were now shifted to the new site of the barrage and the head portions of these canals realigned accordingly.

6. The existing head of the Nara Supply Channel which takes off just above the site of the 1909 Barrage and was to be supplied from that barrage would no longer be utilized, but a new head channel would be excavated from the new site of the barrage to meet the existing Nara Supply Channel at its 5th mile.

7. The great guide banks above the Sukkur-Rohri gorges were to be omitted and instead of these the natural river banks from the gorge to the new site of the barrage were to be protected with stone pitching and aprons.

8. Scouring sluices were provided at either end of the barrage, the pavements of which were to be 3 feet below the pavement of the central portion of barrage.

   These sluices were separated from the central portion by divide walls forming confined channels in front of both Right and Left Bank regulators and they enabled the latter to be scoured free of silt.

9. The site of the ship's lock was shifted from the river bank to the far side of the divide wall beyond the Right Bank scouring sluices.

10. The Summers' supply channel with its bridges and regulators was now omitted.

11. The full supply level to the Nara Supply Channel and to the Khairpur Canals was now commanded by the barrage throughout the year, whereas in the 1909 project, they depended on the natural level of the river and that barrage could not have given them the required level.

12. The full supply level and bed level of the Rohri Canal and the Right Bank Canals was proposed to be raised about 3 feet in the upper reaches thereby saving greatly in excavation, and in the case of the Right Bank Canals, greatly increasing commanded area.

These proposals and the accompanying designs and plans were submitted to the Chief Engineer for Irrigation, Bombay, by the Chief Engineer in Sind demi-officially in May 1916, and were sent back to him demi-officially with the notes of the Chief Engineer for Irrigation (Mr. Beale) on the proposals in September 1916.

Mr. Beale accepted practically all the suggestions and designs in the proposals with the exception of following :—

(*a*) He thought the suggested designs for road-bridge carried on three arches (ribs) of stone masonry would be unsafe, and that instead of these the road-bridge should be carried on reinforced concrete arches and that the roadway should be 20 feet clear (as against 16 feet proposed) with one 5 feet footpath. He considered that at least three-fifths of the cost of this bridge should be paid for by Provincial Funds.

(*b*) He did not consider the high level bridge was necessary, but was prepared for stouter piers to carry the cross girders for supporting the gates and machinery and also for the provision of a light foot-bridge.

(*c*) He considered that the barrage gates might be 18 feet high as proposed, but thought that they should be made in two halves or tiers.

(*d*) He thought the velocity of entry through the regulators had been kept unnecessarily low.

(*e*) He considered that the hydraulic slope (1 in 15·95) proposed in the design of the barrage floor, was rather low and that it would be safer to use a flatter hydraulic slope and provide more protection in impervious masonry down-stream of the gates.

(*f*) He did not approve of the suggestion to head up to 18′ of water provided there was not less than 1·4′ of water downstream, *i.e.*, not to exceed the pressure of 16·6′ head on the 18′ gates. He thought that if 18′ gates were provided and 18′ of water ever to be headed up, then the floor must be designed to enable this 18′ to be headed up even with no water downstream.

(*g*) He considered that a wider foot passage should be provided along the wall of the Ship's Lock below the opening bridge.

In the meantime Mr. Musto had proceeded on Military Duty from 2nd September 1916 being relieved by Mr. A. Nazareth, Executive Engineer.

A little survey work on the proposed new heads for the canals was done in the cold weather of 1916-17 and an alternative alignment for the upper reaches of the Right Bank Canal, which proved to be useless, was investigated.

A conference consisting of the Inspector-General of Irrigation, the Chief Engineer for Irrigation, Bombay, and the Chief Engineer in Sind was held at Sukkur in March 1917, and another conference of the same officers with the Commissioner in Sind was held in Karachi a few days later, to discuss the whole question.

As the result of these conferences it was decided to place an officer of the Revenue and Public Works Departments respectively on special duty to investigate the areas to be irrigated by the proposed canals and to propose rates and intensities, and duties, etc. Messrs. Baker, I.C.S., and Lane, P. W. D., were accordingly placed on this special duty as from January 1918 and are still engaged on this work. The Inspector-General of Irrigation's note on the projects, dated the 22nd March 1917, was forwarded to the Chief Engineer in Sind, under Government Memo. No. I.-4457, dated the 28th April 1917, and by him a copy was sent to Mr. Nazareth under his No. S-321, dated the 7th May 1917, for remarks.

In the Inspector-General of Irrigation's note the following suggestions and remarks were made :—

(*a*) He suggested that each Superintending and Executive Engineer should have made over to him that part of the canal projects which fell within his charge, so that each could study the project and assist the revenue officers and the P. W. D. officers who would eventually be provided to submit the complete project. He was of opinion that canal officers would be able to do much useful work in this connection and that they should study the problems involved and plan and estimate the work to be done in their charge.

(*b*) He referred to an old proposal to feed the Ghar and Western Nara from a single new channel to take off the river above the present Ghar head. He pointed out that such a head could only be made on the alignment of the present Sukkur Canal and that if this were done, two great systems would depend on a single head which might fail. He agreed that this proposal should be dropped.

(*c*) He pointed out the difficulty and cost of constructing and maintaining the proposed Ship's Lock and the very little use it would have. (Accordingly it was decided to omit any provision for a Lock, though this is not definitely stated in the note, but is written in pencil on the plan).

(*d*) He drew attention to the importance of coming to accurate decisions as to the area of culturable land commanded, the intensity of cultivation to be provided for, and the duties to be used in calculating the requirements and the size of canals.

(e) He emphasized the importance of keeping the canals as small as possible in order to encourage economy in the use of water and to prevent water logging the land.

(f) He pointed out that even apart from a Rabi supply, the Right Bank area would be greatly benefitted by the barrage, by having a Kharif supply at a guaranteed level every year, whereas at present it depends on the fluctuations of the natural river.

(g) He emphasized the necessity and importance of designing all channel from the river to the land, to give correct discharges as requisite, and pointed out the difficulty there would be in administering old channels until they had been completely remodelled to suit the new conditions.

(h) He gave much information about the methods adopted in the Punjab for remodelling old canals and designing new ones.

(i) He pointed out that if the Rohri Canal were constructed without the barrage it would still necessitate extensive remodelling of existing canals, and that when the barrage was added afterwards it would be necessary to again remodel these canals, and he was therefore of opinion that every effort should be made to design a productive public work which would enable the barrage to be built concurrently with the canals.

(j) He concluded that there was a *primâ facie* case for believing that the Rohri Canal could be reduced from 15,500 cusecs to about 10,000 cusecs, and that if so, it would need to be redesigned throughout.

(k) He believed that a payable scheme of crops could be worked out by the co-operation of the Revenue and Agricultural and Canal officers, especially if suitable demonstration farms were established for the instruction of the officials as well as the irrigators.

Copies of this note were sent to the Superintending Engineers, Indus Right Bank and Left Bank Divisions, for report as regards the Inspector-General's suggestion in (a). Both Superintending Engineers replied in June 1917 that they considered it would be unfeasible for each Executive Engineer to design and estimate the portions of the proposed canals in his district, owing to the confusion and lack of co-ordination of ideas, that such a procedure must lead to. They considered that the whole work should be done by one special officer and staff, *viz.*, the Executive Engineer, Sukkur Barrage Project District.

Both officers, however, suggested that yearly or periodical reports on the progress made with the projects and on the proposals being developed, should be circulated to all officers concerned, so as to keep them in touch with the work, and enable them to make suggestions and supply information to the designing officer.

The Chief Engineer in Sind, reported to Government accordingly in his No. S.-265, dated 10th May 1918. He stated that Messrs. Baker and Lane had been engaged for some months past in studying the soil features of the Rohri Canal tract and other problems in connection with the substitution of perennial for inundation irrigation.

Also that Mr. Musto, Executive Engineer, had been recalled from Military Duty to design the Barrage and Canal Head Works.

He suggested that a note be prepared at intervals and issued to all officers concerned, showing the results of the work done by the special officers, Messrs. Baker, Lane and Musto.

He further stated that investigations as to through boat traffic at Sukkur showed that there was none and that therefore a lock was unnecessary.

In their Memo. No. I-6533, dated the 28th June 1918, Government informed the Chief Engineer in Sind that it was not intended that local officers should do any part of the designing of the canals, barrage or head-works, but that those through whose districts the new canals will pass should be made to take an interest in the projects. The Chief Engineer in Sind's suggestion for a periodical note to be issued to all these officers was approved.

It was suggested that each Executive Engineer should be supplied with a map showing the proposed distributaries, regulators, road-bridges, etc., in his district and that he be asked to give advice as to whether these were the best alignments, positions, etc., for the works.

A copy of this memo. was sent to the Executive Engineer, Sukkur Barrage Project District, under Chief Engineer's No. S-443, dated the 19th September 1918, with instructions to prepare the necessary notes and plans for circulation.

As the question of the alignments of main and branch canals, and water levels therein was under radical revision at the time and these changes awaited the consideration and sanction of the Government, it was not possible to give any useful definite information at that time, but since the Inspector-General of Irrigation and the Chief Engineer for Irrigation, Bombay, visited Karachi at the beginning of December 1918, and came to decisions on most of these points, it is now possible to give an outline of what is now proposed.

The redesign of all the canal systems, *viz.*, the Rohri Canal, the Eastern Nara System, the Right Bank Canal System and the Khairpur Canals has now also been placed in the charge of Mr. Musto, Executive Engineer, Sukkur Barrage Project District.

The following are the principal changes now proposed by Mr. Musto and tentatively approved as compared with his 1916 proposals outlined above :—

Barrage.

(*a*) The gates will be made 18·5′ high with top at R. L. 194·5.

(*b*) The scouring sluices at each end of the barrage will have their pavements at the same level as the remaining sluices of barrage, *viz.*, R. L. 176·0, *i.e.*, all sluices will be identical, but the scouring sluices will be separated from the central portion of the barrage by divide walls forming scouring channels in front of the canal regulators on each bank of the river. The scouring sluices will be provided with longer pavements than the ordinary sluices of the barrage, as they will be more constantly in operation and under greater heads.

(*c*) The road-bridge will consist of 60′ span eliptical stone masonry arches 25′ wide, with road level at R. L. 215 about.

(*d*) There will be a high level bridge for carrying the gates, counterweights and machinery and to provide a foot-bridge for operation, and to carry a travelling 5-ton crane for removing debris from in front of gates, etc. It will also carry, if necessary, travelling winches for operating the gates.

The bridge will consist of two eliptical masonry arches 60′ span and 5′ wide each, with a gap of 16′ between them, in which the gates and counterweights will operate. The deck of the bridge will be carried on girders (reinforced concrete or steel) spanning the gap between the two arhes and will be 25′ wide between parapets and at R. L. 238·5.

(e) The high level and low level bridges will be carried side by side on the same piers, which will be 10′ thick and about 75′ long. There will be abutment piers, 25′ thick at intervals of 9 spans.

The whole barrage will consist of 66 spans of 60′ each (clear opening).

With the exception of the gates and machinery and the girders for carrying same, the whole structure will be of stone masonry.

This had been shown from carefully prepared and fully detailed estimates to be about 15 per cent. cheaper than a steel superstructure, at pre-war prices for steel-work, and with masonry rates 10 per cent. in excess of pre-war rates.

(f) At either end of the barrage the high-level bridge would have one land span crossing the roadway leading from the barrage road-bridge to the road-bridge over the canal head regulators. Each abutment of the high-level bridge will consist of a masonry tower containing a hydraulic platform lift capable of raising the cranes and other machinery from ground level to the top of the bridge. A staircase would also be provided at the end of the tower for access of work-people and staff to the high-level bridge. The machinery for working the lift would be housed in rooms below this stairway and also in a pit below ground level.

Canal Head Regulators (General).

(a) The head regulators for all the canals on either bank will be of one design with spans of 25′, closed by balanced gates in three tiers, which could completely close the canals in even the highest floods. The gates and counterweights would work in a space between two masonry arches as in the high-level bridge of the barrage, and would be operated by fixed gearing on each gate to be worked by a travelling power unit, running along the gate bridge.

(b) Behind the gate bridge and on the same piers will be built a masonry road bridge on arches of 25′ span, the bridge to have similar roadway and footpaths as the barrage road bridge.

(c) This roadway will pass, at the down stream end, on to the barrage and the canal banks, and at the upstream end will lead on to the river protective banks, along the top of which the main road will be carried to connect with the road systems of Sukkur and Rohri respectively.

(d) The bed of the scouring channels of the barrage being at R. L. 176 all regulators will have permanent masonry sills with tops at R. L. 182·0, leaving a silt collecting pond 6′ deep, in front of the regulators.

This pond can be scoured out at any time by partly opening the barrage scouring sluices, or the latter may be kept slightly open always, to draw off the bottom water of the river, heavily leaden with silt. All regulators will take their supply only over the top of their gates, thus taking only the clearer surface water. The velocity through the regulators will be kept slightly lower than that in the canals, so that all silt carried in suspension through the regulators can also be carried in the canals. The velocity of the river water in the approach channels to regulators will be kept similarly less than that in the canals, so long as the natural level of the river is below the top of barrage gates.

Thereafter the natural velocity of the river will flow through the approach channels, but as only the top few feet of surface water will then be needed there should be no excess of silt passing into the canals.

(e) The regulator floors will be designed capable of standing the full head, of highest floods in the river with the canals empty, so that in the event of breaches, or if repairs are needed, it will be possible to completely close the canals at any time.

Rohri Canal.

Final figures of culturable area, etc., have not yet been submitted by Messrs. Baker and Lane, so no definite figures can be given of proposed discharge of this canal. It will probably be in the neighbourhood of 11,000 cusecs as against 14,300 provided in the 1909 project. This reduction is due to the recommendations made by Messrs. Baker and Lane in respect to revision of the 1909 estimates for intensity of cultivation, duties, etc.

These recommendations were made in their No. 564, dated the 17th May 1918, and were forwarded to the Government of Bombay by the Commissioner in Sind under his No. Rev.-534, dated the 25th June 1918.

The recommendations were provisionally approved by Government in Public Works Department, Government Order No. W.I.-8601, dated 30th August 1918, subject to further report by Messrs. Baker and Lane.

The principal recommendations made in the above letter were as follows :—

(a) *Duties*—

—	At outlet.	Distributary head.	Branch head.	Canal head.
1. Kharif Dry Crop	100	87	82·5	72·5
2. Rice	50	43·5	40	35
3. Rabi	200	174	165	145

These duties allowed for losses by evaporation and absorption as follows :—

In distributaries .. .. .. 15 per cent.

In Branches and Main Canal .. .. 20 „

(b) *Intensities*—

(1) *Kharif*.—27 per cent. of the whole culturable area was recommended for Kharif.

(2) *Rabi*.—Twice the Kharif area or 54 per cent. of culturable area was to be provided for. It was not expected that this area would be reached at any near date, but provision was to be made for it. In the financial estimates only 27 per cent. of culturable would probably be estimated as the Rabi area.

(c) It was proposed to exclude from the Rohri Canal Irrigation area, the areas shown in the 1909 project in Talukas Guni, Tando Bago and Matli and to leave them on their present source of supply, *viz.*, the Fuleli Canal which would be relieved of other parts of its command in Talukas Matli and Hyderabad and thus be in a position to give an improved supply to the remaining area.

Further changes from the 1909 project were proposed by Mr. Musto, Executive Engineer, and were provisionally approved by the Chief Engineer for Irrigation and the Inspector-General of Irrigation in December 1918.

These were as follows :—

(a) Changes in alignment of head reach of main canal. This will now take off immediately above the barrage, *i.e.*, about 3 miles below Rohri, will run on a line parallel to the barrage for about one mile (*i.e.*, a little east of south) and then swing round in a curve of about 24,000 feet radius till it approaches the North-Western Railway near Begmanji Railway Station, and from that point follows the 1909 alignment, except that it will be kept further away from the railway, in order to allow the Khairpur Feeder East to run between it and the railway.

(b) It is proposed to raise the F. S. L. and the bed level of the canal in the first 15 miles (*i.e.*, up to mile 16 of 1909 alignment) by 4·5 feet, making a greater fall at this point to bring the F. S. L. and bed level to the 1909 project levels, as a higher level is not needed in the canal for command purposes. This raising in the upper reaches affects a very large saving in earth-work, as the cutting is deep throughout this portion.

Khairpur Feeders, East and West.

The head reaches of these canals will now be entirely different from the 1909 alignments. The feeders will take off from the barrage on either side of the Rohri Canal.

The East Feeder will run side by side with the Rohri Canal and between the latter and the N.-W. Railway (*i.e.*, to north of railway) until it approaches the existing New Mirwah, just north of Khairpur. Here the feeder will swing round to the south in a short curve and run into the New Mirwah just north of the railway. Thus the present crossing of the railway by the Mirwah will be utilised for the new supply and no new railway bridge will be necessary. In the 1909 project, this feeder took off the river *via* the Summers' Supply Channel, to the south of the railway and did not have to cross the latter, whereas with the new site of the barrage the railway lies between the canal head and its command.

The West Feeder takes off from the barrage on the west side of the Rohri Canal, and will swing round, almost at once, in a curve of about 8,000 feet radius, to the south the Babarlo to meet the 1909 alignment at about the 5th mile of latter, the distance to this point from the new head being roughly only 3 miles.

Full Supply Levels in Khairpur Canals.

In the 1909 project only one F. S. L. was provided, *i.e.*, no provision was made for an extraordinary supply level to give extra discharge at times of maximum demand such as overlapping of crops, transplantation of rice, etc. Such provision was made in both the Right Bank and Left Bank Canal Projects.

Moreover the F. S. L. provided for these canals was dependent on a natural river higher than the top of the barrage gates (R. L. 192), *viz.*, R. L. 194·7 in the river, equivalent to 10·3 on the Bukkur gauge. It was estimated that this level would be available for 90 days in the year, but in 1918 it was available only for 35 days altogether, and only for 9 days after the 23rd June when most needed.

With the present proposals of heightened barrage gates and new site of barrage it will be possible to give a F. S. L. in the feeders at least one foot higher than the 1909 level, and to give this at any time throughout the year.

Eastern Nara.

The present proposals for the canal include a new feeder from the barrage running almost south for half a mile. It then swings round south-east to west of Tando Hussan Khan and Boraha, runs south-east to Ñonani village, passes latter to the east, swinging round into the Aror Valley and running through latter to Aror it swings to the south-east to meet the existing Nara Supply Channel at mile 4 of the latter. It is further proposed to widen the Nara Supply Channel from the 4th to 12th miles.

Full Supply Level.

In the 1909 project no provision was made for an extraordinary F.S.L., higher than the ordinary F. S. L., to give extra discharge at times of maximum demand due to overlapping of crops, etc. Such provision was made in both the Rohri and Right Bank Canals.

The F. S. L. provided in 1909 required a level of R. L. 195·8 in the river, equivalent to 11·4 on Bukkur guage, and 3·8′ higher than the top of the barrage gates (R. L. 192·0).

The canal was therefore dependent, as at present, on a natural river level of 11·4′ on Bukkur, and the barrage could only have helped it up to a level about 4′ below its F. S. L. In the 1909 project it was stated that the required river level could be expected in normal years, from the 15th June to the end of September but from an inspection of the Bukkur guage readings for 10 years, attached to the project, it can be seen that there would have been a deficiency, for part of the season, in 8 years out of the 10 years shown.

In 1918 Bukkur only reached the required level for 7 days after the 15th June, while the average gauge readings and deficiency were as follows :—

—	Bukkur gauge readings.	Deficiency for 1909 project (11·4).
15th to 30th June	10·72	·70
July	8·64	2·76
August	9·10	2·30
September	7·90	3·5

and the 1909 barrage could have given no assistance.

Thus this project did not provide a guaranteed supply and can only be regarded as unsatisfactory.

With the present proposals for new site of barrage, higher gates, new head to Nara, and widening the supply channel from mile 4 to 12, it will be possible to give a guaranteed supply all the year round at as high a level as that provided in the 1909 project (dependent on a natural river level).

Gauge readings and discharges measured over a period of 14 years show that a discharge of 12,000 cusecs (which is to be provided for the Jamrao system and the eventual development of the other canals of the Eastern Nara System) can be passed below the 12th mile of the Nara when the water surface there is at R. L. 189·3.

The distance from 12th mile gauge to the proposed new head is 80, 250′ so if the new head and the widening of existing channel to the 12th mile are given a surface slope of 1 in 16,400 (bed width 350′), the water level required at the head will be R. L. 194·2. Allowing for a loss of 0·3 in the regulator, this requires a level of 194·5 in the river, and this is the proposed level of the top of the barrage gates. Hence the barrage could give the required level at any time of the year.

As, however, there is a fall of 85′ in the 93 miles of the Nara River from 12th mile to Jamrao Head, or an average slope of only 1 in 5,800, and as the section of the Nara River is very wide it is probable that it will be cheaper to remove bars in the bed of the river and thus pass the same discharge with a flatter slope and consequently at a lower level at the 12th mile. Such a fall in level at the 12th mile would enable a steeper slope and therefore a narrower and cheaper section to be given to the new head, and to the widening of the existing channel from miles 4 to 12. This will be carefully investigated in the project, but even without touching the Nara below the 12th mile, the barrage can give the necessary full supply level whenever required.

RIGHT BANK CANAL.

This whole project has been completely changed.

With the increased height of the barrage gates, new site of barrage and shorter head to the main canals, it will now be possible to raise F. S. L. and bed levels by about 4′ at the head and for as far as desirable or necessary. This extra height increases the commanded area very greatly, and it would be possible to make a new branch running north-west passing close to the Garhi Yasin, crossing the Begari at mile 56 and crossing the boundary of Nasirabad Tahsil. It would then swing round almost due west for about 20 miles and then turn south-west until it tails into the Bagh Nai (Lebo Nai) at the south-west corner of Nasirabad Tahsil. This branch would command by perennial flow the following areas not included in the 1909 project :—

	Acres.
In Taluka Garhi Yasin	63,000
,, Jacobabad	146,000
,, Shikarpur	11,000
In Tahsil Nasirabad	197,000
Total ..	417,000

The raised levels will also turn most of the lift area included in the 1909 project into flow command.

For the remaining area (the great bulk of it) included in the 1909 project the raised water level is not required and would be cut out by falls where not needed. But this raised level has the great advantage of raising the bed and thereby reducing the excessive excavation in the upper reaches. A very large saving is thereby effected.

In Government Memo. No. C.E.-161, dated the 9th December 1918, the Chief Engineer for Irrigation, Bombay, gave the following orders for the Right Bank area :—

(a) To provide a feeder channel to supply the Ghar and Western Nara Canal systems with Kharif supply only.

(b) To provide a separate perennial canal for the supply of the Ratodero and Shahdadpur branches and to extend these branches further to the south but to stop at the northern boundary of areas flooded by the Gaj Nai and other hill torrents.

Note.—(The suggested new branch running into Nasirabad would form part of this system.)

(c) Or as an alternative the Ratodero and Shahdadpur branches might be made as branches of the proposed Ghar and Western Nara Feeder, in which case the latter would have to run as a perennial canal, as far as the point of off-take of these branches.

(d) To provide a perennial supply if possible for Kakar and Johi talukas.

There were many difficulties in carrying out these suggestions. These difficulties were pointed out by Mr. Musto, Executive Engineer, in his No. 71, dated the 18th January 1919, to the address of the Chief Engineer in Sind. Messrs. Baker and Lane recorded almost identical views on the difficulties involved, and a conference was held on 3rd February 1919 at Government House, Karachi, under the presidency of the Commissioner in Sind to go into this question more fully.

As a result of this conference Mr. Musto was instructed to submit his proposals for the revised Right Bank Canals systems.

These were submitted to the Chief Engineer in Sind under Mr. Musto's No. 414, dated the 29th March 1919, with full notes and plans explaining the proposals. They consist briefly of the following:—

The whole area that can be commanded should be divided into three separate areas or commands, each supplied by an entirely separate system of canals, the heads of which would be above the barrage.

The northern and western area, which is suitable for perennial irrigation, should be supplied by a perennial canal styled the North-Western Canal. The central area, which is not suitable for perennial irrigation, being principally a rice-growing tract, should be supplied by a large canal, styled the Central Canal, which would flow only during the Kharif season, say from April to September.

The southern and eastern area, which is suitable for perennial irrigation, should be supplied by a separate perennial canal, styled the South-Eastern Canal. The commands of all canals and of all their branches were arranged so as not to interfere with the natural drainage lines of the country and these were all to be conserved and led into the main valley line running from north to south, which empties into the Muncher Lake. A large channel or drain was proposed to be cut from the Muncher Lake to the river in order to drain the latter into the river. Ample provision was thus to be made for thoroughly draining the irrigated areas.

Full proposals were also made for dealing with the great hill floods which now occasionally sweep over parts of the commanded areas. In places these floods were to be diverted outside the commanded area to places where they would do good and the balance provided with ample drainage lines to carry it to the Muncher Lake and thence to the river.

The details of these proposals are too lengthly for description here.

The North-Western Canal command included an area of about 400,000 acres, half in Sind and half in British Baluchistan, which was not included in the 1909 project, but which can now be given perennial water, owing to the changes in the site and height of the barrage. Messrs. Baker and Lane did not agree with the necessity or desirability of including this area, though they admitted it was excellent culturable land. The Agent to Governor-General in Baluchistan in his letter No. 2394/R., dated 27th May 1919, however, expressed the desire that his administration should be associated unreservedly in the investigation of this proposal to irrigate part of British Baluchistan (Nasirabad Tahsil) from the barrage, and expressed his readiness to accept the Sind conditions as to rice cultivation and revenue rates.

Mr. Musto's proposals were forwarded to Government, through the Commissioner in Sind, by the Chief Engineer in Sind, under his No. S.-227, dated the 15th April 1919, with his general support to all the proposals.

The Commissioner ir Sind generally concurred in the remarks of the Chief Engineer in Sind, and pointed out the possibility of having to compensate certain persons whose villages were built alongside existing canals which are to be abandoned, even although such persons will be given a better supply from other new canals.

Mr. Musto's proposals were returned by Government to the Commissioner in Sind under P. W. D. No. W.I.-10381-M., dated 30th July 1919, with the general acceptance by Government of the proposals made in Mr, Musto's No. 414, dated the 29th March 1919.

With regard to his proposal to construct a branch of the North-Western Canal for the irrigation of the southern part of Nasirabad Tahsil in British Baluchistan, Government stated that this question should not be taken up at present, because its consideration would delay the completion and submission of the Sind projects. In submitting these projects to the Government of India that Government would, however, be informed that it seems possible to provide perennial irrigation for the southern part of Nasirabad Tahsil and that if the Baluchistan Agency so desire, the preparation of plans and estimates for the necessary works will be taken in hand by the Government of Bombay. In the meantime the Commissioner in Sind was requested to obtain the views of the Baluchistan authorities on the proposal.

Apparently, therefore, Government has overlooked, or is not aware of, letter No. 2394/R., dated 27th May 1919, to the Commissioner in Sind from the Agent to the Governor-General in Baluchistan, in which he definitely asks to be associated in the project, and expresses his approval of the proposals made by Mr. Musto in this matter.

This point has to be brought to the notice of Government.

APPENDIX B.

Report of Secretary of State's Committee, appointed to investigate the scheme for the Sukkur Barrage and Rohri Canal.

SUMMARY OF REPORT.

PARAGRAPH.

1. List of documents referred to Committee for Report. Classified.
2. Scope of Committee's labours and difficulties due to disagreement of the Engineers submitting the projects.
3. Differences of opinion regarding effect of Punjab and North-West Frontier Canals on the supply in the Indus at Sukkur.
4. "The interests of Sind" defined, and the nature of its present irrigation requirements. The critical months of June and September.
5. Mr. Hill's estimate of lowering of river at Sukkur in September, due to Punjab withdrawals and Sir John Benton's opinion thereon.
6. Dr. Summer's contention and figures showing that the construction of river bunds has lengthened the period of high river.
7. The Bukkur gauge records; their long continuity and value: question of the reliability of the gauge readings.
8. Committee's comparison of river levels in decades from 1872 to 1902-10.
9. Extract from Indian Irrigation Commission's report of 1901-03, regarding effect of Punjab withdrawals, showing that the inundation canals have not suffered, though the Eastern Nara and Fuleli Canals may have done so. Heroic measures not considered necessary to benefit these two canals.
10. Committee reviews Sir John Benton's remarks on above, in which he refers to further withdrawals of the triple canals and Upper Swat, stating that the minimum discharge of Indus at Sukkur is 19,000 to 20,000 cusecs, and not 30,000 to 35,000 as taken by the Indian Irrigation Commission.
11. Committee remarks on effect of withdrawals in Punjab.
12. Points out that the proposed barrage is already too late to prevent loss to Sind Canals from Punjab schemes. They cannot recommend project for this purpose, especially as it only serves part of Sind and leaves other parts no better off.
13. Committee remark on seepage question that although it no doubt increases cold weather supply in Indus, they have no exact information, and so long as Sind remains an inundation country it is not important.
14. Committee considers whether barrage can be recommended on other grounds shows that it is not so important for Sind as for Punjab where each system depends on one river alone, while Sind gets combined effect of five rivers, which never fail simultaneously. The barrage must be considered as a desirable improvement, to be financed from loan funds, and must therefore be remunerative.
15. Shows that the project with 15-year programme is unproductive, and with 13 and 16-year programmes profit is very small and depands on accuracy of estimates.

PARAGRAPH.

16. Barrage is item of great uncertainty. Discusses advantages and disadvantages of site selected, effect of earthquakes, retrogression of levels, and difficulties of construction above gorges.

17. Shows that Government of Bombay recognized these disadvantages and difficulties and the unreliability of the estimates. The Government of India had left open the question of alignment and design of barrage, but Committee consider it essential that all details of design and construction be previously considered.

18. Committee discusses difficulties of construction, and the proposed methods of using cofferdams. They anticipate difficulties in withdrawing piles, and consider piling at ends of cofferdams essential. They refer to difficulties at Esna Barrage on Nile, with construction cofferdams. Points out that no provision has been made for the earthwork in slopes of cofferdams.

19. Refers to difficulty of estimating cost of pumping and refers to experience at Esna. Considers ample provision should be made.

20. Considers that a great excess may be necessary over estimated cost—

Barrage should in any case have Stoney's gates right across river; the alternative design of a weir with shutters should *not* be adopted.

A rate to cover cost of maintenance of barrage and training works, should be included in the rate of working expenses per acre of cultivation.

The project must include provisions for a new head from barrage to supply the Right Bank Canals. If this makes project unremunerative, it is all the more necessary to include it, to show true financial aspect.

The Ghotki floods should also be considered as these affect the Eastern Nara Project for which 33 lakhs has been provided.

The Committee remark on possibility of period of works programme not being attainable, and to increase of interest charges which would result.

21. Remarks on Rohri Canal Project—

Points out that canal as designed does not agree with requirements of the revenue estimate.

Draws attention to the estimate of increased revenue from Sukkur Canal and shows that this may not be realized, as it is not shown whether barrage will give improved supply.

22. Committee unanimously of opinion that complete scheme as submitted will not be a productive work.

23. Discusses Dr. Summer's alternative project.

Sir John Benton and Mr. Hill do not accept his views, and hold that Rohri Canithal wout barrage would not get its supply and would silt heavily.

24. Points out certain misunderstandings regarding bed level of Rohri Canal, considers that if canal would not silt nor be affected by sand shoals in river, it would work successfully and be a productive work, but for other reasons they are unable to support this project.

25. Committee explains situation that would be created in Sind by Rohri Canal without barrage. Shows that this canal would be in same position as to supply, as the Eastern Nara which is unsatisfactory, and the canal could not be regarded perennial.

PARAGRAPH.

26. It must therefore be considered as an inundation canal and as such is not productive.

27. Remarks on proposal to make Summer's Supply Channel to test silting danger and shows it would be useless for the purpose.

28. Committee concludes that the risks of failure of Rohri Canal without barrage are too great to justify the experiment, and that if ever constructed, both canal and barrage should be simultaneously completed.

29. Summarises Committee's conclusions as follows :—

   (1) No evidence that Sind has or will suffer to such an extent as to necessitate perennial irrigation schemes for that reason alone.

   (2) The projects as submitted do not show a productive work.

   (3) Dr. Summer's proposal for canal alone is too risky for acceptance.

30. Committee shows that it was not surprising that their criticisms are destructive.

They argue that as Sind is not liable to famine, nor over-populated; the cultivators are indolent, and satisfied with present system; only a productive project can be justified, and for this a large area of new irrigation must be included, not less than 500,000 to 1,000,000 acres.

31. The increase of revenue to meet great cost of new works must be obtained chiefly from improvements to supply of existing irrigation. Hence very difficult to make a productive project.

32. Committee comment on suggestion for *Rohri Canal followed by barrage* and consider that although risky, it presents more favourable chances of a remunerative project than any other alternative, but they have not sufficient forceasts of revenue and cost to examine it.

33. Committee reverts to whole scheme submitted for sanction and considers it unproductive and premature, but recommends that a complete project for perennial irrigation be prepared and kept in readiness in case of need. If necessary the productive works of Punjab, Sind and North-West Provinces might be considered in combination. No urgency about Sukkur scheme and no finality yet reached on design of barrage and capacity of canals.

34. Committee suggests possibility of finding better site for barrage, somewhere downstream of the gorge. The scheme should include the provision of a feeder for the Ghar and Western Nara Canals.

35. Suggestions for alignment and design of barrage.

36. The advantages of the lower site.

37. Disadvantage of lower site is exclusion of Eastern Nara and Sukkur Canals. These must be carefully investigated and if possible provided for.

38. Effect of Punjab withdrawals must be closlely examined, to show if *Kharif* supply to Sind is affected. If so, works could be justified as protective even if not productive. But otherwise perennial irrigation can only be justified if productive.

SUPPLEMENTARY MEMORANDUM BY SIR JOHN OTTLEY.

SUMMARY.

1. *Unsuitability of site for barrage above gorge.*

He goes further than the Committee in condemning site, and would under no circumstances sanction a barrage at this site—

This prohibits linking up Eastern Nara with barrage.

PARAGRAPH.

2. *The Eastern Nara System—*

Exclusion of Ghotki floods should be undertaken.

Dredging in channel and in river should be provided for.

Canalization of the Eastern Nara River should be considered before widening of the supply channel is undertaken.

He considers there should be no insuperable difficulty in giving required supply without a barrage.

3. *Gauge at Sukkur—*

Recommends that a self-registering gauge be fixed at Bukkur.

4. *Suggestions for selecting alternative site for barrage—*

Not necessary to find a stable reach of river for this as any point can be made stable with weir and guide banks.

Essential points for new site, detailed.

If suitable site is found, both ordinary and self-registering gauges should be installed there and cross sections and discharges observed there.

Necessity of definitely deciding on size of Rohri Canal and Right Bank Canals before preparing project for barrage.

Suggests possibility of "waterproofing" the canals and thereby decreasing size.

Is prepared to submit design for barrage if data are supplied to him.

5. Suggests interchange of Irrigation Officers between Punjab and Sind, in order that Sind Officers may acquire experience of perennial canals.

REPORT

OF THE

SUKKUR BARRAGE COMMITTEE

AND

SUPPLEMENTARY MEMORANDUM

BY

SIR J. W. OTTLEY.

1913.

REPORT OF THE COMMITTEE APPOINTED TO INVESTIGATE THE SCHEME FOR THE SUKKUR BARRAGE AND ROHRI CANAL.

The documents referred to the Committee for report may be conveniently classed under the three following heads :—

(a) The Government of India Despatch No. 30 P. W. of the 24th October 1912, and enclosures, forwarding for sanction an estimate amounting to Rs. 7,81,70,727 for the construction of a barrage across the Indus at Sukkur and of a very large irrigation canal, called the Rohri canal, with its off-take from the river above it ;

(b) Dr. Summer's publications dealing with his alternative scheme for the Rohri Canal alone at a cost of about five crores of rupees the construction of a barrage being postponed until such time as it may be found to be necessary ; and

(c) The Notes by Sir Steyning Edgerley in which he calls attention to the position of the Larkana Collectorate on the right bank, and comments on the effect of the withdrawals of water in the Punjab.

2. The great variety and complexity of the questions involved in these papers have imposed on the Committee a task of much labour and difficulty. It has not been merely a case of the labour unavoidably entailed by a detailed and critical examination of the voluminous enclosures to the Government of India's Despatch ; but in addition there have been the difficulties caused by the manner in which the case has been presented, the want of finality in the proposals, the extraordinary disagreements in the opinions expressed by the engineers employed on the project, and above all the absence of indisputable facts in regard to many points of vital importance.

3. As an instance of the above, attention may be drawn to the differences of opinion and the evidence afforded on the subject of the effect of the canals in the Punjab and the North-West Frontier Province on those in Sind. The abstraction of water from the Indus and its tributaries by the perennial canals north of the Sind border is advanced as the main justification for the costly project recommended for sanction, and the Committee quite agree that the point is one of primary importance. In fact very early in the course of their meetings they were convinced of the necessity of giving prominence to this very question. It seemed to them that if, in an almost rainless tract of country such as Sind, where cultivation is almost wholly dependent on artificial watering of the soil, the irrigation conditions had been, or were likely to be, adversely affected to any appreciable degree, a project, or projects, for saving the situation would be imperatively demanded quite apart from the commercial considerations of the projects in themselves. On the other hand, if no such injury has taken place, or is threatened, any work such as that proposed is of the nature of an improvement, and its sanction depends on its fulfilment of the definition of a productive public work. The Committee are not alone in this opinion Sir Steyning Edgerley has remarked "if the fall of the river at Sukkur is *not* to be feared most of the reason for the scheme fails." Mr. Lawrence at the Karachi conference of February 1910 said that "if the Punjab draw-off will affect Sind to the extent Mr. Hill predicts, then the barrage is a matter of life and death. If not, then it has to be considered "simply as an

improvement." Mr. Lucas, the Commissioner in Sind, in his evidence before the Committee, was equally emphatic. He said that he and his revenue officers had approached the scheme on the understanding that the interests of Sind were seriously threatened ; but if this were not the case there was no necessity for it : it became purely a question whether the work promised to be so remunerative that it was desirable for that reason alone.

4. It therefore appeared to the Committee to be essential to arrive at a clear understanding of the term " the interests of Sind," and to what extent these interests had suffered in the past, or were likely to suffer in the near future. With regard to the first of these questions, it may be said to be admitted on all sides that, owing to the rainless nature of the Sind climate, the agriculture, amounting to nearly 3½ millions of acres annually, is entirely dependent on the irrigation effected by a network of inundation canals, which depend for their supply on the height of the water in the Indus during the inundation season, or the period between the 1st June and 30th September. It is true that, by lowering the beds of some of the canals, it has been found possible to pass a comparatively small volume of water down these channels in the cold weather ; but such canals cannot be classed as perennial, as the term is generally understood, and it may be said that, except in the case of the Jamrao canal, which is served by a weir across the Eastern Nara, such *rabi* cultivation as there is in Sind is for the most part brought to maturity by other means than that of canal water supplied during the cold weather. It is also true that if water could be made available earlier than June and later than September it would be beneficial, but in the case of inundation canals, as those in Sind are, the inundation season of the river can alone be regarded as the reliable period of supply. Of this season it is unnecessary to investigate any question of loss of level in the Indus during July and August, as the discharge of the river in these months is so enormous that the volumes of water drawn off by the canals would not appreciably affect the levels. The critical months then are June and September in fact they were alluded to as such by Mr. Lucas at the Karachi conference. " What," he asked the engineers, " would be the state of the Sind supply without the barrage thirty years hence, especially in the critical months of June and September ? "

5. In reply to this question, Sir John Benton said he had no figures for June and September " but probably the supply in these months would not be appreciably affected. It would be abundant. The critical time is from October to March." Mr. Hill, on the assumption that the total withdrawal in September would eventually be 40,000 cusecs, expressed the opinion that the river levels would be reduced as follows :—

From 10 feet to about 9¼ feet.
,, 9 feet to about 8 feet.
,, 8 feet to about 6 feet 10 inches.
,, 7 feet to about 5 feet 9 inches.

Sir John Benton said that Sind would certainly be detrimentally affected, but not to the extent apprehended by Mr. Hill. It is evident, however, from his references to the *rabi* season October to March, and to *rabi* supplies, that he was thinking of Sind irrigation on the analogy of Punjab perennial canals, and had disregarded the fact that Sind is an inundation canal country and that any analogy between it and the Punjab is impossible. In his review of 1912, he returned to his recommendation of the construction of weirs " if Sind is not to be ruined," but the Committee cannot find that he has based his warnings on any such facts as they could unhesitatingly accept.

6. On the other hand, Dr. Summers has contended that, owing mainly to the construction of the Indus embankments, which synchronise fairly closely with the opening of the Punjab perennial canals of the past, the inundation season, so far from having been curtailed by the withdrawals in the Punjab, is actually some three weeks longer than it was before the Punjab

canals were brought into operation. The following figures, showing a rise in the water-level throughout the whole inundation season, indicate that his contention is well-founded :—

Average levels at Bukkur during the periods shown.

Period.	Average for period of 30 years before construction of embankments, 1848—77.	Average for period of 30 years after construction of embankments, 1878—1907.	Rise in water level.
	(a)	(b)	
1st to 15th June	192·9	194·1	1·2
16th to 30th June	194·3	195·6	1 3
1st to 15th July	195·4	196·9	1 5
16 to 31st July	196·1	197·8	1·7
1st to 15th August	196·7	198·4	1·7
16th to 31st August	196·1	198·1	2·0
1st to 15th September	194·1	195·8	1·7
16th to 30th September	192·0	193·3	1·3

(a) *Vide* Table, page 20, of volume 12. (b) Derived from Appendix II, volume 12.

The further table below exhibits similar information in a different way, and shows that the rises in level in the later period are due to the construction of the river embankments :—

Period.	No. of days (1st June to 30th September) of gauge readings in excess of.					
	8 feet.	9 feet.	10 feet.	11 feet.	12 feet.	13 feet.
32 years, 1848—79 (a)	116	100	79	59	27	....
31 years, 1880—1910 (b)	112	102	89	75	62	44
Differences in later period	—4	+2	+10	+16	+35	+44

7. The above figures are based on the gauge readings of the Indus at Bukkur. This gauge was apparently established on the rock below the fort on the Bukkur island in the year 1848. It has been read regularly, and with the same zero (R. L. 184·44), ever since ; and the readings, extending over a period of 65 years, should therefore constitute a very valuable record. The Committee, however, think it right to mention that some doubts have been expressed regarding the reliability of the readings ; but, whatever the errors arising from various causes may be, the figures over a very long range of years may be held to afford a sufficiently accurate indication of the levels of the Indus during the periods considered, and they do not show that the openings of the various canals in the Punjab have injured Sind.

8. The Committee have also made a careful examination of the Sind Administration Reports for the 39 years from 1872-73 to 1910-11. During this period there were 11 very good years, 13 good years, and 3 fair years, a total of 27 ; against 5 poor and bad years, and 7 very bad years, a total of 12. In other words, there were rather more than two favourable years to one unfavourable year during the whole period. Examined by decades, it will be seen that these proportions have been fairly well maintained, and that there is no reason to suppose that the conditions of irrigation in Sind have been steadily changing for the worse.

1872—81	7	favourable to	3	unfavourable	years.
1882—91	7	"	3	"	"
1892—1901	6	"	4	"	"
1902—10	7	"	2	"	"

(a) Figures deduced from the chart published in Sind Irrigation Report for 1879-80.
(b) Average figures obtained from charts published with annual Sind Irrigation Revenue Reports.

9. It may also be noted that the Indian Irrigation Commission of 1901-03, after a very close study of the circumstances of Sind, reported in Part II, paragraph 93, as follows :—

> "It is the opinion of the Sind Irrigation Officers who came before us that the supplies to the canals have not been appreciably affected by the withdrawals from the Punjab rivers. The full monsoon supplies of the canals which have been opened in the Punjab during the last 20 years amount to 28,000 cusecs ; but such supplies are only run when the rivers are very full, and the withdrawals would not seriously affect the levels in the Indus during the inundation season. The progressive increase in the irrigated area during the same period shows that the efficiency of the canals has not been affected. The *rabi* supplies of the new Punjab canals would amount to about 15,000 cusecs, but the present minimum cold-weather supply of the Indus at Sukkur is from 30,000 to 35,000 cusecs. During this period perennial supplies have been given to the Eastern Nara and Fuleli Canals by lowering their beds or preventing silt deposit, and these supplies may no doubt be affected by future Punjab withdrawals ; but the majority of the Sind canals like the inundation canals in the Punjab have never had cold weather supplies at all. As far as existing Sind cultivation is concerned, heroic measures are not required, and there is, as we have shown, great room for extending existing cultivation by working on existing methods."

10. The Committee are aware that Sir John Benton has not overlooked these remarks. He has contended that the Commission were under the impression that the minimum supply of the Indus was 30,000 to 35,000 cusecs, whereas it is only from 19,000 to 20,000, and that since the time of the Commission's report two new irrigation projects, the triple canals and the Upper Swat, have been sanctioned, and will shortly be in operation. With reference to these contentions, Sir John Benton is doubtless right regarding the absolute minimum discharge of the Indus, but the Commission were obviously referring to an average minimum supply, and with an absolute minimum of probably very short duration the existing Sind irrigation is in no way concerned. And though the Commission did not know what form future schemes might take, they were very well aware that further schemes were in prospect, in fact they had before them at the time the Lower Bari Doab project from the Sutlej, which the triple canals ultimately replaced. The Commission apparently considered, not without reason, that if the larger withdrawals of the past had caused no injury to Sind, it was unlikely that future withdrawals would have a disastrous effect, and that whatever the effect, it might be minimised by recognising Sind to be an inundation canal country, and improving the existing irrigation by existing methods instead of resorting to heroic measures.

11. It has to be borne in mind that although the abstraction of water in the Punjab must necessarily to some extent reduce the volume carried by the Indus in Sind, it does not follow that the amounts so withdrawn by the Punjab represent the actual loss at Bukkur, or that such reductions are necessarily injurious to Sind. It is well known that in the most scientific modern canals, maintained in the highest state of efficiency, the loss of water by absorption is exceedingly serious ; and it must be conceded that a similar but vastly greater loss must occur in the case of water passing for hundreds of miles in the wide and sandy beds of rivers in the arid plains of India. It may be accepted as certain that the actual reduction in the discharge of the Indus in Sind has never in the past amounted to 25,000 cusecs, and will not in the future amount to more than some fraction of 40,000 cusecs. What the actual reduction has been in the past, or will be in the future, it is impossible to say ; but the lowering of the water levels will in any case be considerably less than Mr. Hill has anticipated.

12. The two new projects to be shortly brought under operation are the triple canals and the Upper Swat, and it is desirable that the effect of these works should be carefully watched in order that any necessary measures for the timely protection of Sind may be under-

taken. It may of course be urged that in the event of Sind being prejudicially affected any delay in the sanction of the Sukkur scheme would cause the remedial measures to be too late. But in that sense it is already too late. The Committee understand that the Upper Swat canal will be opened in April next, and the Upper Jhelum, the last link of the triple series, in the succeeding autumn. The Committee are aware that these formal openings do not imply immediate development of the works in question, but development will have taken place many years before the Sukkur project can be completed. And even then the barrage will be only a partial remedy. It will safeguard only that portion of Sind served by the canals dependent on it for assured supplies; it will not improve the supplies to the canals in Upper Sind, nor to those below the barrage, which may on the contrary be detrimentally affected. If there were any such urgency of action the project should have been submitted long ago with far more convincing proof of its necessity. The Committee are not, however, satisfied that Sind is threatened with any calamity. There may be, for want of complete information, shortcomings in the reasons they have advanced; but on such information as is contained in the papers before them, they are unable to recommend that a project calculated to cost eight crores of rupees must, apart from any other consideration, imperatively be sanctioned for the protection of existing irrigation in Sind.

13. It may here parenthetically be mentioned that, on the subject of the supplies of water received by the Indus in Sind, much has been said in the papers on the question of seepage. The Committee therefore touch on the point, although they do not consider it of importance at the present time. There is little doubt that the seepage back to the rivers swells the volume of water carried by the Indus in the cold weather, and that this accession of supply will gradually, but surely, increase; but the Committee have no exact information on the subject before them, and it seems to them that, as long as Sind remains an inundation canal country, the matter possesses little more than an academical interest.

14. The Committee next proceed to the question as to whether sanction to the estimate can be advocated on other grounds. They understand that the ultimate objective in Sind is a comprehensive scheme for dividing the Indus into three reaches of suitable lengths, each with a barrage or weir across the river, and a group of canals with their off-takes above it. It is undeniable that such a scheme must be of the nature of an improvement on existing methods of irrigation; but the necessity is less urgent than in the case of the inundation canals of the Punjab. The Indus in Sind receives the combined waters of all the Punjab rivers. The Swat river, the Jhelum, the Chenab, the Ravi, the Beas, and the Sutlej all feed the Indus. They all have their separate catchment areas, and each river is subject to favourable or unfavourable conditions of supply in any year, but the conditions in one catchment area may be favourable and in another unfavourable, and the Indus fed from so many sources runs far less risks than any of its affluents separately considered. The differences between good and bad years in Sind are, therefore, as pointed out by the Irrigation Commission, much less marked; but a scheme for harnessing the Indus to the service of the Sind canals, subject to all the vicissitudes of inundation channels, has nevertheless to be regarded as a desirable improvement. It would mean that the canals would receive assured supplies, that the cultivation of cotton, already an important crop in Sind, would be fostered and encouraged, that the maturity of the *rabi* crop would be secured, that large areas of lift irrigation would be converted to flow, and that certain areas of land, now uncultivable, would be brought under command. It has, however, to be realised that the expense, both initial and in subsequent maintenance, of constructing weirs on a deltaic river of the size of the Indus would be very great. It would be very much greater than that of similar works on its tributaries in the Punjab, where perennial canal projects have been so successful. The schemes would have to be financed from loan funds, and for that purpose it would have to be shown that the works are likely to be remunerative. The point before the

Committee is then to ascertain whether the Sukkur project, the first of the perennial irrigation schemes in Sind, can be safely regarded as a productive public work.

15. The forecast shows that, excluding enhanced land revenue, the returns per cent. are 4·28, 3·47 or 4·17 according as the period of construction extends over 13, 15, or 16 years. If the enhanced land revenue be included the returns are somewhat more favourable; but it is understood that no just claim can be made to this credit and that the lower figures are those for consideration. With these figures, the project with the 15-year programme is unproductive, and in the other two cases the margin of profit is so small that only if the estimate is extraordinarily accurate can the scheme be regarded as remunerative.

16. Of the two main heads of the estimate, the canal and the barrage, the latter is naturally enough the item of the greater uncertainty. Irrigation engineers have now considerable experience of the construction of weirs across rivers, but the barrage is a work of a kind never previously attempted in India. The site chosen, that at Sukkur, is geographically convenient and desirable, and importance seems also to have been attached to the confinement of the river to a gorge and to the presence of rock. These cannot, however, be said to be unmixed advantages. It is above Sukkur that the Indus is particularly liable to avulsion, That risk obtains whether the project is carried out or not but it is obvious that after the expenditure of eight crores of money there would be greater interest at stake, and it is conceivable that any carelessness in working the gates, or an accident to the machinery for lifting them might greatly increase the danger. The rock is of bad quality, full of fissures, and very irregular in level. There is much uncertainty as to the depth to which the foundations would have to be carried and therefore to the expenditure on the foundations. Below the line of the proposed barrage is a rift said to be from 120 to 150 feet deep; it would seem that this was due to the occurrence of an earthquake some 900 years ago, and should an earthquake again occur it would be at the rock out-crop that its effects would be most severely felt. In any case the existence of the deep ravine below the site constitutes a danger, and retrogression of levels, regarding which nothing has been said, may be feared. In fact the best that can be said for the rock is the plea advanced by Mr. Hill that in a sense it is more stable than sand. Moreover, the great depth and high velocity of the water in the gorge mean great difficulties in constructing and maintaining the necessary cofferdams and an absolutely unknown expenditure in pumping.

17. These points have not escaped attention in India. In their letter of the 5th December 1910, the Bombay Government said: "Having regard to the magnitude of the project and the impossibility of foreseeing the difficulties and problems which may arise in the course of a work intended to dam up the waters of a vast river like the Indus, the Governor in Council feels great diffidence in accepting any estimate of the barrage however skilfully it may be prepared and however great the talent and experience of the engineers engaged, except as an indication of the minimum cost likely to be incurred." And, again, "The Governor in Council considers that it would be safe to assume that the actual cost of the barrage will not exceed double what is now estimated." The Committee entirely agree that however carefully the estimate may be framed, there will be in the actual execution of the work many items of unforeseen expenditure, but that only makes it the more imperative that the estimate should be prepared with the greatest possible prospects of finality and completeness. The Committee find that there have been several alignments and designs. The present Inspector-General has proposed a further change in alignment, and in the matter of design, the last—that of Sir John Benton—is admitted to present certain difficulties and risks of failure. On that account the Government of India have proposed to leave the question open for further discussion. The Committee cannot think that such a position is satisfactory. The provision made for the work by the Government of India is Rs. 2,65,68,571, and to this sum has to be added the 17 lakhs intimated by the Government of Bombay* on account of insufficiency of rates; the

* Viceroy's telegram to Secretary of State, dated 25th September 1913.

total will therefore amount to nearly two millions sterling. With a project so costly and so perilously near the margin of a productive work, it is essential that all details of design and construction should be previously considered. To postpone such matters for subsequent discussion is to court a revised estimate.

18. Apart from questions of alignment and design the Committee doubt whether the engineers have sufficiently appreciated the difficulties of construction at such a site. Their attention has been drawn to the divergence of opinion between Messrs. Hill and Beale regarding the provision made in the estimate and the method proposed for constructing the cofferdam to enclose the foundations during execution. Mr. Beale, who prepared the estimate under instructions, accepts no responsibility for this very important part of the construction work, and the Committee feel there is much to be said from his point of view. From the very short description given in the reports it is understood that lateral cofferdams of earth will be made, and that lines of interlocking piles will be driven through the sand where practicable into rock at such a distance from the area to be cleared as to allow of a 6 to 1 sand slope after excavation is completed. At the end of each season's work it is proposed to withdraw the piles for further operations. The Committee anticipate difficulties in removing the plies, and no terminal piling seems to have been contemplated, although it will certainly be required on most of the work, as the distance between the lateral banks will be roughly about 500 feet. The barrage is approximately 5,400 feet long, and the work in the river-bed is calculated to occupy at least five years in execution. Recent experience in constructing the Esna barrage on the Nile, where the foundations throughout are on fine sand, shows that cofferdams may be a very serious difficulty and often require stone for protection, and sand-bags for construction. At the site of the Sukkur barrage, the conditions of depth, velocity and discharge are far less favourable, there will probably be five seasons' work instead of three, and it is inevitable that the construction of the cofferdams for diverting the river and enclosing each seasons' work will present many difficulties. The detailed estimates show that provision has been made for the piling, but apparently nothing has been entered for the cofferdams. The Committee are of opinion that substantial cofferdams will be necessary at all stages of the work, and that their construction will be necessary at all stages of the work, and that their construction will in many cases be extremely difficult. They therefore consider that the estimate cannot be held to be complete without ample provision for the construction and removal of this item of the work.

19. The Committee are not surprised to find a great difference of opinion on the subject of the pumping allowance. This item must in any case be largely a matter of guess work. Comparisions with other works, even in the immediate neighbourhood, are unreliable, and nothing but actual experience during the execution of the work can be of any value. An accident, such as a breach of the cofferdams, might cause an extra season's work, and this would completely upset any calculation. In drawing up the contract for the construction of the Esna barrage on the Nile, the engineers and contractors differed so widely in opinion as to the cost of pumping that it was agreed to omit that item altogether, and to insert a clause providing that the contractors should be paid at certain rates per pump per day according to the sizes of pumps employed. For the purposes of a project estimate, however, it is necessary to enter some figures, and the Committee are of opinion that a very liberal provision should be made.

20. Briefly, taking the many serious difficulties presented by the site, and the estimated figures for construction, the Committee are of opinion that, even with the extra 17 lakhs proposed by the Government of Bombay the estimate will be exceeded, and the excess might be very great, far more than would be sufficient to remove any claim to productiveness the scheme might otherwise possess. There are in addition the following considerations.

The Committee are of opinion that, whatever the design in other respects, the barrage should be provided with Stoney's gates right across the river, and that the alternative of a weir with shutters should not be adopted. This is necessary in order to ensure a complete command of the river at any time of the year, especially as canals on both banks have to be supplied. This point is referred to in paragraph 12 of the Government of India's letter, but the Committee consider that it would add to the expense of Sir John Benton's design.

The maintenance of the barrage and training works will be a significant item of expense. It is not usual to capitalize such expenditure as a part of the initial outlay in the way Dr. Summers has done, but the working rate per acre should include such charges, and the acreage rate adopted in the project apparently excludes the maintenance of the head-works.

The project estimate should include the cost of linking up the right bank canals, the Ghar and the Western Nara, with a head above the barrage. Sir John Benton, in his evidence before the Committee, explained that the right bank canals had been omitted because (1) no additional revenue could be obtained from them, and (2) it would have meant too much work in progress at the same time. The Committee are unable to accept these reasons. If the barrage project is necessitated by the effect of the Punjab canals, the Ghar and Western Nara must be held to suffer in common with other canals in Sind, and they will suffer still more if the barrage at Sukkur is constructed. The feeder for these two canals should therefore form a part of the scheme. The inclusion would not necessarily mean an addition to the work in progress at any one time. The rate of progress of work in the field depends on the establishment and labour available, and whatever that rate may be it is desirable that a project should be complete in all respects. Moreover, if the work in connection with the right bank canal means additional expenditure without additional revenue, it is all the more necessary to include it if only to exhibit the true financial aspect of the complete scheme.

The question of the Ghotki floods also demand some consideration. The exclusion of these floods from the Eastern Nara is very desirable quite apart from the present project, but inasmuch as the estimate provides 33 lakhs of rupees for widening the Eastern Nara supply channel there will be more at stake if this system of irrigation is not adequately protected.

The Government of India apprehend no difficulty in achieving the 13-year programme of construction, and the Committee do not desire to contest this view more than to utter a word of warning. It does not imply an impossible rapidity of progress, but the expenditure will have to be maintained at an unusually high rate, and it is possible that the attempt may fail, in which case the accumulation of interest charges will affect the financial position for the worse.

21. The Committee have no remarks to offer on the estimate of the Rohri canal. Unlike the barrage it is a work of a straightforward character, and it appears to have been estimated by Dr. Summers with great care and completeness. Nor are the Committee in a position to comment on the anticipated revenue returns, which have been dealt with so exhaustively by the Commissioner. But there are two points they think it is desirable to mention. The canal estimate is that of 1909, and it provided for a canal to irrigate equal areas of *kharif* and *rabi*, but the revenue returns are based on figures of larger *kharif* and smaller *rabi* given by the Commissioner a year later. The size of the canal is fixed by the *kharif* requirements, and the 1909 design does not therefore provide for the *kharif* area laid down by the Commissioner. If then the Commissioner is right in his forecast, the revenue returns may prove to have been over-estimated. To reduce the size of the canal still further in order to save 50 lakhs of rupees as proposed by the late Inspector-General of Irrigation would only add to the discrepancy. The Committee cannot support this proposal and, on the figures before them, consider it might adversely affect the revenue receipts. The case is hardly satisfactory as it stands. It means that the design of the canal is not in consonance with the revenue authority's figures and that, even in such an important matter as the discharging capacity of an enormous canal, it is proposed to defer the ultimate decision until after the estimate has been sanctioned.

The second point alluded to is that of the 1¼ lakhs extra revenue to be derived from the Sukkur canal. Dr. Summers informed the Committee that this additional annual credit was entered by the Commissioner under a misunderstanding. Mr. Lucas had been led to believe that the supply to this canal would be materially improved, but Dr. Summers was of opinion that "the construction of the barrage as proposed would result in the closing of the upper head of the Sukkur canal, and would, as a matter of fact, damage the canal, and even turn some flow irrigation into lift." The Committee agree that the right bank up stream guide-bank must tend to the silting up of the river bend behind it, in fact this is one of the objects of such embankment; and in that case the upper head of the Sukkur will in course of time become inoperative. The Committee have not, however, sufficient information to enable them to judge how far the irrigation of the canal will be affected by the changed conditions. It is a point for local examination but if this extra revenue is not to be earned, the productiveness of the scheme will be still further reduced.

22. Taking all these considerations into account, the Committee are unanimous in their opinion that the project submitted for sanction will fail to satisfy the requirements of a productive work.

23. The next point is that of Dr. Summers' alternative scheme. He does not base his recommendations on the plea of withdrawals of water in the Punjab; on the contrary, he contends that Sind has not suffered in the past and will not suffer in the future. He is of opinion that any project which provides a barrage to be constructed concurrently with the canal, must fail to be remunerative and he claims for his canal, without a barrage, that it will work, that it will be productive, and that it is eminently desirable as affording a sure supply of water to 5,000 square miles of the best soil in Sind, thus enabling the tract to grow from half a million acres upwards of the finest cotton in India. Sir John Benton and Mr. Hill, on the other hand, do not accept Dr. Summers' views. They are of opinion that, without a barrage, the canal could not derive the necessary supplies from the river, that it would probably silt heavily, and that it would therefore prove a financial failure.

24. In examining this question, the Committee would like to draw attention to two misapprehensions that have occurred regarding Dr. Summers' work. In paragraph 151 of his Final Review, the late Inspector-General alludes to the "very regrettable clerical error" in assuming that the head of the canal is 1·2 feet lower than on the project plans, &c. Dr. Summers, in his evidence before the Committee, showed, however, that there had been no such error. The bed level of the canal was deliberately, and with good reason, lowered from R. L. 176·9 in the original project to R. L. 175·7 in the new project. The latter figure is that quoted in the list of levels given in paragraph 42, and is repeated in the headings of the statement in Appendix II of Volume 12 and Dr. Summers drew attention to the provision made in column 7 of the statement on page 92 of the same volume for the "extra cost of deepening by 1·2 feet from head of supply channel to 31st mile." The Committee consider that Dr. Summers should have given great prominence in his report to so important a change, especially as new plans were not submitted nor were the originals corrected. It is not sufficient that important modifications in design should be discovered from figures buried in tables which may fail to arrest attention. There was, however, no other error; the change was intended and the cost was provided for in the final project.

The second point alluded to is the subject discussed in Part XVIII of Sir John Benton's Final Review, which in the Committee's opinion takes an unnecessarily unfavourable view of the working ot the canal without a barrage. Sir John Benton based his results on discharges for the first two sections of the canal, calculated under his own instructions, at 25 per cent. more than would be required under normal conditions*; and therefore arrived at conclusions which cannot be accepted as representing the number of years in which the canal would fail. In fact, assuming for the moment that the canal will not silt and that its supply will not be affected by sand shoals in the river, the Committee are of opinion that it would work successfully, and in that case it would be productive. If the Committee had been prepared to

* Volume XII, Appendix I, Paragraph 44.

recommend the adoption of Dr. Summers' alternative, they would have entered at length into the details of the figures which have led them to this conclusion; but as they are unable to support the proposals for other reasons, it will be unnecessary to dwell on a matter of considerable complexity.

25. The Committee think it very desirable that the situation that would be created by the construction of the canal as proposed by Dr. Summers should be fully understood. It would mean that this canal, the largest yet designed in India and calculated to cost nearly five crores of rupees, would be the sole source of supply of water to an enormous area at present irrigated by a number of small canals. The latter would never fail simultaneously and the failure of any one of them would be comparatively unimportant. On the other hand, the failure of the Rohri canal at a critical time would mean disaster to the vast area of crops depending on it and would force Government to construct the barrage in haste so as to avoid future disasters of the same kind. It has to be admitted that a partial failure would at any rate be liable to occur. Examination of the sections of the Eastern Nara, and other information on the subject of the working of the canal, has shown the Committee how unsatisfactory the conditions of this channel are. The head of the proposed Rohri canal would be in the same position as that of the Eastern Nara, it would be exposed to the same influences, and the silting might be such that the canal could not be regarded as a safe perennial source of supply.

26. It would therefore have to be regarded as an inundation canal, and the question then arises as to whether it can be shown to be productive or otherwise.

The figures, on which the canal alone, without a barrage, is shown to be remunerative, are based on the areas and revenue rates for a perennial canal. The Commissioner has stated in his evidence that if an assured perennial supply cannot be guaranteed, it would be necessary to revise not only the figures of areas and revenue but to demand a canal of greater capacity possibly one of 18,000 cusecs instead of 14,300, in order to meet the requirements of an increased *kharif* crop. The Committee are consequently of opinion that under the conditions stated by the Commissioner, which imply increased cost of construction and decreased returns, the canal as an inundation canal, would probably not be productive.

27. The proposal to test the silting danger by constructing and working the Summers supply channel, as a preliminary precaution, does not meet with the approval of the Committee. They consider that the test channel, of the nature of a loop in the river, would probably silt, and that if used as a supply channel for the Rohri and Khairpur canals, with a regulator below the head of these canals, it would certainly silt. The loop channel worked solely as a test might possibly be successful for a time, but if any conclusion were based on that success it might be attended with disastrous results. The Committee are therefore opposed to an experiment, involving an expenditure of half a crore of rupees, which would not lead to any useful or conclusive result on which a final decision regarding the necessity of constructing a barrage could be based.

28. The Committee recognise the great thought and labour that Dr. Summers has devoted to his project, and the thoroughness and care with which the canal estimate has been prepared, but they are forced to the conclusion that the risks involved are too great to justify the construction of so large and costly a canal without a barrage and that if the complete scheme is ever undertaken, both canal and barrage should be simultaneously completed.

29. The Committees' conclusions on the three main issues discussed above may then be summarised as follows :—

(1) that there is at present no evidence that the irrigation in Sind has suffered in the past, or will so suffer in the future, that it is obligatory to embark on a very expensive remedial scheme of perennial irrigation solely on that account;

(2) that the project submitted for sanction will not prove to be a productive work; and

(3) that Dr. Summers' proposal for a canal alone, although under very fortunate circumstances it might fulfil what has been claimed for it, is attended by too great a risk to justify its acceptance.

30. The Committee regret that their deliberations should have led to criticism mainly of the destructive order, but a just appreciation of the circumstances in Sind will show that this is not surprising. It is known from the literature on the subject that in the past sixty years or so several Sukkur irrigation schemes have been advanced, and that all, without exception, have failed to stand the test of dispassionate examination. The engineers of the day have no doubt more science and experience at their command than had their predecessors but the earlier engineers were by no means always timid in their conceptions, or backward to press the claims of projects in the value of which they believed, and the reasons why the previous schemes were not supported by those who examined them were probably those which have actuated the present Committee in their decisions to a large extent. The Indus carries a bountiful supply of water, but the harnessing of a formidable river in a delta entails many difficulties and great expense. Sind is an almost rainless country, and the demand for water will therefore always be steady; but it is not liable to famine, it is not over populated, and the cultivators are indolent, contented, and unthrifty; they are satisfied with the inundation irrigation to which they have been accustomed, and have not been driven by force of circumstances to the intensive cultivation of large percentage of their holdings. The Irrigation Commission, in discussing the proposal before them at the time, wrote: " It seems to us therefore that if the idea of a weir across the Indus is ever seriously entertained, the scope must be very much wider than Mr. Dawson has contemplated; and that, apart from steadying the supply in as many of the existing canal systems as possible, it should provide for something like half a million or a million acres of new irrigation. If this was done it is quite possible that an expenditure of even 4 crores might be contemplated with some prospect of a remunerative return." *

31. The project under examination has been calculated to cost double the sum mentioned by the Commission; and even at that, it is believed to have been under-estimated. In addition to steadying the supplies of canals at present in operation, it brings an area of 660,000 acres of new land under command but the circumstances of this land are unfavourable to colonization. Of the land which is in large blocks, part is inferior in quality of soil and part is situated in the unhealthy Nara Valley, and the Commissioner is doubtful whether either would attract a desirable class of colonists. For the rest, the waste is scattered over the existing cultivated area and would have to be allotted to the local agriculturists, from whom good agriculture is not to be expected, and who have already as much land as they can farm. The conditions of this land are therefore entirely different from those of the valuable Crown waste in the Punjab, and no great accession of revenue can be expected from it. In the rest of the commanded area, the proposed canal would convert certain lift irrigation into flow, it would enable higher rates to be assessed on account of more assured supplies, and it might encourage an extension of *rabi* cultivation. Desirable as these results would be it will be readily understood that when the revenue on which the income of a work of great magnitude and expense depends, is the additional revenue to be derived from a tract already irrigated, where the cultivators are poor agriculturists, and where there is no incentive to concentrated cultivation, the task of framing a remunerative project is necessarily very difficult, if not altogether impossible.

32. Indeed from the remunerative aspect, it is possible that the only hope would lie in the direction of a scheme for a canal followed by a barrage as a definite project. In addition to the proposal for a Rohri canal without a barrage, or without a barrage for an indefinite time, a question with which the Committee have dealt in paragraphs 23 to 28 of this report,

* Report, Volume II, paragraph 95.

Dr. Summers has suggested the construction of the barrage after the first and second sections of the canal have been completed and opened for irrigation. There is something to be said for this idea. It would mean that the canal would commence to earn revenue at a comparatively early date, and so reduce the burden of the interest debt. There would also be less risk of failure of supply, as without the help of the barrage, water would only be required for the areas pertaining to the first and second sections, and the barrage would be completed before the third, and largest, section came into operation. But it would be attended with some risks and in the absence of very carefully prepared forecasts of revenue and expenditure, accepted by the authorities in India, the Committee are unable to give it the necessary critical examination, and mention it only as a suggestion which has come before them.

33. Reverting to the scheme which has been submitted for sanction, the Committee are of opinion that it is premature, and that it will not be productive. They nevertheless recommend that a complete project should be prepared and kept in readiness in case the necessity for perennial irrigation should become imperative. It is conceivable that, although Sind has not suffered in the past, it may at some time be affected in the future. In that case remedial measures, unremunerative in themselves, may be justifiable for other and wider reasons. The ultimate aim of the irrigation engineers must be held to be the utilization of the waters of the Indus and its tributaries to the fullest possible extent; and if the action taken in the two Northern Provinces can be shown to have an injurious effect on Sind, there seems to be no reason why the productive works of the three Provinces concerned should not be considered in combination. It has been mentioned that the two works shortly to come under operation are the Upper Swat and the Triple Canals, and it will very soon be known how far the Indus in Sind is affected by them. The further projects in contemplation are the Lower Sutlej and the Sind-Sagar ; but of these, the estimate for the former is still in course of preparation, and that of the latter has not been commenced, in fact it seems doubtful whether the Sind-Sagar scheme will ever be undertaken. There is consequently no extreme urgency to embark on an ambitious project in Sind before its details have been sufficiently investigated ; and the Committee cannot too strongly emphasize the fact that in such important matters as the capacity of the canal, and the design of the barrage, no finality of proposals has as yet been reached.

34. The criticisms on the deficiencies and omissions of the project estimate, which have been offered by the Committee in the course of this Report, have been based on the supposition that the site selected at the Bukkur gorge is the best possible position for a canal and barrage combined. They would, however, suggest, as an alternative, that the possibilities of a site down-stream of the gorge should be examined before the final estimate is prepared. The Committee agree with Mr. Beale that a site in the vicinity of the outfall gauge would be unsuitable for the reasons given by him*. But it is possible that a few miles further down-stream a site might be found, where the width of the river would be sufficient to permit of the construction of a barrage of the requisite length to prevent any undue afflux, and where facilities exist for the construction of a feeder for the Ghar and Western Nara Canals, which, in the opinion of the Committee, should form an integral part of the project.

35. Assuming that such a site can be secured, the Committee further recommend that the following points, to which they attach importance, should receive consideration.

They agree with the present Inspector-General† that a straight alignment for the barrage is to be preferred ; and would add that the alignment should be, as far as possible, at right angles to the axis of the stream.

They strongly urge that the barrage should be designed on what may be called the Egyptian type of barrage rather than on the usual Indian type of weir with falling shutters.

* Note, dated 7th August 1913, prepared in view of an enquiry made in the Secretary of State's telegram to the Viceroy, dated 17th July 1913.

† Inspection Note of Mr. M. Nethersole, Inspector-General of Irrigation, dated 13th to 20th December 1912.

The work would be founded on sand throughout, but to this the Committee attach no objection. It would, in fact, be a less formidable undertaking than a similar work at the site above the gorge.

In order to avoid interference with existing conditions, the floor of the barrage should be placed at as low a level as possible, or in other words, as near as may be practicable to the mean-bed level of the river, and there should be no undue narrowing of the waterway.

Regarding the width of openings, the Committee suggest that the most economical size of gate with reference to the initial cost of construction and the recurring charges of maintenance should be investigated and adopted. And they are of opinion that each bay of the barrage should be fitted with two or three gates, and a corresponding number of separate grooves, in place of the 16 feet single gates proposed by Mr. Hill.

36. The advantages of the lower site that suggest themselves to the Committee are :—

(*a*) the avoidance of the special difficulties of construction at the gorge, and of the possible danger to stability due to retrogression of levels ;

(*b*) the saving of the heavy cost of the supply channel, and possibly further economy owing to reduction in length of the main canal ;

(*c*) the probable saving in the cost of the expensive training works up-stream of the gorge, which would be very expensive both to construct and to maintain ;

(*d*) the freedom from the risk of causing an avulsion above Sukkur ;

(*e*) the avoidance of bridges, and any other interference in connection with the railway; and

(*f*) the economy due to a cheaper form of feeder for the right bank canals, from which if they could be supplied with *rabi* water at reasonable cost, the Commissioner said he anticipated satisfactory returns of revenue.

37. The Committee are, however, fully aware that the change of site would eliminate the Sukkur and Eastern Nara Canals from the beneficial action of the barrage. For the purpose of keeping the river free from sand shoals at the heads of these channels, the barrage at the lower site would obviously be wholly inoperative ; and, at the best, it could have little or no effect on the supplies. The question of these canals, therefore, demands the most careful consideration. If the withdrawals of the Punjab canals are likely to cause any injury to the prosperity of Sind all the Sind canals from the protective point of view have to be considered. The Sukkur canal, it is believed, at present draws a good supply from its upper head but the present favourable conditions may not always continue. The Eastern Nara supply channel, it is known, is liable to silt badly, and the supplies of water are often insufficient for the existing area of irrigation. Apart also from the protective aspect of the case, the increased revenue returns from the Eastern Nara have, in the project estimate, been calculated at 7½ lakhs of rupees per annum. Capitalized, this means so large a sum that it is improbable that a corresponding saving could be secured by a change in site. It is possible that, if the conditions of the lower site proved on investigation to be favourable in other ways, necessary improvements might be made in the Eastern Nara by excluding the Ghotki floods and by widening the supply channel in order to increase the discharge. The *pros* and *cons* of the alternative call for local examination before any decision can be formed and the Committee have made the suggestion, not because they believe it will lead to a remunerative project, but because it would remove the many pronounced difficulties of the upper site, and because in a case of such far-reaching importance it is desirable that every possible alternative should be investigated before the final estimate is prepared.

38. The advice of the Committee is then that the question of the effect of the Punjab canals on Sind should be examined far more closely and exhaustively than has hitherto been attempted. In that examination, it is necessary to remember that Sind is an inundation

irrigation country, and that any effect on its *rabi* potentialities does not concern its existing conditions. If, on that understanding, it can be shown that it must assuredly suffer by the action of the canals in the nothern Provinces, projects, even though they failed to meet the recognised requirements of productive works, would be justified from their protective value. But if there is no convincing evidence to this effect, perennial irrigation schemes can only be regarded as improvements on conditions, which, as they at present are, appear to be fairly well suited to the special circumstances of the country. As merely improvements, to be desired but not essential, it may be held that no high remunerative returns need be expected from them ; but it will no doubt be considered that they should not be worked at a loss and represent schemes of unpleasant significance to the general tax-payer. Simultaneously with the above investigation, the Committee advise the preparation of the best possible project, complete in all respects, to be in readiness in case it is required. It is obviously difficult to arrive at a final decision until the effect of the abstraction of water in the Punjab has been precisely determined, and the cost of remedial measures accurately appraised.

(Signed) JOHN W. OTTLEY.
(„) LIONEL JACOB.
(„) W. L. CAMERON.
(„) A. L. WEBB.

1st *December* 1913.

MEMORANDUM ON SOME POINTS IN CONNECTION WITH THE SUKKUR BARRAGE AND ALLIED QUESTIONS.

I.—*The unsuitability of the site selected for the river works above the Bukkur gorge.*

The disadvantages of this site are referred to in paragraph 16 of the Committee's report attention being drawn to the greatly enhanced danger of avulsion to the west, the probability of disaster should an earthquake occur, the danger to be feared from a possible retrogression of levels, and the unsatisfactory nature of the rock foundations.

The subject is again referred to in paragraphs 34 and 36 of the report, it being pointed out that all the above disadvantages, as also others, could be obviated by the selection of another site for the works lower down the river.

It will be observed that the Committee clearly recognised the objections to the site selected, but as they were satisfied that the estimates submitted to them would be so largely exceeded as to forbid any expectation that the project could be classed as a productive public work, and as they also came to the conclusion that there was at present no evidence that the conditions were such as to compel the execution of the works even if they were unremunerative, they considered it sufficient to indicate the objections to the site selected, and to suggest the selection of an alternative one.

Personally, I go a great deal further than this, and am of opinion, which I believe is shared by Sir Arthur Webb, that the risks to be faced are so serious that in no circumstances could I recommend sanction to the construction of any form of weir or barrage at this site.

If this view be accepted by the authorities in India, as in my judgment it certainly ought to be, it follows that all idea of linking up the Eastern Nara Supply Channel with a barrage must be definitely abandoned.

II.—*The Eastern Nara Supply Channel and dependent works.*

It appears that the supply of water to the canals in the Eastern Nara Valley is at present far from satisfactory, and the question arises as to the remedy to be applied.

It would seem that the very first step should be in the direction of the exclusion of the Ghotki floods. This according to the information before the Committee, would not cost more than 8 or 10 lakhs and should not, I think, be delayed.

I gather that the discharge in the supply channel is interfered with by silt deposits in the channel and by the formation of shoals in the river in front of its mouth. In both cases, dredging would appear to be indicated and should be provided for.

The supply channel could also be widened to any extent considered necessary but before doing this I suggest that it would be well to consider the possibility of partially canalising and regulating the channel of the Eastern Nara. I believe that I am one of the very few inspecting officers who have travelled down this channel and my recollection of it leads me to think that money judiciously spent on it would lead to a very considerable conservation of water.

At any rate, I think, this suggestion should be carefully considered before spending large sums on the widening of the supply channel.

The conclusion I have come to after careful consideration is that there should be no insuperable difficulty in providing all the water required in this direction without the assistance of any weir or barrage in the river.

III.—*Installation of a Self-registering Gauge at Bukkur.*

I would invite attention to the desirability of installing a self-registering gauge at Bukkur as a check on the readings of the existing one at that site.

I understand that one of these gauges was erected some years ago at the mouth of the Indus at Keti Bunder, but was subsequently dismantled and placed in store at Kotri. It would be a great advantage if this could be erected at Bukkur, as it is stated that there is considerable difficulty in correctly reading the existing open gauge. So much depends on these readings that it seems essential to secure reliability.

IV.—*Some suggestions as regards selection of an alternative site for Barrage.*

In paragraphs 34 to 36 of their report, the Committee indicated their opinion that an alternative site might be sought some miles below the gorge, but considered that to say more than this would be to travel outside the scope of the reference to them.

They, however, agreed with the present Chief Engineer for Irrigation to the Bombay Government that no site in the vicinity of the outfall gauge would be suitable, but considered it possible that a site might be found a few miles further down stream.

I am led to make the following observations because I find throughout the old correspondence constant references to "stable" points of the river as being the only points at which it was possible to take off canals with any certainty of maintenance of their heads.

This is, of course, absolutely true in the case of *inundation canals*, but it does not appear to have been recognised that the construction of a weir or barrage with sufficient guide banks enables the engineer to make *any* point stable.

Given sufficient money, a weir and a thoroughly protected canal head can be made anywhere. The only question is as to the length of guide banks required. Some parts of the river are more stable than others and naturally—other things being equal—a reach of the river where the river does not swing too much should be selected. It may also be possible to find a reach with a sharp bend which would admit of a cut-off and the construction of the works in the dry.

The essential points appear to be to select such a site as will—

(1) be sufficiently far below the gorge as not to interfere with the flow through it in any way;

(2) admit of the supply to the Rohri Canal area;

(3) admit of the construction of a feeder channel to the Ghar and Western Nara Canals; and

(4) interfere as little as possible with the existing irrigation of the Mir's territory.

So far as I know, there is no *a priori* reason why such a site should not be found.

Assuming that such a site can be found, I would recommend the immediate installation of both an ordinary and a self-registering gauge at the site, and also that cross sections and discharges should be constantly observed with a view to the accumulation of as many data as possible prior to actual construction.

Before spending money on the preparation of a detailed project it is, in my opinion, absolutely essential that a definite understanding should be come to as to the capacity not only of the Rohri Canal, but also of the right bank feeder which should be calculated to afford the necessary kharif supplies required for the existing irrigation (mostly rice) on the Ghar and Western Nara Canals.

I may mention that I understand that during the last two or three years extensive experiments in "waterproofing channels" have been carried out in the Punjab, and that considerable experience has been gained both as to the expense involved and the results obtained. It would seem desirable to take these experiments into consideration before finally deciding on the capacity of the Rohri Canal and right bank feeder channel, as it is quite conceivable that the discharges otherwise considered necessary might in this way be very materially reduced.

As regards the design of the barrage, the Committee have already laid down, in paragraph 35 of the report, the lines which they recommend should be adopted, and, if desired, I should be prepared to submit a sketch of the class of work I would recommend as soon as I was supplied with the necessary data.

V.—*Suggestion as to the interchange of Irrigation Officers between the Punjab and Sind.*

At the present time the interchange lies between Sind and the Presidency proper, but the irrigation work of these officers has little or nothing in common and in neither sphere can any experience be gained in the construction or maintenance of large perennial canals. On the other hand, if Sind is ever to have perennial canals, it would be an unmixed advantage that a considerable number of the staff should have acquired the experience to be gained in the Punjab both in the construction and up-keep of such canals. If it could in any way be arranged, it would be desirable to amalgamate the two establishments but, failing this, there should certainly be very free interchange of officers of all ranks.

16*th January* 1914. JOHN W. OTTLEY.

APPENDIX C.

No. W. I.—10515 OF 1915.

PUBLIC WORKS DEPARTMENT,

Bombay Castle, *23rd September* 1915.

From

H. F. BEALE, Esq., M. INST. C.E.,

Secretary to the Government of Bombay:

To

THE SECRETARY to the GOVERNMENT of INDIA,

Irrigation (Works),
Public Works Department.

SIR,

Government of India No. 270-I of 16th February 1914.
Government of India No. 949-I of 17th June 1914.

In answer to the marginally noted letters from the Government of India on the subject of the Sukkur Barrage and Rohri Canal Project, I am directed to say that the Governor in Council is so strongly impressed with the necessity of introducing assured perennial irration into Sind on a large scale that he hopes the remarks he now proposes to make on the above project will lead the Secretary of State to reconsider the decision recorded in his Despatch Public Works, No. 1, dated 9th January 1914, addressed to the Governor General of India in Council, when the scheme is resubmitted in the somewhat altered form, which will be described below.

2. A rather long delay has taken place in disposing of this reference from the Government of India as the matter under investigation has been of a difficult and rather complicated character. The results finally arrived at appear to the Governor in Council conclusive as far as they can be determined from the information which is available. He has had the advantage of reading certain suggestions thrown out by Sir James Wilson, Sir Thomas Holland and Sir John Benton in regard to the connection between the use of water in the Punjab and the intensity of discharge of the Indus at Sukkur. This is the first point for consideration.

3. The theory is held that the large underground water-supply of the Punjab is diverted towards the Indus by the ridge of tertiary limestones extending mostly underground, through Bikaner and Jaisalmer to Sukkur, and that probably the open gorge at the latter place forms a kind of lip to the great basin, over which the water is forced to flow. To what extent see page from irrigated areas contributes towards this flow cannot be stated, but it is recognized that the progress of this see page must be extremely slow.

4. In the correspondence referred to, the possibility has been discussed of the Indus river leaving its present channel through the Sukkur gorge and carving out for itself a new channel to the west of the Sukkur hills. This contingency has frequently been referred to in recent years. The departure of the river to the west depends in the first instance upon the river and ground-surface levels, and the protection against such a disaster is the efficient maintenance of the Sukkur-Begari river bunds. There is apparently no definite knowledge concerning the extent of the dip in the rocky barrier (if this exists) between Sukkur and the Baluchistan hills.

5. I am to remark that the correspondence referred to indicates some difference of opinion on the extent and effect of see page into the river. The Governor in Council prefers to base

his conclusions on definite facts as far as they are ascertainable; these are the daily river levels at Sukkur recorded since 1848, the river discharges observed since 1901, the monthly rainfall in the catchment area of the Indus recorded at eleven stations since 1866, and the draw-off in the kharif and rabi seasons for the Punjab and North-West Frontier Canals, for which figures are given since 1867. The influence of the last item upon the discharge of the river at the Sukkur pass has been variously described as probably beneficial and as likely to prove disastrous to Sind. The draw-off has been as follows:—

Year.	Kharif cusecs.	Rabi cusecs.
1867-68	5,415	1,434
1910-11	45,695	21,676

indicating a rise of 40,000 and 20,000 cusecs in the kharif and rabi seasons, respectively. It cannot be stated how far this abstraction of water has been felt at Sukkur, but at the 10 feet level the addition of 40,000 cusecs to the discharge would raise the water by 6 inches to 1 foot and at higher levels the difference would be less.

6. The discharge in the river depends upon the rainfall in the catchment area and the melting of the snows. The inundation period is from June to September, and during this period the natural influences indicated may be said to outweigh vastly any possible effect of the withdrawals for irrigation. The variations from year to year shown in Statement XI attached to the Chief Engineer's note II indicate this very clearly. Even in October, *vide* Statement X, the average river discharge is seen to vary from 59,000* cusecs in 1904-05 to 119,000 cusecs in 1906-07, and the Chief Engineer has demonstrated clearly that the increased kharif withdrawals amounting to about 40,000 cusecs in the last 40 years have not affected the general river levels in any definite manner,

*The Kharif withdrawals in these years were:—
1904-05 .. 40,000 cusecs
1906-07 .. 45,000 ,,

7. This conclusion however does not preclude the possibility of some deleterious influence being exerted in special circumstances on the supply at Sukkur, but the extent of this influence can for the present be only a matter of conjecture. The discharging capacity of the river varies very considerably. In some years of low discharging efficiency, of which 1905 may be taken as a type (*vide* tracing No. $\frac{IV}{1}$), small variations in quantity will affect the water level much more than in other years, and on tracings Nos. $\frac{V}{1}$ and $\frac{V}{2}$ the Chief Engineer has shown the difference which would have resulted by the addition or withdrawal *at Sukkur* of certain volumes of water. This may be taken as an indication of the utmost difference that could be produced by the abstraction of water for irrigation in the Punjab. Actually, however, the difference is probably a good deal less than what is shown, because of the moderating influences on the way.

8. I am to say, therefore, that although it is not possible to trace directly any effect of the Punjab withdrawals on the river supply at Sukkur, there is some reason to believe that in the unfavourable conditions of a low river bed combined with a scanty flow from the catchment area, the withdrawals might have an appreciable effect in lowering the water level at Sukkur at the beginning and the end of the inundation season, which are the critical periods for inundation canals. For this reason the Governor in Council is of opinion that though the dangers of further withdrawals in the Punjab have been very much exaggerated, there is still good reason to say that Sind ought to be protected, by the construction of a barrage, from the chance of any such misfortune as that just indicated.

9. A withdrawal of 20,000 cusecs in the rabi-season might reasonably be assumed to be more appreciable at Sukkur than 45,000 cusecs abstracted in the inundation period, but judging by water levels the figures in Statement XIV do not warrant any assertion to the effect that the Punjab irrigation has had any but the smallest effect upon the minimum water level at Sukkur.

10. The next point for consideration is whether Dr. Summers' proposal to make the Rohri Left Bank Canal first and the Barrage at some future and probably distant date is practicable and advisable. While the Governor in Council has no doubt as to its being a practicable scheme, he is very strongly of opinion that it would be a serious mistake to allow so large a canal to draw off a plenteous supply from the river at times when the water level in the river is low. The canal systems on the Right Bank of the Indus have certainly equal claims to those on the Left Bank, and the Revenue authorities are being requested to examine the revenue prospects on the Right Bank somewhat more closely, so as to allow of the elaboration of a complete project as originally intended for both a Left and a Right Bank Canal. The land on the right bank is much higher than the land to be irrigated on the eastern or left bank; there are various falls in the canal on the Rohri side which allow of a reduction in the canal bed level at its mouth, sufficient to take an ample supply from the river at its lowest, but on the Right Bank Main Canal there is no provision for drops. This consideration effectually sets a veto upon any scheme to construct either one or both large canals without a barrage. The Left Bank Rohri Canal alone would deprive the present Right Bank Canals of their fair supply and the two canals together would prove very formidable white elephants, if the barrage were not constructed at once to give them alimentation both in the Kharif and the rabi season.

11. I am to draw attention, to the last sentence of paragraph 24 of Mr. Hill's forwarding letter No. W.I.—2583, dated 5th December 1910, and to say that, as at present advised, the Governor in Council is strongly of opinion that no distinction should be made between the relative importance of securing a good perennial supply to the lands on both the Right Bank and the Left Bank of the Indus. He is convinced that the present conditions of cultivation and irrigation are not suited to the special circumstances of the country, for Sind is calling out loudly for improvements and benefits, which the Punjab and United Provinces have long been enjoying. To regard Sind as an inundation country pure and simple would be to adopt a policy of stagnation, which, in these days of enlightenment and awakening prosperity, the Governor in Council does not find himself able to adopt.

12. It is an unfortunate circumstance that the rules of the Public Works Department make it essential that a productive scheme shall show direct profits from the sale of water sufficient to cover all working expenses and 4 per cent. upon the capital cost (direct and indirect) of the project within 10 years after the probable completion of the work. The true value of the irrigation water is invariably much in excess of what Government deem it advisable to charge the cultivators. In the Deccan water used to be sold 20 to 30 years ago for one-half of the charges now imposed, and that its real value is about double our present figure is shown by the fact that irrigators constantly take the water unauthorizedly, or out of turn, and cheerfully pay double assessment for it. For the Rohri Project the rates that may be imposed for water on the Left Bank of the Indus have been determined with great care by Mr. W. H. Lucas, an unrivalled authority upon all such matters, after very exhaustive enquiry and discussion, in his capacity as Commissioner in Sind, with all the district officers, and these rates, which are a consolidated assessment for land and water combined, are of course based upon those now in force. On the Left Bank the increase provided for is from Rs. 2·71 to Rs. 4·92 per acre, and on the Right Bank from Rs. 3 to Rs. 5·77.

13. The highest rates proposed, 10 years after construction, are—

	Consolidated assessment.	
	Left Bank, per acre.	Right Bank, per acre
	Rs.	Rs.
Rice	5	7
Cotton	6	..
Other Kharif	4	3½
Rabi	4½*	5½†

* Rs. 5 in Hyderabad taluka only. † Rs. 6 in Garhi Yasin taluka only.

When it is remembered that in Sind cultivation away from flooded areas depends entirely upon irrigation, while in the Deccan some sort of crop can frequently be obtained on rainfall alone, and when these figures are compared with those obtained in the Deccan for water only *viz.*—

monsoon four months	..	..	.. Rs.	3	per acre.
rabi four months	..	..	.. ,,	5	,,
sugarcane twelve months	..	..	.. ,,	30	,,

the contrast will readily suggest the probability of somewhat enhanced figures being obtainable in the future. This, therefore, is one argument I am to bring forward in favour of an early sanction for this scheme.

14. The principal kharif crop on the Left Bank is cotton and on the Right Bank rice. In addition to a very considerable increase in the area of these crops it is estimated that the present area of rabi crops will be trebled on the Left Bank and doubled on the Right Bank of the river. This forecast is based on the present condition of Sind, the backwardness and poverty of the cultivators, and the difficulty of allotting the fresh lands to outsiders. The anticipated proportion of kharif to rabi is very roughly as 2 to 1. To satisfy these conditions, which for the present the Government of Bombay accept as inevitable, the proposed canal section must be three or four times larger than required for the rabi area, hence if an increase of cereal crops can by any means be forced in the future, there will be no engineering difficulty in supplying any demand for water that may arise without increased expenditure. This is another direction in which it will not be unreasonable to anticipate some advance upon the figures which the Governor in Council, on the advice of the Commissioner in Sind, proposes to adopt as the forecast of irrigation and revenue in support of the project.

15. But apart from these anticipations, which may be discounted by cautious spirits, the undoubted benefits to the whole Province of Sind of an assured supply of water to serve about 5 million acres of culturable land throughout the year, and in every year, the increase of agricultural activity which will cause a rapid expansion of population and farmyard stock and the vast growth of trade, giving rise to new railway lines and still greater activity at the busy port of Karachi, are all of such incalculable importance that the Governor in Council can by no means endorse the opinion expressed by the London Committee in their last paragraph, namely, that perennial irrigation schemes for Sind could only be regarded as improvements to be desired but not essential, and that though as such it might be held that no high remunerative returns need be expected from them, it would no doubt be considered that they should not be worked at a loss and represent schemes of unpleasant significance to the general tax payer. I am to say that the Committee took the view that a scheme which could not with absolute certainty yield a profit of 4 per cent. after paying working expenses would be working at a loss.

16. In the opening paragraph of this letter it was stated that the scheme the Governor in Council desires to put forward differs to some extent from the one previously submitted: One change has already been indicated, namely, the inclusion of the Right Bank Canal; the next is entirely the outcome of a suggestion made by the London Committee, *viz.*, the abandonment of the original site for the barrage and headworks, and their location at some distance below the gorge. The Chief Engineer for Irrigation has explained this change at length in his note IV, and I am only to remark that there is every reason to believe that the change will be advantageous both in facility and in economy of construction. This position will not affect the Eastern Nara Supply Channel adversely, as it will probably be possible to provide it with a new mouth below the gorge connecting, in a distance of seven miles, on to the present channel through a gap between the Kohistan Hills, said to be a former passage of the river.

17. The question of cost has to be approached with much caution, and the Governor in Council does not by giving the figures below intend to do more than produce a general idea of what the scheme may work out to. The estimate for the Left Bank Canal may be accepted as correct, but for the Right Bank Canal, the original figures being based on data which cannot now be accepted as satisfactory, and the scope of the project being somewhat changed the figure of cost is only a rough approximation. For the barrage, the largest of the estimates (Sir J. Benton's), with an addition of 30 lakhs for a Right Bank Canal Regulator, has been adopted. The cost (direct and indirect) is placed at Rs. 1,120 lakhs and the ultimate revenue (accepting Mr. Lucas' figures without alteration) may be Rs. 63·5 lakhs.* The net revenue is likely to cover the accumulated interest very nearly by the 10th year after completion and, because with both canals the cost of the barrage is spread over a greater area of irrigation, the return is comparatively more favourable. The figure of net revenue anticipated is approximately 5·7 per cent. on the capital cost.

18. I am now to ask for the approval of the Government of India to prepare detailed plans and estimates for a complete project including a barrage below the Sukkur Gorge, with two large canals taking off as originally proposed on the Right and Left Banks of the river to provide a water supply for the perennial irrigation of the areas now served by numerous inundation canals.

* 39·2 Left Bank + 24·3 Right Bank = 63·5, see Explanatory Note attached to Chief Engineer's Note VI.

I have the honour to be,

Sir,

Your most obedient servant,

H. F. BEALE,

Secretary to Government.

Accompaniments :—

(*a*) 6 Notes by Chief Engineer for Irrigation with maps and plans as detailed on the first page of the accompaniments.

(*b*) 1 green book of gauges.

Accompaniments to Government Letter No. W. I.—10515, dated 23rd September 1915

List of maps and plans to accompany the Sukkur Barrage Project.

Serial No.	Particulars.	Sheet No.
1	Curves showing water levels at Bukkur at two critical periods for each year 1848—1914	$\frac{I}{1}$ to $\frac{I}{14}$
2	Curves showing periods for which water rose above certain levels ..	$\frac{II}{1}$ to $\frac{II}{4}$
3	Diagrams showing monthly rainfall in the catchment area of the Indus	$\frac{III}{1}$ to $\frac{III}{3}$
4	Discharge curves at Bukkur, 1901—1914	$\frac{IV}{1}$ to $\frac{IV}{3}$
5	Curves showing results of withdrawals	$\frac{V}{1}$ and $\frac{V}{2}$
6	Diagrams showing sub-soil water levels, 1909 and 1913	$\frac{VI}{1}$ and $\frac{VI}{2}$
7	Maximum and minimum cross sections at outfall gauge site, 1901—1914	$\frac{VII}{1}$ to $\frac{VII}{7}$
8	Plan of Hydrographic survey of the River Indus at Sukkur showing site of proposed barrage below gorge and contours of the country on both banks to determine the alignment of the Right and Left Bank Canals	$\frac{VIII}{1}$
	Right Bank Indus—Plan showing lines of levels 1,000 feet apart to determine alignment of canal from above a barrage proposed at 3 miles from below Sukkur Gorge to join the original Right Bank Canal of 1909 Project	$\frac{VIII}{2}$
	Left Bank Indus—Plan showing levels of country about 2,000 feet apart to determine the alignment of canal from above a barrage proposed at 3 miles below Sukkur Gorge to join the original Rohri Canal line of 1909 Project	$\frac{VIII}{3}$
9	General map of the Punjab showing 50 feet contours and river gauges	IX
10	Sukkur Barrage—Index map showing position of the barrage and guide banks above barrage	X

Notes by the Chief Engineer for Irrigation, Bombay.

The titles of the 6 notes are :—

I. The effect upon the Indus River at Sukkur of the withdrawals of water for the Punjab and North-West Frontier Provinces Canals.

II. The gain by seepage in the Indus River.

III. Dr. Summers' proposal to build the Rohri Left Bank Canal first before the barrage.

IV. The position of the barrage above or below the gorge.

V. The Right Bank Canal.

VI. Financial aspect of the scheme.

1.

Note on the effect upon Indus River at Sukkur of the withdrawals of water for the Punjab and North-West Frontier Provinces Canals.

The draw-off of Punjab and North-West Frontier Provinces Canals in 1867-68 was small, *viz.*, 5,415 cusecs kharif and 1,434 cusecs rabi, and rose gradually as follows :—

	Cusecs.			Cusecs.	
In 1888-89 to	22,160	kharif	and	6,988	rabi.
In 1897-98 to	32,996		„	13,645	„
and in 1903-04 to	42,540		„	20,185	„

2. Observations of the actual discharge of the Indus River at Sukkur have been taken since 1901 only, and the increase in draw-off has not been very great since then. But the gauge readings (*viz.*, water levels) at Bukkur have been recorded since 1848. Had discharge observations for the full period since 1848 been taken, perhaps some definite conclusion as to the exact effect of the withdrawals might have been reached, but with gauge readings only, no such definite conclusion is possible, because for equal readings the river discharges vary considerably. Taking for example the gauge reading of 6 feet at Bukkur, the discharges recorded in the last 14 years of this height vary from 53,533 to 211,460 cusecs (see Statement V). This variation is due to the unstable condition of the river bed. The record of levels from 1848 to date is, however, a valuable one, and it is necessary to examine these levels closely and endeavour to draw some conclusions from them.

3. The Punjab withdrawals might be expected to affect the kharif supply at the beginning and the end of the flood seasons and (if no barrage be constructed) throughout the rabi season. The former is obviously the more important consideration in Sind, as the whole irrigated area of the Province depends upon the inundation levels of the Indus in the kharif season, while only a few of the canals receive a rabi supply. The critical periods in the kharif season are from 15th May to 30th June and from 1st September to 15th October. The examination may, therefore, be confined to these periods, and curves marked A have been plotted (sheets 1 to 14) showing the actual water levels recorded in each year. An effort has been made to compensate for the variations above referred to by reducing the lowest reading of each year to zero and introducing this correction for all the other readings. For example, if the lowest reading (which generally occurs in February or March, but sometimes in January and even as early as December) was +1·2 feet on the 2nd March 1905, then all the readings from 1st September 1904 to 30th June 1905 had 1·2 feet deducted from them. As the period during which the regimé of the river is most liable to change is the inundation season (June—October), this season must form the dividing line from year to year. The " corrected " curves (marked C) have been plotted on the same sheets as the actual gauge curves which are marked A.

4. The corrections thus made are based on the assumption that the minimum discharge in the river does not vary greatly. In Statement IV the variation during 14 years is shown to have been from 19,000 cusecs to 36,000 cusecs, a difference of 17,000 cusecs, or a variation from the mean of 8,500 cusecs. This difference in discharge may connote a difference in level of from 0·4 feet to over 1 foot on the gauge; but during the period of such small discharges the levels may vary rapidly; for example:—

	Bukkur gauge. Feet.	Discharge. Cusecs.
17th January 1906	1·2	22,539
17th February 1906	0·7	30,047

In this case in spite of an increase in discharge of 7,500 cusecs the water level fell by 0·5 feet The "actual" and the "corrected" curves, therefore, may both be examined, but when considering the supply available for inundation canals the "actual" water level is the only one to be considered.

5. To make the conditions of supply somewhat clearer another set of curves has been drawn showing the number of days during the two annual critical periods on which the gauge ("actual" on sheets $\frac{II}{1}$ and $\frac{II}{2}$ and "corrected" on sheets $\frac{II}{3}$ and $\frac{II}{4}$) read more than 4 feet, 6 feet, 8 feet, 10 feet, 12 feet and 14 feet respectively at Bukkur. Readings of 10 feet and over indicate largish floods spreading over the river banks to a certain extent, and there has been a decided increase of flood levels since the construction of the protective embankments above Sukkur from 1876 onwards. Readings of 8 feet and under belong to a volume flowing within the river banks, which is unaffected by the protective embankments. An increase or diminution of the periods on the 4 feet, 6 feet and 8 feet charts would (apart from the variations already referred to) indicate a greater or smaller supply in the river. At first sight it appears that the discharges in recent years are more favourable than the discharges in the earliest years before much irrigation was practised. This may be due to a cycle of good and bad years. But if the period 1867—1914 only is examined it is possible to prove either a gain or a loss by alternative selections of the groups of years to be compared with each other. The most convincing comparison should be between the 13 years of lowest irrigation from 1867 to 1880 and the 13 years of highest irrigation from 1901 to 1914. The corresponding kharif draw-off was:—

	Average draw-off. cusecs.
1867-80	5,443
1901-14	42,133

This comparison might be taken to indicate a reduction of supply to Sind of about 37,000 cusecs in the latter group of years. Both the actual and corrected curves on sheets No. $\frac{II}{1}$ to $\frac{II}{4}$ may be examined. If it should be said that there was apparently some reduction of supply, it can also be asserted that the intermediate period, 1881-1900, while irrigation was increasing, showed a more unfavourable result than either, and certainly that the river levels during the earliest period recorded, *viz.*, from 1848 to 1866, with little irrigation in the Punjab, were very much lower than in recent years.

6. It is, therefore, impossible to draw any definite conclusion to the effect that Punjab irrigation has caused either an increase or a decrease in the river discharge during May—June and September—October.

7. The annual discharge curve of the Indus River represents the mean discharging capacity of the river for each level, based on all the observations taken at Sukkur during the year.

This discharge curve has been plotted for each year since 1901 (tracings No. $\frac{IV}{1}$ to $\frac{IV}{3}$ attached). It will be seen that the range of discharge for various levels has been as follows :—

Reading on Bukkur gauge.	Discharge in cusecs (averages for the year.) From	to
4 feet	40,000	108,000
6 feet	66,000	180,000
8 feet	108,000	272,000

The variation of the individual observations has, of course, been very much greater (*vide* paragraph 2 above).

