Sukkar Barrage Canals Project 1919-20, General Report on Combined for Sukkur Barrage and Right and Left Bank Canal Systems

Vol. V

(1921)

A. A. Musto

SUKKUR BARRAGE CANALS PROJECT
1919-20

Volume V

GENERAL REPORT

ON

COMBINED PROJECT FOR SUKKUR BARRAGE

AND

RIGHT AND LEFT BANK CANAL SYSTEMS

BY

A. A. MUSTO, Esquire

Executive Engineer, Sukkur Barrage Project District

BOMBAY

PRINTED AT THE GOVERNMENT CENTRAL PRESS

1922

[For official use only.]

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ERRATA.

Page.	Paragraph.	Column.	Line.	*For*	*Read*
1	2	3	4	5	6
i	5 ..	..	3	however, easygoing ..	however easygoing
ii	.... ..	..	39	No. of ..	No. 1390 of
„	.... ..	..	48	Dated July ..	Dated 13th July
iii	3 ..	..	3	18,35,91,537 ..	18,35,91,337
„	5 ..	..	6	commencement ..	commencement,
„	10 ..	..	4	13·7 ..	13·8
vi	38 ..	..	7	J. D. Hacem ..	J. D. Haeem
vii	40 ..	..	6	Cainal ..	Canal
5	12 ..	..	2	have ..	has
8	Statement II ..	4	4	2,656 ..	2,056
„	Statement III ..	6	9	44,158 ..	54,158
10	Statement VII ..	3	6	96,760 ..	96,750
14	27 ..	..	2	Eviorude ..	Evinrude
16	.... ..	2	24	Bed with ..	Bed width
„	.... ..	3	24	29-31 ..	29-32
„	37 ..	..	5	Vol. V ..	Vol. VI
17	38 ..	..	8	Vol. V ..	Vol. VI
„	40 ..	..	10	Rates ..	Ratio
„	41 ..	..	4	93 ..	95
„	41 ..	..	5	5 ..	50
18	49 ..	..	2	12½ ..	12½
19	54 ..	..	3	considerable ..	considerably
20	56 (8) ..	..	5	by 1 to 7 ..	by rules 1 to 7
28	93 ..	..	3	an acqueducts ..	and aqueducts
32	Statement ..	9	Heading ..	Critical velocity ..	Ratio to critical velocity
34	105 (e) ..	..	2	previous ..	pervious
„	105 (g) ..	..	5	bearing the ..	bearing for the
„	105 (h) ..	..	3	½ to 1 ..	½ to 1
35	107 ..	..	7	flooring ..	following
36	110 ..	..	3	prepared ..	plotted
37	117 ..	..	2	tend to ..	tends to
„	„ ..	..	10	give ..	gives
„	„ ..	..	11	of level ..	of level,
40	135 (i) ..	..	3	3 inches ..	3 feet
„	.... ..	..	4	The load ..	The loads
41	142 (c) ..	..	6	case ..	ease
„	142 (j) ..	..	2	filled ..	filed
„	Section VI ..	..	Heading ..	Acqueducts ..	Aqueducts
42	146 ..	..	3	particulars— ..	particulars of
44	.... ..	..	6	16,000 ..	1,600
„	.... ..	..	16 equations ..	$Y = \frac{T}{M} = \frac{\frac{2d}{S} + t}{M} = \frac{1}{N}$ ..	$Y = \frac{T}{M} = \frac{\frac{2d}{S} + t}{M} = \frac{1}{N}$
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„	Statement ..	8	last line ..	2 0 ..	12 0
46	.... ..	..	2	feet ..	feet,
„	.... ..	..	19	30 puls ..	30 plus
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49	170 ..	..	2	mile-cusec ..	mile-cusecs
50	178 ..	..	2	this ..	the
„	181 ..	..	1	project the tail ..	project—the tail
51	187 ..	..	4	$\frac{2 \cdot 86}{2 \cdot 35} - 2 \cdot 15$	$\frac{2 \cdot 86}{2 \cdot 35} \times 2 \cdot 15$
52	198 ..	..	5	separated from ..	separated for
„	.... ..	..	6	must be ..	must bear
53	202 ..	..	5	It does not, ..	It does,
„	205 ..	..	1	calculation ..	cultivation
„	207 ..	..	1	Statement C ..	Statement G
54	.... ..	..	30	365 Crude oil 700 lbs. (70 gallons) days	Crude oil 700 lbs. (70 gallons) for 365 days
„	.... ..	..	31	Oil Waste ..	Oil, Waste
56	212 ..	..	2	if were ..	it were
„	213 ..	..	3	ten years ..	ten-year
57	Section III ..	..	Heading ..	Rice (Canals Right ..	Rice Canals (Right
„	223 ..	..	5	enjoy ..	enjoys
59	243 ..	..	3	require than ..	require less than
60	256 ..	..	5	Khairpur Canal ..	Khairpur Canals
77	Foot note ..	..	....	* Please read this as 55,58,078. † Please read this as 66,25,445.	* Please read this as 66,25,445. † Please read this as 55,58,078
78	Statement ..	1	9	Eigh h ..	Eighth

No. Rev.—1873 of 1920.

REVENUE DEPARTMENT.

Office of the Commissioner in Sind,
Government House, Karachi, dated 14th July 1920.

MEMORANDUM.

The Commissioner in Sind has the honour to submit for the consideration of Government the report of Mr. A. A. Musto, Executive Engineer, Sukkur Barrage Project District, on the systems of canals to be supplied by the Sukkur Barrage. The technical points involved have received the consideration of a number of expert authorities, and will doubtless be further considered by Government. The Commissioner need only say that he considers that there is no reason to believe that the estimates from the Revenue point of view are otherwise than correct.

2. There is a small misapprehension in paragraph 238 of the report. Mr. Musto says that when Government waste land is given out on cultivation, it is granted either for 5 years on payment of *malkano* or for 10 years on similar payment or in perpetuity also on payment. Land in Sind, however, is ordinarily given out in perpetuity on the payment of occupancy fee, subject to the payment of the annual land revenue. Where, for any reason, it is not desirable to give it out permanently, it is allowed to be cultivated on one-yearly or *eksali* leases on payment of the assessment only, without any payment of *malkano*. The leases for 5 or 10 years referred to by Mr. Musto have only been given as a temporary measure in the area to be commanded by the proposed canals in view of the undesirability of giving them out permanently; but no *malkano* or occupancy fee has been taken in the case of such 5 or 10 yearly leases. The point, however, is not of importance, as it does not affect the distribution of land when the canals are made. Such distribution will be ordinarily made on permanent tenure; though it may be necessary, in special cases, to give land out on lease only.

3. A reason previously advanced against the urgency of carrying out the works proposed in the scheme was that the present system of inundation canals was good enough for the circumstances of the country. Even if this had been true, the uncertainty of water-supply undoubtedly led to bad cultivation, and this fact increased the natural tendency of the Sindhi cultivator towards carelessness and lack of foresight. But the argument that the present system is good enough can no longer be seriously advanced. The disastrously bad inundation of 1918 led to Sind being for the first time a deficit instead of a surplus Province as regards the production of grain. It had to be supplied from other provinces at a time of general deficiency and general difficulty of transport.

4. There can be no doubt that improved and certain water-supply will lead to improved cultivation. Great efforts will have to be made to stimulate that improvement by teaching and example, and possibly by the introduction, largely for instructional purposes, of colonists from elsewhere. The figures given in the report, however, prove that the scheme will on safe estimates be financially productive. The other arguments in its favour are so strong that the Commissioner hopes that there will be no difficulty in the acceptance of the project.

5. Apart from the material benefit to Government, and still more to the people of the Province, there can be no doubt that the project will have a beneficial and steadying political effect. The agricultural classes of Sind, however, easy-going and careless, were always loyal and well-affected. The great mass of them still remain so, but the leaven of agitation has been introduced among them, and no efforts are being spared to make them discontented with the measures of Government. It is open for agitators at present to point out that comparatively little has been done in Sind of recent years in the way of great works by Government. The engineering projects carried to completion and success in the neighbouring provinces of the Punjab and North-West Frontier are well known to many Sindhis. The more educated have heard of the canal works that have been or are about to be executed in the United Provinces and in Madras. They can read of the schemes sanctioned for the water-ways of Bengal. The great protective irrigation works

in the process of execution in the Deccan are well known. The undertaking of a great scheme such as that now proposed in Sind would undoubtedly have an excellent effect.

6. The province of Sind will also benefit by the great accession of trade which will accrue to the port of Karachi from the execution of these works. The port of Karachi is capable of almost indefinite expansion ; but it is seriously crippled at present by the restriction on the export of grain. Even when these restrictions are removed, it is believed by some that the internal consumption of wheat in India will be so much greater than it was previously that the export trade will not reach its former dimensions. The figures given in Mr. Musto's report show clearly the additional amount of wheat and other products which will be available for export if the combined scheme is carried out. The benefit to Karachi will undoubtedly re-act upon the whole province.

7. The political effect in Baluchistan will also doubtless be of importance ; since it will be possible to irrigate a large area of land within that province, and thus further to attach the Baluch Sardars to the Government of India.

8. The Commissioner would venture to draw attention to the striking unanimity in favour of the project to be found among all the Engineering and Revenue officers who have been associated with, or have had the opportunity of examining the project. Formerly, there were many differences of opinion as to the degree of urgency of the work and the manner in which it should be carried out. Such differences of opinion are no longer found, at least among officers serving in Sind. The authorities of the Khairpur State are most anxious for the project, and are willing to co-operate in it so far as they may be called upon to do so.

9. For these reasons, the Commissioner would venture strongly to recommend the early decision of Government upon the report now submitted.

10. Mr. Musto has brought to the notice of Government the excellent work done by his Assistants and his staff. The Commissioner would desire to emphasize the excellence of Mr. Musto's own work. He has displayed the most untiring industry ; and in spite of severe and repeated attacks of fever, due doubtless to his long period of service without leave, has brought to a conclusion, in a remarkably short space of time, a report involving very great labour and an enormous amount of elaborate calculation.

(Signed) P. R. CADELL,
Commissioner in Sind.

To

The Secretary to Government,
Public Works Department, Bombay.

No. of 1920.

From.

A. A. MUSTO, Esq.,
Executive Engineer,
Sukkur Barrage Project District ;

To.

The SECRETARY to GOVERNMENT,
Public Works Department, Bombay.

Sukkur Barrage Project Office,
Karachi, dated July 1920.

Sir

I have the honour to forward herewith my plans, estimates and reports on the proposed great systems of canals to be supplied by the Sukkur Barrage, for which latter work I submitted plans, estimates and reports under my forwarding letter No. 1430 dated 18th October 1919 to the Chief Engineer in Sind.

2. Attached to this letter is a Summary Statement No. 1 showing at a glance the general position of the Combined Project for Barrage and all canals, and of each Canal Project separately.

3. It will be seen that the total combined cost of all works, including direct and indirect charges, and accumulated arrears of interest up to the 14th year from commencement, or three years after completion of all works, is Rs. 18,35,91,537. Yet in this year, the anticipated nett receipts will pay 5·1 per cent. on this huge sum, thus making the works "Productive" (as defined in paragraph 393 of the Public Works Department Code) in the third year after completion of works.

4. Ten years after completion of all works the Combined Projects will give a return of 8·2 per cent. on Capital invested (including all accumulated arrears of interest up to that year).

Twenty years after completion the return will be 11·8 per cent. on Capital invested (all arrears of accumulated interest wiped out before this year) and thirty years after completion and thereafter the return will be 13·8 per cent. on Capital invested.

5. All accumulated arrears of interest on Capital will be wiped out by the 21st year after commencement of works and if net revenue (after paying 5 per cent. interest on Capital at date) is applied to reduction of Capital, all Capital and arrears of interest can be wiped off by the 34th year from commencement of works, after which all net revenue will be pure gain to Government, and increases from Rs. 2,03,16,104 in the 35th year from commencement to the final anticipated maximum of Rs. 2,21,46,430 in the 41st year after commencement.

6. I have endeavoured to design all works on the most scientific and up-to-date principles and practice, and have nowhere attempted to obtain economy at the expense of efficiency and good design. At the same time great detail and care has been used to obtain the most economical designs consistent with such principles, and it is hoped the results will be found by Government to be satisfactory.

7. The rates at which I have estimated all classes of work are believed to be liberal ones, though with the material and labour market in a state of flux, this is necessarily a somewhat indeterminate question. Generally speaking, the rates allowed are considerably higher than those at present ruling in Sind, where conditions just now are very abnormal due to past famine and pestilence and to the inflation of rates for imported articles.

Whether or not these conditions will improve, is beyond my province or ability to foresee.

8. A very important point to notice about the Financial Forecast however is that at the time the works become productive, *i.e.*, in the 14th year, the cultivation has only increased to 50 per cent. of the culturable area, as against the estimated final cultivation of 81 per cent. of culturable, so that a very large margin is left in case the cost of works should be greater than estimated. These figures are for mixed Rice and other crops. On the Ghar Canal, with a fair inundation supply, the present cultivation already exceeds 75 per cent. of the culturable area commanded, while on many of the other inundation canals supplying mixed cultivation, but mostly other kharif and rabi, the present cultivation varies between 30 per cent. and 40 per cent. of the culturable area.

9. As stated in paragraphs 6 and 7 above, it is believed that the estimates make a very liberal provision for the cost of all works, and if this is granted then the final returns on the Combined Project must be considered most favourable.

10. They show that these great works, which will bring incalculable benefits to the cultivators, and great indirect benefits to the State through Railways and Ports, and to importing and exporting businesses, finally will give Government a direct return of 13·7 per cent. on an outlay of nearly £16,000,000—(Capital exclusive of interest charges paid off)—a proposition which would be considered most handsome by any commercial enterprise.

11. Statement No. 2 attached shows an estimate of the final effect of the anticipated cultivation, as affecting exports, etc. These calculations are only

approximate but give an indication of the enormous increase which may be expected in export of commodities, such as cotton and wheat, which are in world-wide demand. It is believed that the figures shown for exports would necessitate doubling the present capacity of the port of Karachi and possibly increasing the capacity of the North-Western Railway, while numerous feeder railways would find a lucrative field of enterprise in carrying the produce to the main railway. These figures give some idea of the great indirect benefits which would result from the construction of the Barrage and Canals, and for which no credit is taken in the project.

12. The gain to the cultivators, both in extension of crops, even now highly profitable, and an insurance against losses due to low river seasons, floods, etc., is almost incalculable.

13. The preparation of these great canal projects was entrusted to me in January 1919, but the greater part of my time and that of my then very small staff was employed until October 1919 in completing the project for the Barrage itself. Since that date all energies have been devoted to the canal projects, which have thus occupied my and my staff's exclusive time for about 8 months only, as compared with 3 years taken for the preparation of the original projects.

14. The total cost of this District for preparing these fresh canal projects, including all staff and works, has been only Rs. 75,000 or 0·005 per cent. of the estimated cost of the works, which I trust will be considered satisfactorily low. The estimated cost of printing all reports, estimates and plans (including Barrage) is about Rs. 20,000.

15. Messrs. Baker and Lane's Soil Survey cost Rs. 1,37,400 and took about two years.

16. The whole work has been carried out as a rush job, and while every effort has been made to avoid mistakes and check all results and calculations, I must ask for lenient consideration for myself and staff, should mistakes be found.

17. The completion of the work, in the time desired by Government, has necessitated the most careful and thorough organization of the energies of all staff, the working of very long hours at high pressure, and last but not least, the loyal and enthusiastic co-operation of all officers, subordinates and staff employed. I am happy to say that I have been able to thoroughly depend on all my staff to support me in all these respects, and I trust the results show that general organization was satisfactory.

18. For many months my appeals for a reasonable amount of staff met with little or no response, and it was not until the past few months that Government gave me establishment really at all commensurate with the work to be done. But during the last few months every help possible has been given me, both by Government and by the Chief Engineer in Sind.

Appreciation of services of staff.

19. In the preparation of these projects, during this time, I have been fortunate in having the assistance of a very capable, energetic and loyal staff of officers and subordinates. Where all have done such excellent work it would be invidious to draw distinctions, but I must place on record a brief appreciation of the work of each, and my gratitude for their loyal co-operation without which I could not have completed the projects in this short time.

20. The first officer to be attached to my district was Mr. T. S. Mirchandani, who, as Assistant Engineer, came to me in January 1918 and remained in the district for 3 months, when he was transferred as acting Executive Engineer, Nasrat Canals District. During this period he gave me much useful assistance in my preliminary investigations for the general lay-out of the Right Bank Canal System, and also prepared discharge curves for designing the canals, as Kennedy's and Garrett's printed curves do not deal with such flat slopes and large discharges as we required.

Later in February 1920 Mr. Mirchandani, then a permanent Executive Engineer, was retransferred to my District, and has been with me continuously since. During this period, under my instructions, he has prepared the detailed projects

for all the Right Bank Canals. His keenness and energy has been unremitting, while his skill as an engineer has enabled him to make many useful suggestions, and to design the canals in accordance with my rules, in a most scientific and thorough manner. He has also elaborated in the rough the proposals for the Nasirabad Inundation Canal, and for the utilization of surplus Begari inundation water, if the suggested Begari Branch from the Barrage is made.

He also prepared all the various financial forecasts for the several alternative combinations of canals which are submitted herewith.

I have always found him keen to undertake most loyally the very heavy work I have placed in his charge, and his assistance has been invaluable to me.

21. The next officer to be transferred to me, was Mr. G. N. Gokhale, Executive Engineer, who joined the District in July 1919. Until October 1919 he was engaged in assisting me with the Barrage Project and I have already acknowledged his valuable services on that work.

Since October 1919 he has been in charge of the preparation of the detailed project for the Rohri Canal, which he has carried out to my instructions in the most thorough manner. His mathematical and analytical investigations of type sections for banks and canals, of the effect of groynes in canals and of the cost curves of branches, etc., and of many other matters, as well as his many suggestions for minor arrangements of plans and estimates has been of very great value and assistance. The thorough manner in which he has made himself acquainted with all the previous canal projects, and with all the details of the present projects, during this continuous period of service in the District, has made his assistance almost indispensable, and has saved me much time in looking up references. His invariably cheerful and loyal co-operation, in whatever work I have had occasion to give him, has been a source of constant pleasure and encouragement to me, and the projects now submitted owe much to his ability and energy. Besides the detailed project of the Rohri Canal, he has worked out, with me, the outline proposals for the Eastern Nara Canals Project.

22. Mr. F. L. Gordon, Executive Engineer, joined my District on his return from leave, in March 1920. Considering the fact that he came on the projects at a time when many of the more interesting parts were settled, and that he is only one year junior to me and of the same rank, I cannot too warmly express my appreciation of the loyalty and keenness with which he has co-operated with me on this work. I placed Mr. Gordon, from the first, in charge of the preparation of all type and special designs for the masonry works of all canal systems. He has applied his full energy, for long working hours every day, to preparing these designs and estimates. In the few cases where we have not seen eye to eye, he has loyally accepted and developed my decisions, and our work together has been carried out in the pleasantest spirit, and I think that each of us and the project has benefited greatly by our mutual criticisms and discussions. I am under deep obligation to him for his thorough and capable work.

23. Mr. W. E. Bushby, Assistant Engineer, joined the District in February 1920, on his return from Military Duty, in Mesopotamia. His steady and conscientious work has been of much assistance. He has worked out the details for both the Khairpur State Feeders under my instructions, and has also assisted Mr. Gordon with the designs of masonry works, Mr. Gokhale with the Rohri Canal branches, and Mr. Mirchandani with the Nasirabad and Begari schemes. His pleasant cheerful manner has lightened the burden of work for all of us.

24. Mr. J. L. Grant, Assistant Engineer, joined the District on 22nd March 1920 on his return from Military Duty in Mesopotamia. He came very late on the work, but took considerable interest in it, and assisted Mr. Mirchandani in the preparation of the Right Bank Canal Projects, until relieved on the 29th May 1920, to proceed as acting Executive Engineer, Begari Canals.

25. Mr. N. M. Mirchandani, Temporary Assistant Engineer, has been attached to the District since July 1919. Besides his work on the Barrage Project, already acknowledged, he has since October 1919 given very able and useful assistance to Mr. Gokhale on the various works in the latter's charge. I regret that Government has not been able to offer him a continuance of his appointment on terms which he could accept, as I feel that Government is losing a very capable and keen young officer.

26. Among the subordinates attached to the District, I would specially commend to the notice of Government the excellent work done by Mr. Khushaldas Samtani, Supervisor, who carried out in the most thorough and accurate manner very arduous survey and levelling operations for the new heads of the canals, and for the investigations in connection with the Munchar Drainage Project. The latter work was particularly severe, being carried out in hot weather in a most unhealthy and trying climate. He completed this important work in a most excellent manner, but at the expense of his health, which broke down after completion through over-strain, and the Civil Surgeon, Karachi, certified that at least three months' sick leave was necessary for his recovery. He is accordingly now on leave.

27. He was assisted in this work by Messrs. Rochiram, Supervisor, and Atmaram, temporary Overseer, both of whom did very good work under these trying conditions.

28. Rao Sahib Murijmal Malkani, Supervisor, joined the District in February 1920 and has done most excellent work on the preparation of detailed projects. His knowledge of the Canal Districts, long experience, sound judgment, engineering ability and attention to duty are far above the average, and have made his services invaluable.

29. Rao Sahib K. C. Advani, Supervisor, joined in February 1920, and has done very good work. He is steady, reliable and capable.

30. Mr. Tekchand, Supervisor, who joined in March 1920, has also done good work and is a capable hard working engineer. He assisted Mr. Mirchandani in preparing the Right Bank Canal Projects.

31. Rao Sahib Mujumdar, Supervisor, joined in April 1920 and is capable and very hard working. He assisted Mr. Gordon on the design of masonry works.

32. Mr. Moujiram Sharma, temporary Sub-Engineer, joined in November 1919 and has done very good work. He is extremely hard working and painstaking. He assisted Mr. Gokhale on the Rohri Canal Project.

33. Mr. K. T. Hirani, Overseer, joined in March 1920. He is hard working, painstaking and capable, and did very good work under Mr. Gordon on the designs of masonry works.

34. Mr. Kambarali, Supervisor, joined in February 1920, and Mr. Utamchand Overseer, in November 1919. Neither is particularly hard working, and their work can only be classified as fair.

35. Messrs. V. A. Joglekar and G. K. Joshi, Sub-overseers, joined in March 1920. Both are capable hard working subordinates and have done good work.

36. Mr. Hemandas K. Kewalramani, Overseer, joined in April 1920 and has done good work.

37. Mr. D. B. Prabhu, temporary Overseer, joined in May 1920. He is fairly capable and is hard working.

38. The following Surveyors from the Indus River Commission were kindly lent by the Chief Engineer in Sind for about two months, and have been employed on tracings, and checking estimates, etc. They have done useful work and are placed in order of merit.

Mr. B. Solomon	..	..	Surveyor.
„ Naraindas B.	..	..	„
„ J. D. Hacem	..	..	„
„ Vassumal A.	..	..	„
„ Dayalji	..	..	„
„ Mahomed Sharif	..	..	„
„ Utamchand	..	..	„
„ Qurbanali S.	..	..	„ (Overseer).

39. The following temporary drawing office establishment, belonging to this District, have all done good work from the date of engagement shown against each. They are placed in order of merit :—

1.	Mr. Motilal	..	.. Assistant Draftsman	.. June 1919.
2.	„ Tarachand	..	.. Tracer	.. January 1919.
3.	„ Bankal	..	.. „	.. February 1920.
4.	„ Bhagwan Parsad	..	.. „	.. May 1920.
5.	„ Chiman Phooke	..	.. „	.. April 1920.

Nos. 1 and 3 have already obtained other appointments, and will leave as soon as they can be spared. Nos. 2 and 4 are well worth retaining in a Public Works Department office. No. 5 is a fair tracer and neat printer.

40. The following 19 Draftsmen and Tracers were transferred temporarily to this District to assist in completing the plans and were here for an average period of six weeks. Most of them worked very satisfactorily and are placed in order of merit.

Specially commended.	Mr. Mahomed Hussain	Head Draftsman.	Indus Left Bank Division.
	„ Mangatram	Asstt. Draftsman.	Northern Jamrao Cainal.
	„ Gulam Hyder	Tracer	Begari Canal District.
	„ Hemandas	„	Eastern Nara District.
Commended.	„ Chandiram	„	Western Nara Canal District.
	„ Hukumatrai	„	Fuleli Canals District.
	„ Udharam	Asstt. Draftsman.	Nasrat Canals District.
	„ Deori	Tracer	Pravara Canals District.
	„ Joshi	„	Lonand District.
	„ Sarolkar	„	Sholapur District.
Work satisfactory.	„ Karim Bux	„	Karachi Canals District.
	„ Gobindram	„	Ghar Canals District.
	„ Shree Parsad	„	Ahmedabad District.
	„ Shukla	„	Nasik Irrigation District.
Work fair.	„ Kale	„	Poona Buildings District.
	„ Doctor	„	Do. do.
	„ Kewalram	„	Shikarpur Canals District.
Work very poor.	„ Pandit	„	Dharwar Buildings District.
	„ Partab Singh	„	Southern Jamrao Canal.

41. The estimates, statements, financial forecasts and reports have been typed partly by the typist of this District, and partly by typists lent by other offices for short periods.

Among these I would specially commend the following who have worked very hard, fast and accurately:—

Mr. Lekhraj Mulchand	Typist of	Chief Engineer in Sind.
„ Gurmukhdas	„	Executive Engineer, Nasrat Canals District.
„ Deumal	„	Executive Engineer, Ghar Canals District.
„ Parsram	„	Executive Engineer, Sukkur Barrage District.

42. The following also did good work:—

Mr. Jethmal B.	Typist of	Executive Engineer, Karachi Buildings District.
„ Lekhraj Chotanram	„	Executive Engineer, Karachi Canals District.

43. The whole staff of the District has worked together without friction and with real keenness and only thus has it been possible to complete these great projects in such a short space of time.

44. This list of staff looks formidable, but most of them were attached for short periods only, and I consider their work has been most efficient. Not a man has been idle for an hour, during the period the projects have been in hand. The plans and estimates for an £18,000,000 project cannot be prepared without a large staff.

45. I might mention that the 1909 projects, which were smaller and less comprehensive employed a Superintending Engineer, two Executive Engineers, four Assistant Engineers and twenty-two Upper Subordinates, all on special duty, besides a very large staff of Draftsmen and Tracers for about two and a half years, of which about one and a half years were spent by all staff on office work, designing and estimating. The 1910 Barrage Project also was prepared by a Superintending Engineer, with two Assistant Engineers and two Upper Subordinates, besides Draftsmen and Tracers and was over two years in preparation.

46. I may also be allowed to mention that during the past two and a half years during which I have held charge of this District, I have worked longer hours than any other member of my staff or establishment, and this at the end of nine years continuous service without leave, including one and a half years on Military Duty in Mesopotamia, which ended with a big attack of enteric fever, after which I was recalled from Military Duty to work out these projects.

I have not drawn an anna of extra pay for this work, although I have held a much bigger charge than was previously held by the most senior Superintending Engineer in the Presidency, and have had three Executive Engineers and three Assistant Engineers under my orders for the latter part of the time.

I trust, however, that the result of my services will be of more value than my salary would appear to indicate, and that Government will find the projects now submitted to be thorough and satisfactory, so that progress can at last be made with these great and necessary works.

I have the honour to be,

Sir,

Your most obedient servant,

A. A. MUSTO,

Executive Engineer,

Sukkur Barrage Project District.

STATEMENT I.

Statement showing Net Financial Results.

	Combined Project *viz.*, Barrage, and Right and Left Bank Canal Systems.	Rohri Canal and Khairpur State Feeders with share of Barrage.	Eastern Nara with share of Barrage.	Combined Right Bank Canals Systems with Manchar Drain and Regulator and with share of Barrage.
	Rs.	Rs.	Rs.	Rs.
(*a*) Total cost of works—Direct ..	15,46,25,352	5,18,48,797	3,23,42,373	7,04,31,282
(*b*) Total cost of works—Indirect ..	53,38,825	17,55,455	10,46,587	24,91,262
(*c*) Total, Direct and Indirect ..	15,99,64,177	5,36,04,252	3,33,38,960	7,29,22,544
(*d*) All works completed in year from commencement	Eleventh.	Eleventh.	Eleventh.	Tenth.
(*e*) Work becomes productive in years from commencement of work ..	Fourteenth.	Twentieth.	Eleventh.	Twelfth.
(*f*) Accumulated arrears of interest up to year (*e*)	2,36,27,160	1,19,77,486	15,99,962	1,22,37,226
(*g*) Total capital invested in year (*e*) ..	18,35,91,337	6,55,81,738	3,49,88,922	8,51,59,770
(*h*) Net revenue due to improvements in year (*e*)	94,02,085	34,14,823	22,19,003	42,76,554
(*i*) Interest paid in year (*e*) ..	5·1 per cent.	5·2 per cent.	6·3 per cent.	5·02 per cent.
	Third year after completion.	Ninth year after completion.	On completion of work.	2nd year after completion.
10th year after completion of work.				
(*j*) Total capital invested	15,99,64,377	6,42,54,041	3,33,88,960	7,42,74,453
(*k*) Net revenue due to improvements ..	1,39,67,582	39,20,393	42,91,983	57,55,206
(*l*) Interest paid	8·2 per cent.	6·1 per cent.	12·85 per cent.	7·85 per cent.
20th year after completion of work.				
(*m*) Total capital invested	15,99,64,377	5,36,04,252	3,33,88,960	7,29,22,554
(*n*) Net revenue due to improvements ..	1,88,51,844	57,41,258	60,54,048	70,56,538
(*o*) Interest paid	11·8 per cent.	10·7 per cent.	18·15 per cent.	9·7 per cent.
30th year after completion of work.				
(*p*) Total capital invested	15,99,64,377	5,36,04,252	3,33,88,960	7,29,22,554
(*q*) Net revenue due to improvements ..	2,21,46,430	73,37,563	70,14,488	77,87,848
(*r*) Interest paid	13·8 per cent.	13·6 per cent.	21·0 per cent.	10·7 per cent.
(*s*) All accumulated arrears of interest will be wiped out in year from commencement of work	End of 21st year.	End of 27th year.	End of 14th year.	End of 21st year.
(*t*) All capital wiped out in year from commencement of work ..	End of 34th year.	End of 39th year.	End of 26th year.	

Cultivation.		Percentage.		Percentage.		Percentage.		Percentage.
(*u*) Present cultivation in acres ..	2,035,636	31	6,57,300	26	484,579	26	893,657	42
(*v*) Cultivation in year (*e*) when work becomes productive ..	3,288,929	50	12,32,500	48·5	783,750	42	1,272,679	60
(*w*) Ultimate anticipated cultivation in 30 years after completion ..	5,308,408	81	20,53,300	81	1,529,950	81	1,725,158	81
(*x*) Total culturable area ..	6,529,705	100	25,35,020	100	1,873,000	100	2,131,685	100
(*y*) Total Gross commanded ..	7,494,077		29,56,518		2,176,494		2,361,065	

STATEMENT II.

Statement showing the anticipated increase of cultivation in Sind due to the Sukkur Barrage.

Crop.	In tract affected by the Sukkur Barrage.			In whole of Sind.		Remarks
	Present cultivation average of 10 years 1908-09 to 1917-18.	Anticipated cultivation 30 years after completion of all Canals.	Anticipated increase.	Present cultivation.	Future anticipation after construction of Sukkur Barrage.	
1	2	3	4	5	6	7
	Acres.	Acres.	Acres.	Acres.	Acres.	
1. Rice ..	507,381	762,567	255,186	1,101,128	1,356,314	
2. Cotton ..	236,328	759,876	523,548	263,275	786,823	
3. Other Kharif (Jowari, Bajri, etc.) ..	908,676	783,700	—124,976	1,126,404	1,001,428	
4. Rabi (wheat).	186,825	2,540,840	2,354,015	382,686	2,736,701	
5. Other and Leguminous Rabi ..	338,479	622,123	283,644	604,321	887,965	
Total ..	2,177,689	5,469,106	3,291,417	3,477,814	6,769,231	

STATEMENT IIA.

Approximate Forecast of Crop Produce and Export.

Crop.	Tracts affected by Barrage.									Probable Increase. Exports.	
	Present.					After construction of Barrage (30 years). Population increased 75 per cent.					
	Acreage.	Maunds per acre.	Out-turn in maunds.	Local consumption maunds.	Exported maunds.	Acreage.	Maunds per acre.	Out-turn in maunds.	Local Consumption maunds.	Probable exports maunds.	Maunds.	Tons.
Rice	507,381	15	7,610,715	5,145,660	2,465,055	782,567	20	15,251,340	9,064,000	6,187,340	3,722,285	137,000*
Cotton	236,328	6	1,417,968	....	1,417,968	759,876	7	5,319,132	....	5,319,132	3,901,164	143,200
Other Kharif (Jowari, Bajri, Sugarcane, fruit and vegetables) ..	908,676	9	8,178,084	8,178,084	....	783,700	12	9,404,400	9,404,400	....	....	....†
Wheat and Barley ..	186,825	10	1,868,250	1,300,000	568,250	2,010,840	13	26,140,920	2,600,000	23,540,920	22,972,670	844,000‡
Pulses	201,500	8	1,612,000	1,292,000	320,000	230,000	12	2,760,000	2,760,000	....	—320,000	....‡
Oil-seeds	137,000	6	822,000	596,000	226,000	500,000	8	4,000,000	1,500,000	2,500.000	2,274,000	83,300
Leguminous Fodder Crops.	....	..	....	....	....	422,123	..	....	....	....	....	....
Total ..	2,177,710	..	21,509,017	16,511,744	4,997,273	5,489,106	..	62,875,792	25,328,400	37,547,392	32,550,139	1,195,000

* Increased population will require some of the hitherto exported rice.

† The increase of local consumption is not in proportion to increase of population because there is usually a surplus at present fed to cattle. This will in future go to population while cattle will get a large amount of lucerne, berseen, etc., *vide* last item above.

‡ Wheat will be grown for export in preference to pulses; when assured water supply is available, only local requirements will be grown and wheat will replace some pulses as food.

Accompaniment to Executive Engineer, S. B. P. D.'s No. 1390, dated 13th July 1920.

COMBINED PROJECT FOR SUKKUR BARRAGE AND CANAL SYSTEMS.

List of Volumes.

Volume	I—Report on Proposed Barrage on the Indus at Sukkur, Sind, 1919.
,,	II—Appendices to Report on Proposed Barrage on the Indus at Sukkur, Sind, 1919.
,,	III—Estimates for Sukkur Barrage and Guide Banks and for the Head Regulators of all Canals taking off above the Barrage, 1919.
,,	IV—Plans for Sukkur Barrage, 1919.
,,	V—General Report on Combined Project for Sukkur Barrage and Right and Left Bank Canal Systems, 1919-20.
,,	VI—Appendices to Reports, Volumes V, VII, VIII and IX, 1919-20.
,,	VII—Report on Rohri Canal Project including Khairpur State Feeders 1919-20.
,,	VIII—Report on the Right Bank Canal System including outline for irrigation of Nasirabad Tahsil and Improvements to Begari Canal System, 1919-20.
,,	IX—Report on Eastern Nara Canal System, 1919-20.
,,	X—Estimate for Rohri Canal and Khairpur State Canals, Left Bank System, 1919-20.
,,	XI—Estimates for North-Western Perennial Canal, South-Eastern Perennial Canal and Central Rice Canal Right Bank System, 1919-20.
,,	XII—Estimates for Eastern Nara Improvements Project, Left Bank System, 1919-20.
,,	XIII—Report and Estimates, Manchar Drainage and Flood Protective Works, 1919-20.
,,	XIV—Estimate for Type Designs of Masonry Works for All Canal Systems, 1919-20.
,,	XV—Plans, Rohri Canal, Khairpur State Feeders, and Eastern Nara Canals, 1919-20.
,,	XV-A—Topographical Sheets, Rohri Canal, Khairpur State Feeders, and Eastern Nara Canals, 1919-20.
,,	XVI—Plans, Right Bank Canals System, 1919-20.
,,	XVI-A—Topographical Sheets, Right Bank Canals System, 1919-20.
,,	XVII—Plans, Manchar Drainage and Flood Protective Works, 1919-20.
,,	XVIII—Plans, Type Designs for Masonry Works, 1919-20.
,,	XIX—Financial Forecasts for Alternative Combinations, and for each Canal System separately.
,,	XX—Report by Messrs. Baker and Lane, and Order of Bombay Government thereon.

