# REPORT

OF THE

# INDUS COMMISSION

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## (Volume II)

**Review of the Technical Evidence put forward during the Proceedings of the Indus Commission.**

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## SIND'S KHARIF CASE.

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## ABBREVIATIONS.

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|---|---|---|
| Sind Sheet or S. Sheet. | .. (say 20) | Refers to the machine-numbered sheet 20 in the book titled—"Sind Kharif Case". The reference may be on either side of the sheet, as there is only one machine number for the two pages of one sheet. |
| S. II | .. (say 10) | Refers to Sind Kharif Case, Vol. II—and machine numbered sheet 10. |
| P.D. III, etc., or P. Vol. III. | | Refers to Punjab Defence, Vol. III. |
| P. or p. | .. .. .. | Refers to page. |
| N. T. | .. .. | Nicholson Trench. |
| N. T. Report | .. .. | Nicholson Trench report on the probable Bhakra Dam effect on Sind. |
| S. V. P. | .. .. .. | Sutlej Valley Project. |
| I. R. C. | .. .. .. | Indus River Commission (Sind). |
| I. D. C. | .. .. .. | Indus Discharge Committee. |
| C. B. I. | .. .. .. | Central Board of Irrigation. |

# REVIEW OF TECHNICAL EVIDENCE

## SIND'S KHARIF CASE.

### INDEX TO MAIN HEADINGS.

I.—DESCRIPTIVE REMARKS.



II.—METHODS ADOPTED FOR DETERMINING THE PROBABLE DROPS IN LEVELS AND DISCHARGES IN SIND INUNDATION CANALS DUE TO THE CONTEMPLATED PUNJAB WITHDRAWALS.

## III.—ACCRETION OF LEVELS OF RIVER BED IN SIND.

## IV.—EFFECTS OF CONTEMPLATED PUNJAB WITHDRAWALS ON THE SIND INUNDATION CANALS.

# I.—DESCRIPTIVE REMARKS.

## SIND'S KHARIF CASE.

*Issues.*—The claims of Sind against the Punjab were formulated in the following terms, with the agreement of the parties concerned, at the Simla Session of the Indus Commission held in September/October 1941 :—

### I.—SIND'S KHARIF CASE.

1. Which, if any, of the following schemes contemplated by the Punjab should be permitted and subject to what conditions, if any :—

(*a*) The Bhakra Dam Scheme as detailed in paras. 26 and 27 of the Punjab Defence ;

(*b*) The Storage Schemes mentioned in para. 32 of the Punjab Defence ; and

(*c*) The Balloki-Suleimanke Link Scheme mentioned in para. 35 of the Punjab Defence ?

2. Should the limits for the Kharif season fixed in para. 34 (*b*) of the Anderson Committee's Report, Vol. I, be allowed for non-perennial canals in Sind and if so, under what conditions ?

### II.—SIND'S RABI CASE.

Dealt with in Vol. I of the Report.

### III.—CONSEQUENTIAL.

In the event of any of the orders of the Government of India passed on March 30, 1937, upon the recommendations of the Anderson Committee, being modified, what consequential modifications, if any, should be made in any of the other orders ?

NOTE.—In the technical review of the evidence there are a few repetitions in the descriptive remarks of facts given in the legal presentation to facilitate reading of each part.

*Brief History of the Complaint.*—A Committee of the Central Board of Irrigation was appointed in 1935 by the Government of India to examine certain difficulties which had arisen in the distribution of the waters of the Indus River and its tributaries. This Committee submitted its recommendations to the Government of India in 1935, concerning distribution of supplies amongst the Governments of the Punjab, Sind, North West Frontier, Bahawalpur, Bikaner and Khairpur. Sind was administered at that time by the Government of Bombay. The Government of India consulted the

Governments concerned on the Committee's recommendations and thereafter passed orders on the recommendations in their No. I.R. 18, dated the 30th March 1937.

The Committee's proposals regarding Sind were accepted in general by the Government of Bombay in their No. 5997/27-I, dated the 19th March 1936. Sind was separated from Bombay on the 1st April 1936. On a further reference by the Government of India in their letter No. I.R. 18, dated the 3rd July 1936, to the Government of Sind, on certain points outstanding, the Government of Sind replied in their letter No. 304-I, dated the 14th July 1936, that they had no remarks to offer.

The next stage in the matter was a letter, No. 411-I, dated 14th October 1939, from the Government of Sind to the Government of India in which they submitted a note on the conditions of water supply in the Province of Sind and represented the probable effect of contemplated withdrawals by the Punjab on the inundation canals of Sind.

*Action requested under sections 130 and 131 of the Government of India Act, 1935.*—The Governor General was requested to take action under Sections 130 and 131 of the Government of India Act, 1935. After correspondence with other Governments concerned in the 1937 distribution of the Indus waters, the present Commission was formed.

*First Meetings of the Commission. Preliminary Issues.*—The first session of the Indus Commission was held at Simla on the 22nd September 1941. This session continued until the 11th October 1941. The preliminary issues formulated at this session and the Commission's views expressed thereon after hearing the parties, are recorded in paras. 10 and 11 of Sind's Kharif Case, Part I. (Sind Sheet 86.)

The issues formulated at this session for dealing with the Kharif case, are as detailed at the beginning of this report.

*Original Complaint pertained to probable effects on Sind's Inundation Canals.*—It may be noted that the original complaint preferred by Sind in 1939, referred only to the probable effects of the contemplated Punjab withdrawals on the working of the Inundation Canals in Upper and Lower Sind. The Rabi Case was incorporated in 1941. (Punjab Defence, Vol. II, p. 73.)

*Right of Sind to prefer complaint.*—Although an agreement on certain subjects was reached between the parties having water rights on the Indus River and its tributaries in 1935, Sind is not precluded from preferring a complaint on the subjects which constitute the Kharif issues. (Commission's views—incorporated as para. 11, Sind sheet 86.)

# PARTICULARS OF PUNJAB PROJECTS DEALT WITH IN THE " SIND KHARIF CASE ".

## Location of Projects.

1. *Haveli.* (*Constructed*).—The headworks are located on the Chenab at Trimmu—a short distance below the junction of the Jhelum with the Chenab.

2. *Thal*—(*Under Construction*).—The headworks are at Kalabagh on the Indus.

3. *Small Storages*—(*Proposed*) (*i.e., not exceeding half a million acre-feet each.*)—

*Ravi*—

Barbari on Ujh tributary.

Gura Sathiana on Devak tributary.

Samba on Deg tributary.

(This latter has been excluded from the calculations for effect on Sind on the claim by the Punjab that the Deg water spills across the country and very little reaches the main river.)

*Chenab.*—Dursuh or Kern on the E. Tawi tributary.

*Jhelum.*—Woolar Lake.

4. *Balloki-Suleimanke Link* (*Proposed*).—Canal connecting the Ravi at Balloki, at tail end of Upper Chenab Canal, with the Sutlej river at Suleimanke.

4. (*a*) *Pakpattan Link* (*Constructed*).—From the Lower Bari Doab Canal (near Montgomery) to the Pakpattan Canal.

5. *Beas Dam* (*Proposed*).—Proposed location is not furnished. It is a substitute asked for on the main Beas river instead of utilizing the sanctions for half a million acre feet storages on the affluents of the Beas.

5. (*a*) *Bist Doab Canal* (*Proposed*).—A canal proposed from the Beas Dám to supply the Jullundur Doab.

6. *Bhakra Dam* (*Proposed*).—On the main Sutlej River, in Bilaspur, as at present proposed.

6. (*a*) *Bhakra Canal* (*Proposed*).—Proposed to take off from Rupar to feed the project area.

This includes a branch proposed for the Grey inundation canals.

7. *Sailab Areas.*—Provision for sailab irrigation on the Gharra Reach is contemplated by increasing capacity of S. V. P. canals.

## KHARIF WITHDRAWALS CONTEMPLATED BY THE PUNJAB PROJECTS AND AUTHORITY.

EXTENT TO WHICH THE PROJECTS REFERRED TO IN KHARIF ISSUE I ARE COVERED BY THE GOVERNMENT OF INDIA'S ORDERS OF 1937.

1. *Haveli.*—7,750 cusecs—authorized by the Government of India in 1937.

2. *Thal.*—6,000 cusecs—authorized by the Government of India in 1937.

3. *Small Storages.*—Individual storages limited to 500,000 acre feet on the affluents of the main rivers.

Woolar Lake Scheme on the main Jhelum sanctioned as a special case. Storage was only to be done during July and August. Probable availing of this sanction is now set at 1,862,520 acre feet of which 1,428,000 acre feet is claimed to have effect on Sind. Authorized by the Government of India in 1937.

4. *Balloki-Suleimanke Link.*—5,000 cusecs—the original contemplated link was from Madhopur on the Ravi, to the Beas, which proposal is now given up. Authorization exists by Government of India orders of 1937 only for utilizing water set free in the Ravi by the Haveli Project. No unconditional authority exists for transfer of water from the tail end of the Upper Chenab Canal to the Sutlej *via* this link canal.

4. (*a*) *Pakpattan Link.*—700 cusecs—Authorized by the same authority as in item 4.

5. *Beas Dam.*—Live capacity of 2 million acre feet.

This is contemplated in place of the small storages on the Beas, authorized by the Government of India orders of 1937. No authorization exists for this dam on the main Beas river.

5. (*a*) *Bist Doab Canal.*—1,209 cusecs. No authorization from the Beas Dam.

6. *Bhakra Dam.*—Live capacity of 4 million acre feet. No authorization exists for the project in its present form.

This scheme was not dealt with by the 1935 Committee for the reasons given in para. 15 of the Punjab Memorandum, dated 25th January 1935. (P. 36, Vol. II, 1935 C. B. I.* Committee's Report.)

In March 1934, the Government of Bombay had informed the Punjab Government that they would offer no opposition to the construction of the Bhakra Dam. The Bhakra Dam Scheme is still under preparation and the present proposals are different in some

*For abbreviations see list on page 2.

respects from the original scheme. In addition to the Punjab, the scheme is intended to give some supply to certain non-riparian States. The early practicability of the scheme, with classification and method of financing, is a matter for further investigation by the Punjab.

6. (*a*) *Bhakra Canal.*—10,500 cusecs, *plus* 1,946 cusecs for Grey Canals.

No authorization exists. It forms part of project item 6 above.

7. *Sailab Areas.*—1,800 cusecs maximum capacity. No authorization exists.

PROGRAMME OF EXECUTION OF PUNJAB PROJECTS.

No programme for execution of the Punjab projects has been furnished to the Commission and most of the schemes have not yet been finally formulated. A statement put in by the Punjab during the last Simla Proceedings reads as follows :—

"*The Bhakra Dam Scheme* :

(1) The Punjab Government is extremely anxious to take up the scheme as soon as possible, as assurances have been given and hopes held out that this scheme will be taken in hand as soon as circumstances permit.

(2) But having regard to the war situation and the consequences likely to follow from it, the Punjab Government thinks that the scheme cannot be taken in hand for 3 years from now, and it agrees not to commence it for 3 years or during that period to enter into commitments by sale of land, or otherwise.

(3) The Bhakra Dam Scheme will not be completed in less than 6 years from the time construction starts.

*Beas Dam Scheme* :

This scheme will be taken up after the completion of the Bhakra Dam Scheme which is considered by the Punjab Government to be the more urgent.

*Other Storages 1½ million acre feet* :

These are individually small works and it is not possible to lay down the order in which they will be taken up. But the first of those works will not be taken up for 5 years.

*Suleimanke Link* :

This is a small scheme not taking any water after June until the Beas Dam is completed and this will not be started for 3 years.

*Sailab areas*:

This is a concomitant of the Bhakra scheme and the additional withdrawals will not be made until the Bhakra is complete."

BRIEF DESCRIPTION OF SIND AND ITS INUNDATION CANALS.

The following facts regarding Sind may be put down here for information—

1. *Three Main Zones.*—The Sind irrigated area is divided roughly into three main blocks—

(*a*) The inundation area above the Lloyd Barrage.

(*b*) The Lloyd Barrage Zone—(which contains some petty inundation canal areas along the river).

Nearly all of this zone is perennial area, one main block of non-perennial being the Rice Canal area,

and

(*c*) The inundation area below the Fuleli Canal, the larger part of which lies on the left bank of the Indus.

2. *Cultivation areas.*—The cultivation area as given in the 1939-40 Index Map of Sind is as follows :—

| | Barrage Canals. | Inundation Canals and bunds. |
|---|---|---|
| | Lakhs of acres. | Lakhs of acres. |
| British Territory .. .. | 31·51 | 14·79 |
| Nasirabad Tehsil (Kelat) .. | 1·51 | 0·78 |

The final estimated annual cultivation in the Barrage Zone is given as 50·42 lakhs of acres in British Territory, 4·71 lakhs in Khairpur State and 1·42 lakhs in Nasirabad Tehsil against 20·94 lakhs of acres in that zone pre-barrage (apart from Khairpur).

3. *Indus River.*—The River Indus enters Sind at Mithankot. The waters of the Chenab with its branches Jhelum and Ravi and the waters of the Sutlej and its Beas branch combine to form the Panjnad River which joins the Indus proper just above Mithankot and the Indus runs for about 600 miles through Sind.

4. *Marginal Bunds, and cultivation between bunds.*—Marginal bunds exist on both sides of the Indus for most of the length of Sind, to contain the river which runs on a ridge and prevent damage to the canal systems. The land contained between these marginal bunds is of several miles width, subject to flooding at high water in the river and on which "katcha" cultivation is done and forests raised.

5. *River Floods.*—The river floods usually cause the river to rise rapidly about the latter part of May or June—with high floods in July and August and commonly a fairly steep fall in September.

6. *History of the Sind canals and monetary value.*—Most of the inundation canals existed before the British occupation of Sind in 1843. They were either old river channels or smaller channels excavated by the State or its inhabitants.

Since the British occupation, it is stated on Sind Sheet 227, that Rs. 4,31,23,209 have been spent on the construction and improvement of the Sind Inundation Canals—whilst on separation from Bombay, Sind was debited with a liability of Rs. 374 lakhs on account of these inundation canals. The capital outlay according to the Sind Administration Report is about 2 crores. The difference between the figures in this para. is presumably due to interest charges, etc.

7. *Irrigation season for the inundation canals.*—The inundation canals depend for their supply on the uncontrolled flow in the river. They have therefore to accommodate their cultivation to the period at the end of May or early June, when the river rises high enough to enter the canals, till the river falls again about September. This canal supply is subject to the changing bed and bank conditions of the river and the altering conditions of the canal offtakes from the river.

8. *Sukkur Barrage.*—The authorized withdrawals for the Sukkur Barrage are much similar to the supplies taken by the replaced inundation canals for June to September, but for the rest of the year, the Barrage benefits of supply to the area served are specially important. (Sind Sheet 31.)

9. *Upper Sind—Nature of irrigation crops on Sind inundation canals.*—On the *right bank*, 30% of the total cultivation, Kharif and Rabi, is said to be rice. (Rabi on the Inundation Canals is a Bosi-Rabi Crop). The other principal crops grown are Juari 20%, Bajri 6%, Cotton 4% in Kharif, and Wheat 9% with 6% Oilseeds in Rabi.

*Left Bank.*—This is chiefly a Millet area, Millet 56%, Rice 13%, Cotton 6% in Kharif, Wheat 12% with Oilseeds 2% in Rabi.

It is stated that whatever water is saved from Kharif crops after the 20th August, is used for floodings of land for Bosi-Rabi crops. The last doses given to rice are also said to be heavy with the aim of getting a dubari crop after the rice is harvested. Sind accordingly stress the value of September supplies.

*Lower Sind.*—A large part of the land is said to be saline, so that rice is the main crop. There is, accordingly, but little Bosi-Rabi crop. Rice is raised in parts, under the " Pancho " system,—draining off the highly saline water and replacing by fresh, which involves a higher delta for the crop.

In the Fuleli Canals Division the principal crops are Rice 75%, Cotton 2%, Juar and Bajri 11%, Oilseeds 9%.

In the Karachi Canals District the principal crops are Rice 82%, Juar and Bajri 6%, Wheat and Barley 2% and Oilseeds 6%. This district is said to be almost entirely affected by ' kalar ' or salts and consists of shallow bowl shaped basins, which collect drainage during rains, and requires harvesting of crops from boats in such areas.

## SIND'S OBJECTIONS TO THE PUNJAB PROJECTS.

The objections raised by Sind in the first instance to the Punjab projects are given in paras. 4 and 28 of their Complaint,—The Case for Sind, Part I. (Sind sheets 6 and 9). The objections have been restated, after learning Punjab's present intentions, in the Sind Kharif Case, Part I.

The statement of the Sind Case as given in their new presentation, (Sind Sheet 84) is, as follows—

" *Sind's Case.*—Sind's case is that the withdrawals required for the Bhakra Dam Scheme, the small storages including the Woolar Lake Scheme and the two feeders from the Ravi and the Chenab, when superimposed upon the full authorized withdrawals of the Thal and Haveli Projects and of the Sutlej Valley Canals (which were not taken into account in the Nicholson-Trench Report) will cause such lowering of water levels both in Upper and Lower Sind during the kharif months as will seriously affect the efficient working of the inundation canals in these areas.

It is also contended that the reduction in the water level in the Indus during the kharif months may affect Sind adversely in the following ways :—

(*a*) Reduction in the area of rabi cultivation now done on riverain katchas which are flooded in the abkalani.

(*b*) Reduction in the areas of riverain forests which depend for their existence on flooding during abkalani.

(*c*) Reduction in the area of rice cultivation done in lands near the river mouths. This cultivation is done on spill water from the river.

*Sind's Claims.*—Sind has, accordingly, claimed as follows :—

Sind contends that the Full Supply Discharge and High Flood Discharge which she has been accustomed to get in all her inundation canals shall be assured to her at such levels as are necessary, for each canal, to maintain present commands and further that the supplies necessary in May, June and September each year should also be assured. For this purpose, Sind claims :—

(*a*) that the decision to proceed with the Bhakra Dam Scheme and the orders contained in the Government of India letter No. I.R. 18, dated the 30th March 1937, in so far as they relate to storages (including the Woolar Lake Scheme) and the Feeders from the Ravi and the Chenab to the Beas should be modified to the extent considered necessary ; and

(*b*) that should it be decided to maintain the said decision or orders, either wholly or in part, such remedial measures as may be found to be necessary in order to maintain the required discharges and levels for Sind's Canals, should be undertaken at the cost of parties which benefit from the withdrawals objected to in this complaint.

Sind also claims that the limits for the kharif season fixed in paragraph 34 of the 1935 Committee's Report should be allowed for non-perennial canals in Sind."

*General view of the main Punjab withdrawals.*—Most of the Punjab withdrawals will be from the Sutlej river supplies and the most adverse effect of these withdrawals will be felt in Sind in September. Sind have furnished a " Statement showing Sutlej Contribution to the Indus System " (Sind sheet 218) a large part of which contribution, will be removed by the contemplated Punjab withdrawals. The latter part of August withdrawals in the Punjab, will, with the lag worked out by Sind, be felt in Sind in September. In this tabular statement, the addition of columns 4 and 5 for August and 8 and 9 for September will give roughly the balance flow above Mithankot, if all the Sutlej component were withdrawn.

Of the projects detailed above in this report, it is inferred that it is the Sind contention, that none of the Punjab Projects should proceed—(except presumably, Haveli and Pakpattan Link completed and in operation, and the Thal project under execution), until the Sind inundation canals are assured supplies at such river levels, as will secure maintenance of existing commands.

BHAKRA SCHEME—COMPARISON OF SCHEME ACCEPTED BY THE BOMBAY GOVERNMENT AND THAT NOW ENVISAGED.

*Adherence of Sind to Bombay Government acceptance of the Bhakra Scheme.*—In their Chapter I, Vol. III, the Punjab have compared withdrawals contemplated at the time of the Nicholson-Trench Report for the Bhakra Scheme with those now intended under the Punjab calculations, and proceed to state—

> " Thus it will be seen that the 1941 Bhakra Project puts a less total burden on the River than did the Scheme envisaged by Messrs. Nicholson and Trench, to which scheme the Bombay Government gave agreement. The Punjab submits that Sind should be held bound by the said agreement. " (P. 4, P.D. III.)

In replying to the Punjab contention in their Notes on (Punjab) Chapter I, Sind state : " Since the Punjab proposes to proceed with the new Scheme, the question for decision is whether the withdrawals required for this scheme, when superimposed upon the withdrawals of the existing projects would hurt Sind." They also disagree with the Punjab claim that the new scheme does not throw a greater burden on the River, but contend that the subject of " extra burden " is not material for the reason noted above.

This contention of the Punjab was disposed of in the First Simla Session, *vide* Commission's views, referred to above in this report. (P. 8 *ante*.)

BEAS DAM REQUIRES AUTHORIZATION.

*Beas Dam Authorisation.*—The need for the Beas Dam Scheme is explained by the Punjab in their P. D. I, page 17. Authorizations for storages on the Beas are only for small storages below half a million acre feet, with storage occurring in July and August. In their Kharif Case, Part I, Sind refer (Sind sheet 87) to the opinion of the Chief Engineer in Sind, as expressed before the 1935 C. B. I. Committee, that, in cases of small storages on affluents they would not normally be filled except in years of good flood and that their effect would not be definitely detrimental. Punjab also point out that the 1935 Committee stated that small storage works have not proved to be remunerative and Sind concludes that the above explanations influenced the Government of Bombay to accept the proposals for small storages. The necessity for authorization for a scheme such as the Beas Dam on the main Beas River is then referred to by Sind.

Sind also point out that they object not only to the Beas Dam but also to the small storages, less than half million acre feet, which have been authorized (Sind sheet 87).

*Balloki-Suleimanke Link.*—Sind have stated in para. 14·2 of their Kharif Case, Part I, that the Balloki-Suleimanke Link deviates from the recommendations of the Anderson Committee and the orders thereon because it uses more water than is set free by the Haveli in the month of September.

The excess in September as given by the Punjab on page 19 of their Volume I is 410 cusecs, while the excesses given for April and May are 3,301 cusecs and 1,942 cusecs, respectively. On page 18 of P. D. I. it is stated by the Punjab that the use of the Link in July, August and part of September would be for liberating water, for storage in the Beas reservoir and in para. 36, page 18, of the same Volume it is stated that Chenab water will be utilized only in April, May and June (Sind sheet 89). Sind, therefore, urge that should the Balloki-Suleimanke Link be sanctioned, no withdrawals be permitted from the Chenab in July, August and September.

DATES OF FILLING OF SMALL STORAGES.

Sind ask that Punjab be not permitted to store water in the small storages except during the dates 21st July to 10th August (Sind sheet 89). These dates were, however, only Panjnad dates agreed on for convenience of revision of the Sind calculations. There was no intention to impose the limitation of those dates on the actual filling of the small storages (Sind sheet 88).

This subject is dealt with under our recommendations in Vol. I of the Report.

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## II.—METHODS ADOPTED FOR DETERMINING THE PROBABLE DROPS IN LEVELS AND DISCHARGES IN SIND INUNDATION CANALS DUE TO THE CONTEMPLATED PUNJAB WITHDRAWALS.

*Withdrawal at an upper point in the river not reproduced in quantity at lower site.*—The problem of finding the exact effect which the removal of a certain quantity of water in the upper reach of a river will have on the water level in the lower part of a river, is not one that admits of ready solution. It is clear that the removal of a certain quantity of water in the upper reach, will not reproduce itself as the same amount of shortage at the lower site. The problem becomes most involved in a river system such as the Indus with the five large tributary rivers of the Punjab, all having varying conditions of runoff in their catchments, due to rainfall and melting snow, varying conditions of climate and soil in their irrigated areas and with withdrawals made at a large number of different places along the rivers. We have seen no precedents, which could be followed with confidence, for arriving at a close degree of approxima-

tion of such effects during the different months of the year and translating the river effects down long approach channels to canal headworks. It is this problem, however, that is involved in the Sind Kharif Case, *i.e.*, to find out the effect on the Sind inundation canals of withdrawals contemplated in the Punjab,—the programme for and sequence of execution of the concerned projects, being also an unknown factor.

*Definition of term ' Inundation Canal '.*—The term ' inundation canal ' refers to a canal which depends for its supply on the uncontrolled level of the water in the river.

*Previous investigations.*—The Indus Discharge Committee of 1928 laid down the following issue for its own terms of reference in examining for river flow, the questions of loss, gain, time lag, etc.—

" To determine the history of the water of the Indus and its tributaries, during its passage through the Punjab and Sind to Sukkur. "

The Indus Discharge Committee of 1929 had the assistance of the Punjab Government Scientific Research Officer in endeavouring to get out a formula to co-relate the discharges at different points in the river. A formula was evolved which included a rainfall function for co-relating the discharges at Kalabagh and Panjnad with that at Sukkur. It was considered at that time, the formula might give some close prediction in the rabi season. The research by this Committee has not, however, furnished assistance in the various problems connected with this case.

*Nicholson-Trench investigation.*—Messrs. Nicholson & Trench in 1930 made an examination of the effects of the Bhakra Dam scheme—as then visualized—on the Upper Sind inundation canals and Mr. Trench examined also the effect on the Lower Sind inundation Canals. Due to the limited data with which they had to work, their investigation was of an approximate nature. Briefly it was on the following lines, the years 1922 to 1929 being examined.

1. Water estimated to be available for storage was the excess in the Sutlej over three times the Sirhind Canal discharges (pp. 14-16, N. T. Report).

This was on the assumption that the Sutlej Valley Project was to be supplied from the Beas (p. 2, N. T. Report).

The scheme provided for the canal supply to the new areas, inclusive of provision for the Grey Canals.

Under this arrangement, for withdrawals, it was estimated that, normally, there would be no surplus discharge from the Sutlej reaching the confluence with the Beas except in August.

2. The difficulties of calculating the less quantity that would be received at Sukkur due to the Bhakra withdrawals were then emphasized. Unreliability of the figures of discharges and uncertainty of losses due to absorption, regeneration, time lag, etc., were pointed out and it was assumed that the effect of Bhakra withdrawals would be felt at Sukkur, similar to that at withdrawal site.

3. The procedure followed was, then, to deduct from the average monthly discharge at Sukkur for each of the months, June to October, the Bhakra withdrawals as noted above. The gauge for the reduced quantity was then read off the appropriate discharge curve for Sukkur and the difference between this gauge and the actual average gauge was taken as the drop in river level, occasioned by the contemplated Bhakra withdrawals.

The average drop in river level for the 8 years 1921-29 was calculated to be :

| | |
|---|---|
| June .. .. .. .. .. | 0·6 ft. |
| July .. .. .. .. .. | 1·0 „ |
| August .. .. .. .. .. | 0·4 „ |
| September .. .. .. .. | 0·3 „ |
| October .. .. .. .. | 0·1 „ |

and the maximum average monthly reduction of river level was found to be in July 1924 and was 1·6 feet.

4. These river drops at Sukkur were then transferred to the Upper Sind inundation canal head regulators by assuming the same drops there as at Sukkur and subtracting therefrom the cutoffs that existed at each canal head. (Cutoffs are the differences between upstream and downstream gauges at the canal head regulator.)

This gave average monthly probable drops that were very small, when again averaged over the 8 years. The greatest 8 year average drop was 0·8 ft. in July for Unharwah and Sind canals, 0·5 ft. for Sind Canal for June and 0·1 to 0·2 ft. for most other cases.

The report then went on to say " It is clear.....that the only month, which need be considered seriously, is July (p. 16, N. T. Report). It is true that there is a loss of 0·5 ft. in June in the Sind Canal, but.....". Sind have in the Proceedings referred to this as evidence that the Nicholson-Trench Committee regarded drops of 0·5 ft. seriously.

Sind have criticized the Nicholson-Trench procedure for finding the effect of Bhakra withdrawals, (Sind Sheet 6) as they contend that

monthly averages may give misleading results and they quote the opinion of the 1928 Indus Discharge Committee (Para. 6, I. D. C., 1928, Report.) "—.....at certain periods of the year even monthly averages might prove deceptive. An instance was quoted in which the supply had been deficient for the first 20 days in a month although this was not evident from the figures, as the discharges in the last ten days had been so great that the monthly average showed no deficiency ".

They also point out that the Nicholson-Trench report did not examine the effects of the development of the Sutlej Valley Project along with Bhakra withdrawals.

*No previous examination of cumulative effect of all Punjab withdrawals.*—Whilst, then, there had been approximate examinations of the effect on Sind inundation canals of withdrawals for the Bhakra Dam, there had been no examination of the probable cumulative effect on the Sind inundation canals of all the contemplated Punjab withdrawals, prior to the formation of the present Indus Commission.

*Sind's first presentation of effects,—10 day averages.*—In order to establish their case that the contemplated Punjab withdrawals would have a highly adverse effect on the Sind inundation canals, Sind considered it necessary to adopt a shorter period for averages than that in the Nicholson-Trench report. They, accordingly, in their first presentation of the case to the Commission worked out effects for the years 1932-38 on a basis somewhat similar to the Nicholson-Trench procedure—with certain alterations—but using 10 day averages for discharges and the effects were shown in losses on " fair irrigating levels " (Sind Sheet 7).

*5 day averages,—investigation started by Sind* (Sind Sheet 9).—A further investigation had also been started by Sind as it was found that the 10 day average calculations did not represent correctly the Punjab proposals. This new investigation was partly ready, at the time of opening of the first session of the Commission. It was based on five day averages for discharges—time lag was introduced and allowance was made for losses and gains. The years taken up for examination were 1931 to 1940.

*Revision of 5 day averages also found necessary.*—The Punjab Defence indicated that the proposed withdrawals would not be so heavy—especially in the matter of storages and link feeders—as had been adopted by Sind in their 5 day average new investigation.

The calculations for each year, as prepared by Sind, were most extensive, and, if it became necessary to prepare again a complete new set of calculations, a long adjournment would have become necessary to permit Punjab check after Sind's re-preparation, and

to enable the case to proceed. The Punjab had also submitted their " Note on Sind Fresh Investigation of the Probable Effects of Punjab Projects on the Gauges at Sarhad and Kotri " (pp. 88—111, P. D. Vol. II). In this note they raised objections to some of the features of the Sind new calculations.

A basis for revision was then agreed upon by the Sind and Punjab representatives in consultation with the Commission to simplify the revision of calculations and it allowed in part, for some of the Punjab objections. It is unnecessary to incorporate here the Punjab objections and the arrangements agreed upon, for revision of the Sind calculations. The suggestions for revision are dealt with in paragraph 4·2, Punjab Defence Vol. III, and in Sind's Kharif Case, Part I, Sind Sheets 88-92.

*Division of irrigation areas in Sind.*—Sind is divided for irrigation purposes into three main parts (*vide* p. 12 *ante*) :—

(1) Upper Sind—Served by the inundation canals of the Indus River.

(2) Middle Sind—Supplied from the Lloyd Barrage at Sukkur on the Indus River.

(3) Lower Sind—Irrigated by the inundation canals of the Indus River.

*Nature of Inundation Canal irrigation in Sind.*—The nature of inundation canal irrigation in Sind is explained in the Sind " Note on Canal irrigation in Sind "—and the period of supply is described at p. 13 above in this report (Sind Sheets 29-48).

The examination of the effect of Punjab withdrawals is, therefore, confined mainly to the period June to September, with some overlap in May and October. Fuleli Canal in Lower Sind takes water when it is available in the river in April.

*Sind's Method of Examination of Effect on Sind inundation Canals of contemplated Punjab withdrawals.*—The procedure adopted by Sind, to show the effect on their inundation canals, of the contemplated Punjab withdrawals from the Indus and its tributaries, is explained briefly as follows :—

(*a*) *Sind Reference gauges.*—Two river reference gauges were adopted in Sind (*i*) Sarhad gauge for Upper Sind, and (*ii*) Kotri gauge for Lower Sind.

Sarhad gauge was adopted in 1931, though it is not a regular site for measuring discharges, as the old Indus River gauge at Bukkur has become affected by the pond

above the Lloyd Barrage, after the construction of that barrage. Discharges at the site, corresponding to the gauges, are obtained by conversion back from the Sukkur discharges. Kotri gauge is the second oldest gauge on the River Indus in Sind. The gauge readings go back to 1864 and are continuous from that date.

*Punjab objections to Sind reference gauges.* (P. D. Vol. III, pp. 305-307).—The Punjab considers these two gauges to be unsuitable for reference gauges and the Sind replies to the criticisms are given in their Comments on (Punjab) Chap. VI. It is certainly a handicap, that it is not readily possible to get accurate Abkalani discharge measurements at Sarhad and to that extent, the gauge discharge curves of the site are less reliable. The long history of the Kotri gauge lends value to that site as a reference gauge, but further remarks are made on the Kotri gauge, later in this Report.

(*b*) *Years selected for examination.*—Hydraulic data of the river conditions were utilized for certain defined years and the probable revised river conditions were estimated, assuming that the Punjab contemplated projects had been functioning in those defined years. The years which it was agreed upon should be examined—in the first session of the Commission—were the post-barrage years of 1932 to 1936 inclusive and 1939. The reasons that led to the selection of these 6 years were, that 3 years at least in succession were required for examination and some of these 6 years were further advanced in preparation of calculations and also they were considered to be typical years.

Sind have arranged the 11 years 1931-1941 in order of inflows to the Indus, July and August Sarhad gauge and September gauge—*vide* Sind Sheets 214-216—purporting to show that the 6 selected years were, on the whole, above the average of the last 9 years. Subsequently, Sind expressed the opinion that the probable effect could be judged better, if the 11 years' data were examined. The Punjab stated that they would be unable to check the extra 5 years' data, without asking for a longer adjournment of the Commission. The Commission examined the data for the 11 years and the 6 years—and also the corrections which the Punjab had preferred on the 6

years' data—and stated (1) the other 5 years could be put in as unchecked data, and (2) if the Commission found it necessary to have the other 5 years' data checked, an adjournment would be given to permit this to be done by the Punjab. Sind have put in alternative statements of effects for 6 years and 11 years. The Commission found no necessity for an adjournment to institute check of the other 5 years' data by the Punjab.

*Sind's remarks on the 6 and 11 years.*—The remarks of Sind on the 6 and 11 years' data are contained in their Kharif Case, Part I. (Sind Sheets 90-92.)