8. A rainfall curve marked R has been drawn on the sheets Nos. $\frac{III}{1}$ to $\frac{III}{3}$ showing the total monthly rainfall at eleven stations in the catchment area of the Indus. The figures of rainfall from which these diagrams are prepared are shown in Statement IX-A.

9. The variation of rainfall is considerable, and in addition to this, there is a variation in the snow fall, *vide* Statement IX-B and in the rate of melting of the snows. The fluctuation of annual river levels is well shown by the A curves in sheets $\frac{I}{1}$ to $\frac{I}{14}$; compared with this fluctuation the difference in river level due to the Punjab withdrawals is not very marked when the water levels are 10 feet or more.

10. There is, however, another aspect of the case to be taken into account. Unless some proof can be given that see page from the irrigated area back into the river does occur to an appreciable extent, it must be evident that in a bad year the abstraction of water in the Punjab must to a certain extent diminish the already low supply of the river. The 6 feet level in the river gives a very poor supply in most of the inundation canals, and the curves on sheets Nos. $\frac{I}{1}$ to $\frac{I}{14}$ show that the Bukkur gauge ("actual" A) was less than 6 feet between the dates given in the following statement. The purpose of this detailed statement is to show between what dates the scarcity occurred.

Days on which Bukkur gauge was less than 6 feet:—

Year.	15th May to 30th June. (Number of days given in brackets.)	1st September to 15th October. (Number of days given in brackets.)	Number of days.
1848	....	From 23rd September onwards	22
1849	....	From 5th October	10
1850	Till 4th June (19)	From 23rd September—four days (18)	37
1851	....	From 23rd September	22
1852	From 3rd June to 15th June(12).	From 25th September (20) ..	32
1853	From 24th May to 4th June (11)	From 20th September (25) ..	36
1854	Nine days in May (9)	From 21st September (24) ..	33
1855	Till 8th June+six days (29) ..	Eight days, and from 27th September (26)	55
1856	Till 27th May (12)	From 2nd October (13) ..	25
1857	Till 27th May+9 days (21) ..	From 1st October (14) ..	35
1858	Four days in June (4)	Nine days and from 6th October (18)	22
1859	Two days in May (2)	From 24th September (21) ..	23
1860	Three days in June (3) ..	From 16th September (29) ..	32
1861	Three days in May (3)	From 2nd October (13) ..	16
1862	Till 26th May (11)	....	11

Year	15th May to 30th June (Number of days given in brackets)	1st September to 15th October. (Number of days given in brackets)	Number of days.
1863	Till 11th June—three days in May (23)	From 24th September (21) ..	44
1864	....	From 26th September (19) ..	19
1865	....	....	..
1866	....	From 27th September (18) ..	18
1867	Till 14th June—12 days in May and June (17)	From 8th October (7)	24
1868	....	From 23rd September (22) ..	22
1869	....	....	..
1870	Till 23rd May (8)	From 29th September (16) ..	24
1871	Till 27th May (12)	From 24th September (21) ..	33
1872	One day in May (1)	From 3rd October (12) ..	13
1873	Till 31st May—six days (9) ..	From 1st October (14) ..	23
1874	....	From 12th October (4) ..	4
1875	....	....	..
1876	....	....	..
1877	....	From 7th October (8)	8
1878	....	From 14th October (1) ..	1
1879	Five days in May (5)	From 13th October (2) ..	7
1880	....	From 30th September (15) ..	15
1881	One day in May (1)	From 12th October (3) ..	4
1882	....	From 13th October (2) ..	2
1883	....	From 9th October (6)	6
1884	....	From 11th October (4) ..	4
1885	....	From 29th September (16) ..	16
1886	....	From 1st October (14) ..	14
1887	....	From 2nd October (13) ..	13
1888	Six days in May (6)	From 13th October (2) ..	8
1889	....	From 7th October (8) ..	8
1890	Till 25th May (10)	....	10
1891	....	....	..
1892	Six days in May (6)	....	6
1893	....	From 10th October (5) ..	5
1894	....	From 10th October (5) ..	5
1895	....	From 30th September (15) ..	15
1896	....	From 1st October (14) ..	14
1897	....	From 11th October (4) ..	4
1898	Till 8th June—seven days (16)	From 29th September (16) ..	32
1899	....	From 23rd September (22) ..	22
1900	....	....	..
1901	....	....	..
1902	....	From 5th October (10) ..	10
1903	....	....	..
1904	....	From 5th October (10) ..	10
1905	....	From 13th October (2) ..	2
1906	....	From 13th October (2) ..	2
1907	Till 22nd May (7)	From 23rd September (22)	29
1908	Thisteen days in May (13) ..	From 29th September (17) ..	30
1909	Till 3rd June (19)	From 5th October (11) ..	30
1910	One day in May (1)	From 1st October (14) ..	15
1911	....	From 2nd October (13) ..	13
1912	Three days in May (3)	From 23rd September (22) ..	25
1913	Three days in May (3)	From 29th September (16) ..	19
1914	....	From 5th October (10) ..	10

11. The deficiencies in the month of May are comparatively unimportant. Omitting these, there are eleven years for the first critical period (column 2) yielding less than 6 feet in June, of which only two are in recent times (1898 and 1909). For the second critical period

(column 3) there are eleven years in which the gauge was continuously over 6 feet, but less that 6 feet were registered in 31 years in October only, and in 25 years in both September and October. Of the latter, 16 are in the earliest 24 years, 1848-71, only 3 in the 24 years from 1872-95, and 6 in the 19 years from 1896—1914.

12. If it be assumed that the abstraction of kharif water in the Punjab involves a reduction of river discharge which is only slighly compensated for by an increased see page due to the greater fall in river levels (see Note II, para. 12, kharif withdrawals), it is evident that in those years in which 6 feet on the Bukkur gauge gives a discharge of less than 100,000 cusees, the abstraction of 45,000 cusecs would make a serious difference, and with the increased withdrawals of 15,000 in the immediate future = 60,000 cusecs and possibly an ultimate total of 70,000 cusecs later on, there is little doubt that the Sind inundation canals would suffer more severely than they have hitherto done in years of low discharge. Every day gained for irrigation in the September—October period is of importance. For Sind a low mean discharge curve would generally indicate a favourable condition for irrigation, because for given discharges the water level remains higher than usual. The mean discharge curves for 1903, 1904 and 1905 (tracing $\frac{IV}{I}$) all show less than 100,000 cusecs discharge for 6 feet on the Bukkur gauge, and these years are described in the administration reports respectively as good, average and exceptionally good. The following table (based on Statement VI attached) shows how the water levels of 6 and 8 feet in these years might have been affected had the Punjab draw-off been 5,000 cusecs only or if it had been 60,000 or 70,000 instead of about 40,000 cusecs. On tracings No. $\frac{V}{1}$ and $\frac{V}{2}$ red lines have been drawn to indicate the probable water levels that would have been obtained under the various conditions named :—

Punjab withdrawals in cubic feet per second	5,000	40,000	60,000	70,000
Sukkur levels—feet	7·7	6·0	4·7	3·8
Sukkur levels—feet	9·1	8·0	7·2	6·7

The figures show that the greater the abstraction, the more severely it will be felt. They are very rough averages, applicable to the conditions prevailing in years 1904, 1905 and 1906.

13. The first increase of 35,000 cusecs causes a reduction of 1·7 and 1·1 feet and the subsequent increase of 30,000 cusecs causes a further reduction of 2·2 and 1·3 feet at the levels mentioned. Similar lines have been drawn for all the years since 1901 when systematic gauging was commenced (*vide* sheets $\frac{V}{1}$ to $\frac{V}{2}$).

14. Three other statements are attached,—statement VII showing the character of each inundation in Sind as officially reported, statement VIII showing the variation of water levels week by week in the bad years and statement IX the periods of insufficient supply in July and August.

H. F. BEALE,
Chief Engineer, Irrigation.

7th July 1915.

Statements Nos. I to IX-B accompanying Chief Engineer, Irrigation's Note No. I.

Statement No. I.

Statement showing average Kharif withdrawals in the Punjab and North-West Frontier Province.

Year.	Sirhind Canal.	Upper Bari Doab.	Lower Chenab Canal.	Lower Jhelum Canal.	Upper Sutlej Inundation Canal (excluding Lower Sohag and Para Inundation Canals).	Sidhnai Inundation Canal (including Koranga Fazil Tank, etc.).	Indus Inundation Canal.	Shahpur (Imperial) Inundation Canal.	Ghaggar Canal, Northern and Southern.	Lower Sutlej Inundation Canal.	Chenab Inundation Canal.	Muzafargarh Inundation Canal.	Shahpur Provincial Inundation Canal.	Rawi Inundation Canal.	Rangoi Canal.	Lower Sohag and Para Inundation Canals.	Swat and Kabul River and Paharpur Canal.	Total.	Remarks.
1867–68 ..	..	2,015	..	..	900	..	2,500	..	..	..	..	..	..	..	..	..	..	5,415	
1868–69 ..	..	1,971	..	..	800	..	2,000	..	..	..	..	..	..	..	..	..	..	4,771	
1869–70 ..	..	2,419	..	..	1,000	..	2,200	..	..	..	..	..	..	..	..	..	..	5,619	
1870–71 ..	..	2,391	..	..	900	..	2,600	100	..	..	..	..	..	..	..	..	..	5,991	
1871–72 ..	..	2,200	..	..	900	..	2,200	150	..	..	..	..	..	..	..	..	..	5,450	
1872–73 ..	..	2,019	..	..	1,000	..	2,700	150	..	..	..	..	..	..	..	..	..	5,869	
1873–74 ..	..	2,508	..	..	600	..	2,500	150	..	..	..	..	..	..	..	..	..	5,758	
1874–75 ..	..	2,229	..	..	800	..	2,600	150	..	..	..	..	..	..	..	..	..	5,779	Average 5,443.
1875–76 ..	..	1,879	..	..	800	..	2,200	150	..	..	..	..	..	..	..	..	..	5,029	
1876–77 ..	..	1,748	..	..	500	..	2,600	150	..	..	..	..	..	..	..	..	..	4,998	
1877–78 ..	..	1,823	..	..	800	..	2,600	150	..	..	..	..	..	..	..	..	..	5,373	
1878–79 ..	..	2,001	..	..	1,000	..	2,000	200	..	..	..	..	..	..	..	..	..	5,201	
1879–80 ..	..	2,501	..	..	900	..	2,000	100	..	..	..	..	..	..	..	..	..	5,501	
1880–81 ..	..	2,759	..	..	935	..	2,600	150	..	1,800	..	4,500	..	1880	–81	..	..	12,744	
1881–82 ..	..	1,954	..	..	1,403	..	2,700	200	..	2,800	..	4,500	..	..	..	..	..	13,557	
1882–83 ..	..	2,725	..	..	934	..	2,800	200	..	2,700	..	4,500	..	..	..	..	..	13,859	
1883–84 ..	60	3,036	..	..	759	..	2,500	100	..	1,800	..	4,300	..	..	..	..	..	12,555	
1884–85 ..	200	2,860	..	..	1,170	..	2,800	200	..	2,400	..	4,600	..	..	..	..	..	14,230	
1885–86 ..	650	3,196	..	..	1,132	..	2,700	200	..	2,200	..	4,500	..	..	..	729	120	15,427	
1886–87 ..	863	2,365	..	..	1,577	80	2,800	200	..	2,800	..	4,500	..	..	..	506	242	15,933	
1887–88 ..	3,128	3,395	152	..	1,400	500	2,976	250	..	2,000	..	4,500	..	..	..	495	475	19,271	
1888–89 ..	3,691	3,628	381	..	1,318	600	3,807	250	..	2,800	..	4,600	..	..	1888–89	524	561	22,160	
1889–90 ..	3,565	3,593	245	..	2,309	630	3,697	250	..	3,390	2,469	4,600	..	..	..	727	472	25,947	
1890–91 ..	3,949	3,648	409	..	1,745	630	3,699	300	..	1,685	2,798	4,500	200	..	..	663	587	24,813	
1891–92 ..	4,061	3,482	407	..	1,373	646	2,867	300	..	1,601	2,289	3,500	170	..	..	421	523	21,640	
1892–93 ..	4,024	3,620	1,553	..	1,811	854	3,972	300	..	2,467	1,727	3,981	300	..	..	702	630	25,941	
1893–94 ..	4,425	3,196	1,700	..	2,056	880	2,626	150	..	2,441	2,184	3,713	160	..	..	686	495	24,712	
1894–95 ..	3,374	3,292	1,959	..	3,067	931	2,647	371	..	2,701	3,058	5,049	208		1894–95	1,302	423	28,382	
1895–96 ..	5,073	4, 25	2,403	..	1,951	987	2,567	441	..	1,759	2,210	4,594	163	..	..	985	449	27,707	
1896–97 ..	6,163	4,840	2,774	..	2,179	940	2,502	570	..	2,049	2,250	4,645	239	..	..	719	555	30,425	
1897–98 ..	5,495	4,776	4,242	..	2,539	1,004	2,742	664	165	2,741	1,941	4,888	359		1897–98	977	463	32,996	
1898–99 ..	5,479	4,503	5,435	..	2,227	1,109	2,517	301	291	2,219	1,756	3,093	252	..	..	929	606	30,717	
1899–1900.	6,767	5,236	7,409	..	2,728	1,384	2,587	392	302	1,994	2,456	3,451	230	..	..	845	620	36,401	
1900–01 ..	6,149	4,857	8,794	..	3,218	1,642	2,714	466	306	2,885	3,036	3,493	428	..	..	1,106	576	39,670	
1901–02 ..	5,288	4,796	8,459	240	3,541	1,428	2,125	286	325	2,303	2,573	2,894	262	..	..	989	590	36,099	
1902–03 ..	5,966	5,331	9,303	542	3,209	1,204	1,875	374	114	1,626	2,435	3,505	334	..	..	774	713	37,305	
1903–04 ..	6,455	5,267	9,111	1,458	3,248	1,761	2,523	558	677	2,209	2,800	4,020	396	323	1903–04	803	931	42,540	
1904–05 ..	5,941	5,512	9,110	2,157	3,691	1,636	2,276	279	427	1,736	2,859	2,884	337	78	..	No discharges recorded, these apparently have been included in Upper Sutlej Inundation Canals.	820	39,743	
1905–06 ..	6,390	5,543	9,653	2,646	4,730	1,939	3,001	410	245	2,558	3,002	3,028	369	315	73		892	44,794	
1906–07 ..	5,178	4,873	9,162	2,935	5,528	1,887	2,929	363	654	2,795	3,754	3,371	317	351	395		919	45,411	Average 42,133.
1907–08 ..	5,053	5,141	9,226	3,182	2,846	1,414	1,832	413	357	1,905	2,997	2,210	236	291	120		917	38,140	
1908–09 ..	5,199	5,093	9,298	2,987	3,849	1,247	3,415	468	460	2,818	2,335	4,130	375	660	283		904	43,521	
1909–10 ..	3,990	5,189	8,296	3,115	5,408	1,490	2,727	451	677	2,820	2,748	4,835	394	415	284		995	43,834	
1910–11 ..	3,439	5,162	9,223	3,025	4,957	1,831	3,293	583	725	2,466	3,523	5,337	428	584	245		874	45,695	
1911–12 ..	5,300	5,627	9,349	3,278	4,530	2,055	3,572	379	155	1,710	2,993	3,594	276	280	5		1,268	44,371	
1912–13 ..	6,330	5,452	9,749	3,178	4,479	1,443	2,569	481	819	2,327	2,629	5,005	470	439	Not given		1,241	46,611	

64

Statement No. II.

Statement showing average Rabi Draw-off in Punjab and North-West Frontier Canals.

Year.	Swat Canal and Kabul.	Bari Doab.	Sirhind Canal.	Lower Chenab Canal.	Shidhnai Canal.	Jhelum.	Total.
1867–68	..	1,434	..	..	..	..	1,434
1868–69	..	1,728	..	..	..	..	1,728
1869–70	..	1,476	..	..	..	..	1,476
1870–71	..	2,012	..	..	..	..	2,012
1871–72	..	1,946	..	..	..	..	1,946
1872–73	..	1,657	..	..	..	..	1,657
1873–74	..	1,592	..	..	..	..	1,592
1874–75	..	2,050	..	..	..	..	2,050
1875–76	..	1,525	..	..	..	..	1,525
1876–77	..	1,342	..	..	..	..	1,342
1877–78	..	1,130	..	..	..	..	1,130
1878–79	..	1,958	..	..	..	..	1,958
1879–80	..	2,073	..	..	..	..	2,073
1880–81	..	1,950	..	..	..	..	1,950
1881–82	..	1,681	..	..	..	..	1,681
1882–83	..	1,994	..	..	..	..	1,994
1883–84	..	1,658	10	..	..	..	1,668
1884–85	..	2,091	120	..	..	..	2,211
1885–86	249	2,257	918	..	..	..	3,424
1886–87	317	1,950	2,001	..	40	..	4,308
1887–88	392	2,164	3,747	108	50	..	6,461
1888–89	468	2,129	4,041	250	100	..	6,988
1889–90	534	1,862	4,258	282	58	..	6,994
1890–91	471	2,387	4,574	238	108	..	7,778
1891–92	630	2,470	4,505	320	108	..	8,033
1892–93	500	2,764	3,763	1,135	450	..	8,612
1893–94	441	2,784	4,719	1,529	540	..	10,013
1894–95	475	3,019	4,595	2,115	310	..	10,514
1895–96	475	2,558	5,017	2,288	140	..	10,478
1896–97	526	2,793	4,920	3,735	140	..	12,114
1897–98	519	2,739	5,314	4,913	160	..	13,645
1898–99	517	2,638	4,667	5,907	..	..	13,729
1899–1900	607	2,286	5,358	5,877	..	..	14,128
1900–01	535	2,984	4,321	8,318	390	..	16,548
1901–02	571	2,186	4,868	6,293	..	457	14,375
1902–03	586*	2,091	4,563	6,763	..	947	14,950
1903–04	777	2,513	6,485	8,026	450	1,934	20,185
1904–05	671	2,804	4,528	8,263	337	2,592	19,195
1905–06	717	2,678	4,755	7,528	290	3,047	19,015
1906–07	703†	3,166	5,148	7,572	940	3,476	21,005
1907–08	879	2,144	4,379	6,667	..	3,652	17,721
1908–09	831	2,670	4,261	8,080	306	3,239	19,387
1909–10	852	2,916	4,011	8,169	714	3,486	20,148
1910–11	745	3,347	4,839	8,247	975	3,523	21,676
1911–12	1,095	2,697	5,154	8,150	..	3,660	20,756
1912–13	1,059	2,497	4,794	6,364	..	3,578	18,292

* Kabul Canal opened. † Paharpur Canal opened.

STATEMENT No. III.

Statement showing the minimum gauge readings of the river Indus at Bukkur from the year 1848-49.

R. L. of Zero of gauge = 184·44.

Date.	Gauge Reading.	Year.	Remarks.
3rd March 1849	0·58	1848–49	
24th February 1850	0·83	1849–50	
28th December 1850	1·50	1850–51	
8th February 1852	0·25	1851–52	
2nd February 1853	0·25	1852–53	
2nd February 1854	0·10	1853–54	
13th February 1855	—0·17	1854–55	
14th January 1856	0·42	1855–56	
10th January 1857	1·17	1856–57	
25th January 1858	1·67	1857–58	
5th January 1859	2·00	1858–59	
28th January 1860	—0·17	1859–60	
12th March 1861	—0·42	1860–61	
23rd February 1862	—0·92	1861–62	
12th March 1863	—0·50	1862–63	
23rd February 1864	—1·92	1863–64	
25th January 1865	—0·33	1864–65	
10th December 1865	2·08	1865–66	
19th February 1867	—0·33	1866–67	
3rd February 1868	—0·50	1867–68	
4th February 1869	—0·42	1868–69	
14th February 1870	—0·08	1869–70	
13th February 1871	—1·67	1870–71	
16th December 1871	—0·67	1871–72	
13th February 1873	—1·25	1872–73	
27th January 1874	0·08	1873–74	
16th February 1875	0·08	1874–75	
2nd January 1876	1·50	1875–76	
14th January 1877	1·33	1876–77	
17th November 1877	3·33	1877–78	
16th February 1879	1·42	1878–79	
19th February 1880	—0·08	1879–80	
18th December 1880	0·00	1880–81	
12th January 1882	0·00	1881–82	
18th January 1883	1·83	1882–83	
23rd January 1884	1·67	1883–84	
11th January 1885	0·58	1884–85	
14th December 1885	0·42	1885–86	
24th February 1887	1·92	1886–87	
24th January 1888	0·67	1887–88	
31st January 1889	0·75	1888–89	
19th March 1890	0·00	1889–90	
2nd December 1890	2·67	1890–91	
11th March 1892	0·08	1891–92	
9th January 1893	1·42	1892–93	

STATEMENT No. III.—(*continued.*)

Date.	Gauge Reading	Year,	Remarks.
6th January 1894	0·00	1893–94	
17th December 1894	—0·17	1894–95	
26th January 1896	—0·33	1895–96	
15th January 1897	—0·50	1896–97	
19th February 1898	—0·60	1897–98	
16th February 1899	—1·20	1898–99	*Discharge.*
8th March 1900	—0·70	1899–1900	
28th December 1900	1·70	1900–01	(32,000) on 2nd January 1901 + 1·8.
27th March 1902	—0·60	1901–02	(24,000)
9th March 1903	1·00	1902–03	(18,947)
1st March 1904	1·50	1903–04	(29,000)
2nd March 1905	1·20	1904–05	(27,000)
8th February 1906	0·50	1905–06	(24,000) 22,539 on 17th January 1906 + 1·2. *Discharge.*
4th February 1907	—0·60	1906–07	(?) 32,951 on 19th January 1907—0·2.
1st April 1908	—2·00	1907–08	25,712
25th February 1909	—2·40	1908–09	37,410; 36,026 on 17th February 1909—2·2.
23rd February 1910	0·50	1909–10	36,142; 30,813 on 26th March 1910+0·6.
8th January 1911	0·50	1910–11	(?) 33,200 on 10th January 1911+0·6.
30th March 1912	1·60	1911–12	35,311
19th February 1913	1·20	1912–13	23,730
11th February 1914	0·70	1913–14	23,719

Bracketed discharges are those guessed at; the others are actually gauged.

STATEMENT No. IV.

Statement showing the minimum discharge of the Indus at Sukkur for each year from 1901-14.

		Sukkur gauge feet.	Cusecs at outfall gauge site.
1900 ..	..28th December	+1·7	Not given.
1901 ..	..2nd January	+1·8	*32,000*
1902 ..	..27th March	—0·6	*24,000*
1903 ..	..9th March	+1·0	18,947
1904 ..	..1st March	+1·5	*29,000*
1905 ..	..2nd March	+1·2	*27,000*
1906 { ..	..8th February	+0·5	*24,000*
..	..17th January	+1·2	22,539
1907 { ..	..2nd February *	—0·5	33,143 (* On 4th February—0·6
..	..19th January	—0·2	32,951 was a lower reading.)
1908 ..	..1st April	—2·0	25,712
1909 ..	..17th February	—2·2	36,026
1910 { ..	..23rd February	+0·5	36,142
..	..26th March	+0·6	30,813
1911 ..	..10th January †	+0·6	33,200 († On 8th January+0·5 was a lower reading.)
1912 ..	..30th March	+1·6	35,311
1913 ..	..19th February	+1·2	23,730
1914 ..	..11th February	+0·7	23,719

Note.—"Observed" in Roman. "Deduced" in Italics.

STATEMENT No. V.

Statement showing observed discharges with 6 ft. (5·6 to 6·4 ft.) on the Bukkur gauge for each year from 1901-14.

Date.	Discharge in cusecs.	Gauge reading.
1901.		
12th April	101,193	6·1
29th April	104,411	5·8
1902—*Nil.*		
1903.		
28th April	69,281	6·3
26th October	75,406	6·3
28th October	79,274	6·2
30th October	71,076	6·0
2nd November	70,832	5·7
1904.		
5th April	62,593	5·8
6th April	63,236	5·7
7th April	61,911	5·6
9th April	53,533 *Minimum.*	5·8
12th April	72,532	6·0
14th April	76,346	6·0
16th April	77,991	6·0
18th April	79,427	6·0
27th April	76,966	6·2
29th April	65,400	5·9
2nd May	76,710	6·0
6th May	78,617	6·3
5th October	72,235	6·1
7th October	69,353	5·8
10th October	65,333	5·6
1905.		
22nd April	84,110	6·1
11th October	101,050	6·2
13th October	90,728	6·0
1906.		
10th October	136,861	6·4
13th October	119,389	6·1
1907.		
27th April	151,798	6·3
1908.		
1st May	163,391	6·4
8th May	147,742	5·9
13th May	144,072	5·7
15th May	132,465	5·6
27th May	131,631	5·9
30th May	138,511	5·6
9th June	169,930	6·3
1909.		
29th May	119,873	5·6
29th September	211,460 *Maximum.*	6·4
2nd October	177,589	6·1
6th October	149,705	5·6

STATEMENT No. V—(*concluded*).

Date.	Discharge in cusecs.	Gauge Reading.
1910.		
28th April	141,752	5·6
30th April	154,772	5·8
18th May	163,394	5·9
28th May	167,591	5·8
28th September	196,829	6·2
1st October	162,447	6·0
1911.		
19th April	158,958	6·3
1912.		
1st May	136,489	6·2
4th May	119,850	5·7
8th May	126,484	5·7
11th May	150,662	6·4
15th May	129,299	5·8
18th May	124,692	5·9
21st September	138,701	6·1
25th September	128,341	5·8
1913.		
17th May	85,383	5·7
25th September	138,510	6·3
27th September	108,513	6·1
1st October	99,516	5·7
1914.		
15th April	135,013	6·4
18th April	71,209	5·7
22nd April	84,367	5·8
25th April	73,205	5·9
30th May	69,739	6·4
7th October	162,635	5·7
7th November	132,939	5·9

Analysis.

In 1901 the two values averaged 102,000 cusecs.

In 1902 there are no figures.

In 1903 small variations, 70,000 to 80,000.

In 1904 greater variations, 53,000 to 79,000.

In 1905 higher values, 84,000 to 101,000.

In 1906 two values averaged 128,000.

In 1907 only one value, 152,000.

In 1908 variations from 132,000 to 170,000.

In 1909 four values from 120,000 to 211,000 maximum.

In 1910 variations from 142,000 to 197,000.

In 1911 one value only 159,000.

In 1912 variations from 120,000 to 151,000.

In 1913 four values from 85,000 to 138,000.

In 1914 variations from 70,000 to 163,000.

Statement No. VI.

Statement showing actual average discharges at Sukkur for 6, 8 *and* 10 *feet levels at Bukkur* in 1901—13 *and the change of levels that would have occurred had the Punjab withdrawals been less or greater.*

[*Note.*—The discharges are measured off the mean discharge curves $\frac{IV}{1}$ to $\frac{IV}{3}$.]

		1901. Blue cusecs.	1902. Green cusecs.	
6 feet levels.				
6 feet level at Bukkur, discharge		105,000	74,000	
Punjab Kharif withdrawals		36,000	37,000	
Assume Punjab withdrawals		5,000	5,000	
The discharge might have been		105+31 =136,000	74+32 =106,000	
Equivalent to gauge reading of		7·2	7·6	
	1901.		1902.	
Assume Punjab withdrawals	60,000	70,000	60,000	70,000
Discharge might have been	105—24 =81,000	105—34 =71,000	74—23 =51,000	74—33 =41,000
Equivalent to gauge readings of ..	4·8	4·2	4·4	3·3
8 feet levels.				
8 feet level at Bukkur, discharge		160,000	115,000	
Punjab Kharif withdrawals		36,000	37,000	
Assume Punjab withdrawals		5,000	5,000	
Discharge might have been		160+31 =191,000	115+32 =147,000	
Equivalent to gauge readings of		8·8	9·0	
	1901.		1902.	
Assume Punjab withdrawals	60,000	70,000	60,000	70,000
Discharge might have been	160—24 =136,000	160—34 =126,000	115—23 =92,000	115—33 =82,000
Equivalent to gauge readings of ..	7·2	6·9	7·0	6·4
10 feet levels.				
10 feet level at Bukkur, discharge		241,000		193,000
Punjab Kharif withdrawals		36,000		37,000
Assume Punjab withdrawals		5,000		5,000
Discharge might have been		241+31 =272,000		193+32 =225,000
Equivalent to gauge readings of		10·6		10·6
	1901.		1902.	
Assume Punjab withdrawals	60,000	70,000	60,000	70,000
Discharge might have been	241—24 =217,000	241—34 =207,000	193—23 =170,000	193—33 =160,000
Equivalent to gauge readings of ..	9·5	9·2	9·5	9·3

	1903. Yellow cusecs.	1904. Scarlet cusecs.	1905. Pink cusecs.
6 feet levels.			
6 feet level at Bukkur, discharge	67,000	72,000	80,000
Punjab Kharif withdrawals	41,000	39,000	43,000
Assume Punjab withdrawals	5,000	5,000	5,000
The discharge might have been	67+36 =103,000	72+34 =106,000	80+38 =118,000
Equivalent to gauge readings of	7·8	7·6	7·7

Statement No. VI—(*continued*).

	1903.		1904.		1905.	
Assume Punjab withdrawals	60,000	70,000	60,000	70,000	60,000	70,000
The discharge might have been	67—19 =48,000	67—29 =38,000	72—21 =51,000	72—31 =41,000	80—17 =63,000	80—27 =53,000
Equivalent to gauge readings of	4·7	3·8	4·6	3·7	5·1	4·4

8 feet levels.

	1903.	1904.	1905.
8 feet level at Bukkur, discharge.	108,000	118,000	126,000
Kharif withdrawals in Punjab ..	41,000	39,000	43,000
Assume Punjab withdrawals ..	5,000	5,000	5,000
The discharge at Sukkur might have been	108+36 =144,000	118+34 =152,000	126+38 =164,000
Equivalent to gauge readings of .	9·1	9·1	9·2

	1903.		1904.		1905.	
Assume Punjab withdrawals	60,000	70,000	60,000	70,000	60,000	70,000
The discharge at Sukkur might have been ..	108—19 =89,000	108—29 =79,000	118—21 =97,000	118—31 =87,000	126—17 =109,000	126—27 =99,000
Equivalent to gauge readings of	7·2	6·7	7·2	6·7	7·3	6·9

10 feet levels.

	1903.	1904.	1905.
10 feet level at Bukkur, discharge	177,000	188,000	190,000
Punjab Kharif withdrawals ..	41,000	39,000	43,000
Assume Punjab withdrawals ..	5,000	5,000	5,000
Discharge might have been ..	177+36 =213,000	188+34 =222,000	190+38 =228,000
Equivalent to gauge readings of .	10·8	10·8	10·95

	1903.		1904.		1905.	
Assume Punjab withdrawals	60,000	70,000	60,000	70,000	60,000	70,000
Discharge might have been	177—19 =158,000	177—29 =148,000	188—21 =167,000	188—31 =157,000	190—17 =173,000	190—27 =163,000
Equivalent to gauge readings of	9·5	9·2	9·5	9·2	9·5	9·2

6 feet levels.

	1906. Blue cusecs.	1907. Green cusecs.	1908. Yellow cusecs.
6 feet level at Bukkur, discharge.	117,000	136,000	156,000
Punjab Kharif withdrawals ..	45,000	38,000	43,000
Assume Punjab withdrawals ..	5,000	5,000	5,000
Discharge might have been ..	117+40 =157,000	136+33 =169,000	156+38 =194,000
Equivalent to gauge readings of .	7·6	7·1	7·0

	1906.		1907.		1908.	
Assume Punjab withdrawals	60,000	70,000	60,000	70,000	60,000	70,000
Discharge might have been	117—15 =102,000	117—25 =92,000	136—22 =114,000	136—32 =104,000	156—17 =139,000	156—27 =129,000
Equivalent to gauge readings of	5·3	4·9	5·0	4·6	5·4	5·1

8 feet levels.

	1906.	1907.	1908.
8 feet level at Bukkur, discharge.	168,000	196,000	235,000
Punjab Kharif withdrawals ..	45,000	38,000	43,000
Assume Punjab withdrawals ..	5,000	5,000	5,000
Discharge might have been ..	168+40 =208,000	196+33 =229,000	235+38 =273,000
Equivalent to gauge readings of .	9·3	8·9	8·8

STATEMENT No. VI—(*continued*).

	1906.		1907.		1908.	
Assume Punjab withdrawals	60,000	70,000	60,000	70,000	60,000	70,000
Discharge might have been	168—15 =153,000	168—25 =143,000	196—22 =174,000	196—32 =164,000	235—17 =218,000	235—27 =208,000
Equivalent to gauge readings of	7·5	7·1	7·4	7·0	7·6	7·3

10 *feet levels.*

	1906.	1907.	1908.
10 feet level at Bukkur discharge.	198,000	275,000	330,000
Punjab Kharif withdrawals ..	45,000	38,000	43,000
Assume Punjab withdrawals ..	5,000	5,000	5,000
Discharge might have been ..	198+40 =238,000	275+33 =308,000	330+38 =368,000
Equivalent to gauge readings of.	10·2	10·7	10·7

	1906.		1907.		1908.	
Assume Punjab withdrawals	60,000	70,000	60,000	70,000	60,000	70,000
Discharge might have been	198—15 =183,000	198—25 =173,000	275—22 =253,000	275—32 =243,000	330—17 =313,000	330—27 =303,000
Equivalent to gauge readings of	8·5	8·2	9·5	9·2	9·7	9·5

6 *feet levels.*

	1909. Red cusecs.	1910. Pink cusecs.	1911. Blue cusecs.
6 feet level at Bukkur, discharge.	180,000	155,000	158,000
Punjab, Kharif withdrawals ..	44,000	46,000	44,000
Assume Punjab withdrawals ..	5,000	5,000	5,000
Discharge might have been ..	180+39 =219,000	155+41 =196,000	158+39 =197,000
Equivalent to gauge readings of .	6·9	7·2	7·0

	1909.		1910.		1911.	
Assume Punjab withdrawals	60,000	70,000	60,000	70,000	60,000	70,000
Discharge might have been	180—16 =164,000	180—26 =154,000	155—14 =141,000	155—24 =131,000	158—16 =142,000	158—26 =132,000
Equivalent to gauge readings of	5·6	5·4	5·5	5·2	5·6	5·2

8 *feet levels.*

	1909.	1910.	1911.
8 feet level at Bukkur, discharge.	272,000	222,000	245,000
Punjab Kharif withdrawals ..	44,000	46,000	44,000
Assume Punjab withdrawals ..	5,000	5,000	5,000
Discharge might have been ..	272+39 =311,000	222+41 =263,000	245+39 =284,000
Equivalent to gauge readings of .	8·8	8·8	8·8

	1909.		1910.		1911.	
Assume Punjab withdrawals	60,000	70,000	60,000	70,000	60,000	70,000
Discharge might have been	272—16 =256,000	272—26 =246,000	222—14 =208,000	222—24 =198,000	245—16 =229,000	245—26 =219,000
Equivalent to gauge readings of	7·7	7·5	7·5	7·2	7·7	7·5

STATEMENT No. VI—(*concluded*).

10 feet levels.

	1909.	1910.	1911.
10 feet level at Bukkur, discharge	373,000	326,000	342,000
Punjab Kharif withdrawals ..	44,000	46,000	44,000
Assume Punjab withdrawals ..	5,000	5,000	5,000
Discharge might have been ..	373+39 =412,000	326+41 =367,000	342+39 =381,000
Equivalent to gauge readings of	10·7	10·9	10·7

	1909.		1910.		1911.	
Assume Punjab withdrawals	60,000	70,000	60,000	70,000	60,000	70,000
Discharge might have been	373—16 =357,000	373—26 =347,000	326—14 =312,000	326—24 =302,000	342—16 =326,000	342—20 =316,006
Equivalent to gauge readings of	9·7	9·5	9·9	9·7	9·7	9·5

6 feet levels.

	1912. Green.	1913. Yellow.
6 feet level at Bukkur, discharge	138,000	107,000
Punjab Kharif withdrawals	47,000	47,000
Assume Punjab withdrawals	5,000	5,000
Discharge might have been	138+42 =180,000	107+42 =149,000
Equivalent to gauge reading of	6·8	7·1

	1912.		1913.	
Assume Punjab withdrawals	60,000	70,000	60,000	70,000
Discharge might have been	138—13 =125,000	138—23 =115,000	107—13 =94,000	107—23 =84,000
Equivalent to gauge readings of ..	5·7	5·5	5·6	5·0

8 feet levels.

	1912.	1913.
8 feet level at Bukkur, discharge	250,000	188,000
Punjab Kharif withdrawals	47,000	47,000
Assume Punjab withdrawals	5,000	5,000
Discharge might have been	250+42 =292,000	188+42 =230,000
Equivalent to gauge readings of	8·7	8·8

	1912.		1913.	
Assume Punjab withdrawals	60,000	70,000	60,000	70,000
Discharge might have been	250—13 =237,000	250—23 =227,000	188—13 =175,000	188—23 =165,000
Equivalent to gauge readings of ..	7·8	7·6	7·7	7·5

10 feet levels.

	1912.	1913.
10 feet level at Bukkur, discharge	372,000	302,000
Punjab Kharif withdrawals	47,000	47,000
Assume Punjab withdrawals	5,000	5,000
Discharge might have been	372+42 =414,000	302+42 =344,000
Equivalent to gauge readings of	10·6	10·6

	1912.		1913.	
Assume Punjab withdrawals	60,000	70,000	60,000	70,000
Discharge might have been	372—13 =359,000	372—23 =349,000	302—13 =289,000	302—23 =279,000
Equivalent to gauge readings of ..	9·8	9·6	9·8	9·6

Statement No. VII.

Statement showing the character of inundation seasons in Sind from 1873 *to* 1912.

Year.	Character.	Year.	Character.	Year.	Character.	Year.	Character.
1873 ..	Very unfavourable.	1883 ..	Unfavourable.	1893 ..	Anomalous.	1903 ..	Good.
1874 ..	High and good.	1884 ..	Remarkably good.	1894 ..	Almost perfect.	1904 ..	Average.
1875 ..	Not very good.	1885 ..	Exceptionally good.	1895 ..	Disastrous.	1905 ..	Exceptionally good.
1876 ..	Favourable.	1886 ..	Very good.	1896 ..	On the whole satisfactory.	1906 ..	Very good.
1877 ..	Bad.	1887 ..	Very poor.	1897 ..	Exceptionally favourable.	1907 ..	Very poor.
1878 ..	Very good.	1888 ..	Bad.	1898 ..	Poor.	1908 ..	Good.
1879 ..	On the whole favourable.	1889 ..	Exceptionally good.	1899 ..	Very poor.	1909 ..	On the whole good.
1880 ..	Very bad.	1890 ..	Fair.	1900 ..	Most favourable.	1910 ..	On the whole favourable.
1881 ..	Favourable.	1891 ..	Poor.	1901 ..	Normal.	1911 ..	On the whole satisfactory.
1882 ..	Very good.	1892 ..	Very poor.	1902 ..	Very bad.	1912 ..	Not favourable.

Statement No. VIII.

Statement showing the water levels at Bukkur week by week in the unfavourable years.

Year.	May.		June.			
	15—23	24—31	1—7	8—15	16—23	24—30
1850	5·8–5·2	5·2–5·8	5·8–6·0 on 4th, then over 6			
1856	4·2–4·0	4·0–6·0	on 27th, then over 6			
1857	3·8–5·4	5·4–8·4	8·4–7·4	over 7·4	7·4–5·8	5·8–6·2
1863	2·8–4·0	4·0–5·8	5·8–5·3	5·3 to 6 on 12th, then over 6		
1867	4·6–7·0	7·0–4·6	4·6–6·0	(5·6) 6 and less to 6 and over 6		
1871	2·8–3·8	3·8–7·4	then over 6			
1890	4·6–5·0	5·0–7·8	over 6	over 6	over 6	over 6
1898	8·0–5·6	5·6–4·2	4·2–6·2	over 6	over 6	over 6
1909	3·4–5·0	5·0–5·6	5·6 over 6 from 2–7	over 6	over 6	over 6

Year.	September.				October.	
	1—7	8—15	16—23	24—30	1—7	8—15
1848		over 6	over 6	6·0–4·5	4·5–4·0	4·0–4·0
1851		over 6	over 6	6·0–5·0	5·0–4·6	4·6–3·4
1852		over 6	over 6	6·2–4·7	4·7–3·4	3·4–3·4
1853		over 6	over 6 till 21 then 5·6	5·6–4·8	4·8–3·6	3·6–3·0
1854		over 6	over 6 till 21 then 5	5·0–4·7	4·7–4·0	4·0–2·6
1855	4·6–6·0	over 6	over 6	8·6–4·7	4·7–3·6	3·6–2·6
1856		over 6	over 6	over 6	7·2–3·8	3·8–2·6
1859		over 6	over 6	6·2–5·4	5·4–4·8	4·8–3·5
1860		over 6	6·4–5·4	5·4–5·6	5·6–4·0	4·0–3·0
1863		over 6	over 6	6·2–3·8	3·8–2·8	2·8–2·0
1864		over 6	over 6	7·0–4·8	4·8–3·6	3·6–2·8
1885		over 6	over 6	7·3–5·7	5·7–4·2	4·2–3·2
1899		over 6	over 6	6·0–5·0	5·0–3·8	3·8–3·0
1907		over 6	over 6	6·0–5·0	5·0–4·1	4·1–3·3
1908		over 6	over 6	8·0–5·2	5·2–4·6	4·6–3·2

STATEMENT No. IX.

Statement showing periods of insufficient water level in the river Indus in July and August.

Year.	Days in July.	Days in August.	Total days on which the water level at Bukkur fell below 10 feet.
1848	11	4	15
1849	19	2	21
1850	28	....	28
1851	5	3	8
1852	....	4	4
1853	....	12	12
1855	12	15	27
1856	18	....	18
1857	27	....	27
1859	19	6	25
1860	19	....	19
1861	12	5	17
1862	6	....	6
1864	12	4	16
1865	8	....	8
1867	10	3	13
1868	....	1	1
1869	....	6	6
1873	10	....	10
1875	3	....	3
1876	4	....	4

STATEMENT No. IX—(*concluded*).

Year.	Days in		Total days on which the water level at Bukkur fell below 10 feet.
	July.	August.	
1880	....	2	2
1881	5	....	5
1883	....	2	2
1887	6	....	6
1888	2	....	2
1892	14	....	14
1893	....	8	8
1895	14	2	16
1896	....	1	1
1901	10	....	10
1902	4	7	11
1907	26	1	27
1908	5	....	5
1909	17	....	17
1910	2	....	2
1911	10	6	16
1912	7	....	7
1913	13	9	22

Statement No. IX-A.

Statement showing the total rainfall at 11 stations reproduced below, for each month of each year from 1866 to 1913.

(Simla, Murree, Ludhiana, Lahore, Sialkot, Rawalpindi, Peshawar, Dera Ismail Khan, Montgomery, Multan and Kushab.)

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October	November.	December.
1866*	..	..	8·99	15·86	7·33	22·03	53·83	67·23	3·36	0·90	..	..
1867*	3·46	6·20	7·00	19·82	18·13	10·62	37·30	73·24	12·20	2·10	..	4·10
1868..	7·69	11·30	16·86	29·34	12·80	18·60	53·70	33·10	11·06	1·90	0·20	8·96
1869..	14·40	5·50	58·23	4·44	1·39	22·73	93·44	37·41	67·58	8·10	0·03	2·66
1870..	3·39	3.00	25·00	3·80	1·92	44·49	55·22	77·90	21·40	3·50	..	2·62
1871..	2·04	31·66	0·40	4·70	17·60	51·80	82·30	37·50	15·27	0·13	..	5·50
1872..	13·80	9·40	13·10	15·33	16·77	22·90	93·30	67·90	29·90	0·60	2·10	2·20
1873..	6·70	4·60	12·50	2·00	33·50	2·70	85·50	67·30	36·10	4·70	0·40	8·10
1874..	18·60	8·00	16·90	10·40	6·50	28·04	91·82	55·90	24·40	0·50	..	..
1875..	1·10	18·90	3·40	0·20	12·60	15·80	85·00	89·30	71·50	11·20	5·26	6·74
1876..	7·60	6·50	5·70	17·90	9·90	15·40	72·02	81·38	20·00	13·10	7·78	0·30
1877..	22·40	35·60	23·20	44·40	5·60	19·50	33·10	15·50	35·10	21·86	41·82	16·12
1878..	8·60	23·00	1·80	36·90	37·70	8·10	63·00	106·30	7·40	2·70	..	1·70
1879..	0·10	1·80	10·90	0·30	1·30	41·40	49·10	98·70	15·30	0·30	..	..
1880..	1·10	11·60	..	0·40	13·20	30·30	97·50	28·30	21·20	..	2·30	7·50
1881..	1·30	20·10	28·30	20·74	9·76	26·80	63·60	65·90	8·50	3·00	0·10	1·90
1882..	21·20	12·30	3·80	15·60	3·00	13·70	99·30	67·90	44·90	0·10	..	0·70
1883..	18·60	2·60	6·70	5·00	24·50	12·20	64·40	47·20	54·80	3·70	16·70	1·80
1884..	10·80	10·30	19·50	8·00	5·40	29·80	67·60	69·90	51·80	14·00	2·40	1·30
1885..	34·90	5·50	11·10	36·60	44·10	19·80	42·40	78·00	20·80	1·60	..	10·30
1886..	31·40	4·70	42·40	4·30	10·80	25·05	89·20	42·10	11·10	10·00	1·60	5·60
1887..	12·40	1·10	8·80	15·20	0·40	16·70	51·20	80·20	22·00	2·00	..	3·10

*There are no figures available for these years for Murree.

1888..	11·10	12·00	7·20	4·10	2·70	14·20	63·80	70·50	19·20	4·30	7·60	0·60
1889..	31·50	35·20	7·00	12·20	13·30	17·90	97·20	63·87	8·20	..	..	0·60
1890..	6·30	2·84	11·11	12·24	6·51	24·67	93·83	105·25	15·39	6·05	16·89	20·41
1891..	33·34	22·18	31·71	13·36	9·18	5·45	32·38	82·31	27·16	12·80	2·18	..
1892..	3·34	6·71	4·26	0·34	8·87	15·49	91·41	133·89	31·15	0·84	0·99	11·14
1893..	44·95	46·46	14·30	12·01	27·18	40·37	104·01	22·45	56·19	3·57	0·40	5·70
1894..	44·65	24·62	25·46	11·07	6·80	55·73	114·93	57·33	24·73	1·14	4·17	19·35
1895..	25·90	11·97	30·48	13·43	1·83	67·25	37·37	98·68	8·78	1·17	1·15	0·84
1896..	16·66	18·43	12·19	2·51	4·54	23·55	47·32	56·13	12·94	2·48	6·16	5·47
1897..	27·33	12·97	15·66	16·15	8·54	13·39	46·38	96·84	17·60	1·08	..	10·26
1898..	5·31	37·74	5·72	1·60	12·74	19·48	83·49	50·64	32·22	..	0·20	11·67
1899..	1·06	18·72	8·91	8·41	3·53	28·46	49·56	32·46	6·53	2·56	0·40	0·47
1900..	23·30	13·28	8·87	19·15	16·59	5·83	64·00	69·30	54·96	4·26	0·33	20·31
1901..	31·82	24·58	19·52	9·62	38·01	10·21	60·06	69·05	20·07	1·81	..	1·13
1902..	0·10	1·22	9·42	11·30	12·14	33·66	45·40	43·85	26·53	4·82	1·22	..
1903..	13·71	1·85	28·17	5·73	20·62	7·12	72·27	70·84	41·91	1·42	0·43	6·94
1904..	27·80	0·79	53·65	2·90	8·53	9·60	57·35	55·50	13·47	3·91	7·04	8·12
1905..	30·93	26·27	21·38	6·13	5·70	6·47	58·60	37·03	55·76	1·52	0·02	19·68
1906..	9·58	55·98	32·97	4·74	5·14	30·76	55·61	105·69	65·27	1·51	..	9·22
1907..	17·25	43·49	29·05	33·20	7·78	21·45	26·60	86·23	2·12	1·45	0·15	..
1908..	19·91	13·13	3·40	30·88	8·44	5·71	94·36	122·83	54·84	1·77	0·58	7·31
1909..	8·94	19·15	4·59	21·34	3·87	31·15	102·36	67·44	37·78	3·40	..	21·82
1910..	24·01	10·72	5·32	16·69	3·40	47·45	72·18	92·04	18·64	3·38	0·01	6·47
1911..	49·90	5·15	71·89	8·80	2·45	26·44	14·74	47·47	27·72	7·78	13·45	2·53
1912..	24·78	5·64	6·91	23·12	9·59	7·72	63·44	65·89	17·46	0·76	2·24	2·69
1913..	2·34	27·07	16·97	4·71	16·62	35·39	61·34	71·46	13·73	1·10	2·55	9·92

Statement No. IX-B.

Statement showing the nature of the snow-fall in the whole mountain zone surrounding the Punjab.

	Year.	January to March.	April.	May.	Remarks.
	1876	−1·0	+2·0	+1·0	
	1877	+3·0	+2·0	+3·0	Exceptionally heavy.
	1878	+2·0	+2·0	+3·0	Do.
	1879	−1·0	−1·0	0	
	1880	−1·0	−1·0	0	
	1881	−1·0	−1·0	0	
	1882	−1·0	−1·0	0	
	1883	0	−1·0	+3·0	
Less reliable	1884	+1·0	+2·0	+2·0	
	1885	+1·0	+2·0	+3·0	
	1886	+0·5	−1·0	0	
	1887	−1·0	−1·0	0	
	1888	−1·0	−1·0	0	
	1889	−1·0	−1·0	0	
	1890	−2·0	−1·0	0	Very light.
	1891	+3·0	+2·0	+3·0	Exceptionally heavy.
	1892	−3·0	−1·0	0	Very light.
	1893	+3·0	−1·0	0	Heavy.
	1894	+1·0	−1·0	0	
	1895	−0·5	−1·0	0	
	1896	−0·5	−1·0	0	
	1897	+1·0	+2·0	+2·0	
	1898	−2·0	−1·0	+2·0	Very light.
	1899	−1·0	+1·0	+1·0	
	1900	−0·5	+2·0	+2·0	
	1901	+1·0	+2·0	+1·0	
	1902	−2·0	+1·0	0	Light.
	1903	+0·5	+1·0	+2·0	
	1904	+1·0	−1·0	+2·0	
	1905	+3·0	+1·0	0	Heavy.
	1906	+2·0	+2·0	+2·0	Heavy.
	1907	+3·0	+2·0	−1·0	Very heavy.
	1908	−2·0	+1·0	+2·0 ?	Light.
	1909	0	+2·0	0	
	1910	0	−1·0	−1·0	
	1911	+3·0	0	0	
	1912	−2·0	−1·0	+1·0	Very light.
	1913	0	+2·0	0	
	1914	0	0	+1·0	

Scale employed.

± 1 = Slight.

± 2 = Moderate.

± 3 = Great.

II.

Note on the gain by seepage in the Indus River.

Dr. Summers' figures for seepage.

Dr. Summers in Volume 12, page 22, of the Barrage and Canal project has written a note on seepage between Sukkur and Kotri. He shows detailed figures for October only of the years 1903 to 1908, but on page 24 he gives the result of his calculations, showing the average seepage per mile between Sukkur and Kotri for those 6 years, as follows :—

	Seepage.	Average previous fall in river surface.
October	65 cusecs.	5·7 feet.
November	23 „	3·0 „
December	15 „	1·5 „
January	13 „	0·8 „
February	8 „	rise 0·2 „
March	—2 „	„ 0·9 „

His argument is that the floods spread into dhands * and over the banks, and that this water returns to the river when the level falls and its flow is confined to fewer channels or to only one channel.

* *viz.*, old river channels.

Evaporation may be neglected.

2. The argument is undoubtedly correct, but the point for investigation is whether a correct conclusion has been drawn from the figures obtained. The distance from Sukkur to Kotri by the stream is 260 miles and evaporation has been assumed at 0·4 inches per day which is a liberal allowance for the cold weather. On the assumed width of 3,500 feet, this amounts to roughly 1,850 cusecs for the whole length or 7 cusecs per mile. The average monthly discharge of the Indus from October to January varies from 120,000 cusecs to 30,000 cusecs. The loss by evaporation, being under 2,000 cusecs, is hardly appreciable. And as it is only necessary to ascertain what seepage there is in excess of the normal loss by evaporation this item may be neglected.

Draw-off for canals.

3. A further diminution of supply is due to the draw-off by canals, which in October is given as 5,000 to 10,000 cusecs, say, 7,000 cusecs on the average but in the later months it does not exceed 2,000 cusecs. We may assume :—

October	7,000 cusecs.	
November	3,000 „	
December, January, February and March ..	2,000 „	each.

As there are no tributaries to the Indus in the length considered, the discharge at Kotr should be less than at Sukkur roughly by these figures.

Comparison of 6 months' cold weather discharge at Sukkur and Kotri.

4. In Statement No. X the cold weather discharges at Sukkur and Kotri are compared. The seepage back to the river is generally most pronounced in October, as there is always a very abrupt fall in water level in September and October. Another Statement No. XIII is attached giving the falls in water levels a fortnight before the month periods of October, November and December. The greater and more rapid the fall the more pronounced should be the gain by seepage.

Analysis of statements.

5. It may be noted that the river discharges have been gauged throughout with Haskell's current meter, and the operations at Sukkur have been always under the direct superintendence of the present temporary Assistant Engineer, Mr. G. Davies. The work is being done very carefully. An examination of the figures of 13 years given in the statements mentioned in paragraph 4 shows that there is no great regularity in these figures, and certain extraordinary variations seem to prevent definite reliable conclusions being drawn.

The years, which do not conform at all to the average, are—

1901, 1909

and to some extent,

1912, 1906 and 1908

all of these showing too small a gain by seepage for the fall in water level. It is evident that an appreciable amount of seepage does occur, but it is attributable only to the river overflow, and this will continue as long as the floods in the Indus and its tributaries are not seriously interfered with. The figures given do not in any way indicate that water given for irrigation returns in any great quantity to the river. To prove this assertion we may compare the losses in the inundation season, with the gain in the cold weather.

Comparison of 4 months' inundation discharge at Sukkur and Kotri.

6. The average kharif discharge of all the canals between Sukkur and Kotri is 32,000* cusecs, and the loss during June, July, August and September between Sukkur and Kotri after deducting this draw off is shown in Statement No. XI.

* (20,000 to 30,000 British.) (2,500 to 5,500 Khairpur.)

Comparing loss and gain in the two periods.

7. The loss in those 4 months is compared with the gain in the subsequent 6 months in Statement No. XII and, with the exception of 1902–1903, and 1907–08, this clearly demonstrates that, quite apart from the amount of water used for irrigation, a vast amount of flood water spreads into the ground between Sukkur and Kotri and does not return to the river within that distance. Hence, these figures cannot be used to prove by analogy a gain in seepage from the increased area of irrigation in the Punjab. It is impossible to tell how much of the 32,000 cusecs a month withdrawn for canals between Sukkur and Kotri in the inundation period would, if left in the river, spread to the sides and then return to the river by seepage in the cold weather, but it is safe to say it would make very little difference, as this discharge would add in flood time only a few inches to the water level. The loss † between Sukkur and Kotri in excess of the draw-off (during the inundation season) is about equal to the draw-off on the average, *viz.*, 4×32,000 cusecs= 128,000 cusecs, and it might be argued from this that with double the draw-off by canals there would be *on the average* no further losses, and hence possibly no gain by seepage, but averages are of no use in such a case. The years of least loss were—

† See columns 6 and 7 of Statement No. XI.

1902 .. .. .. 35,100 cusecs for 4 months.

1907 .. .. .. 20,100 „ „ „

and these were the only years in which the gain by seepage in 6 months was greater than the loss in 4 months. In the years of greatest discharge the total gains by seepage (excluding losses during the 6 months' period (see column 4 of Statement No. XII) were often very small, see 1909-10 and 1912-13. And the following contrast is specially striking :—

	Losses in 4 months.	Gain in 6 months.	Gain alone in 6 months' period.
1907-08	20,100	27,600	27,600
1908-09	288,500	19,400	28,400

Irregularity of seepage figures.

8. The table at the foot of Statement No. XIII shows the irregularity of the figures, month by month, for various years.

The river level does not seem to influence the total seepage in any very definite manner as shown by the following examples :—

Year.		River levels (S) (K). at Sukkur & Kotri 15 Sept.	15 Dec.	Total Fall. Ft.	Gain in 6 months. Cusecs.	Gain alone in 6 months' period. Cusecs.
1909-10	.. S	12·7	0·7	12·0	—14,700	1,500
	K	20·4	6·4	14·0		
1912-13	.. S	6·8	1·7	5·1	—3,000	5,200
	K	15·3	6·7	8·6		

These are the 2 years of smallest gains.

Conclusions from above data.

9. The conclusions that may be arrived at are that :—

(*a*) there is generally seepage back to the river for some part of the period from October to March inclusive ;

(*b*) the seepage is usually very much more in October than in other months, following on the invariably rapid fall of water level in the river in September and October.

(*c*) the seepage may be entirely from the flooded area, and there is nothing to show that it is affected by any underground flow back from the irrigated area.

(*d*) there is no evidence in Sind of any definite quantity of water used for irrigation returning to the river. Irrigation water is spread thinly over a great area of ground and if it finds its way back to the river its progress must be very slow and the period of its return must be much more extended than the period of its application.

Observations in sub-soil water table.

10. Some observations have been made of the sub-soil water level in Sind up to a distance of 5 miles from the river at different stages of the river. These generally show that the water in the river is higher than in the ground on either side, but occasionally the sub-soil water surface slopes towards the river (*vide* sheets Nos. $\frac{VI}{1}$ and $\frac{VI}{2}$).

Sir John Benton's figures for seepage in the Punjab.

11. In Volume 12 of the project Appendix I, p. xii, Dr. Summers quotes Sir J. Benton, late Inspector-General of Irrigation, under the caption *seepage from irrigated tracts, Punjab,* he writes :

"Observations made on the Ravi, Chenab and Sutlej rivers go to show that the rate of inflow varies from 4 to 7 cusecs per mile of length of channel, and that it is about 5·5 cusecs on the average."

Also

"*Data, rough.* There have not been sufficient observations made to show very fully what the actual average amount of seepage will be, the figures given in paragraph 1 *supra* relate to observations made in 1906-07 and 1907-08."

Dr. Summers' figures in Sind are based on the figures of 6 years in succession, and are shown not to be universally applicable. It is not known what was the nature of the observations taken on the Ravi, Sutlej and Chenab, but the Punjab authorities have been asked if they can supply any information upon the movements of sub-soil water and upon the discharges of the Chenab and Sutlej above their junction.

Kharif withdrawal in Punjab and North-West Frontier Provinces.

12. The total kharif withdrawals for Punjab and North-West Frontier Provinces Canals are for the present about 46,000 cusecs, the Upper Swat and Triple Project will add 15,000 cusecs=61,000 cusecs and the Upper Sutlej when constructed, another 8,000 cusecs, making a future total of nearly 70,000 cusecs. If the seepage in the Punjab is, as in Sind, derived from the inundated river area, an increase of kharif withdrawals would to a certain extent induce increased seepage, because it would cause a more rapid reduction in the river level (see Note I, paragraph 12). It has been shown in Note I that the study of river discharges and of river levels has not yielded any proof that the Punjab withdrawals have affected the season supplies in Sind as a whole, but that, in certain conditions of the river bed, there may be a serious reduction of water level at the critical periods due to heavy withdrawals in the Punjab.

If, however, the seepage is derived principally from the area irrigated and not merely, from the inundated river area, then Sind may perhaps count upon an increased cold weather flow at some future date. For the present as shown by the following remarks, there is no evidence to show that the general cold weather regimé has been affected in any way.

Rotation of Punjab seepage to cold weather supply in Sind.

Variation in minimum river level at Bukkur.

13. To judge of the effect of seepage from up-country the variation of the minimum river gauge at Bukkur in each year may be studied. The following groups of years may be compared :—

(a) 1848-1867 .. .. 20 years.
(b) 1868-1893 .. .. 26 „
(c) 1894-1903 .. .. 10 „
(d) 1904-1913 .. .. 10 „

See Statement No. XIV attached.

The last two periods may be compared with each other, but they should be taken together as in column 4 of Statement No. XIV for comparison with the previous two.

The similarity between the first period of 20 years (column 2) and the last period (column 4) is striking and the difference between them and the intervening 25 years period (column 3) is not great. There is, however, a small downward tendency in the figures.

An exceptional year.

14. The year 1877-78 is altogether extraordinary. The lowest reading of that year *viz.*, 3·33 feet, occurred in November 1877, while the period of lowest supply is usually much later, mostly in February. The year 1877-78 must be left out of account as the readings throughout the cold weather were extraordinarily high, *vide* green book of gauges, attached to this note.

H. F. BEALE,
Chief Engineer, Irrigation.

7th July 1915.

Statements Nos. X to XIV accompanying Chief Engineer, Irrigation's Note No. II.

Statement No. X.

Statement comparing the cold weather discharges at Sukkur and Kotri.

(The figures are the average discharge in each month in cusecs.)

Gauges. S.	Gauges. K.	Year.	Month.	Sukkur.	Kotri.	Difference.	Losses by draw-off.	Gain seepage in excess of loss by evaporation.	Total gain in 6 months.
4·5	5·8	1901	October ..	99,193	53,142	*46,051*	7,000	*—39,100*	
2·8	2·0		November ..	59,433	54,767	*4,666*	3,000	*—1,700*	
1·4	1·7		December ..	37,000	39,968	2,968	2,000	5,000	*—24,200*
8·7	9·5								
		1902	January ..	30,484	31,000	516	2,000	2,500	
			February ..	27,964	29,714	1,750	2,000	3,800	
			March ..	25,451	28,742	3,291	2,000	5,300	
5·5	3·9	1902	October ..	64,806	73,032	8,226	7,000	15,200	
1·5	1·2		November ..	41,300	51,767	10,467	3,000	13,500	
1·2	1·5		December ..	30,097	36,935	6,838	2,000	8,800	45,600
8·2	6·6								
		1903	January ..	24,774	27,548	2,774	2,000	4,800	
			February ..	26,000	25,929	*71*	2,000	1,900	
			March ..	24,684	24,129	*555*	2,000	1,400	
6·6	3·9	1903	October ..	104,548	116,710	12,162	7,000	19,200	
3·1	3·2		November ..	56,800	63,467	6,667	3,000	9,700	
1·9	2·0		December ..	37,935	43,005	5,070	2,000	7,100	51,000
11·6	9·1								
		1904	January ..	37,968	39,484	1,516	2,000	3,500	
			February ..	33,690	40,724	7,034	2,000	9,000	
			March ..	52,161	52,613	452	2,000	2,500	
3·9	3·6	1904	October ..	58,935	66,968	8,033	7,000	15,000	
2·0	2·0		November ..	34,633	36,400	1,767	3,000	4,800	
0·8	1·4		December ..	31,710	31,710	..	2,000	2,000	43,600
6·7	7·0								
		1905	January ..	29,467	37,129	7,662	2,000	9,700	
			February ..	34,286	37,321	3,035	2,000	5,000	
			March ..	31,259	36,387	5,128	2,000	7,100	
5·4	3·2	1905	October ..	82,258	85,710	3,452	7,000	10,500	
2·6	2·4		November ..	43,000	49,967	6,967	3,000	10,000	
1·5	1·6		December ..	29,968	36,419	6,451	2,000	8,500	15,700
9·5	7·2								
		1906	January ..	29,129	37,740	8,611	2,000	10,600	
			February ..	40,857	33,210	*7,647*	2,000	*—5,600*	
			March ..	72,161	51,838	*20,323*	2,000	*—18,300*	
7·9	5·1	1906	October ..	118,935	130,419	11,484	7,000	18,500	
3·7	4·6		November ..	62,433	59,533	*2,900*	3,000	100	
1·4	1·9		December ..	39,548	41,806	2,258	2,000	4,300	45,600
13·0	11·6								
		1907	January ..	37,452	40,290	2,838	2,000	4,800	
			February ..	55,321	60,964	5,643	2,000	7,600	
			March ..	69,806	78,064	8,258	2,000	10,300	

STATEMENT No. X—(*continued*).

Gauges. S.	Gauges. K.	Year.	Month.	Sukkur.	Kotri.	Difference.	Losses by draw-off	Gain see page in excess of loss by evaporation.	Total gain in 6 months.
4·2	3·5	1907	October ..	75,419	78,419	3,000	7,000	10,000	
2·5	2·4		November ..	43,500	47,367	3,867	3,000	6,900	
1·2	1·4		December ..	35,903	36,710	807	2,000	2,800	27,600
7·9	7·3								
		1908	January ..	34,429	34,193	*236*	2,000	*1,800*	
			February ..	29,931	31,552	1,621	2,000	3,000	
			March ..	27,549	28,032	483	2,000	2,500	
11·3	9·9	1908	October ..	93,000	109,387	16,387	7,000	23,400	
2·9	4·1		November ..	56,433	58,468	2,035	3,000	5,000	
1·5	1·8		December ..	44,645	40,000	*4,645*	2,000	*—2,600*	19,400
15·7	15·8								
		1909	January ..	41,677	38,387	*3,290*	2,000	*—1,300*	
			February ..	38,229	33,429	*4,800*	2,000	*—2,800*	
			March ..	54,484	50,161	*4,323*	2,000	*—2,300*	
8·3	8·2	1909	October ..	116,935	103,935	*13,000*	7,000	*—6,000*	
2·3	3·6		November ..	59,967	57,667	*2,300*	3,000	700	
1·4	2·2		December ..	46,774	41,452	*5,322*	2,000	*—3,300*	
12·0	14·0								
		1910	January ..	59,387	51,645	*7,742*	2,000	*—5,700*	*—14,700*
			February ..	43,678	42,429	*1,249*	2,000	800	
			March ..	37,645	34,419	*3,226*	2,000	*—1,200*	
4·5	6·4	1910	October ..	107,742	116,290	8,548	7,000	15,500	
2·2	3·8		November ..	58,533	55,433	*3,100*	3,000	*—100*	
0·9	1·9		December ..	41,000	38,225	*2,775*	2,000	*—800*	*—4,000*
7·6	12·1								
		1911	January ..	55,129	52,548	*2,581*	2,000	*—600*	
			February ..	70,321	77,372	7,051	2,000	9,000	
			March ..	165,613	136,645	*28,968*	2,000	*—27,000*	
3·1	4·9	1911	October ..	104,806	104,484	*322*	7,000	6,700	
1·5	2·9		November ..	57,033	55,567	*1,466*	3,000	1,500	
0·7	1·5		December ..	50,258	41,000	*9,258*	2,000	*—7,300*	*—17,000*
5·3	9·3								
		1912	January ..	47,804	34,097	*13,707*	2,000	*—11,700*	
			February ..	51,241	45,896	*5,345*	2,000	*—3,300*	
			March ..	40,193	35,323	*4,870*	2,000	*—2,900*	
2·6	4·4	1912	October ..	68,419	63,613	*4,806*	7,000	2,200	
1·9	2·4		November ..	46,967	43,533	*3,434*	3,000	*—400*	
0·6	1·8		December ..	35,645	34,935	*710*	2,000	1,300	*—3,000*
5·1	8·6								
		1913	January ..	29,260	29,000	*260*	2,000	1,700	
			February ..	26,464	18,455	*8,009*	2,000	*—6,000*	
			March ..	33,935	30,161	*3,774*	2,000	*—1,800*	

STATEMENT No. X—*(concluded)*.

Gauges. S. K.	Year.	Month	Sukkur.	Kotri.	Difference.	Losses by draw-off.	Gain see page in excess of loss by evaporation.	Total gain in 6 months.
3·0 5·4	1913	October ..	71,258	72,258	1,000	7,000	8,000	
1·4 1·8		November ..	42,900	43,600	·700	3,000	3,700	
1·1 1·5		December ..	32,774	31,806	*968*	2,000	1,000	10,800
5·5 8·7								
	1914	January ..	29,419	25,903	*3,516*	2,000	*1,500*	
		February ..	29,714	26,964	*2,750*	2,000	*—750*	
		March ..	36,322	34,581	*1,741*	2,000	300	

Foot Note.—All the figures reported are accepted as correct; it may be stated, however, that the average monthly discharges have been obtained by totalling the figures for each day and dividing by the number of days in the month. Inasmuch as actual discharge observations are not taken daily, it is necessary to interpolate approximate figures of discharge for intervening days. In recent years the discharges are taken regularly 3 times a week throughout the year but in the first few years (*vide* Indus River Records) the observations were irregular and at much longer intervals, hence the figures given for the earlier years are less reliable than those of recent years.

STATEMENT No. XI.

Statement comparing the discharge at Sukkur and Kotri in the inundation season.

(The figures given show the average discharge for each in cubic feet per second.)

Year	Month.	Sukkur.	Kotri.	Difference.	Difference for period of 122 days *minus* draw-off 4 × 32,000 ‖ 128,000.	Total loss for 4 months in excess of draw-off.
1	2	3	4	5	6	7
1901 ..	June ..	208,000	190,433	17,600	269,100	
	July ..	307,677	238,968	68,700	—128,000	
	August ..	563,580	392,325	171,300		141,100
	September ..	299,300	287,826	11,500		
1902 ..	June ..	247,333	211,100	36,200	163,100	
	July ..	303,968	231,064	72,900	—128,000	
	August ..	273,871	238,581	35,300		35,100
	September ..	188,867	170,233	18,700		
1903 ..	June ..	221,500	159,200	62,300	317,500	
	July ..	325,032	239,419	85,600	—128,000	
	August ..	550,356	421,879	128,500		189,500
	September ..	362,267	321,167	41,100		
1904 ..	June ..	282,200	202,567	79,600	280,000	
	July ..	346,613	229,548	117,100	—128,000	
	August ..	441,613	356,290	85,300		152,000
	September ..	168,200	170,233	—2,000		
1905 ..	June ..	394,210	286,950	107,200	217,700	
	July ..	429,355	372,493	56,900	— 128,000	
	August ..	340,852	298,652	42,200		89,700
	September ..	271,733	260,279	11,400		

STATEMENT No. XI—(*continued*).

Year.	Month.	Sukkur.	Kotri.	Difference.	Difference for period of 122 days *minus* draw-off 4×32,000 = 128,000.	Total loss for 4 months in excess of draw-off
1	2	3	4	5	6	7
1906 ..	June ..	249,900	227,167	22,700	245,300	
	July ..	403,935	344,000	59,900	—128,000	
	August ..	524,613	365,806	158,800	———	117,300
	September ..	421,267	417,433	3,900		
1907 ..	June ..	235,033	205,567	29,400	148,100	
	July ..	230,338	193,322	37,000	—128,000	
	August ..	390,376	305,161	85,200	———	20,100
	September ..	171,633	175,067	—3,500		
1908 ..	June ..	250,767	177 067	73,700	416,500	
	July ..	423,908	297,226	126,700	—128,000	
	August ..	502,162	489,586	12,600	———	288,500
	September ..	512,767	309,300	203,500		
1909 ..	June ..	275,133	223,600	51,500	396,400	
	July ..	397,516	305,161	92,300	—128,000	
	August ..	535,677	378,774	156,900	———	268,400
	September ..	437,000	341,267	95,700		
1910 ..	June ..	349,700	240,833	108,900	369,400	
	July ..	452,806	334,871	117,900	—128,000	
	August ..	559,355	431,110	128,300	———	241,400
	September ..	356,633	342,267	14,300		
1911 ..	June ..	444,167	323,700	120,500	259,400	
	July ..	378,226	320,935	57,300	—128,000	
	August ..	352,129	317,226	34,900	———	131,400
	September ..	301,667	255,000	46,700		
1912 ..	June ..	271,267	168,133	103,200	569,500	
	July ..	523,452	268,968	254,500	—128,000	
	August ..	557,258	394,452	162,800	———	441,500
	September ..	234,081	185,133	49,000		
1913 ..	June ..	281,068	216,082	65,000	275,600	
	July ..	341,484	255,290	86,200	—128,000	
	August ..	431,516	337,516	94,000	———	147,600
	September ..	255,667	225,267	30,400		

Foot note.—All the figures reported are accepted as correct; it may be stated, however, that the average monthly discharges have been obtained by totalling the figures for each day and dividing by the number of days in the month. Inasmuch as actual discharge observations are not taken daily, it is necessary to interpolate approximate figures of discharge for intervening days. In recent years the discharges are taken regularly three times a week throughout the year, but in the first few years (*vide* Indus River Records) the observations were irregular and at much longer intervals, hence the figures given for the earlier years are less reliable than those of recent years.

STATEMENT No. XII.

Statement showing comparison of net losses between Sukkur and Kotri in June, July, August and September with net gains in six following months October—March.

[*Note*—To convert the figures into a correct volume, they must be multiplied by the number of seconds in one month.]

Year.	Losses in 4 months apart from Canal withdrawals.	Gain by seepage in 6 months.	Gains omitting figures of loss in this period.	Total loss apart from Canal withdrawals.	Gain.
1	2	3	4	5	6
1901-02	141,100	*—24,200*	16,600	165,300	
1902-03	35,100	45,600	45,600		10,500
1903-04	189,500	51,000	51,000	138,500	
1904-05	152,000	43,600	43,600	108,400	
1905-06	89,700	15,700	39,600	74,000	
1906-07	117,300	45,600	45,600	71,700	
1907-08	20,100	27,600	27,600		7,500
1908-09	288,500	19,400	28,400	269,100	
1909-10	268,400	*—14,700*	1,500	283,100	
1910-11	241,400	*—4,000*	24,500	245,400	
1911-12	131,400	*—17,000*	8,200	148,400	
1912-13	441,500	*—3,000*	5,200	444,500	
1913-14	147,600	10,800	13,000	136,800	

NOTE:—

Column 2 is taken from Column 7 of Statement XI.
Column 3 „ „ „ 8 of „ X.
Column 4 „ „ „ 7 of „ X, totals of positive values only.
Column 5 is column 2 *minus* column 3.
Column 6 is column 3 (when greater) *minus* column 2.

Statement No. XIII.

Statement showing the fall of water level at Sukkur and Kotri, permitting of seepage water entering the river.

—		1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.
15th September to 15th October	Sukkur ..	4·5	5·5	6·6	3·9	5·4	7·9	4·2	11·3	8·3	4·5	3·1	2·6	3·0
	Kotri ..	5·8	3·9	3·9	3·6	3·2	5·1	3·5	9·9	8·2	6·4	4·9	4·4	5·4
15th October to 15th November	Sukkur ..	2·8	1·5	3·1	2·0	2·6	3·7	2·5	2·9	2·3	2·2	1·5	1·9	1·4
	Kotri ..	2·0	1·2	3·2	2·0	2·4	4·6	2·4	4·1	3·6	3·8	2·9	2·4	1·8
15th November to 15th December	Sukkur ..	1·4	1·2	1·9	0·8	1·5	1·4	1·2	1·5	1·4	0·9	0·7	0·6	1·1
	Kotri ..	1·7	1·5	2·0	1·4	1·6	1·9	1·4	1·8	2·2	1·9	1·5	1·8	1·5
Total ..	Sukkur ..	8·7	8·2	11·6	6·7	9·5	13·0	7·9	15·7	12·0	7·6	5·3	5·1	5·5
	Kotri ..	9·5	6·6	9·1	7·0	7·2	11·6	7·3	15·8	14·0	12·1	9·3	8·6	8·7

	Fall in water level at Sukkur.	Kotri.
1901 and 1902 and 1905 do not differ much either in level or reduction of levels, but		
in 1901 there was loss of *—39,100* October and *—1,700* November and gain+5,000 December	8·7	9·5
and 1902, there was gain by seepage + 15,200 October and + 13,500 November and + 8,800 December	8·2	6·6
and 1905, there was gain by seepage + 10,500 October and + 10,000 November and + 8,500 December	9·5	7·2
1906 and 1909 are similar in levels and reduction, but		
in 1906, there was gain by seepage + 18,500 in October and + 100 November	13·0	11·6
in 1909, there was loss of *—6,000* October and gain + 700 in November	12·0	14·0

Highest.					October.	November.	December.	Lowest.				October.	November.	December.
In order :—	1908 reduction *	15·7	seepage gain ..		23,400	+5,000	*—2,600*	1912 reduction *	5·1	seepage gain ..		2,200	*—400*	+1,300
	1906 „	13·0	„ „ ..		18,500	+ 100	+ 4,300	1911 „	5·3	„ „ ..		6,700	+1,500	*—7,300*
	1909 „	12·0	„ „ ..		*—6,000*	+ 700	*—3,300*	1913 „	5·5	„ „ ..		8,000	+3,700	+1,000
	1903 „	11·6	„ „ ..		19,200	+ 9,700	+7,100	1904 „	6·7	„ „ ..		15,000	+4,800	+2,000

* At Sukkur only.

* At Sukkur only.

Statement No. XIV.

Statement showing variations in minimum gauge readings at Bukkur, and Punjab rabi withdrawals for the same period.

Period.	1848—1867.		1868—1893.		1894—1913.	
	20 years.		25 years, omitting 1877-78.		20 years.	
1	2		3		4	
Minimum gauge reading at Bukkur varied from—	—1.9 to 2.1		—1.7 to 2.2		—2.4 to 1.7	
	No. of years.	Proportion.	No. of years.	Proportion.	No. of years.	Proportion.
No. of years above 2 ft. ..	2	0.1	1	..	..	..
,, below 2 ft. ..	18	0.9	24	1.0	20	1.0
,, ,, 1 ft. ..	15	0.75	17	0.6	15	0.75
,, ,, 0 ..	9	0.45	6	0.2	10	0.5
,, ,, —1 ft. ..	2	0.1	2	0.1	2	0.1
,, ,, —2 ft. ..	..	..	..	..	1	0.05

	1848—1867.						1868—1893.						1894—1913.					
Horizontally—No. of years ..	2	18	15	9	2	0	1	24	17	6	2	0	0	20	15	10	2	1
Punjab and N. W. Frontier Province rabi draw-off.	No figures available.						1342	3329	3377	1709	1839	0	0	16395	15083	14659	18554	19387

Period.	1894—1903.	1904—1913.
	10 years.	10 years.
Minimum gauge reading at Bukkur varied from	—1.2 to 1.7	—2.4 to 1.6
No. of years below 2 ft.	10	10
,, ,, 1 ft.	8	7
,, ,, 0	7	3
,, ,, —1 ft.	1	1
,, ,, —2 ft.	0	1

Too short a period for comparison.

III

Note on Dr. Summers' proposal to build the Rohri Left Bank Canal first before the Barrage.

Dr. Summers in his letter to the Secretary of State, dated 1st June 1913, estimated the cost of the proposed Rohri Left Bank Canal at Rs. 500 lakhs and net revenue at 35·6 lakhs. The latter, he says, is subject to correction by the Revenue Department, but is based on Mr. Lucas' report.

2. On page v in the summary of his report on the alternative Project for the Rohri Canal 1913, he asserts that there are no valid objections to the *canal alone* that he knows of ; on page 2 of the report he mentions three objections which have been brought forward.

3. The whole question hinges on the water-supply, and the Government of India have asked if definite figures can be given to prove or disprove the assertion that ample water is available for a large Left Bank Canal without the construction of a barrage. On the assumptions (i) that the feeder of the proposed canal (to be called Summers' Supply Channel) can be kept clear of silt, and (ii) that the feeder and canal beds can be lowered sufficiently (on page 6 he suggests 2 feet, but as the canal has many falls in the first 30 miles, the bed might be lower still), there is no doubt that an ample supply of water could be drawn into this canal for kharif and rabi irrigation. Assumption (ii) is merely a question of design, but assumption (i) introduces an element of risk. This risk however, would be diminished if, instead of constructing Summers' Supply Channel as proposed, the Left Bank Canal were made to take off direct from the river in its narrow portion a short distance below the gorge. In the latter case, the natural weir effect caused by the rock-gorge at Rohri could not be taken advantage of. The heading up due to this gorge is shown in the following table (it is, however, subject to considerable variation) :—

Zero level at Outfall 184·13.
Zero level at Bukkur 184·44.
Distance apart 2 miles.

Bukkur reading and level. Feet.		Outfall reading and level. Feet.		Difference Feet.
0	184·44	0	184·13	0·31
2·1	186·54	2	186·13	0·41
6·3	190·74	6	190·13	0·61
9·1	193·54	8·6	192·73	0·81
11·7	196·14	10·2	194·33	1·81
15·5	199·94	12·0	196·13	3·81
17·0	201·44	13·7	197·83	3·61

Thus for the inundation period the difference in level varies from 0·8 to 3·8 feet, but for low readings it is generally less than 0·5 feet.

4. Unless the water-supply throughout both the kharif and rabi seasons can be absolutely assured there is no justification for counting on the enhanced water rates, which the Commissioner in Sind, Mr. Lucas, recommended in his report, Volume 2, of the proposed Barrage on Indus. These rates were not applicable to a canal whose supply could be curtailed by silt deposit or any other means. As a case of uncertainty in supply the example of the Jamrao Canal may be cited.

The attached Statement No. XV shows how the Jamrao rabi area increased until the silting in 1906 and 1908 of the Eastern Nara Supply Channel interfered with what appeared to be a reasonably safe supply. The figure of rabi irrigation was rising steadily, and in 1905-06 reached 132,351 acres, but it dropped to 20,337 acres in 1908-09. Even on the old Mithrao Canal, the principle canal in the Eastern Nara System, which is dependent upon the same Supply Channel, a serious set-back was experienced.

5. Mr. Hill, as Chief Engineer for Irrigation, Bombay, opposed Dr. Summers' "*Canal alone*" Scheme on the assumption that the canal bed would not be lowered and that water would have to be supplied to the full area of 3 million acres. But Dr. Summers on page 6 of his alternative report of 1913 does not adhere to either of these conditions, and it may be conceded that the canal proposed by him could be made to receive a good supply, if silting could with certainty be avoided.

Volume 11 of the Barrage Project.

With the offtake above the gorge, and if no barrage be constructed, the absence of silting at the head of the Supply Channel on the Left Bank of the river could not be guaranteed.

6. But the real objection to the *Left Bank Canal alone* is that it would abstract a large quantity of water from the river at the critical periods of the year and consequently diminish the supply to the other canals on the Left Bank, *viz.*, the Eastern Nara Supply and the Khairpur State Canals, as well as to the large British Canal systems on the Right Bank.

It has been shown in Note I, paragraph 12, that in years of bad supply an abstraction of 10,000 cusecs may reduce the water-level by as much as 0·9 ft. in October.

On page 54 of his Rohri Canal and Sukkur Barrage Project, 1913, Dr. Summers details the discharges required in different months. He has changed the duty of water for cotton from 70 acres in September to 140 acres in October. This does not seem correct but it is in accordance with Sir J. Benton's proposal, paragraph 47 (iii) of his final review, page 26; maintaining the 70 acres duty the discharges required are :—

	Cusecs.		Cusecs.
October	11,870	instead of	8,375
November	10,100	" "	6,700

7. It is even now difficult in some years to satisfy the demands of all the inundation canals at the end of the season, and it is evident that a great additional draw-off would be certain to affect the canals mentioned very materially.

In Note VI the effect of the interruption of supply and curtailment of cultivation in Sind is described. The prosperity of the Ghar Canal particularly is demonstrated by figures in that note. A reduction of supply, always a serious matter, would be felt most keenly in this area, and rightly resented, if it were known to be the result of increased withdrawals for the benefit of the Left Bank Canal.

The conclusion, therefore, is that the Rohri Left Bank Canal should not be constructed alone, inasmuch as its success would be bought at the expense of other systems.

8. The Government of Bombay pointed out in paragraph 23 of their forwarding letter No. W. I—2583, dated 5th December 1910, that they consider " it a matter of pressing importance that no delay should occur in devising means to supply the Ghar and Western Nara direct from the Barrage, not only because it is almost certain that such a project would be very remunerative, but because it is possible that at times of low water the barrage will deprive of some of their supply the Ghar and Nara Canals which are as much affected as any other canal in Sind by the draw-off in the Punjab." The figures now given show that this view was correct and that the Left Bank Canal cannot be built without building the Right Bank Canal, and that neither of them can be efficiently and fairly administered without the help of a barrage.

H. F. BEALE,

Chief Engineer, Irrigation.

7th July 1915.

STATEMENT No. XV.

Statement showing the area of rabi irrigation on the Jamrao and Eastern Nara Canal Systems before and after occurrence of heavy silt deposits in the Eastern Nara Supply Channel.

(Area of rabi irrigation in acres.)

Before silting.

	1902-03.	1903-04.	1904-05.	1905-06.	1906-07.	Total.	Average.
Jamrao	105,289	108,335	123,944	132,351	88,724	558,643	111,729
Eastern Nara	67,949	69,085	73,974	97,988	175,951	484,947	96,989
Total ..	173,238	177,420	197,918	230,339	264,675	1,043,590	208,718

(Area of rabi irrigation in acres.)

Since silting.

	1907-08.	1908-09.	1909-10.	1910-11.	1911-12.	1912-13.	Total.	Average.
Jamrao	47,990	20,337	46,224	47,318	75,587	76,178	313,634	52,272
Eastern Nara ..	43,831	96,011	49,521	69,199	55,526	44,277	358,365	59,727
Total ..	91,821	116,348	95,745	116,517	131,113	120,455	671,999	111,999

IV.

Note on the position of the barrage above or below the gorge.

The position for the barrage above the gorge was chosen for the following reasons :—

(i) It gave foundations on material harder than sand or clay to found on. It was termed rock or soft rock, but was not expected to be water-tight. It was material which would certainly stand the weight of the structure to be built upon it, and would not be blown out by the water pressure on the upstream side.

(ii) There was a rocky abutment on each bank which would prevent the barrage from being outflanked.

(iii) Being above the gorge, where the railway bridges cross the two arms of the Indus, no change in the condition of the river channel and floods due to this barrage could affect the bridges adversely.

(iv) The position was favourable for the Eastern Nara Supply Channel and the Sukkur Canal. Near the latter head the Right Bank Canal was to take off. For the Left Bank Canal, however, the take-off was not at all convenient, but the advantages of a barrage upstream of the gorge were considered so important that five alignments were carefully investigated for the Supply Channel. It was decided to provide an escape for this channel so that if silt accumulated it could be washed through into the river on the downstream side, and thus save the canals from getting any silt at all.

(v) There was a good width of river in which ample accommodation could be given for the necessary width of flood openings.

2. The London Committee have recommended that the barrage should be placed at some distance below the gorge, and have given reasons in paragraph 36 of their report. Of these reasons the following may be accepted as distinct advantages at the lower site :—

(*b*) the saving of cost of the Supply Channel, and reduction in the length of the Left Bank Canal ;

(*c*) the saving of some of the cost of upstream protective works ;

(*d*) the less increase of flood levels in the Indus above Sukkur.

3. When the reference was made to the Chief Engineer for Irrigation by the London Committee he raised various objections to a downstream barrage, which may be discussed in turn :—

(*a*) Narrow waterway.

(*b*) Too deep foundations if rock of any kind be wanted.

(*d*) Drowning valuable roads, lands and houses on the Sukkur and Rohri banks.

These 3 points may be considered first. We have fortunately had the largest measure flood on record in 1914. It was nearly 950,000 cusecs, but the local gauge reading was only 13·7 feet, compared with :—

	Local gauge.		Discharge.			
	13·4 ft.	for	699,000	cusecs	in	1901
and	13·6	„	616,000	„	„	1906.

On the Bukkur gauge the reading was 17·0 ft. with the maximum discharge and the next day 17·3 ft. compared with the highest recorded reading 17·9 ft. in 1896.

In the year 1908 the following were recorded :—

Local gauge.		Discharge.			
11·7 ft.	for	513,000	cusecs	in	July
11·8	„	821,000	„	„	September.

See Statement No. XVI attached.

The width of the river at the outfall gauge is between two well-defined banks, and is about 3,500 feet. It follows from the above that there is no tendency to undue rises in the river, as the heavy rush through the gorge seems to continue its scouring action to a certain extent at the outfall gauge site. The velocity for the maximum discharge is generally below 10 feet per second.

A waterway which is too narrow, would cause excessive heading up of the water-level.

4. There is an appreciable heading up at the gorge every year in flood time compared with the water-level at the outfall site. The difference in gauge readings for maximum discharge in each year varies from 1·5 ft. to 3·3 ft. (allowing for the difference in the zeros of the gauges

RL	
184·44	at Bukkur, and
184·13	at the outfall
0·31	

the actual water level is from 1·8 to 3·6 ft. higher at the gorge than at the outfall gauge). Thus any fresh heading up on the downstream side must affect the level above the gorge. The latter is more or less vertical sided and the difference can be roughly calculated ; for example, a heading up downstream of 2 ft. will (if the discharge remains the same) most probably produce a rise of level of less than 1½ ft. above the gorge. Apart from raising the water-level, which is objectionable, there is a definite advantage in having a well defined channel of not too great width above the barrage, as this will prevent the accumulation of sand island or shoals, which accumulation was, as pointed out in paragraph 10 of the Chief Engineer's note to the London Committee, dated 7th August 1913 (accompaniment to Bombay Government letter No. W. I.—8329 of 14th August 1913), a very serious drawback to the original design.

5. That the foundations should be on rock (or hard material) is not of importance at the lower site. For the site above the gorge the present Chief Engineer for Irrigation was strongly opposed to a barrage built on sand due to possible retrogression from the deep part of the gorge (see paragraph 3 of the note just referred to), but at the lower site with a proper talus and careful maintenance there should be no fear of failure.

6. It is not proposed to have a barrage very much wider than the river, but the highest flood level must be kept within reasonable bounds and a pitched embankment on the Left Bank, and a suitable wall on the Right Bank may be erected to protect the low-lying ground from submersion.

7. The further objections were :—

(*c*) greater rise in flood levels,

(*e*) raising flood level under railway bridges,

(*i*) possible silting in gorge which would cause further rise in flood levels and cost for protective works.

The advantages of the lower site are so great that every effort should be made to counteract the above objections.

8. Taking the crest level of the original design, *viz.*, RL 176 and 60 ft. openings it is found that if 1,100,000 cusecs could pass off in the present river with a high flood level of RL 200 (nearly 16 ft. on the gauge) it could probably be got through the barrage with a heading up of 1 ft. (RL 201). With 1,500,000 cusecs the water would probably head up to between RL 205 and 206. There is a great deal of guess work about these calculations, and the question requires further consideration. With a crest level of RL 173 the conditions in flood time would be more favourable, but the water would have to be ponded up 19*ft. by gates instead of 16 ft. in order to get the required flow in the canals. There is no doubt that a suitable crest level between RL 173 and 176 can be obtained, and the remarks made above show that the heading up above the gorge will be somewhat less than with a barrage at the upper site, especially if an accumulation of silt in the gorge can be avoided.

9. It is highly improbable that under existing conditions the greatest flood will exceed 1,100,000 cusecs, a figure which was adopted by Mr. Beale, as Superintending Engineer, Indus River Commission, after a very careful examination of the records, but there is the possibility of new conditions being introduced causing a more rapid concentration of flow. The late Chief Engineer for Irrigation, Mr. Arthur Hill, held the view very strongly that :—

(i) the Left Bank of the Indus above Rohri should be entirely protected from floods by a continuous bund, and

(ii) a central channel should be arranged for the river in long straight lines and pitched embankments erected on either side, so as to prevent the usual oscillation, spread of water surface, and inland erosion, which occur every year, and cause such heavy annual expenditure in maintenance of old bunds and erection of new ones on retired lines.

10. If in future years these two proposals should be revived and actually carried out, it is evident that the water which now flows towards the Eastern Nara River will remain in the river increasing its volume, and that instead of floods being moderated as they now are by spreading over vast tracts of land within a width of 8 to 10 miles and more, they will flow rapidly down the central channel and arrive in full force at Sukkur. Hence it is important to consider what would happen with a flood of 1,500,000 cusecs and to arrange that the barrage at any rate will not be endangered in any way by its arrival.

* RL 192—RL 173=19.

11. The effect of such a flood upon the river upstream of the gorge need not for the present be considered. It will be sufficient to take as the normal maximum flood 1,100,000 cusecs and debit the Barrage Project with all the measures necessary for the safe disposal of this volume of discharge. Other schemes involving heavier floods at Sukkur must bear their own expense.

12. The raising of the flood level under the railway bridges to the extent proposed, *viz.*, probably 3 or 4 ft. at the most is not important as regards boat traffic.

13. Further objections were :—

(*g*) will not get rid of guide banks above gorge,

(*h*) will necessitate more ample protection by raising river bunds, etc.

For any rise of level above the gorge it will be necessary to provide additional protection. This will consist of raising the long line of protective embankments for some miles or in addition to this of constructing guide banks to prevent dangerous loops forming east and west of Sukkur. Provision for both of these items is advisable. On the whole, however, it may be conceded that the danger will be less than in the original design, because, the river-bed upstream of the gorge will still be able to scour deeply in parts, and will not be obstructed by islands or shoals much more than at present. As stated already, this consideration will, to a certain extent, influence the selection of a suitable level for the barrage crest.

14. Finally—

(*f*) Nara Supply Channel not protected against silt banks.

This is one of the most serious objections and to overcome it special expenditure will be necessary. In recent years the mouth of this channel has been kept open by dredging but it has been a very difficult task, and it is preferable to avoid having to deal with the accumulation of the heavy silt banks. The best solution of the question yet suggested is to construct a new mouth for the Nara Supply below the gorge. A convenient line 7 miles long has been found passing through a gap in the Kohistan hills, but it has not yet been examined in detail. The cost of this must be added to the project when comparing the proposals above and below the gorge, but it does not form part of the Barrage Project. It is debitable to the Improvement of the Eastern Nara.

15. The London Committee suggested that a site for the weir might be found a few miles further down the stream, where the width of the river would be sufficient to permit of the construction of a barrage of the requisite length to prevent any undue afflux (paragraph 34 of their report), and Sir J. Ottley has made some remarks on this subject in his note, Part IV. The whole length of the river from the Ghár mouth up to the gorge has been considered, and the site half mile below the outfall gauge has been chosen, because—

(i) it gives the width required,

(ii) the river channel above it is not wide enough to permit the accumulation of shoals or sand islands,

(iii) it avoids the very heavy expense for training banks, which would be required in a broader portion of the river, and

(iv) it provides very suitable canal heads and has shorter canal lines to join the original alignment without loss of head.

H. F. BEALE,

Chief Engineer, Irrigation.

7th July 1915.

STATEMENT No. XVI.

Showing maximum discharge of Indus River at Sukkur in each year.

Serial order in volume of flow.	Outfall gauge reading Zero 184·13 feet.	Bukkur gauge reading Zero 184·44 feet.	Discharge gauge in cusecs.	Month and year.	Mean velocity feet per second.	Difference in gauge readings.
5	13·4	16·3	699,000	August 1901	9·60	2·9
	11·1	13·5	475,000	August 1902	8·20	2·4
9	12·5	15·3	592,000	September 1903 ..	9·18	2·8
	13·2	15·7	542,000	August 1904	7·76	2·5
	14·2	16·7	530,000	July 1905	6·94	2·5
8	13·6	16·4	616,000	August 1906	8·43	2·8
	10·6	12·1	425,000	August 1907	8·58	1·5
	(11·7)	(14·2)	(513,000)	(July 1908)	(8·63)	2·5
2	11·8	14·6	821,000	September 1908 ..	9·68	2·8
6	11·8	14·4	632,000	August 1909	10·23	2·6
4	12·2	14·3	700,000	September 1910 ..	9·16	2·1
	11·7	14·0	582,000	June 1911	9·30	2·9
3	12·8	14·8	721,000	July 1912	8·36	2·0
7	12·9	14·6	621,000	August 1913	8·46	1·7
1	13·7	17·0	949,000	August 1914	10·18	3·3

The variation of discharges with nearly equal gauge readings is very striking.

Note on the Right Bank Canal.

References were made to the Right Bank Canal in paragraph 3 of the letter of the Government of Bombay, No. W. I.—2583 of 5th December 1910, forwarding the Barrage and Rohri, Project, also in Volume 2 of the report, pp. 7, 73, 79 and 155, and in Volume 12 of the Report, p. 107, and Appendix XIV.

2. The Commissioner in Sind made as close an estimate as possible of the probable irrigation and revenue.

3. The nature of cultivation is quite different in the Right Bank from that on the Left.

4. The average rainfall on the Right Bank is from 3 to 4 inches (only Sehwan has 5 inches), while on the Left Bank it varies from 6 to 8 inches (Appendix IX, Volume 12). The former is principally a rice-growing area and cannot grow cotton nor has it much scope for perennial irrigation except in the southern talukas Dadu, Johi and Sehwan (Volume 2, p. 73).

5. The estimate for a Right Bank Canal with branches and a whole system of distribution as shown on the Index Map, Volume 12, Plate I, amounted to 468 lakhs of rupees for direct and indirect charges. This was for a canal 140* miles in length, with branches, etc., and discharging at the head 14,000* cusecs.

* Volume 8, page 38.

6. This, however, is an insufficient discharge, being based on too high a duty for rice cultivation, and in Volume 12, Appendix XIV, it is shown that 19,000 cusecs would be the correct figure and that the cost might consequently be Rs. 550 lakhs. The Commissioner in Sind showed (Volume 2, p. 155) that the scheme was not a promising one, even on the lower estimate, so it is now proposed to limit the work on the Right Bank to the construction of a large feeder channel to supply water to the Ghar and Western Nara and Pritchard Canal systems with three branches, Shahdadpur, Ratodero and Johi. Certain improvements will have to be made in the existing channels, and later on, when the demand arises, all the old canals can be gradually replaced by a complete canal net-work of modern design.

7. A rough estimate for this proposal has been made based upon the original estimates; the direct and indirect charges amount to Rs. 411 lakhs with an increased revenue, if the

Commissioner's full figure be adopted, of Rs. 24 lakhs or nearly 6 per cent. (excluding share of barrage).

8. The figures of cultivation were :—

	Present acres.	Proposed acres.
Rice	339,000	490,000
Other Kharif	214,000	130,000
Rabi	183,000	358,000
Total	736,000	978,000

out of a cultivable area (excluding Jaghir) 1,524,000 acres.

	Rs.	Rs.
Average rate per acre	3·3	5·77
Gross revenue	24,30,000	56,46,500
Deduct land share	—2,43,000	—5,64,600
Irrigation revenue	21,87,000	50,82,000
Working expenses at	0·96 per acre.	1·2 per acre.
	7,06,560	11,73,600
Net Irrigation revenue	14,80,000	39,08,000
Fresh revenue	24,28,000	

H. F. BEALE,

Chief Engineer, Irrigation.

8th July 1915.

VI.

Note on the financial aspect of the Barrage and Rohri Canals Projects.

The London Committee condemned the project submitted to the Secretary of State on the score that it could not certainly be predicted to be remunerative, and they recommended in their paragraph 38 that a perennial canal in Sind should be looked upon merely as an improvement to be desired but not essential, aid that if calculations showed it would be worked at a loss, the scheme should not be approved.

2. I submit that this narrow view of the proposals cannot be accepted. Many reasons can be given for condemning the above conclusions, but as in all one P. W. D. schemes we are tied down to the necessity of showing direct profits on the irrigation, I propose before re-submitting the project to prepare a fresh estimate of the whole scheme with such modifications as may be required, and the Commissioner in Sind has been asked to make a careful investigation regarding the revenue forecasts, and to include the figures for a large Right Bank Canal. The project submitted gave carefully selected figures of revenue for the Left Bank, but for the Right Bank they were admittedly somewhat rough, and included only the Ratodero and Shahdadpur branches, and improvements on the Sukkur Canal,* whereas now it is proposed to include the areas under the large and important Ghar and Western Nara systems the irrigation of which is to be helped by the construction of a large Right Bank Canal.

* The Commissioner in Sind, Mr. Lucas, gave figures also for the complete Right Bank Canal Scheme.

3. It is never very satisfactory to deal by rough approximation with such large figures as are here involved for the estimate either of expenditure or of revenue. As an example, I may instance the fact that the first approximate estimate for the Barrage was Rs. 141 lakhs, but in the project submitted to the Secretary of State the figure set down was Rs. 265 lakhs.

4. At the recent conference in Sukkur, when the Inspector-General of Irrigation met the Bombay Engineers, certain figures of probable savings were put down, but it would not be safe to accept the balance on the previous estimate to determine the cost of the new barrage proposals.

5. For the purpose of this note it is necessary to make some assumptions, and I shall adopt some figures in my forecast, which may be accepted as reasonably safe, pending the preparation of the new designs, estimates and forecasts, which are now to be taken in hand.

6. I have written a separate note (attached) upon the advantages of perennial over inundation canals in Sind, so now I will proceed to contrast the revenue and the maintenance charges of the two systems.

The Jamrao is the most important large canal worked as a perennial system in Sind, and it may therefore be compared with three typical large inundation canals, the Begari, Ghar and Dad. Statements have been prepared giving results for 14 years, and striking the averages for 10 years for the purpose of comparison.

The results are as follows :—

Canal.	Area irrigated	Gross Revenue assessed.	Working expenses.	Net Revenue assessed.	Capital lakhs.	Net profit after deducting interest.
	Acres.	Rs. per acre.	Rs. per acre.	Rs. per acre.	Rs.	Rs.
49—Begari ..	225,910	2·21	0·67	1·54	23½ (nearly)	2,80,285
43—Ghar ..	258,425	3.24	0.75	1.49	5¾	6,25,628
49—Dad ..	95,026	2.29	1.26	1.03	25½	17,606
49—Jamrao ..	231,929	2.98	1.41	1.57	84	78,485

This shows only a small advantage for the Jamrao compared with Begari in net Revenue per acre, but if interest on capital expenditure be taken into account the advantage vanishes altogether, because of the vast difference in Capital expenditure between perennial and inundation works.

7. But there are good reasons for saying that the Jamrao is not a fair example of a perennial canal, while the other systems are true types of inundation canals. The latter are liable to interruption of flow and to periodical heavy charges for the clearance of silt or for the excavation of new mouths when the river changes its course. The disastrous results of this action of the river is shown in the case of the Begari records by the reduced figures of revenue and the heavy increase of expenditure in recent years. In the first statement attached it is seen that the Begari Canal irrigated about 285,000 acres in 1900-01 and in 1913-14, and somewhat less in other years, but in the two years from 1911 to 1913 the area of irrigation was only 120,000 acres on the average. This sudden decline was disastrous, not only to Government revenues, but to the whole country side in throwing men out of employment, and depriving them of crops to the value of Rs. 38 lakhs. It is easy to see that among an agricultural population events of this dire nature give an opportunity for turbulent spirits to produce trouble, and those in distress often seek relief in objectionable forms of activity such as cattle lifting and other crimes.

Both the Ghar and the Dad have had some years of excessive charges for the same reasons. Accidents of this nature ought not to occur with perennial canals, and they will be precluded in the case of the large Left and Right Bank Rohri Canals by correct design.

8. Unfortunately the Eastern Nara Supply Channel, which feeds the Jamrao system, is liable to both of these mishaps and thus reduces the value of the Jamrao Canal as a perennial one. The result is seen in the poor revenue returns for the years from 1907 to 1911. Apart from 1904-05—a year of heavy expenditure on groynes in the canal, and of some diminution of irrigation, there was a continuous increase in the area of irrigation up to 1906, when silt was deposited heavily in the Eastern Nara Supply Channel. The same thing happened again in 1908, and the repeated failure to supply rabi water was a severe blow to this canal, from which it appears to be recovering now, but only very slowly. Without the danger of interruption an area of 300,000 acres could easily be irrigated every year.

9. Until 1904-05 the irrigation share, *viz.*, $\frac{8}{10}$ of the consolidated revenue assessed amounted to a rate of about Rs. 1·9 per acre irrigated; then from 1905-06 it has been Rs. 2.8. For an assured supply guaranteed by a barrage the Commissioner in Sind has suggested a rate of Rs. 4·8 per acre, but even with a little more than Rs. 3, a certain yield of Rs. 10 lakhs could be secured; allowing Rs. 4 lakhs for working expenses, the net revenue would be Rs. 6 lakhs per annum, or a clear profit of 3·20 lakhs or 4 per cent. on the capital expenditure after deducting Rs. 2·8 lakhs for interest.

