



Government of Bombay
Public Works Department

Technical Paper No. 28

Note on Research Work done by the Special
Irrigation Division since its formation
in June 1916

BY

C. C. INGLIS, Esq., B.A., B.A.L., M.INST.C.E.,
Superintending Engineer, Irrigation Development and Research Circle.

FIRST EDITION

[Price—Annas 8 or 10d.]

S. 3316

231,9N:1

BOMBAY

PRINTED AT THE GOVERNMENT CENTRAL PRESS

1929

231,9N:1
F9
017516

From the Superintendent of Government Printing and Stationery,
from the High Commissioner for India, 42 Grosvenor Gardens,
W.1, London; or through any recognized Bookseller

List of Bombay Public Works Department Technical Papers.

Paper No.	Subject	Price	Year of publication	No. of copies in stock (May 1929)
		Rs. a. p.		
1	Reinforced Concrete Flooring in the Hostel for the High School at Satara (Bombay Presidency), by W. L. C. Trench, B.A.I. A.M.I.C.E., Executive Engineer, and T. S. Mirchandani, B.Sc. (Edin.), Assistant Engineer.	....	1913	Out of stock.
2	Famine Relief Road Works carried out in the Banda District, United Provinces, in the Famine of 1913-14, by D. R. H. Browne, A.K.C., Executive Engineer.	....	1915	Do
3	Note on the Lower Ganges Bridge Works at Sara, Bengal, by D. R. H. Browne, A.K.C., Executive Engineer.	....	1915	Do.
4	Report on experiments on Concrete Flooring carried out at Poona (Bombay Presidency), by Conductor T. H. Naughton, Sub-Engineer.	....	1917	Do.
5	Reinforced Concrete Works in the Bombay Presidency by J. C. Gammon, B.Sc., A.C.G.I., late Assistant Engineer, Bombay, Public Works Department.	....	1917	Do.
6	Reinforced Concrete Roof Construction for use with ceiling tiles, by J. M. Mackay, A.M.I.C.E., Executive Engineer.	....	1917	Do.
7	Report on the Felling of the Masonry Chimney at Dapuri (Bombay Presidency), by H. W. Oddin Taylor, A.C.G.I., B.Sc., Executive Engineer.	....	1920	Do.
8	Note on the Tests carried out with Reinforced Concrete Brick Walling Loaded as a Beam, by Khan Saheb J. D. Dubash, Assistant Engineer.	....	1920	Do.
9	Note on the Manufacture of Hydraulic Lime in the Nasik and Ahmednagar Districts of the Bombay Presidency, 1920, by Rao Saheb V. K. Chapekar, Temporary Engineer.	....	1921	Do.
10	Glossary of Irrigation Terms applicable to the Deccan Canals.	....	1921	Do.
11	Report on the Malir River, Boring Investigations for the Karachi Water Supply by H. O. B. Shoubridge, M.Inst.C.E., Chief Engineer, for Irrigation.	....	1925	Do.
12	A Note on the Design Application and Construction of Masonry Semi Modules as used on the Jamrao Canal by W. Kirkpatrick, Executive Engineer (2nd Edition).	....	1925	Do.
13	Soil and Sub-soil Surveys in the Deccan Canal Areas by C. C. Inglis, Executive Engineer, and V. K. Gokhale, Deputy Soil Physicist.	....	1926	Do.
14	A short Note on the Improvement of Damaged lands in the Canals Irrigation Tracts of the Bombay Deccan by C. C. Inglis, Executive Engineer.	0 4 6	1927	4
15	Notes on Standing Wave Flumes and Flume Meter Falls, by C. C. Inglis, Executive Engineer, Special Irrigation Division.	2 8 0	1928	121
16	Note on Irrigation on the Block System in the Deccan Canal Tracts, by C. C. Inglis, I.S.E., Executive Engineer, Special Irrigation Division.	0 5 0	1927	42
17	Note on the Effluent Farm near Poona (1918-19 to 1925-26), by C. C. Inglis, B.A., B.A.I., M.Inst.C.E., Executive Engineer, Special Irrigation Division.	0 15 0	1927	34
18	Note on the use of Hydro-Electric Power by small Industries in Switzerland, Norway and Sweeden, by F. O. J. Rose, M.I.M.E., M.I.E.E., Electrical Engineer to Government.	1 14 0	1928	148
19	Note on the design of distributaries and their outlets in the Bombay Deccan, by C.C. Inglis, B.A., B.A.I., M. Inst.C.E., Executive Engineer, Special Irrigation Division.	0 14 0	1928	31
20	Note dated November 1927 on "Model experiments to ascertain the effect of partial lining of the Malegaon Cut" in miles 38 and 39 of the Nira Left Bank Canal, by C. C. Inglis, B.A., B.A.I., M.Inst.C.E., Executive Engineer, Special Irrigation Division, and D. V. Joglekar, B.E., Assistant Engineer.	1 0 0	1928	154