(*c*) *Loss and lag Statements.*—Loss and lag statements were prepared for different reaches of the rivers affected by the proposed withdrawals for each of the years considered. The lag is the time taken for the river flow at one point on the river to reach another specified point. It is measured to the nearest day, by timing of the prominent flood peaks or troughs passing from point to point down the river and varies to some extent throughout the season and from year to year. The loss is the diminution of discharge that takes place in a measured volume at one site in passing down to the selected lower site after allowing for measured withdrawals and inflow in the reach. Gains are, similarly, increases that occur in the river discharge, for measured volumes at one site, passing down to the lower site. These losses and gains have been converted to percentages, for convenience of application to the withdrawal quantities.

(*d*) *Treatment of contemplated Punjab withdrawals.*—Sind have prepared tabular statements of contemplated Punjab withdrawals of water, and knowing the sites at which these withdrawals are to occur have worked out the equivalent amounts of these withdrawals at the different measurement sites, assuming that the loss and gain percentages referred to in the preceding paragraph may be applied in a proportionate manner to the withdrawal amount. In a similar manner, allowance has been made for extra water that could have been withdrawn by the Punjab under their existing authorizations, for cases where the Punjab have withdrawn less than the authorized amounts, for the Sirhind, Grey, Sutlej Valley, Haveli and Panjnad Canals.

(*e*) *Gauge Discharge Curves.*—Gauge Discharge Curves have been prepared for each year for both rising and falling stages at Sarhad and Kotri.

(*f*) *Conversion of withdrawals to Drops.*—The withdrawals for the several projects, limited by the actual amounts available in the river at the different sites and allowing for extras to bring actual withdrawals up to existing authorizations, have been converted to their equivalent amounts at Sarhad and Kotri, with the necessary co-relation for lag and averaged for 5 day periods. These equivalent withdrawals for the several projects are subtracted progressively from the actual discharge at Sarhad and Kotri for the corresponding period and the gauges for the successive reduced discharges read off the relevant gauge discharge curve. The successive difference in the gauges gives the drop due to the respective project withdrawals.

(*g*) *Translation of reference gauge drops to effects on the inundation canals.*—The Sarhad gauge drops are then translated to drops in gauges and discharges for the major inundation canals in Upper Sind and similarly for Kotri gauge drops, for Lower Sind, by a graph projection method. The Sarhad gauges and the reduced gauges due to the drops are plotted on a time base. Immediately below, on a similar time base, are plotted the upstream and downstream canal gauges and on a similar time base below the canal gauge graph, is plotted the canal discharge graph. The procedure is explained in the Sind Kharif Case. (Sind Sheet 318, P. D. III, p. 309.)

For Minor Inundation Canals, "cut-off" statements were prepared in which the drop effect was assumed to be the same on the upstream gauge of the canal, as at the respective river reference gauge Sarhad or Kotri. The discharge effect was obtained from the respective canal gauge—discharge tables.

*Presentation of Sind Case.*—The Sind case is, then, presented largely on data obtained from the above procedure, without carrying the examination to the effect on extent of cultivated areas suffering loss of command. This is due to the difficulty expressed by Sind, of arriving at such data.

*Sutlej component at Panjnad used by Sind in revision as the Punjab proposed withdrawals for five out of the six selected*

*years.*—It was expected when the suggestions for revision of the Sind data were made at the first session of the Commission that there would be an inappreciable amount of water passing Panjnad from the Sutlej, after all the Punjab projects came into operation, for most years. The Punjab withdrawals from the Sutlej were, therefore, taken as the Sutlej component at Panjnad up to the time the Bhakra and Beas filled, except for 1933, a good supply year. This simplified the revision.

## REMARKS ON GENERAL PRINCIPLES OF THE SIND METHOD OF TRANSLATING WITHDRAWALS AT AN UPPER SITE TO ITS EQUIVALENT EFFECT AT A LOWER SITE.

*Difficulty of predicting effects on Sind.*—Reference has been made earlier in this report to the difficulty felt by the Indus Discharge Committees, 1928 and 1929, and Messrs. Nicholson and Trench (as well as other irrigation officers in times past) in predicting effects in Sind from known conditions of river flow in the Indus and its tributary rivers above Sind.

*Difficulty still persists.*—We would say that the difficulty still persists, even though a longer period of data is now available *and the claims of the two provinces should be read with full knowledge of this condition.* We recognize the great industry shown by Sind in trying to evolve a more accurate method of translating river effects from an upper to a lower site—both before, and during the progress of this Commission. In a similar manner, the criticisms offered by the Punjab and alternative methods put forward, have made useful contributions to the literature on the subject.

The remarks that follow, involve some reiteration of remarks, made in the rabi case on the subject of regeneration.

*Sind assumption* re. *loss and gain effects.*—The Sind method of calculating loss and gain effects for projected withdrawals,—assumes that the percentage effects obtained by computing loss and gain of discharges under existing conditions, will apply to the withdrawals and the resultant balance at the lower site. This assumption was made by Sind and the Punjab in their calculations, till, later in the Proceedings, Punjab produced " Set C " calculations, wherein the effect of gains was limited to unity, when applied to the withdrawal quantity. [The same limitation was later applied to loss or gain on a rising river (P. D. Vol. III, p. 131).] The same remarks apply to time lag, *i.e.*, the time of passage of peaks and troughs is taken to be the same before and after the withdrawals.

*River storage.*—One of the chief difficulties in solving this problem, is due to the additions to and yield from river storage. When

there is an increased inflow in the river, part of the water is used up in adding to the storage of the river bed, as the water level rises. This causes an apparent loss in a rising river, when computing the discharge at the lower station and an apparent gain as the water level falls and the storage represented by the fall, passes down the river. It is not possible to separate out the computed losses or gains into their respective causes and classify the portion of each which may be affected in a measurable amount by the contemplated withdrawals at different sites in the rivers. Apart from apparent losses and gains in river flow, which are due to river storage, there are direct losses due to percolation of the river water into the subsoil and by evaporation, whilst there are direct gains due to rainfall, unmeasured inflow and regeneration back into the river, from subsoil water, as the river water becomes lower in level.

The relative value of each one of these factors will vary throughout the year and from year to year, *e.g.*, the percolation will increase with depth of flow for the same condition of subsoil water level, whilst the regeneration or return flow from the subsoil will increase with the fall of river water level for the same condition of subsoil water level.

An example of how the percentage losses work out in the Sind calculations, is given below for September 1933, for one reach of the river. 1933 was a flood year and the net gains common in September did not occur in that month :—

| Col. 42, page 16, Sind's revised calculation book. | | Page 9, Sind's addendum book of calculations for 1933. |
|---|---|---|
| Date at Sukkur (with Lag). | Actual average Discharge at Sukkur— *Cusecs.* | Percentage Loss—Panjnad—Ghazighat to Sukkur. |
| Sept. 13-16 | 244296 | 12·6 |
| 17-21 | 214901 | 3·4 |
| 22-25 | 223150 | 23·8 |
| 26-30 | 234910 | 1·0 |
| Oct. 1-5 | 161534 | 7·1 |
| 6-10 | 125681 | 10·0 |

From the above it will be seen how the influences interact, without observable consistency. Thus, the drop in discharge 13-16 and 17-21 is properly reflected by a reduction in the loss. 17-21 to

22-25, the percentage discharge increase bears no similar proportion to the increase in percentage loss. 22-25 to 26-30,—although there is still an increase in discharge, it is not reflected in this case by an increased loss, but the percentage loss drops to 1%.

On the last day of the last Commission hearings, a note was put in by Punjab on " Are Losses Proportionate to Discharge Passing ". Comparison was made with the percolation loss formula of canals, and a table was given purporting to show, that, for the reach Rupar-Islam, there is a proportionality between the loss in the river and the discharge passing in any month, the relationship being different for different months. The table does not seem to support the claim. So far as percolation is concerned, the loss does normally vary with the depth of flow and the wetted surface, but there is much difference in the depth in the cross section of a river such as the Indus, from deep bed, to the spread out to the flood banks. This does not exist in a canal. Even in this one feature of loss, there is much variation in percentage depth effects throughout the river cross section by change of volume.

The Punjab is willing to accept, that computed loss may be applied in a proportionate manner for withdrawals. It reduces the effect on Sind of the Punjab withdrawals.

GAINS—

*Gains.*—On the subject of gains there is difference of opinion between Punjab and Sind. Sind have stated,—" It is surely logical, if losses—even apparent losses due to the filling up of river storage—are to be allowed for in assessing the effect of withdrawals, that gains caused by the giving back of such storage must also be taken into account " (para. 3·8, Sind Sheet 190). This statement does not, however, throw any light on the claim, that withdrawals from an upper site will have a *proportionate* increased effect in periods of gains, at a lower site (*vide* last page of Proceedings dated 18th May 1942 and 11th May 1942).

Sind have put forward their views in regard to gains, in their " Criticism of the Punjab Alternative Drop Statements ", claiming that water is given back from storage in September, and thereby reduction of this stored water by Punjab withdrawals, may have an effect greater than unity in Sind (Sind Sheet 190). A statistical analysis was made by Sind of the Punjab figures of withdrawals, allowing 13 days lag and Sukkur Discharges in September. It is claimed the analysis shows for September at Sukkur, that, if the period from 1911-40 is examined, 100 cusecs withdrawal in the Punjab produces a reduction of discharge 1·52 times greater at Sukkur and for the period 1926-41,—2·26 times greater.

The Punjab, in replying to this point, give figures for the period 1901-40 as follows (Punjab Defence, Volume III-A, p. 78) :—

| | Rate of increase of Punjab withdrawals. | Rate of decrease of Sukkur discharges. |
|---|---|---|
| September .. .. | 1451 | 1919 |
| October .. .. | 960 | 789 |

Punjab Defence Vol. III, p. 144.

*Gains in September—greater than unity on withdrawals.*—Both sets of figures, therefore, show a greater effect at Sukkur in September than unity, for Punjab withdrawals. These figures of Punjab were from ratios without regard to lag. The extent to which this is cause and effect cannot, of course, be stated. As will be seen, October shows a less effect. Further, loss and gain take place in different months and different reaches throughout the season,—*e.g.*, in 1933 for the period 3rd September to the end of that month at Sukkur, there were no gains shown in the Sind calculations for the reach, Ghazi Ghat—Panjnad to Sukkur, whilst gains are shown in the same reach from 18th July to the 2nd September period.

*Sind opinion on gains.*—On the last day of the Commission's hearings a further note was put in by Sind on the " Statistical Examination of the effect during gains on withdrawals ". This note considers the opinion of the 1928 Indus Discharge Committee to be incorrect, that, in the formula for Sukkur discharge got out by the Punjab Research Officer, the co-efficient of the Panjnad discharge could not be greater than unity. The subject was referred to the Director, Statistical Laboratory, Calcutta, and an extract of his letter was enclosed with the note. The extract explained that the problem was complicated and that the conclusions of the then Punjab Research officer would require further examination before acceptance. The Sind note refers then for proof of the effect of gains beyond unity, on withdrawals, by citing another co-relation for September Sukkur discharge for the years 1905-41, and it was stated that they had got out another formula connecting Sukkur Discharge with inflow and Punjab withdrawals allowing for a uniform lag. The result was said to indicate that 1,000 cusecs withdrawn from the Punjab is equal to a decrease of 1,484 cusecs at Sukkur. It is not stated whether this applies only to September.

Beyond contending, however, that the effects of withdrawals during periods of gains have results greater than unity at a lower site it does not establish a proportionate relationship.

*Punjab opinion on gains.*—Punjab have, in their Chap. III, given figures of gains on the rising river between Sukkur and Kotri

where the Punjab withdrawals have been multiplied in the Sind calculations by a gain factor (P. D. Vol. III, p. 139). The figures purport to show that the gains are due to causes other than river storage and cannot be connected with Punjab withdrawals.

In their reply under " Sind Comments on the Punjab Defence, Volume III, Chap. III ", Sind furnished figures claiming that the periods referred to by Punjab are not continuous rises but that a large part of the gain is a consequence of an earlier fall.

*Previous opinion of Punjab on gains.*—Sind have also referred to the previous opinion expressed by the Punjab in connection with the withdrawals, where gains were allowed for on withdrawals, similar to losses (*vide* Sind Sheet 264.)

TIME LAG,—

*Time lag—N. T. opinion.*—Opinions in regard to how time lag should be allowed for, have varied from time to time. In their Report, Messrs. Nicholson and Trench stated, " In the present state of our knowledge, it is impossible to obtain a satisfactory quantitative solution of the time lag problem considered separately " (p. 15, N. T. Report).

Sind state that Punjab would not agree in April 1941, to a uniform time lag and it was decided to take the actual lag, which is the nearest approximation to the existing conditions (S. II. 18). Some examples of variability of time lag in 1932 are given at page 88(7), Punjab Defence, Volume II. On the same page, Punjab stated " However, in the absence of any better procedure the (Sind) method may be accepted ".

The Punjab have apparently altered their opinion again, in Chap. III of their Vol. III, where the difficulty is explained of applying the varying time lag, also the change that would occur in the time lag after the withdrawals, and they state,—" So it would have been equally accurate and far simpler if a uniform time lag had been adopted for the periods under consideration " (P. D. III, p. 129).

Punjab have also in their Chapter III suggested that an average value of time lag be taken for each month of the year. The calculated values were said to vary unaccountably. (P. D. III, p. 151).

A small error in calculation of the time lag may change a loss to a gain and *vice versa*. Generally, a shorter time lag is found in the months of higher discharges.

The Indus starts rising usually from about March and starts falling usually after the middle of August.

During a rising river there is very considerable loss of water to storage in the river itself and to absorption into the dry sub-soil. The lag as measured from peak to peak or from trough to trough may vary as much as 100% at some point where the stream rises above the river bed proper and spreads over the katchas.

Again as regards a falling river, there is a table on P. D. I, p. 68 which gives the inflow into the Indus basin. The average August losses at Kotri are about *nil* but the September gains there average about 105,000 cusecs. This table takes no account of rainfall in the plains which may account for a portion of the September gains, and there is no attempt to evaluate lag in the different elements of the table.

Suppose the September gain is, say, 70,000 cusecs. The measurement of lag by means of a peak or trough of only a few thousand cusecs difference in flood may give a wrong picture of lag for the main stream which is producing this large gain.

The following table abstracted from pp. 170 to 175 of P. D. III, shows the gauge of the worst 5-day periods in each half month during the selected six years 1932-36 and 1939 and monthly inflows :—

| Year. | Worst Gauge. | Period. | Inflow Figures. | | | |
|---|---|---|---|---|---|---|
| | | | Month. | Volume. | Month. | Volume. |
| 1935 .. | 12·3 | First half of July .. | June .. | 365349 | July .. | 679995 |
| 1932 .. | 16·6 | Second half of July .. | „ | 364551 | „ .. | 616998 |
| 1936 .. | 17·7 | First half of August .. | July .. | 585950 | Aug. .. | 514734 |
| 1939 .. | 17·0 | Second half of August | „ .. | 623409 | „ .. | 487293 |
| 1934 .. | 13·5 | First half of Sept. .. | Aug. .. | 578904 | Sept. .. | 232730 |
| 1934 .. | 10·5 | Second half of Sept. .. | „ .. | „ | „ .. | „ |

This table may be compared with the average monthly inflow during 1932-41 abstracted from P. D. I, p. 68 :

| | |
|---|---|
| April | = 146,378 |
| May | = 284,348 |
| June | = 478,203 |
| July | = 623,710 |
| August | = 567,004 |
| September | = 256,667 |

When the figures of inflow are plotted against the Kotri gauges for different years allowing about ½ month lag, the great variability in lag relationship is seen, showing the inconclusiveness of deductions based on present knowledge of the laws affecting the flow.

The following figures are also of interest. The drop in September inflow during the decade 1932-41 compared with the decade 1922-31 was 21,418 cusecs. The drop in Kotri average monthly discharge for the same periods was 88,700 cusecs in September (P. D. III, p. 55). The increase in Punjab and States withdrawals for the period 1932-40 over 1922-31 was negligible for August and about 16,000 for September (P.D. I., p. 68). The Sind and Khairpur withdrawals also decreased about 1/6 to 1/7 in August and September in the same periods but there were large changes in losses and gains.

For examining the extent of the damage possible to Sind, we have abstracted the proportion of the Sutlej Contribution to the river Indus from the Table in the Sind Kharif Case, page 218, for the years 1922 to 1941.

The results are given in the following table excluding a freak discharge of 332,394 cusecs shown as occurring in the Sutlej from 11-20th September 1936 :—

| Month. | Period. | Sutlej component at Panjnad. | Chenab component at Panjnad. | Indus at Ghazi-ghat. | Total discharge. | Sutlej component in % of the total discharge. |
|---|---|---|---|---|---|---|
| August .. | 1st—10th .. | 70,112 | 131,734 | 315,332 | 517,178 | 14% |
| | 11th—20th .. | 72,800 | 128,950 | 301,660 | 503,410 | 14½% |
| | 21st —31st .. | 74,184 | 113,694 | 272,950 | 460,828 | 16½% |
| September | 1st—10th .. | 53,638 | 99,805 | 208,292 | 361,735 | 15% |
| | 11th—20th .. | 31,800 | 61,117 | 145,221 | 238,138 | 13½% |
| | 21st—30th .. | 15,606 | 33,178 | 104,080 | 142,864 | 11% |

The mean monthly Total discharges are :—

August = 493,805
September = 247,579

The Sutlej component will be principally affected by the new withdrawals, as Thal is only 6,000 cusecs and the Chenab small storages will not affect materially the September supplies.

This table read with page 218, Sind Kharif Case, shows that in certain bad years the loss of the Sutlej component which will be withdrawn for canals and storages will reduce the river volume in Sind by an appreciable amount, particularly in August and September.

Although the subsequent criticisms in this note will be based on the assumption made by both parties as to lag, it should be borne in mind that the Commission does not accept the assumption as correct and it does not affect their conclusion that the future Punjab withdrawals to storage in Bhakra and Beas will have a material effect on levels in inundation canals in Sind.

In this connection it may also be noted that the set of the river at the head of an inundation canal may affect the supply level by as much as 2 feet while a further effect may be introduced by silting at the mouth of the inundation canal up to, possibly, 1½ feet.

In some years this silt can be removed but in other years it will return almost at once after removal.

Hence the deductions made by both parties from water levels as they existed in the inundation canals during the years 1932-36 and 1939 do not represent the worst possible conditions which may occur in Sind in any future year, when there may be at any particular canal at its head the drop of 2 feet, caused by unfavourable river set, accentuated by up to, say, 1½ feet of silt in the mouth of the canal.

## CONCLUSION ON LOSSES, GAINS AND TIME LAG.

We have not received convincing evidence, that the same percentages of losses and gains got out for the conditions existing in the river for the respective years, can be applied to the withdrawal amounts proposed, to give with confidence the probable quantities of water received in Sind, under the revised hydraulic conditions applying after the withdrawals. Superficially, it is evident that such will not be the case. The degree of accuracy which this method may give, will vary throughout the year, and in different years, and it is not possible to express an opinion on this degree of accuracy—compared with the calculated percentage effects in Sind—from the evidence that has been adduced in these hearings.

Both Sind and Punjab have accepted the percentage method for losses. It is possible that the percentage effect may be rationally more applicable to losses caused by percolation, than to other factors of loss or of gain.

In regard to the claim of Punjab that withdrawals during gain periods or on the rising river can have no value at the lower site greater than unity, it may be stated that the figures given under "Gains", by both Punjab and Sind, indicate that Punjab withdrawals affecting Sind—with time lag in September,—may have an effect greater than unity in Sind. With other conception of time lag, the result might be different.

In regard to other periods of the year, it is not possible to furnish an opinion on the data produced.

Suffice it to say, that with the changing conditions in river storage, during rise and fall of the river, an alteration in the amount of water going to that storage will affect the cross sectional area of the river, the wetted surface and the surface slope, in such a way, that there may, certainly, be occasions, where the withdrawal amount may express itself as an amount greater than unity in Sind during a period of gain. This would also apply to gains on a rising river, where the rise has been immediately preceded by a fall.

So far as time lag is concerned, it will undoubtedly alter with the revised hydraulic conditions in the river after the withdrawals, but it is not possible to say to what extent this will affect the computed results in Sind, which have been based on the time lag under the actual conditions that existed in the years examined.

Finally it may be stated that there is no proved mathematical exactitude in the methods followed by either Sind or the Punjab in getting out the probable quantity of water arriving in Sind, pursuant to withdrawals of water in the Punjab.

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## PUNJAB CRITICISMS OF SIND'S METHOD OF TRANSLATING EFFECTS OF PUNJAB WITHDRAWALS TO SIND INUNDATION CANALS.

*Sets A, B & C.*—The Punjab have termed the Sind calculations for showing the effects of the Punjab withdrawals in Sind—as Set 'A'. Two other sets of calculations got out by Punjab are called Sets B and C.

*Explanatory notes on Sind's methods of calculations.*—The first explanatory notes on the Sind method and use of the various statements employed in assessing the effect of Punjab withdrawals on the Sarhad and Kotri gauges, are given in the Sind printed books called "The Probable Effects of Punjab Projects on the gauges at Sarhad and Kotri for.....year".

As explained previously in this report it became necessary to revise the Sind calculations and the revised explanatory remarks are given in Sind Sheets 343-357. A separate method is given for the year 1933, *vide* Sind Sheets 358-361, in accordance with the suggestions agreed on for revision at the first Simla Session. (Sind Sheet 88.)

*Punjab claims modifying factors on withdrawals.*—In Punjab Chapter III, Volume III, are discussed modifying or ameliorative

factors applying to Punjab withdrawals, and the claim is made that failure by Sind to allow adequately for these moderating influences has produced exaggerated results (P.D. III, p. 129). Sind have replied to this criticism in " Sind's Comments on the Punjab Defence Volume III, Chapter III". Some of the points were discussed in the Rabi case. The points listed are :—

(*a*) *Time lag.*—This has been dealt with separately under that heading.

(*b*) *Reduced Losses.*—Certain errors in computing losses involved in unequal time lag are cited, but Sind claims that they about balance out.

Effects due to unmeasured inflow such as rain, regeneration and gains as the gauge falls, are also referred to. The claim is made that on a rising river the maximum factor for gain or loss should be unity. This point was also dealt with previously in this Report. Over-debits on a falling river are also discussed, but the conclusions are disputed by Sind, due to error claimed in the range of gauge taken by the Punjab. No remarks are called for on this, as the calculations are not based on any actual plans. Beneficial result from regeneration—due to extra water put on the land by Bhakra and Beas —is also disputed by Sind. They point out the less regeneration that takes place in the kharif months and they state that the Bhakra supply is for an area whose subsoil slopes to the Jumna. There was no evidence adduced in support of this latter statement regarding direction of subsoil flow.

(*c*) *Further remarks.*—On regeneration, storages in ponds above weirs, surpluses probably due to difficulty of regulating when certain torrents flow, and canal closures further remarks are made, none of which are of special importance, compared with other factors.

(*d*) *Reduction of demand for Canal Supply due to rain.*

*Sind over-emphasizes effect of withdrawals during rains.*—The Punjab have, under this head, dealt with capacity factors introduced into their Set C. Calculations and comments thereon will be made in dealing with that set of calculations. There is no doubt that the Sind calculations, in providing throughout for authorized discharges in withdrawals—(except as certain reductions were made in the agreed modifications in revision of their calculations),—have over-emphasized probable withdrawals during times when rain may be of material amount in the irrigated area. (S. Sheets 88, 89.)

Reference is, in this connection, drawn to the Sind statement in their Kharif Case, Part I. (Sind Sheet 90).—

" Since the Punjab claim to draw the authorized maximum supplies and also a right of diversion to other canals or projects, it is but

fair that they should be debited with the full difference between the authorized and actual withdrawals".

The argument is, however, not correct, as water saved during periods of less demand due to rain on the irrigated areas, can seldom be used elsewhere, without introduction of other projects requiring separate authorization.

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## PUNJAB METHODS OF TRANSLATING EFFECTS OF WITHDRAWALS TO SIND REFERENCE GAUGES.

*As previously stated, Punjab have put in 2 sets of calculations—Sets B and C.*

### SET B.

*Set B.*—Withdrawals proposed are much the same as Set A, except that the Punjab consider that the Gharra reach withdrawals provided in Set A, should be reduced and they have done so in Set B (P. D. III, pp. 204-206 and 208). There is difference of opinion between Punjab and Sind in regard to the interpretation of the suggestions given in the first Simla Session for revision of Sind calculations. It will be seen from Punjab Vol. III, pp. 293—304, Appendices XV-A and XV-B (*vide also* Tables 20 and 21 of the same Vol. pp. 286-289) that there is no material difference from Set A in the results for drops at Sarhad and Kotri, except for the month of September in the years 1932 and 1936 and a few cases in August. On page 221 of their Vol. III, Punjab submit that both Sets A and B calculations be ignored.

### SET C.

*Set C.*—As the Punjab contend that the Sind calculations, even after the revision agreed on in the first session, over-emphasize the effects on Sind of the Punjab withdrawals, they have produced another set of calculations, called Set C. The method of working out Set C is given in para. 4·9·1 of Chap. IV. of the Punjab Vol. III, and certain other assumptions made are given in para. 4·5 of the same Chapter.

One of the differing features of Set C is the introduction of Capacity Factors to be applied to the withdrawals for the Gharra reach and for the Bhakra Project and Bist Doab Canals, to provide for less demand due to rainfall and other causes. These are given in Appendices XII-A and XII-B of Punjab Vol. III. The effect of gains in transit is restricted to unity for the withdrawals in the Set C calculations. This subject has been dealt with previously in this Report.

The Sind comments on the Set C, are contained in their " Criticism of the Punjab alternative drop statements " (Sind Sheets 190—194). To this there was received " Punjab Rejoinder IV-A " (P. D. III-A, pp. 71—90) and again " Sind Comments on the Punjab Rejoinder ". Sind objections to the capacity factors of Set C are also contained in " Sind Comments on the Punjab Defence Vol III, Chap. III," and further Sind criticism is contained in " Sind Comments on Chap. IV " [(S. II, 80) (S. II, 23) (S. II, 32—35)].

*History of Set C.*—Before examining the criticisms of Set ' C ', it is necessary to point out that the first set of these calculations was not submitted by Punjab to Sind for check, until 23rd March 1942. Sind then pointed out that it would be necessary to ask for a further postponement of the ensuing Session of the Commission, if they were to check the Set ' C ' calculations. After inspection of the Set ' C ' calculations, (which were not accompanied by proof for the formulae used for the capacity factors), the Commission found a further adjournment was not justified for the purpose of Sind's arithmetical check of Set ' C ', but Sind were asked to offer their criticism on the methods employed by the Punjab in getting out this set of calculations.

It is also a fact that both the provinces were handicapped by the time element in presenting their cases, and revision of ideas and calculations followed during the progress of the investigation, as sets of calculations or presentations gave unfavourable results to either side.

*Capacity Factors.*—The criticism of the capacity factors will now be examined.

(*a*) *Capacity Factor of Canals on Gharra reach of the Sutlej.*

The method agreed on, at the first session, for revising the Sind original calculations (which were based on authorizations of the S. V. P. canals), to agree more closely with probable actuals, is given at p. 203, Punjab Defence, Vol. III. This was worded as, " to allow for lack of full development ". The figures adopted were arrived at from inspection of withdrawals in earlier years, with those in their later years and were only intended as a rough approximation to permit revision to proceed. The Punjab now state " * * * * * the greater part of the underdrawal was due to fluctuation in demand for canal water, owing to rainfall and to rhythm of agricultural operations (P. D. III, p. 176). It is contended that the highest average discharge run in any five-day period in a year, when supplies are available, is a measure of the stage of development reached in that

year. If the highest discharge thus drawn in any year is less than the highest in the previous years it is because of the reasons enumerated * * * ". Capacity factors for each year are got out on this basis and applied to the extra quantities allowed on the preceding assumption for full development, as well as to the amount provided for sailab areas.

*Sind Sheet 190, para. 1-1.*—Sind state, "Sind still considers, that, among other things, full allowance should be made for the authorized withdrawals of the Sirhind and Sutlej Valley Canals, because the Punjab have definitely claimed their right to these amounts either to be used in canals or to be diverted at will ".

The contention of Sind is presumably based on the permission given, pursuant to para. 46, Vol. I, 1935 C. B. I.'s report, for a province to distribute allotted water at its own discretion. Sind also claim that the full allowance for Thal and Haveli should be taken into account for July and August, unless the Punjab guarantee to apply a capacity factor of 0·9 as taken in the calculations (Sind Sheet 190, para. 1·2).

With regard to this claim of Sind, it may be stated, that the purpose of this investigation is to show the probable effect on Sind of certain authorizations for Punjab withdrawals, as they would actually work in practice. It is clear that full authorizations are not commonly used during periods of appreciable rain in the irrigated area, so that when full authorization is allowed for in withdrawal throughout the whole of the kharif season, it must result in some exaggeration of the probable effect in Sind.

With regard to the assumption of the Punjab that the stage of development can be worked from the highest 5 days of the year, it may be said that this was roughly the formula agreed on in the first sessions, for the purpose of expediting revision, but there is really no authority for such an assumption. (The S. V. Project has been in operation for about 14 years.)

It is not possible to say how close to probable actuals, the additional requirements will be represented by the application of the capacity factors to the extras assumed for full development. The procedure is, however, fairly logical, if the assumption in regard to the extras should be correct.

(*b*) *Capacity Factor for Grey Canals Areas.*

The method of arriving at the capacity factors, is explained on page 148, Punjab Vol. III. It is seen from the tabular statements (pp. 180—191), that there are exceptions to the rule prescribed by the

Punjab, where unity factor is not applied with a discharge below Rupar of less than 30,000 cusecs. Punjab have replied to the Sind criticism, that it would be indefensible to apply capacity factors got out for inundation canal conditions, to the smaller sized controlled supply canal intended for the same area,—by stating that the longer season with the controlled supply would offset this. The 3,000 cusec inundation canals are being replaced by a 1946 cusec canal.

As irrigation practice and crops planted will likely alter with the provision of a controlled supply, it may be stated that the method employed for getting out these capacity factors, does not seem too consistent. The magnitude of the factors, however, appears somewhat reasonable for the area.

(c) *Capacity Factors for the Hissar, Etc., New Bhakra Areas.*

This is taken as :

Existing Sirhind Canal Capacity factor × Rain Ferozepur/Rain Hissar, and when rain is less than 1", Sirhind capacity factor is taken.

It is the Sind contention that even where the rainfall is the same, the Hissar canals should have a larger capacity factor than the Sirhind Canal, in view of the greater canal length to feed the new area.

On pages 180—191, Punjab Vol. III, capacity factors are given for 5-day periods for the Sirhind Canal together with the monthly rainfall, purporting to show the variation of the factors, with the rainfall, for that canal. No proof is offered that there is a linear relationship as in the formula used. Sind have given some example for the Western Jumna and conversely applied the same reasoning to Sirhind, to indicate that the formula does not work for those cases. (S. II, 24).

Since the incidence of rainfall governs the period that a canal can work at a reduced capacity, it is clear that a monthly rainfall factor will not provide for this. It cannot be said to what degree of accuracy the formula will work, though superficially it might be inferred that a larger proportionate factor than Sirhind may be required for the longer new canals and to that extent it would underestimate the Punjab withdrawals. On the contrary, it is seen for a year such as 1933, with a large amount of rainfall in Hissar, that the Sind Set ' A ' calculations would greatly over-estimate the effects in August and September (P. D. III, pp. 182-183).

Sind refer to the capacity factors of 1·0, for June, August and September, with 0·9 for July, furnished to them by the Punjab in

December 1940, as authority for the withdrawals taken by them (*vide* Sind Sheet 262).

*(d) Capacity Factor for the Bist Doab Area.*

The capacity factor formula used for this area is :

$1 - \frac{\text{Actual rainfall} - 1}{6}$. The reason given for the formula is furnished on p. 150, P. Defence, Vol. III. Sind have furnished some examples to show where the formula did'nt work. (S. II, pp. 23-24). Punjab were asked to support the formula by evidence from canals other than Sirhind and on the last day of the sessions a note was put in, on " Capacity Factors and Rainfall ", purporting to show fair agreement with the formula for the Lower Jhelum Canal.

It will be seen from the data furnished, pp. 180—191, P. Vol. III, that the area served is one of considerable rainfall and the demand for canal water will be limited. (Some months, the canal is shown as closed entirely, by applying the formula.) The canal is one of proposed capacity, 1,209 cusecs.

*Conclusion Set 'C' Capacity Factors.*—Finally, with respect to the Capacity Factors in Set 'C', it may be said, that, though some are inadequately proved, yet they do show that the Sind Set 'A' calculations have not allowed sufficiently for the withdrawals,—less than authorized,—that actually take place in the practical working of canals.

In this connection may be mentioned claims by Sind to underestimation of the withdrawals for certain unassessed items, such as evaporation from the surface of the reservoir, supplementing supply to the canal requirements when the river fell below this amount during the monsoon, and a few other minor items (Sind Sheet 90).

BALLOKI-SULEIMANKI LINK.

Another Sind criticism of Set 'C', is the provision of only 10% for losses in this link, (which makes more water available for storage). The Punjab say the canal may be lined. Superficially the percentage seems to be somewhat low on the basis of Balloki-Sidhnai river losses, if this is not done.

*Sind Sheet 192.*—Criticism of accuracy of discharges in the Gharra Reach for some months in 1932, 33 and 34, are made by Sind, but the errors may not make much more difference to Set 'C', than to Set 'A' calculations.

COMPARISON OF SETS A AND C, FOR RELATIVE AMOUNTS OF WITHDRAWALS.

Tabular statements of the amounts of contemplated Punjab withdrawals with their equivalents at Sarhad and Kotri are furnished on pp. 273—283, P. Vol. III.