These are not fanciful figures; they can be guaranteed with an assured supply of water every year. A return of 8 per cent., excluding interest charges, is an excellent result.

10. In spite of its recent troubles the Begari shows on the 10 years' average a net revenue (excluding interest) of 15 per cent., on his capital expenditure, and including interest a return of 12 per cent., but the Dad Canal (which lies in the area to be commanded by the Left Bank Canal) often shows a loss.

11. The Ghar system is quite peculiar; though so large, it is classed as a minor irrigation work under Irrigation Head "43," because the capital expenditure on it has been small and has not been charged to loan funds. It is a remarkably profitable system. The large Right Bank Canal must be made to serve the area under the Ghar Canal also, and give it all the water it requires. It will therefore be rather difficult when comparing the Ghar with Right Bank Canal merely in regard to direct revenue to show figures in favour of the perennial project, but the progress of and the general benefit to the country supply sufficiently potent reasons for the adoption of perennial schemes even in this part of Sind.

12. Accepting the largest estimate for the Barrage, *viz.*, Rs.* 266 lakhs and adding Rs. 30 lakhs for a Right Bank Regulator.

		Rs.
Cost of Barrage	∴=	296 lakhs.
,, Left Bank Canal	..=	483 ,,
,, Right Bank Canal	..=	411 ,,
Total	..	1,190 ,,

This total should not be exceed.

Certain reductions were suggested at the Sukkur Conference, *viz.*:—

		Rs.
Supply Channel	.. ..	50 lakhs.
Railway Crossing	.. ..	6·5 ,,
A—Part of River Training	..	20 ,,
Cheaper Khairpur Channels	..	5 ,,
Shorter Canals .	.. ..	6.5 ,,
Total	..	88 ,,

* Eastern Nara has not been included in the above figures.

So the estimate might be Rs. 1,100 lakhs, but it would be advisable to add Rs. 20 lakhs for A—River Training works = Rs. 1,120 lakhs. Total Capital cost, Rs. 1,120 lakhs.

Revenue.

Net Irrigation Revenue increase due to new works :—

		Rs.
Left Bank	.. .. ..	39·2 lakhs.
Right Bank	.. .. ..	24·3 „
Total	..	63·5 „

Thus the ultimate return upon the capital expenditure will be 5·67 per cent. (see explanatory note attached).

H. F. BEALE,
Chief Engineer, Irrigation.

8th July 1915.

Begari Canal.

Year.	Area irrigated.	Gross Revenue assessed from all sources.	Rate per acre.	Working Expenses.	Rate per acre.	Net Revenue assessed.	Rate per acre.	Interest on Capital.	Net profit.	Capital.
	Acres.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
1900–01	285,550	5,57,654	1·96	1,05,387	0·37	4,52,267	1·58	66,302	3,85,965	17,06,799
1901–02	222,515	4,35,379	1·96	91,346	0·41	3,44,033	1·54	66,302	2,77,731	17,06,799
1902–03	225,612	4,23,225	1·86	1,18,096	0·52	3,05,129	1·35	66,302	2,38,827	17,06,799
1903–04	271,009	5,41,677	2·00	1,10,645	0·41	4,31,032	1·59	66,302	3,64,730	17,06,799
1904–05	232,598	4,74,774	2·04	1,17,917	0·51	3,56,857	1·53	66,302	2,90,555	17,06,799
1905–06	251,044	5,21,450	2·08	1,43,242	0·57	3,78,208	1·51	66,302	3,11,906	17,06,799
1906–07	264,163	5,76,958	2·10	94,626	0·36	4,82,332	1·82	58,133	4,24,199	17,76,201
1907–08	265,969	6,33,934	2·37	99,635	0·37	5,34,299	2·09	62,334	4,71,965	19,84,686
1908–09	274,265	6,43,338	2·34	1,46,986	0·54	4,96,352	1·81	67,391	4,28,961	21,13,235
1909–10	230,752	5,69,404	2·45	1,20,127	0·52	4,49,277	1·95	70,395	3,78,882	21,99,433
1910–11	224,580	5,64,164	2·49	2,21,043	0·98	3,43,121	1·53	71,647	2,71,474	21,65,054
1911–12	108,470	2,23,919	2·04	1,50,752	1·38	73,167	0·67	73,127	40	22,58,244
1912–13	136,257	2,55,484	1·86	3,17,343	2·33	*—61,859*	....	78,000	*—1,39,859*	23,28,036
1913–14	284,155	5,79,862	2·03	3,05,667	1·08	2,74,195	0·96	76,849	1,97,346	23,45,330
Average for 10 years (*viz.*, 1903-04 to 1912-13).	225,910	5,00,510	2·21	1,52,232	0·67	3,48,278	1·54	67,993	2,80,285	23,45,330

Ghar Canal.

Year.	Area irrigated.	Gross Revenue assessed from all sources.	Rate per acre.	Working Expenses.	Rate per acre.	Net Revenue assessed.	Rate per acre.	Interest on Capital.	Net profit.	Capital.
1900–01	274,689	7,82,558	2·82	1,84,250	0·67	5,98,308	2·18	16,654	5,81,654	4,42,765
1901–02	278,312	7,97,627	2·84	1,86,818	0·67	6,10,809	2·19	16,836	5,93,973	4,50,934
1902–03	267,078	7,71,272	2·85	1,83,628	0·69	5,87,644	2·20	16,986	5,70,658	4,51,181
1903–04	284,475	8,21,488	2·86	1,76,625	0·62	6,44,863	2·27	16,986	6,27,777	4,51,181
1904–05	251,537	7,51,323	2·95	1,66,581	0·66	5,84,742	2·32	17,850	5,66,892	4,98,602
1905–06	280,649	8,51,228	3·00	1,78,240	0·64	6,72,988	2·40	19,534	6,53,454	5,43,618
1906–07	285,815	9,09,514	3·15	1,79,941	0·63	7,29,573	2·55	18,139	7,11,434	5,69,953
1907–08	219,844	6,37,568	2·86	1,58,392	0·72	4,79,176	2·18	18,461	4,60,715	5,72,386
1908–09	281,679	8,39,297	2·95	1,63,255	0·58	6,76,042	2·40	18,331	6,57,711	5,72,386
1909–10	230,333	7,53,523	3·22	2,14,357	0·93	5,39,166	2·34	18,190	5,20,976	5,72,386
1910–11	255,398	9,47,727	3·67	3,10,257	1·21	6,37,470	2·49	18,293	6,19,177	5,72,386
1911–12	232,119	8,95,801	3·80	1,93,141	0·83	7,02,660	3·03	18,423	6,84,237	5,72,386
1912–13	262,398	9,85,402	3·71	2,12,527	0·81	7,72,875	2·94	18,959	7,53,916	5,72,386
1913–14	251,837	10,06,150	3·94	2,26,985	0·90	7,79,165	3·09	18,436	7,60,729	5,77,481
Average for 10 years (*viz.*, 1903-04 to 1912-13).	258,425	8,39,287	3·24	1,95,342	0·75	6,43,955	2·49	18,317	6,25,628	5,77,481

Dad Canal.

	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
1900–01	....	....	....	....	....	....	....	49,257	*—49,257*	15,73,736
1901–02	56,241	1,09,657	1·94	51,926	0·92	57,731	1·03	65,817	*—8,086*	18,94,791
1902–03	60,256	1,03,738	1·71	1,28,754	2·14	*—25,016*	....	75,821	50,805	21,27,750
1903–04	73,797	1,50,406	2·02	1,05,551	1·43	44,855	0·61	81,632	*—36,777*	22,23,592
1904–05	68,085	1,34,512	1·95	1,29,680	1·90	4,832	0·07	84,144	*—79,312*	22,69,473
1905–06	79,609	1,61,805	2·01	1,12,603	1·41	49,202	0·62	85,372	*—36,170*	23,05,212
1906–07	1,02,662	2,26,903	2·19	1,46,473	1·43	80,430	0·78	76,569	3,861	23,17,357
1907–08	89,306	1,95,300	2·15	93,515	1·05	1,01,785	1·14	76,355	25,430	23,27,912
1908–09	1,15,642	2,79,619	2·39	1,01,671	0·88	1,77,948	1·54	76,159	1,01,789	23,44,097
1909–10	1,07,821	2,68,422	2·45	1,05,356	0·98	1,63,066	1·51	75,936	87,130	23,50,595
1910–11	1,09,975	2,68,619	2·41	98,218	0·89	1,70,401	1·55	77,197	93,204	23,91,765
1911–12	1,03,453	2,51,089	2·39	1,32,143	1·28	1,18,946	1·15	79,324	39,622	24,50,898
1912–13	99,908	2,36,558	2·34	1,75,593	1·76	60,965	0·61	83,686	*—22,721*	25,12,296
1913–14	1,06,508	2,58,366	2·39	1,72,021	1·62	86,345	0·81	82,779	3,566	25,57,502
Average for 10 years (*viz.*, 190-304 to 1912-13).	95,026	2,17,323	2·29	1,20,080	1·26	97,243	12·03	79,637	17,606	25,57,502

Jamrao Canal.

	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
1900–01	1,72,347	3,52,065	2·02	76,451	0·44	2,75,614	1·59	2,76,955	*—1,341*	75,90 760
1901–02	2,16,514	4,42,123	2·00	1,71,089	0·79	2,71,034	1·25	3,01,456	*—30,422*	80,02.965
1902–03	2,69,358	6,93,447	2·51	2,42,733	0·90	4,50,714	1·67	3,14,346	1,36,368	83,07,240
1903–04	2,71,728	6,94,058	2·49	2,38,779	0·88	4,55,279	1·67	3,22,408	1,32,871	84,62,523
1904–05	2,60,031	6,74,049	2·56	3,56,313	1·37	3,17,736	1·22	3,21,371	*—3,635*	82,59,134
1905–06	2,94,508	8,66,885	2·89	3,43,391	1·17	5,23,494	1·78	3,15,884	2,07,610	81,65,344
1906–07	2,46,204	7,29,214	2·92	3,05,939	1·24	4,23,275	1·72	2,72,301	1,50,974	81,27,012
1907–08	2,08,338	6,35,039	2·99	3,29,219	1·58	3,05,820	1·47	2,69,263	36,557	81,07,361
1908–09	2,05,198	5,99,266	2·86	3,74,582	1·83	2,24,684	1·09	2,67,591	*—42,907*	81,62,207
1909–10	1,74,105	5,47,824	3·04	3,05,268	1·75	2,42,556	1·39	2,67,749	*—25,193*	82,44,283
1910–11	1,93,333	6,38,181	3·17	3,20,641	1·66	3,17,540	1·64	2,71,480	46,060	82,97,638
1911–12	2,23,196	7,32,200	3·16	3,35,114	1·50	3,97,086	1·78	2,74,715	1,22,371	83,23,770
1912–13	2,42,647	7,95,247	3·17	3,50,943	1·45	4,44,304	1·83	2,84,162	1,60,142	83,83,679
1913–14	2,32,790	8,01,201	3·20	3,53,789	1·52	4,47,412	1·92	2,76,448	1,70,964	84,08,780
Average for 10 years (*viz.*, 1903-04 to 1912-13).	2,31,929	6,91,196	2·98	3,26,019	1·41	3,65,177	1·57	2,86,692	78,485	84,08,780

Explanatory Note attached to Note VI.

The figures submitted by the Bombay Government are explained in Mr. Hill's memo. attached to letter No. 1580-I of 17th February 1912.

Net revenue for project submitted :—

	Rs.
25th year	33,31,850
35th "	41,68,991

These figures include Rs. 10 lakhs for the following :—

Eastern Nara without improvements	7,53,364
Present revenue said to be over-estimated by . ..	1,00,000
Sukkur Canal Right Bank	1,46,636
	10,00,000

Hence for Rohri Left Bank Canal alone the figures would be—

25th year	23,31,850
35th "	31,68,991

this corresponds with the ultimate revenue allowed for by the Commissioner in Sind, Volume 2, page 8.

He gives—

	Rs. lakhs.
Rohri Canal	31·69
Eastern Nara	7·53
	39·22

Sir J. Benton on page 91 states that the reduction of present revenue by Re. 1 lakh cannot be accepted and in his figures, page 93, he shows—

	Rs.
25th year	32,31,850
35th "	40,68,991

the latter being—

		Rs. lakhs.
Left Bank { Rohri Canal	31·69	39·22
Left Bank { Eastern Nara	7·53	
Right Bank, Sukkur		1·47
		40·69

The Left Bank ultimate return should therefore be Rs. 39·22 lakhs, but at the 25th year it may be Rs. 30·85 lakhs.

In my note I take the ultimate return—

Left Bank Canal	39·2
Right Bank "	24·3
	63·5

while at the 25th year, if that be assumed to be the 10th year after construction, the return might be very roughly Rs. 50 lakhs.

H. F. BEALE,

Chief Engineer, Irrigation.

Note on the superior value of perennial canals to inundation canals for Sind by the Chief Engineer for Irrigation.

The following arguments in favour of perennial canals may be recorded to show why the advice given by the London Committee to maintain Sind in the condition of an inundation canal country should be rejected.

Security or certainty of supply.

2. A perennial canal has an assured supply of water throughout the year; a definite quantity of water can therefore be guaranteed in the dry season, and in consequence of this a corresponding area of cultivation can usually be counted on in countries like Sind, where no crop can be grown without the aid of irrigation or the inundation of land.

3. With inundation canals, on the other hand, there is not only a dearth of water throughout the cold weather (when the river is low)* but there is the constant danger of a scarcity of supply occurring at some time during the flood season, and a low inundation year is disastrous to the country.

4. When a large canal system is deprived of its normal supply the effects may be far reaching. An agricultural community lives on the produce of the land, and the absence of crops means starvation or very great distress. The average value of a crop in Sind is Rs. 23 and 100,000 acres more or less means a difference of Rs. 23 lakhs. Scarcity is at once followed by an increase of crime.

5. The uncertainty of supply can be entirely got rid of by the introduction of perennial canals taking off from a weir or barrage across the river, with due precautions for the prevention of silt deposits interfering with the supply.

Enhancement of land values.

6. An immediate consequence of this security of supply is a very considerable enhancement in land values. The soil in the Jamrao Canal area is admittedly inferior to that in other parts of Sind commanded by inundation canals, yet its value per acre is said now to be four times that of the latter. The Jamrao Canal does not possess an absolutely assured supply, because the Nara Supply Channel, which feeds it is liable to heavy silting. Hence the value of land under a perfect system of perennial irrigation will be still higher.

7. In his report on Revenue Prospects (page 5, paragraph 8), Vol. 2—Proposed Barrage on the Indus, Mr. W. H. Lucas, the Commissioner in Sind, considered Rs. 10 per acre to be a safe and moderate figure for the whole project, though he said " under exceptionally favourable circumstances much higher rates than this may be realized in individual cases."

Agricultural advantages.

8. Another consequence of having a supply which can be absolutely relied upon is the creation of agricultural facilities resulting in various advantages, *viz.*—

All kinds of crops.

(*a*) The possibility of growing all kinds of crops suited to the climate.

This would permit of crops being grown to meet any public demand. A few years ago there was a great demand for cotton, but at present cotton is not so much wanted as wheat, and this being a rabi crop it can only be irrigated by canals flowing in the cold weather, *i.e.*, perennial canals. At other times a special demand may arise for oil-seed crops, or sugarcane, and the supply could be met only if perennial canals were provided ;

More valuable and more useful crops.

(*b*) The possibility of growing more intrinsically valuable or useful crops, such as perennial, or bersim ;

* Most of the Sind Canals are dry for this period.

Better duty for water.

(*c*) The possibility of getting a better duty out of the water, *viz.*, bringing larger areas of crops to maturity with the same supply flowing in the canals.

With inundation canals water is used on a lavish scale as all the irrigation has to be done as rapidly as possible. The perennial supply will be normal and as constant as may be required.

Greater average outturn.

(*d*) The certainty of getting average outturns of greater value than the average under inundation irrigation.

As an example of possible benefit it may be stated that, when a crop suffers from frost, it has been found that an immediate application of water to the roots will save it. The damage from frost occurs of course in the winter when the river is generally at its lowest and inundation canals are dry.

More intensive cultivation.

(*e*) The possibility of cultivating a greater proportion of the land commanded, *i.e.*, adopting intensive as opposed to extensive cultivation. For the purpose of economy in canal construction it is desirable to have a rabi area about equal to the kharif area. It is stated that this proportion is not attainable in Sind; the Commissioner in Sind allowed in his report, Vol. 2, page 27, Statement A, 351,990 acres of rabi to 742,060 acres of kharif crops.

With intelligent irrigators it should be possible to get equal areas of kharif and rabi. The case of the Jamrao Canal may be mentioned on which the rabi area was rising rapidly, and approaching in extent the kharif area in 1905-06, when it received two serious set-backs, on in 1906 and the other in 1908, due to the silting of its Supply Channel and consequent failure of rabi water.

Scientific modern agriculture.

(*f*) The possibility of insisting on ordered agricultural activities, the levelling and improvement of lands to which water is granted and the maintenance of labour all the year round. Also the encouragement to purchase all kinds of modern plant for agriculture and for the treatment of produce.

Prosperity and increase of trade.

(*g*) Thus industries will be fostered, and bring in their train prosperity to the cultivators, the construction of railways and growth of trade, both inland and for export, on a much larger scale than is now possible.

Conversion of lift into flow irrigation.

9. One great advantage of the Rohri Perennial Canals, both Right and Left Bank, has yet to be mentioned, that is the superior command obtained by the canals, because they take off at much higher level than the numerous inundation canals which they will replace. Irrigation by flow undoubtedly uses more water than irrigation by lift, but this can be allowed for, and a higher rate is charged. Flow irrigation is much more rapid, and therefore much more extensive, while using at the same time less labour both in men and cattle. The latter are then made available for ploughing and the carriage of produce.

H. F. BEALE,

Chief Engineer, Irrigation.

18*th July* 1915.

Sukkur Barrage below gorge—Approval of the Government of India to the preparation of detailed plans and estimates for a complete project for the—

GOVERNMENT OF BOMBAY.

PUBLIC WORKS DEPARTMENT,
Resolution No. W. I.—4945.
Bombay Castle, 11th May 1916.

Letter to the Government of India, Public Works Department, No. W. I.—10515,* dated 23rd September 1915.

Letter from the Government of India, Public Works Department, No. 273-1., dated 10th March 1916, as under :—

"In reply to your letter No. W. I.—10515, dated the 23rd September 1915, I am directed to say that, in the circumstances explained, the Government of India approve of the preparation of detailed plans and estimates for a complete project including a barrage below the Sukkur Gorge, with two large canals taking off as originally proposed on the Right and Left Banks of the Indus river, to provide a water-supply for the perennial irrigation of the areas now served by numerous inundation canals.

"2. I am at the same time to forward copy of a note† on the project, dated the 7th January 1916, by the Inspector-General of Irrigation, and to ask that, if the Governor in Council sees no objection, the several points dealt with in paragraphs 20 to 26 thereof may receive the careful consideration of the Government of Bombay before the project is finally drawn up."

RESOLUTION.—The letter from the Government of India and the note† by the Inspector-General of Irrigation accompanying it, together with copies of this Government letter No. W. I.—10515, dated 23rd September 1915, and its accompaniments should be communicated to the officers concerned for information and guidance.

2. In preparing the project the suggestions made by the Inspector-General of Irrigation should be carefully studied. Arrangements should be made to gauge the silt-bearing capacity of the water above the gorge and at the outfall gauge site, particularly in flood time. The quantity of silt in suspension at these places and at Kotri should be compared. Also a few observations should be made in flood time at the mouth of large canals, such as the Begari and Fuleli, for comparison with what will occur at the lower Barrage site.

3. Orders regarding the formation of a new temporary executive district for the preparation of this project are being issued separately.

W. N. CARTLAND,
Under Secretary to Government,
Irrigation and Railways.

To

The Revenue Department, Secretariat.
The Commissioner in Sind.
The Chief Engineer in Sind.
The Superintending Engineer, Indus Right Bank Division.
The Superintending Engineer, Indus Left Bank Division.
The Accountant General, Bombay.
All Collectors in Sind (including the Deputy Commissioner, Upper Sind Frontier).
All Executive Engineers in Sind.
The Private Secretary to His Excellency the Governor.

} With copies of the Bombay Government letter No. W. I.—10515, dated 23rd September 1915 and its accompaniments (except plans).

* Being communicated with this Resolution.

† Printed as an accompaniment.

Accompaniment to Government Resolution No. W. 1.—4945, dated 11th May 1916.

Note by Mr. M. Nethersole, C.S.I., Inspector-General of Irrigation in India on the Sukkur Barrage Project, Sind, dated the 7th January 1916.

In the Secretary of State's Despatch No. 1 of 9th January 1914 returning the Sukkur Project unsanctioned His Lordship drew attention in paragraph 6 to recommendations made by the London Committee in paragraphs 30—38 of their Report, *viz.*, that certain further technical investigation was necessary before either the necessity for, or the proper treatment of, a scheme for perennial irrigation in Sind could be determined ; and simultaneously with this investigation they advised the preparation of the best possible project to be held in readiness in event of perennial irrigation for Sind being found necessary.

2. The Bombay Government letter deals with the further technical investigation, recommended by the London Committee, formulates the general lines of the project which they consider best, and asks approval of the Government of India to the project being prepared.

3. The proposals of the Bombay Government are in general accord with the recommendations of a Committee which met at Sukkur in March 1915 for the purpose of considering further data which had then been collected, and which are now more fully dealt with by the Chief Engineer in the notes accompanying the forwarding letter. I note as briefly as possible on the main points where necessary in extension of what was already recorded in the Proceedings of the Sukkur Committee.

4. Firstly with regard to the probable effect on the Sukkur gauges of further withdrawals in the Punjab. Owing to periodic changes in the state of the river bed above and below the Sukkur gorge as also to periodic changes in the length of the river between Sukkur and Kotri both of which affect the Bukkur gauge it has been found impossible to accept equal gauge readings at Sukkur in different years as representing equal discharges. This renders the determination even of the general effect on the River discharges at Sukkur of the past and future Punjab withdrawals difficult, and its exact determination quite impossible.

5. Nevertheless there is direct evidence briefly summarised in the statement on page 7 of the Memorandum of the Sukkur Committee's Proceedings and amplified in paragraphs 12 and 13 and statement VI of Mr. Beale's Note No. 1 to show that in certain years shortage of supply has been experienced on the Inundation Canals to the detriment of irrigation in the past, more especially during the late monsoon periods, and that any possible diminution of these short supplies by further withdrawals from the Punjab must undoubtedly enhance this menace to Sind agriculture.

6. Further there are certain indications referred to in paragraph 9 of the Bombay Government letter that there has been some, though very slight, reduction in the minimum gauges recorded at Bukkur corresponding with the increased withdrawals by the Punjab Canals during the Rabi season.

7. In this connection there is a point which it is desirable that I should clear in order to avoid any possibility of future misunderstanding. In the closing paragraph Part I of the Memorandum of Proceedings of the Sukkur Committee it is recorded from a consideration of the same evidence referred to in paragraph 9 of the Bombay letter that it "appears to indicate that the Punjab Rabi withdrawals have affected adversely the minimum supplies at Bukkur" while the Bombay Government records that it has not had "any but the smallest effect."

8. The explanation of these somewhat discrepant deductions from consideration of the same data is to be found in paragraph 14 of Mr. Beale's note II in which he points out the ab-

normal character of the minimum supply in the year 1877-78. The Sukkur Committee included this exceptional year in framing their deductions while Mr. Beale on further consideration thought that it ought to be excluded. I consider that he is correct in excluding it and in the consequent conclusion arrived at as regards the effect of Punjab withdrawals on the minimum gauges at Bukkur being very slight which is recorded in paragraph 9 by the Bombay Government.

9. The Bombay Government refer also to certain correspondence subsequent to the London Committee's Report as between Sir James Wilson, Sir Thomas Holland and Sir John Benton, which has also been received by the Public Works Department of the Government of India unofficially through the Revenue Department. While this correspondence is of some academic interest, there is, in my opinion, no possible means of determining the correctness of either of the conflicting theories advanced with regard to the under ground flow being intercepted at Sukkur nor is there anything to show that the seepage back into the Indus at or above this point is at all commensurate with the abstraction of water for the Punjab irrigation higher up.

10. All the direct evidence available, so far as it can be considered conclusive, is in accord with what may be confidently advanced as the common sense theory that the abstraction of water from any river for irrigation must inevitably reduce supplies lower down the river and cannot induce return seepage equal to or greater than the abstraction. There are not wanting in other Indian Rivers many practical proofs of the soundness of this common sense theory and I consider that no examination of the figures and data which we have available in connection with the Bukkur gauges and observed discharges of the Indus can possibly be held to justify any theory to the contrary.

11. These general conclusions as to the effect of the Punjab withdrawals on the Sukkur gauge are those adopted by the Bombay Government as a result of a further examination of the available data, *vide* paragraphs 8 and 9 of their letter, and in them I concur.

12. One point made by the London Committee in their Report paragraphs 5-7 has not been dealt with specifically in the Bombay Government letter, namely, that there has been a general rise in the average gauge readings at Bukkur since the Punjab irrigation has developed owing to protective embankments having been constructed along the Indus above Sukkur. This point was dealt with in the Proceedings of the Sukkur Committee Part I (1) as follows :—

> " The effect on the Indus gauge at Sukkur during floods higher than about 8′ is very marked, since protective bunds above Sukkur were commenced about 1876 but there has been no appreciable effect on the Bukkur gauges below this level."
> This conclusion is fully borne out by Mr. Beale's diagrams I, 1-14 and II, 1-2.

13. It is necessary however to point out that it is not a general rise in average gauges which is of importance to the Sind Irrigation, but the possible reduction in the critical gauges below about 8′ during critical periods of the crops, that is at the early and late monsoon periods, and the Bombay conclusions on this point together with the evidence on which they are based have already been noticed.

14. The proposal advanced by Dr. Summers to construct the Rohri Canal first and the Barrage only when it might be found necessary later on, referred to in the London Committee's Report paragraphs 23-28, is dealt with in the Bombay Government letter paragraph 10 and Mr. Beale's note No. III. The Bombay Government agree with the London Committee that it is inadvisable basing their conclusion not only on the risk of the Rohri Canal itself failing from silting but also because of the risk to the Right Bank inundation system which would certainly suffer from the additional heavy withdrawal from the river so near their out-takes. In this I concur though I have to note further on the point later.

15. Paragraphs 11—15 of the Bombay letter are a plea for perennial irrigation in the general interest of progressive agriculture and development in Sind which will doubtless be admitted as desirable and supported by the Government of India provided the scheme can be shown to be financially sound, but cannot be accepted until the final estimates are prepared.

16. The inclusion of the Right Bank Canal in the perennial scheme now advocated by the Bombay Government in their paragraph 11 is in accord with the London Committee's recommendations.

17. Paragraph 16 of the Bombay letter refers to the change of site for the Barrage below the gorge which is the outcome of a suggestion made by the London Committee and which has *primâ facie* strong economic advantages, *vide* Sukkur Committee's Report (Part IV).

18. Paragraph 17 is an approximate estimate of the general financial prospects of the proposed project which, though admittedly rough, is, I consider, sufficient to justify the preparation of the proposed project in detail for which approval is asked by the Bombay Government and which I recommend should be accorded.

19. It is perfectly certain in view of the past history of the scheme and of the conflicting opinions which have been and may still be held by the many officers past and present who have been connected with it that any scheme which may be now put forward will be subjected to extremely acute criticism and will possibly meet with strong opposition. Thus while I am of opinion as the result of the further investigations carried out by the Bombay Government that the general proposals as now advanced by them are worthy of further investigation in detail it is obviously desirable that we should as far as possible examine closely all points which may be open to adverse criticism and I note the following for careful consideration.

20. Firstly with regard to the Rohri Canal without the barrage. It might be quite feasible in my opinion to construct such a canal above the gorge with its head placed in advance of the existing sand deposits on the Left Bank in which supply might be maintained without the barrage and without undue risk of silting as Dr. Summers has throughout strongly advocated.

21. The risk of silting however cannot be altogether ignored and quite apart from this the main and insuperable objection to such a scheme is that put forward by the Bombay Government that it would very seriously affect the efficiency of the Inundation Canals lower down the river on the Right Bank.

22. This objection has however not yet been specifically examined. In his notes Nos. I and II Mr. Beale has very carefully analysed the probable effect of future Punjab withdrawals on the Bukkur gauges during critical years. But to make these investigations complete as to the possible effect of the proposed Rohri Canal without a barrage I consider that similar analysis should be made as to the possible effect of the Punjab plus Rohri Canal withdrawals on the actual recorded gauges of the Right Bank Canals in critical years. The number of days on which the critical gauges would have been adversely affected in the early and late monsoon periods should be shown as has been done in examining the probable effect of the Punjab withdrawals on the Bukkur gauge.

23. It should also be considered whether it would be possible to make good this loss of level to the Right Bank Canals by moving their heads further upstream.

24. The next point in which I suggest further investigation is necessary is in regard to a possible objection to the weir at the lower site that the silt accumulations above the gorge which are of regular occurrence on a falling flood will be carried forward through the gorge at a high velocity on a rising flood down to the lower site and that this will tend to greater silting trouble in the Canal at the lower site than would be experienced in a canal taking off from above the gorge. This objection which may be important should be carefully examined by comparative silt observation at the two sites if this be possible during the next flood season. The

velocities in the river during high floods are great and it may not be possible to obtain satisfactory observation at the upper site. Such observations have already been taken and are on record in the neighbourhood of the lower site but these by themselves are of no use for the purpose in view, namely, to ascertain the comparative silting conditions at the two sites for similar stages of the river and it is for this purpose that I suggest concurrent observations are necessary.

25. The next point to which I would draw attention is as to the cost of the weir. Mr. Beale has accepted the highest estimate for the weir at the higher site and added thereto rough sum for the cost of the Right Bank Regulator as the probable cost of the weir at the lower site. The London Committee questioned the adequacy of the estimate formerly submitted for the barrage at the upper site. The work at this site was of an unusual construction in India river works. There are no other canal Headworks in India in which the physical conditions are quite similar. It is possible that they were correct in their criticism.

26. At first sight it might appear that the weir at the lower site must prove cheaper for reasons and in the items given in the Sukkur Committee's Report Part IV.

On the other hand there is no other case in India of a barrage built on a river in which the minimum supply is so great as in this case. It will be extremely difficult to carry out the work, the pumping difficulties specially will be enormous. It is therefore very necessary that the design and method of construction should be most carefully considered and fully estimated with ample provision for unforeseen difficulties before the project again goes forward to the Secretary of State. I do not consider that the probable cost can be judged by comparison with existing works of a similar nature in India where the physical conditions are so much less severe than they are in this case.

M. NETHERSOLE,

Inspector-General of Irrigation in India.

APPENDIX D.

A note by the Honourable Mr. H. S. Lawrence, C.S.I., I.C.S., Commissioner in Sind.

Dated, January 1919.

THE SUKKUR BARRAGE.

The importance of the early construction of this scheme has been more clearly established than ever before by the conditions of the present season. The province of Sind, which has always hitherto been able to feed its population on its own produce of millets and rice, and to export a considerable surplus of rice and wheat and pulses, has for the first time in authentic record been compelled to import food for its own population.

2. The position may be summarised in round figures as follows :—

(*a*) With a population of 4 millions, Sind had an average cultivation of 4 million acres; of which 3 million acres were under food-grains and 1 million acres under cotton and oilseeds. Of the cultivation, a small amount depended on rainfall, but this rainfall is so precarious that the outturn was always doubtful; and it is sufficient to confine the survey to the irrigated crops alone, which on the average exceeded 90 per cent. of the whole.

The irrigated crops may be taken as—

11	lakhs of acres	.. Rice.
3	,, ,, ...	.. Wheat.
12	,, ,, ...	.. Millets.
3	,, ,, ...	.. Pulses.
29	,, ,, ...	.. Total food-grains.
4	,, ,, ...	.. Cotton.
3	,, ,, ...	.. Oilseeds.
36		

And their outturn and consumption may be estimated as under :—

(*Figures are given in lakhs*).

		Outturn.	Locally consumed Percentage.	Exported Percentage.
Rice	Tons.	4	3 (75)	1 (25)
Wheat	,,	2·2	1·9 (86)	·3 (14)
Millets	,,	4	3·3 (85)	·7 (15)
Pulses and other food-grains	,,	1	·5 (50)	·5 (50)
Total foodgrains	,,	11·2	8·7 (77)	2·5 (23)
Cotton	Cwt.	3	....	3 (100)
Oilseeds	Tons.	3	1 (33)	2 (66)

(*b*) In the current season the inundation of the river failed to reach a height at which the majority of the canals could effectively irrigate the lands commanded. Large areas were therefore not sown at all, and in other areas the cultivation season was cut short and the crops withered. Accurate statistics are not available, but it is estimated that the summer harvest of food-grains has decreased in area by 8 lakhs of acres, or 33 per cent.; and the outturn of the area cultivated has fallen short of the normal outturn by 400,000 tons of rice and millets, and the winter harvest of wheat and pulses will fall short of the average outturn by 100,000 tons ; that is, a total reduction of the food-supplies of the province from 1,100,000 tons to 600,000 tons. Instead of being able to supply 250,000 tons to alleviate scarcity in other parts of India. Sind is herself for the first time on record a deficit province, and will require, in order to feed her own population until the next summer harvest comes in, an amount of 300,000 tons.

3. If the Barrage and the main canals dependent thereon had been constructed, the position would have been very different. These canals are estimated to supply water for the annual cultivation of—

(a) On the Right Bank ..	.. 6 lakhs	of acres of	Rice.
(b) On the Left Bank ..	.. 3 ,,	,,	Jowari.
	4 ,,	,,	Cotton.
	10 ,,	,,	Wheat.
	4 ,,	,,	Pulses.
	27 lakhs	of acres.	

Of these 27 lakhs of acres of cultivation, 9 lakhs are lands at present wholly uncultivated and on 18 lakhs of acres of old cultivation the crops would be made secure and 9 lakhs of acres of new cultivation would be added.

4. In a year of distress such as the present, the outturn and value of these safeguarded crops would have been as under :—

	Outturn.	Present Price (Crores of rupees).	Total Value (Millions sterling).
Rice .. .. Tons.	300,000	6·6	4·4
Wheat .. .. ,,	500,000	9·5	6·3
Millets .. .. ,,	100,000	2·2	1·5
Cotton (lint) .. .. Cwt.	130,000	·6	·4
		20·3	13·5

5. This year, in place of 18 lakhs of acres cultivated it is probable that not more than 12 lakhs will have been cultivated. The high prices have raised the value of the outturn very greatly, nevertheless a liberal estimate would place the crops at £3 per acre, or say £3½ million pounds. With the outturn that may be confidently expected upon a secure supply of water, the value would on a conservative estimate be not less than £5 per acre ; and this rate on 27 lakhs of acres would represent £13½ million pounds. Thus the surplus value of the crops that would have resulted from the existence of the Barrage would be £10 million. The cost of the Barrage and the canals combined is not yet accurately known, but it has been roughly computed at this same figure of £10 million. Thus the whole of the capital cost would have been saved to the country by the harvest of this single year.

6. This is a purely financial statement of the case, for the other aspects scarcely need elaboration. In a year when the resources of the Indian Empire are strained to feed the people and their livestock, Sind, instead of being a weakness, would have been a pillar of strength. These canals would not only have fed the people of Sind, but would have enabled Sind to export 400,000 tons for the relief of the famine in Central and Southern India. The Zamindars and cultivators, instead of being reduced to extreme poverty and distress, would have added to their store of wealth, and would have added their new resources to the improvement of fertility of their soil. It is doubtful if there is any work contemplated in India which should prove so rapidly remunerative to Government, and so beneficial for the protection of the interests of the people.

APPENDIX E.

SUKKUR BARRAGE.

A Note on Surface and Bed Levels of the River Indus at Sukkur during great floods and the estimated Afflux due to Barrage.

BY LIEUTENANT A. A. MUSTO, *Executive Engineer, Sukkur Barrage Project District.*

Summary.

The argument developed in the accompanying note is briefly as follows :—

(a) That it is desired to find the surface and bed levels of the river, as certain points below Bukkur, for an estimated possible flood of 1,500, 000 cusecs, which it has been assumed would pass Bukkur at a surface level of R. L. 205·0.

(b) That from the recorded surface levels of past floods, it is seen that the surface slope from Bukkur to Outfall, and from Outfall to Barrage, is consistently steeper as the surface level rises, and that by analogy from these records, and by plotting curves connecting recorded surface levels and slopes, it is possible to estimate the respective slopes between these points for any other surface level at Bukkur. The surface level at each of these points, corresponding to a level of R. L. 205·0 at Bukkur, for a flood of, 1,500,000 cusecs is thereby obtained.

(c) That from an examination of many hundreds of discharge measurements at Outfall, shown in the Indus River Commission Records, it is found that the highest mean velocity over the stream occurs on a rising flood, and increases to a critical value, such that the bed is scoured away as fast as the discharge increases (the inference being that at a lower velocity scour occurs less slowly than discharge increases, so that the increasing discharge gradually rises in velocity, until it reaches the critical value at which scour occurs as fast as discharge increases). This critical mean velocity at Outfall is found to be about 11 ft./sec., and as the surface level for the assumed flood of 1,500,000 cusecs has already been found, and the width of the river is known, it is possible to calculate the mean depth (and hence bed level) to give the required critical mean velocity.

(d) An inspection of the recorded bed levels at Outfall and Barrage shows, that the upward slope of the bed, from Outfall to Barrage, increases consistently with the depth of the bed at Outfall; and by plotting a curve for past floods, connecting bed level at Outfall with bed slope below Outfall, it is possible to estimate the slope of the bed for any other bed level at Outfall. Thus the upward bed slope for the estimated bed level at Outfall, due to the estimated flood of 1,500,000 cusecs is found, and hence the bed level at Barragé for this flood is found.

(e) We have now obtained the bed level and surface level at Barrage for this estimated flood of 1,500,000 cusecs, and as the width is known, the mean velocity can be calculated. This is found to be 12 ft. per second which is considerably more than the highest velocity (8·2 ft./sec. with a discharge of 708,000 cusecs) hitherto recorded at this site. But the bed scour at this site is never very rapid or deep, even in the biggest floods hitherto recorded, and it is found that whereas in the low water season the river tends to run in narrow deepish channels, yet when the floods come down, instead of these channels deepening, the higher portions of the bed are scoured, thus forming a practically regular section right across the river. This seems to indicate that at the deeper levels to which the bed has hitherto been

scoured, it is hard enough to resist scour at higher velocity than the highest *mean* velocity yet recorded.

As the estimated *mean* bed level for the flood of 1,500,000 cusecs is about 3′ lower than the deepest *mean* bed hitherto recorded, and it is about at the same level as the deepest portion of the latter, it is considered that at this level of harder bed, the calculated velocity of 12 ft./sec. would probably be required to scour it away as fast as discharge increased.

(*f*) Scour would continue at a slower rate with the falling flood until the bed had been scoured to the estimated level, another 3′ lower, by which time the velocity would be reduced to about 9 ft./sec. and it is considered that, at this greater mean depth and harder bed, scour would cease at such a velocity ; and with a further decrease in discharge and velocity, fill would recommence.

Observations at actual bed levels at this site have not been taken for a sufficiently long period to enable a reliable check on these calculations, but the records and an inspection of the plotted longitudinal section, appear to indicate that the assumptions are reasonable. Since the bed will here be adequately protected against erosion, it is not of vital importance to arrive at a quite accurate estimation of bed levels, especially on the falling flood. Some approximation of the bed levels is necessary in order to design the floor, and as a rough check on the estimated water surface levels, found by the method of analogy.

(*g*) Having thus obtained an approximation of the surface level, bedlevel, and velocity, for the estimated maximum flood, at the Barrage site, to be anticipated with an unobstructed natural river, the effect of inserting a parallel throat (formed by the regulators), in the tapered stream, is estimated. Also the effect of lowering the natural bed to the designed floor level of the Barrage. Finally the effect of the obstruction due to the piers is calculated and the sum of these effects is the estimated afflux due to the Barrage and gives the estimated highest water level for such a flood after the construction of the Barrage.

Indus River Levels in great floods and the effect thereon of the proposed Sukkur Barrage.

1. The first point to be considered is the maximum flood which may be anticipated and adopted for purposes of design. This point was fully and carefully considered by Messrs. Hill and Beale in connection with the original project for the Sukkur Barrage above the gorge, and it was decided by Government as the result of various approximations and calculations (see Sukkur Barrage Project Report, 1910, Volume 4, pages 3, 4, 24 and 90 to 94) to estimate for a flood of 1,500,000 cusecs passing Sukkur with water surface at R. L. 205·0 at Bukkur (gauge reading 20.56). This flood and level have been adopted in the present project, although later information seems to show that the reasoning on which the surface level was estimated gives too high a figure. Thus on page 93 Mr. Hill estimates by similar reasoning that a flood of 900,000 cusecs would be passed with water surface at Bukkur R.L. 203 and a velocity at out fall section of 9 ft./sec., but actually on 1st August 1914 a flood of 949,000 cusecs passed Bukkur with water level R. L. 201·44 at Bukkur and velocity at Outfall 10·18 ft.sec., while on 5th August 1914 a flood of 885,000 cusecs passed Bukkur with surface at R. L. 201·74 and, velocity 8·96 ft./sec. at outfall. The above estimate for surface level R. L. 205 at Bukkur for an estimated flood of 1,500,000 cusecs may therefore be rather high, but is on the safe side, since the feature of danger is not the quantity of the possible flood, but the level at which it will pass.

2. Starting then with an estimated flood of 1,500,000 cusecs, passing Bukkur with a surface level of R. L. 205·0 it is necessary to find at what level this flood would pass the new Barrage site 4 miles below Bukkur if the river were unobstructed as at present. Having obtained this level we can then estimate the afflux which would be caused by the Barrage obstruction.

To estimate the water levels at various points below Bukkur for a flood of 1,500,000 *cusecs passing Bukkur with surface R. L.* 205.

3. I have made many calculations to endeavour to find these levels at various points, but the conditions of the river in this length are so extraordinarily variable and irregular that I have found all calculations useless. Most equations for the flow of water in open channels, are based on the fundamental assumption that flow is *steady, i.e.*, that velocity, depth and width of channel are constant throughout the length considered. None of these conditions apply in the present case. Integral equations for flow in channels of varying section can be evolved in terms of the bed slope, water slope, co-efficient of friction, and length and width of the channel, but again in the present case the first three of these terms are unknown and constantly changing ; and after many lengthy calculations assuming values for these terms, taken from available data of past discharges, I find they all lead to absurdities or impossibilities and I am compelled to consider that (with the constantly changing and indeterminate conditions at the Barrage site it is impossible to calculate the conditions at a given section from any application of the theory of flow. It remains then to find some method of reaching a decision, other than pure guess work ; and I have adopted what may be described as a method of Rational Analogy.

Method adopted for estimating maximum flood levels at Barrage.

4. In the following argument and in drawing No. 40 only two sections, in each year considered, have been used. It may be thought that more reliable results could be obtained by considering the averages of many sections, but I do not agree with this point of view.

5. The Indus River Commission has compiled many thousands of measured data taken during regular observations spread over many years, and averages of every kind have been

worked out. Yet not a single expression has been evolved from these averages which gives the slightest reliable connection between the varying phenomena, or explains in any way the vagaries, of the river. It appears to me that, in such cases, averages merely hide the characteristics and typical developments of the regime of the river; and that a far better idea of what actually occurs, can be obtained by studying one cycle of changes at a time. I have accordingly taken two of the largest discharges of each of the three years considered (we are dealing at present only with large discharges) and which follow one another without intervening fluctuations of levels, the change of water surface between two observations in each year, being in each case a gradual one, the higher discharge on a rising river, and the lower one on the succeeding fall.

6. During the years 1917 and 1918 careful measurements of the river section have been taken at two points below Bukkur. At the Outfall section, the river section is measured twice weekly and the discharge also measured on the same day. At the Barrage site the river section only is measured, twice monthly. It has hitherto been measured one day previous to a discharge measurement at Outfall, and hence the measurements at the two sections, being on different days, are not exactly comparable, but as the section changes very little at the Barrage site the error involved is small. Arrangements have now been made for all future measurements at Barrage Site to be made once weekly on the same day as those at the Outfall, and immediately after the latter is finished, so that the two sections will in future compare accurately for the same discharge.

7. In addition to these sectional measurements, careful readings of water level are taken daily on gauges fixed opposite one another on each bank at the outfall, at the Barrage site, at points 4,000′ below the Barrage and at points about 7,400′ below the Barrage.

8. Thus the mean surface levels on any date can be plotted, while the mean bed levels at outfall and Barrage can be plotted for the days on which the observations are taken, *i.e.*, twice monthly (in future they will be weekly). This has been done in drawing No. 40 for the largest floods occurring in the present and past year, and in 1914 and from these longitudinal sections much valuable information can be obtained, and inferences drawn by analogy, as to probable conditions with other discharges. This is what I describe as a method of Rational Analogy and it appears to me to be the most reliable method available, although the accuracy of the results can only be approximate.

9. Referring now to Table A (see page 126) and to drawing No. 40 on which 2 large discharges in 1914, 1917 and 1918, respectively, have been plotted, some remarkable facts are visible, and the difficulty of applying any theoretical calculations is at once seen from the plan and longitudinal section.

10. The first point of importance to note is that, in the length from Bukkur to Outfall, the higher the water surface is, the steeper becomes the slope. Similarly in the other three reaches below Outfall, the slope is always steeper with a high water level. Hence we may assume that this condition would continue for still higher gauge readings.

11. Next examining the bed levels we see that the deeper the bed at Outfall, the steeper becomes the upward slope of the bed to Barrage. Hence we may assume a similar steepening of this slope for a still deeper bed at outfall.

12. A further very important point to notice is the extremely small change in the average bed level at the Barrage for floods of very different quantity, indicating that this portion of the stream bed, forms a natural bar which regulates the velocity and levels above it. At Outfall on the contrary the bed is scoured or filled through very wide limits by the regulating effect of the natural bar below it.

13. Again it will be noticed from the drawing (No. 40) and also from Table A attached that whereas the surface slope in the reach from Outfall to Barrage is consistently less than

in the reach from Bukkur to Outfall, the slope from Barrage downstream is consistently steeper than in the reach above the Barrage. This again shows that the Barrage Site is a natural river bar.

14 We can now by analogy arrive at an approximate estimate of the water levels and bed levels at these points with the estimated flood of 1,500,000 cusecs. Starting with R. L. 205 at Bukkur we may assume that the surface slope to Outfall will be steeper than it was with a discharge of 949,000 (1 in 2,720).

15. The following table shows the details of this reach of river :—

TABLE B.

Date.	Discharge.	Water level at Bukkur.	Water level at Outfall.		Slope.
				Fall.	
31st July 1918	261,000	192·34	191·46	·88	1 in 11100
17th July 1918	403,000	194·14	193·12	1·02	1 in 9600
12th August 1914	405,000	195·44	194·33	1·11	1 in 8880
22nd August 1917	680,000	198·74	196·43	2·31	1 in 4240
8th August 1914	711,000	199·74	196·73	3·01	1 in 3260
15th August 1917	708,000	200·24	197·22	3·02	1 in 3240
1st August 1914	949,000	201·44	197·83	3·61	1 in 2720
Estimated	1,200,000	201·92	198·0	3·92	1 in 2500
Do.	1,500,000	205·0	200·0	5·00	1 in 1960

16. The level of the water surface at Outfall depends not only on the water and bed levels at Barrage Site, but also on the bed level at Outfall itself. The actual bed levels at this section as recorded are confusing and at first sight there seems to be little relation between discharge, surface level, and bed level here. Thus on 15th August 1917 the bed level was 176·63 with a discharge of 708,000 cusecs and water level 197·22, while on 22nd August 1917 the bed level was 171·73 (*i.e.*, 4·9, lower) with a less discharge (680,000 cusecs) and water level 196·43 (*i.e.*, only ·79′ lower); while on 1st August 1914 with a discharge of 949,000 cusecs the bed was 169·94 and water level 197·83. It would appear that the deposits on the river bed at this point are easily disturbed, and that scour having been started by a sudden increase of discharge it continues for some time even with a falling water surface and decreasing discharge of clearer water, and this action appears to continue until the sand scoured from Outfall section has raised the bed below Barrage Site or the flood has filled up the river channel, thereby raising the water level again, until the velocity at Outfall is reduced to an amount which is unable to further erode the bed. A further increase of discharge bringing heavily silt laden water, further raises the water level and silting occurs at Outfall, until the velocity is again increased sufficiently to restart scouring.

17. Records show that in any given cycle of changes the highest water level occurs at the top of a rising flood, and that thereafter the water level drops while bed level also falls. It is these highest water levels with which we are concerned. For the deeper bed levels at Outfall after the maximum flood there will be some tendency to increase the deepening to a less degree at Barrage, but the Barrage floor will be made of material (stone) which will be able to resist any tendency to scour. The upstream apron of loose stone will settle into any scour hole above it and prevent further scour.

18. The following table shows what the bed levels were at Outfall and Barrage for the floods shown on drawing No. 83 and what it is estimated they would be for the estimated maximum flood of 1,500,000 cusecs.

TABLE C.

Date.	Discharge.	Bed level at Outfall.	Bed level at Barrage.	Rise.	Slope.	
31-7-1918	261,000	177·89	180·28	2·39	1 in 2550	Mean velocity at Barrage.
15-8-1917	708,000	176·62	181·12	4·50	1 in 1355	8·2
17-7-1918	403,000	174·61	180·17	5·56	1 in 1097	
22-8-1917	680,000	171·73	180·07	8·34	1 in 731	
1-8-1914	949,000	170·64	179·94	9·30	1 in 660	8·3 Estimated.
8-8-1914	711,000	166·73	179·03	12· 3	1 in 500	7·4
Estimated	1,500,000 at end of rise.	161· 0	177·20	16· 2	1 in 375	12·3
Do.	1,200,000 after above flood.	154·35 estimated.	174·35	20· 0	1 in 300	9·3

19. It will be seen that the upward slope of the bed and the bed level at Barrage Site, does not depend upon the discharge, but depends on the bed level at Outfall at the time. The records show that in early August 1917 the bed at Outfall was steadily deepening *until the 22nd idem*, while the water surface rose rapidly *until the 18th idem only* and then slowly fell *the bed again rising* after the 22nd August.

20. Again on the 1st August 1914 the bed level at Outfall on a rising river with the greatest recorded flood (949,000 cusecs) was only 1·09′ lower than on 22nd August 1917 (discharge 680,000 cusecs) although the discharge on the former date was 40% greater, and the water level only ·61 higher. The mean velocity on 1st August 1914 was 10·18 ft. / sec. as against 8·07 ft. / sec. on 22nd August 1917 and as against 10·06 on 15th August 1917 when the discharge was 708,000 cusecs.

21. The observations of many discharges in past years show that the mean velocity at Outfall only occasionally exceeds 10 ft. / sec. though it has once been as high as 11·70 ft. / sec. and a few times as much as 11 ft. / sec. so that it appears that for floods hitherto recorded, the bed at Outfall adjusts itself so that velocity does not exceed about 10 to 11 ft. / sec. Assuming that the estimated maximum flood of 1,500,000 cusecs may scour out the bed even deeper than any recorded levels in the past, it is also reasonable to assume that this bed, which has perhaps not been disturbed for centuries will be fairly hard (borings show this characteristic at the greater depths) and that it will require the highest velocity hitherto recorded, or say 11 ft. / sec. to keep scour going, so that it keeps pace with the rising discharge. With a discharge of 1,500,000 cusecs, surface level at R. L. 200 as assumed, and the mean velocity at Outfall 11 ft. sec. the bed level would be 161·0, or 6′ lower than ever recorded. This seems to show that the previous method of reasoning by which the surface level was estimated is a reasonable one. It appears from analogy with previous floods and bed levels, that this maximum velocity of say 11 ft. / sec. at Outfall will probably occur before the maximum discharge is reached, but that with the increasing discharge the bed will scour out with this velocity as fast as the discharge increases. That is to say, with this higher critical velocity scour will occur so quickly as to prevent any considerable increase above the higher critical velocity. After the maximum discharge has passed, scour will still continue with a lower velocity, but more slowly than with the higher critical velocity, and this scour will continue until a lower critical velocity, which is insufficient to move the bed at all, is reached.

22. The observations of bed levels with big discharges in 1914 and 1917 show that scour ceases, and fill recommences, at Outfall, at velocities between 7·5 and 8 feet per second. Hence at the greatest depth (and harder bed) assumed to be scoured by the assumed flood of 1,500,000 cusecs, it may be assumed that scour would cease with a velocity of about 8 feet per second. Hence assuming that on the Falling flood a discharge of 1,200,000 cusecs is passed with a level of 198 at Outfall, and mean width 3,440′, the mean depth for a mean velocity of 8 feet per second would be $\frac{12,00,000}{3,440 \times 8}$ =43·65. Hence mean bed level would be R. L. 198—43·65=154·35 or 8·83′ lower than ever recorded. With this bed level at Outfall it is estimated by analogy (see drawing 83 and table C) that the mean bed level at a Barrage Section (unobstructed) would be R. L. 174·35. This gives a natural bed level of about R. L. 169 at the position of the *upstream end* of the undersluice floor whose top is to be laid at R. L. 173 and bottom at R. L. 167 while at the *upstream end* of the central portion of Barrage floor proper, the natural bed level would be about 173·0, and the top of apron is to be laid at R. L. 176 and bottom at R. L. 167.

See Table B.

See Drawing No. 40.

23. Thus it is probable that if such a flood occurred there would be a tendency for the bed at the upstream edge of the Barrage and the undersluice aprons to be scoured out and the latter undercut. But these aprons are made of loose stone which is specially designed to fall into any such scour and prevent further erosion. Hence the position and levels of these floors may be considered satisfactory. The prevention of this scour would give increased afflux, but the resulting water level with the falling flood would not be as high as that estimated for the maximum flood, and need not therefore be considered.

24. With the depths arrived at above *for Barrage Section*, with floods of 1,500,000 cusecs and 1,200,000, the velocities would be 12 ft. / sec. and 9·3 ft. / sec. respectively. As the bed level for the greater discharge is 2·74′ lower than that for the greatest discharge hitherto recorded, and the bed at this level may be expected to be harder than at the frequently disturbed upper levels, the resulting mean velocity of 12 ft. / sec. is probably not excessive. It is noticed from recorded observations that at the deeper mean bed levels, the scour is very regular all over the section which tends to show that at the deeper levels the bed resists scour, and compels the higher portions to be eroded, rather than for deep channels to form in places. Thus on 22nd August 1917 (the lowest bed levels actually recorded at Barrage Section) the deepest channel in the whole width of the river was only 3′ below the mean bed level, or the *deepest* scour was to R. L. 177 which is practically the same level as assumed for the *mean* bed level with the maximum flood of 1,500,000 cusecs ; and 2·65′ higher than the *mean* bed level assumed for the deepest river to be formed by the falling flood of 1,200,000 cusecs after the greatest discharge has passed.

25. The assumption is, that while the river is rising to its maximum discharge it will require a mean velocity of 12 ft. / sec. to scour the bed at the Barrage, to the depth assumed, by the time the flood has risen to its maximum, and that thereafter scour will continue on the falling flood, until the bed is lowered another 3 feet, and velocity reduced to about 9 ft. / sec. after which the hard permanent bed at this depth would no longer bescoured by this velocity; and with a further reduction of the discharge it would begin to refill.

26. When the Barrage floor has been laid all these conditions will change and scour will be prevented, below R. L. 176·0 which is the depth of natural scour for the greatest estimated discharge of 1,500,000 cusecs. The effect of the Barrage therefore will be to maintain the *decreasing* flood at a level higher than it would naturally assume ; or to prolong the period of high levels *above* the Barrage. It will make little or no difference to river levels below the Barrage.

27. Now from Outfall to Barrage recorded water slopes were as follows arranged in order of magnitude of discharge :—

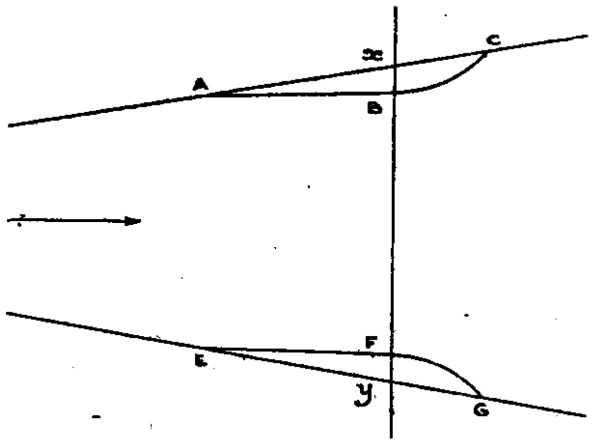
TABLE D.

Date.	Discharge.	Water level at Outfall.	Water level at Barrage.	Fall.	Slope.
31-7-1918	261,000	191·46	191·28	·18	1 in 34000
17-7-1918	403,000	193·12	192·88	·24	1 in 25400
12-8-1914	405,000	194·33	193·90*	·43	1 in 14200*
22-8-1917	680,000	196·43	195·83	·60	1 in 10150
8-8-1914	711,000	196·73	196·12*	·61	1 in 10000*
15-8-1917	708,000	197·22	196·58*	·64	1 in 9540
1-8-1914	949,000	197·83	197·16*	·67	1 in 9100*
	1,200,000*	198·0*	197·29*	·71	1 in 8600*
	1,500,000*	200·0*	199·13*	·87	1 in 7000*

*Estimated.

28. If a curve is plotted from these it shows it would be reasonable to assume a slope of 1 in 7,000 in this length for the estimated flood of 1,500,000 cusecs, which gives a level at the Barrage Site of R. L. 199·13. Below the Barrage we are not so much interested in the levels but they would probably be approximately as shown on drawing No. 40.

29. In the tapered section of the river it is proposed to insert flank walls (the regulators) 1,200′ long and parallel to one another and these will run into the natural bank upstream. Downstream they will be splayed sharply back to the natural bank again as shown in sketch.



30. Assume first that there is no barrage but only these flank walls, and assume natural bed level unaltered. There will be no shock losses at entry A E as the flank walls run into the banks. Then from A E to B F extra depth or velocity will be required to pass the discharge through the reduced section B F as compared with the original X Y. But from B F to C G reduced depth or velocity will be required to pass the discharge through the increased section C G as compared with B F. But as A E and C G are the original sections of the river the only change between the velocities at A E and C G will be that caused by the additional shock losses due to the more sudden expansion of the section from B F (equal to A E) to C G, as compared with the original gradual expansion from A E to C G. This will be comparatively small. We may allow for a rise from 199·13 to 199·5 at B F on this account.

31. But with the barrage there is another change in these sections, that is, the bed level is lower than the natural bed. It has been assumed (see drawing No. 40) that the natural bed level at A E is R. L. 173, at B F is 176, and at C G (Barrage site) is 177·20. It is proposed to keep this bed at 173 at A E, and 176 at B F, and to lower it to 173 at C G. Hence assuming (as shown) that the surface level with original bed level is only slightly raised by the introduction of the flank walls A B C and E F G, *viz.*, that it is R. L. 199·5 instead of R. L. 199·13 at Barrage Section, we may see how the surface level will be affected with the bed lowered about 1 foot at this point. If we assume the velocity to remain unchanged the surface level must drop also ; but as the bed of the river at some distance downstream will probably remain unchanged, and the surface level be very little altered, the extra depth of the Barrage floor will only have a local effect (if any) in lowering the water surface at the Barrage, but the velocity

there will be reduced more or less in proportion to the increased depth due to the lowering of the floor. It may however be assumed that the effect of lowering the bed here would partly counteract the increased head necessary to overcome the extra shock loss due to the sudden expansion in width between B F and C G. Hence we may assume that the afflux will be that due to the obstruction of the piers ; and the water level immediately downstream of the piers may be taken as R. L. 199·5. Afflux will now be calculated.

32. *For barrage of 66 similar sluices with pavements at* R. L. 176·0

	R. L.
Assumed water level without piers, *i.e.*, Water level down stream of barrage	=199·5.

Now if there are 66 spans there will be 65 piers and 2 land abutments.

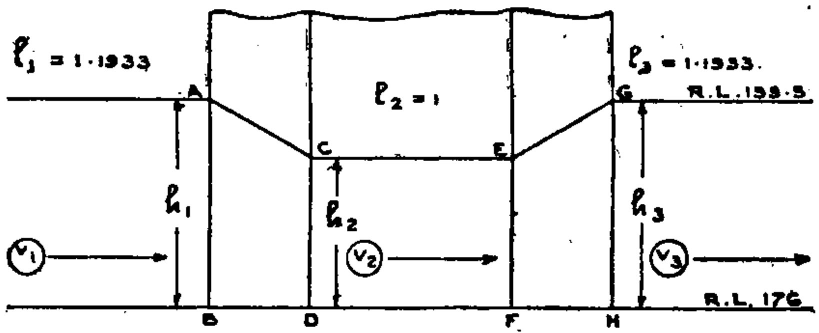
Assuming that 7 of the piers are abutment piers each 25′ thick. Then there will be 58 ordinary piers 10′ thick. Allow 5′ for half outwater of each land abutment. Then total width between regulators will be

$$(66\times 60'+7\times 25'+58\times 10'+2\times 5')$$

$$= 3960'+175'+580+10' = 4725' = l_1 = l_3$$

and width of waterway $66\times 60' = 3960' = l_2$

To calculate afflux—



Discharge 1,500,000 cusecs $= \dfrac{1,500,000}{3960}$ per ft. of opening

$= 379$ cusecs „ „

$$l_2 = 3960 = 1$$

$$l_3 = l_1 = 4725 = 1\cdot1933.$$

Consider Sections E F & G H

Pressure at E F in direction of flow

$$(i) = \frac{W}{2} l_2 h_2^2$$

Pressure at G H in direction of flow, due to easewater

$$(ii) = \frac{W}{2}(l_3 - l_2) h_3^2$$

Pressure at G H against flow

$$(iii) = \frac{W}{2} l_3 h_3^2$$

Change of pressure = iii—ii—i

$$= \frac{W}{2}(l_3 h_3^2 - l_2 h_2^2 - (l_3 - l_2) h_3^2$$

$$\frac{W}{2}(l_2 h_3^2 - l_2 h_2^2) = \frac{Wl_2}{2}(h_3^2 - h_2^2.$$

Change of momentum E F to G H

$$= \frac{W}{g}(cl_2 h_2 v_2^2 - l_3 h_3 v^2;$$

Equating changing of pressure to change of momentum we have

$$\frac{W}{g}\left(cl_2\, h_2\, v_2^2 - l_3\, h_3\, v_3^2\right) = \frac{Wl_2}{2}\left(h_3^2 - h_2^2\right)$$

$$\text{but } v_2^2 = \frac{Q^2}{c^2\, l_2^2\, h_2^2} \text{ and } v_3^2 = \frac{Q^2}{l_3^2\, h_3^2}$$

$$\therefore \frac{Q^2\, W}{g}\left(\frac{1}{cl_2\, h_2} - \frac{1}{l_3\, h_3}\right) = \frac{Wl_2}{2}\left(h_3^2 - h_2^2\right)$$

$$\text{or } \frac{2\, Q^2}{g}\left(\frac{1}{cl_2\, h_2} - \frac{1}{l_3\, h_3}\right) = l_2\left(h_3^2 - h_2^2\right)$$

Substituting values we have

$$\frac{2 \times 379^2}{32 \cdot 2}\left(\frac{1}{\cdot 95 \times 1 \times h_2} - \frac{1}{1 \cdot 1933 \times 23 \cdot 5}\right) = 1\left(23 \cdot 5^2 - h_2^2\right)$$

$$\frac{2 \times 379^2}{32 \cdot 2}\left(\frac{28 \cdot 042 - \cdot 95 h_2}{26 \cdot 64}\right) = 552 \cdot 3 h_2 - h_2^3$$

$$\frac{2 \times 379^2}{32 \cdot 2 \times 26 \cdot 64}\left(28 \cdot 042 - \cdot 95 h_2\right) = 552 \cdot 3 h_2 - h_2^3$$

$$334 \cdot 9\left(28 \cdot 042 - \cdot 95 h\right) = 552 \cdot 3 h_2 - h_2^3$$

$$9391 - 318 \cdot 2\, h_2 = 552 \cdot 3 h_2 - h_2^3$$

$$h_2^3 - 870 \cdot 5\, h_2 = -9391$$

If $h_2 = 20 \cdot 06 \quad 8072 - 17462 = -9391$

$\therefore h_2 = 20 \cdot 06 =$ R. L. 196·06

Then to find h_1 we have

$$\frac{V_1^2}{2g} + \left(h_1 - h_2\right) = \frac{V_2^2}{2g} \times 1 \cdot 1 \text{ (allowing for shock loss on cutwaters)}$$

$$\therefore h_1 - h_2 = 1 \cdot 1 \frac{V_2^2}{2g} - \frac{V_1^2}{2g} \text{ but } v_2^2 = \frac{Q^2}{c^2\, l_2^2\, h_2^2} \text{ and } v_1^2 = \frac{Q^2}{l_1^2\, h_1^2}$$

$$\therefore h_1 - h_2 = \frac{Q^2}{2g}\left(\frac{1 \cdot 1}{c^2\, l_2^2\, h_2^2} - \frac{1}{l_1^2\, h_1^2}\right)$$

$$\text{OR, } h_1 - 20 \cdot 06 = \frac{379^2}{64 \cdot 4}\left(\frac{1 \cdot 1}{\cdot 902 \times 1 \times 20 \cdot 66^2} - \frac{1}{1 \cdot 1933^2 \times h_1^2}\right)$$

$$h_1^3 - 20 \cdot 06\, h_1^2 = \frac{379^2}{64 \cdot 4 \times 363 \times 1 \cdot 424}\left(1 \cdot 1 \times 1 \cdot 424\, h_1^2 - 363\right)$$

$$= 4 \cdot 31\left(1 \cdot 566 h_1^2 - 363\right)$$

$$h_1^3 - 20 \cdot 06 h_1^2 = 6 \cdot 749 h_1^2 - 1565$$

$$h_1^3 - 26 \cdot 809 h_1^2 = -1565$$

$$14050 - 15610 = -1565 \quad (h = 24 \cdot 12)$$

$\therefore h_1 = 24 \cdot 12 =$ R.L. 200·12

afflux due to piers $= 24 \cdot 12 - 23 \cdot 5 = 0 \cdot 62$

Total calculated and assumed afflux

$200 \cdot 12 - 199 \cdot 13 = 0 \cdot 99$

33. Hence total afflux due to Barrage equals afflux due to flank walls (*vide* paragraph 31) assumed to be ·37′, plus afflux due to piers = 0·62. Total afflux = 0·99.

TABLE A.

Date.	Discharge.	Water level. Bukkur.	Water level. Outfall.	Fall from Bukkur to Outfall.	Surface slope from Bukkur to outfall.	Water level at Barrage.	Fall from Outfall to Barrage.	Surface slope from Outfall to Barrage.	Water level at Mirwah Bachal Shah.	Fall from Barrage to Mirwah Bachal Shah.	Surface slope from Barrage to Mirwah Bachal Shah.	Water level 1½ miles below Barrage.	Fall from Mirwah Bachal Shah to 1½ miles below Barrage.	Surface slope from Mirwah Bachal Shah to 1½ miles below Barrage.
	Cusecs.	R. L.	R. L.	Feet.		R. L.	Feet.		R. L.	Feet.		R. L.	Feet.	
31-7-1918	261,000	191·34	191·46	·88	1 in 11,000	191·28	·18	1 in 34,000	190·97	·31	1 in 12,900	190·25	·72	1 in 4,720
17-7-1918	403,000	194·14	193·12	1·02	1 in 9,600	192·88	·24	1 in 25,400	192·53	·35	1 in 11,400	191·90	·63	1 in 5,400
12-8-1914	405,000	195·44	194·33	1·11	1 in 8,880	193·90	·43	1 in 14,200	..	..	..	..	..	..
22-8-1917	680,000	198·74	196·43	2·31	1 in 4,240	195·83	·60	1 in 10,150	195·18	·65	1 in 6,200	..	..	..
8-8-1914	711,000	199·74	196·73	3·01	1 in 3,260	196·12	·61	1 in 10,000	..	..	..	..	..	..
15-8-1917	708,000	200·24	197·22	3·02	1 in 3,240	196·58	·64	1 in 9,540	196·33	·24	1 in 16,700	? ..	..	..
1-8-1914	949,000	201·44	197·83	3·61	1 in 2,720	197·16	·67	1 in 9,100	..	..	..	..	..	..
Esti-	1,200,000	201·92	198·0	3·92	1 in 2,500	197·29	·71	1 in 8,600	..	..	..	..	..	..
mated.	1,500,000	205·0	200·0	5·0	1 in 1,960	199·13	·87	1 in 7,000	..	..	..	..	..	..

APPENDIX F.

TABLE OF HEIGHTS

OF

The River Indus on Bukkur Gauge.

Corrigenda.

January.

Year.	Date.				
1855 ..	4th ..	For	0·5	read ..	0·4
	6th ..	,,	0·6	,,	0·5
	8th ..	,,	0·5	,,	0·6
	10th ..	,,	0·4	,,	0·5
	14th ..	,,	0·6	,,	0·4
	15th ..	,,	1·4	,,	0·6
1860 ..	5th ..	,,	0·3	,,	0·2
	24th ..	,,	0·1	,,	0·0
1873 ..	26th ..	,,	—9·7	,,	—0·7
1874 ..	4th ..	,,	9·5	,, ..	0·5
1888 ..	28th ..	,,	9·7	,, ..	0·7
1891 ..	26th ..	,,	8·2	,,	5·2
1897 ..	5th ..	,,	—6·	,,	—0·2
1898 ..	26th ..	,,	0·0	,, ..	0·1
1907 ..	From 16th to 31st read all minus instead of plus.				

February.

Year.	Date.				
1861 ..	8th ..	For	—0·3	read	—0·4
	9th ..	,,	—0·1	,,	—0·2
1864 ..	2nd ..	,,	—1·7	,, ..	—1·8
1866 ..	4th ..	,,	5·0	,,	5·1
	5th ..	,,	5·0	,,	5·1
	7th ..	,,	4·5	,,	4·7
1870 ..	17th ..	,,	—0·1	,, ..	0·1
	18th ..	,,	—0·1	,, ..	0 1
1871 ..	21st ..	,,	0·6	,,	—0·6
1880 ..	22nd ..	,,	—0·2	,,	0·2
	23rd ..	,,	—0·7	,,	0·7
1885 ..	23rd ...	,,	2·9	,, ..	1·9
	24th ...	,,	2·7	,,	1·7
	25th ...	,,	2·7	,, ..	1·7
	26th ..	,,	2·5	,,	1·5
	27th ..	,,	2·5	,, ..	1·5
	28th ..	,,	2·5	,, ..	1·5

Year.		Date.					
1888	..	21st	..	For	2·9	read	1·9
		22nd	..	„	2·8	„	1·8
		23rd	..	„	2·7	„	1·7
		24th	..	„	2·6	„	1·6
		25th	..	„	2·5	„	1·5
		26th	..	„	2·5	„	1·5
		27th	..	„	2·4	„	1·4
		28th	..	„	2·4	„	1·4
		29th	..	„	2·3	„	1·3
1890	..	23rd	..	„	9·3	„	0·3
1892	..	17th	..	„	3·4	„	0·4
1902	..	28th	..	„	0·1	„	—0·1
1907	..	From 1st to 7th read all minus instead of plus.					

March.

Year.		Date.					
1852	..	30th	..	For	5·9	read	5·7
1858	..	18th	..	„	2·2	„	3·2
		21st	..	„	3·3	„	3·2
		24th	..	„	3·4	„	3·3
		25th	..	„	3·5	„	3·4
		26th	..	„	3·7	„	3·5
		27th	..	„	4·0	„	3·7
		29th	..	„	2·2	„	4·2
		30th	..	„	2·2	„	4·2
1860	..	11th	..	„	2·2	„	2·3
1862	..	6th	..	„	—0·5	„	—0·6
1871	..	21st	..	„	9·3	„	0·3
1875	..	17th	..	„	1·3	„	2·3
		20th	..	„	3·6	„	3·0
1877	..	4th	..	„	4·2	„	4·3
		5th	..	„	4·3	„	4·0
1886	..	6th	..	„	1·2	„	1·3
1893	..	30th	..	„	5·8	„	5·7
1897	..	9th	..	„	0·4	„	0·3

April.

Year.		Date.					
1851	..	30th	..	For	7·3	read	7·2
1856	..	23rd	..	„	2·2	„	3·2
		24th	..	„	2·2	„	3·2
		25th	..	„	2·1	„	3·1
1860	..	20th	..	„	4·0	„	4·1
1862	..	8th	..	„	2·1	„	2·5
1872	..	30th	..	„	4·6	„	4·5
1882	..	10th	..	„	6·6	„	6·8

May.

Year.		Date.					
1850	..	2nd	..	For	5·4	read	5·3
1853	..	5th	..	„	6·8	„	3·3
1859	..	20th	..	„	7·9	„	7·7
1872	..	12th	..	„	5·4	„	5·3
1872	..	27th	..	„	6·7	„	7·6
1876	..	2nd	..	„	7·2	„	7·6
1893	.	28th	..	„	8·7	„	10·7

June.

Year.		Date.					
1856	..	26th	..	For	8·5	read	8·4
1861	..	2nd	..	”	8·2	”	8·1
		3rd	..	”	8·4	”	8·1
1862	..	21st	..	”	10·6	”	10·5

July.

Year.		Date.					
1872	..	17th	..	For	14·9	read	12·9
1882	..	1st	..	”	13·7	”	13·0
1885	..	25th	..	”	14·6	”	14·3
1889	..	31st	..	”	13·7	”	13·6
1891	..	14th	..	”	10·0	”	11·0
1895	..	3rd	..	”	14·2	”	14·3
1896	..	9th	..	”	12·7	”	15·7
1899	..	30th	..	”	12·3	”	13·3
		31st	..	”	12·0	”	12·8
1905	..	15th	..	”	15·0	”	16·0
		16th	..	”	16·9	”	16·0
		18th	..	”	16·0	”	16·2

August.

Year.		Date.					
1850	..	30th	..	For	11·0	read	11·8
1872	..	30th	..	”	10·5	”	10·9
1884	..	18th	..	”	15·0	”	15·4
1900	..	29th	..	”	12·2	”	13·2

September.

Year.		Date.					
1856	..	30th	..	For	8·7	read	7·7
1859	..	20th	..	”	7·7	”	7·8
1890	..	21st	..	”	7·0	”	8·0
1900	..	3rd	..	”	13·3	”	13·3
		19th	..	”	13·1	”	13·4

October.

Year.		Date.					
1860	..	18th	..	For	2·1	read	2·6
1872	..	20th	..	”	3·1	”	3·0
1899	..	27th	..	”	2·7	”	2·1

November.

Year.		Date.					
1884	..	30th	..	For	1·3	read	1·9
1889	..	25th	..	”	3·5	”	2·5

Note to accompany " Tables of heights of the River Indus on the Bukkur gauge for 60 *years from* 1848 *to* 1907."

The Bukkur gauge was fixed in January 1848 by Captain Baker, Bengal Engineers. In 1858, its zero was connected with the G. T. S. bench mark at Mari, 3 miles south of Shikarpur and was taken to be 183·84 feet above Karachi mean sea level. The zero was checked by G. T. S. levellers and by the Indus River Commission staff in 1905, when it was ascertained to be 184·44, which is now taken as the reduced level.

The gauge is on an island between the towns of Sukkur and Rohri, and is fixed in a well which has free communication with the River.

The heights are given in feet to one decimal, instead of in feet and inches as in the former table.

THOS. SUMMERS,
Superintending Engineer,
Indus River Commission.

Karachi, 7th August 1907.

Readings of Bukkur Gauge for January.

Date.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.	1864.	1865.	1866.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	..	1·2	1·1	1·6	1·3	0·7	0·2	0·3	0·8	1·3	1·8	2·1	0·2	-0·7	0·2	0·5	-1·0	1·2	4·7
2	..	1·2	1·2	1·7	1·3	0·7	0·2	0·3	0·7	1·4	1·8	2·1	0·2	-0·7	0·2	0·5	-1·1	0·9	4·3
3	..	1·2	1·2	1·7	1·3	0·7	0·2	0·4	0·7	1·3	1·8	2·1	0·2	-0·8	0·2	0·5	-1·1	0·7	3·8
4	..	1·2	1·2	1·7	1·2	0·7	0·2	0·4	0·6	1·3	1·8	2·1	0·2	-0·9	0·2	0·4	-1·2	0·6	3·3
5	..	1·1	1·2	1·7	1·2	0·7	0·2	0·5	0·6	1·3	1·8	2·0	0·2	-0·7	0·2	0·4	-1·2	0·5	3·1
6	..	1·1	1·2	1·7	1·2	0·6	0·2	0·5	0·7	1·2	1·8	2·1	0·2	-0·7	0·2	0·4	-1·2	0·4	2·9
7	..	1·1	1·2	1·7	0·8	0·5	0·2	0·6	0·7	1·2	1·8	2·1	0·2	-0·8	0·1	0·3	-1·2	0·3	2·8
8	..	1·0	1·1	1·7	0·5	0·5	0·2	0·6	0·6	1·2	1·8	2·0	0·2	-0·8	0·0	0·3	-1·2	0·2	2·8
9	..	1·0	1·1	2·0	0·5	0·5	0·2	0·5	0·5	1·2	1·8	2·0	0·1	-0·8	0·0	0·2	-1·2	0·2	2·7
10	..	1·0	1·1	3·1	0·5	0·4	0·2	0·6	0·5	1·2	1·8	2·0	0·1	-0·7	-0·1	0·2	-1·2	0·2	2·6
11	..	1·1	1·1	3·3	0·4	0·4	0·2	0·4	0·6	1·2	1·8	2·0	0·0	-0·7	-0·2	0·2	-1·1	0·1	2·6
12	..	1·0	1·0	4·6	0·4	0·4	0·2	0·4	0·5	1·2	1·8	2·0	0·0	-0·7	-0·2	0·2	-1·0	0·0	2·5
13	..	1·0	1·0	4·9	0·4	0·4	0·2	0·4	0·5	1·2	1·7	2·0	-0·1	-0·8	-0·2	0·1	-1·0	0·0	2·6
14	..	1·0	1·0	4·2	0·4	0·5	0·2	0·4	0·4	1·2	1·7	2·1	-0·1	-0·8	-0·2	0·1	-1·1	0·0	2·6
15	..	1·0	1·0	4·2	0·4	0·4	0·2	0·6	0·5	1·2	1·7	2·1	-0·1	-0·8	-0·2	0·1	-1·2	0·0	2·7
16	..	1·0	1·0	4·0	0·4	0·4	0·2	1·6	0·5	1·2	1·8	2·1	-0·1	-0·7	-0·2	0·0	-1·2	-0·1	2·7
17	..	1·0	1·1	3·6	0·5	0·4	0·2	1·4	0·4	1·2	1·8	2·2	-0·1	-0·8	-0·2	0·0	-1·2	-0·2	2·7
18	..	1·1	1·1	3·3	0·5	0·4	0·2	1·2	0·4	1·2	1·8	2·2	-0·1	-0·8	-0·2	0·0	-1·3	-0·2	2·7
19	..	1·2	1·3	3·4	0·5	0·4	0·2	1·2	0·5	1·2	1·7	2·2	-0·1	-0·8	-0·2	-0·1	-1·3	-0·2	2·7
20	..	1·0	2·4	3·7	0·5	0·5	0·2	1·2	0·6	1·3	1·8	2·3	0·0	-0·8	-0·2	-0·2	-1·4	-0·2	2·7
21	..	1·0	2·4	3·7	0·5	0·6	0·2	1·1	0·6	1·5	1·9	2·7	0·1	-0·8	-0·2	-0·2	-1·5	-0·2	2·6
22	..	1·2	2·4	3·3	0·5	0·6	0·2	0·9	0·6	1·5	1·9	3·1	0·2	-1·0	-0·2	-0·2	-1·5	-0·2	2·5
23	..	1·5	2·3	3·2	0·5	0·5	0·2	0·8	0·6	1·4	1·9	3·2	0·1	-0·8	-0·2	-0·2	-1·6	-0·2	2·3
24	..	1·7	2·2	3·2	0·5	0·5	0·2	0·7	0·7	1·5	1·8	3·1	0·0	-1·0	-0·2	-0·2	-1·6	-0·2	2·3
25	..	1·8	2·0	3·2	0·4	0·5	0·3	0·7	0·6	1·7	1·7	3·0	0·0	-1·0	-0·2	-0·2	-1·6	-0·3	2·2
26	0·6	1·8	1·8	3·0	0·4	0·5	0·4	0·5	0·6	1·7	1·7	2·9	0·0	-0·9	-0·2	-0·2	-1·6	-0·2	2·3
27	0·6	2·0	1·4	2·7	0·4	0·4	0·5	0·4	0·7	1·8	1·7	2·8	-0·1	-1·0	-0·2	-0·2	-1·6	-0·3	2·3
28	0·6	4·0	1·7	2·5	0·4	0·4	0·5	0·4	0·7	1·8	1·7	2·8	-0·2	-0·9	-0·2	-0·2	-1·6	-0·2	2·3
29	0·6	4·6	1·5	2·5	0·5	0·4	0·4	0·2	0·7	1·8	1·7	2·7	-0·2	-0·8	0·0	-0·2	-1·6	-0·1	2·3
30	0·6	3·7	1·4	2·2	0·5	0·3	0·3	0·2	0·6	1·8	1·7	2·7	0·1	-0·7	0·2	-0·2	-1·7	0·0	2·3
31	0·6	2·8	1·4	2·4	0·4	0·3	0·2	0·1	0·6	1·7	2·2	2·6	1·2	-0·7	0·2	-0·2	-1·7	0·1	2·3
Averages	0·6	1·5	1·4	2·9	0·6	0·5	0·2	0·6	0·6	1·4	1·8	2·4	0·1	-0·8	-0·1	0·1	-1·3	0·1	2·7

Date.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	0·7	-0·1	0·2	0·7	-0·8	-0·7	-0·6	0·7	1·2	1·6	1·8	5·5	2·4	0·4	0·2	0·2	2·1	2·2
2	0·7	-0·1	0·2	0·8	-0·9	-0·7	-0·6	0·7	1·2	1·5	1·8	8·2	2·4	0·4	0·1	0·2	2·1	2·1
3	0·7	-0·2	0·2	0·9	-0·9	-0·6	-0·7	0·6	1·1	1·5	1·7	11·3	2·3	0·4	0·1	0·2	2·0	2·1
4	0·6	-0·2	0·2	0·9	-0·9	-0·6	-0·7	0·5	1·0	1·5	1·7	10·7	2·2	0·4	0·2	0·2	2·0	2·1
5	0·6	-0·2	0·2	0·9	-1·0	-0·5	-0·8	0·4	1·0	1·5	1·7	9·9	2·2	0·4	0·2	0·2	2·0	2·0
6	0·5	-0·2	0·2	0·9	-1·0	-0·5	0·8	0·4	0·9	2·0	1·7	9·2	2·2	0·4	0·2	0·1	1·9	2·0
7	0·5	-0·2	0·2	0·9	-1·0	-0·5	-0·8	0·4	0·9	2·6	1·6	8·2	2·1	0·4	0·2	0·1	1·9	2·0
8	0·5	-0·2	0·2	0·9	-1·0	-0·4	-0·8	0·9	0·8	2·9	1·6	7·6	2·1	0·4	0·3	0·1	1·9	2·0
9	0·4	-0·2	0·2	0·7	-0·9	-0·4	-0·8	1·7	0·8	2·9	1·6	7·1	2·1	0·5	0·3	0·1	1·9	1·9
10	0·2	-0·2	0·2	0·7	-0·9	-0·4	-0·8	1·7	0·8	2·7	1·5	6·7	2·1	0·5	0·3	0·1	1·9	1·9
11	0·1	-0·2	0·2	0·7	-0·9	-0·4	-0·8	1·5	0·7	2·5	1·5	6·6	2·2	0·6	0·3	0·1	1·9	1·9
12	0·0	-0·2	0·2	0·7	-0·9	-0·3	-0·8	1·2	0·7	2·3	1·5	6·2	2·1	0·5	0·4	0·0	1·9	1·9
13	0·0	-0·3	0·2	0·6	-0·9	-0·2	-0·8	0·9	0·7	2·2	1·5	5·9	2·1	0·6	0·4	0·0	1·9	1·9
14	0·0	-0·3	0·1	0·6	-0·9	0·1	0·2	0·7	0·7	2·2	1·3	5·7	2·1	0·5	0·4	0·0	1·9	1·9
15	0·0	-0·3	0·0	0·5	-0·9	0·2	0·4	0·7	0·7	2·1	1·3	5·6	2·1	0·4	0·6	0·0	1·9	1·9
16	-0·1	-0·2	-0·1	0·5	-0·9	0·3	0·3	0·7	0·7	2·1	1·3	5·4	2·1	0·4	0·6	0·0	1·9	1·9
17	-0·2	0·0	-0·2	0·4	-0·9	0·3	0·2	0·7	0·7	2·8	1·3	5·2	2·0	0·4	0·5	0·0	1·9	1·8
18	-0·2	0·1	-0·2	0·4	-0·9	0·2	0·1	0·6	0·7	2·7	1·4	6·0	1·9	0·4	0·7	0·0	1·8	1·8
19	-0·2	0·1	-0·2	0·4	-1·0	0·1	-0·1	0·5	0·7	3·0	1·9	4·9	1·9	0·3	0·7	0·2	1·8	1·7
20	-0·2	0·0	-0·2	0·3	-1·1	-0·1	-0·2	0·4	0·7	3·0	2·6	4·8	1·8	0·3	0·7	0·2	1·8	1·7
21	-0·1	0·0	-0·2	0·3	-1·1	-0·2	-0·4	0·4	0·0	2·6	2·7	4·7	1·7	0·3	0·7	0·2	1·8	1·7
22	0·0	0·0	-0·2	0·3	-1·1	-0·2	-0·5	0·4	0·6	2·7	2·5	4·6	1·7	0·2	0·7	0·7	1·8	1·7
23	0·0	0·0	-0·2	0·2	-1·1	-0·2	-0·6	0·2	0·5	2·5	[illegible]	4·6	1·7	0·2	0·7	1·1	1·8	1·7
24	0·1	0·0	-0·2	0·2	-1·2	-0·2	-0·7	0·2	0·5	2·8	2·2	4·6	1·6	0·1	0·7	1·3	1·8	1·7
25	0·1	0·0	-0·2	0·2	-1·2	-0·4	-0·7	0·2	0·6	3·6	2·2	4·5	1·7	0·1	0·7	1·4	1·8	1·7
26	0·0	-0·2	-0·2	0·1	-1·2	-0·4	-0·0	0·2	0·6	3·7	2·2	4·5	1·6	0·0	0·7	1·4	1·8	1·7
27	0·0	-0·3	-0·2	0·1	-1·8	-0·4	-0·7	0·1	0·6	3·4	2·2	4·3	1·7	0·0	0·7	1·3	1·9	1·7
28	0·0	-0·3	-0·2	0·1	-1·3	-0·4	-0·7	0·4	0·5	3·2	2·4	4·2	1·6	0·0	0·7	1·3	1·8	1·7
29	0·0	-0·3	-0·2	0·2	-1·4	-0·5	-0·7	1·4	0·5	3·2	2·7	4·2	1·6	0·0	0·7	1·2	1·8	1·7
30	0·1	-0·4	-0·2	0·2	-1·4	-0·5	-0·7	1·7	0·4	3·2	2·7	4·2	1·5	0·0	0·8	1·1	2·0	1·7
31	0·1	-0·4	-0·2	0·3	-1·5	-0·4	-0·8	1·7	0·4	3·1	2·5	4·2	1·0	0·0	0·8	1·0	2·0	1·7
Averages	0·2	-0·2	-0·0	0·5	-1·0	-0·3	-0·5	0·7	0·7	2·5	1·9	6·1	2·0	0·3	0·5	0·5	2·0	1·9

Date.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	1·2	1·1	2·2	1·0	1·2	1·3	3·2	1·6	1·7	0·2	0·2	0·2	-0·1	0·5	-0·4	-0·2	1·8	1·4	1·9
2	1·1	1·0	2·3	0·9	1·2	1·3	3·4	1·5	1·6	0·2	0·7	0·2	-0·1	0·5	-0·4	-0·2	1·8	1·4	1·9
3	1·0	1·0	2·4	0·9	1·2	1·3	3·6	1·5	1·6	0·1	1·1	0·2	-0·2	0·4	-0·4	-0·2	1·9	1·4	1·9
4	0·9	1·0	2·5	0·9	1·2	1·2	3·7	1·5	1·6	0·1	1·2	0·2	-0·2	0·4	-0·4	-0·2	2·2	1·3	1·9
5	0·9	1·0	2·4	0·9	1·2	1·2	4·0	1·4	1·5	0·1	1·2	0·2	-0·2	0·4	-0·4	-0·3	2·5	1·3	1·8
6	0·9	1·0	2·6	0·9	1·2	1·2	4·0	1·4	1·5	0·0	1·0	0·2	-0·2	0·3	-0·5	-0·3	2·8	1·3	1·8
7	0·8	0·9	2·7	0·9	1·2	1·2	3·9	1·4	1·5	0·0	0·8	0·1	-0·3	0·3	-0·5	-0·3	2·9	1·3	1·7
8	0·8	0·9	2·8	0·8	1·2	1·2	3·7	1·4	1·5	0·0	0·7	0·1	-0·3	0·3	-0·5	-0·3	2·8	1·3	1·7
9	0·7	0·7	2·7	0·8	1·1	1·2	3·6	1·3	1·4	0·2	0·7	0·1	-0·3	0·2	-0·5	-0·3	2·7	1·2	1·6
10	0·7	0·7	2·6	0·8	1·1	1·1	3·6	1·3	1·4	1·7	0·6	0·1	-0·4	0·2	-0·5	-0·3	2·5	1·1	1·6
11	0·6	0·7	2·5	0·8	1·1	1·1	3·6	1·2	1·4	2·1	0·6	0·1	-0·4	0·3	-0·5	-0·3	2·4	1·1	1·6
12	0·6	0·7	2·5	0·8	1·0	1·1	3·7	1·2	1·5	2·1	0·5	0·1	-0·4	0·3	-0·5	-0·3	2·3	1·1	1·5
13	0·6	0·7	2·4	0·7	1·0	1·1	3·6	1·2	1·6	1·9	0·5	0·0	-0·4	0·3	-0·5	-0·3	2·3	1·1	1·5
14	5·5	0·6	2·4	0·7	1·0	1·1	3·5	1·2	1·7	1·7	0·3	0·0	-0·4	0·2	-0·5	-0·3	2·2	1·1	1·5
15	7·0	0·6	2·3	0·7	1·0	1·0	3·3	1·2	1·9	1·6	0·3	0·0	-0·5	0·2	-0·4	-0·3	2·2	1·0	1·5
16	5·8	0·6	2·3	0·7	0·9	1·0	3·3	1·2	2·2	1·6	0·3	0·0	-0·4	0·2	-0·4	-0·3	2·3	1·0	1·5
17	4·8	0·7	2·3	0·7	0·9	0·9	3·2	1·2	2·1	1·6	0·3	-0·1	-0·4	0·2	-0·4	-0·4	2·3	1·0	1·5
18	4·3	0·7	2·4	0·7	0·9	0·9	3·1	1·2	2·1	1·4	2·7	-0·2	-0·4	0·2	-0·4	-0·4	2·2	0·9	1·5
19	3·5	0·7	2·4	0·7	0·9	0·9	3·2	1·2	2·0	1·2	3·2	-0·2	-0·4	0·2	-0·5	-0·4	2·7	0·9	1·4
20	2·9	0·7	2·3	0·7	0·9	0·8	3·2	1·2	2·0	1·2	3·1	-0·2	-0·5	0·2	-0·5	-0·4	5·3	0·9	1·4
21	2·4	0·7	2·2	0·7	0·9	0·8	3·3	1·1	1·8	1·2	2·7	-0·2	-0·2	0·2	-0·5	-0·4	5·2	0·8	1·3
22	2·3	0·8	2·2	0·7	0·8	0·8	6·6	1·1	1·8	1·2	2·3	-0·2	1·8	0·2	-0·5	-0·4	5·5	0·8	1·3
23	2·2	0·9	2·6	0·7	0·8	0·7	8·2	1·1	1·8	1·2	2·0	-0·2	2·2	0·1	-0·6	-0·4	5·5	0·8	1·3
24	2·2	0·8	2·9	0·7	0·8	0·7	7·0	1·1	1·7	1·2	1·5	-0·2	1·0	0·1	-0·6	-0·4	4·8	0·7	1·2
25	2·2	0·8	3·0	0·7	0·8	0·7	5·8	1·1	1·7	1·2	1·2	-0·2	1·6	0·1	-0·6	-0·5	4·2	0·7	1·2
26	2·2	0·8	3·0	0·7	0·8	0·7	5·2	1·1	1·7	1·2	1·2	-0·3	1·2	0·1	-0·6	-0·4	3·8	0·7	1·2
27	2·2	1·1	2·8	0·7	0·8	0·7	5·0	1·1	1·8	1·2	1·2	-0·3	1·0	0·0	-0·6	-0·4	3·6	0·7	1·2
28	2·2	2·1	2·7	0·7	0·8	0·7	4·8	1·0	1·8	3·5	1·2	-0·2	0·8	0·0	-0·7	-0·4	3·4	0·7	1·2
29	2·1	2·2	2·5	0·7	0·8	0·7	4·7	0·9	1·7	4·2	1·1	-0·2	0·7	0·0	-0·7	-0·3	3·3	0·6	1·1
30	2·1	3·1	2·4	0·7	0·8	0·7	4·5	0·9	2·2	4·5	1·1	-0·2	0·7	-0·1	-0·7	-0·2	3·3	0·6	1·1
31	2·0	3·1	2·5	0·7	0·7	0·7	4·2	0·8	4·0	4·5	1·6	-0·1	0·7	-0·2	-0·7	-0·1	3·6	0·6	1·1
Averages	2·2	1·1	2·5	0·8	1·0	1·0	4·2	1·3	1·8	1·4	1·2	-0·1	0·2	0·2	-0·6	-0·4	3·1	1·0	1·5

Date.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	2·0	2·2		0·7	-0·9	-1·6	0·9	0·8	2·2	1·6	1·9	2·3	-0·2	0·9	1·0	0·3		
2	1·9	2·1	2·3	0·7	-0·9	-1·6	0·8	0·7	2·2	1·6	1·6	2·2	-0·2	0·9	1·0	0·3		
3	1·9	2·1	2·3	0·7	-0·9	-1·7	0·8	0·7	2·1	1·6	1·6	2·2	-0·3	0·9	0·9	0·3		
4	1·9	2·0	2·2	0·6	-0·9	-1·7	0·7	0·6	2·1	1·6	1·5	2·2	-0·3	0·8	0·9	0·3		
5	1·9	1·9	2·1	0·6	-1·0	-1·7	0·7	0·6	2·1	1·6	1·6	2·2	-0·3	0·8	1·0	0·3		
6	1·9	1·9	2·1	0·5	-1·0	-1·6	0·5	0·6	2·1	1·6	1·6	2·2	-0·3	0·7	1·0	0·3		
7	1·9	1·8	2·0	0·4	-1·0	-1·6	0·5	0·6	2·0	1·6	1·6	2·1	-0·3	0·7	1·0	0·3		
8	1·9	1·8	1·9	0·3	-1·0	-1·6	0·5	0·5	2·0	1·5	1·5	2·0	-0·3	0·6	1·0	0·3		
9	1·8	1·7	1·7	0·2	-1·0	-1·5	0·5	0·6	2·1	1·5	1·5	2·0	-0·4	0·5	1·0	0·2		
10	1·8	1·7	1·7	0·2	-0·9	-1·5	0·5	0·6	2·1	1·5	1·4	2·0	-0·4	0·5	1·0	0·2		
11	1·8	1·6	1·7	0·1	-0·9	-1·5	0·6	0·7	2·1	1·5	1·4	1·9	-0·4	0·4	1·0	0·2		
12	1·9	1·6	1·6	0·1	-1·0	-1·5	0·7	2·9	2·1	1·6	1·3	1·8	-0·5	0·4	1·0	0·2		
13	1·9	1·5	1·5	0·1	-1·0	-1·6	0·7	3·2	2·0	1·5	1·3	1·9	-0·5	0·4	1·0	0·2		
14	2·0	1·5	1·5	0·0	-1·1	-1·6	0·8	3·2	2·0	1·5	1·3	1·8	-0·5	0·4	1·0	0·2		
15	1·9	1·4	1·4	0·0	-1·1	-1·7	0·7	3·0	2·2	1·5	1·4	1·8	-0·6	0·4	1·0	0·2		
16	1·9	1·4	1·4	-0·1	-0·8	-1·7	0·6	2·6	2·2	1·4	1·4	1·8	-0·6	0·4	0·9	0·2		
17	2·0	1·4	1·3	-0·2	1·3	-1·7	0·5	2·3	2·2	1·4	1·5	1·8	-0·7	0·3	0·9	0·1		
18	2·1	1·5	1·2	-0·2	1·6	-1·7	0·5	2·1	2·2	1·4	1·5	1·8	-0·7	0·3	0·9	0·1		
19	2·0	1·5	1·2	-0·2	1·2	-1·7	0·5	2·0	2·2	1·4	1·5	1·8	-0·7	0·3	0·8	0·1		
20	3·4	1·5	1·2	-0·3	0·5	-1·6	0·5	1·9	2·1	1·4	1·5	2·0	-0·7	0·3	0·8	0·1		
21	5·1	1·5	1·1	-0·3	0·1	-1·6	2·4	2·0	2·1	1·5	1·5	1·9	-0·7	0·3	0·9	0·0		
22	5·3	1·4	1·1	-0·3	-0·3	-1·6	3·7	2·3	2·1	1·5	1·4	1·9	-0·7	0·3	0·9	0·0		
23	5·1	1·8	1·0	-0·2	-0·5	-1·1	3·7	2·7	2·2	1·5	1·4	1·9	-0·8	0·2	0·8	0·0		
24	4·7	1·3	1·0	-0·1	-0·6	-1·4	3·2	3·0	2·2	1·4	1·3	1·9	-0·8	0·2	0·7	0·0		
25	4·2	1·3	1·0	-0·0	-0·6	-1·5	2·6	3·0	2·2	1·4	1·3	1·8	-0·8	0·2	0·7	-0·1		
26	3·9	1·3	1·0	-0·0	-0·7	-1·6	1·9	2·9	2·2	1·4	1·3	1·8	-0·9	0·2	0·7	-0·1		
27	3·6	1·3	0·9	-0·1	-0·8	-1·6	1·6	2·7	2·3	1·4	1·2	1·8	-0·9	0·2	0·7	-0·1		
28	3·4	1·3	0·9	-0·2	-0·9	-1·6	1·3	2·7	2·4	1·4	1·2	1·8	-0·9	0·1	0·7	-0·1		
29	3·3	1·3	0·8	-0·2	-1·0	-1·6	1·2	2·7	2·5	1·4	1·2	1·8	-0·9	0·1	0·7	-0·1		
30	3·2	1·5	0·8	-0·3	-1·0	-1·7	1·3	3·6	3·9	1·4	1·2	1·8	-0·9	0·1	0·7	-0·1		
31	3·1	2·0	0·7	-0·4	-1·1	-1·7	1·2	4·2	4·0	1·4	1·2	1·8	-0·9	0·1	0·7	-0·1		
Averages	2·7	1·7	1·4	0·1	0·6	-1·6	1·2	2·0	2·3	1·5	1·4	1·9	-0·6	0·4	0·9	-0·1		

Readings of Bukkur Gauge for February.