Paper No.	Subject	Price	Year of publication	No. of copies in stock (May 1929)
		Rs. a. p.		
21	Note on the outturn and profit from sugarcane crops grown in the Deccan Canal Tracts, by C. C. Inglis, B.A., B.A.I., M.Inst.C.E., Superintending Engineer, Irrigation Development and Research Circle.	1 3 0	1928	81
22	Note on Experiments carried out at the Hydraulic Testing Station at Distributary No. 5, Mutha Right Bank Canal, near Poona with a Lindlay type Standing Wave Flume, by C. C. Inglis, B.A.I., M.Inst.C.E., Superintending Engineer, Irrigation Development and Research Circle, Bombay, with the assistance of D. V. Joglekar, B.E., Assistant Engineer.	0 10 0	1928	73
23	A note on Standing Wave Pipe Outlets by C. C. Inglis, B.A.I., M.Inst.C.E., Superintending Engineer, Irrigation Development and Research Circle, Bombay.	1 2 0	1928	25
24	Report on Land Drainage Experiments at Baramati by C. C. Inglis, B.A.I., M.Inst.C.E., Superintending Engineer, Irrigation Development and Research Circle, Bombay.	2 1 0	1928	101
25	Moduling operations on Distributary No. 8, Nira Left Bank Canal, and application of the results to other distributaries by C. C. Inglis, B.A.I., M.Inst.C.E., Superintending Engineer, Irrigation Development and Research Circle, Bombay, with D. V. Joglekar, Assistant Engineer.	0 12 0	1928	125
26	Reports on tests made on a model of the group of Regulators at Oderolal at mile 169 approximately of the Rohri Main Canal, Sind, by C. G. Hawes, M.C., B.Sc. (Lon.), A.C.G.I., A.M.Inst.C.E., Executive Engineer, Central Designs Division, Karachi, and C. C. Inglis, B.A.I., M.Inst.C.E., Superintending Engineer, Irrigation Development and Research Circle, Poona.	1 11 0	1928	81
27	Report on experiments on model culverts made with Hume Pipes by C. G. Hawes, M.C., B.Sc. (Lon.), A.C.G.I., A.M.Inst.C.E., Executive Engineer, Central Designs Division, Karachi.	.....	In Press	....

Copies obtainable from the Superintendent, Government Printing and Stationery, Bombay, or through any recognised bookseller.

INDEX

1. Introduction
2. Original orders on work to be done by the Special Irrigation Division
3. Difficulties
4. Solution
5. Quick, cheap field methods
6. Fertility
7. Reclamation
8. Sub-soil conditions
9. Drainage schemes
10. Restriction of irrigation
11. Salinity, and levels of sub-soil water
12. Soil maps
13. Sewage (Effluent) Irrigation
14. Experimental Farms
15. Irricultural problems
16. Hydrodynamic research
17. General object of the investigations
18. List of investigations and Reports
19. Index to subjects dealt with by the Special Irrigation Division and the Irrigation Development and Research Circle

ILLUSTRATIONS AND PLANS.

NOTE ON "RESEARCH WORK DONE BY THE SPECIAL IRRIGATION DIVISION SINCE ITS FORMATION IN JUNE 1916."

1. *Introduction.*—In the Deccan when a large perennial Canal is opened, widespread waterlogging ensues, due to percolation from the Canal. Some of this water-logging dries out later, but the area of damage extends rapidly into the valleys, and unless steps are taken to set matters right, the later damage—consisting mainly of salt efflorescence—becomes permanent.