CORRIGENDUM.

1. Owing to an unfortunate arithmetic error in Statement B. I. (common to Volumes VII, VIII and IX), in taking out the proportions, of the cost of the Barrage proper, debitable to each separate canal system, the financial statements for each canal system separately are not strictly accurate. This error in the sub-division does not, however, affect the accuracy of the financial statements for the whole combined scheme, in which the whole cost of the Barrage, Head Regulators and the whole cost of all canal systems is included.

2. Thus in the Financial summaries shown on page ix, the figures in the first column, *viz.*, for the combined project, are correct and unaffected.

3. But the figures in the remaining three columns, *i.e.*, for the three great canal systems, require adjustment among themselves for the correct distribution of the cost of the Barrage between them.

4. To carry out the corrections in all the detailed statements would involve a great deal of labour, and the result would be insignificant even for the consideration of the canal systems separately, while as already stated, it makes no difference to the combined project for Barrage and all Canals.

5. If the correct distribution of the Barrage cost among each of the canal systems is made, the result affects the Direct and Indirect Charges, and the accumulated arrears of Interest up to the year when each canal system becomes productive.

6. The net effect of these corrections is as follows :—

I. *Rohri Canal System.*—In the 9th year after completion of the work, *i.e.*, in the 20th year after commencement of all works (when the work is shown as productive) the total capital cost invested in the canal, will be reduced from Rs. 6,55,81,738, as shown in Statement I, to Rs. 6,49,42,000. As the nett revenue in that year is not affected by this correction in cost, and is Rs. 34,14,823, the return on capital becomes $\frac{34,14,823}{6,49,42,000} = 5{\cdot}25$ per cent. as against 5·2 per cent. shown in Statement I.

In the 30th year after completion the return will be 13·8 per cent. as against 13·6 per cent. shown in Statement I.

II. *Eastern Nara System.*—In the year of completion of the work, *i.e.*, in the 11th year after commencement of all works, the total capital cost invested in the canal system will be reduced from Rs. 3,49,88,922, as shown in Statement I, to Rs. 3,46,45,922.

The nett revenue in that year is Rs. 22,19,003, and the return on capital is therefore $\frac{22,19,003}{3,46,45,922} = 6{\cdot}4$ per cent. as against 6·3 per cent. shown in Statement I.

In the 30th year after completion the return will be 21·5 per cent. as against 21·0 per cent. shown in Statement I.

III. *Right Bank Canal System.*—In the 2nd year after completion of the works, *i.e.*, in the 12th year after commencement of all works, the total capital cost invested in this canal system will be increased from Rs. 8,51,59,770, as shown in Statement I, to Rs. 8,60,07,000. The nett revenue in that year is Rs. 42,76,554 and the return on capital becomes $\frac{42,76,554}{8,60,07,000} = 4{\cdot}97$ per cent. as against 5·02 per cent. shown in Statement I. Hence the work is barely productive in the 2nd year after completion, but will give a return of about 7·8 per cent. in the 10th year after completion. In the 30th year after completion the return is 10·4 per cent. as against 10·7 per cent. shown in Statement I.

VOLUME V.

GENERAL REPORT

CONTENTS.

PART IV.

RATES.

PART V.

ESTIMATING.

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THE COST OF THE BARRAGE AND HEAD REGULATORS—METHOD OF DISTRIBUTING AMONG CANAL SYSTEMS.

PART VII.

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PART VIII.

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PART IX.

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COMBINED PROJECT FOR SUKKUR BARRAGE AND CANALS SYSTEMS.

PART I.

GENERAL OUTLINE OF PROJECTS.

INDEX.

Section I.

Introduction.

1. The full history of all the canal projects up to July 1919 is given in Volume II "Appendices to the Report on the proposed Barrage on the Indus at Sukkur" in Appendix A.

2. It will be sufficient to deal here with the points which affect the projects now submitted.

These projects are as follows :—

A—Left Bank Systems.

(1) Rohri Canal
(2) Khairpur State Canals } Project.
(3) Eastern Nara Project.

B—Right Bank Systems.

(1) North-Western Perennial Canal
(2) Central Kharif Canal } Project.
(3) South Eastern Perennial Canal

3. Projects were prepared for all these systems, in a more or less modified form, in 1909, but none of these projects will suit the Revised Sukkur Barrage Project of 1919, and all have had to be redesigned.

4. *Rohri Canal.*—In the case of the Rohri Canal Project although it has been necessary to entirely redesign the whole canal system, for reasons which will be explained later, yet Dr. Summers' very fine and elaborate project of 1909 has been of immense assistance in the preparation of the revised project, and his alignments and water levels have been followed almost throughout, except in the head reach, and in a few distributaries near the tail.

5. This has made the revision of this project a comparatively simple and easy matter, and with the exception of the altered duties of water, and intensity of cultivation, the irrigation aspect of the project is practically identical with that proposed by Dr. Summers, whose long and valuable study and work on this canal has thus been fully utilized.

6. It has been necessary to revise all rates for work owing to the increased cost of labour and materials, but Dr. Summers' rates were so carefully elaborated that it has only been necessary to add to them certain percentages to bring them up to date ; all his methods of calculating them being retained unaltered. The masonry works have all been re-estimated on type designs, which have been modified in various ways giving greater safety and considerable economy in some cases.

7. *Khairpur State Canals.*—Similarly Dr. Summers' proposals for supplying the State canals have been retained, although the change in the design of the Barrage has enabled much more satisfactory water levels to be given, and large savings to be effected in the length and design of the new channels.

8. *Eastern Nara System.*—Considerable changes in the method of supplying this system have been proposed, as compared with the 1909 project, but here again it has been possible to utilize the previous proposals for distributing the supply

of the canals, and the 1909 project has formed a useful basis for calculating the cost of the proposed works, many of Mr. Vachha's proposals being retained.

9. *Right Bank Canal System.*—The 1909 Project for this system could not be described as well thought out. It was unsuitable for the country it commanded, and neglected entirely the very important and difficult drainage problems involved. It has been entirely abandoned, and no part of it has been of any use in the fresh project now submitted, which provides for a completely different system of canals, and of distribution of irrigation, while proper provision for drainage and for protection against hill floods, has been made.

The cost of the present project will be nearly double that of the 1909 Project, but will command a much greater area, will provide for a higher intensity of cultivation, and the project shows a satisfactory return on the Capital outlay, which the 1909 Project fails to do.

10. With reference to the remarks at the end of Appendix A, Volume II, regarding the orders of the Bombay Government for the omission of the Khirtar Branch from the Project, I was so convinced that this must eventually be included, and that to redesign for it afterwards would involve so much difficulty and alteration to the rest of the Project, that I ventured to disregard Government Orders in this matter and to estimate fully for this canal.

11. It is fortunate that I did so, as the Government of Bombay in their Memorandum No. D.—39 dated 26th April, which reached me on the 1st May 1920, instruct me to include in my project this Khirtar Branch, and have since approved it, and also to make rough proposals for the irrigation of the remainder of Nasirabad Tahsil not commanded by my perennial Branch. This would have meant a long delay had not the perennial Branch been already estimated.

12. For the same reasons I have included in the Project, my proposals for the Begari Rice Branch of the Central Rice Canal hoping it would meet with the approval of Government, particularly as a conference of Revenue and Public Works Department Officers, convened by the Commissioner in Sind on 8th April 1920, unanimously approved the proposals for this branch, provided they were shown to be profitable and to meet the technical approval of Government. The Financial Statements submitted with the Project show that the proposals are entirely profitable, and these have now been approved by Government from the technical point of view also, and are included in the Project.

Munchar Drainage.

12 (*a*). Although a complete Project for the protection of all irrigated lands from the hill floods, have been prepared and is submitted in Volume XIII of this Project, it has been considered desirable to exclude these works from this Irrigation Project, as the Protective Works form an Agricultural Work and should be paid for by a special protective cess, independent of the irrigation rates.

12 (*b*). It has therefore been decided to include in this Project only such works as are necessary to ensure the satisfactory drainage of the irrigated areas. These works consist of the great high level and low level drains from the Munchar Lake to the River, with the Combined Head Regulator for same. The cost of these works is estimated at Rs. 76,43,121 and is debited to the Right Bank Canal System, no special revenue being credited to the Project on their account.

12 (*c*). These arrangements provide for draining off accumulated floods at a fairly rapid rate, as the river falls, but do not alter any of the present flooding conditions at the time floods are entering the Lake. The entering floods will still damage kharif crops, as at present, and the whole country up to the highest level (R.L. 124·0) to which the floods accumulate, will be covered with water for some months in a bad year.

12 (*d*). It is therefore decided, in the latter area, to allow for no increase of cultivation, and to provide for present cultivated area at the enhanced rates taken by Messrs. Baker and Lane, since the supply will be improved by the new canals; but to deduct from the total revenue thus obtained, remissions equivalent to 30 per cent. of Revenue obtained from kharif cultivation, but no remissions from rabi, as it is assumed that the new drain will free all present rabi areas, in time for cultivation.

12 (*e*). For the remaining area which was flooded in 1917, *i.e.*, between contour 124·0 and the northern limit of flooding, full rabi development is allowed for, as this area can be rapidly drained, and the kharif is assumed to increase from the present area half way to the anticipated area (as calculated for protected lands in the rest of the Project).

12 (*f*). All the Flood Diversion, Valley and Lake-containing Banks are omitted from this Project, but the complete Protective Scheme is sent up with this Project in Volume XIII and the remaining works may be considered later if desired, as an Agricultural Work.

Section II.

Reasons for preparing these projects.

13. These reasons have already been fully explained in Section II, Part I, Volume I (Report on Sukkur Barrage Project, 1919).

It is shown there in paragraphs 15 and 16, that the Government of Bombay were of opinion that the proposed barrage and canal systems were necessary and desirable, even if they could not be shown to be directly profitable to Government, since the indirect profits to the country and to Government would be enormous.

14. It is satisfactory, in submitting these projects, that I am able to show that they will be directly profitable to Government, apart from the very great indirect benefits they will confer on the country.

Section III.

Total supply required for all Canals.

15. This question was dealt with fully in Section VII, Part I, Volume I, but the proposed canal discharges there assumed were provisional figures only.

16. Statement No. I below gives the final figures of canal discharges required for all the projects now submitted.

17. Statements Nos. II to VIII give the details of this total, as calculated for each canal system separately.

18. Statement No. IX show the maximum and minimum discharges in the Indus for 16 years at the Outfall Discharge Section about one mile below Bukkur Island.

At the foot of the statement is shown the averages of these minima and maxima discharges, but these figures are of very little value, since these minimum values only last for a day or two at a time, and would not affect the canals, owing to the reservoir capacity created by the Barrage.

19. Statement No. X shows the average discharges *throughout each month* of the same 16 years, and at the foot of the statement is shown the average of all these years for each month.

20. To these discharges must be added the actual discharge of the Eastern Nara Supply Channel, *vide* statement XI, which now takes off above the river discharge section, and which will be closed entirely after construction of the new canals. The proposed discharge for the new head of the Nara Supply Channel is already included in statement No. 1 showing required total discharge for all canals.

21. Statement XII shows the combined average monthly discharges of the Indus at Outfall and of the Eastern Nara existing Head. It is these figures which show the real working conditions between river and canals, since it is on these average discharges throughout the month that the canals will depend for their supply.

From this statement it will be seen that the minimum *average* discharge throughout a month, occurred in March 1917 and was 20,474 cusecs, while the average of 16 years lowest discharge in each month of the year occurred in January and was 39,282 cusecs.

22. Comparing statements Nos. I and XII it will be seen that in only two months, March and April 1917, out of 16 years, did the river discharge fall below that required for all the canals combined. In all other months of all years, the river discharge was far greater than required. Even in those two months it is probable that the reservoir capacity created by the Barrage would have assisted considerably to reduce the deficiency, but at the worst there is a deficiency of 2,800 cusecs in one month, and of 5,200 cusecs for one month out of the 192 months.

23. But in that year it was obvious that deficiency was likely to occur, and in a similar year after construction of the new canals it would be possible to delay the early waterings for rice (in April) on all canals and this would reduce the requirements by 6,460 cusecs, leaving more than sufficient water for the perennial systems.

Similarly in March, the early watering of cotton and other kharif could be delayed without much harm to the crops.

24. For calculating the discharge required in each canal month by month, as shown in statements Nos. III to VIII the proportions of crops, taking water each month, as adopted by Messrs. Baker and Lane on page 6 of their printed report, have been adopted.

STATEMENT I.

Total combined discharge of all proposed canals month by month.

Month.	Rohri Canals.	Khairpur State Canals.	Right Bank Canals.	Eastern Nara Canals.	Total.
January	9,900	..	6,164	6,692	22,656
February	9,900	..	6,164	6,692	22,656
March	10,760	..	5,939	6,755	23,454
April	9,820	2,000	9,209	8,000	29,029
May	10,100	3,000	15,758	10,683	39,543
June	10,250	4,030	19,446	12,200	45,926
July	10,250	4,030	19,446	12,200	45,926
August	10,250	4,030	19,446	12,200	45,926
September	10,250	4,030	19,446	12,200	45,926
October	10,480	3,000	5,805	6,612	25,897
November	8,880	3,000	5,548	6,112	23,540
December	9,900	3,000	6,164	6,692	25,656

Statement II.

Abstract of total monthly discharges required by the three canals on the Right Bank.

Month.	North-Western.	Central.	South-Eastern.	Total.
January	3,639	..	2,525	6,164
February	3,639	..	2,525	6,164
March	3,618	..	2,321	5,939
April	3,380	3,773	2,656	9,209
May	3,952	9,312	2,494	15,758
June	4,313	12,346	2,787	19,446
July	4,313	12,346	2,787	19,446
August	4,313	12,346	2,787	19,446
September	4,313	12,346	2,787	19,446
October	3,532	..	2,273	5,805
November	3,275	..	2,273	5,548
December	3,639	..	2,525	6,164

Statement III.

Statement showing discharges required at North Western Perennial Canal for each month during the year.

Month.	Kharif.						Rabi.			Total supply required.	Remarks.
	Cotton and other dry kharif.			Rice.							
	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty 75	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty 37·5	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty 150		
		p. c.			p. c.			p. c.			
January ..		....	..		....	..		100 545,922	3,639	3,639	
February ..		....	..		....	..		100 545,922	3,639	3,639	
March ..		50 107,484	1,435		....	..		60 327,553	2,183	3,618	
April ..		90 193,472	2,583		30 16,247	433		10 54,592	364	3,380	
May ..		100 214,969	2,870		75 40,619	1,082		....	..	3,952	
June ..	214,969	100 214,969	2,870	54,158	100 54,158	1,443	545,922	....	..	4,313	
July ..	acres.	100 214,969	2,870	acres.	100 54,158	1,443	acres.	....	..	4,313	
August ..		100 214,969	2,870		100 54,158	1,443		....	..	4,313	
September ..		100 214,969	2,870		100 44,158	1,443		....	..	4,313	
October ..		47 101,035	1,349		....	..		60 327,553	2,183	3,532	
November ..		....	..		....	..		90 491,330	3,275	3,275	
December ..		....	..		....	..		100 545,922	3,639	3,639	

STATEMENT IV.

Statement showing discharges required at the South-Eastern Canal for each month during the year.

Month.	Kharif.						Rabi.			Total supply required.	Remarks.
	Cotton and other dry kharif.			Rice.							
	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty. 68·8	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty. 34·4	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty. 137·6		
		Per cent.			Per cent.			Per cent.			
January ..		....	..		....	..		100 347,441	2,525	2,525	
February ..		....	..		....	..		100 347,441	2,525	2,525	
March ..		50 55,460	806		....	..		60 208,465	1,515	2,321	
April ..		90 99,828	1,451		30 12,134	353		10 34,744	252	2,056	
May ..		100 110,920	1,612		75 30,336	882		....	..	2,494	
June ..		100 110,920	1,612		100 40,447	1,175		....	..	2,787	
July ..		100 110,920	1,612		100 40,447	1,175		....	..	2,787	
August ..		100 110,920	1,612		100 40,447	1,175		....	..	2,787	
September ..		100 110,920	1,612		100 40,447	1,175		....	..	2,787	
October ..		47 52,132	758		....	..		60 208,465	1,515	2,273	
November ..		....	..		....	..		90 312,697	2,273	2,273	
December ..		....	..		....	..		100 347,441	2,525	2,525	
	110,020 acres.			40,447 acres.			347,441 acres.				

STATEMENT V.

Statement showing discharges required at Central Rice canal for each month during the year.

Month.	Kharif.						Rabi.			Total supply required at Canal Head.	Remarks.
	Cotton and other dry kharif.			Rice.							
	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty. 77·8	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty. 38·9	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty.		
		Per cent.			Per cent.						
January ..		....	..		....	..		....	..	..	
February ..		....	..		....	..		....	..	..	
March ..		....	..		....	..		....	..	..	
April ..		50 13,631	174		30 139,849	3,599		....	..	3,773	
May ..		90 24,535	314		75 349,622	8,998		....	..	9,312	
June ..		100 27,261	349		100 466,162	11,997		....	..	12,346	
July ..		100 27,261	349		100 466,162	11,997		....	..	12,346	
August ..		100 27,261	349		100 466,162	11,997		....	..	12,346	
September ..		100 27,261	349		100 466,162	11,997		....	..	12,346	
October ..		....	..		....	..		....	..	..	
November ..		....	..		....	..		....	..	..	
December ..		....	..		....	..		....	..	..	
	27,261 acres.			466,162 acres.							

Statement VI.

Statement showing discharges required at Rohri canal head for each month during the year.

Month.	Kharif.						Rabi.			Total supply required.	Remarks.
	Cotton and other dry kharif.			Rice.							
	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty. 70·3	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty. 35·6	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty. 137		
		Per cent.			Per cent.			Per cent.			
January ..		....	..		....	..		100 1,355,000	9,900	9,900	Capacity provided at Head of Rohri Canal 10,992 cusecs.
February ..		Nearly.	..		....	..		100 1,355,000	9,900	9,900	
March ..		50 338,500	4,820		....	..		60 813,000	5,940	10,760	
April ..		90 609,300	8,650		30 6,400	180		10 135,500	990	9,820	
May ..	677,000 acres.	100 677,000	9,650	21,300 acres.	75 16,000	450	1,355,000 acres.	....	..	10,100	
June ..		100 677,000	9,650		100 21,300	600		....	..	10,250	
July ..		100 677,000	9,650		100 21,300	600		....	..	10,250	
August ..		100 677,000	9,650		100 21,300	600		....	..	10,250	
September ..		100 677,000	9,650		100 21,300	600		....	..	10,250	
October ..		47 319,000	4,540		....	..		60 813,000	5,940	10,480	
November ..		....	..		....	..		90 1,217,500	8,880	8,880	
December ..		....	..		....	..		100 1,355,000	9,900	9,900	

Statement VII.

Statement showing discharges required at head of Khairpur state canals for each month during the year.

Month.	Kharif.						Rabi.			Total supply required.	Remarks.
	Cotton and other dry kharif.			Rice.							
	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty. 50	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty.	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty.		
January ..		....	..		....	..		....	..	..	Early rice.
February ..		....	..		....	..		....	..	..	
March ..		....	..		....	..		....	..	..	
April ..		....	..		Early waterings for Rice.	Say 2,000		....	..	2,000	
May ..		....	..			3,000		....	..	3,000	
June ..	96,760 for West Canal 104,250 for East Canal. 201,000		4,030		....	..		....	..	4,030	
July ..			4,030		....	..		....	..	4,030	
August ..			4,030		....	..		....	..	4,030	
September ..			4,030		....	..		....	..	4,030	
October ..		....	..		....	..		Bosi watering only.	..	3,000	For Bosi
November ..		....	..		....	..		....	..	3,000	
December ..		....	..		....	..		....	..	3,000	

Statement VIII.

Statement showing discharges required in the Eastern Nara Channel for each month during the year.

Month.	Kharif.						Rabi.			Total.	Add for Khairpur Outlets.	Losses in the Nara River.	Total.
	Cotton and other dry kharif.			Rice.									
	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty. 78	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty 39.	Area permissible.	Anticipated area under irrigation during the month.	Supply required at head at duty 156.				
		Per cent.			Per cent.			Per cent.					
January ..		....	....		....	....		100 914,500	5,860	5,860	..	832	6,692
February ..		....	....		....	....		100 914,500	5,860	5,860	..	832	6,692
March ..		50 187,275	2,403		....	....		60 548,700	3,520	5,923	..	832	6,755
April ..		90 336,695	4,325		30 72,150	1,857		10 91,450	586	6,768	400	832	8,000
May ..	374,550 acres.	100 374,550	4,801	240,500 acres.	75 180,375	4,650	914,500 acres.	....	....	9,451	400	832	10,683
June ..		100 374,550	4,801		100 240,500	6,167		....	....	10,968	400	832	12,200
July ..		100 374,500	4,801		100 240,500	6,167		....	....	10,968	400	832	12,200
August ..		100 374,500	4,801		100 240,500	6,167		....	....	10,968	400	832	12,200
September ..		100 374,500	4,801		100 240,500	6,167				10,968	400	832	12,200
October ..		47 176,500	2,260		....	....		60 548,700	 3,520	5,780	..	832	6,612
November ..		....	....		....	....		90 823,050	5,280	5,280	..	832	6,112
December ..		....	....		....	....		100 914,500	5,860	5,860	..	832	6,692

STATEMENT IX.

Maxima and Minima discharges in the Indus at Outfall Discharge Section, Sukkur, 1901-1917.

Year.	January.		February.		March.		April.		May.		June.	
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
1901 ..	91,000	32,000	91,000	41,000	66,747	37,000	156,000	63,219	387,000	75,593	284,220	127,985
1902 ..	32,000	29,000	29,000	27,000	27,000	24,000	37,000	28,000	272,000	36,111	370,719	124,000
1903 ..	27,000	22,000	32,000	21,000	34,298	18,947	70,240	31,360	207,131	74,000	338,714	148,831
1904 ..	62,000	31,000	39,000	30,000	90,000	29,000	93,034	45,000	164,000	76,710	428,270	146,707
1905 ..	33,000	27,751	40,000	28,000	41,000	27,000	155,899	42,000	346,827	115,114	480,000	256,447
1906 ..	33,000	22,539	110,000	24,000	122,000	52,000	155,000	89,000	300,385	133,678	320,000	208,000
1907 ..	43,173	32,951	91,000	33,143	91,665	60,536	186,478	60,685	237,217	116,310	336,529	168,918
1908 ..	57,000	30,164	33,925	27,809	28,748	26,462	280,000	25,712	181,000	113,339	330,000	169,930
1909 ..	45,325	40,000	41,684	36,026	61,000	37,000	95,357	41,429	128,000	82,748	375,000	115,000
1910 ..	126,000	42,351	58,146	36,142	55,516	30,813	168,000	51,000	257,000	92,000	440,063	275,000
1911 ..	113,000	33,200	140,000	38,000	554,000	44,411	249,812	142,224	262,510	164,851	582,742	272,000
1912 ..	77,071	42,180	74,000	39,367	48,065	35,311	119,000	35,311	213,878	119,850	369,000	165,026
1913 ..	32,020	27,428	32,565	23,730	39,151	24,996	68,608	35,089	310,000	358,909	401,000	201,000
1914 ..	33,000	27,502	48,793	23,719	44,000	31,350	244,000	40,000	249,000	69,739	476,000	104,000
1915 ..	55,686	41,012	114,000	40,664	101,000	45,741	299,000	75,000	427,000	142,129	382,000	215,028
1916 ..	31,754	26,117	31,974	25,546	32,000	25,559	66,000	32,267	83,963	52,665	488,000	67,000
1917 ..	32,744	24,153	97,861	23,394	22,487	17,722	26,592	17,568	104,000	27,000	470,000	122,000
	54,398	31,256	60,585	30,502	85,804	35,168	145,295	51,466	242,328	91,220	396,286	175,078

Year.	July.		August.		September.		October.		November.		December.	
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
1901 ..	447,000	196,357	701,000	385,061	530,172	146,792	124,000	76,000	76,000	46,000	46,000	31,000
1902 ..	442,000	166,580	475,225	174,000	248,000	110,035	90,000	47,000	45,000	33,000	33,000	27,000
1903 ..	494,686	203,535	615,000	433,413	592,147	155,272	138,614	71,076	70,832	44,000	44,000	33,000
1904 ..	482,000	253,126	562,000	282,234	260,929	96,178	85,000	37,270	37,771	32,000	34,000	30,150
1905 ..	530,842	324,000	423,069	260,997	423,454	160,000	138,158	69,465	50,000	32,000	35,000	28,000
1906 ..	474,000	330,000	616,580	407,156	578,147	230,628	194,000	82,528	84,000	53,219	43,650	36,777
1907 ..	280,000	189,396	425,289	286,000	295,000	139,013	119,000	49,400	48,296	40,000	40,000	31,048
1908 ..	527,000	240,206	650,000	462,599	821,511	158,135	154,000	65,224	64,000	51,000	51,505	39,760
1909 ..	518,000	305,385	631,796	430,964	597,808	211,460	189,000	78,000	75,000	50,088	69,742	40,892
1910 ..	537,000	264,000	674,531	492,658	700,440	171,000	162,447	76,000	36,000	44,663	46,389	32,448
1911 ..	570,000	297,080	434,097	256,406	457,456	211,089	188,000	68,000	68,505	49,581	59,767	45,349
1912 ..	730,000	289,000	715,138	375,000	429,000	105,230	85,000	54,000	52,000	45,018	46,000	33,423
1913 ..	462,610	201,498	638,000	251,439	452,000	100,000	99,516	53,000	53,300	34,935	33,770	30,692
1914 ..	888,000	417,153	997,000	151,000	601,288	290,000	363,000	91,000	132,939	82,000	100,127	56,337
1915 ..	548,000	215,000	445,000	353,000	380,613	127,000	190,338	69,560	69,000	46,272	44,615	32,461
1916 ..	520,000	319,705	735,348	391,624	484,000	121,574	139,000	75,527	64,572	43,477	43,498	43,317
1917 ..	437,000	213,000	740,279	413,644	603,131	380,630	530,442	85,908	208,085	65,323	58,689	43,318
	518,471	260,438	616,433	356,714	492,435	178,511	157,734	68,297	72,665	46,695	48,809	35,587

STATEMENT X.

Average monthly discharges in the Indus at outfall discharge section, Sukkur, 1905—1920.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1905 ..	..	..	..	..	..	394,800	426,700	340,900	271,400	82,100	38,400	30,000
1906 ..	28,200	40,900	72,200	115,400	203,600	249,900	403,900	524,600	414,400	118,900	62,400	35,500
1907 ..	37,500	55,300	69,800	113,700	172,200	235,000	232,000	389,000	171,600	75,400	43,500	35,900
1908 ..	35,500	29,900	27,500	134,300	138,500	250,800	423,900	502,200	512,800	93,000	56,400	44,600
1909 ..	41,700	38,700	54,500	71,700	108,100	275,100	397,500	535,700	436,800	111,000	60,000	47,000
1910 ..	59,000	43,700	37,600	76,200	145,300	349,700	451,400	556,000	356,600	108,600	58,500	41,100
1911 ..	54,700	68,600	161,500	173,600	195,900	444,200	378,200	359,500	301,700	105,700	57,000	50,300
1912 ..	47,700	50,900	40,300	58,800	148,900	271,300	518,400	559,600	234,500	68,700	47,000	35,700
1913 ..	29,600	26,300	33,800	49,000	127,100	281,100	339,100	435,100	255,700	71,700	42,900	32,800
1914 ..	29,400	30,400	36,200	82,600	129,200	246,700	689,500	597,700	462,100	140,000	101,000	68,800
1915 ..	46,700	59,900	66,600	148,700	325,700	297,500	345,100	381,100	236,100	119,200	56,300	37,800
1916 ..	28,800	28,300	27,000	41,700	65,900	267,900	418,200	587,400	265,700	106,100	51,100	37,300
1917 ..	27,200	25,300	19,800	22,700	56,700	241,100	276,600	610,500	432,800	210,800	107,600	50,600
1918 ..	42,000	35,100	58,600	143,200	230,600	441,900	315,700	319,300	197,500	56,100	35,200	27,900
1919 ..	24,500	29,300	38,300	76,300	114,400	278,300	391,100	455,300	249,600	69,800	40,500	34,800
1920 ..	35,900	35,100	43,600	..	..	..	..	..	..	..	..	..
	37,893	39,847	52,487	93,421	154,371	301,687	400,540	476,927	319,953	89,140	57,187	40,673

STATEMENT XI.

Average monthly discharges at the head of the Eastern Nara Supply Channel, 1905—1920.

Year.	January	February	March	April	May	June	July	August	September	October	November	December.
1905 ..	..	..	..	..	..	19,679	19,765	17,226	14,542	6,724	4,056	2,987
1906 ..	2,645	2,675	3,650	1,163	2,600	13,580	16,676	13,507	5,212	3,055	2,282	1,175
1907 ..	983	1,720	2,565	1,978	5,434	8,572	8,626	11,302	5,519	3,131	1,520	882
1908 ..	889	697	492	2,728	4,446	8,074	14,246	Regulator closed.	5,090	1,411	103	9
1909 ..	155	98	378	1,037	2,304	5,673	9,277	14,651	13,515	3,557	2,326	1,598
1910 ..	1,620	1,633	1,548	2,390	4,784	10,072	11,570	6,780	5,849	4,074	2,628	1,869
1911 ..	2,413	2,674	Regulator	closed.	5,688	13,568	10,357	11,283	8,033	3,663	2,431	1,293
1912 ..	857	1,770	1,273	2,989	6,916	9,669	15,597	17,719	9,071	3,698	2,304	2,181
1913 ..	2,123	1,927	2,450	3,031	6,547	13,409	12,099	16,152	8,057	4,770	2,859	2,017
1914 ..	1,525	1,583	2,056	3,810	5,736	9,331	21,269	12,066	10,443	5,507	4,503	3,405
1915 ..	2,185	2,677	3,560	5,583	7,841	8,596	9,705	12,486	8,347	5,212	2,440	1,598
1916 ..	1,174	1,175	1,250	2,410	3,868	9,872	12,222	13,914	6,132	5,321	2,513	1,444
1917 ..	1,104	1,064	674	995	3,031	8,192	9,645	19,792	12,409	6,282	3,078	1,600
1918 ..	1,303	1,118	2,062	4,677	7,470	12,220	8,012	9,497	5,466	2,198	1,234	955
1919 ..	878	1,354	1,433	3,492	3,958	9,458	14,278	16,150	6,549	2,301	1,112	682
1920 ..	982	1,102	1,528	..	..	..	..	..	..	..	..	..
	1,389	1,551	1,661	2,592	5,045	10,664	12,890	12,835	8,289	4,060	2,359	1,580

STATEMENT XII.

Average monthly combined discharge of the River Indus at outfall discharge section and the Eastern Nara Supply Channel, 1905–1920.

Year.	January	February	March	April	May	June	July	August	September	October	November	December
1905 ..	..	..	..	..	..	414,479	446,465	358,126	285,942	88,824	42,456	32,987
1906 ..	30,845	43,575	75,850	116,563	205,600	263,480	420,576	538,107	419,612	121,955	64,682	36,675
1907 ..	38,483	57,020	72,365	115,678	177,634	243,572	240,626	400,302	177,119	78,531	45,020	36,782
1908 ..	36,389	30,597	27,992	137,028	142,946	258,874	438,146	502,200	517,890	94,411	56,503	44,609
1909 ..	41,855	38,798	54,878	72,737	110,404	280,773	406,777	550,351	450,315	114,557	62,326	48,598
1910 ..	60,620	45,333	39,148	78,590	149,784	359,772	462,970	562,780	362,449	112,674	61,128	42,969
1911 ..	57,113	71,274	161,500	173,600	201,588	457,768	388,557	370,763	309,733	109,363	59,431	51,593
1912 ..	48,557	52,670	41,573	61,789	155,816	280,969	533,997	577,319	243,571	72,398	42,304	37,881
1913 ..	31,723	28,227	36,250	52,031	133,647	294,509	351,199	451,252	263,757	76 470	45,759	34,817
1914 ..	30,925	31,933	38,256	86,410	134,936	256,031	710,769	609,766	472,643	145,507	105,503	72,205
1915 ..	48,885	62,577	70,160	154,283	333,541	306,096	354,805	393,586	244,447	124,412	58,740	39,398
1916 ..	29,974	29,475	28,250	44,110	69,768	277,772	430,422	601,314	271,832	111,421	53,613	38,744
1917 ..	28,304	26,364	20,474	23,695	59,731	249,292	286,245	630,292	445,209	217,082	110,678	52,200
1918 ..	43,303	36,218	60,662	147,877	238,070	454,120	323,712	328,797	202,966	58,298	36,434	28,855
1919 ..	25,378	30,654	39,733	79,792	118,358	287,758	406,178	471,450	256,149	72,101	41,612	35,482
1920 ..	36,882	36,202	45,128	..	..	..	..	..	..	..	..	..
	39,282	41,398	54,148	96,013	159,416	312,351	413,430	489,762	328,242	93,200	59,546	42,253

SECTION IV.

Navigation on Canals.

25. Navigation for the public is not provided for on any canal, but all canal regulators and bridges have been designed to give a minimum clear headway of 5 feet above Full Supply Level to underside of gates when fully raised, and 6 feet clearance between F.S.L. and the soffit of all arches. This will allow for boats carrying materials etc., to pass along certain sections of the canals, and for row boats, or motor boats (with awning lowered) to pass with Inspecting Officers, if desired.

26. No provision has been made, however, for such boats to pass through fall regulators, or simple falls, nor has clearance been proposed under railway bridges for this purpose. Inspection will be done almost entirely from the banks, and boats will only be used in the ordinary way for conveying canal stores from one point to another along reaches of the canals. Separate boats must be kept for this purpose where required on both sides of railway bridges, falls and fall regulators.

27. For occasional canal journeys and inspections row boats can be used, fitted with Eviorude Motors, which can be quickly removed from one boat, carried round the fall or bridge, and fixed in the boat on the other side.

SECTION V.

Communications.

28. Land communication throughout the canal irrigated tracts is already provided by existing District and Village roads of varying condition. Wherever such roads cross main or branch canals, a bridge is provided. District Road Bridges have a clear width of 16 feet between wheel guards, and Village Road Bridges a clear width of 8 feet. Wherever possible these bridges are combined with canal regulators, falls, syphons or acqueducts, as thereby economy is effected.

29. On the main canals, wherever there is no existing road crossing the canal for a length of more than 6 miles, a Village Road Bridge has been provided, so that the maximum distance between any two bridges is 6 miles, the average distance being much less.