Date.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.	1864.	1865.	1866.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	0·6	2·4	1·4	2·3	0·4	0·3	0·2	0·1	0·6	2·7	2·7	2·5	1·5	—0·6	0·2	—0·2	—1·8	0·1	2·4
2	0·6	2·2	1·3	2·4	0·4	0·2	0·1	0·0	0·6	3·7	2·8	2·4	1·4	—0·6	0·1	—0·1	—1·8	0·1	4·1
3	0·6	2·1	1·2	2·4	0·3	0·2	1·7	0·0	0·6	3·7	2·8	2·4	1·2	—0·6	0·0	0·1	—1·7	0·1	5·0
4	0·6	2·0	1·2	2·4	0·3	0·3	3·8	0·0	0·6	3·2	2·7	2·3	1·1	—0·7	0·0	0·2	—1·3	0·0	5·1
5	0·6	1·8	1·2	2·2	0·3	0·3	4·2	—0·1	0·6	2·6	2·7	2·4	1·0	—0·7	—0·1	0·4	—1·2	0·0	5·1
6	2·1	1·8	1·1	2·2	0·3	0·3	3·7	—0·1	0·7	2·2	2·6	2·5	0·9	—0·7	—0·2	0·6	—1·2	0·1	4·8
7	2·2	1·7	1·0	2·4	0·3	0·3	3·3	—0·1	0·7	1·9	2·5	2·5	0·8	—0·7	—0·2	0·7	—1·2	2·0	4·7
8	2·1	1·7	1·0	2·6	0·2	0·4	3·2	—0·1	0·7	3·2	2·3	2·4	0·7	0·4	—0·3	1·2	—1·3	2·7	4·2
9	2·2	1·7	1·0	2·7	0·2	0·4	3·0	—0·1	0·7	6·0	2·2	2·4	0·7	0·2	—0·4	1·4	—1·3	2·6	3·7
10	2·2	1·6	1·2	2·8	0·2	0·6	2·7	—0·1	0·7	6·1	2·2	2·3	0·6	0·1	—0·4	1·3	—1·3	2·2	3·6
11	2·2	1·5	1·2	2·9	0·3	0·7	2·5	—0·1	0·8	4·9	2·2	2·2	0·5	0·1	—0·5	1·1	—1·4	1·9	3·5
12	2·1	1·4	1·2	7·4	0·4	0·7	2·3	—0·1	0·8	4·2	2·2	2·2	0·4	—0·1	—0·5	1·1	—1·4	1·7	3·2
13	2·0	1·3	1·2	7·0	0·5	0·7	2·2	—0·2	1·0	3·9	2·2	2·2	0·3	—0·1	—0·6	1·2	—1·5	1·5	3·1
14	1·9	1·3	1·2	5·8	0·5	0·7	2·0	—0·2	0·9	2·8	2·2	2·2	0·2	—0·2	—0·7	1·2	—1·6	1·4	3·2
15	2·0	1·2	1·1	5·2	0·5	0·9	1·8	—0·2	0·9	2·5	2·2	2·2	0·2	—0·2	—0·7	1·2	—1·7	1·4	3·2
16	2·0	1·2	1·1	5·2	0·4	1·2	1·8	—0·2	0·8	2·2	2·3	2·3	0·2	—0·3	—0·7	1·1	—1·7	1·4	3·3
17	2·0	1·0	1·1	5·2	0·4	1·3	1·9	—0·2	0·8	2·1	2·4	2·7	0·2	—0·3	—0·7	1·0	—1·7	1·9	3·4
18	2·0	1·0	1·0	8·7	0·4	1·7	1·8	—0·1	0·8	2·2	2·4	3·2	0·1	—0·4	—0·7	0·8	—1·7	2·7	3·6
19	2·1	0·9	1·0	8·4	0·4	1·5	1·8	—0·1	0·8	2·1	2·3	3·2	0·0	—0·5	—0·7	0·8	—1·8	2·8	3·6
20	1·9	0·9	1·0	7·2	0·5	1·4	1·8	0·0	0·8	2·1	2·2	3·1	0·0	—0·6	—0·7	0·7	—1·8	2·6	3·3
21	1·9	0·8	0·9	6·7	0·4	1·2	1·9	0·1	0·8	2·1	2·2	3·0	0·1	—0·6	—0·8	0·6	—1·8	2·4	3·2
22	1·9	0·8	0·9	6·2	0·4	1·2	2·4	0·1	0·8	2·2	2·2	2·9	0·1	—0·7	—0·8	0·5	—1·8	2·1	3·1
23	1·9	0·8	0·9	5·7	0·4	1·2	3·0	0·2	0·8	2·1	2·2	2·8	0·0	—0·7	—0·9	0·4	—1·9	2·1	3·0
24	1·9	0·7	0·8	5·0	0·4	1·3	3·2	0·2	0·8	2·0	2·3	2·7	0·0	—0·7	—0·9	0·3	—1·5	2·2	2·9
25	1·9	0·7	0·8	4·4	0·4	1·5	3·2	0·2	0·8	1·9	2·2	2·7	0·0	—0·8	—0·9	0·2	—1·0	2·2	2·9
26	1·9	0·7	1·0	4·2	0·5	1·5	3·0	0·1	0·9	1·9	2·2	2·6	—0·1	—0·8	—0·8	0·2	—0·7	2·0	2·9
27	2·1	0·7	1·3	4·1	0·4	1·6	2·8	0·1	1·1	2·1	2·2	2·5	0·0	—0·9	—0·7	0·1	—0·7	1·9	2·8
28	2·2	0·7	1·3	3·9	0·4	1·7	2·7	0·2	1·1	2·1	2·3	2·5	0·1	—0·9	—0·5	0·0	—0·6	1·9	2·8
29	5·2	..	..	..	0·4	..	..	..	1·2	..	..	..	0·3	..	..	..	—0·6	..	..
Averages ..	1·9	1·3	1·1	4·6	0·4	0·9	2·4	—0·0	0·8	2·9	2·3	2·5	0·4	—0·5	—0·5	0·6	—1·4	1·6	3·5

Date.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	0·0	—0·4	—0·3	0·3	—1·5	—0·4	—0·9	1·4	0·3	3·0	2·2	6·1	1·6	0·0	0·8	0·9	2·1	1·7
2	0·0	—0·4	—0·3	0·3	—1·5	—0·4	—0·9	1·2	0·3	2·9	2·1	6·7	1·6	0·2	0·8	0·8	2·1	1·7
3	0·0	—0·5	—0·3	0·3	—1·5	—0·3	—0·9	1·2	0·3	2·7	2·0	7·5	1·7	0·2	0·8	0·7	2·2	3·2
4	—0·1	—0·5	—0·4	0·3	—1·5	—0·2	—1·0	1·2	0·2	2·7	2·0	7·2	1·7	0·3	0·8	0·7	3·4	3·7
5	—0·1	—0·5	—0·4	0·3	—1·5	—0·2	—1·0	1·1	0·2	2·6	1·8	6·8	1·7	0·3	0·9	0·7	3·8	3·2
6	—0·1	—0·3	—0·3	0·3	—1·5	—0·2	—1·0	0·9	0·2	2·5	1·8	5·9	1·5	0·3	0·9	0·8	3·9	2·7
7	—0·2	—0·2	—0·3	0·3	—1·4	—0·2	—1·1	0·8	0·2	2·4	1·8	5·5	1·6	0·2	0·9	1·0	3·7	2·5
8	—0·2	—0·2	—0·2	0·2	—1·4	0·0	—1·1	0·7	0·2	2·3	1·9	5·2	1·6	0·2	0·9	1·1	3·4	2·2
9	—0·2	—0·2	—0·2	0·2	—1·4	0·9	—1·1	0·7	0·2	2·3	2·0	5·0	1·6	0·2	0·9	1·1	3·2	2·2
10	—0·2	—0·2	0·0	0·1	—1·5	1·4	—1·2	0·8	0·2	2·3	2·2	4·7	1·6	0·1	1·0	1·1	3·0	2·2
11	—0·2	—0·2	0·4	0·1	—1·6	1·3	—1·2	0·7	0·2	2·5	2·4	4·7	1·6	0·0	1·0	0·9	2·8	2·2
12	—0·2	—0·2	1·0	0·1	—1·6	1·2	—1·2	0·7	0·2	2·7	2·5	4·6	1·5	0·0	1·0	0·9	2·7	2·2
13	—0·2	—0·2	1·2	0·0	—1·7	1·0	—1·2	0·8	0·2	2·8	5·2	4·7	1·5	0·0	1·0	0·9	2·6	2·5
14	—0·2	—0·2	1·1	—0·1	—1·7	0·8	—1·2	0·9	0·2	2·8	5·6	4·7	1·5	0·0	1·0	1·2	2·5	2·8
15	—0·2	—0·3	0·9	0·0	1·7	0·6	—1·2	1·0	0·2	2·8	5·6	4·9	1·5	0·0	1·0	1·4	2·5	3·2
16	—0·2	—0·3	0·7	0·0	—1·7	0·5	—1·2	1·1	0·1	2·7	5·5	6·8	1·4	0·0	1·2	1·4	2·4	3·3
17	—0·2	—0·3	0·6	0·1	—1·7	0·5	—1·2	1·1	0·1	2·5	4·9	7·7	1·4	0·0	1·2	1·4	2·3	3·2
18	—0·2	—0·3	0·5	0·1	—1·7	0·6	—1·2	1·1	0·1	2·3	4·2	8·2	1·5	0·0	1·2	1·4	2·3	3·1
19	—0·3	—0·3	0·4	0·0	—1·6	0·6	—1·2	1·3	0·2	2·2	3·8	7·9	1·6	—0·1	1·2	1·3	2·2	2·9
20	—0·3	—0·2	0·2	0·0	—1·5	0·6	—1·2	1·7	0·2	2·1	3·6	7·3	1·7	0·0	1·2	1·2	2·2	2·9
21	—0·2	—0·1	0·2	0·0	0·6	0·6	—1·0	1·8	0·2	2·1	3·4	6·9	1·7	0·0	1·2	1·3	2·2	2·7
22	—0·2	0·1	0·1	0·0	0·6	0·6	—0·7	1·8	0·2	2·0	3·2	6·6	1·7	0·2	1·2	2·2	2·2	2·7
23	0·0	0·2	0·1	0·0	1·0	0·6	—0·6	1·7	0·3	2·1	3·1	6·2	1·7	0·7	1·2	2·6	2·2	2·7
24	0·1	0·3	0·0	0·0	0·8	0·5	—0·7	1·7	0·2	2·1	3·0	6·0	1·7	0·8	1·2	2·7	2·1	2·6
25	0·2	0·3	0·0	0·1	0·7	0·5	—0·7	1·6	0·9	2·2	2·9	5·9	1·7	0·9	1·2	2·6	2·1	2·5
26	0·2	0·3	0·0	0·2	0·9	0·5	—0·8	1·4	1·5	2·4	2·8	5·8	1·7	1·2	1·2	2·5	2·1	2·4
27	0·2	0·4	0·0	0·2	0·8	0·4	—0·8	1·3	1·7	2·7	2·7	5·7	1·7	1·5	1·2	2·5	2·0	2·4
28	0·2	0·4	0·0	0·3	0·7	0·4	—0·8	1·2	1·8	2·7	4·1	5·7	1·7	1·3	1·2	2·2	2·0	2·3
29	..	0·4	..	..	..	0·4	..	..	..	2·7	..	..	..	1·1	..	..	..	2·3
Averages ..	—0·1	—0·1	0·2	0·1	—0·9	0·4	—1·0	1·2	0·4	2·5	3·1	6·1	1·6	0·3	1·1	1·4	2·6	2·7

Date.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F.D.	F. D.
1	1·9	2·9	2·5	0·7	0·7	0·7	4·2	0·8	4·3	3·9	1·7	—0·1	0·7	—0·2	—0·8	—0·1	3·9	0·6	1·1
2	1·8	2·8	2·5	0·7	0·7	0·7	4·3	0·7	4·3	3·3	2·0	—0·1	0·7	—0·2	—0·8	—0·1	3·9	0·6	1·1
3	1·8	2·9	2·6	0·8	0·7	0·7	4·3	0·7	3·9	2·7	1·8	—0·1	0·6	—0·2	—0·9	—0·1	3·7	0·5	1·1
4	1·9	2·8	2·5	1·1	0·7	0·7	4·3	0·7	3·9	2·5	1·6	—0·1	0·5	—0·2	—0·9	—0·2	3·3	0·5	1·1
5	2·0	2·6	2·5	1·1	1·8	0·7	4·4	0·7	4·6	2·9	1·5	—0·1	0·5	—0·3	—0·9	—0·2	3·1	0·4	1·2
6	2·1	2·3	2·4	1·2	3·0	0·8	4·5	0·7	4·4	3·3	1·3	—0·1	0·5	—0·3	—1·0	—0·1	3·0	0·4	1·5
7	2·2	2·2	2·3	1·2	3·7	0·9	6·2	0·7	4·1	3·0	1·3	—0·1	0·4	—0·4	—1·0	—0·1	2·9	0·4	1·7
8	2·5	2·0	2·2	1·2	4·2	0·9	8·1	0·7	3·9	2·6	3·7	—0·2	0·4	—0;4	—1·0	0·0	2·8	0·4	2·0
9	2·6	2·0	2·2	1·2	3·8	0·8	7·7	0·7	3·7	2·6	5·2	—0·2	0·4	—0·4	—1·1	0·0	2·7	0·3	2·1
10	2·6	2·1	2·2	1·3	3·2	0·7	6·6	0·6	3·7	2·6	4·8	—0·2	0·4	—0·5	—1·1	—0·1	2·5	0·3	2·2
11	2·4	2·1	2·2	1·3	2·9	0·7	5·9	0·6	3·6	2·5	4·2	—0·1	0·4	—0·4	—1·1	—0·2	2·5	0·3	2·2
12	2·2	2·1	2·2	1·3	2·7	0·7	5·4	0·6	3·6	2·3	3·5	0·0	0·3	—0·5	—1-1	—0·2	2·4	0·3	2·2
13	2·6	2·0	2·1	1·3	2·5	0·7	5·2	0·5	3·4	2·3	3·0	0·1	0·2	—0·5	—1·1	—0·3	2·5	0·3	2·1
14	3·0	1·9	2·1	1·8	2·3	0·6	5·0	0·5	2·8	2·3	2·7	0·2	0·2	—0·5	—1·1	—0·4	4·7	0·3	2·0
15	3·3	1·6	2·1	2·1	2·2	0·6	4·7	0·4	2·7	2·0	2·6	0·3	0·2	—0·5	—1·1	—0·4	5·5	0·2	2·0
16	3·3	1·4	2·1	2·2	2·2	0·6	4·5	0·4	2·7	2·4	2·4	0·4	0·3	—0·4	—1·2	—0·4	5·3	0·2	1·9
17	3·0	1·3	2·2	2·1	2·1	0·5	4·4	0·4	2·9	2·8	2·2	0·5	0·3	—0·4	—1·2	—0·5	4·9	0·2	1·8
18	2·7	1·2	2·2	2·0	2·1	0·5	4·2	0·4	3·2	3·2	2·1	0·4	0·2	—0·5	—1·2	—0·5	4·5	0·2	1·8
19	2·5	1·2	2·2	2·0	2·1	0·4	4·2	0·4	3·2	3·4	2·0	0·4	0·2	—0·6	—1·2	—0·5	4·1	0·1	1·7
20	2·3	1·2	2·2	2·0	2·1	0·4	4·2	0·4	3·2	3·3	1·8	0·4	0·2	—0·6	—1·2	—0·6	3·9	0·1	1·6
21	2·2	1·0	2·2	1·9	2·1	0·3	3·7	0·4	3·1	3·0	1·7	0·4	0·3	—0·6	—1·1	—0·6	3·9	0·1	1·6
22	2·1	0·9	2·2	1·8	2·1	0·3	3·7	0·4	3·1	2·8	1·7	0·4	0·3	—0·5	—0·9	—0·6	3·5	0·1	1·5
23	1·9	0·7	2·0	1·7	2·1	0·3	3·7	0·4	3·3	3·1	1·7	0·3	0·3	—0·4	—0·9	—0·6	3·3	0·0	1·4
24	1·7	0·7	1·9	1·6	2·0	0·2	3·5	0·4	3·6	4·3	1·7	0·2	0·3	—0·3	—0·7	—0·6	3·2	0·0	1·4
25	1·7	0·7	1·9	1·5	2·0	0·2	3·3	0·4	3·7	4·6	1·7	0·2	0·2	0·1	—0·6	—0·5	3·1	0·0	1·4
26	1·5	0·9	2·0	1·5	2·0	0·2	3·2	0·3	3·8	4·7	1·6	0·2	0·2	1·7	—0·6	—0·5	2·9	0·0	1·3
27	1·5	1·0	2·0	1·4	2·1	0·2	3·3	0·3	3·7	4·6	1·5	0·1	0·2	2·3	—0·5	—0·5	2·8	0·0	1·3
28	1·5	1·0	2 1	1·4	2·2	0·2	4·2	0 3	3·5	4·5	1·5	0·1	0·2	2·3	—0·3	—0·5	2·7	—0·1	1·2
29	..	..	..	1·3	..	..	..	0 3	..	..	..	0·0	..	..	..	..	..	..	..
Averages ..	2·3	1·7	2·2	1·5	2·3	0·6	4·7	0·5	3·6	3·2	2·3	0·1	0·3	—0 2	—1·0	—0·3	3·5	0·3	1·7

Date.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	3·0	2·4	0·7	0·5	—1·1	—1·7	1·2	4·5	3·8	1·5	1·2	1·8	—0·9	0·1	0·6	—0·1		
2	2·9	2·6	0·7	0·5	—1·1	—1·7	1 3	5·6	3·6	1·5	1·1	1·8	—0·9	0·1	0·6	—0·2		
3	2·8	2·5	0·6	0·5	—0·9	—1·8	1·2	5·2	3·3	1·5	1·1	1·8	—0·9	0·2	0·6	—0·2		
4	2·8	2·4	0·6	0·6	—0·6	—1·9	1·1	4·8	3·2	1·5	1·1	1·7	—0·9	0·2	0·6	—0·1		
5	2·8	2·3	0·6	0·5	—0·5	—1·9	1·1	3·6	3·0	1·5	1·0	1·5	—0·9	0·2	0·9	—0·1		
6	4·8	2·2	0·6	0·3	—0·5	—1·9	0·9	3·3	2·8	1·5	1·0	1·5	—1·0	0·3	0·9	—0·2		
7	2·8	2·4	0·6	0·1	—0·6	—1·9	0·8	3·0	2·8	1·5	0·9	1·5	—1·0	0·3	0·9	—0·2		
8	2·8	2·6	0·5	0·2	—0·6	—2·0	0·8	2·9	2·7	1·5	0·9	1·6	—1·0	0·4	0·8	0·0		
9	2·7	2·9	0·5	0·3	—0·6	—2·0	0 7	2·8	2·7	1·5	0·8	1·6	—0·9	0·4	0·8	1·2		
10	2·7	3·1	0·5	0·5	—0·7	—2·0	0·7	2·7	2·8	1·4	0·8	1·6	—1·0	0·5	0·8	1·8		
11	2·6	3·0	0·5	0·9	—0·8	—2·1	0·7	2·6	2·8	1·4	0·7	1·6	—1·0	0·4	0·7	1·9		
12	2·5	2·8	0·5	0·8	—0·8	—2·1	0·6	2·5	2·8	1·3	0·7	1·6	—0·9	0·4	0·6	1·8		
13	2·5	2·7	0·5	0·5	—0·8	—2·1	0·6	2·3	2·8	1·3	0·7	1·6	—0·5	0·4	0·6	1·5		
14	2·4	2·5	0·5	0·4	—0·8	—2·1	0·6	2·2	2·7	1·3	0·8	1·7	—0·2	0·4	0·5	1·4		
15	2·3	2·4	0·7	0·4	—0·9	—2·2	0·5	2·1	2·6	1·3	0·8	4·3	—0·1	0·3	0·4	1·3		
16	2·3	2·4	0·8	0·7	—0·9	—2·2	0·5	2·0	2·6	1·3	0·8	4·9	0·0	0·3	0·4	1·2		
17	2·1	2·4	0·7	1·3	—1·0	—2·2	0·6	1·9	2·6	1·3	0·8	4·6	—0·1	0·2	0·3	1·1		
18	2·0	2·2	1·0	3·6	—1·0	—2·2	0·6	1·8	2·5	1·2	0·9	4·1	—0·2	0·2	0·3	1·0		
19	1·9	2·1	1·1	4·6	—1·1	—2·3	0·5	1·7	2·4	1·2	0·9	3·5	—0·3	0·1	0·3	0·9		
20	1·9	2·0	1·1	4·4	—1·1	—2·3	0·5	1·7	2·4	1·2	0·9	3·1	—0·3	0·1	0·2	0·9		
21	1·9	1·8	1·3	3·7	—1·1	—2·3	0·5	1·6	2·3	1·2	0·9	3·0	—0·4	0·1	0·2	0·8		
22	1·8	1·7	1·4	3·0	—1·1	—2·3	0·5	1·6	2·3	1·2	1·8	2·8	—0·5	0·1	0·2	0·7		
23	1·7	1·6	1·5	2·6	—1·1	—2·2	0·5	1·5	2·2	1·2	2·8	2·7	—0·6	0·0	0·0	0·7		
24	1·7	1·6	2·3	2·9	—1·2	—2·3	0·8	1·5	2·2	1·3	3·2	2·7	—0·7	0·0	0·0	0·6		
25	1·6	1·5	3·0	3·7	—1·2	—2·4	1·0	1·6	2·1	1·3	3·3	3·0	—0·7	—0·1	0·0	0·5		
26	1·6	1·4	3·2	4·0	—1·3	—2·4	1·3	1·6	2·0	1·3	3·3	3·3	—0·8	—0·1	—0·1	0·5		
27	1·6	1·4	6·3	4·1	—1·3	—2 3	1·4	1 6	2·0	1·3	3 2	3·4	—0·8	—0·1	—0·1	1 0		
28	1·6	1·3	6·8	4·1	—1 4	—2·3	1·4	1·8	2·0	1·3	3 2	3·3	—0·8	—0·1	—0·1	1·5		
29	1·6	..	..	..	—1·4	..	..	..	2·0	..	..	..	—0·8	..	..	..		
Averages ..	2·3	2.2	1. 4	1·6	—1.0	—2·1	0. 8	2·6	2 6	1·3	1·4	2·6	—0·7	0·2	0·4	0·8		

Date.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	7·1	0·7	2·1	3·9	0·5	1·7	2·5	0·2	1·2	2·1
2	6·7	0·7	2·1	3·8	0·7	1·7	2·4	0·2	1·2	2·0
3	5·1	0·6	2·1	3·8	0·7	1·7	2·3	0·2	1·2	2·0
4	4·9	0·6	1·9	3·7	0·9	1·7	2·2	0·2	1·2	2·0
5	4·0	0·7	1·9	3·8	2·7	1·7	2·2	0·2	1·2	1·9
6	3·6	0·7	1·8	4·0	2·5	1·7	2·2	0·1	1·2	2·0
7	3·3	0·7	1·9	4·0	4·2	1·8	2·2	0·0	1·2	2·0
8	3·2	0·8	1·8	3·9	4·4	1·8	2·1	0·0	1·2	2·0
9	3·1	0·9	1·8	4·0	5·0	1·7	2·2	0·0	1·2	2·0
10	3·0	1·0	1·9	4·0	4·5	1·7	2·3	0·0	1·3	1·9
11	2·9	1·1	1·9	4·2	4·2	1·7	2·8	0·1	1·4	2·0
12	2·9	1·1	1·8	4·2	3·7	1·7	3·7	0·2	1·5	2·1
13	2·8	1·2	1·8	4·2	3·3	1·7	4·5	0·2	1·6	2·1
14	2·8	1·2	1·8	4·2	3·0	1·7	4·3	0·9	1·6	2·1
15	2·9	1·3	1·8	4·2	3·0	1·7	4·0	2·5	1·7	2·0
16	2·8	1·3	1·7	4·3	2·6	1·7	4·0	2·2	1·7	2·0
17	2·8	1·3	1·7	4·2	2·3	1·7	3·8	1·8	1·7	2·0
18	2·7	1·3	1·6	4·3	2·2	1·7	3·8	1·7	1·7	2·0
19	2·7	1·3	1·6	4·4	2·4	1·7	3·7	1·8	1·7	2·0
20	2·7	1·3	1·6	5·8	2·5	1·7	3·7	1·9	1·7	1·9
21	2·6	1·3	1·6	6·3	3·2	1·8	3·8	1·7	1·7	1·8
22	3·6	1·6	1·9	6·2	3·8	1·9	4·2	1·7	1·8	1·8
23	4·3	2·2	1·9	5·6	4·0	1·9	4·4	1·7	2·0	1·9
24	4·3	2·6	2·1	5·2	4·0	2·3	4·3	1·6	2·1	1·9
25	3·9	2·7	2·1	4·9	3·9	2·4	4·2	1·7	2·1	2·0
26	3·5	2·6	2·2	5·1	4·2	2·5	4·2	1·7	2·2	2·0
27	3·2	2·5	2·2	5·8	4·4	2·4	4·1	1·8	2·2	2·0
28	3·1	2·4	2·2	6·2	5·7	2·3	4·1	1·8	2·2	2·0
29	3·0	2·4	2·2	6·1	5·7	2·2	4·2	1·7	2·5	2·1
30	3·0	2·3	2·2	5·9	5·7	2·2	4·3	1·7	2·4	2·1
31	3·0	2·4	2·3	5·6	6·2	2·2	4·4	1·7	2·4	2·2
Averages ..	3·5	1·4	1·9	4·7	3·4	1·9	3·4	1·1	1·7	2·0

Date.	1858.	1859.	1860.	1861.	1862.	1863.	1864.	1865.	1866.	1867.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	2·9	2·5	0·4	—1·1	—0·4	0·0	—0·6	2·2	2·9	0·2
2	3·0	2·5	0·4	—1·0	—0·4	—0·1	—0·7	2·2	2·9	0·1
3	2·9	2·9	0·5	—1·2	—0·4	—0·1	—0·7	3·2	2·9	0·1
4	2·8	3·7	1·0	—1·1	—0·5	—0·2	—0·7	3·5	2·9	0·0
5	2·7	5·2	3·0	—1·2	—0·5	—0·2	—0·7	3·6	2·8	0·0
6	2·7	6·2	3·4	—1·3	—0·6	—0·3	—0·7	3·8	2·7	0·0
7	2·6	5·8	3·2	—1·3	—0·6	—0·3	—0·7	5·7	2·7	0·0
8	2·6	5·2	2·8	—1·2	—0·5	—0·4	—0·7	6·7	2·7	0·0
9	2·6	4·5	2·7	—1·3	—0·5	—0·4	—0·7	7·2	2·7	0·0
10	2·7	4·2	2·4	—1·2	—0·5	—0·4	—0·9	7·7	2·7	0·0
11	3·0	4·0	2·3	—1·3	—0·4	—0·4	—0·9	7·3	2·8	—0·1
12	3·2	3·9	2·2	—1·4	—0·4	—0·5	—1·0	6·5	3·4	—0·2
13	3·2	3·8	2·2	—1·3	—0·4	—0·5	—1·1	5·5	4·4	—0·2
14	3·2	3·7	2·0	—1·3	—0·5	—0·4	—1·2	5·1	4·9	—0·2
15	3·2	3·7	2·0	—1·2	—0·5	—0·3	—1·2	4·7	5·0	—0·2
16	3·2	3·7	2·0	—1·1	—0·5	—0·3	—1·3	5·8	5·1	—0·1
17	3·3	3·9	2·0	—1·1	—0·5	—0·2	—1·3	7·7	5·3	—0·1
18	3·2	3·8	1·9	—1·1	—0·5	—0·2	—1·4	7·2	5·3	—0·1
19	3·3	4·2	1·9	—1·1	—0·5	0·0	—1·4	5·7	5·2	0·0
20	3·2	4·3	1·8	—1·1	—0·5	0·3	—1·4	5·5	5·2	0·0
21	3·2	4·1	1·7	—1·2	—0·6	0·0	—1·5	5·1	5·0	0·0
22	3·3	3·9	1·6	—1·2	—0·3	1·2	—1·4	4·8	4·8	0·0
23	3·3	3·8	1·5	—1·2	—0·2	1·5	—1·2	4·7	4·8	0·0
24	3·3	3·7	1·5	—1·2	0·0	1·5	—1·1	4·7	5·2	0·0
25	3·4	3·7	1·6	—1·3	0·0	1·3	—1·0	4·4	5·5	0·0
26	3·5	3·6	3·2	—1·3	0·0	1·2	—0·8	4·3	5·5	—0·1
27	3·7	3·4	3·7	—1·3	0·2	1·2	—0·7	4·2	8·7	0·0
28	4·0	3·3	3·9	—1·3	0·6	1·1	—0·3	4·0	8·1	0·1
29	4·2	3·3	3·8	—1·2	1·1	1·1	—0·1	4·0	7·3	0·2
30	4·2	3·3	3·7	—1·2	1·2	1·0	0·2	4·1	6·6	0·3
31	4·0	3·3	3·4	—1·0	1·2	0·9	0·1	3·9	6·3	0·4
Averages ..	3·2	3·9	2·2	—1·2	—0·2	0·2	—0·9	5·0	4·6	0·0

Date.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	0·6	0·1	0·3	0·8	0·3	—0·9	1·2	1·7	2·7	5·5
2	1·0	0·2	0·2	2·2	0·3	—0·9	1·2	1·7	2·6	5·5
3	2·5	0·2	0·2	2·7	0·3	—0·9	1·2	1·6	2·4	4·9
4	2·5	0·2	0·2	2·9	0·3	—0·9	1·1	1·6	2·4	4·3
5	2·4	0·3	0·2	2·7	0·3	—0·9	1·1	1·8	2·3	4·0
6	2·2	0·5	0·2	2·4	0·2	—0·8	1·1	2·2	2·3	3·8
7	1·8	0·7	0·2	1·9	0·3	—0·8	1·0	2·3	2·3	3·8
8	1·7	0·8	0·2	1·7	0·5	—0·7	1·1	2·3	2·2	3·8
9	1·5	0·8	0·2	1·5	1·2	—0·5	1·1	2·2	2·2	3·8
10	1·3	0·7	0·1	1·4	1·8	—0·5	1·1	2·0	2·2	3·8
11	1·4	0·6	0·1	1·2	1·9	—0·4	1·0	1·9	2·3	3·7
12	1·6	3·3	0·1	1·1	1·9	—0·3	1·0	1·7	2·4	3·7
13	1·6	4·5	0·1	0·9	1·7	—0·3	1·0	1·6	2·5	3·7
14	1·7	4·1	0·2	0·9	1·7	—0·4	1·0	1·6	2·7	3·7
15	1·7	3·2	0·2	0·8	1·7	—0·5	1·7	1·5	2·8	3·7
16	1·7	3·2	0·2	0·7	1·7	—0·5	3·2	1·7	3·1	3·7
17	1·7	3·2	0·2	0·6	1·6	—0·5	3·6	2·3	3·2	3·8
18	1·7	3·2	0·2	0·5	1·6	—0·6	3·3	2·8	3·6	3·9
19	1·8	3·1	0·2	0·4	1·5	—0·6	3·1	3·0	4·8	4·3
20	2·0	3·0	0·2	0·4	1·4	—0·7	2·9	3·0	4·9	4·7
21	2·1	6·1	0·2	0·3	1·3	—0·7	2·7	2·9	4·7	5·1
22	2·2	7·6	0·2	0·3	1·3	—0·7	2·7	2·7	4·4	5·0
23	2·2	7·2	0·3	0·2	2·2	—0·6	2·5	2·7	4·3	5·0
24	2·2	6·2	0·4	0·2	3·3	—0·7	2·3	2·7	4·0	5·2
25	2·0	5·2	0·3	0·0	3·6	—0·4	2·2	3·7	4·0	5·3
26	1·9	4·9	0·3	0·0	3·4	—0·2	2·2	2·7	3·8	5·2
27	1·9	4·9	0·2	0·3	3·8	0·2	2·1	2·8	3·7	5·2
28	1·9	6·9	0·2	0·6	3·1	0·2	2·2	2·7	3·7	6·6
29	1·8	9·2	0·2	0·7	3·1	0·2	2·2	2·7	3·7	7·2
30	2·2	9·5	0·4	0·6	3·0	0·2	2·1	2·7	3·7	6·8
31	3·4	9·4	0·4	0·5	3·0	0·7	2·0	2·6	3·8	6·4
Averages ..	1·9	3·6	0·2	1·0	1·7	—0·5	1·9	2·3	3·2	4·7

Date.	1878.	1879.	1880.	1881.	1882.	1883.	1884.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	5·7	1·7	0·9	1·2	2·3	2·0	2·2
2	5·8	1·6	0·7	1·2	2·3	2·1	2·2
3	8·2	1·6	0·7	1·2	2·3	2·4	2·2
4	10·2	1·6	0·6	1·1	2·2	2·7	2·2
5	9·7	1·6	0·6	0·9	2·2	2·7	2·2
6	8·4	1·6	0·5	0·1	2·0	2·7	2·2
7	7·7	1·5	0·4	0·3	1·9	2·7	2·2
8	7·4	1·5	0·4	0·4	1·7	2·6	2·2
9	7·2	1·5	0·4	0·5	1·7	2·5	2·2
10	6·8	1·4	0·5	0·6	1·7	2·5	2·2
11	6·5	1·5	0·6	0·7	1·6	2·5	2·2
12	6·3	1·6	0·6	0·8	1·5	2·4	2·5
13	6·3	1·7	0·6	1·6	1·4	2·4	2·7
14	6·2	2·0	0·6	2·0	1·4	2·4	2·8
15	6·2	2·1	0·6	2·1	1·5	2·4	2·8
16	6·1	2·1	0·5	2·2	1·7	2·4	2·8
17	6·1	2·1	0·5	1·8	1·7	2·4	3·0
18	6·2	2·0	0·6	1·7	1·8	2·5	3·2
19	6·4	1·9	0·6	1·6	1·8	2·7	3·2
20	6·5	1·9	0·6	1·5	1·9	2·7	3·2
21	6·6	1·8	0·7	1·4	1·9	2·8	3·2
22	7·0	1·8	0·7	1·3	1·9	2·8	3·2
23	7·5	2·0	0·9	1·3	1·9	2·7	4·0
24	7·7	2·2	1·0	1·3	1·8	2·7	4·8
25	7·7	2·7	1·2	1·4	1·8	2·7	5·1
26	7·7	3·0	1·5	1·4	1·8	2·7	5·0
27	7·6	3·1	1·6	1·4	1·8	2·7	4·8
28	7·4	3·0	1·7	1·8	1·8	2·6	4·6
29	7·4	2·7	1·8	1·2	2·3	2·6	4·5
30	7·5	2·7	1·9	1·2	2·3	2·8	4·4
31	8·2	2·5	2·1	1·2	3·8	2·9	4·2
Averages ..	7·2	2·0	0·9	1·2	2·0	2·6	3·1

Date.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	1·4	1·6	2·2	1·2	5·9	0·2	4·6	0·3	3·7	4·3
2	1·3	1·7	2·2	1·2	9·0	0·2	4·7	0·3	5·2	4·1
3	1·3	1·6	2·2	1·1	8·7	0·2	4·7	0·2	5·3	3·9
4	1·2	1·4	2·3	1·1	7·9	0·2	4·7	0·2	5·2	3·8
5	1·2	1·3	2·4	1·1	7·2	0·2	4·7	0·2	4·8	3·7
6	1·2	1·3	2·4	1·2	6·3	0·2	4·7	0·2	4·7	3·6
7	1·2	1·4	2·5	1·2	5·7	0·2	4·7	0·2	4·7	3·4
8	1·2	1·4	2·6	1·2	5·6	0·2	5·8	0·2	4·7	3·2
9	1·2	1·5	2·7	1·2	5·2	0·2	6·0	0·2	4·6	5·3
10	1·1	1·6	2·7	1·2	4·7	0·2	5·7	0·2	4·3	6·9
11	1·1	1·8	2·9	1·2	4·6	0·2	5·7	0·1	4·1	6·7
12	1·1	2·2	3·8	1·5	4·4	0·2	5·6	0·1	3·8	7·0
13	1·1	2·2	3·0	1·5	4·2	0·1	5·4	0·1	3·7	6·8
14	1·1	2·2	3·8	1·6	4·2	0·1	5·3	0·1	3·7	6·0
15	1·2	2·2	3·7	1·6	4·2	0·1	5·2	0·1	3·7	5·2
16	1·2	2·1	3·7	1·6	4·3	0·1	5·1	0·3	3·8	4·7
17	1·3	2·0	3·6	1·6	4·2	0·1	5·0	0·5	4·2	4·5
18	1·3	2·0	3·4	1·4	4·2	0·1	4·8	0·6	4·4	4·3
19	1·4	2·1	3·4	1·5	4·2	0·0	4·7	0·7	4·2	4·2
20	1·5	2·3	3·5	1·5	4·3	0·1	4·7	0·7	3·0	4·2
21	1·5	2·3	3·5	1·5	4·3	0·1	4·7	0·6	3·8	4·2
22	1·6	2·7	3·5	1·5	4·3	0·2	4·7	0·6	3·8	4·1
23	1·7	7·0	3·4	1·7	4·3	0·2	4·7	0·6	3·7	3·8
24	1·7	8·6	3·6	1·7	4·5	0·1	5·1	0·6	3·7	3·7
25	1·7	8·1	3·6	1·7	4·6	0·1	5·8	0·7	3·8	3·7
26	1·9	6·6	3·7	1·8	4·9	0·0	6·2	0·7	4·1	4·0
27	2·0	5·8	3·7	1·8	5·7	0·0	6·2	0·7	4·7	4·2
28	2·1	5·5	3·6	1·8	5·7	0·0	6·0	0·7	5·6	4·2
29	2·2	5·4	3·5	1·8	5·6	0·0	5·8	0·7	5·7	4·2
30	2·2	5·4	3·4	1·8	5·5	0·0	5·7	0·8	5·7	4·1
31	2·3	5·2	3·3	1·7	5·6	0·0	5·7	0·9	5·5	4·0
Averages ..	1·5	3·0	3·2	1·5	5·4	0·1	5·3	0·4	4·4	4·5

Date.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	1·4	0·0	0·2	2·1	—0·3	—0·5	2·7	—0·1	1·2	1·5
2	1·6	0·0	0·2	1·7	—0·3	—0·5	2·6	—0·1	1·2	1·5
3	1·6	0·0	0·2	1·5	—0·3	—0·5	2·5	—0·1	1·2	1·8
4	1·5	—0·1	0·2	1·5	—0·4	—0·6	2·4	—0·1	1·1	1·8
5	1·4	—0·2	0·2	1·3	—0·5	—0·6	2·4	—0·2	1·1	1·7
6	1·4	—0·2	0·1	1·2	—0·6	—0·6	2·4	—0·2	1·0	1·6
7	1·4	—0·2	0·0	1·0	—0·7	—0·6	2·5	—0·2	1·0	1·7
8	1·4	0·0	0·0	0·8	—0·8	—0·7	2·4	—0·2	1·0	1·7
9	1·5	0·2	0·3	0·7	—0·9	—0·7	2·3	—0·3	1·0	1·8
10	1·5	0·4	0·5	0·6	—0·9	—0·7	2·2	—0·3	1·0	2·9
11	1·6	0·6	0·6	0·5	—1·0	—0·7	2·1	—0·3	1·1	3·4
12	1·7	0·6	0·7	0·4	—1·0	—0·6	2·1	—0·3	1·1	5·9
13	1·7	0·5	0·7	0·3	—1·0	—0·5	2·3	—0·4	1·0	7·2
14	1·7	0·4	0·8	0·3	—1·1	—0·5	2·2	—0·4	1·1	6·4
15	1·7	0·4	0·8	0·3	—1·1	—0·5	2·2	—0·4	1·1	5·5
16	1·8	0·4	0·8	0·3	—1·1	—0·5	2·4	—0·4	1·3	4·6
17	1·9	0·5	0·8	0·3	—1·2	—0·5	2·7	—0·5	1·4	4·5
18	2·0	0·4	0·8	0·2	—1·2	—0·5	3·1	—0·5	1·6	4·7
19	2·2	0·5	0·8	0·2	—1·2	—0·6	3·2	—0·5	1·7	4·9
20	2·6	0·6	0·8	0·0	—1·2	—0·5	3·3	—0·6	1·8	4·9
21	3·7	0·7	1·1	0·0	—1·1	—0·5	3·3	—0·6	1·7	4·8
22	4·2	0·8	1·4	0·0	—1·1	—0·6	3·4	—0·6	1·8	4·9
23	4·4	1·0	1·7	0·1	—1·1	—0·7	3·7	—0·6	2·0	4·9
24	4·2	1·2	1·7	0·1	—0·9	—0·7	3·8	—0·6	2·4	5·0
25	4·2	1·3	1·7	2·3	—0·1	—0·7	3·8	—0·6	2·9	5·1
26	4·2	1·3	1·8	2·3	0·6	—0·7	3·6	—0·6	3·2	5·1
27	3·9	1·3	1·9	2·9	0·8	—0·7	3·5	—0·6	3·3	5·0
28	3·7	1·3	2·0	2·6	0·9	—0·4	3·4	—0·6	3·3	4·9
29	3·6	1·2	2·1	2·2	0·9	0·2	3·3	—0·6	3·2	4·9
30	6·1	1·2	2·1	1·9	1·0	1·3	3·3	—0·4	3·2	4·8
31	8·2	1·2	2·2	1·7	0·9	2·0	3·3	0·0	3·2	4·6
Averages ..	2·7	0·6	1·0	1·0	—0·5	—0·6	2·9	—0·4	1·8	4·0

Date.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	1·3	6·0	3·7	—1·5	—2·3	1·3	1·9	2·0	1·8	2·9
2	1·2	5·2	3·2	—1·5	—2·2	1·1	1·9	2·0	1·3	2·8
3	1·2	4·8	2·8	—1·6	—0·4	1·0	1·9	1·9	1·4	2·7
4	1·3	4·7	2·3	—1·6	0·0	0·9	1·9	1·9	1·4	2·6
5	1·3	4·5	2·2	—1·5	0·3	0·8	1·9	1·9	1·6	2·6
6	1·4	4·3	2·0	—1·5	0·5	0·8	1·9	2·0	2·2	2·6
7	1·3	4·0	1·8	—1·6	0·5	0·8	2·0	2·2	2·5	2·7
8	1·4	3·8	1·9	—1·6	0·5	0·9	2·0	2·3	2·7	2·7
9	1·3	3·6	1·8	—1·6	0·5	1·0	2·1	2·3	2·7	2·6
10	1·3	3·5	1·8	—1·6	0·4	1·1	2·2	2·3	2·7	2·5
11	1·4	3·5	1·9	—1·6	0·3	1·2	2·4	2·3	2·6	2·3
12	1·5	3·5	1·9	—1·6	0·3	1·2	2·5	2·3	2·4	2·3
13	1·7	3·5	2·0	—1·6	0·2	1·2	2·5	2·2	2·4	2·2
14	1·9	3·4	2·2	—1·6	0·1	1·2	2·7	2·1	2·5	2·1
15	1·9	3·4	2·1	—1·5	0·0	1·2	2·9	2·1	2·7	2·1
16	1·8	3·4	2·1	—1·5	0·0	1·0	3·3	2·1	2·8	2·2
17	1·8	3·4	2·6	—1·6	0·1	1·0	7·5	2·0	2·8	2·2
18	1·8	3·4	4·0	—1·6	0·2	0·9	8·0	1·9	2·8	2·2
19	1·8	3·3	4·9	—1·6	0·4	0·9	8·0	1·9	2·8	2·3
20	1·9	3·3	4·6	—1·6	0·4	0·9	8·6	1·8	2·7	2·4
21	2·1	3·2	4·1	—1·7	0·4	0·8	8·2	1·8	2·8	2·6
22	2·4	3·1	3·6	—1·7	0·3	0·8	10·5	1·7	3·0	2·6
23	2·5	3·2	3·2	—1·7	0·3	0·7	11·6	1·7	3·1	3·2
24	2·6	3·4	3·0	—1·7	0·3	0·7	9·9	1·7	3·1	3·3
25	2·6	3·5	2·9	—1·8	0·3	0·7	8·6	1·6	3·1	3·2
26	2·5	3·5	2·6	—1·8	0·2	0·6	7·5	1·6	3·1	3·2
27	2·5	3·5	2·5	—1·9	0·0	0·6	6·7	1·7	3·1	3·1
28	2·5	3·5	2·3	—1·9	0·0	0·7	6·0	1·7	3·1	3·0
29	2·9	6·1	2·2	—1·9	—0·1	1·2	5·5	1·7	2·9	3·0
30	3·1	6·8	2·1	—2·0	—0·2	2·0	5·2	1·6	2·9	3·2
31	3·2	7·1	2·4	—2·0	—0·1	2·2	5·0	1·6	2·9	3·4
Averages ..	1·9	4·1	2·8	—1·7	0·1	1·1	4·9	1·9	2·6	2·7

Date.	1915.	1916.	1917.	1918.	1919.	1920.	1921.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	3·1	—0·8	—0·2	—0·1	1·9		
2	2·9	—0·7	—0·2	—0·1	1·9		
3	2·8	—0·7	—0·2	—0·2	1·8		
4	2·7	—0·7	—0·3	—0·2	1·7		
5	2·6	—0·7	—0·3	—0·3	1·6		
6	2·6	—0·7	—0·3	—0·3	1·5		
7	2·5	—0·6	—0·3	—0·3	1·4		
8	2·5	—0·7	—0·3	—0·3	1·3		
9	2·5	—0·8	—0·4	—0·3	1·2		
10	2·6	—0·8	—0·3	—0·3	1·1		
11	2·6	—0·8	—0·4	—0·3	1·0		
12	2·5	—0·8	—0·5	—0·3	0·9		
13	2·5	—0·8	—0·5	—0·2	0·8		
14	2·5	—0·8	—0·5	0·1	0·8		
15	2·4	—0·9	—0·5	0·1	0·9		
16	2·4	—0·9	—0·6	0·1	1·1		
17	2·4	—1·0	—0·6	0·1	1·1		
18	2·8	—1·0	—0·6	0·1	1·2		
19	4·6	—1·0	—0·6	0·1	1·2		
20	5·0	—1·0	—0·6	0·0	2·0		
21	5·2	—0·9	—0·7	0·0	2·3		
22	5·2	—0·9	—0·7	0·1	2·5		
23	5·0	—0·9	—0·7	3·0	2·6		
24	4·7	—0·9	—0·7	3·6	2·6		
25	4·5	—0·9	—0·7	3·4	2·7		
26	4·4	—0·8	—0·6	3·1	2·8		
27	4·3	—0·8	—0·7	5·2	2·8		
28	4·3	—0·8	—0·7	8·2	2·7		
29	4·2	—0·8	—0·7	7·5	4·7		
30	4·0	—0·5	—0·7	5·6	5·4		
31	4·0	0·1	—0·7	4·6	5·1		
Averages ..	3·4	—0·8	—0·5	1·3	2·0		

Readings of Bukkur Gauge for April.

Date.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863	1864.	1865.	1866.	1867.	1868	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	3·1	2·4	2·4	5·2	6·2	2·2	4·3	1·7	2·4	2·2	3·8	3·3	3·3	—0·8	1·3	0·8	0·0	4·2	6·2	0·6	4·1	8·3	0·6	0·4	3·1	1·5	2·0	2·6	4·0	6·1	9·9	2·4	2·2	1·1	4·0	3·0	
2	3·2	2·5	2·5	5·1	5·7	2·2	4·3	1·7	2·3	2·3	3·7	3·2	3·1	—0·7	1·3	0·7	—0·1	4·2	5·9	0·7	4·4	7·1	0·9	0·4	3·1	1·7	2·1	2·5	4·4	5·8	10·2	2·4	2·4	0·9	4·1	3·2	4·2
3	3·2	2·5	2·5	5·1	5·5	2·3	4·5	1·8	2·4	2·5	3·7	3·3	3·1	—0·7	1·4	0·7	—0·1	4·3	5·7	1·2	4·7	6·2	1·1	0·3	3·2	1·7	2·2	2·5	4·7	5·7	10·1	2·3	2·5	0·8	4·1	3·3	4·5
4	3·3	2·6	2·6	5·1	5·1	2·4	4·6	1·9	2·3	2·7	3·7	3·2	3·2	—0·7	1·6	0·7	—0·1	4·7	6·5	1·7	4·9	5·7	1·1	0·3	3·2	1·6	2·6	2·6	4·7	5·7	10·0	2·2	2·5	0·7	4·1	3·4	4·8
5	3·3	2·7	2·5	5·1	4·8	2·7	4·5	1·7	2·5	2·7	4·3	3·3	3·2	—0·7	1·7	0·6	—0·1	4·8	5·4	2·1	4·7	5·3	1·2	0·2	3·4	1·6	2·8	2·7	4·4	5·6	9·7	2·2	2·6	0·7	4·1	3·5	5·1
6	3·4	2·7	2·6	5·0	4·5	2·8	4·6	1·7	2·5	2·9	4·9	3·4	3·2	—0·7	2·1	0·6	—0·2	5·0	5·2	2·2	5·7	5·2	2·4	0·3	3·7	1·6	2·9	2·7	4·3	5·5	9·8	2·2	2·6	0·7	4·4	3·6	5·1
7	3·7	2·8	2·7	5·0	5·6	2·9	4·4	1·6	2·6	2·9	5·1	3·6	3·5	—0·7	2·4	0·5	—0·2	5·1	5·2	2·0	7·6	5·0	4·2	0·3	4·6	1·7	2·7	2·8	4·2	5·5	11·6	2·8	2·5	0·7	4·7	3·6	5·0
8	3·9	2·9	2·9	5·1	6·4	3·0	4·6	1·5	2·7	3·0	5·2	3·8	4·0	—0·7	2·5	0·4	—0·1	6·3	5·2	2·1	7·5	5·0	4·7	0·3	4·6	1·7	2·7	3·0	4·2	5·2	13·2	2·4	2·5	0·8	4·9	3·6	4·8
9	4·3	3·2	3·0	5·1	6·2	3·0	5·8	1·5	2·7	3·0	5·4	4·0	4·3	—0·7	2·3	0·4	0·2	6·7	5·0	2·0	5·4	5·0	4·5	0·4	4·5	1·8	2·7	3·0	4·2	5·1	13·2	2·5	2·5	0·8	5·4	3·6	4·6
10	5·1	3·5	3·2	5·2	5·9	3·0	6·5	1·5	2·5	3·1	5·7	4·2	4·4	—0·7	2·2	0·4	0·2	7·5	5·0	2·0	5·5	4·9	4·2	0·4	4·5	2·0	2·9	3·0	4·4	5·0	12·5	2·6	2·6	1·0	6·8	3·6	4·6
11	5·6	3·9	3·3	5·4	6·4	3·0	8·7	1·4	2·5	3·0	5·6	4·6	3·9	—0·8	2·2	0·5	0·5	7·7	5·0	2·1	5·1	4·9	3·8	0·6	4·5	2·0	3·6	3·1	4·7	5·0	11·6	2·7	2·7	1·2	7·0	3·7	4·7
12	6·2	4·0	3·2	5·7	5·0	3·2	9·2	1·4	2·7	3·2	5·3	4·8	3·9	—0·7	2·7	0·7	1·3	7·9	5·1	2·2	5·0	4·8	3·6	0·8	4·3	2·0	4·0	3·3	4·8	4·8	10·9	2·8	3·2	1·5	6·7	3·7	5·0
13	6·4	3·7	3·3	5·7	4·7	3·3	9·0	1·5	2·8	3·3	5·1	5·2	3·9	—0·7	3·8	1·1	2·2	8·2	5·0	2·3	4·8	4·9	3·4	1·2	4·7	2·2	4·0	3·6	4·7	4·8	10·7	3·0	3·3	2·0	6·5	3·7	5·2
14	6·6	3·7	3·3	6·2	4·2	3·5	8·0	1·4	3·0	3·3	5·0	5·3	3·9	—0·6	4·4	1·2	2·2	7·5	5·1	2·6	4·8	5·1	3·4	1·7	5·4	2·4	3·8	3·7	4·7	4·7	10·5	3·1	3·4	2·6	7·8	3·8	5·1
15	6·8	3·9	3·3	6·8	3·7	3·4	5·8	1·3	3·0	3·4	4·7	5·2	3·9	—0·3	4·8	1·5	2·2	6·8	4·9	2·8	4·7	5·2	3·4	2·0	5·5	2·7	3·8	3·9	4·6	4·5	10·3	3·2	3·4	2·9	9·2	3·9	5·2
16	6·9	4·5	3·5	6·2	3·5	3·2	5·7	1·3	3·0	3·6	4·7	5·1	4·0	0·0	4·8	1·0	2·4	6·2	4·8	2·7	4·8	5·3	3·4	2·1	5·5	2·7	4·0	4·0	4·4	4·7	10·7	3·2	3·2	3·0	8·7	4·1	5·2
17	6·7	4·7	3·6	5·8	3·7	5·0	5·3	1·2	2·9	3·6	4·6	5·2	3·9	0·1	4·7	2·2	5·5	5·8	4·8	2·8	5·4	5·3	3·4	2·0	5·1	2·5	5·5	4·0	4·2	4·7	11·8	3·6	3·2	3·1	7·9	4·2	5·5
18	6·7	4·7	3·7	5·7	3·4	5·6	5·2	1·2	2·9	3·7	4·6	5·5	3·9	0·2	4·6	2·1	6·8	5·8	4·8	2·9	5·7	5·3	3·5	1·9	4·9	2·3	6·2	3·8	4·2	4·8	12·7	3·8	3·2	3·2	7·3	4·2	5·6
19	6·6	4·6	3·9	5·7	3·7	4·2	5·0	1·3	3·0	4·1	4·7	5·9	3·9	0·4	4·3	2·0	6·9	6·0	4·8	3·2	5·9	5·2	3·6	1·9	4·9	2·2	6·4	3·8	5·2	5·4	13·1	3·8	3·2	5·2	6·6	4·2	5·4
20	6·7	4·4	4·3	5·8	3·9	4·7	4·7	1·2	3·2	5·2	5·1	7·5	4·1	0·4	4·2	2·0	5·8	6·1	4·9	3·3	5·4	5·0	3·6	1·8	4·7	2·2	6·2	4·1	6·8	9·1	13·0	3·7	3·1	6·6	6·2	4·2	5·3
21	6·8	4·3	5·5	5·8	3·8	4·4	4·6	1·4	3·4	4·9	5·4	7·6	4·3	0·3	4·1	2·1	4·9	6·4	4·9	3·8	5·2	4·8	3·6	1·7	4·5	2·7	6·0	4·4	7·0	9·6	12·5	3·7	3·0	6·2	5·0	4·2	5·3
22	6·8	4·2	5·0	5·8	3·8	3·8	4·5	1·4	3·4	4·5	5·5	6·7	4·7	0·3	4·2	2·2	5·1	6·9	5·0	4·0	5·2	4·7	3·3	1·7	4·4	3·0	5·8	4·5	6·7	8·9	11·8	3·5	2·8	5·4	5·8	4·5	5·4
23	6·5	4·2	4·8	6·3	4·0	3·2	4·3	1·5	3·2	4·3	5·4	6·3	5·3	0·4	4·2	2·2	5·3	8·7	5·0	4·2	7·2	5·0	3·5	1·7	4·4	2·9	5·7	4·5	6·3	9·5	11·0	3·5	2·7	5·1	5·7	5·2	5·7
24	6·2	4·4	4·8	7·2	4·2	3·2	4·2	2·2	3·2	4·4	5·3	6·1	5·2	0·6	4·5	2·4	5·0	8·5	5·0	4·2	7·7	5·5	3·9	1·7	4·6	2·8	5·6	4·6	6·2	10·2	10·7	3·4	2·7	4·9	5·6	5·5	6·2
25	6·1	4·8	4·9	7·1	4·2	3·2	4·2	2·9	3·1	4·4	5·4	5·8	5·3	0·9	4·7	2·4	4·8	8·7	5·1	4·1	7·8	5·7	4·4	1·7	4·8	2·7	5·4	4·8	5·8	10·0	10·6	3·5	2·7	4·7	5·6	5·5	6·1
26	5·9	5·0	4·4	6·7	4·3	3·2	4·2	3·2	3·0	4·5	5·4	5·7	5·4	1·3	4·8	2·5	4·9	8·7	5·2	4·0	7·9	5·6	4·5	1·8	4·7	2·7	5·5	4·9	5·7	0·2	11·0	3·4	2·7	4·6	5·7	5·5	5·9
27	5·6	4·9	4·3	6·7	4·5	3·2	4·2	3·4	2·8	4·4	5·7	5·6	5·4	1·6	4·7	2·6	4·9	9·1	5·4	4·0	8·1	5·8	4·3	2·3	4·7	2·7	5·5	4·8	5·8	8·7	11·2	3·4	2·7	4·4	6·0	5·3	5·6
28	5·3	4·8	4·1	6·7	4·7	2·8	4·2	3·2	2·7	4·2	5·8	5·4	5·4	1·7	4·5	2·6	4·6	9·5	5·5	4·0	8·2	5·8	4·2	3·5	4·6	2·5	5·5	4·7	7·2	8·3	11·3	3·4	2·7	4·3	6·3	5·3	5·5
29	5·1	4·7	4·6	7·0	5·2	2·7	4·4	3·2	2·8	4·2	6·0	5·4	5·5	1·8	4·5	2·7	4·1	9·9	5·6	4·1	7·7	6·8	4·3	4·0	4·5	2·6	5·5	4·5	8·2	8·0	11·2	3·4	2·8	4·4	6·6	5·3	5·8
30	4·9	4·7	5·3	7·2	5·7	2·7	4·7	3·3	2·8	4·0	6·0	5·4	5·8	1·9	4·5	2·6	3·9	10·2	5·7	4·1	7·2	7·1	4·7	4·2	4·5	2·7	5·5	4·5	8·2	7·7	11·0	3·4	3·8	4·6	6·7	5·4	5·2
Averages ..	5·3	3·9	3·7	5·9	4·7	3·3	5·2	1·8	2·8	3·6	5·0	5·0	4·2	0·1	3·5	1·5	3·8	6·9	5·2	2·8	5·9	5·5	3·3	1·4	4·4	2·2	4·8	3·7	5·3	6·6	11·3	3·1	2·9	3·0	6·1	4·2	5·3

Date.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	2·5	4·4	3·2	1·8	5·4	0·0	5·5	1·0	6·1	4·1	7·8	1·2	2·4	1·7	0·8	2·2	3·4	0·3	3·4	4·6	3·3	7·2	2·9	—2·0	0·0	2·3	5·0	1·6	2·9	3·7	4·0	0·5	—0·7	4·0	4·6		
2	2·7	4·4	3·2	1·7	5·6	0·0	5·4	1·1	5·0	4·1	6·4	1·3	2·8	1·7	0·8	2·2	3·4	0·8	3·7	4·9	3·3	7·0	3·3	—1·9	0·1	2·3	5·0	1·6	3·0	3·7	4·1	0·6	—0·7	3·8	4·3		
3	5·0	6·0	3·2	1·8	6·1	0·0	5·2	1·2	4·7	4·1	5·6	1·5	3·0	1·6	0·8	2·1	3·8	0·9	4·0	5·7	4·5	6·7	3·2	—1·9	0·1	2·2	5·0	1·7	3·0	3·6	4·2	0·6	—0·7	3·6	4·2		
4	5·2	8·9	3·4	1·8	6·6	0·0	5·1	1·2	4·5	4·1	5·0	1·7	3·0	1·6	0·8	2·1	4·5	0·9	4·2	5·8	4·6	6·6	2·9	—1·7	0·2	2·1	5·0	1·7	2·9	3·6	4·3	0·5	—0·7	3·5	4·1		
5	6·3	9·7	3·5	2·0	6·7	0·1	4·9	1·3	4·4	4·2	5·0	2·1	3·2	1·6	0·9	2·0	4·8	0·9	4·3	5·8	6·8	6·6	2·7	—1·5	0·3	2·1	5·2	1·7	2·8	3·5	4·3	0·4	—0·6	3·4	4·1		
6	10·7	9·5	3·7	2·2	6·4	0·1	4·9	1·5	4·4	4·2	4·9	2·3	3·8	1·8	1·0	1·9	4·8	0·8	4·3	5·7	7·2	6·5	2·6	—1·3	0·4	2·4	5·5	1·9	2·7	3·4	4·3	0·3	—0·6	3·4	3·9		
7	12·2	7·4	3·7	2·3	6·1	0·1	4·8	1·7	4·4	4·3	4·8	2·7	4·0	2·0	1·4	1·8	4·8	0·8	4·2	5·6	6·5	6·3	2·6	—1·1	0·7	3·2	6·5	2·1	2·7	3·5	4·6	0·3	—0·5	3·5	3·9		
8	11·3	6·7	3·7	2·4	5·9	0·2	4·8	2·0	4·7	4·6	4·7	3·5	4·2	2·0	1·7	1·7	4·8	0·7	4·1	5·7	6·0	6·2	2·5	—0·9	0·9	3·3	7·5	2·4	2·5	3·5	4·7	0·3	0·0	6·0	3·9		
9	9·9	6·0	3·7	2·7	5·6	0·3	4·9	2·2	4·7	4·8	4·7	3·7	4·2	2·2	2·1	1·8	5·0	0·7	4·0	5·8	5·8	6·0	2·4	—0·8	0·9	3·2	7·3	2·9	2·5	3·6	5·0	0·3	0·3	8·4	3·9		
10	9·7	5·7	3·7	2·8	5·5	0·4	5·0	2·2	6·4	4·9	4·8	3·7	3·9	2·3	2·0	1·8	5·2	0·7	4·2	5·9	5·6	6·0	2·2	—0·5	0·9	3·0	7·0	3·1	2·5	3·8	6·1	0·3	0·5	9·8	3·9		
11	9·9	5·3	3·7	2·9	5·8	0·5	5·3	2·2	7·2	5·1	5·1	3·6	3·9	2·7	1·8	2·1	5·8	0·7	4·9	6·0	5·5	6·2	2·0	0·9	0·9	2·9	6·8	3·1	2·5	4·9	6·5	0·3	0·5	10·7	4·0		
12	10·3	5·2	3·6	2·9	5·8	0·5	5·7	2·2	7·3	5·4	5·4	3·7	3·8	2·9	1·8	2·6	6·1	0·8	5·4	6·0	5·4	6·2	1·8	2·0	0·9	2·9	6·5	3·0	2·5	8·8	6·7	0·4	0·6	10·7	4·0		
13	10·6	5·0	3·5	2·9	6·0	0·5	6·2	2·2	7·2	5·7	5·7	4·2	3·7	3·1	1·8	3·5	6·0	0·7	5·5	6·0	5·3	6·4	1·7	6·0	1·0	2·9	6·0	3·1	2·5	9·5	6·5	0·5	0·5	9·2	4·1		
14	9·6	5·1	3·5	3·0	7·5	0·4	6·4	2·2	6·8	6·0	5·5	4·2	3·7	3·1	1·8	3·5	5·8	0·7	5·4	6·0	5·3	6·5	1·8	7·9	1·0	2·9	6·0	3·3	2·4	7·5	6·0	0·5	0·5	8·0	4·3		
15	9·6	5·0	3·6	3·1	7·3	0·3	6·3	2·2	6·5	6·4	5·4	3·9	3·7	3·0	1·8	3·5	5·6	0·6	5·2	5·9	5·5	6·7	3·3	8·5	1·0	2·9	6·0	3·6	2·5	6·4	5·7	0·4	0·5	7·0	4·6		
16	8·0	5·4	3·7	3·2	7·0	0·3	6·3	2·3	6·5	6·4	5·2	3·9	3·7	3·0	2·1	4·5	5·5	0·6	5·1	6·0	5·5	7·9	4·5	8·4	1·1	2·9	6·2	3·8	2·9	6·1	7·0	0·4	0·5	6·3	4·8		
17	7·7	6·0	3·9	3·2	8·4	0·2	6·5	2·3	6·4	6·3	5·0	3·9	3·7	3·2	2·4	4·9	5·5	0·6	5·0	6·0	5·6	8·1	5·5	7·3	1·3	2·8	6·3	3·8	3·3	5·9	8·7	0·5	0·5	5·7	5·1		
18	7·7	6·2	4·1	3·1	8·6	0·2	6·6	2·4	6·5	5·9	4·8	3·9	3·6	3·3	2·6	4·8	5·5	0·5	5·0	6·1	5·6	8·0	6·2	7·1	1·4	2·7	6·3	3·8	3·5	5·7	8·9	0·6	0·6	5·4	6·0		
19	7·7	6·1	4·2	3·0	7·9	0·2	6·8	2·5	6·5	5·7	4·7	6·0	3·6	3·4	2·6	4·7	5·5	0·6	5·0	6·2	5·7	7·6	7·8	7·2	1·8	2·6	6·3	3·8	3·7	5·5	8·1	0·8	0·6	5·1	5·8		
20	8·0	5·9	4·3	3·0	7·4	0·3	7·2	2·7	6·4	5·7	4·7	8·5	3·6	3·4	2·7	4·4	5·9	0·8	5·0	6·5	5·8	7·4	7·9	6·4	2·3	2·5	6·3	3·7	3·9	5·5	7·5	1·2	0·8	4·8	5·6		
21	8·0	5·6	4·7	2·9	6·9	0·5	7·5	2·8	6·6	7·2	4·8	8·2	3·6	3·3	2·7	4·1	7·6	1·2	5·1	6·8	5·9	7·2	7·3	6·0	2·4	2·4	6·3	3·7	4·5	5·6	7·4	1·5	1·0	4·6	5·5		
22	7·8	5·3	5·5	2·8	6·7	0·7	7·6	2·8	6·9	7·7	5·0	6·7	4·1	3·4	2·7	4·2	7·8	1·7	5·2	7·0	6·1	7·1	6·7	5·5	2·5	2·4	6·4	3·7	4·5	5·8	7·1	1·6	1·0	4·5	5·5		
23	7·4	5·2	5·7	2·8	6·5	1·1	7·6	2·8	7·6	7·2	5·2	6·2	4·7	4·8	2·7	4·1	7·4	1·8	5·2	7·0	6·4	7·2	6·7	5·3	3·1	2·5	6·4	3·9	4·5	6·1	6·9	1·8	1·1	4·4	5·2		
24	7·2	5·1	5·6	2·8	6·6	1·4	7·7	2·8	7·7	6·7	6·0	5·6	5·0	5·5	2·6	3·9	7·0	1·9	5·4	6·0	6·6	7·6	7·3	5·1	3·5	2·6	6·6	4·1	4·5	6·2	6·5	2·0	1·2	4·4	5·2		
25	7·0	5·1	5·7	3·0	6·5	1·7	7·7	2·9	7·6	6·5	7·0	5·1	7·7	5·4	2·5	4·0	6·8	1·9	5·7	6·5	6·6	8·1	7·0	5·1	3·4	2·7	7·0	4·5	4·5	5·9	6·2	2·6	1·2	4·3	5·3		
26	6·9	5·0	5·7	3·5	6·5	1·8	7·5	3·2	7·7	6·2	6·8	4·7	8·7	5·1	2·4	4·1	6·6	1·8	6·0	6·3	6·7	8·4	6·7	5·3	3·5	3·2	7·5	4·8	4·5	5·7	6·0	3·2	1·2	4·3	5·3		
27	6·9	5·0	5·5	3·8	6·4	1·9	7·7	3·3	7·5	6·2	6·6	4·6	8·7	5·0	2·2	4·1	6·3	1·8	6·2	6·2	8·5	8·3	6·3	5·5	3·6	3·9	8·1	4·9	4·6	5·5	6·0	3·3	1·2	4·4	5·8		
28	6·9	5·2	5·4	4·2	6·4	2·2	7·7	3·5	7·5	6·2	6·4	4·2	7·5	4·9	2·1	4·1	6·0	1·9	6·3	6·0	9·6	7·9	6·3	5·6	3·7	5·6	8·4	5·1	4·6	5·4	6·2	3·4	1·1	4·4	6·4		
29	6·9	5·7	5·4	5·0	7·4	3·0	7·9	3·7	7·7	6·4	6·3	4·2	7·3	5·3	2·2	4·0	5·8	1·8	6·3	5·9	9·6	7·7	6·6	6·0	3·5	6·0	8·8	5·3	4·6	5·3	6·3	3·4	1·1	4·6	6·5		
30	6·9	6·4	5·5	5·2	7·6	3·4	8·2	4·0	7·7	6·6	6·7	4·2	7·2	5·5	2·6	3·9	5·7	1·8	6·6	5·9	9·1	7·5	7·0	6·2	3·5	5·8	8·6	5·7	4·7	5·2	6·3	3·2	1·1	5·1	6·4		
Averages ..	7·9	5·9	4·3	2·9	6·6	0·7	6·4	2·4	6·4	5·7	5·6	4·1	4·6	3·3	2·0	3·3	5·6	1·1	5·0	6·1	6·2	7·1	4·5	3·5	1·6	3·1	6·5	3·4	3·4	5·3	6·1	1·2	0·4	5·6	4·9		

Readings of Bukkur Gauge for May.

Date.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.	1864.	1865.	1866.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	4·7	4·7	5·4	7·1	6·2	2·8	4·7	3·4	2·9	3·9	7·0	5·3	5·9	2·1	4·7	2·5	3·9	10·2	6·0
2	4·7	4·7	5·3	7·0	7·2	2·7	4·8	4·0	3·1	3·8	7·7	5·3	6·0	2·4	4·6	2·5	3·9	10·0	6·2
3	4·9	4·7	5·0	7·3	7·1	2·8	5·0	5·7	3·1	3·7	7·7	5·4	5·7	2·8	4·7	2·4	4·0	10·1	6·2
4	5·2	4·7	4·9	7·6	6·7	2·8	5·4	6·1	3·1	3·7	7·5	5·8	5·6	3·3	5·0	2·2	3·9	10·4	6·5
5	5·5	4·6	4·6	7·2	6·7	3·3	6·0	5·6	3·2	3·7	7·2	6·1	5·4	3·7	5·7	2·4	3·0	10·4	6·7
6	5·4	4·5	4·7	6·9	6·0	3·9	6·0	5·0	3·7	3·7	7·2	6·1	5·4	3·9	5·8	2·5	4·1	10·4	6·7
7	5·3	4·4	4·8	6·7	5·5	4·2	6·0	4·5	4·4	3·9	7·1	5·7	5·2	4·4	5·8	2·4	4·7	10·2	6·5
8	5·2	4·5	4·9	6·4	5·2	4·4	5·9	4·2	5·0	4·2	7·3	6·5	5·2	5·7	5·7	2·4	5·4	9·9	6·5
9	5·0	4·8	5·1	6·7	5·2	4·7	6·2	4·2	5·2	4·1	8·0	5·2	5·2	6·7	5·5	2·4	5·4	9·5	6·7
10	5·1	6·1	5·5	6·7	5·2	4·2	6·5	4·3	5·4	4·0	7·5	5·2	5·2	7·1	5·5	2·5	5·2	9·0	7·0
11	5·3	6·1	5·7	6·8	5·8	4·0	6·8	4·3	5·2	3·9	7·2	5·2	5·5	7·2	5·7	2·6	5·7	8·8	7·7
12	5·7	5·9	6·0	7·0	5·4	4·2	7·3	4·6	4·9	3·9	7·2	5·3	5·8	6·8	5·7	2·7	7·1	9·0	8·8
13	6·1	5·7	5·9	7·2	5·9	4·0	7·7	4·8	4·7	3·9	7·2	5·6	6·2	6·6	5·7	2·7	7·4	9·2	8·9
14	6·4	5·6	6·1	7·4	6·6	3·9	7·7	4·9	4·5	3·8	7·8	6·2	6·2	6·4	5·3	2·7	7·3	9·2	8·3
15	6·7	5·7	5·9	7·5	7·2	3·8	7·4	4·9	4·8	3·8	8·7	6·9	6·2	6·2	5·2	2·7	6·9	9·2	7·7
16	7·0	6·2	5·7	7·7	7·3	3·7	6·8	5·2	4·2	8·9	9·0	7·0	6·1	5·8	5·0	2·7	6·4	9·2	7·2
17	7·0	7·0	5·6	7·7	7·5	3·8	6·2	5·7	4·2	3·9	9·2	6·6	6·2	5·7	4·8	3·0	6·2	9·0	7·1
18	7·0	7·3	5·5	7·8	7·9	7·6	5·7	6·1	4·2	3·9	9·5	6·2	6·5	5·8	4·8	3·2	6·2	8·7	7·0
19	7·8	7·4	5·2	7·9	7·8	7·8	5·6	5·8	4·1	3·9	9·3	5·9	7·0	6·1	4·9	3·5	6·2	8·3	7·0
20	7·2	7·4	5·0	7·8	7·7	7·7	5·5	5·4	4·0	4·1	9·5	5·9	7·3	6·5	5·1	3·7	6·2	8·3	7·0
21	7·7	7·8	5·0	7·8	7·2	7·1	5·7	5·2	3·9	4·2	9·2	6·1	7·8	6·8	5·2	3·7	6·4	8·7	7·5
22	8·2	7·3	5·1	7·7	6·9	6·8	6·3	5·1	3·9	4·4	9·5	6·5	8·1	7·2	5·5	3·8	6·7	9·2	7·6
23	8·9	7·3	5·2	7·8	7·2	6·7	6·8	4·8	4·0	4·8	9·8	7·2	8·4	7·6	5·7	4·0	7·2	9·4	7·7
24	9·2	7·7	5·6	7·8	7·4	5·4	6·7	5·0	4·1	5·4	9·9	7·7	8·4	7·9	5·8	4·6	7·2	9·3	7·7
25	9·5	8·2	5·7	7·9	7·5	5·1	6·6	5·1	4·4	5·7	9·9	7·7	7·9	8·1	5·8	5·7	6·9	9·4	8·1
26	9·6	8·7	5·5	7·8	7·8	5·0	6·2	5·0	5·1	5·7	10·2	7·6	7·4	8·3	6·1	6·0	6·7	9·6	8·2
27	9·7	8·9	5·4	8·0	8·3	4·7	5·9	4·7	6·0	5·7	10·4	7·5	7·1	8·3	7·3	6·2	6·5	9·8	8·0
28	9·8	9·1	5·4	8·2	7·4	4·6	5·7	4·6	8·0	6·4	10·2	7·2	7·0	8·1	7·6	6·5	6·5	10·4	7·8
29	9·8	9·5	5·4	8·0	6·6	4·7	5·7	4·6	7·2	7·4	10·0	7·0	6·8	8·1	7·6	6·2	6·7	10·7	8·0
30	9·7	9·6	5·6	8·0	6·4	4·8	6·1	4·7	7·7	7·9	9·8	6·8	6·7	8·1	7·2	6·0	6·9	11·2	8·1
31	9·3	9·4	5·7	8·2	6·5	5·0	6·5	5·0	8·2	8·4	9·2	6·7	7·1	8·0	7·7	5·9	7·4	11·5	8·1
Averages	7·0	6·6	5·4	7·5	6·7	4·7	6·2	4·9	4·7	4·6	8·6	6·3	6·4	6·2	5·7	3·6	6·0	9·6	7·4

Date.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	4·1	6·8	7·2	5·3	4·0	4·5	3·0	5·5	4·4	7·8	7·9	10·9	3·4	4·6	4·7	6·5	6·4	5·5
2	4·1	6·7	6·8	5·7	3·8	5·1	3·8	5·6	4·6	7·6	7·8	10·7	3·6	4·7	5·2	6·2	7·5	5·7
3	4·2	6·7	6·4	5·7	3·6	5·9	4·6	5·4	4·9	7·3	7·8	10·6	3·7	4·8	5·2	5·9	7·7	5·8
4	4·2	6·9	6·2	5·3	3·5	6·1	5·4	5·6	5·9	7·2	8·0	10·4	3·7	4·7	5·0	5·9	7·4	5·9
5	4·4	7·8	6·0	5·2	3·4	5·7	6·5	6·9	6·7	7·3	8·3	10·7	3·7	4·7	4·7	5·9	7·2	6·0
6	4·4	7·7	6·2	5·1	3·4	5·4	6·7	8·4	7·0	7·3	8·5	10·7	3·7	4·7	4·7	6·1	7·2	6·0
7	4·3	7·4	6·7	5·1	3·3	5·1	6·7	8·5	7·0	7·4	8·9	11·0	3·8	4·0	4·7	6·3	7·7	6·2
8	4·2	6·8	7·5	5·0	3·3	4·9	6·8	8·2	7·1	7·5	9·2	11·2	4·4	5·0	5·1	6·5	7·9	6·3
9	4·1	6·7	8·4	4·9	3·2	4·8	6·4	7·4	7·3	7·6	9·2	11·1	4·8	5·3	5·7	6·5	7·7	6·4
10	4·1	6·6	8·7	4·8	3·2	4·7	6·2	7·0	8·5	7·7	9·1	11·0	4·9	6·4	5·7	6·6	7·4	6·7
11	4·0	6·7	8·9	5·5	3·1	4·7	6·1	6·7	9·8	7·9	9·2	11·3	4·9	7·3	5·3	6·4	7·4	7·2
12	4·0	6·8	8·7	6·2	3·1	4·8	6·2	6·7	10·1	8·0	9·6	11·8	4·7	8·0	5·1	6·2	7·2	7·2
13	4·1	6·8	8·7	6·4	2·9	5·0	6·4	6·8	10·2	8·2	9·4	12·2	4·7	9·2	4·8	6·3	7·2	7·5
14	4·2	7·0	8·7	6·2	2·9	5·2	6·5	7·0	9·9	8·4	9·2	12·0	4·7	9·2	4·7	6·5	7·2	7·9
15	4·4	7·6	8·6	6·1	2·8	5·7	6·3	7·4	9·6	8·7	9·2	11·7	4·7	8·7	4·8	6·7	7·2	9·3
16	5·2	7·8	8·7	5·0	2·7	6·2	6·3	7·7	9·2	8·9	9·4	11·6	5·2	8·6	5·4	6·8	7·2	9·9
17	5·7	7·9	9·0	5·7	2·7	7·2	6·4	7·9	8·8	9·1	9·9	11·6	5·8	8·7	6·8	6·8	7·2	10·2
18	5·7	7·8	9·2	5·7	2·7	7·4	6·2	8·0	8·7	9·2	10·1	11·7	6·0	8·7	8·3	7·0	7·1	9·6
19	6·4	7·5	9·7	5·5	2·9	7·3	6·3	8·0	8·5	10·1	10·0	11·9	6·2	8·3	8·7	7·2	7·1	9·4
20	7·7	7·2	9·7	5·5	3·2	7·4	6·3	7·9	8·2	10·4	10·0	12·0	6·5	7·7	9·0	7·5	7·2	9·2
21	8·2	7·0	9·8	5·5	3·5	7·6	6·2	7·8	8·0	10·3	10·2	12·2	7·2	7·4	8·7	7·9	7·1	9·1
22	8·1	7·0	9·7	5·7	3·6	7·7	5·8	7·6	7·7	10·2	10·2	12·3	7·0	7·2	8·5	7·7	7·0	8·9
23	7·4	7·2	9·9	6·0	3·5	8·4	5·7	7·5	7·6	10·0	9·7	12·4	6·7	6·8	8·8	7·6	6·9	8·7
24	6·7	7·5	9·9	6·7	3·7	8·1	5·5	7·6	7·4	9·8	9·4	12·4	6·7	6·0	9·2	7·2	6·8	8·4
25	6·0	7·7	9·9	8·1	4·1	7·7	5·2	7·7	7·6	9·3	9·0	12·4	6·7	7·1	9·5	7·0	6·7	8·4
26	5·7	7·7	10·1	9·1	5·1	7·7	5·1	7·8	8·3	8·7	8·8	12·6	6·4	7·2	9·7	7·1	6·6	8·3
27	5·5	8·2	10·5	9·5	6·0	7·6	4·9	8·2	9·5	8·2	8·8	12·9	6·4	7·2	9·6	7·2	6·7	8·2
28	5·3	8·5	10·8	9·6	6·9	7·1	4·8	8·2	10·2	8·0	8·9	13·2	6·1	7·5	9·3	7·5	7·1	8·0
29	5·3	8·3	11·1	9·4	7·8	6·8	4·7	8·7	10·5	8·0	8·9	13·4	5·9	8·3	8·9	7·3	7·6	7·7
30	5·3	8·3	11·2	9·3	7·8	6·8	4·8	9·2	10·6	8·3	8·9	13·6	6·2	9·0	8·5	7·3	[illegible]	7·6
31	5·5	7·8	11·3	9·2	7·4	7·2	5·6	9·8	10·3	8·9	8·7	13·6	6·6	9·0	8·1	7·2	8·2	7·6
Averages	5·2	7·4	8·8	6·4	3·9	6·8	5·7	7·5	8·2	8·5	9·1	11·8	5·3	7·1	6·8	6·7	7·3	7·7

Date.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	6·9	7·1	5·7	5·3	7·3	3·4	8·5	4·3	7·7	6·8	7·2	4·2	7·1	5·6	2·7	3·8	5·5	1·8	6·8
2	7·1	7·2	5·7	5·4	7·8	3·2	8·7	4·3	7·8	7·6	7·5	4·2	7·1	5·8	2·6	3·7	5·3	1·8	7·0
3	8·5	7·0	5·7	5·7	8·3	3·2	8·3	4·3	8·0	7·8	7·5	4·0	7·2	6·0	2·4	3·6	5·2	2·0	7·1
4	9·4	6·8	5·7	5·9	9·2	3·2	8·0	4·1	8·3	7·7	7·3	4·2	7·6	6·0	2·2	3·7	5·1	2·5	7·8
5	9·1	7·1	5·8	5·9	9·5	4·2	7·8	3·9	8·3	7·7	7·0	4·2	7·4	5·9	2·1	3·8	5·0	3·9	8·4
6	8·3	7·7	6·9	5·8	9·4	5·2	8·2	3·7	8·2	7·7	7·2	4·2	7·2	5·6	2·0	3·7	4·9	4·5	9·0
7	7·8	8·1	6·1	5·7	9·2	5·1	8·4	3·5	8·0	7·5	7·4	4·5	7·2	5·5	1·7	3·5	4·9	4·3	9·3
8	7·4	8·5	6·1	5·7	8·7	4·7	8·2	3·4	7·6	7·5	7·3	4·8	7·3	5·6	1·6	3·4	4·9	4·2	9·0
9	7·2	8·8	6·2	5·7	8·3	4·4	8·1	3·3	7·4	7·7	7·2	5·1	7·5	6·0	1·7	3·4	8·2	4·2	8·4
10	7·2	9·0	6·2	5·7	7·9	4·2	8·2	3·3	7·8	8·0	6·9	5·3	7·8	6·5	2·0	3·3	11·2	4·3	7·8
11	7·2	9·4	6·2	5·8	7·7	4·4	8·5	3·8	7·3	8·4	6·8	5·5	8·4	6·7	2·8	3·5	12·9	4·4	7·5
12	7·2	10·6	6·3	5·9	7·6	4·5	8·8	3·2	7·7	8·7	6·8	5·7	8·9	6·8	3·9	4·0	13·7	4·6	7·7
13	7·2	11·2	6·8	5·8	7·4	4·7	8·8	3·1	7·9	8·5	6·9	6·2	9·1	6·8	4·5	5·3	12·8	4·7	7·9
14	7·2	10·7	8·2	5·7	7·2	4·8	8·7	4·8	8·1	8·7	7·2	7·0	8·8	7·5	4·8	7·1	9·8	5·1	8·1
15	7·4	9·4	8·6	5·4	7·1	4·7	9·0	6·9	8·2	9·1	7·9	7·9	8·2	7·9	5·4	7·6	8·7	7·9	8·1
16	7·7	8·7	8·6	5·2	7·2	4·5	10·1	7·2	8·7	9·8	9·0	8·5	7·7	7·7	6·9	7·1	8·3	9·3	8·1
17	8·3	8·4	8·5	5·2	7·1	4·5	10·0	6·9	9·0	10·2	9·4	9·1	7·5	7·4	7·9	6·9	7·8	9·9	8·0
18	9·2	8·2	8·6	5·2	7·0	4·6	9·6	6·5	9·1	10·2	9·7	9·4	7·5	7·4	8·5	6·8	7·6	9·9	7·8
19	9·6	8·2	8·7	5·5	6·8	4·6	9·4	6·4	8·8	9·9	9·6	9·1	7·4	7·2	8·1	7·2	7·5	9·5	8·0
20	9·6	8·0	8·6	6·8	6·8	4·7	9·5	5·9	8·4	9·7	9·4	8·6	7·2	6·9	7·5	8·3	7·6	8·9	10·1
21	9·3	8·2	8·4	9·2	6·9	4·5	9·5	5·6	8·0	9·2	9·2	8·1	7·0	6·6	6·9	9·0	8·0	8·7	10·0
22	9·2	8·4	8·2	10·8	6·9	4·4	9·7	5·2	7·8	9·2	8·8	8·2	6·9	6·2	6·6	9·5	8·9	8·6	9·8
23	9·0	8·6	7·9	11·2	6·8	4·6	9·8	5·1	7·8	9·0	8·7	8·6	6·9	5·9	6·5	9·9	9·8	8·5	9·9
24	8·5	8·8	7·7	11·1	6·7	4·9	10·2	5·0	7·9	9·0	8·6	8·9	7·0	5·7	6·8	10·5	9·7	8·3	10·5
25	8·7	8·2	7·4	9·8	6·7	5·5	10·5	5·2	7·7	8·9	8·7	9·2	7·3	5·4	7·6	10·3	9·2	8·4	10·8
26	8·9	8·1	7·2	9·0	6·7	6·7	10·8	6·7	7·7	8·7	8·7	9·4	7·5	5·2	8·1	10·3	8·7	8·4	10·3
27	9·6	8·0	7·5	8·3	6·7	7·1	10·5	8·1	8·8	8·4	8·7	9·8	7·6	5·1	8·4	9·8	8·5	8·7	9·9
28	10·0	8·1	8·1	8·1	7·2	7·1	10·4	8·7	10·7	8·4	8·3	10·2	7·5	5·0	8·7	9·5	8·3	9·7	9·6
29	10·2	8·1	8·3	8·2	8·0	6·9	10·1	8·7	11·2	8·7	8·4	10·6	7·5	4·9	8·9	9·1	8·1	10·3	9·5
30	10·2	8·8	8·5	8·4	8·3	6·7	9·6	8·6	12·1	8·7	9·4	10·9	7·5	4·6	8·7	9·4	7·8	11·0	9·3
31	10·2	8·7	8·2	9·2	8·2	6·9	9·2	8·5	12·7	8·6	10·4	10·7	7·5	4·4	8·6	9·9	7·5	10·9	9·5
Averages	8·5	8·4	7·3	7·0	7·7	4·9	9·2	5·4	8·5	8·6	8·2	7·8	7·6	6·2	5·3	6·6	8·1	6·7	8·8

Date.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	5·0	8·7	7·2	7·1	6·4	3·3	5·3	8·5	6·2	4·7	5·2	6·4	3·0	1·2	6·0	6·2		
2	6·0	8·4	7·2	6·0	7·0	3·3	4·9	8·3	6·0	4·7	5·3	6·5	2·9	1·3	6·0	6·1		
3	6·3	8·0	7·1	6·7	7·0	3·3	5·2	8·1	5·8	4·9	5·4	7·8	2·9	1·4	5·8	6·1		
4	6·5	7·9	7·2	6·7	6·6	4·2	5·9	7·8	5·7	5·2	6·0	7·9	2·9	1·6	5·6	6·0		
5	6·4	8·0	7·3	6·7	6·1	5·2	6·2	7·6	5·6	5·2	6·5	8·0	2·9	1·8	5·4	5·9		
6	6·3	8·2	7·4	8·6	6·0	5·4	5·9	7·3	5·6	5·1	6·6	7·6	3·0	1·8	5·6	5·9		
7	6·4	8·5	7·4	9·5	6·0	5·4	5·3	7·2	5·7	5·0	6·7	7·5	2·9	1·9	6·3	5·8		
8	6·7	9·5	7·1	9·3	5·9	5·2	5·0	6·9	5·7	5·1	6·8	7·5	2·8	1·9	6·8	5·9		
9	7·1	10·5	7·0	8·5	5·8	5·1	5·0	6·7	5·8	5·2	7·5	7·8	2·9	1·9	7·	6·0		
10	7·3	10·8	6·9	7·9	5·8	5·0	5·0	6·6	6·2	5·3	8·0	7·8	2·9	2·0	6·7	6·2		
11	7·4	10·8	7·3	7·3	5·8	4·8	5·1	6·8	6·4	5·4	8·6	8·1	3·0	2·2	6·6	6·6		
12	7·6	10·9	8·0	7·0	5·8	4·6	5·1	7·2	6·2	5·5	8·7	8·8	3·0	2·4	6·7	7·4		
13	8·1	10·6	8·1	6·7	5·7	4·3	5·2	7·5	5·8	5·5	8·4	8·8	3·0	2·4	7·3	8·5		
14	8·8	10·9	8·0	6·5	5·7	4·1	5·3	7·8	5·8	5·5	8·5	9·1	2·9	2·4	7·5	8·6		
15	8·9	11·1	8·0	6·1	5·6	4·0	5·6	7·8	5·8	5·5	8·5	9·1	2·8	2·5	7·8	8·3		
16	8·5	11·5	8·7	5·9	5·5	3·9	6·1	7·6	5·8	5·6	8·4	9·2	2·7	3·2	8·4	8·3		
17	8·4	11·7	9·3	5·8	5·3	3·6	6·6	7·5	5·8	5·7	8·0	9·2	2·7	3·9	9·6	8·0		
18	8·1	11·7	9·3	5·5	5·0	3·5	6·6	7·1	5·9	6·0	7·5	9·4	3·1	4·9	9·2	8·0		
19	8·3	11·8	9·1	5·4	4·7	3·4	6·3	7·2	6·1	6·7	7·1	9·5	4·3	5·1	9·4	7·9		
20	8·7	12·2	9·1	5·3	4·5	3·4	6·1	7·3	6·4	7·0	6·9	9·9	4·7	5·1	9·2	7·9		
21	8·9	12·8	10·2	5·6	4·4	3·8	6·1	7·2	6·5	7·1	6·7	10·0	4·5	4·8	8·9	8·0		
22	8·9	13·2	11·0	5·9	4·3	4·5	6·9	7·5	6·9	7·0	6·5	10·1	4·3	4·6	9·0	8·1		
23	8·7	13·2	11·3	6·5	4·3	5·0	7·1	7·7	7·2	7·1	6·5	10·1	4·2	4·3	9·0	8·1		
24	8·5	12·5	11·4	7·4	5·0	5·0	6·8	7·9	7·3	7·5	6·7	10·2	4·5	4·3	8·9	8·0		
25	8·3	11·8	11·6	8·3	6·0	4·8	6·3	8·1	7·4	8·1	7·0	10·1	4·8	4·2	8·8	8·0		
26	8·1	11·0	11·6	8·5	6·0	4·6	6·2	8·3	7·7	9·2	6·8	9·8	4·8	4·3	8·8	8·0		
27	7·9	10·6	11·7	8·5	5·9	4·5	6·3	8·5	7·6	9·5	6·6	9·7	4·7	4·3	8·9	7·8		
28	7·6	10·6	11·8	8·5	5·8	4·9	7·0	8·9	7·1	9·8	6·4	9·4	4·5	4·3	9·1	7·6		
29	7·6	11·0	11·4	8·4	5·6	5·6	7·8	9·1	6·8	10·0	6·2	9·2	4·4	4·4	9·5	7·4		
30	7·6	11·5	11·0	8·5	5·6	5·8	8·6	9·3	6·6	9·9	6·1	8·7	4·3	4·5	10·0	7·4		
31	8·2	12·0	11·5	9·1	6·1	5·5	9·3	9·3	6·6	9·8	6·4	8·5	4·4	5·2	10·4	7·5		
Averages	7·8	10·7	9·0	7·3	5·7	4·5	6·2	7·8	6·8	6·6	7·0	8·8	3·6	3·2	7·9	7·3		

Readings of Bukkur Gauge for June.

Date.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	8·8	9·3	5.8	8·0	6·4	5·1	6·9	5.3	8·7	8·3	8·9	6·7
2	8·6	9·5	5.7	8·0	6·2	5·6	7·5	5·2	8·5	8·2	8·6	6·7
3	8·4	9·7	5.7	7·8	5·9	5·7	8·0	5·0	8·2	8·1	8·4	6·9
4	8·7	9·8	6.2	7·9	5·6	6·2	8·2	4·8	7·5	7·7	8·1	6·9
5	8·7	10·0	6·9	7·9	5·3	6·9	8·3	4·7	7·0	7·7	8·0	7·0
6	8·8	10·2	7·3	7·7	5·2	7·7	8·4	4·7	6·6	7·3	7·8	7·2
7	8·9	10·2	7·5	7·9	5·1	8·1	8·6	5·2	6·3	7·2	7·5	8·0
8	9·0	9·9	7·7	8·2	5·0	8·3	8·6	6·5	6·3	7·4	7·1	8·7
9	9·4	9·7	7·9	8·6	5·1	8·4	8·5	7·2	6·3	7·9	6·7	8·9
10	9·7	9·6	8·2	9·4	5·2	8·2	8·4	7·0	6·6	8·2	6·4	9·1
11	9·8	9·7	8·2	9·4	5·0	8·0	8·3	6·9	6·7	8·6	6·0	9·2
12	9·8	10·0	8·5	10·0	5·2	7·7	8·3	6·5	6·6	8·3	5·8	9·2
13	10·1	10·3	9·0	10·2	5·4	7·5	8·7	6·1	6·2	8·1	5·7	9·2
14	10·2	10·5	9·1	10·2	5·7	7·7	9·2	5·7	6·0	7·8	5·8	9·2
15	10·5	10·6	9·1	10·6	6·3	7·7	9·2	5·4	6·1	7·2	6·0	9·2
16	10·7	10·4	9·6	10·7	6·7	8·3	9·3	5·2	6·2	6·8	6·2	9·5
17	10·6	9·8	9·8	10·7	6·7	8·7	9·7	5·2	6·2	6·5	6·6	9·6
18	10·6	9·4	9·3	10·8	8·2	8·8	9·9	5·3	6·2	6·2	7·3	10·0
19	10·5	9·6	8·7	10·0	9·8	9·2	10·0	6·0	6·6	5·7	8·0	10·2
20	10·4	9·9	8·2	11·1	10·1	9·8	10·3	6·6	7·2	5·7	8·6	10·4
21	10·4	10·2	7·8	11·4	10·2	10·1	10·3	6·7	8·1	5·8	8·9	10·7
22	10·2	10·5	7·3	11·5	10·3	10·2	10·3	6·5	8·5	6·1	9·2	11·1
23	9·8	10·7	7·4	12·4	10·5	10·3	10·7	6·3	8·9	5·8	9·3	11·2
24	9·2	10·9	7·5	12·4	10·7	10·4	11·1	6·2	9·0	5·7	9·0	11·4
25	9·2	11·0	7·9	12·4	10·3	10·6	11·2	6·5	8·8	5·6	9·0	11·6
26	9·2	11·1	8·4	12·2	10·3	10·9	11·3	6·9	8·4	5·6	9·0	11·9
27	9·4	11·2	8·4	11·7	10·2	11·0	11·4	7·4	8·0	6·0	9·3	12·0
28	9·3	11·5	8·8	11·3	10·3	11·0	11·7	7·7	8·1	6·6	9·9	12·1
29	9·2	11·5	8·8	10·8	10·6	11·1	11·8	8·2	8·2	6·2	10·7	12·3
30	9·2	11·7	8·7	9·7	10·1	10·9	12·0	8·2	8·2	6·2	11·0	12·5
Averages ..	9·6	10·3	8·0	10·1	7·6	8·7	9·5	6·2	7·3	7·0	7·9	9·6

Date.	1860.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	7·2	8·1	9·1	5·7	7·9	11·8	8·0	5·7	8·0	11·2	8·7	7·4	7·6
2	7·1	8·1	9·1	5·6	8·9	12·2	7·7	5·8	8·2	11·0	8·1	7·7	7·5
3	7·0	8·1	8·6	5·7	9·6	12·0	7·7	6·0	9·3	10·6	7·7	8·4	7·2
4	7·3	8·7	8·1	5·6	10·5	11·7	7·8	6·1	9·4	10·3	7·4	9·3	6·7
5	7·2	8·9	7·6	5·6	11·0	11·6	8·1	6·5	10·0	10·2	7·4	9·6	6·5
6	7·0	8·8	7·7	5·5	11·4	11·4	8·5	6·7	10·7	10·2	7·3	9·7	6·5
7	6·7	8·6	7·8	5·3	11·5	10·6	8·9	6·5	11·2	10·2	7·2	9·9	6·6
8	6·4	8·2	7·9	5·3	11·5	10·2	9·2	6·2	11·9	10·0	7·4	10·7	6·9
9	6·2	7·7	7·9	5·2	11·3	9·7	9·4	5·8	11·9	9·7	7·7	10·9	7·4
10	6·2	7·6	7·9	5·3	10·2	9·1	9·5	5·7	11·9	9·4	8·3	11·3	7·7
11	6·2	7·1	8·0	5·8	9·1	8·8	9·7	5·7	12·1	9·3	8·8	11·7	7·9
12	6·0	7·2	8·6	7·0	8·4	8·4	9·8	5·6	12·1	9·3	9·2	12·0	8·1
13	5·9	7·0	9·7	7·6	8·1	8·6	10·0	5·5	11·9	9·8	9·2	12·1	8·3
14	5·9	7·1	10·2	7·8	7·7	8·8	10·2	5·7	12·0	10·5	8·9	12·1	9·2
15	5·0	7·0	10·7	8·1	7·7	9·2	10·5	7·2	12·2	11·2	9·0	12·1	9·6
16	6·2	7·0	11·1	8·2	7·7	9·6	10·7	8·0	12·3	11·5	8·8	12·1	9·9
17	6·5	7·0	11·7	8·4	7·9	10·0	11·0	8·7	12·4	11·5	8·8	12·2	10·5
18	7·2	7·2	11·5	8·7	7·9	10·2	11·5	8·6	12·4	11·4	9·2	12·4	10·8
19	7·7	7·4	11·2	8·9	8·2	10·2	11·9	8·3	12·6	11·0	9·3	12·3	11·1
20	8·1	8·1	11·0	8·0	8·5	10·2	12·2	8·0	12·6	10·8	9·5	12·3	11·2
21	8·6	8·1	10·5	9·0	8·6	10·2	12·3	8·1	12·5	10·2	9·7	12·5	11·4
22	8·6	8·8	10·1	9·1	8·7	10·4	12·4	7·8	12·6	10·1	9·4	12·5	11·6
23	8·7	9·2	9·2	9·3	9·0	10·5	12·6	7·7	12·7	10·2	9·2	12·5	11·6
24	8·7	9·6	9·2	9·7	9·2	10·4	12·7	7·4	12·7	10·4	9·0	12·6	11·7
25	8·6	9·9	9·2	9·7	9·2	9·5	12·9	7·4	12·7	10·8	9·2	12·8	11·7
26	8·6	9·6	9·6	10·0	9·1	8·9	12·8	7·7	12·6	11·0	9·4	12·7	11·8
27	8·7	9·8	10·0	10·0	8·8	8·7	12·6	8·6	12·6	11·0	9·7	12·7	11·7
28	8·8	10·2	10·2	10·0	8·6	8·5	12·7	9·2	12·4	11·2	10·1	12·7	12·0
29	9·3	10·4	10·4	10·2	8·2	8·2	12·7	9·6	12·1	11·3	10·5	12·7	11·9
30	10·0	10·3	10·4	10·5	8·2	8·3	12·7	10·0	11·6	11·5	11·0	12·9	11·8
Averages ..	7·4	8·4	9·5	7·7	9·1	10·0	10·6	7·2	11·7	10·5	8·8	11·4	9·5

Date.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	7·9	10·4	10·1	9·8	8·7	13·2	6·7	8·7	7·7	7·2	8·3	7·7
2	8·2	11·4	10·0	10·6	8·8	12·7	6·6	8·6	7·4	7·6	8·1	7·7
3	8·0	11·6	9·8	11·2	9·3	12·5	6·3	8·6	7·7	8·8	8·0	7·7
4	8·6	11·9	9·6	11·6	10·0	12·2	6·1	8·5	8·1	9·7	8·2	8·2
5	8·9	12·2	9·7	11·8	10·4	11·7	6·2	8·5	8·7	11·0	8·4	9·6
6	9·0	12·3	9·8	11·8	10·6	11·5	7·9	8·7	9·6	11·4	8·2	10·4
7	8·7	12·7	9·4	11·5	10·8	11·2	9·7	8·9	10·0	11·7	8·0	11·0
8	8·4	12·9	8·7	11·0	11·2	11·2	10·6	9·1	10·6	12·2	8·1	11·2
9	8·0	12·8	8·6	10·8	11·7	11·2	10·6	8·9	10·8	12·1	9·6	11·2
10	7·8	12·6	8·5	10·7	11·9	11·1	10·2	8·6	11·2	12·2	10·6	10·8
11	7·8	12·8	8·4	10·7	12·2	11·3	9·8	8·4	11·7	12·2	10·7	10·6
12	8·0	12·8	8·7	10·6	12·2	11·3	8·8	8·5	12·2	12·0	10·7	10·6
13	8·2	12·7	9·1	10·6	12·0	11·6	8·4	8·7	12·8	12·0	10·7	10·8
14	8·8	12·9	9·2	10·8	11·7	12·1	7·9	9·2	13·1	12·3	10·8	11·5
15	9·2	13·0	9·8	11·2	11·5	12·3	7·7	9·7	13·3	12·5	10·9	12·2
16	9·6	13·0	10·2	11·4	11·2	12·5	7·6	10·8	13·7	12·7	11·0	12·4
17	9·8	13·4	10·7	11·7	10·9	12·8	7·7	10·8	14·2	13·2	11·2	12·6
18	10·2	13·2	11·2	11·8	10·4	12·9	7·8	11·5	14·2	13·5	11·1	12·7
19	10·2	13·0	11·7	12·1	10·1	13·1	8·2	12·0	14·3	14·0	10·9	12·7
20	10·2	12·7	12·0	12·2	9·8	13·2	9·9	12·2	14·4	14·0	10·5	12·5
21	9·7	12·4	11·8	12·5	9·7	13·3	11·1	12·4	14·0	14·2	10·2	12·6
22	9·7	12·4	11·6	12·7	9·3	13·5	11·7	12·8	13·7	14·4	10·0	12·7
23	9·7	12·2	10·9	12·7	9·2	13·4	11·8	12·6	13·0	14·3	9·8	12·8
24	9·8	11·9	10·2	12·6	8·8	13·4	12·2	12·2	12·7	14·0	9·9	13·0
25	9·6	11·7	9·8	12·2	8·7	13·6	12·3	12·0	12·6	13·8	9·9	13·4
26	9·7	11·3	9·5	11·8	8·7	13·6	12·2	11·7	12·5	13·7	9·8	13·5
27	9·7	11·2	9·2	11·3	8·9	13·7	12·3	11·6	12·2	13·5	9·7	13·2
28	9·4	11·5	9·0	11·0	8·9	13·7	12·5	11·7	11·8	13·3	9·7	12·8
29	8·8	11·8	9·2	10·5	8·9	13·7	12·7	12·1	11·7	13·2	9·8	12·4
30	8·2	12·1	9·2	10·2	9·2	13·9	12·9	12·5	11·7	13·1	10·0	12·0
Averages ..	9·0	12·3	9·9	11·4	10·2	12·6	9·5	10·3	11·7	12·3	9·8	11·5

Date.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	10·3	9·2	7·9	10·7	8·2	7·8	9·0	8·5	12·6	8·6	10·4	10·3
2	10·2	9·5	7·8	11·2	8·1	9·2	8·9	8·5	12·6	8·4	10·3	10·0
3	9·5	10·0	7·7	11·9	7·9	9·6	8·9	8·2	12·7	8·3	10·2	9·4
4	9·2	10·2	8·1	12·2	7·7	9·8	9·1	7·9	12·0	8·5	10·5	9·0
5	9·2	10·2	9·2	12·5	7·8	10·0	9·2	7·4	10·6	8·7	10·6	8·8
6	9·2	10·0	10·1	12·2	8·0	9·9	9·2	7·2	9·5	9·1	10·5	8·9
7	9·2	9·8	10·3	12·0	8·5	9·9	9·6	7·5	8·7	9·2	10·3	9·1
8	9·2	9·5	10·4	12·0	8·7	9·7	9·8	7·7	8·3	9·0	10·2	9·2
9	8·8	9·1	10·2	12·1	8·9	9·8	10·2	7·8	8·0	8·8	10·2	9·5
10	8·7	8·7	10·2	11·9	9·2	9·8	10·7	7·7	7·7	9·8	10·3	9·7
11	8·7	8·5	9.8	11·7	9·4	10·2	11·2	7·7	7·6	9·2	10·0	10·0
12	8·7	8·2	9.7	12·0	9·6	10·3	11·5	8·3	7·4	10·1	10·9	10·0
13	8·6	8·1	9.4	12·0	9·2	10·3	11·8	8·7	7·3	10·9	11·4	9·8
14	8·7	8·0	9.2	11·7	9·5	10·5	11·7	8·3	7·5	11·5	11·9	9·6
15	8·8	7·9	9.0	11·1	10·3	10·6	11·8	8·1	7·8	11·7	12·4	9·4
16	9·1	8·1	9.0	10·3	11·1	10·2	11·7	7·7	8·3	11·8	12·7	9·5
17	9·4	8·8	9.1	9·8	11·6	9·8	11·7	7·5	8·7	12·0	13·1	9·7
18	9·7	9·8	9.3	9·6	12·1	9·4	11·5	7·4	8·7	12·0	13·6	10·1
19	9·9	11·2	9.4	9·4	12·2	9·4	11·4	7·5	8·7	12·0	14·0	10·7
20	10·1	11·6	9.2	9·2	12·6	9·6	11·0	7·6	8·8	12·0	14·1	11·1
21	10·5	12·0	9.2	8·8	12·9	9·9	10·8	7·4	9·2	12·2	14·0	11·7
22	10·8	12·5	9.1	8·5	13·1	10·5	10·5	7·8	9·3	12·2	13·8	12·0
23	10·8	12·6	9.1	8·2	13·0	10·7	10·1	7·2	9·7	12·4	13·2	12·3
24	11·0	12·6	9.0	8·0	13·0	10·6	9·6	7·2	10·2	12·7	12·8	12·5
25	11·2	12·7	8.9	7·9	13·1	10·5	9·2	7·1	10·7	13·0	11·4	12·2
26	11·7	12·7	9.2	8·0	13·2	10·7	8·9	6·9	11·1	13·2	10·8	12·1
27	12·1	13·1	9.2	8·2	13·3	11·0	8·8	6·8	11·3	13·3	10·7	12·2
28	12·2	13·2	9.2	8·4	13·6	11·2	8·7	6·6	12·1	13·7	10·7	12·6
29	12·7	13·7	8.9	8·6	13·7	11·7	8·8	6·5	12·7	14·0	10·8	12·9
30	12·8	13·8	8.7	8·8	13·3	12·0	9·1	6·5	13·2	14·3	11·6	13·3
Averages ..	10·0	10·6	9·1	10·3	10·8	10·2	10·2	7·6	9·8	11·1	11·6	10·0

Date.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.	1909.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	7·5	4·2	8·4	10·5	7·2	10·8	9·5	8·8	12·4	12·0	10·0	6·7	5·2
2	7·5	4·2	8·6	10·6	7·0	10·5	9·5	8·9	13·0	12·4	10·3	7·2	5·0
3	7·8	4·1	8·8	10·1	7·1	9·9	9·5	8·8	13·4	12·4	9·9	7·2	5·5
4	8·7	4·2	8·9	9·5	7·1	9·8	9·4	8·8	13·8	12·0	9·3	7·1	7·9
5	9·2	4·6	8·8	9·1	7·6	8·9	9·5	8·7	14·0	11·5	9·0	7·0	8·4
6	9·5	5·2	8·0	9·1	8·9	8·6	9·7	8·8	13·6	10·8	9·1	6·7	9·0
7	9·9	5·8	7·5	9·4	9·9	8·6	10·0	10·0	14·0	10·5	9·3	6·7	9·1
8	10·0	6·2	7·2	9·7	10·3	8·8	10·1	11·0	14·2	10·1	9·3	6·3	8·9
9	10·2	7·4	7·1	10·0	10·3	9·3	10·3	11·5	14·4	9·6	8·6	6·3	8·4
10	9·5	7·8	7·4	10·0	10·1	10·0	10·5	11·8	14·4	9·7	8·1	7·2	8·0
11	9·1	8·0	8·3	9·8	9·8	10·7	10·8	11·8	14·5	9·8	7·8	7·9	8·1
12	8·4	8·5	9·0	10·0	9·4	11·2	10·8	12·0	14·4	10·2	7·7	8·3	8·3
13	8·3	8·9	9·4	10·2	8·9	11·3	10·7	12·1	13·7	10·5	8·8	8·5	8·3
14	8·3	9·4	9·8	10·4	8·3	11·5	10·7	12·5	13·0	10·8	10·8	8·8	8·4
15	8·7	10·0	10·1	11·0	8·0	11·6	10·5	13·0	12·1	11·0	11·0	8·7	8·7
16	9·4	10·6	10·4	11·4	8·0	11·7	10·6	13·2	11·7	10·5	10·0	8·4	8·8
17	10·0	10·8	10·6	11·5	8·1	11·3	10·7	13·6	11·8	10·2	8·5	8·1	8·9
18	10·6	10·9	10·7	11·4	8·5	11·0	10·8	13·6	12·2	10·0	7·8	7·8	9·0
19	11·0	11·2	10·6	11·4	9·1	10·9	11·0	12·8	12·8	10·0	7·3	7·9	9·0
20	11·3	11·4	10·4	11·3	9·7	10·9	11·4	12·0	13·3	10·0	7·0	8·0	9·1
21	11·1	11·6	10·2	11·3	10·0	11·0	11·0	11·3	13·9	10·1	7·0	8·4	9·2
22	10·7	11·8	9·8	11·0	9·8	11·3	12·2	11·0	14·2	10·1	7·2	8·6	9·4
23	10·4	11·5	9·5	10·6	9·7	11·6	12·5	10·8	14·3	10·3	7·4	9·1	9·4
24	10·2	11·2	9·3	10·3	9·8	12·1	12·8	10·8	14·5	10·8	7·7	9·1	9·4
25	10·4	10·8	9·4	10·1	9·9	12·3	13·1	11·0	14·9	11·0	7·0	9·1	9·5
26	10·6	10·5	9·7	10·2	10·2	12·3	13·2	11·3	14·9	11·1	8·1	9·3	9·5
27	11·2	10·4	10·1	10·5	10·5	12·5	13·0	11·6	15·1	11·2	8·5	9·4	9·3
28	11·8	10·4	10·6	10·8	10·8	12·3	12·8	11·6	15·2	11·4	8·7	9·4	8·8
29	12·2	10·4	11·1	10·9	10·7	11·3	12·6	11·4	15·3	12·0	9·2	9·0	8·5
30	12·2	10·4	11·6	11·1	10·7	10·4	12·6	11·0	15·1	12·5	9·1	8·8	8·2
Averages ..	9·8	8·7	9·4	10·5	9·2	10·8	11·1	11·2	13·8	10·8	8·7	8·1	8·5

Date.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	9·9	9·5	6·6	8·8	6·7	8·4	4·6	6·0	10·7	7·6		
2	10·1	9·6	6·5	8·6	7·6	8·4	4·5	5·8	10·8	7·8		
3	10·3	9·8	6·5	8·8	8·6	8·4	4·2	5·7	10·8	7·9		
4	10·6	9·9	6·6	8·9	9·2	8·4	3·9	5·9	10·8	8·2		
5	10·8	10·1	6·7	8·9	10·2	8·5	3·9	7·5	11·0	8·4		
6	10·8	10·4	6·9	8·9	10·4	8·5	4·0	8·3	11·1	8·4		
7	11·0	10·7	7·1	8·8	10·6	8·3	5·2	8·5	11·1	8·5		
8	11·2	10·9	7·4	9·0	11·0	8·3	6·8	8·9	11·4	8·6		
9	11·3	11·2	7·5	9·2	11·3	8·2	6·9	9·1	11·4	8·8		
10	11·3	11·7	7·8	9·6	11·4	8·4	7·4	8·7	11·4	9·0		
11	11·0	12·0	8·5	10·1	11·2	8·5	8·2	8·4	11·2	9·3		
12	10·5	12·5	8·7	10·6	10·8	8·8	8·8	7·8	10·8	9·5		
13	10·2	12·6	9·0	11·1	10·4	9·0	9·1	7·9	10·5	9·8		
14	10·6	12·4	9·8	11·3	10·0	8·9	9·5	7·9	10·6	10·0		
15	10·7	12·6	9·6	11·5	9·9	9·1	10·1	7·9	10·9	10·4		
16	10·8	12·7	9·8	12·1	9·5	9·3	10·8	7·8	11·3	10·6		
17	11·0	13·0	9·9	12·7	9·2	9·3	11·1	7·8	11·4	10·7		
18	11·2	13·3	9·6	12·4	8·9	9·5	11·1	7·7	11·6	10·9		
19	11·5	13·5	9·3	11·5	8·9	9·7	10·2	7·5	11·8	10·9		
20	11·6	14·0	9·3	10·4	8·9	9·8	9·6	7·4	11·6	11·1		
21	11·7	14·0	9·4	9·6	9·2	10·1	9·7	7·4	11·7	11·2		
22	11·9	14·0	9·5	8·9	9·4	10·1	9·9	7·5	11·5	11·2		
23	12·1	13·9	9·4	8·7	9·8	9·9	10·0	8·0	11·4	11·4		
24	12·4	13·7	9·2	8·7	9·9	9·4	10·5	9·2	11·1	11·6		
25	12·2	12·6	9·1	8·8	10·4	9·2	11·0	10·4	10·6	11·9		
26	11·4	12·0	8·9	8·9	10·7	8·8	11·0	11·0	10·0	12·2		
27	10·2	12·0	8·6	9·3	11·1	8·6	11·6	9·8	9·5	12·5		
28	9·7	12·0	8·4	9·7	11·4	8·5	11·8	8·2	9·1	12·6		
29	9·5	12·3	8·4	10·2	12·0	8·5	12·0	7·8	9·0	12·8		
30	9·4	12·4	8·6	10·4	12·4	8·4	12·3	7·4	9·0	12·7		
Averages ..	10·9	12·0	8·4	9·9	10·0	8·9	8·6	8·0	10·8	10·2		

Readings of Bukkur Gauge for July.