*Comparison of withdrawals Sets A and C. (P. D. III, pp. 209, 215).*—The tables for the Kharif Season are listed below, in thousand cusec days :—

| Year. | Volume at offtake. | | Equivalent at Sarhad. | | Equivalent at Kotri. | |
|---|---|---|---|---|---|---|
| | Set 'A'. | Set 'C'. | Set 'A'. | Set 'C'. | Set 'A'. | Set 'C'. |
| 1932 .. .. | 7,455 | 6,656 | 7,326 | 4,795 | *7,534* | 4,336 |
| 1933 .. .. | 7,279 | 6,266 | 7,134 | 4,706 | 6,807 | 4,188 |
| 1934 .. .. | 6,700 | 6,340 | 5,701 | 3,773 | 5,756 | 3,493 |
| 1935 .. .. | 5,570 | 5,762 | *5,767* | 4,226 | 5,418 | 3,795 |
| 1936 .. .. | 6,895 | 6,200 | 6,378 | 4,606 | 6,034 | 4,274 |
| 1939 .. .. | 4,400 | 5,060 | 3,863 | 3,502 | 3,664 | 3,241 |

In the 2 cases italicized of Set 'A' for years 1932 and 1935, the equivalent at Kotri and Sarhad respectively come to more than the withdrawals over the whole season, which is highly unlikely. In "Sind's Comments on Chap. IV" (S. II. 33), this is attributed by Sind to probable errors in discharge measurement, as, *e.g.*, in 1935 the amount in excess at Sarhad is only about 0·5 % of the daily discharge, for the kharif season.

It will be seen from the above table, that the calculation of losses and gains in transit from the offtake to the reference gauges, has much more to do with the reduced effects of Set 'C' than the introduction of the capacity factors.

Apart from the suitability of the particular capacity factors adopted in Set 'C', the justification for the use of such factors will be seen by reference to the water consumption diagrams of the Punjab canals for any year—as given in the "Statistics of Irrigation Water Distribution of the Canals in the Punjab".

The impossibility of fixing any definite gain ratio to be applied to withdrawals, on the evidence furnished, has been discussed already in this report and the limitation of this to unity in the Set 'C' Calculations will operate to show a less adverse effect of Punjab withdrawals in Sind.

The manner in which drops on the 2 reference gauges correspond, under the 2 Sets of calculations, is seen from the tabular statements in Appendices XV-A and XV-B of the P. Defence, Vol. III,

pp. 293—304. Monthly average drops are worked out in Tables 20 and 21 of the same volume and the relative effects for September are shown below for Sarhad (P. Vol. III, pp. 286—289). (Sind objects to consideration of monthly averages on the claim that it masks the effect of the high drops making up the average.)

## SARHAD SEPTEMBER DROPS.

*Comparison of monthly averages of drops—Sarkad, Sets A and C.*

| Year. | Average drop for the month. | | Maxm. drop for the month for the periods in Punjab Appendices XV-A, XV-B. | |
|---|---|---|---|---|
| | Set A. | Set C. | Set A. | Set C. |
| 1932 .. .. | 1·32 | 0·56 | 1·3 | 0·7 |
| 1933 .. .. | 0·39 | 0·16 | 0·8 | 0·3 |
| 1934 .. .. | 0·59 | 0·36 | 1·3 | 0·8 |
| 1935 .. .. | 0·72 | 0·45 | 0·8 | 0·6 |
| 1936 .. .. | 1·40 | 0·36 | 2·2 | 0·4 |
| 1939 .. .. | 0·67 | 0·59 | 1·1 | 1·0 |

Other figures of the drops by 5 day periods for September at Sarhad and also for Kotri,—under Set A calculations are furnished at Sind Sheets 95 and 96, for the 6 selected years and also for 11 years.

## TRANSLATING THE DROPS AT RIVER REFERENCE GAUGES TO DROPS IN LEVELS AND DISCHARGES AT THE INUNDATION CANAL HEAD SLUICES.

### (1) Sind Method—Major canals.

*Converting drops on river gauge to canal gauge.*—The graph projection method adopted by Sind to transfer drops at the river reference gauges to the inundation canal head sluices is explained in para. 6·3 of Punjab Vol. III, pp. 309-10. The Punjab representation of the defects of the method is explained in para. 6·4 of the same Volume, and Sind's reply thereto is contained in " Sind's Comment on (Punjab) Chap. VI " (S. II 46).

*Difficulties in co-relating drops,—canal and river.*—The difficulties of co-relating a river reference gauge to a canal head sluice gauge are as follows :—

(*a*) The conditions at the head of the inundation canal approach channel will be different from that at the river reference gauge, so that influences which affect one may not affect the other in the same way. With the shifting bed conditions of the Indus, the gauge discharge relationship at the river gauge is continuously changing, a separate graph to show that relationship being commonly necessary for rising and falling stages, separately, for each site.

(*b*) Some of the inundation canals have long approach channels, which are at times operating under cutoff conditions. The water surface slope in this approach channel will be altering with the rise and fall of the river, but at a rate varying from that of the river.

One of the complaints of the Punjab is, that the Sind method throws all the defects of the canal approach channel and of the canal itself, on the Punjab additional withdrawals. The method is, however, intended to represent the effect of the drops under conditions as they actually existed in certain years. Relieving Punjab of responsibility for inadequate Sind maintenance of the canals is another matter.

The Chairman's Notes pointing out mathematically the limitations of the Sind Projection method are given in Appendices XVI-A and XVI-B, Punjab Vol. III, (pp. 323-326). To meet one of the points in the Notes, Sind have arbitrarily adopted 10 days on either side of the day under consideration as the limit for the projection method (*i.e.*, for projecting from the reduced gauge graph to the original gauge graph).

It is not possible to say how this period of limitation will average out in representing probable actual conditions.

It is also pointed out that an error in taking the lag between the river and canal gauges may make a material difference in the calculated drops, especially on a rapidly rising or falling river.

For the cases where the projection method breaks down and the drop at the canal is taken to be the same as at the reference gauge, it is unlikely the results will be, on the whole, exaggerated.

There is no doubt that the Sind method is only an approximate method of translating river drop effects to the canal head sluices, with many limitations and may give exaggerated results in some cases.

The difficulty remains to suggest a method which can be employed with a greater feeling of confidence.

(2) PUNJAB METHOD.

This is explained in para. 6·6 of the Punjab Defence Volume III, p. 313, and in their rejoinder (P. Vol. III-A, pp. 121—139).

The objections by Sind to the Punjab method are contained in " Sind's Comments on Chap. VI " (S. II 46) and in " Criticism of the Punjab method of translating river drops to reduction in discharge of Sind major inundation canals due to additional Punjab withdrawals ", (Sind Sheets 196—213), and in " Sind's Comments on the Punjab rejoinder " (S. II 99).

*Punjab authority for co-relation curves,—river to canal.*—The Punjab first endeavour to obtain a co-relation between the river reference gauge and the gauge upstream of the head regulator of the canal. A quotation from Parker's Control of Water is given which reads as follows :—

> " It will be found in certain rivers that the bed alters in form at the gauging site ; and consequently, in place of obtaining one approximately definite relationship between Q and H, (H=gauge reading) we find (after long studies) that a sheaf of two or more discharge curves exists
>
> * * * * * *.
>
> * * * It appears that after three or four years' study, it is usually possible to reduce the sheaf to three or four curves, and that the change from one curve to another occurs not gradually, but ' per saltum,' one curve being accurate for three or four months at a time and then another curve becoming applicable the next day. " (P. Vol. III, p. 312).

On this analogy, the Punjab have, therefore, tried to arrive at a series of co-relation factors between the upstream canal regulator and the river reference gauge.

*Whether the Punjab curves are reliable.*—Though the quotation did not refer to this class of relationship, it is reasonable to infer that there may be such a relationship in some cases where the head sluice is close to the river and where the ' per saltum ' changes are similar at both sites. The Fuleli Canal 1935—shown on the graph—Plate I, p. 170, Punjab Volume III-A, seems to indicate such an example. With a long approach channel, it is, however, unlikely that the " per saltum " changes in the river will agree with those in the canal approach channel. Further, the quotation makes no inference that the curves will be necessarily linear or parallel, both of which have been adopted in most of the Punjab graphs.

It is seen from examination of the Punjab graphs that the scatter of the points is such, that it would require much study and knowledge of local conditions to establish " per saltum " curves in many cases. This may be seen by reference to the Plates 1-P and 2-P for Baghar Canal 1935 and Unhar canal 1935 (P. Vol. III-A, pp. 168-169), respectively, accompanying the Punjab rejoinder, where there seem little justification for the slopes adopted for September in either case. The effect of the ratio curve actually drawn, is to show greatly reduced drops on the canals, rather than if curves more consistent with the September points were drawn.

Sind claim to have made a statistical analysis of the co-relation co-efficient for certain canals (Sind Sheet 197). This analysis does not support the values utilized by the Punjab. In reply, the Punjab states that" Sind have obviously taken even such dates for which data is utterly unreliable ". However, if the ' per saltum ' changes should be conceded, it would be difficult to prove the ratios by statistical analysis on a monthly basis.

The Punjab then proceed to get out the ratios,—river to canal gauges, by the drops at the river reference gauge and the corresponding drop at the canal gauge from one day to the next (P. Vol. IIIA, p. 126). The statements submitted do not, however, carry any conviction as a support for these ratios, as so many omissions have been made of what are termed " obviously absurd values ", to get the averages sought for. A perusal of the statements shows the very great variability in the co-relation factors got out on this basis, indicating that the method is not suitable for the major canals. Some examples of this large variance for the same amount of cutoff, are given on pp. 128—130 of Punjab Vol. III-A, for Choi and Begari Canals. The day to day variation, which is given for the Begari, 1934—*vide* p. 165, Punjab Vol. III-A—shows how impossible it is to fit a co-relation factor to such conditions. For the 2 cases cited above of Baghar and Unhar for September 1935, there are 8 omissions out of 22 for Baghar and for Unhar 17 out of 30, to arrive at the Punjab ratio. (P. Vol. III A, pp. 143 and 151.)

*Sind Begari experiments.*—In order to prove their claim that the ratio of drop at canal head regulator to drop at the head of a long approach channel, was normally much greater than 1, model experiments of the Begari approach channel were carried out by Sind. They purported to show also, that for lower cutoffs the co-relation factor is higher than for higher cutoffs.

A Punjab research officer inspected the model and submitted a report to the effect, that, due to defects in the model, etc., the results were valueless (P. Vol. III-A, pp. 180—198).

A rejoinder was put in by Sind answering the criticism, and stating " [The Models] were built solely to check the behaviour of the gauge on the Head Regulator of the Begari, when constant discharge was passed by it, with variations in water level at the head of the approach channel—The model has yielded satisfactory results in this respect ". (S. II 109.)

*Conclusion on Punjab co-relation factors river to canal gauges.*—Finally with respect to these ratio curves it may be stated, that some of them do not seem to show correct relationships and in view of the large day to day variations, such curves are not suitable for use in translating effects shown on the river reference gauge to the canal gauge, except where the local conditions influencing the rise and fall of the water level may be similar in the 2 cases.

## SIND'S CALCULATIONS OF THE RESULTANT DIMINUTION OF LEVELS AT THE CANAL HEADS FOR MINOR INUNDATION CANALS.

In order to show the probable effects of the Punjab withdrawals on the minor inundation canals, most of which have only a very short approach channel from the river, Sind made a selection of 10 canals. The selection is criticised by Punjab in their Chap. VII (P. Vol. III-A, p. 3) and replied to by Sind in their " Comments on (Punjab) Chap. VII " (S. II. 57).

*Sind adopt the same drop at Canal head regulator for the Minor Canals as drop at the river gauges.*—Sind have adopted the same drop at the Canal head regulator as at the river reference gauge for these minor canals. This was done—it is stated—(*a*) to save time (*b*) because the approach channels are short and (*c*) the small canals have little or no cutoff, being mainly high level canals (S. II 57).

The Punjab claim to have verified this arbitrarily chosen ratio of 1·0 by their graphs, but the latter are subject to the same criticism as applies to the graphs for the major canals (P. Vol. III-A, p. 4).

## CONVERTING UPSTREAM CANAL DROPS TO DIMINUTION OF DISCHARGES.

### Major and Minor Canals.

Again to convert the drops upstream of the canal head sluices to effect on discharges, the Punjab have selected year gauge discharge curves, which purport to represent the most efficient working of the canal, without reference to the actual gauge discharge relationship, that existed in the year under examination. Sind claims that conditions in an inundation canal during any given season are controlled by conditions in the river and are beyond the control of the

Engineers in Charge of the canal, and they also claim that they have had to abandon trying to regulate inundation canals from gauge discharge curves. (S. II 47). The Punjab does not accept this explanation, but claims that in the Punjab the same gauge discharge curves remain in force in their inundation canals from year to year.

The Punjab consider that this most efficient gauge discharge curve method, represents the limit of their liability. It does not, however, represent a condition which actually existed except for the one year selected—nor would it be possible to maintain such a relationship throughout the season, with the changing conditions upstream and downstream in an inundation canal. It does not, therefore, represent the probable effects on Sind, for conditions as they were in the years under examination.

REDUCTION IN DISCHARGES OF SIND INUNDATION CANALS, DUE TO PUNJAB ADDITIONAL WITHDRAWALS.

This will be dealt with in Chapter IV of this report.

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## III.—ACCRETION OF LEVELS OF RIVER BED IN SIND.

*Accretion of levels. Importance of subject.*—The subject matter dealt with under this heading pertains to the rise of bed levels of the River Indus in Sind. The importance of the subject is obvious in relation to the functioning of inundation canals that depend for their supplies on the uncontrolled level of the water in the river. If any tendency for the river bed to rise steadily could be established, it would be an influence moderating the logical effect expected, of lower water levels in Sind, pursuant to withdrawals of water in the Punjab.

The Indus River Committee, 1929, apprehended that the Bhakra Dam scheme would reduce the duration of flow in the Sind inundation canals and also the number of days on which the "Fair irrigating level" would be realized, for the canals between Mithankot and Sukkur. They found themselves unable to express an opinion with the data available, as to the probable amount of this effect on the Sind inundation canals, and the extent to which accretion might be a moderating factor. They, accordingly, recommended that two Superintending Engineers be appointed to examine the subject.

*Nicholson-Trench Report.*—Messrs. Nicholson and Trench (Superintending Engineers of the Punjab and Bombay respectively) were therefore appointed and they presented their report on the 15th December 1930. The report is contained in the book titled "Report of the Committee of Superintending Engineers from Bombay and the Punjab, dated the 15th December 1930, on the

probable effects of the Bhakra Dam Scheme on the Inundation canals of the Indus between Mithankot and Sukkur ". Mr. Trench also appended a note on the effects on the canals below Sukkur. They dealt with the following aspects of the problems to the extent they were able to obtain data of the Punjab rivers :—

(*a*) Natural regime changes of level of the rivers.

(*b*) The effect on river regime of the construction of weirs and weir-controlled canals, with sympathetic changes occasioned thereby.

(*c*) The regime with reference to tortuosity and slope.

In connection with (*a*), they drew certain conclusions as to the changes that might be expected by the time the Bhakra Dam Scheme matured and in connection with (*b*), the probable effect of the Lloyd Barrage—then under construction, was also incorporated in the Report.

The following conclusions were expressed in their report :—

*Quotations.*—" The inference from what has been shown to take place at all the headworks dealt with above, is therefore very strong, that after the construction of a weir in an alluvial river, the upstream slope tends to recover and over a sufficient term of years will recover its former value; also, that, irrespective of reduction of discharge, the levels downstream of a weir will in a period which may extend to 20 or 30 years, recover and even rise above their former value while specific levels will show a greater rise." (P. 9, N. T. Report) and again dealing with Upper Sind—

" In fact the rise of regime levels taking place at present and for many years past at the rate of 0·11 ft. per annum for discharges of 200,000 cusecs and over, as shown by the specific discharge graphs has only to continue for the whole of the estimated reduction in level at Bukkur due to the Bhakra Scheme withdrawals to be wiped out in the course of the next 9 or 10 years " (P. 18, N. T. Report),—and again a separate note incorporated by Mr. Trench for Lower Sind dealing with the probable effects of the Lloyd Barrage.

" In these circumstances and in view of the fact, that, on the most unfavourable hypotheses, the reductions of levels in the canals are small, it does not appear probable that conditions 10 or 12 years hence, the earliest date on which the Bhakra withdrawals could take effect

will be any worse for the inundation canals below Sukkur, than they are at the present day and, in fact, owing to regime rises conditions may be better, even allowing for the estimated adverse effect of the Bhakra Scheme withdrawals" (P. 172, N. T. Report).

Mr. Trench also pointed out in regard to regime changes expected in Lower Sind, as below,

> " Taking therefore 0·05 ft. per year as a reasonable rate of rise, in 12 years time, before it is likely that the Bhakra Scheme will function, the rise will be 0·6 ft. and the whole of the estimated reduction of water levels in the canals will have been made good in almost all the canals in anticipation of the withdrawals taking place." (P. 171, N. T. Report).

These quotations are reproduced here in view of their importance in influencing the Government of Bombay to accept the Bhakra Scheme in 1934 and in view of the references to this report, in the present case, by both Sind and the Punjab. This Commission therefore finds it necessary to comment on the deductions of the Nicholson Trench Report, as the period mentioned in the report has now matured and to say,—

(*a*) Whether it can be accepted that the rise in bed expected has occurred.

or

(*b*) Whether the period of time post barrage is too short to give data on the effect of the Lloyd Barrage, in assisting accretion.

*Sind criticism N. T. Report.*—The conclusions of the Nicholson Trench report in regard to the probable amounts of drops in river and canal levels due to the Bhakra Scheme have been criticized by Sind for reasons which they have cited in paras. 5 to 8, Part I of their book called " The Case for Sind " (Sind Sheet 6), and the Punjab remarks thereon are given in the Punjab Defence, Vol. I, but that particular point is not of importance in regard to the general deductions made as to rise of bed levels.

In paras. 9 to 12, Part I of the same book Sind claimed (Sind Sheet 6) that :—

(1) The rise in bed level in the river above Sukkur has not occurred.

(2) For Kotri gauge, the rise in level in the last 15 years is small for the discharges at which inundation canals normally work.

(3) Scours in the bed due to high floods are liable to wipe out any such accretions.

The Punjab contradict the above claims and have put forward other interpretation of the data available.

Sind have also criticized the compilation of the Nicholson Trench data and application of their deductions to Sind conditions (Sind Sheets 158, 164).

*Direct method of examination of the subject.*—Superficially, the most direct method to determine whether there has been rise of bed level would seem to be to compare cross-sectional surveys of the river bed at the same sites over a period of years. The problem cannot be solved in this direct manner, however, due to the unstable nature of the alluvial bed and banks of the river Indus in Sind. The river is several miles in width with continuous caving in of banks, change of deep bed of the river and shifting of river shoals during the flood season. Further the only 2 sites where discharges are measured on a continuous programme in Sind are Sukkur and Kotri. In the I. R. C. records there is a graph giving a datum from which scour and silt are measured. The parties were asked during the proceedings whether there was sufficient material available of the Kotri discharge site cross section, to establish directly for that site, figures of permanent rise in bed levels, but no proof was produced.

## GENERAL FEATURES OF RIVER FLOW IN THE INDUS, FOR INTERPRETING HYDRAULIC DATA OF GAUGES AND DISCHARGES.

### General Features.

The flow from the five rivers of the Punjab,—Jhelum, Chenab, Ravi, Beas and Sutlej passes into the Indus River, where the Panjnad joins it, a short distance above the Sind boundary.

(*i*) *Bunds.*—Prior to the construction of river embankments, flood flow of the Indus River spread over Sind and passed to the sea by channels which have changed their courses at various times in the past. Construction of flood embankments was started in Sind as early as 1875 and has been pursued since that date gradually restricting the limit of flood spill of the river. The present position is that all the area served by canals on the right bank is protected from floods and also on the left bank, except for a portion of the area between Bahawalpur boundary and Kasampur.

Sind have furnished a " Note on the River Bund System in Sind ", (Sind Sheet 302), which explains the works undertaken in the past, the maintenance work necessary and the effect on mainte-

nance anticipated with the probable flood heights after the Punjab withdrawals.

The dates of construction of bunds has relevance in considering the homogeneity of data used in arriving at statistical trends and is referred to in dealing with that part of the subject. Sind have claimed that gauges earlier than 1910 should not be considered in arriving at trends of river level in view of the incompleteness of bunding done prior to 1910. The Punjab have contended that the construction of bunds was continued to a much later date than 1910—*vide, e.g.,* page 304 Sind Kharif Case, in order to support their case for starting trends from earlier dates. Sind, however, claimed that the addition to the length of marginal bunds for containing the floods after 1910 was only small.

It would, however, appear that the dispersion of floods over the Sind delta was much curtailed by 1910. It is not possible to say to what extent such bunding in itself has contributed to accretion or scour in the river bed, with consequent changes in river levels.

*Mr. P. J. Corbett's Note on supposed rise of Indus bed.*—So long ago as 1872, certain principles were enunciated in regard to the effect of embankments on the regime of a river and these are mentioned in the Sind document titled, " Notes on the supposed rise of the bed of the Indus in Sind owing to the construction of embankments on either side of the river ". These notes were written by Mr. P. J. Corbett in 1900. It is seen from his notes that even at that time there was a common belief that the bed of the Indus in Sind especially below Kotri was rising, due to the construction of embankments and that this was shown by the supposed annual increase in the flood heights of the Bukkur and Kotri gauges. The writer contended that there were no indications that the bed and flood levels were rising due to the construction of embankments. He pointed out that the maximum flood height had risen at Bukkur from 11′ 11″ in 1848 to 15′ 10″ in 1876, (Sind state in their note on Punjab's Note on rise of levels that the first Government bund was constructed in 1869), before any embankments were built and considered that the rise in flood levels was probably attributable to many factors, *e.g.*, destruction of forests in the catchment area—changes in climatic conditions—changes in the upper reaches which might have reduced spill and confined the flow, etc. Whilst the embankment of a river augments the (confined) maximum flood discharge, in the Lower reach of a river this may be met by a small permanent rise in river level to accommodate the excess discharge, but there is no question of continuous annual rise of flood level due to this embanking. Theoretically there is no reason why the embankment should not lower the flood level due to increased scour of the alluvial bed and banks due to the increased

volume of water. It was also contended that the effect of possible rise due to advance of the delta into the sea was so slow, that it could have no appreciable effect on the level of the bed within modern times. Increased meandering of the river was also given as another probable cause of rise of river levels (P. Vol. 3, p. 157.)

Sind have, however, given figures of cold weather length of the lower Indus, in "Sind Comments on the Punjab Defence Vol. 3, Chap. 3," purporting to refute the suggestion that the river course is lengthening (S. II 25).

The general difficulty in arriving at definite indications of effect of embankments on the river Indus bed conditions, pointed out by the above writer in 1900, still remains, and no authoritative data can be referred to, to give the relative value of a statistical trend which is started before the construction of river embankments in Sind, with that started after most of such embankments had been built.

(*ii*) *Scour and Silting.*—The gauge level of the water surface at which a *definite quantity* of water passes a certain site in the alluvial river bed and bank conditions of the Indus river in Sind, varies up to several feet. This variation continues throughout the rising and falling flood and also from year to year. The river floods in their passage from the catchment to the sea, carry or move, a continuously changing amount of silt. They pick up silt, scouring the bed and banks in one place and deposit part of this silt in another place, part being carried to the sea. As the subject has been discussed in past reports it will not be dealt with here, except as may be necessary for understanding the reasons for different interpretations of the same initial hydraulic data. A rising flood usually scours or moves material along the bed while in a falling flood the rolling silt is deposited. One would therefore expect in the gauge discharge graphs covering a season's flood, that the falling curve would lie above the rising curve. This is not always the case, however, in the Indus and the local reasons for variation are not always readily understandable, *e.g.*, at Kotri the falling curve does lie above the rising curve, but at Sarhad there is variation sometimes in the same year and also in different years.

Whilst in the case of a river gauging site with a rocky or stable bed, it may be possible to calibrate a gauge discharge curve that will enable the changes in discharge to be read from the gauges, this is not the case with the Indus with its changing bed conditions.

(*iii*) *Local effects on river gauges.*—Certain local changes in the regime of a river, that affect the gauge level at which a specified discharge will pass may be briefly noted—

(*a*) *River Set.*—When the main current of the river has its direction towards the gauge, it may raise the water

surface level, to as much as, say, 2 feet above that when the main river course is away from the gauge. In a similar manner when the head of the inundation canal takes off from the concave side of a bend the water level will be higher than if it takes off from the convex side. Sind have noted the set of the river for the different years on some of their graphs.

(*b*) If the river scours out a short cut just above the gauge, the water surface level may rise for the same specific discharge, whereas if the river lengthens its course above the gauge, the surface may fall.

*Specific gauge discharge graphs.*—It was agreed by both Sind and Punjab that the most direct method of determining rise of bed levels is by means of specific Gauge Discharge Graphs (page 14, Commission Proceedings 6-5-42, and sheet 158 Sind Kharif Case). These graphs have a time base with units of one year ; the ordinates being the average gauge at which a specified discharge passes the gauge. There is therefore a separate graph for each discharge selected. Some of the graphs are for discharges of 40,000, 70,000, 100,000, 200,000, 300,000 and 400,000 cusecs. The first two discharges are not of much importance, so far as the inundation canals are concerned, because of the low level at which they pass and the number of reliable discharges above 300,000 cusecs are commonly too few to give continuous results.

The original graphs prepared for the selected sites have undergone revision during the course of the Proceedings, as the need for other compilation of the data became evident on the criticisms raised. Some of the opinions expressed, therefore, by Sind and the Punjab, on the original graphs, may not necessarily apply to the revised graphs.

*Sind Kharif case, Sheets 160, 161, 320, 321.*—Some of the changes made in revising the Sind specific discharge gauge graphs to correct errors or omissions are given below.

*Alterations made during the Commission for the specific gauge discharge graphs.*—

1. There are only 2 discharge measurement sites, Sukkur and Kotri wherefrom the discharges are deduced for the other specific gauge discharge sites. Withdrawals and losses *en route* from the selected site to Sukkur or Kotri as the case may be, are allowed for in the revision. Losses may not agree with the final revised calculations made by Sind in getting out revised figures of drops, but the difference will, it is claimed, be only small.

2. Alterations in lag for some sites are made.

3. Separate graphs are now got out for the rising and falling stages. Whilst mean graphs are also prepared, it is the contention of Sind that they have no meaning, as they do not represent any stage of the river, but only a mean of the data of rising and falling stages. The original Sind graphs did not provide for the two stages separately.

4. The original graphs—including those of the Nicholson Trench report—were plotted from guage and discharge readings which were selected from the recorded data of rising and falling stages of the river. This selection may result in misleading results, so in the revised graphs the ordinates were obtained from smoothed gauge discharge curves, got out for the rising and falling stages, separately. This preparation of smoothed curves has also been a matter in which the Punjab and Sind did not agree in some cases. The location of the smoothed curves with respect to the plotted points permits some difference of opinion.

5. Up to 1924 measurements of discharge were made by meters suspended by cables. Sind have carried out certain experiments, from which they have concluded that the cable suspension over-measures the discharges. They have accordingly in their later graphs made correction for this over-measurement in the I. R. C. figures of discharges, as they claimed it made greater homogeneity of data. Punjab objected to this alteration of data which had been accepted over a long period.

After drawing the graphs, a statistical analysis has been made to observe the trends of the graphs.

*Statistical Analysis.*—Although statistical analysis is the most scientific manner of reading the trend of a graph it is subject to the following limitations when trying to get agreed results.

(*a*) *Period.*—The trend of a graph is affected by the point from which the graph begins and Sind and Punjab have not agreed in many cases, as to which year should be taken as the starting point of the analysis.

(*b*) *Homogeneity of data.*—It is obvious that the trend of a graph will have no meaning, if the data on which the graph is based, is not of a homogeneous nature and likely to repeat itself. This has been another point on which there has been difference of opinion.

To obtain data of supplies available for future projects the necessity for systematic gauging of the Indus River at selected sites was emphasized by the then Inspector General of Irrigation in 1920. The hydraulic data obtained since that time in Punjab and Sind

has made possible the detailed investigation, which is seen in the cases presented. There is, however, still no agreement on the relative value of some of the data utilized by Sind and the Punjab. In this connection the remarks of Messrs. Nicholson and Trench (Page 21 of their 1930 report) may be noted here,—" While a considerable amount of the discharge data available has been of great use to us in arriving at our conclusions, we have found that much of it is so unreliable as to be valueless for the purpose of making any deductions therefrom. The remark applies in particular to the record of all sites in alluvium, where an attempt has been made to utilize a calibrated discharge curve and also at several sites, where discharges are reputed to have been actually observed. "

We would remark, also, that data has similarly been put before us, of which the accuracy was much in doubt, and conclusions have been read into some of the data, in the notes furnished in support of the respective claims, which were hardly justified. The reason for this is partly inherent in the practical difficulty of knowing just what data available from past records should be discarded, and what other data, approximate only though it may be, should be retained, for the weightage that it may have in a long term view of the subject.

The subject of the homogeneity of data is dealt with further, under the examination of simple gauges for evidence of accretion.

(c) *Trends* are described as being significant or non-significant. Significance is further defined with relation to its percentage conformance to certain accepted standard deviations from the trends,—5 per cent. being the limit in these analyses, beyond which the trends are defined as non-significant. Non-significant trends are held to be due only to chance occurrences and therefore of no value as trends, though attempt has been made to " weigh " them in, in some of the notes furnished to us as showing a tendency one way or another. Another point of difference of opinion was, as to whether a trend could be accepted for a gauge site, when, *e.g.*, there was a significant trend for one particular discharge, but when there was no similar trend at other specific discharges at the same site and whether a significant trend

on a rising flood has any value, if it is not supported by a similar effect on a falling flood.

(*d*) Where possible a straight line is fitted by method of least squares to show the trend. Where a straight line does not fit the data, a polynomial of the second degree has been tried, to see whether a parabolic trend of a fall followed by a rise, or *vice versa* exists.

These are some of the difficulties in interpreting statistical results and are definite limitations on obtaining decisive conclusions by specific gauge discharge graphs.

UPPER SIND—SPECIFIC GAUGE DISCHARGES.

*Sites selected by Sind for purpose of specific gauge discharges.*—The sites selected by Sind in Upper Sind, to verify the deductions made by Messrs. Nicholson and Trench on specific gauge discharge data were as follows:—

*Upper Sind—*

| | | Gauge Site. | Distance from Barrage. |
|---|---|---|---|
| Section | IA | Old Sukkur Canal Head .. .. | ·4 miles. |
| „ | IIA | Rahuja Head .. .. .. | 18 „ |
| „ | IIIA | Rajib Canal .. .. .. .. | 23 „ |
| „ | IVA | Satabani Loop, mile 2 .. .. | 32 „ |
| „ | VA | Begari Head .. .. .. | 53 „ |
| „ | VIA | Unhar Wah .. .. .. .. | 61 „ |
| „ | VIIA | Opposite Sarhad .. .. .. | 70 „ |
| „ | VIIIA | Machka .. .. .. .. | 98 „ |

These sites were selected, it is stated, before the effect of the Lloyd Barrage was known, and Sind now claim that the first four sites given above are under the influence of the Barrage pond and that their trends are not of value, but this is not accepted by the Punjab (Proceedings 6-5-42, page 5). The selection of the gauges was made in 1934. The only large inundation canal within the limits of the first four gauge sites is the Sind (Col. Fife) canal and the smaller canals Rajib, Chitti, Garang and Janib, so the trends are not so important for these gauges.

An examination is made below, *seriatim*, of the results shown by the specific gauge discharge graphs for the Upper Sind sites.

Remarks for the first four sites are based on the original graphs, as these are the graphs discussed by Punjab and Sind. As Sind

claim the results of these sites are vitiated by the Barrage pond, as noted above, they have not furnished a statistical analysis of those graphs.

IA—Old Sukkur Canal.

*Specific gauge discharge site IA.*—This is so close to the barrage that it has no significance but accretion is shown at all discharges.

IIA—Rahuja Head—Original Graphs, Serial No. 6.

*Specific gauge discharge site IIA.*—

| | | |
|---|---|---|
| 1 lakh cusecs | .. | Not available. |
| 2 lakhs cusecs | .. | Fall—Punjab view,—slight rise, Sind view. |
| 3 lakhs cusecs | .. | Steady. |
| 4 lakhs cusecs | .. | Steady. |

IIIA—Rajib Canal—Original Graphs, Serial No. 6.

*Specific gauge discharge site IIIA*—

| | | |
|---|---|---|
| 1 lakh cusecs | .. | Not available. |
| 2 lakhs cusecs | .. | Rise of 2½′ between 1932 and 1940. |
| 3 lakhs cusecs | .. | Rise of 2′ between 1932 and 1940. |
| 4 lakhs cusecs | .. | Rise of 1′ between 1932 and 1940. |

all the rises are non-significant.

IVA—Satabani Loop, Mile 2—Original Graphs, Serial No. 6.

*Specific gauge discharge site IVA.*—Same remarks as for IIIA according to the Punjab, whereas Sind explain there is a downward trend from 1932.

The trends are non-significant, but there is scour up to 1935 and a final gain of 1½ feet on the 2 lakh stage and fall on the 3 and 4 lakh stages, whereas the revised graphs show a non-significant rise on all stages, attributed by Sind to ponding effect.

VA—Begari Head—Revised Graph 1931-41.

*Specific gauge discharge site VA.*—This shows a fall on all stages, but the falls are non-significant, except for the rising stage at 3 lakhs discharge and the 4 lakh discharge. Punjab claims that the history of the gauge is unsatisfactory, but this is contradicted by Sind. The Punjab also state, that, prior to 1934, the gauges were only observed once a week. The Punjab claim that the drop in level between 1931 and 1941 of 1½-ft. to 4¾-ft. on different stages, proves the inaccuracy of the data, as the Sarhad gauge does not show this change. Sind explain this, by saying there was a set of the river towards Sarhad between 1935 and 1940. Superficially, there seems no

reason to discard the evidence of this site any more than some of the others.

VIA—Unhar Wah—Revised Graphs, 1931-41.

*Specific gauge discharge site VIA—*

| | | |
|---|---|---|
| 1 lakh rising | .. | non-significant fall. |
| 1 lakh falling | .. | rise, significant at 5 per cent. level. |
| 2 lakhs rising | .. | fall, significant at 1 per cent. level. |
| 2 lakhs falling | .. | non-significant rise. |
| 3 lakhs rising | .. | fall, significant at 0·1 per cent. level. |
| 3 lakhs falling | .. | non-significant fall. |
| 4 lakhs rising | .. | fall, significant at 1 per cent. level. |
| 4 lakhs falling | .. | fall, non-significant. |

The contradictory trends of this gauge are difficult to interpret, but seem to indicate a probable fall. Punjab have criticized the history of the gauge. Sind claim that the gauge has not been shifted during the period examined. There are only weekly gauge readings up to March 1932, out of the period 1931-41, but the rest are daily readings. There seems to be no reason why the evidence of this site should not be considered along with the other sites.