The seriousness of the menace was realised as early as 1888—that is 3 years after the opening of the Nira Left Bank Canal, and the controversy regarding the relative effect of channel losses and wasteful irrigation, and the best methods to adopt to safeguard the land, became yearly more acute.

Various experiments were carried out at the instance of the Agricultural Department—especially between 1908 and 1913—and in 1910 Agricultural Bulletin No. 39 "The Salt lands of the Nira Valley" was published; but by 1913 it was clear that all the methods tried had completely failed.

In 1914 an Officer of the Revenue Department, who had been acting as the Director of Agriculture, was put on Special Duty "to select soil for cane in the Deccan Canal Tracts." A large part of his selection assumed successful drainage; and—as the exact causes of damage were still unknown and all experiments to meet the conditions had completely failed—it was decided to open a Special Irrigation Division to investigate the question of Canal Development, especially as regards safeguarding the soil.

2. *Original orders on work to be done by the Special Irrigation Division.*—In June 1916 the Special Irrigation District was formed and the work was thus briefly described in paragraph 4 of Government Resolution, P. W. D. No. E-12138 of 5th November 1915:—

"To contour the commanded area, make a careful survey and classification of the surface and subsoil, select and mark out definite areas suitable for "blocks" for perennial and other crops, design the drainage required, and indicate suitable lines of communication, and centres for the establishment of crushing, grinding, refining and other machinery for trade purposes. The Special Officer will also make a study of the reclamation of waste lands, and areas damaged by waterlogging and salt efflorescence and the growth of useful timber in such tracts, and along the main canal."

3. *Difficulties.*—It soon became evident that land drainage under Deccan conditions was not a straightforward engineering problem, and it appeared that the probable explanation of the unsatisfactory and confusing results hitherto obtained would be found in the deep subsoil conditions; but owing to the subsoil water being found at less than five feet below ground level almost everywhere in the canal tracts the investigation was beset with difficulties. All the generally known "samplers" and boring machines were tried, but with poor results; and little headway was made until "Iwan" post-hole augers were obtained. With these, detailed surveys of certain areas were carried out, and from the information obtained it was found that in many cases what had once been deep valleys had in the course of time become completely filled with eroded material, which had clogged the natural drainage. The existing naals were usually situated at the flanks of the old valleys, sometimes hundreds or even thousands of feet away from the old valley lines. It was difficult to collect reliable data from depths extending to 30 feet at a reasonable cost; but from auger surveys, lines were plotted along which porous material—usually "Murum"—i.e. disintegrating trap rock—was found at a depth of 8 feet. These lines were called 'murum isobaths'—and with these it was possible to understand why certain areas were damaged; while others, which appeared to be similar, were unharmed.

The first attempts at drainage showed, however, that even when the general contours of the deep substrata were known, the problem of how to drain was still far from solution.

4. *Solution.*—The next step was to measure the porosity of the subsoil. Everything obtainable on the subject was read, but although many laboratory

tests had been worked out in several countries, no method for measuring the permeability of deep substrata 'in situ' had—so far as could be ascertained—been developed. It was eventually achieved by the measurement of recuperation, from which coefficients could be worked out. This proved a simple and satisfactory solution and revolutionised the work, which could never have been successful without this information. Even then, however, it was found that a permeable stratum did not necessarily yield much water, because sometimes small pockets of highly permeable material were surrounded by impervious clay. Thus, before conditions could be sufficiently clearly grasped to design a successful drainage scheme, it was necessary to consider how the various strata had been formed, their physical properties, and the strata lying above and below. This necessitated a study of both the geology and soil physics of the valleys; in fact in the early stages soil physics was the most important branch of the work, and through it success was attained.

5. *Quick, cheap field methods.*—If unlimited money had been available the task would have been comparatively easy; but to continue to spend as much as had been spent on earlier surveys was not permissible, so cheap methods had to be evolved. To this end a "soil series" classification was worked out—based on the fact that when a certain set of surface conditions was found, subsoil conditions could generally be inferred. Laboratory tests were also replaced by quick field tests, so that doubtful points could be verified in the field. The eye is untrustworthy as a judge of salt content, and chemical analysis is too costly and slow. The American Bridge was tried and found unsatisfactory; but eventually Evershed and Vignolle's Dionic water tester was obtained and proved successful, giving results in a few minutes at a negligible cost.