30. The following statement shows the average distance between bridges on the main canals of each system :—

	Average distance between bridges.
Rohri Canal	3·3 miles.
Right Bank North-Western Canal	4·1 „
„ „ South-Eastern „	3·9 „
„ „ Central Canal	4·2 „
Eastern Nara Jamrao Canal	4·7 „
„ „ Mithrao Canal	2·9 „
„ „ Khipra Canal	3·1 „

31. For inspection of the canals in the first few years after opening, the inspection paths will be along the top of both canal banks and have the following widths, *viz* :—

For all main canals and branches	8′ top width.
„ „ distributaries (50 to 200 cusecs)	5′ „ „
„ „ minors (below 50 cusecs)	3′ „ „

32. Eventually, when canal berms have silted up to F.S.L., the silt deposited near canal edge will be excavated and used to raise the inner portion of the silted berm to one foot above F.S.L. The excavated portion will again silt up and the process will be continued till the full width of the berm has been raised to 1 foot above F.S.L. When this stage has been reached, the inspection paths or service roads will be run along the berms throughout the canal system.

33. The final minimum width of silted berm allowed for is as follows :—

Channel carrying—	Width of final silted berm 1′ above F.S.L.
more than 2,000 cusecs	30 feet.
from 2,000 to 1,500 cusecs	25 „
„ 1,500 to 1,000 „	20 „
„ 1,000 to 750 „	15 „
„ 750 to 500 „	10 „
„ 500 to 200 „	10 „
„ 200 to 50 „	7·6 „
below 50 cusecs	5 „

PART II.

THE GENERAL PRINCIPLES ADOPTED FOR THE DESIGN OF THE CANAL SYSTEMS.

INDEX

Section I.

The Prime Record.

34. The 1 inch to 1 mile Topo sheets, on which are plotted the contours obtained by the survey and levelling operations, will form the prime record, and base of all measurements and designs for the canals.

The main canals, branches, distributaries and drains will be laid off on these plans, the gross area of command under each branch, etc., will be measured by planimeter from them, the longitudinal sections of all channels plotted by reference to the lengths and contours, and the lengths of all channels measured from the plan.

35. When the project is sanctioned all such channels as marked on the plans, will be set out on the ground, and the longitudinal section (and cross sections where necessary) be levelled and plotted. From this section the final estimates and working drawings of each channel will be prepared.

Section II.

Culturable area—how calculated.

36. From the gross area of each separate distributary command, will be deducted the area of unculturable land, as obtained from Messrs. Baker and Lane's Dehwar statements. A further deduction of 6 per cent. of the gross area will be made, to allow for lands occupied by canals, watercourses, roads and villages. The balance will be taken as the *culturable area.*

37. This procedure was approved by Government in the case of the Rohri Canal, in Government Memorandum No. C.E.—I—1, dated the 17th January 1920, and in the case of the Right Bank Canals in Government Memorandum No. I.—6053, dated the 23rd March 1920. For details see Appendices A and B, Volume V.

Section III.

The intensity of cultivation to be provided for.

38. This varies with the different canal systems, according as they are to supply a large area of rice lands or not. Distinct rules are used for—

(*a*) The Rohri Canal and the perennial canals of the Eastern Nara System.

(*b*) the Right Bank perennial canals.

(*c*) Rice Canals.

The rules adopted and approved by Government are as follows.

Vide Appendices A and B, Volume V.

39. *Rohri Canal* (and perennial branches of Eastern Nara System)—27 per cent. of the culturable area will be provided for dry kharif cultivation.

54 per cent. of the culturable will be provided for rabi cultivation, *i.e.*, the total intensity of cultivation is 81 per cent. of culturable.

Note—The area of rice allowed on Rohri Canal is very small, only 21,321 acres or about 1 per cent. of total cultivation.

40. *The Right Bank Perennial Canals.*—The culturable area having been found as before, the area of rice cultivation given by Messrs. Baker and Lane in their Dehwar statements is assumed to be 95 per cent. of the area suitable for rice, the balance 5 per cent. being dhoros and occasional fallows. The rice cultivation is therefore multiplied by 100/95 to give the rice land area. This area is deducted from the total culturable leaving a balance of culturable land suitable for perennial cropping. Of this perennial culturable area, on any given distributary or branch, the total intensity of cropping (kharif plus rabi) is taken as 82 per cent. (as in the Rohri Canal Tract).

Out of this total of 82 per cent. the rates of rabi to dry kharif is varied between 2 to 1 and 3 to 1, so as to give the total kharif discharge of the channel (rice plus dry kharif) as nearly equal as possible to the rabi discharge.

41. *Rice Canals* on Right Bank and on Eastern Nara system. The culturable area is found as before. 90 per cent. of this culturable area is taken as being rice lands, and 10 per cent. as being suitable for dry kharif cultivation.

Of the rice lands 93 per cent. is allowed for rice cultivation every year, and of the dry kharif lands 5 per cent. is allowed for cultivation every year, so that total cultivation is 90·5 per cent. of cultivable.

Section IV.

"Duty" of water for various crops.

42. In paragraph 16, page 5 of their Report, Messrs. Baker and Lane show the duties adopted by them for the various crops. Their reasons for adopting these duties are given on pages 3 to 5, and their recommendations in this matter have been accepted by Government and are adopted here in designing the canals.

43. As all canals are designed from the tail and distributary heads, upwards, the basis of calculation is the duty at distributary heads. The duties at Branch and Main Canal heads are derived from the Distributary head duty, after adding for absorption losses en route. Messrs. Baker and Lane estimated these absorption losses on a percentage basis and hence arrived at the duties shown.

44. The more accurate method of calculating these losses from the wetted perimeter of channels can only be adopted after the channels are designed, and this has now been done. The losses by evaporation and absorption are calculated as 8 cusecs per million square feet of designed wetted perimeter. This figure is generally accepted throughout India as sufficiently accurate and has been found to be approximately correct from actual observations on working canals.

45. The duties adopted at distributary heads are as follows:—

Kharif Rice	..	..	.. 43·5 acres per cusec.
Kharif Dry (Cotton, etc.)	..	..	.. 87·0 „ „ „
Rabi	..	..	.. 174·0 „ „ „

Section V.

"Overlap" allowance and discharge of Canals.

46. In the 1909 Rohri Canal Project and in the Right Bank Canal Projects, two different Full Supply Levels were taken, *viz.*, a maximum F. S. L. and an ordinary F. S. L.

The difference in depth of canal due to the raising of water surface from the ordinary to the maximum F. S. L. was sufficient to increase the discharge of the canals by 25 per cent. above the ordinary discharge. This increased discharge was provided to meet periods of extra heavy demand when kharif and rabi crops overlapped. It has been the practice in Sind and the Punjab to design on this method.

47. But with such a system it should have been possible to command all land for flow irrigation with the *ordinary* F. S. L. Actually this was not possible with either the Rohri or Right Bank Canal Systems, the flow area being taken as that commanded by maximum F. S. L. This was a mistake in design, and was pointed out by Mr. Herbert (*vide* pages 2 and 3, Volume 9, 1909 Reports) in connection with the Right Bank Projects.

48. In the Punjab it has been found that the 25 per cent. extra reserve supply to meet periods of overlap is not, in practice, retained for that purpose, but that once the canal has been worked up to the maximum F. S. L. it is thereafter kept at that level (if water is available) and fully utilized throughout the season, while at periods of overlap the crops go somewhat short of water. The maximum supply therefore becomes the normal supply, without any reserve margin.

49. At the beginning of 1918 when Messrs. Baker and Lane were estimating the discharge of canals, they allowed for an overlap allowance of 12½ per cent. above normal supply. I wrote pointing out to Mr. Lane that a more accurate method was to calculate the supply required in each month for the area of each crop then sown, and to vary the watering from the age and state of the crop. Mr. Lane considered this an unnecessary refinement and did not adopt the suggestion. But shortly afterwards he worked out the discharges required, month by month, allowing for a variation in the area of crops only, month by month, and not making any allowance for different depths of watering according to the age of the crops. This is the system Messrs. Baker and Lane have adopted in their Report, and which has been accepted by Government.

50. According to this method of calculation the maximum discharge in the Rohri Canal is required in the month of March, and is about 7·3 per cent. higher than the purely kharif supply, as calculated from kharif areas and duties. The canals on which there is little or no rice, *e.g.*, Rohri Canal system and Jamrao, have accordingly been designed to carry, with normal F. S. L., a discharge of 7·3 per cent. greater than the purely kharif discharge.

51. The smaller discharges required in the rabi season, and in kharif months when there is no overlapping with rabi crops, will be run with the same depth at regulators, so that the F. S. L. is constant and is sufficiently high to give flow water to the areas commanded. If in some months a smaller supply than the calculated maximum supply is actually run, this will flow at slightly lower velocity than that designed for the maximum discharge. In almost all sections the velocity for maximum supply has been kept higher than the critical silting velocity (but below scouring velocity) so that water can be run at a lower velocity before reaching silting point.

52. In the case of Perennial canals, on which a considerable area of rice is provided for, the total kharif discharge (rice plus other kharif) is greater than the discharge at periods of overlap of other kharif and rabi; since the rice crop does not overlap with the rabi. Hence for these canals the designed discharge is that required for rice plus other kharif. These conditions apply to the Right Bank Perennial Canals and to the Mithrao and Khipro Canals of the Eastern Nara System.

53. In the case of rice canals there is of course no overlap, there being only the kharif crop, and canal being closed throughout the rabi season. The duty proposed by Messrs. Baker and Lane, and accepted by Government, is 43·5 acres per cusec at distributary head. This is considerably higher than the *average* duty now obtained on inundation canals, but is considered reasonably liberal, for the

certain guaranteed supply with the new canals properly regulated and distributed. The present duties with inundation canals are hardly comparable and are bound to be much lower, owing to the natural tendency of the cultivator, when dealing with a fluctuating and unreliable supply, to take as much water as he can, whenever he can get it, in order to tide over possible and probable periods of deficiency a few days hence.

54. But even with the new canals the demand of the rice crops will not be constant, and for about two months during which transplantation is in progress, a considerable heavier supply than the normal will be needed. This extra demand will occur in the months of June and July when there is always a large discharge in the Indus and there would be no difficulty in heading up water to the top of the Barrage gates, or even higher by passing surplus water under all gates. During this month therefore it would always be possible—if found necessary—to raise the F. S. L. in the rice canals by about 6 inches and thereby to increase the normal discharge by about $7\frac{1}{2}$ per cent.

All canal banks and masonry works are provided with ample free-board to allow of such raising, which would only be permitted during the transplantation season, and then only if found really necessary. It seems likely that with the absolute certainty of a regular supply at constant level the duties for rice will be greatly improved.

Section VI.

Nomenclature adopted and symbols used on Plans.

55. The following classifications are adopted for all projects :—

Canal System.—This is the general heading for all canals on each side of the river, *i.e.*, Left Bank System and Right Bank System.

Main Canals.—These are the principal channels each of which takes off either from the Sukkur Barrage or from a weir on the Eastern Nara System. The Main Canal starts at its head regulator and ends where it furcates into branches or distributaries. They all have names and are denoted on the plans by the letters M.C.

Branch Canals.—A branch is any channel other than a Main Canal carrying more than 200 cusecs. It may take off from the Main Canal or from another branch. They all have names and are denoted on the plans by an abbreviation of the name and the letters Br.

Distributaries.—A distributary is any channel carrying more than 50 and less than 200 cusecs. It may take off the Main Canal, a branch, or another distributary. These are numbered serially on each bank from the head of each separate channel from which they take off and are denoted on the plans thus $\frac{\text{D. 3 L}}{\text{Nt. Br.}}$ meaning Distributary No. 3 on Left Bank of Nasrat Branch.

Minors.—A minor is any Government channel carrying less than 50 cusecs. It may take off the Main Canal, a branch or a distributary. These are numbered serially from the head of each separate channel from which they take off and are denoted on the plans thus $\frac{\text{M.1.R.}}{\text{M. C.}}$ meaning Minor No. 1 on the Right Bank of Main Canal.

Watercourses.—A watercourse is a channel owned by the Zamindars for supply to their lands. It may take off from a minor, a distributary or a small branch. These will be similarly numbered serially on each distributary or minor.

Canal Banks.—These are the artificial banks formed of consolidated earthwork, made to contain the F. S. L. of their channels.

Spoil Banks.—These are banks roughly formed from the surplus excavation of canals, not required for canal banks. They are not consolidated, and may be of any economical height.

Inspection paths and Service Roads.—These are made along the natural or silted berms or on the top of the banks of the channels and are intended for canal establishment only. They are not designed to serve as lines of communication for the district.

Section VII.

Alignment and design of Canals and Drains.

56. The following are the office instructions I issued for the design of canals :—

(1) Align canals and distributaries on the contoured plans, to run on ridges as far as possible, the line selected being generally the highest and flattest line on the country.

(2) Decide drainage lines, or artificial boundaries, between commands of all branches and distributaries.

(3) Take out by planimeter the gross area of each separate command thus defined.

(4) From gross area, by methods approved, obtain the areas of kharif and rabi cultivation.

(5) Calculate kharif and rabi discharges required at heads of distributaries by duties and methods approved.

(6) Add absorption losses in each distributary over 200 cusecs at the rate derived from approximate curve of absorption losses (obtained from Dr. Summers' Project figures).

Similarly add absorption losses in each length of branch and main canal. By these means obtain approximate total discharge required in each distributary, branch and main canal.

(7) For these figures of discharges take out from the discharge curves the approximate section and slope of each channel, starting from the lowest distributaries then designing the section of the branch or main canal to feed it and so on to head of canal, allowances being made for loss of head in regulators. Great detail and accuracy are not necessary for this preliminary set of calculations.

(8) Having decided by these means the sections, slopes, and F. S. Ls. of all channels, and having thus obtained the F. S. L. required at the head of the main canal, this F. S. L. must now be checked with the F. S. L. which can be provided by the Barrage, *viz.*, R.L. 193·0 (or otherwise, *vide* Report) at canal head (downstream side of regulator). If the F. S. L. found by 1 to 7 is higher than that to be given by the Barrage, the whole operation must be repeated to modify the level to suit that available.

(9) If the required F. S. L. as per steps 1 to 7 proves to be the same as or lower than that available from the Barrage, then the whole canal system can now be checked accurately, exact sections being calculated for all distributaries, branches and main canal, the wetted perimeters being calculated (for all channels carrying 200 cusecs or more), and the absorption losses at 8 cusecs per million square feet added. This will be the final project design of the channels.

(10) Plot longitudinal sections of all canals, branches and distributaries and where land to be commanded by watercourses is flatter than the ground line of the distributary, plot such lines also.

(11) (*a*) The F. S. L. must not be less than 1 foot above the highest point of ground level anywhere along the alignment of the distributary (excluding very small high patches).

(*b*) At the extreme tail of the distributary, *i.e.*, where it enters the drain, the minimum depth must not be less than 6 inches and may be as much more as condition (*a*) necessitates, while the bed level must not be below ground level.

(*c*) The above conditions must be combined with a F. S. L. at the head of the distributary, which will give a resulting surface slope in the distributary, which is not less steep than the slope in the branch from which the distributary takes off. This is not a *sine qua non*, but it is generally a desirable result. Where necessary it need not be worked to, provided that every channel has a non-silting velocity.

(12) For arriving at the first approximate F.S.L. of distributaries, after complying with conditions 11 (*a*) and (*b*) the surface slopes may be taken roughly for trial, to be not less steep than the following :—

For distributaries of—

50	cusecs	or	less,	minimum	slope	1	in	7,000
100	,,	,,	,,	,,	,,	1	in	8,000
200	,,	,,	,,	,,	,,	1	in	9,000
500	,,	,,	more	,,	,,	1	in	10,000

(13) In all canals, branches, and distributaries if the surface slope changes in different lengths of the same channel it must *invariably* become *steeper* towards the tail, and never be flatter than in a length above it.

57. The following further rules were issued for guidance in design.

(*a*) The value of ' N ' in Kutter's formula should be taken as ·020 for all channels of more than 200 cusecs discharge and as ·0225 for all channels carrying less than 200 cusecs, *vide* paragraph 62 of Inspector General of Irrigation's Note dated 29th January 1907 (Appendix K, Volume 6, 1909 Report).

(*b*) *Design of channels.*—The maximum velocity (mean) in any channel must not exceed 3·26 feet per second, which may be taken as the average velocity at which scour commences in Sind soils, *vide* Inspector General of Irrigation's Note dated 29th January 1907, para. 62 (Appendix K, Volume 6 of 1909 Reports).

(*c*) The critical non-silting velocity for all channels may be taken as ·75 times those given by Kennedy's formula for Punjab Canals, *vide* para. 21 of Inspector General of Irrigation's Note dated 17th February 1908 (Appendix K, Volume 6 of 1909 Reports). As the critical non-silting velocity for a depth of 13 feet by this rule is 3·26 feet per second, no channel may be more than 13 feet deep.

(*d*) In designing all channels, the section must be selected to give a velocity not less than the critical non-silting velocity for the depth of water used in the section.

(*e*) For any section of less depth than 13 feet, the critical non-silting velocity will be lower than the limiting non-scouring velocity. Any channel may be designed for a velocity anywhere intermediate between the non-silting and non-scouring velocity, and whenever possible it will be an advantage to design for a velocity, with full supply, somewhat higher than the non-silting velocity. This will usually give a more economical section, and also allows for a drop in velocity (and thereby a reduction of discharge, should this be necessary at any season) without inducing silting.

(*f*) Where, at a cross regulator on a canal, it is desired to reduce the depth of water below the regulator, while maintaining the same surface level as above the regulator, the reduction from the normal depth of canal up-stream may be obtained by making the bed of canal up-stream of regulator level, *i.e.*, without gradient, for a sufficient distance to give the reduction of depth. In order to get the required normal discharge in the shallowed section the width must be increased, so that at every point the velocity will be not less than the critical non-silting velocity for the depth at that point, and so that the resulting discharge shall be the normal canal discharge.

At no place should the canal bed be brought *up* in a step, as this would obstruct the steady flow of the lowest silt laden water.

(*g*) The sill level of any branch canal (or distributary) must be not higher than the bed level of the channel from which it takes off. If the bed level of the branch has to be higher than that of the main channel, a sloping floor should be made from sill level (at main channel bed level) to the required bed level of the branch, while the opening of the sluice for the branch should be of the submerged type, designed to pass the required discharge at a velocity sufficiently high to ensure the rising sloping floor to bed of branch, being kept clear of silt.

(*h*) In calculating the canal sections it should be assumed that the side slopes of the canal are at ½ to 1, as this is the slope to which they will eventually silt. But in estimating earthwork, these side slopes will be calculated as 1 to 1, to which they will probably need to be excavated.

(*i*) Where F.S.L. or bed level is above natural ground level, it will be necessary to assist the berms or bed to silt up to the desired levels. For this purpose brushwood and stake groynes will be provided at every 500 feet interval, and masonry profiles at every 4,000 feet. Where F.S.L. is more than 4 feet above ground level the groynes will be double ones, and where less they will be single.

Section VIII.

Design of Banks and Berms.

58. The following table shows the general dimensions of canal banks, which are incorporated in the type designs for various depths, included in the project plans :—

Channels.	Top width of side banks.	Free-board (Top of Bank above F.S.L.)	Berm outside banks giving vertical cover above 4 to 1 line of	Minimum width of final silted berm 1′ above F.S.L.
Main Canal and branches above—				
2,000 cusecs	8′	3′-0″	4′-0″	30′
1,500–2,000 cusecs	8′	2′-9″	3′-6″	25′
1,000–1,500 cusecs	8′	2′-6″	3′-0″	20′
750–1,000 cusecs	8′	2′-3″	2′-6″	15′
500–750 cusecs	8′	2′-0″	2′-0″	10′
200–500 cusecs	8′	2′-0″	1′-0″	10′
Distributaries—				
50—200 cusecs	5′	2′-0″	*Nil*	7′-6″
Minors—				
below 50 cusecs	3′	2′-0″	*Nil*	5′-0″

The following rules are followed in these type designs :—

(*a*) Top width of banks for all channels carrying more than 200 cusecs to be 8 feet. For smaller channels as shown in table.

(*b*) Free-board of banks varies from 3 feet maximum to 2 feet minimum according to size of channel, as shown in table.

(*c*) Side slopes on both sides of bank to be 1½ to 1, but on the outer side is added a sloping berm of 4 to 1 slope where necessary, to bring the 4 to 1 saturation line, drawn from the point where the F.S.L. meets the inner slope of bank, within this extended berm, with such vertical cover as shown in the table above. This vertical cover varies according to the size and importance of the channel from a maximum of 4 feet for the largest canals to a minimum of 1 foot for the smallest Branch of 200 cusecs capacity. For distributaries carrying less than 200 cusecs and all smaller channels, the 4 to 1 saturation line is kept just within the outer toe of bank, no vertical cover being considered necessary for these smaller channels.

(*d*) The width of the berm at F.S.L. is kept equal to twice the height of the F.S.L. above ground level (with the minimum widths shown in table above), this width being measured from the edge of the final canal section (with ½ to 1 side slopes) to the inner slope of the bank at F.S.L. When the berm is made of this width, a line drawn at a slope of 6 to 1 from F.S.L. at the edge of the final canal will meet at ground level the 4 to 1 saturation line, drawn from F.S.L. on inner slope of bank, thus giving always, for the final section, the vertical cover shown in above table, above the 6 to 1 saturation line.

When the minimum width of berm, as per table, is greater than that given by above rules, the 6 to 1 line falls further inside the bank, thus giving still greater cover than that laid down in the table.

(*e*) *Borrow pits.*—Where the quantity of earthwork in the banks is not greater than the excavation to form the canal section, the banks will be formed entirely from the excavation spoil, but where the quantity of bank-work is greater than canal excavation the balance will be obtained from borrow pits. Wherever possible and economical, these borrow pits will be made in the bed of canal. In order, however, to prevent their increasing the virtual section of the canal, and to induce them to silt up, the pits will not be made continuous, but each pit will be 90 feet long, with a solid bar of soil 10 feet wide between each two pits. A narrower bar, say, 2 or 3 feet wide between pits would be sufficient theoretically and would reduce the depth (by increasing the length) of the borrow pits but such a bar is liable to be trodden down or broken by the water when canal is first opened and hence does not serve its purpose. With the wide bars provided it is believed there will be no trouble in these respects and that silting will readily occur in the pits. Even if it does not do so, however, there will be a 10 feet wide profile at every 100 feet interval, so that the canal section is fixed. The depth of such borrow pits has been limited to 5 feet and the width kept 10 feet less than canal bed width, thus leaving a 5-feet berm at bed level along both sides of canal.

(*f*) Where this will not provide sufficient earth for the banks, the balance is obtained from other borrow pits, limited to a depth of one foot, made in private land beyond the limits of land to be acquired. The Commissioner in Sind's Order permits Government to make borrow pits not exceeding one foot deep in private land, without paying compensation, as such pits do no harm to the land, and usually the Zamindars have no objection.

Section IX.

Spoil Banks.

59. (*a*) Where the area of canal-cutting is greater than the area of the two canal banks, the balance of the excavated soil will be deposited behind the banks, in the form of a spoil bank.

Taking each foot of lift as equivalent to 12 feet of lead, it is found that the height of spoil bank to give the minimum average lead is given by the formula $H = \sqrt{\frac{A}{12}}$ where H = height of spoil bank, A = area of spoil bank, 12 = equivalent lead for 1 foot lift: and from above formula the mean width of spoil bank must be $\sqrt{12A}$, since mean width × mean height = area; or $\sqrt{12A} \times \sqrt{\frac{A}{12}} = A$.

This formula does not take into account the saving in cost of land which could be effected by making the height greater and width less, but it is found by trial that the saving in cost of the land has hardly any effect, unless the land be very expensive, say, above Rs. 600 per acre.

(*b*) The above rule for mean width and height of spoil bank has, therefore, been adopted. The spoil banks have been kept at such a distance from the canal banks as to allow for a 6-feet berm at canal bank level and a gutter 1 foot deep, 3 feet bed width and 6 feet top width between the canal bank and the berm of spoil bank.

(*c*) Adopting these rules, type sections have been drawn to suit each canal system, for various bed widths and depths of cutting.

From these sections the mean total lead is found by taking out graphically the centres of gravity of the cutting and the bank-work and spoil, and scaling the distances between them; each foot of vertical distance between the centres of gravity being multiplied by 12 to give equivalent lead, and added to the horizontal distance.

As the rates for earthwork are varied only for each 50 feet of lead, this method gives quite sufficiently accurate results, and is very simple. The bed widths and depths for the type sections have been so selected that intermediate values will not make a difference of mean lead greater than 50 feet, which is the minimum difference affecting the rate.

Section X.

Obtaining the cheapest section for Canals.

60. In lengths of canal situated below a fall regulator, the F.S.L. required to command the land by flow and the surface slope selected determine the lowest bed level of canal necessary. But in many cases this bed level and F.S.L. necessitate much cutting for the canal section, and it is often cheaper to raise canal bed and F.S.L. higher than required for command purposes. The cheapest position for the bed at any point is when the depth of cutting is such that the quantity of excavation is equal to the quantity of earthwork required for the banks. This depth is known as the " Balancing Depth " and is measured below ground level. The usual practice is to decide on a bed level and to measure above this the balancing depth, giving an imaginery ground line, the bed level being so fixed as to keep this imaginary ground line as near to actual average ground line as possible. If the ground were regular this would give an approximate result but as ground is very uneven this is a very rough and inaccurate method.

61. In the projects now submitted a more accurate but quite simple method has been adopted.

The surface slope, bed width and Full Supply Depth of the channel having been decided, there is only one " Balancing Depth " for this channel to give area of cutting equal to area of bankwork.

Hence if this balancing depth is measured above the proposed bed line at any section, the point thus given should correspond with the ground line.

62. A balancing depth line is therefore marked on the longitudinal section of the canal alignment parallel with the bed, and the two lines together then raised or lowered to bring the balancing depth line to touch the actual ground line at as many points as possible.

This gives the approximate economical section. Then the actual depth of cutting at every 4,000 feet point of the section is scaled off to the nearest half foot and the quantities of bank-work and excavation are calculated. (The bank-work quantities for the actual height of F.S.L. above ground level can be read off the type sections straight away.)

63. Now at first sight it would appear that if the total quantity of excavation in a given length of canal were just equal to the total quantity of bank-work, this would be most economical position for the bed. This is, however, a fallacy for the following reasons.

64. Assume that at a given point in the length being considered say at Mile 5, the quantity of bank-work is much greater than the quantity of excavation, while at Mile 6 the reverse is the case. Then if the totals of excavation and bank-work at these two points are equal it might appear that this is the most economical arrangement. But the surplus excavation at Mile 6 cannot be carried to Mile 5 to make good the extra earth required there, over and above the excavation at Mile 5, to form the bank at Mile 5.

65. Hence at every point calculated, *either* bank-work *or* excavation is considered according to which is the greater, the lesser quantity being neglected.

Then for the whole reach considered the totals of these greater quantities are taken giving a total of bank-work and of excavation for the whole reach.

66. If the trial position chosen for the bed was the most economical one possible, then these totals give the minimum possible quantities. To check this all quantities are again calculated for two different positions of the bed, *viz.* :—

(*a*) 6″ above the first trial position.

(*b*) 6″ below the first trial position.

Again the totals of bank-work or excavation of each section, whichever is greater, are taken out and compared with those obtained by the first trial.

67. Whichever of the total quantities obtained by trials (*a*) or (*b*) is found to be less than those obtained by the first trial, indicates that the bed should be either raised or lowered and by inspection it can be seen whether further raising or lowering (and by how much) will give the most economical position.

The final position is thus found and adopted and final quantities calculated for every reach of the canal, *i.e.*, between all points of off-take.

68. The operation is not so lengthy as it sounds, and it results in very great economy. The closer the intervals at which the sections are calculated, the more accurate will be the estimate, but it has been found by actual calculation that for a *given position of the bed* the quantities come to practically the same (difference ·03 per cent.) whether the sections are taken by actual ground levels at 500 feet intervals or at 4,000 feet intervals. But this position of the bed, although the most economical when calculating by 4,000 feet intervals, may not be the most economical possible, and by repeating the above procedure but calculating at 500 feet intervals, it is possible that a more economical position of the bed might be found. This can be done, after all canal alignments are set out on the ground and levelled. It may give a saving on the estimates now submitted.

Section XI.

Width of land acquired.

69. As the silted berms will eventually be used as service roads or inspection paths and at the opening of canals the top of bank will be used for this purpose, no provision is made for service roads outside the canal banks. The districts are moderately well served by country cart tracks and if further roads are required, these should be made out of District or Provincial funds. It is not a function of an irrigation project to provide roads for developing the country. Only a narrow strip of vacant land is acquired outside the banks, the total width being kept to an even multiple of 33 feet, as this facilitates the revenue survey greatly, these surveys being made always with the Gunter's chain of 33 feet.

Section XII.

Defining boundaries of Government Land.

70. The boundaries of the acquired land are everywhere defined by a small earthen bank, the contents of which are obtained from the excavation of a small drain on the inner side of the bank.

The small bank will prevent cultivators continuing their ploughing into the Government limits and the small drain will not only act as such, but forms the most difficult method of marking to obliterate.

On the main canals, above 2,000 cusecs discharge, the dimensions of the bank are 2 feet top width, 4 feet bed width and 1 foot height, while the drain has the same dimensions reversed. There is a small berm 2 feet wide between bank and drain so that the boundary of the Government land is always 8 feet from the centre of drain. In addition to these marks, boundary stones are fixed on the boundary line at intervals of 1,000 feet on both banks. For smaller channels the dimensions of bank and drain are slightly reduced, but boundary stones are fixed at similar intervals.

Section XIII.

Drainage Channels.

71. All natural valleys and drainage lines have been marked on the 1" Topo sheets in continuous green lines. In all cases these lines are left unobstructed and form the boundaries of irrigation of the distributaries, etc., on either side of them. Where it is necessary to carry the canal across drainage line, this is done either in a syphon, or an acqueduct, so as not to interfere with drainage. Where no natural drainage line exists as a convenient boundary for irrigation from any particular branch or distributary a suitable irrigation boundary is marked in dotted green on the Topo sheets, but no drain is excavated along such line. If found necessary, they could be cut afterwards, but they are unlikely to be needed.

72. All natural drains separating the commands of main canals and principal branches are called Main Drains. All natural drainage lines separating the commands of distributaries and minors are called Branch Drains.

73. It being essential to keep the drainage lines open and unobstructed, land will be acquired along all these.

On Main Drains a strip of land 99 feet wide, giving 12 acres per mile, is acquired and on Branch Drains a strip 49½ feet wide giving 6 acres per mile is acquired.

74. In many places the drains follow existing depressions, but may be blocked by ridges in places, and need some grading. Provision is therefore made for excavating along all drains a " directing channel " the depth of which will be varied to give a more or less steady gradient.

The provision made for this directing channel is for excavation 25 feet wide and average depth 4 feet along all Main Drains, and 15 feet wide and 3 feet deep along all Branch Drains.

75. Where Main or Branch Drains are crossed by important roads, provision is made for paved dropped causeways across the drains. Bridges are not necessary as there will be very little flow of water in these channels for most of the year.

76. (*a*) In the Right Bank Canal Systems, all drainage lines eventually tail into the Muncher Lake, and thence by the proposed great drain into the Indus at Sehwan.

(*b*) On the Rohri Canal System all Branch Drains run into Main Drains, and there are 8 of the latter, of these five drain into the Indus, two into the Dhoro Puran and thence to the sea and one into the Fuleli Canal (which also tails into Dhoro Puran).

(*c*) On the Eastern Nara System all drains flow into the Dhoro Puran, and thence to the sea.

77. Wherever the highest flood level in the river is greater than the ground level at the tail of a drain, a regulator is provided on the latter to prevent such high floods from flowing back into the drain. In such cases the drain could only work or empty itself after the river had fallen slightly.

Section XIV.

Escapes.

78. At a few places along the main canal where a large quantity of water is abstracted by an important branch, or branches, taking off above a cross regulator, it is very desirable, if possible, to make an escape from above the regulator on the main canal.

Then in the event of a serious breach in the main canal or of heavy rainfall below this regulator, it is possible to close the regulator, but still keep the main canal and the branches above the regulator working.

It is not necessary to make the capacity of the escape equal to that of the main canal below the regulator, since on the occurrence of such a breach, the head regulator of the canal should be at once manipulated to considerable reduce the supply in the canal, and all intermediate regulators should be manipulated to maintain F. S. L. on their upstream sides, with the reduced discharge.

79. But even supposing the regulator next above the escape, were almost completely closed, the closing of the regulator just below the escape would tend to head up the water and create a flatter slope, and a reservoir capacity in the canal above it.

It is to reduce this heading up and to take off the accumulated water, that the escape is first needed. Thereafter when normal F. S. L. is restored, the escape may carry off a sufficient proportion of the discharge otherwise flowing past the main canal cross regulator, to maintain, with the discharges of the branches, a moderate velocity in the main canal above this point, and thus prevent undue silting until the breach is repaired, and normal working conditions restored throughout the canal.

80. Escapes have accordingly been designed on all canal systems at suitable points, where possible, to pass a discharge varying from one-half to one-third of the discharge of the main canal below the point at which the escape takes off.

81. On the *Rohri Canal System* three escapes are provided. These all drain into the Indus and can work with F. S. L. in the canals and Highest Flood Level in the river.

82. On the Right Bank there are three systems of canals :—

(*a*) *North-Western Perennial Canal System.*—On this two escapes are provided from main canal and one from the Khirtar Branch. As the canal flows directly away from the river none of the escapes can be made direct into the river. They are all made to discharge into one or other of the drainage lines described in Section XI above, through which the water finds its way to the Munchar Lake and thence to the River. If the suggested containing banks for the Munchar Lake are constructed, the water can accumulate harmlessly therein and be drained into the river, whenever the relative levels of Lake and River permit.

(*b*) *South-Eastern Perennial System.*—On this system three escapes are provided from the main canal, and one from the Johi Branch. All three of the main canal escapes drain into the river and two of them can work with Highest Flood Level in the River and F. S. L. in canal. The third can work when the river is about one foot below H. F. L.

The escape from the Johi Branch drains into the main Western Nara Valley and thence to the Munchar Lake.

(*c*) *The Central Rice Canal.*—Two escapes, both into the Indus, are provided on this system. One can work with F. S. L. in Canal and H. F. L. in river, but the other can only work when the river is about 6 feet below its Highest Flood Level. It would be generally workable only during the rabi season or at the beginning and end of kharif season.

83. *The Eastern Nara System.*—Two escapes already exist on the Jamrao System and these drain into the Dhoro Puran. Two escapes are provided for the Mithrao Canal, and one for the Kipro Canal, all these draining into Dhoro Puran, and thence to the sea.

Section XV.

Plantations.

84. *Avenues.*—Provision is made on all canal systems for planting avenues of trees along the canal berms.

Two rows of trees will be planted on each berm of all channels carrying 2,000 cusecs or more. On these channels the berms have a minimum width of 30 feet and one row of trees will be close to the inner toe of the canal bank, and one row about 10 feet from edge of canal.

On all branch canals carrying between 2,000 and 200 cusecs a single row of trees is provided on each berm.

85. *Broadcast Plantations.*—On all canals it will be necessary to have stakes for repairing breaches, etc., and firewood for the local establishment. This will be obtained by sowing broadcast the seed of babul, etc., on the tops of spoil banks of all canals and branches. The width of these varies according to ground level, size of canal, etc., but provision is made for an average of 5 acres per mile, which is equivalent to a continuous strip about 20 feet wide, on each side of canal. This should be ample for all requirements, and will probably yield a balance for sale, at considerable profit to Government, but no credit is taken for such.

86. *Gardens at Inspection Bungalows.*—Lump sum provision is made for laying out vegetable and flower gardens at all inspection bungalows on all canals. A sum of Rs. 1,000 is made for a garden at a first class bungalow and Rs. 300 for that at a second class bungalow. These will add greatly to the comfort and amenities of life of the establishment.

Section XVI.

Mile stones, distance marks, bed level stones and discharge sites.