VIIA—Opposite Sarhad—Revised Graphs 1931-41.

*Specific gauge discharge site VIIA*—The trends for all gauges show rises, none of which are significant. In the original graphs the 1940 level was higher than 1931 and the intervening years. In the revised graphs, 1941 was added and this brought the 1941 level below that of 1931 for the following stages 1, 2 and 3 lakhs falling and for 4 lakhs the overall rise was within about half a foot for both stages, rising and falling.

The Punjab claims in regard to this gauge were based on the graphs, before 1941 was added. It is largely on the results quoted for this gauge, in paragraph 3·9 Chapter III, Vol. III, Punjab Defence, without 1941, that the figures were adopted by the Punjab for moderating their Set B. and Set C. drops for rise in bed in Upper Sind (P. Vol. III, p. 155). *As noted above, 1941 alters the results.* Sind also furnish a quotation from " Statistical Methods " (*vide* their comments on Punjab's note on rise of levels of the River

Indus in Sind S. II 72) to the effect that a trend is useless for purpose of prediction, when the regression is non-significant.

Sind also state that the river set has been towards the gauge for the last 6 years, and they would attribute the non-significant rise largely to this feature.

Sarhad is the site selected by Sind as the reference gauge for Upper Sind, for which they have calculated probable drops due to the Punjab contemplated withdrawals.

*Pp. 28 and 29 of Sind's comments on Punjab's Defence, Vol. 3, Chap. 3.*—Sind have also objected to the method adopted by the Punjab in applying the whole of the moderating influence of claimed rise in bed level, *i.e.*, $9 \times 0{\cdot}15 = 1{\cdot}35$ feet for Upper Sind in 1932 and reducing the amount thereafter by annual stages (P. Vol. III, p. 155). As, however, the amount of the compensating factor claimed on the basis of Sarhad (and Machka) graphs is not supported by the examination of specific gauge discharge graphs made herewith, the method of application of the same need not be pursued.

## VIIIA—Machka—Revised Graphs 1931—41.

*Specific gauge discharge Site VIIIA.*—Sind have given the trends for the years 1928—41. There is no linear significant trend for any of the stages (Sind Sheets 162 and 326). The parabolic curve fitted to this data shows the falling portion of the parabola continues up to about 1935, with the rise thereafter. Punjab have referred to the history of the Machka gauge, which indicated that readings prior to 1931 were unreliable and so Sind have re-analyzed the data from 1931—41.

For all stages the trend is on the rising arm of a parabola, but the following stages only are significant,—1 lakh rising and falling (S. II 72).

Sind state that during the years 1938 to 1940 the river shortened its course upstream of Machka and the current switched towards the Machka side, but they also state that the set in recent years has, mostly, been normal. Sind claim that the negative B term in the statistical trend, except for the 1 lakh rising curve, indicates an " overall " fall. The general trend of this gauge has been upward of recent years, but it is not possible to assess the permanency of the trend with the parabolic and non-significant features shown at the different discharges.

## SUMMARY FROM THE SPECIFIC GAUGE DISCHARGE GRAPHS OF UPPER SIND.

*Summary of results, Specific gauge discharges, Upper Sind.*—It seems likely that the improvement in the gauges shown up to the 3rd or 4th gauge site may be more or less permanent, but the few inundation canals taking off in this reach, total only about 1/11th or 1/12th of the full supply capacity of all the Upper Sind Canals.

For the gauges higher up the Indus, the evidence furnished, does not support any indication of rise of bed, that could be assessed in amount as having a permanent value, for levels at which the inundation canals function.

### Middle and Lower Sind—Specific Gauge Discharges.

*Middle and Lower Sind—Sites selected for Specific gauge discharges.*—The Discharge Division Officers of Sind and the Punjab selected the sites noted below in Lower Sind for Specific Gauge Discharges :—

(*i*) *Bachalshah.*—Close below the Lloyd Barrage.

(*ii*) *Bhago Toro.*—90 miles above Kotri.

(*iii*) *Kotri.*—270 miles below Sukkur.

(*iv*) *Kalri.*—60 miles below Kotri.

(Middle Sind is also commonly classed with Lower Sind. Where the term Middle Sind is used in connection with the inundation canals, it refers to the few canals between Sukkur and Fuleli canal head, the latter canal being classed in Lower Sind.)

### (*i*) Bachalshah.

*Specific gauge discharge site, Bachalshah.*—There are no inundation canals in the vicinity of this gauge, so an examination of the results obtained for this gauge is not of special importance, except to show the degradation that occurred at this site immediately below the barrage, after the construction of the same and the subsequent recovery. Punjab claims that the effect of the degradation was also felt upstream of the barrage, with the result that the accretion might otherwise have been more than that shown.

*Sind Sheets 163 and 325.*—Whilst the trend for this gauge for the period 1923—41 shows significant rises on the falling stages for 1 to 3 lakhs discharges,—when the trend is taken from 1931—41, none of the discharge stages are significant. (S. II 72.)

Due to the completion of the barrage in 1932, the longer term trend is not of value.

(*ii*) BHAGO TORO—GRAPHS FOR YEARS 1923—41.

*Specific gauge discharge site, Bhago Toro.*—The graphs show a downward trend at all stages, of which the only curves that are significant, are the falling stages at 1, 2 and 3 lakhs. (*Sind Sheet 325*). Punjab criticizes the data for this site as discharges were worked out by Sind (by oversight it is explained by Sind) from Sukkur discharges, rather than from Kotri,—and as the scatter of the points on the gauge discharge curves is high. The former objection is not very material, as the loss and lag were worked out on the Sukkur and Kotri discharges. The affected inundation canals in the vicinity of this gauge are not important.

Analysis is made for the years 1931—41 and the fall for that period is found to be non-significant at all stages (S. II 73).

The remarks of Punjab and Sind on the inferences to be drawn from the gauges Bachalshah and Bhago Toro in support of Messrs. Nicholson Trench observations will now be examined.

OBSERVATIONS IN THE NICHOLSON TRENCH REPORT IN REGARD TO DEGRADATION OF LEVELS AND RECOVERY BELOW WEIRS AND APPLICATION TO LLOYD BARRAGE.

*Degradation and recovery below the Lloyd Barrage.*—The following opinions were expressed in the N. T. Report. P. 171.

1. Below all weirs constructed there has been a degradation of levels, but how far that degradation extends has not been ascertained.
2. The degradation lasts for only a short period, amounting to probably 3 to 5 years, and then an accretion begins, which more than wipes out the former degradation. As the period of degradation is short, it is probable that it does not extend far and, certainly, not so far as Sukkur to Kotri.

Punjab reads into the Bachalshah gauge a degradation of levels of 2 feet due to the barrage construction, with subsequent recovery, as evidence of proof of the above Nicholson-Trench observations,—and with regard to recovery above the barrage,—points to the first four gauges above the barrage, dealt with in the preceding remarks on these gauges. (P. Vol. IIIA, p. 67) They contend this evidence is in support of the opinions of Messrs. Nicholson and Trench in paragraph 33, page 9 of their report.

Sind, on the contrary, claims that the degradation of the Bachalshah gauge is possibly due to the high flood of 1933 and states that the set of the river was to the left bank from 1932 to 1936 and towards the right bank, *i.e.*, towards Bachalshah from 1937 and that the variation in the specific discharge gauge is due, partly, to this factor. Sind also point to Bhago Toro downward trend as evidence that retrogression, which started after the Barrage commenced operating, shows no signs of termination and that Messrs. Nicholson Trench's deduction is not realized at this gauge (*Sind Sheets 165 and 166*).

There is, however, no indication that Mr. Trench in his observations expected the degradation to extend even as far as Bhago Toro, nor is there any surety, that the downward trend at this site is due to the condition which was referred to by Messrs. Nicholson and Trench, *i.e.*, as degradation below weirs. Bachalshah is close below the Lloyd Barrage and it is quite reasonable to assume that the usual action above and below a weir referred to by Messrs. Nicholson and Trench may have taken place within the limits discussed in the preceding remarks on these gauges *i.e.*, Bachalshah below and probably up to the first 3 or 4 gauges above the Barrage.

### (*iii*) Kotri.

*Specific gauge discharge site, Kotri.*—This is the reference gauge utilized by Sind in calculating probable drops, due to the contemplated Punjab withdrawals. It is the only regular discharge measurement site in Lower Sind. The present permanent discharge measurement site came into operation in 1910. Prior to that date discharges were measured at various sites (*Sind Sheet 164*).

*Sind's 1910—41 graph—*

1 lakh rising and falling stages .. rise significant at 0·1%.

2 lakhs falling stage .. .. non-significant rise.

2 lakhs rising stage, 3 and 4 lakhs rising and falling stages. non-significant fall.

2 lakhs rising stage has a parabolic trend-significant at the 5% level—of a fall followed by a rise with present levels the same as 1911.

3 lakhs rising and falling stages.. non-significant fall.

40,000 and 70,000 cusecs discharges were also analysed, but these discharges are not of much importance to inundation canals in lower Sind. The curves at these discharges show overall rises.

The 5-year and 9-year average are plotted on the same curves and show the following results :—

| | |
|---|---|
| 1 lakh—rising and falling stages .. | rising. |
| 2 lakhs—falling stage .. .. | no special trend. |
| 2 lakhs—rising stage .. .. | parabolic trend, now upward. |
| 3 lakhs—rising and falling stages .. | no conclusions can be drawn. |

Sind claim that the Kotri gauge discharge curves do not show that rise in the bed at Kotri has occurred. Their analysis for 1932—41 gives non-significant results for 1, 2 and 3 lakhs discharges.

Punjab object to the Sind graphs from 1910—41 claiming—

(1) The smoothed gauge discharge curves are a mixture of observed and interpolated discharges and objection is taken to the actual smoothed curves as drawn.

(2) The propriety of correcting at this date, the old discharges prior to 1924 for cable suspension, is questioned.

(3) Disagreement is voiced at the curves being started by Sind at 1910—on the Sind contention of the earlier data not being homogeneous.

These points are referred to elsewhere in other connections.

The Punjab show statistically significant rises at the 5% level, if the graphs are started from 1901, for all discharges and using the original discharges recorded in the I. R. C. records without correction.

A further set of specific gauge discharge curves for Kotri are those prepared by Messrs. Nicholson and Trench from 1901 and brought up to date. Sind object to these curves for reasons which they have cited in Part III of Sind's Kharif Case (Sind Sheets 164-165) but have analysed the results from 1911, on the Nicholson Trench basis in their "Comments on Punjab's Note on rise of levels of the River Indus in Sind". (S. II 73).

The general indications are, that there is an upward long term trend on the low discharges up to about 1 lakh or more, but the evidence of any permanent accretion at higher discharges is less sure. The extent to which this long term trend is being continued in recent years is dealt with elsewhere under the deductions from simple gauge records.

(*iv*) KALRI—1924—41.

*Specific gauge discharge site, Kalri.*—The Sind specific gauge discharge graphs for this site give the following results:

| | | |
|---|---|---|
| 1 lakh discharge | .. | .. no data available. |
| 2 lakhs discharge | .. | .. rising and falling stages—data incomplete but downward trend. |
| 3 lakhs discharge | .. | .. rising and falling—statistically significant fall at 0·1% level. |

This site does not show any indications of accretion of bed.

*Summary for specific gauge discharges in Middle and Lower Sind.*—The graphs do not show evidence of sustained rise of bed, that can be assessed in amount as an offset to the drops which may occur with further Lloyd Barrage withdrawals to come up to authorized withdrawals and which may occur with future Punjab withdrawals, but the indications are, that the significant rise shown by the Kotri gauge up to about 1 lakh or more may be useful to the Fuleli and Pinyari canals, when they are able to draw supply at this low river level.

EVIDENCE OF ACCRETION FROM SIMPLE GAUGES.

*Simple gauges.*—The Punjab are of the opinion that deductions can be made from simple mean monthly gauge graphs as to probable accretion of bed, *vide* paragraph 1 (*b*) of Punjab " Note on rise of levels of the river Indus in Sind" and in paragraph 4 of the same note detail the limitations of reliability of the Specific Gauge Discharge data and graphs.

'Sind have, however, furnished copy of a note accompanying a letter from the Secretary to Government P. W. D., Punjab, to the Secretary, P. W. D., Bombay, dated the 7th September 1933 in which the limitations of any deductions from simple gauges are pointed out, *vide* page 14, Proceedings of the Commission, of the 6th May 1942. An extract is given below :—

> " * * * * * * Conclusions as to river bed movement, based on the existing Simple gauge graphs, have to be formed on the assumption that the discharge from year to year is roughly constant, but this is by no means true and even when averaged over a number of years may be very far from the truth as may

be seen from the recorded discharges of any river site
* * * * * * * "

The letter then proceeds to explain the proposals for specific gauge discharge graphs " to obtain a more accurate measure of river bed movements".

*Average of 50 highest days—Kotri.*—In the I. R. C. records is furnished a graph of the average stage of the highest 50 days of each year at Kotri, the graph starting at 1864-65. The Punjab have analysed this graph in their plan $\frac{20}{1}$ and find it shows a statistically significant rise of about $\frac{3}{4}$ inches per year over the 76 years. On the same graph are plotted, June—September discharges from 1901. These indicate a parabolic trend, first rising and then falling and purport to show but little net change in June—September discharges over the period from 1901. A ratio is also struck of the $\frac{\text{Average gauge June to September}}{\text{June—September discharge}}$ from 1901, which gives a small upward trend, the indication being, that the rise at Kotri is not due to increased discharge, but is a regime rise and it is claimed to be continuing to this day.

Sind do not accept that there is any upward trend of the Kotri gauge at present. They have submitted a note on the " Examination of Punjab Document $\frac{20}{1}$ etc." (Sind Sheet 225).

Their explanation of the lower gauges 1864 to 1894 is, that it is probably due to dissipation of the flood waters before the construction of flood embankments. Objection is also taken by Sind to the mean monthly gauge discharge ratios given by the Punjab on page 197 of their Volume III. They consider that the gauge readings prior to 1910 are not homogeneous with later readings,—also, that as the gauge to discharge relation does not follow a linear law, the ratios cannot be assessed for trend. They also criticize the accuracy of gauging, for the Punjab discharges (Sind Sheet 167).

Sind have made a statistical analysis of the average of the 50 highest gauges from 1911 and state it gives no significant rise or fall (but a non-significant fall).

It is however evident from the Punjab graphs that there is a long term upward trend, but it is also seen from the graph that the trend is not continuing in recent years. The averages of the 50 highest gauges from 1864-65 are reproduced below, from which it will be seen that the average for the 8 years pre and post barrage is practically the same, *i.e.*, no indication of rise in recent years, reading the gauges by themselves.

## Average of 50 highest gauges in the year at Kotri.

*(1864-65 to 1939-40)**

| Year. | Average Gauge Feet. | Year. | Average Gauge Feet. | Year. | Average Gauge Feet. | |
|---|---|---|---|---|---|---|
| 1864-65 .. .. | 16·1 | 1895-96 | 17·2 | 1925-26 | 20·4 | |
| | | 1896-97 | 18·6 | 1926 | 20·3 | |
| 1865-66 .. .. | 15·0 | 1897-98 | 20·1 | 1927 | 19·4 | |
| 1866-67 .. .. | 17·2 | 1898-99 | 17·4 | 1928 | 18·4 | |
| 1867-68 .. .. | 15·4 | 1899-00 | 17·2 | 1929 | 21·6 | average 20·2 |
| 1868-69 .. .. | 16·1 | | | | | |
| 1869-70 .. .. | 15·4 | 1900-01 | 18·4 | 1930 | 22·0 | |
| | | 1901-02 | 18·0 | 1931 | 18·5 | |
| 1870-71 .. .. | 16·3 | 1902-03 | 14·7 | 1931-32 | 21·1 | |
| 1871-72 .. .. | 16·5 | 1903-04 | 18·2 | | | |
| 1872-73 .. .. | 17·1 | 1904-05 | 16·9 | 1932-33 | 22·9 | |
| 1873-74 .. .. | 15·6 | | | 1933-34 | 21·2 | |
| 1874-75 .. .. | 18·2 | 1905-06 | 17·9 | 1934-35 | 21·4 | |
| | | 1906-07 | 19·8 | | | |
| 1875-76 .. .. | 16·3 | 1907-08 | 16·8 | 1935-36 | 19·3 | average 20·2 |
| 1876-77 .. .. | 17·9 | 1908-09 | 21·6 | 1936-37 | 18·8 | |
| 1877-78 .. .. | 14·3 | 1909-10 | 20·3 | 1937-38 | 20·2 | |
| 1878-79 .. .. | 19·1 | | | 1938-39 | 19·2 | |
| 1879-80 .. .. | 18·1 | 1910-11 | 20·0 | 1939-40 | 18·8 | |
| | | 1911-12 | 19·4 | | | |
| 1880-81 .. .. | 16·2 | 1912-13 | 20·1 | | | |
| 1881-82 .. .. | 16·6 | 1913-14 | 18·8 | | | |
| 1882-83 .. .. | 19·1 | 1914-15 | 21·8 | | | |
| 1883-84 .. .. | 16·4 | | | | | |
| 1884-85 .. .. | 17·8 | 1915-16 | 18·3 | | | |
| | | 1916-17 | 20·4 | | | |
| 1885-86 .. .. | 18·9 | 1917-18 | 21·5 | | | |
| 1886-87 .. .. | 19·3 | 1918-19 | 18·0 | | | |
| 1887-88 .. .. | 17·9 | 1919-20 | 21·1 | | | |
| 1888-89 .. .. | 16·8 | | | | | |
| 1889-90 .. .. | 19·1 | 1920-21 | 19·8 | | | |
| | | 1921-22 | 19·9 | | | |
| 1890-91 .. .. | 18·1 | 1922-23 | 20·0 | | | |
| 1891-92 .. .. | 18·8 | 1923-24 | 19·5 | | | |
| 1892-93 .. .. | 19·3 | 1924-25 | 22·4 | | | |
| 1893-94 .. .. | 19·5 | | | | | |
| 1894-95 .. .. | 21·7 | | | | | |

*From 1864-65 to 1925-26, the year is the 'financial' year. From 1926-1931, the Calendar year was taken. From 1931-32 onwards the seasonal year, beginning in October, has been adopted.

*Average of 50 highest days—Bukkur.*—The I. R. C. records also furnish a graph of the average of the 50 highest days of Bukkur from 1848-49. This gauge is, however, now in the barrage pond, and its trend is, therefore, not of special value.

In speaking of this gauge Punjab say, on page 154 of their Vol. III, " * * * * But for this factor, the Bukkur gauge would undoubtedly have shown a small rise in the period 1886 to 1942." Such a surmise cannot now be verified.

*Average gauges and average discharges—1st June to 30th September—Kotri.*—The average gauge at Kotri from 1st June to 30th September for the period 1901 to 1941 is given at page 192 of the Punjab Defence, Chapter III, Vol. III. On the same page is given the ratio of the $\frac{\text{Average gauge 1st June to 30th September}}{\text{Discharge 1st June to 30th September}}$ from 1901. The Sind objections to this ratio are given in their "Comments on Punjab's note on Rise of Levels of the River Indus in Sind", and Sind sheet 225 (S. II 70) *vide* p. 64 *ante*.

It is this ratio for 1901-1905 and 1936-40 which the Punjab have used to arrive at the trend increase of gauge of 0·075 feet per annum over 40 years for moderating the drops on Set B and Set C calculations for Lower Sind (P. Vol. III, pp. 157 & 158).

If however the intermediate ratios are filled in for the 5 year periods between 1901-1905 to 1936-1940 there does not seem to be sufficient consistency to warrant adopting ratios of the 2 end periods as a satisfactory indication of probable future rise of bed level, under conditions that would be different after the Punjab withdrawals. This is apart from the other features of the value of the ratio as an indication of rise of bed level and homogeneity of data. The 5 years' average ratios in sequence from 1901-1905 are as follows (P. Vol. III, p. 192):

0·472, 0·474, 0·512, 0·496, 0·474, 0·578, 0·528, 0·574.

The following 10-year average figures of gauges and discharges are abstracted from the same page and from the 50-day gauges, for the Kotri gauge site:

| Years. | Average gauge 1st June to 30th September. | Average of 50 highest days. | Discharge 1st June to 30th September. |
|---|---|---|---|
| | Feet. | Feet. | Million cusec days. |
| 1902—1911 .. .. .. .. | 16·6 | 18·6 | 351 |
| 1912—1921 .. .. .. .. | 17·2 | 20·0 | 350 |
| 1922—1931 .. .. .. .. | 17·7 | 20·3 | 336 |
| 1932—1941 .. .. .. .. | 17·3 | 20·2 | 310 |

## Further remarks on Homogeneity of data.

Contentions of the Punjab and Sind, in regard to the periods that should be taken for trends, with respect to the homogeneity of data in the periods, will now be examined. This has special pertinence when making deductions from simple gauges. Some of the remarks below in regard to homogeneity of data were given

under the specific gauge discharge examination and are repeated to co-relate them with the examination of simple gauges.

The only two gauges in Sind, in the vicinity of which discharges have been measured over a long period, are Bukkur and Kotri and the former is now merged in the Lloyd Barrage pond. The Punjab are of the opinion that the long term records of Kotri should be examined for trend, whilst Sind claim that only the data from 1910 is homogeneous. The Punjab graph $\frac{20}{1}$, taken from the I. R. C. records, starts from 1864-65. Whilst remarks are furnished below on the evidence given for homogeneity, it may be repeated that the long term trend has got but little value so far as the present case is concerned, if the data does not show continuance of the long term trend in recent years.

*Dates of construction of bunds in Sind.*—Sind have replied to the claim of the Punjab, that the construction of bund lines has been continuous up to date and does not affect the homogeneity of the data, in their Appendix to " Sind Comments on Punjab's Note on Rise of Levels of the River Indus in Sind" (S. II 74). From this note, it is seen that the main construction of river bunds, restraining largely the flood spill was completed about 1910. For the reasons mentioned earlier in this report, it would not be possible to ascribe either accretion or scouring permanent effects to this cause within the period under examination. Whatever may be the effects, however, it seems evident that flood spill was much curtailed by 1910.

*Frequency of Discharge observations.*—It is stated in the same Sind note, that it was only after 1911 that regular bi-weekly observations of discharge were made at Sukkur and Kotri. From statement I, which accompanies the note, it is seen, that, so far as Kotri is concerned, June to September discharge observations have been fairly frequent (except for 1907) from 1902.

*Method of gauging.*—From 1901 meters were used for discharge observations at both Sukkur and Kotri, but cable suspension was used for the meters up to 1924 and Sind claims this also calls for a correction, when used with later observations, to get homogeneity of discharges.

*Gauging site at Kotri.*—The present permanent discharge measurement site came into operation in 1910. Prior to that date measurements were made at various sites.

*Construction of Kotri Bridge.*—The Kotri bridge was constructed in 1898. The drop in gauge for 1902, which was a year of low discharge, is much more marked at Kotri—relative to the immediately preceding and succeeding years—than at Bukkur, as seen from the

50 highest gauge days given in the I. R. C. records for both years. It is not possible to say to what extent this was influenced by the bridge construction at Kotri.

KOTRI—SIMPLE GAUGES—MAY TO OCTOBER.

In Sind graphs K7, Exhibits 11-12, the river levels at Kotri can be superimposed in groups of years, 1921 to 1925, 1926 to 1930, 1931 to 1935 and 1936 to 1940 with one graph for 1941.

If these tracings are superimposed one over the other, the following conditions are observed :—

1931—35—superimposed on 1921—25.—marked reduction in river level in May, June, September and October for the later years.

—superimposed on 1926—30.—Same as above, but not so marked in September and October.

1936—40—superimposed on 1921—25.—The latter years are better in May and June but worse in September and October.

—superimposed on 1926—30.—The latter years are better in May to July and worse in September and October.

1941—This year was on the average better in May, June and July with reduced levels in September and October.

Superimposing these graphs shows the reductions in river levels at Kotri, post barrage, over Pre-Barrage in September and October for the year groups examined, but no conclusions can be drawn from them in regard to accretion of bed levels. Reference may be made to page 72 of this Report to illustrate the heavy drop in discharges at Kotri in September.

SARHAD—SIMPLE GAUGES—MAY TO OCTOBER.

Two gauge groups, similar to the Kotri gauge groups dealt with above, are available for Sarhad for the years 1931 to 1935 and 1936 to 1940. When the latter group is superimposed on the earlier group, there is indication of higher river level at Sarhad in June for the later years, but lower levels in October. No inference in regard to accretion of bed levels can be seen from the graphs.

EVIDENCE OF GAUGE DISCHARGE CURVES FOR KOTRI AND SARHAD—YEARS 1932—40.

*Gauge Discharge Curves, Kotri and Sarhad.*—Speaking of the rise in bed, the Punjab state in their Chapter V,

" That this has actually been taking place, is shown in a general way by the gauge discharge curves for Kotri (Punjab

Chart 26) and those for Sarhad (Punjab Chart 27). (P. Vol. III, page 285). The curves for the earlier years lie at the bottom of the band while 1940 lies towards the top."

An inspection of the graphs will show that there is such a variability in the curves for rising and falling stages at different discharges that it would be difficult to draw any conclusions from them, such as implied by the Punjab statement, *e.g.*, in chart 26, the 1933 falling curve is near the top of the band, from 1½ lakhs discharge and not the bottom. When 1941 is added to the curves, the value of the claim is further reduced.

The evidence for accretion of the plotting of the 1939 gauge hydrograph over that of 1932 is also claimed by the Punjab,—1939 is above 1932 for most of the curve. (P. Vol. III, p. 285.) The reply of Sind in their "Comments on (Punjab) Chap. V" is, however, that the gauge hydrograph is merely a reflection of the discharge hydrograph, except for the peak period. (S. II 40.) The higher peak of 1939 is ascribed to less scour in 1939.

The evidence of only 2 particular years' curves in hydrographs of this kind is not very determinative, however.

EFFECT OF PAST WITHDRAWALS OF PUNJAB AND STATES ON RIVER LEVELS OBTAINED IN SIND OVER A LONG TERM OF YEARS.

*Effect of past withdrawals on river levels.*—The Punjab have put forward in their Chapter II, Vol. III, their views on the indications of rise of bed levels in Sind as shown by the effect of past withdrawals in the Punjab and States on river levels in Sind.

1. *Past Apprehensions.*—Reference is made to opinions expressed by officers in the past, that the Punjab withdrawals have had no harmful effect on Sind (P. Vol. III, pp. 35, 41 to 43 and 59 to 65). Punjab also point out an instance of "alarmist representation" by Sind in 1925 in regard to the contemplated effect of the Sutlej Valley withdrawals on the Sukkur rabi discharges, of 1914—21, and the much smaller shortages actually experienced in 1929—34.

2. *Extent of withdrawals upstream of Sind.*—The kharif withdrawals have increased from—

9,449 cusecs in 1867—71, to 86,558 cusecs in 1936—41.

*or*

55,670 cusecs in 1911—12, to 86,558 cusecs in 1936—41.

*or*

70,953 cusecs in 1921—22, to 86,558 cusecs in 1936—41. (P. Vol. III, p. 36.)

Punjab have, also, made certain calculations of increase of withdrawals in Sind (P. Vol. III, pp. 36 & 37). Sind have disputed the accuracy of these figures in their "Notes on Punjab Defence Vol. III, Chap. II" and state that Sind, as a whole, has not drawn more water, at any rate, since 1900 (S. II 10). They also state that September discharges have shown a steady decline since 1926 in spite of the fact that Ghotki Floods have been reduced and in spite of the Punjab weirs having reduced the peak discharges of the inundation canals. Sind also refer to their graphs serial No. 31 and $\frac{31}{1}$, to show the deterioration of September gauges.

Having pointed out these extra upstream withdrawals and at the same time the fact that Sind withdrawals as a whole have not decreased, Punjab state that it is thereby proved that Punjab extractions have had no harmful effects on Sind (P. Vol. III, p. 37).

Whether, if the claim is accurate, the same effect will continue will be examined in other parts of the Report. Sind have frequently stated that their inundation canals are now on the verge of failure and that they can stand no more withdrawals.

The Punjab again refer to the graphs of the 50 highest daily gauges as being indices of the working of the Inundation Canals. (These have been dealt with elsewhere in this Report.) The Sind reply to this is, that the 50 highest days does not give any index of the maturing period in September,—(on which they have presented evidence under probable effects of Punjab withdrawals).

The working of the inundation canals is then dealt with on the basis of Punjab charts $\frac{19}{1}$, to $\frac{19}{22}$ (P. Vol. III, pp. 38-40). These charts are somewhat difficult to read, as the 3 ten daily gauges of the month for one year, are made continuous with those of the next year, thus making trends for short lengths difficult to see superficially.

Punjab purport to show by this analysis. (P. Vol. III, p. 40) :

(1) The less efficient working of the Lower Sind inundation canals, due to the Sukkur Barrage.

(2) The necessity to examine the working of the canals over a long period.

(3) That some of the defects of working are due to administrative acts of Sind, and

(4) Increased withdrawals in the upstream part of the river have had no material deteriorating effect on the Sind Inundation Canals.

*Comments on Punjab analysis.*—Inundation canals are subject to many disabilities in working that are inherent in their nature, as they depend largely for their successful working on the set of the river. The ability of the local officers to forecast probable changes in the river course and make timely changes in the approach channel is an important factor. In order to be able to interpret charts such as Punjab $\frac{19}{1}$ to $\frac{19}{22}$, it is necessary to know the full history of each canal during each of the months examined, if it is intended to read into the canal graphs, effects due to river changes. The changes in upstream and downstream gauges may be due to many factors, such as alterations in the location of the approach channel—seasonal shoaling—execution of canal control works—changes in cutoff due to feeding branch channels, rain effects, etc. It is not possible to separate out the extent of the deleterious effects of the Lloyd Barrage on the Lower Sind Canals. Post Barrage, the barrage canals have only drawn more than the replaced inundation canals—in the month of September, during the last 10 days of September. (P. Vol. III, p. 49).

The Punjab also refer to the increase in the Fuleli canal discharges of Lower Sind, but Sind point out, that this is due to the fact that the canal was widened to take greater discharges, and its full supply level was not raised.

Whether above or below the barrage, September discharges have, in general, been less post barrage—*e.g.*, the average discharges are compared below for a few canals.

| Canal. | Average Discharge—cusecs. | |
|---|---|---|
| | 1923-31. | 1932-40. |
| **Upper Sind.** | | |
| Begari .. .. .. .. | 4,388 | 3,675 |
| Desert .. .. .. .. | 2,226 | 1,364 |
| **Lower Sind.** | | |
| Fuleli .. .. .. .. .. | 6,575 | 5,532 |
| Pinyari .. .. .. .. .. | 2,363 | 1,539 |

This may be partly due to the fact, that, after the flood year 1933, the average river inflow in August and September was less from 1934—40 than for the decade pre barrage. (P. Vol. I, App. IV.)

The fall in river discharges in Sind, in recent years is shown in Appendix 13-D (pp. 196-197, P. D. III), for the months of June to September from 1901 to 1941, at Kotri.

The following table in lacs of cusecs, indicates the large drop in recent years (in the month of September).

TABLE A.

| Years. | June. | July. | August. | September. |
|---|---|---|---|---|
| 1901-1910 .. .. | 21·25 | 27·85 | 36·79 | 27·93 |
| 1911-1920 .. .. | 22·4 | 29·53 | 37·82 | 24·59 |
| 1921-1930 .. .. | 17·98 | 27·75 | 38·07 | 28·11 |
| 1931-1940 .. .. | 18·56 | 27·49 | 36·87 | 20·08 |

It is also a fact that some of the inundation canal recent adverse September gauges, are seen to have existed even in early years, as *e.g.*, Unhar September Graphs.

Finally, it may be stated with reference to these Punjab graphs, that it is not possible to read from them, what effect the past Punjab withdrawals have had on the Indus river levels in Sind and therefrom the change in working of the inundation canals.

*History of discharges received by the inundation canals.*—The Punjab point out that a study of the working of the inundation canals based on discharges is handicapped by the fact that long term records of discharges are not available. They then proceed to deduce figures to show that for the 10 years pre and post barrage,—

Group A.—*i.e.*, Upper Sind inundation canals, got a small increase post barrage for the average of the whole kharif season, but a small decrease in September, whilst.

Group C.—*i.e.*, Lower Sind canals got a large decrease in September and a small decrease over the whole season.

Sind contend in their "Notes on Punjab Defence Vol. III, Chap. II," that the Punjab have incorrectly got out the extent of inundation canals merged in the Lloyd Barrage Project and that the discharges are also incorrect. (S II 12).

This subject of effect of past withdrawals by Sind is dealt with also, in the next Chapter of this Report.

EFFECTS OF HIGH FLOODS AND CHANGE IN LENGTH OF RIVER COURSE.

*Sind sheet 166.*—Sind have contended that a high flood is always liable to wipe out a rise in bed and hence possible bed rise cannot be accepted as a cure for Punjab withdrawals. They also point to the similar effects, occasioned by changes in length of the river course, due to cutting off of bends by flood conditions.

In regard to the effect of high floods, no generalization can be made in regard to the probable permanent effect on a rise in bed. The Punjab have, during the Proceedings, shown from the I. R. C. records, that, the scour, occasioned at Kotri by the 1933 September flood, was more than restored by the end of that month. On the contrary, a number of the Specific gauge discharge graphs show a drop in gauge after the 1933 floods, lending support for these particular sites, in that year, to the Sind contention. The Lloyd Barrage construction was completed in 1932, bringing in another moderating factor. The 1933 drop effect is seen in the graphs for Machka —(but not Sarhad)—Bachalshah and Kotri.

EFFECTS ON THE RIVER BED LEVELS DUE TO REDUCTION OF RIVER DISCHARGES CONSEQUENT ON PUNJAB WITHDRAWALS ON ANALOGY OF CANALS.