Date.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	9·8	11·8	8·7	9·0	11·2	10·8	12·1	7·8	8·1	8·8	11·5	12·8
2	9·7	11·9	8·6	9·2	11·2	10·8	12·2	8·0	7·7	9·2	12·0	12·8
3	10·1	12·0	8·6	9·3	11·2	11·9	12·2	8·3	7·3	9·7	12·1	12·7
4	10·2	12·2	8·7	9·5	12·1	11·1	12·8	8·9	7·1	9·9	12·2	12·5
5	10·3	12·0	8·7	9·4	12·2	11·2	12·8	8·7	6·7	9·7	12·2	12·4
6	10·4	11·8	8·7	10·4	11·6	11·1	12·8	8·9	6·6	9·8	12·0	12·1
7	10·5	11·4	8·7	10·7	11·9	11·1	13·1	8·7	6·7	9·7	12·2	12·0
8	10·5	10·2	8·7	11·0	11·8	11·2	12·9	8·9	6·7	9·6	11·8	11·3
9	10·6	9·3	8·7	10·8	12·2	11·2	13·1	8·7	7·3	9·6	12·0	10·8
10	10·6	9·2	8·5	10·8	12·2	11·2	13·2	9·0	7·7	9·6	12·0	10·5
11	10·7	9·5	8·4	11·0	12·4	11·2	13·2	9·2	7·8	9·8	12·1	9·3
12	10·7	9·8	8·6	11·2	12·5	11·2	13·2	9·7	8·3	9·9	12·2	9·3
13	10·7	10·2	8·4	11·2	12·5	11·1	13·1	10·5	8·5	9·9	12·2	9·2
14	10·7	10·4	8·1	11·3	12·3	11·7	13·1	11·8	8·7	9·9	12·2	9·1
15	10·8	10·5	8·1	11·5	12·2	12·0	12·8	11·3	9·0	9·5	12·2	8·7
16	10 5	10·0	7·7	11·7	12·2	11·9	12·3	11·5	9·1	9·4	12·4	8·4
17	10·5	9·1	7·5	11·7	12·2	11·7	11·6	11·8	9·2	9·3	12·6	8·2
18	10·2	8·6	7·3	11·9	11·9	11·7	11·4	12·2	9·7	9·2	12·8	8·2
19	10·2	8·3	7·6	12·2	11·8	11·5	11·6	12·1	10·0	9·2	13·0	8·8
20	10·0	8·3	7·8	12·2	12·2	11·4	11·8	12·2	10·2	9·5	13·3	8·4
21	9·7	8·4	7·9	12·2	12·2	11·3	11·8	12·2	10·5	9·3	13·2	8·6
22	9·7	8·4	8·0	12·4	12·3	11·6	11·9	12·1	10·6	9·5	13·3	8·2
23	9·7	8·4	8·0	12·4	12·3	11·7	11·7	12·2	10·1	9·6	13·4	8·4
24	9·7	8·3	8·4	12·4	12·5	11·7	11·6	12·3	11·1	9·6	13·6	8·4
25	9·7	8·2	8·7	12·6	12·6	11·8	11·8	12·0	11·2	9·5	13·3	8·8
26	9·7	7·8	8·9	12·6	12·8	12·0	12·0	12·5	11·5	9·6	13·6	9·2
27	9·7	7·8	9·4	12·5	12·7	12·2	12·2	12·4	11·5	9 9	13·7	9·5
28	9·7	7·9	9·6	12·8	12·5	12·1	12·7	12·8	11·6	10·3	13·7	9·8
29	9·8	8·2	10·0	12·8	12·5	12·0	12·8	12·6	11·7	11·2	13·7	9·7
30	10·1	8·5	10·4	12·7	12·7	11·8	12·9	12·7	11·9	11·4	13·3	10·1
31	10·3	8·9	10·6	12·7	12·7	11·8	13·4	12·6	12·0	11·5	13·6	10·5
Averages	10·2	9·6	8·6	11·4	12·2	11·5	12·5	10·8	9·2	9·8	12·7	9·9

Date.	1860.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	10·2	9·6	10·4	10·7	8·3	8·4	13·0	10·6	11·3	11·5	11·8	13·0
2	10·5	9·2	10·7	11·0	8·5	8·5	13·1	10·7	11·3	11·7	11·9	13·2
3	10·5	9·0	10·7	11·1	8·5	8·6	13·2	10·8	11·6	11·7	12·2	13·2
4	10·6	8·6	11·0	11·1	8·7	8·7	13·3	11·0	11·6	11·6	12·3	13·1
5	10·2	8·6	11·0	11·2	9·2	8·9	13·4	11·2	11·8	11·2	12·5	13·0
6	9·6	9·5	11·2	11·5	9·7	9·2	13·4	11·2	11·9	10·9	12·7	13·0
7	8·3	10·2	11·3	11·7	9·9	9·7	13·5	11·3	12·2	10·9	12·7	12·9
8	7·7	10·7	11·5	11·7	9·9	9·9	13·6	11·6	12·1	11·0	12·7	12·9
9	7·4	10·8	11·8	12·0	9·5	10·1	13·8	11·8	12·1	11·1	12·7	12·9
10	7·4	10·8	12·1	12·1	9·4	10·3	13·8	11·8	11·7	11·3	12·5	12·9
11	7·6	10·7	12·2	12·3	9·3	10·4	13·8	12·1	11·1	11·2	12·2	12·7
12	7·9	10·1	12·2	12·3	9·7	10·6	13·9	12·0	10·6	11·2	12·2	12·5
13	8·2	9·8	12·2	12·3	10·0	10·7	14·0	12·0	10·4	11·2	12·2	12·2
14	8·5	9·7	12·4	12·4	10·3	11·0	13·9	12·1	10·3	11·2	12·1	12·1
15	8·6	9·1	12·5	12·5	10·4	11·3	13·8	12·1	10·4	11·2	12·1	12·2
16	8·5	8·9	12·5	12·6	10·5	11·4	13·8	12·0	10·4	11·2	12·3	12·3
17	8·3	9·0	12·6	12·6	10·7	11·7	13·7	11·5	10·7	11·2	12·5	12·6
18	8·1	9·4	12·7	12·6	10·7	11·8	13·9	10·9	10·8	11·5	12·6	12·7
19	7·9	10·7	12·7	12·7	10·7	12·2	13·8	9·9	11·2	11·7	12·7	12·7
20	8·1	11·0	12·8	12·7	10·8	12·4	13·7	9·0	11·2	12·0	12·2	12·8
21	8·6	11·1	12·9	12·7	10·9	12·7	13·8	8·5	11·5	12·2	11·9	12·7
22	9·1	11·2	12·8	12·6	10·9	12·6	13·9	8·4	11·6	12·3	11·6	12·6
23	9·6	11·0	12·7	12·6	10·9	12·2	13·9	8·9	11·7	12·5	11·6	12·6
24	9·7	11·2	12·7	12·7	10·9	11·5	13·7	8·9	11·7	12·6	11·9	12·7
25	10·1	11·2	12·9	12·5	11·3	11·3	13·4	9·2	11·7	12·6	12·1	12·7
26	10·2	11·5	13·0	12·2	11·5	11·2	13·2	9·7	11·9	12·6	12·2	12·7
27	10·4	11·5	13·0	12·1	11·7	11·2	13·0	10·1	12·0	12·8	12·2	12·7
28	10·6	11·6	12·9	12·0	11·9	11·4	12·8	10·2	12·1	12·8	12·4	12·7
29	10·7	11·6	12·9	12·0	11·9	11·6	12·7	10·1	12·2	12·8	12·5	12·7
30	11·1	11·7	12·7	11·9	12·0	11·7	12·7	9·4	12·4	12·9	12·7	12·7
31	11·3	11·7	12·5	12·1	12·1	11·5	12·9	9·4	12·4	13·0	12·6	12·7
Averages	9·2	10·3	12·2	12·1	10·4	10·8	13·5	10·6	11·5	11·8	12·3	12·7

Date.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	11·8	7·9	12·2	9·2	10·1	10·2	14·0	13·6	13·0	11·8	13·0	10·7	11·7
2	12·1	7·7	12·4	9·6	10·0	11·2	14·0	13·6	13·6	12·0	12·9	11·4	11·5
3	12·2	7·8	12·5	9·8	9·9	12·0	14·0	13·7	13·8	12·0	12·8	12·2	11·3
4	12·3	8·1	12·7	10·2	9·8	12·6	14·0	13·8	14·2	11·8	12·9	12·7	11·2
5	12·3	8·5	13·0	10·7	9·7	13·2	14·2	13·4	14·3	11·5	12·9	12·9	11·4
6	12·3	8·9	13·0	11·4	9·8	13·6	14·3	13·5	14·6	11·0	12·9	13·4	11·8
7	12·6	9·6	13·1	12·2	10·2	14·1	14·4	14·1	14·8	10·5	13·3	13·7	12·2
8	12·7	9·9	13·2	12·5	10·7	14·1	14·4	14·2	14·9	10·0	13·5	14·3	12·5
9	12·7	10·0	13·4	12·5	11·1	14·2	14·7	14·2	14·7	9·6	13·7	14·6	13·0
10	12·8	10·0	13·6	12·2	11·5	14·1	14·7	14·2	14·2	9·5	13·8	14·7	13·4
11	12·9	9·8	13·7	12·2	11·9	13·5	14·7	14·2	14·0	9·4	14·4	15·0	13·5
12	12·9	9·8	13·8	12·5	12·2	12·6	14·5	13·9	13·9	9·4	14·6	15·0	13·6
13	12·9	10·0	13·9	13·0	12·6	11·8	14·7	13·8	13·9	9·7	14·7	15·1	13·6
14	13·0	10·2	13·9	13·5	13·0	11·2	15·0	13·5	14·0	10·2	15·0	15·2	13·2
15	13·0	10·6	14·1	13·8	13·2	11·0	15·1	13·7	14.2	11·0	15·1	15·5	12·7
16	13·0	10·8	14·0	14·0	13·5	10·9	15·2	14·1	14·2	11·7	15·1	15·6	12·6
17	12·9	11·2	14·2	14·1	13·7	10·9	15·0	14·2	13·7	12·2	15·2	15·9	12·2
18	12·9	11·3	14·3	14·2	13·9	11·1	15·1	14·6	13·5	12·5	15·2	15·7	12·0
19	12·7	11·4	14·2	14·5	14·0	11·3	15·2	14·6	13·2	12·7	15·3	15·7	12·0
20	12·6	11·7	14·1	14·7	14·2	11·7	15·2	14·5	13·2	12·7	15·6	15·7	11·9
21	12·6	11·7	14·2	14·7	14·5	12·2	15·1	14·1	13·3	12·7	15·7	15·8	11·9
22	12·6	12·2	14·1	14·9	14·7	12·8	15·0	13·7	13·4	12·9	15·9	15·8	12·1
23	12·7	12·2	14·1	14·8	14·8	13·0	14·9	13·4	13·8	13·0	15·9	15·6	12·6
24	12·8	12·5	14 0	14·8	15·0	13·1	14·7	13·4	14·2	12·9	16·0	15·2	13·3
25	12·7	12·7	14·0	14·7	15·1	13·1	14·7	13·4	14·7	12·6	16·4	14·7	14·0
26	12·7	12·7	14·2	14·4	15·3	13·0	14·7	13·6	14·7	12·8	16·5	14·0	14·2
27	12·7	12·6	14·1	14·2	15·5	12·4	14·7	13·7	14·7	12·4	16·7	13·3	14·4
28	12·7	12·6	14·1	14·2	15·4	11·8	14·7	14·0	14·2	12·6	17·0	12·7	14·9
29	12·7	12·5	14·2	14·5	15·4	11·7	14·7	14·2	13·6	12·7	17·2	12·4	15·1
30	12·8	12·5	14·2	14·6	15·3	11·6	14·7	14·3	13·0	12·8	17·5	12·2	15·5
31	12·7	12·6	14·2	14·6	15·5	11·5	14·9	14·4	13·2	12·7	17·2	12·2	15·5
Averages	12·6	10·7	13·7	13·1	12·9	12·3	14·7	13·9	14·0	11·6	15·0	14·2	12·9

Date.	1885.	1886.	1887.	1888.	1889	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	13·0	14·0	8·4	9·0	14·2	12·3	9·2	6·7	13·5	14·5	12·8	13·7	12·2
2	13·2	13·6	8·3	9·5	14·3	12·7	10·1	6·7	13·7	15·0	13·7	14·2	12·0
3	13·4	13·0	8·5	10·2	14·5	12·8	10·6	6·9	13·9	14·9	14·3	14·7	11·6
4	13·7	12·7	8·7	11·0	14·7	12·7	11·1	7·4	14·2	14·7	14·5	14·9	11·6
5	13·2	12·3	9·2	11·3	15·0	12·3	11·5	8·2	14·4	14·4	14·1	15·1	11·6
6	13·1	12·6	9·7	12·0	14·9	12·2	11·7	8·7	14·4	14·6	12·6	15·7	11·3
7	13·0	12·9	10·4	12·2	15·0	12·4	12·0	9·0	14·4	14·7	11·2	15·7	10·9
8	13·2	13·2	10·7	12·2	15·1	12·5	11·7	9·1	14·7	14·5	10·8	15·7	10·9
9	13·6	13·7	11·2	12·1	15·2	12·7	11·4	9·1	14·8	14·3	9·7	15·7	11·1
10	13·7	14·0	11·6	11·7	15·3	12·7	11·4	9·0	14·8	14·6	9·9	15·6	11·4
11	14·2	14·4	12·0	11·4	15·6	13·0	11·2	8·7	15·2	14·7	10·2	13·4	11·8
12	14·3	15·0	12·7	11·2	15·7	13·3	11·2	8·7	15·4	15·0	10·9	15·0	12·4
13	14·5	15·2	13·0	10·9	15·7	13·2	11·2	9·2	15·6	15·1	11·7	14·1	12·8
14	14·5	15·1	12·7	10·8	16·0	13·2	11·0	9·8	15·7	15·1	12·4	12 7	13·1
15	14·7	15·1	12·7	11·2	15·9	12·9	10·7	10·2	15·7	15·3	13·0	11·7	13·2
16	14·7	15·3	12·2	11·7	15·9	12·7	10·7	11·0	15·7	15·6	12·7	11·2	13·4
17	14·8	15·4	12·4	12·0	16·3	12·4	10·8	11·7	15·6	15·7	12·2	11·3	13·8
18	15·3	15·5	13·0	12·3	16·2	12·2	11·2	11·9	15·4	15·7	11·2	11·7	14·2
19	15·3	15·5	13·1	12·6	16·6	12·3	11·7	12·2	15·2	15·7	10·3	12·0	14·2
20	15·4	15·7	13·1	12·8	16·4	12·4	12·2	12·1	15·1	15·6	9·6	12·4	14·5
21	15·4	15·9	12·8	12·7	15·7	12·6	12·7	12·5	14·8	15·8	8·8	13·2	14·6
22	15·2	16·2	13·0	12·7	15·5	12·6	13·0	13·3	14·8	15·9	8·4	13·7	14·6
23	14·7	16·2	13·3	12·5	15·1	12 7	13·1	13·0	14·8	16·0	8·2	14·0	14·5
24	14·5	16·1	13·7	12·1	14·9	12·7	12·8	12·8	15·0	16·2	8·4	14·2	14·5
25	14 3	15·6	14·0	11·9	14·7	12·5	12·7	11·8	15·1	16·2	8·5	13·9	14·4
26	14·2	15·3	14·1	12·2	14·7	12·5	12·2	11·8	15·1	16·3	8·3	13·7	14·7
27	14·4	14·7	14·5	12·8	14·7	12·6	12·3	11·7	15·2	16·2	8·2	13·5	14·7
28	14·2	14·4	15·0	13·2	14·4	12·7	12·5	11·7	15·5	16·0	8·8	13·7	14·9
29	14·1	14·6	15·2	13·7	13·9	12·8	12·7	11·6	15·7	15·7	8·9	13·7	15·2
30	14·1	14·7	15·2	13·5	13·7	13·0	13·2	12·4	15·8	15·6	9·3	13·7	15·2
31	14·2	15·0	15·5	13·2	13·6	13·1	13·5	13·1	15·6	15·2	9·7	13·6	15·0
Averages	14·2	14·6	12·2	11·9	15·2	12·8	11·8	10·3	15·0	15·4	10·8	13.9	13.2

Date.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.
	F. D.	F. D.	F. D.	F. D.	D. F.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	10·5	12·0	11·2	10·4	9·8	12·6	10·8	15·1	13·1	8·9	8·8	8·2	9·3
2	10·7	12·1	11·2	9·9	9·5	12·7	10·9	14·8	13·8	8·6	9·0	8·3	9·6
3	1 ·0	12·2	11·2	9·6	9·7	12·6	11·0	14·4	14·1	8·7	9·3	8·5	10·1
4	11·2	12·3	11·1	9·4	9·7	12·3	11·2	14·2	14·5	8·9	9·6	9·0	11·0
5	11·7	12·7	11·2	9·3	10·0	11·8	11·6	14·2	14·8	9·2	9·8	9·4	11·6
6	12·1	12·4	11·4	9·1	10·6	11·6	12·0	14·5	15·0	9·5	10·2	9·9	12·0
7	12·3	12·1	11·5	9·2	11·1	11·3	12·2	14·7	15·2	9·5	10·5	9·8	12·4
8	12·5	11·9	11·7	9·1	11·4	11·2	12·2	14·8	15·4	9·3	10·7	9·1	12·5
9	12·2	11·9	11·8	9·1	12·0	10·9	12·1	15·0	16·1	9·3	10·7	9·0	12·4
10	11·4	12·0	11·9	9·2	12·3	10·6	11·7	15·2	16·2	8·6	10·5	9·3	11·9
11	10·9	12·1	12·2	9·8	12·5	10 6	11·2	15·3	16 0	8·0	10·4	9·9	11·4
12	10·8	12·2	12·3	10·4	12·6	10·5	11·0	15·4	16·0	8·0	10·5	10·5	11·3
13	11·0	12·4	12·2	10·9	12·6	10·6	10·9	15·8	15·8	8·2	11·2	11·1	11·7
14	11·3	12·8	12·3	11·4	12·5	10·7	10·6	15·9	15·7	8·4	11·6	11 5	12·1
15	11·6	13·0	12·5	11·6	12·0	11·0	10·6	16·0	15·3	8·8	11·7	11·4	12·4
16	12·5	12·8	12·6	11·5	11·5	11·5	10·6	16·0	15·1	9·0	11·9	10·3	12·5
17	13·0	12·3	12·7	11·1	11·3	12·0	10·6	16·0	14·7	9·0	12·3	9·6	12·5
18	13·4	12·3	12·8	11·0	11·3	12·1	10·7	16·2	14·4	8·6	12·7	9·3	12·5
19	13·3	12·3	12·9	11·2	11·5	12·2	10·7	16·4	14·4	8·2	13·1	9·0	12·6
20	12·7	12·1	13·0	11·4	11·6	12·5	10·8	16·7	13·3	7·9	13·6	9·1	12·5
21	11·6	12·3	13·1	11·2	11·8	12·7	11·1	16·7	13·2	7·7	13·9	9·5	12·3
22	10·5	12·6	13·4	11·2	11 8	12·9	11·6	16·2	13·4	7·8	14·2	9·8	12·0
23	10·2	13·0	13·2	11·2	11·6	13·2	12·0	15·5	13·6	8.1	14·6	10·2	12·0
24	10·2	13·0	12·9	11·4	11·6	13·7	12·6	14·7	13·6	8.5	14 8	10·9	12·1
25	10·0	13·0	12·9	11·9	11·4	14·3	13·0	14·0	13·5	8.9	15·1	11·5	12·4
26	10·0	12·9	13·9	12·5	11·3	14·8	13·4	13·5	13·2	9·6	15·3	12·0	12·5
27	10·4	13·4	13·1	13·1	11·8	15·0	13·2	13·6	13·2	10·0	15·5	12·8	12·7
28	10·6	13·4	13·2	13·4	11·6	15·2	13·2	14·1	13·4	10·3	15·5	13·1	12·8
29	11·5	13·4	13·2	13·5	12·2	15·2	13·2	14·5	13·2	10·5	15·2	13·2	13·0
30	12·2	13·3	13·0	13·2	12·7	14·3	13·6	14·7	13·3	10 9	15·2	13·3	13·1
31	13·0	12·8	12·9	13·0	13·2	15·1	14·2	14·6	13·5	11·0	15·4	13·3	13·1
Averages	11·5	12·6	12·5	11·0	11·5	12·5	11·8	15·1	14·5	9·1	12·3	10·4	12·0

Date.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D
1	12·7	8 7	10·6	12·6	8 4	12·2	7·2	9·0	12·6		
2	13·3	8·9	10·9	13·0	8·6	11·3	7·2	8·6	12·5		
3	13·0	8·8	11·1	13·4	8·0	9·8	7·5	8·4	12·2		
4	11·7	8·8	11·5	13·5	9·0	9·5	8·2	8·1	11·7		
5	10·6	8·8	11·7	13 9	9·1	9·2	8·6	7·8	11·8		
6	10·1	9·0	11·7	14·6	9·6	9·2	8·8	7·6	11·0		
7	10·2	9·4	11·0	15·0	9·9	9·2	9·0	7·7	10·8		
8	10·1	10·0	10·3	15·1	10·2	9·2	8·5	8·1	11·0		
9	9·8	10·5	9·8	15·2	10·4	9·0	8·0	8·4	11·1		
10	9·2	11·0	9·5	15·3	10·6	9·0	7·6	8·5	11·1		
11	8·5	11·3	9·4	15·4	10·9	9·0	7·1	8·6	11·1		
12	8·3	11·5	8·9	15·2	10·7	9·0	7·1	8·6	11·1		
13	8·3	11·7	8·7	14·5	10·5	9·2	7·3	8·8	11·1		
14	8·5	11·7	8·4	13·4	10·0	9·6	7·6	9·0	11 2		
15	9·0	11 6	8·2	13·4	9·8	9·8	7·7	9·1	11·3		
16	9·5	11·7	8·2	13·8	9·5	10·0	8·1	9·8	11·3		
17	10·2	12·1	8·5	13·6	9·6	10·7	9·0	9·7	11·3		
18	10·6	12·6	8·9	14·0	9·7	10·8	9·8	9·8	11·3		
19	10·8	13·1	9·2	14·2	10·0	10·7	10·4	10·1	11·5		
20	10·6	13·5	9·7	14·6	10·4	10·8	10·0	10·2	12·0		
21	10·2	13·7	9·8	14·6	10·7	11·3	9·1	10·8	12 5		
22	10·2	13·9	10·3	14·5	10·8	11·8	8·7	10·1	12·7		
23	10 2	14·0	10·8	14·7	10·7	11·9	8·6	9·6	13·0		
24	10·3	14·2	11·2	14·6	10·5	11 8	8·6	8·9	13·0		
25	10·6	14·3	11·4	14·6	10·3	11·7	8·6	8·2	13·2		
26	10·8	14·5	11·6	15·3	10·4	11·5	8·6	7·6	13·4		
27	10 9	14·8	11·9	15·5	10·8	11·6	8·6	7·4	13·8		
28	10·9	14·9	12·1	15·5	10·9	11·6	8.8	7·2	14·0		
29	10·6	14·8	12·3	15·8	11·0	11·5	9·4	7·4	14·1		
30	9·8	13·6	12·5	16·2	10·8	11·0	10·6	7·8	14·3		
31	8·8	13·1	12·5	16·5	10·5	10·5	11·4	7·9	14·3		
Averages	10·3	11·9	10·4	14·6	10·1	10·4	8·6	8·6	12·2		

Readings of Bukkur Gauge for August.

Date.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.	1864.	1865.	1866.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	10·4	9·4	10·7	12·8	12·8	11·8	13·2	12·7	12·0	11·5	13·9	10·9	11·4	11·5	12·2	12·1	12·2	11·1	12·8
2	10·7	9·7	10·7	12·7	12·9	11·7	13·4	12·4	12·0	11·6	13·7	11·1	11·4	11·4	11·7	12·1	12·2	10·5	12·8
3	10·8	10·3	10·7	12·8	12·9	11·7	13·2	12·2	12·3	11·8	13·7	11·9	11·7	11·0	11·3	12·2	12·2	10·3	12·7
4	11·0	10·5	10·8	12·7	13·2	11·7	13·2	12·2	12·2	11·7	13·5	10·8	11·7	10·4	11·2	12·1	12·4	10·7	12·9
5	11·2	10·7	10·7	12·6	13·2	11·7	13·0	11·6	12·0	12·0	13·0	10·9	11·9	9·7	11·3	12·1	12·6	11·0	12·9
6	11·3	11·2	10·5	12·7	13·2	11·7	13·2	11·3	12·0	12·2	12·5	11·1	12·0	9·1	11·3	12·1	12·7	11·4	13·2
7	11·4	11·5	10·2	12·7	13·1	11·7	12·7	11·1	12·0	12·2	12·3	11·1	12·2	8·9	11·4	12·2	12·7	11·9	13·3
8	11·5	11·7	10·0	12·6	13·0	11·8	12·5	11·2	12·0	12·3	12·3	11·0	12·1	9·2	11·4	12·2	12·7	12·4	13·3
9	11·5	11·7	10·2	12·4	12·9	11·8	12·2	11·2	12·0	12·2	12·1	11·2	12·1	9·7	11·5	12·2	13·0	12·2	13·4
10	11·7	11·9	10·5	12·8	12·8	11·8	11·8	11·6	12·0	12·0	12·1	11·2	12·2	10·2	11·4	12·3	13·0	12·1	13·3
11	11·9	12·1	10·7	12·7	12·7	11·8	11·8	11·2	12·1	11·4	12·2	11·2	12·1	10·3	10·7	12·4	13·0	11·7	13·4
12	11·9	12·1	11·2	12·3	12·6	11·7	12·3	10·6	12·1	11·1	12·1	11·0	12·1	10·9	10·2	12·3	13·1	11·7	13·4
13	11·9	12·1	11·2	12·4	12·3	11·5	11·9	10·4	11·9	11·0	12·3	11·1	12·1	11·1	9·8	12·3	13·2	11·7	13·5
14	11·7	12·1	11·2	12·3	12·2	11·5	11·7	10·1	12·2	11·3	11·9	11·1	12·1	11·2	9·5	12·1	13·2	11·6	13·5
15	11·5	12·2	11·4	11·9	12·0	11·6	11·6	10·1	11·7	11·9	12·1	11·2	12·1	11·4	9·2	12·1	13·2	11·9	13·5
16	10·7	12·2	11·3	11·7	12·1	11·2	11·3	10·4	11·9	12·2	12·1	11·6	12·0	11·5	9·3	12·1	13·2	11·0	13·3
17	10·6	12·2	11·3	11·4	11·9	11·3	11·7	9·9	11·9	12·2	12·0	11·5	12·1	11·6	9·5	12·2	12·9	11·9	13·2
18	10·6	12·1	11·3	11·4	11·7	11·0	11·8	9·2	12·1	12·4	12·2	11·5	11·9	11·6	9·9	12·2	12·7	11·9	13·1
19	10·7	12·1	11·4	11·7	11·4	10·8	11·7	8·2	12·2	12·4	12·2	11·6	12·2	11·8	10·3	12·2	12·4	12·2	12·9
20	10·7	12·1	11·2	11·8	11·2	9·5	11·5	7·4	12·0	12·1	12·1	11·1	12·0	11·9	10·7	12·2	12·0	12·3	12·7
21	10·7	11·9	10·7	11·5	11·2	9·0	11·7	6·8	12·1	12·2	11·9	10·5	12·0	11·9	10·7	12·2	11·8	12·5	12·6
22	10·2	12·1	10·3	11·5	11·1	8·7	12·0	6·5	12·4	11·9	11·6	10·1	12·0	11·8	10·7	12·2	11·7	12·7	12·3
23	9·8	12·2	10·4	11·4	11·0	8·2	12·0	6·5	12·8	11·7	11·4	9·7	11·7	11·7	10·8	12·2	11·6	12·8	12·5
24	9·6	12·2	10·9	11·9	11·1	7·5	11·9	6·8	12·5	11·1	11·2	9·7	11·3	11·3	10·8	12·3	11·6	13·0	12·5
25	9·7	12·4	11·2	10·7	10·7	7·4	11·9	6·9	12·7	10·6	11·2	10·0	10·9	11·3	10·8	12·4	11·4	13·2	12·2
26	9·9	12·4	11·7	11·0	10·6	7·4	12·6	7·2	12·7	10·4	11·2	10·3	10·7	11·8	10·8	12·6	10·7	13·2	12·0
27	10·3	12·5	12·1	10·7	10·1	7·5	12·2	7·2	12·6	10·4	11·2	10·2	10·7	11·4	10·8	12·7	10·0	13·3	11·7
28	10·6	12·5	12·2	10·4	9·7	7·7	12·8	6·9	12·8	10·4	11·3	9·9	10·7	11·5	10·9	12·5	9·2	13·4	11·3
29	11·0	12·2	12·4	9·9	9·5	7·8	12·2	5·9	12·6	10·3	11·3	9·8	11·0	11·7	10·8	12·4	8·5	13·3	11·6
30	11·2	11·9	11·8	9·0	9·8	8·2	12·5	5·0	12·4	10·0	11·3	9·7	11·2	11·8	11·0	12·1	8·5	13·5	11·2
31	11·2	11·7	10·5	8·2	9·3	8·2	12·3	5·0	12·2	10·1	11·2	9·9	11·4	12·1	11·2	11·5	8·6	13·5	11·0
Averages ..	10·9	11·8	11·0	11·7	11·7	10·2	12·2	9·2	12·2	11·5	12·1	10·8	11·7	11·0	10·7	12·2	11·9	12·1	12·7

Date.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874	1875	1876	1877	1878	1879	1880	1881	1882	1883	1884
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	9·7	12·6	13·0	12·7	12·9	12·7	12·7	14·2	14·6	15·5	11·5	15·0	14·2	13·4	12·5	17·1	12·2	15·5
2	9·8	12·6	13·0	12·7	12·8	12·7	13·0	14·3	14·7	15·6	11·7	15·1	14·2	13·5	12·6	17·1	12·2	15·6
3	10·2	12·7	12·8	12·7	12·7	12·7	13·0	14·2	14·9	15·3	12·0	15·2	13·7	13·5	12·8	17·1	12·0	15·5
4	10·3	12·7	12·7	12·8	12·7	12·8	13·0	14·3	14·9	15·7	12·4	15·2	13·1	13·5	13·1	17·0	11·5	14·6
5	10·5	12·7	12·5	12·9	12·8	12·9	12·9	14·2	15·0	15·7	12·8	15·2	12·9	13·8	13·5	17·0	11·1	14·3
6	8·7	12·8	12·3	13·0	12·8	12·9	12·8	14·4	15·0	15·5	13·3	15·2	13·0	14·1	13·8	17·3	11·1	14·2
7	11·0	12·7	11·9	13·2	12·7	13·0	13·0	14·2	14·8	15·5	13·7	15·1	13·1	14·3	13·9	17·6	11·2	13·8
8	11·2	12·6	11·5	13·2	13·2	13·1	13·2	14·2	14·9	15·4	13·8	15·1	13·2	14·4	13·9	17·6	11·9	13·7
9	11·3	12·6	11·3	13·4	13·2	13·1	13·2	14·2	14·9	15·2	13·4	15·1	13·6	14·7	13·9	17·0	12·6	13·7
10	11·5	12·6	11·6	13·5	13·2	12·9	13·5	14·1	15·0	15·3	12·4	15·0	14·1	14·7	13·7	16·8	13·1	13·7
11	11·7	12·1	11·8	13·5	13·2	13·0	13·5	14·2	15·0	15·4	11·9	15·1	14·4	14·6	13·2	16·6	13·2	14·0
12	11·6	12·2	12·0	13·6	13·1	13·1	13·6	14·1	15·1	15·4	11·7	15·1	14·8	14·4	13·0	16·4	13·6	14·3
13	11·3	11·5	12·2	13·7	13·1	13·0	13·6	14·2	15·1	15·5	11·7	15·0	15·0	14·2	12·7	16·4	13·7	14·3
14	11·3	10·8	12·2	13·7	13·0	13·0	13·5	14·2	15·2	15·5	11·8	15·0	15·2	13·7	12·7	16·3	13·8	14·8
15	10·8	10·6	12·1	13·7	13·0	13·0	13·6	14·1	15·1	15·7	11·8	15·0	15·3	13·2	13·0	16·2	13·9	14·6
16	10·7	10·7	11·7	13·7	12·9	13·0	13·6	14·2	15·1	15·7	11·9	15·0	15·5	12·9	13·1	16·0	13·6	14·7
17	10·7	11·1	11·1	13·7	12·9	12·0	13·8	14·1	15·2	15·7	12·1	15·0	15·6	12·6	13·2	15·5	13·2	15·0
18	10·9	11·2	10·3	13·5	13·0	12·9	13·9	14·2	15·2	15·8	12·2	15·0	15·7	12·6	13·2	15·3	13·0	15·4
19	11·2	11·3	9·7	13·5	12·9	12·8	13·1	14·2	15·2	15·7	12·5	15·1	15·8	12·4	13·0	15·4	12·9	15·7
20	11·7	11·2	9·5	13·3	12·9	12·7	13·0	14·2	15·2	15·8	12·4	15·2	16·1	12·1	13·1	15·5	12·3	15·7
21	12·0	11·2	9·6	13·2	12·8	12·3	12·8	14·0	15·2	15·8	12·4	15·2	16·0	11·9	13·2	15·5	11·7	15·7
22	12·1	11·1	9·7	13·1	13·0	12·2	12·5	13·8	15·1	15·7	12·4	15·2	15·9	11·7	13·4	15·4	10·9	15·6
23	12·1	11·1	10·0	12·9	13·0	11·5	12·3	13·7	15·0	15·6	12·4	15·2	15·9	11·5	13·7	15·0	10·2	15·3
24	12·3	11·2	10·4	12·7	13·0	11·2	12·2	13·6	14·9	15·6	12·4	15·5	15·8	11·3	13·7	14·2	9·9	15·0
25	12·3	11·6	10·8	12·7	12·9	11·2	12·4	13·7	14·7	15·6	12·6	15·5	15·8	11·0	13·3	14·0	9·8	14·5
26	12·5	11·5	10·9	12·7	12·9	11·5	12·4	13·8	14·0	15·6	12·6	15·4	15·8	10·7	13·2	13·8	10·0	14·3
27	12·4	11·2	10·4	12·7	12·8	11·5	12·2	13·9	13·3	15·5	12·4	15·2	15·9	10·2	12·9	13·9	10·2	14·4
28	12·3	10·7	10·1	12·8	12·7	11·5	12·2	14·2	12·7	15·5	12·0	14·8	16·0	10·0	12·6	13·9	10·8	14·6
29	12·5	10·1	10·1	12·9	12·6	11·1	11·8	14·1	12·2	15·7	11·5	14·8	15·9	10·0	12·4	13·9	10·5	14·8
30	12·4	9·8	9·8	12·8	12·7	10·9	11·6	13·9	12·0	15·6	11·2	14·8	15·7	9·9	12·6	13·5	10·5	15·0
31	12·8	10·0	9·8	12·4	12·7	10·1	11·0	13·4	12·2	15·5	11·0	14·7	15·7	9·7	12·6	12·8	10·2	15·0
Averages ..	11·3	11·6	11·2	13·1	12·9	12·4	12·8	14·1	14·6	15·6	12·3	15·1	14·9	12·7	13·2	15·8	11·9	14·7

Date.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902	1903
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	14·3	15·2	15·5	13·1	13·7	13·4	13·7	13·5	15·2	15·0	9·7	13·7	14·7	13·0	12·3	12·9	13·3	13·5	15·4
2	14·2	15·4	15·7	12·9	13·8	13·3	13·9	13·9	14·7	15·3	9·7	13·8	14·6	12·6	11·3	13·8	13·8	13·4	15·7
3	14·0	15·5	15·6	13·1	13·9	13·3	14·0	14·8	13·9	15·7	10·3	14·0	14·4	12·0	10·7	13·4	14·0	12·8	15·9
4	13·8	15·6	15·2	13·3	14·0	13·3	14·2	14·6	13·7	15·7	11·2	14·0	14·2	12·3	10·4	13·5	14·3	12·1	16·1
5	12·8	15·6	14·0	13·6	14·1	13·2	14·2	14·7	12·9	16·0	11·9	14·3	14·2	12·5	10·3	13·8	14·3	11·3	16·2
6	11·6	15·6	15·2	14·0	14·4	13·4	14·0	15·2	12·2	16·2	12·1	14·6	14·5	12·7	10·3	13·5	14·5	10·8	16·3
7	11·2	15·5	15·1	14·1	14·5	13·5	13·6	15·4	12·2	16·4	12·1	14·7	14·7	12·4	10·4	13·6	14·7	10·6	16·3
8	11·2	15·4	15·6	14·1	14·5	13·7	14·1	15·4	12·7	16·4	12·5	14·5	14·7	12·0	10·6	13·7	14·7	10·5	16·2
9	11·6	15·4	15·7	13·8	14·2	13·8	14·3	15·5	13·0	16·2	13·0	14·5	15·0	12·0	10·6	14·0	14·2	10·5	16·4
10	12·2	15·4	15·7	13·6	14·8	14·2	14·3	15·7	13·2	16·1	14·0	14·5	15·0	12·1	10·7	14·1	14·2	10·5	16·6
11	12·6	15·4	16·0	13·7	13·3	14·2	14·4	15·8	13·4	15·8	15·1	14·7	14·8	12·1	10·9	14·1	14·5	10·4	16·8
12	12·8	15·4	16·0	13·8	13·1	14·7	14·4	16·2	13·7	15·6	15·2	14·4	14·9	12·0	11·1	14·3	15·0	10·3	16·8
13	13·1	15·4	16·3	14·1	13·3	14·8	14·6	16·2	13·3	15·4	14·7	14·2	15·0	12·0	11·4	13·9	15·2	10·5	16·5
14	13·5	15·8	16·2	14·2	13·5	15·0	14·7	16·2	13·7	15·2	13·7	14·3	15·2	12·3	11·5	14·0	15·8	10·7	16·0
15	13·6	15·7	16·3	14·2	13·7	15·3	14·7	16·2	13·6	15·2	12·7	14·3	15·4	12·7	11·4	14·4	16·4	11·0	15·6
16	14·0	15·6	16·3	14·0	14·2	15·4	14·7	16·4	13·4	15·0	12·1	14·6	15·8	12·8	11·1	14·5	16·3	11·5	15·5
17	14·1	14·7	16·2	13·1	14·5	15·4	14·6	16·6	12·7	15·0	11·4	14·7	16·2	12·7	10·7	14·3	16·0	12·2	15·6
18	14·3	13·6	16·6	12·2	14·6	15·6	14·3	16·7	11·7	15·0	11·4	14·9	16·2	12·6	10·5	14·1	13·9	12·8	15·8
19	14·5	12·5	16·5	11·5	14·7	15·7	13·8	16·4	11·2	14·7	12·0	14·7	16·3	12·5	10·7	14·0	12·6	13·3	16·1
20	14·6	12·6	16·4	11·8	14·9	15·5	13·8	16·4	10·7	14·3	13·1	14·5	16·5	12·4	11·1	13·9	12·8	13·0	16·3
21	14·6	12·8	15·9	11·6	14·8	15·6	13·9	16·2	10·1	13·7	14·0	13·8	17·0	12·2	11·3	13·9	13·2	11·9	16·9
22	14·6	13·5	15·4	12·0	14·7	15·7	14·2	16·2	9·7	14·4	14·4	12·8	17·1	11·8	11·4	13·7	13·6	10·8	17·1
23	14·7	14·1	15·2	12·6	14·8	16·0	14·2	16·0	9·6	14·4	15·0	12·5	17·3	10·9	10·9	13·5	13·8	10·1	17·1
24	14·9	13·9	15·3	13·1	14·7	15·7	14·2	15·5	9·6	14·3	15·2	12·5	17·3	11·1	10·5	13·4	13·4	9·7	16·4
25	14·9	13·7	14·9	13·6	14·4	15·7	13·9	15·3	9·4	14·2	14·9	12·6	17·4	11·3	10·8	13·5	13·0	9·5	15·3
26	15·0	13·1	14·2	13·8	14·1	15·9	13·4	14·8	9·6	14·1	13·2	13·0	17·7	11·4	10·5	13·5	12·7	9·5	14·2
27	15·4	12·5	14·2	14·2	13·6	15·5	12·7	14·2	9·7	14·1	11·4	13·4	17·8	11·6	10·8	13·6	12·9	9·4	13·8
28	15·2	11·8	14·6	14·3	13·5	14·9	12·2	13·2	9·9	14·3	10·6	13·2	17·9	11·8	11·1	13·3	13·1	9·4	14·2
29	15·1	12·0	14·7	14·4	13·3	13·8	11·7	13·2	10·1	14·4	10·2	12·2	17·9	11·8	11·3	13·2	13·4	9·5	14·3
30	15·1	12·2	14·1	14·3	13·2	13·0	11·7	13·4	10·1	14·6	10·2	10·6	17·7	12·0	10·9	13·1	12·8	9·9	15·0
31	14·4	12·5	12·9	14·2	13·2	12·1	12·0	13·6	9·8	14·7	10·6	9·7	17·5	12·1	10·4	13·1	14·2	10·3	15·1
Averages ..	13·7	14·4	15·5	13·5	14·1	14·4	13·9	15·3	12·0	15·1	12·6	13·7	16·0	12·1	10·9	13·7	14·2	11·0	15·9

Date.	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1021
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	14·6	14·3	13·7	10·9	15·2	13·4	13·0	8·4	12·9	12·8	17·0	10·3	9·9	11·6	8·3	14·1		
2	15·0	13·9	14·0	10·6	15·1	13·5	12·9	8·1	12·9	13·0	17·3	10·4	9·6	11·4	8·5	14·2		
3	15·2	13·7	14·2	10·7	15·1	13·5	12·8	8·5	13·0	13·2	17·4	10·5	9·4	11·1	8·5	14·4		
4	15·5	13·7	14·5	10·8	14·7	13·1	12·9	8·9	13·0	13·4	17·4	10·3	9·8	11·1	8·2	14·5		
5	15·7	13·9	14·7	11·0	14·5	12·2	13·1	9·5	12·8	13·6	17·3	10·1	10·1	11·3	8·0	14·2		
6	15·8	14·2	15·1	11·3	15·0	11·5	12·9	10·4	13·8	13·8	17·0	10·2	10·7	12·0	7·6	13·9		
7	15·7	14·4	15·1	11·4	15·2	10·9	12·8	11·0	14·0	13·8	16·5	10·4	11·4	12·5	7·6	13·7		
8	15·5	14·5	15·1	11·5	15·4	10·6	12·7	11·8	14·5	13·8	15·3	10·8	11·8	12·8	7·7	13·5		
9	15·3	14·5	15·2	11·9	15·6	11·0	12·8	12·4	15·0	13·8	14·4	11·1	12·0	13·4	8·0	14·0		
10	14·8	14·7	15·4	12·1	15·7	10·9	12·9	12·4	15·5	13·9	13·1	11·5	12·1	13·7	8·1	14·3		
11	14·6	14·6	15·4	12·5	15·0	11·1	12·8	12·0	15·3	14·2	12·0	11·5	12·2	13·9	8·4	14·3		
12	14·6	14·3	15·6	12·8	16·1	11·6	12·8	11·7	15·5	14·4	11·0	10·9	12·5	14·1	8·5	14·4		
13	15·0	14·1	15·9	13·1	16·1	11·9	12·5	11·4	15·8	14·6	12·2	10·5	12·8	14·6	8·6	14·4		
14	15·3	14·0	16·0	13·1	16·1	12·1	12·3	10·9	14·2	14·9	14·0	10·5	13·2	15·0	9·0	14·6		
15	15·5	14·0	16·0	13·1	16·0	12·0	12·3	10·5	13·6	15·0	14·4	10·4	13·5	15·5	9·4	14·7		
16	15·6	14·0	16·2	13·3	15·9	11·9	12·4	10·3	13·2	14·7	14·4	10·4	13·6	15·8	9·6	14·7		
17	15·6	14·1	16·4	13·5	15·6	11·6	12·5	10·5	13·0	13·0	13·9	10·4	13·5	15·8	9·9	14·4		
18	16·6	14·4	16·5	13·6	15·8	11·8	12·8	10·8	13·0	10·9	13·1	10·5	13·0	15·8	9·8	14·1		
19	15·4	14·6	16·5	13·6	15·1	11·6	13·1	10·9	13·2	9·9	12·3	10·9	12·9	15·7	9·4	12·4		
20	15·2	14·8	16·3	13·7	15·0	11·9	13·4	11·0	13·0	9·5	11·4	11·1	12·6	15·4	8·9	12·0		
21	14·6	15·8	16·4	13·7	14·9	12·8	13·6	11·1	12·7	9·4	10·8	11·5	12·8	14·7	8·9	12·2		
22	13·5	15·0	16·6	13·7	14·9	12·9	13·5	11·4	12·7	9·3	10·8	11·6	13·0	14·3	9·0	12·4		
23	13·0	14·0	16·4	13·5	15·2	13·1	13·4	11·5	12·7	9·3	11·0	11·9	13·0	13·6	9·2	12·9		
24	13·0	12·8	16·2	12·7	14·0	13·5	13·4	11·6	13·0	9·3	11·1	12·2	13·0	13·9	9·4	13·1		
25	13·0	11·9	16·1	12·1	14·7	13·9	13·4	11·8	12·9	9·5	11·1	12·4	12·6	13·9	9·6	13·1		
26	13·5	11·7	16·0	11·4	14·3	14·1	13·3	11·8	12·3	9·9	11·2	12·7	12·9	14·0	10·1	13·0		
27	14·1	11·7	16·0	10·9	14·0	14·3	13·1	11·5	12·0	9·8	11·0	12·6	13·0	13·5	10·5	12·8		
28	13·8	11·8	16·0	10·7	13·6	14·4	13·3	10·8	11·6	10·8	10·5	12·2	12·5	13·5	10·9	12·7		
29	13·2	12·0	15·8	10·5	13·6	14·2	13·6	10·4	11·5	10·6	10·2	11·8	11·5	13·7	11·0	12·9		
30	12·2	12·3	15·6	10·0	13·8	14·0	13·7	10·0	11·4	11·0	9·9	11·5	10·8	14·2	11·1	12·9		
31	11·7	12·5	15·4	9·3	14·4	13·8	13·8	9·9	11·5	11·5	9·6	11·3	10·4	14·3	10·6	12·8		
Averages ..	14·5	13·8	15·7	12·1	15·1	12·6	13·0	10·7	13·8	12·1	13·2	11·1	12·0	13·7	9·1	13·6		

Date.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.	1864.	1865.	1866.
	F. D.	F. D.	F.D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	10·7	11·3	9·7	7·8	9·3	7·2	12·2	4·9	12·2	10·3	11·1	9·7	11·4	12 1	11·4	10·5	8·2	13·5	10·8
2	10.2	10·9	8·8	8·1	10·1	6·7	11·5	4·5	11·9	10·6	10·7	9·3	11·4	12·1	11·6	9·3	8·2	13·5	10·4
3	8·9	10 7	8·7	8·0	10·2	6·7	10·2	4·5	11·7	10·7	11·2	9·1	11·0	12·2	11·6	8·6	8·7	13·6	10·0
4	8·0	10·4	9·0	7·8	10·3	6·5	8·8	4·8	11·4	11·2	10·7	8·6	9·8	12·0	11·4	8·0	9·2	13·7	9·6
5	8·9	10·2	9·0	7·7	10 3	6·4	7·8	5·1	10·9	11·4	11·2	8·1	8·5	11·8	11·3	7·7	9·7	13·7	9·9
6	7·0	9·9	8·4	7·7	10·3	6·3	7·3	5·2	10·3	11·6	11·0	7·8	7·9	11·3	10·9	7·7	10·2	13·8	10·4
7	7·7	9·6	8·6	7·7	10·2	6·3	6·7	5·5	10·2	11·8	10·9	7·8	7·7	10·2	10·6	7·4	10·5	13·7	10·6
8	7·7	9·3	8·4	7.7	10·2	6·4	6·4	5·9	10·1	11·8	10·2	7·8	7·5	8·9	10·3	7·5	10·9	13·2	10·2
9	8·7	9·2	8·3	7·6	10·2	6·0	6·2	6·4	10·0	11·9	9·3	7·5	7·6	8 4	10·2	7·5	10·6	12·8	10·0
10	8·0	9·2	7·4	7·6	10·1	6·7	6·0	7·3	9·8	12·0	8·2	8·0	7·5	8·2	10·2	7·6	10·0	12·4	9·6
11	8·4	9·8	7·0	7·5	19·0	6·7	6·3	7·6	10·0	11·8	7·5	8·0	7·6	8·2	10·3	7·2	9·3	12·1	8·7
12	8·2	9·5	6·6	7·5	10·0	6·6	6·5	8·2	10·0	11·8	7·1	8·2	7·6	8·4	10·4	7·1	8·8	11·8	8·2
13	7·0	10·1	6·5	7·0	10 1	6·7	7·0	8·9	10·0	11·3	7·1	8·3	7·8	8·6	10·7	6·9	8·2	11·6	7·8
14	7·5	10·2	6·5	6·8	9·1	6·9	7·5	9·2	9·7	10·7	7·3	8·4	6·9	8·7	10·8	6·7	7·0	11·5	7·5
15	6·0	10·1	6·6	6·7	9·1	7·2	8·3	8·2	9·0	10·5	7·9	8·2	6·4	8·8	10·7	6·6	7·7	11·7	7·2
16	6·6	10·1	6·6	6.7	9·2	7·5	8·8	8·0	8·1	10·4	8·2	8·0	6·1	9·2	10·6	6·5	7·4	11·7	7·2
17	6·2	9·0	6·7	6·4	9·2	7·6	9·1	8·2	7·7	10·4	8·3	8·2	5·8	9·6	10·3	6·6	7·4	11·9	7·2
18	6·2	9·6	6·7	6·5	9·2	7·4	9·2	6·9	7·7	10·3	8·4	8·1	5·5	9·7	9·9	6·8	7·2	11·6	7·3
19	6·3	9·3	6·6	6.4	8·4	7·0	8·6	6·7	7·2	10·2	6·7	8·2	5·3	9·7	9·3	7·0	7·2	11·2	7·4
20	6·5	9·3	6·4	6·5	8·0	6·2	7·0	7·7	6·8	10·2	6·2	7·8	5·8	9·2	8·7	7·0	6·8	11·4	7·7
21	6·8	9·4	6·2	6·3	7·2	5·9	6·2	8·6	6·6	10·1	5·9	7·3	5·4	8·9	8·1	6·7	7·0	12·0	7·4
22	6·9	9·3	6·2	6·2	7·2	5·7	5·7	8·9	6·4	9·8	5·6	6·6	5·3	8·8	7·7	6·5	7·2	12·3	7·9
23	6·8	9·1	6·0	6·0	6·4	5·5	5·0	8·7	6·5	9·7	5·4	6·2	5·4	8·5	7·3	6·2	7·1	12·7	7·5
24	6·4	9·1	6·0	5·8	6·2	5·3	5·0	8·2	6·6	9·8	5·5	6·0	5·5	7·9	7·3	6·0	6·8	12·8	7·0
25	5·1	9·0	5·8	5·5	6·2	5·1	5·0	7·5	6·6	8·6	6·0	5·9	5·6	7·4	6·8	5·6	6·5	11·1	6·7
26	5·8	8·7	5·7	5·2	5·7	4·9	5·0	6·6	6·7	8·0	6·3	5·7	5·7	7·1	6·5	5·3	6·2	10·1	6·5
27	5·5	8·3	5·9	5·2	5·3	5·1	5·0	5·9	7·3	7·2	6·1	5·6	5·8	6·8	6·5	5·1	5·8	9·6	6·2
28	5·2	7·9	5·9	5.1	5·2	5·1	5·0	5·8	7·7	6·7	5·7	5·5	5·8	6·6	6·4	4·9	5·4	9·2	5·7
29	4·0	7·3	6·2	5·1	5·2	4·9	4·9	5·0	8·4	6·3	5·6	5·5	5·7	6·4	6·5	4·5	5·1	8·9	5·4
30	4 5	7·2	6·5	5·1	4·7	4·8	4·9	4·8	7·7	6·1	5·4	5·4	5·5	6·2	6·5	4·1	4·8	8·7	5·2
Averages ..	6·9	9·5	7·1	6·7	8·4	6·3	7·1	6·7	8·8	10·1	7·9	7·5	7·0	9·1	9·4	6·8	7·8	11·9	8·1

Date.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D
1	12·4	10·1	9·7	11·5	12·6	9·4	10.7	12·8	12·7	15·5	10·7	14·5	15·7	9·5	12·7	12·2	10·1	14·9
2	12·4	10·2	9·7	10·7	12·4	8·9	10.3	12·2	13·0	15·5	10·3	14·5	15·6	9·2	12·9	12·0	10·0	14·6
3	12·4	10·5	9·7	10·4	11·9	9·2	9.9	12·0	13·0	15·5	10·4	14·5	15·7	9·0	13·0	11·9	9·9	13·7
4	12·5	10·5	9·5	10·7	11·7	9·2	9·5	11·4	12·9	15·5	10·5	14·3	15·6	8·8	13·0	12·7	10·1	12·7
5	12·6	10·1	9·0	10·7	11·3	9·2	9·3	11·1	12·5	15·4	10·6	14·5	14·9	8·8	13·0	13·4	11·0	12·3
6	12·5	9·6	8 6	10·9	10·8	9·3	9·2	11·0	12·2	15·4	10·5	14·3	14·0	8·9	13·2	13·9	11·7	12·7
7	12·4	9·1	8·2	11·2	10·5	9·9	9·2	10·8	11·8	15·3	10·4	14·1	13·1	9·0	13·2	14·0	12·3	13·1
8	12·2	8·8	8·0	11·3	10·6	10·3	9·3	10·9	11·6	15·1	10·3	13·8	12·2	9·2	13·4	14·0	12·7	12·8
9	11·5	8·7	8·0	11·5	10·1	10·7	9·3	11·0	11·2	14·6	11·4	13·6	11·6	9·5	13·4	13·6	12.7	12·1
10	10·6	8·7	8·2	11·4	9·8	10·6	9·3	11·3	10·7	14·1	12·2	13·2	10·9	9·6	13·3	12·2	12·7	11·4
11	10·1	8·6	8.7	11·1	9·5	10·4	9·2	11·9	10·8	13·9	12·0	12·8	10.8	10·0	13·4	11·1	12·5	10·9
12	9·8	8·5	9·1	10·7	9·8	10·0	9·0	12·2	10·2	13·7	11·4	12·6	10·9	10·8	12·7	10·2	12·4	10·9
13	9·8	8·2	9·3	9·9	9·8	9·8	8·7	12·7	10·2	13·3	10·8	12·3	10·7	11·4	11·7	9·6	12·3	11·2
14	10·0	8·0	9·8	9·4	9·9	9·6	8·2	12·7	10·3	12·7	10·4	12·0	10·8	11·6	10·6	9·8	12·3	11·2
15	9·7	7·8	10·6	8·9	10·1	9·3	7·9	12·7	10·5	12·1	10·0	11·5	10·1	11·6	10·1	9·1	12·1	11·2
16	9·0	7·6	11·4	8·7	9·5	8·8	7·6	12·2	11·6	11·7	9·7	11·2	10·1	11·2	9·7	9·1	11·6	11·0
17	8·0	7·4	11·7	8·9	8·7	8·5	7·5	11·8	12·7	11·2	9·7	11·0	10·3	11·3	9·6	10·8	11·0	10·6
18	7·7	7·2	11·5	9·1	8·0	8·0	7·5	11·2	12·7	11·0	9·4	11·0	10·7	11·3	9·5	12·5	10·5	10·2
19	7·5	7·1	11·1	8·7	7·4	7·7	7·4	11·0	12·7	10·8	9·0	11·0	10·7	10·7	9·5	13·4	9·9	10·5
20	7·7	6·9	10·7	8·3	7·0	7·5	7·2	10·9	12·8	10·7	8·7	11·3	10·2	10·2	9·8	14·1	9·5	11·1
21	7·5	6·7	10·1	8·1	6·8	7·2	7·1	10·2	13·1	10·4	8·6	11·5	9·6	9·6	9·9	14·1	9·3	11·7
22	7·4	6·4	9·7	7·5	6·7	7·3	7·3	9·5	13·2	10·4	8·2	11·2	8·9	9·1	9·7	13·6	9·0	11·4
23	7·3	6·1	9·8	6·9	6·5	7·2	8·4	9·1	13·2	10·2	8·1	11·0	8·5	8·6	9·8	11·7	8·3	10·7
24	7·8	5·8	10·2	6·7	6·2	7·2	8·3	8·8	12·2	9·8	7·8	10·6	7.0	8·0	9·9	10·8	8·2	9·5
25	7·3	5·7	10·7	6·5	5·9	7·7	8·2	8·7	11·4	9·7	7·7	10·3	7·7	7·7	10·2	9·5	8·0	8·1
26	7·2	5·7	11·0	6·5	5·7	7·8	7·7	8·6	10·8	9·4	7·6	10·1	7·4	7·2	10·0	9·0	7·8	7·6
27	7·1	5·7	10·8	6·4	5·7	8·4	7·2	8·4	10·7	9·5	7·3	9·7	7·2	6·8	9·6	8·4	7·5	7·5
28	7·0	5·7	10·8	6·2	5·6	8·8	6·7	8·2	11·2	9·6	7·8	9·4	6·8	6·6	8·7	8·1	7·3	7·4
29	6·7	5·6	9·7	6·1	5·7	9·1	6·5	8·2	11·7	9·4	7·2	9·2	6·7	6·8	8·1	7·8	7·2	7·2
30	6·6	5·4	9·3	5·7	5·6	8·6	6·2	8·1	12·1	9·1	7·1	9·0	6·7	6·1	7·7	7·7	7·0	7·2
Averages ..	9·4	7·7	9·8	9·0	8·7	8·8	8·3	10·7	11·8	12·3	9·5	12·0	10·7	9·3	11·0	11·3	10·3	11·0

Date.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.
	F. D.	F. D.	F. D.	F. D	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F.D.	F. D.	F. D.	F. D.
1	14·0	12·5	12·8	13·7	13·5	11·3	12·3	13·8	9·7	14·5	10·8	9.2	16·5	12·3	9·9	13·2	14·3	10·7	15·3
2	13·9	12·4	13·1	13·2	13·7	11·1	12·6	13·8	9·6	14·0	11·2	8.9	15·7	12·7	9·4	13·2	14·3	11·0	14·9
3	13·5	12·2	12·8	12·7	13.8	10·0	12·2	14·0	9·3	13·7	11·7	8·8	14·8	12·7	9·3	13·3	14·3	10·8	13·8
4	13·0	12·0	12·5	12.2	13·6	11·2	11·6	13.6	9·3	13·7	12·1	8.8	14·6	12·6	9·1	12·0	14·1	10·6	12·5
5	12·7	11·8	11·6	11·6	13·2	11·6	10·7	12·8	9·3	13·9	12·0	8·8	14·3	12·3	8·8	12·6	13·9	10·6	12·0
6	12·5	11·2	11·5	11·2	12·6	11·7	10·3	11·8	9·2	14·0	11·7	8·7	14·0	11·9	8·5	12·5	14·0	10·8	11·6
7	12·2	11·2	11·5	10·9	11·9	11·7	10·1	11·0	9·2	14·4	11·2	8·6	13·7	12 1	8·0	12·5	14·3	9·8	11·6
8	12·8	11·2	11·9	10·6	11.3	11.2	9·8	10·9	9·4	14·7	10·3	8·4	13·2	12·1	7·8	12·8	14·3	9·8	11·4
9	13·3	11·7	12·1	10·3	10·9	10.7	9.4	9·5	10·5	14.5	9·4	8·2	12·8	12·0	7·9	13·2	13·9	9·8	11·3
10	12.2	12·2	11·7	10·2	10.5	10·2	9·2	9·8	11·0	14·2	9·2	8·2	12·8	11·6	7·9	13·3	12·7	10·2	11·4
11	11·9	12·0	10·7	10·2	9·9	9.8	8·9	9·8	10·7	13·9	9·2	8·0	12·2	11·2	8·1	13·4	12·0	10·4	12·0
12	11·4	12.0	0·2	10·1	9·4	9·7	8·8	9·6	10·2	13·6	9·2	7·7	11·7	10·9	7·9	13·6	11·8	10·1	12·4
13	10·[illegible]	12·0	9·7	9·9	9·2	9·6	8·7	10·2	10·2	12·9	9·0	7·8	11·0	10·9	7·7	13·4	11·2	10·1	12·9
14	10·7	11·7	9·2	9.7	9·2	9·2	8·7	10.4	10 3	12·0	8·8	7·8	10·4	10·5	7·4	13·3	10·9	10·4	13·7
15	9·7	10.7	9·0	9.4	9·3	9·5	8·7	10·2	10·4	11·3	9·0	7·2	9·9	10·2	7·2	13·0	10·7	10·7	14·1
16	9·0	9·9	8·7	9·2	9·5	8·9	8·7	9·8	10·6	10·4	9·2	7·3	9·4	10·0	6·9	12·9	10·6	10·9	14·6
17	8·4	9.4	8·4	9·0	9·7	8·8	8·5	9·2	11·1	9·8	9·3	7·4	9·0	9·8	6·7	12·8	10·3	10·9	15·0
18	8·2	8·8	8.2	8.7	9·7	8·7	8·3	8 7	10·7	9·3	8·8	7·4	8·8	9·7	6·6	13·1	10·2	10·7	15·3
19	7·9	8·5	7·9	8·5	9·7	8.5	8·2	8·7	9·8	8·8	8·2	7·4	8·6	10·0	6·6	13·4	10·0	10·4	15·1
20	7·7	8·2	7·7	8·2	9·7	8·2	8·2	9·2	9·3	8·3	7·8	7·4	8·4	10·3	6·5	13·4	9·8	10·2	14·3
21	7·6	8.0	7.5	8·0	9·7	8·0	8·4	9·4	8·9	7·9	7·7	7·4	8·7	9·8	6·3	12·9	9·7	9·9	13·2
22	7·5	8·0	7·2	7·9	9.6	7·7	8·7	9·7	8·8	7·7	7·0	7·5	8·7	9·1	6·1	11·7	9·3	9·6	12·0
23	7·3	7·8	6.9	9.9	9·6	7·2	8·8	9·8	9·2	7·5	7·4	7·4	8·6	8·5	6·0	11·3	8.8	9·2	11·1
24	7·2	7·8	6.7	7·9	9.3	7.1	9·1	9·5	9·7	7·3	7·1	7·2	8·4	8·0	5·9	11·5	8.6	8·5	10·6
25	7·0	7·2	6·5	7·8	9·0	7.0	9·2	9·2	10·4	7·2	6·9	7·2	8·2	7·5	5·8	12·0	8.6	8·1	10·2
26	6·8	6·9	6·8	7·7	8·7	6·8	9·2	8 7	11·2	7·2	6·7	7·2	8·2	7·0	5.6	12·1	8.5	7·8	10·0
27	6·7	6·7	7·4	8·0	8·2	6.7	9·4	8·4	11·0	7·2	6·5	6·9	7·9	6·5	5.5	12·3	8.4	7·5	9·8
28	6·4	6·3	7·3	8·3	7.9	6·7	9·6	8·1	10·6	7·2	6·4	6·7	7·6	6·3	5.4	13·0	8.2	7·8	9·6
29	6·1	6·2	7.0	8.6	7·6	6·8	9·4	8·1	10·3	7·2	6·3	6·5	7·4	6·0	5.2	13·4	8.0	6·9	9·5
30	5·9	6·1	6.7	8.2	7·2	7·0	9·2	8·1	10·0	7·1	6·2	6·2	7·3	5·9	5·0	13·5	7.8	6·7	9·4
Averages ..	9·8	9·8	9·4	9·7	10·3	9·1	9·6	10·2	10·0	10·9	8·9	7·8	10·8	10·0	7·2	12·9	11·2	9·7	12·4

Date.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D	F. D.
1	11·9	12·6	15·2	8·9	14·6	14·1	14·2	10·1	11·5	12·0	9·9	11·3	10·1	14·3	10·2	12·6		
2	11·9	12·6	14·6	8·7	14·6	14·0	14·3	10·4	11·2	12·2	10·1	11·3	9·9	13·8	10·4	12·0		
3	11·6	12·7	14·2	8·2	14 3	14·1	14·4	10·8	10·5	12·1	10·1	11·0	10·7	13·0	10·6	11·2		
4	11·7	12·9	14·3	8·1	14·1	13·9	14·5	11·1	10·1	11·6	10·4	10·7	11·0	12·4	10·6	10·6		
5	11·7	12 6	14·5	7·9	14·0	13·8	14·2	11·7	10·0	11·0	10·5	10·3	10·4	11·7	10·4	10·4		
6	11·5	12·0	14·7	7·7	14·3	13·7	12·5	12·1	9·8	10·4	11·0	10·0	10·4	11·2	10·2	10·6		
7	11·3	11·4	14·7	7·7	14·6	13·7	11·2	11·9	9·5	10·2	11·2	9·8	10·3	10·8	10·0	10·6		
8	11·0	10·6	14·6	7·6	14·9	13·8	10·4	11·0	9·3	9·8	11·4	9·7	10·0	10·9	9·7	10·8		
9	10·6	10·1	13·6	7·5	15·3	14·1	9·9	9·8	9·0	9·4	11·5	9·5	9·4	10·5	9·4	11·1		
10	10·1	10·0	12·8	7·6	15·4	14·1	9·5	8·9	8·4	8·9	11·1	9·4	8·7	10·3	9·1	11·0		
11	9·9	10·1	12·4	7·9	15·5	14·1	9·3	8·1	7·8	8·8	10·3	8·9	8·0	10·2	8·8	9·6		
12	9·6	10·2	12·5	8·1	15·7	13·8	9·2	7·6	7·3	8·4	9·9	8·3	7·5	10·5	8·4	8·6		
13	9·3	10·4	12·4	8·0	15·4	13·4	8·9	7·4	7·0	8·1	9·9	7·7	7·2	9·8	8·2	8·0		
14	9·1	10·6	13·0	7·7	15·1	12·7	8·9	7·2	6·7	7·8	10·1	7·3	6·9	10·5	7·9	7·5		
15	8·8	11·0	13·7	7·5	14·5	12·7	8·5	7·4	6·8	7·4	10·4	7·1	6·7	10·2	7·7	7·2		
16	8·4	12 2	14·0	7·2	12·9	12·7	8·6	7·7	7·1	7·2	10·7	6·9	6·6	9·8	7·5	7·0		
17	8·3	13·0	14·0	7·0	11·5	13·1	8·8	8·3	7·2	6·9	10·9	6·8	6·7	10·1	7·2	6·8		
18	8·2	13·9	14·0	7·0	10.2	12·4	9·0	9·2	6·9	6·8	10·5	6·6	6·8	10·5	7·1	6·6		
19	8·5	14·5	13·4	6·9	9.5	11·1	9·5	9·7	6·5	6·7	10·2	6·5	6·9	11·5	7·1	6·3		
20	9·0	14·6	13·3	6·7	8.7	10·1	9·5	9·5	6·3	6·8	9·9	6·3	7·1	12·0	7·2	6·2		
21	9·3	14·5	13·8	6·5	8.4	9·0	9·2	9·1	6·1	6·8	9·5	6·2	7·5	11·9	6·9	6·0		
22	9·2	13·6	14·0	6·2	8·2	8·0	8·3	8·5	6·0	6·8	9·4	6·3	7·9	11·9	6·7	6·0		
23	8·9	11·8	14·2	6·0	8·0	7·4	7·8	8·3	6·0	6·7	9·2	6·6	8·0	11·8	6·5	6·1		
24	8·5	10·9	14·0	5·8	7·4	7·0	7·8	7·9	5·9	6·4	9·1	6·9	8·2	11·2	6·2	6·2		
25	8·2	10·0	13·6	5·7	7·1	6·8	7·1	7·8	5·8	6·3	9·3	6·9	7·0	11·1	5·9	6·3		
26	7·9	9·4	13·0	5·5	6·6	6·6	6·7	8·0	5·6	6·2	9·4	6·9	7·4	11·1	5·7	6·1		
27	7·7	9·2	11·3	5·5	6·2	6·6	6·5	7·9	5·5	6·1	9·5	6·8	7·0	11·7	5·5	5·7		
28	7·5	8·8	10·0	5·4	6·0	6·5	6·4	7·9	5·4	6·1	9·4	6·8	6·5	12·2	5·4	5·5		
29	7·4	8·6	9·8	5·3	5·6	6·4	6·2	7·7	5·3	5·9	9·2	6·9	6·2	12·8	5·3	5·4		
30	7·1	8·4	8·6	5·1	5·4	6·2	6·1	7·1	5·1	5·7	9·0	7·1	6·0	13·9	5·2	5·1		
Averages ..	9·5	11·5	13·3	7·1	11·5	11·2	9·6	9·0	7·5	8·2	10·1	8·1	8·1	11·5	7·9	8·1		

Readings of Bukkur Gauge for October.

Date.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	4·5	6·9	6·5	5·0	4·7	4·7	4·7	4·7	7·2	6·0	5·7	5·4	5·5
2	4·2	6·6	6·4	5·0	4·5	4·7	4·7	4·4	6·3	5·9	6·8	5·2	5·4
3	4·2	6·5	6·0	5·0	4·2	4·4	4·6	4·3	5·5	5·7	7·2	5·2	5·4
4	4·1	6·2	5·8	4·8	4·2	4·2	4·4	4·1	5·0	5·7	6·9	5·1	5·2
5	4·1	6·0	5·5	4·7	4·1	3·8	4·4	4·0	4·7	5·7	6·3	5·1	4·8
6	4·0	5·9	5·5	4·7	3·7	3·7	4·2	3·8	4·3	5·7	5·8	5·0	4·5
7	4·1	5·7	5·4	4·5	3·6	3·6	4·2	3·6	4·1	5·7	5·5	4·9	4·2
8	4·2	5·7	5·2	4·5	3·5	3·5	4·0	3·5	3·8	5·7	5·2	4·8	4·0
9	4·2	5·7	5·2	4·3	3·3	3·4	3·8	3·2	3·6	5·7	5·0	4·7	3·8
10	4·1	5·5	5·1	4·2	3·3	3·3	3·3	3·2	3·4	5·7	4·8	4·6	3·7
11	4·1	5·5	5·9	4·2	3·3	3·2	3·0	3·0	3·3	5·7	4·8	4·2	3·3
12	4·0	5·5	5·8	4·2	3·9	3·0	2·9	2·8	3·2	5·8	4·6	4·0	3·1
13	4·0	5·4	5·8	4·0	4·0	3·1	2·7	2·7	2·9	5·6	4·5	3·7	3·1
14	4·0	5·2	4·8	3·5	4·0	3·2	2·6	2·8	2·7	5·0	4·3	3·7	3·0
15	3·8	5·2	4·7	3·3	3·5	3·6	2·7	2·7	2·7	4·7	4·2	3·5	3·0
16	3·7	5·0	4·7	3·2	3·0	3·7	4·2	2·7	2·7	4·6	4·0	3·4	2·9
17	3·6	4·8	4·6	3·2	3·0	3·7	4·8	2·4	2·5	4·3	4·0	3·3	2·7
18	3·7	4·7	4·5	3·2	2·8	3·6	4·6	2·2	2·4	4·0	3·8	3·3	2·6
19	3·7	4·4	4·6	3·1	2·7	3·5	3·9	2·2	2·4	3·8	3·8	3·2	2·4
20	3·7	4·2	4·7	3·1	2·7	3·3	3·5	2·1	2·3	3·7	3·7	3·2	2·6
21	3·7	4·1	4·7	3·1	2·7	3·2	2·9	2·1	2·3	3·6	3·7	3·1	2·3
22	3·7	4·0	4·4	3·0	2·6	3·2	2·7	2·0	2·2	3·5	3·7	3·0	2·2
23	3·7	3·8	4·2	3·0	2·4	3·0	2·4	2·0	2·2	3·4	3·7	2·9	2·1
24	3·6	3·7	4·2	3·0	2·4	2·7	2·1	2·1	2·2	3·2	3·6	2·7	2·0
25	3·6	3·7	4·0	3·0	2·3	2·7	2·2	2·1	2·1	3·2	3·5	2·7	1·9
26	3·6	3·7	3·7	3·0	2·2	2·7	1·9	2·1	2·1	3·1	3·2	2·6	1·9
27	3·5	3·6	3·7	3·0	2·2	2·6	1·9	2·1	2·1	3·1	3·2	2·5	1·8
28	3·4	3·5	4·0	3·0	2·2	2·6	1·8	2·1	2·1	3·1	3·1	2·3	1·7
29	3·4	3·5	4·2	3·0	2·2	2·5	1·7	2·1	2·1	3·1	3·0	2·2	1·7
30	3·3	3·4	4·2	2·7	2·2	2·4	1·7	2·2	2·1	3·1	3·0	2·5	1·6
31	3·2	3·3	4·0	2·8	2·1	2·3	1·6	2·1	2·0	3·0	3·0	2·5	1·5
Averages	3·8	4·9	4·9	3·7	3·1	3·3	3·2	2·8	3·2	4·5	4·4	3·7	3·1

Date.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	6·2	6·7	3·9	4·7	8·3	4·7	6·5	5·2	9·5	5·6	5·5	7·7
2	6·0	6·7	3·7	4·4	8·1	4·7	6·5	5·1	9·6	5·5	5·2	6·5
3	5·8	6·7	3·4	4·2	7·9	4·7	6·5	4·8	9·7	5·5	5·2	5·7
4	5·8	6·7	3·2	4·0	7·8	4·7	6·6	4·7	9·7	5·5	5·0	5·4
5	5·8	6·7	3·2	3·9	7·7	4·7	6·5	4·7	9·5	5·5	5·0	5·1
6	5·9	7·1	3·0	3·8	7·5	4·3	6·3	4·5	8·7	5·4	5·1	4·8
7	6·2	7·4	2·9	3·7	7·5	4·2	6·2	4·3	8·1	5·4	5·1	4·6
8	6·0	7·3	2·8	3·6	7·5	4·2	6·0	4·2	7·6	5·3	4·9	4·4
9	5·7	7·3	2·7	3·4	7·5	4·0	5·7	4·2	7·4	5·1	4·7	4·2
10	5·5	7·5	2·7	3·3	7·3	4·0	5·4	4·1	7·2	4·9	4·6	4·0
11	5·3	8·0	2·7	3·2	7·1	3·9	5·1	4·0	7·0	4·8	4·4	4·0
12	5·1	8·4	2·5	3·2	6·9	3·9	4·8	3·8	6·8	4·8	4·3	3·8
13	4·8	8·4	2·5	3·1	6·8	4·0	4·5	3·7	6·5	4·7	4·2	3·7
14	4·6	7·4	2·4	3·0	6·7	3·9	4·2	3·5	6·2	4·6	4·1	3·5
15	4·4	6·5	2·2	2·9	6·7	3·8	4·0	3·4	6·1	4·5	4·0	3·4
16	4·2	6·0	2·2	2·8	6·7	3·7	3·8	3·3	5·9	4·4	3·9	3·2
17	4·1	5·8	2·1	2·7	6·6	3·7	3·8	3·2	5·7	4·3	3·8	3·2
18	3·9	5·6	2·0	2·6	6·5	3·7	3·7	3·3	5·5	4·3	3·6	3·2
19	3·8	5·5	2·0	2·5	6·4	3·6	3·5	3·0	5·4	4·2	3·5	3·1
20	3·7	5·5	1·8	2·4	6·3	3·6	3·4	2·8	5·3	4·2	3·4	3·0
21	3·7	5·3	1·7	2·3	6·2	3·6	3·2	2·7	5·2	4·0	3·2	2·9
22	3·6	5·0	1·7	2·2	6·1	3·5	3·2	2·7	5·0	3·8	3·2	2·7
23	3·5	4·8	1·7	2·2	5·8	3·4	3·1	2·6	5·0	3·7	3·1	2·7
24	3·4	4·7	1·7	2·2	5·6	3·3	3·0	2·5	5·0	3·6	3·0	2·6
25	3·3	4·6	1·6	2·1	5·5	3·3	2·8	2·4	5·1	3·4	2·9	2·6
26	3·2	4·3	1·5	2·0	5·3	3·2	2·7	2·3	5·2	3·2	2·7	2·6
27	3·2	4·2	1·4	2·0	5·2	3·2	2·7	2·2	5·1	3·1	2·5	2·6
28	3·1	4·0	1·3	1·9	5·1	3·1	2·7	2·2	4·9	2·9	2·5	2·6
29	3·0	4·0	1·2	1·8	4·9	3·0	2·7	2·1	4·7	2·8	2·3	2·6
30	2·9	3·9	1·1	1·7	4·7	3·0	2·7	2·0	4·4	2·7	2·3	2·6
31	2·7	3·8	0·9	1·7	4·7	2·9	2·6	1·9	4·2	2·6	2·0	2·5
Averages	4·5	6·0	2·2	2·9	6·5	3·8	4·3	3·4	6·5	4·3	3·8	3·7

Date.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	6·0	8·0	12·2	8·7	6·9	8·6	6·7	5·8	7·2	7·5	7·0	8·0
2	5·7	7·8	12·5	8·4	6·8	8·2	6·5	5·6	6·9	7·2	6·9	8·9
3	5·7	7·7	12·8	8·2	6·7	7·9	6·5	5·5	6·7	7·2	6·7	9·1
4	5·6	7·6	12·8	8·0	6·7	7·7	6·5	5·2	6·7	7·1	6·8	8·8
5	5·6	7·4	12·7	7·7	6·5	7·4	6·7	5·0	6·6	7·0	6·7	7·5
6	5·7	7·2	12·1	7·5	6·2	7·2	6·9	4·7	6·6	6·9	6·7	6·7
7	5·7	7·1	11·6	7·4	6·2	7·0	6·7	4·6	6·5	6·7	6·5	6·8
8	5·4	6·8	11·5	7·3	6·0	6·7	6·5	4·5	6·4	6·7	6·2	6·3
9	5·2	6·5	11·2	7·3	5·8	6·6	6·2	4·3	6·3	6·7	6·0	6·6
10	5·1	6·2	10·9	7·2	5·7	6·5	6·0	4·2	6·2	6·4	5·8	6·6
11	4·8	6·1	10·5	6·9	5·6	6·5	5·7	4·2	6·1	6·3	5·5	6·2
12	4·7	5·9	9·8	6·8	5·4	6·4	5·4	4·0	5·9	6·2	5·2	5·5
13	4·6	5·7	9·3	6·7	5·4	6·2	5·3	3·9	5·7	6·0	5·2	5·2
14	4·4	5·6	9·2	6·6	5·3	6·1	5·1	3·8	5·6	5·9	5·1	4·8
15	4·2	5·5	8·9	6·3	5·2	5·9	5·1	3·7	5·3	5·8	4·9	4·6
16	4·1	5·3	8·2	6·2	5·1	6·0	4·9	3·6	5·1	5·7	4·7	4·2
17	3·9	5·2	7·7	6·2	5·2	5·7	4·7	3·5	4·9	5·6	4·7	4·2
18	3·7	5·1	7·4	6·2	5·6	5·6	4·5	3·4	4·7	5·3	4·6	4·2
19	3·6	4·9	7·2	6·0	5·8	5·6	4·4	3·3	4·7	5·3	4·6	4·1
20	3·5	4·8	6·9	6·0	5·7	5·3	4·3	3·2	4·6	5·3	4·4	4·0
21	3·5	4·7	6·8	6·0	5·4	5·2	4·2	3·2	4·5	5·2	4·3	3·8
22	3·3	4·6	6·7	6·0	5·2	5·1	4·1	3·0	4·4	5·2	4·2	3·7
23	3·2	4·5	6·4	6·1	5·1	4·9	3·9	3·0	4·3	5·2	4·2	3·6
24	3·2	4·5	6·2	6·0	5·0	4·9	3·8	2·9	4·2	5·1	4·2	3·5
25	3·1	4·4	6·1	5·7	4·9	4·7	3·7	2·8	4·2	5·0	4·0	3·5
26	3·1	4·2	6·0	5·7	4·8	4·8	3·6	2·7	4·0	4·9	4·0	3·4
27	3·1	4·2	5·8	5·6	4·7	4·7	3·5	2·6	3·8	4·8	3·9	3·2
28	3·0	4·2	5·8	5·4	4·6	4·4	3·4	2·5	3·7	4·7	3·8	3·2
29	2·9	4·2	5·7	5·2	4·5	4·4	3·2	2·4	3·7	4·7	3·7	3·1
30	2·7	4·1	5·5	5·2	4·3	4·3	3·1	2·3	3·6	4·6	3·7	3·1
31	2·7	4·0	5·4	5·0	4·2	4·2	2·9	2·2	3·5	4·5	3·7	3·1
Averages	4·2	5·6	8·8	6·6	5·5	6·0	5·0	3·8	5·3	5·8	5·2	5·2

Date.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894	1895.	1896.	1897.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	5·7	6·0	6·4	7·9	7·0	7·1	8·9	8·2	8·8	6·8	5·8	6·0	7·2
2	5·6	5·8	6·0	7·8	6·8	7·1	8·6	8·3	8·1	6·7	5·4	5·6	7·1
3	5·4	5·7	5·5	7·8	6·7	7·1	8·3	8·2	7·5	6·7	5·1	5·5	7·6
4	5·0	5·7	5·3	7·7	6·4	7·2	7·8	8·2	7·2	6·6	5·0	5·2	7·9
5	4·9	5·7	5·2	7·3	6·2	7·3	7·5	7·8	6·7	6·6	4·7	5·0	7·6
6	4·7	5·7	5·0	7·2	6·2	7·4	7·2	7·7	6·7	6·5	4·6	4·7	7·0
7	4·5	5·7	4·8	6·8	6·0	7·3	6·8	7·4	6·5	6·4	4·5	4·4	6·7
8	4·2	5·7	4·7	6·7	5·8	7·2	6·7	7·0	6·5	6·2	4·4	4·2	6·6
9	4·0	5·7	4·7	6·6	5·7	7·0	6·7	6·9	6·2	6·1	4·3	4·1	6·4
10	3·8	5·4	4·7	6·6	5·5	6·8	6·9	6·7	6·0	5·8	4·3	3·9	6·2
11	3·7	5·2	4·6	6·6	5·4	6·7	6·8	6·4	5·8	5·7	4·3	3·7	6·1
12	3·6	5·1	4·7	6·2	5·3	6·6	6·7	6·3	5·5	5·5	4·2	3·7	5·8
13	3·5	5·2	4·6	6·0	5·2	6·4	6·7	6·2	5·3	5·3	4·2	3·6	5·6
14	3·3	5·6	4·5	5·8	5·2	6·2	6·4	6·1	5·2	5·1	4·0	3·6	5·5
15	3·2	5·7	4·5	5·7	5·0	6·1	6·0	6·0	5·2	4·8	4·0	3·5	5·4
16	3·2	5·7	4·4	5·4	4·9	5·9	5·7	5·9	4·9	4·7	3·9	3·4	5·2
17	3·2	5·5	4·3	5·3	4·8	5·7	5·5	5·7	4·8	4·6	3·9	3·2	5·2
18	3·1	5·2	4·2	5·2	4·7	5·7	5·3	5·7	4·7	4·3	3·8	3·2	4·9
19	3·0	5·0	4·2	5·1	4·7	5·5	5·2	5·7	4·4	4·1	3·7	3·1	4·8
20	3·0	4·8	4·1	4·9	4·6	5·3	5·2	5·6	4·1	4·0	3·7	2·9	4·7
21	3·0	4·7	4·0	4·7	4·5	5·2	5·1	5·5	4·0	3·8	3·5	2·8	4·6
22	3·0	4·6	4·0	4·6	4·4	5·2	5·0	5·3	3·9	3·7	3·5	2·7	4·4
23	2·8	4·6	4·0	4·5	4·2	5·2	4·9	5·2	3·8	3·7	3·4	2·7	4·2
24	2·8	4·5	4·0	4·4	4·2	5·0	4·7	5·2	3·7	3·5	3·3	2·6	4·1
25	2·6	4·3	3·9	4·3	4·1	4·9	4·6	5·2	3·6	3·4	3·2	2·6	4·0
26	2·6	4·2	3·8	4·2	4·0	4·8	4·5	5·2	3·6	3·3	3·1	2·4	3·9
27	2·5	4·0	3·8	4·1	3·9	4·7	4·5	5·1	3·4	3·2	3·1	2·4	3·7
28	2·4	4·0	3·7	4·0	3·8	4·7	4·4	5·0	3·3	3·1	3·0	2·3	3·7
29	2·3	3·9	3·7	3·9	3·7	4·6	4·4	4·9	3·2	3·1	2·8	2·2	3·5
30	2·3	3·8	3·6	3·8	3·7	4·5	4·2	4·9	3·2	2·9	2·7	2·1	3·4
31	2·3	3·7	3·6	3·7	3·7	4·5	4·2	4·4	3·1	2·7	2·7	2·1	3·3
Averages	3·6	5·1	4·5	5·6	5·1	6·0	6·1	6·3	5·2	4·9	4·0	3·6	5·1

Date.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	5·8	4·9	12·7	7·5	6·5	9·3	6·8	8·1	8·2	5·0	5·2	6·2	6·0
2	5·7	4·7	11·3	7·3	6·4	9·3	6·6	7·8	7·8	4·9	5·1	6·1	5·7
3	5·7	4·5	10·3	7·1	6·1	9·2	6·5	7·7	7·7	4·9	5·0	6·1	5·7
4	5·7	4·8	9·7	6·9	6·1	9·1	6·3	7·4	7·5	4·8	4·9	6·0	5·5
5	5·6	4·1	9·3	6·6	6·0	9·1	6·1	7·2	7·4	4·6	4·7	5·9	5·3
6	5·4	4·0	9·0	6·5	5·8	9·0	5·9	7·0	7·2	4·4	4·6	5·6	5·1
7	5·4	3·9	8·5	6·4	5·8	8·9	5·8	6·8	7·0	4·2	4·6	5·4	4·9
8	5·4	3·8	8·1	6·3	5·7	8·8	5·7	6·6	6·8	4·1	4·7	5·2	4·6
9	5·3	3·6	7·8	6·1	5·5	8·8	5·6	6·5	6·6	4·0	4·6	5·1	4·5
10	5·0	3·5	7·6	6·0	5·5	8·6	5·6	6·3	6·4	3·9	4·4	5·0	4·3
11	4·9	3·4	7·3	6·0	5·5	8·4	5·5	6·2	6·1	3·8	4·2	4·8	4·1
12	4·7	3·3	7·2	6·1	5·4	8·2	5·4	6·2	6·1	3·6	3·9	4·7	4·2
13	4·5	3·2	7·0	6·4	5·4	8·0	5·2	6·0	6·1	3·5	3·7	4·5	4·2
14	4·4	3·0	6·8	6·4	5·3	7·7	5·1	5·8	5·9	3·4	3·5	4·4	4·1
15	4·3	2·9	6·6	6·2	5·2	7·5	4·9	5·6	5·8	3·3	3·2	4·4	4·0
16	4·2	2·9	6·4	6·1	5·1	7·3	4·8	5·5	5·7	3·2	3·1	4·4	3·9
17	4·1	2·8	6·3	6·0	5·1	7·2	4·7	5·5	5·5	3·1	3·0	4·3	3·9
18	3·2	2·7	6·1	6·1	5·0	7·1	4·7	5·3	5·4	3·0	2·9	4·2	3·9
19	3·6	2·6	5·9	6·1	4·9	6·9	4·6	5·2	5·3	2·9	2·7	4·0	3·7
20	3·5	2·5	5·8	5·8	4·9	6·9	4·5	5·1	5·2	2·8	2·7	3·9	3·7
21	3·5	2·5	5·6	5·6	4·9	6·8	4·4	5·0	5·1	2·7	2·7	3·9	3·6
22	3·5	2·4	5·5	5·5	4·7	6·6	4·3	5·0	4·8	2·5	2·6	3·8	3·5
23	3·5	2·4	5·4	5·4	4·7	6·5	4·2	4·9	4·7	2·4	2·5	3·6	3·4
24	3·4	2·3	5·2	5·3	4·5	6·4	4·1	4·8	4·6	2·3	2·5	3·6	3·3
25	3·3	2·2	5·1	5·2	4·5	6·4	4·0	4·7	4·5	2·2	2·4	3·6	3·1
26	3·3	2·2	5·0	5·1	4·4	6·3	3·9	4·6	4·4	2·1	2·4	3·5	3·1
27	3·0	2·1	4·9	5·0	4·3	6·3	3·9	4·5	4·3	2·0	2·3	3·5	3·0
28	3·0	2·0	4·8	4·9	4·3	6·2	3·8	4·5	4·2	2·0	2·3	3·5	2·9
29	2·9	1·9	4·7	4·8	4·3	6·1	3·7	4·4	4·1	1·8	2·1	3·4	2·8
30	2·9	1·9	4·6	4·6	4·3	6·0	3·7	4·3	4·0	1·6	2·0	3·2	2·7
31	2·8	1·9	4·6	4·5	4·2	5·9	3·6	4·2	3·9	1·5	1·9	3·1	2·7
Averages	4·2	3·0	7·0	5·9	5·2	7·6	5·0	5·8	5·9	3·2	3·5	4·5	4·0

Date.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D	F. D.	F. D.
1	6·4	5·0	5·7	8·8	7·5	5·9	14·3	5·1	5·1		
2	5·9	4·9	5·6	8·2	7·6	5·6	14·6	4·9	5·0		
3	5·6	4·9	5·5	7·2	7·6	5·4	14·5	4·8	4·8		
4	5·3	4·7	5·4	6·6	7·6	5·2	12·5	4·6	4·5		
5	5·1	4·6	5·3	6·1	7·6	5·2	11·5	4·6	4·5		
6	5·0	4·5	5·2	5·8	7·7	5·0	10·2	4·4	4·3		
7	4·8	4·4	5·2	5·7	7·5	5·0	9·4	4·2	4·1		
8	4·7	4·4	5·1	5·4	7·8	5·2	8·5	4·1	3·9		
9	4·7	4·4	5·0	5·3	6·9	5·2	7·8	4·0	3·7		
10	4·6	4·3	4·8	5·2	6·4	5·4	7·5	3·8	3·5		
11	4·5	4·4	4·8	5·1	6·2	6·1	7·2	3·6	3·4		
12	4·5	4·4	4·7	5·0	5·8	6·4	7·0	3·6	3·3		
13	4·4	4·3	4·6	4·9	5·5	6·3	6·9	3·5	3·1		
14	4·4	4·2	4·5	4·8	5·2	6·1	6·7	3·4			
15	4·3	4·2	4·4	4·7	5·0	5·8	6·6	3·3			
16	4·3	4·1	4·4	4·6	4·7	5·4	6·3	3·3			
17	4·2	4·1	4·3	4·5	4·4	5·2	5·9	3·2			
18	4·0	4·0	4·2	4·5	4·2	5·2	5·5	3·1			
19	3·8	4·0	4·2	4·4	4·0	5·2	5·3	3·0			
20	3·7	3·9	4·2	4·3	3·9	5·2	5·1	2·9			
21	3·6	3·8	4·1	5·0	3·7	5·1	4·9	2·8			
22	3·5	3·8	4·1	5·3	3·6	4·6	4·8	2·7			
23	3·4	3·7	4·0	4·9	3·4	4·3	4·5	2·6			
24	3·3	3·5	3·9	4·7	3·4	4·2	4·3	2·5			
25	3·2	3·5	3·8	4·6	3·2	4·0	4·1	2·4			
26	3·2	3·3	3·7	4·8	3·2	3·8	4·0	2·3			
27	3·3	3·3	3·6	4·8	3·1	3·7	3·9	2·2			
28	3·2	3·2	3·6	4·7	3·0	3·6	3·8	2·2			
29	3·1	3·1	3·5	4·4	2·9	3·5	3·7	2·1			
30	3·1	3·0	3·4	4·1	2·8	3·3	3·6	2·0			
31	3·1	3·0	3·4	4·1	2·8	3·3	3·3	2·0			
Averages	4·2	4·0	4·5	5·2	5·1	5·0	7·0	3·3	..		

Reading of Bukkur Gauge for November.