6. *Fertility.*—The next investigation taken up was to determine the fertility of the various types of soils, their liability to damage and their susceptibility to improvement. The soils and subsoils have now been classified and their suitability worked out; but the dominant factor in fertility is the condition of the soil—in other words the skill of the cultivator—and expert cultivators can grow good crops on very poor land by careful cultivation with light irrigation.

7. *Reclamation.*—Another parallel line of work was the reclamation of lands after drainage. To this end, the worst salt area on any Deccan Canal was acquired and, despite predictions of failure from Officers then in the Agricultural Department, the greater part of this land is now producing heavy crops of cane. Some portions were easily reclaimed, but others have necessitated a wide variety of treatments, manurial and chemical. It is safe to say that almost all the damaged areas can now be reclaimed at a reasonable cost.

8. *Subsoil conditions.*—The soil work has now reached such a stage that trained staff can infer subsoil conditions to a depth of ten feet or more from surface indications—such as the colour, texture, and general look of the ground, the strata exposed in rivers and wells, the subsoil water level, waterlogging and salt efflorescence; but the best guides are weeds and the general appearance. A single indication is not reliable; but a combination of several indications enable those with a natural gift for the work and long experience to draw definite conclusions. The cost of such a survey is about one penny per acre, and over a million acres have now been classified.

9. *Drainage schemes.*—Some ten drainage schemes have been completed or are nearing completion and some 20 more have been prepared and will be carried out as funds permit. Government propose to drain the whole of the Deccan Canals within the next 20 years.

10. *Restriction of irrigation.*—In order to reduce damage, crops are now restricted to soils which are suitable for the intensities of irrigation required. Thus, before irrigation was allowed on the new Nira Right Bank Canal, the whole area was divided up into 6 categories, taking soil suitability and drainage possibilities into account.

11. *Salinity and levels of subsoil water.*—Conductivity tests are carried out with a Dionic water tester to study the salinity of water samples from wells and auger bores. These give information regarding the natural drainage; and, where drainage schemes have been carried out, they indicate the progress of leaching. Water levels of about 7,500 wells—which have been classified according to the average depth of water below ground level—are observed periodically throughout

the year on the Godavari, Pravara and Nira Canals. From the observations, 4 ft. and 10 ft. hydro-isobaths—*i.e.* lines on which water is found at equal depths of 4' and 10' respectively below ground level—are marked on plans every year and the changes in the hydro-isobaths—whether they are extending or retiring—are noted, to see which areas require immediate drainage. The object is to correlate well water levels with—

(i) percolation from canals and

(ii) percolation from irrigated fields.

Limitation of perennial blocks to suitable soils has resulted in the retreat of hydro-isobaths in many places.

12. *Soil maps*, showing the classification [*e.g.* uncommanded areas; coarse (soft and hard) *murum* soils; fine soil; *chopan* black soil; *murum* isobaths; damaged areas—waterlogged and salt affected; *chopan* and cut-up areas] have been printed for the Godavari Canals, the Pravara Canals and the Nira Right Bank Canal (Lonand section) and the plans for the remaining Canals are nearly ready for printing.

Section maps for the use of sectional officers are also being printed for the Nira Left Bank Canal.

13. *Sewage (Effluent) Irrigation*.—The disposal of Poona sewage, by mixing with Canal water and using for irrigation, was started on Distributary 5 of the Mutha Right Bank Canal in 1916 and has been very successful. Started on a small scale with 1 cusec average discharge, a scheme for disposing of 11 cusecs has since been sanctioned; and a similar scheme for Sholapur—to dispose of 7 cusecs of effluent—is now under consideration.

14. *Experimental Farms*.—In 1918 the Effluent Farm was opened on Distributary No. 5 of the Mutha Right Bank Canal—to investigate questions arising out of effluent irrigation, such as the best dose of effluent, the value of effluent per lb. of nitrogen, its effect on the soil, etc. Experiments on the relationship between the quantity of water applied and the outturn, and the effect of various periods between waterings and delayed waterings have also been under investigation; and the Farm is now largely concerned with irricultural investigations—*i.e.* the interaction of irrigation and agriculture—*our aim being to modify agricultural methods to fit in with irrigation limitations and to mould irrigation practice to meet agricultural requirements.*

A second Farm was opened in 1921 at Baramati, on the Nira Left Bank Canal, to reclaim the area of very heavily salt-affected land which had previously been drained in the period 1916-20. A large part of the area has been reclaimed and much valuable experience gained.