87. *Mile stones.*—These will be fixed on canal berm on one side of the channel only. Each stone will have the mileage cut on two opposite faces so as to be readable from either side of canal. They are provided at liberal rates on all channels carrying more than 200 cusecs.

88. *Distance marks.*—These will be stones set at every 1,000 feet on the berm on the opposite side of channel to the mile stones. They will similarly have the chainage cut on two opposite faces so as to be readable from either bank, and are provided on all Government channels of whatever size.

89. *Bed level stones.*—These will be stones about 1′—6″ by 6″ by 6″ set vertically in canal with their tops flush with designed bed level. They will be set at every 500 feet in all canals, branches and distributaries.

90. *Discharge sites.*—Specially prepared sections will be provided at the heads of all canals and branches and at the downstream side of the cross regulators of canals, where important branches take off, for the measurement of the discharge passing through the section.

These discharge sections will be 100 feet long and will be constructed with masonry profiles of designed canal section, at each end, and the space between profiles will be paved on bed and sides to correct section, with 6″ brick on edge, laid on 6″ broken ballast. This will ensure a steady velocity through the section and will obviate the necessity of measuring the section by soundings, as the true bed level and width will be recorded, and from the water level the exact sectional area and depth at each point can be calculated. It will only be necessary to measure the velocity by rods at each division of the width desired.

Arrangements will be provided for stretching measuring wires across each end of the section with hanging tags to mark the distances.

Section XVII.

Masonry works.

91. For project estimating it is neither necessary nor possible to give detailed working drawings of every masonry work separately.

Such working plans will be required for every separate work before construction is started, but before these plans are made it will be necessary to set out, on the ground, all canal alignments and to take trial pits at the site of each masonry work. This has not yet been done, but when the information is available the plans of each work will be prepared to suit the exact conditions, and it is probable that the foundations of regulators, etc., will be varied according to the nature of the soil.

92. In the absence of such detailed information it is necessary to estimate for all works being constructed under the worst possible conditions. Any modifications in the final designs will then result in savings. For simplicity and economy it is desirable to adopt, as far as possible, type designs for works of one nature.

93. In these projects, all regulators, road-bridges, falls and fall regulators have been estimated from certain type designs submitted with the projects. For syphons an acqueducts the numbers were so limited and the conditions of each so different that type designs were useless, and each work of these classes has been designed and estimated in detail.

94. For Regulators, Road-bridges, Falls and Fall-Regulators, of each of which there are a great number which could be divided into a few classes, the method of estimating has been as follows.

A Type Design for each kind of work has been worked out in detail for varying conditions of depth of water, width of canal, span of opening, etc. The cost of these has been estimated and the results plotted as curves.

95. The method of plotting these curves and the bases used, will be explained later in detail under each class of masonry work. From these curves the cost of each work of their class, for the designed dimensions of channel at site, was then read off and adopted in the estimates.

Section XVIII.

Buildings.

96. In his 1909 project for the Rohri Canal Dr. Summers worked out detailed designs and estimates for all Inspection Bungalows, Subordinates quarters, offices, servants quarters, stables, etc.

In the present project no plans have been prepared, and the estimates for buildings are based on plinth areas, usually taken from Dr. Summers' plans, but in some cases modified, and these areas are multiplied by suitable plinth area rates, to give total cost of each building. These rates are much higher than those taken by Dr. Summers, and allow for the increased cost of construction.

97. The actual provision for cost of inspection bungalows is about double the provision made in the Barrage Project, Volume I, for officers' bungalows at Sukkur, but the extra provision is necessary as these inspection buildings will be scattered in small units all over the country, so that rates will be higher. Also accommodation cannot be economically arranged in single units as in a big concentrated station. At Sukkur many amenities are provided separately from cost of bungalows, such as water supply, roads, lights, fans, Gymkhana, etc. It is considered therefore that the provision for inspection bungalows, etc. is reasonable. They will be detailed under each canal system.

Section XIX.

Canal sections—Ratio of bed width to depth.

97 (*i*) In designing some of the canals and branches it was necessary to adopt the flattest possible surface slope, in order to obtain water at as high a level as possible, for command purposes in the lower reaches.

In the case of canals with comparatively small discharges, when adopting these flat slopes, it was necessary to keep the depth of channel small, and the width greater, in order to obtain critical non-silting velocities. In no case is a canal designed to have less than its critical velocity, but in some cases the resulting channel has a bed width which bears a rather high ratio to its depth.

97 (*ii*) In a note dated 28th July 1917, Mr. F. W. Woods, Chief Engineer. Irrigation Works, Punjab, discusses this question with reference to Punjab Canals.

But it is a fact accepted by Government, that the critical velocity for Sind conditions, is much lower than that for the Punjab, and the Inspector General of Irrigation's orders allow us to take ·75 of the Punjab critical velocities for Sind channels. This difference in critical velocities makes a great change in all the deductions drawn in Mr. Woods' paper.

In this paper he lays down a table showing ratios of bed widths to depths, which may be adopted in the design of Punjab Channels of various sizes; but these ratios are admittedly only empirical, and are based upon measurements of actual channels, which have been found to work efficiently. They would be more convincing were they supported by measurements of other channels, with greater ratios, which had been found *not* to work efficiently.

But in any case, owing to the difference in the critical velocity, and the characteristics of Sind silt, they do not apply to Sind conditions.

97 (*iii*) A very valuable contribution to this subject is found in Mr. Gebbie's Completion Report on the Jamrao Canal, page 70, paragraphs 41 to 44, reproduced below :—

> "41. All the minors have silted to a certain extent and for the first four years, this silt was annually removed according to the general practice in Sind; but careful observations were taken every year when the minors were re-opened after clearance. In every case it was found that within one month

after reopening, silt had again accumulated to exactly the same extent as just before the clearance was done and that it did not increase appreciably during the remainder of the year. As full supply can be put into all minors, even when silted, by raising the water in the main canal at the regulators, it was decided in 1905 not to clear any minors. In April 1906, there was no more silt in the minors than in May 1904. It seems to be clear that the minors have been silted to sections suitable to the volume of water they are required to discharge and that clearance, in addition to removing the water-tight lining formed by the silt, is mere waste of money. In spite of this, orders were issued last April that certain minors were to be cleared between the middle and end of that month. These orders were carried out and all minors were re-opened after clearance not later than May 5th. They all began to silt immediately and before the middle of June, as much silt had accumulated as had just been removed. No one, except the contractors, derived the slightest benefit from this clearance because kharif cultivation is not begun till the 15th of June at the earliest.

" 42. As originally excavated, the proportion which the depth of water at head bore to the bed width appears to have been much too small except in the case of four of the minors. The following table shows the designed depths of water and bed widths at head of the principal minors and the present silted and apparently stable sections. It will be seen that, as designed, the proportion of depth to bed width in the majority of minors was not greater than 1 to 1.5, while in the silted sections this proportion is, with one exception, not less than 1 to 3.

" 43.

Designed sections.			MINOR.	Actual sections.		
Depth.	Bed width.	Proportion of depth to bed width.		Depth.	Bed width.	Proportion. of depth to bed width.
4.0	14.0	1 to 3.5	Jamsahib	2.8	12.0	1 to 4.5
4.0	10.0	1 to 2.5	Ahmedabad	1.9	9.0	1 to 4.7
7.0	19.0	1 to 2.7	Dim	5–2	23.0	1 to 4.4
6.0	6.5	1 to 1·1	Rawatiani	3.0	9.0	1 to 3.0
4.5	6.0	1 to 1.3	Rind	2.6	12.0	1 to 4.6
4.5	6.0	1 to 1.3	Sinjhoro	2.4	8.0	1 to 3.3
8.0	9.5	1 to 1.2	Dalor	4.4	13.0	1 to 3.0
8.0	9.5	1 to 1.2	Patoi	3.6	14.0	1 to 3.9
5.0	5.75	1 to 1.15	Berani	1.8	9.0	1 to 5.0
6.0	12.0	1 to 2.0	D. Dhararo	2.2	14.0	1 to 6.4
6.0	9.5	1 to 1.6	Mirpur	3.5	16.0	1 to 4.6
6.0	10.0	1 to 1.7	Kahu	5.5	12.0	1 to 4.5
5.25	7.25	1 to 1.4	Sanro	3.0	14.0	1 to 4.6
6.5	9.0	1 to 1.4	Bareji	2.6	20.0	1 to 7.7
8.0	12.0	1 to 1.5	Puran	6.0	18.0	1 to 3.0
6.0	6.0	1 to 1.0	Labko	2.6	10.0	1 to 4.0
6.5	10.0	1 to 1.5	Dengan	2.7	24.0	1 to 8.8
6.0	10.0	1 to 1.7	Daleri	4.0	16.0	1 to 4.0
6.5	9.5	1 to 1.5	Juriasar	4.0	12.0	1 to 3.0
4.8	16.0	1 to 3.3	Silor	3.7	14.0	1 to 3.8
4.3	16.5	1 to 3.8	Bagi	3.3	14.0	1 to 4.2
4.1	7.5	1 to 1.8	Kapri	2.5	8.0	1 to 3.2
4.0	12.0	1 to 3.0	Lakhaki	3.2	12.0	1 to 3.8
5.7	6.5	1 to 1.1	Bhitaro	3.4	10.0	1 to 4.0
5.5	5.5	1 to 1.0	Daulatpur	3.2	10.0	1 to 3.1
4.5	5.0	1 to 1.1	Gorchani	2.5	10.0	1 to 4.0
7.0	9.0	1 to 1.3	Digri	3.6	22.0	1 to 6.1
6.7	8.0	1 to 1.2	Murid	6.1	10.0	1 to 1.64

" 44. The Murid minor is the only one in which the proportion of depth to bed width in the silted section is less than 1 to 3. This minor has a bed fall of 9" per mile and it also takes off the West Branch in the 42nd mile, *i.e.*, very nearly 100 miles from the canal. There is, therefore, probably less silt in the water than higher up the canal. This and the steep bed fall will account for the section being so different from those of all the minors. The Bareji and Dengan, in which the proportion of depth to bed width is very great, have bed falls of only 4" per mile and the Doso Dhararo, in which the proportion is also high, has no cultivation in its first four miles. "

97 (*iv*) The table in paragraph 43 would have been still more interesting and useful had the discharges and surface slopes of each minor been given. I have obtained these figures for the most extreme case Dengan Minor in the table.

It will be seen that this minor had originally a width depth ratio of 1.5 to 1 and a depth of 6.5, while the bed slope was 1 in 16,000. If the surface slope was parallel to bed slope, the discharge of the channel must have been 130 cusecs (now only 75 cusecs), while the calculated velocity was 1.45 feet per second, as against 2.08 feet per second, the Sind critical velocity for a depth of 6.5. Hence the channel was bound to silt. Silting occurred and the channel had to be widened as shown by Mr. Gebbie, until the width-depth ratio had increased to nearly 9 to 1, after which it worked satisfactorily, and is still of the same dimensions.

The channel now carries 75 cusecs with a surface slope of 1 in 10,560. The actual mean velocity is 1.09 feet per second and the Sind critical velocity for its depth 2.7″ is 1.1 feet per second, so that with this large ratio of width to depth it works satisfactorily with a velocity slightly less than the accepted critical velocity.

But this is the *minimum* width-depth ratio at which this channel will work satisfactorily and there is nothing to show that, if desired, it would not work, satisfactorily with a still higher ratio.

97 (*v*) At the head of the Jamrao Canal the bed width is 165 feet and depth only 5 feet, or a ratio of 33 to 1. This gives some trouble owing to the difficulty of passing the required discharge over the high bed, and to the high velocity of water in the weir approach channel, during the flood season; and this ratio may be considered unsuitably high for such a shallow depth.

97 (*vi*) Even at the heads of the proposed canals, where the depth is much greater, the maximum ratio has been limited to 27 to 1, whereas in the Punjab for a canal of similar discharge Mr. Woods allows a ratio of about 50 to 1.

97 (*vii*) On a few branches of the proposed Right Bank canals it is necessary to use as flat slopes as possible, and to give a fairly high ratio of bed width to depth, especially in a few short reaches above regulators, where depth of canal has to be reduced without changing the slopes.

At all such points the velocity is kept slightly above the critical velocity, so there should be no fear of silting, and in only one case *viz.*, immediately above the head of the tail distributary of the Khirtar Branch, is the ratio unusually high, *viz.*, 22 to 1. At this place the ratio steadily reduces in a length of 4 miles to the normal ratio of the canal *viz.*, 8.4 to 1 for a depth of 4.4 feet.

97 (*viii*) The table below shows the most extreme cases of the Projects now submitted, and from my own practical experience, and study of the question, I have no hesitation in recommending them as reasonable and likely to work satisfactorily. It must be remembered that only surface water will be taken from the river, and that the velocity in the approach channels to canals at the Barrage, will be kept low.

97 (*ix*)—

Details of channel.	Slope.	Depth.	Width.	Ratio Width / Depth.	Discharge.	Velocity.	Critical velocity.
1 2	3	4	5	6	7	8	9
Khirtar Branch—							
above regulator at head of tail distributary — reducing in 4 miles length to	1/12,000	3	67	22	274	1·33	1·05
above regulator at head of tail distributary — the normal ..	1/12,000	4·4	37	8·4	282	1·63	1·0
above regulator No. 2 — reducing in 12,000′ length to ..	1/12,000	4·7	66	14	574	1·79	1·05
above regulator No. 2 — the normal ..	1/12,000	5·6	50·5	9	580	1·94	1·02
at head of D 3 L—Kh. Br. — reducing in 12,000′ length to ..	1/13,000	5·7	77·5	13·5	901	1·97	1·04
at head of D 3 L—Kh. Br. — the normal ..	1/13,000	6·4	65	10·1	988	2·08	1·01
at head of D 2 L—Kh. Br. — reducing in 10,000′ length to ..	1/13,000	6·4	75·5	11·7	1,065	2·11	1·02
at head of D 2 L—Kh. Br. — the normal ..	1/13,000	7·0	66	9·5	1,070	2·2	1·01
Kurshah Branch—							
head of tail distributary .. normal ..	1/12,000	4·3	41	9·5	306	1·63	1·02
head of D 1 L—Kur. Br. — reducing in 8,000′ length to ..	1/12,000	4·7	49	10·4	422	1·74	1·02
head of D 1 L—Kur. Br. — the normal ..	1/12,000	5·3	41	7·75	425	1·48	1·0
Johi Branch—							
head of D 3 L—J. Br. — reducing in 12,000′ length to ..	1/12,000	4·5	57	12·7	452	1·72	1·04
head of D 3 L—J. Br. — the normal ..	1/12,000	5·5	41·5	7·5	488	1·86	1·0
at head Eastern Nara Supply Channel ..	1/16,400	11·5	350	30·9	12,200	2·99	0·99
at head R. B. Rice Canal ..	1/15,500	12·75	291·5	22·8	12,346	3·25	1·01
at head S. E. Perennial Canal ..	1/13,000	9 75	98	10·0	2,757	2·78	1·03
at head N. W. Perennial Canal ..	1/15,000	9·5	165·5	17·4	4,313	2·67	1·00
at head Rohri Canal ..	1/15,600	13	253	19·5	10,992	3·26	1·00

PART III.

THE DESIGNS AND ESTIMATES FOR MASONRY WORKS.

INDEX

PART III.

DESIGNS AND ESTIMATES OF MASONRY WORKS.

Section I.

General.

98. All designs for masonry works, whether type designs or for particular works, have been prepared by Mr. F. L. Gordon, Executive Engineer, assisted by Mr. W. E. Bushby, Assistant Engineer, under my instructions.

I accept full responsibility for the general designs of all works, which were all roughly outlined by me, and most of the general features either done to my instructions or elaborated by Mr. Gordon and approved by me. For the details of the designs and for all calculations and estimates Mr. Gordon accepts full responsibility, the short time at my disposal and the amount of the work to be supervised making it impossible for me to check calculations, although by frequent inspections of the designs I have been able to suggest many modifications of details.

99. It is not claimed that the plans represent the very best possible design for any particular case, but an endeavour has been made to provide type designs which give thorough stability in every respect, combined with reasonable economy, permanence and ease of operation. Had more time been available it is probable that both Mr. Gordon and I would have been able to make alterations giving better or more economical designs, but the time for completion has been so limited by Government, that it has been a continuous rush to merely complete all designs and estimates. It is hoped, however, that they will be found to be based on sound engineering practice and theory, and to be both economical and of good appearance.

100. In the case of reinforced concrete structures, such as aqueducts and syphons, these have been designed by accepted theory to the best of our ability, and are believed to provide fairly economical and practical design. The actual disposal of the reinforcement is not of great importance from the point of view of this project as the estimates are based on a through rate for reinforced concrete. The designs were necessary to obtain the dimensions and quantities approximately needed. However, as neither Mr. Gordon, nor myself, is a reinforced concrete expert, it is very probable that more experienced designers could redesign the structures to be more economical. All such modifications should create savings, as in all structures our endeavour has been to provide an ample margin of safety. Each class of structure will now be described.

Section II.

Regulators—Type Designs.

The pavement and protection of Bed and Sides.

101. The floors of the regulators have been designed like the floors of the Barrage and the Head Regulators of all canals, by the method given by Bligh in Chapter VI of his book " Practical Design of Irrigation Works."

102. The hydraulic gradient, or ratio of length of creep to head of water, has been taken as 15 to 1, on the assumption that the foundations may be in fine sand. If trial pits at any actual site of a regulator show that the soil at foundation level will be different, then the final working drawings of that regulator can be designed to suit, and any such variation will give a saving on the project estimate.

103. In the 1909 Project for Rohri Canal, Dr. Summers had at his disposal information as to the actual soil at the site of each of his main canal regulators and accordingly he designed two types of floors. In one type he states he adopted a hydraulic gradient of 1 in 10 for floors founded on sand and in the other type a hydraulic gradient of 1 in 6 for floors founded on clay. (See File No. 2—Estimates of Regulators and Syphons—1909 Project.)

104. On his plan No. 47, Volume V, he shows a diagram and calculations for a floor designed for 6 to 1 hydraulic gradient, but there are several rather serious errors in this design. In the first place Dr. Summers does not design for full cut off, *i.e.*, for full water level upstream of gates and canal empty below, whereas Government orders are to design for these conditions in every case. Secondly, he takes the weight of his floor masonry as having specific gravity 1·8 or about 112 lbs. per cubic foot, which is its weight in air, whereas it should be considered as submerged masonry, in which case its specific gravity is reduced by the weight of water it displaces, *i.e.*, to 0·8.

Thirdly, he calculated as though his impervious floor ends at 57 feet from the gates (giving a 6 to 1 hydraulic gradient for 9·5 feet head assumed) at which point water should be free to ooze out at bed level with no resistance, whereas he actually has an impervious floor extending another 100 feet, giving total length from gates 157 feet and an actual hydraulic gradient of 16·5 to 1 for which his floor is far too light.

This is one of the very few details of Dr. Summers' Project in which any serious error has been found.

105. (*a*) A hydraulic gradient of 1 in 15 is necessary for fine sand and has been adopted throughout the present projects, in the absence of definite information about foundation soils.

(*b*) All floors are designed for full cut off, *i.e.*, F. S. L. in canal upstream of gates and canal empty downstream of gates.

(*c*) The weight of masonry in the floors is taken as 110 lbs. per cubic foot (brickwork in lime) and is treated as submerged in calculating its weight for resisting upward pressure, *i.e.*, its effective weight is 48 lbs./cft.

(*d*) As much as possible of the total necessary length of impervious floor is kept upstream of the gates as this reduces the thickness required, but a minimum length of about 50 feet is kept downstream of the gates, which gives about 15 feet beyond the end of the easewaters to protect the area covered by eddies around the latter.

(*e*) Beyond this point it is assumed that protection from all scour can be given by a previous flooring of brick pitching, etc.

(*f*) Stability diagrams are drawn showing the upward pressure at each point of the floor and the effective weight of masonry provided to resist it. This weight is everywhere not less than 33 per cent. in excess of the upward pressure.

The thickness of the floor is reduced downstream by steps, as the upward pressure is decreased by the resistance of the soil through which the water travels.

(*g*) The longitudinal section of the floor is constant under all spans and piers, the latter being built on the surface of the floor which will form the foundation for the piers. In some cases, however, the floor thickness near the downstream end of the piers is less than 4 feet, and in such places the floor is thickened to 4 feet just below the pier, to give sufficient foundation bearing the latter.

(*h*) Throughout the length of the impervious floor upstream of the gates, the sides of the canal are also made impervious by a layer of solid masonry laid at a slope of $\frac{1}{3}$ to 1 while downstream solid masonry wing walls extend to the end of the impervious floor.

(*i*) In all masonry works it has been made an invariable rule that solid masonry, whether on bed or sides, should not adjoin natural soil (at surface level), as the latter is certain to be eroded by eddies at the edge of the masonry.

In all cases an intervening protection of loose pitching is provided between the end of natural soil and the beginning of solid masonry. This pitching can settle into the slight scour which will occur at its junction with soil, but will protect the end of solid masonry.

(*j*) Thus on the upstream side of all regulators provision is made for pitching on bed and sides for a length of 20 feet beyond the end of the impervious masonry floor.

(*k*) On the downstream side of regulators, protection against scour is provided partly by loose concrete blocks laid on brick ballast and partly by dry brick pitching and ballast for such a total length as to bring the end of the protection on bed and sides to a distance, from the gates, equal to 20 times the full head of water.

(*l*) In the case of ordinary regulators the length provided by concrete blocks is 50 feet, and this consists of blocks 12″ deep × 3½′ × 2′ in plan, laid on 12″ of brick ballast. While beyond this the balance of protection as above consists of dry brick pitching laid on brick ballast, and the thickness of both is reduced in steps according to the total length provided, varying from 12″ brick on 12″ ballast, to 3″ brick on 3″ ballast.

(*m*) In the impervious masonry of the main floor, the top 12″ layer consists of 12″ bricks set on end in hydraulic lime mortar.

(*n*) The clear width of waterway through regulators is kept the same as the normal mean width of waterway of the canal below the regulator.

Superstructure.

106. (*a*) In all regulators, falls, etc., a district road bridge is combined with them, and is formed on brick masonry arches carried, side by side with the regulator superstructure, on the same piers.

(*b*) The regulator superstructure consists of two separate brick arches with a gap of 6 feet clear between them. In this gap will be suspended the gates and counterweights.

(*c*) On the type designs, the gates are in all cases shown as single leaf gates, and the counterweights are designed of double the weight of gates, with half the travel of gates.

If it is desired instead to use double tier gates, these and their counterweights will be of less thickness than the single ones shown, and the 6 feet gap allows sufficient room for adopting these double gates if desired.

(*d*) The gates and counterweights will be supported on pulleys and machinery fixed on the top of piers and on girders spanning the gap, in the same way as in the design for the Canal Head Regulators. (See Volume I, Part III, Sections III, IV and VII.)

(*e*) All machinery will be worked by hand, and will require very little labour and be quick and delicate in operation.

(*f*) Provision is made for steel gates fitted with Ashford's Roller Bearing Roller Boxes.

(*g*) The counterweights will be made of reinforced concrete, the cost of which and of all machinery is included in the through rate of Rs. 45 per square foot of gate.

(*h*) At the top of the Regulator Bridge the 6 feet gap between the two arches is spanned by reinforced concrete beams, covered with slab flooring, while parapet walls are built on each outer side of bridge giving a clear working platform 12 feet wide between parapets. All machinery is fixed on, and will be operated from, this platform or bridge. Access to this is given at one end of the regulator by a staircase leading up from bank level.

107. Type Designs on these lines have been prepared for Regulators of the following spans :—

25 feet clear span—12 feet depth of water.

20 feet clear span—13 feet depth of water.

15 feet clear span—13 depth of water.

10 feet clear span—13 feet depth of water.

And for Regulator floors for total cut off with the flooring depths of full supply in canal, *viz.*, for every even foot of depth from 5 feet to 13 feet depth, *i.e.*, 9 designs.

The Estimates.

108. The type estimates have been prepared from these designs, for the following :—

(*a*) One running foot width of each kind of floor.

(*b*) One abutment and all wing walls, approaches and side protection to canal down to bed level together with complete half span of whole superstructure (Regulator bridge and Road bridge).

(*c*) One ordinary pier down to floor level together with all superstructure for a complete half span on either side of it.

109. From these type estimates, by selection and combination, it is possible to obtain the estimate for any complete regulator of any number of spans, of any width, for any head of water required, within the limits of the type designs which are sufficient to cover all regulators required.

The curves of cost.

110. To prepare such composite estimates, however, even from the type estimates, is a fairly lengthy process, and as there is a great number of regulators a curve of costs was prepared from certain specific estimates prepared, and from this curve the cost of any required regulator can be read off at once.

111. From careful investigation of the results obtained from the specific estimates, it was found that the cost varied almost proportionately with the variation of the area of waterway in the regulator, but that the *rate* of variation also differs according as the area of waterway is given by great or small depths of water. To allow for this two separate curves were plotted, one for depths up to 9 feet, and the other for depths above 9 feet.

112. These curves are attached (see plate No. 1) and the actual estimated costs of specific cases, from which they were prepared, are shown thereon. It will be seen that the curves follow the actual cost points very closely, and are therefore quite sufficiently accurate for project estimates.

113. The abcissa of the curves is in square feet of waterway and the ordinates in rupees of cost.

In similar curves of cost, used in Punjab estimates, the abcissa is in running feet of clear waterway, but we find the cost does not vary evenly with this dimension, but with the *area* of waterway.

Section III.

Plain Falls and Fall Regulators—Type Designs.

114. Where a drop is required in the F. S. L. of any canal a masonry structure is required to effect the fall. This structure may be, either—

(*a*) a Plain Fall, *i.e.*, a structure in which the waterway is so limited as to require a high velocity to pass the discharge of the canal through it, thereby using up vertical head and causing a fall in water surface below the structure, or

(*b*) it may be a Fall Regulator, *i.e.*, a structure in which the waterway is similarly restricted, but with the addition of regulating gates by means of which the waterway can be entirely or partially closed.

115. Fall Regulators are only provided at those places, where it may be advantageous to completely or partially close the canal in the event of a breach or for other cause requiring a reduction of discharge and water level downstream. Such places will be only where a branch or an escape takes off immediately above the Fall Regulator. Where a fall in water surface is provided in order to reduce height of banks, and there are no channels taking off immediately above the fall, it would be no advantage to have a regulator at the fall, since the next regulator above the fall might equally well be closed, and would not cut off the supply of any more branches than would a regulator at the fall itself.

Plain Falls.

116. The method of restricting the waterway through a " Plain Fall " may be effected in several ways—

(*a*) By restricting the horizontal width and keeping full upstream depth through the Fall.

(*b*) By restricting the vertical depth and keeping full horizontal width.

(*c*) By a combination of both methods (*a*) and (*b*) using rectangular openings.

117. Methods (*b*) and (*c*) have the disadvantage that any obstruction raised above the upstream bed of the canal tend to cause silt deposit above the fall.

Method (*a*) may be effected in two ways—

(*i*) by making rectangular openings of constant width down to bed level ;

(*ii*) by making V shaped openings or notches having the narrow part of opening at upstream bed level.

The notch method has this advantage, that where the water level in the canal upstream is liable to fluctuations, the notch gives a proportionate decrease of level and discharge downstream ; whereas the restricted rectangular opening for a given decrease of level and discharge upstream give a greater than proportionate decrease of level and less than proportionate decrease of discharge downstream. But where a fluctuation of F.S.L. in the canal is not likely there is no advantage in the notch system, and it is far more expensive.

118. But for all the canal systems now designed the F.S.L. and discharge can be guaranteed all the year round by the Barrage, and this F.S.L. must be maintained at all times to command the irrigated areas by flow. Hence it is no advantage, nor is there any necessity, to provide notched falls, and all falls are therefore designed as rectangular openings.

119. The floor of the openings being kept at upstream canal bed level it is necessary to restrict the horizontal width of opening according to the loss of head required and this results in a great shortening of the structure and thereby greatly reduces the cost.

120. In his 1909 Project, Dr. Summers made the width between abutments of all Falls and Fall Regulators equal to the canal bed-width on the downstream side. By the method adopted in the present projects a very large saving over his designs has been effected, in spite of the new designs providing a much heavier pavement (designed for 1 in 15 hydraulic gradient), all masonry rates being increased by over 30 per cent. and the weir wall being made of heavier section.

121. In the case of Plain Falls the cost of revised designs, for any given conditions, at revised rates is not more than Dr. Summers' original estimates, and in the case of Fall Regulators the revised estimates, for given conditions, are 50 per cent. less than Dr. Summers' estimates, owing to the great saving in cost of gates, due to the shortening of the regulator.

122. At such a Fall Regulator it will be necessary before construction to design carefully the arrangement of the heads of branches and distributaries taking off above it, so as to effect the reduction of width in the most economical manner and to give good hydraulic properties to the reducing section.

As an example of how this can be conveniently done, one of the most complicated cases on the Rohri Canal has been drawn out as a type arrangement. This is shown on Plan No. 17—Rohri Canal (Volume XV).

123. It is seen that if full provision for the floor and superstructure of the Fall Regulator, and for each of the branch or distributary head regulators, is taken from the type designs, this allows more than sufficient masonry for the combined structure ; and hence no extra provision is made in the estimates for combining them.

Rules adopted for design of Falls and Fall Regulators.

PLAIN FALLS.

124. (*a*) The floors are designed on the same principles, as those of the Regulators.

(*b*) The sill has been kept level with upstream canal bed.

(*c*) The width of clear opening has been designed to give a calculated discharge, adopting 0·60 as the coefficient of discharge, of 10 per cent. in excess of the required downstream discharge. This 10 per cent. excess is given to allow for possible error in coefficients. If, in actual working, it is found that the actual discharge is greater than that required, it will be very easy to further restrict the area of waterway either by inserting vertical needles, for which provision could be made at time of construction, or by building a low pierced masonry sill on the weir wall of the fall. The pierced openings would prevent the accumulation of silt upstream. If the fall were built to the exact dimensions estimated to be necessary and the calculations were inaccurate, it would be extremely difficult to increase the waterway, but if it is considered that information is sufficiently reliable to design accurately, the waterway of the falls can be built at once to estimated size. This would effect a saving on the estimates now submitted.

(*d*) The weir walls are of ample section designed on Bligh's rules for such walls.

(*e*) The top 12″ layer of the impervious flooring consists of 12″ bricks laid on end in cement mortar.

(*f*) No drop tank, below downstream bed level, has been provided below the weir wall, as it has been proved both practically and theoretically that this is unnecessary, there being no impact.

The normal downstream bed level of the canal continues along the floor, right up to the back of the weir wall. The omission of this tank gives a great saving in cost of floor, and of piers, and abutments.

(*g*) As the velocity of approach upstream increases as the canal section is narrowed to the Fall, extra provision has been made for protecting the bed and sides of canal. This consists of a length of 50 feet of concrete blocks 12″ × 3′-6″ × 2′-0″ laid on 12″ brick ballast and beyond this a length of 50 feet of 12″ dry brick pitching laid on 6″ brick ballast and beyond this again 40 feet of 6″ brick pitching on 3″ ballast, giving protection for a total length upstream about 150 feet from the edge of the Fall.

(*h*) On the downstream side the impervious floor extends about 15 feet beyond the end of the Road-bridge piers, at about 40 feet beyond the toe of the weir wall, and the masonry wing walls of the abutments extend the same distance. Beyond this point concrete blocks laid on 12″ ballast extend for 100 feet further, on both bed and sides, and beyond this again dry brick pitching on brick ballast, for such a distance as to make the total downstream protection, to bed and sides, extend to a length equal to 20 times the full supply depth upstream.

(*i*) A District Road Bridge is combined with all Falls.

125. Type designs for the following Plain Falls are accordingly submitted :—

Four spans of 25′	Fall 5′	Depth upstream 13′
Three spans of 20′	Fall 4′	Depth upstream 12′

Estimates for these two types are worked out.

126. In his 1909 Project, Dr. Summers designed in detail a large number of notched falls, and detailed estimates for many falls on the Sutlej Valley Project are also available. On analysing these carefully it was found that the cost of a fall did not vary merely with the depth of fall, but with depth of fall *plus* F. S. Depth upstream.

Thus in canal of given width and depth 13 feet, the cost of a 5′ Fall does not cost $\frac{5}{2}$ times that of a 2′ Fall, but $\frac{13+5}{13+2}$ times the latter. The sum of the depth and fall may be called the " false depth " and if this is multiplied by the clear width of waterway in the fall, it will give the " false area of waterway ". In plotting curves of cost, therefore, the " false waterway " has been used as the abcissa and cost in rupees as the ordinates.

127. It was found that for all Plain Falls in the present projects the false waterway lay between or near those obtained from the two type estimates, and these two therefore gave sufficient length of curve for estimating others required. Plate No. 2 shows the curves of costs obtained from—

(*a*) Dr. Summers' estimates.

(*b*) Sutlej Valley Project Estimates.

(*c*) The type designs submitted with present projects.

FALL REGULATORS.

128. The design of floors of Fall Regulators combine the rules for design of ordinary regulators floors and Plain Fall floors, the designed head being taken as F. S. L. upstream of the regulator and no water downstream.

129. The design of the superstructure is the same as for ordinary regulators, except that the piers are deeper on the downstream side of the weir wall.

130. Type designs for the following conditions have been prepared, but of these only the first two are submitted with the fair project :—

(*i*)	Fall regulator,	span	25′,	depth u/s	13′,	fall	5′
(*ii*)	,,	,,	,,	20′	,,	,,	13′	,,	3′
(*iii*)	,,	,,	,,	20′	,,	,,	6′	,,	2′
(*iv*)	,,	,,	,,	25′	,,	,,	13′	,,	2′
(*v*)	,,	,,	,,	25′	,,	,,	7′	,,	2′
(*vi*)	,,	,,	,,	15′	,,	,,	12′	,,	4′
(*vii*)	,,	,,	,,	15′	,,	,,	7·5′	,,	2·5′

131. From each of these designs detailed estimates were prepared for fall regulators actually required in the projects. These points are plotted in a curve of costs shown on Plate No. 3.

In this case it was found that cost follows very closely the " false waterway " obtained by multiplying the clear width of opening of the regulator by the sum of depth of F. S. upstream and drop in canal bed. These false waterways are plotted as abcissa and the cost in rupees as the ordinates of the curve.

132. The cost of all fall regulators in the present projects has been read from these curves.

SECTION IV.

Road Bridges—Type Designs.

133. Only two types of road bridges are adopted, *viz.* :—

(*a*) District road bridge, width between parapets 18 feet, and between wheel guards, *i.e.*, clear roadway 16 feet.

(*b*) Village road bridge, width between parapets 10 feet, and between wheel guards 8 feet, *i.e.*, clear roadway.

134. All bridges are designed with brick masonry arches, of varying spans, to suit the various sized channels they have to bridge.

In wide channels large span arches will generally be used, so that pier obstruction in the canal may be reduced as much as possible. A span of 25 feet is an economical one, and easy to construct.

135. The following rules have been observed in designing :—

(*a*) Springing level of arches to be kept 1 foot above F. S. L. of canal. This allows for a possible raising of the F. S. L., should this ever prove necessary.

(*b*) The rise of arches is in all cases 5 feet, giving a total clearance of 6 feet between F. S. L. and soffit.

(*c*) All parapet walls are 3 feet high above road level, and are provided on the inside with a continuous kerb, or wheel guard, 1 foot wide.

(*d*) The width between the abutments will be kept, as nearly as possible, the same as canal bed width. The obstruction caused by piers, etc., is counterbalanced by increasing the depth through the bridge, so that the total area of waterway shall be the same as in the canal. This is done by lowering the canal bed between the piers.

In the type designs this lowering is shown as 18 inches, but each bridge will be calculated separately to suit its conditions and the lowering varied between one foot and two feet, so as to give a mean velocity, through bridge, not less than the critical non-silting velocity for its depth. With the eddies created by cut-waters the bed under the bridge is not likely to silt.