Date.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.	1864.	1865.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1 ..	3·2	3·2	3·7	2·7	2·1	2·3	1·4	2·1	2·2	3·0	3·0	2·4	1·5	2·7	3·7	0·9	1·7	4·6
2 ..	3·3	3·2	3·5	2·7	2·0	2·2	1·4	2·1	2·1	3·0	2·9	2·3	1·5	2·6	3·7	0·8	1·6	4·4
3 ..	3·3	3·2	3·5	2·7	2·0	2·2	1·3	2·1	1·9	3·0	2·9	2·2	1·4	2·5	3·5	0·7	1·6	4·3
4 ..	3·4	3·2	3·5	2·5	2·0	2·0	1·2	2·1	1·9	3·1	2·9	2·1	1·3	2·4	3·3	0·8	1·5	4·2
5 ..	3·4	3·2	3·4	2·5	2·0	1·7	1·1	2·4	1·9	3·0	2·8	2·0	1·3	2·3	3·0	1·9	1·5	4·2
6 ..	3·4	3·2	3·3	2·4	2·1	1·7	1·1	2·5	2·0	3·0	2·8	1·9	1·2	2·2	3·0	2·2	1·5	4·0
7 ..	3·3	3·2	3·3	2·4	2·2	1·7	1·1	2·5	1·9	3·0	2·8	1·8	1·2	2·2	3·0	1·9	1·4	3·9
8 ..	3·2	3·1	3·2	2·0	2·0	1·8	1·0	2·4	1·9	2·9	2·8	1·7	1·2	2·1	3·0	1·7	1·3	3·7
9 ..	3·1	2·9	3·2	2·0	2·0	1·8	1·0	2·4	1·9	2·8	2·8	1·7	1·1	2·0	2·8	1·6	1·3	3·7
10 ..	3·0	2·8	3·2	2·2	2·0	1·8	1·0	2·3	1·9	2·7	2·8	1·6	1·0	1·9	2·7	1·3	1·3	3·7
11 ..	2·8	2·8	3·2	2·2	1·9	1·7	0·9	2·4	2·0	2·8	2·8	1·6	1·0	1·8	2·7	1·2	1·3	3·6
12 ..	2·7	2·7	3·0	2·2	1·9	1·6	0·9	2·3	2·0	2·7	2·8	1·5	1·1	1·7	2·6	0·9	1·2	3·5
13 ..	2·6	2·7	3·0	2·0	1·9	1·4	0·9	2·3	2·1	2·7	2·8	1·5	1·0	1·7	2·5	0·7	1·2	3·3
14 ..	2·5	2·7	3·1	2·0	1·8	1·3	0·8	2·4	2·2	2·6	2·7	1·5	1·0	1·7	2·4	0·7	1·1	3·2
15 ..	2·4	2·7	3·0	2·0	1·8	1·2	0·9	2·2	2·2	2·6	2·8	1·4	1·0	1·7	2·3	0·7	1·1	3·2
16 ..	2·3	2·7	3·0	2·0	1·7	1·1	0·8	2·1	2·2	2·6	2·7	1·3	0·9	1·6	2·3	0·7	1·1	3·2
17 ..	2·2	2·7	3·1	1·8	1·7	1·0	0·7	1·9	2·2	2·4	2·7	1·3	0·8	1·6	2·3	0·6	1·0	3·1
18 ..	2·3	2·7	3·1	1·8	1·7	0·9	0·7	1·8	2·2	2·4	2·7	1·3	0·8	1·6	2·2	0·5	0·9	3·0
19 ..	2·3	2·6	3·0	1·8	1·6	0·9	0·7	1·7	2·2	2·3	2·7	1·3	0·7	1·6	2·2	0·4	0·9	2·9
20 ..	2·2	2·6	2·7	1·7	1·5	0·9	0·7	1·7	2·2	2·4	2·7	1·2	0·7	1·5	2·0	0·4	0·9	2·8
21 ..	2·2	2·4	2·7	1·6	1·5	0·8	0·7	1·6	2·2	2·3	2·7	1·2	0·6	1·5	2·0	0·4	0·9	2·8
22 ..	2·2	2·3	2·6	1·5	1·5	0·7	0·6	1·6	2·2	2·3	2·7	1·2	0·5	1·5	1·9	0·4	0·9	2·8
23 ..	2·2	2·2	2·6	1·5	1·4	0·7	0·6	1·5	2·1	2·3	2·7	1·2	0·5	1·4	1·9	0·3	0·8	2·6
24 ..	2·2	2·2	2·4	1·6	1·4	0·7	0·6	1·5	2·0	2·3	2·7	1·1	0·5	1·4	1·8	0·2	0·8	2·7
25 ..	2·1	2·1	2·4	1·6	1·4	0·8	0·7	1·5	1·9	2·3	2·7	1·0	0·5	1·3	1·8	0·2	0·7	2·7
26 ..	2·0	2·0	2·3	1·5	1·3	0·8	0·7	1·6	1·8	2·3	2·7	1·0	0·5	1·3	1·7	0·1	0·7	2·7
27 ..	2·0	2·0	2·2	1·4	1·3	0·7	0·7	1·7	1·9	2·2	2·6	1·0	0·5	1·3	1·7	0·0	0·7	2·6
28 ..	1·9	2·0	2·2	1·4	1·2	0·7	0·7	1·6	1·9	2·2	2·6	0·8	0·5	1·2	1·6	0·0	0·6	2·6
29 ..	1·8	1·9	2·2	1·3	1·2	0·7	0·7	1·4	2·0	2·2	2·4	0·8	0·4	1·2	1·6	0·0	0·6	2·5
30 ..	1·8	1·9	2·1	1·4	1·2	0·7	0·7	1·7	2·1	2·2	2·4	0·8	0·3	1·2	1·6	0·1	0·5	2·5
Averages ..	2·6	2·6	2·9	1·9	1·7	1·3	0·9	2·0	2·0	2·6	2·7	1·4	0·9	1·8	2·4	0·7	1·1	3·3

Date.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1 ..	2·9	2·3	1·8	4·0	2·4	1·9	2·4	2·8	4·0	5·2	4·9	4·2	4·2	2·8	2·2	3·4	4·4	3·7	3.0
2 ..	2·8	2·1	1·7	3·9	2·4	1·8	2·2	2·6	3·9	5·1	5·0	4·1	4·0	2·7	2·2	3·2	4·4	3·6	3.0
3 ..	2·7	2·3	1·7	3·8	2·4	1·7	2·2	2·5	3·9	5·0	5·0	4·0	4·0	2·6	2·1	3·2	4·3	3·5	3.0
4 ..	2·7	2·2	1·7	3·7	2·3	1·7	2·2	2·4	3·9	4·8	5·1	3·8	4·0	2·6	2·1	3·0	4·2	3·4	3.0
5 ..	2·6	2·2	1·6	3·5	2·3	1·7	2·0	2·3	3·8	4·7	5·2	3·7	3·9	2·5	2·1	3·0	4·2	3·3	2.0
6 ..	2·5	2·2	1·6	3·4	2·3	1·7	1·9	2·3	3·8	4·7	5·0	3·7	3·8	2·5	2·1	2·9	4·1	3·3	2.9
7 ..	2·4	2·1	1·5	3·3	2·3	1·6	1·8	2·3	3·7	4·6	4·7	3·7	3·8	2·3	1·9	2·8	4·0	3·3	2.9
8 ..	2·3	2·1	1·4	3·3	2·2	1·5	1·7	2·3	3·7	4·5	4·7	3·7	3·7	2·3	1·8	2·7	4·0	3·2	2.9
9 ..	2·2	2·0	1·4	3·2	2·0	1·5	1·7	2·3	3·7	4·3	4·7	3·7	3·7	2·2	1·7	2·6	3·8	3·2	2.9
10 ..	2·2	1·9	1·4	3·1	1·9	1·3	1·7	2·2	3·7	4·3	4·6	3·7	3·7	2·2	1·7	2·5	3·8	3·2	2·9
11 ..	2·2	1·9	1·4	2·9	1·8	1·2	1·7	2·2	3·6	4·2	4·5	3·7	3·7	2·1	1·5	2·4	3·7	3·1	2·9
12 ..	2·1	1·8	1·3	2·8	1·7	1·2	1·6	2·2	3·6	4·1	4·4	3·6	3·6	2·1	1·5	2·3	3·7	3·1	2·8
13 ..	2·0	1·8	1·3	2·7	1·7	1·1	1·6	2·1	3·5	3·9	4·2	3·6	3·5	2·0	1·4	2·2	3·6	3·0	2·8
14 ..	1·9	1·8	1·2	2·7	1·6	1·1	1·6	2·1	3·4	3·8	4·2	3·5	3·4	2·0	1·3	2·2	3·4	3·0	2·7
15 ..	1·9	1·7	1·2	2·6	1·5	1·0	1·2	2·0	3·3	3·7	4·2	3·4	3·4	1·9	1·2	2·2	3·4	3·0	2·7
16 ..	1·9	1·7	1·2	2·5	1·4	1·0	1·1	1·9	3·3	3·6	3·9	3·3	3·4	1·8	1·2	2·1	3·3	2·9	2·6
17 ..	1·8	1·6	1·2	2·3	1·4	0·9	1·0	1·9	3·2	3·5	3·9	3·3	3·3	1·7	1·2	2·0	3·2	2·9	2·5
18 ..	1·8	1·5	1·1	2·2	1·2	0·8	0·9	1·8	3·2	3·4	3·7	3·4	3·3	1·7	1·0	2·0	3·1	2·9	2·5
19 ..	1·7	1·5	1·1	2·2	1·1	0·8	0·8	1·7	3·1	3·3	3·7	3·5	3·3	1·6	0·9	1·9	3·1	3·3	2·5
20 ..	1·7	1·4	1·0	2·2	1·0	0·7	0·8	1·7	3·0	3·2	3·6	3·4	3·3	1·6	0·9	1·8	3·1	4·0	2·5
21 ..	1·7	1·3	1·0	2·1	1·0	0·7	0·7	1·4	3·0	3·2	3·5	3·4	3·3	1·6	0·8	1·7	3·1	4·4	2·4
22 ..	1·7	1·3	0·9	2·1	0·9	0·7	0·7	1·3	2·9	3·1	3·4	3·5	3·2	1·6	0·7	1·7	3·1	4·4	2·4
23 ..	1·6	1·2	0·9	2·0	0·9	0·7	0·6	1·2	2·8	3·1	3·3	3·6	3·2	1·5	0·7	1·6	3·1	4·2	2·3
24 ..	1·5	1·2	0·9	1·9	0·8	0·7	0·5	1·2	2·8	3·0	3·2	4·9	3·2	1·4	0·7	1·5	3·1	4·0	2·2
25 ..	1·4	1·2	0·8	1·9	0·8	0·7	0·5	1·1	2·7	2·9	3·2	6·2	3·2	1·3	0·7	1·5	3·0	3·8	2·2
26 ..	1·4	1·2	0·8	1·9	0·7	0·5	0·4	1·1	2·7	2·9	3·2	6·6	3·2	1·3	0·7	1·4	2·9	3·7	2·1
27 ..	1·3	1·1	0·8	1·8	0·7	0·5	0·3	1·1	2·7	2·8	3·1	6·5	3·2	1·2	0·6	1·4	2·9	3·5	2·1
28 ..	1·3	1·1	0·8	1·8	0·7	0·5	0·3	1·2	2·7	2·8	3·0	6·2	3·1	1·2	0·6	1·3	2·8	3·4	2·0
29 ..	1·3	1·0	0·7	1·7	0·7	0·4	0·2	1·2	2·6	2·7	3·0	8·5	3·1	1·1	0·5	1·2	2·7	3·2	1·9
30 ..	1·2	1·0	0·7	1·7	0·6	0·3	0·2	1·2	2·5	2·7	3·0	12·0	3·1	1·1	0·5	1·2	2·7	3·1	1·9
Averages ..	2·0	1·7	1·2	2·6	1·5	1·1	1·2	1·8	3·3	3·8	4·0	4·5	3·5	1·9	1·3	2·2	3·5	3·5	2·6

Date.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1 ..	2·2	3·6	3·5	3·7	3·5	4·6	4·1	4·3	3·0	2·6	2·7	2·1	3·2	2·8	1·9	4·5	4·4	4·1
2 ..	2·2	3·6	3·4	3·6	3·4	4·5	4·1	4·3	2·9	2·5	2·7	2·1	3·1	2·7	1·9	4·4	4·3	4·0
3 ..	2·2	3·6	3·4	3·5	3·3	4·4	4·0	4·2	2·8	2·1	2·7	2·1	3·0	2·6	1·8	4·4	4·2	3·9
4 ..	2·2	3·5	3·3	3·4	3·2	4·4	4·0	4·2	2·7	2·0	2·6	2·1	3·0	2·6	1·7	4·3	4·2	3·8
5 ..	2·0	3·4	3·2	3·4	3·2	4·2	3·9	4·0	2·7	1·8	2·5	1·9	2·8	2·5	1·6	4·2	4·1	3·8
6 ..	1·8	3·3	3·2	3·3	3·2	4·2	3·8	4·0	2·6	1·7	2·4	1·9	2·7	2·4	1·6	4·2	4·0	3·7
7 ..	1·8	3·3	3·2	3·3	3·2	4·2	3·7	3·9	2·6	1·6	2·3	1·9	2·7	2·4	1·5	4·1	3·9	3·7
8 ..	1·7	3·3	3·1	3·0	3·2	4·1	3·7	3·9	2·5	1·6	2·3	1·9	2·7	2·4	1·5	4·0	3·9	3·6
9 ..	1·7	3·2	3·0	3·0	3·2	4·0	3·6	3·7	2·4	1·5	2·2	1·7	2·6	2·3	1·4	4·0	3·9	3·6
10 ..	1·9	3·2	2·9	2·9	3·2	3·8	3·5	3·7	2·3	1·4	2·2	1·7	2·5	2·2	1·4	3·9	3·8	3·6
11 ..	1·9	3·0	2·8	2·8	3·1	3·7	3·4	3·7	2·3	1·3	2·0	1·7	2·5	2·1	1·3	3·8	3·8	3·9
12 ..	1·8	3·0	2·8	2·8	3·1	3·7	3·2	3·7	2·2	1·2	2·0	1·6	2·5	2·0	1·3	3·8	3·6	4·0
13 ..	1·7	2·9	2·8	2·7	3·0	3·6	3·2	3·5	2·2	1·2	1·9	1·5	2·4	2·0	1·2	3·8	3·6	3·9
14 ..	1·7	2·8	2·7	2·6	3·0	3·5	3·2	3·5	2·0	1·2	1·8	1·4	2·3	1·9	1·2	3·7	3·4	3·8
15 ..	1·7	2·8	2·7	2·6	2·9	3·4	3·2	3·4	1·9	1·2	1·8	1·4	2·3	1·8	1·1	3·7	3·4	3·7
16 ..	1·6	2·7	2·7	2·5	2·9	3·3	3·2	3·4	1·9	1·2	1·8	1·4	2·2	1·5	1·1	3·6	3·3	3·6
17 ..	1·6	2·7	2·6	2·4	2·8	3·2	3·2	3·2	1·9	1·3	1·7	1·4	2·1	1·6	1·1	3·5	3·3	3·5
18 ..	1·5	2·7	2·6	2·4	2·7	3·1	3·0	3·2	1·8	1·2	1·6	1·4	2·1	1·5	1·0	3·4	3·2	3·4
19 ..	1·5	2·7	2·5	2·3	2·7	3·0	2·9	3·2	1·8	1·1	1·5	1·4	2·0	1·4	1·0	3·3	3·1	3·3
20 ..	1·4	2·7	2·5	2·3	2·7	2·9	2·9	3·0	1·7	1·0	1·5	1·4	1·9	1·3	0·9	3·3	3·1	3·3
21 ..	1·4	2·6	2·5	2·4	2·7	2·9	2·8	3·0	1·7	1·0	1·5	1·3	1·9	1·4	0·9	3·2	3·1	3·2
22 ..	1·3	2·6	2·5	2·4	2·6	2·9	2·8	2·9	1·7	0·9	1·5	1·3	1·8	1·3	0·9	3·1	3·0	3·2
23 ..	1·2	2·6	2·4	2·3	2·6	2·8	2·7	2·8	1·6	0·7	1·5	1·2	1·8	1·2	0·8	3·1	2·9	3·1
24 ..	1·2	2·5	2·4	2·2	2·5	2·8	2·7	2·7	1·6	0·7	1·4	1·2	1·7	1·2	0·8	3·0	2·9	3·1
25 ..	1·2	2·4	2·3	2·2	2·5	2·8	2·7	2·7	1·5	0·7	1·3	1·2	1·7	1·2	0·7	2·9	2·9	3·1
26 ..	1·2	2·3	2·3	2·2	2·4	2·8	2·7	2·5	1·5	0·6	1·3	1·2	1·6	1·2	0·7	2·9	2·8	3·0
27 ..	1·2	2·3	2·2	2·1	2·4	2·9	2·7	2·5	1·5	0·5	1·2	1·2	1·6	1·0	0·6	2·8	2·8	3·0
28 ..	1·2	2·2	2·2	2·1	2·3	2·9	2·6	2·5	1·5	0·5	1·2	1·1	1·6	1·0	0·6	2·8	2·7	3·0
29 ..	1·1	2·2	2·2	2·1	2·3	2·8	2·6	2·4	1·4	0·4	1·1	1·1	1·6	0·9	0·6	2·8	2·7	3·0
30 ..	1·1	2·2	2·2	2·1	2·2	2·7	2·5	2·4	1·4	0·4	1·1	1·0	1·5	0·9	0·5	2·7	2·6	2·9
Averages ..	1·6	2·9	2·8	2·7	2·9	3·5	3·2	3·4	2·1	1·3	1·9	1·6	2·3	1·7	1·1	3·5	3·4	3·4

Date.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1 ..	5·8	3·6	4·1	3·8	1·5	1·7	3·1	2·7	3·1	3·0	3·4	3·9	2·7	3·2	3·6	1·9			
2 ..	5·7	3·5	4·0	3·3	1·4	1·6	3·1	2·6	3·1	3·0	3·4	3·8	2·7	3·1	6·7	1·8			
3 ..	5·6	3·5	4·0	3·3	1·4	1·4	2·9	2·5	3·0	2·9	3·3	3·8	2·6	3·1	7·3	1·8			
4 ..	5·5	3·4	3·9	3·2	1·4	1·3	2·9	2·4	2·9	2·8	3·3	4·7	2·6	3·0	7·5	1·8			
5 ..	5·4	3·4	3·8	3·1	1·3	1·2	2·9	2·3	3·0	2·7	3·3	5·5	2·5	2·9	7·8	1·7			
6 ..	5·3	3·3	3·8	3·0	1·2	1·1	2·9	2·2	3·0	2·7	3·2	5·8	2·4	2·8	6·8	1·6			
7 ..	5·2	3·2	3·7	2·9	1·2	1·0	2·9	2·2	3·0	2·6	3·2	5·9	2·4	2·7	5·6	1·6			
8 ..	5·1	3·2	3·6	2·8	1·1	0·9	2·7	2·1	3·0	2·6	3·1	5·8	2·4	2·6	4·9	1·5			
9 ..	5·0	3·2	3·5	2·7	1·1	0·8	2·6	2·0	3·0	2·6	3·1	5·6	2·2	2·5	4·5	1·5			
10 ..	4·9	3·2	3·4	2·7	1·0	0·7	2·6	2·0	3·0	2·6	3·1	5·4	2·1	2·5	4·2	1·5			
11 ..	4·8	3·2	3·3	2·6	0·9	0·6	2·6	1·9	2·9	2·5	3·1	5·2	2·0	2·5	3·9	1·4			
12 ..	4·6	3·1	3·2	2·3	0·8	0·5	2·3	1·9	2·8	2·4	3·1	4·8	1·9	2·4	3·5	1·4			
13 ..	4·5	3·1	3·1	2·3	0·8	0·4	2·3	1·9	2·8	2·4	3·1	4·7	1·9	2·4	3·2	1·4			
14 ..	4·5	3·0	3·0	2·2	0·8	0·4	2·2	1·8	2·8	2·3	3·0	4·5	1·8	2·4	3·1	1·4			
15 ..	4·4	2·9	3·0	2·1	0·8	0·3	2·1	1·8	2·8	2·3	3·0	4·5	1·7	2·3	2·9	1·4			
16 ..	4·3	2·9	2·9	2·1	0·7	0·3	2·0	1·8	2·8	2·3	3·0	4·4	1·7	2·2	2·7	1·4			
17 ..	4·3	2·8	2·9	2·1	0·7	0·2	1·9	1·8	2·8	2·3	2·9	4·2	1·6	2·1	2·7	1·3			
18 ..	4·2	2·8	2·8	2·0	0·7	0·1	1·9	1·7	2·8	2·3	2·9	4·1	1·6	2·0	2·6	1·3			
19 ..	4·1	2·7	2·8	1·9	0·6	0·0	1·9	1·6	2·8	2·3	2·9	4·0	1·5	2·0	2·5	1·2			
20 ..	4·0	2·7	2·7	1·8	0·6	—0·1	1·8	1·6	2·7	2·2	2·8	3·9	1·4	2·0	2·5	1·1			
21 ..	4·0	2·6	2·7	1·7	0·5	—0·2	1·8	1·5	2·7	2·2	2·8	3·7	1·4	1·9	2·3	1·0			
22 ..	3·9	2·6	2·6	1·7	0·5	—0·2	1·8	1·5	2·7	2·2	2·8	3·7	1·4	1·9	2·2	1·0			
23 ..	3·7	2·6	2·5	1·7	0·5	—0·3	1·8	1·5	2·7	2·2	2·8	3·5	1·3	1·9	2·1	0·9			
24 ..	3·7	2·5	2·6	1·6	0·4	—0·3	1·7	1·4	2·7	2·1	2·8	3·5	1·2	1·8	2·1	0·9			
25 ..	3·5	2·6	2·4	1·5	0·4	—0·3	1·7	1·4	2·7	2·1	2·7	3·4	1·2	1·7	2·0	0·8			
26 ..	3·4	2·6	2·4	1·5	0·3	—0·4	1·6	1·3	2·7	2·1	2·7	3·4	1·1	1·7	2·0	0·8			
27 ..	3·4	2·6	2·3	1·4	0·3	—0·4	1·6	1·3	2·7	2·1	2·6	3·4	1·1	1·7	1·9	0·8			
28 ..	3·3	2·5	2·2	1·3	0·3	—0·5	1·5	1·3	2·6	2·0	2·6	3·4	1·0	1·5	1·9	0·8			
29 ..	3·2	2·6	2·2	1·3	0·3	—0·5	1·5	1·3	2·5	2·0	2·6	3·3	1·0	1·6	1·9	0·7			
30 ..	3·2	2·6	2·2	1·3	0·2	—0·6	1·4	1·3	2·5	2·0	2·5	3·3	1·0	1·6	1·8	0·7			
Averages ..	4·4	3·0	3·0	2·2	0·8	0·4	2·2	1·8	2·8	2·4	3·0	4·3	1·8	2·3	3·6	1·3			

Readings of Bukkur Gauge for December.

Date.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.
	F. D.	F. D.	F. D.	F D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	1·7	1·8	2·1	1·4	1·2	0·6	0·7	1·7	2·2	2·2	2·4	0·7	0·3	1·1	1·6	—0·2	0·4	2·4	1·2	1·0	0·7	1·7	0·6	0·2	0·1	1·2	2·4	2·7	2·9	12·3	3·0	1·0	0·4	1·2	2·7	3·0	1·9
2	1·7	1·7	2·1	1·4	1·2	0·7	0·7	1·6	2·0	2·2	2·4	0·7	0.3	1·1	1·5	—0·2	0·4	2·3	1·2	1·0	0·7	1·7	0.5	0·2	0·1	1·1	2·4	2·7	2·8	10·9	2·9	1·0	0·4	1·1	2·7	2·9	1·9
3	1·7	1·7	2·1	1·5	1·2	0·6	0·6	1·5	1·9	2·2	2·4	0·7	0·2	1·0	1·5	—0·4	0·4	2·3	1·2	0·9	0·7	1·6	0·5	0·1	0·1	1·1	2·3	2·6	2·8	9·1	2·9	0·9	0·4	1·0	2·6	2·8	1·9
4	1·7	1·7	2·1	1·5	1·3	0·6	0·6	1·5	1·8	2·2	2·4	0·7	0·2	0·9	1·4	—0·4	0·4	2·2	1·2	0·9	0·7	1·5	0·4	0·1	0·1	1·1	2·2	2·5	3·0	8·0	2·8	0·9	0·3	0·9	2·6	2·8	1·9
5	1·7	1·7	2·0	1·5	1·2	0·6	0·5	1·6	1·8	2·2	2·4	0·7	0·2	0·9	1·4	—0·4	0·3	2·2	1·2	0·8	0·7	1·5	0·4	0·1	0·1	1·0	2·2	2·4	3·2	7·4	2·8	0·9	0·3	0·9	2·6	2·7	1·9
6	1·7	1·6	1·9	1·6	1·2	0·6	0·5	1·4	1·6	2·2	2·4	0·7	0·2	0·8	1·6	—0·4	0·3	2·2	1·1	0·8	0·7	1·4	0·3	—0·2	0·0	1·0	2·2	2·3	3·2	6·9	2·8	0·9	0·3	0·9	2·6	2·7	1·9
7	1·7	1·6	1·8	1·6	1·2	0·6	0·5	1·5	1·8	2·2	2·3	0·7	0·2	0·8	1·7	—0·5	0·2	2·2	1·1	0·8	0·7	1·4	0·2	—0·2	0·0	0·9	2·2	2·4	3·2	6·7	2·8	0·8	0·2	0·8	2·5	2·6	1·9
8	1·6	1·6	1·8	1·6	1·3	0·6	0·5	1·4	1·7	2·3	2·2	0·7	0·2	0·7	1·8	—0·5	0·2	2·2	1·0	0·7	0·6	1·4	0·1	—0·2	0·0	0·9	2·2	2·7	3·2	6·4	2·8	0·7	0·2	0·8	2·4	2·6	1·9
9	1·6	1·6	1·8	1·5	1·2	0·6	0·4	1·4	1·7	2·3	2·2	0·7	0·2	0·7	1·7	—0·6	0·2	2·2	1·0	0·7	0·6	1·3	0·1	—0·2	—0·1	0·8	2·2	3·7	3·1	6·1	2·8	0·7	0·2	0·8	2·4	2·6	1·9
10	1·5	1·5	1·7	1·4	1·2	0·4	0·4	1·2	1·7	2·3	2·2	1·0	0·2	0·7	1·6	—0·7	0·2	2·1	1·0	0·7	0·6	1·2	0·1	—0·3	—0·1	0·8	2·1	3·9	2·9	5·9	2·7	0·7	0·2	0·7	2·4	2·6	1·8
11	1·5	1·5	1·7	1·4	1·2	0·3	0·6	1·2	1·7	2·3	2·2	1·3	0·2	0·7	1·5	—0 7	0·2	2·1	1·0	0·6	0·5	1·2	0·0	—0·4	—0·2	0·8	2·1	3·7	2·8	5·8	2·7	0·7	0·2	0·7	2·4	2·4	1·7
12	1·5	1·4	1·7	1·3	1·2	0·3	0·9	1·2	1·7	2·3	2·2	1·3	0·1	0·7	1·4	—0·7	0·1	2·2	0·9	0·6	0·5	1·2	0·0	—0·5	—0·3	0·7	2·0	3·3	2·6	5·7	2·7	0·7	0·1	0·7	2·4	2·4	1·7
13	1·5	1·4	1·7	1·3	1·0	0·2	1·2	1·1	1·7	2·2	2·2	1·2	0·0	0·7	1·3	—0·7	0·1	2·3	0·9	0·5	0·5	1·2	—0·1	—0·5	—0·4	0·7	2·0	3·2	2·6	5·5	2·7	0·7	0·1	0·7	2·3	2·2	1·7
14	1·5	1·4	1·9	1·3	0·9	0·2	1·1	1·0	1·7	2·2	2·2	1·2	—0·1	0·7	1·2	—0·8	0·1	2·4	0·9	0·4	0·5	1·2	—0·2	—0·6	—0·5	0·7	2·0	3·1	2·5	6·7	2·7	0·6	0·1	0·7	2·3	2·3	1·7
15	1·5	1·3	1·9	1·3	0·8	0·2	1·0	1·1	1·7	2·2	2·2	1·1	—0·2	0·7	1·2	- 0·8	0·1	2·3	0·9	0·4	0·4	1·1	—0·3	—0·6	—0·5	0·7	1·9	2·9	2·4	8·4	2·8	0·6	0·1	0·7	2·3	2·2	1·6
16	1·4	1·3	2·0	1·3	0·7	0·2	0·9	1·0	1·7	2·1	2·2	1·1	—0·1	0·7	1·1	- 0·8	0·1	2·2	0·9	0·4	0·4	1·1	—0·4	—0·7	—0·6	0·7	1·9	2·7	2·3	8·8	2·9	0·7	0·1	0·7	2·3	2·2	1·6
17	1·4	1·3	1·9	1·3	0·7	0·5	0·7	0·9	1·6	2·1	2·2	1·0	—0·0	0·7	1·0	—0·9	0·1	2·2	0·9	0·4	0·4	1·1	—0·4	—0·7	—0·6	0·7	1·8	2·6	2·2	8·2	2·9	0·7	0·0	0·7	2·3	2·2	1·7
18	1·4	1·4	1·8	1·2	0·7	0·5	0·7	0·9	1·6	2·1	2·2	0·8	—0·2	0·7	1·0	—1·0	0·1	2·2	0·9	0·3	0·3	1·0	—0·5	—0·7	—0·7	0·7	1·8	2·5	2·2	7·5	2·7	0·6	0·0	0·6	2·2	2·2	1·5
19	1·4	1·4	1·8	1·2	0·7	0·6	0·7	0·9	1·6	2·1	2·2	0·7	—0·2	0·8	1·0	—1·0	0·1	2·2	0·9	0·3	0·3	0·9	—0·5	—0·7	—0·7	0·7	1·8	2·4	2·2	6·7	2·7	0·6	0·0	0·6	2·2	2·2	1·5
20	1·5	1·4	1·7	1·2	0·7	0·4	0·6	0·9	1·6	2·1	2·2	0·7	—0·1	0·8	1·0	—1·0	0·1	2·2	0·9	0·2	0·2	0·8	—0·5	—0·7	—0·7	0·7	1·7	2·2	2·2	6·0	2·7	0·6	0·0	0·6	2·2	2·1	1·5
21	1·6	1·3	1·7	1·2	0·7	0·4	0·6	0·8	1·5	2·1	2·2	0·7	—0·2	0·8	1·0	—0·7	0·2	2·2	0·8	0·2	0·2	0·7	—0·5	—0·6	—0·8	0·7	1·7	2·2	2·3	5·7	2·7	0·6	0·0	0·6	2·2	2·1	1·5
22	1·5	1·3	1·7	1·2	0·7	0·3	0·5	0·9	1·5	2·0	2·2	0·5	—0·3	0·8	0·9	—0·7	0·4	2·2	0·8	0·2	0·2	0·7	—0·5	—0·6	—0·8	0·6	1·7	2·1	2·3	5·2	2·7	0·6	0·0	0·6	2·1	2·1	1·4
23	1·5	1·2	1·7	1·2	0·7	0·3	0·4	1·0	1·3	1·9	2·2	0·5	—0·3	0·7	0·8	—0·7	0·5	2·2	0·8	0·2	0·2	0·7	—0·5	—0·6	—0·8	0·6	1·7	2·1	2·3	5·2	2·7	0·6	0·0	0·7	2·1	2·2	1·4
24	1·4	1·2	1·7	1·2	0·7	0·3	0·4	1·1	1·5	1·9	2·2	0·5	—0·4	0·7	0·8	—0·7	0·6	2·2	0·8	0·1	0·2	0·7	—0·6	—0·6	—0·9	0·5	1·6	2·0	2·2	5·3	2·7	0·5	0·0	0·6	2·1	2·2	1·3
25	1·4	1·2	1·7	1·2	0·7	0·3	0·3	1·1	1·4	1·9	2·2	0·4	—0·4	0·5	0·7	—0·7	0·7	2·2	0·7	0·1	0·2	0·7	—0·6	—0·5	—0·9	0·5	1·5	1·9	2·2	6·0	2·7	0·5	0·0	0·6	2·1	2·2	1·3
26	1·4	1·2	1·6	1·2	0·7	0·3	0·2	1·0	1·4	1·8	2·2	0·3	—0·4	0·5	0·7	—0·8	1·2	2·2	0·7	0·1	0·2	0·7	—0·6	—0·5	—0·9	0·5	1·5	1·8	2·2	6·5	2·7	0·5	0·0	0·6	2·1	2·2	1·2
27	1·4	1·2	1·6	1·2	0·7	0·3	0·3	0·8	1·3	1·8	2·2	0·3	—0·5	0·4	0·7	—0·8	1·6	2·2	0·7	0·1	0·2	0·7	—0·6	—0·5	—0·9	0·5	1·4	1·8	2·1	6·2	2·7	0·5	0·0	0·5	2·1	2·2	1·2
28	1·4	1·2	1·5	1·2	0·7	0·2	0·2	1·1	1·3	1·8	2·1	0·2	0·4	0·3	0·7	—0·9	1·9	2·2	0·7	0·1	0·2	0·7	—0·7	—0·6	—0·9	0·5	1·4	1·8	2·1	6·1	2·6	0·5	0·0	0·5	2·1	2·2	1·2
29	1·3	1·2	1·6	1·2	0·7	0·2	0·3	1·0	1·3	1·8	2·1	0·2	—0·5	0·2	0·7	—0·9	2·0	2·2	0·7	0·1	0·2	0·7	—0·7	—0·6	—0·7	0·5	1·3	1·7	2·0	5·5	2·6	0·5	0·3	0·4	2·1	2·2	1·2
30	1·3	1·1	1·7	1·3	0·7	0·2	0·3	0·9	1·3	1·8	2·1	0·2	—0·6	0·2	0·7	—0·9	1·7	2·2	0·7	0·0	0·2	0·7	—0·7	—0·7	—0·6	0·5	1·3	1·7	1·9	5·2	2·5	0·4	0·4	0·3	2·1	2·2	1·2
31	1·2	1 1	1·7	1·3	0·7	0·2	0·3	0·8	1·3	1·9	2·1	0·2	—0·6	0·2	0·6	—1·0	1·4	3·2	0·7	0·1	0·2	0·7	—0·7	—0·7	—0·6	0·6	1·2	1·6	1·9	5·3	2·5	0·4	0·3	0·3	2·1	2·2	1·2
Averages ..	1·5	1·4	1·8	1·3	0·9	0·4	0·6	1·1	1·6	2·1	2·2	0·7	—0·1	0·7	1.2	—0·7	0·5	2·2	0·9	0·4	0·4	1·1	—0·2	—0·4	—0·4	0·7	1·9	2·5	2·5	6·8	2·8	0·6	0·2	0·6	2·4	2·4	1·6

Date.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.
	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.	F. D.
1	1·1	2·2	2·1	2·1	2·2	2 7	2·5	2·4	1·3	0·3	1·1	1·0	1·5	0·8	0·5	2·7	2·6	2·9	3·1	2·5	2·1	1·3	0·1	—0·6	1·3	1·2	2·5	2·0	2·4	3·1	0·9	1·6	1·8	0·7			
2	1·1	2·2	2·0	2·4	2·2	2·7	2·4	2·4	1·3	0·3	1·1	1·0	1·4	0·8	0·5	2·7	2·6	2·9	3·1	2·4	2·1	1·2	0·1	—0·6	1·3	1·2	2·4	2·0	2·4	3·0	0·9	1·6	1·7	0·7			
3	1·1	2·2	2·0	2·6	2·2	2·7	2·4	2·4	1·2	0·3	1·0	0·8	1·4	0·7	0·4	2·6	2·5	2·8	3·1	2·4	2·0	1·1	0·1	—0·7	1·2	1·2	2·4	1·9	2·4	3·0	0·8	1·5	1·6	0·6			
4	1·0	2·3	2·0	2·6	2·2	4·0	2·4	2·3	1·2	0·2	1·0	0·8	1·3	0·7	0·4	2·6	2·4	2·8	3·0	2·3	2·0	1·1	0·0	—0·7	1·2	1·2	2·4	1·9	2·4	2·9	0·8	1·5	1·5	0·6			
5	1·0	2·3	1·9	2·4	2·2	4·7	2·3	2·3	1·2	0·2	1·0	0·7	1·3	0·6	0·4	2·5	2·4	2·7	3·0	2·3	2·0	1·1	0·0	—0·8	1·1	1·2	2·3	1·9	2·4	2·8	0·7	1·5	1·4	0·6			
6	0·7	2·3	1·9	2·3	2·1	4·7	2·3	2·3	1·2	0·2	0·8	0·7	1·3	0·6	0·4	2·5	2·4	2·7	2·9	2·3	1·9	1·0	0·0	—0·8	1·1	1·2	2·2	1·9	2·3	2·8	0·7	1·4	1·4	0·6			
7	0·6	2·3	1·8	2·2	2·1	4·6	2·2	2·3	1·2	0·2	0·8	0·7	1·3	0·5	0·4	2·4	2·4	2·7	2·9	2·2	1·9	1·0	—0·1	—0·9	1·0	1·2	2·2	1·9	2·2	2·7	0·6	1·4	1·4	0·5			
8	0·6	2·3	1 8	2·2	2·0	4·4	2·2	2·3	1·1	0·1	0·8	0·6	1·2	0·5	0·3	2·4	2·3	2·6	2·8	2·2	1·8	0·9	—0·1	—0·9	1·0	1·2	2·2	1·8	2·2	2·8	0·6	1·4	1·3	0·5			
9	0·5	2·3	1·7	2·1	2·0	4·2	2·2	2·2	1·1	0·2	0·8	0·6	1·2	0·4	0·3	2·4	2·2	2·6	2·8	2·2	1·8	0·8	—0·1	—0·9	1·0	1·2	2·2	1·8	2·2	2·8	0·6	1·4	1·4	0·4			
10	0·5	2·3	1·7	2·0	1·9	3·9	2·2	2·2	1·1	0·2	0·8	0·6	1·2	0·4	0·3	2 3	2·2	2·6	2·7	2·1	1·8	0·8	—0·2	—0·9	1·0	1·2	2·2	1·8	2·2	2·8	0·5	1·4	1·4	0·4			
11	0·5	2·3	1·7	1·9	1·9	3·8	2·2	2 2	1·0	0·2	0·8	0·7	1·2	0·4	0·3	2·3	2·2	2·6	2·7	2·1	1·8	0·8	—0·2	—1·0	0·9	1·1	2·1	1·8	2·1	3·6	0·5	1·4	1·5	0·4			
12	0·5	2·3	1·6	1·9	1·7	3·7	2·2	2·2	1·0	0·1	0·8	0·7	1·2	0·3	0·3	2·3	2·1	2·6	2·7	2·1	1·7	0·8	—0·2	—1·0	0·9	1·0	2·1	1·8	2·0	4·5	0·5	1·3	1·5	0·4			
13	0·5	2·3	1·6	1·9	1·8	3·7	2·2	2·2	0·8	0·1	0·8	0·7	1·1	0·3	0·3	2·2	2·1	2·5	2·6	2·1	1·7	0·7	—0·3	—1·1	0·9	1·0	2·1	1·8	2·0	4·5	0·5	1·3	1·5	0·4			
14	0·4	2·3	1·5	1·8	1·7	3·6	2·1	2·2	0·8	0·0	0·8	0·7	1·0	0·2	0·2	2·2	2·0	2·5	2·6	2·1	1·6	0·7	—0·3	—1·1	0·8	0·9	2·1	1·7	1·9	4·0	0·4	1·3	1·5	0·3			
15	0·7	2·2	1·5	1·8	1·7	3·6	2·1	2·2	0·7	0·0	0·8	0·6	1·0	0·2	0·2	2·2	2·0	2·5	2·5	2·1	1·5	0·7	—0·4	—1·2	0·7	0·9	2·1	1·7	1·9	3·6	0·4	1·3	1·5	0·3			
16	0·7	2·2	1·4	1·8	1·7	3·6	2·0	2·2	0·7	—0·1	0·7	0·6	1·0	0·1	0·3	2·1	2·0	2·4	2·5	2·1	1·6	0·6	—0·4	—1·2	0·7	0·9	2·1	1·8	1·9	3·4	0·3	1·3	1·4	0·3			
17	0·6	2·2	1·4	1·7	1·7	3·5	2·0	2·1	0·7	—0·2	0·6	0·6	0 9	0·1	0·3	2·1	1·9	2·4	2·4	2·0	1·5	0·5	—0·4	—1·3	0·6	0·8	2·1	1·7	1·9	3·3	0·3	1·3	1·3	0·3			
18	0·7	2·2	1·3	1·7	1·7	3·4	2·0	2·1	0·6	—0·2	0·6	0·5	0·9	0·1	0·3	2·1	1·9	2·3	2·4	2·0	1·5	0·5	—0·4	—1·3	0·6	0·8	2·2	1·7	1·8	3·2	0·3	1·3	1·2	0·2			
19	0·7	2·2	1·3	1·7	1·7	3·2	1·9	2·1	0·5	—0·1	0·5	0·5	0·9	0·1	0·3	2·0	1·9	2·3	2·3	1·9	1·5	0·5	—0·5	—1·3	0·6	0·7	2·2	1·7	1·8	3·2	0·2	1·2	1·2	0·2			
20	0·7	2·2	1·4	1·7	1·7	3·2	1·9	2·0	0·5	0·0	0·5	0·4	0·8	0·0	0·3	2·0	1·8	2·3	2·3	1·9	1·4	0·5	—0·5	—1·3	0·6	0·7	2·1	1·7	1·8	3·2	0·2	1·2	1·2	0·2			
21	0·7	2·2	1·4	1·7	1·6	3·2	1·9	2·0	0·5	1·0	0·5	0·4	0·8	—0·1	0·2	2·0	1·8	2·3	2·2	1·9	1·3	0·4	—0·5	—1·3	0·6	0·7	2·1	1·6	1·8	3·1	0·2	1·2	1·1	0·3			
22	0·7	2·2	1·3	1·6	1·5	3·1	1·8	2·0	0·4	1·3	0·4	0·4	0·8	—0·1	0·1	1·9	1·7	2·3	2·2	1·8	1·3	0·4	—0·5	—1·4	0·6	0·7	2·2	1·6	1·7	3·0	0·1	1·2	1·1	0·1			
23	0·7	2·2	1·2	1·6	1·5	2·9	1·8	1·9	0·4	1·6	0·4	0·4	0·8	—0·1	0·1	1·9	1·7	2·2	2·2	1·8	1·3	0·3	—0·6	—1·4	0·6	0·7	2·2	1·6	1·7	2·8	0·1	1·1	1·0	0·3			
24	0·7	2·1	1·2	1·5	1·5	2·8	1·8	1·9	0·4	1·5	0·4	0 3	0·9	—0·2	0·1	1·9	1·6	2·2	2·1	2·1	1·3	0·3	—0·6	—1 4	1·7	0·7	2·2	1·6	1·7	2·8	0·1	1·1	1·0	0·2			
25	0·7	2·1	1·2	1·5	1·4	2·8	1·7	1·8	0·3	1·6	0·3	0·3	0·9	—0·2	0·0	1·8	1·6	2·1	2·1	2·4	1·3	0·3	—0·6	—1·4	2·0	0·7	2·3	1·6	1·7	2·7	0·0	1·0	1·0	0·2			
26	0·7	2·1	1·2	1·4	1·4	2·8	1·7	1·8	0·3	1·2	0·3	0·2	0·9	—0·2	0·0	1·8	1·6	2·1	2·1	2·6	1·3	0·3	—0·7	—1·5	1·9	0·7	2·2	1·6	1·6	2·6	0·0	1·0	0·9	0·3			
27	1·2	2·1	1·2	1·4	1·4	2·7	1·7	1·8	0·2	0·7	0·3	0·2	0·9	—0·2	—0·1	1·8	1·6	2·1	2·0	2·7	1·3	0·7	—0·7	—1·5	1·7	0·7	2·2	1·6	1·6	2·4	—0·1	1·0	0·9	0·5			
28	1·6	2·1	1·2	1·3	1·4	2·7	1·7	1·8	0·2	0·5	0·3	—0·1	0·8	—0·3	—0·1	1·7	1·5	2·1	2·0	2·6	1·6	0·9	—0·8	—1·6	1·5	0·7	2·2	1·6	1·6	2·3	—0·1	1·0	0·9	0·5			
29	1·5	2·1	1·2	1·3	1·4	2·7	1·6	1·7	0·2	0·4	0·3	—0·1	0·7	—0·3	—0·1	1·8	1·5	2·0	2·0	2·4	2·3	0·9	—0·8	—1·6	1·3	0·9	2·2	1·6	1·6	2·3	—0·1	1·0	0·9	0·5			
30	1·3	2·1	1·2	1·2	1·3	2·7	1·6	1·7	0·2	0·3	0·3	—0·1	0·7	—0·3	—0·1	1·8	1·4	2·0	2·0	2·3	2·6	0·8	—0·9	—1·6	1·2	0·9	2·2	1·6	1·6	2·3	—0·1	1·0	1 0	0·5			
31	1·2	2·1	1·1	1·2	1·3	2·9	1·6	1·7	0·2	0·3	0·3	—0·1	0 7	—0·3	—0·2	1·8	1·4	1·9	2·0	2·2	2·6	0·7	—0·9	—1·6	1·1	0·8	2·2	1·6	1·6	2·3	—0·2	1·0	1·0	0·4			
Averages ..	0·8	2·3	1·6	1·9	1·8	3·4	2·1	2·1	0·8	0·4	0·7	0·6	1·1	0·1	0·3	2·2	2·0	2·5	2·5	2·3	1·7	0·6	—0·4	—1·2	1·1	0·9	2·2	1·7	1·9	3·0	0·3	1·3	1·3	0·4			

APPENDIX G.

A Note by Mr. A. A. Musto, Executive Engineer, on the design of floors of Weirs and Undersluices.

According to the theoretical (or rather empirical) rules for design laid down by Bligh the critical factor in the length of *impervious* pavement, is the proportion required to withstand scour.

It is found that the length of *impervious* floor necessary and sufficient to provide the required hydraulic gradient, or length of creep, does not necessarily according to Bligh's rule give sufficient length of *impervious* masonry to withstand scour. The undersigned contends that provided the length of *impervious* masonry is sufficient to provide a safe hydraulic gradient then scour can be provided against, beyond this point, by *pervious* masonry. The disadvanage of giving an unnecessary length of *impervious* masonry is that it necessitates increasing also the thickness of the whole floor, and also is a more expensive of construction in itself. In view, however, of information and opinions collected during his recent tour in the Punjab, and also from the study of the section of the Esna Barrage in Egypt, which has been drawn out in English units the undersigned ventures respectfully to reopen the question.

Turning first to the Esna Barrage cross section (Drawing No. 41), it will be seen that the hydraulic gradient after taking full credit for puddle apron upstream and sheet piling below the structure is only 1 in 14·2. This weir is founded on fine sand and depends entirely on the hydraulic gradient for its safety against undermining.

The next point to notice is that the working head is 15′ while the length of *impervious* masonry provided downstream of the gates is only 65, *i.e.*, 4·33 times the head. The design of the pervious talus beyond the pakka floor presents points of considerable interest. It originally consisted of a layer of stone pitching 6½′ thick and 127′ long, and it appears that the stones were rather small.

After the first season's flood it was found that opposite the three bays on the west, a hole had been scoured in this stone pitching in the manner shown on the cross section. The form of the scoured hole is interesting and instructive. It will be noticed that the solid end of pukka masonry held firm and protected the pitching adjacent to it, so that a small portion of the original pitching was left against it. Scour then extended downstream moving out the light stone pitching, and shifting it further downstream. It actually piled some of this stone on the top of the end of the original stone and left it there, the remainder being evidently carried on down the scoured bed beyond the end of the talus.

It appears, therefore, that the pitching stone, adjacent to the pukka floor, was not sufficiently large and heavy to resist displacement at that part, but at the end of the talus it was quite satisfactory. The only movement at the extreme end of the talus was of the small portion of the stone which projected above the scoured bed of the river beyond. Such scour of the bed is certain to occur to a greater or less degree, and it would therefore appear wise to slope down the end of the talus so that it may conform more or less to the slope which the bed beyond will eventually scour to.

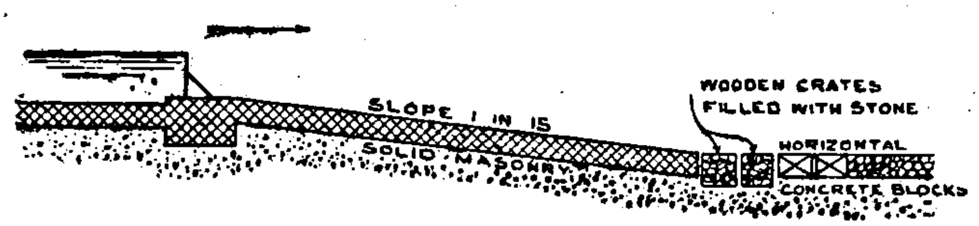
The *upstream* pitching also scoured slightly and it is probable that by giving the surface of this pitching a slope leading up to the floor this scour could also have been prevented.

The steps taken to repair this damage are also instructive. The scour hole was filled up with large stone pitching to within 2′ 4″ of the floor level. It was originally proposed to cover this stone with 3 layers of cement concrete, in sacks, but, in two experiments it was found that the bags would not adhere to one another and the proposal was finally abandoned, in favour of covering it with concrete blocks 5′ ×3′ ×2·3′. These were layed under water by divers. The pavement has given no trouble since, in three seasons' working.

It appears, therefore, that all that was necessary, was to provide sufficiently heavy blocks, to resist displacement, and these blocks 5′ × 3′ × 2′ have been quite successful *only* 65′ *from the gates.*

At Esna the sheet piles were tongued and grooved, C. I. piles with the gaps grouted, but Willcocks says he considers that steel interlooking sheet piling would have been better.

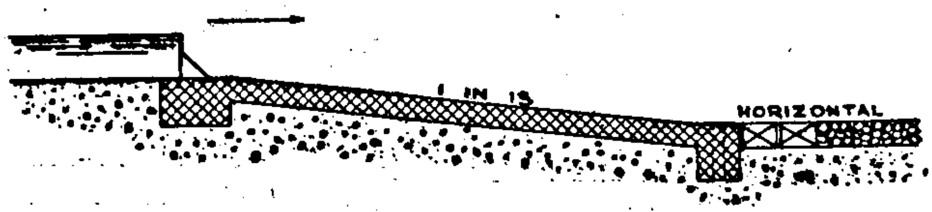
In the Punjab the only weir where they have experienced any trouble with the concrete blocks is at Khanki and this is undoubtedly due to faulty design (Mr. Ward, Chief Engineer, agreed with undersigned at to the cause of the trouble as did also the Executive Engineer Mr. Middleton). The section of the weir is as shown below :—



The first defect in the design appears to the undersigned, to be the change of gradient from 1 in 15 *down*, to level. The effect of this change of slope is that water rushing down the slope impinges obliquely on the horizontal talus. In the opinion of the undersigned a change of slope *upwards* should never be made against a flowing stream, if it can be avoided, but if absolutely necessary, then the floor at the point of change and for such distance downstream until the water is again flowing parallel to the bed, should be made of solid masonry, and loose blocks or stone pitching be never expected to affect the change of direction of flow of the current. At Khanki they not only have this change of direction, but the immediate point of change is composed of wooden crates filled with loose stones. These stones are naturally washed out of the crates and water is then able to impinge directly on the up-stream face of, and even below, the concrete blocks with the inevitable result that they are washed out. They are actually lifted out and deposited *on top of those further down where they remain unmoved.*

At Rasul the conditions and design are exactly similar except that instead of these crates of loose stone, they have a solid wall of wells. The solid top of this serves to deflect the current in a horizontal direction, and no trouble whatever is experienced with shifting of the concrete blocks. The obvious remedy at Khanki is to replace the crates of stones by solid masonry.

RASUL WEIR.



Every officer consulted in the Punjab agreed that so long as length of creep were provided or by means of sufficient length of impervious masonry, then scour beyond this point could be readi y combated with concrete blocks.

APPENDIX H.

Report by Captain Townshend, R.E., Executive Engineer, attached Sukkur Barrage Project District.

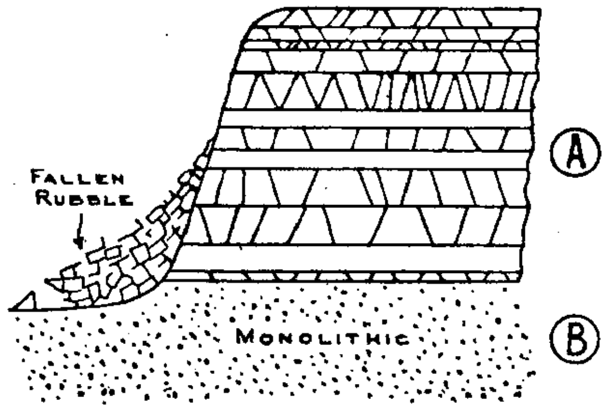
Stone Quarries near Barrage Site.

I returned this morning from Sukkur. During my visit Mr. Rochiram took me to see stone hills about 1 mile South-West of Aror. There I saw large masses of stone exposed, including a block which would yield a 7 ft. cube. I should judge the quality of it to be rather soft, but this can only be decided by tests.

Note.—The B Group sample stones from Aror were taken from the hillside alongside this big block and were of exactly the same quality.

2. It would probably help to make matters clearer if I briefly describe the general characteristics of the stone hills of the neighbourhood. The upper parts of the hills are being stratified horizontally. The different strata are seldom more than 1 ft. to 1 ft. 3 in. thick and the quality of the stone varies considerably in them. (Group "A").

These are also stratified vertically so that blocks cannot be obtained larger than about 15" cube. In fact it is a pack of small blocks.



Underneath this group of strata there lies a softer rock *B* from which stone can be cut up to any manageable size, say up to 10 ft. ×10 ft. ×5 ft.

The whole of the above described formation can be seen at Rohri. At Aror and Kalka the appearance of the hills is the same. *B* cannot usually be seen owing to the masses of fallen rubble. (Such masses of fallen rubble do not exist at Rohri when the demand for stone is great and quarries are in active work.)

The samples of stone which have been received and tested by you are from Aror and Kalka. (*Group A.*)

Such large stones as are required for voussoirs, etc., must come from *B* which at Rohri is stated to be softer than "A."

The *B* stone at Rohri appeared excellent. Very even and homogeneous—easily worked—good colour.

I would suggest your testing Rohri stone—Groups *A* and *B* and later perhaps it might be found advisable to test *B* stone at Aror and Kalka.

APPENDIX I.

TESTS FOR COMPRESSIVE STRENGTH OF KALKA AND AROR LIMESTONE.

Tests were made on 3rd July 1918 by Messrs. Thorpe and Musto, Executive Engineers, at the North Western Railway Loco. Works, Karachi. A steel-yard testing machine giving pressures up to 12 tons 17 cwts. was used. All specimens tested were 2″ cubes, accurately sawn to size with an ordinary engineer's hack-saw working through a special frame made to guide the saw vertically through two slots 2″ apart. The two surfaces to be pressed were afterwards filed and scraped to an accurate bearing on an iron surface-plate, and the two faces made exactly parallel. In the testing machine, the stone cube rested direct on a machined steel block and the press head of the machine was also a machined steel block taking its thrust from a spherical head, thus ensuring a true bearing on the test specimen.

Two kinds of stone were tested, *viz.* :—

1. Specimens cut from a block of " A " Group average lime-stone from Aror Quarries. Described as Aror " A " stone. Aror is about 5 miles from Rohri.
2. Specimens cut from a block of " A " Group lime-stone from Kalka Quarries. Described as Kalka " A " stone. Kalka is about 6 miles from Rohri.

These stones are not obtainable in large blocks, but could be obtained up to $1' \times 1' \times 1 \cdot 25'$ quite easily, and possibly larger with efficient methods of quarrying.

Both stones are exceedingly fine grained, regular and compact. The stones are almost milk white with a few lines of a black substance, probably mica.

Both are entirely free from faults of any kind.

The Kalka " A " stone is undoubtedly superior but the Aror " A " stone is also excellent. Kalka is about 1 mile further from Rohri than Aror which is only about 5 miles by road from Rohri. Both the places are about equidistant, *viz.*, about 6 miles from the Barrage site.

In the case of all tests except No. 4 Aror " A " stone, the pressure was applied steadily and gradually by traversing the moving weight along the steel-yard. In the case of No. 4 test, the pressure of 9 tons was applied suddenly by bringing the press head down on to the specimen and suddenly lifted the steel-yard set to 9 tons weight. This is not a fair ordinary test, as impact probably has considerable effect. This test is omitted when taking the average of compressive strengths. Most of the specimens failed suddenly without any previous sign of stress, proving that the pressure was evenly applied.

Aror " A " Stone.

No. 1 *Specimen.*—Failed suddenly without any previous sign of failure at a pressure of 9 tons 17 cwts.

No. 2 *Specimen.*—Showed a very fine crack with pressure of 12 tons 10 cwts. The weight on the steel-yard was shifted to its maximum registering position at 12 tons 17 cwts without any further sign of failure, and considerably greater pressure was then applied by the press head screw to break the specimen. It probably failed at about 14 tons but this could not be read on the machine.

No. 3 *Specimen.*—One fine straight crack appeared at 11 tons 15 cwts. pressure, and the sample broke suddenly after sustaining the full registered pressure of the machine, 12 tons 17 cwts. for several seconds. The floating table of the machine was shaken by one of the attendants thereby putting flexure on the specimen and causing failure.

No. 4 *Specimen.*—This specimen had a load of 9 tons suddenly applied to it and failed. Not an ordinary test.

No. 5 *Specimen.*—Failed suddenly without any previous sign of failure at pressure of 11 tons 4 cwts.

No. 6 *Specimen.*—Failed suddenly without previous sign of failure at pressure of 10 tons 5 cwts.

Aror "A" Stone.

Average of above tests (omitting No. 4).

	First sign of failure.	*Destruction.*
No. 1	9 tons 17 cwt.	9 tons 17 cwt.
,, 2	12 ,, 10 ,,	14 ,, 0 ,,
,, 3	11 ,, 15 ,,	12 ,, 17 ,,
,, 5	11 ,, 4 ,,	11 ,, 4 ,,
,, 6	10 ,, 5 ,,	10 ,, 5 ,,
,, 5	55 tons 11 cwt.	58 tons 3 cwt.
Average per 4 sq. inches	11·11 tons	11·63 tons.
or, per sq. inch.	2·78 tons/sq. in.	2·91 tons/sq. in.
or,	6,267 lbs./in².	6,518 lbs./in².

Kalka "A" Stone.

No. 1 *Specimen.*—This was tested up to the limit of the steel-yard machine, *viz.*, 12 tons 17 cwts. without the slightest sign of distress. The specimen was then removed from the machine, and taken to a hydraulic press. The latter was a very rough machine and the pressing surfaces did not have true bearing on the specimen. Also the hydraulic pressure gauge was sticky and registered the pressure in jerks, so the result is not a satisfactory test. However, the stone finally crushed with a pressure of 19·6 tons equivalent to 11,000 lbs./in² with a good bearing and steady machine it will probably stand a much higher pressure. Further tests will be made of this stone.

Further tests made by Messrs. Musto and Gokhale, Executive Engineers, on the same steelyard testing machine at North-Western Railway Loco. Works, Karachi, on 22nd August 1919. Test specimens prepared as before. Two samples of *Aror* "B" group (*i.e.*, monolithic mass) stone were tested.

Specimen No. 1.—This failed suddenly without any previous sign of distress at a pressure of exactly 9 tons.

Specimen No. 2.—This developed fine cracks at a pressure of 8 tons 4 cwts. and after standing a few moments with that pressure, failed by sides falling away. The central column about 1" square although crushed did not fall away and it was only when pressure was removed that the top and bottom prisms could be lifted clear of one another. These two prisms were not quite concentric seeming to show that pressure was not quite evenly distributed. The first specimen after failure left an almost symmetrical prism.

Average of two specimens $= \frac{17 \text{ tons } 4 \text{ cwt.}}{2}$

= 8 tons 12 cwt. per 2″ cube.
= 2 tons 3 cwt. per sq. inch.
= 4816 lbs./sq. inch.

∴ factor of safety with 316 lbs./in^2 pressure.

$$= \frac{4816}{316} = 15 \cdot 2.$$

or for weakest sample = 8 tons 4 cwt. per 2″ cube.
= 2 tons 1 cwt. per sq. inch.
= 4592 lbs./in.^{2}

∴ factor of safety $= \frac{4592}{316} = 14 \cdot 5$

The highest intensity of pressure estimated in any of the arches is 316 lbs./in^2, so it is considered that the *Aror* " B " stone which gives a factor of safety of about 15 is amply strong enough, and will be a more suitable stone to use for this work than would the " A " group stones, as the latter cannot be obtained in large blocks and it would be necessary to build the voussoirs in courses, if this stone were used. The "B" stone, on the other hand, is perfectly regular in quality and can be cut in any size blocks, so that the voussoirs could be cut in one piece each, of full depth of arch.

This would avoid many joints, which are usually a source of weakness, and would probably more than balance the extra strength of the " A " stone.

Moreover, the " B " stone is much easier to work, and the single stone voussoirs would be more expeditiously handled and laid, than would numerous small stones for coursed voussoirs.

(Sd.) A. A. MUSTO,
Executive Engineer,
Sukkur Barrage Project District.

Further independent Tests of A and B group stones from Kalka, Aror and Rohri quarries have been made by the Professor of Civil Engineering, at the College of Science, Poona, and his report is attached.

CRUSHING STRENGTH OF STONE.

RESULTS OF TESTS CARRIED OUT BY PROFESSOR C. GRAHAM SMITH OF THE COLLEGE OF ENGINEERING, POONA.

(*Vide Letter No.* 2947, *dated* 22-12-1919 *from Principal, College of Engineering, Poona*).

——	Aror A.	Aror B.	Rohri A.	Rohri B.	Kalka A.	Kalka B.
	35,950*	17,570	71,080	20,360	47,350	11,700
	44,730*	16,710	45,990	21,330	62,310	14,990
	42,260*	13,870	53,280	26,060	36,640	13,380
	62,440	23,250	60,230	19,860	52,700	19,890
	69,990	17,580	46,630	11,580	38,570	18,590
	79,900	17,060	54,460	19,930	57,170	15,570
Average crushing load on sample in lbs. ..	70,777	17,673	55,278	19,853	49,123	15,570
Do. per sq. inch. ..	17,694	4,418	13,819	4,963	12,281	3,892

* The first three results of Aror A are unreliable and are certainly too low as the briquettes were crushed on their wrong faces.

2. All briquettes were 2-inch cubes.

3. The figures in the table are the actual loads in pounds carried by the briquette on a sectional area of 4 square inches. To obtain the crushing stress these loads must be divided by 4.

4. The briquettes were surfaced top and bottom and tested dry on the 5th December 1919, in a Richle Testing Machine.

APPENDIX J.

Average monthly gauge readings at Bukkur for ten years 1909-1919 during period of pumping in cofferdams, *i.e.*, November to March.

Year.	Average Bukkur Gauge Readings for				
	November.	December.	January.	February.	March.
1909	2·19	1·06	..	..	..
1910	1·82	0·93	1·18	0·82	1·01
1911	2·80	2·21	2·00	2·60	4·93
1912	2·39	1·42	2·27	2·71	1·93
1913	2·96	1·95	1·48	1·35	2·56
1914	4·30	3·26	1·42	1·41	2·67
1915	1·78	0·38	1·94	2·56	3·43
1916	2·27	1·27	—0·58	—0·68	—0·78
1917	3·61	1·27	0·42	0·19	0·51
1918	1·28	0·40	0·88	0·42	1·34
1919	..	..	0·12	0·76	2·03
Total for 10 years	25·40	14·15	11·13	12·14	18·60
∴ Average gauge reading for 10 years	2·54	1·41	1·11	1·21	1·86

Highest Bukkur Gauge Readings for years 1909 to 1919 during the months 1st November to 31st March.

1909.		January 25	2·6
November 1 & 2	3·1	November 2	2·6
„ 3 to 7	2·9	„ 3	2·5
„ 8	2·7	„ 4	2·4
„ 9	2·6	„ 5	2·3
„ 10	2·5	„ 6 & 7	2·2
1910.		March 31	2·2
January 22 & 23	3·7	November 8	2·1
„ 24	3·2	„ 9	2·0
November 1	2·7	March 30	2·0

Highest Bukkur Gauge Readings for years 1909 to 1919 during the months 1st November to 31st March *contd.*

1911.

March 23	11·6
„ 22	10·5
„ 24	9·9
„ 20 & 25	8·6
„ 21	8·2
„ 18 & 19	8·0
„ 17 & 26	7·5
„ 27	6·7
„ 28	6·0
February 2	5·6

1912.

January 31	4·0
„ 30	3·9
February 1	3·8
„ 2	3·6
„ 3	3·3
„ 4	3·2
„ 5	3·0
November 1	3·0
„ 2	3·0
„ 3	2·9
„ 4	2·8
„ 5 & 6	2·7
„ 7, 8, 9 & 10	2·6

1913.

November 1 & 2	3·4
„ 3, 4 & 5	3·3
„ 6 & 7	3·2
„ 8 to 13	3·1
March 23 to 29	3·0
November 14 to 16	3·0
March 22	3·0
November 17, 18 & 19	2·0
March 29, 30 & 31	2·0
November 20, 21, 22, 23	2·8
March 16, 17, 18, 19 & 21	2·7
November 24 & 25	2·7
March 8, 9, 10, 15 & 20	2·7
November 26, 27, 28 & 29	2·6
March 11	2·6
November 30	2·5
March 7 & 14	2·5

1914.

November 7	5·9
„ 6 & 8	5·8
„ 9	5·6
„ 10	5·4
„ 11	5·2
„ 12	4·8
„ 13 & 14	4·7
„ 14 & 15	4·5
December 12 & 13	4·5
November 16	4·4
„ 17	4·2

1915.

March 21 & 22	5·2
„ 20 & 23	5·0
February 16	4·9
March 24	4·7
February 17	4·6
March 25	4·5
„ 26	4·4
„ 27 & 28	4·3
February 15	4·3
March 24	4·2
February 18	4·1

1916.

November 1	3·2
„ 2 & 3	3·1
„ 4	3·0
„ 5	2·9
„ 6	2·8
„ 7	2·7
„ 8	2·6
„ 9, 10 & 11	2·5
„ 12, 13 & 14	2·4
„ 15	2·3

1917.

November 4	7·5
„ 3 & 5	7·3
„ 6	6·8
„ 2	6·7
„ 7	5·6
„ 8	4·9
„ 9	4·5
„ 10	4·2
„ 11	3·9
„ 12	3·5

1918.

March 28	8·2
„ 29	7·5
„ 30	5·6
„ 27	5·2
„ 31	4·6
„ 24	3·6
„ 25	3·4
„ 26	3·1
„ 23	3·0
November 1	1·9

1919.

March 30	5·4
„ 31	5·1
„ 29	4·7
„ 26 & 27	2·8
„ 25 & 28	2·7
„ 23 & 24	2·6
„ 22	2·5
„ 21	2·3
„ 20	2·0
„ 1 & 2	1·9
November 1	1·9

APPENDIX K.

A Note on Suction Dredgers by Mr. A. A. Musto, Executive Engineer, Sukkur Barrage Project District.

1. The steam suction Dredger "Mudlark" which used to belong to the Indus River Commission and was intended for dredging channels from the river at the mouths of inundation canals in Sind did no useful work in Sind and must be considered to have been a complete failure in Sind. As this fact may be considered an argument against using dredgers on the Barrage construction it is necessary to give the subsequent history of the "Mudlark."

2. Her failure was not so much due to any inherent defect in the ship—though she was not well designed in many respects—as to the fact that she was not fitted with suitable appliances and auxiliaries for the conditions under which she had to work. Also none of the officers under whose control she came, had sufficient mechanical knowledge to make the best of her, or to know and instruct the Dredge Master how she should have been worked.

3. The writer has the advantage of being a fully trained mechanical engineer and after testing the ship at the mouth of the Nasrat Canal in 1915, I reported fully what alterations and additions were necessary, in my opinion, to make her successful and suitable for the work. The Chief Engineer in Sind, (Mr. Gebbie), however, considered that the expenditure recommended was not advisable, and nothing was done in the matter.

4. In May 1916 the dredger was sent to Mesopotamia for sale to the Port Administration, I. E. F. D. at Basra. A Dredge Master (not a trained dredging man) and crew from Sind went with her. I went to Mesopotamia in September 1916 and was engaged under the Port Administration. Up till the end of 1916 the dredger did no useful work, as she had been fitted up with a long suction head, originally supplied in Sind and found to be a failure.

5. At the time I first saw her in January 1917, she was being refitted with her rotary helical cutter, although the Dredge Master stated that she could not work it satisfactorily. On being consulted by the Deputy Director of Port Administration I said I was sure she could do good work with the rotary cutter, as I had tested her with it. She was finally started at work with her cutting gear in January 1917 dredging a creek near Basra and reclaiming land with the spoil. She did moderately good work, her best day's dredging being about 27,000 c. ft. of soil dredged in 10 hours.

6. In the middle of March 1917 the dredger was put under my complete control for the reclamation of about 12 acres of marshes to form a military post at Fao, on the mouth of the Shatt-el-Arab. I now had an excellent opportunity of testing the ship, and as the Dredge Master was under my military orders, I was able to insist on all my own ideas, and methods of work being used.

7. These met at first with considerable dislike and scepticism from the Dredge Master but he was compelled to obey orders, and when he found how much better results he was obtaining with his ship, he became quite keen and thereafter did his best to get the utmost out of his ship. The results were most satisfactory.

8. The ship dredged under most difficult conditions and discharged through her overside pipe to a distance of 90′ from her side, working 10 hours per day. In 14 days including all stoppages for shifting moorings and for clearing large stones out her pump, which had been picked up in dredging she dredged 394,000 cubic feet of clay (measured by accurate measurements of the river bank excavated) or an average of over 28,000 cubic feet per day. Her best day's work was 37,150 cubic feet of soil in 9 hours actual dredging, or over 4,000 cubic feet per

hour. (I am told that she has since done over 40,000 cubic feet per day.) The ship cut for herself a dock 600′ long × 70′ wide right into the clay bank of the river. This bank was just submerged at high tide, and the range of tide was about 12′ maxmium. She dredged down to 4′ below lowest tide level or a depth of 16′ into the river bank; and for a length of about 200′ she dredged down to 9′ below lowest tide level, working only at low tides, as she can only dredge to 12′ below water surface.

9. The work both of dredging and reclamation was a complete success. Since then the ship has been working regularly on similar jobs and is now considered a most valuable piece of machinery. This is the ship which for lack of appliances and intelligent handling was a total failure in Sind.

10. For the work at Fao she had only the same appliances and gear as she always had in Sind, but some of the changes I suggested in 1915 had been made and I had the assistance of a steam tug, when necessary, for lifting her moorings. Since then she has been fitted with a new floating discharge pipe and terminal pontoon which make her still more useful.

11. Had the whole of my suggestions been carried out in 1915 the ship would probably never have left the Indus, and would be doing valuable work to-day in Sind.

12. I would undertake to clear the river-mouth of any canal in Sind, with the "Mudlark" provided I were given the suitable steam tender which I asked for in 1915, for lifting her anchors and the other alterations suggested, and was allowed complete control of the ship. The above facts should dispose of any doubts as to the practicability of dredging at Sukkur.

13. Turning now to the dredgers proposed for the Barrage work these are required for the following purposes.—

(*a*) to dredge foundations and form sand slopes in coffer-dams,
(*b*) to dredge river bed in front of regulators for stone pitching apron,
(*c*) to dredge river bed along site of divide walls for loose stone bed of walls,
(*d*) to dredge river bank along toe of guide bank for laying loose stone apron.

They will also probably be used for—

(*a*) widening the existing Eastern Nara Supply Channel from mile 4 to mile 12,
(*b*) deepening ditto where required,
(*c*) reclaiming, *i.e.*, raising level of sites for bungalows on Sukkur side.

Eventually when the new works are finished one of these ships could be kept in the Eastern Nara and would be most valuable for dredging out the silt accumulated by the floods of past years and generally canalizing the natural river course.

14. The limiting factor for the required capacity of the dredgers is found from the amount of dredging to be done in the coffer-dams before the latter are closed, as this work must be completed as quickly as possible. This is a maximum in the 2nd season's work and will be about 7,500,000 cubic feet of dredging. This must be completed in $1\frac{1}{2}$ months, say 45 days. Therefore output of dredgers must be $= \frac{7,500,000}{45} = 1,66,500$ c. ft. per day, or if 2 dredgers are employed they must each dredge 58,000 cubic feet per day.

If the ships work 12 hours per day, this means they must each dredge 7,000 cubic feet per hour, including all stoppages for shifting moorings, etc.

15. As shown above, the "Mudlark" with a 15″ pump dredged *in clay* under most difficult conditions, continually interrupted by large stones getting into pump on an average about 30,000 c. ft. per day of 10 hours, or 3,000 c. ft. per hour, while under more favourable conditions she did over 4,000 cubic feet per hour. The steam suction Dredger "Madras" when working pure sand takes on an average in her best month's work 90 minutes to fill her hoppers,

i.e., to dredge 900 tons or, say, 21,000 cubic feet. Hence she does 14,000 cubic feet per hour. She has 2—20″ pumps.

Assuming discharge is proportion to the cross sectional area of the suction pipes (and pumps).

We have area of "Mudlark's" pipe $= \frac{\pi}{4} \times 15^2$.

,, ,, "Madras" ,, $= \frac{\pi}{4} \times 2 \times 20^2$.

Omitting the constant $\frac{\pi}{4}$ we have the ratio of their discharges as 225 is to 800.

Taking the discharge of the "Mudlark" under good conditions as 4,000 c. ft. per hour the "Madras" should do $4{,}000 \times \frac{800}{225} = 14{,}200$ cubic feet per hour, which very nearly agrees with her actual output. Hence discharge may be assumed proportional to area of suction pipes.

16. We require for Barrage work, 7,000 c. ft. per hour. The "Madras" dredges 14,000 c.ft. per hour with 2—20″ pumps. Hence one 20″ pump should give our required discharge. This, however, allows nothing for emergency or margin. A margin can always be had by working the ship for longer hours per day. With a few extra men in the crew these ships can easily work 16 hours per day, giving a 33% increase of output over that estimated. On the Hammar Lake in Mesopotamia we worked the dredgers 16 and 18 hours per day in the hot weather when the water of the Lake was too hot to bathe in and Chinese labour on the ship died of heat stroke. The conditions at Sukkur will never approximate to these in severity.

17. Hence we require 2 suction dredgers each with 20″ suction pipes and pumps.

18. Each dredger should be supplied with 1,000′ of steel floating discharge pipe with ball and socket joints and with a terminal pontoon to discharge to a height of 25′ above water line and to a distance of 80′ clear from either side or *end* of pontoon.

19. The dredgers should be capable of discharging both ahead and astern if possible, the necessary gays and stays being fitted to the first length of ahead discharge pipe to keep it clear of the suction head derrick.

This would be a great convenience for placing material when starting work in an existing waterway or canal.

20. If this cannot be conveniently arranged it must be omitted and an overside discharge on either side at deck level might be substituted.

21. If the suction pipe of dredgers can be made to swivel sideways at the bows, it would be a great convenience, as it would enable the ship to work in a much narrower channel than she could with a fixed central suction pipe.

With a fixed central suction head it is necessary to cut a channel much wider than the ship to enable her bows and stern to clear the edges of the dredged channel, when she is swung for dredging. Thus the "Mudlark" with a beam of only 32′ cannot cut a channel of less than 60′ width for continuous dredging, whereas with a swinging suction head she could easily work in a 40′ channel.

22. To serve the two dredgers a paddle steamer launch is required for lifting and placing anchors and bringing in cables. This launch is absolutely essential if rapid work is to be done. The heavy anchor boat propelled by oars, as supplied with the "Mudlark" is quite useless and unsuitable for such work. She is too deep in draught, too heavy for rapid work in a heavy

stream, and she has no winches or other arrangements for lifting the heavy anchors deeply embedded in the sand.

23. Under the most favourable conditions of dredging it is necessary to shift one or two anchors after every few hours' dredging, and with the "Mudlark's" anchor boat, it took half a day to move one anchor, and was often almost impossible. In the meantime the whole of the expensive ship stands idle.

24. What is essential, is a shallow draft, flat bottomed paddle launch, with independent paddles. She should draw not more than one foot of water when fully laden with crew of 10 men, 2 heavy anchors and 4 coils of steel hawser, in addition to her own full working weight. She should be high in the bows and be fitted with a powerful geared steam winch set high and capable of lifting the heaviest anchors out of the sand. The winch should have its own very heavy wire cable for lifting the anchor and all fairleads and fittings must be particularly heavy and well designed to get a vertical lift on the anchor. Deck space and a large steam driven winding drum should be available at the stern for paying out or taking in the anchor cables to dredger. A strong davit should be provided at the stern for swinging out the anchor when laying and the deck space should be sufficient to accommodate 2 anchors and 4 coils of cable at the stern.

With such a launch, anchors and moorings could be quickly laid and lifted in any sort of stream, and delays in working the dredger would be reduced to a minimum.

25. Cutter gear.

The suction pipe should be fitted with a helical cutter and gearing, driven by an independent engine controlled from the dredging bridge. The cutter must be provided with ample power for breaking up branches of trees embedded in the mud, up to say, 5″ or 6″ diameter.

Inside the helical cutter and over the mouth of the suction pipe should be fitted an easily removable grid, which would prevent stones or other debris, too large to pass through the pump, from entering the suction pipe. This grid would only be used when necessary and should be capable of simple attachment and removal without disturbing the cutter in any way.

26. Dredging pump.

There should be ample room in the pump hold, for easily removing covers of pump for inspection. *Short* lengths of suction and delivery pipes, easily removable (not cramped for room) should be fitted to either side of the pump, for rapidly opening up and inspecting pump and pipes.

27. The feed water and circulating water inlets should be in such a position (preferably at stern) as not to become clogged with mud when the ship rubs against the side of cut. If they must be kept at the side of ship they should be recessed and protected by a steel rubbing-piece flush with the side of ship. The "Mudlark" gave constant trouble in this respect.

28. An efficient indicator visible from all parts of the bridge should be fitted to show the depth of the *bottom* of cutter below water surface.

29. All stations for men working warping winches should be provided with roofs to give effective protection from the sun, but these roofs must not interfere with the view of winches from the bridge, nor with any of the hoisting tackle or stays.

30. All warping winches both fore and aft should be fitted with friction clutch connections from the drums to the engines, and with powerful rapid action brakes worked by hand wheels.

31. Separate telegraphs and indicators should be fitted on bridge and at machines for every warping winch and speaking tubes to bridge should also be fitted.

32. Ample accommodation and deck space should be provided for all officers, if possible, on upper deck and for crew on main deck.

33. Boilers should be fitted for oil fuel.

34. Searchlights should be provided fore and aft for night work.

35. A motor launch to carry 20 men and travel at 12 knots should be provided as tender for each dredger.

36. Usual ships boats and one light dinghy suitable for fitting light rudder motors should be provided.

37. The dimensions of ships may be approximately 200′×40′ and the draft, when fully laden, must not exceed 3 feet. They must be able to dredge to 30′ below water level.

38. The draft of the terminal pontoon must not exceed 18″ with pipe full of water and stand.

39. The speed of the dredger when towing her full compliment of pipes (on flats, or on their own pontoons) should be about 7 miles per hour.

40. For the acceptance trial, the capacity of the dredger when working in ordinary silt and sand or in clay banks in the Indus at Sukkur with occasional branches and roots of trees embedded, etc., must be not less than 70,000 cubic feet of materials dredged, per day of 10 hours. This rate of progress should be an average over 5 days continuous work, *i.e.*, for 50 hours' working and to include all time spent in putting out and shifting moorings, cables, etc., and in shifting discharge pipe and pontoon, after latter is connected up for work.

The discharge to be delivered through the full 1,000′ of discharge pipe and out of the terminal pontoon, outlet 25′ above water line and 80′ clear from edge of pontoon. The quantity dredged, to be decided by accurate measurements taken daily before and after work of the side dredged, and if possible to be checked by measurements of the material deposited inside a bunded area, due allowance being made after testing waste water for the small quantity carried over the waste weir.

41. Many other details of the specification for these ships have been noted, but are omitted here for brevity. The ships should be built to the specification and under the observation and constant inspection of an officer with mechanical and dredging experience and if possible of the officer who is to have charge of them.

42. Cost of Dredgers.

I estimate the approximate cost of these two ships complete with pipe lines, terminal pontoons, launches and all gear to be described in detailed specification, at £40,000 each.

Competitive designs and tenders should be invited from several good builders such as Messrs. Vickers, Messrs. Beardmore, Messrs. Simons, Messrs. Cammel Laird and Company and others. For the shallow draft paddle launch to lay anchors, Messrs. Yarrow and Messrs. Thornycroft, who are both specialists in shallow draft steamers might be asked to submit designs and estimates. Messrs. Simons & Co. are not specialists in this line.

43. For details of working expenses, cost of dredging and saving to be effected by their use, see Part VIII, Section XIV, of Report pp. 207-210.

44. Besides being indispensable for the coffer-dam work, and for the widening and deepening of the Eastern Nara Supply Channel and being a great convenience for many jobs, these dredgers, in my opinion, will save their whole cost during the construction of the Barrage and Canals.

APPENDIX L.

List of Calculation Sets.

Stability Calculations for

Barrage.

Set No. 1.

DESIGN OF BARRAGE FLOOR TO STAND HEAD OF 18·5′.

Undersluice portion. *Drawing No. 42.*

If hydraulic g radient is to be 1 in 17, total length of creep must be 17 × 18·5=315′.

Assume length of paving downstream of gates is, 120′ then the balance 315—120=195 must be made up of length upstream of gates plus sheet piling. If length upstream of gates is 70′, this leaves 195—70=125 to be made up of vertical creep. If the upstream and downstream piling are each made 12′ deep (minimum) this gives 48′ of creep leaving 125′—48′= 77′. There will be 4′ drop at front of paving and 4′ rise at end of paving=8′ leaving 69′. If centre paving is 11′ thick there will be one vertical rise of 5′ plus one inclined rise adding 2′ to creep=7′ leaving 62′ for the two lots of centre piling. If the downstream centre piles are 12′ long this leaves 62′—24′=38′ for the upstream centre piling or latter must be 19′ long, say 20′ long.

Investigation of stability against upward pressure.

The floor must be safe as far as the gate on upstream side, since the downward pressure of water is always equal to or greater than the upward pressure.

Immediately below the gates.

Loss of head to gate.

Upstream paving	40′+4′	=44′	creep.
„ piling	12′	=24′	„
Centre floor to gate	30′+2′	=32′	„
Upstream centre piling	20′	=40′	„
		140′	„

Creep = 140′

$$\therefore \text{ Loss of head} = \frac{140}{17} = 8\cdot24$$

Balance of upward pressure	=18·5—8·24
	=10·26
Add—33 per cent. for safety	=3·42
Total downward pressure required	=13·68′ of water.

If masonry is 11′ thick and its specific gravity submerged is 1·25, its effective weight will be 11 × 1·25=13·75′ of water which is sufficient.

2. *At downstream paving upstream end, i.e.,* junction with central masonry floor.

From below gate to end of centre floor=50′		= 50′	creep.
downstream centre piling	12′	= 24′	„
Step up to downstream paving	5′	= 5′	„
		= 79′	„
Add—creep to gate		= 140′	
		219′	creep.

$\therefore$ Loss of head to this point

$$= \frac{219}{17} = 12\cdot88$$

Balance of upward pressure .. .. = 18·5 — 12·88
= 5·62

Add—33 per cent. for safety .. = 1·87

Downward pressure required .. .. .. = 7·49′ head of water.

If masonry is 6′ thick and specific gravity submerged is 1·25′, its effective weight will be $6 \times 1 \cdot 25 = 7 \cdot 5'$ head of water which is just sufficient.

3. *End of paving upstream edge of piling.*

Brought down .. = 219′ creep.
Downstream paving =65′ = 65′

284′ „

$\therefore$ loss of head $= \dfrac{284}{17} = 16 \cdot 7$

Balance of upward pressure = 18·5 — 16·7
= 1·8

Add—33 per cent. for safety = ·6

Downward pressure required .. = 2·4′ head of water.

Hence 2′ of masonry would be sufficient here but this would be too thin for general reasons and a minimum thickness of 4′ will be used.

Loss of head to end of pavement.

Brought forward ..	284′	creep.
Downstream piling	12′=24′	„
Paving beyond piling	5′ = 5′	„
Step up	= 4′	„
	317′	creep.

which is what was required for a gradient of 1 in 17.

Note.—For undersluice portion, more protection is desirable *downstream* and less upstream, than in the case of the Barrage ordinary spans, because the undersluices will run much more continuously and the greatest wear is *downstream* of the gates. Also at the undersluices there will be loose stone protection upstream, for the full length of the regulators, and this will slope down with the natural bed of river so that much masonry is not needed upstream of the gates.

The extra protection downstream of the undersluices will be provided by a greater length of concrete blocks, and loose stone pitching.

Undersluice portion.

This design gives 120′ of pakka paving below the gates or 6·5 times the head (18·5′) as against 4·33 times the head (15′) allowed at the Esna Barrage.

Beyond this point there will be large concrete blocks for a distance of 103′ making 223′ protection from the gates or 12 times the head (18·5) as against 10 times the head (15′) allowed at Esna (after repairs.) Beyond this will be a talus of loose stone pitching for a further 150″ making total protection, 373′ or 20 times the head (18·5) as against 12·8 times the head (15′) allowed at Esna originally (too little and caused scour below) and 20 times the head (15′) allowed after repairs in scoured bed.

Ordinary Barrage Sluices.

Here there will be only 83′ of concrete blocks making total 203′ to end or 11 times the head (18·5′) as against 10 times the head (15′) at Esna. Beyond this will be loose stone protection for a further 100′ making total 303′ or 16·5 times the head (18·5′) as against 20 times the head at undersluices and as against 12·8 times the head (15′) allowed at Esna originally (and found too little, owing to small size of stone).

Set No. II.

STABILITY DIAGRAM FOR ORDINARY PIER OF BARRAGE LONGITUDINAL SECTION AND PRESSURE ON SAND.

Drawing No. 48.

Plan No. 48 shows the stability diagram of the ordinary 10 piers in a longitudinal direction. In a cross direction, there may at times be a slight difference of level in the water on two sides of the same pier (due to different regulation by the gates on either side) but the side pressure exerted will be so small in comparison with the great weight on the piers, that it has not been considered necessary to calculate its effect. The calculations show that *the worst possible conditions* give an intensity of pressure of 99 *lb./sq. in. in the masonry at the base* of the upstream toe of the piers.

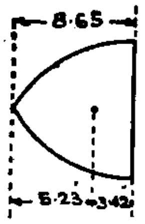
Also that the maximum possible intensity of *pressure on the sand* below the foundation block is 31 *lb./sq. in. or* 1·98 *tons* per square foot.

(1) Calculations—

Vertical forces—

Tons.

(*a*) Cutwater—



Centre of gravity as found graphically.

Weight from R. L. 176 to 207—Top of caps.

area

31 × 61·5 × 150 = 2,85,975 lb. = 127·5 tons. — 127·5

(*b*) Pilasters—R.L. 207 to 238·5

1·5 × 8 × 31·5 × 150 lb. = 25·3 tons. — 25·3

	Tons.	
(c) Upstream gate arches—		
R. L. 176 to 219.		
10 × 8 × 43 × 150 = ...	230·5	
R. L. 219 to 238·5.		
1 × 8 × 19·5 × 150 = ...	10·4	
Arch Drawing No. 53.		
2 × 8 × 78,888 lb. = ...	563·4	
	804·3	
		801·3
(d) Pier between ribs—		
R. L. 176 to 238·5.		
16 × 10 × 62·5 × 150 lb. = ...	670	
		670

(*e*) Downstream gate arches— Tons.

R. L. 176 to 219

$10\times5\times43\times150$ lb.= 144

Between arches R. L. 219 to 238·5.

$5\times2\times19\cdot5\times150$ lb.= .. .. .. 13·1

Arch Drawing No. 54.

$2\times5\times80{,}810$ lb.= .. .. 360·5

517·6 — 517·6

(*f*) Pilaster, etc., between gate and road-bridge—

R. L. 176 to 214·25.

$10\times1\frac{1}{2}\times38\cdot25\times150$ lb.= .. .. .. 38·4

R. L. 214·25 to 238·5.

$8\times1\frac{1}{2}\times24\cdot25\times150$ lb.= .. .. .. 19·5

57·9 — 57·9

(*g*) Road bridge—

Road bridge—

Pier R. L. 176 to 201.

$25\times10\times25\times150$ lb.= 420

Road Arch Drawing No. 52.

$2\times48283\times25$= 1,075

1,495 — 1,495

(*h*) Pilaster—

R. L. 207 to 214·25.

$1\frac{1}{2}\times8\times7\cdot5\times150$ lb.= .. .. .. 6 — 6

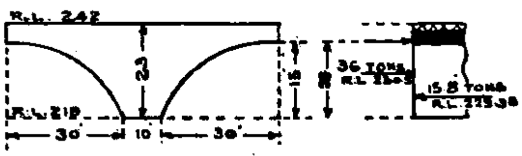
(*i*) Ease water—

Same as cut water .. .. 127·5

Horizontal forces.

(*j*) Wind—

Pressure at 40 lb. per square foot on face of gate bridge arches and spandrils and parapets.



Wind pressure .. .. $=70\times23\times50$ lb.

$=36$ tons acting at R. L. 230·5.

Deduct area of intrados .. $=\frac{\pi}{2}\times30\times15\times50$ lb.

$=15\cdot8$ tons acting at R. L. 225·35

$(219+15\times\cdot4244)=219+6\cdot35$.

Taking moments round R. L. 219.

$(36-15\cdot8)\,x \quad .. \quad .. \quad = 36\times11\cdot5 - 15\cdot8\times6\cdot35.$

$= 414 - 100\cdot33.$

$\therefore\ 20\cdot2\,x \quad .. \quad .. \quad .. \quad = 313\cdot66.$

$\therefore\ x \quad .. \quad .. \quad .. \quad = 15\cdot53.$

∴ We have the resultant .. =20·2 tons acting at R. L. 234·53 (219+15·53).

(*k*) Wind on counterweight—

R. L. 224 to 232.

60×8×50 lb. .. .. =10·7 tons at R. L. 228.

(*l*) Wind on Road-bridge—

Face of arch and spandrils and parapet.

R. L. 201 to 219 Top of parapet.

Rectangle ..70×8×50 lb.=28·1 tons acting at R. L. 210.

Deduct opening .. .. $= \frac{\pi}{2}\times30\times10\times50$ lb.

=10·5 tons.

(at 201+4·244).

=205·244.

Taking moments round R. L. 201, we have

$(28\cdot1-10\cdot5)\,x \quad .. \quad .. \quad = 28\cdot1\times9 - 10\cdot5\times4\cdot244.$

$\therefore\ 17\cdot6\,x \quad .. \quad .. \quad .. \quad = 252\cdot9 - 44\cdot56.$

$= 208\cdot34.$

$\therefore\ x \quad .. \quad .. \quad .. \quad = 11\cdot84.$

∴ Resultant .. .. .. 17·6 tons acting at R. L. (201+11·84)=212·84.

(*m*) Wind on pier—

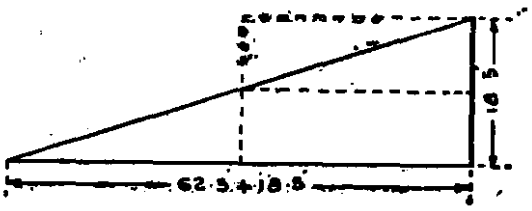
R. L. 194·5 to 201.

$10\times6\frac{1}{2}\times50$ lb. .. .. =1·49 tons at R. L. 197·75.

(*n*) Water pressure on pier and gate—

$$70\times18\cdot5\times\frac{62\cdot5\times18\cdot5 \text{ lb.}}{2} = 335 \text{ tons at R. L. } \left(176+\frac{18\cdot5}{3}\right)$$

i.e., 182·16.



Horizontal Forces. Taking moments at R. L. 176.

Forces.	R. L.	Arm from R. L. 176.	Amount.	Moments.
			Tons.	
J.	234·53	58·53	20·2	1,182
K	228	52·00	10·7	557
L	212·84	36·84	17·6	649
M	197·75	21·75	1·49	32·5
N	182·16	6·16	335	2,060
Total Horizontal Thrust			384·99	4,480·5

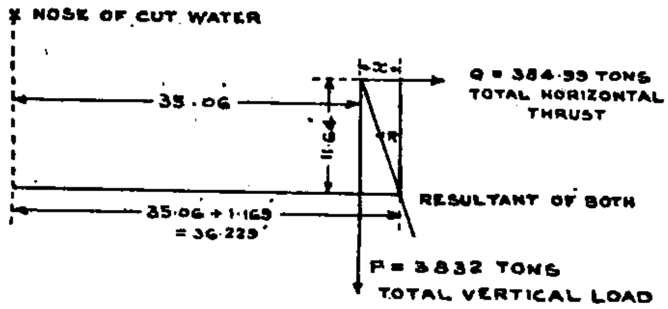
∴ Resultant of all horizontal forces act at $\frac{4480\cdot5}{384\cdot99}$ =11·64 ft. from 176, *i.e.*, R. L. 187·64.

Vertical Forces. Taking moments round nose of cut-water.

—	Amount.	Arm.		Moments
a	128 tons.	5·23 .. .. =	5·23	670
b	25 "	8·65—0·75 .. .. =	7·90	197
c	804 "	8·65+4 .. .. =	12·65	10,170
d	670 "	8·65+8+8 .. .. =	24·65	16,515
e	518 "	8·65+8+16+2·5 .. .. .. =	35·15	18,200
f	58 "	35·15+2·5+0·75 .. .. .. =	38·40	2,230
g	1,495 "	38·40+0·75+12·5 .. .. .. =	51·65	77,217
h	6 "	51·65+12·5+0·75 .. .. .. =	64·90	390
i	128 "	64·90+3·42 .. .. =	68·32	8,750
Total ..	3,832 tons.			134,339

∴ Resultant of all vertical forces act at $\frac{134339}{3832}$ =35·06 ft. from nose of cut water.

Resultant of Horizontal and Vertical Pressures.



To find X :—

384·99×11·64 .. .. =3,832×X.

∴ X .. .. $=\frac{384\cdot99\times11\cdot64}{3832}$ ft.

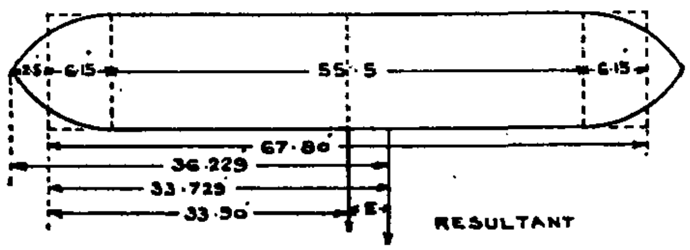
=1·169 feet.

∴ The final resultant cuts base of pier at distance 35·06+1·169 ft.

=36·229 feet from nose of cut water.

Intensity of pressure in masonry at base of pier.

Case I. Gates lowered water and wind pressure considered.



∴ E =33·90–33·729 = 0·171 feet

and A =67·8×10.

Y =33·90.

$$S = \frac{Q}{A}\left(1\pm\frac{EY}{K^2}\right)=$$

$$=\frac{3832}{678}\left(1\pm\frac{0\cdot171\times33\cdot9}{67\cdot8\times67\cdot8}\times12\right).$$

$$=5\cdot65\left(1\pm\frac{1\cdot026}{67\cdot80}\right)=5\cdot65\,(1\pm0\cdot01515).$$

∴ Greatest pressure .. .. .. $=5 \cdot 65 \times 1 \cdot 01515$.
$=5 \cdot 74$ tons/sq. ft.
$=89 \cdot 29$ lb./sq. in., say 90 lb./sq. in. at upstream toe.

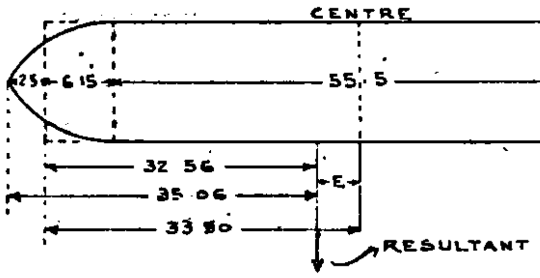
∴ *Maximum pressure at base of pier will be 90 lb./sq. in.* at the upstream toe.

Minimum pressure $5 \cdot 65 \times 985$ .. .. $=5 \cdot 55$ tons/sq. ft.
$=86 \cdot 5$ lb./sq. in.
say 86 lb. at downstream toe.

Case II. *Gates raised and wind pressure not considered.*

The eccentricity is greater when water pressure and wind pressure are not considered.

The resultant then is :—



$E = 33 \cdot 90 - 32 \cdot 56$.
$= 1 \cdot 34$.
$A = 67 \cdot 80 \times 10$.
$Y = 33 \cdot 90$.

$$S = \frac{Q}{A}\left(1 \pm \frac{EY}{K^2}\right)$$

$$= \frac{3832}{678}\left(1 \pm \frac{1 \cdot 34 \times 33 \cdot 90 \times 12}{67 \cdot 80 \times 67 \cdot 80}\right)$$

$$= 5 \cdot 65\left(1 \pm \frac{8 \cdot 04}{67 \cdot 80}\right)$$

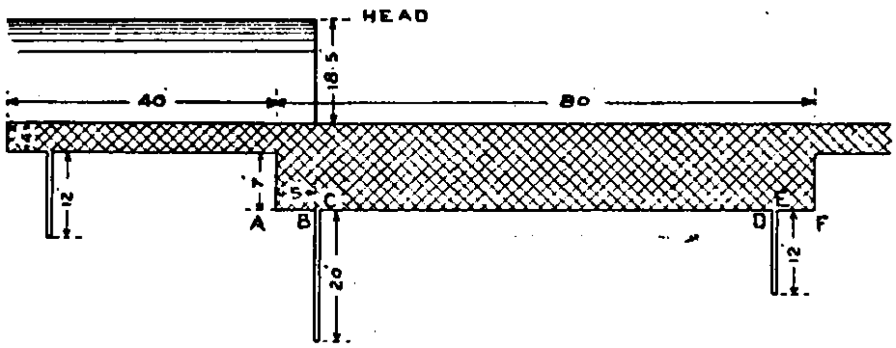
$= 5 \cdot 65 \, (1 \pm 0 \cdot 119)$.
$= 6 \cdot 3$ *tons/sq. ft.*
$= 98 \cdot 5$ *lb./sq. in.* say 99 lb./sq. in.

∴ 99 *lb/ sq. in. is the maximum pressure* that can possibly occur at upstream toe if there is no horizontal thrust, *i.e.*, if the gates are out of water and there is no wind at all.

Minimum pressure .. .. $=5 \cdot 65 \times 881$ tons.
$=4 \cdot 97$ tons/sq. ft.
$=72 \cdot 5$ lb./sq. in. say 72 lb. at downstream toe.

2. *Pressure on sand at foundations level.*—

Case I.—Gates lowered maximum water and wind pressure considered. Upward pressure of water on foundation.



Upward pressure at A = ... $18 \cdot 5 - \dfrac{\text{Creep at A}}{\text{Hydraulic gradient.}}$

$$=18 \cdot 5 - \frac{4+40+12+12+7}{17 \cdot 1}$$

$$=18 \cdot 5 - \frac{75}{17 \cdot 1} = 18 \cdot 5 - 4 \cdot 386$$

$$=14 \cdot 114'.$$

Upward pressure at B .. .. $=18 \cdot 5 - \dfrac{80}{17 \cdot 1} = 18 \cdot 5 - 4 \cdot 68 = 13 \cdot 82'$.

" " C .. .. $=18 \cdot 5 - \dfrac{120}{17 \cdot 1} = 18 \cdot 5 - 7 \cdot 02 = 11 \cdot 48'$.

" " D .. .. $=18 \cdot 5 - \dfrac{190}{17 \cdot 1} = 18 \cdot 5 - 11 \cdot 11 = 7 \cdot 39'$.

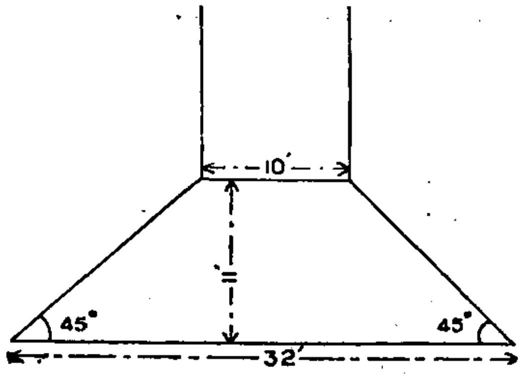
" " E .. .. $=18 \cdot 5 - \dfrac{214}{17 \cdot 1} = 18 \cdot 5 - 12 \cdot 51 = 5 \cdot 99'$.

" " F .. .. $=18 \cdot 5 - \dfrac{219}{17 \cdot 1} = 18 \cdot 5 - 12 \cdot 8 = 5 \cdot 7'$.

∴ Mean head between A & B .. $= \dfrac{14 \cdot 114 + 13 \cdot 82}{2} = 13 \cdot 967'$.

" " C & D .. $= \dfrac{11 \cdot 48 + 7 \cdot 39}{2} = 9 \cdot 44'$.

" E & F .. $= \dfrac{5 \cdot 99 + 5 \cdot 7}{2} = 5 \cdot 85'$.



Supposing weight spreads at an angle of 45°.

∴ Upward pressure on A B .. $=13{\cdot}967\times32\times5\times62{\cdot}5$ lb.

(S) .. $=139670$ lb.

$=62{\cdot}4$ tons acting at $2{\cdot}42'$.

∴ Upward pressure on C D—

(T) .. $=9{\cdot}44\times32\times70\times62{\cdot}5$ lb.

$=590$ tons at $37{\cdot}50'$.

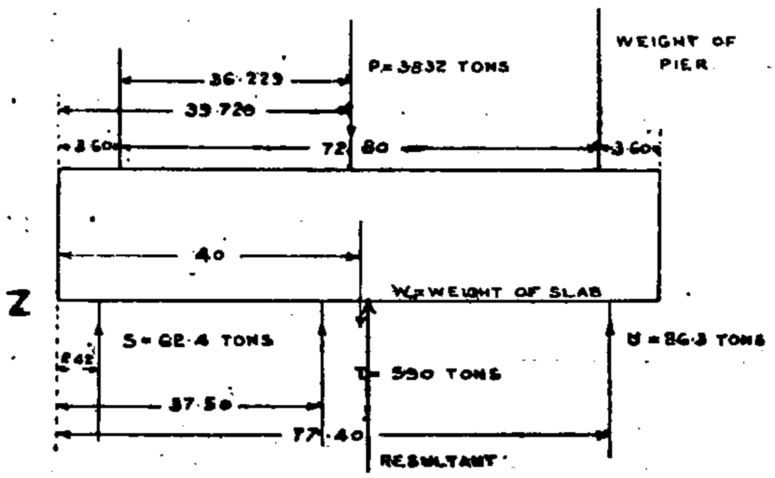
∴ Upward pressure on E F—

(U) .. $=5{\cdot}85\times32\times5\times62{\cdot}5$ lb.

$=26{\cdot}3$ tons at $77{\cdot}40'$.

Note.—The distance of the point of application of the pressure in the above 3 cases is got by graphic construction.

The total forces acting on the sand therefore are as follows :—



$$W=80\times32\times11\times140 \text{ lb.} \quad .. \quad \frac{80\times32\times11\times140}{2240} \text{ ton}=1{,}760 \text{ tons.}$$

Taking moments round Z, we have as follows :—

Amount.	Force.	Amount.	Arm.	Moments.	
	W ..	1,760	40	70,400	
	P ..	3,832	39·729	152,241	
+5592 Downward.					222,641
	S ..	62·4	2·42	150	
	T ..	590	37·50	22,150	
Upward —678·7.	U ..	26·3	77·40	2,035	
					24,3335
4913·3 Surplus Downward.	Net			Net	198,306

The resultant therefore acts at a distance of .. $\frac{198{,}306}{4913\cdot3}$ ft.$=40\cdot36$ ft.

$\therefore$ E .. .. $=40\cdot36=40-0\cdot36$ ft.

A .. .. $=32'\times80'=2{,}560$ sq. ft.

Y .. .. $=40.$

K .. .. $=\frac{1}{12}(80^2).$

S .. .. $=\frac{Q}{A}\left(1\pm\frac{EY}{K^2}\right)$

$$=\frac{4913\cdot3}{2560}\left(1\pm\frac{0\cdot36\times6}{80}\right)$$

$$=1\cdot93\left(1\pm\frac{2\cdot1}{80}\right)$$

$$=1\cdot93\,(1\pm\cdot02625).$$

$=1\cdot98$ *tons/sq. ft.*$=$*Greatest pressure.*

$=30\cdot8$ *lb./sq. in., say* 31 *lb.* at downstream toe.

Minimum pressure .. .. $=1\cdot93\times\cdot974.$

.. .. $=1\cdot88$ tons/sq. ft.

.. .. $=29\cdot2$ lb., say 29 lb./sq. in. at upstream toe.

STABILITY CALCULATIONS FOR ABUTMENT PIERS IN CROSS SECTION.

Two cases have been investigated.

CASE I.—This shows all stresses when the pier is loaded with *full pressures from both gate bridge and road bridge* arches, when the latter are complete and fully loaded *on one side only* of the pier; it being assumed that the arches on other side have collapsed. To support such a load in the event of accident is one function of these abutment piers.

The calculations show that the resultant at the base of the masonry pier, falls just within the middle third, *the maximum intensity of pressure* at the outer edge of the pier being 93 *lb./sq. in.* or 6·0 *tons/sq. ft.*, and the average pressure over the whole pier base being 48·25 lb./sq. in. or 3·1 tons/sq. ft. The *maximum intensity* of pressure *on the sand* below the foundation block is 42 *lb./sq. in.* or 2·70 *tons/sq. ft.*, and the average pressure over whole base area being 26·3 lb./sq. in. or 1·69 tons/sq. ft.

CASE II.—This represents *normal working conditions* with both Gate Bridge and Road Bridge completed on both sides of pier and each carrying its full designed load. The resultant pressure is vertical, through the centre line of the pier, the intensity of pressure at *the base of the masonry pier being* 55 *lb./sq. in.* or 3·55 tons/sq. ft., and the pressure *on the sand* below the foundation block being 32·6 *lb./sq. in. or* 2·1 *tons/sq. ft.*

STABILITY CALCULATIONS FOR ABUTMENT PIER.

Cross Section.

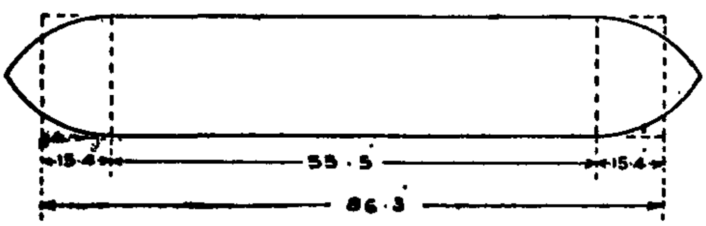
Loads at base of abutment pier :—

Abutment pier masonry as per estimate	76,114	c. ft.
Pilasters „ „ „	7,938	„
Spandrils not included in arch—		
Road Bridge— 1×25×13·25	= 331·25	„
Downstream Gate Bridge, 2×5×19½′	= 195	„
Upstream „ „ 1×8×19½′	= 156	„
	84,734	c. ft.
at 150 lb. ..	=1,27,10,137	lb.
	=5,674	tons.

CASE I.—Arches built only on one side fully loaded.

Supposing arches on one side only are built and fully loaded. The weight of 5,674 tons compounded with the thrusts of the Gate Bridge and Road Bridge Arches gives a net resultant as found graphically, of 6,760 tons acting in line which cuts base of abutment pier 3·9 feet from centre, which is just within the middle third. The normal head here being 6,660 tons.

Intensity of pressure in masonry at base of abutment pier.



$E \;..\; = 3{\cdot}9$

$A \;..\; = 86{\cdot}3 \times 25$

$Y \;..\; = \frac{25}{2}$

$K^2 \;..\; = \frac{25^2}{12}$

$$\therefore S = \frac{Q}{A}(1 \pm \frac{EY}{K^2}) = \frac{6660}{2157}\left(1 \pm \frac{3 \cdot 9 \times 12 \times 12 \cdot 5}{25 \times 25}\right)$$

$$= 3 \cdot 1\,(1 \pm \frac{23 \cdot 4}{25}) = 3 \cdot 1\,(1 \pm \cdot 935).$$

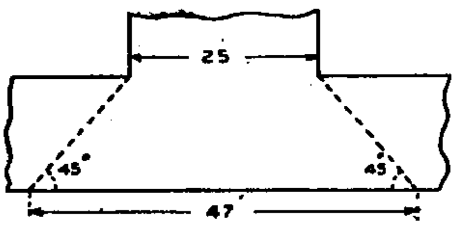
$\therefore$ Maximum intensity .. $= 3 \cdot 1 \times 1 \cdot 935 = 6 \cdot 0$ *tons/sq. ft.*
$= 93$ *lb./sq. in. at outer toe.*

$\therefore$ Minimum intensity .. $= 3 \cdot 1 \times \cdot 065 = \cdot 20$ tons/sq. ft.
$= 3 \cdot 1$ lb./sq. in. at inner toe.