The Punjab have referred to the co-relation found by Mr. G. Lacey with respect to canals; that, when, regime conditions are attained the slope of the canal is an inverse function of discharge. (P. Vol. III, p. 158.) The Punjab conclude, that there will be instantaneous rises, as and when the Punjab withdrawals take place, owing to the reduction of the scouring effect of the floods and to the river taking up a steeper slope to suit the average reduced discharges, consequent on Punjab additional withdrawals.

The Sind reply to this conclusion is—

(*a*) It is doubtful if the above mentioned co-relation got out for canal regime, was intended to apply to rivers;

(*b*) River slopes flatten from the source to the mouth and there is little reason to believe the Punjab withdrawals would alter the condition;

and

(*c*) Sind experience is, that erosion is most active on rising and falling stages and reduces when the Katchas are flooded. As it will take longer to flood the Katchas after the withdrawals, the period of active erosion will be longer. (S. II 25.)

No evidence was produced that even for canals, a small change in volume produced the bed changes claimed.

The following opinion was given by Messrs. Nicholson and Trench in their 1930 report in regard to the effect of varying discharge of the river. (Some extracts from their opinions on the probable effects of the barrage are given in preceding paras. of this Report.)

> "* * * * * An increase or reduction in discharge is, therefore, accompanied at Sukkur by a regime alteration tending to obscure the resulting effect on the water levels; while at Kotri the change of regime levels accentuated the alteration in actual levels. (P. 5, N. T. Report.) Which of these results occur at any site depends on the special conditions at the site in question,"

and again Mr. Trench's opinion,—

> "Subsequent to the opening of the Barrage canals there will be less water passing Kotri in the rabi season and therefore, less energy available for the transport of silt, which arrived in the flood season * * * *. These conditions would tend to cause a rise of regime levels throughout the year at Kotri * * *."

The varying effect of the high flood of 1933 at Kotri,—compared with some other sites,—on the river bed conditions, has been referred to in the previous heading dealing with "Effects of High Floods". It seems reasonable to expect that the steepening of the river bed with reduction of discharge, may parallel to some degree the condition that is claimed to exist in canals. It is not possible, however, to predict whether this may be evident in certain months with more attendant scour in other months, (*vide, e.g.*, the gain in August and September, with drop in October associated with decreasing discharges at Bukkur, page 116, Nicholson Trench Report, or whether and to what extent, a permanent regime rise of bed levels may set in to offset the drops calculated to result from the withdrawals.

### Final conclusions on accretion of levels of river bed in Sind.

From the foregoing examination of the evidence put forward on this subject the following conclusions are arrived at:—

1. There is no definite evidence that the general rise of river bed levels expected in the Nicholson Trench Report has occurred in the time and to the extent defined, in that report.

2. The fact that there are no significant linear rising trends shown in the graphs dealt with either for Upper or Lower Sind, except for 1 lakh discharge at Kotri (and Unhar 1 lakh falling stage at 5% level); (S. II 40)—whilst there are significant falling trends at certain discharges for Begari, Unharwah, Bhago Toro, 1923—41 (non-significant for 1931—41) and Kalri—does not support the permissibility of taking a definite annual amount of rise in either Upper or Lower Sind, which can be used to moderate the computed effects of probable drops, due to Punjab withdrawals. This does not, of course, mean that such rises in bed level will not take place, but simply, that from the evidence produced, no assessment of the effect can be rationally applied to the calculated probable drops.

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## IV.—EFFECTS OF CONTEMPLATED PUNJAB WITHDRAWALS ON THE SIND INUNDATION CANALS.

While investigating the probable effects of the contemplated Punjab withdrawals on the Sind Inundation Canals, it is necessary to recall :—

*Considerations in interpreting the results presented by Sind and Punjab.—*

1. No programme for execution of the Punjab projects exists. This programme will, presumably, depend largely on the course of the war.

2. The presentation of the Sind Case is, to show the ultimate effect on Sind, if and when all the contemplated withdrawals defined in the Punjab Defence, Vol. I, become effective. This may not be for 40 years or more.

3. The great difficulty of predicting the quantitative and river water level effects of upstream withdrawals on Sind, has been explained in this report. We have no confidence that either "Set A" or "Set C" calculations, express closely the probable diminution of levels and discharges in Sind, for the reasons given in this Report, under loss, gain, time lag, translating effects, etc.

So far as we have been able to weigh up the results, the Sind "Set A" calculations over-emphasize the probable effects on Sind, whilst the Punjab "Set C" calculations under-estimate the probable effects. ("Set B" does not warrant separate consideration). The behaviour of the river is too inadequately under-

stood, at the present time, to permit any close estimate of the probable results.

*Uncertain factors in the problem :—*

(*a*) Rain in the several different river catchments, all of which have different characteristics.

(*b*) Melting snow, as influenced by the climatic changes.

(*c*) Rain in the irrigated areas, reducing irrigation demands and with effects on the subsoil water.

(*d*) Inadequate information on slopes of subsoil water flow throughout the season, with its contribution to river flow on the falling river.

(*e*) Insufficient surveys to properly assess the river storage in different reaches and at specified levels.

(*f*) Inadequate information on the influences governing, losses, gains and time lag, throughout the different reaches and throughout the year, errors in taking discharge measurements in the past both for withdrawals and for river flow, effect on past river gauges of set, changing course, etc.

It will be evident from the above that it may be some time before knowledge will be available, to allow for all contributing factors, in a manner to predict effects with confidence, in the Indus.

Sind have furnished a large number of notes on the probable effects on Sind from the contemplated Punjab withdrawals, from different aspects. As the notes are based on the Sind calculations, it is unnecessary to deal with them in particular detail.

*Examination of effects of past Punjab withdrawals on Sind, for evidence in support of predictions.*—Before dealing with the predicted effects of Punjab withdrawals on the Sind supplies, an examination will be made of the evidence which has been produced to show the effects on Sind of the past Punjab withdrawals. Certain features of these effects have been dealt with in the last Chapter. Speculations have ranged in the past, from claims that the Punjab withdrawals have been beneficial to Sind due to extra regeneration, bed changes with reduced volumes, etc., to the opposite claim, that each successive withdrawal will be disastrous to Sind. Although it is the effect on water levels, which is the most important to examine, yet the several factors contributing to river flow are themselves so variable, that it is difficult to separate out one variable, *i.e.*, the withdrawals, and to see what effect it has actually had in the past.

*Range of inflow. Range of increase of withdrawals.*—Ignoring for the moment the question of lag, and considering the inflow into the

Indus over the years 1922-23 to 1940-41 for which particulars are furnished by the Punjab (pages 69 & 70 of their Vol. I), the variation in inflow compared with the variation in withdrawals will be seen from the following figures :—

JULY—1922-23 to 1940-41.

| | Maximum Cusecs. | Minimum Cusecs. |
|---|---|---|
| Inflow .. .. .. .. .. | 735,416 | 441,591 |
| Punjab withdrawals in same period .. | 105,367 | 82,672 |

(Sind sheet 65.)

*i.e*, whilst the range in inflow in July is nearly 3 lakhs cusecs, the maximum increase in withdrawals is less than $\frac{1}{4}$ lakh cusecs for the same period.

Similarly for—

AUGUST

the range in inflow is nearly 3 lakhs cusecs and the increase in withdrawals is over 1/3 lakh cusecs.

SEPTEMBER.

The range in inflow is over $1\frac{1}{2}$ lakhs cusecs and the increase in withrawals is over 1/3 lakh cusecs.

The following figures furnish a rough idea of the order of the variation in river discharges—Kotri gauge and the Punjab withdrawals.

*Mean discharges and gauges—Kotri and Sukkur, and Punjab withdrawals.*

| Year. | 5 years' *mean* discharge—1st June to 30th September in million cusec days. | | 5 years' *mean* Kharif withdrawals by Punjab Canals. | 5 years' *mean* September Kotri Gauge. | September discharge at Sukkur. | September 5 years' *mean* of Sukkur Discharges. |
|---|---|---|---|---|---|---|
| | Kotri. | Bukkur. | Cusecs. | Feet. | Cusecs. | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1901 .. .. | 32·28 | 41·68 | 46,983 | 14·9 | 270,620 | 236,816 |
| 1902 .. .. | | | | | 179,350 | |
| 1903 .. .. | | | | | 319,530 | |
| 1904 .. .. | | | | | 161,450 | |
| 1905 .. .. | | | | | 253,130 | |
| 1906 .. .. | 37·31 | 48·05 | 49,435 | 18·3 | 356,770 | 327,198 |
| 1907 .. .. | | | | | 161,990 | |
| 1908 .. .. | | | | | 424,510 | |
| 1909 .. .. | | | | | 379,470 | |
| 1910 .. .. | | | | | 313,250 | |

| Year. | 5 years' *mean* discharge—1st June to 30th September in million cusecs days. | | 5 years' *mean* Kharif withdrawals by Punjab Canals. | 5 years' *mean* September Kotri Gauge. | September discharge at Sukkur. | September 5 years' *mean* of Sukkur Discharges. |
|---|---|---|---|---|---|---|
| | Kotri. | Bukkur. | Cusecs. | Feet. | Cusecs. | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1911 .. .. | 34·91 | 48·19 | 54,642 | 16·6 | 272,300 | 268,042 |
| 1912 .. .. | | | | | 218,790 | |
| 1913 .. .. | | | | | 235,440 | |
| 1914 .. .. | | | | | 394,150 | |
| 1915 .. .. | | | | | 219,530 | |
| 1916 .. .. | 35·34 | 43·92 | 60,582 | 17·2 | 242,010 | 254,092 |
| 1917 .. .. | | | | | 375,740 | |
| 1918 .. .. | | | | | 184,340 | |
| 1919 .. .. | | | | | 229,230 | |
| 1920 .. .. | | | | | 239,140 | |
| 1921 .. .. | 37·64 | 46·84 | 68,915 | 18·4 | 340,730 | 291,428 |
| 1922 .. .. | | | | | 341,610 | |
| 1923 .. .. | | | | | 266,740 | |
| 1924 .. .. | | | | | 314,080 | |
| 1925 .. .. | | | | | 193,940 | |
| 1926 .. .. | 30·83 | 40·02 | 71,397 | 17·9 | 360,220 | 280,494 |
| 1927 .. .. | | | | | 211,550 | |
| 1928 .. .. | | | | | 261,820 | |
| 1929 .. .. | | | | | 353,230 | |
| 1930 .. .. | | | | | 215,650 | |
| 1931 .. .. | 32·61 | 39·18 | 72,252 | 16·7 | 257,060 | 222,180 |
| 1932 .. .. | | | | | 191,550 | |
| 1933 .. .. | | | | | 319,510 | |
| 1934 .. .. | | | | | 187,380 | |
| 1935 .. .. | | | | | 155,400 | |
| 1936 .. .. | 30·47 | 37·02 | 83,869 | 15·7 | 241,480 | 196,700 |
| 1937 .. .. | | | | | 200,750 | |
| 1938 .. .. | | | | | 185,060 | |
| 1939 .. .. | | | | | 227,960 | |
| 1940 .. .. | | | | | 128,250 | |
| 1941 .. .. | 24·92 | .. | 81,552 | .. | 169,670 | .. |

*N. B.*—

(*i*) Cols. 2 and 3 are deduced from Punjab Defence Vol. III, pages 192—193.

(*ii*) Cols. 4, 6 and 7 are taken from Sind Sheet No. 65.

(*iii*) Col. 5 is deduced from Punjab Defence, Vol. III, page 196.

(*iv*) Bukkur gauge is in Sukkur pond since 1932 and hence not given.

(*v*) Col. 6 above does not agree with Punjab discharges for Sept. given on page 199 of Punjab Vol. III.

(*vi*) To get 5 years' average daily discharge in Cols. 2 & 3 to compare relative proportion with Col. 4 divided by 122.

*Sind evidence on effects of past withdrawals.*—Evidence regarding the effects of the past Punjab withdrawals is contained in the Sind note on " Punjab withdrawals and their effects on Sukkur discharges and Sind inundation canals up to date " (Sind sheets 59—68). The arguments regarding the adverse effects are :

(1) Analysis for the month of September is made regarding reduction of Sukkur discharges with steady increase of Punjab withdrawals (Sind sheet 60). This is similar to the analysis referred to previously in this Report under " gains " and indicates an effect greater than unity on Sind in September, of Punjab withdrawals.

(2) Sind plans K 7—are then referred to, to show that the river has fallen more rapidly in September and October of recent years. Remarks on this series of plans are given previously in this Report under " Accretion " (simple gauges).

Sind have contended in their analysis that the period from 1926 should be studied to see the adverse effects of the sudden increase of Punjab withdrawals by the Sutlej Valley Project (Sind sheet 60) and examination prior to 1926 would be incorrect, due to lack of homogeneity of data, etc. Punjab have replied that the reason for the Sind preference for 1926 is, that it is the 4th highest September Sukkur discharge (P. Vol. III-A, page 44). (Sind sheet 65).

Further, by reference to the statements of mean monthly Punjab withdrawals (Sind sheet 65), it will be seen that no proper reason has been adduced by Sind to warrant the beginning of their analysis from 1926 and making deductions therefrom, as to special effects of the Sutlej Valley Project. The Punjab have further pointed out the fallacy of the Sind arguments on the Sutlej Valley Project effects in their table on page 43, Punjab Defence Vol. III-A, which shows no extra water was taken by the Sutlej Valley Project till 1928 in June, till 1937 in July, till 1934 in August and till 1929 in September.

Sind have submitted a note on the " Net percentage returns on various inundation canals in Sind ", (Sind sheet 79), where, again, it is claimed that deterioration in returns from the canals started from 1926, which claim is not supported either by the figures of dates of Sutlej Valley Project withdrawals just cited, nor by appendix D to the " Note on Canal Irrigation in Sind ".

*Variability of data, Sukkur discharges measured pre and post 1926.* Another indication of the variability of the data and difficulty of interpreting it, is seen from para. 8·2, Sind sheet 61. A statistical analysis was made of the September Sukkur discharges for a 15 year period prior to 1926, as well as an equal period subsequent thereto. Sukkur discharges showed, for the earlier period, a non-

significant rise,—for the latter period, Sind's analysis gives a drop of 9,191 cusecs per year, significant at 0·1 % (Sind sheet 61).

By reference to Sind sheet 65, it will be seen there was increase of Punjab withdrawals throughout both periods. Had different beginning and ending years been taken for the analysis, quite different results would again have been shown.

*Sind analysis Kotri gauge pre and post 1926.*—A similar result was found by Sind from analysis of the Kotri gauge. The month of September from 1901—26 shows a rise of gauge of 0·12 ft. per year, significant at 5 %, whilst the period 1926—41 shows a fall of 0·25 ft. per year, significant at 5% (Sind sheet 61).

(3) *Remissions.*—Increase in remissions in Upper Sind from 1930 has been referred to, as evidence of the effects of worse river conditions.

From the Sind remarks in the last session of the Simla proceedings, the unreliability of the Sind remission figures, as a measure of inadequacy of water supply will be seen (Sind sheets 61 and 66). (The remissions, in the flood year 1933 were the maxima for two out of the 4 canals given by Sind on their sheet 66 and nearly the maxima for the other 2.)

(4) *Sarhad gauge.*—Sarhad gauge was analysed by Sind for the month of September for the period of 1930—41, but it is stated that the annual fall shown is non-significant (Sind sheet 61).

(5) *Canal graphs, relative discharges of Canals covered by Lloyd Barrage, pre-barrage, and drops in discharge Lower Sind.*—Reference is then made to certain canal graphs, but apart from some deterioration in September, there is not direct evidence which might be interpreted as effect of Punjab withdrawals. Figures are quoted to show that the August withdrawals of the canals covered by the Lloyd Barrage have been less post-barrage than the replaced inundation canals pre-barrage, while the excess drawn in September is only petty, (668 cusecs) and hence the September deterioration in the Lower Sind canals is not due to that cause.

The conclusion is then drawn, that since the Indus inflow affecting Sind in September, has been more post-barrage than the same period pre-barrage, the adverse effect is due to Punjab withdrawals. The extent of the drop in discharge for the pre and post barrage periods is then shown from the discharges of the Lower Sind canals as below: (Sind Sheet 64 para. 13·4, P. D. Vol. III pp. 108 and 119.)

| | August. | September. |
|---|---|---|
| 1922-23 to 1931-32 .. .. .. | 27,374 | 20,221 |
| 1932-33 to 1940-41 .. .. .. | 25,622 | 11,576 |

Sind have also furnished in connection with remarks on discharges to which their inundation canals are entitled, the following particulars of average discharges drawn in 1921—30 and 1931—40, for the 45 highest days of the year.

*Comparative statement showing discharges of Sind inundation canals as actually withdrawn (Average of 45 highest days in each year for which data are available).*

| Canals in— | Average Discharge obtained during 45 days. | |
|---|---|---|
| | 1921 to 1930. | 1931 to 1940. |
| | Average of 9 years. | Average of 10 years. |
| Upper Sind .. .. .. .. .. .. | 37,183 | 37,039 |
| Lower Sind .. .. .. .. .. .. | 35,428 | 31,261 |

(Sind sheet 57.)

(1) Daily discharge data of canals are only available from 1922; hence it is not possible to show similar figures for the previous decade 1911—20.

(2) The small difference in the 2 periods in Upper Sind will be seen from the above statement—*i.e.*, for the period of high flood discharge—

*Upper Sind—September discharges*—P. D. III, pp. 66 and 77.

| | Cusecs. |
|---|---|
| Pre-barrage period—1922—31 .. .. .. | 11,365 |
| Post-barrage period—1932—41 .. .. .. | 10,199 |

Sind appears to have accepted these figures for Upper Sind, which show a drop in discharge of Upper Sind Canals of about 10%—*vide* para. 13·0 Sind Sheet 64. The drop in discharge for particular canals, *vide* page 71 *ante* would indicate the fall in September discharges in Upper Sind was greater than 10%.

Sind also claim to have analysed the Sukkur June discharges for 1926—41 (Sind sheets 67 & 68), and weighed them with the inflow and Punjab withdrawals and found that the results prove the effects of diminution of Sukkur discharges by increasing Punjab withdrawals. In a supplementary note on the effects of the Punjab withdrawals in June, on the discharge arriving in Sind, they have added

in another factor, *i.e.*, Sind withdrawals. They claim that the analysis shows that for the same inflow, the discharge arriving in Sind decreases by 1·48 times the increase in Punjab withdrawals, and that the equation obtained is significant.

*Remarks on Sind evidence of past withdrawals.*—Finally with respect to this Sind Note, it may be said that it adduces but little direct evidence of effect of Punjab withdrawals in the past, on levels in Sind. The adverse conditions in September in the Sind inundation canals (especially Lower Sind) are consistent with the evidence of reduced discharges at Sukkur and Kotri.

*Punjab's arguments regarding ratio of Punjab withdrawals to Sukkur discharges.*—The Punjab have given the inflows of the Indus and also Sutlej-*cum*-Beas in order of magnitude for the months of June to September for the period 1922—41 in their Chapter II-A (P. D. Vol. III-A, pages 33 & 34). The Punjab have, also, in this same Chapter II-A, outlined an argument to show that there is no proof that upstream withdrawals in September have a larger effect on Sukkur discharges than their quantitative amount. (P. D. Vol. III-A, page 42). Sind have replied to the arguments in their "Comments on the effect of Punjab withdrawals on supplies to the Sind Inundation Canals, Punjab Note 2 A." (*vide* also Sind Sheet 60 and page 28 *ante*) (S. II 62).

On page 144 of their Vol. III, Punjab have worked out a ratio of decrease at Sukkur to Punjab withdrawals for September of 1·31.

The Punjab in their same note 2-A then proceed to evaluate, in, however, an unconvincing manner, the effect that reduction in rainfall has made and claim that the Punjab withdrawals have had only a modified effect in reducing the Sukkur discharges and no effect on the levels at which these discharges are received. The average withdrawals of the last 40 years are then compared with the proposed withdrawals as follows:

*Increase in withdrawals in 1,000 cusecs.*

| Month. | Set A. | Set C. | 1901-1940. |
|---|---|---|---|
| June .. .. .. .. | 23·2 | 23·5 | 43·4 |
| July .. .. .. .. | 86·6 | 86·6 | 38·1 |
| August .. .. .. .. | 77·3 | 55·8 | 37·0 |
| September .. .. .. | 26·0 | 18·9 | 51·4 |

(P. D. Vol. III-A, page 46.)

To show the effect on the Sukkur discharges of the last 40 years withdrawals the average discharges at Sukkur are compared for the years 1901—05 with those of 1936—40. This shows a larger discharge

in all months except August and September in the latter period—in spite of Punjab withdrawals—

| | | Cusecs. |
|---|---|---|
| Average Sukkur discharge—1901—05—August | .. | 376,440 |
| Average Sukkur discharge—1936—40—August | .. | 373,160 |
| Average Sukkur discharge—1901—05—September | .. | 239,160 |
| Average Sukkur discharge—1936—40—September | .. | 196,700 |

It is, however, to be observed that the discharges of this period, 1901-05, were the lowest 5 year set in the 25 years starting from 1901, and hence may not be representative, in showing the little effect of the Punjab withdrawals, [*vide* the tabular statement on the " Mean Discharges and gauges, Kotri and Sukkur ", furnished under the same subject, pages 77-78 *ante.*]

## REDUCTION OF GAUGES AND CUTOFFS IN RECENT YEARS —TO SHOW EFFECT OF PAST PUNJAB WITHDRAWALS.

It would be thought that information could be obtained of the effect of the increasing Punjab withdrawals on Sind by studying the reductions—if any—in the inundation canals cutoffs for years of like inflow. Sind have furnished a note on the subject but unfortunately little information is available (Sind sheet 70). The only canal in Upper Sind that is available for study is Unharwah. The head sluices of Begari and Desert Canals are headed up to supply branch canals, and there are no other Upper Sind Canals, that have had head sluices for a lengthy period.

In Lower Sind, Fuleli and Hassanali are selected and a few cases worked out for years of similar inflow to show reduced gauge and less cutoff in August or September in the later years. The periods are, however, short and the examples too few to make any deductions from them, that they are the direct result of extra Punjab withdrawals (*e.g.*, for Unharwah, September, one case is given for 1929-30 with average cutoff of 1·6 and in 1932-33 average cutoff is 0·1).

Sind have also submitted a note showing, " The effects on the Lower Sind Canals and the causes thereof " (Sind sheet 74). This note furnishes data to show that the Lower Sind Canals, including Fuleli, got more supply in the months of May and June, post-barrage 1932—41, than they did in 1922—31, but they got less supply in July, August and September. (Figures for August and September are given on page 80 in this Report). Figures of discharges are furnished for 1922—31 and 1932—41 for the canals above Fuleli, to show that these canals drew less post-barrage, so it is claimed that the reduction in supply in the Lower Sind Canals is not due to the Lloyd Barrage.

Statements accompanying the note show a reduction in cutoff for Fuleli and Hassanali head regulators in September, post-barrage. Some of the reasons furnished by Sind to explain why the upstream gauges of the Lower Sind Canals show a greater drop than Upper Sind Canals are (Sind sheet 75);

(*a*) Upper Sind Canals in general had longer approach channels than the Lower Sind Canals.

(*b*) Upper Sind Canals have had large "cutoffs" even in September, which they have been able to draw on, but there is no available balance left.

*N. B.*—Cases cited in proof are few, as noted previously.

(*c*) Flood of 1933 caused some bed scour and lowering of river levels in Lower Sind on account of Baran River floods.

(*d*) Short circuiting of big river bends causing steepening of hydraulic gradient and bed scour.

It is then attempted to show that the drops due to (*c*) and (*d*) are small as compared with (*a*) and (*b*) and Punjab withdrawals.

*Conclusion.*—To conclude the examination of effects on Sind of past Punjab withdrawals, it may be said that it is difficult to determine the adverse effect from the evidence, for July and August. This is due to the large range in inflows in July and August compared with the small range of increase in Punjab withdrawals in those months. The less favourable conditions in September, especially in the later years, is partly due to the increasing Punjab withdrawals. The effect greater than unity, on the Sind discharges of the Punjab withdrawals is unproved, as the very large drop in September in recent years in Sind must be largely due to other causes.

## EFFECTS OF CONTEMPLATED PUNJAB WITHDRAWALS EXAMINED BY PERIODS.

### (1) September supplies.

*Sind emphasizes necessity of September supplies.*—In the rabi case, Sind laid emphasis on the vital importance of March supplies for the rabi crop. Sind, in a similar manner, for the kharif case emphasise the necessity of good supplies in September for the inundation canals and stress their inability to stand further drops in levels and discharges for that month. It has been shown in this Report that there is already deterioration in the September supplies of recent years, especially in Lower Sind. An indication of this may be seen from the following statement of gauges got out from a Sind Exhibit, for which knowledge of history of the canal heads is necessary to interpret the figures properly.

## SEPTEMBER.

SIND'S EXHIBIT SHOWING UPSTREAM MEAN GAUGE READINGS OF SIND INUNDATION CANALS FOR THE WHOLE MONTH OF SEPTEMBER *and last ten days* OF SEPTEMBER.

(In the last decade river inflow in September was about 21,000 cusecs lower than in the previous decade.)

*N.B.*—Sukkur Barrage opened on the 16th December 1931.

| Period covered by Sind Statement | Name of Inundation Canal. | No. of years covered by the Statement. | Mean for the whole month of September for the | | Mean for the last 10 days for September for | |
|---|---|---|---|---|---|---|
| | | | Period in Col. (1). | Period Post Barrage, *i.e.*, 9 years 1932-40. | Period in Col. (1). | Period Post Barrage, *i.e.*, 9 years 1932—40. |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| | *Upper Sind.* | | | | | |
| 1922—1940.. | Begari .. | 19 | 10·2 | 10·1 | 7·7 | 7·7 |
| 1896—1940.. | Unharwah .. | 45 | 7·2 | 7·3 | 5·5 | 5·4 |
| 1922—1940.. | Mirpur Dhand .. | 19 | 3·7 | 2·0 | 1·6 | 0·4 |
| 1922—1940.. | Desert .. | 19 | 4·5 | 4·4 | 2·7 | 2·7 |
| 1924—1940.. | Gudu Dhand .. | 17 | 6·2 | 5·9 | 4·5 | 4·2 |
| 1914—1940.. | Sind .. .. | 27 | 9·9 | 11·1 | 7·7 | 9·55 Barrage pond. |
| | *Middle Sind.* | | | | | |
| 1896—1940.. | Fuleli .. .. | 45 | 15·2 | 14·3 | 12·6 | 11·4 |
| | *Lower Sind.* | | | | | |
| 1915—1940.. | Pinyari .. | 26 | 12·7 | 10·3 | 9·26 | 6·7 |
| 1916—1940.. | Sattah .. | 25 | 7·3 | 4·3 | 4·5 | 1·2 |
| 1927—1940.. | Baghar .. | 14 | 7·6 | 6·6 | 3·6 | 2·8 |
| 1916—1940.. | Kalri .. .. | 25 | 9·5 | 6·3 | 6·2 | 2·7 |

In their " Note on Canal Irrigation in Sind ", Sind have given a description of their practice of irrigation (Sind sheet 29). On page 18 of that note, it is stated as follows (Sind sheet 37) :

> " Generally speaking, all canals draw as much water as they can during September. It may be taken that the requirements for a good season are,—that the canals

should get full supply discharge in the beginning of the month and 40% of the full supply at the end of the month. Satisfactory supplies in September are vital to Inundation Canals in Sind."

This statement is examined for the Inundation Canals listed in Sind Exhibit No. 1, List 11, Part II. "Statement showing the discharges withdrawn by the Inundation Canals to estimate normal demands". For the "beginning" of the month the first 10 day averages are taken and for the "end" the last 10 day averages are used.

*N. B.*—The particulars abstracted from this statement may be taken as approximate.

| Canal. | Full supply discharge cusecs. | 40% of the full supply discharge cusecs. | Period. | | No. of years in the period that there was realised, | |
|---|---|---|---|---|---|---|
| | | | Years. | No. of years. | F. S. discharge in the beginning of September. | 40% of F. S. in the end of September. |
| *Upper Sind.* | | | | | | |
| Begari .. .. | 7,750 | 3,100 | 1922—40 | 19 | 0 | 5 |
| Desert .. .. | 3,964 | 1,585 | Do. | 19 | 3 | 2 |
| Unharwah .. .. | 2,200 | 880 | Do. | 19 | 6 | 7 |
| Choi Distr. .. | 850 | 340 | 1932—40 | 9 | 1 | 5 |
| Kandhkot .. .. | 600 | 240 | Do. | 9 | 0 | 0 |
| Adjo .. .. | 350 | 140 | Do. | 9 | 1 | 1 |
| Sind .. .. | 2,225 | 890 | 1922—40 | 19 | 5 | 8 Under Barrage *influence* Small deficiency only for some years. |
| Gudu Dhund .. | 2,250 | 900 | Do. | 19 | 4 | 4 |
| Miranpur Dhund .. | 1,060 | 400 | 1932—40 | 9 | 0 | 0 |
| *Lower Sind.* | | | | | | |
| Fuleli .. .. | 11,500 | 4,600 | 1922—40 | 19 | 0 | 12 |
| Hassanali .. .. | 900 | 366 | 1932—40 | 9 | 2 | 1 |
| Pinyari .. .. | 5,542 | 2,216 | 1922—40 | 19 | 0 | 0 |
| Kalri .. .. | 1,686 | 676 | Do. | 10 | 0 | 2 |
| Baghar .. .. | 5,100 | 2,040 | Do. | 19 | 9 | 7 |

It will be seen from the above examination that there have been comparatively few seasons which have satisfied the requirements of a good season as defined by Sind in the quotation given above.

Sind have presented their case for September, in their " Kharif Case, Part II " (Sind sheet 94). The percentage reductions in discharges, according to their calculations, at Sarhad and Kotri,—due to the Punjab contemplated withdrawals,—are furnished for each year 1931—41 for 10 day periods, and the drops in 5 day periods for Sarhad and Kotri. The results are given for the 6 selected years [as well as for all the 11 years] (Sind sheets 95 & 96).

*Authorized Barrage extra withdrawals omitted by mistake.*—Sind then pointed out that by oversight, they neglected to add the extra drops that would be occasioned at Kotri by providing for the difference between the authorised discharges for the Lloyd Barrage and the actuals taken. Another set of overall drops, to provide for this Kotri omission, is given (Sind sheets 96 & 97).

" *Required* " *gauges.*—Tabular statements are prepared for 4 canals of Upper Sind and 4 Canals of Lower Sind to establish what are termed " sufficient " and also " Reasonable " Sarhad and Kotri gauges (Sind sheet 98). The latter, " Reasonable " Sarhad and Kotri gauges, are then termed the " required " gauges and these are compared with the existing and after (Punjab) projects levels, for 5 day periods in September. These tabular statements do not, however, seem to give any idea of the responsibility of the Punjab projects in making the canals unworkable, even if the original calculations were correct. Sarhad gauge, table X (Sind Sheet 99), may be examined,—1933 was a flood year and for that year, the " existing " gauge was higher than the " required " for 5 out of 6, 5 day periods, but in the other five years out of the six selected years, the existing gauge was less than the " required " gauge throughout, except for 5, five day periods out of thirty. The existing conditions of the canals on this basis, are far below the " required " standard fixed and the deductions are then made, that,—after the projects, conditions will be disastrous.

*Major canals drops.*—In their Table XIV, Sind have tabulated for 10 day periods in September, the drops in gauges and discharges due to the contemplated withdrawals, over the existing conditions, for the principal inundation canals during the selected 6 years (Sind sheet 103). The average drop in gauge and discharge for the first 10

days is given below for a few of the larger canals.

| Canals. | Average Drop in gauge ft. | Average drop in Discharge percentage. |
|---|---|---|
| *Upper Sind—* | | |
| Desert .. .. .. .. | 1·0 | 25% |
| Begari .. .. .. .. | 0·3 | 7% |
| Unhar .. .. .. .. | 0·9 | 23% |
| Sind .. .. .. .. | 0·8 | 10% |
| Gudu .. .. .. .. | 1·0 | 21% |
| Miranpur .. .. .. .. | 1·0 | 42% |
| *Lower Sind—* | | |
| Fuleli .. .. .. .. | 1·2 | 16% |
| Kalri .. .. .. .. | 1·3 | 32% |
| Pinyari .. .. .. .. | 1·1 | 20% |
| Baghar .. .. .. .. | 1·8 | 33% |

*Minor canals drops.*—The drops for the minor canals are given in Table XV (Sind sheet 104). It is said that the analysis gives much more unfavourable results for the small canals, (as they have comparatively higher commands). The range of the drop of discharges is higher in this table, and the averages are also somewhat higher on the whole.

*Comparison of 6 & 11 years.*—Similar tables of drops in levels and discharges are got out for all the 11 years in Tables XVI and XVII (Sind sheets 105 & 106). It will be seen from comparing these tables with the 6 selected years, that, on the whole, there is not a great difference generally between the results shown by the 2 sets of years.

*Sind graphs for Unharwah and Desert Canals—Remissions—Discharge relationships, etc.*—Sind then proceed to obtain relationships for the 2 Upper Sind Canals, Unharwah and Desert, purporting to show (Sind sheets 107—111) :

(1) Increase in remissions due to the reduction in canal discharge, 11—30th September.

(2) Reduction in the Rabi area due to the reduction in discharge during the period, 21st August to 30th September.

(3) Co-relation between Equivalent Dry Kharif cultivation and Mean Discharge. It is stated, that this latter graph can give no idea of crops actually matured.

It has been pointed out elsewhere that the Sind Administration reports do not furnish the remission figures, due to shortage of water,

for the inundation canals and they are, in general, difficult to interpret (*vide* Proceedings of 21st April 1942, pages 26-27). Sind also state the Equivalent Dry Kharif Conversion factor has not been proved (Sind sheet 111). These co-relations got out from 2 canals, Desert and Unharwah, have not been utilized in any way to try and assess the Punjab responsibility for the contemplated drops and hence they require no examination, as the data for their preparation is of doubtful reliability.

*September withdrawals decreasing in Sind—not effect of Lloyd Barrage.*—To show that the Sind withdrawals are decreasing in recent years in Lower Sind, a statement is furnished of the withdrawals for September 1922—40 (Sind sheet 111). To show that this is not the effect of the Lloyd Barrage, the withdrawals for Upper and Middle Sind are worked out to be :

| | | | |
|---|---|---|---|
| *September* | .. | 1922—31 .. | 47,785 cusecs. |
| | | 1932—40 .. | 47,285 „ |

(Sind sheet 112.)