(*e*) The bed between piers is paved with 6 inches brick on edge in lime mortar, laid on 6 inches concrete and a head wall is provided upstream and downstream at the ends of piers and drop. The bed and sides of canal for a length of 20 feet upstream and downstream of bridge are protected with 3 inches dry brick pitching on 3 inches brick ballast.

(*f*) Curved return walls are carried into the banks from the back of the abutments and are provided with parapet walls and kerbs at road level.

(*g*) Short masonry wing walls are made upstream and downstream of abutments to run the side slope of canals into the vertical face of abutments.

(*h*) Small paved ponds with steps are formed in the berms on both sides to a depth of two feet below F. S. L., from which the villagers and passers-by may obtain drinking water without damaging the canal sides.

(*i*) The foundations of the piers are carried 4 feet below the paved bed level between them, and are given 3 offsets of 6 inches each on each side of pier to increase base width of founds to 3 inches more than that of the pier. The load on piers and foundation soil are kept very low.

(*j*) The canal banks are raised to meet the road bridge level by gradients of 1 in 30 on each side of bridge.

(*k*) The District road approaches the bridge on either side by an embankment with a gradient of 1 in 50, and top width of 16 feet.

136. Village Road Bridges are of exactly the same design and dimensions as District Bridges except that the width of bridge is decreased by 8 feet.

137. Type designs have been prepared for District Road Bridges having 25 feet span, 20 feet span, 15 feet span and 10 feet span.

From these type designs, type estimates have been prepared for—

(*a*) The cost of an abutment and approaches with all side and bed protection and superstructure for half a span on one side.

(*b*) The cost of one pier with half a span on either side, including all bed protection, foundations and superstructure.

138. From these type estimates particular cases were estimated for various bridges, and these were plotted on a curve, using clear waterway through bridge as the abcissa and cost as ordinates. A similar curve was plotted from the estimates prepared by Dr. Summers in 1909, and both curves follow similar laws (see Plate No. 4).

139. On comparing the cost of Village Road Bridges with that of District Road Bridges for the same channels, it was found that the cost of the former was almost exactly three-fourths of the latter.

The same curve of costs has therefore been used for both types of bridge, the cost of any particular case of Village Road Bridge being taken as three-fourths the cost read from curve.

The waterway through bridge is the same as the waterway in the canal.

140. *Railway Bridges.*—No designs are submitted for bridging the canals where railways cross them, but approximate estimates, supplied by the railways concerned, according to the particulars of canals sent to them, are included in the estimates of works. In the case of one bridge for the North-Western Railway, crossing the Johi Branch at R. D. 44,000, the Executive Engineer, Sukkur, has delayed so long in sending an estimate (not yet received) that this has been estimated here at most liberal rates.

In the case of the Jacobabad-Larkana Railway, now under construction, all bridges at proposed points of crossing by the new canals, have been similarly estimated here approximately at very liberal rates.

Section V.

Syphons—Designs and Estimates.

141. No type designs were possible for these, and as the number is limited, separate designs for each have been prepared.

142. The general principles observed in the designs are as follows :—

(*a*) The barrels of all syphons are made of reinforced cement concrete.

The concrete will be of 1: 2: 4 mixture the aggregate consisting of good broken stone ballast, or good shingle, if available.

Working stress of steel in tension is taken as .. 16,000 lbs/in^2

Working stress of concrete in compression as .. 600 lbs/in^2

(*b*) Syphons are designed to withstand the upward pressure due to water standing at H. F. L. (or F. S. L.) on the upstream side of the syphon, while the channel over the syphon is assumed to be just empty.

(*c*) To prevent water from creeping from one channel to the other, staunch walls are provided on all sides, and so placed as to form a good junction with the banks of channels.

In estimating the length of these walls the "creep factor" or hydraulic gradient has been taken as 1 in 15, although the line of saturation in the banks or around is taken as 1 in 6 only. The difference is due to the greater case of travel between soil and masonry, as compared with that through soil only.

(*d*) The inspection path along the berms of the channel crossing the syphon, are continued across the syphon, on a ballasted roadway, with parapet on outside, and kerb on canal side. The width of this roadway is made 16 feet on large channels and 10 feet on small channels.

(*e*) The side slopes of channel over syphon are made 1 to 1, and are protected with 12 inches brick-on-edge pitching, laid on 18 inches brick ballast. The brick pitching rests on a toe wall of concrete at canal bed level, and is finished at the top with brick in lime masonry, supporting the kerb of roadway.

(*f*) The wing walls of the syphon are splayed outward at 45° to meet the top of canal cutting.

(*g*) The canal bed and sides at entrance to syphon are protected for 30 feet from head wall by masonry laid on concrete, and for a further 20 feet by brick pitching on ballast.

(*h*) The sloping floor from canal bed to syphon bed level is made of such a gradient that the area of waterway at the head wall (entrance to syphon) is equal to the waterway of the canal.

(*i*) To each estimate is attached a statement showing the details of discharge and velocity through the syphon and principal dimensions of the structure.

(*j*) The detailed calculations for the structure are not submitted, but are filled in the office records.

Section VI.

Acqueducts—Designs and Estimates.

143. There are only four aqueducts in all. Of these three are constructed with flumes of reinforced concrete, and one of brick masonry throughout.

The reinforced concrete flumes are necessary in these cases, as this form of construction requires much less headroom over the stream beneath and in these three cases there was very little headroom between canal bed level and H. F. L. in the drain.

144. The following rules have been adopted in designing :—

(*a*) Working tension in steel .. .. .. 16,000 lbs./in^2.

Working compression in concrete .. .. 600 lbs./in^2.

(*b*) Where spare head is available in the canal, it has been utilized to increase the slope and velocity in the aqueduct, and thereby reduce the size of latter. The maximum velocity allowed in the concrete flumes is 8 feet per second.

(*c*) The value of Kutter's " N " has been taken as 0·01 for a smooth cement concrete surface.

(*d*) Where no spare head is available in canal, the area of waterway in the flume has been kept the same as that in canal, thereby avoiding any change in the surface slope of latter.

(*e*) To prevent creep of water below the wing walls of aqueduct, the canal bed upstream and downstream of the aqueduct abutments has been protected with a floor of impervious masonry.

This floor extends to such a distance that the 6 to 1 line of saturation along the shortest line of creep from its end, will fall inside the extended canal banks.

(*f*) The staunch walls, or wing walls, from the back of aqueduct abutments, are extended to such a point as to meet the normal canal banks.

(*g*) The latter are carried round the outside of the wing walls in a curve, leaving a berm outside the abutment at ground level, and these curves form guide banks for the flood water passing under the aqueduct. The curved portions of banks are pitched to the slope of canal bank to a height of 2 feet above estimated H. F. L. in the drain.

(*h*) The side walls of flumes are reinforced and provided with buttresses made homogenous with the bottom girders of the flume.

(*i*) The top of the side walls is provided with flanges of concrete 3 feet wide, having small supporting ribs at intervals of 3′-3″.

These flanges act as compression booms, and also provide footpaths across the aqueduct. Reinforced concrete standards are built on the flanges, to carry wire rope hand-rails.

(*j*) The bottom of flume is designed and reinforced as a continuous floor, with added reinforcement to withstand the lateral bursting strains due to the pressure on the side walls.

(*k*) Free-board of 1 foot is allowed on side walls above F. S. L. of canal.

(*l*) The bed of the drain under the aqueduct is kept level with the bed of the drainage channel, and is protected between the piers, and for a length 10 feet downstream, with brick masonry 12 inches thick in hydraulic lime mortar, laid on 6 inches lime concrete, with curtain wall on either end.

(*m*) The foundations of piers are 6 feet wide and 5 feet 6 inches deep below floor level.

(*n*) The waterway under the aqueduct has been calculated for varying conditions, according as head is available, or not, to give high velocity through the bridge, but where plenty of head is available (always less than 1 foot afflux) the aqueduct is designed to give the required discharge with a velocity not exceeding 6 feet per second.

145. For the masonry aqueduct there was sufficient head-room between the H. F. L. of the stream below it (N. E. Valley) and the bed of the canal passing over the aqueduct, to allow of building arches to support the canal floor. The side walls of the flume are of masonry of sufficient gravity section to be safe under the pressure on them. The tops of walls are corbelled out to give a footpath 3 feet wide along them.

146. Detailed estimates for each aqueduct have been prepared from the separate designs of each.

To each estimate is attached a statement showing the leading particulars—the channels crossing, and of the design as calculated.

PART IV.

RATES.

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PART IV.

RATES.

Section I.

General.

147. The general basis for calculation of all rates for earthwork and masonry works, has been taken as the schedule of rates adopted by Dr. Summers in his 1909 Project for the Rohri Canal.

These rates were calculated or ascertained with great care, and were considered by Dr. Summers to be about 25 per cent. above the then ruling rates in Sind.

He considered this margin necessary to allow for rise of rates during the period required for sanctioning the project, and for constructing the works.

148. The Government of Bombay in their letter No. C.E.I.—1 dated 17th January 1920—*vide* Appendix A—have instructed that the earthwork rates for the present projects should be taken as 30 per cent. in excess of Dr. Summers' rates, while masonry rates should be taken from the schedule of rates attached to the Barrage (1919) Report, Volume I, Part XIV. This schedule however includes, principally, rates for stone and stone-masonry works, while on the canal systems, stone will not be cheaply obtainable, and brick masonry will be used almost everywhere.

149. I have therefore taken Dr. Summers' schedule of rates and added to the items such percentages as my enquiries lead me to believe will give liberal rates for work. The extra is usually about 30 per cent.

150. The Government instructions, for cost of steel-work, are to add 100 per cent. to pre-war rates, for materials required within the next two years, and 50 per cent. to pre-war rates for materials not required for about 8 years.

151. The tables below give details of all rates, and show the comparison with Dr. Summers' 1909 schedules.

Section II.

Earthwork Rates.

152. *Dr. Summers' method of calculating rates for earthwork.*—As shown in the table below, the rates of earth-work are calculated for leads from 50′ to 550′ allowance being made for every 10 feet in leads from 50′ to 100′, and of 25 feet in leads from 100′ to 550′.

In calculating the rates, the method described in Marryat's Specifications is adopted, the cost of carriage being taken as including dressing banks, and the cost of digging only, as 2·5 rupees.

Table for ascertaining the cost of 1,000 cubic feet of earthwork for various leads.

Let L = total load = 1,000 cubic feet.

l = cooly load = $\frac{5}{8}$ cubic feet.

d = total lead in feet = actual horizontal lead plus 12 into vertical lift.

X = the proportion of (L) to (l); that is, the number of unit loads or trips of a cooly that will be necessary = $\frac{1{,}000}{5/8} = 16{,}000$.

Y = the fraction of a working day taken by a cooly to make one trip to (d) and back.

Z = wages of a cooly for a working day = 8 annas = 0·5 Re.

M = the number of minutes in a working day = 500.

t = time in minutes taken to load and unload a unit = $\frac{1}{2}$.

S = the average speed in feet per minute of a cooly = 200.

T = time in minutes taken by a cooly to make one trip to (d) and back.

N = the number of such trips made in a working day.

Then

$$T = \frac{2d}{S} + t. \qquad N = \frac{M}{T} = \frac{M}{\frac{2d}{S} + t}.$$

$$Y = \frac{T}{M} = \frac{\frac{2d}{S} + t}{M} = \frac{l}{N}$$

Total lead or distance in feet (actual horizontal lead + 12 times vertical lift).	Time of a trip to (D) and back.	No. of trips to (D) and back in a day.	Fraction of a day taken to make one trip to (D) and back expressed in decimals.	X × Y = 1600 Y.	The cost of carriage = X × Y × Z = 800 Y.	Total cost of earthwork including rupees 2·5 for cost of digging (Dr. Summers rate in 1909 Project).		Rate adapted in 1920 Project 30 per cent. in excess of 1909 rates.
D.	T.	N.	Y.	X × Y	X × Y × Z	In Rs. and decimals.	In Rs. and annas.	In Rs. and annas.
Feet.	Minutes.	No.	Day.	Day.	Rs.	Rs.	Rs. As.	Rs. As.
50	1·0	500	·0020	3·20	1·60	4·10	4 2	
60	1·1	455	·0022	3·52	1·76	4·26	4 4	
70	1·2	417	·0024	3·84	1·92	4·42	4 7	
80	1·3	385	·0026	4·16	2·08	4·58	4 9	5 14
90	1·4	357	·0028	4·48	2·24	4·74	4 12	
100	1·5	333	·0030	4·80	2·40	4·90	4 14	
125	1·75	286	·0035	5·60	2·80	5·30	5 5	6 13
150	2·00	250	·0040	6.40	3·20	5·70	5 11	
175	2·25	222	·0045	7.20	3·60	6·10	6 2	8 0
200	2·50	200	·0050	8.00	4·00	6·50	6 8	
225	2·73	182	·0055	8.80	4·40	6·90	6 14	8 15
250	3·00	167	·0060	9·60	4·80	7·30	7 5	
275	3·25	154	·0065	10·40	5·20	7·70	7 11	10 0
300	3·50	143	·0070	11·20	5·60	8·10	8 2	
325	3·75	133	·0075	12·00	6·00	8·50	8 8	11 1
350	4·00	125	·0080	12·80	6·40	8·90	8 14	
375	4·25	118	·0085	13·60	6·80	9·30	9 5	12 2
400	4·50	111	·0090	14·40	7·20	9·70	9 11	
425	4·75	105	·0095	15·20	7·60	10·10	10 2	13 3
450	5·00	100	·0100	16·00	8·00	10·50	10 8	
475	5·25	95	·0105	16·80	8·40	10·90	10 14	14 4
500	5·50	91	·0110	17·60	8·80	11·30	11 5	
550	6·00	83	·0120	19·20	9·60	12·00	2 0	15 9

Section III.

Masonry Rates.

153. Schedule of rates for estimating masonry works on Barrage Canal Projects 1920.

No.	Item.	Unit.	Dr. Summers' 1909 rate.	Proposed rate for 1920 project.
		Cubic feet.		
1	Excavation for foundations dry in main canals and branches over 100 feet wide	1,000	7	9
2	Do. do. wet ..	,,	10	13
3	Do. do. dry in branches less than 100′ wide	,,	5	7
4	Do. do. wet ..	,,	..	10
5	Earth filling rammed	,,	5	7
6	Do. lead and ramming only	,,	3	4/8
7	Concrete of B. B. and hydraulic lime 1 : 2 : 4 ..	100	22	32
8	Do. do. and white lime ..	,,	..	26
9	Concrete of stone metal and hydraulic lime near Sukkur and Rohri only	,,	24	25
10	Foundation masonry of random rubble in hydraulic lime near Sukkur and Rohri only	,,	..	30
11	Do. do. of B. B. and Hydraulic lime	,,	..	37
12	Pavement of do. do. brick on end or sides ..	,,	..	39
13	Do. do. on end laid in cement mortar 1 : 2 ..	,,	..	55
14	Superstructure of B. B. and Hydraulic lime with struck joints	,,	34	42
15	Arch work in B. B. and Hydraulic lime with struck joints.	,,	38	50
16	Cut stone work in cement	,,	200	200
17	Cement concrete 1 : 2 : 4	,,	..	80
18	Reinforced concrete flooring 1 : 2 : 4	,,	..	150
19	Do. do. beams do.	,,	..	180
20	Dry brick pitching	100	16	25
21	Dry brick ballast	100	..	18
22	Stone pitching dry	100	7	8
23	Road metalling	100	10	18
		Sft.		
24	Consolidating Roads	100	..	4
25	Guard stones	each.	5	4

Section IV.

Iron Work Rates.

154. Details of rate for gates.

Gates for Head Regulators of Canals at Sukkur.

Gate.	Height of gate.	Weight as per Mr. Ashford's design.
Sill	4′ 8″	91·4 lbs./sq. ft.
Middle Gate	8′ 9″	73·4 ,,
Upper Gate	10′ 6″	57·1 ,,
Average for whole set	23′ 11″	69·8 ,,
Average for 2 Upper gates only	19′ 3″	64·5 ,,

For intermediate regulators only single gates are required. Suppose the weight of gate is 60 lbs./square feet then 25′ × 13′ gate would weigh 8·75 tons.

Abstract of cost of Regulator Gate 25′ × 13′.

	Rs.
8·75 tons at Mr. Ashford's rate of Rs. 420 per ton	3,670
Roller boxes .. } at Mr. Ashford's rate {	455
Cast Iron Grooves . } at Mr. Ashford's rate {	1,100
Counterweights (Reinforced concrete with pulley boxes)	1,000
Mechanism for lifting gates	1,500
Total ..	7,725
Add Carriage at 15 per cent. and contingencies at 5 per cent. = 20 per cent. ..	1,545
Total for one gate 25′ × 13′ ..	9,270
i.e., for one square foot	28·6
Add 50 per cent. for post-war rates	14·3
Total ..	42·9
per square foot including carriage and contingencies say ..	43·0

Compare with	Rate per square foot. Rs.	Cost for erection Rs.
Mr. Beale's rate for Canal Head Regulator Gate	30 *puls*	3
Mr. Beale's rate for Barrage	50 „	5
Dr. Summers' rate for Canal Regulator Gate	20	..
1919 Project—Barrage	52	..
1919 Project—Canal Head Regulator Gate	55	..

so, rate for gate for intermediate regulator on canals has been taken as Rs. 43 *puls* 2 for erection, *i.e.*, Rs. 45 per square foot.

PART V.

ESTIMATING.

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PART V.

ESTIMATING.

Section I.

Estimating Earthwork in Canals.

General Instructions.

155. By the orders of the Bombay Government, *vide* their No. C.E.I.—1, dated 17th January 1920 (Appendix A) only channels carrying 2,000 cusecs or over are estimated in detail. For all channels carrying between 2,000 and 200 cusecs, *i.e.*, Branches, the cost to be taken from a curve of costs, to be derived from—

(*a*) Dr. Summers' 1909 Project estimates.

(*b*) Jamrao Canal Completion Report.

(*c*) A few typical branches to be estimated in detail in the present project. The cost of distributaries to be estimated on an acreage rate to be derived from Dr. Summers' rate, but varied to suit intensity of water-supply per area.

Section II.

Estimating cost of Branches over 2,000 Cusecs.

156. These channels have accordingly been estimated in detail by the methods explained below.

157. *For the Rohri Canal System*—all large channels were laid out on the ground by Dr. Summers in 1909, and levels taken at every 500 feet. He estimated his sections in detail at every 500 feet. This led to a very large amount of work and as on other canal systems we have not got levels at 500 feet intervals, but have to interpolate levels from the contours on the one inch Topo sheets, it was desired to estimate at longer intervals, and 4,000 feet was found to be a convenient unit for the longitudinal sections.

158. In order to ascertain whether lengthening the intervals led to any considerable error, a length of 100 miles of the Rohri Canal, as designed in 1909, was calculated with 4,000 feet intervals only. On comparing the quantities thus estimated, with those estimated by Dr. Summers at 500 feet intervals, it was found that the difference was only 1½ per cent., the 4,000 feet intervals giving the greater quantities.

159. Similarly a length of 23 miles of the Main Canal to the present revised design for Rohri Canal, was estimated both at 4,000 feet intervals and at 500 feet intervals, and the difference was found to be ½ per cent. excess for 4,000 feet intervals. Also a length of 14 miles of the Sehra Branch was similarly estimated and gave a difference of 0·03 per cent. deficit for 4,000 feet intervals.

It was therefore considered amply near enough to estimate at 4,000 feet intervals for all canals.

160. As it is found on the construction of canals, that actual quantities invariably exceed the estimated quantities, however closely the sections are estimated, an allowance has been made, in the present projects, of 10 per cent. excess over calculated quantities, for those cases where the canal alignments have been actually levelled on the ground.

161. In the case of canals whose longitudinal sections have been interpolated from the contours only, a larger provision, *viz.*, 15 per cent. excess over calculated quantities, has been allowed.

162. For each project, type sections of excavation and bank-work, for various widths and depths of canals, have been drawn out, and are included in the portfolio of plans of each project.

These type sections show the mean lead for earth in each case and the width of land required (see later).

The types are worked out for each 2 feet difference in depth of cutting, and for about every 50 feet width of cutting. The difference of lead between any two type sections is not more than 50 feet; and for any specific case, that type section which is nearest the case is adopted, and hence the error in lead cannot be more than 25 feet and does not affect the rate, which is only varied for 50 feet intervals.

Each type section is numbered, and in the estimates a reference is made to the number of the section used, at every 4,000 feet interval estimated.

163. The lead as obtained from the type section is tabulated in the accompaniment to earth-work estimates, and the rate at which earth-work is charged, is that for the 50 feet range of lead, within which this figure falls.

164. The actual quantity of canal excavation is worked out in detail at every 4,000 feet section, while the quantity of bank-work is read from the table of bank-work quantities, prepared from the type sections of banks for every half foot height of bank.

Whichever of these two quantities, *viz.*, canal excavation or bank-work, is the greater, is entered in the estimate as the quantity of excavation, and is grouped under the 50 feet range of lead to which it belongs.

165. In addition to this provision for excavation, a further provision for ramming the full quantity of bank-work is made in a separate column, and is estimated at Rs. 2 per 1,000 c. ft.

The width of land required.

166. In the type sections, the width of land required to accommodate the canal, its berms, its containing banks, and its spoil banks, is shown to scale. Beyond the toe of the spoil bank a small strip of land is taken up sufficient for the boundary trench and bank. The total width of land thus acquired is made an even multiple of 33 feet, for simplicity in the Revenue Survey.

167. In using the type sections for any specific case, that section nearest the case is adopted, *i.e.*, for a depth differing by not more than 1 foot.

An example of the limits of bed width between which any type section is assumed to be correct, is given in the table below (Rohri Canal Project).

168.

Type sections Nos.	Bed width on type sections Feet.	Actual widths of canal and limits between which type section is taken as correct.	Depth of full supply Feet.	Discharge cusecs.
1-9	240	219 to 253	13·0	Above 2,000
10-17	150	130 to 172	12·5	" "
18-24	110	85 to 130	12·0	" "
25-32	110	85 to 130	10·0	" "
33-38	75	60 to 90	10·0	" "
39-43	75	60 to 90	8·0	1,500 2,000
44-48	40	30 to 50	8·0	1,000 1,500
49-53	40	30 to 50	8·0	750 1,000
54-56	30	20 to 40	8·0	500 750
57-59	30	20 to 40	6·0	200 500

Section III.

Estimating Cost of Branches carrying between 2,000 and 200 Cusecs.

169. The mile cusecs of a branch are calculated as follows. The *main* discharge of each reach of the branch (absorption losses make discharge vary in any reach) is multiplied by the length of the reach in miles, and the total of all these gives the mile-cusec measure of the branch.

170. A curve of costs has been plotted from the 1909 Rohri Canal Project, using mile-cusec as the abcissa and total cost of works as the ordinates.

171. Points have also been plotted for the cost of some of the branches of Punjab Canals (obtained from Diagram No. 23 of the Sutlej Valley Project, 1917— Report).

172. In addition to these figures, a number of channels between 200 and 2,000 cusecs in the present Rohri Canal Project were estimated in detail, and a curve prepared therefrom. The cost of the remaining branches of the Rohri Canal, and that of a few minor branches of the Right Bank Canals, was read from this curve, but it was not of great use, as most of the branches of the Right Bank Canals were too abnormal to be obtained from the curve, and were all estimated in detail.

173. The 1909 and 1920 curves for the Rohri Canal branches are interesting, however, as they show that in spite of the increase of 30 per cent. in most rates, the total cost of the 1920 branches is only about 10 per cent. higher than that of the 1909 branches. This is mainly due to careful grading and approximation to balancing depth, more economical bank sections, as well as to some reduction in the provision for buildings and other sundry items. As every effort was made to keep down costs as much as possible, without sacrificing efficiency and safety, the results are considered satisfactory.

174. The curve of costs gives cost of works only, and provision is made for establishment and tools and plant—which are common to the whole project—in the summary of total cost of direct charges.

175. In addition to the provision for Main Canals and Branches as described above, separate provision is made for the distributary systems as shown below.

Section IV.

Cost of Distributaries.

176. The actual cost of the distributaries on the Jamrao Canal System worked out to Rs. 1·27 per acre of gross area commanded. In his 1909 Project Dr. Summers worked out in detail the cost of three distributaries and found they came to an average of Rs. 1·90 per acre of gross area. He attributed the difference to the higher cost of land in the Rohri Canal tract, and to the greater intensity of cultivation for which he allowed.

This allowance was as follows :—

> He took 25 per cent. of the gross area as kharif cultivation with a duty of 85 at the head of distributary. To this he added 25 per cent. to allow for overlap of crops, giving a resulting water-supply of 2·35 cusecs per square mile of gross area.

177. In the present Rohri Canal Project, the intensity of Kharif cultivation depends upon the rice on each channel, but for the whole tract the average kharif is 24·3 per cent. of the gross, after allowing the equivalent of the rice area as other kharif. The allowance for overlap of crops has been reduced to 7·3 per cent., *vide* Part II, Section V *ante*.

This gives a resulting water-supply of 1·79 cusecs per square mile of gross area commanded.

178. For the Rohri Canal Distributaries the cost per acre has been worked out from Dr. Summers' rate accordingly, allowing for this increase in unit cost of works, lands, etc., as follows :—

179.

Head of estimate.	Provision in rupees per acre of gross command.		
	Dr. Summers' provision.	Increase in rates.	As proposed in 1920.
		Per ent.	
A. Preliminary expenses ..	0·02	50	0·03
B. Land	0·16	66	0·24
C. Works	0·40	50	0·60
L. Earthwork	1·06	30	1·88
O. Miscellaneous	0·05	30	0·07
Outlets at Rs. 150	0·14	at Rs. 300 with modules	0·28
P. Maintenance	0·08	25	0·10
Total ..	1·90	..	$2\cdot70\times\frac{1\cdot79}{2\cdot35}$ = Rs. 2·05

180. The rate evolved above, *viz.*, Rs. 2·05 per acre is for channels carrying from 50 to 100 cusecs, as worked out by Dr. Summers.

For channels carrying less than 50 cusecs—now called Minors—Dr. Summers took a rate of Rs. 1·70 per acre. This rate has been increased in the same proportion as that for distributaries to $\frac{2\cdot05}{1\cdot90}\times 1\cdot70$ = Rs. 1·83 per acre.

181. In working out an example in detail for the present project the tail Sehra Branch—it was found that the cost of the main channel alone, from the point where the discharge was 200 cusecs, to the point where it was 100 cusecs, came to Re. 1 per acre of gross area commanded by the whole 200 cusec channel.

182. The rate for channels carrying between 100 and 200 cusecs has therefore been obtained by adding Re. 1 per acre to the above rate of Rs. 2·05 per acre for channels carrying from 50 to 100 cusecs.

183. The final rates adopted for the Rohri Canal are therefore as follows :—

	Gross area.
Channels carrying less than 50 cusecs ..	1·83 per acre.
,, ,, 50 to 100 ,, ...	2·05 ,,
,, ,, 100 to 200 ,, ...	3·00 ,,

184. For watercourses, Dr. Summers took a rate of Rs. 1·50 per acre of gross commanded. This has now been increased to Rs. 1·70 per acre, but as all expenditure under this head will be recovered from the zamindars or Colonists, it does not affect the total estimate for the project.

Section V.

Variation of Rates for Right Bank Projects.

185. For the Right Bank Canal Perennial Projects different rates are necessary owing to the different intensity of watering adopted, and to the higher value of land on this side, which has been taken at a rate of about Rs. 110 per acre for distributaries on the Perennial Canals.

186. Dr. Summers' rate for distributaries carrying from 50 to 100 cusecs, when altered to suit revised costs of present time works out as follows :—

Head of estimate.	Provision in rupees per acre of gross command.		
	Dr. Summers' provision.	Increase.	Present rate.
		per cent.	
A. Preliminary expenses	0·02	50	0·03
B. Land	0·16	150	0·40
C. Works	0·40	50	0·60
L. Earthwork	1·06	30	1·38
O. Miscellaneous	0·05	30	0·07
Outlets @ 150..	0·14	at Rs. 300 with modules.	0·28
P. Maintenance	0·08	25	0·10
Total ..	1·90		2·86 Dr. Summers' at revised rates.

187. Dr. Summers' intensity of watering was 2·35 cusecs per square mile, while for the Right Bank Perennial Canals the average intensity works out to 2·15 cusecs per square mile.

The cost per acre of gross command therefore works out to $\frac{2\cdot86}{2\cdot35} - 2.15 =$ Rs. 2·62 per acre.

188. For distributaries carrying 100 to 200 cusecs the rate is increased by Re. 1 as before (see paragraph 181 *ante*) to say Rs. 3·60 per acre.

189. The rate for Minors carrying less than 50 cusecs was taken by Dr. Summers as Rs. 1·70 per acre, as against Rs. 1·90 for distributaries carrying 50 to 100 cusecs. The present rate for Minors is obtained by a proportionate reduction from the present rate for distributaries carrying 50 to 100 cusecs, and is as follows :—

$$\frac{1\cdot70}{1\cdot90} \times 2\cdot62 = \text{Rs. } 2.35 \text{ per acre.}$$

190. The cost per acre for remodelling existing distributaries has been taken as one-third of the cost of new distributaries, as was done by Dr. Summers.

The Central Rice Canal.

191. There are only two new distributaries on this system, and the rate for these has been taken as one and a half times the rate for the perennial distributaries.

192. All the remaining new channels are branches carrying more than 200 cusecs, and the cost of these has been taken from the mile-cusec curve for branches.

193. The cost of remodelling old distributaries and small branches in this rice tract has been taken as one-fifth the cost of constructing a new one. This is based on detailed estimates worked out for the tail branches of the Begari and Dhamrao Branches, and which were found to come to about one-fifth the cost of new ones.

Section VI.

The Eastern Nara System.

194. The cost of branches, distributaries and all works has been taken from the 1909 Project, and an addition of 30 per cent. made to all items to allow for increased rates. Our detailed estimates for the revised design of the Rohri Canal, compared on a mile-cusec basis with the 1909 estimates of Dr. Summers, show that the present designs, at present rates, do not cost more than 6 per cent. in excess of 1909 estimates, and hence the above method of obtaining cost of Eastern Nara works may be considered to give a very liberal margin.

195. The cost of the New Supply Channel for the Eastern Nara System, and of widening the existing Supply Channel has been estimated in detail at liberal rates, as also has the cost of the new head regulator, and of road bridges and railway bridges over the new Supply Channel.

PART VI.

THE COST OF THE BARRAGE AND HEAD REGULATORS—METHOD OF DISTRIBUTING AMONG CANAL SYSTEMS.

INDEX

PART VI.

THE COST OF THE BARRAGE AND HEAD REGULATORS—METHOD OF DISTRIBUTING AMONG CANAL SYSTEM.

Section I.

General Principles.

196. Although all canal systems will be in progress at the same time, or for part of the same time, as the Barrage works, it is convenient, for simplicity in calculations, to keep the Barrage accounts for capital expenditure, and for interest during construction, entirely separate until completion of the Barrage works.

197. After completion, *i.e.*, at the end of the seventh year from commencement, the Barrage accounts are closed, and the capital cost, and accumulated interest, are then distributed among the canal systems, and the share pertaining to each is added to the capital cost of each canal system. In the eighth year after commencement of works, and thereafter, each canal is debited with interest, not only on its own capital expenditure, but on that of its share of the Barrage.

Section II.

The Cost of the Canal Head Regulators.

198. The total cost of Permanent Works comprising the 1919 Barrage Project, *vide* page 4, Volume III, is Rs. 1,71,96,283. This sum includes the cost of the head regulators of each of the canals, details of which can be found separately in the estimates. The cost of other works (*e.g.* Service Works, etc.) for the Barrage Project is not however separated from the Barrage proper, and for each Canal Head Regulator, but each of the latter must be a proportion of these charges equal to the proportion of the cost of its permanent works to the total cost of all permanent works.

199. Similarly the cost of Establishment and of Tools and Plant must be proportionately divided to give the total direct charges to each canal head regulator, debitable to its canal system.

The cost of each head regulator, arrived at by these methods, is shown in Statement B.

200. Indirect charges of each Head Regulator are similarly divided, and are shown in Part II of the Financial forecasts of each canal system.

Section III.

The Cost of Barrage Proper.

201. If the total direct charges for all Head Regulators, as found in paragraphs 198 and 199 above, are deducted from the total direct charges of the Barrage Project, the balance, *viz.*, Rs. 1,84,00,513 gives the direct charges due to the Barrage Proper.

These charges again have to be distributed among all the canal systems, and this is done on the following principle sanctioned by Government, *vide* Chief Engineer for Irrigation's No. 20 dated the 6th April 1920.

202. The Barrage is required for the benefit of all canals fed by it, and it might at first sight appear that the correct way to apportion the cost among the various canals, would be in proportion to the discharge of each canal. But for the Rice Canals the Barrage is of no benefit in the rabi season, as these canals are then closed. It does not, however, confer a very great benefit on these canals by giving them a guaranteed Full Supply Level during the whole period for which they are flowing.

These canals take a very large quantity of water in proportion to the area irrigated, but they take it only for 6 months in the year.

The Perennial Canals on the other hand take a smaller quantity of water for area irrigated, but they take it all the year round.

203. Hence the fairest way to distribute the cost of the Barrage is to divide it, not in proportion to the discharge of canals, but in proportion to the total area each canal will be able to irrigate eventually.

204. In the Chief Engineer for Irrigation's letter referred to, he states that the distribution should be in proportion to the increased area irrigated on each canal, but in the example he gives, he uses the figures of total anticipated irrigation on each canal, *i.e.*, new irrigation *plus* present irrigation, and this is presumably what is intended since the present irrigation benefits equally with the new, by the operation of the Barrage.

205. Statement B-1 shows the anticipated calculation on each canal system and the percentage it bears to the total cultivation on all systems.

The Direct charges for the Barrage Proper are divided in these proportions among all the canal systems, and the amounts debitable to each are shown in the statement.

206. The Indirect charges for the Barrage Proper are divided in the same proportions, and are shown for each canal system in Part II of the Financial Forecast of that system.

Section IV.

Interest during Construction and thereafter.

207. In Statement C accompanying Part IV of the Financial Forecast of each canal system, is shown the simple interest on the capital outlay for the Barrage works. It shows the accumulated interest to end of the 7th year from commencement, *i.e.*, to completion, and the annual interest thereafter. Both these sums are transferred by allocation to the various canal systems.

208. Twenty-two per cent. of both accumulated interest and of annual interest after completion, is the share due to the Head Regulators of all canals, and is divided among them in the proportions mentioned in paragraphs 198 and 199 *ante*.

209. The remaining 78 per cent. of each is the share due to Barrage Proper, and this is divided among all canal systems in the proportions mentioned in paragraphs 203 to 206 *ante*.

Section V.

Maintenance charges for Barrage and Head Regulators.

210. A detailed statement is attached showing the estimated working expenses for maintaining and working the Barrage and Head Regulators of all canals.

The total cost of this is divided among all canals, in proportion to the area irrigated by each, as shown in Part IV of the Financial Statements of each canal system, and in Statement E attached to Part IV.

Working Expenses of the Sukkur Barrage.

Establishment.

	Per month. Rs.	Per year. Rs.
* 1 Executive Engineer at Rs. 1,250	625	..
1 Assistant Engineer at Rs. 800	400	..
2 Overseers at Rs. 150 each	150	..
1 Mechanical Superintendent at Rs. 500	500	..
	1,675	20,100

Barrage Out-door Establishment.

4 Fitters at Rs. 100 each	400	..
20 Coolies at Rs. 25 „	500	..
	900	10,800

Workshops—Salvage value written back.