Intensity of Pressure on Sand at bottom of foundations.

Supposing weight spreads out at an angle of 45°

Total weight is spread out over area 47′×100 sq. ft.



Loads.—Weight of block (submerged) at 88 lb.

100×47×11′×88 lb. =2,035 tons.

Upward Pressure.—Taking this as the minimum at the lower end (as per calculations Set No. II), *viz.*, 5·7 feet head of water, the pressure will be—

100×47′×5·7×62·5 lb. =750 tons.

The load on sand due to the foundation will therefore be—

2,035—750 tons =1,285 tons.

This compounded with 6760—weight of superstructure gives a resultant cutting the bottom of foundation 4·7 feet from centre : (see diagram) normal pressure being (6660+1285)=7,945 tons.

The intensity of pressure on foundation therefore is—

$E = 4 \cdot 7$

$Y = \frac{47}{2}$

$K^2 = \frac{47^2}{12}$

$A = 47 \times 100$

$$S = \frac{Q}{A}(1 \pm \frac{EY}{K^2}) = \frac{7945}{4700}(1 \pm \frac{4 \cdot 7 \times 47 \times 12}{2 \times 47 \times 47})$$

$$= 1 \cdot 69\,(1 \pm \frac{28 \cdot 2}{47}) = 1 \cdot 69\,(1 \pm \cdot 6)$$

$\therefore$ Maximum intensity .. $= 1 \cdot 69 \times 1 \cdot 6 = 2 \cdot 70$ *tons./sq. ft.*
$= 42$ *lb./sq. in.*

Minimum intensity .. $= 1 \cdot 69 \times \cdot 4 = 0 \cdot 696$ tons/sq. ft.
$= 10 \cdot 8$ lb. sq. in.

Average=1·69 tons/sq. ft. = 26·3lb./sq. in.

CASE II.—When arches on both sides are built and fully loaded. The abutment is of course stable on both sides.

Loads.—

Weight of abutment pier		5,674 tons.
Vertical Gate Bridge 8′ arch, 2×280	=	560 ,,
,, ,, ,, 5′ arch, 2×180	=	360 ,,
,, Road Bridge, 2×528	=	1,056 ,,
		7,650 tons.

The Intensity of Pressure in masonry at base of abutment pier therefore—

$$= \frac{7650 \text{ tons.}}{86 \cdot 3 \times 25'} = 3 \cdot 55 \textit{ tons/sq. ft.}$$

$$= 55 \cdot 0 \textit{ lb./sq. in. uniform} \text{ on the whole base.}$$

Intensity of pressure on sand in foundations—

Add weight of foundation block submerged 7650+2035=9,685 tons.

Resultant acts at centre and so the pressure can be taken to be evenly distributed on the whole Section.

$$\therefore \text{ Intensity of Pressure } .. = \frac{9685}{47 \times 100} = 2 \cdot 06 \textit{ tons/sq. ft.} = 32 \cdot 0 \textit{ lb./sq. in.}$$

SET No. IV.

Drawing No. 50.

THE END ABUTMENTS OF THE ROAD BRIDGE.

These abutments are extended upstream to carry the last pier of the Gate Bridge. Stability has been investigated for this combined homogeneous abutment and pier. Three cases are investigated.

Case No. 1.—Shows the conditions with *the abutment only built,* and supporting *the full load of earth filling* up to formation level behind it, with lowest water level (R. L. 185) in the river. The calculations show that the abutment is just stable under these conditions, while the maximum intensity of pressure at the river-side toe is *only* 80 *lb./sq. in.*, there being very slight tension of 6 lb./sq. in. at the inner toe. Actually, conditions would *never be as severe* as shown. For calculation it has been assumed that the filling is very wet (practically liquid) sand weighing 125 *lb./c.ft. with an angle of repose of* 30° .

Case No. 2.—Shows the conditions if all arches were built and *fully loaded, before any filling were done* behind the abutment. This also shows the section to be perfectly stable, the mass intensity of pressure in masonry being 77 lb./sq. in. or 4·95 tons/sq. ft. at the inner toe.

Case No. 3.—Shows *the final conditions* after completion of the bridges, *i.e.*, with earth filling up to formation level, and with all arches fully loaded.

This shows the abutment to be perfectly safe, the resultant pressure cutting the base almost vertically near its centre, and *the maximum intensity of pressure* in the *masonry toe, being* 68 *lb./sq. in. or* 4·35 *tons/sq. ft.*

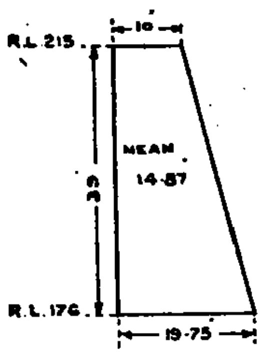
The maximum pressure on the sand below the foundations is 28 *lb./sq. in. or* 1·81 *tons/sq. ft.*

Case 1.—*Abutment is built up to road level R. L.* 215 *and earth filling behind is done, but arches not done.*

Calculations :—

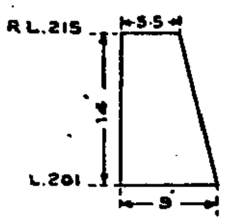
Weights :—

(*a*) Under Gate Bridge—

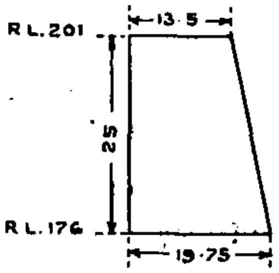


		Tons.	Arm.	Moment.
	30·5×14·87×39×150 lb. ..	1,185	7·6	9006

Under Road Bridge—



		Tons.	Arm.	Moment.
	25×7·25×14×150 lb. ..	170	8·3	1410



		Tons.	Arm.	Moment.
25×16·62×25×150 lb. ..	..	696	8·4	5850
Total	..	2051		16266

tons acting at 7·93 ft.

(*b*) Total earth Pressure .. .. $=$Area of triangle AFD.

$$=55\cdot5\times\frac{15\cdot7\times39}{2}\times125 \text{ lb.}$$

$=948$ tons.

(*c*) Water pressure with water at R. L. 185, in low water level

$$=9\times55\cdot5\times\frac{9}{2}\times62\cdot5 \text{ lb.}$$

$=62\cdot7$ tons.

The resultant of all of three—weight of abutment, earth pressure and water pressure cuts the base of abutment 3·8 feet from centre. This is just outside the *middle third.*

In that case.

E .. .. $=3\cdot8$

Y .. .. $=\dfrac{19\cdot75}{2}$

K^2 .. .. $=\dfrac{(19\cdot75)^2}{12}$

A .. .. $=19\cdot75\times55\cdot5.$

S .. .. $=\dfrac{Q}{A}\left(1\pm\dfrac{EY}{K^2}\right)$

$$=\frac{2600}{19\cdot75\times55\cdot5}\left(1\ \frac{3\cdot8\times19\cdot75\times12}{2\times19\cdot75\times19\cdot75}\right)$$

$=2\cdot37\ (1\pm1\cdot155).$

$=2\cdot37+1\cdot155$ tons/sq. ft.

$=2\cdot65$ tons/sq. ft.

$=79\cdot5$ lb./sq. in., say, 80 lb.

∴ *The maximum intensity of pressure* at outer toe (*vertical face*) *is* 80 *lb. per sq. in.*

Tension—

$=2\cdot37\times\cdot155$ tons.

$=\ \cdot25$ tons/sq. ft.

$=5\cdot7$ lb./sq. in.

$=$*say* 6 *lb./sq. in.*

∴ At the inner toe (Battered face), there is a tension in masonry of intensity 6 lb./sq. in. This is the worst case, filling behind the abutment is done with very wet sand having an angle of repose of 30° and weighing 125 lb. per cubic foot.

Case 2.—*All arches built and fully loaded, earth filling behind abutment not done.*

We see from the diagram that this will give a resultant of 3,920 tons cutting the base of abutment 1′ 4″ from centre.

The abutment is therefore quite safe against overturning and there is no tension in the masonry. For Intensity of Pressure in masonry :—

$$E = 1\cdot33$$

$$Y = \frac{19\cdot75}{2}$$

$$A = 19\cdot75 \times 55\cdot5$$

$$K^2 = \frac{19\cdot75 \times 19\cdot75}{12}$$

$$S = \frac{Q}{A}\left(1 \pm \frac{EY}{K^2}\right) = \frac{3850}{19\cdot75 \times 55\cdot5}\left(1 \pm \frac{1\cdot33 \times 19\cdot75}{2} \times \frac{12}{19\cdot75 \times 19\cdot75}\right)$$

$$= 3\cdot52\left(1 \pm \frac{7\cdot98}{19\cdot75}\right) = 3\cdot52 \times 1\cdot405$$

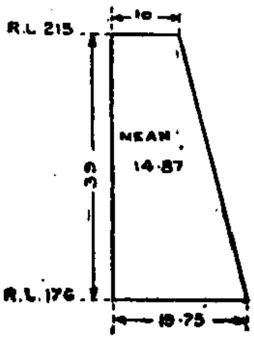
= 4·95 tons/sq. ft.
= 77 lb./sq. in. maximum pressure
Inner toe.

and 3·52 × ·595 tons.
= 2·1 tons/sq. ft. = 32·6 lb./sq. in. minimum Pressure
Riverside toe.

Case 3.—Final conditions.

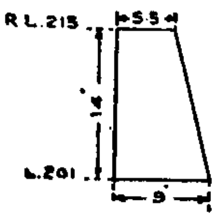
Calculations :—

Vertical loads R. L. 219 to R. L. 238·5 ..	Load in tons.	Arm from left face.	Moments
(a) Pilaster, 8×1·5×19½×150 lb.	=15·7	5' (for items above)	
Upstream gate arch, 1×8×19½×150 lb. ..	=10·4		
Between ribs, 10×16×19½×150 lb. ..	=209		
Downstream gate arch, 2×5×19½×150 lb.	=13·05		
Pilaster, 8×1×19½×150 lb.	=10·4		
	258·55		1292·75

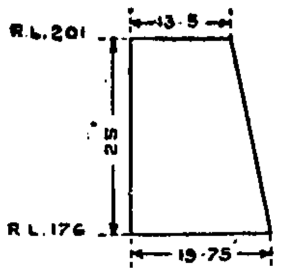


R. L. 215 to R. L. 219.

	Load in tons.	Arm from left face.	Moments
(b) 10×29×4×150 lb.	=78	5	390·00
(c) Under Gate Bridge, 30·5×14·87×39×150 lb.	=1185	7·6 (graphically).	9006·00



	Load in tons.	Arm from left face.	Moments
(d) Under Road Bridge, 25×7·25 ×14×150 lb.	=170	8·3 (graphically).	1410·00
Carried Forward	1691·55		12098·75



	Load in tons.	Arm from left face.	Moments
Brought Forward	1691·55		12098·75
Under Road Bridge 25×16·62×25×150 lb. = 696 (graphically).	696	8·4	5850·00
	2,387·55		17948·75

$$= \frac{17948 \cdot 75}{2387 \cdot 55} \text{ ft.}$$

∴ Resultant of all vertical forces acts = 7·52 feet from base of abutment.

The total weight of 2,387 tons is compounded with thrust of the Gate Bridge and Road Bridge arches and also the pressure of earth behind the abutment. The net resultant of these as per drawing No. 50 come to 4,400 tons, cutting the base of abutment 3″ from centre.

The abutment is therefore quite safe against overturning and there is no tension in the masonry.

Pressure at Base of Pier :—

$$E = 0 \cdot 25.$$

$$A = 19 \cdot 75 \times 55 \cdot 5.$$

$$Y = \frac{19 \cdot 75}{2}$$

$$S = \frac{Q}{A}\left(1 \pm \frac{EY}{K^2}\right) = \frac{4390}{19 \cdot 75 \times 55}\left(1 \pm \frac{0 \cdot 25 \times 19 \cdot 75}{2} \times \frac{12}{19 \cdot 75 \times 19 \cdot 75}\right).$$

$$= 4 \cdot 05 \left(1 \pm \frac{1 \cdot 5}{19 \cdot 75}\right) = 4 \cdot 05 \, (1 \pm \cdot 07).$$

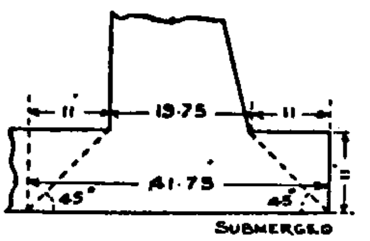
$$= 4 \cdot 35 \text{ tons/sq. ft.}$$

67·5 lb./sq. in. maximum, say 68 lb.
Pressure at Riverside Toe.

and $4 \cdot 05 \times \cdot 93$
$= 3 \cdot 76$ tons/sq. ft.
= 585 lb.
say 58 lb./sq. in. minimum pressure at inner toe.

Pressure on sand.

Foundation slab.



Weight of slab = 41·75×80×11 at 88 lb. = 1,440 tons.

Neglecting upward pressure of water at one corner acting at centre of *slabs*. Compounded with weight of abutment this gives a resultant on diagram, cutting the bottom of foundation 3′ from centre and 5,800 tons normal.

$$S = \frac{Q}{A}\left(1 \pm \frac{EY}{K^2}\right) \qquad E = 0{\cdot}25$$

$$A = 41{\cdot}75 \times 80.$$

$$= \frac{5800}{80 \times 41{\cdot}75}\left(1 \pm \frac{0{\cdot}25 \times 41{\cdot}75}{2} \times \frac{12}{41{\cdot}75 \times 41{\cdot}75}\right)$$

$$= 1{\cdot}74\left(1 \pm \frac{1{\cdot}5}{41{\cdot}75}\right) = 1{\cdot}74 \times 1 \pm {\cdot}036$$

= 1·81 *tons/sq. ft.* = 28 *lb. sq. in. maximum Pressure*
and 1·67 tons/sq. ft. = 26 lb./sq. in. minimum Pressure.

LAND ABUTMENTS OF GATE BRIDGE.

The two separate arches of this bridge are each founded on long abutment walls 13′ and 10′ thick respectively joined together by cross walls 8′ thick at their extremities thus forming a heavy hollow rectangular structure below formation level. This structure is supported on a foundation slab of solid masonry 10′ thick, 55′ long by 55′ wide.

It has been assumed that all these walls act together as one structure, supporting the thrust of both arches. The calculations show that the resultant thrust is well within the middle third of the base width, the maximum intensity of pressure in the masonry being 45 lb./sq. in. or 2·88 tons/sq. ft. The pressure of the above structure is distributed over the masonry foundations giving a maximum intensity of pressure on the sand below of 38·6 lb./sq. in. or 2·4 tons/sq. ft. *Calculations.*

Total weight of abutment.

N.B.—Decking and lift flow partition walls are neglected.

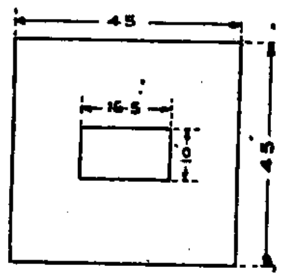
Details as per estimate.

	Cubic feet.	Weight at 150 lb.	Arm from lower edge.	Moments.
L. 180·5—183·5	6,075	407	22½	9,158
183·5—186·5	5,483	378	22½	8,505
186·5—189·9	5,104	344	23	7,900
189·5—192	3,949	264	23½	6,200
192 —200	11,396	762	23½	17,950
200 —208	11,100	743	23	17,100
208 —215	9,453	634	22½	14,270
Total ..	..	3532	..	81,083
Deduct Central Well	8,490	568	22½	12,780
Net Total ..	..	2,964	..	68,303
Add above R. L. 215. R. L. 215—219				
2×35·5×4×13 at 150 lb.	..	123	22	2,700
Spandrils, R. L·219 to 238·5				
Upstream Arch, 31×19½×8 at 150 lb... ..	..	324	24¼	7,857
Downstream Arch, 31½×19½×5 at 150 lb. ..	..	206	24	4,944
Pilasters—				
4×8·5×2×7·5 at 150 lb.				
4×8·5×1½×16 at 150 lb.	..	89	20	1,780
Total .	..	3,706	..	85,584

The resultant weight of 3,706 therefore acts at a distance $= \frac{85584}{3706}$ feet.

$= 23$ feet from lower edge.

This weight of 3,706 tons compounded with Combined thrust of the Gate Bridge arches gives a resultant of 4,125 tons cutting the base at 2·5 feet from centre, the normal pressure being 4,100 tons.



$E = 2{\cdot}5$

$\text{Area} = 45\times45 - 16\tfrac{1}{2}\times10 = 1{,}860$

$Y = \dfrac{45}{2}$

$I = \dfrac{45^4 - 10\,(16\tfrac{1}{2})^3}{12}$

$= \dfrac{41{,}00{,}000 - 45{,}000}{12}$

$= \dfrac{40{,}55{,}000}{12}$

$K^2 = \dfrac{40{,}55{,}000}{1{,}860\times12} = 181{\cdot}5$

$$S = \frac{Q}{A}\left(1 \pm \frac{YE}{K^2}\right)$$

$$= \frac{4{,}100}{1{,}860}\left(1 \pm \frac{2{\cdot}5\times45}{2}\times\frac{1}{181{\cdot}5}\right)$$

$$= 2{\cdot}20\,(1 \pm {\cdot}31)$$

Maximum intensity of Pressure at base of abutment is therefore—

$2{\cdot}20\times1{\cdot}31 = 2{\cdot}88$ *tons/sq.*

$= 45$ *lb./sq. in. at outer toe.*

Minimum intensity of Pressure—

$= 2{\cdot}20\times{\cdot}69 = 1{\cdot}57$ Tons/sq. ft.

$= 23{\cdot}6$ lb./sq. in.

Intensity of Prssure in Sand in foundations.

The resultant of 4,125 tons when compounded with the weight of the foundation Block ($55\times55\times10$ at $140 = 1{,}890$ tons) gives a resultant which cuts the base 2·3 feet from centre, the normal pressure being 5,990 tons.

$E = 2{\cdot}3$

$$S = \frac{Q}{A}\left(1 \pm \frac{EY}{K^2}\right) = \frac{5{,}990}{55\times55}\left(1 \pm \frac{2{\cdot}3\times55\times12}{2\times55\times55}\right)$$

$A = 55\times55$

$$= 1{\cdot}98\,(1 \pm {\cdot}25)$$

$Y = \dfrac{15}{2}$

$\therefore$ Maximum intensity of pressure $= 1{\cdot}98\times1{\cdot}25 = 2{\cdot}48$ *tons/sq. ft.*

$= 38{\cdot}6$ *lb./sq. in.*

and Minimum do. $= 1{\cdot}98\times{\cdot}75 = 1{\cdot}48$ *tons/sq. ft.*

$= 23$ lb./sq. in.

SET *No. VI.*

Drawing No. 52.

ROAD BRIDGE ARCH.

The system of loading is explained in paragraphs 182 to 186 *ante.*

As mentioned in paragraph 271 it has been assumed in *case No. I that masonry would weigh* 160 *lb./c.ft.* This gives the worst possible conditions, using the hardest stone which is not necessary. *In Case No. II the weight of masonry has been taken at* 150 *lb. per c. ft.*, which represents actual condition with the stone recommended. The two cases show that under the actual conditions the stresses are lighter than in Case I (with the heavier masonry).

In *Case No. I* the maximum intensity of pressure in the arch ring *at crown is* 316 *lb./sq. in. or* 20·3 *tons/sq.ft.* and at the *joint of rupture* 311 *lb./sq. in., or* 20 *tons/sq. ft.*

In *Case No. II* the maximum unit of pressure in the arch ring *at crown is* 303 *lb./sq. in. or* 19·2 *tons/sq.ft.* and at the *joint of rupture is* 298 *lb./sq. in. or* 19·1 *tons/sq.ft.*

Case No. I.

Assuming weight of masonry 160 lb./c. ft. arch full width of road 25′.

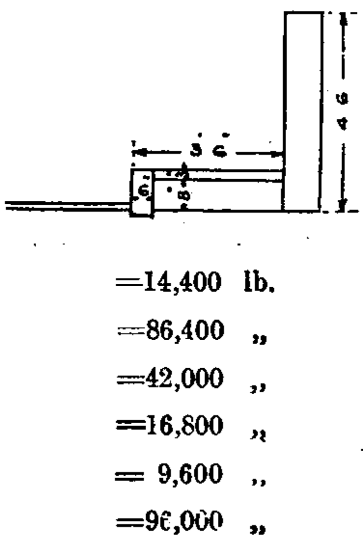
Details.

Span=60 feet.

Arches Elliptical Rise	.. 10 feet.
Thickness at Crown	.. 2′—9″
„ „ Springing	.. 4′—6″
Spandril depth	.. 6″ at Crown.

(1) *Note* :—All spandril filling less than 12″ to be done in cement concrete.

(2) Total overload above spandril.



(*a*) *Dead Load* :—

Parapet caps ..	2×60×1·5×·5×160	=14,400 lb.
„ walls ..	2×60×1×4·5×160	=86,400 „
Footpaths, concrete ..	2×60×3·5×66×150	=42,000 „
Pavement	2×60×3·5×3″×160	=16,800 „
Kerb	2×60×6″×12″×160	= 9,600 „
Road metal	1×60×16×8″×150	=96,000 „
		265,200 lb.

i.e., 265,200 lb. divided over a 25 feet arch.

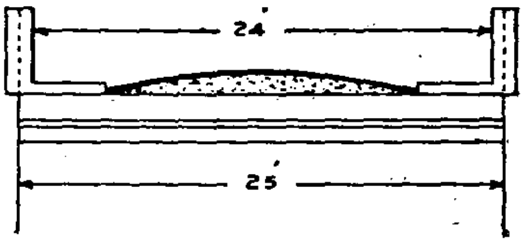
∴ Per foot run=10,608 lb.

„ sq. foot=176·8 lb.

equivalent to thickness of masonry of $\frac{177}{160}$ feet = 1·11 feet.

(*b*) *Live Load.*

Crowd of people, 100 lb./sq. ft.



on a width of 24 ft. $=1\times 60\times 24\times 100=144{,}000$ lb.

Add to live load 13 p.c. per Farr's Rule to bring to equivalent dead load .. .. .. as 18,720

162,720 lb.

Divided on a 25′ arch, per foot run=6,508 lb.

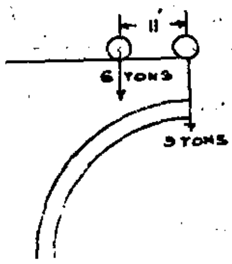
Per sq. foot=108·5, say 109 lb.

equivalent to a thickness of masonry of $\frac{109}{160}$ = ·68 feet.

∴ *Point loads.*

(*c*) *Add weight of Traction engine* :— 15 tons on two axles.

distributed over whole 25′ width of arch.



At A

Per foot $=\frac{9}{25}$ ton.

$=\frac{2240\times 9}{25}=809$ lb

At B

6 tons on 25 feet.

∴ Per foot width $=\frac{2240\times 6}{25}=537$ lb.

∴ We have loads on arches :—

Equivalent thickness of masonry

(*a*) Dead load .. 1·11 ft.

(*b*) Distributed live load .. 0·68 ft.

(*c*) Point loads—

Traction engine—

Rear axle. 809 lb. at A

Front „ 537 lb. at B

The weight of each Voussoir and over load is taken from the measured areas and the diagram and point loads added as follows :—

Loads.	Diagonal	Offsets.		Mean offset.	Each at 160 lb./c.ft.	Total.	Progressive Total.
Point Load A ..	..	..	..	..	809	809	809
Voussoir I—							
Voussoir No. 1 ..	4·8	2·3	2·3	2·30	160×4·8×23 =1,770		
Overload No. 1 ..	4·6	2·0	2·1	2·05	1,510	3,280	4,089
Voussoir II—							
Voussoir No. 2 ..	4·8	2·3	2·3	2·3	1,770		
Overload No. 2 ..	4·7	2·10	2·35	2·23	1,675	3,445	7,534
Voussoir III—							
Voussoir No. 3 ..	4·8	2·3	2·3	2·3	1,770		
Overload No. 3 ..	4·8	2·25	2·6	2·42	1,860	3,630	11,164
Point Load B ..	..	..	..	..	537	537	11,701
Voussoir IV—							
Voussoir No. 4 ..	4·8	2·35	2·25	2·30	1,770		
Overload No. 4 ..	5·1	2·5	3·0	2·75	2,240	4,010	15,711
Voussoir V—							
Voussoir No. 5 ..	4·8	2·35	2·30	2·32	1,785		
Overload No. 5 ..	5·5	2·75	3·40	3·08	2,710	4,495	20,206
Voussoir VI—							
Voussoir No. 6 ..	4·8	2·4	2·3	2·35	1,807		
Overload No. 6 ..	6·15	3·05	3·8	3·42	3,360	5,167	25,373
Voussoir VII—							
Voussoir No. 7 ..	3·5	1·8	1·6	1·7	955		
Overload No. 7 ..	6·3	1·95	2·20	2·08	2,090	3,045	28,418

Loads.	Diagonal	Offsets.		Mean offset.	Each at 160 lb./c. ft.	Total.	Progressive Total.
Voussoir VIII—							
Voussoir No. 8 ..	3·05	1·80	1·65	1·73	1,010		
Overload No. 8 ..	7·10	2·0	2·3	2·15	2,440		
						3,450	31,868
Voussoir IX—							
Voussoir No. 9 ..	3·85	1·85	1·65	1·75	1,080		
Overload No. 9 ..	8·0	1·95	2·25	2·10	2,580		
						3,760	35,628
Voussoir X—							
Voussoir No. 10 ..	4·20	2·1	1·7	1·9	1,280		
Overload No. 10 ..	9·1	2·0	2·4	2·2	3,200		
						4,480	40,108
Voussoir XI—							
Voussoir No. 11 ..	5·5	3·3	1·7	2·5	2,200		
Overload No. 11 ..	10·7	2·35	3·35	2·85	4,870		
						7,070	47,178
						47,178	
			Grand	total ..	47,178	lb.	

i.e., 21·1 tons per foot width whole arch 527·5, say 528 tons.

The line of pressure is then drawn from these loads and it is found that it cuts the middle third extremities at crown and at joint No. 7 where the normal pressures are 62,600 and 69,000 lb. respectively.

The maximum intensity of pressure at these joints therefore is

(1) *Thrust at Crown* where line of pressure just touches upper third.

$$S = \frac{2Q}{A} = \frac{62600 \times 2}{12'' \times 33''} = 316 \text{ lb./sq. in.} = 20{\cdot}3 \text{ tons/sq. ft.}$$

(2) *At joint of rupture No. 7*

where line of pressure just touches lower third.

$$S = \frac{2Q}{A} = \frac{2 \times 69000}{12'' \times 37''} = 311 \text{ lb./sq. in.} = 20 \text{ tons./sq. ft.}$$

Case II.

When weight of masonry per cubic foot is taken at 150 *lb.*

Dead Load—

as per calculations on page 178.

176·8 lb./c.ft.

equivalent to masonry at 150 lb./c. ft.

$$\frac{176 \cdot 8}{150} = 1 \cdot 18 \text{ feet thick.}$$

Live Load—

as per details on page 179.

109 lb./c. ft.

equivalent to masonry at 150 lb.

$$\frac{109}{150} = \cdot 73 \text{ feet thick.}$$

Total addition to spandril for dead and live loads will be 1·18+·73 =1·91 feet of masonry in place of 1·79, *i.e.*, ·12 feet extra.

Areas of each voussoir and overload taken from measured areas on diagram. After adding ·12 feet above, the Loads will then be—

Loads.	Weight at 160 lb.	Weight at 150 lb.	Add ·12 strip at 150 lb.	Total weight.	Total.	Progressive Total.
Point Load A..	..	..	..	..	809	809
Voussoir No. 1 ..	1,770	1,660	..	1,660		
Overload „	1,510	1,415	71	1,486	3,146	3,955
Voussoir No. 2	1,770	1,660	..	1,660		
Overload „	1,675	1,570	72	1,642	3,302	7,257
Voussoir No. 3	1,770	1,660	..	1,660		
Overload „	1,860	1,750	70	1,820		
					3,480	10,737
					537	11,274
Point Load B.						
Voussoir No. 4	1,770	1,660	..	1,660		
Overload „	2,240	2,100	72	2,172	3,832	15,106
Voussoir No. 5	1,785	1,670	..	1,670		
Overload „	2,710	2,540	72	2,612	4,282	19,388
Voussoir No. 6	1,807	1,695	..	1,695		
Overload „	3,360	3,150	70	3,220	4,915	24,303

Loads.	Weighr at 160 lb.	Weight at 150 lb.	Add ·12 strip at 150 lb.	Total weight.	Total.	Progressive Total.
Voussoir No. 7	955	895	..	895		
Overload „	2,090	1,960	36	1,996	2,891	27,194
Voussoir No. 8	1,010	945	..	945		
Overload „	2,440	2,290	38	2,328	3,273	30,467
Voussoir No. 9	1,080	1,010	..	1,010		
Overload „	2,680	2,510	36	2,546	3,556	34,023
Voussoir No. 10	1,280	1,200	..	1,200		
Overload „	3,200	3,000	38	3,038	4,238	38,261
Voussoir No. 11	2,200	2,060	..	2,060		
Overload „	4,870	4,560	43	4,603	6,663	44,924
	Grand Total		..	..	44,924	44,924

With these loads the line of pressure is drawn on the diagram and it is found that it cuts the middle third extremities at crown and at joint No. 7, the normal pressures at these points being 60,000 lb. and 66,200 lb.

The maximum intensities of pressure will therefore be *at crown.*

$$S = \frac{2Q}{A} = \frac{2 \times 60{,}000}{12'' \times 33''} = 303 \text{ lb./sq. in.} = 19 \cdot 5 \text{ tons./sq. ft.}$$

at joint of rupture No. 7

$$S = \frac{2Q}{A} = \frac{2 \times 66{,}200}{12'' \times 37''} = 298 \text{ lb./sq. in.} = 19 \cdot 2 \text{ tons./sq. ft.}$$

SET No. VII.

Drawing No. 53.

GATE BRIDGE.

Upstream Arch, 8′ wide.

The system of loading is fully explained in paragraphs 186A to 186F *ante.* The weight of the masonry is taken as 160 lb./c. ft. which gives more severe conditions than will actually occur. (*Vide* Set No. VI, Cases I and II *ante.*)

The maximum intensity of pressure in the arch *at crown is* 315 *lb./sq. in. or* 20·3 tons/*sq. ft.*, and at joint of rupture is 313 *lb./sq. in. or* 20·2 tons/sq. ft

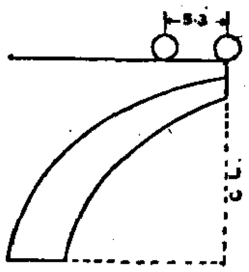
Stability diagram for Gate Bridge upstream arch.

(Arch=8 feet wide).

Calculations.—

(1) Point Loads.—

(a) Load due to travelling crane—



Weight with 3 tons load = 15 tons.

The worst position of the crane *for the bridge arches* will be when one pair of wheels coincides with the c. l. of the arch, thus. This assumes that the crane track is laid on the arch itself.

Assume the axles are 5·3′ apart (same span as cross girders for floor) and that there are point loads under each wheel. (The load will actually be partly distributed by rails and longitudinal sleepers.)

Now on 60′ span, Farr says add only 13%=2 tons to live load for equivalent dead load=17 tons as the crane may give partial shocks of 3 tons due to sudden lifting of load, add another 3 tons making 5 tons added or about 33% of live load. Total equivalent dead load = 20 tons or 10 tons per axle. Hence total load at these points is 10 tons due to crane.

(b) Load due to Reinforced Concrete cross girders with floor and load.—

Weight of 20″×10″ concrete girder 16′ long @ 140 lb.=1·49 tons.

Weight of Reinforced Concrete slabs—

16×5·3×3½″ @ 140 lb.	= 44 lb. 1 sq. ft.
Distributed live load	= 45 lb.
Add 22% for impact as per Farr's rule	= 10 lb.
	99 lb.
	say 100 lb./sq. ft.

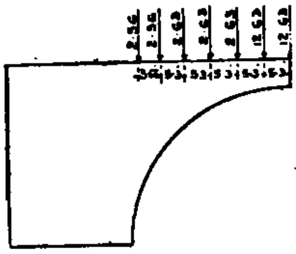
Total load 16×5·3×100 lb. $= \frac{3\cdot78}{5\cdot27}$

i.e., 2·63 tons at each support.

(c) Load due to compound girders carrying gates and counterweights—as per calculations Set XI .. .. 25·6 tons (including weight of floor).

Summary.—

The Point loads therefore are as shown below and on the diagram.



∴ On each foot width.

$$\frac{25 \cdot 6}{8} \text{ tons} = 7{,}160 \text{ lb.}$$

$$\frac{2 \cdot 63}{8} \text{ tons} = 735 \text{ lb.}$$

$$\frac{12 \cdot 63}{8} \text{ tons} = 3{,}540 \text{ lb.}$$

The only additional load on the arches will be the distributed load due to—

(a) masonry spandrils,

(b) live load @ 45 lb./sq. ft. (equivalent of 56 lb./sq. ft. dead load) on the width of the arch itself,

(c) the parapet walls,

(d) the travelling motor trolley for inspection and for working machinery—the weight of this is negligible. It will be less than ½ ton probably.

The parapet walls are 3′ 6″×1′ = 3·5 sq. ft./ft. run $= \frac{3 \cdot 50}{8} = \cdot 44$ ft. of masonry over full width (8′) of arch.

The width of arch left for people to stand on is 7′

Taking equivalent dead load as 56 lb./sq. ft. $= 7 \times 56 = 392$ lb./ft. run of arch.

$$= \frac{392}{160} = 2 \cdot 45 \text{ ft. of masonry.}$$

or divided over 8′ width $= \frac{2 \cdot 45}{8}$ ·31′ of masonry.

∴ Total distributed load above top of spandrils $= \cdot 44 + 31 = \cdot 75$

= say ·8 ft.

The weight of each voussoir and overload is taken from the measured areas on diagram and point loads added as follows :—

—	Diagonal.	Horizontal length.	Offsets.		Mean offset.	Weight at 160 lb. per c. ft.	Total.	Progressive Total.
Voussoir No. 1—								
Overload	..	4	2·3	2·4	2·35	1,504		
Pointload	..	1·5	26 × 2240		..	3,540		
Voussoir 1	4·94	..	2·42	2·31	2·37	1,869	6,913	6,913
Voussoir No. 2—								
Overload	..	4	2·4	2·76	2·58	1,651		
Pointload	..	1·526	× 2240		..	3,540		
Voussoir 2	5	..	2·3	2·42	2·36	1,888	7,079	13,992
Voussoir No. 3—								
Overload	..	4	2·76	3·4	3·08	1,971		
Pointload	..	·35	25 × 2240		..	735		
Voussoir 3	5	..	2·30	2·45	2·37	1,900	4,606	18,598
Voussoir No. 4—								
Overload	..	4	3·4	4·3	3·85	2,463		
Pointload	..	·35	25 × 2240		..	735		
Voussoir 4	5	..	2·26	2·52	2·39	1,912	5,110	23,708
Voussoir No. 5—								
Overload	..	4	4·3	5·6	4·95	3,168		
Pointload				Nil.				
Voussoir 5	5·1	..	2·32	2·62	2·47	2,015	5,183	28,891

	Diagonal.	Horizontal length.	Offsets.		Mean offset.	Weight at 160 lb. per c. ft.	Total.	Progressive Total.
Voussoir No. 6—								
Overload	..	4	5·6	7·32	6·46	4,134		
Pointload	..	·35	25×2240		..	735		
Voussoir 6	5·32	..	2·4	2·75	2·58	2,192	7,061	35,952
Voussoir No. 7—								
Overload	..	2	7·32	8·46	7·89	2,524		
Pointload				Nil.				
Voussoir 7	4·1	..	1·6	1·96	1·78	1,168	3,692	39,644
Voussoir No. 8—								
Overload	..	2	8·46	·976	9·11	2,915		
Pointload	..	3·20×	2240	..	..	7,160		
Voussoir 8	4·16	..	1·7	2·08	1·89	1,258	11,333	50,977
Voussoir No. 9—								
Overload	..	2	9·76	11·4	10·58	3,386		
Pointload				Nil.				
Voussoir No. 9	4·35	..	1·75	2·22	1·98	1381	4,767	55,744
Voussoir No. 10—								
Overload	..	2	11·4	15·52	13·46	3,987		
Pointload	..	..	3·20×2,240		..	7,160		
Voussoir 10..	4·65	..	1·78	2·53	2·15	1,603	12,750	68,494
Voussoir No. 11—								
Overload	..	2·5	13·52	20·28	16·90	6,760		
Pointload	..	..	Nil.	..	..	..		
Voussoir 11..	7	..	2·51	4·12	3·32	3,713	10,473	78,967
					Grand	Total .. i.e. 35 tons.	..	78,967

The line of pressure is then drawn from these loads and it is found that it cuts the middle third extremities at the crown and at joint No. 5, where the normal pressures are 68,000 and 67,800, respectively.

The maximum intensities of pressure therefore are :—

(1) *At crown*—

$A = 36 \times 12$

$$S = \frac{2Q}{A} \text{ because } E = \frac{d}{6}$$

$$= \frac{2 \times 68{,}000}{36 \times 12}$$

$= 315$ *lb./sq. in.*

$= 20{\cdot}3$ tons/sq. ft.

(2) *At joint of rupture No.* 5—

$Q = 36{,}900 \times 2$

$A = 3{\cdot}2 \times 12 \times 12$

$E = {\cdot}51 \times 12$

$Y = 1{\cdot}6 \times 12$

$$K^2 = \frac{h^2}{12} = \frac{3{\cdot}2^2 \times 12^2}{12} = 3{\cdot}2 \times 3{\cdot}2 \times 12$$

$$S = \frac{Q}{A}\left(1 \pm \frac{EY}{K^2}\right)$$

$$= \frac{36{,}900 \times 2}{3{\cdot}2 \times 12 \times 12}\left(1 \pm \frac{6{\cdot}12 \times 19}{3{\cdot}2 \times 3{\cdot}2 \times 12}\right)$$

$= 160{\cdot}2\ (1 \pm {\cdot}956)$

$= 313$ *lb./sq. in.*

$= 20{\cdot}2$ tons/sq. ft.

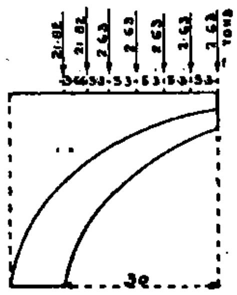
GATE BRIDGE.

Downstream Arch (5′ *wide*).

The system of loading is identical with the upstream arch, except that there is no crane to be carried, and the reactions of the girders supporting the gates and counterweights are different in amount to those on the upstream arch. The point loads are therefore as shown below and on the stability diagram. The maximum intensity of pressure in the arch ring *at crown is* 316 *lb./sq. in.* or 2·3 tons/sq. ft. and at joint of *rupture is* 313 *lb./sq. in.* or 2·2 tons/sq. ft.

Stability diagram for Barrage gate down stream arch 5′ wide.

Point loads are as follows :—



∴ Loads per foot width.

$$=\frac{21\cdot82}{5}=9{,}770 \text{ lb.}$$

$$=\frac{2\cdot63}{5}=1{,}180 \text{ lb.}$$

(2) The only additional load on the arches will be the distributed load due to

(a) masonry spandrils,

(b) live load at 45 lb./sq. ft. (equivalent of 56 lb. per sq. ft. dead load) on the width of the arch itself.

(c) the parapet walls.

The parapet walls are 3′ 6″×1′=3·5 sq. ft./ft. run $=\frac{3\cdot5}{5}=0\cdot70'$ of masonry over full width of arch (5 ft.)

The width of arch left for people to stand on is 4′.

Taking equivalent dead load as 56 lb./sq. ft.=4×56=224] lb./ft. run of arch

$$=\frac{224}{160}=1\cdot4 \text{ ft. of masonry.}$$

or divided over 5′ width $=\frac{1\cdot4}{5}=0\cdot28'$ of masonry.

∴ Total distributed load above top of spandrils

$= 0\cdot7+0\cdot28$

$= 0\cdot98'$

$= 1$ ft. say.

The weight of each voussoir and overload is taken from measured areas on the diagram and point loads added as follows :—

Loads.	Horizontal length.	Diagonal	Offsets.		Mean offset.	Each at 160 lb. per c. ft.	Total.	Progressive Total.
Voussoir No. 1—								
Overload	4	..	3·0	3·1	3·05	4×3·05 ×160 =1,952		
Pointload	..	·564×	2,240	..	..	1,180		
Voussoir 1	..	4·62	2·06	2·13	2·10	1,548	4,680	4,680
Voussoir No. 2—								
Overload	4	..	3·1	3·48	3·29	2,105		
Pointload	..	·564×	2,240	..	..	1,180		
Voussoir 2	..	4·68	2·07	2·17	2·12	1,587	4,872	9,552
Voussoir No. 3—								
Overload	4	..	3·48	4·1	2·79	2,425		
Pointload	..	·564×	2,240	..	..	1,180		
Voussoir 3	..	4·70	2·08	2·18	2·13	1,602	5,207	14,759
Voussoir No. 4—								
Overload	4	..	4·1	5·03	4·57	2,918		
Point load	..	·564×	2,240	..	..	1,180		
Voussoir 4	..	4·76	2·08	2·22	2·15	1,637	5,735	20,494
Voussoir No. 5—								
Overload	4	..	5·03	6·32	5·67	3,635		
Pointload				*Nil.*				
Voussoir 5	..	4·85	2·10	2·32	2·21	1,715	5,350	25,844
Voussoir No. 6—								
Overload	4	..	6·32	8·1	7·21	4,614		
Pointload	..	·5	64×2,240	..	..	1,180		
Voussoir 6 ..	..	5·03	2·17	2·48	2·33	1,871	7,665	33,509

Loads.	Horizontal length.	Diagonal	Offsets.		Mean offset.	Each at 160 lb. per c. ft.	Total.	Progressive Total.
Voussoir No. 7—								
Overload	4	..	8·1	10·52	9·31	5,958		
Pointload	..	21·82 / 5	×2,240	..	..	9,770		
Voussoir 7	..	5·30	2·2	2·73	2·46	2,090	17,818	51,327
Voussoir No. 8—								
Overload	2	..	10·52	12·26	11·39	3,645		
Pointload				*Nil.*				
Voussoir 8	..	4·08	1·7	2·2	2·95	1,273	4,918	56,245
Voussoir No. 9—								
Overload	2	..	12·26	14·56	13·41	4,291		
Pointload	..	21·82 / 5	×2,240	..	..	9,770		
Voussoir 9	..	4·35	1·78	2·47	2·12	1,479	15,540	71,785
Voussoir No. 10—								
Overload	2	..	14·56	20·5	17·53	5,610		
Pointload			*Nil.*					
Voussoir 10 ..	..	6·2	2·25	3·8	3·03	3,000	8,610	..
					Grand Total		.. ..	80,395

= 36 tons.

for 5 feet arch = 180.

The line of pressure is then drawn from these loads and it is found that it cuts the middle third at crown and joint No. 6 where the normal pressures are 57,000 and 66,200 lb. respectively.

Maximum intensities of pressure therefore are :—

(1) *Thrust at crown* where line of pressure just touches upper third.

$$Q = 57{,}000 \text{ lb.} \qquad \therefore S = \frac{2Q}{A} = \frac{2 \times 57{,}000}{30 \times 12} = 316 \cdot 6 \textit{ lb./sq. in.}$$

$$S = 30 \times 12$$

$$E = \frac{d}{6} = \frac{30}{6} = 5''$$

(2) *Joint of Rupture No.* 6.

$$Q = 66{,}200 \qquad \therefore S = \frac{2Q}{A} = \frac{2 \times 66{,}200}{2 \cdot 94 \times 144} = 313 \textit{ lb./sq. in.}$$

$$A = 2 \cdot 94 \times 12 \times 12$$

$$E = \frac{d}{6}$$

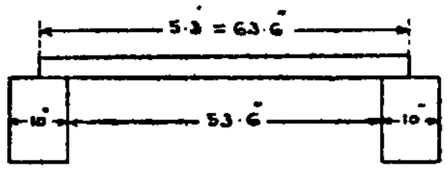
SET No. IX.

REINFORCED CONCRETE SLABS FOR BRIDGE DECKING.

This decking has been designed to be entirely removable at any point of the bridge for inspection of and access to any part of the gates or machinery. The slabs are 5·3′ long by 2′ 7½″ wide and 3½″ thick. Each slab is cast with 4 holes, one near each corner, 2½″ diameter for drainage and lifting. They will weigh about 600 lb. each, and eight men (two at each corner) would be able to lift them on ropes and carry to one-side for stacking. They are supported on reinforced concrete girders which could also be easily removed, if necessary. If a removable floor is not considered necessary, a continuous slab floor could be more cheaply made.

One advantage of the removable floor is that all slabs and girders can be made in the yards at any convenient time, without centering, and be ready to place in position when needed.

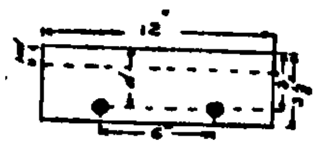
Calculations for Reinforced Concrete slabs for flooring of gate-bridge of Barrage.



Take load as 200 lb./sq. ft. including weight of slab which is about 44 lb./sq. ft.
Load for full slab = 5·3 ×200 = 1,060 lb.
Maximum bending moment per foot width taking span from centre to centre of beam.

$$= 1/8\,W\,l$$
$$= \frac{1}{8} \times 1{,}060 \times 5{\cdot}3 \times 12 \text{ inch-lb.}$$
$$= 8{,}427 \text{ inch-lb.}$$

Try 3″ slab with two ⅜″ rods.



Area of steel = 2 ×0·11 = 0·22 sq. in.

Area of concrete = 12 ×3 = 36 sq. in.

$$p = \frac{0{\cdot}22}{36} = {\cdot}0061$$

$$\therefore\ pn = {\cdot}0061 \times 10 = {\cdot}061, \text{ if } n = \frac{E_s}{E_c} = 10.$$

Then $K = \sqrt{(pn^2+2pn} - pn$ (Trautwine, p. 1,118).

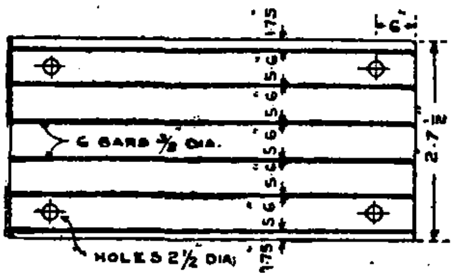
$$= \sqrt{0{\cdot}00372+0{\cdot}122} - {\cdot}061$$
$$= \sqrt{{\cdot}12572} - {\cdot}061$$
$$= {\cdot}3547 - {\cdot}061$$
$$= {\cdot}2937$$

We have $\dfrac{M}{bd^2} = fc\ \dfrac{K.\ (1\text{-}K/3)}{2}$ (Trautwine, p. 1,118)

$\therefore \dfrac{8{,}427}{12 \times 9} = fc\ \dfrac{\cdot 2937\ (1 - \cdot 0979)}{2}$

$\therefore$ fc = 590 lb./sq. in., which is within the permissible limit of 600 lb./sq. in.

The design will therefore be as follows :—



CALCULATIONS OF REINFORCED CONCRETE BEAMS TO CARRY FLOORING OF GATE BRIDGES OF BARRAGE.

These beams will be cast with a tongue at the top 3" wide and 3½" high along the centre line, forming a ledge of 3½" width on each side for seating the reinforced concrete slabs.

Calculations.

Loads :—

(*a*) Only a few people for works will be on the bridge and so a uniform distributed load of 45 lb./sq. ft. is enough. The equivalent dead load making an allowance of 25 % for impact will be =56 lb./sq. ft.

(*b*) 3½" reinforced concrete slabs will weigh 44 lb./sq. ft.

∴ Total load = 56+44 = 100 lb./sq. ft.

N.B.—The weight of the motor trolley will be much less than the weight of the crowd it will displace.

The beams will be 5·3 feet apart centres. The load on each beam will be

= 16×5·3×100

= 8,480 uniforming distributed load.

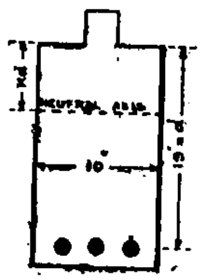
∴ Maximum bending moment for the 16 ft. span

$= \frac{1}{8} \times 8{,}480 \times 16$ ft.-lb.

= 16,960 ft.-lb.

= 203,520 in.-lb.

Gammon's tables show that a beam 20"×10" with three (3) ⅝" rods in reinforcement would be quite ample.



Area of 3-⅝" rods = ·9 sq. in.

$$\therefore p = \frac{\cdot 9}{19 \times 10} = \cdot 00475$$

If n is ratio of elasticity of steel and concrete = 10

$\therefore pn = \cdot 0475$

$$\therefore K = \sqrt{(pn)^2 + 2pn} - pn \quad \text{(Trautwine p. 1118).}$$

$$= \sqrt{(\cdot 0475)^2 + \cdot 095} - \cdot 0475$$

$$= \sqrt{\cdot 09725} - \cdot 0475$$

$$= \cdot 3118 - \cdot 0475 = \cdot 2643$$

We have

$$\frac{M}{bd^2} = fc \, \frac{K\left(1 - \frac{K}{3}\right)}{2} \quad \text{(Trautwine, p. 1118)}$$

$$\therefore \frac{2{,}03{,}520}{10 \times 19 \times 19} = fc \, \frac{0 \cdot 2643\left(1 - \frac{\cdot 2643}{3}\right)}{2}$$

$$= fc \, \frac{0 \cdot 2643 \times \cdot 9119}{2}$$

$$\therefore fc = \frac{2{,}03{,}520}{10 \times 19 \times 19} \times \frac{1}{\cdot 1183}$$

= 475 lb./sq. in. which is quite low and within the permissible limit of 600 lb./sq. in.

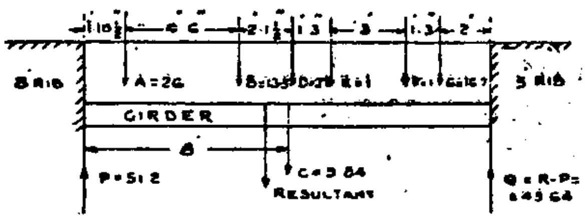
The beam will therefore be made* 20"×10" *with* 3 *rods* ⅝" *diameter spaced* 3" *apart at* 19" *from surface.

COMPOUND STEEL GIRDERS TO CARRY GATE SUPPORTS, ETC.

The rough design calculated and shown is not intended to be the final working drawing for these girders. The provision of steel made is more than sufficient to carry the stresses, and the final design, which would be left to the construction engineers, would be more economical. That submitted is merely a diagramatic representation of the beams, providing more than sufficient material.

The diagram at the left of the plan shows the reactions at either end of the beams, due to all loads supported.

Calculations for Compound Beam to carry gates and counterweights, winches, etc.



	Load.	Tons.	Arm.	Moment.
½ Counterweight	A	26	1·875	48· 8
Pulley	B	13· 3	6·375	85· 0
Weight of beam and floor	C	9·84	8· 0	78· 8
Pulley	D	27	8· 5	230· 0
A frames	E	1	9· 75	9·75
	F	1	12· 75	12·75
Gate pulley	G	16· 7	14· 0	234·00
	..	94·84	..	699· 10

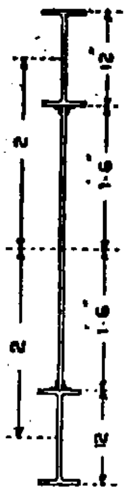
= Maximum bending moment

$$\therefore \text{Arm} = \frac{699 \cdot 10}{94 \cdot 84} = 7 \cdot 37$$

$$\therefore P = \frac{94 \cdot 84 \times 8 \cdot 63}{16} = 51 \cdot 2 \text{ tons}$$

and Q = 43·64 „

Note :—Since there are 2 girders on each rib, the reaction on each girder will be $\frac{51 \cdot 2}{2}$ and $\frac{43 \cdot 64}{2}$ tons, respectively, *i.e.*, 25·6 and 21·82 tons.



Maximum B.M. $= P \times 7 \cdot 37 = 21 \cdot 82 \times 7 \cdot 37$

$= 188$ ft. tons

Neglecting Bracing

$I_{xx} = I + \text{area.}\ 24^{2} = 260 \cdot 9 + (24^{2} \times 11 \cdot 47)$

$= 260 \cdot 9 + 6610 = 6871$

$$M = \frac{I_{xx}\ f}{y} \quad \therefore \quad f = \frac{M\,y}{I_{xx}} = \frac{M \times 30'' \times 12}{6871 \times 2}$$

$$= \frac{188 \times 30}{6871 \times 2} = 4 \cdot 93 \text{ tons}$$

per sq. in. for steel, which is quite low.

The design of the beam will be two I beams joined together.

Weight as follows :—

4 Plates	9″ × 3′ = 9 sq. ft. × 10·20	=	92 lb.
,,	6′ × 3′ = 18 ,, ,, × 10·20	=	184 ,,
2 Angles	2½″ × 2″ × ¼″ × 24′ @ 3·61 lb. }	=	324 ,,
2′ ,,	2½″ × 2″ × ¼″ × 21′ @ 3·61 lb. }		
12 ,,	2″ × 2″ × ⅜″ × 3′ @ 4·62 lb.	=	167 ,,
4 ,,	2″ × 2″ × ⅜″ × 6′ @ 4·62 lb.	=	110 ,,
	Total	..	877 lb.
	Add for rivets	..	272 lb.
2 Girders	(12 × 5) × 24′ @ 39 lb./ft. ..	..	1,872 lb.
	Total	..	3,021 lb.
		=	1·35 *tons.*

Reactions at support will be

25·60 *tons* on 8′ *arch.*

21·82 *tons on* 5′ *arch.*

STABILITY CALCULATIONS FOR FLOOR OF REGULATORS.

The floor is designed in exactly the same manner as the Barrage floor (see Calculations, Set No. I), *i.e.*, for founding on sand.

Head is 20′. (200·5 H. F. L. —180·5 Canal Bed Level).

(1) Hydraulic gradient required is 1 in 17 which gives *length of creep required* 340′.

Total length of creep actually provided = 5
30
55
6
7·5
40
45
5·5
40
7·5
4
70
22
3

340·5

The floor is therefore safe against piping.

(2) *Stability* against upward pressure.

Note.—1 foot of masonry of specific gravity 2·25, will have specific gravity of 1·25 when submerged. Allowing one-third excess weight for safety this will balance

$1 \cdot 25 \times \frac{3}{4}$ feet head of water.

1 foot of masonry submerged will be safe when the balance of creep is $1 \cdot 25 \times \frac{3}{4} \times 17 = 15 \cdot 93'$

At Point *a*

Creep = 5+30+55+6+7·5+40+6·5 = 150.

∴ Balance of creep = 340·5—150 = 190·5 feet.

Masonry required $= \frac{190 \cdot 5}{15 \cdot 93} = 11 \cdot 9$ feet.

" provided = 12·5 feet.

***Point b*:—**

Length of creep :—

Balance at a = 340·5—150 = 190·5

Deduct a to b 5·5

∴ Balance of creep = 185

∴ Masonry required $= \frac{185}{15 \cdot 93} = 11 \cdot 58'$

Masonry provided at b 12′.

Point c :—Length of creep —balance at b = 185

Deduct 8+1·5 = 9·5

Balance of creep .. .. .. = 175·5

$\therefore$ Masonry required = $\frac{175 \cdot 5}{15 \cdot 93}$ = 11·0 ft.

,, provided at c = 11·3 ,,

Point d :—Balance of creep at c = 175·5

Deduct 8+1·5 9·5

Balance of creep .. .. .. 166·0

$\therefore$ Masonry required = $\frac{166}{15 \cdot 93}$ = 10·40′

,, provided at d=11·3·—1·5+·8=10·60′

Point e :—Balance of creep at d = 166

Deduct 8+1 = 9

$\therefore$ Balance of creep at e 157

$\therefore$ Masonry required = $\frac{157}{15 \cdot 93}$ 9·86′

,, provided at e = 10·6—1+·8 = 10·4′

Point f :—Balance of creep at e = 157

Deduct 6+1 = 7

Balance at f = 150

$\therefore$ Masonry required = $\frac{150}{15 \cdot 93}$ = 9·43 ft.

,, provided at f = 10·4—1+·6 = 10 ,,

Point g :—Balance of creep at f = 150

Deduct 40+3·5 = 43·5

Balance of creep .. .. .. 106·5

$\therefore$ Masonry required = $\frac{106 \cdot 5}{15 \cdot 93}$ = 6·69 ft.

,, provided at g = 10 ,,

Point h :—Balance of creep at g = 106·5

Deduct 7·5+4 = 11·5

Balance of creep 95

$\therefore$ Masonry required = $\frac{95}{15 \cdot 93}$ = 5·96 ft.

,, provided at 6 ,,

Point i :— Balance of creep at h = 95

Deduct 65

Balance of creep 30

$\therefore$ Masonry required $= \frac{30}{15 \cdot 93}$ = 1·88 ft.

,, provided at i = 3 ,,

Point j :— Balance of creep at i = 30

Deduct 22+5+3 = 30

Balance of creep .. .. .. = 0

$\therefore$ Upward pressure *nil*.

(3) *Protection against scour.*

In addition to the masonry apron the bed is further protected for a length of 85 feet with heavy concrete blocks on rubble , making up 196′ from gates, *i.e.*, about ten times the head.

The bed is protected with 2·0 thick pitching of loose stone for a further length of 200′ making up the total protection of 396 or about twenty times the head.

Hence the floor is *safe against piping, against upward pressure and against scour.*

STABILITY CALCULATIONS FOR ORDINARY PIER OF REGULATORS (LONGITUDINAL SECTION).

As in the case of the Barrage piers it has not been considered necessary to calculate the cross sectional stability of these ordinary piers as the slight difference of depth of water which might exist on the two sides of pier (due to different regulation of the gates on either side) would have a negligible effect in comparison with the great weight of the superstructure.

The following stability calculations in a longitudinal direction show that the worst possible conditions, *i.e.*, with full flood level and wind on the river side and with an empty canal, give a *maximum intensity of pressure* in the masonry at the downstream toe of the pier of 74 *lb./sq. in.* or 4·76 *tons/sq. ft.* Also that the *maximum possible intensity of pressure on the sand below* the foundation block will be 18 *lb./sq. in. or* 1·18 *tons/sq. ft* :—

STABILITY DIAGRAM FOR ORDINARY PIER OF REGULATOR (LONGITUDINAL SECTION).

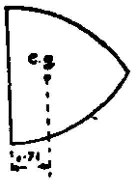
Take the worst case when the road is at R. L. 215.

Calculations.

Vertical forces.

	Tons.	Arm from toe.	Moments at toe.
(*a*) Pilaster. R.L 180·5 to 219— 1 × 5 × 38·5 at 160 lb.	13·75	0·5	6·875
(*b*) Piers gate bridge up to springing R.L. 180·5—202— 20·5 ×5×21½ at 160 lb.	157·5	11¼	1,773
(*c*) Gate bridge arches upstream— 2×47½ tons (see calculations, Set XVII) ..	95 }	3′	285
Between ribs 1×4×17 at 160 lb.	4·86 }	3′	14·58
(*d*) Masonry between ribs R. L. 202-219— 12½×5×17 at 160 lb.	76	11·25	855
(*e*) Gate bridge arches downstream— 2×47½ tons (see calculations Set XVII) ..	95 }	19·5	1,850
Between ribs 1×4×17 at 160 lb.	4·86 }	19·5	94·75
(*f*) Pier under road bridge R. L. 180·5 to 202— 25×5×21½ at 160 lb.	192	34	6.528

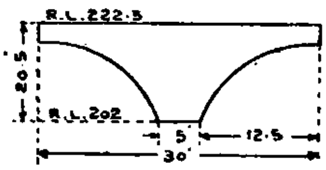
Stability Diagram for Ordinary Pier of Regulator (Longitudinally)—*contd.*

	Tons.	Arm from toe.	Moments at toe.
(*g*) Road bridge— 2×190 tons(see calculations Set, XVI)	380	34	12,920
(*h*) Easewater, area 15·38×24 at 160 lb.	26·4	49·21	1,300
 1·71 feet as found graphically.			
(*i*) Pilaster 203—214— 1×5×11 at 160 lb.	3·93	47	184·5
	1,049·3	..	25,812

Total resultant of vertical forces of P.=1,049 tons will therefore act at $\frac{25,812}{1,049 \cdot 3}$ feet=24·6 feet.

Horizontal forces—

(*j*) Wind pressure on face of arches, spandrils and parapets at 50 lb./sq. ft.



	Tons.	Arm.	Moments.
Wind pressure 30×20·5 at 50 lb.	13·8	10·2·5	141·5
Deduct area of intrados $\frac{\pi}{2}\times 12\frac{1}{2}\times 12\frac{1}{2}$ at 50 lb. ..	5·5	53	29·52
acting at distance $4/3\times\frac{12\frac{1}{2}}{\pi} = 5 \cdot 3$ ft.			
(*j*) Resultant ..	8·3	..	112·3
acting at $\frac{112 \cdot 3}{8 \cdot 3}$=13·55 feet above R.L. 202, *i.e.*, at R.L. 215·55.			

(*k*) Wind on counterweights—

On two counterweights R.L. 202 to 209—

25×7×50 lb =3·9 tons acting at 3½ feet above 202, *i.e.*, at R.L. 205·5

(l) Wind on road bridge—

		Arm	Moments.
Area. Intrados of gate bridge	$=\dfrac{\pi \times 25 \times 25 \text{ lb.}}{2 \times 2 \times 2}$	5·3	$\dfrac{5{\cdot}3 \times \pi \times 25 \times 25}{8}$
Area. Intrados of road bridge	$=\dfrac{\pi \times 25 \times 25}{2 \times 2 \times 3}$	3·54	$\dfrac{3{\cdot}54 \times \pi \times 25 \times 25}{12}$

Tons. Moments.

Resultant $=\dfrac{\pi \times 25 \times 25 \times 50 \text{ lb.}}{24} = 1{\cdot}83$ $\qquad \pi \times 25 \times 25\ ({\cdot}663 - {\cdot}295).$

$= \pi \times 25 \times 25 \times {\cdot}368.$

Acting at $\dfrac{\pi \times 25 \times 25}{\pi \times 25 \times 25} \times {\cdot}368 \times 24 = 8{\cdot}83$ feet, *i.e.*, R.L. 210·83.

(*m*) Wind on pier 200·5 to 202.

$5 \times 1\tfrac{1}{2} \times 50$ lb. $=$ ·17 tons at R.L. 201·25.

(*n*) Water pressure on pier and gate (Head 20 feet).

$30 \times 20 \times \dfrac{20 \times 62{\cdot}5}{2}$ lb. $= 168$ tons acting at R.L. $180{\cdot}50 + 6{\cdot}66 = 187{\cdot}16$

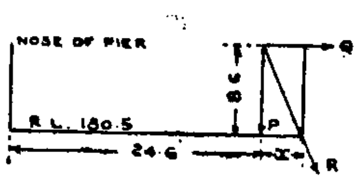
Horizontal forces taking moments at R.L. 180·5.

Force.	Acting at R.L.	Arm R.L. 180·5	Amount.	Moments.
			Tons.	
j	215·55	35·05	8·3	292
k	205·5	25·0	3·9	97·5
l	210·83	30·33	1·83	55·5
m	201·25	20·75	·17	3·5
n	187·16	6·66	168	1120
Total ..	..	..	182·20	1568·5

Q $=$ Resultant of all horizontal forces $=$ 182·2 tons.

Acting at $\dfrac{1568{\cdot}5}{182{\cdot}2}$ feet $= 8{\cdot}6'$ above R.L. 180·5, *i.e.*, at R.L. 189·1.

Compounding these two resultants of all vertical and horizontal forces acting at the pier



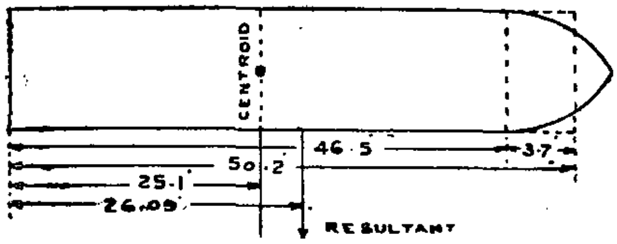
To find x

$P \times x = Q \times 8{\cdot}6$

$\therefore\ x = \dfrac{Q}{P} \times 8{\cdot}6$

$= \dfrac{182{\cdot}2}{1049{\cdot}3} \times 8{\cdot}6 = 1{\cdot}49$

The resultant of all forces 1,070 tons therefore cuts base of pier 24·6+1·49 = 26·09 feet from river face of pier, *i.e.*, 26·09—25·1 = 0·99 feet from centre as shown below.



Intensity of pressure in masonry at base of pier.

$$S = \frac{Q}{A}\left(1 \pm \frac{EY}{K^2}\right) = \frac{1{,}070}{5 \times 50 \cdot 2}\left(1 \pm 0 \cdot 99 \times \frac{50 \cdot 2}{2} \times \frac{12}{50 \cdot 2 \times 50 \cdot 2}\right).$$

$$= 4 \cdot 26\left(1 \pm \frac{5 \cdot 94}{50 \cdot 2}\right) = 4 \cdot 26\,(1 \pm \cdot 118).$$

∴ *Maximum Intensity of Pressure*—

= 4·26 × 1·118 tons = 4·76 *tons/sq. ft.*
= 74 *lb./sq. in.*

Minimum pressure = 4·26×·982 = 4·18 tons/sq. ft.
= 65 lb./sq. in.

Intensity of Pressure on sand at bottom of foundations.

Supposing weight spreads out at an angle of 45° where block is of minimum thickness, *viz.*, 10 feet.

The base area will be 60 × (10 + 5 + 10) = 1,500 sq. feet.

To find centre of gravity of foundation block below R.L. 180·5 (see estimates for details submerged masonry).

		Tons.	Arm from front end.	Moments.
	10 feet on each side.			
Portion	A—20×5×11·0 at 88 lb.	43·2	2½	108
	B—20×9×17·0 at 88 lb.	120	9½	1,140
	C—20×5×12·5 at 88 lb.	49·1	16½	810
Under Pier	BC—5×14×15·5 at 88 lb.	42·5	12	510
	D—20×8×12·4 at 88 lb.	78	23	1,796
Under Pier	D—5×8×15·0 at 88 lb.	23·6	23	543
	E—20×8×11·7 at 88 lb.	73·5	31	2,280
Under Pier	E—5×8×13·5 at 88 lb.	21·2	31	657
	F—20×8×11·0 at 88 lb...	69·2	39	2,700
Under Pier	F—5×8×12·0 at 88 lb.	18·9	39	737
	G—20×6×10·7 at 88 lb.	50·5	46	2,320
Under Pier	G—5×6×11·0 at 88 lb.	13·0	46	597
	H—20×11×10·0 at 88 lb...	86·4	54½	4,710
Under Pier	H—5×11×10·0 at 88 lb...	21·6	54½	1,176
	Total ..	710·7	Moments.	20,084

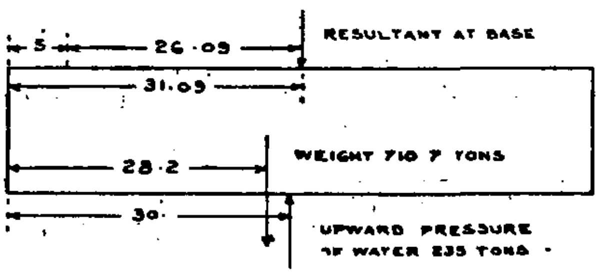
∴ Total weight of Block acts at $\frac{20084}{710 \cdot 7}$ = 28·2.

feet from edge = 28·2 feet.

Upward pressure of water supposing it is the minimum at the outer toe, *viz.*, 5·6′ head of water on the whole Block.

$$\text{Total upward pressure} = (10+5+10) \times 60 \times 5\cdot6 \times 62\cdot5 \text{ lb.}$$
$$= 235 \text{ tons acting 30 feet from edge.}$$

The forces acting on the Block therefore are—



These forces compounded on diagram give a net resultant of 1,540 tons cutting bottom of foundation at 31·6 feet from river edge, *i.e.*, 1·6 feet from centre, the normal pressure being 1,524 tons.

Intensity of pressure,

$$\therefore S = \frac{2Q}{A}\left(1 \pm \frac{EY}{K^2}\right) = \frac{1,524}{25\times60}\left(1 \pm \frac{1\cdot6\times60}{2} \times \frac{12}{60\times60}\right)$$
$$= 1\cdot016 \ (1 \pm \cdot16)$$

Maximum intensity of pressure $= 1\cdot016 \times 1\cdot16 = 1\cdot18$ *tons/sq. ft.*
$= 18\cdot7$ *lb./sq. in.*

Minimum intensity of pressure $= 1\cdot016 \times 0\cdot84 = 0\cdot854$ tons/sq. ft.
$= 13\cdot5$ lbs./sq. in.

SET No. XIV.

Drawing No. 66.

STABILITY CALCULATIONS FOR ABUTMENT PIER OF REGULATOR.

CROSS SECTION.

Two cases have been investigated.

Case I.—This shows all stresses when the pier is loaded *with full pressures* from both gate-bridge and road-bridge arches, when the latter are complete and fully loaded on one side only of the pier; it being assumed that *the arches on other side have collapsed.* To support such a load in the event of accident is one function of these abutment piers. The calculations show that the resultant at the base of the pier falls just outside the middle third (within the middle half) and that it would therefore cause slight tension on one side of the base. Under these conditions the maximum intensities of pressure will be—

Compression 86 lb./sq. in. or 5·5 tons/sq. ft.

Tension 17 lb./sq. in. or 1·1 tons/sq. ft.

If it is assumed that the masonry can carry no tension, then the *compressive stress* at the other edge of base will be 102 *lb./sq. in. or* 6·6 *tons per sq. ft.* This is a very low figure and may be considered satisfactory for such extreme and unlikely conditions.

The maximum intensity of pressure on the sand below the foundation block (assuming that only a 10′ width of the continuous 10′ thick floor on either side, acts with the pier) will be 23 *lb. per sq. in. or* 1·47 *tons/sq. ft.*

Case II.—This shows the *normal conditions* when all arches and superstructure are completed and both bridges carrying full loads. The maximum intensity of pressure *in the masonry* at the base of the pier is 48 *lb./sq. in. or* 3·06 *Tons/sq. ft.* while the uniform intensity of pressure *on the sand below* the foundation block is 35 *lb./sq. in. or* 2·22 *tons/sq. ft.*

Stability investigated at R. L. 180·5 C. B. L.

Loads.

		Tons.
(1)	Weight of abutment pier from R. L. 180·5 to 202 46·5×10×21½ @ 150 lb. .. .. .. =	670
(2)	Pilaster 202 to 219 1×10×17′ @ 150 lb... .. .. =	11·4
(3)	Between Gate Bridge Arches 2×6×4×17′ @ 150 lb. .. .. =	54·6
(4)	Between up and down stream arches of Gate Bridge 10×12½×17′ @ 150 lb. .. .. =	14·3
(5)	Between Road Bridge Arches 5×25×12′ @ 150 lb. .. .. =	10·1
(6)	Ease Water, area 61·5×24′ @ 150 lb. .. .. =	98·5
	Total ..	858·9

say 859 Tons.

acting at centre of abutment pier.

Case I.—When the arches on one side only are built and fully loaded.

The thrusts as per calculations Sets XVI and XVII when combined with the weight of the abutment pier give a resultant 1,160 tons which cuts base of abutment pier at R. L. 180·5, 2·5 feet from centre as per diagram, normal pressure being 1,146 tons.

Intensity of pressure in masonry at base. ±

area 46·5×10+61·5 = 465+61·5 = 526·5 sq. ft.

$$S = \frac{Q}{A}\left(1 \pm \frac{EY}{K^2}\right) = \frac{1{,}146}{526 \cdot 5}\left(1 \pm 2 \cdot 5 \times \frac{10}{2} \times \frac{12}{10 \times 10}\right)$$

$$= 2 \cdot 2 \quad (1 \pm 1 \cdot 5)$$

Maximum intensity of pressure in masonry at Base of abutment pier

$= 2·2 \times 2·5 = 5·5$ tons/sq. ft. } Compression.
= 86 lb./sq. in.

Minimum intensity $= 2·2 \times (-0·5) = 1·1$ tons/sq. ft. } Tension.
= 17 lb./sq. in.

Supposing the masonry is incapable of resisting by tension the whole thrust will have to be borne by the area in compression = 7·5′×46·5 (see diagram) and the average pressure here will be $= \frac{1{,}146}{46 \cdot 5 \times 7 \cdot 5} = 3 \cdot 3$ tons/sq. ft. The maximum intensity of pressure in masonry at the outer toe will be twice this, *i.e.*,

= 6·6 *tons/sq. ft.*

= 102 *lb./sq. in.—This is the worst case.*

Intensity of pressure on Sand at bottom foundations.

Weight of foundation block. Supposing weight spreads out at an angle of 45°, where slab is of the least thickness, *viz.*, 10 feet. Area at base = (10+10+10)×60 = 1,800.

See Estimate. Submerged masonry at 88 lb.

			Tons.
Portion	A ..	20× 5×11·0 @ 88 lb.	= 43·2
„	B ..	20× 9×17·0 @ 88 lb.	=120·0
„	C ..	20× 5×12·5 @ 88 lb.	= 49·1
Under pier	B & C..	10×14×15·5 @ 88 lb.	= 85·0
Portion	D ..	20× 8×12·4 @ 88 lb.	= 78·0
Under pier	D ..	10× 8×15·0 @ 88 lb.	= 47·2
	E ..	20× 8×11·7 @ 88 lb.	= 73·5
Under pier	E ..	10× 8×13·5 @ 88 lb.	= 42·4
	F ..	20× 8×11·0 @ 88 lb.	= 69·2
Under pier	F ..	10× 8×12·0 @ 88 lb.	= 37·8
	G ..	20× 6×10·7 @ 88 lb.	= 50·5
Under pier	G ..	10× 6×11·0 @ 88 lb.	= 26·0
	H .. }		
Under pier	H .. }	30×11×10·0 @ 88 lb.	=129·6
		Total	=851·5 say 852 tons.

From this deduct upward pressure of water, supposing it is the minimum at the outer toe, *viz.*, 5·6 feet head of water on the whole block.

Total upward pressure=30×60×5·6×62·5 lb.=281 tons.

Deducting this from the weight of the foundation—Block both acting at centre, we get a net weight of 852–281 = 571 tons.

This weight compounded with the pressure at base of abutment pier, on the diagram, gives a resultant 1,730 tons cutting the bottom of foundation 2·7 feet from centre, the normal pressure being 1,720 tons.

Intensity of pressure on sand therefore is:—

$$S = \frac{Q}{A}\left(1 \pm \frac{EY}{K^2}\right) = \frac{1720}{30\times60}\left(1 \pm 2\cdot7 \times \frac{30}{2} \times \frac{12}{30\times30}\right)$$

$$= \cdot955\ (1 \pm \cdot54).$$

Maximum intensity of pressure $= \cdot955 \times 1\cdot54.$

$= 1\cdot47$ *tons/sq. ft.*

$= 23$ *lb./sq. in.*

Minimum intensity of pressure $= \cdot955 \times \cdot46.$

$= \cdot44$ tons/sq. ft.

$= 6\cdot8$ lb./sq. in.

Average intensity of pressure being $\cdot955$ *tons/sq. ft.*

$= 14\cdot9$ *lb./sq. in.*

Case II.—Final conditions.

When arches on both sides are built and fully loaded—

		Tons.
Weight of abutment	.. =	859
Vertical component of gate bridge arches, 2×2×47½ ..	.. =	190
Vertical component of road bridge arches, 2×190	.. =	380
		1,429

The horizontal components of the arch thrusts balance each other and the final resultant is at centre. Pressure is uniform in masonry and intensity

$$= \frac{1,429}{46\cdot5\times10} = 3\cdot06 \text{ tons/sq. ft.}$$

$$= 48 \text{ lb./sq. in.}$$

Intensity of pressure on sand at bottom of foundation.

To 1,429 tons add weight of foundation block 852 tons and deduct upward pressure of water .. .. 1,429+852 = 2,281

Deduct 281

Acting at centre and uniformly distributed— 2,000

$$\text{Intensity of pressure therefore} = \frac{2,000}{30\times30} = 2\cdot22 \text{ tons/sq. ft.}$$

$= 34\cdot6$ lb./sq. in.

say 35 lb./sq. in.

STABILITY CALCULATIONS FOR END ABUTMENT OF REGULATORS.

The design of these abutments is similar to that of the Barrage abutments and two similar conditions are investigated.

Case I. shows the condition with the abutment only built, and supporting *the full load of earth filling*, up to formation level, behind it, and with *no* water or other *pressure on the canal side.* This condition might exist for a short time during construction, but can be avoided. Under these conditions the resultant pressure falls slightly outside the middle third, and if the masonry is considered incapable of resisting by tension, *the maximum intensity of compressive stress* on the outer toe would be 91 *lb./sq. in. or* 5·86 *tons/sq. ft.* This is a very low and safe limit.

If the masonry can carry tension the maximum intensity of compression would be only 81 lb./sq. in. and the maximum tension would be 19 lb./sq. in.

The assumed conditions of loading are so extreme, and unlikely to occur, that the above results may be considered satisfactory.

Case II. shows *the normal conditions* after completion of work, *i.e.*, with all arches and superstructure completed and both bridges carrying full loads. The calculations show that the abutment is perfectly safe, the resultant falling well within the middle third, and *the maximum intensity of pressure in the masonry* at canal bed level (R.L. 180·5) is 70 *lb./sq. in. or* 4·50 *tons/sq. ft.*

The maximum intensity of pressure *on the sand* below the foundation block is 32 *lb./sq. in. or* 2·06 *tons/sq. ft.*, the average pressure over the whole base being 26 lb./sq. in. or 1·64 tons sq. ft.

Calculations for weight of abutment.

	Tons.	Arm from face.	Moments.
(1) Pilaster, R.L. 180·5 to 219 10×1×38·5 at 150 lb.	25·8	5	129
(2) Gate Bridge arches, R.L. 180·5 to 202 2×4×12·7×21½ at 150 lb.	146	diagram. 6·45	945
(3) Spandril, R.L. 202 to 219 2×4×8×17′ at 150 lb.	73	6	438
(4) Between Gate Bridge arches 12½×10×17′ at 150 lb.	142	5	710
(5) Road Bridge, R.L. 180·5 to 202 mean 1×25×12·7×21½ at 150 lb.	457	diagram. 6·45	2,950
(6) Spandril, R.L. 202 to 214 25×7½×12′ at 150 lb.	150·6	6·25	941
Total ..	994·4		6,113
acting at $\frac{6,113}{994 \cdot 4}$ feet = 6·1 ft. from face.			

Case I.—If abutment is built up and earth filling behind done up to road level, but no arches.

Weight of abutment, 994 tons at 6·1 feet from face. Earth pressure as obtained from diagram—

$$= 33{\cdot}5 \times \frac{18{\cdot}1}{2} \times 125 \text{ lb. per foot on } 41\tfrac{1}{2} \text{ feet length (after allowing for connecting wall).}$$

$$\text{Total earth pressure} = \frac{33{\cdot}5}{2} \times 18{\cdot}7 \times \frac{125 \times 41\tfrac{1}{2} \text{ tons.}}{2240} = 726 \text{ tons in direction, obtained on}$$

diagram.

Compounding these two we find that the resultant of 1,545 tons cuts the base 4·15 feet from centre the normal pressure being 1,430 tons.

Intensity of pressure in masonry at R.L. 180·5 will be

$$S = \frac{Q}{A}\left(1 \pm \frac{EY}{K^2}\right) = \frac{1430}{15{\cdot}4 \times 46{\cdot}5}\left(1 \pm 4{\cdot}15 \times \frac{15{\cdot}4}{2} \times \frac{12}{15{\cdot}4 \times 15{\cdot}4}\right)$$

$$= 2{\cdot}0\left(1 \pm \frac{24{\cdot}90}{15{\cdot}4}\right)$$

$$= 2{\cdot}0\,(1 \pm 1{\cdot}61) \text{ tons.}$$

Maximum intensity of pressure $= 2{\cdot}0 \times 2{\cdot}61 = 5{\cdot}22$ tons/sq. ft.
$= 81$ lb./sq. in.

Minimum intensity of pressure $= 2{\cdot}0 \times -0{\cdot}61 =$
$= -1{\cdot}22$ tons/sq. ft. Tension.
$= -19$ lb./sq. in. Tension.

If the masonry is incapable of resisting by tension, the area in compression alone will have to bear the whole pressure.

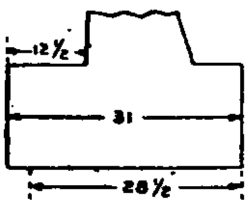
The average pressure then will be $\dfrac{1430}{46{\cdot}5 \times 10{\cdot}5} = 2{\cdot}93$ tons/sq. ft.

Maximum pressure being twice this $= 2 \times 2{\cdot}93$ tons.
$= 5{\cdot}86$ *tons/sq. ft.*
91 *lb./sq. in.*

Pressure on Sand in foundation.

Quantity in foundation block as per estimate = 22,498 c. ft.

for 31 feet. So for $28\tfrac{1}{2}' = \dfrac{22498 \times 28\tfrac{1}{2}}{31}$ c. ft.



Weight $= \dfrac{28\tfrac{1}{2} \times 88 \text{ lb.} \times 22498 \text{ lb.}}{31}$

submerged masonry = 815 tons.

Add superstructure—

R.L. 177·5 to 180·5 as per estimate 970 ft. at 88 lb. = ... 38

Tons.

Total weight .. 853

acting at centre of Block.

This compounded with the resultant at R.L. 180·5 gives a resultant of 2,370 tons cutting base of foundation at R.L. 107·5, 3′ from centre, normal pressure being 2,270 tons.

Intensity of pressure on Sand therefore is—

$$S = \frac{Q}{A}\left(1 \pm \frac{EY}{K^2}\right) = \frac{2270}{28\frac{1}{2}\times 55}\left(1 \pm \frac{3\cdot 28\frac{1}{2}}{2} \times \frac{12}{28\frac{1}{2}\times 28\frac{1}{2}}\right).$$

$$= 1{\cdot}45\,(1 \pm {\cdot}63).$$

∴ Maximum intensity of pressure $= 1{\cdot}45 \times 1{\cdot}63.$

$= 2{\cdot}44$ *tons/sq. ft.*

$= 37{\cdot}8$ *lb./sq. in.*

Case II.—Final conditions.

Compounding the resultant of arch thrust and weight of abutment with the earth pressure, we get a final resultant of 1,780 tons cutting at R.L. 180·5, 2·2 feet from centre, the normal pressure being 1,730 tons.

Intensity of pressure :—

$$S = \frac{Q}{A}\left(1 \pm \frac{EY}{K^2}\right) = \frac{1730}{15{\cdot}4\times 46{\cdot}5}\left(1 \pm \frac{2{\cdot}2\times 15{\cdot}4}{2} \times \frac{12}{15{\cdot}4\times 15{\cdot}4}\right).$$

$$= 2{\cdot}42\,(1 \pm {\cdot}86).$$

∴ *Maximum intensity of pressure* $= 2{\cdot}42\times 1{\cdot}86.$

$= 4{\cdot}50$ *tons/sq. ft.*

$= 70{\cdot}0$ *lb./sq. in.*

Minimum intensity of pressure $= 2{\cdot}42\times 0{\cdot}14.$

$= {\cdot}34$ tons/sq. ft.

$= 5{\cdot}27$ lb./sq. in.

Intensity of pressure on sand below foundation.

Compounding this with the weight of the foundation Block we get a resultant 2,620 tons, cutting base 1·2 feet from centre, the normal pressure being 2,580 tons.

Intensity of pressure on sand :—

$$S = \frac{Q}{A}\left(1 \pm \frac{EY}{K^2}\right) = \frac{2580}{28\frac{1}{2}\times 55}\left(1 \pm \frac{1{\cdot}2\times 28\frac{1}{2}}{2} \times \frac{12}{28\frac{1}{2}\times 28\frac{1}{2}}\right).$$

$$= 1{\cdot}64\,(1 \pm {\cdot}25).$$

Maximum intensity of pressure $= 1{\cdot}64\times 1{\cdot}25.$

$= 2{\cdot}06$ *tons/sq. ft.*

$= 32$ *lb./sq. in.*

Minimum intensity of pressure $= 1{\cdot}64\times {\cdot}75.$

$= 1{\cdot}23$ tons/sq. ft.

$= 19$ lb./sq. in.

SET No. XVI.
Drawing No. 67.

STABILITY CALCULATIONS FOR ROAD BRIDGE OVER REGULATORS.

The system of loading.—This was first worked out as shown below for an equivalent distributed dead load of 200 lb./sq. ft., which, calculations for the Barrage Road Bridge arches, *vide* paragraph 185 of Report, show to be as severe, as the more complicated system of anticipated loading, *viz.*, a distributed live load of 100 lb./sq. ft., plus a heavy traction engine at centre. Under the assumed loading of 200 lb./sq. ft. the stresses are so light that it was not considered necessary to make a further diagram for the anticipated system of loads, which would give almost identical pressures.

The calculated *maximum intensity of pressure* at the *crown is* 101 *lb./sq. in. or* 6·5 *tons/sq. ft.*, and at the *joint of rupture is* 106 *lb./sq. in. or* 6·82 *tons/sq. ft.*

(25 feet road bridge carried on continuous arch span 25 feet—rise 8·33 ft. elliptical—thickness at crown 1′-6″ and at springing 2′-6″).

Calculations :—

(1) Point loads—

There are no point loads.

(2) Distributed loads —

(*a*) Spandril top 6″ above crown of arch over which the footpath and road metal will be laid.

Dead load above spandrils —

		lb.	lb.
Parapet cap	1×25×0·5×1·5 at 160 =		3,000
„ wall	1×25×4·5×1 at 160 =		18,000
Footpath concrete filling ..	25×7 ×0·66 at 150 =		17,500
Paving stone	25×7 ×0·25 at 160 =		7,000
Kerb	2×25×0·5×0·75 at 160 =		3,000
Road metal	25×16 ×0·66 at 160 =		40,000
			88,500

lb.

∴ On 25′ width of arch = 88,500

∴ Per foot strip = 3,540

∴ Per square foot = 141·6

= equivalent to a thickness of masonry at 160 lb.

$$= \frac{141 \cdot 6}{160} = 0 \cdot 885 \text{ ft.}$$

(*b*) Live load of 100 lb./sq. ft. on width 24′.

∴ Equivalent dead load = 200 lb./sq. ft.

∴ Total live load = 24×25×200.

= 120,000 lb. on 25′ width.

= 4,800 lb. per ft. strip.

= 192 lb. per sq. ft.

equivalent to a thickness of masonrat 160 lb.

$$= \frac{192}{160} = 1 \cdot 2 \text{ ft.}$$

∴ Total distributed load above top of spandril = 0·885+1·2 ft.

= 2·085 ft.

(c) Weight of voussoirs and overloads are calculated from the measured areas on diagram and the total loads are then as follows :—

Loads.	Diagonal.	Offsets.		Mean offset.	Diagonal × mean offset.	Weight at 160 lb.	Total.	Progressive Total.
Voussoir 1 ..	2·44	1·16	0·98	1·07	2·60	416		
Overload 1 ..	3·10	1·44	1·48	1·46	4·52	723	1,139	1,139
Voussoir 2 ..	2·20	1·06	1·06	1·06	2·33	372		
Overload 2 ..	3·08	1·68	1·44	1·56	4·82	771	1,143	2,282
Voussoir 3 ..	2·20	1·10	1·02	1·06	2·33	372		
Overload 3 ..	3·22	1·38	1·50	1·46	4·70	752	1,124	3,406
Voussoir 4 ..	2·24	1·12	1·00	1·06	2·37	379		
Overload 4 ..	3·46	1·40	1·56	1·48	5·12	819	1,198	4,604
Voussoir 5 ..	2·26	1·10	1·00	1·05	2·37	379		
Overload 5 ..	3·80	1·36	1·56	1·46	5·54	886	1,265	5,869
Voussoir 6 ..	2·32	1·12	1·00	1·06	2·46	393		
Overload 6 ..	4·26	1·36	1·56	1·46	6·45	1,032	1,425	7,294
Voussoir 7 ..	2·36	1·10	1·00	1·05	2·50	400		
Overload 7 ..	4·84	1·24	1·40	1·32	6·80	1,088	1,488	8,782
Voussoir 8 ..	2·42	1·14	1·00	1·07	2·68	428		
Overload 8 ..	5·52	1·20	1·40	1·30	7·38	1,180	1,608	10,390
Voussoir 9 ..	2·54	1·14	0·98	1·06	2·68	428		
Overload 9 ..	6·40	1·06	1·26	1·16	7·40	1,184	1,612	12,002
Voussoir 10 ..	2·60	1·26	0·96	1·11	2·87	459		
Overload 10 ..	7·38	0·86	1·00	0·93	6·72	1,075	1,534	13,536
Voussoir 11 ..	2·74	1·22	0·90	1·06	2·90	464		
„ 12 ..	2·80	1·22	0·90	1·06	2·96	473		
„ 13 ..	2·80	1·14	0·98	1·06	2·96	473		
Overloads 11, 12 & 13	8·54	1·28	1·84	1·56	13·40	2144	3,554	17,090 lb.
			Total	per foot	width	..	17,090	

∴ For 25′ width = 17,090 × 25 lb.
= 191 tons.

With these loads the line of pressure is drawn on the diagram. It is found that it cuts the middle third extremities at crown and at joint No. 8, the normal pressure being 10,900 lb. and 15,000 lb. respectively.

(*d*) The intensity of pressure in masonry arch therefore at crown is—

$$S = \frac{2\,Q}{A} = \frac{2 \times 10900}{18'' \times 12''}$$
$$= 101 \text{ lb. /sq. in.}$$
$$= 6{\cdot}5 \text{ tons /sq. ft.}$$

(2) At joint of rupture No. 8—

$$S = \frac{2\,Q}{A} = \frac{30000}{23\frac{1}{2} \times 12}$$
$$= 106 \text{ lb. /sq. in.}$$
$$= 6{\cdot}82 \text{ tons /sq. ft.}$$

SET No. XVII.
Drawing No. 67.

STABILITY DIAGRAM FOR GATE BRIDGE ARCHES OVER REGULATORS.

System of loading.—This is similar to the Barrage Gate Bridge arches, which is fully explained in paragraph 186A to 186F *ante*. Details of all loads are shown below.

The pressures in both upstream and downstream arches of this bridge are identical as the loading is symmetrical about the centre of the bridge.

The maximum intensity of pressure in either arch *at the crown joint is* 122 *lb./sq. in.* or 7·85 tons /sq. ft., and *at the joint of rupture is* 155 *lb. /sq. in.* or 10 tons per square foot.

Calculations.

(1) *Point loads.*—

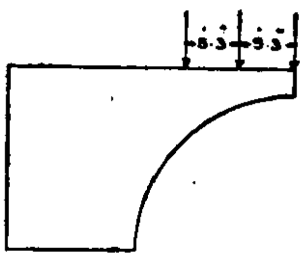
(*a*) Weight due to R.C. cross girders with floor load.—

Weight of 15″ × 9″ R.C. beams 12½×15″×9″ at 140 lb. .. .. = 1,640 lb.

Weight of 3½″ slabs	44 lb. per sq. ft.	
Live load at	45 lb. „ „	
Add 22% for impact as per Farr's rule	11	
	100 lb.	
	100 lb. per sq. ft.	
Total load 12½′ × 5′-3″ × 100 lb.		= 6,550 lb.
Total on two arches		= 8,190 „
On each arch 4′ wide		= 4,095 „
Total per foot		= 1,024 „

(*b*) Weight due to girders carrying gates and machinery—

	lb.
39 lb. Rolled steel Beams to carry machinery, 12½×39 lb. ..	= 488
Machinery	=22,400
Slabs including crowd of people as per details above. 12½ × 3′-7½″ at 100 lb.	= 4,530



On two arches	=27,418
On each arch 4′ wide	=13,709
Per foot width	= 3,427

(2) *Distributed loads.*—

(*a*) Above spandril 3′ thick at crown—parapet 3′×1′— equivalent to ¾′ thick masonry spread over the whole rib.

(*b*) Crowd of people on 3′ width of arch at 45 lb. /sq. ft. plus an allowance of 22% for live load as per Farr's rule, *i.e.*, 56 lb. on 3 feet distributed over 4′ width of arch $= \frac{56\times3}{4} = 42$ lb. /sq. ft. equivalent to $\frac{42}{160} = 0\cdot26$ feet of masonry.

Total distributed load above top of spandril = ·75 + ·26 = 1·01, say 1 foot of masonry.

Loads.	Diagonal.	Offsets.		Mean offset.	Weight at 160 lb.	Total.	Progressive Total.
Point load 1.					1024	1,024	1,024
Voussoir 1	2·60	1·30	1·16	1·23	512		
			2				
Overload 1	4·6	1·95	2·05	2·0	1470	1,982	3,006
Voussoir 2	Same	as 1			512		
Overload 2	4·7	1·95	2·15	2·05	1542	2,054	5,060
Voussoir 3	Same	as 1.	..		512		
Point load	..	..	..	..	1024		
Overload 3	5·10	1·90	2·25	2·07	1690	3,226	8,286
Voussoir 4	2·26	1·16	1·06	1·11	405		
Overload 4	5·70	1·40	1·65	1·52	1385	1,790	10,076
Voussoir 5	Same	as 4			405		
Overload 5	6·50	1·30	1·55	1·42	1480	1,885	11,961
Voussoir 6	2·32	1·22	1·08	1·15	427		
Overload 6	7·45	1·20	1·40	1·30	1550		
Point load	..	..	..		3427	5,404	17,365
Voussoir 7	Same	as 6	..		427		
Overload 7	8·60	1·10	1·25	1·17	1610	2,037	19,402
Voussoir 8	3·26	1·52	1·40	1·46	762		
Overload 8	9·90	1·45	1·85	0·95	1505	2,267	21,669
Voussoir 9	3·32	1·58	1·46	1·52	812		
Overload 9	12·35	0·95	1·20	1·08	2140	2,952	24,621
Voussoir 10	3·40	1·64	1·50	1·57	855		
Overload 10	15·05	0·40	0·45	0·42	1010	1,865	26,486
			Total per	foot	26,486	lb.	

For four feet width $= 26486 \times 4$ lb.

$= 47\frac{1}{2}$ tons.

With these loads the line of pressure is drawn on diagram and it is found that it cuts the extremities of the middle third at crown and at joint No. 5, the normal pressures being 13,200 lb. and 17,700 lb. respectively.

The maximum intensity of pressure in masonry arch, therefore,

(1) At Crown

$$= S = \frac{2\,Q}{A} = \frac{2 \times 13200}{18'' \times 12''} = 122 \text{ lb, 1 sq. in.} = 7{\cdot}85 \text{ tons/sq. ft.}$$

(2) At joint of rupture No. 5

$$= S = \frac{2\,Q}{A} = \frac{2 \times 17700}{12'' \times 19''} = 155 \text{ lb./sq. in.} = 10 \text{ tons/sq. ft.}$$

Set No. XVIII.

REINFORCED CONCRETE SLABS FOR GATE BRIDGE OF REGULATORS.

The span in the case of the regulators is 5·25 feet instead of 5·3 in the case of the Barrage. The loads to be carried are exactly the same and so the same design is adopted. For details, see calculations Set No. IX.

Set No. XIX.

CALCULATIONS FOR REINFORCED CONCRETE BEAMS FOR GATE BRIDGE OF REGULATORS.

Loads :—

45 lb./sq. ft. for crowd of people
25 per cent. allowance for live load .. .. = 56 lb./sq. ft.
Add weight of slabs .. .. = 44 lb./sq. ft.

Total .. = 100 lb./sq. ft.

Weight of each beam $= 12'\text{-}6'' \times 5'\text{-}3'' \times 100$ lb.

$= 6562$ lb., uniformly distributed on a span of 12′-6″.

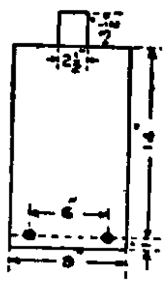
Maximum bending moment $= \frac{1}{8}$ W.L.

$= \frac{1}{8} \times 6562 \times 12\frac{1}{2} \times 12$ inch lb.

$= 123048$ inch lb.

Gammon's tables give a beam 9″×14″ as enough two $\frac{5}{8}''$ rods—area = 0·6 sq. in.

area of concrete = 9×14 = 126.



$$\therefore\ pn = \frac{\cdot 6}{126} = \cdot 00476.$$

$$\therefore\ pn = \cdot 0476,\ \text{if } n = \frac{ES}{E_c} = 10.$$

$$\therefore\ K = \sqrt{(pn)^2 + 2pn} - pn \quad \text{(Trautwine, p. 1118).}$$

$$= \sqrt{(\cdot 0476)^2 + \cdot 0952} - \cdot 0476.$$

$$= \sqrt{\cdot 002265 + \cdot 0952} - \cdot 0476.$$

$$= \sqrt{\cdot 097465} - \cdot 0476 = \cdot 3122 - \cdot 0476.$$

$$= \cdot 2646.$$

$$\frac{M}{bd^2} = fc\,\frac{K(1 - K/3)}{2}$$

$$\text{or } \frac{123048}{9 \times 15 \times 15} = fc.\,\frac{\cdot 2646\,(1 - \cdot 0882)}{2}$$

$$= fc.\,\frac{\cdot 2646 \times \cdot 9118}{2}$$

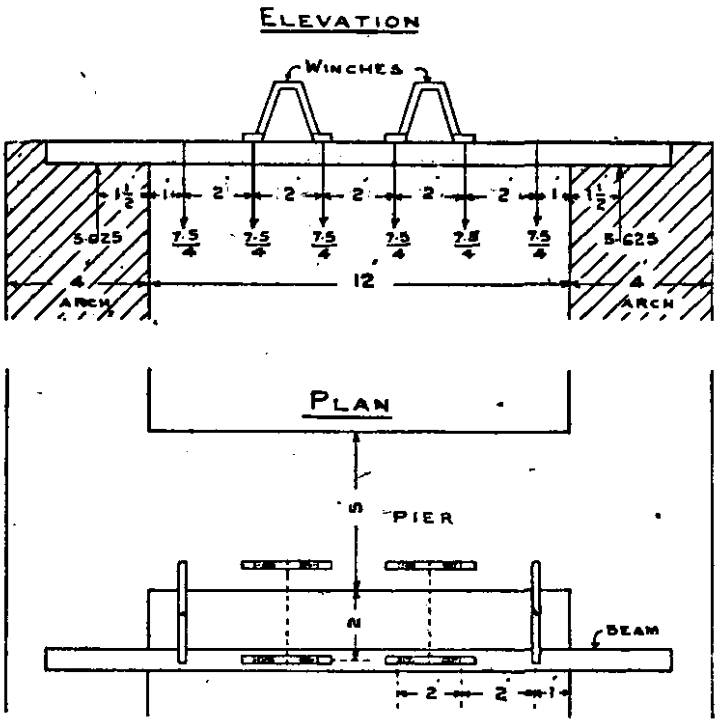
$$= fc. \times 1\cdot 206$$

$$\therefore\quad fc. = \frac{123048}{9 \times 15 \times 15 \times 1\cdot 206} = 504 \text{ lb./sq. in.}$$

which is quite within the permissible limit of 600 lb. per sq. in.

∴ *The beam will be 9″×15″ to allow for cover with 2 rods $\frac{5}{8}''$ diameter, spaced 6″ apart. A tongue will be made on top $2\frac{1}{2}'' \times 3\frac{1}{2}''$.*

CALCULATIONS FOR GIRDER CARRYING GATES AND WINCHES OF REGULATORS.



Taking 15′ span :—

B. M. at d =5·625×7·5—1·875 (5+3+1).

=42·175—16·875=25·30 ft. tons.

B. M. at C =5·625×6·5—1·875 (4+2).

=36·55—11·25=25·30 ft. tons

equivalent distributed load $= \frac{25 \cdot 3 \times 8}{15} =$ 13·48 tons.

= say 13·5 Tons.

Taking 14′ span only :—

Maximum B. M. =5·625×6—1·875 (4+2).

=33·75—11·25 22·5 ft. tons

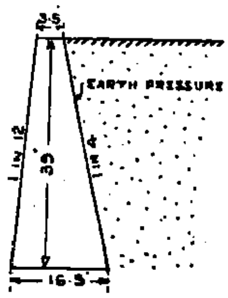
equivalent dead load $= \frac{22 \cdot 5 \times 8}{14} =$12·85 tons.

=say 13 tons.

A 12″×5″ at 32 lb. girder would be sufficient, but *take a* 12×5 *at* 39 *lb. girder for safety and stiffness. This will carry* 15 *tons on a span of* 14′.

STABILITY CALCULATIONS FOR CONNECTING WALL.

This is designed on Sir B. Baker's rule for retaining walls. Mean width=$\frac{1}{2}$ height. Detailed calculations show that resultant is within the middle third and the pressures are low



Calculations.

Weight of wall $=\dfrac{3{\cdot}5+16{\cdot}5}{2}\times 39\times 150$ lb.=58,500 lb. it acts at 7 feet from the outer toe from diagram.

Total earth pressure of very wet sand with(ϕ)=30° and weight 125 lb./c. ft.

Direction of pressure is obtained from diagram according to Professor Reilley's method.

Amount of Earth Pressure$=\dfrac{15{\cdot}7\times 39}{2}\times 125$=3,820 lb. Combining these two we get the resultant 60,400 lb. cutting the base of the wall 1·7 feet from the centre the normal pressure being 60,300 lb.

$E = 1{\cdot}7$

$Y = \dfrac{16{\cdot}5}{2}$

$A = 16{\cdot}5\times 1$ (for 1 foot length).

$K^2 = \dfrac{d^2}{12} = \dfrac{16{\cdot}5\times 16{\cdot}5}{12}$

$Q = 60{,}300$

$\therefore\ S = \dfrac{Q}{A}\left(1\pm\dfrac{EY}{K^2}\right)$

$= \dfrac{60300}{16{\cdot}5}\left(1 \dfrac{1{\cdot}7\times 16{\cdot}5\times 12}{2\times 16{\cdot}5\times 16{\cdot}5}\right)$

$= 3666\,(1\pm{\cdot}62)$/sq. ft.

$\therefore$ *Maximum pressure* $=\dfrac{3666\times 1{\cdot}62}{144}$ lb./sq. in.

=41 *lb./sq. in.*

or=2·62 *tons/sq. in.*

$\therefore$ Maximum intensity of pressure at the outer toe will be 41 lb./sq. in. or 2·62 tons/sq. ft.

inimum pressure $=\dfrac{3{,}666\times 0{\cdot}38}{144}$ lb./sq. in.

=9·6 *lb./sq. in.* at the inner toe.

or=0·62 *tons/sq. ft.* at the inner toe.

The wall section is therefore amply strong. There is no tension and the pressure in masonry is low.

Intensity of pressure on Sand in foundation.

Weight of foundation block—

$$=22\times5' \text{ at } 88 \text{ lb. submerged} = 9{,}700 \text{ lb.}$$

Compounding this with the resultant at base, we get a final resultant of 70,300 lb. cutting base of foundation 1·9 feet from centre, the normal pressure being 70,200 lb.

Intensity of pressure :—

$$S = \frac{Q}{A}\left(1 \pm \frac{EY)}{K^2}\right) = \frac{70200}{22'\times12''\pm12''}\left(1 \pm \frac{1\cdot9\times22}{2} \pm \frac{12}{22\times22}\right).$$

$$=22\cdot2\,(1+\cdot52).$$

Maximum pressure $=22\cdot2\pm1\cdot52$ lb.