The Lower Sind withdrawals post-barrage have decreased as shown below :

| | | | |
|---|---|---|---|
| *September* | .. | 1922—31 .. | 21,931 cusecs. |
| | | 1932—40 .. | 11,780 „ |

(Sind sheet 112.)

(These figures are not greatly different from the Punjab figures—*vide* page 80 *ante*).

Since 1911, Punjab withdrawals are said to have increased in September at the rate of 1,600 cusecs per year (Sind sheet 112).

*Evidence on importance of a few days supply at end of season.*—The evidence of Mr. Trench (the then Chief Engineer in Sind), before the Central Board of Irrigation 1935 Committee is referred to, to show how important a few days at the end of the season are, to inundation canals and how, even small drops of 0·2 or 0·5 ft. would affect the canals (Sind sheet 107). Mr. Trench's remarks were,—

"* * * * * These may seem very small differences to those who are not used to inundation canals but as a matter of fact, they are of vital importance in every year except in an exceptionally good year. This year when the river fell away early,—as everybody knows,—the effect on the Fuleli canal was such, that one more watering would have saved a large part of the rice crop. The loss of 5 or 6 days at that period would be a very great hardship to cultivators."

*Explanation of effects by change in inflow in recent years.*—The Sind reply to the Punjab contention that the inflow has been less in 1932-33 to 1940-41 is contained in their note, Sind Sheet 111, giving a contrary opinion.

*Conclusion on September supplies after the contemplated withdrawals.*—Finally with respect to the examination of this Sind presentation in regard to September, it may be stated that deterioration in the September supplies of later years is evident, and that it is not due to the extra Lloyd Barrage withdrawals. Even though the further reduction in levels and discharge is unlikely to be so marked as put forward by Sind, yet the indications are, that, when all the contemplated Punjab withdrawals are made, the higher level lands are likely to be subjected to a considerable shortening of the season.

*Note.*—No attempt is made to assess the degree of accuracy of the claims of Sind under sub paras. (2) to (4) below, for reasons given on pages 33, 76 and 99.

(2) JULY AND AUGUST (*i.e.* period of maximum demand).

*Effects—July and August.*—Sind have presented the calculated effects for the growing period in their note, " Effects of Punjab Projects during July and August, *i.e.*, during the maximum demand period " (Sind sheet 114). The presentation is made in a manner similar to that described for September and the probable drops in discharge for the major and minor canals are furnished (Sind sheets 122 & 123). The percentages are, in general, considerably less than for September as would be expected.

(3) MAY AND JUNE.

*Effects—May & June.*—Information in regard to probable drops in May and June according to the Sind calculations are contained in their note, " Effects of Punjab withdrawals, May and June " (Sind sheet 125). The drops in discharges calculated for the major and minor canals are heavy, according to the Sind method of calculation (Sind sheets 127 & 128). The period contains the rising river with the steep portion of the hydrograph, and hence drops are liable to show a high percentage.

(4) IN INDIVIDUAL YEARS.

(*a*) *1932.*

Sind contends, that, if the effects of the Punjab withdrawals in 3 years out of 11, are such, that the canals will fail partially or completely, a case would have been established showing that remedial measures are essential (Sind sheet 135).

The effect of delay in opening a canal is stressed, as transplantation in Lower Sind must be completed before the rains start. Exami-

nation of the conditions in the canals in 1932 is made, to show that they would have suffered very severely after the Punjab projects,—*i.e.*, according to the Sind method of calculations. Drops in discharges at certain periods of 20 to 70% etc., are shown—A loss of crop of 1·75 to 2 crores is estimated (Sind sheet 140).

(*b*) *1931 and 1941.*

A similar examination of canals is made for 1931 and it is concluded that it is doubtful whether any canal could have yielded any return and that 1941 would have shown results similar to 1932 (Sind sheet 143).

(*c*) *1934.*

It is claimed that serious damage would have occurred by the drops (Sind sheet 144).

(*d*) *1935.*

This was a year of good gauges. It is claimed that reduction in September discharges would have been serious (Sind sheet 150).

(*e*) *1937 and 1938.*

The effects in 1937 are said to be similar to those of 1934,—and 1938 more serious (Sind sheet 146).

(*f*) *1936, 1939 and 1940.*

Serious damage would have occurred, according to the Sind investigation (Sind sheet 147).

(5) DURATION OF FLOW.

*Considerations for opening and closing canals.*—The time of opening of the inundation canals is said to be, when (Sind sheet 130)—

(*i*) The river level is high enough to admit such discharge into the canal, as can be immediately utilized by the bulk of the cultivators, and

(*ii*) the river shows signs of a rise that will be sustained.

The date of opening and the gauge at which the canal is opened, therefore, varies from year to year.

Similarly the gauge and date of closing varies from year to year, dependent on when the river falls below bed level of the head reach.

The number of days of reduced flow after the Punjab projects is worked out for the major canals to be from 11 days to 43 days, as an average of 11 years (Sind sheet 132).

It may, however, be stated that due to the very variable rate of rise and fall and the petty flow for some time at the low levels, the actual figures of period of flow are not readily interpretable.

*Even now Sind canals not getting Full Supply for 45 days.*—Sind have claimed that full supply is required for at least 45 days for their inundation canals. It will be seen, however, from Sind statements III and IV, accompanying their " Note on Duration of flow " (Sind sheet 133), that they are far from getting this so-called requirement under present conditions. 2 canals out of 17 got the " requirement " for 6 out of 6 years and one canal out of 17 got the " requirement " for 11 years out of 11. Desert canal only got it for one year out of 6 or 2 out of 11 years.

Sind have quoted the opinion of the Chief Engineer, Punjab, in his note dated 2nd August 1915 (Sind sheet 283) as to the effects of weir construction on the Punjab inundation canals.

The opinion given was : " The result of every new weir thrown across a river has indubitably proved unfavourable to the Inundation Canals of the South Punjab—they have started flowing slightly later and have dried up slightly earlier in consequence."

Reference may be made in this connection to the graph appearing in the Indus River Commission Records–showing dates for specific water levels obtained during the falling stage of River Indus at Kotri from 1922. The gradual shortening of the season is seen from this graph.

(6) EFFECTS ON KATCHA CULTIVATION, FORESTS AND RICE CULTIVATION, AT RIVER MOUTH.

Katcha cultivation is that done on the river berms, which have been flooded by the kharif high water, permitting a rabi crop being grown on the saturated ground after the floods recede. It is claimed that after the projects these areas will have to be given canal supply, if possible (Sind sheet 152). It is seen from the table furnished by Sind, that there has been no reduction in katcha cultivation in Upper Sind in recent years, but there has been a large reduction in Lower Sind.

A note was prepared by the Sind Conservator of Forests, to show the probable adverse effect on the Sind forests due to the lower water levels anticipated after the Punjab projects (*i.e.*; anticipated under the Sind calculations). Reduction in revenue from wood, charcoal, grazing, etc. is anticipated.

Graphs have been submitted by Sind purporting to show the relationship between forest areas in Sind below Sukkur—and above Sukkur—and the average of the ten highest gauges at Kotri 1908—40 (S. II 125 and 126). Both Upper and Lower Sind show a large reduction after 1934 in the forest area for the same average Kotri gauges. In Sind sheet 152, the deterioration is claimed to be due

to the bad years after 1936. In Sind Volume II, page 117, the co-relation is said to be the same, without reference to the time trend. The latter contention does not seem to be borne out by the graphs which show the deterioration after 1934. We are not able to interpret the graphs, whether they show a change in forest policy or whether the deterioration is due to natural causes. On Sind sheet 155, the Conservator of Forests (Sind), stated that in the period 1931—35, the Department had a large reserve of forest area which had little present worth. It was katcha land flooded too deeply to make artificial regeneration possible. The charts may represent exclusion of such areas in recent years.

Considerable rice cultivation is said to be done near the river mouth which may be injuriously affected, if there is inadequate flow to allow of fresh water reaching the fields at every tide.

Punjab have replied to the Sind presentation, pointing out certain non-reconciliation of figures for the katcha cultivation, claiming that the water level in the lower reach will be more dependent on tides than discharge in the river, and the Conservator, Sind, had but recently written an article, expressing other views for the decline in forest area (P. D. III-A, p. 231).

Sind have replied that the figures quoted by the Punjab are those within the command of irrigation canals and supplied through ' Bund sluices ' and not ' katcha cultivation ' (S. II 131).

*Conclusion on Katcha cultivation, etc.*—In regard to this claim for protection of interests now served by flood spill, it may be stated that the probable drops in flood levels by the contemplated Punjab withdrawals are not likely to be so great as calculated by Sind. However, with the development of the river and gradual reduction of water wasted to the sea, the extent of spill area served is sure to reduce, except as moderated by possible rise in river bed level. It may therefore be in the interest of Sind to provide for such areas set free from flood spill irrigation, by controlled supply, to the extent that it is found possible.

## EFFECTS OF METEOROLOGICAL CHANGES.

Neither Punjab nor Sind have produced a detailed investigation, as an official exhibit, of the effect of long period changes in meteorological conditions, which would explain the vagaries of the river discharges throughout the period for which information is available.

It is understood that the examination made, was not very explanatory of the river changes.

*Final comparison of the effects on the discharges of the Sind Inundation Canals, by the contemplated Punjab withdrawals—as calculated by Sind "Set A" methods & as calculated by Punjab "Set C" methods.*

SET A.

1. Set A was revised according to certain agreed suggestions at the first session, for giving an approximate idea of the probable drops due to the contemplated Punjab withdrawals. The method probably over-emphasizes the extent of probable withdrawals, with the dates of fillings of Bhakra and Beas adopted.

2. Sind does not provide much reduction, in the way of capacity factors on withdrawals, to allow for less requirements during rainfall in the irrigated area.

3. Losses and gains are applied in a proportionate manner to withdrawals.

SET C.

1. Assumptions different from Sind are made, in regard to amount and place of draw-off of certain items of withdrawals.

2. Capacity factors of a liberal nature are applied to canal withdrawals, showing reduced effects.

3. Losses are taken in a proportionate manner in application to withdrawals. Gains on withdrawals are restricted to unity factor.

4. Co-relation factors between river reference gauge and canal upstream gauge are adopted. The factors are of doubtful reliability.

5. The inundation canals are assumed to work to a year gauge discharge curve, of maximum efficiency,—irrespective of the actual gauge discharge curve of the year investigated.

*S. II 57.*—Sind have objected in their "Comments on (Punjab) Chapter VII" to the limitation imposed by the Punjab in para. 7.2.2 (*b*) of their Chapter VII, for the minor canals, *i.e.*,

> "On certain dates some of the smaller canals were drawing even more than the authorised high flood discharge. On such dates, Punjab has limited them to the authorised high flood discharge in working out the reduction." P. D. Vol. III A, Page 5.

The contention of Sind is, that, " The small canals have always drawn as much water as possible in peak discharges, because their duration of flow is short and they have to draw the maximum quantity of water when it is available."

*S. II 57.*—Sind in their " Comments on Chap. VII," have compared several alternative methods for determining the reduction in discharge in important periods for the minor canals,—with the method employed by the Punjab,—purporting to show that the Punjab method gives the lowest figures—" due to the unfair assumptions made ".

| Method. | Minor Canals. Reduction in discharge. Masuwah. | Mulchandwah. |
|---|---|---|
| (*a*) Sind method of cutoff statement (co-relation factor 1) .. .. | 51·9% | 31·3% |
| (*b*) Sind Projection method .. .. | 46·0% | 41·0% |
| (*c*) Gauge Discharge curves of Sind & co-relation factor 1 .. .. | 60% | 43·0% |
| (*d*) Using Punjab plotted gauge discharge curve and co-relation factor 1 .. .. .. | 62% | 39·0% |
| & | | |
| (*e*) Punjab method of co-relation factor 1 and *lowest* gauge discharge curve of any year .. .. .. | 5·09% | 14% |

The year for which the above figures were got out is not stated by Sind.

In the Proceedings of 28th April 1942, it was pointed out, that, under existing conditions some of the minor inundation canals were operating under a very short season for supply, even 2½ months or less,—much shorter than the period set by Sind, as a requirement for working of the Sind inundation canals. Sind replied that certain dry kharif crops, mostly jawari, could be raised, but the rice areas of Sind would be unsuitable for such crops.

Sind have presented a " Note on the Necessity of June and September Supplies for Rice cultivation " (S. II 171). After explaining the Sind practice in rice cultivation and the shortening of the season, it is said that it might help, to shift the season earlier to 15th May, in years in which the river rose early like the last year. It is, however, claimed that the discharges available in June would be inadequate after the Punjab withdrawals, as transplantation requires full supply or over.

An examination is then made of a number of the canals, for the selected and other years, purporting to show the particular times in the several years in which the various canals would have suffered due to the Punjab withdrawals. The heavy remissions in 1941 in certain 'dehs' due to deficiency of water (and locusts) are also cited.

*Modified for rise in bed.*—The Punjab have submitted tabular statements of drops in levels and discharges with columns for Set B & C drops, "modified for rise in bed". The evidence put forward by the Punjab on this feature has been examined under the heading, "Accretion of levels" and found to be inconclusive; hence these columns do not call for any examination.

*Monthly average results not favoured by Sind.*—Tabular statements are furnished at the end of this Chapter, of percentage drops, for certain inundation, major and minor canals, under the methods of calculation adopted by Sind and Punjab. It has been the contention of Sind, that such comparisons cannot be properly made by monthly averages as the latter obscure the full extent of the probable damage. Sind illustrate this objection in their "Comments on Chapter V" (Punjab), by referring to Sarhad September drops S.II 40. The 1936 mean monthly drop (under Set A) is 1·40, while for 20 days the drops are of the order of 2·1 to 2·2 ft. The average drop over the 6 years for the month of September, becomes 0·85 ft. Sind, therefore, prefers to deal with the effects by short term periods and by 'operation' seasons, as sowing, season of heaviest demand and maturing period. Monthly averages have, however, long been used for comparison of irrigation hydraulic particulars. The Sind contention would have more force, if there was greater confidence in the accuracy of the results predicted. Again, it needs no reminder that irrigation supplies have often to be taken, as and when they become available, irrespective of the period of optimum application and this applies especially to inundation canals. Hence monthly averages, though certainly not fully descriptive, give a summary of value for comparisons. The much higher percentage drops in September will be seen from the tables.

*Sarhad and Kotri Drops due to Punjab withdrawals.*—In their Chapter V, P. D. Vol. III, the Punjab have given tabular statements of drops on the Sarhad and Kotri reference gauges, both by short-term periods of 4 and 5 days, etc., and by monthly averages, under Sets A, B and C calculations. In the same Chapter, the probable effects of these drops, with respect to river gauges applying in May and June (at time of canal opening) and other aspects are discussed.

*Objection to comparison of Set C with N. T. drops.*—Sind have replied to the remarks in Punjab Chapter V, drawing attention to the 'range' in drops not shown by the monthly averages and objecting to comparison of Set C with the Nicholson-Trench calculated drops,—as the latter investigation did not take into account the additional withdrawals for the Sutlej Valley canals, the Haveli, Thal, the Beas Dam, the small storages and the feeders.

*Kotri suitable for reference gauge.*—The incorrect assumption by the Punjab of the range of river levels at Aghimani is also corrected and figures are furnished purporting to show that the range at Aghimani is more than at Kotri. The range at Jherruck is also said to be about the same as at Kotri, so that Kotri is not unsuitable as a reference gauge.

Sind also object to comparing resultant levels after the drops, with the figure of 17 ft. given in the Sind Administration Reports, prior to 1934, as the fair irrigating level at Kotri [*Vide* Sind Sheet 7, para. 16(*v*)] and its Appendix G read with S. II 41 and P. D. III 290. (In the Sind case it is given as 20 ft.) (Sind sheet 24). It is claimed that 17 ft. would not give a capacity factor of 0·75, for even low lying canals like Fuleli and Pinyari. The reason for the confusion in fair irrigating gauges has not been clearly explained by Sind.

*Final drops. Set A.*—Final corrected drops at Sarhad and Kotri according to Set A calculations,—the latter allowing also, for full development of the Lloyd Barrage, are furnished by Sind in Sind sheets 298 and 300.

## SUMMARY OF DISCUSSION OF THE PROBABLE EFFECTS OF THE CONTEMPLATED PUNJAB WITHDRAWALS ON THE SIND INUNDATION CANALS.

It has been explained in this Report, that Sind did not carry their analysis of the probable effects of the Punjab withdrawals into a computation of the areas of land that would be thrown out of cultivation, either partly or wholly, in different years. Probable drops in levels on the two river reference gauges and probable drops in discharges for certain of the Major and Minor Sind inundation canals are given at the end of this Chapter, as got out by the Sind Method A and Punjab Method C. These tables do not show the ranges of drops, but are only averages, to give a general idea of the order of the drops for the periods selected. It becomes necessary, therefore, for the Commission to say, as definitely as it can,—on the evidence furnished, —what is their opinion of the probable effects. In order that there may be no misapprehension, as to the possibility, or otherwise, of saying, whether the results by the Sind or Punjab method are correct, we will review the different aspects of the problem.

I. The fact that withdrawals of water in the upper part of a river do not reproduce themselves, as the same amount of shortages in the lower part of the river, was pointed out and it was stated on page 25 *ante* that the difficulty of predicting effects in Sind from known factors in the upper part of the river, still persists.

We had to adopt certain approximate assumptions, to facilitate revision of the Sind calculations. Apart then from the reliability of the methods of computation of probable effects, these approximations introduce an element of uncertainty.

II. The calculations for translating withdrawals of water in the Punjab to their effects on Sind, involve allowances for three main factors, *losses* of water in transit, *gains* of water in transit and *time lag* or time element from the point of withdrawal of the water to the concerned reference point in Sind. Now these elements are affected by many other factors—such as, rain, evaporation, regeneration, unmeasured inflow, river storage—all of which are continuously varying. We have expressed our opinion on these subjects on pages 32 and 33 *ante.*

The unproved proportionate effects of these elements on withdrawals, apply to both the Sind and Punjab calculations. Whilst we consider the restriction to unity on expression of gains on withdrawals adopted by the Punjab is wrong, yet we also do not consider the Sind method has been proved, nor is it possible on the evidence to apportion the degree of accuracy pertaining to each set of calculations, but we are satisfied that during periods of gain—commonly occurring in the latter part of August and September— the volumetric effects of the Punjab withdrawals on the river discharge in Sind will not be less than the amount of the Punjab withdrawals. Hence these withdrawals will have a material effect on the Sind canals during the periods of gain.

III. *Capacity Factors on withdrawals.*—We have commented on the fact that Sind has not allowed adequately for capacity factors. This over-emphasizes the effect of Punjab withdrawals on Sind, *vide* pages 35, 37 and 40 *ante.* On the other hand, the unproved nature of the Punjab capacity factors is explained on pages 37, 38 and 39 *ante.*

IV. *Translating drops at river reference gauges to drops in discharges at the Inundation Canal Head Sluices.*—The limitations of the Sind method of Projection have been explained. The method is unsuitable for application at many parts of the graphs. Nevertheless we consider it is the best method presented to us, *vide* pages 42 and 43 *ante.*

The Punjab graphs for co-relation between the river reference gauge and the canal gauge, we have found largely unsuitable,

*vide* page 45 *ante*, and as for the Punjab method of assessing diminution of discharges, we have said on page 46 *ante*, that it does not represent the effects for conditions as they existed in the selected years.

V. *Accretion of bed—Ameliorating effects.*—So far as the evidence of the specific gauge discharge graphs of Upper Sind are concerned, our opinion is given on page 59 *ante* and for Middle and Lower Sind at page 63 *ante*. The evidence of simple gauges was found inconclusive, as was also that of gauge discharge curves. Conclusions on other evidence offered for accretion have also been given and the final conclusion in regard to the unproved nature of accretion is given on pages 74 and 75 *ante*.

It will be obvious from the many uncertain features of the calculations by both the Sind and Punjab Methods, that no purpose will be served, by attempting to discuss the degree of accuracy of the Sind claims as to the extent of probable damage in the different months and different years claimed by Sind,—which are based on their own calculations.

In regard to the month of September, which Sind considers to be of special importance, our conclusions in general terms are given on pages 84 and 90 *ante*. The deterioration of the September Sukkur discharges will be seen on page 78 *ante*, and further evidence of September deterioration in Sind will be seen from pages 68, 71, 78, 80, 81—83 and 85 *ante*.

The Sind predicted percentage drops in September are given for certain canals on page 88 *ante*.

In regard to the relative accuracy of Sets A and C calculations—in representing probable actuals—we are only able to register general impressions. With respect to the drops on the reference gauges by the two methods, *vide*, *e.g.*, pp. 100 and 101 *infra* it is not possible to assess relative degrees of accuracy, in view of remarks on capacity factors, losses, gains, etc. With respect to the drops in discharges at the canals, we would refer to the previous remarks on co-relations of river to canal reference gauges, adopted by the Punjab, and the latter's use of the maximum efficiency year gauge discharge curves for calculating diminution of discharges. The probabilities in our opinion are, that the Set A calculations may be a closer guide than Set C, in translating drops in river reference gauge levels to drops in canal discharges.

Finally we would say that quite apart from the results of the predicted effects by Set A or Set C methods, we have no doubt

that in periods of gain—common in the later part of the *kharif* season—the Punjab withdrawals will have their full effect on the river in Sind.

In the absence of any evidence of sustained accretion of bed, they must therefore have a material effect on those inundation canals, which have no cutoff at the time.

It follows that the contemplated Punjab withdrawals will cause material damage to the Sind inundation canals, especially in the month of September, and curtail the duration of useful flow.

## MONTHLY AVERAGES—CALCULATED DROPS ON SARHAD AND KOTRI GAUGES DUE TO PUNJAB ADDITIONAL WITHDRAWALS.

(*In feet.*)

FROM PUNJAB CHAPTER V, TABLES 20 AND 21.

| Month and Year. | Sarhad. | Sarhad drops corresponding to | | Kotri. | Kotri drops corresponding to | |
|---|---|---|---|---|---|---|
| | Actual Gauge. | Set A. | Set C. | Actual Gauge. | Set A. | Set C. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| MAY last half— | | | | | | |
| 1932 .. .. | 4·86 | 1·97 | 1·85 | 9·01 | 2·54 | 2·81 |
| 1933 .. .. | 5·96 | 1·09 | 0·99 | 10·81 | 1·00 | 0·98 |
| 1934 .. .. | 3·01 | 1·21 | 1·18 | 5·35 | 2·55 | 2·40 |
| 1935 .. .. | 8·22 | 0·43 | 0·39 | 12·22 | 0·83 | 0·68 |
| 1936 .. .. | 9·40 | 0·34 | 0·31 | 13·95 | 0·60 | 0·56 |
| 1939 .. .. | 9·71 | 0·29 | 0·88 | 16·40 | 0·37 | 0·43 |
| AVERAGE .. | 6·86 | 0·89 | 0·84 | 11·29 | 1·32 | 1·31 |

| Month and Year. | Sarhad. | Sarhad drops corresponding to | | Kotri. | Kotri drops corresponding to | |
|---|---|---|---|---|---|---|
| | Actual Gauge. | Set A. | Set C. | Actual Gauge. | Set A. | Set C. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| JUNE— | | | | | | |
| 1932 .. .. | 8·61 | 0·36 | 0·37 | 13·21 | 0·60 | 0·58 |
| 1933 .. .. | 9·13 | 0·19 | 0·15 | 14·32 | 0·49 | 0·47 |
| 1934 .. .. | 7·54 | 0·42 | 0·40 | 10·80 | 1·03 | 1·00 |
| 1935 .. .. | 8·98 | 0·25 | 0·26 | 12·92 | 0·50 | 0·52 |
| 1936 .. .. | 12·07 | 0·26 | 0·23 | 18·47 | 0·39 | 0·38 |
| 1939 .. .. | 10·21 | 0·26 | 0·18 | 16·12 | 0·38 | 0·30 |
| AVERAGE .. | 9·42 | 0·29 | 0·27 | 14·31 | 0·57 | 0·54 |
| JULY— | | | | | | |
| 1932 .. .. | 10·80 | 0·31 | 0·28 | 16·00 | 0·62 | 0·45 |
| 1933 .. .. | 11·93 | 0·81 | 0·65 | 19·20 | 1·33 | 1·10 |
| 1934 .. .. | 12·48 | 0·57 | 0·48 | 19·82 | 1·35 | 1·09 |
| 1935 .. .. | 12·08 | 0·42 | 0·33 | 16·91 | 0·84 | 0·77 |
| 1936 .. .. | 11·98 | 0·59 | 0·44 | 18·99 | 1·31 | 1·03 |
| 1939 .. .. | 11·95 | 0·46 | 0·43 | 18·38 | 0·47 | 0·38 |
| AVERAGE .. | 11·87 | 0·53 | 0·43 | 18·22 | 0·99 | 0·80 |
| AUGUST— | | | | | | |
| 1932 .. .. | 12·98 | 1·97 | 1·20 | 22·20 | 2·75 | 1·84 |
| 1933 .. .. | 13·31 | 1·09 | 0·58 | 22·64 | 2·45 | 0·99 |
| 1934 .. .. | 12·40 | 0·90 | 0·28 | 21·52 | 2·09 | 0·78 |
| 1935 .. .. | 13·96 | 0·88 | 0·46 | 22·25 | 2·63 | 1·63 |
| 1936 .. .. | 11·96 | 0·68 | 0·47 | 18·77 | 2·07 | 1·54 |
| 1939 .. .. | 12·33 | 0·97 | 0·89 | 19·10 | 1·25 | 1·18 |
| AVERAGE .. | 12·82 | 1·08 | 0·65 | 21·08 | 2·21 | 1·33 |
| SEPTEMBER— | | | | | | |
| 1932 .. .. | 7·61 | 1·32 | 0·56 | 16·09 | 3·18 | 0·94 |
| 1933 .. .. | 10·07 | 0·39 | 0·16 | 20·52 | 0·73 | 0·30 |
| 1934 .. .. | 9·03 | 0·59 | 0·36 | 14·73 | 0·92 | 0·51 |
| 1935 .. .. | 9·13 | 0·72 | 0·45 | 15·19 | 1·27 | 0·68 |
| 1936 .. .. | 9·89 | 1·40 | 0·36 | 16·80 | 1·45 | 0·63 |
| 1939 .. .. | 10·33 | 0·67 | 0·59 | 16·26 | 0·72 | 0·57 |
| AVERAGE .. | 9·34 | 0·85 | 0·41 | 16·60 | 1·38 | 0·61 |
| OCTOBER first half— | | | | | | |
| 1932 .. .. | 4·72 | 0·58 | 0·48 | 10·56 | 1·51 | 1·10 |
| 1933 .. .. | 6·95 | 0·80 | 0·30 | 14·57 | 1·59 | 0·65 |
| 1934 .. .. | 5·33 | 0·89 | 0·69 | 9·75 | 0·34 | 1·08 |
| 1935 .. .. | 5·79 | 0·78 | 0·67 | 10·01 | 1·67 | 1·24 |
| 1936 .. .. | 5·75 | 0·85 | 0·65 | 12·57 | 0·86 | 0·53 |
| 1939 .. .. | 5·73 | 0·74 | 0·63 | 10·86 | 1·16 | 0·89 |
| AVERAGE .. | 5·71 | 0·77 | 0·57 | 11·39 | 1·36 | 0·92 |

## SIND—SET A.

*Statement showing average percentage reduction in mean supply of major inundation canals average of years.*

*1932, 1934, 1935, 1936 and 1939.*

| Name of Canal. | % reduction in June. | | | % reduction in July (1—31) | | % reduction in August (1—31). | | % reduction in September. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1-10. | 11-20. | 21-30. | After 4 projects. | After 5 projects. | After 4 Projects. | After 5 Projects. | 1-10. | 11-20. | 21-30. |
| 1. Adio .. | 23 | 32 | 22 | 7 | 8 | 18 | 21 | 44 | 48 | 59 |
| 2. Desert .. | 13 | 5 | 3 | 2 | 3 | 7 | 9 | 22 | 25 | 40 |
| 3. Kandhkot Rajwah. | 19 | 17 | 15 | 12 | 13 | 20 | 24 | 47 | 54 | 77 |
| 4. Unhar .. | 22 | 4 | 3 | 5 | 6 | 6 | 7 | 23 | 32 | 42 |
| 5. Begari .. | 3 | 1 | 2 | 2 | 2 | 2 | 3 | 5 | 10 | 8 |
| 6. Choi .. .. | 10 | 4 | 3 | 2 | 2 | 4 | 4 | 17 | 9 | 9 |
| 7. D. I. R. .. | 0 | 8 | 7 | 5 | 5 | 10 | 12 | 29 | 25 | 41 |
| 8. Sind .. .. | 29 | 10 | 2 | 1 | 1 | 3 | 3 | 8 | 12 | 9 |
| 9. Mahi .. .. | 46 | 4 | 6 | 5 | 6 | 10 | 12 | 19 | 26 | 41 |
| 10. Sehar .. | 42 | 14 | 12 | 17 | 22 | 26 | 31 | 37 | 52 | 74 |
| 11. Miranpur .. | 57 | 23 | 12 | 16 | 20 | 27 | 34 | 46 | 49 | 85 |
| 12. Fuleli .. | 26 | 8 | 6 | 3 | 4 | 4 | 6 | 16 | 20 | 29 |
| 13. Hassanali .. | 37 | 29 | 17 | 6 | 6 | 8 | 12 | 17 | 38 | 55 |
| 14. Pinyari .. | 18 | 22 | 9 | 5 | 6 | 8 | 12 | 17 | 42 | 53 |
| 15. Baghar .. | 22 | 27 | 15 | 17 | 23 | 26 | 33 | 33 | 52 | 73 |
| 16. Kalri .. | 21 | 44 | 26 | 19 | 23 | 22 | 31 | 31 | 64 | 58 |

# PERCENTAGE REDUCTIONS IN DISCHARGES

*Kharif season (1·6 to 30·9) and September.*

*Comparison of reduction of discharges of Major Inundation Canals due to Punjab Additional withdrawals—Sind Set A calculations and Punjab Set C calculations—Reductions are in percentages of actual discharge—for the 6 selected years abstracted from Punjab Appendices XXII and XXIII—Punjab Vol. III—pages 348—377. for the Inundation canals listed, over 1,000 cusecs*

*N. B.*—Other figures for the Set A mean supply reduction s are given by Sind in their sheet 122.

| Canal. | | 1932. | | | | 1933. | | | | 1934. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name. | Full Supply Discharge | 1·6 to 30·9 | | Sept. | | 1·6 to 30·9 | | Sept. | | 1·6 to 30·9 | | Sept. | |
| | | Set A. | Set C. | Set A. | Set C. | Set A. | Set C. | Set A. | Set C. | Set A. | Set C. | Set A. | Set C. |
| *Upper Sind.* | | | | | | | | | | | | | |
| Desert .. | 3,964 | 8·4 | 3·3 | 39·0 | 10·5 | 6·1 | 3·1 | 19·2 | 0·8 | 9·9 | 4·6 | 19·3 | 6·0 |
| Begari .. | 7,750 | 2·1 | .. | 8·0 | 0·1 | 0·4 | .. | 1·8 | .. | 2·6 | .. | 20·2 | .. |
| Unhar .. | 2,200 | 9·8 | 2·6 | 38·0 | 11·2 | 1·6 | 0·6 | 6·3 | 2·6 | 3·7 | 1·7 | 13·8 | 7·0 |
| Sind .. .. | 2,225 | 11·2 | 0·7 | 24·0 | 2·7 | 0·4 | .. | .. | .. | 2·2 | 0·2 | 8·0 | 0·8 |
| Mahiwah .. | 1,862 | 15·2 | 6·9 | 29·0 | 3·1 | 2·4 | 0·3 | 4·2 | 1·2 | 7·9 | 1·2 | 14·5 | .. |
| Miranpur Dhand | 1,000 | 24·7 | 2·8 | 72·0 | .. | 13·0 | 0·71 | 27·5 | .. | 22·1 | .. | 41·3 | .. |
| *Lower Sind.* | | | | | | | | | | | | | |
| Fuleli .. .. | 11,500 | 12·7 | 3·8 | 39·0 | 5·2 | 3·0 | 2·3 | 3·2 | 0·7 | 5·1 | 1·8 | 18·0 | 2·0 |
| Pinyari .. | 3,400 | 14·0 | 2·4 | 51·1 | 9·0 | 2·8 | 1·0 | 1·1 | .. | 4·6 | 2·1 | 23·1 | 10·8 |
| Kalri .. .. | 1,686 | 26·1 | 10·4 | 62·0 | 13·8 | 14·9 | 4·0 | 6·0 | .. | 20·2 | 6·5 | 39·5 | 0·8 |
| Baghar .. | 5,100 | 29·4 | 17·8 | 60·0 | 8·9 | 16·4 | 10·4 | 6·2 | .. | 27·4 | 7·6 | 24·4 | 0·1 |

| Canal. | | 1935. | | | | 1936. | | | | 1939. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name. | Full Supply Discharge | 1·6 to 30·9 | | Sept. | | 1·6 to 30·9 | | Sept. | | 1·6 to 30·9 | | Sept. | |
| | | Set A. | Set C. | Set A. | Set C. | Set A. | Set C. | Set A. | Set C. | Set A. | Set C. | Set A. | Set C. |
| *Upper Sind.* | | | | | | | | | | | | | |
| Desert .. | 3,964 | 5·0 | 1·1 | 49·2 | 10·2 | 8·1 | 3·4 | 30·0 | 9·0 | 0·1 | 0 | .. | .. |
| Begari .. | 7,750 | 1·7 | .. | 4·6 | .. | 2·0 | .. | 3·2 | .. | 8·4 | .. | 7·9 | .. |
| Unhar .. | 2,200 | 4·1 | 0·8 | 27·8 | 0·3 | 13·4 | 1·8 | 34·6 | 4·5 | 13·0 | 6·1 | 16·7 | 11·0 |
| Sind .. .. | 2,225 | 1·6 | 0·1 | 4·5 | .. | .. | .. | 0·2 | .. | 3·7 | 2·1 | 8·2 | 1·0 |
| Mahiwah .. | 1,862 | 7·3 | .. | 28·7 | .. | 9·9 | 0·8 | 31·7 | 1·4 | 3·7 | 3·2 | 5·6 | 4·2 |
| Miranpur Dhand | 1,000 | 20·0 | .. | .. | .. | 31·7 | .. | 55·0 | .. | 27·4 | 16·8 | 26·9 | 24·8 |
| *Lower Sind.* | | | | | | | | | | | | | |
| Fuleli .. .. | 11,500 | 5·7 | 0·6 | 17·3 | .. | 4·8 | 1·5 | 8·0 | .. | 10·6 | 3·1 | 15·8 | 1·6 |
| Pinyari .. | 3,400 | 7·7 | 5·0 | 35·1 | 16·4 | 13·1 | 8·6 | 7·0 | 2·3 | 4·0 | 1·3 | 4·2 | .. |
| Kalri .. .. | 1,686 | 19·3 | 16·8 | 17·1 | .. | 31·5 | 10·1 | 34·0 | 1·6 | 19·4 | 13·8 | 21·1 | 15·6 |
| Baghar .. | 5,100 | 24·6 | 8·6 | 40·3 | .. | 26·8 | 5·8 | 32·0 | 4·1 | 19·6 | .. | 24·2 | .. |

# COMPARISON

OF

## *Reduction in Discharges of Sind Minor Inundation Canals due to Punjab Additional withdrawals.*

## *Average of years 1932—36 and 1939.*

## *Mean supply in season and Mean September.*

*N.B.*—(*i*) Average reductions in Col. 3 do not agree with Sind sheet 123.