The work carried out on these farms has shown that the secret of Deccan Irrigation is to use water and manure in very much smaller quantities than has been the practice. It has, in fact, been shown that heavy crops—far superior to those grown by the cultivators—can be obtained using little more than half the manure and half the water normally applied; and that when this is done, the physical state of the soil is conserved and improved, instead of being damaged—which hitherto caused a continuous falling off in returns.

This line of work has been so successful that both the Secretary of the Sugar Bureau of the Government of India and a Revenue Officer who was deputed to investigate Deccan irrigation problems have recommended that the development of Deccan Canals should be under the Superintending Engineer, Irrigation Development and Research Circle.

15. *Irricultural problems* have been investigated not merely in the farms but also in the fields of the cultivators; and large numbers of investigations into agricultural methods and irrigation problems have been carried out. These are too numerous to detail here; but the various Papers dealing with them are enumerated in paragraph 18.

16. *Hydrodynamic research*.—Most of the hydrodynamical research has been carried out either at the Hydrodynamic Research Station at Distributary 5 of the Mutha Right Bank Canal (with small models and a discharge up to 10 cusecs) or at Khadakvasla dam, at the Head of the Mutha Canals (with full scale or large scale models discharging up to 500 cusecs). Much of the work has

been concerned with Deccan problems, but a large part of it has a direct bearing on general irrigation problems and recently much of the work has been in connection with Sind irrigation and the Barrage.

17. *General object of the investigations.*—Some of the investigations have been carried out for a particular purpose, but most of the work has been closely co-ordinated and dovetailed together. The basic idea has been that the area commanded by a large Canal should be looked on as a large estate needing careful development; and it has been held that to construct a canal and then leave it to develop on its own lines, leads not merely to an enormous waste of money, but also to a maximum of damage. Where, as in Northern India, the demand exceeds the supply, it is possible “to restrict the supply and allow the cultivators to irrigate as large an area as they wish with the water supplied.” This system gives a great incentive to efficiency and the problem then becomes one of efficient distribution of available river supplies; but in the Deccan, where the demand and the supply vary widely from year to year (due to variations in rainfall), it is impossible to give a constant supply, and it would be wasteful to do so even if it were possible. The Deccan problem, therefore, is to supply an ever-varying supply to meet an ever-varying demand (bearing in mind all the time that the reserves available are strictly limited, and dependent to a considerable extent on the succeeding monsoon). Consequently, a Canal Officer must not merely have a very high degree of skill at irrigation distribution—backed up by modules and measuring devices—, but he must also have a wide knowledge of the variations of rainfall and run-off in the catchment combined with information regarding water requirements of crops and the varying demand.

The necessary information required by the Canal Officer had been, and is being, collected and systematised; and a new method of irrigation with modules is being perfected. This has been shown to increase the area irrigated with the same supply by over 20 per cent. This, in its turn, reduces damage. The restriction of perennial crops to suitable soils has also reduced damage; and, where damage has been inevitable, drainage schemes have been proposed and are being constructed.

As a result of selection, several unsuitable channels have been omitted from the Nira Right and Left Bank Canals, the total cost of which was estimated at considerably more than the cost to date of the Special Irrigation Division. The increase of duties from the adoption of the new system of irrigation now being introduced on the Nira Left will make it possible to reduce the cost of enlarging Vir Dam by half a crore—if not to do away with its necessity altogether.

This year (1928) a Class was held during August and September at which lectures and demonstrations of Special Irrigation work were given by the staff to—

- 3 Assistant Executive Engineers,
- 2 Temporary Engineers,
- 2 Assistant Engineers,
- 2 Stipendiaries,

and 1 Upper Subordinate,

from the Deccan Irrigation and the Irrigation Development and Research Circles.