Rs.			
35,000	Machinery.		
10,000	Buildings, erection.		
16,000	Power Supply Plant 75 b. h. p.		
6,000	Transmission lines.		
3,000	Housing.		
20,000	Batteries.		
90,000			
say 1,00,000	Annual interest on this sum		5,000
	Depreciation machinery at 2 per cent.		700
	„ Batteries at 10 „		2,000

Workshop Establishment and running charges.

1 Engine Driver at Rs. 100	100	..
1 Engine Driver at Rs. 70	70	..
3 Electricians	120	..
2 Greasers at Rs. 25 each	50	..
	340	4,080
365 Crude oil 700 lbs. (70 gallons) days per day for 75 b. h. p. engine 10 hours a day at Rs. 16 per day		5,840
Oil Waste at Rs. 50 a month		600
Stores at Rs. 50 a month		600
Repairs to Transmission lines 33 per cent. on Rs. 6,000 per year		2,000
Workshop materials and stores		15,000
Coal for smithy 100 tons at Rs. 20		2,000

Regulators Establishment.

Each Bank—		
1 Overseer at Rs. 150	150	..
2 Fitters at Rs. 50 each	100	..
15 Coolies at Rs. 25 „	375	..
	625	..
Add for other bank	625	..
	1,250	15,000

* Half cost charged to Barrage and half to canals.

Steam Tug.

	Per month.	Per year.
	Rs.	Rs.
Rs. 62,500 Capital cost—Interest at 5 per cent. on		3,125
1 Master at Rs. 200	200	..
1 Engineer at Rs. 150	150	..
1 Engineer at Rs. 100	100	..
2 Mechanics at Rs. 60 each	120	..
2 Greasers at Rs. 25 „	50	..
4 Stokers at Rs. 25 „	100	..
5 Crew at Rs. 25 „	125	..
	845	..
Depreciation at 5 per cent.	250	..
Repairs	400	..
Fuel	3,000	..
Stores	300	..
	4,795	57,540

Motor Launches (Two).

Each—		
Rs. 10,000 Capital Cost—Interest at 5 per cent. on		500
„ „ for second launch		500
Depreciation at 12 per cent.	100	..
Repairs	50	..
1 Driver at Rs. 70	70	..
1 Khalasi at Rs. 30	30	..
Fuel	240	..
Stores	40	..
	530	..
Add for second launch	530	..
	1,060	12,720

Painting.

Barrage girders—once in six years	1,000
„ machinery „ „	1,000
„ gates, No. 66, at Rs. 150 each gate	9,900
Regulator girders—each side at Rs. 200	400
„ machinery— „ at Rs. 200	400
„ gates, No. 45, at Rs. 60 per gate	2,700

Repairs to Masonry.

Parapets	1,000
Masonry pointing	2,000
Roadway on Regulators and Barrage, 2 miles at Rs. 1,000	2,000
Repairs to Guide banks 5 miles, at Rs. 5,000	25,000
Total per year	2,03,505

Divided up as follows—

5·7	per cent	Khairpur Canals	11,150
37·6	„	Rohri Canal	76,400
28·1	„	Eastern Nara Canals	57,100
7·7	„	South Eastern Canal	15,600
8·4	„	Central Rice Canal	17,855
12·5	„	North Western Canal	25,400
100·0	per cent.	Total ..	2,03,505

PART VII.

THE FINANCIAL FORECASTS OF THE CANAL PROJECTS.

INDEX.

PART VII.

FINANCIAL FORECASTS OF THE CANAL PROJECTS.

Section I.

General.

211. Financial Forecasts are attached showing the anticipated results of each canal system, including its share of the cost of the Barrage, and also a forecast of results for all systems combined.

212. Since all canals are equally dependent on the Barrage, and as, even if if were desired to do so, no one system could be made without the others being also made (since any one new system would adversely affect the existing canals of the other systems), the only true method of considering these great projects, is to treat all as comprising one indivisible whole. It is useful and interesting to see how each canal system affects the combined project, but no one system can correctly be considered alone.

Section II.

Method of estimating anticipated growth of cultivation on Perennial Canals.

213. In their report on the Barrage Canals Messrs. Baker and Lane have shown figures of total culturable area, and of their estimate of future cultivation during the first, second and third ten years periods, after the opening of the canals.

214. As the boundaries of irrigation of some of the canal projects now submitted do not coincide with those used by Messrs. Baker and Lane in their report, the estimates of future cultivation will similarly differ.

215. In those cases where the total final area of estimated cultivation in these projects is the same as Messrs. Baker and Lane's estimate, *e.g.*, the Rohri Canal, the estimate of cultivation at the end of ten years is taken the same as their estimate.

216. In cases where the total area of estimated final cultivation differs from their estimate, the cultivation at the end of ten years and twenty years is estimated from the revised figure of total cultivation, in the same proportion as Messrs. Baker and Lanes ten year and twenty year estimates bear to their estimate of final cultivation.

217. But Messrs. Baker and Lane do not show how the area of cultivation increases from the present cultivation to that at the end of ten years.

218. I have estimated this as follows :—

(*a*) Where present rabi cultivation is less than present kharif cultivation, *i.e.*, on the Rohri Canal, and the North-Western Perennial Canal, I have assumed that the rabi cultivation will increase in the first year after opening to 75 per cent. of the present kharif area. Thereafter there will be a steady increase until in the tenth year, the figure estimated for that year, as shown in paragraphs 215 and 216 above is reached.

(*b*) On the South Eastern Perennial Canal, where the present rabi area is already equal to the present kharif area, it is assumed that rabi increases steadily every year until, in the tenth year, the estimated cultivation of that year is reached (calculated as shown in paragraph 216 above).

(*c*) From the 10th to 20th years, and from 20th to 30th years, the increase is assumed to be steady throughout each year of those periods, giving at the 30th year the final anticipated cultivation.

Section III.

Anticipated growth of cultivation on Rice (Canals Right Bank Central Canal).

219. On these canals it is assumed that the area of kharif cultivation will increase from the present area to the full anticipated area in the first year after opening. The anticipated intensities are as follows :—

	Percentage of culturable.	Percentage of gross.
Rice	85·5 Per cent.	77 Per cent.
Other Kharif	5 „	4·5 „
Total ..	90·5	81·5

Already the present cultivation on the Ghar Canal is 75 per cent. of the culturable area commanded.

Experience shows that wherever a reliable supply for rice is available the cultivators will utilize it to the full immediately.

220. It may be noted that in their estimates of cultivation and revenue, Messrs. Baker and Lane have assumed the full anticipated area for each ten year period, to be constant throughout that period, *i.e.*, they allow for a sudden jump of cultivation in the first year after opening, and this area to remain constant throughout ten years, and then again sudden jumps at the tenth and twentieth years.

221. The method of estimating now adopted in these projects is, therefore, a more moderate and safer one than Messrs. Baker and Lane's.

Section IV.

Rates of Assessment for flow Irrigation.

222. Messrs. Baker and Lane propose certain rates for the first ten year period, increased rates for the second ten year period and further final increased rates for the third ten year period and thereafter.

223. In the accompanying projects it has been assumed that the increased rates (for first ten year period) come into operation on each section of the canals, as soon as that section is opened, and that at the end of ten and twenty years, the rates in that section increase as shown by Messrs. Baker and Lane.

That is to say it is assumed that every section of the canals enjoy the lower rates for ten and twenty years after the opening of that section, before reaching the final maximum assessment.

224. Thus the rate paid in any given year on a particular branch will depend on the year in which it was opened, and this rate will not be uniform all over the canal tracts, until 20 years after the last section is opened.

225. On the Eastern Nara system Messrs. Baker and Lane's rates have not been adopted, as they proposed no improvements (and provided no funds whatever for such improvements) on this system. Thus they did not debit to the system, any share of the cost of the Barrage, nor any charge for the necessary new head to the Eastern Nara Supply Channel.

226. In the present project provision has been made for this new head; also for widening the existing Supply Channel, and for embanking the Eastern Nara River throughout. Without these works the Eastern Nara system would not benefit by the Barrage.

227. In addition, provision has been made for remodelling existing canals where necessary, and for making new canals where required, and the resulting project is a most promising and lucrative one.

228. Mr. Baker agreed that similar intensities and duties to those assumed for the Rohri Canal, might be expected on this system, if improved as now proposed (*vide* Appendix C, Volume VI).

It therefore appears only reasonable to assume that these areas when thus improved, should pay the same rates as the adjoining Rohri Canal area, and such rates have therefore been adopted in the project, for all branches of this system, including the Jamrao Canal, which will be greatly benefitted and will obtain a guaranteed supply.

Section V.

Rates of assessment for lift Irrigation.

229. On the North-Western and South-Eastern Canals of the Right Bank system, there are small areas which it is not possible to command by flow, although in every case there is flow at the tail of the distributaries supplying these areas.

230. The rates of assessment for all crops in these lift areas have been assumed as half the flow rates allowed by Messrs. Baker and Lane.

231. On present inundation canals, the rate for lift irrigation is about 66 per cent. of flow rates, so that the above assumption is a very safe one.

Section VI.

Dubari Cultivation.

232. On all rice lands there will be a considerable area of dubari rabi cultivation, *i.e.*, crops sown on the wet lands after the rice crop is cut, and brought to maturity without further waterings.

233. No rate is levied on such crops as they are to be encouraged in order to utilize the excess water from the saturated lands, and thus minimise water-logging effects.

Section VII.

Jagir Lands.

234. The gross area of these has been taken from Messrs. Baker and Lane's deh-war statements in the case of the Right Bank Canals, and agrees with the 1909 project figures.

235. In the case of the Rohri Canal the gross area has been taken from Dr. Summers' project figures, as Messrs. Baker and Lane have omitted some Jagirs, apparently by oversight.

236. The future intensity of cultivation in these Jagirs has been estimated to be the same as in Government lands.

237. It is assumed that the Jagir kharif cultivation pays one quarter the rates charged to Government land, and their rabi cultivation one-half the rates for Government land.

Section VIII.

Malkano Receipts.

238. When Government waste land is given out for cultivation, it is leased to the Zamindars on certain conditions. These are as follows :—

(*a*) The rights of cultivation may be granted for a period of five years renewable at the option of both parties on payment of one lump sum fee per acre known as "Malkano" (Sindhi for "Ownership")

(*b*) The right of cultivation may be for a period of 10 years on malkano fees.

(*c*) The right of cultivation may be granted in perpetuity on malkano fees.

239. In addition to the malkano fees the occupant has to pay the usual annual combined assesment for land and water rates.

240. All Government culturable waste lands have been classified by Messrs. Baker and Lane in groups A, B and C of which A lands are good culturable lands.

241. Of the A lands on the Rohri Canal they assume that half the area will be leased out on malkano and annual interest at 5 per cent. on the whole amount of this malkano is credited to the project annually.

This area is about equal to one-third of all unoccupied culturable land, the area for which malkano is credited being 240,000 acres, out of total unoccupied culturable of 758,000 acres.

242. On the Right Bank system, Messrs. Baker and Lane have taken credit for malkano on the whole of the A class lands.

They apparently assume that no A lands will be given free on this system, but they have not taken any malkano on the B and C class lands of which there are about 230,000 acres altogether.

Section IX.

Forests.

243. All forest areas for which the Forest Department have asked for a water supply (*vide* Appendix G, Volume VI) are fed by distributaries or branches and will get a supply at such periods as the crops require than the normal supply. Thus in the months December to May there is always surplus capacity available in the canals.

244. At any time during this period heavy floodings can be given to the forests, of which the total area is comparatively very small, as shown below : —

	Total kharif cultivation.	Forest area.
Rohri Canal	6,77,000	17,000
Right Bank Canal	4,21,000	70,859

245. *Revenue* from forest lands has been credited at the rate of Rs. 1-8-0 per acre as per Government Resolution No. A.I.—1129, dated the 26th April 1909.

Section X.

Opening of Sections of Canals.

246. The Rohri Canal will be completed in three sections, and each section will be opened as soon as completed. Ten years after opening the section, the rates thereon will be increased to those of the second ten-year period, so that the different sections in certain years will be paying different rates according to the time they have been in operation.

247. The first section is opened in the sixth year after commencement, and the revenue for that year's work is credited in the seventh year and so on.

Second section is opened in eighth year after commencement. Third section is opened in tenth year after commencement.

Right Bank Canals.

248. The North-Western and South-Eastern Canals are each completed in two sections. The first section of each is opened in the sixth year from commencement, second section of each canal is opened in seventh year from commencement.

249. *The Central Rice Canal* is completed in three sections.

1st section is opened in ninth year from commencement,
2nd „ „ tenth „ „ „
3rd „ „ eleventh „ „ „

250. *Eastern Nara Canals* are opened by canals.

The Thar-wah is opened in sixth year from commencement,
Khipro „ „ eighth „ „ „
Mithrao „ „ tenth „ „ „
Jamrao will benefit from sixth year from commencement.

251. By "commencement" is meant the commencement of the combined project for Barrage and all canals.

252. The construction and opening of each section is arranged, so as not to interfere with the present systems of inundation canals, connections to existing canals being made during the rabi season, when the inundation canals are dry.

253. For existing canals, until the new canals are completed, the existing heads from the river will be left uninterrupted, though during the period between the commencement of operation of the Barrage, and the completion of the final sections of the canals, the existing canals, not then connected to the new systems, may suffer slightly by the operation of the Barrage; or it may be necessary to do only partial operation of the Barrage during those four or five years.

254. Some such balancing arrangement for this transition period is unavoidable, but will not be serious and in the then state of development may be entirely negligible.

Section XI.

Programme of Works.

255. Works have been arranged to be in progress in such a way as to give the most profitable results due to opening the sections as completed.

256. The Barrage will be ready for operation in the 6th year from commencement, and as soon as it is ready there will be the following canals ready to take advantage of it, *viz.* :—

Rohri Canal.	..	.. First section.
Khairpur Canal	..	.. Both feeders.
Right Bank North-Western Canal	..	.. First section.
„ „ South-Eastern „	..	.. First section.
Eastern Nara	..	.. Jamrao, Thar. Also present branches of Eastern Nara will benefit.

257. Thereafter the other sections of all canals will be opened as soon as they can be completed.

258. The programme of construction of all works has been limited to give a total expenditure not exceeding 171 lakhs per annum for works only or 209 lakhs including establishment and tools and plant, etc.

On the Triple Canals Projects in the Punjab the maximum expenditure was 144 lakhs per annum. Considering that all rates are now about 33 per cent. higher than they were at the time these projects were carried out, the present equivalent expenditure would be about 192 lakhs per annum.

259. As the Barrage Canals will be spread over a much greater area than the Triple Canals, (about 72 lakhs of acres against 40 lakhs of latter), and much of our

work will be in partly developed country, where food and water and other amenities are readily available for imported labour, it is assumed that such progress is possible.

260. Efficient recruiting arrangements for collecting and organizing labour in, say, the United Provinces, etc., will be essential. No special provision has been made for such recruiting establishment, but it may be assumed to be covered by the usual percentage charge for establishment allowed in each canal project, and which in practice, is usually found to be more than sufficient.

Section XII.

Miscellaneous Receipts.

261. Under this heading a small lump sum of Rs. 10,000 has been credited to both Right Bank and Left Bank systems. This includes estimated increases in the following :—

(*a*) Rents of Government Buildings.

(*b*) Sale of grazing rights in canal lands.

(*c*) Sale of fruit and vegetables in canal gardens.

(*d*) Sale of fishery rights in canals, etc.

(*e*) Sale of trees, etc.

Section XIII.

Working expenses of Canals.

262. In the financial estimates for the present canal projects, contained in their Report, Messrs. Baker and Lane have taken the working expenses for maintaining and administering the canals at the same rate (Rs. 1·20 per acre) as was assumed by Dr. Summers in his 1909 Project (*vide* paragraph 19 of Messrs. Baker and Lane's Report).

263. It is necessary to explain therefore how Dr. Summers arrived at his assumed rates. Below is given a copy of paragraph 77 and its accompanying statements from Volume VI (Dr. Summers' 1909 Report on Rohri Canal). "77. Working expenses—In the revised Jamrao Canal Project of 1904, the rate for working expenses was taken as Rs. 0·70 per acre, and judging by this, while submitting the Preliminary Rohri Canal Project in July 1906, I assumed a rate of Rs. 0·80, at the same time stating that there was a possibility of its being increased to Re. 1 in the detailed project now submitted, but from the statement on page 61 it will be seen that even Re. 1 is far too low, and that the average for the three years, 1904-1905 to 1906-1907, when the supply in the Jamrao was ample during both the kharif and rabi seasons, was Rs. 1·26, which is almost exactly the figure (Rs. 1·23) given by Sir Thomas Higham in a note on the financial forecasts submitted with the project estimate for the extension of the Chenab Canal, dated 1st September 1891, as about the average rate on the Punjab perennial canals at that time.

As this important item is apt to be underestimated, and as the Jamrao is a new canal and the only one in Sind which is worked on the Punjab perennial system, I have collected information regarding it from the Punjab, so as to avoid as far as possible, any error in the estimate, and have prepared another statement, *vide* page 62, showing the average working expenses per acre, on the 5 million acres cultivated on 6 perennial canals in the Punjab, from which it appears that the present rate is about Rs. 1·40 per acre, and judging from conversation with Punjab Engineers, it appears that this rate is not likely to decrease; but on the contrary, may increase, as the rate of wages rises. Even the Chenab Canal, the finest in the Punjab, which we can hardly hope to come up to in Sind, shows an average rate of Rs. 1·15 for the last three years. The average rate of Rs. 1·5 for working expenses per acre of perennial cultivation in Egypt is very little greater than the average of Rs. 1·39 for the three years ended 1908-1909, for 5 million acres cultivated on the 6 perennial canals given in the above statement.

"In this estimate, I have allowed a rate of Rs. 1·20 for working expenses which does not include any charges on account of the Barrage.

In round figures taking the estimate as 500 lakhs and the total cultivation as 1½ million acres each decimal makes a difference of 1½ lakhs, or 0·3 per cent. on the return."

264. It will be noted that Dr. Summers stated he has allowed nothing in his rate of Rs. 1·20 per acre, for the working expenses of the Barrage and Head Regulator, although the figures he quotes for working expenses of the Jamrao Canal include the cost of working the Weir and Headworks and the long Eastern Nara Supply Channel and its Headworks. Similarly the figures quoted for working expenses of Punjab Canals must include the cost of working their weirs and Headworks, etc.

265. As Messrs. Baker and Lane took this same figure of Rs. 1·20 per acre of cultivation, and Government has not questioned it, I have also adopted the same rate in the accompanying financial forecasts, but in addition I have allowed separately for liberal working expenses of the Barrage and Head Regulators, the cost of which works out to about Re. 0·065 per acre of cultivation in the 11th year (completion of works) and to about Re. 0·055 in the 17th year, when works become productive.

266. Although the cost of establishment has increased since Dr. Summers framed his estimate, yet the intensity of cultivation assumed in the present projects is much higher than that assumed by Dr. Summers, and this will make working expenses proportionately lower per acre of cultivation, so that the figure assumed is probably safe.

267. In round figures taking the cost of the combined project as 1,614 lakhs, and the total cultivation as 5·3 million acres, each decimal in the rate of working expenses, makes a difference of 5·3 lakhs to the nett final profits, or ·212 per cent. to the return on Capital outlay.

268. Accurately calculated it is found that an increase of 50 per cent. in this rate of working expenses, *i.e.*, to Rs. 1·80 per acre, reduces the final return on the Capital invested, from 13·7 per cent. to 11·7 per cent. and delays the productivity of the combined works by five years, to the eighth year after completion.

Statement showing the total cultivation and cost per acre of the working expenses on the Jamrao Canal for 1900-01 to 1908-09.

Year.	Working Expenses.					Cultivation.			Cost of working expenses per acre.	Remarks.
	Improvements.	Maintenance and repairs	Revenue Collection charges.	Indirect charges.	Total.	Government.	Jagir.	Total.		
1	2	3	4	5	6	7	8	9	10	11
	Rs.	Rs.	Rs.	Rs.	Rs.	Acres.	Acres.	Acres.	Rs.	
1900-01	..	64,711	10,176	1,564	76,461 *	1,68,567	3,780	172,347	·44	Only a small portion of the revenue establishment was appointed in these years.
1901-02	..	1,52,889	12,924	5,276	1,71,089	2,12,348	4,166	216,514	·79	
1902-03	2,012	2,16,274	16,335	8,112	2,42,733	2,64,788	4,570	269,358	·90	
1903-04	1,401	2,08,530	19,300	9,548	2,38,779	2,67,568	4,160	271,728	·88	
1904-05	1,473	3,13,999	19,434	21,407	3,56,313	2,55,491	4,540	260,031	1·37	Average of 3 years during which full revenue establishment was employed, Rs. 1·26.
1905-06	2	2,95,235	26,957	21,197	3,43,391	2,89,839	4,669	294,508	1·17	
1906-07	5,653	2,61,876	19,527	18,883	3,05,939	2,42,430	3,774	246,204	1·24	
1907-08	647	2,91,831	18,572	18,169	3,29,219	2,05,332	3,006	208,338	1·58	Working expenses per acre were abnormally high owing to failure of the rabi water-supply and crops.
1908-09	521	3,42,312	13,435	18,314	3,74,582	2,02,045	3,153	205,198	1·88	

Note.—The canal was opened late in 1899-1900 and only a few acres of late rabi were cultivated in that year.

* Please read this as 76,451.

Statement showing the total cultivation and cost per acre of working

Year.	Sirhind Canal (Patiala, Nabha and Jind States).			Lower Chenab Canal.			Lower Jhelum Canal.			
	Total cultivation.	Working expenses		Total cultivation.	Working expenses		Total cultivation.	Working expenses		Total cultivation.
		on total cultivation.	per acre.		on total cultivation.	per acre.		on total cultivation	per acre.	
	Acres.	Rs.	Rs.	Acres.	Rs.	Rs.	Acres.	Rs.	Rs.	Acres.
1903-04 ..	308,568	2,58,070	0·84	1,982 714	17,84,226	0·90	279,260	2,91,816	1·04	663,792
1904-05 ..	347,416	5,64,858	1·62	1,945,675	18,15,350	0·93	305,900	5,05,341	1·65	760,220
1905-06 ..	425,656	6,32,539	1·49	1,804,619	18,56,477	1·03	446,659	6,98,161	1·56	856,425
1906-07 ..	473,293	6,19,962	1·31	1,570,853	19,61,473	1·25	435,083	7,87,795	1·81	851,752
1907-08 ..	400,942	7,18,008	1·79	1,705,296	19,80,570	1·16	543,529	7,70,521	1·42	753,335
1908-09 ..	359,672	7,50,754	2·09	1,992,219	20,44,457	1·03	617,696	8,79,988	1·42	654,390

expenses on the 6 Punjab Perennial Canals for 1903-04 to 1908-09.

Western Jumna Canal.		Upper Bari Doab Canal.			Sirhind Canal (British).			Average working expenses per acre for the 6 canals.		
Working expenses			Working expenses			Working expenses			Working expenses	
on total cultivation.	per acre	Total cultivation.	on total cultivation.	per acre.	Total cultivation	on total cultivation	per acre.	Total cultivation.	on total cultivation	per acre.
Rs.	Rs.	Acres.	Rs.	Rs.	Acres.	Rs.	Rs.	Acres.	Rs.	Rs.
9,59,022	1·44	936,687	10,53,527	1·12	732,261	9,05,724	1·24	4,903,282	52,52,385	1·07
10,70,625	1·41	955,741	11,87,478	1·24	813,454	9,80,224	1·21	5,128,406	61,23,876	1·19
12,21,692	1·43	1,129,624	12,17,714	1·08	759,008	9,28,227	1·22	5,421,991	65,54,810	1·21
11,72,377	1·38	1,038,746	12,47,443	1·20	724,419	11,00,187	1·52	5,094,146	68,89,237	1·35
11,56,548	1·54	907,516	15,51,222	1·71	788,301	9,83,643	1·25	5,098,939	71,60,512	1·44
11,49,840	1·76	1,039,477	14,14,694	1·36	559,527	9,53,304	1·70	5,222,981	71,93,037	1·38

PART VIII.

CONFERENCE OF REVENUE, IRRIGATION AND AGRICULTURAL OFFICERS HELD TO DISCUSS THE PROJECTS.

INDEX.

Section I.

Method of Settling disputed Points.

269. Since 1916, when the sanction of the Government of India to the preparation of a revised project for the Barrage and Canals was received, the practice of holding conferences of officers of all departments concerned has been adopted, to thoroughly thrash out all points on which divergence of opinions existed.

270. The effect of these conferences has been invaluable. By their means many misapprehensions have been avoided or cleared away, the various departments concerned have been kept in touch with the proposals for, and progress of, the work; and officers of one department have been enabled to assist those of another in their particular work.

271. As a result, this project represents either the unanimous views of all officers and departments concerned, or the accepted compromises where differences of opinion formerly existed, and it is believed that all local officers are prepared to accept and recommend the proposals now submitted.

272. As regards the Revenue side of the matter, the deputation of Mr. Baker, I.C.S., a Senior Collector, on special duty, assisted by Mr. Lane, Executive Engineer, and by Mr: Tamhane, Agricultural Department, to thoroughly investigate the Revenue and Agricultural features of the project, has resulted in their joint report to Government, giving their recommendations for duties, intensities, and rates of assessment, which have been duly endorsed by conferences of officers of all departments and by the Commissioner in Sind; and have been accepted by the Government of Bombay in their Public Works Department Resolution No. W. I.-11055, dated the 20th August 1919, *see* Volume XX of this Project.

Section II.

List of Conferences held to discuss the Barrage and Canal Projects.

273. The following conferences were held and copies of the Minutes of Proceedings, as far as available, are printed at the end of Report by Messrs. Baker and Lane, Volume XX. Copies of notes, etc., by the Inspector General of Irrigation in India are given in Appendix D, Volume VI.

March 1915.

Conference at Karachi to discuss technical matters, attended by :—

Mr. M. Nethersole, C.S.I., Inspector General of Irrigation in India.

Mr. H. F. Beale, Chief Engineer and Secretary to Government, Bombay.

Mr. G. McC. Harrison, Chief Engineer in Sind.

Mr. F. St. J. Gebbie, Superintending Engineer, Indus Right Bank Division.

Mr. R. T. Harrison, Superintending Engineer, Indus Left Bank Division.

March 1917.

Conference at Sukkur and Karachi to discuss technical matters, attended by :—

Mr. T. R. J. Ward, C.I.E., M.V.O., M.I.C.E., Inspector General of Irrigation in India.

Mr. F. St. J. Gebbie, Chief Engineer and Secretary to Government, Bombay.

Mr. F. Wright, Chief Engineer in Sind.

19th January 1918.

Conference at Karachi to discuss Revenue and Agricultural aspects, attended by :—

The Honourable Mr. H. S. Lawrence, C.S.I., I.C.S., Commissioner in Sind.

Mr. T. R. J. Ward, C.I.E., M.V.O., M.I.C.E., Inspector General of Irrigation in India.

Mr. F. St. J. Gebbie, Chief Engineer and Secretary to Government of Bombay, Public Works Department.

Mr. F. Wright, Chief Engineer in Sind, Public Works Department.

Mr. C. M. Baker, I.C.S., Collector, on special duty.

Mr. G. S. Henderson, Imperial Agriculturist.

Mr. W. Roberts, Principal and Professor of Agriculture, Lyallpur.

Mr. C. M. Lane, Executive Engineer, on special duty.

20th January 1918.

Conference at Karachi to discuss Revenue and Agricultural aspects, attended by :—

The Honourable Mr. H. S. Lawrence, C.S.I., I.C.S., Commissioner in Sind.

Mr. G. S. Henderson, Imperial Agriculturist.

Mr. W. Roberts, Principal and Professor of Agriculture, Lyallpur.

30th November 1918.

Conference at Karachi to discuss Revenue and Agricultural aspects of the Project, attended by :—

The Honourable Mr. H. S. Lawrence, C.S.I., I.C.S., Commissioner in Sind.

Mr. T. R. J. Ward, C.I.E., M.V.O., M.I.C.E., Inspector General of Irrigation in India.

Mr. F. St. J. Gebbie, Secretary to Government of Bombay, Public Works Department.

Mr. F. Wright, Chief Engineer in Sind, Public Works Department.

Mr. C. M. Baker, I.C.S., Collector, on special duty.

Mr. G. S. Henderson, Agricultural Controller.

Mr. C. M. Lane, Executive Engineer, on special duty.

Mr. A. A. Musto, Executive Engineer, Sukkur Barrage.

3rd February 1919.

Conference at Karachi to discuss Revenue and Agricultural aspects of the Project, attended by :—

The Honourable Mr. H. S. Lawrence, C.S.I., I.C.S., Commissioner in Sind.

Mr. F. St. J. Gebbie, Secretary to the Government of Bombay, Public Works Department.

Mr. F. Wright, Chief Engineer in Sind, Public Works Department.

Mr. C. M. Baker, I.C.S., Collector, on special duty.

Mr. C. M. Lane, Executive Engineer, on special duty.

Mr. A. A. Musto, Executive Engineer, Sukkur Barrage.

Mr. T. F. Main, Deputy Director of Agriculture, Sind.

Mr. V. A. Tamhane, Agricultural Chemist.

March 1919.

Conference at Government House, Karachi, to explain Mr. Musto's proposals for Khirtar Branch, attended by :—

The Honourable Mr. H. S. Lawrence, C.S.I., I.C.S., Commissioner in Sind.

Mr. A. A. Musto, Executive Engineer, Sukkur Barrage.

24th March 1919.

Conference at Karachi to discuss the Khirtar Branch for Nasirabad, attended by :—

The Honourable Mr. H. S. Lawrence, C.S.I., I.C.S., Commissioner in Sind.
The Honourable Mr. F. W. Johnstone, Revenue and Judicial Commissioner, Baluchistan.
Mr. A. A. Musto, Executive Engineer, Sukkur Barrage.

May 1919.

Conference at Karachi to discuss Khirtar Branch for Nasirabad Tahsil, attended by :—

Mr. H. O. B. Shoubridge, M.I.C.E., Chief Engineer in Sind.
Mr. V. M. Griffiths, Superintending Engineer, Indus Right Bank Division.
Mr. R. MacGregor, Irrigation Officer, Baluchistan.
Mr. A. A. Musto, Executive Engineer, Sukkur Barrage.
Mr. C. M. Lane, Executive Engineer, on special duty.

January 1920.

Conference at Karachi to discuss technical matters and questions of establishment, attended by :—

Mr. T. R. J. Ward, C.I.E., M.V.O., M.I.C.E., Inspector General of Irrigation in India.
Mr. F. St. J. Gebbie, Secretary to Government of Bombay, Public Works Department.
Mr. H. O. B. Shoubridge, M.I.C.E., Chief Engineer in Sind.
Mr. A. A. Musto, Executive Engineer, Sukkur Barrage.

8th April 1920.

Conference at Karachi to discuss Begari Rice Branch, attended by :—

The Honourable Mr. P. R. Cadell, C.S.I., C.I.E., I.C.S., Commissioner in Sind.
Mr. V. M. Griffiths, Chief Engineer in Sind.
Mr. H. Montgomery, I.C.S., Collector of Sukkur.
Mr. J. W. Smyth, I.C.S., Deputy Commissioner, Upper Sind Frontier.
Mr. A. A. Musto, Executive Engineer, Sukkur Barrage Project.

June 1920.

Conference at Karachi to discuss final project and financial forecasts, attended by :—

The Honourable Mr. P. R. Cadell, C.S.I., C.I.E., I.C.S., Commissioner in Sind.
Sir T. R. J. Ward, C.I.E., M.V.O., M.I.C.E., Inspector General of Irrigation in India.
The Honourable Mr. H. O. B. Shoubridge, M.I.C.E., Secretary to Government of Bombay, Public Works Department.
Mr. A. A. Musto, Executive Engineer, Sukkur Barrage Project.

PART IX.

FINANCIAL FORECAST STATEMENT.

INDEX.

Section I.

Summary showing Net Financial Results.

	Combined Project, viz., Barrage, and Right and Left Bank Canal Systems.
(a) Total Cost of Works—Direct	154,625,552
(b) Total Cost of Works—Indiret	5,338,825
(c) Total, Direct and Indirect	159,964,377
(d) All works completed in year from commencement	Eleventh.
(e) Work becomes productive in years from commencement of work	Fourteenth.
(f) Accumulated arrears of interest up to year (e)	23,627,160
(g) Total Capital invested in year (e)	183,591,537
(h) Net Revenue due to improvements in year (e)	9,402,085
(i) Interest paid in year (e)	5·1 per cent. Third year after completion.
Tenth year after completion of work.	
(j) Total Capital invested	159,964,377
(k) Net Revenue due to improvements	13,967,582
(l) Interest paid	8·2 per cent.
Twentieth year after completion of work.	
(m) Total Capital invested	159,964,377
(n) Net Revenue due to improvements	18,851,844
(o) Interest paid	11·8 per cent.
Thirtieth year after completion of work.	
(p) Total Capital invested	159,964,377
(q) Net Revenue due to improvements	22,146,430
(r) Interest paid	13·8 per cent.
(s) All accumulated arrears of interest will be wiped out in year from commencement of Work	End of 21st year
(t) All Capital wiped out in year from commencement of work	End of 34th year

Cultivation.

	Acres.	Percentage.
(u) Present cultivation in acres	2,035,636	31 per cent.
(v) Cultivation in year (e) when work becomes productive ..	3,288,929	50 per cent.
(w) Ultimate anticipated cultivation in 30 years after completion..	5,308,408	81 per cent.
(x) Total Culturable area	6,529,705	100 per cent.
(y) Total Gross commanded	7,494,077	

SECTION II.

General abstract by heads of classification showing cost of all Canals and Barrage (including Head Regulators).

Heads of classification.	Rohri Canal (Section II, Part X, Vol. VII).	Right Bank Canalsincluding Manchar Regulatorand Drain (Section II, Part X, Vol. VIII).	Eastern Nara Canals. (Vol. IX.)	Barrage including Head Regulators (Page 4, Vol. III).	Total.
	Rs.	Rs.	Rs.	Rt	Rs.
Total——I Works	3,26,70,277	4,90,83,973	1,89,75,135	2,35,34,600	12,42,63,985
II Establishment	64,03,525	97,13,362	38,85,407	55,98,506	2,56,00,800
III Tools and Plant	5,82,139	8,83,034	3,53,218	43,82,176	62,00,567
Total, *A—Direct* ..	3,96,55,941	5,96,80,369	2,32,13,760	3,35,15,282	15,60,65,352
Capitalization of abatement of Land Revenue	6,08,970	9,35,980	3,13,740	66,290	19,24,980
Leave and Pension allowances	8,96,493	13,59,891	5,43,957	6,13,504	34,13,845
Total, *B—Indirect* ..	15,05,463	22,95,871	8,57,697	6,79,794	53,38,825
Total, Direct and Indirect ..	4,11,61,404	6,19,76,240	2,40,71,457	3,41,95,076	16,14,04,177
Deduct share of cost of Barrage only payable by Khairpur State					14,40,000
Net cost of works (Direct and Indirect) chargeable to British Government.					15,99,64,177

Section II.

Financial Statements.

Part I.

Summary of the estimated direct charges to Capital Account.
(For details see Statement A.)