(*ii*) Col. 2 is abstracted from Sind sheet 123, and other particulars from Punjab Vol. IIIA, pages 5 to 8.

| Canal. | Mean Supply 1·6 to 30·9 Percentage Reductions. | | | *September.* Percentage Reductions. | |
|---|---|---|---|---|---|
| | Range of Reduction Set A. | Average Reduction. | | Set A. | Set C. |
| | | Set A. | Set C. | | |
| 1 | 2 | 3 | 4 | 5 | 6 |
| *Upper Sind.* | | | | | |
| Janib .. .. .. | 1 to 25 | 7·5 | *Punjab table 40.* 1·2 | 27·7 | *Punjab table 41.* .. |
| Masuwah .. .. | 15 to 24 | 18·3 | 1·8 | 28·5 | 4·5 |
| Rajib .. .. .. | 1 to 8 | 2·9 | 0·6 | 5·8 | 1·7 |
| Mahro .. .. .. | 15 to 30 | 22·4 | 9·0 | 24·5 | 10·9 |
| Lundi .. .. .. | 18 to 36 | 22·3 | 1·4 | 24·7 | 2·5 |
| Dengro .. .. .. | 8 to 25 | 16·7 | 1·5 | 29·1 | 3·8 |
| *Lower Sind.* | | | | | |
| Dhadko .. .. .. | 19 to 35 | 28·8 | 8·5 | 33·3 | 6·3 |
| Sada Bahar .. .. | 14 to 69 | 32·4 | 15·9 | 43·7 | 7·8 |
| Ghar Marho .. .. | 9 to 39 | 22·1 | 10·6 | 24·7 | 7·9 |
| Moolchand .. .. | 15 to 28 | 21·3 | 7·3 | 28·6 | 6·4 |

## V.—REMEDIAL MEASURES.

(SUPPLEMENTARY TO REMARKS UNDER "RECOMMENDATIONS VOL. I".)

PUNJAB CLAIMS OF WASTAGE ON THE SIND INUNDATION CANALS AND AMELIORATING EFFECT OF PUNJAB WITHDRAWALS, BY MORE EFFICIENT USAGE OF WATER.

The Punjab have submitted a Note (Punjab Note 6A) on the "Effect of Punjab Additional Withdrawals on the Sind Inundation Canals" (P. Vol. IIIA, p. 92).

Reference is made to the very great waste of water in the Sind Inundation Canals. The Sind Administration Reports do not give separately for each canal, the remission due to failure of water. Further the Punjab point out, that the overall canal remission figures modified by the general percentage given in the Sind Administration Report for remission due to shortage of water—bear no relationship to the supplies received and areas irrigated for different years. This makes difficult the determination of a reasonable standard of proper utilization. The Punjab point out that it would be unfair to penalise that province, if the computed reductions due to their contemplated withdrawals would not reduce the area of Sind irrigation,—provided the supplies are properly distributed and properly utilized.

*Punjab calculations purporting to show no adverse effects in Sind if water properly utilized.*—Pointing out that the deltas are high in Upper Sind, but very high in Lower Sind, the very great waste in Lower Sind is emphasized. The Punjab then refer to water utilizations made by certain canals under certain conditions, revealed bp their study of that portion of the remissions, calculated to be due to shortage of water. They arrive at deltas required for Upper and Lower Sind Canals for the sowing, growing and maturing periods. Applying these figures to the balance of supplies available under Set A calculations, after the Punjab withdrawals, for certain of the Inundation Canals, tabular statements are prepared to show that there will be no reduction either in Kharif or Rabi areas—with a few exceptions—if the water is properly utilized.

*Sind's reply to the Punjab claim of improper utilization of water.*—Sind have replied to the Punjab Note in their "Comments on the Punjab Note 6 A". They repeat their remarks in regard to remissions as follows (Sind Vol. II, p. 89).

"Remissions in Sind, as has been made very clear, are only given when there is an almost total failure of crops and therefore cannot be taken as an index of the efficiency, or otherwise, of supply received by a canal. It is therefore not surprising that the estimated value of remissions due to water supply, bears no relationship to the

supplies utilized and areas cultivated for different years. *Remissions in Sind*, therefore, do not in any way indicate the condition or yield of the crop. They can only serve to indicate approximately the proportion of the cultivated area which was severely damaged. Therefore no conclusions regarding wastage of supplies should be drawn from remission figures."

Again they point out that it is incorrect to apply the overall percentage of remission due to deficiency of water supply, to individual canals.—as, among other reasons,—the overall percentage includes the remissions in the Barrage areas, where, for practical purposes, the remissions due to deficiency of water are negligible.

Explanation of the much higher deltas in Lower Sind is given by Sind as due to the fact, that in Lower Sind the area on all the major canals is almost entirely rice and the system of "Pancho" watering is unavoidable, because of the saline nature of the soils (*vide* "Note on Performance of 12 of Sind's Major Inundation Canals * * * *" Sind Sheets 308—310). Under this "Pancho" System the salt affected water from the kalarish soil has to be run off and be replaced with fresh water. Certain errors in the Punjab figures are pointed out and it is said that, for Baghar Canal the water wasted to the sea is not deducted. Tail and Cross regulators to that Canal were only built in 1937 and 1938.

The Sind note contends that the Punjab method of assessing reasonable requirements is unacceptable as :—

1. It is misleading to get out overall deltas without reference to the kind of crops grown, *i.e.*, proportion of dry kharif to rice, in the different years.
2. It implies that the canals work to weir—controlled conditions, as it assumes constancy of supply and demand, whereas on inundation canals higher supplies have to be taken when available, due to the fluctuating nature of supplies.

Comparision is then made of the supplies taken by the Punjab Muzaffargarh Inundation Canals, with the water taken by the Sind, Desert and Unhar, Inundation Canals, purporting to show that the Punjab Inundation Canals are more wasteful than the Sind Inundation Canals.

*Conclusion.*—Finally, with respect to this claim of the Punjab, that the adverse effects of the withdrawals could be met by more efficient use of the water already available in the selected years,—it may be stated that there is certainly evidence of much waste of water in the Sind Inundation canals, when the river inundation is high but

it is not quite so evident how this can be cured, under the inefficient conditions that are inseparable from inundation canals. Sind will undoubtedly try to utilize in the most efficient manner the balance of supplies available, after the contemplated Punjab withdrawals, if the canals are then functioning as Inundation Canals.

*Change in Cropping Conditions.*—The Punjab have submitted a note on the "Change of Cropping Conditions in Sind" (P. Vol. III A, p. 241). Reference is made to para. 17 of the Indus Discharge Committee's Report 1929, wherein it is stated in suggesting the appointment of two Superintending Engineers (Page 119 of the "Punjab Correspondence Volume").

"* * * * they will discuss * * * the possibility of any detriment likely to accrue (from the Bhakra Project) being counteracted by a change in the conditions of cropping". Messrs. Nicholson and Trench in their report make the observation, "It is, however, well known in the Punjab and also in Sind, *e.g.*, in the case of Mithrao Canal, that methods of cropping adjust themselves automatically to economic conditions and to the supplies which are available."

Attention is also directed in this connection to the very short periods of flow for some of the Sind Minor Inundation Canals under present conditions.

Sind have submitted a Note in "Reply to Punjab Note on the Change of Cropping Conditions in Sind", answering some of the Punjab remarks (Sind Vol. II, p. 137).

It will be necessary for the Sind Agricultural Research Department to pursue development of short period crops that can be grown most effectively on the high level lands under the Inundation Canals, which will be more adversely affected by the Punjab withdrawals.

1. *Factors to be considered in connection with barrages in Sind.*—Sind have said during the Proceedings of this Commission, that barrages are not essential, if no more Punjab withdrawals are permitted. Even under present conditions, however, it is seen from the large remissions that are commonly given in Sind, that cultivation under the inundation canals is rather precarious. A reference to Sind Sheet 66 will give an idea of the high order of these remissions, in Upper Sind. An examination of the remissions for Upper and Lower Sind—for certain canals, is also given below, which shows that the existing conditions in the Sind Inundation Canals are far beyond the "knife-edge" conditions, referred to in Sind Sheet 31. All of these remissions, however, are not due to shortage of water.

## EXAMINATION OF REMISSIONS AND NET REVENUE FOR UPPER AND LOWER SIND AND IRRECONCILABILITY WITH MEAN DISCHARGES.

Information furnished by Sind on pages 365—368 Sind Vol. I is for 1931-32 to 1938-39. For Upper Sind,—Desert, Unhar, Begari and Sind Canals are taken and for Lower Sind,—Fuleli, Pinyari, Baghar, Kalri and Hassanali Canals :—

| Year. | Net Revenue Upper Sind. Rupees. | Remission. Rupees. | Percentage Remission/ Net Revenue. | Net Revenue Lower Sind. Rupees. | Remission. Rupees. | Percentage Remission/ Net Revenue. |
|---|---|---|---|---|---|---|
| 1931-32 | 1,522,504 | 630,567 | 41 | 133,370 | 299,038 | 22 |
| 1932-33 | 1,459,217 | 669,895 | 46 | 1,103,266 | 635,290 | 53 |
| 1933-34 | 1,342,038 | 823,712 | 61 | 858,588 | 308,332 | 40 |
| 1934-35 | 1,224,558 | 754,587 | 61 | 579,329 | 598,590 | 103 |
| 1935-36 | 1,381,552 | 580,941 | 42 | 818,981 | 304,033 | 37 |
| 1936-37 | 1,698,555 | 393,400 | 23 | 968,920 | 196,413 | 20 |
| 1937-38 | 1,761,617 | 465,018 | 26 | 110,519 | 159,108 | 14 |
| 1938-39 | 1,325,225 | 545,839 | 49 | 103,747 | 359,320 | 35 |

These canals—selected by Sind—show a slightly less proportion of Remissions/Net revenue, for Lower Sind than Upper Sind, though the period is post barrage and deterioration in September is more in Lower Sind. The reliability of the remissions as an index of water supply is therefore questionable.

Remissions/Net Revenue for whole of the Sind inundation canals on above figures=40 % which is much above the average for all Sind canals.

The lack of relationship between remission and mean discharge may be seen from the following examination of one canal which may be typical.

## DESERT CANAL.

| Year. | Mean supply from Sind's Canal Abstract Data. Cusecs. | Net Revenue. Rupees. | Remissions from Sind's letter under reference in this note. Rupees. | Remarks. |
|---|---|---|---|---|
| 1931 .. .. | 3,165 | 380,132 | 193,963 | Compare with 1933. |
| 1932 .. .. | 2,818 | 357,226 | 184,857 | |
| 1933 .. .. | 3,367 | 306,324 | 269,296 | |
| 1934 .. .. | 2,515 | 217,747 | 260,931 | |
| 1935 .. .. | 2,758 | 310,484 | 195,576 | Compare lack of relation. |
| 1936 .. .. | 2,735 | 385,077 | 101,788 | |
| 1937 .. .. | 2,971 | 449,258 | 103,495 | |
| 1938 .. .. | 2,939 | 408,767 | 159,762 | |

2. Some indication of the falling off of net consolidated revenue on the Sind Inundation Canals especially in Lower Sind can be seen from the statement accompanying the "Note on Canal Irrigation in Sind". This statement was revised during the Proceedings and it is not clear whether the areas incorporated in the Barrage have been fully allowed for in the revised statements.

3. The exact time, at which supply conditions to the Sind Inundation Canals may become markedly worse,—so that without barrages, cultivation of large areas, now receiving satisfactory supply would be seriously threatened,—cannot be definitely fixed. Some factors making for this uncertainty are :—

(*i*) No programme exists for the contemplated Punjab withdrawals. The successful execution of some of the projects depends on arrangements with other States. It is not known if and when such arrangements will be concluded to permit execution of the projects.

(*ii*) Prediction of exact effect on Sind of withdrawals in the Punjab, has not yet been perfected.

## SIND ROUGH ESTIMATES OF COST OF BARRAGES AND FEEDERS IN UPPER AND LOWER SIND.

*Sind estimates of barrages.*—Sind have furnished a "Note on Remedial Measures" purporting to be a rough estimate of the cost of barrages in Upper and Lower Sind (Sind Sheet 169).

*Nicholson Trench Report, pp. 19 and 20.*—Reference is made to the remedial measures, suggested by Messrs. Nicholson and Trench in 1930, to counteract the effects of lower water levels in the river. The Nicholson Trench Report, however, concluded that no remedial measures would be necessary.

*Remedial Measures already carried out.*—Sind then proceed to explain how they have already carried out some of these remedial measures and are proceeding with others, which may be feasible.

*Feeders alone not practicable.*—The practicability of providing feeders for the major canals has been examined by Sind and it is pointed out that this is feasible only if the gain in water level by the river course is more than the extra head required for the concerned feeder itself.

NOTE ON SIND'S ROUGH ESTIMATE FOR BARRAGES IN UPPER AND LOWER SIND.

The main features are set out below.

| —— | Upper Sind. | Lower Sind. |
|---|---|---|
| Proposed Location .. | Opposite Desert Head (Gudu) | Hajipur. |
| Feeder Canals and Capacities | Desert Feeder 10,392 cusecs.<br>Begari Feeder. 13,927 cusecs.<br>Left Bank Feeder. 9,125 cusecs. | Pinyari & Other Canals 16,126 cs.<br>Fuleli 15,013 cs.<br>Right Bank 8,712 cs. |
| Nature of Canals .. .. | All kharif canals except for bosi rabi. | Fuleli—some rabi to extent supplies available. Other canals kharif—except for rabi drinking water. |
| Cost—Rupees .. .. | Barrage & Head Regulators 4·32 crores.<br>Feeders 2·83 crores.<br>Developing irrigation ·78 crores.<br>Total .. 7·93 crores. | 3·93 crores.<br>2·58 crores.<br>1·35 crores.<br>7·86 crores. |
| | *Say 8 crores for each barrage.* | |

*N.B.*—(*i*) Proposals are based on Lloyd Barrage and costs of barrages are high compared with Punjab recent barrages.

(*ii*) These figures may be read with the total net consolidated assessment of Upper and Lower Sind inundation canals post barrage, of 27·4 lakhs (and a minimum in 1934-35 of 20·8 lakhs). (Sind Sheet 222). The outlay on basis of conserving net revenue would require greater justification than above figures indicate.

(*iii*) Comparsion is made below of the large area served by the present Lloyd Barrage and the present area of cultivation under the inundation canals of Upper and Lower Sind. The financial state of the present Lloyd Barrage is based on this large area. The necessity for large extensions of irrigation under the two new barrages will also be seen. The figures are taken from the 1938-39 Sind Administration Report pp. 117, 135 and 141, and pp. 84 and 85.

| | |
|---|---|
| Total Cultivation,—Inundation Canals,—Upper and Lower Sind. Productive and Unproductive Kharif+ Rabi (Bosi). | 1,500,190 acres. |
| | 1,094,081 acres. |
| Total Cultivation—Lloyd Barrage, Kharif+Rabi .. | 3,223,027 acres. |
| | 2,686,622 acres. |

*Upper Sind.*—For Upper Sind it was found that with a silt factor of 1·0, feeders, without a barrage for the Desert and Left Bank Canals, are not feasible. The rough cost of feeders was, however, worked out to be nearly 3 crores for Upper Sind.

*Note on Feeders without Barrages—Upper and Lower Sind.*—Sind have furnished notes on the feeders, without barrages—for Upper and Lower Sind. A note is also furnished on Lacey's Silt Factor,—explaining the factors that it is necessary to adopt in the special conditions applying in Sind, and the working gradients required (Sind sheets 229—238).

*Lower Sind.*—Although it is stated feeders without a barrage cannot command the Right Bank Areas and the Vazirani system with a silt factor of 0·9,—yet a rough estimate of 6·42 crores is given as the cost of feeders with a silt factor of 0·8.

*Sind claims against the Punjab for barrages.*—Financial forecasts are furnished by Sind, which show that both the barrages would be very definitely non-productive, though it is pointed out that the forecasts are based on 6 per cent. interest, in the absence of information of what the value of money will be post-war for such enterprises. In order to relieve Sind of the burden of non-productive barrages, they ask for a general decision that, " the Punjab should be required to contribute to the costs of both Barrage Schemes in Sind to an extent necessary to make both the projects productive ". They also say that this would be met by ten yearly payments by the Punjab of Rs. 53·97 lakhs and Rs. 58·88 lakhs for the Upper and Lower Sind Barrages respectively, on the basis of the Sind forecasts and 6 per cent. interest. This would reduce under these Sind calculations to 10 yearly payments of Rs. 31·18 lakhs and Rs. 40·65 lakhs respectively with a rate of interest of 4 per cent. (Sind sheet 171.)

With respect to this claim by Sind, it may be stated :—

1. That the rough estimates of cost are very high compared with the cost of recent barrages in the Punjab,

according to figures furnished by the Punjab during the Proceedings.

*Sind replies to Criticism of the two Barrage Estimates.*—Sind have submitted at the end of the last session, a "Note on Criticism Made by Punjab on Barrage Projects". It is stated that the reasons for the lower Punjab costs were :—

(*i*) that the Punjab projects were built when rates were low,

(*ii*) the machinery used was transferred from one barrage to another and

(*iii*) the sites at which the Punjab Barrages are built, are all much less difficult ones, than that of the Gudu Barrage. (Sind Vol. II, p. 153).

It is further contended that it is not possible to reduce the size of the feeders by altering the cropping intensities provided, as,—

*Upper Sind*—

(*i*) There is no rabi supply available, so the canals must be non-perennial,

(*ii*) It would not be possible to change to dry kharif, when large areas of rice are established ;

*and for Lower Sind*—

(*i*) Rabi supplies of 2000 cusecs only can be depended on in February/March ;

(*ii*) Due to the saline soil rice crops only are suitable.

However, there seems little prospect of Barrages for Sind if better financial forecasts do not mature, after the investigation for new barrages—which, it is understood, is now in progress—is completed. This will be dealt with by the Committee proposed under "Recommendations" in Vol. I of this Report.

2. The forecasts are so prepared that the capital cost of the barrages would be liquidated in a few decades.

3. Whatever may be the accuracy of the financial forecasts, —the figures produced, would discourage consideration of such schemes. It is pointed out that the total increase in cultivation proposed under the 2 barrages is only 19 lakhs of acres (Sind Vol. 1, Sheets 174—180), which, apart from the improvement to the existing area of cultivation, makes a high acreage rate at a 16 crore

initial capital cost. The payments required of the Punjab would amount to injunctions against their schemes.

In view of the large drops post barrage in net consolidated assessment of Sind Inundation Canals, shown by Appendix D to their "Note on Canal Irrigation in Sind" (Sind Sheet 40), Sind were asked by the Commission to examine the feasibility of assessing the compensation to be claimed from Punjab—due to the contemplated Punjab withdrawals, by—(Sind Sheet 274).

(*a*) co-relating the drop in canal gauge reading in September pre and post barrage calculated for certain canals, with the drop in the net consolidated revenue, obtained on those canals, and

(*b*) co-relating the mean discharge for the period, 1st June to 30th September, with the net consolidated revenue, pre and post barrage.

An amended statement of Net Consolidated Assessment Totals for Upper and Lower and for whole of Sind, was later put in by Sind, superseding the Appendix D (Sind Sheets 222 and 223).

The object was to use the drops in revenue, due to drops in levels as a yard stick for applying to the calculated drops due to the additional Punjab withdrawals.

Subsequently,—as pointed out elsewhere in this report,—Sind furnished figures to show that the Lloyd Barrage did not withdraw more than the Inundation Canals replaced, in the months July and August and only a small excess in September. (Sind Sheet 64.) (Punjab Vol. III, pp. 87 and 98.)

*Sind not agreeable to work out Punjab responsibility on basis of drop in revenue etc.*—Sind was, also, not agreeable to work out Punjab responsibility on basis of probable loss of revenue, as that does not represent the total amount of damage which would be sustained by the Province (Sind Sheet 171).

Sind again refer to their remission rules and state :—

"From the data available in the Administration Report, it is not possible to say how any given sum of remission is made up. It may be partial, or some partial and some total or all total remission. The remission given is, thus, no guide at all to the total loss likely to occur from lower supplies in the Sind Canals".

Various other objections are offered by Sind to this method of assessing their claim against the Punjab. It is further stated that the Sind calculations, purporting to show the loss in revenue on the Desert and Unhar Canals, which would result from the contemplated Punjab withdrawals and of the reduction in rabi cultivation, were made only to show the order of the effect of the Punjab withdrawals on remissions and rabi cultivation, and not with any idea of formulating a money claim (Sind Sheet 172).

*Sind claim against Punjab Projects operating before Sind Barrages.*—Sind further claim that the Punjab Projects should not commence to operate until the two barrages and the necessary feeders, etc., in Sind have been completed.

*Further Sind Note on claim against the Punjab.*—Sind were again asked by the Commission to formulate in more definite terms their claim against the Punjab,—apart from the question of barrages. A reply was given in a note on " Probable effect of Punjab withdrawals on Inundation Canals in Sind " (Sind Sheet 183).

In this Note, Sind stated that her position was, that the injury caused to Sind (by the additional Punjab withdrawals) would be irreparable, that is,—Sind could not be adequately compensated in damages.

During the Proceedings Sind was also asked if she could not work out the area that would be thrown out of command on the inundation canals due to the Punjab withdrawals. This was stated to be not readily possible.

In this Note also, it is stated, " It is difficult to estimate the area that will be thrown out of command without detailed investigations ". However certain percentages are worked out and it is stated that the depreciation of the land will exceed 18 crores of rupees. Loss due to reduction of Katcha cultivation and forests is also referred to, with the conclusion that a contribution to barrages would be less costly to the Punjab.

In the Proceedings of 25th April 1942, the Sind Counsel stated, " Section 54 of the Specific Relief Act [sub-clauses (*b*) and (*c*)] applies here absolutely. Pecuniary compensation could not form adequate relief and you cannot measure pecuniary compensation, for it is quite impossible to measure. I am not going to try it * * * * * * * * * "

This attitude has not been helpful to the Commission in trying to assess the probable damage to Sind due to the Punjab contemplated withdrawals and to arrive at a workable figure of assistance to Sind.

*Punjab Note on Additional Supplies by two Barrages.*—The Punjab have submitted a graph (Punjab No. 43) with supporting statements purporting to show the "Additional Supplies which will become available to Sind by the construction of two new barrages in Sind." The purpose of the submission has not been explained in a Punjab Note. Sind have submitted a note called "Criticism of P. 43" in which certain difficulties are expressed by Sind in understanding the graph. (Sind Vol. II, p. 157).

We would point out with respect to both the Punjab note and the Sind rejoinder, that the Appendix I to the Punjab Note and the Revised Appendix I in the Sind rejoinder—*vide* S. II, 158, work from discharges at Kotri for the average of years 1932-40. By referring to the actual withdrawals at Sukkur that took place in the rabi months in the year just after opening of the barrage it is seen they were much below the authorizations for those months for the Lloyd Barrage. The authorizations have also not been commonly fully utilized throughout the rabi months. If, therefore, full authorizations are reserved for the Lloyd Barrage and the extra for Panjnad taken as in the Rabi case statements, the balance that will go to the sea in the rabi months will be much reduced.

## EXPLANATORY NOTE

ON

COMPENSATION WHICH MAY BE CONSIDERED AS EQUITABLY DUE TO SIND, FOR THE PUNJAB WITHDRAWALS CONTEMPLATED IN THEIR DEFENCE, HAVING REGARD TO—

1. What may be considered as fairly due to Punjab of Indus tributary waters under equitable apportionment.

2. The probable effects on the Sind inundation canals of the withdrawals contemplated in the Punjab Defence.

3. Expressions of opinion given in the past by the Government of the Punjab and Government of India on the protection of inundation canal interests.

4. Waste of water inherent in the continuance of inundation canals, beyond the period when the upper province is financially able to utilize that water in an economic manner.

It is accepted by both provinces that the problem is not one that admits of any exact computation of respective rights and liabilities. It resolves itself into a question of the extent to which the upper province can fairly assist the lower province, in extricating itself from difficulties inherent in an outmoded system of irrigation, when that upper province finds it necessary by pressure of

population to encroach on rights hitherto enjoyed by the lower province.

Punjab expresses confidence that Sind will not be materially injured by the withdrawals contemplated in the Punjab. Sind does not share that confidence. It is desirable for the Punjab to know the extent of her probable commitments before embarking on new schemes. The assessment of charges on other States sharing in the new projects cannot be properly arrived at otherwise. It is also desirable for Sind to know the extent of assistance which she may expect. This will enable her to work out such schemes to assist the inundation canal areas, which may be affected adversely by the projected Punjab withdrawals, as may be found financially feasible.

The following rough basis of assessing the amount of this compensation is explanatory of one approach to the problem. It is fully recognized that there is no feasible solution which can meet all the ramifications of the problem as it affects both Punjab and Sind. The figures adopted for the drops and the value of land, may, or may not, be close to probable actuals. In any event, weighing in all the factors, we consider two crores compensation a suitable figure, as a contribution towards protective measures for Sind.

It is not known if and when barrages may be found feasible for Upper and Lower Sind,—(this is dealt with under the heading remedial measures),—but certain rough relationships can be deduced from the costs of such measures.

(*a*) Cost of Barrages for Upper and Lower Sind.

Figures worked out by Sind are very high compared with the cost of recently constructed barrages in the Punjab. The rough figures furnished to the Commission by Sind are per lineal feet, Rs. 11,790 for Gudu and Rs. 12,010 for Hajipur. Punjab constructions have cost about Rs. 4,000 to 5,000 per L. F. A figure of Rs. 8,000 L. F. may be used for this purpose to allow for probable greater difficulties in construction in the lower main Indus river.

Waterway lineal feet.

Gudu 3,390, Hajipur 2,970, Lloyd Barrage 4,725.

Punjab about 3,000 to 4,000.

Adopt 8,000 lineal feet altogether for both barrages. Cost of both barrages would then be 6·4 crores, say, $6\frac{1}{2}$ crores.

Cost of feeders without cost of developing irrigation as given by Sind comes to about $5\frac{1}{2}$ crores. Punjab disclaims responsibility for share in the construction of feeders as they claim that the proposed barrages are not sited merely to maintain the existing protection to the inundation canals, with least cost for feeders. This may be so, but it would also not be desirable to locate the barrages with this object only in view, as the maximum efficiency would be necessary to enable the barrages to be productive in any event.

The total cost of 2 barrages and their feeders, without cost for developing irrigation may then be roughly $6\frac{1}{2}+5\frac{1}{2}=12$ crores.

If it be assumed that the Sind and Punjab figures of September drops in discharges due to the Punjab contemplated withdrawals give some idea of the area of land that will go out of economic cultivation, then the percentage may be taken as $\frac{*16\cdot1+2\cdot5}{2}$ or, say, 10 per cent.

* The average drops in September discharges for the 6 selected years for the Sind Major Inundation Canals is worked out by the Punjab at page 322 of their Volume 3 to be—Set A calculations=16·1 per cent., Set C calculations=2·5 per cent. for the whole of Sind Province. The figures are not sufficiently reliable to warrant taking the drops separately for Upper and Lower Sind. September discharges are probably the most vital to Sind Inundation Canals, as explained in this report, but are, of course, not a full measure of damage.

(During the Proceedings Sind was asked, if they could furnish figures of the extent of land that would go out of command after the Punjab Projects, but they were unable to do so.)

The area of occupied land on this basis that would be rendered unsaleable would be, (Sind Sheet 174)—

160,925 acres in Upper Sind, with a value of 1,60,925 × 80 = Rs. 1,28,74,000.

(Rs. 80 was the value given on Sind sheet 173 for Upper Sind land),

and

1,07,978 acres in Lower Sind with a value of 1,07,978 × 50= Rs. 53,98,900. Rs. 50 was the value given in Sind Sheet 177, for Lower Sind land (Sind Sheet 178).

Total value of this land going out of economic cultivation=1·8 crores or, say, 2 crores.

This figure could be adopted as a reasonable amount for the Punjab contribution to the barrages. (This amount might have to be applied by Sind, all on the construction of one barrage,

possibly for Lower Sind, to permit a closer approach to a productive enterprise. The average percentage drop in discharge for all Lower Sind Major Inundation Canals is more than the total average for Upper Sind. (Punjab. Vol. III, p. 316).

The reasonableness of the suggested figure of Rs. 2 crores may be looked at from the following points of view :—

(*a*) On pp. 8 and 9 of the Punjab Defence Vol. I, expenditure on famine relief, direct and indirect is given as about 3½ crores in about 3 or 4 years. Part of such expenditure would be saved to the Punjab by the contemplated Punjab projects. There is also the possibility that some part of the burden might be passed on to Sind. Punjab have explained in the last session of the Commission that the figures of expenditure quoted by them in their Defence Vol. I for famine relief were exceptionally high.

(*b*) The figures of probable cost of the Bhakra Dam as furnished during the proceedings was Rs. 10 to 12 crores inclusive of canals. The relief proposed for Sind is within reasonable limits, especially when past opinions of the Governments in regard to protection to inundation canals are examined and when it is noted that the contemplated Punjab withdrawals may force at least one, if not two, costly barrages on Sind.

B. N. RAU, *Chairman.*

P. F. B. HICKEY
E. H. CHAVE } *Members.*

SIMLA,
*July 13, 1942.*

# APPENDIX I.

## GLOSSARY OF TECHNICAL AND VERNACULAR TERMS IN CONNECTION WITH IRRIGATION IN THE PUNJAB AND SIND.

(The Glossary is based on the Central Board of Irrigation Publication No. 5.)

# APPENDIX I.

GLOSSARY OF TECHNICAL AND VERNACULAR TERMS IN CONNECTION WITH IRRIGATION IN THE PUNJAB AND SIND. (The Glossary is based on the Central Board of Irrigation Publication No. 5.)