18. *List of investigations and Reports.*—The following is a list of the various investigations carried out by the Special Irrigation Division. They have been grouped under 5 heads:—

- I. Irrigation.
- II. Irriculture.
- III. Soil Physics.
- IV. Drainage and Reclamation.
- V. Hydrodynamic Research.

(*Note.*—The notes that are not printed are given index numbers such as S. I. D. No. 14 or I. D. R. No. 12 etc. Numbers marked with an asterisk, e. g., I. D. R. No. *15, mean that either the notes are to be written—the data being complete, or the experiments are yet in progress.)

I—Irrigation—

- (1) *Duty of Irrigation water in relation to the capacity of Canals in the Deccan.*
(Paper No. 30 read before the Bombay Engineering Congress; see Vol. V of 1918—Spl. Irrign. Dn. Library No. Mnl./5 and Mnl./5 a; and for discussion of the above subject see Vol. VI of 1919—Spl. Irrign. Dn. No. Mnl./6.)
- (2) *Some important factors affecting the design and working of Deccan Canals.*
 - (i) *Aquatic weed growth* showing that silt in suspension was the dominant factor and that this depended largely on the design of the pick-up weir.
 - (ii) *Percolation and absorption.*
In alluvial soils, losses are by absorption and vary as the wetted perimeter; but in the Deccan, canal losses are mainly by percolation and the total losses from any particular channel vary as Q within normal working limits. Nevertheless losses from channels of different sizes flowing with the same ratio of full supply give relative losses varying as \sqrt{Q} (both in Northern India and the Deccan).
(Paper No. LXVIII read before the Bombay Engineering Congress—*vide* Vol. XI of December 1922—Spl. Irrign. Dn. Library No. Mnl./10 and Bombay P. W. D. Technical Paper No. 19.)
- (3) *Seepage losses of Deccan Canals (by discharge observations).*
(I.D.R. No. 15*—Revised note No. 2 above with additional data.)
- (4) *Weeds in Deccan Canals.*
(I.D.R. No. 21*—A supplementary note to Bombay Engineering Congress Paper LXVIII above.)
- (5) *The Block system of Irrigation in the Deccan Canal Tracts.*
(Bombay P. W. D. Technical Paper No. 16.)
- (6) *Modules and Semi-modules for irrigation.*
(Bombay Engineering Congress Paper No. XLVIII—*vide* Vol. X of December 1921. Spl. Irrign. Divn. Library No. Mnl-9.)
- (7) *The Design of distributaries and their outlets in the Bombay Deccan.*
(Bombay P. W. D. Technical Paper No. 19.)
- (8) *Moduling Distributary No. 8 of the Nira Left Bank Canal and its application to other distributaries.*
(Bombay P. W. D. Technical Paper No. 25.)
- (9) *Methods suitable for reducing losses from Deccan Canals.*
(Bombay Engineering Congress Paper of 1928, I.D.R.No. 4.)
- (10) *River gauging and rain gauging in the Bombay Deccan for the past 25 years.*
This work was taken over by the Special Irrigation Division in 1922. (Report with graphs submitted to Government under Spl. Irrign. Dn. No. 1301, dated 3rd March 1927 and the Superintending Engineer, Deccan Irrigation Circle's No. 1622, dated 22nd March 1927.)
(S. I. D. No. 22.)
- (11) *Losses from Lakes and Tanks (by evaporation and absorption).*
(S. I. D. No. 16.)
- (12) *Isohyet map, showing lines of equal rainfall of the Bombay Ghats, Maval and Deccan.*
(See I. D. R. Drawing No. 65.) (Spl. Irrign. Dn. Library No. P-a-37.)
- (13) *Hume Concrete Pipes—where suitable for irrigation works.*
(I. D. R. No. 2.)
- (14) *Enhancement of land values in irrigated tracts.*
(First Note, S. I. D. No. 2. Second Note under preparation.)
- (15) *Distribution of Effluent for irrigation. Difficulties and how they are overcome.*
(S. I. D. No. 6.)
- (16) *Relationship between Maximum floods and size of catchments.*
(I. D. R. No. 25.)