Year.	Works.	Establishment.	Tools and Plant.	Total.	Less receipts on Capital Account.	Net Total.
1	2	3	4	5	6	7
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
Preliminary	33,68,398	4,21,336	47,88,560	85,78,294	....	85,78,294
First	73,79,748	15,10,336	79,24,474	1,68,14,558	....	1,68,14,558
Second	1,21,73,924	19,10,336	7,81,864	1,48,66,124	....	1,48,66,124
Third	1,40,60,070	29,18,336	5,38,744	1,75,17,150	....	1,75,17,150
Fourth	1,71,39,132	32,53,056	5,59,744	2,09,51,932	....	209,51,932
Fifth	1,79,84,268	31,34,534	—19,40,998	1,91,77,804	....	191,77,804
Sixth	1,39,31,187	21,97,720	—25,69,614	1,35,59,293	3,00,000	132,59,293
Seventh	1,49,27,099	24,50,000	—32,13,770	1,41,63,329	4,00,000	137,63,329
Eighth	1,37,79,196	28,41,757	2,14,524	1,68,35,477	*19,40,000	148,95,477
Ninth	87,59,613	19,50,000	1,55,000	1,08,64,613	6,00,000	102,64,613
Tenth	49,93,984	14,58,127	1,33,012	65,85,123	8,00,000	57,85,123
Eleventh	9,46,521	3,38,932	45,367	13,30,810	10,50,000	2,80,810
Twelfth	—4,55,842	....	....	—4,55,842	10,73,313	—15,29,155
Total ..	12,89,87,298	2,43,84,470	74,16,897	16,07,88,665	61,63,313	15,46,25,352

* This amount is made up of Rs. 5,00,000 recoveries from watercourses and Rs. 14,40,000 payable by Khairpur State.

STATEMENT

Accompaniment to Financial

Details of

	Preliminary.	1st year.	2nd year.	3rd year.	4th year.	5th year.
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
Works.						
Sukkur Barrage ..	26,62,398	40,29,748	70,23,924	34,80,070	32,56,430	26,10,148
Rohri Canal ..	....	10,00,000	14,00,000	45,00,000	46,69,356	48,09,574
Eastern Nara ..	....	10,50,000	10 50,000	10,50,000	15,33,346	17,75,000
Right Bank Canals ..	7,06,000	13,00,000	27,00,000	39,00,000	52,30,000	61,48,401
Manchar ..	....	....	....	11,30,000	24,50,000	26,41,145
Total ..	33,68,398	73,79,748	1,21,73,924	1,40,60,070	1,71,39,132	1,79,84,268
Establishment.						
Sukkur Barrage ..	3,61,336	8,70,336	8,70,336	8,70,336	6,31,056	6,31,056
Rohri Canal ..	....	1,20,000	2,30,000	8,00,000	8,00,000	8,00,000
Eastern Nara ..	....	1,20,000	2,10,000	2,10,000	3,10,000	3,50,000
Right Bank Canals ..	60,000	4,00,000	6,00,000	8,00,000	10,00,000	8,00,000
Manchar ..	....	....	....	2,38,000	5,12,000	5,53,478
Total ..	4,21,336	15,10,336	19,10,336	29,18,336	32,53,056	31,34,534
Tools and Plant.						
Sukkur Barrage ..	47,76,560	77,74,474	6,61,864	3,56,744	3,56,744	—21,59,496
Rohri Canal ..	....	1,00,000	50,000	50,000	50,000	50,000
Eastern Nara ..	....	20,000	20,000	20,000	30,000	50,000
Right Bank Canals ..	12,000	30,000	50,000	80,000	85,000	70,000
Manchar ..	....	....	....	32,000	38,000	48,498
Total ..	47,88,560	79,24,474	7,81,864	5,38,744	5,59,744	—19,40,998
Grand Total ..	85,78,294	1,68,14,558	1,48,66,124	1,75,17,150	2,09,51,932	1,91,77,804
Less receipts on Capital Account.						
Rohri Canal ..	....	....	....	....	....	....

A.

Statements Part I.

annual expenditure.

6th year.	7th year.	8th year.	9th year.	10th year.	11th year.	12th year.	Total.
Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
7,65,452	−2,93,570	....	....	....	....	....	2,35,34,600
55,00,000	48,95,669	39,00,000	39,59,019	20,13,451	7,46,521	....	3,73,93,590
20,75,000	27,75,000	26,65,172	20,29,828	21,71,789	8,00,000	....	1,89,75,135
55,90,735	75,50,000	72,14,024	27,70,766	8,08,744	−6,00,000	−4,55,842	4,28,62,828
....	....	....	....	....	....	....	62,21,145
1,39,31,187	1,49,27,099	1,37,79,196	87,59,613	49,93,984	9,46,521	−4,55,842	12,89,87,298
1,47,720	....	....	....	....	....	....	43,82,176
9,50,000	8,00,000	7,00,000	6,00,000	4,00,000	2,03,525	....	64,03,525
4,50,000	6,00,000	6,00,000	4,50,000	4,50,000	1,35,407	....	38,85,407
6,50,000	10,50,000	15,41,757	9,00,000	6,08,127	....	....	84,09,884
....	....	....	....	....	....	....	13,03,478
21,97,720	24,50,000	28,41,757	19,50,000	14,58,127	3,38,932	....	2,43,84,470
−27,29,614	−34,38,770	....	....	....	....	....	55,98,506
50,000	50,000	50,000	50,000	50,000	32,139	....	5,82,139
50,000	50,000	40,000	30,000	30,000	13,218	....	3,53,218
60,000	1,25,000	1,24,524	75,000	53,012	....	....	7,64,536
....	....	....	....	....	....	....	1,18,498
−25,69,614	−32,13,770	2,14,524	1,55,000	1,33,012	45,357	....	74,16,897
1,35,59,293	1,41,63,329	1,68,35,477	1,08,64,603	65,85,123	13,30,810	−4,55,842	16,07,88,665
3,00,000	4,00,000	5,00,000 +14,40,000 Khairpur State	6,00,000	8,00,000	10,50,000	10,73,313	61,63,313
							15,46,25,352

Section III.

Financial Statements.

Part II.—*Summary of the estimated indirect charges to Capital Account.*

Year.	Capitalization of Land Revenue abated.	Charges for Leave and Pension allowances.	Total.
	Rs.	Rs.	Rs.
Preliminary	89,790	58,900	1,48,690
First	1,29,221	2,11,300	3,40,521
Second	97,501	2,67,300	3,64,801
Third	1,03,041	4,08,400	5,11,441
Fourth	97,501	4,55,800	5,53,301
Fifth	1,56,497	4,38,607	5,95,104
Sixth	2,21,317	3,08,104	5,29,421
Seventh	3,15,397	3,43,000	6,58,397
Eighth	3,15,397	3,97,846	7,13,243
Ninth	2,29,157	2,73,000	5,02,157
Tenth	1,70,161	2,04,138	3,74,299
Eleventh	....	47,450	47,450
Total ..	19,24,980	34,13,845	53,38,825

Section IV.

Financial Statements.

PART III.—*Statement showing the estimate of growth of irrigation and revenue receipts and charges.*

Year.	Irrigated area at end of year Statement C.	Revenue Receipts and Charges.						
		Gross Revenue due to work.			Charges both Direct and Indirect against revenue account Statement E.	Net revenue column 5 minus column 6.	Deduct present net revenue.	Balance due to improvements Col. 7 minus 8.
		Direct Receipts Statement D.	Enhanced Land Revenue or Indirect Revenue.	Total columns 3 + 4.				
1	2	3	4	5	6	7	8	9
	Acres.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
Present ..	20,35,636	61,51,691	....	61,51,691	19,54,210	41,97,481	41,97,481	*Nil.*
7th ..	22,40,142	97,92,631	11,75,000	99,67,631	26,09,044	73,58,587	41,97,481	31,61,106
8th ..	23,53,636	1,08,34,944	1,75,000	1,10,09,944	28,06,595	82,03,349	41,97,481	40,05,868
9th ..	25,09,391	1,15,87,124	2,10,000	1,17,97,124	30,09,550	87,87,574	41,97,481	45,90,093
10th ..	27,09,937	1,33,76,101	2,10,000	1,35,86,101	32,87,234	1,02,98,867	41,97,481	61,01,386
11th ..	29,84,733	1,55,63,296	2,70,000	1,58,33,296	37,26,797	1,21,06,499	41,97,481	79,09,018
12th ..	31,06,429	1,65,85,426	2,70,000	1,68,55,426	38,82,970	1,29,72,456	41,97,481	87,74,975
13th ..	31,91,487	1,70,02,816	2,70,000	1,72,72,816	39,85,036	1,32,87,780	41,97,481	90,90,299
14th ..	32,76,049	1,74,16,080	2,70,000	1,76,86,080	40,86,514	1,35,99,566	41,97,481	94,02,085
15th ..	33,61,404	1,78,33,020	2,70,000	1,81,03,020	41,88,820	1,39,14,200	41,97,481	97,16,719
16th ..	34,40,289	1,82,52,516	2,70,000	1,85,22,516	42,84,602	1,42,37,914	41,97,481	1,00,40,433
17th ..	35,19,358	1,98,94,749	2,70,000	2,01,64,749	43,78,485	1,57,86,264	41,97,481	1,15,88,783
18th ..	35,74,168	2,03,45,690	2,70,000	2,06,15,690	44,44,256	1,61,71,434	41,97,481	1,19,73,953
19th ..	36,28,718	2,08,76,037	2,70,000	2,11,46,037	45,09,716	1,66,36,321	41,97,481	1,24,38,840
20th ..	36,86,878	2,14,38,524	2,70,000	2,17,08,524	45,79,508	1,71,21,016	41,97,481	1,29,31,535
21st ..	37,41,078	2,25,39,611	2,70,000	2,28,09,611	46,44,548	1,81,65,063	41,97,481	1,39,67,582
22nd ..	38,05,828	2,29,82,688	2,70,000	2,32,52,688	47,22,249	1,85,30,439	41,97,481	1,43,32,958
23rd ..	38,65,578	2,32,21,593	2,70,000	2,35,91,593	47,93,949	1,87,97,644	41,97,481	1,46,00,163
24th ..	39,33,328	2,37,05,598	2,70,000	2,39,75,598	48,75,249	1,91,00,349	41,97,481	1,49,02,868
25th ..	39,97,078	2,40,66,695	2,70,000	2,43,36,695	49,51,749	1,93,84,946	41,97,481	1,51,87,465
26th ..	40,60,828	2,44,22,950	2,70,000	2,46,92,950	50,28,249	1,96,64,701	41,97,481	1,54,67,220
27th ..	41,37,819	2,53,75,292	2,70,000	2,56,45,292	51,20,638	2,05,24,654	41,97,481	1,63,27,173
28th ..	42,28,564	2,59,39,241	2,70,000	2,62,09,241	52,29,652	2,09,79,589	41,97,481	1,67,82,180
29th ..	43,21,880	2,66,69,788	2,70,000	2,69,39,788	53,41,511	2,15,98,277	41,97,481	1,74,00,796
30th ..	44,19,019	2,75,69,736	2,70,000	2,78,39,736	54,58,078	2,23,81,658	41,97,481	1,81,84,177
31st	45,24,164	2,83,63,577	2,70,000	2,86,33,577	55,84,252	2,30,49,325	41,97,481	1,88,51,844 + 3,66,065 per year.
40th ..	53,08,408	3,25,99,356	2,70,000	3,28,37,256	65,25,445	2,63,43,911	41,97,481	2,21,46,430

Statements C, D and E.

Statement showing the Annual Cultivation and Revenue Forecast and Working Expenses.

	Present.	7th year.	8th year.	9th year.	10th year.	11th year.	12th year.	13th yaer.
Total Cultivation.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
Rohri Canal ..	657,300	745,300	754,900	808,500	832,900	995,300	1,024,100	1,054,500
Eastern Nara ..	484,679	560,150	603,550	676,950	740,350	783,750	809,650	935,500
Right Bank ..	893,657	934,692	995,186	1,023,941	1,136,687	1,205,683	1,272,679	1,301,437
Manchar ..	*Nil.*	*Nil.*	....	....	....	....	....	....
Total ..	2,035,636	2,240,142	2,353,636	2,509,391	2,709,937	2,984,733	3,106,429	3,191,487
Total Gross Revenue.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
Rohri Canal ..	18,96,000	26,70,330	27,18,058	31,54,717	32,26,309	44,02,489	47,46,460	48,99,985
Eastern Nara ..	15,04,139	30,42,950	32,02,300	37,17,650	39,78,000	41,98,350	43,32,700	44,67,050
Right Bank ..	27,51,552	42,54,351	47,89,586	49,24,757	63,81,792	72,32,457	77,76,266	79,05,781
Manchar ..	*Nil.*	*Nil.*	....	....	....	....	....	....
Total ..	61,51,691	99,67,631	1,08,09,944	1,17,97,124	1,35,86,101	1,58,33,296	1,68,55,426	1,72,72,816
Working Expenses.								
Rohri Canal ..	6,31,008	8,63,485	8,85,205	9,64,564	9,91,328	12,70,760	13,05,320	13,41,800
Eastern Nara ..	4,65,292	6,52,180	7,24,260	8,12,340	8,88,420	9,40,500	9,71,580	10,02,660
Right Bank ..	8,57,910	10,93,379	11,97,130	12,32,646	14,07,486	15,15,537	16,06,070	16,40,576
Manchar ..	*Nil.*	*Nil.*	....	....	....	....	....	....
Total ..	19,54,210	26,09,044	28,06,595	30,09,550	32,87,234	37,26,797	3,882,970	39,85,036
Indirect Receipts.								
Rohri Canal ..	*Nil.*	40,000	40,000	70,000	70,000	1,20,000	1,20,000	1,20,000
Eastern Nara ..	*Nil.*	*Nil.*	....	....	....	....	....	....
Right Bank ..	*Nil.*	1,35,000	1,35,000	1,40,000	1,40,000	1,50,000	1,50,000	1,50,000
Manchar ..	*Nil.*	*Nil.*	....	....	....	....	....	....
Total ..	....	1,75,000	1,75,000	2,10,000	2,10,000	2,70,000	2,70,000	2,70,000

	14th year.	15th year.	16th year.	17th year.	18th year.	19th year.	20th year.	21st year.
Total Cultivation.	Acres.	Acies.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
Rohri Canal ..	1,084,900	1,116,100	1,141,300	1,175,080	1,193,260	1,212,080	1,232,500	1,255,000
Eastern Nara ..	860,950	886,350	911,350	935,750	966,150	995,550	1,023,950	1,052,350
Right Bank ..	1,330,199	1,358,954	1,387,639	1,408,528	1,414,758	1,421,088	1,430,428	1,433,728
Manchar ..	....	....	....	....	....	....	....	....
Total ..	3,276,049	3,361,404	3,440,289	3,519,358	3,574,168	3,628,718	3,686,878	3,741,078
Total Gross Revenue.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
Rohri Canal ..	50,51,035	52.06,904	53,63,419	57,46,478	58,70,111	61,09,378	62,35,215	67,67,785
Eastern Nara ..	45,99,400	47,31,750	48,62,150	55,67,150	57,37,650	60,05,650	64,19,650	65,93,650
Right Bank ..	80,35,645	81,64,366	82,96,947	88,51,121	90,07,929	90,31,009	90,53,659	94,48,176
Manchar ..	....	....	....	....	....	....	....	....
Total ..	176,86,080	181,03,020	185,22,516	201,64,749	206,15,690	211,46.037	217,08,524	228,09,61
Working Expenses.								
Rohri Canal ..	13,78,230	14,15,600	14,45,960	14,86,496	15,08,312	15,30,896	15,55,400	15,82,400
Eastern Nara ..	10,33,140	10,63,620	10,94,620	11,22,900	11,59,380	11,94,660	12,28,740	12,62,820
Right Bank ..	16,75,094	17,09,600	17,44,022	17,69,089	17,76,564	17,84,160	17,75,368	17,99,328
Manchar ..	....	....	....	....	....	....	....	....
~~Total~~ ..	~~40,86,514~~	~~41,88,820~~	~~42,84,602~~	~~43,78,485~~	~~44,44,256~~	~~45,09,718~~	~~45,79,508~~	46,44,548
Indirect Receipts.								
Rohri Canal ..	1,20,000	1,20,000	1,20,000	1,20,000	1,20,000	1,20,000	1,20,000	1,20,000
Eastern Nara ..	....	....	....	....	....	....	....	....
Right Bank ..	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000
Manchar ..	....	....	....	....	....	....	....	....
Total ..	2,70,000	2,70,000	2,70,000	2,70,000	2,70,000	2,70,000	2,70,000	2,70,000

STATEMENTS C, D AND E—*concld.*

Statement showing the Annual cultivation and revenue forecast and Working Expenses.

	22nd year.	23rd year.	24th year.	25th year.	26th year.	27th year.
Total Cultivation.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
Rohri Canal ..	1,284,500	1,310,000	1,343,500	1,373,000	1,402,500	1,436,960
Eastern Nara ..	1,081,300	1,109,250	1,137,200	1,165,150	1,193,100	1,220,250
Right Bank ..	1,440,028	1,446,328	1,452,628	1,458,928	1,465,228	1,480,609
Manchar ..	....	....	....	....	....	....
Total ..	3,805,828	3,865,578	3,933,328	3,997,078	4,060,828	4,137,819
Total Gross Revenue.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
Rohri Canal ..	69,40,210	70,89,835	72,85,060	74,57,485	76,29,910	78,76,739
Eastern Nara ..	67,68,450	69,35,250	71,02,050	72,68,850	74,35,650	78,55,575
Right Bank ..	95,44,028	95,66,508	95,88,488	96,10,360	96,27,390	99,12,978
Manchar ..	....	....	....	....	....	....
Total ..	232,52,688	235,91,593	239,75,598	243,36,695	246,92,950	256,45,292
Working Expenses.						
Rohri Canal ..	16,17,800	16,48,400	16,88,600	17,24,000	17,59,400	18,00,752
Eastern Nara ..	12,97,560	13,31,100	13,64,640	13,98,180	14,31,720	14,64,300
Right Bank ..	18,06,889	18,14,449	18,22,009	18,29,569	18,37,129	18,55,586
Manchar ..	....	....	....	....	....	....
Total ..	47,22,249	47,93,949	48,75,249	49,51,749	50,28,249	51,20,638
Indirect Receipts.						
Rohri Canal ..	1,20,000	1,20,000	1,20,000	1,20,000	1,20,000	1,20,000
Eastern Nara ..	....	....	....	....	....	....
Right Bank ..	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000
Manchar ..	....	....	....	....	....	....
Total ..	2,70,000	2,70,000	2,70,000	2,70,000	2,70,000	2,70,000

	28th year.	29th year.	30th year.	31st year.	40th year.
Total Cultivation.	Acres.	Acres.	Acres.	Acres.	Acres.
Rohri Canal ..	1,474,320	1,514,360	1,558,300	1,610,300	2,053,300
Eastern Nara ..	1,247,900	1,275,550	1,303,100	1,330,650	1,529,950
Right Bank ..	1,506,344	1,531,970	1,557,619	1,583,214	1,725,158
Manchar ..	....	....	....	....	....
Total ..	4,228,564	4,321,880	4,419,019	4,524,164	5,308,408
Total Gross Revenue.	Rs.	Rs.	Rs.	Rs.	Rs.
Rohri Canal ..	80,76,448	84,43,433	86,67,880	90,15,010	1,11,42,915
Eastern Nara ..	80,22,825	82,41,075	85,22,375	86,89,675	98,89,475
Right Bank ..	101,09,968	102,55,280	1,06,49,481	1,09,28,892	1,18,04,866
Manchar ..	....	....	....	....	....
Total ..	262,09,241	269,39,788	2,78,39,736	2,86,33,577	3,28,37,256
Working Expenses.					
Rohri Canal ..	18,45,704	18,93,632	19,46,360	20,08,760	25,40,360
Eastern Nara ..	14,97,480	15,30,660	16,63,720	15,96,780	18,36,040
Right Bank ..	18,86,468	19,17,219	19,47,998	19,78,712	22,49,045
Manchar ..	....	....	....	....	....
Total ..	52,29,652	53,41,511	†54,58,078	55,84,252	*65,25,445
Indirect Receipts.					
Rohri Canal .	1,20,000	1,20,000	1,20,000	1,20,000	1,20,000
Eastern Nara .	....	....	....	....	....
Right Bank .	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000
Manchar .	....	....	....	....	....
Total ..	2,70,000	2,70,000	2,70,000	2,70,000	2,70,000

* Please read this as 55,58,078.
† „ „ „ 66,25,445.

SECTION V.

Financial Statements.

PART IV.—*Estimate of net financial results up to the year when work becomes productive.*

Year.	Direct Capital outlay during the year—Part I.	Direct Capital outlay to end of year.	Simple interest at 5 per cent. on capital outlay to end of previous year plus half outlay during the year.	Net Revenue including enhanced land revenue Cl. 9 of Part III.	Simple interest less net Revenue.	Net Revenue less simple interest.	Remarks.
1	2	3	4	5	6	7	8
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	
Preliminary ..	85,78,294	85,78,294	2,14,457	..	2,14,457	....	
First Year..	1,68,14,558	2,53,92,852	8,49,279	..	8,49,279	....	
Second ,, ..	1,48,66,124	4,02,58,976	16,41,296	..	16,41,296	....	
Third ,, ..	1,75,17,150	5,77,76,126	24,50,878	..	24,50,878	....	
Fourth ,, ..	2,09,51,932	7,87,28,058	34,12,604	..	34,12,604	....	
Fifth ,, ..	1,91,78,004	9,79,06,062	44,15,852	..	44,15,852	....	
Sixth ,, ..	1,32,59,293	11,11,65,355	52,26,785	..	52,26,785	....	
Seventh ,, ..	1,37,63,329	12,49,28,684	59,02,351	31,61,106	27,41,245	....	
Eigh h ,, ..	1,48,95,477	13,98,24,161	66,18,821	40,05,868	26,12,953	....	
Ninth ,, ..	1,02,64,613	15,00,88,774	72,47,823	45,90,093	26,57,730	....	
Tenth ,, ..	57,85,123	15,58,73,897	76,49,067	61,01,386	15,47,681	....	
Eleventh ,, ..	2,80,810	15,61,54,707	78,00,715	79,09,018	....	1,08,303	All works complete.
Twelfth ,, ..	15,29,155	15,46,25,552	77,69,506	87,74,975	....	10,05,469	
Thirteenth ,, ..	....	....	77,31,278	90,90,299	....	13,59,021	
Fourteenth ,, ..	....	....	77,31,278	94,02,085	....	16,70,807	
					2,77,70,760	41,43,600	
			Accumulated arrears of simple interest			2,36,27,160	

Definition of productive Public Works.

Article 393. To admit of a work being classed at a Productive Public Work the following conditions must be satisfied.

(*a*) There must be good reason to believe that the Revenue derived from it will, within 10 years after the probable date of its completion, repay the annual interest on the Capital invested calculated at 5 per cent., but in preparing a Project for sanction no deduction is to be made from the total capital outlay on account of anticipated excess of Revenue over Simple Interest.

NOTE.—Capital invested includes (1) Direct Charges (2) Indirect charges, and (3) all arrears of simple interest, if any, *i.e.*, balance of total interest over total net Revenue.

(P. W. D. Code, Chapter V. Tenth Edition.)

Financial Statements.

SECTION V.

Part V—Recapitulation.

	Rs.
(1) Direct charges, including share of Barrage as per Part I ..	15,46,25,552
(2) Indirect charges as per Part II	53,38,825
(3) Accumulated arrears of simple interest as per Part IV ..	2,36,27,160
Total, Capital invested	18,35,91,537
Revenue derived in 14th year (*i.e.*, three years after completion of works) *vide* column 5 of Part IV	94,02,085

$$\text{Percentage of Return} = \frac{94,02,085}{18,35,91,537} = 5{\cdot}1 \text{ per cent.}$$

Therefore the work is productive in terms of Article 393 of Public Works Department Code, Chapter V, 10th Edition.

NOTE (*i*).—The percentage of return at the end of first ten years after completion on total capital

$$\text{invested} = \frac{1,39,67,582}{15,99,64,377} = 8{\cdot}2 \text{ per cent.}$$

Do. do.

$$\text{second ten years} = \frac{1,88,51,844}{15,99,64,377} = 11{\cdot}8 \text{ per cent.}$$

Do. do.

$$\text{third ten years} = \frac{2,21,46,430}{15,99,64,377} = 13{\cdot}8 \text{ per cent.}$$

NOTE (*ii*).—The whole of the accumulated interest will be wiped off by the end of 21st years, *i.e.*, 10 years after completion.

NOTE (*iii*).—The whole of the capital (Direct and Indirect) will be wiped out by the end of 34th year, *i.e.*, 23 years after completion (*vide* Statement H).

Financial Statements.

STATEMENT H.

Statement showing estimate of period in which arrears of interest and capital will be wiped off.

Year.	Direct outlay.	Simple interest on Direct outlay.	Net revenue Col. 9, Part III.	Net Revenue minus simple interest.	Accumulated arrears of simple interest.	Total Capital invested at end of year Col. 2 *plus* 6 *plus* Rs. 53,38,825.	Interest on balance of total outlay.	Remarks.
1	2	3	4	5	6	7	8	9
	Rs.	Rs.	Rs.	Rs.	Rs. 2,36,27,160	Rs.	Rs.	
15th ..	15,46,25,552	77,31,278	97,16,719	19,85,441	2,16,41,719	18,35,91,537	5·3	
16th ..	15,46,25,552	77,31,278	1,00,40,433	23,09,155	1,93,32,564	18,16,06,096	5·6	
17th ..	15,46,25,552	77,31,278	1,15,88,783	38,57,505	1,54,75,059	17,92,96,941	6·5	
18th ..	15,46,25,552	77,31,278	1,19,73,953	42,42,675	1,12,32,384	17,54,39,436	6·9	
19th ..	15,46,25,552	77,31,278	1,24,38,840	47,07,562	65,24,822	17,11,96,761	7·4	
20th ..	15,46,25,552	77,31,278	1,29,31,535	52,00,257	13,24,565	16,64,89,199	7·9	
21st ..	15,46,25,552	77,31,278	1,39,67,582	62,36,304	....	16,12,88,942	8·9	All arrears of interest wiped off.
22nd ..	14,97,13,132	74,85,657	1,43,32,958	68,47,301	....	15,50,51,957	9·6	
23rd ..	14,28,66,531	71,43,327	1,46,00,163	74,56,836	....	14,82,05,356	10·2	
24th ..	13,54,09,695	67,70,485	1,49,02,868	81,32,383	....	14,07,48,520	11·1	
25th ..	12,72,77,312	63,63,866	1,51,87,465	88,23,599	....	13,26,16,137	12·1	
26th ..	11,84,53,713	59,22,686	1,54,67,120	95,44,434	....	12,37,92,538	13·3	
27th ..	10,89,09,279	54,45,464	1,63,27,173	1,08,81,709	....	11,92,48,117	16·5	
28th ..	9,80,27,570	49,01,379	1,67,82,108	1,18,80,729	....	10,33,66,395	18·0	
29th ..	8,61,46,841	43,07,342	1,74,00,796	1,30,93,454	....	9,14,85,666	21·8	
30th ..	7,30,53,387	36,52,669	1,81,84,177	1,45,31,508	....	7,83,92,212	27·6	
31st ..	5,85,21,879	29,26,094	1,88,51,844	1,59,25,750	....	6,38,60,704	30·0	
32nd ..	4,25,96,129	21,29,806	1,92,17,909	11,70,88,103	....	4,79,34,954	38·0	
33rd ..	2,55,08,026	12,77,544	1,95,83,974	1,83,06,430	....	3,08,46,851	130·0	All capital invested Direct and Indirect wiped out.
34th .. Direct	72,01,592	3,60,079	1,99,50,039	1,95,89,960	....	1,25,40,417		
Indirect	53,38,825		Net Profit.					
	1,25,40,417		70,49,543					
35th ..			2,03,16,104					
36th ..			2,06,83,169					
37th ..			2,10,48,234					
38th ..			2,14,14,299					
39th ..			2,17,80,364					
40th ..			2,21,46,430 Every year onward.					

PART X.

LEADING PARTICULARS OF PROJECTS.

INDEX.

Leading Particulars of the Project.

	Rohri Canal.	Eastern Nara Canals.	Right Bank Canals.	Total.
1. Cost of Project—Direct and Indirect—including share of Barrage	53,604,252	33,338,960	72,922,544	159,964,377
2. Ultimate Nett Revenue anticipated due to Project ..	7,337,563	7,014,488	7,787,848	22,146,430
3. Return on Capital Outlay—				
10th year after completion ..	6·1	12·85	7·85	8·2
20th year after completion ..	10·7	18·15	9·7	11·8
30th year after completion ..	13·6	21· 0	10·7	13·8
4. Gross Area Commanded ..	2,956,518	2,176,494	2,361,085	7,494,077
5. Culturable Commanded ..	2,535,020	1,873,000	2,131,685	6,539,705
6. Percentage of culturable to gross	85·5 per cent.	86·0 per cent.	90·0 per cent.	87·0 per cent.
7. Proposed Final Annual cultivation	2,053,300	1,529,950	1,725,158	5,308,408
8. Percentage of cultivation to culturable	81 per cent.	81 per cent.	81 per cent.	81 per cent.

Leading Particulars of the Project—concluded.

	Khairpur Canals.		Rohri Canal.	E. Nara Supply Channel.	Jamrao Canal.	Mithrao Canal.	Khipra Canal.	N.W.P. Canal.	Rice Canal.	S.E.P. Canal.	Total.
	East.	West.									
9. Discharge of Canals at head	2,094	1,940	10,992	12,200	2,406	2,923	1,423	4,313	12,346	2,787	46,672
10. Length of Main Canal without Distributaries miles	1 (new channel).	12 (new channel).	205	15	117	86	45	97	87	140	805
11. Total length of Branches .	..	..	203	..	63	46	13	117	294	30	766
12. Total length of Distributaries	..	..	2,100	..	461	286	172	363	48	294	3,724
13. Bed width of Canal at Head	85′	79′	253′	350′	125′	98′	66′	165′	291′	98′	
14. Full Supply Depth at Canal Head . ..	9′	9′	13′	11·5′	8′	10′	7′	9·5′	12·75′	9·75′	
15. Velocity at Canal Head ..	2·60	2·58	3·26	3·0	..	2·90	2·48	2·67	3·25	2·78	
16. Number of Road Bridges on Canal	3	..	60	3	26	27	15	18	18	32	202
17. Average distance apart miles	4	..	3·3	..	4·5	3·2	3·0	4·1	4·2	4·0	3·7
18. Number of Regulators and Fall Regulators including Head Regulator ..	1	1	9	1	11	7	6	6	6	9	57
19. Average distance apart omitting first 38 miles ..	..	..	20	..	11	12	7·5	12	13	14	13
20. Number of Falls ..	..	..	7	..	1	..	..	..	1	..	9
21. Number of Syphons ..	..	..	1	..	1	..	..	3	3	1	9
22. Number of Acqueducts ..	..	..	..	..	..	..	..	2	1	2	5
23. Number of Inspection Bungalows (New) ..	..	..	26	..	..	18	..	..	46	..	90
24. Number of Inspection Bungalows (Old) ..	..	..	20	..	..	29	..	..	20	..	69
25. Anticipated Wheat crop..	..	..	..	..	..	..	..	..	..	..	935,000 tons
26. Anticipated Rice crop ..	..	..	..	..	..	..	..	..	..	..	545,000 tons
27. Anticipated Cotton crop..	..	..	..	..	..	..	..	..	..	..	190,000 tons
28. Anticipated Jowar and other crop	..	..	..	..	..	..	..	..	..	..	575,000 tons
29 Anticipated Increase of Exports	..	..	..	..	..	..	..	..	..	..	1,195,000 tons

PART XI.

DIAGRAMS.

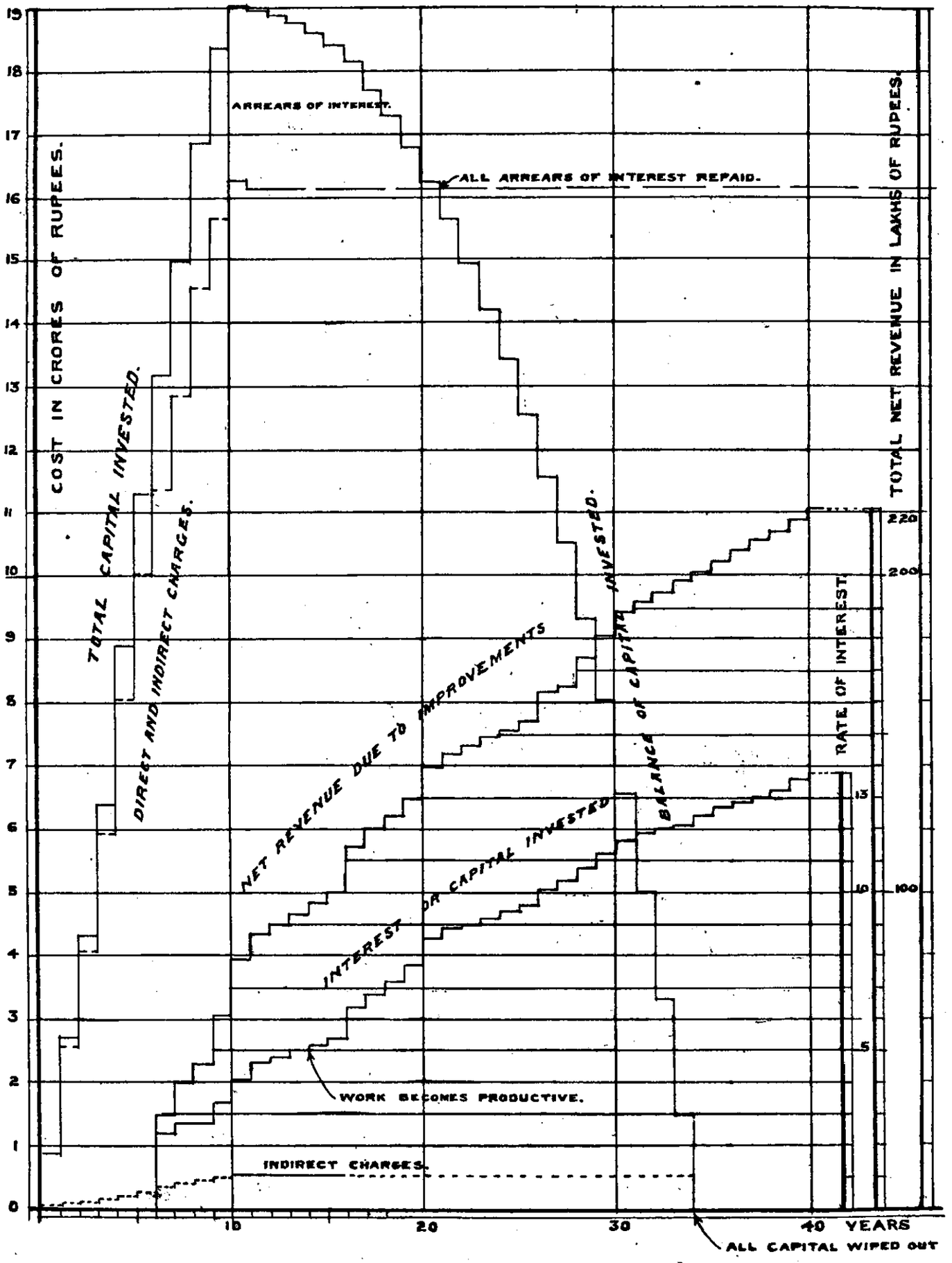
INDEX.

SUKKUR BARRAGE CANAL PROJECTS 1919-20

DIAGRAM

SHOWING

ANTICIPATED FINANCIAL RESULTS



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EXECUTIVE ENGINEER

PART XII.

SUMMARY OF FINANCIAL FORECASTS FOR ALTERNATIVE COMBINATIONS AND FOR EACH CANAL SYSTEM SEPARATELY GIVEN IN VOLUME XIX.

Statement showing net financial results.