$=33\cdot8$ *lb./sq. in.*

$=2\cdot17$ *tons/sq. ft.*

Minimum pressure $=22\cdot2\times\cdot48.$

$=10\cdot6$ lb./sq. in.

$=\cdot69$ tons/sq. ft.

APPENDIX M.

LIST OF STATEMENTS.

APPENDIX M.

Statement No. I.

Table showing minimum and average discharges at Sukkur in each month for the years 1901 *to* 1918.

Month.	Approximate total requirements of all canals when fully developed.	1901.			1902.			1903.		
		Minimum.		Average.	Minimum.		Average.	Minimum.		Average.
		Bukkur Gauge Reading.	Discharge.	Discharge.	Bukkur Gauge Reading.	Discharge.	Discharge.	Gauge Reading.	Discharge.	Discharge.
January	21,754	1·8	32,000	53,741	0·7	29,000	30,484	1·1	22,000	24,774
February	21,754	2·4	41,000	60,428	*—0·1*	27,000	27,964	1·2	21,000	26,000
March	21,664	2·1	37,000	48,161	*—0·7*	24,000	25,451	1·0	18,947	24,684
April	27,277	3·4	63,219	98,666	0·4	28,000	29,900	3·4	31,360	50,133
May	37,821	5·0	75,593	171,356	1·8	36,111	115,080	6·8	74,000	137,419
June	44,322	7·1	127,985	208,000	8·6	118,000	247,333	9·5	148,831	221,500
July	44,322	9·1	196,857	307,677	9·7	166,580	303,968	10·6	203,535	325,032
August	44,322	12·6	385,061	563,580	9·4	174,000	273,871	14·2	433,214	550,355
September	44,322	7·8	129,000	299,300	6·7	94,000	188,867	9·4	155,272	362,267
October	24,049	4·5	76,000	99,193	4·2	47,000	64,806	5·9	70,000	104,548
November	19,581	2·6	46,000	59,433	2·9	33,000	41,300	3·2	44,000	56,800
December	21,754	1·4	31,000	37,000	1·9	27,000	30,097	2·0	33,000	37,935

STATEMENT No. I.—*contd.*

Table showing minimum and average discharges at Sukkur in each month for the years 1901 *to* 1918—contd.

Month.	1904.			1905.			1906.			1907.		
	Minimum.		Average.	Minimum.		Average.	Minimum.		Average.	Minimum.		Average.
	Gauge Reading.	Discharge.	Discharge.	Gauge Reading.	Discharge.	Discharge	Gauge Reading.	Discharge.	Discharge.	Gauge Reading.	Discharge.	Discharge.
January	1·8	31,000	37,968	1·3	27,751	29,467	1·2	22,539	29,129	—0·2	32,951	37,452
February	1·7	30,000	33,690	1·4	28,000	34,286	0·7	24,000	40,857	—0·5	33,143	55,321
March	1·5	29,000	52,161	1·2	27,000	31,259	3·1	52,000	72,161	1·9	60,536	69,806
April	4·6	45,000	72,767	3·3	42,000	86,240	6·0	89,000	120,333	1·8	60,685	113,733
May	5·9	76,710	111,903	8·0	115,114	223,031	7·1	133,678	203,033	5·5	116,310	172,193
June	8·8	146,707	282,200	11·7	256,447	394,210	9·6	208,000	249,900	7·2	168,918	235,033
July	10·8	253,126	346,613	13·5	324,000	429,355	13·1	330,000	403,935	8·2	189,396	230,338
August	11·7	282,234	441,613	11·8	260,997	340,852	13·7	407,156	524,613	10·9	286,000	390,376
September	7·1	96,178	168,200	8·4	160,000	271,733	8·6	207,000	421,267	5·1	120,000	171,633
October	3·6	37,270	58,935	4·2	53,000	82,258	4·6	82,528	118,935	2·0	49,400	75,419
November	2·6	32,000	34,633	2·2	32,000	43,000	1·3	44,000	62,433	0·3	40,000	43,500
December	1·9	30,150	31,710	1·4	28,000	29,968	0·3	36,777	39,548	—0·9	31,048	35,903

STATEMENT No. I.—*contd.*

Table showing minimum and average discharges at Sukkur in each month for the years 1901 *to* 1918—contd.

Month.	1908.			1909.			1910.			1911.		
	Minimum.		Average.	Minimum.		Average.	Minimum.		Average.	Minimum.		Average.
	Gauge Reading.	Discharge.	Discharge.	Gauge Reading.	Discharge.	Discharge.	Gauge Reading.	Discharge.	Discharge.	Gauge Reading.	Discharge.	Discharge.
January	*—1·0*	30,164	34,429	*—1·75*	40,000	41,677	0·5	42,350	59,387	0·6	33,200	55,129
February	*—1·4*	27,809	29,931	*—2·2*	36,026	38,229	0·5	36,142	43,678	1·5	38,000	70,321
March	*—1·6*	26,462	27,549	*—2·3*	37,000	54,484	0·6	30,813	37,645	2·0	44,411	165,613
April	*—2·0*	25,712	133,881	0·0	49,429	71,733	2·1	51,000	76,167	5·0	142,224	174,233
May	4·3	108,000	138,452	3·4	82,748	108,097	4·9	92,000	145,064	6·6	164,851	196,645
June	6·3	169,930	250,767	5·0	115,000	275,133	9·4	275,000	349,700	9·5	272,000	444,167
July	8·8	240,206	423,908	8·2	305,385	397,516	9·3	264,000	452,806	8·8	291,000	378,226
August	13·6	462,599	502,162	11.3	430,964	535,677	12·9	492,658	559,355	8·1	256,406	352,129
September	5·4	158,135	512,767	6·2	200,000	437,000	6·1	171,000	356,633	7·1	211,089	301,667
October	1·9	65,224	93,000	3·1	78,000	116,935	2·7	76,000	107,742	3·1	68,000	104,806
November	*—0·6*	51,000	56,433	1·4	48,000	59,967	1·3	44,663	58,533	2·8	49,581	57,033
December	—1·6	39,760	44,645	0·6	40,892	46,774	0·8	32,448	41,000	2·2	45,349	50,258

STATEMENT I—*contd.*

Table showing minimum and average discharges at Sukkur in each month for the years 1901 *to* 1918—contd.

Month.	1912.			1913.			1914.			1915.		
	Minimum.		Average.	Minimum.		Average.	Minimum.		Average.	Minimum.		Average.
	Gauge Reading.	Discharge.	Discharge.	Gauge Reading.	Discharge.	Discharge.	Gauge Reading.	Discharge.	Discharge.	Gauge Reading.	Discharge.	Discharge.
January	2·1	42,180	47,804	1·5	27,428	29,260	1·2	27,502	29,419	1·8	41,012	46,645
February	2 0	39,367	51 241	1·2	23,730	26,464	0·7	23,719	29,714	1·5	40,664	59,571
March	1·6	35,311	40,193	1·3	24,996	33,935	2·1	31,350	36,322	2·4	45,741	67,194
April	1·7	35,311	58,833	2·5	35,089	49,034	3·4	40,000	82,633	4 0	75,000	148,733
May	5·7	119,850	150,064	4·9	58,909	130,129	6·1	69,739	127,677	6·4	142,129	327,194
June	6·7	165,026	271,267	8·6	201,000	281,068	6·7	104,000	246,700	8·4	215,028	297,500
July	8·7	289,000	523,452	8·2	201,498	341,484	12·6	417,153	692,032	8·4	215,000	346,968
August	11·4	375,000	557,258	9·3	251,439	431,516	9·6	151,000	592,226	10·4	353,000	381,742
September	5·1	90,000	234,081	5·7	100,000	255,667	9·9	290,000	462,100	6·2	127,000	236,100
October	3·0	54,000	68,419	3·4	53,000	71,258	4·3	91,000	138,935	2·8	69,560	117,903
November	2·1	45,018	46,967	2·6	34,935	42,900	3·3	82,000	100,967	1·1	46,272	56,333
December	1·6	31,000	35,645	1·7	30,692	32,774	2·3	56,337	68,516	*—0·1*	32,461	37,677

STATEMENT I—*contd.*

Table showing minimum and average discharges at Sukkur in each month for the years 1901 *to* 1918—concld.

Month.	1916.			1917.			1918.		
	Minimum.		Average.	Minimum.		Average.	Minimum.		Average.
	Gauge Reading.	Discharge.	Discharge.	Gauge Reading.	Discharge.	Discharge.	Gauge Reading.	Discharge.	Discharge.
January	*—0·9*	26,117	28,710	0·1	24,153	27,097	0·7	38,523	41,903
February	*—0·9*	25,546	28,310	*—0·1*	23,394	25,429	*—0·1*	29,500	35,393
March	*—1·0*	25,559	27,000	*—0·7*	17,722	19,871	*—0·3*	28,083	60,484
April	0·3	32,267	41,700	*—0·7*	17,568	22,733	3·4	83,611	143,167
May	2·7	52,665	66,387	1·2	27,000	57,484	5·4	117,000	233,000
June	3·9	67,000	267,933	5·7	122,000	241,100	9·0	309,702	441,900
July	9·2	319,705	420,774	7·2	213,000	277,516	7·6	208,025	316,419
August	9·4	391,624	587,968	11·1	413,644	611,000	7·7	240,000	320,129
September	6·0	121,574	265,733	10·2	354,000	432,833	5·2	84,000	197,467
October	3·3	68,000	105,420	3·3	85,908	207,258	2·0	41,851	55,806
November	1·6	43,477	51,100	1·8	59,000	107,600	0·7	31,230	35,133
December	1·0	33,317	37,161	0·9	43,318	50,355	0·2	24,643	27,871

APPENDIX M.

Statement No. II.

Table showing minimum and average discharges at Kotri in each month for the years 1901 *to* 1918.

Month.	Approximate total withdrawals of all canals at Sukkur when fully developed.	Average discharge of Fuleli for 1903-1918.	1901.			1902.			1903.			
			Minimum.		Average.	Minimum.		Average.	Minimum.		Average.	Average.
			Gauge Reading.	Discharge.	Discharge.	Gauge Reading.	Discharge.	Discharge	Gauge Reading.	Discharge.	Discharge.	Discharge of Fuleli.
January	21,754	965	5·3	38,000	51,700	4·4	26,405	31,000	4·0	24,899	27,548	..
February	21,754	911	6·4	52,000	60,857	4·3	27,367	29,714	3·9	25,156	25,929	..
March	21,664	912	6·0	48,000	53,355	2·9	24,882	28,742	3·7	19,772	24,129	..
April	27,277	..	7·0	58,000	82,966	3·0	7,000	31,700	5·3	34,688	49,567	..
May	37,821	..	8·5	76,000	167,774	5·0	39,270	78,516	7·7	71,200	124,613	..
June	44,322	..	10·6	123,000	190,433	11·4	152,000	211,100	11·2	110,000	159,200	..
July	44,322	..	12·2	180,000	238,968	12·8	183,427	231,064	12·7	168,006	239,419	..
August	44,322	..	16·8	338,000	392,325	2·3	162,905	238,581	16·8	346,000	421,879	..
September	44,322	..	12·7	172,000	287,826	10·2	109,248	170,233	13·8	166,767	321,167	..
October	24,049	..	9·2	64,211	85,355	8·0	64,000	73,032	10·1	82,000	116,710	..
November	19,581	1,550	6·6	45,000	54,767	6·4	44,000	51,767	7·4	49,000	63,467	1,671
December	21,754	1,102	5·6	35,000	39,968	5·3	30,000	36,935	5·9	37,000	43,005	1,123

STATEMENT No. II—*contd.*

Table showing minimum and average discharges at Kotri in each month for the years 1901 *to* 1918—contd.

Month.	Approximate total withdrawals of all canals at Sukkur when fully developed.	Average discharge of Fuleli for 1903-1918.	1904,				1905.				1906.			
			Minimum.		Average.	Average.	Minimum.		Average.	Average.	Minimum.		Average.	Average.
			Gauge Reading.	Discharge.	Discharge.	Discharge of Fuleli.	Gauge Reading.	Discharge.	Discharge.	Discharge of Fuleli.	Gauge Reading.	Discharge.	Discharge.	Discharge of Fuleli.
January ..	21,754	965	5·6	35,000	39,484	1,277	5·4	34,000	37,129	1,337	6·2	33,000	37,740	1,191
February ..	21,754	911	5·8	36,000	40,724	1,223	5·4	34,000	37,321	1,400	5·8	30,000	33,210	988
March ..	21,664	912	5·4	34,000	52,613	1,226	5·4	34,000	36,387	1,452	7·9	46,000	51,838	1,013
April ..	27,277	..	7·2	60,620	71,533	..	6·9	38,000	48,400	..	9·6	67,000	85,533	..
May ..	37,821	..	8·4	60,147	92,452	..	11·3	109,000	188,693	..	10·8	87,000	145,484	..
June ..	44,322	..	10·0	90,000	202,567	..	14·4	210,567	286,950	..	14·2	193,549	227,167	..
July ..	44,322	..	14·1	186,668	229,548	..	17·4	294,000	372,493	..	15·4	244,000	344,000	..
August ..	44,322	..	16·0	295,000	356,290	..	16·4	243,726	298,652	..	18·3	308,480	365,806	..
September ..	44,322	..	11·6	106,000	170,233	..	13·5	169,323	260,279	..	17·8	340,000	417,433	..
October ..	24,049	..	8·5	44,000	66,968	..	10·2	60,000	85,710	..	11·7	80,000	130,419	..
November ..	19,581	1,550	7·3	34,000	36,400	1,667	8·0	41,000	49,967	1,822	7·9	49,000	59,533	1,503
December ..	21,754	1,102	6·1	30,000	31,710	1,448	6·9	38,000	40,000	1,314	6·7	37,000	41,806	1,029

STATEMENT No. II.—*contd.*

Table showing minimum and average discharges of Kotri in each month for the years 1901 *to* 1918—contd.

Month.	Approximate total withdrawals of all canals at Sukkur when fully developed.	Average discharge of Fuleli for 1903-1918.	1907.				1908.				1909.			
			Minimum.		Average.		Minimum.		Average.		Minimum.		Average.	
			Gauge Reading.	Discharge.	Discharge.	Discharge of Fuleli.	Gauge Reading.	Discharge.	Discharge.	Discharge of Fuleli.	Gauge Reading.	Discharge	Discharge.	Discharge of Fuleli.
January ..	21,754	965	6·0	35,587	40,290	953	6·3	31,000	34,193	808	6·0	34,467	38,387	798
February ..	21,754	911	5·5	35,000	60,964	1,048	6·0	28,815	31,552	1,125	4·7	29,405	33,429	797
March ..	21,664	912	8·0	57,713	78,064	1,140	5·2	26,000	28,032	952	4·7	29,000	50,161	822
April ..	27,277	..	8·1	66,000	110,833	..	5·2	26,089	94,433	..	6·6	48,711	62,467	..
May ..	37,821	..	10·8	99,836	177,387	..	10·7	122,000	136,000	..	9·8	82,195	104,613	..
June ..	44,322	..	12·9	150,000	205,567	..	11·7	135,000	177,067	..	11·6	121,556	223,600	..
July ..	44,322	..	13·2	153,306	193,322	..	15·8	237,000	297,226	..	16·2	253,727	305,161	..
August ..	44,322	..	15·3	220,000	305,161	..	20·4	411,996	489,586	..	20·0	356,935	378,774	..
September ..	44,322	..	12·1	115,000	175,067	..	15·8	178,000	309,300	..	14·8	178,000	341,267	..
October ..	24,049	..	9·7	54,923	78,419	..	10·7	74,437	109,387	..	10·6	76,000	103,935	..
November ..	19,581	1,550	7·8	42,000	47,367	1,783	7·9	46,257	58,468	1,477	7·3	45,006	57,667	1,683
December ..	21,754	1,102	6·5	32,000	36,710	1,131	6·2	36,000	40,000	1,149	5·9	37,519	41,452	1,195

STATEMENT No. II.—*contd.*

Table showing minimum and average discharges at Kotri in each month for the years 1901 *to* 1918—contd.

Month.	Approximate total withdrawals of all canals at Sukkur when fully developed.	Average discharge of Fuleli for 1903--1918.	1910.				1911.				1912			
			Minimum.		Average.		Minimum.		Average.		Minimum.		Average.	
			Gauge Reading.	Discharge.	Discharge.	Discharge of Fuleli.	Gauge Reading.	Discharge.	Discharge.	Discharge of Fuleli.	Gauge Reading.	Discharge.	Discharge	Discharge of Fuleli.
January ..	21,754	965	5·7	37,531	51,645	1,292	6·0	35,000	52,548	1,047	6·0	30,907	34,097	1,337
February ..	21,754	911	5·2	33,665	42,429	1,147	6·8	45,849	77,372	855	5·6	35,000	45,896	1,283
March ..	21,664	912	4·9	31,954	34,419	1,127	6·7	37,094	136,645	803	4·9	26,000	35,323	840
April ..	27,277	..	5·0	33,000	51,133	..	11·7	122,000	157,733	..	4·8	25,382	39,067	..
May ..	37,821	..	10·6	87,589	111,452	..	13·2	161,000	181,581	..	9·8	82,000	111,064	..
June ..	44,322	..	14·2	145,000	240,833	..	15·2	222,000	323,700	..	11·8	118,000	168,133	..
July ..	44,322	..	16·3	250,000	334,871	..	17·2	245,000	320,935	..	14·7	186,000	268,968	..
August ..	44,322	..	20·2	373,000	431,110	..	17·0	255,212	317,226	..	20·1	337,995	394,452	..
September ..	44,322	..	15·0	182,000	342,267	..	15·5	191,682	255,000	..	11·8	86,000	85,133	..
October ..	24,049	..	10·1	74,000	116,290	..	9·3	67,521	104,484	..	9·7	52,000	63,613	–
November ..	19,581	1,550	7·5	45,636	55,433	1,472	7·6	48,000	55,567	1,307	7·5	38,411	43,533	505
December ..	21,754	1,102	5·9	34,000	38,225	1,153	6 2	36,000	41,000	1,349	6·2	31,168	34,935	92

STATEMENT No. II.—*contd.*

Table showing minimum and average discharges at Kotri in each month for the years 1901 *to* 1918—contd.

Month.	Approximate total withdrawals of all canals at Sukkur when fully developed.	Average discharge of Fuleli for 1903–1918.	1913.				1914.				1915.			
			Minimum.		Average.		Minimum.		Average.		Minimum.		Average.	
			Gauge Reading.	Discharge.	Discharge.	Discharge of Fuleli.	Gauge Reading.	Discharge.	Discharge.	Discharge of Fuleli.	Gauge Reading.	Discharge.	Discharge.	Discharge of Fuleli.
January ..	21,754	965	5·4	27,573	29,000	29	5·9	24,178	25,903	602	8·1	36,389	41,194	1,235
February ..	21,754	911	4·8	24,163	26,000	8	5·1	24,556	26,964	455	7·4	31,358	44,036	1,194
March ..	21,664	912	4·7	24,198	30,161	49	6·8	31,319	34,581	912	8·3	38,000	55,258	1,025
April ..	27,277	..	5·8	29,287	35,600	..	7·7	37,000	98,067	..	9·7	59,355	146,467	..
May ..	37,821	..	8·7	45,000	93,387	..	9·6	76,101	129,065	..	12·5	142,732	271,871	..
June ..	44,322	..	14·5	164,818	216,082	..	10·8	85,000	235,033	..	15·3	194,000	254,430	..
July ..	44,322	..	14·5	162,000	255,292	..	18·0	322,000	475,416	..	14·9	166,771	237,807	..
August ..	44,322	..	17·0	227,040	337,516	..	18·7	322,000	495,742	..	17·6	283,122	310,797	..
September ..	44,322	..	11·8	115,578	225,267	..	18·2	262,000	310,200	..	14·2	119,000	217,800	..
October ..	24,049	..	9·3	55,000	72,258	..	12·3	105,000	141,484	..	11·0	66,000	116,161	..
November ..	19,581	1,550	7·6	37,352	43,600	1,264	10·8	63,341	92,367	2,284	8·8	44,432	53,633	2,364
December ..	21,754	1,102	6·2	25,036	31,806	829	9·4	52,000	63,000	1,371	7·3	31,776	36,065	1,663

STATEMENT No. II.—*contd.*

Table showing minimum and average discharges at Kotri in each month for the years 1901 *to* 1918—concld.

Month.	Approximate total withdrawals of all canals at Sukkur when fully developed.	Average discharge of Fuleli for 1903-1908.	1916.				1917.				1918.			
			Minimum.		Average.		Minimum.		Average.		Minimum.		Average.	
			Gauge Reading.	Discharge.	Discharge.	Discharge of Fuleli.	Gauge Reading.	Discharge.	Discharge.	Discharge of Fuleli.	Gauge Reading.	Discharge.	Discharge.	Discharge of Fuleli.
January ..	21,754	965	6·1	28,569	30,065	1,067	5·9	26,948	29,129	981	7·0	32,736	36,645	339
February .	21,751	911	5·9	26,214	28,379	950	5·2	20,733	25,821	845	5·6	24,000	28,250	354
March ..	21,661	912	5·8	23,563	25,355	918	4·7	18,992	21,387	771	4·9	21,001	36,645	339
April ..	27,277	..	5·7	24,291	33,733	..	4·5	17,353	21,500	..	10·4	80,651	149,967	..
May ..	37,821	..	9·4	49,371	58,645	..	5·8	24,855	45,613	..	11·1	94,000	189,548	..
June ..	44,322	..	10·1	57,000	164,700	..	9·7	58,000	184,333	..	16·9	272,221	348,935	..
July ..	44,322	..	17·2	177,000	225,129	..	13·7	140,000	204,226	..	15·0	158,011	244,452	..
August ..	44,322	..	19·1	232,996	305,258	..	17·2	242,000	442,226	..	15·0	190,000	219,323	..
September ..	44,322	..	15·0	141,768	224,167	..	19·8	423,188	506,800	..	11·2	89,000	187,667	..
October ..	24,049	..	11·0	72,448	100,935	..	13·1	96,023	257,161	..	8·9	40,000	56,806	..
November ..	19,581	1,550	8·0	37,568	48,933	1,687	10·9	64,389	108,733	661	7·2	32,222	34,700	1,641
December ..	21,754	1,102	6·5	30,937	35,161	1,211	8·0	39,000	48,839	253	6·5	27,000	29,290	1,320

APPENDIX M.

Statement No. III.

Comparison between Sukkur and Kotri discharges, taking average discharge in cusecs in each month.

No.	Month.	Sukkur.	Kotri.	Reduction at Kotri.	Surplus at Kotri.	Remarks.
	1901.					
1	January	53,741	51,700	2,041	..	
2	February	60,428	60,857	..	429	
3	March	48,161	53,355	..	5,194	
4	April	98,666	82,966	15,700	..	
5	May	171,356	167,774	3,582	..	
6	June	208,000	190,433	17,567	..	
7	July	307,677	238,968	68,709	..	
8	August	563,580	392,325	171,255	..	
9	September	299,300	287,826	11,474	..	
10	October	99,193	85,355	13,838	..	
11	November	59,433	54,767	4,666	..	
12	December	37,000	39,968	..	2,968	
	1902.					
1	January	30,484	31,000	..	516	
2	February	27,964	29,714	..	1,750	
3	March	25,451	28,742	..	3,291	
4	April	29,900	31,700	..	1,800	
5	May	115,080	78,516	36,564	..	
6	June	247,333	211,100	36,233	..	
7	July	303,968	231,064	72,904	..	
8	August	273,871	238,581	35,290	..	
9	September	188,867	170,233	18,634	..	
10	October	64,806	73,032	..	8,226	
11	November	41,300	51,767	..	10,467	
12	December	30,097	36,935	..	6,838	

STATEMENT No. III.—*contd.*

No.	Month.	Sukkur.	Kotri.	Reduction at Kotri.	Surplus at Kotri.	Remarks.
	1903.					
1	January	24,774	27,548	..	2,774	
2	February	26,000	25,929	71	..	
3	March	24,684	24,129	555	..	
4	April	50,133	49,567	566	..	
5	May	137,419	124,613	12,806	..	
6	June	221,500	159,200	62,300	..	
7	July	325,032	239,419	85,613	..	
8	August	550,355	421,879	128,476	..	
9	September	362,267	321,167	41,100	..	
10	October	104,548	116,710	..	12,162	
11	November	56,800	63,467	..	6,667	
12	December	37,935	43,005	..	5,070	
	1904.					
1	January	37,968	39,484	..	1,516	
2	February	33,690	40,724	..	7,034	
3	March	52,161	52,613	..	452	
4	April	72,767	71,533	1,234	..	
5	May	119,903	92,452	27,451	..	
6	June	282,200	202,567	79,633	..	
7	July	346,613	229,548	117,065	..	
8	August	441,613	356,290	85,323	..	
9	September	168,200	170,233	..	2,033	
10	October	58,935	66,968	..	8,033	
11	November	34,633	36,400	..	1,767	
12	December	31,710	31,710	..	..	

STATEMENT No. III.—*contd.*

No.	Month.	Sukkur.	Kotri.	Reduction at Kotri.	Surplus at Kotri.	Remarks.
	1905.					
1	January	29,467	37,129	..	7,662	
2	February	34,286	37,321	..	3,035	
3	March	31,259	36,387	..	5,128	
4	April	86,240	48,400	37,840	..	
5	May	223,031	188,693	34,338	..	
6	June	394,210	286,950	107,260	..	
7	July	429,355	372,493	56,862	..	
8	August	340,852	298,652	42,200	..	
9	September	271,733	260,279	11,454	..	
10	October	82,258	85,710	..	3,452	
11	November	43,000	49,967	..	6,967	
12	December	29,968	40,000	..	10,032	
	1906.					
1	January	29,129	37,740	..	8,611	
2	February	40,857	33,210	7,647	..	
3	March	72,161	51,838	20,323	..	
4	April	120,333	85,533	34,800	..	
5	May	203,033	145,484	57,549	..	
6	June	249,900	227,167	22,733	..	
7	July	403,935	344,000	59,935	..	
8	August	524,613	365,806	158,807	..	
9	September	421,267	417,433	3,834	..	
10	October	118,935	130,419	..	11,484	
11	November	62,433	59,533	2,900	..	
12	December	39,548	41,806	..	2,258	

STATEMENT No. III.—*contd.*

No.	Month.	Sukkur.	Kotri.	Reduction at Kotri.	Surplus at Kotri.	Remarks.
	1907.					
1	January	37,452	40,290	..	2,838	
2	February	55,321	60,964	..	5,643	
3	March	69,806	78,064	..	8,258	
4	April	113,733	110,833	2,900	..	
5	May	172,193	177,387	..	5,194	
6	June	235,033	205,567	29,466	..	
7	July	230,338	193,322	37,016	..	
8	August	390,376	305,161	85,215	..	
9	September	171,633	175,067	..	3,434	
10	October	75,419	78,419	..	3,000	
11	November	43,500	47,367	..	3,867	
12	December	35,903	36,710	..	807	
	1908.					
1	January	34,429	34,193	236	..	
2	February	29,931	31,552	..	1,621	
3	March	27,541	28,032	..	491	
4	April	133,881	94,433	39,448	..	
5	May	138,452	136,000	2,452	..	
6	June	250,767	177,067	73,700	..	
7	July	423,908	297,226	126,682	..	
8	August	502,162	489,586	12,576	..	
9	September	512,767	309,300	203,467	..	
10	October	93,000	109,387	..	16,387	
11	November	56,433	58,468	..	2,035	
12	December	44,645	40,000	4,645	..	

STATEMENT No. III.—*contd.*

No.	Month.	Sukkur.	Kotri.	Reduction at Kotri.	Surplus at Kotri.	Remarks.
	1909.					
1	January	41,677	38,387	3,290	..	
2	February	38,229	33,429	4,800	..	
3	March	54,484	50,161	4,323	..	
4	April	71,733	62,467	9,266	..	
5	May	108,097	104,613	3,284	..	
6	June	275,133	223,600	51,533	..	
7	July	397,516	305,161	92,355	..	
8	August	535,677	378,774	156,903	..	
9	September	437,000	341,267	95,733	..	
10	October	116,935	103,935	13,000	..	
11	November	59,967	57,667	2,300	..	
12	December	46,774	41,452	5,322	..	
	1910.					
1	January	59,387	51,645	7,742	..	
2	February	43,678	42,429	1,249	..	
3	March	37,645	34,419	3,226	..	
4	April	76,167	51,133	25,034	..	
5	May	145,064	111,452	33,612	..	
6	June	349,700	240,833	108,867	..	
7	July	452,806	334,871	17,935	..	
8	August	559,355	431,110	128,245	..	
9	September	356,633	342,267	14,366	..	
10	October	107,742	116,290	..	8,548	
11	November	58,533	55,433	3,100	..	
12	December	41,000	38,225	2,775	..	

STATEMENT No. III.—*contd.*

No.	Month.	Sukkur.	Kotri.	Reduction at Kotri.	Surplus at Kotri.	Remarks.
	1911.					
1	January	55,129	52,548	2,581	..	
2	February	70,321	77,372	..	7,051	
3	March	165,613	136,645	28,968	..	
4	April	174,233	157,733	16,500	..	
5	May	196,645	181,581	15,064	..	
6	June	444,167	323,700	120,467	..	
7	July	378,226	320,935	57,291	..	
8	August	352,129	317,226	34,903	..	
9	September	301,667	255,000	46,667	..	
10	October	104,806	104,484	322	..	
11	November	57,033	55,567	1,466	..	
12	December	50,258	41,000	9,258	..	
	1912.					
1	January	47,804	34,097	13,717	..	
2	February	51,241	45,896	5,345	..	
3	March	40,193	35,323	4,870	..	
4	April	58,833	39,067	19,766	..	
5	May	150,064	111,064	39,000	...	
6	June	271,267	168,133	103,134	..	
7	July	523,452	268,918	254,454	..	
8	August	557,258	394,452	162,806	..	
9	September	234,081	185,133	48,948	..	
10	October	68,419	63,613	4,806	..	
11	November	46,967	43,533	3,434	..	
12	December	35,647	34,935	712	..	

STATEMENT No. III.—*contd.*

No.	Month.	Sukkur.	Kotri.	Reduction at Kotri.	Surplus at Kotri.	Remarks.
	1913.					
1	January	29,260	29,000	260	..	
2	February	26,464	26,000	464	..	
3	March	33,935	30,161	3,774	..	
4	April	49,034	35,600	13,434	..	
5	May	130,129	93,387	36,742	..	
6	June	281,068	216,082	64,986	..	
7	July	341,484	255,290	86,194	..	
8	August	431,516	337,516	94,000	..	
9	September	255,667	225,267	30,400	..	
10	October	71,258	72,258	..	1,000	
11	November	42,900	43,600	..	700	
12	December	32,774	31,806	968	..	
	1914.					
1	January	29,419	25,903	3,516	..	
2	February	29,714	26,964	2,750	..	
3	March	36,322	34,581	1,741	..	
4	April	82,633	98,067	..	15,434	
5	May	127,677	129,065	..	1,388	
6	June	246,700	235,033	11,667	..	
7	July	692,032	475,416	216,616	..	
8	August	592,226	495,742	96,484	..	
9	September	462,100	310,200	151,900	..	
10	October	138,935	141,484	..	2,549	
11	November	100,967	92,367	8,600	..	
12	December	68,516	63,000	5,516	..	

STATEMENT No. III.—*contd.*

No.	Month.			Sukkur.	Kotri.	Reduction at Kotri.	Surplus at Kotri.	Remarks.
	1915.							
1	January	..	..	46,645	41,194	5,451	..	
2	February	..	..	59,571	44,036	15,535	..	
3	March	..	..	67,194	55,258	11,936	..	
4	April	..	..	148,733	146,467	2,266	..	
5	May	..	..	327,194	271,871	55,323	..	
6	June	..	..	297,500	254,430	43,070	..	
7	July	..	..	346,968	237,807	109,161	..	
8	August	..	..	381,742	310,797	70,945	..	
9	September	..	..	236,100	217,800	18,300	..	
10	October	..	..	117,903	116,161	1,742	..	
11	November	..	..	56,333	53,633	2,700	..	
12	December	..	..	37,677	36,065	1,612	..	
	1916.							
1	January	..	..	28,710	30,065	..	1,355	
2	February	..	..	28,310	28,379	..	69	
3	March	..	..	27,000	25,355	1,645	..	
4	April	..	..	41,700	33,733	7,967	..	
5	May	..	..	66,387	58,645	7,742	..	
6	June	..	..	267,933	164,700	103,233	..	
7	July	..	..	420,774	225,129	195,645	..	
8	August	..	..	587,968	305,258	282,710	..	
9	September	..	..	265,733	224,167	41,566	..	
10	October	..	..	105,420	100,935	4,485	..	
11	November	..	..	51,100	48,933	2,167	..	
12	December	..	..	37,161	35,161	2,000	..	

STATEMENT No. III.—*contd.*

No.	Month.	Sukkur.	Kotri.	Reduction at Kotri.	Surplus at Kotri.	Remarks.
	1917.					
1	January	27,097	29,129	..	2,032	
2	February	25,429	25,821	..	392	
3	March	19,871	21,387	..	1,516	
4	April	22,733	21,500	1,233	..	
5	May	57,484	45,613	11,871	..	
6	June	241,100	184,333	56,767	..	
7	July	277,516	204,226	73,290	..	
8	August	611,000	442,226	168,774	..	
9	September	432,833	506,800	..	73,967	
10	October	207,258	257,161	..	49,903	
11	November	107,600	108,733	..	1,133	
12	December	50,355	48,839	1,516	..	
	1918.					
1	January	41,903	36,645	5,258	..	
2	February	35,393	28,250	7,143	..	
3	March	60,484	36,645	23,839	..	
4	April	143,167	149,967	..	6,800	
5	May	233,000	189,548	43,452	..	
6	June	441,900	348,935	92,965	..	
7	July	316,419	244,452	71,967	..	
8	August	320,129	219,323	100,806	..	
9	September	197,467	187,667	9,800	..	
10	October	55,806	56,806	..	1,000	
11	November	35,133	34,700	433	..	
12	December	27,871	29,290	..	1,419	

APPENDIX M.

STATEMENT No. IV.

Date.			Indus at Kotri.		Fuleli Head regulator at Jamshora.			Remarks.
Day.	Month.	Year.	Gauge Readings.	Discharge.	Gauge Reading. Up.	Gauge Reading. Down.	Discharge.	Discharge at
7	November ..	1903	9·4	73,000	7·0	5·0	1,841	Fuleli stone bridge.
13	,, ..	,,	8·8	64,000	6·4	5·0	1,583	,,
18	,, ..	,,	8·4	59,000	5·9	5·0	1,613	,,
26	,, ..	,,	7·7	52,000	5·1	5·0	1,600	,,
5	December ..	,,	7·0	45,000	4·6	4·5	1,055·55	,,
7	,, ..	,,	6·9	44,000	4·7	4·6	1,281	,,
5	January ..	1904	5·7	36,000	4·1	4·0	876	,,
12	,, ..	,,	5·6	35,000	4·0	3·9	871	,,
18	,, ..	,,	5·6	35,000	4·2	4·1	963	,,
25	,, ..	,,	8·1	56,000	6·5	6·4	2,231·41	,,
1	February ..	,,	6·9	44,000	5·2	5·0	1,441	,,
7	,, ..	,,	6·6	42,000	4·8	4·7	1,269	,,
14	,, ..	,,	6·5	42,000	4·7	4·6	1,254	,,
21	,, ..	,,	6·2	40,000	4·5	4·4	1,253	4th mile.
7	March ..	,,	5·6	35,000	4·1	4·0	911	Stone bridge.
15	,, ..	,,	8·4	71,000	8·5	5·0	1,346	4th mile.
22	,, ..	,,	7·3	62,000	6·2	5·0	1,312	,,
29	,, ..	,,	7·5	67,000	6·8	5·0	1,309	Stone bridge.
17	November ..	,,	7·6	35,000	5·1	5·0	1,747	4th mile.
26	,, ..	,,	7·3	34,000	4·9	4·8	1,524	,,

STATEMENT No. IV.—*contd.*

Date.			Indus at Kotri.		Fuleli Head regulator at Jamshora.			Remarks.
Day.	Month.	Year.	Gauge Readings.	Discharge.	Gauge Reading. Up.	Gauge Reading. Down.	Discharge.	Discharge at
10	December ..	1904	6·7	32,000	4·9	4·8	1,413	4th mile.
16	" ..	"	6·4	31,000	4·7	4·7	1,338	"
24	" ..	"	6·1	30,000	4·5	4·4	1,193	"
30	" ..	"	6·5	34,000	4·9	4·8	1,571·72	"
7	January ..	1905	6·3	37,000	4·8	4·7	1,438	"
13	" ..	"	6·0	36,000	4·6	4·5	1,270	"
28	" ..	"	5·4	34,000	4·2	4·1	1,254	"
11	February ..	"	6·5	38,000	5·1	Not received	1,433	"
25	" ..	"	6·4	37,000	5·3	5·0	1,455	"
11	March ..	"	5·4	34,000	4·5	Gauge washed away.	1,317	"
18	" ..	"	6·5	38,000	4·9		1,509	"
25	" ..	"	6·5	38,000	5·0	"	1,523	"
11	November ..	"	9·2	54,000	6·3	6·3	1,950	Stone bridge.
18	" ..	"	8·6	47,000	5·6	5·6	1,780	"
25	" ..	"	8·2	42,000	5·4	5·4	1,750	"
2	December ..	"	7·8	41,000	5·2	5·2	1,496	"
9	" ..	"	7·4	40,000	5·1	5·1	1,356	"
23	" ..	"	7·0	39,000	4·8	4·8	1,236	"
30	" ..	"	6·8	38,000	4·8	4·8	1,007	"
6	January ..	1906	7·7	44,000	5·7	5·7	1,427	"
13	" ..	"	7·0	39,000	5·2	5·2	1,243	"
20	" ..	"	6·6	35,000	5·2	5·2	1,177	"
27	" ..	"	6·3	34,000	5·1	5·1	1,065	"
3	February ..	"	6·1	33,000	5·0	5·0	1,007	"
10	" ..	"	5·9	31,000	4·6	4·6	879	"
17	" ..	"	5·8	30,000	4·6	4·6	908	"
24	" ..	"	6·7	35,000	5·1	5·1	1,012	"

STATEMENT No. IV.—*contd.*

Date.			Indus at Kotri.		Fuleli Head regulator at Jamshora.			Remarks.
					Gauge Reading.			
Day.	Month.	Year.	Gauge-Readings.	Dis-charge.	Up.	Down.	Dis-charge.	Discharge at
3	March ..	1906	10·3	77,000	10·4	5·8	1,400	Stone bridge.
10	„ ..		8·3	50,000	7·6	5·0	921	„
17	„ ..		7·9	46,000	7·4	5·0	953	„
24	„ ..		8·0	46,000	7·5	5·0	908	„
31	„ ..		8·3	50,000	8·9	5·0	1,032	„
10	November ..	„	9·8	62,000	7·0	6·1	1,670	„
17	„ ..	„	8·9	55,000	6·0	5·6	1,381	„
24	„ ..	„	8·3	53,000	5·2	5·2	1,381	„
1	December ..	„	7·8	48,000	4·8	4·8	1,394	„
8	„ ..	„	7·5	45,000	4·5	4·4	983	„
15	„ ..	„	7·2	41,000	4·3	4·2	1,043	„
22	„ ..	„	6·9	40,000	4·2	4·1	932	„
29	„ ..	„	6·7	37,000	4·1	4·0	942	„
5	January ..	1907	7·0	55,000	4·6	4·5	1,059	„
12	„ ..	„	6·5	43,000	4·5	4·4	1,060	„
19	„ ..	„	6·1	38,000	4·2	4·2	904	„
26	„ ..	„	6·0	38,000	4·2	4·2	903	„
..	..	..	..	..	..	..	783	date not given.
9	February ..	1907	5·5	36,000	3·5	3·5	738	Stone bridge.
16	„	„	6·7	62,000	4·5	4·5	1,028	„
23	„ ..	„	9·9	103,000	7·8	7·8	2,305	„
2	March ..	„	10·1	102,000	9·0	5·5	1,508	„
9	„ ..	„	8·3	61,000	6·6	4·4	960	„
16	„ ..	„	8·1	64,000	6·6	4·5	1,065	„
23	„ ..	„	10·1	105,000	9·4	5·4	1,220	„
30	„ ..	„	8·4	76,000	7·1	4·3	937	„

STATEMENT No. IV—*contd.*

Date.			Indus at Kotri.		Fuleli Head Regulator at Jamshora.			Remarks.
					Gauge Reading.			
Day.	Month.	Year.	Gauge Reading.	Dis-charge.	Up.	Down.	Dis-charge.	Discharge at.
9	November ..	1907	8·9	50,000	7·0	6·6	1,886	Fuleli.
16	" ..	"	8·4	48,000	6·6	6·2	1,775	"
22	" ..	"	8·1	45,000	6·3	5·9	1,740	6th furlong.
30	" ..	"	7·8	42,000	6·1	5·7	1,633	"
6	December ..	"	7·5	39,000	6·0	5·6	1,462	"
13	" ..	"	7·2	38,000	5·9	5·5	1,416	"
20	" ..	"	6·9	36,000	5·9	3·9	832	"
27	" ..	"	6·7	33,000	5·7	3·6	762	"
3	January ..	1908	6·4	32,000	5·4	3·5	760	"
10	" ..	"	6·2	31,000	5·2	3·3	709	"
17	" ..	"	6·1	32,000	5·0	3·1	702	"
24	" ..	"	7·7	47,000	6·9	4·3	827	"
31	" ..	"	6·3	33,000	5·2	4·7	1,170	"
7	February ..	"	6·0	29,000	5·9	4·4	1,037	"
14	" ..	"	6·4	34,000	5·3	4·8	1,213	"
21	" ..	"	6·2	31,000	5·2	4·7	1,152	"
28	" ..	"	6·0	32,000	5·0	4·7	1,083	"
6	March ..	"	5·6	29,000	4·5	4·0	947	"
13	" ..	"	5·5	28,000	4·2	3·8	894	"
20	" ..	"	5·5	28,000	4·5	4·0	902	"
27	" ..	"	5·2	27,000	4·3	3·8	899	"
6	November ..	"	9·9	71,000	7·4	5·9	1,577·15	Stone bridge.
13	" ..	"	9·1	59,000	6·9	5·4	1,507·98	"
21	" ..	"	8·4	55,000	6·2	5·4	1,535·00	"
27	" ..	"	8·0	47,000	5·9	5·1	1,241	"

STATEMENT No. IV—*contd.*

Date.			Indus at Kotri.		Fuleli Head Regulator at Jamshora.			Remarks.
Day.	Month.	Year.	Gauge Readings.	Discharge.	Gauge Reading. Up.	Gauge Reading. Down.	Discharge.	Discharge at.
5	December ..	1908	7·6	45,000	5·7	5·0	1,328	5/2 mile.
11	,, ..	,,	7·2	40,000	5·4	4·7	1,229	Stone bridge.
25	,, ..	,,	6·5	38,000	4·8	4·3	1,022·07	,,
1	January ..	1909	6·1	34,000	4·7	4·2	987·29	,,
8	,, ..	,,	6·2	38,000	4·55	4·3	992·05	,,
15	,, ..	,,	6·0	38,000	4·6	4·1	947·15	,,
22	,, ..	,,	5·8	37,000	4·7	3·0	389·89	,,
5	February ..	,,	5·6	36,000	4·3	3·9	884·90	,,
12	,, ..	,,	5·3	34,000	4·1	3·7	790·59	,,
26	March ..	,,	4·7	29,000	6·4	2·8	842·77	Mile 3/1.
6	November ..	,,	9·7	65,000	7·7	2·7	1,036	,,
13	,, ..	,,	8·8	59,000	6·8	5·5	2,326	,,
20	,, ..	,,	8·0	53,000	6·3	5·0	2,407	,,
27	,, ..	,,	7·5	48,000	6·0	4·9	1,051	,,
4	December ..	,,	7·0	44,000	5·7	4·7	1,385	,,
10	,, ..	,,	6·6	40,000	5·5	4·6	1,302	,,
17	,, ..	,,	6·3	38,000	5·4	4·3	1,173	,,
24	,, ..	,,	6·0	38,000	5·2	4·2	1,009	,,
31	,, ..	,,	7·3	50,000	6·5	4·4	1,197	,,
7	January ..	1910	6·3	41,000	5·7	5·1	2,398	,,
11	February ..	,,	6·4	44,000	6·2	3·3	1,153	,,
23	,, ..	,,	5·4	34,000	5·1	3·7	1,039	,,
25	,, ..	,,	5·3	34.000	5·0	3·8	1,022	,,
4	March ..	,,	5·8	38,000	5·7	4·0	1,062	Below stone bridge.

STATEMENT No. IV—*contd.*

Date.			Indus at Kotri.		Fuleli Head Regulator at Jamshora.			Remarks.
Day.	Month.	Year.	Gauge Readings.	Discharge.	Gauge Reading. Up.	Gauge Reading. Down.	Discharge.	Discharge at.
11	March ..	1910	5·0	33,000	5·2	3·7	1,076	Below stone bridge.
18	" ..	"	5·2	35,000	5·3	4·0	1,136	"
25	" ..	"	4·9	33,000	5·1	3·9	1,101	"
4	November ..	"	9·6	67,000	7·2	6·4	1,650	"
18	" ..	"	8·3	52,000	6·0	5·5	1,505	"
25	" ..	"	7·8	49,000	5·9	4·3	1,284	"
2	December ..	"	7·3	45,000	5·5	4·4	1,168	"
16	" ..	"	6·4	36,000	5·0	4·5	1,172	"
23	" ..	"	6·1	36,000	4·6	4·3	1,140	"
30	" ..	"	5·9	34,000	4·6	4·3	1,091	"
6	January ..	1911	6·0	37,000	4·7	4·3	1,139	"
13	" ..	"	5·7	36,000	4·6	4·2	1,123·5	"
20	" ..	"	8·1	62,000	7·1	4·5	1,147·7	"
27	" ..	"	8·8	68,000	8·0	3·4	804·13	"
10	February ..	"	9·3	81,000	8·6	3·0	863	"
17	" ..	"	8·3	64,000	7·8	2·0	794	"
24	" ..	"	7·1	51,000	6·4	3·5	926	"
31	March ..	"	13·1	157,000	12·4	2·1	781	"
3	November ..	"	9·3	69,000	7·8	4·2	1,229·90	"
11	" ..	"	8·7	57,000	7·0	4·7	1,561	"
17	" ..	"	7·9	50,000	6·6	4·7	1,232	Mile 5/3.
24	" ..	"	7·8	52,000	6·3	4·7	1,230	"
1	December ..	"	7·5	47,000	6·0	4·6	1,227·6	"
8	" ..	"	7·2	45,000	5·6	5·2	1,563·49	"
22	" ..	"	6·3	37,000	5·3	4·9	1,228·17	"
29	" ..	"	6·3	37,000	5·4	5·0	1,236·26	"

STATEMENT No. IV—*contd.*

Date.			Indus at Kotri.		Fuleli Head Regulator at Jamshora.			Remarks.
Day.	Month.	Year.	Gauge Reading.	Dis-charge.	Gauge Reading.		Dis-charge.	Discharge at.
					Up.	Down.		
11	January ..	1912	5·8	34,000	5·2	4·8	1,349·6	Mile 5/3.
19	„ ..	„	5·6	35,000	5·0	4·6	1,272	„
26	„ ..	„	5·7	35,000	5·0	4·6	1,280·48	„
2	February ..	„	7·8	59,000	7·3	4·7	1,303	„
9	„ ..	„	7·3	51,000	6·5	5·0	1,427·68	„
16	„ ..	„	6·9	46,000	6·1	5·0	1,334·3	„
23	„ ..	„	6·2	38,000	5·8	4·7	1,303	„
1	March ..	„	5·6	35,000	5·1	4·6	1,200·2	„
8	„ ..	„	5·4	40,000	5·4	0·9	300·6	„
15	„ ..	„	6·0	51,000	5·6	3·0	646·8	„
22	„ ..	„	5·3	30,000	4·8	4·4	1,184·2	„
29	„ ..	„	4·9	26,000	4·4	4·0	995·2	„
1	November ..	„	9·6	51,000	6·9	6·3	1,308·3	„
8	„ ..	„	9·0	46,000	6·5	5·9	1,049·5	„
17	„ ..	„	8·3	44,000	6·1	5·6	410	„
22	„ ..	„	8·0	41,000	5·6	5·1	201·5	„
29	„ ..	„	7·6	39,000	5·3	4·7	108·5	„
6	December ..	„	7·2	37,000	5·0	4·5	98·9	„
15	„ ..	„	6·7	36,000	4·8	4·3	90·3	„
20	„ ..	„	6·5	34,000	4·7	4·2	83·6	„
28	„ ..	„	6·2	32,000	4·6	4·2	77·3	„
3	January ..	1913	6·1	30,000	4·5	4·1	73·5	„
10	„ ..	„	5·8	30,000	4·3	3·9	34·5	„
30	„ ..	„	5·4	28,000	4·0	3·7	2·0	Mouth.

STATEMENT No. IV—*contd.*

Date.			Indus at Kotri.		Fuleli Head Regulator at Jamshora.			Remarks.
Day.	Month.	Year.	Gauge Reading.	Dis-charge.	Gauge Reading. Up.	Gauge Reading. Down.	Dis-charge.	Discharge at
8	February ..	1913	5·3	28,000	3·9	3·7	5·0	Mo uth
25	" ..	"	4·8	24,000	3·8	3·5	7·0	"
11	March ..	"	5·4	31,000	4·3	3·9	45·0	
18	" ..	"	6·2	36,000	4·7	4·2	50·0	
29	" ..	"	6·7	31,000	5·3	4·6	88·5	
7	November ..	"	8·8	47,000	6·7	6·4	1,476·0	Mile 5/3
14	" ..	"	8·5	43,000	6·3	6·0	1,243	"
21	" ..	"	8·0	40,000	6·0	5·7	1,233·9	"
28	" ..	"	7·7	39,000	5·7	5·4	1,041·0	"
5	December ..	"	7·4	39,000	5·5	5·2	909	"
12	" ..	"	7·1	34,000	5·3	5·0	858	"
19	" ..	"	6·7	29,000	5·0	4·7	781	"
26	" ..	"	6·4	27,000	5·0	4·7	765	"
2	January ..	1914	6·2	25,000	4·6	4·3	720	"
9	" ..	"	6·1	28,000	4·7	4·4	707	"
16	" ..	"	5·9	25,000	4·6	4·3	575	"
23	" ..	"	6·0	25,000	4·6	4·3	570	"
30	" ..	"	5·9	25,000	4·4	4·1	551	"
6	February ..	"	5·6	26,000	4·2	3·9	447	"
13	" ..	"	5·1	25,000	3·9	3·6	369	"
22	" ..	"	5·1	29,000	3·8	3·5	324	"
27	" ..	"	7·0	36,000	5·5	5·3	799	"
6	March ..	"	7·5	34,000	6·1	5·8	925	"
16	" ..	"	6·9	33,000	5·5	5·2	879	"
20	" ..	"	6·8	31,000	5·4	5·1	775	"
27	" ..	"	7·6	35,000	6·1	5·8	1,048	"

STATEMENT No. IV—*contd.*

Date.			Indus at Kotri.		Fuleli Head Regulator at Jamshora.			Remarks.
Day.	Month.	Year.	Gauge Reading.	Dis-charge.	Gauge Reading. Up.	Gauge Reading. Down.	Dis-charge.	Discharge at
6	November ..	1914	11·9	96,000	9·7	8·3	2,799	Mile 5/3
13	,, ..	,,	12·8	110,000	11·3	7·5	2,142	,,
20	,, ..	,,	11·5	85,000	9·8	7·5	2,149	,,
27	,, ..	,,	10·8	63,000	9·0	7·5	2,151	,,
5	December ..	,,	10·3	69,000	8·5	5·9	1,434	,,
12	,, ..	,,	9·7	54,000	7·9	5·5	1,318	,,
18	,, ..	,,	10·4	67,000	8·7	5·5	1,345	,
25	,, ..	,,	9·8	59,000	8·0	5·5	1,323	,,
1	January ..	1915	9·3	50,000	7·0	6·0	1,072	,,
8	,, ..	,,	8·9	43,000	7·0	6·6	1,649	,,
15	,, ..	,,	8·4	40,000	6·7	6·3	1,454	,,
22	,, ..	,,	8·2	38,000	6·6	4·8	922	,,
29	,, ..	,,	8·1	36,000	6·6	4·8	882	,,
5	February ..	,,	7·9	35,000	6·1	5·7	1,302	,,
12	,, ..	,,	7·4	31,000	5·7	5·4	940	,,
19	,, ..	,,	10·1	73,000	9·3	5·8	1,338	,,
26	,, ..	,,	8·7	49,000	7·0	6·0	1,409	,,
6	March ..	,,	8·6	48,000	7·1	4·5	1,012	,,
13	,, ..	,,	8·4	41,000	6·8	4·5	825	,,
19	,, ..	,,	8·2	39,000	6·6	4·4	807	,,
26	,, ..	,,	10·5	84,000	9·7	5·4	1,219	,,
5	November ..	,,	10·6	61,000	8·4	8·0	2,670	Below stone bridge.
12	,, ..	,,	10·0	54,000	8·0	7·0	2,203	Mile 5/3.
19	,, ..	,,	9·4	51,000	7·4	6·5	2,325	Below stone bridge.
26	,, ..	,,	9·1	47,000	6·5	6·5	2,313	Mile 5/3.

STATEMENT No. IV.—*contd.*

Date.			Indus at Kotri.		Fuleli Head Regulator at Jamshora.			Remarks.
Day.	Month.	Year	Gauge Reading.	Dis-charge.	Gauge Reading. Up.	Gauge Reading. Down.	Dis-charge.	Discharge at
3	December ..	1915	8·7	42,000	6·7	6·3	2,133	Mile 5/3.
10	" ..	"	8·3	38,000	6·4	6·0	1,968	"
17	" ..	"	7·8	34,000	6·0	5·6	1,460	"
24	" ..	"	7·5	33,000	5·8	5·4	1,428	"
1	January ..	1916	7·1	32,000	5·5	5·1	1,232	"
7	" ..	"	6·8	31,000	5·4	5·0	1,211	"
14	" ..	"	6·5	30,000	5·0	4·6	1,090	"
21	" ..	"	6·4	29,000	4·8	4·1	955	"
28	" ..	"	6·1	29,000	4·5	4·2	955	"
5	February ..	"	5·9	26,000	4·4	4·1	935	"
11	" ..	"	5·9	26,000	4·3	4·0	930	"
18	" ..	"	6·3	31,000	4·7	4·4	953	"
25	" ..	"	6·5	31,000	4·9	4·6	997	"
3	March ..	"	6·0	26,000	4·4	4·1	912	"
11	" ..	"	6·0	26,000	4·5	4·2	936	"
17	" ..	"	5·9	25,000	4·5	4·2	929	"
24	" ..	"	5·7	24,000	4·3	4·0	895	"
31	" ..	"	5·7	24,000	4·3	4·0	898	"
3	November ..	"	10·6	64,000	8·5	7·7	2,178·93	"
11	" ..	"	9·6	48,000	7·7	6·9	1,898	"
18	" ..	"	9·0	49,000	7·2	6·4	1,770	"
24	" ..	"	8·4	43,000	6·8	6·0	1,398	"
2	December ..	"	7·7	37,000	6·2	5·8	1,348	"
8	" ..	"	7·4	37,000	6·0	5·6	1,321	"
15	" ..	"	7·0	36,000	5·7	5·3	1,207	"
23	" ..	"	6·6	34,000	5·5	5·1	1,130	"
29	" ..	"	6·5	32,000	5·5	5·1	1,113	"

STATEMENT No. IV.—*contd.*

Date.			Indus at Kotri.		Fuleli Head Regulator at Jamshora.			Remarks.
Day.	Month.	Year.	Gauge Reading.	Discharge.	Gauge Reading.		Discharge.	Discharge at
					Up.	Down.		
5	January ..	1917	6·4	31,000	5·3	4·9	1,038	Mile 5/3
12	,, ..	,,	6·1	30,000	5·1	4·7	989	,,
19	,, ..	,,	5·9	28,000	4·9	4·5	988	,,
26	,, ..	,,	5·8	27,000	4·8	4·4	935	,,
2	February ..	,,	5·6	28,000	4·5	4·1	858	,,
9	,, ..	,,	5·5	26,000	4·5	4·1	833	,,
17	,, ..	,,	5·6	25,000	4·7	4·3	851	,,
23	,, ..	,,	5·3	27,000	4·7	4·3	876	,,
11	March ..	,,	4·9	23,000	4·4	4·0	763	,,
17	,, ..	,,	4·8	21,000	4·4	4·0	760	,,
23	,, ..	,,	4·6	21,000	4·3	3·9	738	,,
17	November ..	,,	12·2	91,000	9·9	4·5	840	,,
23	,, ..	,,	11·4	76,000	9·1	2·6	388	,,
1	December ..	,,	10·4	64,000	8·2	1·7	292	,,
7	,, ..	,,	9·8	55,000	7·5	1·2	235	,,
15	,, ..	,,	9·3	49,000	7·1	1·5	243	,,
23	,, ..	,,	8·6	43,000	6·3	1·5	266	,,
28	,, ..	,,	8·2	41,000	5·9	2·0	309	,,
5	January ..	1918	8·1	41,000	6·1	2·3	337	,,
11	,, ..	,,	7·8	38,000	5·9	2·5	371	,,
18	,, ..	,,	7·5	36,000	5·7	2·3	348	,,
25	,, ..	,,	7·1	33,000	5·5	2·2	366	,,
1	February ..	,,	7·0	32,000	5·4	2·3	350	,,
8	,, ..	,,	6·8	30,000	5·3	2·3	349	,,
22	,, ..	,,	5·9	26,000	4·3	2·3	349	,,

STATEMENT No. IV.—*contd.*

Date.			Indus at Kotri.		Fuleli Head Regulator at Jamshora.			Remarks.
					Gauge Reading.			
Day.	Month.	Year.	Gauge Reading.	Dis-charge.	Up.	Down.	Dis-charge.	Discharge at
1	March ..	1918	5·6	24,000	4·1	2·3	385	Mile 3/5
8	" ..	"	5·1	22,000	3·8	2·3	351	"
16	" ..	"	4·9	21,000	3·8	2·2	339	"
22	" ..	"	5·2	25,000	4·3	2·2	339	"
31	" ..	"	13·2	136,000	12·7	1·9	292	"
1	November ..	"	8·8	39,000	6·9	6.7	1,924·09	"
8	" ..	"	8·4	36,000	6·4	6·2	1,758·11	"
15	" ..	"	7·9	34,000	6·2	6·0	1,682·03	"
22	" ..	"	7·6	33,000	5·9	5·7	1,501·38	"
29	" ..	"	7·2	32,000	5·6	5·4	1,454·17	"
6	December ..	"	7·0	31,000	5·4	5·2	1,380·75	"
13	" ..	"	6·8	29,000	5·3	5·1	1,351·07	"
20	" ..	"	6·7	29,000	5·0	4·8	1,321·81	"
27	" .	"	6·5	27,000	4·8	4·6	1,224·51	"
4	January .	1919	6·6	29,000	4·8	4·6	1,172·52	"
10	" ..	"	6·4	28,000	4·7	4·5	1,177·28	"
17	" ..	"	6·2	26,000	4·6	4·4	1,170	"
24	" ..	"	6·1	26,000	4·5	4·3	1,055·05	"
31	" .	"	6·0	25,000	4·3	4·1	987·55	"
4	February ..	"	5·8	25,000	4·2	4·0	880·46	"
13	" ..	"	6·5	30,000	5·0	4·7	1,022·61	"
20	" ..	"	7·3	35,000	5·8	4·2	981	"
28	" ..	"	6·5	27,000	5·2	4·1	972	"
7	March ..	"	7·4	31,000	6·0	4·7	1,166	"
14	" ..	"	6·9	29,000	5·5	4·6	1,149	"
21	" ..	"	6·5	26,000	5·2	4·9	1,296	"
28	" ..	"	7·9	41,000	6·6	4·4	1,269	"

APPENDIX M.

Statement No. V.

I.—*Statement showing the average monthly discharges of the* (5) *Khairpur State Canals for the years* 1905 *to* 1918 (14 *years*).

Serial No.	Name of Canal.	1905.						1906.						1907.						1908.						1909.					
		Kharif.				Rabi.		Kharif.				Rabi.		Kharif.				Rabi.		Kharif.				Rabi.		Kharif.				Rabi.	
		June.	July.	August.	September.	October.	November.	June.	July.	August.	September.	October.	November.	June.	July.	August.	September.	October.	November.	June.	July.	August.	September.	October.	November.	June.	July.	August.	September.	October.	November.
1	Khaharwah	48	70	70	17	..	..	16	89	81	27	..	..	..	12	28	..	..	..	14	27	35	21	..	..	7	19	58	47	..	..
2	Sathiowah	720	1,179	1,099	862	286	100	747	872	1,265	962	515	75	604	742	874	571	180	..	826	1,114	1,320	876	109	..	770	962	1,354	1,215	275	50
3	Mirwah (New)	773	791	777	388	4	..	678	814	867	217	..	..	..	156	293	12	..	..	240	614	786	482	28	..	350	541	810	570	15	..
4	Mirwah (Old)	1,780	1,822	1,501	918	10	..	1,081	2,052	2,207	1,585	109	..	499	891	1,675	279	18	..	671	1,739	1,740	843	2	..	466	960	1,676	1,330	..	..
5	Mainwah	362	450	400	300	..	..	285	410	634	495	..	..	130	180	350	133	..	..	204	400	624	381	..	..	198	289	553	536	..	..
	Total for State	3,683	4,312	3,847	2,485	300	100	2,807	4,237	5,054	3,286	624	75	1,233	1,981	3,220	995	198	..	1,955	3,894	4,505	2,603	139	..	1,791	2,771	4,451	3,698	290	50
	Mean of Season	3,582				200		3,846				350		1,857				99		3,239				70		3,178				170	

I.—*Statement showing the average monthly discharges of the* (5) *Khairpur State Canals for the years* 1905 *to* 1918 (14 *years*)—contd.

1910

Serial No.	Name of Canal.	Kharif season. June.	July.	August.	September.	Rabi season. October.	November.
1	Khaharwah .. } Mirwah Chario.	13	19	46	13	..	..
2	Sathiowah .. } Mirwah Chario.	752	714	1,061	736	121	..
3	Mirwah New No. 1 } Mirwah Chario.	314	468	457	254	..	..
4	Mirwah New No. 2 ..	..	..	..	..	..	..
5	Mirwah Old ..	908	1,342	2,122	970	149	..
6	Mainwah ..	285	373	408	276	..	..
	Total for State ..	2,272	2,916	4,094	2,249	270	..
	Mean of Season ..	2,880				135	

1911

Serial No.	Name of Canal.	Kharif season. June.	July.	August.	September.	Rabi season. October.	November.
1	Khaharwah	30	15	15	5	..	..
2	Sathiowah	806	921	1,044	734	284	..
3	Mirwah New No. 1	608	427	519	320	2	..
4	Mirwah New No. 2	..	..	..	..	..	..
5	Mirwah Old	1,610	1,160	1,160	702	7	..
6	Mainwah	517	352	336	191	..	..
	Total for State	3,571	2,875	3,074	1,952	293	..
	Mean of Season	2,868				146·5	

1912

Serial No.	Name of Canal.	Kharif season. June.	July.	August.	September.	Rabi season. October.	November.
1	Khaharwah	2	55	42	..	135	..
2	Sathiowah	980	1,634	1,585	455	..	..
3	Mirwah New No. 1	321	851	1,065	185	..	..
4	Mirwah New No. 2	434	1,167	1,171	90	..	..
5	Mirwah Old	..	..	..	..	..	..
6	Mainwah	205	605	798	95	..	..
	Total for State	1,942	4,312	4,661	825	135	..
	Mean of Season	2,935				67·5	

1913

Serial No.	Name of Canal.	Kharif season. June.	July.	August.	September.	Rabi season. October.	November.
1	Khaharwah	13	16	23	3	..	..
2	Sathiowah	913	813	1,165	750	259	113
3	Mirwah New No. 1	335	431	660	223	3	..
4	Mirwah New No. 2	278	345	488	194	1	..
5	Mirwah Old	..	..	..	..	..	..
6	Mainwah	257	321	491	182	5	..
	Total for State	1,796	1,926	2,828	1,352	268	113
	Mean of Season	1,975·5				190·5	

1914

Serial No.	Name of Canal.	Kharif season. June.	July.	August.	September.	Rabi season. October.	November.
1	Khaharwah	9	35	42	8	..	..
2	Sathiowah	651	1,039	1,301	747	330	238
3	Mirwah New No. 1	284	618	546	334	69	..
4	Mirwah New No. 2	320	711	683	428	120	..
5	Mirwah Old	..	..	..	..	..	..
6	Mainwah	201	531	581	278	46	..
	Total for State	1,465	2,934	3,153	1,785	565	238
	Mean of Season	2,380				401·5	

NOTE.—After October 1911, Mirwah Old stopped flowing, and was bunded up, a new head was given to the Canal which was henceforth called Mirwah New No. 2.

I.—*Statement showing the average monthly discharges of the* (5) *Khairpur State Canals for the years* 1905 *to* 1918 (14 *years*)—contd.

Name of Canal.	1915.						1916.						1917.						1918.						1919.						REMARKS.
	Kharif.				Rabi.		Kharif				Rabi.		Kharif.				Rabi.		Kharif				Rabi.		Kharif.				Rabi.		
	June.	July.	August.	September.	October.	November.	June.	July.	August.	September.	October.	November.	June.	July.	August.	September.	October.	November.	June.	July.	August.	September.	October.	November.	June.	July.	August.	September.	October.	November.	
Mirwah-Chario	2,556	2,486	3,055	1,511	606	147	2,508	2,852	3,742	1,959	1081	155	2.024	2,478	4,028	3,074	1216	..	2,878	2,378	2,676	1,937	522	..	2,813	3,310	..	..	..	..	Note 1.
Mirwab No. 2	..	23	214	20	..	..	.	..	..	..	..		..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Note 3.
Khaharwah..	..	11	9	..	..	..	12	11	36	8	..	..	..	7	57	24	..	..	2	6	6	9	..	..	16	19	..	..	..	..	Note 2.
Malnwah ..	234	252	361	102	..	..	196	241	336	50	..	..	..	140	710	398	55	..	384	150	248	198	..	..	345	836	..	..	..	..	
Total for State	2,790	2,772	3,630	1,633	606	147	2,716	2,104	4,114	2,012	1081	155	2,024	2,625	4,795	3,491	1271	..	3,264	2,534	2,930	2,144	522	..	3,174	4,165	..	..	..	..	
Mean of Season	2,708·5				376·5		2,986·5				618		3,233				635·5		2,718				261		3669·5 Average for June and July only.						

Note 1.—This new mouth (Mirwah Chario) feeds Khaharwah, Sathiowah, Mirwahs No. 1 and No. 2.

Note 2.—Discharge section of Mirwah Chario fixed below the point, where Khaharwah takes off, owing to erosion at the head on and after 9th July 1915.

Note 3.—Old mouth of this Canal has also been opened on 29th July 1915.

II.—*Statement showing the average monthly discharges of all the Khairpur State Canals* (11) *for the years* 1905 *to* 1910 (6 *years*).

Serial No.	Name of Canal.	1905.						1906.						1907.					
		Kharif Season.				Rabi.		Kharif.				Rabi.		Kharif.				Rabi.	
		June.	July.	August.	September.	October.	November.	June.	July.	August.	September.	October.	November.	June.	July.	August.	September.	October.	November.
1	Khaharwah	48	70	70	17	..	..	16	89	81	27	..	..	..	12	28	..	..	—
2	Sathiowah	720	1,179	1,099	862	286	100	747	872	1,265	962	515	75	604	742	874	571	180	..
3	Mirwah (New)	773	791	777	388	4	..	678	814	867	217	..	..	—	156	293	12	..	..
4	Mirwah (Old)	1,780	1,822	1,561	918	10	..	1,081	2,052	2,207	1,585	109	..	499	891	1,675	279	18	..
5	Mainwah	362	450	400	300	..	..	285	410	634	495	..	..	130	180	350	133	..	..
6	Bodliwah	20	32	46	14	..	..	15	32	64	20	..	..	8	13	30	5	..	..
7	Lalanwah	75	127	110	77	..	..	55	120	198	147	..	..	28	52	100	36	..	..
8	Ahulwah (below head of Faiz Nahar)	660	982	787	546	41	..	525	804	983	771	41	..	443	362	615	225	..	..
9	Faiz Nahar .. —	219	543	340	199	3	..	60	204	319	286	7	..	40	71	194	45	..	..
10	Madhuwah	92	245	203	79	4	..	77	126	162	94	3	..	..	2	71	5	..	..
11	Jadiwah	80	137	95	75	4	..	211	554	729	555	4	..	3	80	204	45	..	..
	Total for State	4,829	6,378	5,488	3,475	352	100	3,750	6,077	7,504	5,159	679	75	1,755	2,561	4,440	1,356	198	..
	Mean of Season	5,043				226		5,623				377		2,528				99	

II.—*Statement showing the average monthly discharges of all the Khairpur State Canals* (11) *for the years* 1905 *to* 1910 (6 *years*)—contd.

Serial No.	Name of Canal.	1908.						1909.						1910.					
		Kharif Season.				Rabi.		Kharif.				Rabi.		Kharif.				Rabi.	
		June.	July.	August.	September.	October.	November.	June.	July.	August.	September.	October.	November.	June.	July.	August.	September.	October.	November.
1	Khaharwah	14	27	35	21	..	..	7	19	58	47	..	..	13	19	46	13	..	..
2	Sathiowah	826	1,114	1,320	876	109	..	770	962	1,354	1,215	275	50	752	714	1,061	736	121	..
3	Mirwah (New)	240	614	786	482	28	..	350	541	810	570	15	..	314	468	457	254	..	..
4	Mirwah (Old)	671	1,739	1,740	843	2	..	466	960	1,676	1,330	..	..	908	1,342	2,122	970	149	..
5	Mainwah	204	400	624	381	..	..	198	289	553	536	..	..	285	373	408	276	..	..
6	Bodliwah	11	28	60	13	..	..	10	21	51	18	..	..	..	..	76	78	..	..
7	Lalanwah	42	113	175	75	..	..	41	81	124	69	..	..	..	..	180	213	..	..
8	Ahulwah (below head of Faiz Nahar)	456	752	878	353	..	..	452	666	740	420	..	..	..	..	1,389	714	..	..
9	Faiz Nahar	98	230	348	138	..	..	101	162	182	76	..	..	..	..	359	208	..	..
10	Madhuwah	18	105	204	69	..	..	31	245	203	79	..	..	..	..	152	90	..	..
11	Jadiwah	135	547	1,083	412	..	..	68	171	282	259	..	..	..	..	762	690	..	..
	Total for State	2,715	5,669	7,253	3,663	139	..	2,494	4,117	6,033	4,619	290	50	2,272	2,916	7,010	4,242	270	..
	Mean of Season	4,825				70		4,316				170		4,110				135	

III.—*Statement of average discharges (each month) for all Canals for years* 1905—1910 (6 *years*).

Months during which Canals flowed.	Years. 1905.	1906.	1907.	1908.	1909.	1910.	Average for 6 years discharge for each month.	REMARKS.
1	2	3	4	5	6	7	8	9
June	4,829	3,750	1,755	2,715	2,494	2,272	2,969	The names of the Canals of which the discharges were measured are— (1) Khaharwah. (2) Sathiowah. (3) Mirwah (New). (4) Mirwah (Old). (5) Mainwah. (6) Bodliwah. (7) Lalanwah. (8) Ahulwah. (9) Faiz Naharwah. (10) Madhuwah. (11) Jadiwah.
July	6,378	6,077	2,561	5,669	4,117	2,916	4,620	
August	5,488	7,504	4,440	7,253	6,033	7,010	6,288	
September	3,475	5,159	1,356	3,663	4,619	4,242	3,753	
Mean discharge for 4 months, June to September	5,043	5,623	2,528	4,825	4,316	4,110	4,408	
October	352	679	198	139	290	270	321	
November	100	75	....	....	....	....	38	
Mean discharge for 2 months, November and December ..	226	377	99	70	170	135	180	

APPENDIX N.

COMPARATIVE ESTIMATES

FOR

BARRAGE WITH MASONRY SUPERSTRUCTURE

AND

BARRAGE WITH STEEL SUPERSTRUCTURE.

In the following estimate No. 1 for Barrage with masonry superstructure, the design is identical with that shown in Drawing No. 43 and Estimate No. 4, except that the upstream arch of the Gate bridge is made only 5′ wide instead of 8′ as shown on the plan.

Thus the Gate bridge consists of two arch ribs each 5′ wide. This gives sufficient strength to carry all loads due to the gates, etc., and to people on the bridge. The design of flooring over the gap between the arches is identical with that shown on plan 43. This bridge as per estimate No. 1 corresponds in effect with the steel superstructure shown in Drawing No. 47 and Estimates Nos. 2 and 3, *i.e.*, it provides only for a foot bridge and for supporting the gates and machinery. The object of the 8′ wide upstream arch, shown on Drawing No. 43 and Estimate No. 4, is to carry the 3-ton travelling crane. This is not provided for, nor is it possible with the steel superstructure, and provision for it is therefore omitted in this comparative estimate *No.* 1. The comparative estimates include, in each estimate, all piers and superstructure complete, above floor level, but not the floor, gates and machinery which are common to all designs.

The rates adopted for the masonry work in all estimates are the same as those in the general estimates of the Project, *i.e.*, they are about 20 per cent. above pre-war prices.

In Estimate No. 2, the rates taken for steel superstructure and steel lattice girder bridges for road bridge are the *pre-war rates* given by Mr. Ashford.

In Estimate No. 3 the rates for steelwork have been increased by 50 per cent. to allow for rise in post-war prices.

Estimate No. 4 is for the masonry superstructure now actually proposed, *i.e.*, strengthened to carry a 3-ton travelling crane on the gate bridge. As the steel superstructure cannot in any case carry such a load, this estimate No. 4 is not really comparable with estimates 2 and 3, but it will be seen that even with this large extra provision, the masonry structure is cheaper than the steel structure even when the latter is calculated at pre-war prices.

The attached statement shows the comparison of all these estimates.

Abstract showing Comparative Cost of Masonry and Steel Superstructure for Barrage.

	Rs.
Estimate No. 1—*Masonry* superstructure for similar loads to steel superstructure, *i.e., without craneway* (details on page 263)	24,60,683
Estimate No. 2—*Steel* superstructure at *pre-war* rates (page 262)	29,29,467
Saving by substituting masonry for steel	4,68,784
Estimate No. 1—As above..	24,60,683
Estimate No. 3—*Steel* superstructure *at* 50 *per cent. above pre-war rates* (page 262)	37,66,264
Saving by substituting masonry for steel	13,05,581

	Rs.
Estimate No. 4—Masonry superstructure actually proposed, *i.e., including* provision for *craneway and 3-ton travelling crane* (page 262) ..	28,05,604
Estimate No. 3—Steel superstructure *at* 50 *per cent. above pre-war rates* (page 262) ..	37,66,264
Saving in favour of proposed design	9,60,660

Comparison of Steel and Masonry. *Details.*

Mr. Ashford's design with steel superstructure.

		Rs.	
Steel Work—Gate Bridge—			
35 tons at Rs. 13-8 a maund		13,000	
Hand railing and floor		650	
		13,650	
Road Bridge—Steel Work		10,500	
		(A)	24,150

Roadway—

		Rs.
	Cement concrete in troughs 65′×25′×6″ average = 815 c. ft. at Rs. 45 per 100	366
Same as masonry design	Concrete for footpath 2×70×3×8″ = 280 c. ft. at Rs. 17-8 per 100	49
	Kerb stone 2×70×6×12″ = 70 c. ft. at Rs. 150 per 100	105
	Paving 2×70×3×3″ = 105 c. ft. at Rs. 70 per 100	73
	Road metal 1×70×16×8″ = 747 c. ft. at Rs. 4 per 100	30
	Consolidation 70×16 = 1,120 s. ft. at Rs. 10 per 100	112
	(B) ..	735

Piers—

R. L. 176 to 215

Cut and ease waters

39 feet.

2×61·5×39 .. .. = 4,797 c. ft.

Pier—

1×55·5×10′×39′ .. = 21,645 c. ft.

26,442 c. ft.

	Rs.
at Rs. 40 per 100	10,577
	(C)

End abutments—

55·5×14·87×39 .. .. = 31,088

Downstream Wing wall same as masonry design.. .. = 12,432

43,520 c. ft.

	Rs.
at Rs. 40 per 100	17,408
	(D)

Estimate No. 2.

Abstract.

					Rs,
(A)	66 Spans	*Steel Work* Rs.	at	24,150	15,93,900
(B)	Roadway ..	Rs.	at	735	48,510
(C)	65 Piers ..	Rs.	at	10,577	6,87,505
(D)	2 End Abutments ..	Rs.	at	17,408	34,816
					23,64,731
Cost of painting in first 6 years					1,54,000
Capitalized cost of painting thereafter once in 5 years					2,50,000
Capitalized cost of depreciation of timber decking					42,500
Contingencies at 5 per cent. on Rs. 23,64,731					1,18,236
				At pre-war rates ..	Rs. 29,29,467

Estimate No. 3.

For post-war rates—

	Rs.
Cost at pre-war rates ..	29,29,467
Add 50 *per cent. advance on steel work—*	
50 per cent. of 15,93,900 ..	7,96,950
Contingencies on same ..	39,847
Rs.	37,66,264

Estimate No. 4.

Cost of Masonry design for Barrage.

With arrangements for crane and craneway—

			Rs.
(1)	Land abutments	2 at Rs. 53,346	1,06,692
(2)	End abutments (omitting regulator connecting walls)	2 at Rs. 39,509	79,018
(3)	Abutment piers	7 at Rs. 60,066	4,20,462
(4)	Ordinary piers	58 at Rs. 28,686	16,63,788
(5)	Centering	Set	2,66,419
(6)	Crane track and crane (Rs. *plus* 22,540 Rs. 12,000)		34,540
		Rs.	25,70,919
	Add cost of painting steel girders in first 6 years		15,840
	Capitalized cost of painting steel girders after 6 years every 5 years		40,000
	Capitalized cost of annual repairs to parapets, etc., and pointing arches at Rs. 2,000 per annum		50,000
	Contingencies at 5 per cent. on Rs. 25,70,919		1,28,545
	Cost of masonry design as proposed with cranes and craneway Rs.		28,05,304

Cost of masonry design without crane and craneway ..	24,60,683
Extra cost for providing travelling cranes and increasing strength of bridge ..	3,34,921

ESTIMATE No. 1.

Cost of Masonry design without crane and craneway.

Using 9 sets of centres and 7 abutment piers, cast iron bracket supports—

		Rs.
66 spans of arches, etc., for Road bridge and Gate bridge 66×13,042 ..	=	8,60,772
66 spans girders and flooring for Gate bridge 66×2,150	=	1,41,900
7 abutment piers 7×40,414	=	2,82,898
58 ordinary „ 58×10,819	=	6,27,502
2 land abutments 2×45,000 (approximate)	=	90,000
Extra for filling in slots in piers—		
59 ordinary piers 59×(48 *plus* 32)	=	4,720
9 abutment „ 9×(108 *plus* 72)	=	1,620
2 sets of centres and supports for abutment piers for Road bridge less salvage value 2×10,920	=	21,840
2 sets ditto for Gate bridge 2×7,458	=	14,916
7 sets ditto for ordinary piers, Road bridge, 7×10,818	=	75,726
7 sets ditto „ „ Gate bridge 7×7,388	=	51,716
2 extra sets of *C. I. brackets*, beams, etc., for Road bridge ordinary piers 2×1,793 ..	=	3,586
2 ditto. ditto Gatebridge 2×1166 ..	=	2,332
Total cost of placing and removing all centres and supports for Road bridge ..	=	15,090
Ditto. ditto. Gate bridge ..	=	15,090
Cost of timber staging on barges (10,000 *plus* 3,000)	=	13,000
Cost of special tackle, jacks, winches, rollers, etc., and lifting tackle, less salvage value, say	=	20,000
		22,42,708
Add—Contingencies at 5 per cent.		1,12,135
		23,54,843
Add cost of painting steel girders in first 6 years		15,840
„ capitalized cost of painting steel griders thereafter once in 5 years ..		40,000
„ capitalized cost of annual repairs to parapets, etc., and pointing arches, etc., at Rs. 2,000 per annum		50,000
Total cost Rs. ..	=	24,60,683

APPENDIX O.

SAVING DUE TO MAKING COUNTERWEIGHTS FOR BARRAGE, GATES OF REINFORCED CONCRETE.

SECTION I.

Barrage Counterweights.

In Mr. Ashford's design, the counterweights for Barrage gates are made up of a steel casing filled with sand. The weight of the steel casing is estimated at 25 tons. This at pre-war rate of Rs. 370 per ton would cost Rs. 9,250.

Sand weighs only 95 lb. per c. ft. and the counterbalance casing has to be made sufficiently large to contain enough sand to make up the weight of 92 tons. The size of the casing require is 60′×8′×6′.

A solid concrete counterweight reinforced with steel rods, need be only 62′×3′×8′. Details of cost of such a counterweight are given below, from which it will be seen that the net saving per counterweight, by adopting, this design will be Rs. 6,000 (excluding contingencies) or Rs. 3,96,000 for the Barrage alone.

The width of the concrete counterweight will be only 3′ as compared with 6′ of the steel casing and so the gap between the two arches forming the Gate Bridge can be made 3′ less in width, thereby shortening the piers by 3′. This again will effect a saving of Rs. 1,07,806 in the cost of the Barrage as per details given below:

The total probable saving on the Barrage alone, if counterweights for gates are made of concrete, will thus be Rs. 5,03,806.

If the rate for steel counterweights is taken at 50 per cent. above pre-war prices they will cost each Rs. 13,875 and the saving by substituting reinforced concrete weights will be Rs. 10,625 each or over Rs. 7,00,000 for the whole Barrage apart from the saving of over Rs. 1,00,000 in cost of piers.

SECTION II.

Regulator Counterweights.

The counterweights for regulator gates can also be made of concrete similarly reinforced, and these again will effect a considerable saving.

ABSTRACT.

Items.	Rate.	Per	Amount.
BARRAGE.	Rs. a. p.		Rs.
Saving due to making counterweight of concrete and reducing the width of Gate Bridge by 3 ft.			
No. For Details, see page 265 and 266.			
2 land abutments	1,260 0 0	Each.	2,520
2 end abutments	1,658 0 0	„	3,316
58 pier spans	1,439 0 0	„	83,462
7 abutment pier spans	2,644 0 0	„	18,508
Total saving on masonry—Indirect ..	....	..	1,07,806

ABSTRACT—*contd.*

Items.	Rate.	Per.	Amount.
	Rs. a. p.		Rs. a.
Saving in cost of counterweights alone—			
Steel counterweight costs	9,250 0 0		
Concrete counterweight costs	3,250 0 0		
For Details, see page 10.			
Saving ..	6,000 0 0		
On 66 gates Saving = ...	3,96,000 0 0		
Total saving on counterweights—Direct ..	....	..	3,96,000
Total saving due to making counterweights for gates of reinforced concrete and reducing the width of Gate bridge by 3 ft. = ...	....	..	5,03,806
Saving due to shortening pier by 3 ft.			
For each pier and 2 half spans—			
1,470 c. ft. Random rubble Floor	27 0 0	100	397 0
1,875 „ Pier Masonry	40 0 0	100	750 0
675 „ R. S. Beams	250 0 0	Ton.	168 0
47 „ R. C. Beams	150 0 0	100	70 0
45 „ R. C. Slabs	120 0 0	100	54 0
		Total ..	1,439 0
For each abutment Pier and 2 half spans—			
1,785 c. ft. Random rubble Floor	27 0 0	100	482 0
4,687 „ Abutment Masonry	40 0 0	100	1,870 0
675 „ R. S. Beams	250 0 0	100	168 0
47 „ R. C. Beams	150 0 0	100	70 0
45 „ R. C. Floor	120 0 0	100	54 0
		Total ..	2,644 0

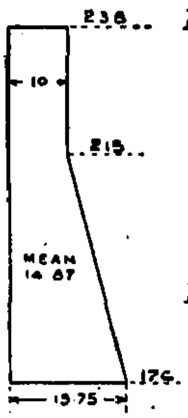
ABSTRACT—*contd.*

Items.	Rate.	Per.	Amount.
For the End Abutment of Road Bridge—	Rs. a. p.		Rs. a.
1,092 c. ft. Random rubble Floor	27 0 0	100	295 0
42 s. ft. Steel Sheet Piling	4 0 0	One.	168 0
2,445 c. ft. Masonry	40 0 0	100	978 0
3,375 „ R. S. Beams	250 0 0	Ton.	84 0
53 „ R. C. Beams	150 0 0	100	79 0
45 „ R. C. Slabs	120 0 0	100	54 0
		Total ..	1,658 0
For the End Abutment of Gate Bridge—			
1,320 c. ft. Random rubble Floor	27 0 0	100	357 0
1,800 „ Masonry	40 0 0	100	720 0
3/20th ton R. S. Beams	140 0 0	Ton.	21 0
74 „ R. C. Beams	150 0 0	100	111 0
43 „ R. C. Slabs	120 0 0	100	51 0
		Total ..	1,260 0

MEASUREMENT.

Saving due to reducing width of Gate Bridge by 3 feet.

—	No.	Length.	Breadth.	Depth.	Quantity Decim.	Total.
1. Floor—Random rubble—						
Pier span ..	1	70	3	7	1,470	c. ft.
Abutment pier span.	1	85	3	7	1,785	,,
End abutment ..	1	52	3	7	1,092	,,
Land abutment ..	..	3	44	10	1,320	,,
2. Superstructure—						
Pier, R. L.. 238·5 .. 176·0 62·5	1	3	10	62·5	1,875	c. ft.
Abutment pier do.	1	3	25	62·5	4,687	,,
End abutment.	1	3	10	23·5	705	
	1	3	14·87	39	1,740	2,445 c. ft.
Land abutment	2	3	10	11·5	690	
	2	3	9	8·0	432	
	2	3	8	8·0	384	
	2	3	7	7·0	294	1,800 c. ft.
3. Steel Sheet Piling—						
End abutment	..	3	14	..	42	s. ft.



MEASUREMENT—*contd.*

—	No.	Length.	Breadth.	Depth.	Quantity Decim.	Total.
4. Pier and Abutment Pier—						
R. S. Beams.						
These will be 21	feet instead of	24 feet.				
Cost will decrease	by $\frac{1}{8}$th.					
	$\frac{1}{8}$	5·4	tons.		·675	tons.
5. *R. C. Beams*	$\frac{1}{8}$	3	78	..	47	c. ft.
6. *R. C. Slabs*	..	3	60	3″	45	c. ft.
End abutment of Road Bridge—						
4A. R. S. Beams	$\frac{1}{8}$	27	..	·3375	Tons.	
5A. R. C. Beams	$\frac{1}{8}$	424	...	53	c. ft.	
6A. R. C. Slabs	2	3	60	3″	45 c. ft.	
Land abutment for Gate bridge—				..		
4B. R. S. Beams	4	3	at 30 lbs.	..	360 lbs.	
5B. R. C. Slabs	..	3	30	3″	22·5	
	..	3	22	3″	16·5	
	..	3	5	3″	5	
					44 c. ft. 74	
5B. R. C. Beams	$\frac{1}{8}$	591	..	..		c. ft.

See Drawing No. 47.

Reinforced Concrete Counterweights for Barrage.

Actual weight of counterweight—

		c. ft.
	52′ 8″ × 8′ × 3′ .. .. .. =	1,264
Ends	2 × 4′ 8″ × 3′ × 4′ .. .. =	112
		1,375
Deduct pockets—		
	6′ × 6′ × 2′ 6″ × 12″ .. .. =	90
		1,286 c. ft. of reinforced concrete at 150 lb.
		Tons.
		=86
	Add for pulleys and wall boxes ..	2
	—	88

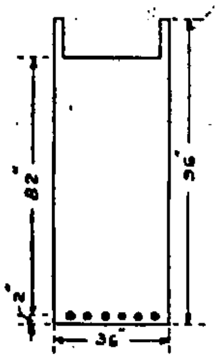
90 c. ft. of small concrete blocks will weigh 6 tons and by adding such blocks in the recesses provided, the weight of the counterweight can be adjusted between 88 to 94 tons, whereas the estimated weight required is 92 tons.

Calculations for reinforcement—

The distance between centres of pulleys is 57′, but the clear span is 60′, when the weight are resting in the grooves. They then have to support their weight on this span.

	Tons.
Maximum weight with all adjusting blocks .. .. =	94
Add for margin, say	6
	100

Maximum bending moment $= \frac{1}{8} \times Wl = \frac{1}{8} \times 100 \times 60 \times 12'' = 9{,}000$ inch tons.—
Section at centre.



Take maximum permissible stress in concrete = 600 lb./sq. in.

Do. do. in steel = 16,000 lb./sq. in.

and n = ratio of elasticity,
= 15.

Economical percentage, when both concrete and steel reach the full limit of pressure together.

$$= \frac{0 \cdot 5}{\frac{t_s}{fc}\left(\frac{t_s}{nfc}+1\right)}$$ Trautwine, page 1118.

$$= \frac{0 \cdot 5}{\frac{16{,}000}{600}\left(\frac{16{,}000}{15 \times 600}+1\right)}$$

$= \cdot 00675$

or $\cdot 675$ per cent.

Area of concrete $= 82'' \times 36''$

Area of steel at $\cdot 675$ per cent. $= 19 \cdot 926$ sq. in.

Try No. 12 steel bars $1\frac{1}{2}''$ diameter $= 12 \times 1 \cdot 767$
$= 21 \cdot 204$ sq. in.

$$p = \frac{21 \cdot 204}{82 \times 36} = \cdot 0072$$

$n = 15 \quad \therefore \quad pn = \cdot 108$

$$K = \sqrt{(p\,n)^2 + 2\,pn} - pn$$ (Trautwine, page 1116).

$$= \sqrt{(\cdot 108)^2 + \cdot 216} - \cdot 108$$

$= \cdot 369$

Moment of resistence of concrete—

$$M_e = b\,d^2 \times fc\ K \frac{(1-\frac{K}{3})}{2}$$

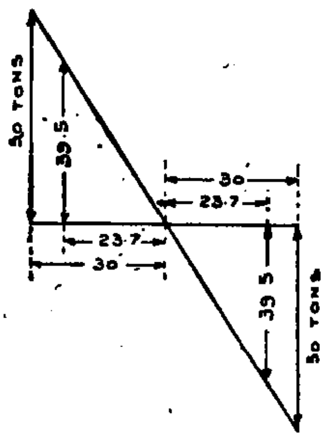
$$= 36 \times 82 \times 82 \times 600 \times \cdot 369 \frac{(1-\cdot 123)}{2}$$

=10,500 inch tons.

which is more than the required 9,000 inch tons.

Shear Stresses—

Resistence of concrete to shear at 30 lb. per sq. in. =82 × 36 × 30 lb.=39·6 tons.



The value of shearing stress varies uniformly from 50 tons at end to zero at centre of beam, so the stress will be 39·5 tons at a distance $30 \times \frac{39\cdot 5}{50}$ ft. from centre=23·7.

So for a distance of 23·7′ on either side of the centre the concrete can take all the shearing stresses : a few stirrups will however be provided to allow for shocks, etc.

(*a*) The first stirrup will be at 2′ from end of weight, *i.e.*, one foot inside edge of support. The average shearing stress on this will be—

$$\frac{50+46\frac{2}{3}}{2} = 48\frac{1}{3} \text{ tons.}$$

Out of this the concrete will take 46 × 36 × 30 lb.=22 tons.

The iron stirrups will take $48\frac{1}{3}$—22=$26\frac{1}{3}$, say 27 tons.

For this six stirrups of $\frac{3}{4}$″ diameter *rods* are provided which will give for both legs 2 × 6 × ·442 area × 12,000 lb.=28·5 tons.

(*b*) The shearing stress decreases as we go towards the centre. Two sets of stirrups of the same size as above will be put in at distances of 2′ and 4′ from the 1st stirrup. We shall thus have provided for 7′ from each end.

(*c*) In the central 46 feet, a similar set of stirrups five feet apart will be provided to insure better transmission of strains and to allow for shocks.

ABSTRACT.

Items.		Rate.	Per.	Amount.
		Rs. a. p.		Rs. a.
Cost of Reinforced concrete counterweights for Barrage.				
2·75 tons	Steel Rods reinforcement	180 0 0	Ton.	495 0
1·6 „	End boxes for bearings	480 0 0	„	768 8
⅓rd „	Bearing plates	180 0 0	„	60 0
1 „	Four pulleys, each 5 cwts.	360 0 0	„	360 0
2 Nos.	Shafts and collars	50 0 0	Each.	100 0
4 „	Plumer blocks	100 0 0	„	400 0
1,464 c. ft.	Cement Concrete	45 0 0	100 c. ft.	659 0
Lump	Forms	....	..	100 0
	Rs. Lauuching and erection in place 75 men one day at Rs. 2 .. = 150 Tug and launches .. .. = 50 = 200	....	..	200 0
Lump	Friction rollers	....	..	100 0
	Cost of R. C. concrete counterweight ..	....	..	3,242 0
			Say ..	3,250 0
	Cost of steel counterbalance casing	....	..	9,250 0

Note.—Contingencies are omitted in both cases.

MEASUREMENT.

Barrage Counterweight of Reinforced Concrete.

—	No.	Length.	Breadth.	Depth.	Quantity Decimal.	Total.
1. *Steel rods,* 1½ diameter—			Length.			
(*a*) bottom..	6	64	384			
(*b*) turned up 6′ 6″ ..	4	68	272			
(*c*) ,, 13′ ..	2	61	122			
		R. ft.	778 at	6 lbs.	4,668	
Stirrups, ¾″ diameter ..	6×6	18	648			
near ends	2×6	12	144			
		R. ft.	792	at 1·5 lb.	1,188	
					5,856	lbs.
				= Say	2·75 tons for binding	including wire rods.
2. *Boxes for bearings*—						
				Area.		
Steel plate ⅜″	2	·4″	3′	24		
	3	3″	1½′	13½		
	4	3″	1¼′	15		
For roller box ..	1	3′	1′9″	5		
			s. ft.	58		
			at 15·	30 lbs.	890	lbs.
Angles—			c. ft.			
Verticals	8	3	24			
Horizontals	11	3	33			
For roller boxes.. ..	3	3	9			
	8	15″	10			
		r. ft.	76	at 7·18	lbs. 550	lbs.

MEASUREMENT—*contd.*

Barrage Counterweight of Reinforced Concrete.

—	No.	Length.	Breadth.	Depth.	Quantity.	Total.
Channels—						
15″×4″	2	3	6 r. ft.	at 42 lbs.	252	lbs.
Bolts—						
1″ rods for bolts ..	2	10	20			
Lewis bolts	8	1½	12			
		r. ft.	32	at 2·71bs.	86	lbs.
					1,778	lbs.
		Add	for oth	er end.	1,778	
					3,556	lbs.
				=	1·59 tons	=say 1·6 tons.
3. *Bearing plates*, ½″ ..	2	5	3	at 20·40	lbs.	
			=	612 lbs.		
			=	·27 tons		
			=	say ⅓	*ton.*	
4. *Pulleys*	..	..		say 1	*ton.*	
5. *Shafts and collars* .	..	..	..	*Two*		
6. *Plumer blocks*	..	..	..	*Four.*		
7. *Cement concrete overall*	6	61	8	3	1,464 c. ft.	
8. *Forms*	..	..	..	*Lump.*		
9. *Launching and erection* ..	..	..	..	Rs. 200		
10. *Friction Rollers* .. .	.	..	..	Rs. 200		

APPENDIX P.

Cost of Road Bridge—Debitable to Provincial Funds.

1. As the Road bridge is entirely unnecessary for the working or stability of the Barrage, or for communication along the latter (this being provided by the high level Gate bridge), but provided solely for ordinary traffic, the cost of the Road bridge might fairly be debited to Provincial Funds.

2. It is proposed to debit to this head the cost of the Road bridge arches, and superstructure complete, and a 25' length of the piers on which they stand down to pavement level. This 25' length is not needed for Barrage stability. It is not proposed to charge to the Road bridge any portion of the cost of the Barrage floor, which forms the foundation and protection for the piers, as this is needed for the Barrage stability.

3. It is, however, proposed to charge to the Road bridge a share of the whole cost of establishment, tools and plant, buildings, etc., in the same proportion as the cost of the permanent work on the Road bridge bears to the cost of the whole permanent works.

4. It is not proposed to charge to Provincial funds any share of the cost of the Road bridges across the Regulators, which connect with the Barrage Road bridge as the former may perhaps be considered a necessary provision in any case for communication along the river bank, which would otherwise be interrupted by the canals.

5. The attached estimates give details of the cost proposed to be debited to Provincial funds.

ABSTRACT.

Abstract of cost of Road Bridge only.

Items.	For details see page.	Rate.	Per	Amount.
		Rs. a. p.		Rs.
Permanent works—				
2 end abutments and half span ..	279	10,942 0 0	Each.	21,884
7 abutment piers and 2 half spans ..	277	20,168 0 0	„	1,41,176
58 ordinary piers and 2 half spans ..	275	14,079 0 0	„	8,16,582
				9,79,642
Add contingencies at 5 per cent. ..		....	..	48,982
Permanent works only		...	..	10,28,624

ABSTRACT—*contd.*

Items.	Rate.	Per	Amount.
Rs.			Rs.
Total cost of Project—Direct charges .. 3,35,15,282 *Deduct* cost of permanent work .. 1,71,96,283 (Actual expenditure on service works, plant, establishment for the whole project with permanent works of value Rs. 1,71,96,283). 1,63,18,999 The cost of permanent works in the Road bridge is Rs. 10,28,624 and so the proportionate charges on this head for *service works, plant, establishment, etc.,* will be $= \text{Rs. } 1{,}63{,}18{,}999 \times \frac{10{,}28{,}624}{1{,}71{,}96{,}283} =$	....	..	9,07,702
Total cost of Road bridge only	....	..	19,36,326

ABSTRACT.

Road Bridge only.

Items.	Rate. Rs. a. p.	Per	Amount. Rs.
Cost of one pier and 2 half spans of arches—			
6,250 c. ft. 1. Pier masonry	40 0 0	100 c. ft.	2,500
5,555 „ 2. Arch masonry with centering ..	144 8 0	„	8,020
5,925 „ 3. Spandrils	40 0 0	„	2,370
657 „ 4. Parapets	90 0 0	„	591
146 „ 5. String courses	90 0 0	„	131
109 „ 6. Parapet capping	90 0 0	„	98
280 „ 7. Concrete	17 8 0	„	49
70 „ 8. Kerbstones	150 0 0	„	105
105 „ 9. Paving	70 0 0	„	73
747 „ 10. Road metal	4 0 0	„	30
1,120 s. ft. 11. Consolidation	10 0 0	100 s. ft.	112
		Total ..	14,079
Total cost for one pier and 2 half spans ..	....	..	14,079

MEASUREMENT.

Road Bridge only.

—	No.	Length.	Breadth.	Depth.	Quantity. Decim.	Total.
Ordinary Pier and 2 half spans of arches.						
1. Pier masonry—up to springing of Road bridge .	..	25	10	25	6,250	6,250 c. ft.
2. Arch masonry—Road bridge—details in Barrage.	1	25′ 3″	Area. 220	..	5,555	5,555 ,,
3. Spandrils	1	25	237	..	5,925	5,925 ,,
4. Parapets	2	73	1	4·5	657	657 ,,
5. String courses	2	73	Area. 1	..	146	146 ,,
6. Parapet capping ..	2	73	1·5	0·5	109	109 ,,
7. Concrete below foot-path	2	70	3	8″	280	280 ,,
8. Kerbstones	2	70	6″	12″	70	70 ,,
9. Paving	2	70	3′	3″	105	105 ,,
10. Road metal	1	70	16	8″	747	747 ,,
11. Consolidation	1	70	16	..	1,120	1,120 s. ft.

ABSTRACT.

Road Bridge only.

Items.				Rate.	Per	Amount.
				Rs. a. p.		Rs.
Cost of one abutment pier and 2 half spans of arches—						
15,625	c. ft.	1.	Pier masonry	40 0 0	100 c. ft.	6,250
5,555	,,	2.	Arch masonry including centering	144 8 0	,,	8,020
10,900	,,	3.	Spandrils	40 0 0	,,	4,360
873	,,	4.	Parapets	90 0 0	,,	785
194	,,	5.	String courses	90 0 0	,,	174
145·5	,,	6.	Parapet capping	90 0 0	,,	131
340	,,	7.	Concrete	17 8 0	,,	60
85	,,	8.	Kerbstones	150 0 0	,,	127
128	,,	9.	Paving	70 0 0	,,	89
907	,,	10.	Road metal	4 0 0	,,	36
1,360	s. ft.	11.	Consolidation	10 0 0	100 s. ft.	136
					Total ..	20,168
			Total cost for one abutment pier and 2 half spans ..			Rs. 20,168

MEASUREMENT.

Road Bridge only.

—	No.	Length.	Breadth.	Depth.	Quantity. Decimal.	Total.
One Abutment Pier and 2 half spans of arches—						
1. Pier masonry	..	25	25	25	15,625	15,625 c. ft.
2. Arch masonry	..	25′ 3″	Area. 220	..	5,555	5,555 ,,
3. Spandrils	..	25	436	..	10,900	10,900 ,,
4. Parapets	2	97	1	4·5	873	873 ,,
5. String courses	2	97	Area. 1	..	194	194 ,,
6. Parapet capping ..	2	97	1·5	0·5	145·5	145·5 ,,
7. Concrete below foot-path	2	85	3	0·66	340	340 ,,
8. Kerbstones	2	85	6″	12″	85	85 ,,
9. Paving	2	85	3	3″	128	128 ,,
10. Road metal	1	85	16	8″	907	907 ,,
11. Consolidation	1	85	16	..	1,360	1,360 s. ft.

ABSTRACT.

Road Bridge only.

Items.				Rate.			Per	Amount.
				Rs.	a.	p.		Rs.
Cost of End Abutment and half span—								
10,391	c. ft.	1.	Abutment masonry	40	0	0	100 c. ft.	4,156
2,778	,,	2.	Arch masonry including centering.	144	8	0	,,	4,010
5,225	,,	3.	Spandrils	40	0	0	,,	2,090
374	,,	4.	Parapet	90	0	0	,,	337
83	,,	5.	String courses	90	0	0	,,	74
62	,,	6.	Parapet capping	90	0	0	,,	64
160	,,	7.	Concrete	17	8	0	,,	28
40	,,	8.	Kerbstones	150	0	0	,,	60
60	,,	9.	Paving	70	0	0	,,	42
427	,,	10.	Road metal	4	0	0	,,	17
640	s. ft.	11.	Consolidation	10	0	0	100 s. ft.	64
						Total	.. ..	10,942
Total cost for end abutment and half span				..	..		.. ..	10,942

MEASUREMENT.

Road Bridge only.

—	No.	Length.	Breadth.	Depth.	Quantity. Decimal.	Total.
End Abutment and half span—						
1. Abutment masonry ..	1	25	Mean. 16·62	25	10,391	10,391 c. ft.
2. Arch masonry	1	25′ 3″	Area. 110	..	2,778	2,778 ,,
3. Spandrils	1	25	209	..	5,225	5,225 ,,
4. Parapets	2	41·5	1	4·5	374	374 ,,
5. String courses	2	41·5	Area. 1	..	83	83 ,,
6. Parapet capping ..	2	41·5	1·5	0·5	62	62 ,,
7. Concrete	2	40	3	8″	160	160 ,,
8. Kerbstones	2	40	6″	12″	40	40 ,,
9. Paving	2	40	3	3″	60	60 ,,
10. Road metal	1	40	16	8″	430	430 ,,
11. Consolidation	1	40	16	..	640	640 s. ft.

The Times Press, Bombay 411·20.