- (17) *A critical study of annual rainfall and run-off, in the Deccan.*
(I. D. R. No. 7.)
- (18) *Unitisation of irrigated areas.*
(I. D. R. No. 6.)
- (19) *Movement of subsoil water in soil on irrigating a field.*
(I. D. R. No. 8.)
- (20) *Note on formation and demarcation of blocks in the Deccan.*
(I. D. R. No. 12*.)
- (21) *Absorptive capacity of a lake and cumulative run-off.*
(I. D. R. No. 14*.)
- (22) *Corrosive effect of effluent on metal.*
(S. I. D. No. 1.)
- (23) *Note on the use of Tacheometric Plane Table.*
(S. I. D. No. 5.)
- (24) *Bitumen (Mexphalte) lining.*
(S. I. D. No. 7.)
- (25) *Cost of Canals, distributaries, dams, etc., of the Deccan.*
(S. I. D. No. 13.)
- (26) *Note on duties at Distributary No. 5, Mutha Right Bank Canal.*
(S. I. D. No. 14.)

II—Irriculture (inter-relationship of irrigation and agriculture)—

- (27) *Outturn and profit from sugarcane crops grown in the Deccan Canal tracts.*
(Bombay P. W. D. Technical Paper No. 21.)
- (28) *The Effluent Farm near Poona. (1918-19 to 1925-26).*
In which full data of experiments to ascertain value of nitrogen in sewage effluent, water required, etc. (see Bombay P. W. D. Technical Paper No. 17) are shown.
- (29) *Agricultural development on the Deccan Canals.*
(I. D. R. No. 9.)
- (30) *Causes that lead to variation from the standard 10 day interval of watering.*
(S. I. D. No. 3.)
- (31) *Valuation of soils on Revenue Department basis.*
(Bhag anna.) (S. I. D. No. 4.)
- (32) *Note dealing with basic reasons why irrigation cannot be handed over to the irrigators or the Agricultural Department.*
(S. I. D. No. 17.)
- (33) *Statement showing cost of various manures in years 1915-16 to 1921-22, 1925-26 and 1926-27.*
(S. I. D. No. 18.)
- (34) *Note dealing with difficulties encountered in the distribution of irrigation water.*
(S. I. D. No. 19.)
- (35) *Irrigation from river flow and storage.*
(S. I. D. No. 20.)
- (36) *Conversion of the present sugar import duty into an effective, protective duty.*
(S. I. D. No. 21.)

III—Soil Physics—

- (37) *Soil and subsoil surveys in the Deccan Canal areas.*
(Bombay P. W. D. Technical Paper No. 13.—out of stock.)
- (38) *The Physical properties of Deccan Soils.*
(I. D. R. No. 16*.)
- (39) *The relationship between readings of the Dismic Water Tester (conductivity meter) and concentrations of various salts.*
(I. D. R. No. 28.)

(40) *Chemical analysis of*

- (a) Soil.
 - (b) Water.
 - (c) Effluent.
- (I. D. R. No. 17*.)

(41) *Changes in the chemical composition of subsoil water as it moves from ridge to valley.*

(I. D. R. No. 19*.)

(42) *Changes in composition of effluent.*

(I. D. R. No. 20*.)

IV—Drainage and Reclamation—

(43) *Improvement of damaged land in the Canal irrigated Tracts of the Bombay Deccan.*

(Bombay P. W. D. Technical Paper No. 14.)

(44) *Land drainage experiments at Baramati.*

(Bombay P. W. D. Technical Paper No. 24.)

(45) *Land Drainage of the Deccan Canal areas, comprising,*

- (a) Preparation,
 - (b) Execution,
 - (c) Maintenance.
- (I. D. R. No. 10*.)

(46) *Reclamation and soil improvement in drained areas of the Deccan Canal Tracts.*

(I. D. R. No. 18*.)

(47) *Hydro-isobaths on Godavari and Pravara Canals.*

(S. I. D. No. 15.)

V—Hydrodynamic Research—

(48) *Lindley type Standing Wave Flume.*

(Bombay P. W. D. Technical Paper No. 22.)

(49) *Standing Wave Pipe Outlet.*

(Bombay P. W. D. Technical Paper No. 23.)

(50) *Crumpp type Standing Wave Flume.*

Two years of experiments, which led to standardisation of design. The data collected showed factors leading to steadiness of coefficient and high recovery of head.

(Bombay P. W. D. Technical Paper No. 15.)