	Combined Project and Manchar. (Without Kalat and Begari Branches). Without Cess.		Combined Project and Manchar. (Without Kalat and Begari Branches). With Cess of Rs. 3 per acre.	
Set No.	1		2	
Including share of cost of Barrage.				
(a) Total cost of Works—Direct ..	63,052,230		163,052,230	
(b) Total cost of Works—Indirect ..	5,307,103		5,307,103	
(c) Total Direct and Indirect ..	168,359,333		168,359,333	
(d) All works completed in year from commencement ..	Eleventh.		Eleventh.	
(e) Work becomes productive in years from commencement of work.	Seventeenth.		Fifteenth.	
(f) Accumulated arrears of interest up to year (e) ..	29,895,398		26,106,448	
(g) Total Capital invested in year (e) ..	198,254,731		194,467,781	
(h) Net Revenue due to improvements in year (e) ..	10,910,269		10,183,869	
(i) Interest paid in year (e) ..	5·50 per cent. 6th year after completion.		5·23 per cent. 4th year after completion.	
Tenth year after completion of work.				
(j) Total Capital invested ..	181,575,567		173,278,429	
(k) Net Revenue due to improvements ..	13,261,165		14,360,665	
(l) Interest paid ..	7·30 per cent.		8·27 per cent.	
Twentieth year after completion of work.				
(m) Total Capital invested ..	168,359,333		168,359,333	
(n) Net Revenue due to improvements ..	18,073,544		19,284,044	
(o) Interest paid ..	10·7 per cent.		11·4 per cent.	
Thirtieth year after completion of work.				
(p) Total Capital invested ..	168,359,333		168,359,333	
(q) Net Revenue due to improvements ..	21,277,331		22,577,831	
(r) Interest paid. ..	12·6 per cent.		13·4 per cent.	
(s) All accumulated arrears of interest will be wiped out in year from commencement of work.	At end of 24th year.		End of 21st year.	
(t) All Capital wiped out in year do. ..	End of 37th year.		End of 35th year.	
Cultivation.	*Acres.*	*Percentage.*	*Acres.*	*Percentage.*
(u) Present Cultivation in acres ..	1,945,114	31 per cent.	1,945,114	31 per cent.
(v) Cultivation in year (e) when work becomes productive.	3,439,726	55 per cent.	3,439,726	55 per cent.
(w) Ultimate anticipated cultivation in 30 years after completion.	5,199,437	83 per cent.	5,199,437	83 per cent.
(x) Total Culturable Area ..	6,272,675	100 per cent.	6,272,675	100 per cent.
(y) Total Gross Commanded ..	7,205,484		7,205,484	

	Combined Project and Manchar. (With Kalat and Begari Branches). Without Cess.	Combined Project and Manchar. (With Kalat and Begari Branches). With Cess of Rs. 3 per acre.
Set No.	3	4
Including share of cost of Barrage.		
(*a*) Total cost of Works—Direct ..	170,785,706	170,785,706
(*b*) Total cost of Works—Indirect ..	5,615,668	5,615,668
(*c*) Total Direct and Indirect ..	176,401,374	176,401,374
(*d*) All works completed in year from commencement...	Eleventh.	Eleventh.
(*e*) Work becomes productive in years from commencement of work.	Seventeenth.	Fourteenth.
(*f*) Accumulated arrears of interest up to year (*e*) ..	29,243,291	28,477,492
(*g*) Total Capital invested in year (*e*) ..	205,644,665	204,878,866
(*h*) Net Revenue due to improvements in year (*e*) ..	11,673,708	10,519,219
(*i*) Interest paid in year (*e*) ..	5·7 per cent. 6th year after completion.	5·15 per cent. 3rd year after completion.
Tenth year after completion of work.		
(*j*) Total Capital invested ..	187,318,714	179,493,237
(*k*) Net Revenue due to improvements ..	14,135,438	15,234,938
(*l*) Interest paid ..	7·5 per cent.	8·5 per cent.
Twentieth year after completion of work.		
(*m*) Total Capital invested ..	176,401,374	176,401,374
(*n*) Net Revenue due to improvements ..	19,121,241	20,331,741
(*o*) Interest paid ..	10·8 per cent.	11·5 per cent.
Thirtieth year after completion of work.		
(*p*) Total Capital invested ..	176,401,374	176,401,374
(*q*) Net Revenue due to improvements ..	22,420,670	23,721,168
(*r*) Interest paid ..	12·6 per cent.	13·4 per cent.
(*s*) All accumulated arrears of interest will be wiped out in year from commencement of work.	End of 23rd year.	End of 21st year.
(*t*) All Capital wiped out in year do. ..	End of 37th year.	End of 35th year.

Cultivation.	*Acres.*	*Percentage.*	*Acres.*	*Percentage.*
(*u*) Present Cultivation in acres ..	2,035,636	31 per cent.	2,035,636	31 per cent.
(*v*) Cultivation in year (*e*) when work becomes productive.	3,628,038	55·5 per cent.	3,386,716	55·5 per cent.
(*w*) Ultimate anticipated cultivation in 30 years after completion.	5,446,530	83 per cent.	5,446,530	83 per cent.
(*x*) Total Culturable Area ..	6,540,669	100 per cent.	6,540,669	100 per cent.
(*y*) Total Gross Commanded ..	7,494,077		7,494,077	

	Combined Project without Manchar without Kalat and Begari Branches.		Combined Project without Manchar with Kalat and Begari Branches.	
Set No.	5		6	
Including share of cost of Barrage.				
(*a*) Total cost of Works—Direct ..	136,588,855		148,422,231	
(*b*) Total cost of Works—Indirect ..	4,642,213		5,150,778	
(*c*) Total Direct and Indirect ..	141,231,068		153,573,009	
(*d*) All works completed in year from commencement ..	Eleventh.		Eleventh.	
(*e*) Work becomes productive in years from commencement of work.	Twelfth.		Twelfth.	
(*f*) Accumulated arrears of interest up to year (*e*) ..	25,177,107		24,580,168	
(*g*) Total Capital invested in year (*e*) ..	166,408,175		178,153,177	
(*h*) Net Revenue due to improvements in year (*e*) ..	8,425,752		9,352,118	
(*i*) Interest paid in year (*e*) ..	5·16 per cent. 1st Year after completion.		5·26 per cent. 1st Year after completion.	
Tenth year after completion of work.				
(*j*) Total Capital invested ..	141,231,068		153,573,009	
(*k*) Net Revenue due to improvements ..	13,445,415		14,589,688	
(*l*) Interest paid ..	9·5 per cent.		9·5 per cent.	
Twentieth year after completion of work.				
(*m*) Total Capital invested ..	141,231,068		153,573,009	
(*n*) Net Revenue due to improvements ..	18,237,804		19,555,491	
(*o*) Interest paid ..	12·9 per cent.		12·75 per cent.	
Thirtieth year after completion of work.				
(*p*) Total Capital invested ..	141,231,068		153,573,009	
(*q*) Net Revenue due to improvements ..	21,441,581		22,854,918	
(*r*) Interest paid ..	15·2 per cent.		14·85 per cent.	
(*s*) All accumulated arrears of interest will be wiped out in year from commencement of work.	End of 20th year.		End of 19th year.	
(*t*) All Capital wiped out in year do. ..	End of 32nd year.		End of 32nd year.	
Cultivation.	*Acres.*	*Percentage.*	*Acres.*	*Percentage.*
(*u*) Present Cultivation in acres ..	1,945,114	31 per cent.	2,035,636	31 per cent.
(*v*) Cultivation in year (*e*) when work becomes productive.	2,985,061	47·6 per cent.	3,160,774	55·5 per cent.
(*w*) Ultimate anticipated cultivation in 30 years after completion.	5,199,437	83 per cent.	5,390,530	83 per cent.
(*x*) Total Culturable Area ..	6,272,675	100 per cent.	6,540,669	100 per cent.
(*y*) Total Gross Commanded ..	7,205,484		7,494,077	

	Rohri Canal with Barrage share without Kalat and Begari Branches		Rohri Canal with Barrage Share with Kalat and Begari Branches.	
Set No.	7		8	
Including share of cost of Barrage.				
(*a*) Total cost of Works—Direct ..	52,251,697		51,848,797	
(*b*) Total cost of Works—Indirect ..	1,755,455		1,755,455	
(*c*) Total Direct and Indirect ..	54,007,152		53,604,252	
(*d*) All works completed in year from commencement ..	Eleventh.		Eleventh.	
(*e*) Work becomes productive in years from commencement of work.	Twentieth.		Twentieth.	
(*f*) Accumulated arrears of interest up to year (*e*) ..	12,310,486		11,977,486	
(*g*) Total Capital invested in year (*e*) ..	66,317,638		65,581,738	
(*h*) Net Revenue due to improvements in year (*e*) ..	3,414,823		3,414,823	
(*i*) Interest paid in year (*e*) ..	5·15 per cent. 9th year after completion.		5·2 per cent. 9th year after completion.	
Tenth year after completion of work.				
(*j*) Total Capital invested ..	65,010,941		64,254,041	
(*k*) Net Revenue due to improvements ..	3,920,393		3,920,393	
(*l*) Interest paid ..	6·0 per cent.		6·1 per cent.	
Twentieth year after completion of work.				
(*m*) Total Capital invested ..	54,007,152		53,604,252	
(*n*) Net Revenue due to improvements ..	5,741,258		5,741,258	
(*o*) Interest paid ..	10·6 per cent.		10·7 per cent.	
Thirtieth year after completion of work.				
(*p*) Total Capital invested ..	54,007,152		53,604,252	
(*q*) Net Revenue due to improvements ..	7,337,563		7,337,563	
(*r*) Interest paid ..	13·5 per cent.		13·6 per cent.	
(*s*) All accumulated arrears of interest will be wiped out in year from commencement of work.	End of 27th year.		End of 27th year.	
(*t*) All Capital wiped out in year do. ..	End of 39th year.		End of 39th year.	
Cultivation.	*Acres.*	*Percentage.*	*Acres.*	*Percentage.*
(*u*) Present Cultivation in acres ..	657,300	26 per cent.	657,300	26 per cent.
(*v*) Cultivation in year (*e*) when work becomes productive.	1,232,500	48·5 per cent.	1,232,500	48·5 per cent.
(*w*) Ultimate anticipated cultivation in 30 years after completion.	2,053,300	81 per cent.	2,053,300	81 per cent.
(*x*) Total Culturable Area ..	2,535,020	100 per cent.	2,535,020	100 per cent.
(*y*) Total Gross Commanded ..	2,956,518		2,956,518	

	Eastern Nara Canals with share of Barrage without Kalat and Begari Branches.		Eastern Nara Canals with share of Barrage with Kalat and Begari Branches.	
Set No.	9		10	
Including share of cost of Barrage.				
(*a*) Total cost of Works—Direct ..	32,717,373		32,342,373	
(*b*) Total cost of Works—Indirect ..	1,046,587		1,046,587	
(*c*) Total Direct and Indirect ..	33,763,960		33,388,960	
(*d*) All works completed in year from commencement ..	Eleventh.		Eleventh.	
(*e*) Work becomes productive in years from commencement of work.	Eleventh.		Eleventh.	
(*f*) Accumulated arrears of interest up to year (*e*) ..	1,795,962		1,599,962	
(*g*) Total Capital invested in year (*e*) ..	35,559,922		34,988,922	
(*h*) Net Revenue due to improvements in year (*e*) ..	2,219,003		2,219,003	
(*i*) Interest paid in year (*e*) ..	6·25 per cent. On completion of work.		6·3 per cent. On completion of work.	
Tenth year after completion of work.				
(*j*) Total Capital invested ..	33,763,960		33,388,960	
(*k*) Net Revenue due to improvements ..	4,291,983		4,291,983	
(*l*) Interest paid ..	12·7 per cent.		12·85 per cent.	
Twentieth year after completion of work.				
(*m*) Total Capital invested ..	33,763,960		33,388,960	
(*n*) Net Revenue due to improvements ..	6,054,048		6,054,048	
(*o*) Interest paid ..	18·0 per cent.		18·15 per cent.	
Thirtieth year after completion of work.				
(*p*) Total Capital invested ..	33,763,960		33,388,960	
(*q*) Net Revenue due to improvements ..	7,014,488		7,014,488	
(*r*) Interest paid ..	20·83 per cent.		21·0 per cent.	
(*s*) All accumulated arrears of interest will be wiped out in year from commencement of work.	End of 14th year.		End of 14th year.	
(*t*) All Capital wiped out in year do. ..	End of 26th year.		End of 26th year.	
Cultivation.	*Acres.*	*Percentage.*	*Acres.*	*Percentage.*
(*u*) Present Cultivation in acres ..	484,679	26 per cent.	484,679	26 per cent.
(*v*) Cultivation in year (*e*) when work becomes productive	783,750	42 per cent.	783,750	42 per cent.
(*w*) Ultimate anticipated cultivation in 30 years after completion.	1,529,950	81 per cent.	1,529,950	81 per cent.
(*x*) Total Culturable Area ..	1,873,000	100 per cent.	1,873,000	100 per cent.
(*y*) Total Gross Commanded ..	2,176,494		2,176,494	

	Combined Project for N.-W., S.-E., and Central Canals and Manchar (except Kalat and Begari Branches, without Cess.		Combined Project for N.-W., S.-E., and Central Canals and Manchar (except Kalat and Begari Branches with Cess.	
Set No.	11		12	
Including share of cost of Barrage.				
(*a*) Total cost of Works—Direct ..	76,624,266		76,624,266	
(*b*) Total cost of Works—Indirect ..	2,459,540		2,459,540	
(*c*) Total Direct and Indirect ..	79,083,806		79,083,806	
(*d*) All works completed in year from commencement ..	Tenth.		Tenth.	
(*e*) Work becomes productive in years from commencement of work.	Twentieth.		Twelfth.	
(*f*) Accumulated arrears of interest up to year (*e*) ..	16,158,890		13,416,857	
(*g*) Total Capital invested in year (*e*) ..	95,242,696		92,500,663	
(*h*) Net Revenue due to improvements in year (*e*) ..	4,804,460		4,700,692	
(*i*) Interest paid in year (*e*) ..	5·03 per cent. 10th year after completion.		5·1 per cent. 2nd year after completion.	
Tenth year after completion of work.				
(*j*) Total Capital invested ..	94,269,449		79,083,806	
(*k*) Net Revenue due to improvements ..	4,961,888		6,061,388	
(*l*) Interest paid ..	5·26 per cent.		7·7 per cent.	
Twentieth year after completion of work.				
(*m*) Total Capital invested ..	79,083,806		79,083,806	
(*n*) Net Revenue due to improvements ..	6,191,337		7,401,837	
(*o*) Interest paid ..	7·84 per cent.		9·4 per cent.	
Thirtieth year after completion of work.				
(*p*) Total Capital invested ..	79,083,806		79,083,806	
(*q*) Net Revenue due to improvements ..	6,838,279		8,138,779	
(*r*) Interest paid ..	8·7 per cent.		10·3 per cent.	
(*s*) All accumulated arrears of interest will be wiped out in year from commencement of work.	End of 31st year.		End of 21st year.	
(*t*) All Capital wiped out in year do. ..	End of 49th year.		End of 38th year.	
Cultivation.	*Acres.*	*Percentage.*	*Acres.*	*Percentage.*
(*u*) Present Cultivation in acres ..	857,135	41·6 per cent.	857,135	41·6 per cent.
(*v*) Cultivation in year (*e*) when work becomes productive	1,185,773	57·7 per cent.	1,185,773	57·7 er cent.
(*w*) Ultimate anticipated cultivation in 30 years after completion.	1,666,187	81 per cent.	1,666,187	81 per cent.
(*x*) Total Culturable Area ..	2,050,691	100 per cent.	2,050,691	100 per cent.
(*y*) Total Gross Commanded ..	2,284,472		2,284,472	

	Combined Project for N.-W., S.-E., and Central Canals, and Manchar (including Kalat and Begari Branches). Without Cess.		Combined Project for N.-W., S.-E., and Central Canals and Manchar (including Kalat and Begari Branches). With Cess.	
Set No.	13		14	
Including share of cost of Barrage.				
(*a*) Total cost of Works—Direct ..	85,151,636		85,151,636	
(*b*) Total cost of Works—Indirect ..	2,768,105		2,768,105	
(*c*) Total Direct and Indirect ..	87,919,741		87,919,741	
(*d*) All works completed in year from commencement ..	Tenth.		Tenth.	
(*e*) Work becomes productive in years from commencement of work.	Eighteenth.		Twelfth.	
(*f*) Accumulated arrears of interest up to year (*e*) ..	15,725,848		14,224,071	
(*g*) Total Capital invested in year (*e*) ..	103,645,589		102,143,812	
(*h*) Net Revenue due to improvements in year (*e*) ..	5,493,702		5,321,547	
(*i*) Interest paid in year (*e*) ..	5·3 per cent. 8th year after completion.		5·2 per cent. 2nd year after completion.	
Tenth year after completion of work.				
(*j*) Total Capital invested ..	98,009,428		87,919,741	
(*k*) Net Revenue due to improvements ..	5,923,065		7,022,565	
(*l*) Interest paid ..	6·1 per cent.		8·0 per cent.	
Twentieth year after completion of work.				
(*m*) Total Capital invested ..	87,919,741		87,919,741	
(*n*) Net Revenue due to improvements ..	7,056,441		8,536,435	
(*o*) Interest paid ..	8·03 per cent.		9·7 per cent.	
Thirtieth year after completion of work.				
(*p*) Total Capital invested ..	87,919,741		87,919,741	
(*q*) Net Revenue due to improvements ..	8,068,517		9,369,017	
(*r*) Interest paid ..	9·2 per cent.		10·7 per cent.	
(*s*) All accumulated arrears of interest will be wiped out in year from commencement of work.	End of 27th year.		End of 20th year.	
(*t*) All Capital wiped out in year do. ..	End of 44th year.		End of 36th year.	
Cultivation.	*Acres.*	*Percentage.*	*Acres.*	*Percentage.*
(*u*) Present Cultivation in acres ..	947,657	41 per cent.	947,657	41 per cent.
(*v*) Cultivation in year (*e*) when work becomes productive	1,358,597	58 per cent.	1,358,597	58 per cent.
(*w*) Ultimate anticipated cultivation in 30 years after completion.	1,913,280	83 per cent.	1,913,280	83 per cent.
(*x*) Total Culturable Area ..	2,318,685	100 per cent.	2,318,685	100 per cent.
(*y*) Total Gross Commanded ..	2,573,065		2,573,065	

	Combined Project for N.-W., S.-E., and Central Canals without Manchar (except Kalat and Begari Branches.		Combined Project for N.-W., S.-E., and Central Canals without Manchar (including Kalat and Begari Branches).	
Set No.	15		16	
Including share of cost of Barrage.				
(*a*) Total cost of Works—Direct ..	54,260,791		62,788,161	
(*b*) Total cost of Works—Indirect ..	1,994,650		2,303,215	
(*c*) Total Direct and Indirect ..	56,255,441		65,091,376	
(*d*) All works completed in year from commencement ..	Tenth.		Tenth.	
(*e*) Work becomes productive in years from commencement of work.	Eleventh.		Eleventh.	
(*f*) Accumulated arrears of interest up to year (*e*) ..	8,768,301		9,165,382	
(*g*) Total Capital invested in year (*e*) ..	65,023,742		74,256,758	
(*h*) Net Revenue due to improvements in year (*e*) ..	3,352,071		4,082,674	
(*i*) Interest paid in year (*e*) ..	5·2 per cent. 1st year after completion.		5·5 per cent. 1st year after completion.	
Tenth year after completion of work.				
(*j*) Total Capital invested ..	56,255,441		65,091,376	
(*k*) Net Revenue due to improvements ..	5,146,138		6,107,315	
(*l*) Interest paid ..	9·1 per cent.		9·4 per cent.	
Twentieth year after completion of work.				
(*m*) Total Capital invested ..	56,255,441		65,091,376	
(*n*) Net Revenue due to improvements ..	6,355,587		7,490,185	
(*o*) Interest paid ..	11·3 per cent.		11·5 per cent.	
Thirtieth year after completion of work.				
(*p*) Total Capital invested ..	56,255,441		65,091,376	
(*q*) Net Revenue due to improvements ..	7,002,529		8,232,767	
(*r*) Interest paid ..	12·4 per cent.		12·65 per cent.	
(*s*) All accumulated arrears of interest will be wiped out in year from commencement of work.	End of 17th year.		End of 17th year.	
(*t*) All Capital wiped out in year do. ..	End of 32nd year.		End of 31st year.	
Cultivation.	*Acres.*	*Percentage.*	*Acres.*	*Percentage.*
(*u*) Present Cultivation in acres ..	803,135	43 per cent.	893,657	42 per cent.
(*v*) Cultivation in year (*e*) when work becomes productive	1,079,773	58 per cent.	1,252,597	59 per cent.
(*w*) Ultimate anticipated cultivation in 30 years after completion.	1,560,187	84 per cent.	1,807,280	85 per cent.
(*x*) Total Culturable Area ..	1,863,691	100 per cent.	2,131,685	100 per cent.
(*y*) Total Gross Commanded ..	2,072,472		2,361,065	

	North Western Perennial Canal without Kalat section of Khirtar Branch.		North Western Perennial Canal with Kalat section of Khirtar Branch.	
Set No.	17		18	
Including share of cost of Barrage.				
(*a*) Total cost of Works—Direct ..	15,857,000		20,415,235	
(*b*) Total cost of Works—Indirect ..	484,020		607,400	
(*c*) Total Direct and Indirect ..	16,341,020		21,022,635	
(*d*) All works completed in year from commencement ..	Sixth.		Sixth.	
(*e*) Work becomes productive in years from commencement of work.	Eleventh.		Tenth.	
(*f*) Accumulated arrears of interest up to year (*e*) ..	2,719,195		3,142,755	
(*g*) Total Capital invested in year (*e*) ..	19,060,215		24,165,390	
(*h*) Net Revenue due to improvements in year (*e*) ..	1,000,652		1,220,967	
(*i*) Interest paid in year (*e*) ..	5·26 per cent. 5th year after completion.		5·05 per cent. 4th year after completion.	
Tenth year after completion of work.				
(*j*) Total Capital invested ..	16,879,822		21,252,993	
(*k*) Net Revenue due to improvements ..	1,553,857		1,966,968	
(*l*) Interest paid ..	9·3 per cent.		9·25 per cent.	
Twentieth year after completion of work.				
(*m*) Total Capital invested ..	16,341,020		21,022,635	
(*n*) Net Revenue due to improvements ..	1,839,179		2,208,736	
(*o*) Interest paid ..	11·25 per cent.		11·0 per cent.	
Thirtieth year after completion of work.				
(*p*) Total Capital invested ..	16,341,020		21,022,635	
(*q*) Net Revenue due to improvements ..	2,437,901		3,079,214	
(*r*) Interest paid ..	14·85 per cent.		14·6 per cent.	
(*s*) All accumulated arrears of interest will be wiped out in year from commencement of work.	End of 17th year.		End of 17th year.	
(*t*) All Capital wiped out in year do. ..	End of 31st year.		End of 32nd year.	
Cultivation.	*Acres.*	*Percentage.*	*Acres.*	*Percentage.*
(*u*) Present Cultivation in acres ..	289,246	36 per cent.	326,502	33 per cent.
(*v*) Cultivation in year (*e*) when work becomes productive	388,577	48·4 per cent.	461,139	47 per cent.
(*w*) Ultimate anticipated cultivation in 30 years after completion.	647,083	80·5 per cent.	815,048	83 per cent.
(*x*) Total Culturable Area ..	804,351	100 per cent.	984,911	100 per cent.
(*y*) Total Gross Commanded ..	902,250		1,094,783	

	South Eastern Perennial Canal without Kalat section of Khirtar Branch and Begari Branch.		South Eastern Perennial Canal with Kalat section of Khirtar Branch and Begari Branch.	
Set No.	19		20	
Including share of cost of Barrage.				
(*a*) Total cost of Works—Direct ..	16,525,566		16,390,053	
(*b*) Total cost of Works—Indirect ..	486,927		486,927	
(*c*) Total Direct and Indirect ..	17,012,493		16,876,980	
(*d*) All works completed in year from commencement ..	Sixth.		Sixth.	
(*e*) Work becomes productive in years from commencement of work.	Fourteenth.		Fourteenth.	
(*f*) Accumulated arrears of interest up to year (*e*) ..	2,406,100		2,365,144	
(*g*) Total Capital invested in year (*e*) ..	19,418,593		19,242,124	
(*h*) Net Revenue due to improvements in year (*e*) ..	979,958		979,958	
(*i*) Interest paid in year (*e*) ..	5·05 per cent. 8th year after completion.		5·1 per cent. 8th year after completion	
Tenth year after completion of work.				
(*j*) Total Capital invested ..	18,508,982		18,359,617	
(*k*) Net Revenue due to improvements ..	1,209,420		1,209,420	
(*l*) Interest paid ..	6·53 per cent.		7·16 per cent.	
Twentieth year after completion of work.				
(*m*) Total Capital invested ..	17,012,493		16,876,980	
(*n*) Net Revenue due to improvements ..	1,471,577		1,471,577	
(*o*) Interest paid ..	8·65 per cent.		8·7 per cent.	
Thirtieth year after completion of work.				
(*p*) Total Capital invested ..	17,012,493		16,876,980	
(*q*) Net Revenue due to improvements ..	1,937,442		1,937,442	
(*r*) Interest paid ..	11·4 per cent.		11·5 per cent.	
(*s*) All accumulated arrears of interest will be wiped out in year from commencement of work.	End of 21st year.		End of 20th year.	
(*t*) All Capital wiped out in year do. ..	End of 35th year.		End of 34th year.	
Cultivation.	*Acres.*	*Percentage.*	*Acres.*	*Percentage.*
(*u*) Present Cultivation in acres ..	250,705	41·7 per cent.	250,705	41·7 per cent.
(*v*) Cultivation in year (*e*) when work becomes productive	345,754	57·5 per cent.	345,754	57·5 per cent.
(*w*) Ultimate anticipated cultivation in 30 years after completion.	498,809	83·0 per cent.	498,809	83·0 per cent.
(*x*) Total Culturable Area ..	601,554	100 per cent.	601,554	100 per cent.
(*y*) Total Gross Commanded ..	659,798		659,798	

	Central Rice Canal without Kalat section of Khirtar Branch and Begari Branch.		Central Rice Canal with Kalat section of Khirtar Branch and Begari Branch.	
Set No.	21		22	
Including share of cost of Barrage.				
(*a*) Total cost of Works—Direct ..	21,878,225		25,982,873	
(*b*) Total cost of Works—Indirect ..	1,023,703		1,208,888	
(*c*) Total Direct and Indirect ..	22,901,928		27,191,761	
(*d*) All works completed in year from commencement ..	Tenth.		Tenth.	
(*e*) Work becomes productive in years from commencement of work.	Eleventh.		Eleventh.	
(*f*) Accumulated arrears of interest up to year (*e*) ..	3,315,073		3,492,761	
(*g*) Total Capital invested in year (*e*) ..	26,217,001		30,683,911	
(*h*) Net Revenue due to improvements in year (*e*) ..	1,437,899		1,875,128	
(*i*) Interest paid in year (*e*) ..	5·5 per cent. 1st year after completion.		6·1 per cent. 1st year after completion.	
Tenth year after completion of work.				
(*j*) Total Capital invested ..	22,901,928		27,191,761	
(*k*) Net Revenue due to improvements ..	2,150,078		2,662,033	
(*l*) Interest paid ..	9·4 per cent.		9·8 per cent.	
Twentieth year after completion of work.				
(*m*) Total Capital invested ..	22,901,928		27,191,761	
(*n*) Net Revenue due to improvements ..	2,544,535		3,133,461	
(*o*) Interest paid ..	11·1 per cent.		11·5 per cent.	
Thirtieth year after completion of work.				
(*p*) Total Capital invested ..	22,901,928		27,191,761	
(*q*) Net Revenue due to improvements ..	2,627,184		3,216,110	
(*r*) Interest paid ..	11·5 per cent.		11·8 per cent.	
(*s*) All accumulated arrears of interest will be wiped out in year from commencement of work.	End of 16th year.		End of 14th year.	
(*t*) All Capital wiped out in year do. ..	End of 31st year.		End of 30th year.	
Cultivation.	*Acres.*	*Percentage.*	*Acres.*	*Percentage.*
(*u*) Present Cultivation in acres ..	263,184	52·5 per cent.	316,450	58 per cent.
(*v*) Cultivation in year (*e*) when work becomes productive	369,105	80·5 per cent.	448,232	82 per cent.
(*w*) Ultimate anticipated cultivation in 30 years after completion.	414,296	90·5 per cent.	493,423	90 per cent.
(*x*) Total Culturable Area ..	457,786	100 per cent.	545,220	100 per cent.
(*y*) Total Gross Commanded ..	510,424		606,484	

	Kalat section of Khirtar Branch.	Nasirabad Canal (Inundation) 1920.
Set No.	23	24
Including share of cost of Barrage.		
(*a*) Total cost of Works—Direct ..	5,002,550	4,550,000
(*b*) Total cost of Works—Indirect ..	123,380	115,000
(*c*) Total Direct and Indirect ..	5,125,930	4,665,000
(*d*) All works completed in year from commencement ..	Fifth.	Fourth.
(*e*) Work becomes productive in years from commencement of work.	Fourteenth.	Twelfth.
(*f*) Accumulated arrears of interest up to year (*e*) ..	909,222	890,250
(*g*) Total Capital invested in year (*e*) ..	6,035,152	5,555,250
(*h*) Net Revenue due to improvements in year (*e*) ..	304,390	290,000
(*i*) Interest paid in year (*e*) ..	5·04 per cent. 9th year after completion.	5·28 per cent. 8th year after completion.
Tenth year after completion of work.		
(*j*) Total Capital invested ..	5,819,889	5,280,750
(*k*) Net Revenue due to improvements ..	339,376	377,000
(*l*) Interest paid ..	5·73 per cent.	7·15 per cent.
Twentieth year after completion of work.		
(*m*) Total Capital invested ..	5,125,930	4,665,000
(*n*) Net Revenue due to improvements ..	395,661	377,000
(*o*) Interest paid ..	7·72 per cent.	8·05 per cent.
Thirtieth year after completion of work.		
(*p*) Total Capital invested ..	5,125,930	4,665,000
(*q*) Net Revenue due to improvements ..	553,987	377,000
(*r*) Interest paid ..	10·8 per cent.	8·05 per cent.
(*s*) All accumulated arrears of interest will be wiped out in year from commencement of work.	End of 21st year.	End of 19th year.
(*t*) All Capital wiped out in year do. ..	End of 45th year.	End of 45th year.

Cultivation.	*Acres.*	*Percentage.*	*Acres.*	*Percentage.*
(*u*) Present Cultivation in acres ..	37,256	20·6 per cent.	33,000	12·8 per cent.
(*v*) Cultivation in year (*e*) when work becomes productive	92,652	51·5 per cent.	98,000	38·0 per cent.
(*w*) Ultimate anticipated cultivation in 30 years after completion.	148,192	80·0 per cent.	118,200	46·0 per cent.
(*x*) Total Culturable Area ..	180,560	100·0 per cent.	257,255	100 per cent.
(*y*) Total Gross Commanded ..	192,533		285,794	

	Nasirabad Canal Inundation (1918).		Begari Branch.	
Set No.	25		26	
Including share of cost of Barrage.				
(*a*) Total cost of Works—Direct ..	9,856,000		4,364,526	
(*b*) Total cost of Works—Indirect ..	246,000		185,185	
(*c*) Total Direct and Indirect ..	10,102,000		4,549,711	
(*d*) All works completed in year from commencement ..	Tenth.		Eighth.	
(*e*) Work becomes productive in years from commencement of work.	Thirty-first.		Tenth.	
(*f*) Accumulated arrears of interest up to year (*e*) ..	1,327,074		643,314	
(*g*) Total Capital invested in year (*e*) ..	11,429,074		5,193,025	
(*h*) Net Revenue due to improvements in year (*e*) ..	571,851		434,254	
(*i*) Interest paid in year (*e*) ..	5·0 per cent. Not productive.		8·36 per cent. 2nd year after completion.	
Tenth year after completion of work.				
(*j*) Total Capital invested ..	12,219,584		4,549,711	
(*k*) Net Revenue due to improvements ..	571,851		434,254	
(*l*) Interest paid ..	4·67 per cent.		9·54 per cent.	
Twentieth year after completion of work.				
(*m*) Total Capital invested ..	11,508,125		4,549,711	
(*n*) Net Revenue due to improvements ..	571,851		509,010	
(*o*) Interest paid ..	4·97 per cent.		11·2 per cent.	
Thirtieth year after completion of work.				
(*p*) Total Capital invested ..	10,717,615		4,549,711	
(*q*) Net Revenue due to improvements ..	571,851		585,952	
(*r*) Interest paid ..	5·32 per cent.		12·9 per cent.	
(*s*) All accumulated arrears of interest will be wiped out in year from commencement of work.	End of 47th year.		End of 12th year.	
(*t*) All Capital wiped out in year do. ..	End of 110th year.		End of 30th year.	
Cultivation.	*Acres.*	*Percentage.*	*Acres.*	*Percentage.*
(*u*) Present Cultivation in acres ..	49,470	12·5 per cent.	53,266	61 per cent.
(*v*) Cultivation in year (*e*) when work becomes productive.	181,000	46·0 per cent.	79,127	91 per cent.
(*w*) Ultimate anticipated cultivation in 30 years after completion.	181,000	46·0 per cent.	79,127	91 per cent.
(*x*) Total Culturable Area	393,525	100 per cent.	87,434	100 per cent.
(*y*) Total Gross Commanded	437,250		96,060	

	Utilisation of 2,000 cusecs of Begari Canal.	Manchar works without cess.	Manchar works with Cess of Re. 3 per acre.
Set No.	27	28	29
Including share of cost of Barrage.			
(*a*) Total cost of Works—Direct ..	1,800,000	22,363,475	22,363,475
(*b*) Total cost of Works—Indirect ..	Negligible.	464,890	464,890
(*c*) Total Direct and Indirect ..	1,800,000	22,828,365	22,828,368
(*d*) All works completed in year from commencement ..	Third.	Non-productive.	Non-productive.
(*e*) Work becomes productive in years from commencement of work.	Seventh.		
(*f*) Accumulated arrears of interest up to year (*e*) ..	100,000		
(*g*) Total Capital invested in year (*e*) ..	1,900,000		
(*h*) Net Revenue due to improvements in year (*e*) ..	95,000		
(*i*) Interest paid in year (*e*) ..	5 per cent. 4th year after completion.		
Tenth year after completion of work.			
(*j*) Total Capital invested ..	1,800,000		
(*k*) Net Revenue due to improvements ..	150,000		
(*l*) Interest paid ..	8·33 per cent.		
Twentieth year after completion of work.			
(*m*) Total Capital invested ..	1,800,000		
(*n*) Net Revenue due to improvements ..	150,000		
(*o*) Interest paid ..	8·33 per cent.		
Thirtieth year after completion of work.			
(*p*) Total Capital invested ..	1,800,000		
(*q*) Net Revenue due to improvements ..	150,000		
(*r*) Interest paid ..	8·33 per cent.		
(*s*) All accumulated arrears of interest will be wiped out in year from commencement of work.	End of 11th year.		
(*t*) All Capital wiped out in year do. ..	End of 37th year.		

Cultivation.	*Acres.*	*Percentage.*	*Acres.*	*Percentage.*	*Acres.*	*Percentage.*
(*u*) Present Cultivation in acres ..	117,442	35 per cent.	54,000	29 per cent.	54,000	29 per cent.
(*v*) Cultivation in year (*e*) when work becomes productive	149,442	44·5 per cent.				
(*w*) Ultimate anticipated cultivation in 30 years after completion.	167,774	50·0 per cent.	106,000	56·7 per cent.	106,000	56·7 per cent.
(*x*) Total Culturable Area ..	335,551	100 per cent.	187,000	100 per cent.	187,000	100 per cent.
(*y*) Total Gross Commanded ..	372,834		212,000		212,000	

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