## PART I.

### *Glossary of Technical Terms.*

| | |
|---|---|
| Absorption Loss .. | Loss of water from a canal or reservoir by capillary action and percolation. |
| Accretion of Levels .. | Converse of degradation or retrogression of levels. A rise in specific levels of the bed of the channel at any site. |
| Acre Foot .. .. | A unit of volume used in irrigation practice. It means the volume of water required to cover an acre to a depth of one foot. It amounts to 43,560 cubic feet. |
| Annual Intensity .. | The term applied to the percentage of the culturable irrigable (Punjab,—commanded) area irrigated during the year. The Project Intensity is the annual intensity aimed at in the project. |
| Annual Mean Monthly Range Averaged or Smoothed over five years. | The average of 5 successive annual mean monthly ranges (plotted in the graphs at the 3rd or central year). |
| Area Assessed .. .. | The area irrigated upon which water rates are levied. |
| Area Matured .. .. | The area irrigated upon which crops have matured. |
| Area Remitted .. .. | The area irrigated for which water rates are remitted owing to failure to mature or other reasons. |
| Authorized (or Designed) Full Supply Discharge. | The maximum discharge for which a channel is designed. In irrigation practice the authorized full supply discharge should never be exceeded. |
| Available Supply .. | (*a*) In the river.—The discharge passing at the moment.<br>(*b*) In a tank.—The quantity of water stored in the tank above cill of lowest sluices or minimum authorized water level.<br>(*c*) At the head of a canal.—The authorized share of the river discharge pertaining to a canal.<br>(*d*) Other channels.—The discharge flowing. |
| Average Supply .. | The average supply in a channel is the sum of the daily discharges at the head of the channel divided by the number of days when the channel is in flow. |
| Barrage .. .. | A weir equipped with a series of sluice-gates to regulate the water surface level above it. |
| Base, Base Days or Base Period. | The number of days in a crop. For example, in the Punjab it numbers 183 for Kharif and 182 for Rabi. |
| Canal Losses .. .. | See Total Losses. |
| Capacity .. .. | (*i*) When applied to a channel, the authorized full supply discharge.<br>(*ii*) When applied to a reservoir or tank, the Gross Capacity is the quantity of water stored between lowest sluice level and the level of the cill of the waste weir. |

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| Capacity Factor .. | The ratio of the mean supply to the authorized full supply or capacity. |
| Conveyance or Transmission Loss. | Loss of water from a channel due to evaporation and absorption. |
| Crop Ratio .. .. | The Crop Ratio or Kharif to Rabi ratio is defined as the ratio between the anticipated areas to be irrigated of these two crops. |
| Culturable Commanded area | The gross area commanded less the area of unculturable land included in the gross area. See also page 124, Vol. III, 1935, C. B. I. Committee's Report. |
| Culturable Irrigable area (Or C. C. A. in Sind). | The gross irrigable area less the area not available for cultivation, *e.g.*, village areas, roads and isolated patches of unculturable lands. |
| Cusec .. .. .. | The unit of discharge used in irrigation practice and means a rate of flow of one cubic foot per second. |
| Cusec Day .. .. | A unit of volume used in irrigation practice and means the volume of water resulting from a discharge of one cusec for one day (24 hours). It amounts to 86,400 cubic feet of water.<br>It will be noticed that a Cusec Day is 1·98 acre feet (ordinarily taken=2). |
| Cusec Month .. .. | The volume of water resulting from a discharge of one cusec for one month. |
| Cut-off.. .. .. | The difference between the water levels up-stream and down-stream of a regulator, or the difference in levels between a parent and off-taking channel. |
| Dam .. .. .. | A structure erected to impound water, thus forming a reservoir. |
| Delta .. .. .. | An expression used in irrigation practice to mean the depth of water that would result over a given area from a given discharge for a certain length of time. Alternatively, the Delta may be defined as the total volume of water delivered, divided by the area over which it has been spread.<br>It will be noticed that a cusec day on one acre results in a delta of 2 feet. It is clear that owing to the total losses in a channel, the delta will vary with the place at which the discharge is measured which should be stated thus : at field, outlet or head of channel. |
| Designed or Authorized Full Supply Discharge. | See under Authorized or Designed Full Supply Discharge. |
| Discharge .. .. | The rate of flow at a stated site, *i.e.*, the quantity of water passing in unit time. |
| Double Crop .. .. | The raising of two successive crops on the same field in one irrigation season. The crop that is first cut is called the " first crop " and the crop harvested later in the season is called " second crop ". |
| Dry Crop .. .. | A crop which is raised entirely with the help of rainfall. Also crop other than rice or sugar in Sind. |

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| Duty .. .. .. | Duty is the relation between the area irrigated and the quantity of water required to irrigate it.<br>When applied to a channel it is the area irrigated during a base period divided by the mean supply utilized in cusecs. When applied to tank irrigation it is the number of acres of irrigation per million cubic feet of impounded water. |
| Duty on Capacity (Punjab—Full Supply Duty). | The full supply factor attained by a project system or channel after it has been opened for irrigation. |
| Duty of Water .. .. | The relation between the area of land served and the quantity of irrigation water used. When applied to a channel, it is the area irrigated during a base period divided by the mean supply utilised in cusecs. |
| Flow Irrigation or Flow area. | Area which can be irrigated from the source of water, by flow under gravity alone. |
| F. S. L. .. .. | Full Supply Level. |
| Full Supply Factor .. | The area estimated to be irrigated during the base period divided by the authorized, or designed full supply discharge of the channel at head (F. S. F. at distributary head) or at the outlet (F. S. F. at outlet).<br>NOTE (*i*).—The full supply factor is assessed for purposes of project making, in the light of experience.<br>NOTE (*ii*).—Once a project is opened for irrigation, the full supply factor attained is usually known as the Duty on Capacity. |
| Gross area .. .. | The total area within the extreme limits set for irrigation by a *project system or channel.* |
| Gross Commanded area .. | This is the total area which can be irrigated economically from a canal scheme on the supposition that unlimited water is available.<br>NOTE.—In Sind by economical lift also. |
| Gross Irrigable area .. | The gross area less such large compact areas as are excluded from the project by reason of their being unsuitable for irrigation either on account of the nature of the soil, or because the ground is too high to be economically irrigated by "lift." |
| Gross Lift Area .. .. | That portion of the gross irrigable area which can be irrigated economically by "lift" only. Gross Commanded Area plus Gross Lift Area equals Gross Irrigable Area. |
| Head or Head Regulator .. | This term is usually applied to the control work constructed at the off-take of a channel subsidiary to a main canal. |
| Head Works .. .. | The works constructed at the off-take of a main canal. It includes the weir on the river, the dam at the storage site, etc. |
| High Flood Level (H.F.L.) | The highest level of the water surface of a reservoir or tank. Also applied to streams and rivers. |
| *Hydrograph* .. .. | *A graph showing the stage, flow, velocity, or other property of* water, with respect to time. |
| Hydro-Isobaths .. | Contours of similar depth of the sub-soil water table below the ground surface. A 5 foot hydro-isobath is a line indicating where the sub-soil water table is at a depth of 5 feet from the ground surface. |

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| Intensity .. .. | The term applied to the percentage of the culturable irrigable area irrigated during a year or during a crop. |
| Inundation Canal .. | This term is ordinarily applied to a canal with or without some form of head regulator, and dependant upon the surface level of the water in the river for its supplies. It follows that Inundation Canals will only run when the supply in the river rises to a level which permits of feeding the canals. |
| Lift Irrigation or Lift Area | Area of which the level is too high to allow of irrigation by flow from the source, but which can be economically irrigated by water raised by pumps or other lifting devices to the necessary level, at some point in the supply system. |
| Long Crop .. .. | The term is used generally to denote a crop, that takes more than four months to mature. As a relative term, it denotes the longer of the two crops on a double-cropped land, the other crop being called " short crop ". |
| Mean Monthly Discharges | Discharges, observed or interpolated daily, and averaged over a calendar month. |
| Mean Monthly Discharges Averaged or Smoothed Over Five or Nine Years. | Mean monthly discharges for the same month averaged over five or nine successive years. Plotted in the hydrographs at the central year in each case. |
| Mean Monthly Gauge Readings or Levels. | Gauge readings or reduced levels read daily and averaged over a calendar month. |
| Mean Supply .. .. | The sum of the daily discharges at the canal head divided by the number of days in the base period. |
| Non-Perennial Area .. | The area served by a non-perennial channel. |
| Non-Perennial Channel .. | A channel which is designed to irrigate during only part of the year, usually in the " Kharif " or summer season and at the beginning and end of the " Rabi " or winter season. |
| Perennial Area .. | The area served by a perennial channel. |
| Perennial Channel ... | A channel which is designed to irrigate all the year round. |
| Retrogression of Levels .. | The lowering of the water surface level due entirely to the abstraction of water and consequent diminution in the flow downstream, and/or the lowering of the specific level, *i.e.*, of the level of the water surface for a given discharge. |
| Riparian .. .. | Pertaining to the banks of a stream or body of water ; a riparian owner is one who owns the banks ; a riparian right is the right to control and use water by virtue of the ownership of the bank or banks. |
| Rotational Working .. | When the demand exceeds the available supply, recourse is had to the system known as Rotational Working. This system is applied to channels or to groups of outlets. Each channel or group of outlets takes a turn of full supply for a certain number of days, the others being closed to admit of this. The unit period for which the channels or outlets run, or are closed is known as a Rotational Turn. |

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|---|---|
| Specific Gauge Reading or Level. | The gauge reading or level of the water surface at any particular site for a given discharge. |
| Time Factor .. .. | The ratio of the number of days the channel is in flow to the base days. |
| Time-Lag .. .. | The time elapsing between the occurrence of any alteration of discharge or level at one point on the river and its occurrence at another point. |
| Total Losses .. .. | The sum of loss of water by absorption, percolation and evaporation. The total losses in a channel may be defined as the difference between the discharge at head of a channel and the useful discharge, *i. e.*, the sum of the off-taking discharges. These are also called " Canal Losses " and are usually expressed in terms of cusecs per million square feet of wetted perimeter. |
| Undersluices .. .. | Weir sluices designed to maintain the course of a river in the desired position. |
| Water Course .. .. | The term applied to an irrigator's channel taking its supply from a Government channel, from which fields are irrigated directly. |
| Water-Logged .. .. | Land may be classified as water-logged when the water-table is permanently located at ground level. The approach of this condition is indicated when the yield of crops commonly grown in the locality is reduced, by the rise of the water table, below the normal that would be expected from the soil type of that area. |
| Water Allowance .. | The outcome of all considerations of the duty of water, intensity, proposed crop rates, water available, etc., is the fixing of the Water Allowance.<br><br>Water Allowance may be defined as the number of cusecs of outlet capacity, authorised per 1,000 acres of culturable irrigable area. The Water Allowance, therefore, not only defines the size of outlet for each outlet area but also forms the basis for the design of the distributing channels in successive stages. |
| Water Requirement .. | The total quantity of water, regardless of its source, required by crops for their normal growth under field conditions. See also Irrigation Requirement. |
| Weir .. .. .. | An artificial barrier across a river (or canal) to raise the water above the natural level in order to supply a canal or canals taking off above it and to pass over its top the excess water. |
| Weir Controlled Canal .. | A canal taking its supply from a river or branch of a river in which there is some artificial obstruction which raises the level of water in the river above its natural level so that the canal may be fed. |

## Part II.

*Glossary of Vernacular Terms.*

| Vernacular Expression. | English Equivalent. | Province. |
|---|---|---|
| Abiana .. .. | Water rate .. .. .. .. | Punjab. |
| Abkalani .. .. | The inundation season .. .. It extends from the 1st May to the 15th October. | Sind. |
| Barani .. .. | Lands on which crops are grown on rain water only or depending on rain. Also cultivation done on rain. | Punjab. |
| Bela .. .. | River valley, or shoal or island in a river | Punjab and Sind. |
| Beldar .. .. | A labourer .. .. .. .. | Punjab. |
| Bosi .. .. | A crop sown with the aid of canal water but receives no further watering after sowing. | Sind. |
| Bund .. .. | Earthen embankment .. .. | India. |
| Chahi .. .. | Irrigated by wells .. .. .. | Punjab. |
| Chak Boundary .. | The irrigation boundary of an outlet .. | Punjab. |
| Chakha or Hurlo .. | A Persian wheel .. .. .. | Sind. |
| Charkhi .. .. | Watered by lift .. .. .. | Sind. |
| Desi .. .. | Of the country .. .. .. | Punjab and Sind. |
| Dhand .. .. | A lake .. .. .. .. | Sind. |
| Dhoro .. .. | A natural depression or ancient river channel. | Sind. |
| Dofasli .. .. | Double cropped or two crops per season | Punjab. |
| Dubari .. .. | A second crop grown on the irrigated land of the first crop, without further watering. | Punjab. |
| Ekfasli .. .. | Yielding one crop per season .. .. | Punjab. |
| Fasal .. .. | Crop .. .. .. .. | Northern India and Bengal. |
| Gaur .. | A hot weather crop grown chiefly for fodder. | Sind. |

| Vernacular Expression. | English Equivalent. | Province. |
|---|---|---|
| Hakabo .. .. | Water tax paid by Jagirdars .. .. | Sind. |
| Hari .. .. | Cultivator or ploughman .. .. | Sind. |
| Jowar .. .. | A millet grown in the hot weather .. | Sind. |
| Kabuli .. .. | Occupied .. .. .. .. | Sind. |
| Kalar .. .. | Salt impregnated soil in Sind .. .. | Sind and Punjab. |
| Kairo .. .. | Watercourse .. .. .. | Sind. |
| Katcha .. .. | Low lying tract along a river which generally gets submerged during inundation season. | Sind. |
| Khadi .. .. | River valley ; low alluvial lands .. | Punjab. |
| Kharaba .. .. | Failed crop .. .. .. | Punjab and Sind. |
| Khatedar .. .. | The occupant of a separate holding, a small land owner. | Sind. |
| Kor .. .. | First watering after crop is sown .. | Punjab. |
| Malkano .. .. | The amount paid to Government for the possession of land. | Sind. |
| Murabba .. .. | Literally a square—the term means a square or a rectangle of land. On the Lower Chenab Canal, land was allotted in squares of about 28 acres each. On the new canals rectangles of 25 acres were allotted. | Punjab. |
| Nakabuli .. .. | Unoccupied .. .. .. | Sind. |
| Pancho .. .. | Water drained off from rice fields .. | Sind. |
| Rabi .. .. | Winter season (October to March) or the winter crop harvested in spring. | Sind and Punjab. |
| Raoni .. .. | First or preliminary watering of a field | Punjab. |
| Rah .. .. | Land with high salt content .. .. | Punjab. |
| Rej .. .. | Irrigation. The first watering given to land before sowing. | Sind. |
| Sailab .. .. | Flood .. .. .. .. | Punjab. |
| Sailaba .. .. | Flood irrigation .. .. .. | Punjab. |

| Vernacular Expression. | English Equivalent. | Province. |
|---|---|---|
| Sailabi .. .. | Watered by flood or river overflow .. | Sind. |
| Sawni .. .. | Summer crop .. .. .. | Punjab. |
| Sclab .. .. | An inundation flooding. Natural overflow of water from floods. | Sind. |
| Sem .. .. | Seepage .. .. .. .. | Punjab and Sind. |
| Shikargah .. | Hunting grounds .. .. .. | Sind. |
| Takavi .. .. | An advance given by Government to an agriculturist for buying seed, etc. | Punjab and Sind. |
| Thar .. .. | Any arid desert. The desert lying to the east of Sind. | Sind. |
| Tibba (Sand) .. | Wind drifted sand dunes .. .. | Punjab. |
| Wah .. .. | Main water Channel .. .. .. | Sind. |
| Waro .. .. | Turn or rotation .. .. .. | Sind. |
| Zaid-Kharif .. | Late summer crop .. .. .. | Punjab. |
| Zaid-Rabi .. | Late winter crop .. .. .. | Punjab. |
| Zamindar .. .. | Landowner .. .. .. | Punjab and Sind. |

# APPENDIX II.

## LISTS OF PLANS, GRAPHS, DRAWINGS AND RELEVANT STATEMENTS PRODUCED BY SIND AND PUNJAB.

(Other than the main volumes produced by them, namely, Sind "Rabi Case" and "Kharif Case—Volumes I and II" and the "Punjab Defence", Volumes I, II, III and III-A.)

# PART I.—LISTS OF GRAPHS, PLANS, AND OTHER DOCUMENTS PRODUCED BY SIND.

(APART FROM THE MAIN VOLUMES—"RABI CASE", AND "KHARIF CASE", VOLS. I AND II.)

## LIST I.—*Graphs, Plans, etc.*

| Serial No. | Details of Graph or Plan. | Drawing No. | Total number of sheets. |
|---|---|---|---|
| 1 | Graphs showing daily maximum average temperature of ten years 1930-39 for stations in Sind and Punjab. | .. | 1 |
| 2 | Graphs showing meteorological conditions in Sind and Punjab in Rabi season. | R/8 *a* | 1 |
| 3 | Graphs showing meteorological conditions in Sind and Punjab in Kharif season. | R/8 *b* | 1 |
| 4 | Graphs showing correlation of Forest areas and average of ten years highest gauges at Kotri 1908-40. | .. | 1 |
| 5 | Demand graphs of Inundation Canals .. .. | .. | 15 |
| 6 | Graphs showing Specific Discharge Gauge Curves for 8 sites above Barrage (uncorrected for losses and withdrawals) from 1932-1940. | K/1/1-8 | 16 |
| 7 | Specific Discharge Gauge Graphs for Sarhad for rising and falling and mean (in two sheets) corrected for losses and withdrawals from 1931-40. | K/3/1-2 | 2 |
| 8 | Kotri Specific Discharge Gauge Curve (Extension of Nicholson-Trench graphs to bring it up-to-date). | K/4 | 1 |
| 9 | Kotri Specific Discharge Gauge Curve plotted from Smoothed Gauge Discharge Curves. (1912-1940). | K/6 | Replaced by item No. 53. |
| 10 | Smoothed Gauge Discharge Curves for Kotri for item 9 above from 1910-30. | K/5/1-21 | 21 |
| 10A | Sarhad and Kotri Gauge Discharge Smoothed Curves for 1931-40 (corrected for loss and withdrawals). | K/5/Sarhad<br>K/1/1931-40 | 22 |
| 11 | Superimposed Sarhad Gauge Graphs for 1931-41 .. | K/7/Sarhad | 1 |
| 12 | Superimposed Kotri Gauge Graphs for 1921-41 .. | K/7/Kotri | 1 (In two pads.) |
| 13 | Attock Gauge Graph for 1921-41 (Superimposed) .. | ... | 1 |
| 14*a* | Smoothed Gauge Discharge Curves for Bhago Toro for the years 1932-40 (corrected for losses and withdrawals). | ... | 14 |
| 14*b* | Do. Machka Do. .. | ... | 14 |
| 14*c* | Do. Bachalshah Do. ... | ... | 19 |

| Serial No. | Details of Graph or Plan. | Drawing No. | Total number of sheets. |
|---|---|---|---|
| 15 | Specific Gauge Discharge Curves for Machka (corrected for losses and withdrawals). | .. | Superseded by item No. 35. |
| 16 | Graph showing 10-days average gauges at Sukkur for April, May, June and September 1920-41. | K/8/1-4 | 4 |
| 17 | Graphs showing 10-days average gauges at Kotri for April, May, June and September 1914-41. | K/9/1-4 | 4 |
| 18 | Graphs showing cultivation in the Karachi Canals Division 1929-30 to 1939-40. | .. | 1 |
| 19 | Do. Fuleli Canals 1927-28 to 1939-40 .. | .. | 1 |
| 20 | Graphs showing effects of Punjab withdrawals on Sarhad Gauge. | K/1/S | Replaced by item No. 51. |
| 20A | Do. Kotri Gauge .. .. .. | K/1/K | |
| 21 | Punjab Graph P-92 brought up-to-date .. .. | R/1 | 1 |
| 22 | Graph of supplies available and anticipated after Haveli and Thal projects mature showing Rabi five-day average hydrograph of deficiencies at Sukkur. | R/3 | 1 |
| 22A | Graph of supplies available and anticipated after Haveli and Thal projects and deficits below Zero showing Rabi five-day average hydrograph of authorized withdrawals of Sukkur Barrage deducted from balances at Sukkur after Thal withdrawals. | R/3A | 1 |
| 23 | Graph showing cultivation in the Rabi sowing season | R/6 | 1 |
| 24 | Plate III (part) of D. W. I. Committee Proceedings Vol. III modified to show mean discharge at Sukkur in 1922-23 to 1933-34 in relation to authorized withdrawals. | R/4 | 1 |
| 24A | Do. for 1934-35 to 1940-41 (R/4 extended) | R/4A | 1 |
| 24B | Do. showing discharge at Sukkur less discharge at Islam in 1922-23 to 1926-27 and authorized withdrawals of Punjab and Sind. | R/4B | 1 |
| 25 | Graphs showing effects of Sutlej Valley and Punjnad, Haveli and Sukkur Barrage on the gauge at Kotri for 1932-1940. | .. | 9 |
| 26 | Graph showing daily, 5-day, 10-day and monthly mean Sarhad Gauges for 1935. | .. | 1 |
| 27 | Yearly graphs for daily observed losses or gains between Kalabagh, Panjnad and Sukkur during Rabi months (1924-40). | .. | 16 |
| 28 | September monthly, last 10-day average G. Rs. with 5 yearly trends for Unharwah for 1931-40. | .. | 1 |

| Serial No. | Details of Graph or Plan. | Drawing No. | Total number of sheets. |
|---|---|---|---|
| 29 | Graph comparing the actual discharge at Kotri with the average 2-day, 5-day, 10-day and monthly gauges at Kotri predicted from the Sukkur discharges and withdrawals. | .. | 1 |
| 30 | Graph showing the net consolidated land revenue from lands irrigated by some major Inundation Canals in Sind in the years 1920-21 to 1938-39. | .. | 1 |
| 31 | Graphs showing the average 10-daily gauges in September of the major Inundation Canals in Sind. | .. | 11 |
| 32 | Map of portion of Shikarpur Collectorate (1859) .. | .. | 1 |
| 33 | Map of Canals in Hyderabad Collectorate .. .. | .. | 1 |
| 34 | Map of a portion of Lower Sind (1853) .. .. | .. | 1 |
| 35 | Specific discharge gauge curve for Machka, 1928-41 .. | .. | 2 |
| 36 | Specific discharge gauge curve for Site No. 5, Begari Head. | .. | 2 |
| 37 | Specific discharge gauge curve for Site No. 6, Unharwah, 1931-41. | .. | 2 |
| 38 | Specific discharge gauge curve for Bachalshah, 1923-41 .. | .. | 2 |
| 39 | Specific discharge gauge curve for Bhagotoro, 1928-41 .. | .. | 2 |
| 40 | Smoothed gauge discharge curve for Site No. 5, Begari Head, 1931-41. | .. | 11 |
| 41 | Graph showing the statistical correlation between discharge and— | .. | 1 |
| | (1) Rabi .. .. .. .. .. | .. | |
| | (2) Rice cultivation .. .. .. .. | .. | |
| | (3) Equivalent Dry Kharif .. .. .. | .. | |
| | and the statistical correlation between the discharge and the remission for Desert Canal. | .. | |
| 42 | Graph showing the statistical correlation between the discharge and— | .. | 1 |
| | (1) Rabi .. .. .. .. .. | .. | |
| | (2) Rice cultivation, and .. .. .. | .. | |
| | (3) Equivalent Dry Kharif .. .. .. | .. | |
| | the statistical correlation between the discharge and remission on the Unharwah Canal. | .. | |
| 43 | Graphs showing periodogram curves for rainfall in Sutlej catchment 1865-1940. | .. | 1 |

| Serial No. | Details of Graph or Plan. | Drawing No. | Total number of sheets. |
|---|---|---|---|
| 44 | Graph showing frequency distribution of Kharif rainfall for the combined Sutlej, Beas and Chenab catchments. | .. | 1 |
| 45 | Graph showing frequency distribution of Kharif rainfall for the Indus catchment. | .. | 1 |
| 46 | Graph showing frequency distribution of rainfall in Sutlej catchment, 1865-1940. | .. | 1 |
| 47 | Smoothed gauge curves for Site No. 6, Unharwah, 1931-41. | .. | 11 |
| 48 | Graph showing cultivation, revenue, remission, rainfall and the corresponding discharges for various years for Desert Canal. | .. | 1 |
| 49 | Graph showing cultivation, revenue, remission, rainfall and the corresponding discharges for various years for Unharwah Canal. | .. | 1 |
| 50 | Canal hydrographs showing levels and gauges and discharges as well as reference gauge reading with likely drops due to Punjab projects. | .. | 183 |
| 51 | Sarhad and Kotri gauge hydrographs showing likely drop due to Punjab projects required for reference gauge reading. | .. | 22 |
| 52 | Index Plan of Sind showing the eroded and existing bunds in the Province of Sind. | .. | 1 |
| 53 | Kotri specific discharge gauge curves plotted from smoothed gauge discharge curves (1912-1940). | .. | 1 |
| 54 | Specific gauge discharge curves for Indus at Kalri (1924-1941). | .. | 2 |
| 55 | Smoothed gauge discharge curve for Kalri 1924-41 .. | .. | 18 |

## List II—*Statements.*

1. Statement showing discharges withdrawn by Inundation Canals in years 1922-1940.
2. Gauge discharge statements and curves of Inundation Canals showing reference gauge required during different periods of Inundation, 1931-41.
3. Statement showing Forest Areas and the average of the best 10 gauge readings at Sarhad and Kotri from 1908 to 1941.
4. Statement showing ten days mean gauges and discharges for Kotri for the months of April, May, June and September for the years 1914-1941.
5. Statement showing ten days mean gauges and discharges for Sukkur for 1920-1941.
6. Statement showing Sarhad gauges for Specific Discharges read from smoothed curves for 1 lac to 6 lacs for rising, falling and mean stages separately, for the years 1931-41.

7. Statement showing daily computed discharges at Sarhad after accounting for all the withdrawals between Sarhad and Sukkur and also for losses and gains in that reach (1931-41).

8. Statement of mistakes in Graph P-92.

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NOTE.—Some of the plans, graphs and statements mentioned in Lists I and II above as originally supplied by Sind were up to the year 1940, while those subsequently received are up to the year 1941.

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LIST III.—*Further Sind documents concerning some of the graphs, etc., in List I.*

1. Explanatory notes on Graphs R/1, R/3, R/4, R/4-A and R/4-B.

2. Note to accompany the Graph showing the net consolidated assessments on the inundation canals in Sind.

3. Statements showing daily and mean ten-day gauges and discharges actual and after various projects for the years, 1931-41.

4. Abstract of canal graph reading showing various details.

5. Statement showing the likely reduction in the gauge and discharges as a result of the Punjab projects for the smaller inundation canals.

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LIST IV.—*Calculation books.*

The probable effects of Punjab projects on the gauges at Sarhad and Kotri for the years 1931-41 (Set ' A ').

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LIST V.—*Other documents filed by Sind.*

(*a*) *Miscellaneous documents.*

1. A Statement of expenditure incurred on Improvements and Maintenance and Repairs.

2. A note on watering experiments at Daur.

3. A note on experiments on Water requirements of Wheat at the Agricultural Research Station at Sakrand.

4. Appendix " E " for the Note on Canal Irrigation in Sind (Part II) showing net consolidated assessment of Sind Inundation Canals in the years 1919-20 to 1938-39 after superimposing the figures of the merged canals from 1932 onwards—the year of working of the Sukkur Barrage.

5. Parts I and II of the Administration Reports of Irrigation and Civil Works in Sind for the years, 1937-38 to 1939-40.

6. Blue prints showing Rabi Cultivation in the Barrage Zone.

7. Agricultural Leaflets. (Returned to Sind in original as requested by them.)

8. History sheets of gauges in Sind.

9. Sind comments on the Memorandum dated the 2nd February 1942 by Khairpur State on sharing of supplies between Sind and Khairpur on the supply available in the Indus at Sukkur being insufficient.

10. Mr. Corbett's Note on discharge observations, relation between flood heights, silt experiments and supposed rise of bed of the River Indus.

11. Statement No. I showing hydraulic gradient and average depth of water near Barrage.

*(b) Documents filed by Sind during the course of the proceedings of the session held in New Delhi (apart from those contained in the Sind Rabi Case book).*

1. Note on the allotment of Rabi supplies to Khairpur.

2. (*a*) Paragraph 7 of Joint Report of the Executive Engineer, Development and Research Division in Sind and the Executive Engineer, Discharge Division in Lahore, 1933-34.

   (*b*) Paragraph 7 of Joint Report of the Executive Engineer, Development and Research Division in Sind and the Executive Engineer, Discharge Division in Lahore, 1934-35.

   (*c*) Paragrah 7 of Joint Review of the Executive Engineer, Development and Research Division, Sind and the Executive Engineer, Discharge Division, Lahore for the 5 years ending 1935.

3. (1) Statement of deltas at the field taken by the Lower Bari Doab Canal and the Khanewal Division of the same canal for years 1934-35 to 1938-39.

   (2) Daily rainfall in inches of Lower Bari Doab Canal.

   (3) Statement showing percentage of cotton and wheat of the Kharif and rabi cultivation respectively.

   (4) Comparative statement showing maximum normal temperature in March in Lower Bari Doab Canal and Sukkur Barrage.

4. Calculations for the maximum amount of storage possible in the Barrage Pond.

5. Statement showing supplies worked out on the Khanewal basis given for all 10 years at the Canal Heads for three different periods, *i.e.*, October-November, December-January and February-March.

6. (1) Alternative statement showing percentages of wheat on the total rabi cultivation.

   (2) Statement showing net daily discharge at Sukkur allowing for Sutlej Valley withdrawals in January and February 1917.

7. (1) Statement showing the information required as per Item (1) of R. O.'s Note dated 11th January 1942.

   (2) Statement based on ten years' Khanewal data (1931-32 to 1940-41) showing the cultivation on the Sind Sukkur Barrage Canals which can be matured with balance available supplies after allowing for shortages with a note appended to it.

8. Note on a statistical examination of the comparative trend in the increase of the Punjab withdrawals and in the decrease of Sukkur discharges.

9. Note on the increased gains by regeneration due to additional withdrawals.

10. (1) Statement of areas on Lloyd Barrage from Land Revenue Administration Report, 1939-40.

(2) Statement comparing the % of return on the capital invested as per project and actual for the year 1940-41.

11. Statement showing the area which will be denied water owing to shortages during February and March on the basis of Khanewal data.

12. Statement showing the areas which would get water during the months of February and March on the basis of Khanewal data.

13. Note on the Punjab claim for extra regeneration and reduced absorption losses due to increase of Punjab withdrawals.

14. 3 plans showing difference contours for 1932-40.

15. (1) Calculation of reduction likely to be caused by the Punjab future withdrawals on the Sarhad and Kotri gauges in Sind for the year 1934.

(2) Calculation of reduction likely to be caused by the Punjab future withdrawals on the Sarhad and Kotri gauges in Sind for the year 1935.

(3) Subsidiary statements. 1939.

# PART II.—LISTS OF MAPS, ETC., CALCULATION BOOKS AND OTHER DOCUMENTS PRODUCED BY THE PUNJAB.

(APART FROM THE "PUNJAB DEFENCE", VOLS. I, II, III AND III-A.)

## LIST I.—*Maps, etc.*

| No. of Maps, etc. | Description of Maps, etc. |
|---|---|
| 5 | Map of hill catchment areas of the Punjab rivers showing Rain Gauge Stations. |
| 6 | Map of hill catchment areas of the Punjab rivers showing Iso-Hyetal Lines (lines of equal Rainfall) in Summer. |
| 7 | Map of hill catchment areas of the Punjab rivers showing Iso-Hyetal Lines (lines of equal Rainfall) in Winter. |
| 8 | Irrigation Department Punjab's printed map of 1930-31 showing position of Well observation line (June) Provincial. |
| 9 | L. Section of Provincial line No. XII, June observation. |
| 10 | Index plan of the Punjab showing water table contours, June 1928. |
| 11 | Index plan of the Punjab showing water table contours, June 1940. |
| 12 | Indus River System chart showing Punjab and Sind withdrawals and water going to sea from 1926-27 to 1940-41. (This is a plot of data in Appendix IV, Punjab Defence.) |
| 13 | Chart showing discharges available at Sukkur and the effect of Thal and Haveli on Rabi Supplies (on monthly basis). |
| 13-A | Chart showing discharges available at Sukkur and the effect of Thal and Haveli on Rabi Supplies (on ten-day basis). |
| 13-B | Chart showing discharges available at Sukkur and the effect of Thal and Haveli on Rabi Supplies (on 10-daily basis) (taking regeneration into account). |
| 14 | Plan showing reduction in Sarhad-Discharges and gauges due to additional withdrawals on account of S. V. P., Panjnad, Haveli, Thal, etc., in accordance with the Punjab (*a*) calculations. |
| 16/1—24 | Graphs showing discharges by months at Sukkur and Kotri and Sind and Punjab withdrawals. |
| 18/1—25 | Specific gauge discharge curves of Punjab sites. |
| 19/1—22 | Graphs of upstream and downstream gauges of important Sind Inundation Canals. |

| No. of Maps, etc. | Description of Maps, etc. |
|---|---|
| 20 | Charts showing average of 50 highest gauges at Kotri and Bukkur. |
| 1—2 & 20A | Kotri gauges and discharges, June to September, 1901 to 1941. |
| 1 | |
| 22 | Gauge discharge curve for Sarhad (rising). |
| 22-A | Gauge discharge curve for Sarhad (falling). |
| 23 | Gauge discharge curve, Sarhad 1932. |
| 24 | Area irrigated by canals in the Punjab and Sind (figures taken from Agricultural Statistics of India). |
| 25 | Relationship between levels in main river and canal head on Inundation Canals with long approach channels. |
| 26 | Gauge discharge curve (rising and falling) of River Indus at Kotri (1932-40). |
| 27 | Gauge discharge curve (rising and falling) of River Indus at Kotri (1932-40). |
| 28 | Sukkur discharges 1940-41 (October-April) with prediction curves. |
| 29, 29 1 & 29 2 | Relationship of inflow and losses or gains in transit on the Indus system from foothills to Kotri 1922-23 to 1940-41 from January to March respectively. |
| 30 | Specific gauge discharge curve of river Indus at Bachalshah site. |
| 31 1—15 | Gauge discharge curves for Major Sind Inundation canals for the years 1932, 1933, 1934, 1935, 1936 and 1939. |
| 32(a) 1—6 to 32 (o) 1—6 | Graphs showing Correlation factor for Major Sind Inundation Canals between U. S. Regulator and Sarhad/Kotri for the years 1932, 1933, 1934, 1935, 1936 and 1939. |
| 33 1—6 & 33(a) 1—6 | Effects of Punjab withdrawals, gauges and discharges at Sarhad and Kotri (based on 5-day period at Rupar). |
| 34 | Graphs showing correlation between forest areas (in Sind) above Sukkur and average of 10 highest gauges at Sarhad. |
| 34-A | Graphs showing correlation between forest areas (in Sind) below Sukkur and average of 10 highest gauges at Kotri. |

| No. of Maps., etc. | Description of Maps, etc. |
|---|---|
| 35 1—10 | Gauge discharge curves of Sind minor Inundation Canals. |
| 36 | Comparison Hydrographs of Sarhad, 1932 and 1939. |
| 37 | Maximum Temperatures (daily) Average for 10 years 1930-39 (Traced from Sind plan No. R 7-A). |
| 38 (*a*) 1—6 to 38 (*j*) 1—6 | Relationship between Sarhad and Kotri gauges and U/S Head Regulator gauges of Sind 10 minor Inundation Canals. |
| 39 | Comparative Specific gauge-discharge curves of river Indus at Machka, Sarhad and Bachalshah (traced from Sind documents Nos. 7, 35 and 38). |
| 40 1—4 | Enclosures to Punjab Rejoinder on Sind's criticism of Punjab correlation method of calculating reduction in canal discharges. |
| 41 | Chart showing Khairpur Sailab irrigation in acres and Bachalshah Specific gauge-discharge curve rising to 400,000 cusecs. |
| 43 | Chart showing additional available supplies on construction of two new Barrages in Sind and actual supplies before and after Punjab additional withdrawals. (Average of years 1932-40). |

## List II.—*Calculation Books.*

1. Calculations for reduction in discharges of Sind major/minor inundation canals due to Punjab additional withdrawals, Punjab alternative I, based on Set "B" calculations without taking rise of river bed into consideration for the years 1932-36 and 1939.

2. Calculations for reduction in discharges of Sind major inundation canals due to Punjab additional withdrawals, Punjab alternative II, based on Set "C" calculations, without taking rise of river bed into consideration for the years 1932-36 and 1939.

3. *Set "C".*—Calculations for assessing the probable effects of estimated additional withdrawals for the various Punjab projects on the supplies and levels at Sarhad and Kotri.

LIST III.—*Other Documents.*

1. Note on Estimate of Withdrawals for Bhakra Dam Scheme.
2. Withdrawals and discharge statements, Indus System.
3. The probable effect of Punjab Projects on the Sarhad Gauge.
4. Comparison of gauges and discharges at Kotri in 1925 and 1930 (September).
5. Punjab Volume of Correspondence.
6. Yield of Rice per acre in the Punjab and in Sind.

MS1Indus Com.—162—12-8-42—GIPS