(51) *A short note on how to design Standing Wave Flumes.*

(An official Publication.)

(52) *List of symbols used in Hydraulic Research.*

(I. D. R. No. 1 ; printed as an official publication.)

(53) *Standing Wave Flumes.*

(Paper No. CV read before the Bombay Engineering Congress—vide vol. XV of 1926. Special Irrigation library No. Mnl/14.)

(54) *Standing Wave Flume Fall.*

Combining accurate measurement, effective dissipation of energy and low cost. (Bombay P. W. D. Technical Paper No. 15.)

(55) *Effect of partial lining of the Malegaon Cut in miles 38 and 39 of the Nira Left Bank Canal.*

(Bombay P. W. D. Technical Paper No. 20.)

(56) *An adaptation of the Standing Wave Principle to Hydraulic Testing.*

(Bombay Engineering Congress Paper No. LXXIV—vide vol. XII of November-December 1923. Spl. Irrign. Library No. Mnl/11.)

- (57) *Fluming masonry works to reduce cost without extra loss of head.*
Fluming of Aqueduct No. 23 of Nira Right Bank Canal. (Bombay P. W. D. Technical Paper No. 26 & I. D. R. No. 22*.)
- (58) *Pier, cut-water and ease-water experiments to ascertain the best design for the Sukkur Barrage.*
(I. D. R. No. 11.)
- (59) *Experiments to ascertain the effect of scour on the downstream protection of the Barrage.*
(I. D. R. No. 11.)
- (60) *Effect of design of Barrage sill on coefficient of discharge.*
(I. D. R. No. 11.)
- (61) *Silt draw experiments (with models) to ascertain the best design for approach channels and the best method of working the gates of the Sukkur Barrage to prevent deposition of silt.*
(Experiments in progress I. D. R. No. 24*.)
- (62) *Determination of the coefficient of discharge of Lake Fife Waste Weir Gates by model experiments.*
(Experiments are still in progress. I. D. R. No. 23*.)
- (63) *Comparison of baffle-boom, biff-wall and Standing Wave for dissipating energy below falls.*
Small models at Distributary No. 5 Hadapsar and a 6.5 feet fall model at Khadakvasla for carrying discharges up to 50 cusecs per foot width and 500 cusecs total discharge. (Experiments in progress I. D. R. No. 26*.)
- (64) *The adaptation of the Gibb Module to make it rateable.*
(I. D. R. No. 3.)
- (65) *Report on tests made on a model of the Group of Regulators at Oderolal at Mile 169 (approximately) of Rohri Canal, Sind.*
(Bombay P. W. D. Technical Paper No. 26.)
- (66) *Experiments with Crump Adjustable proportional Modules.*
(Experiments in progress. I. D. R. No. 13*.)
- (67) *Experiments with V notch.*
(S. I. D. No. 9.)
- (68) *Dethridge meter calibration.*
(S. I. D. No. 10.)
- (69) *Factors affecting the design and efficiency of Siphon Spillways.*
(I. D. R. No. 5*.)
- (70) *Effect of addition of sodium carbonate on quick setting of cement.*
(S. I. D. No. 8.)
- (71) *Calibration of Standing Wave Orifice Outlets.*
(S. I. D. No. 11.)
- (72) *Evaluation of curves by graphical and mathematical methods.*
(S. I. D. No. 12.)
- (73) *Discussion on Mr. N. S. Joshi's paper on solid liquid friction.*
(I. D. R. No. 27.)

**Alphabetical Index of Subjects dealt with by the Special Irrigation
Division since its formation in 1916 and the Irrigation
Development and Research Circle.**

Explanation of abbreviations.

- | | | | | | |
|-------------------------------|----|----|----|----|---|
| (1) T.P. 21 | .. | .. | .. | .. | Bombay Public Works Department
Technical Paper No. 21. |
| (2) B.E.C. XXX | .. | .. | .. | .. | Bombay Engineering Congress Paper
No. 30. |
| (3) Agri. Journal I.S.C. 1919 | | | .. | .. | Publication of the Indian Science
Congress 1919 in Agricultural
Journal. |
| (4) 'Pf' '6 | .. | .. | .. | .. | Special Irrigation Division Library
No. |
| (5) G.R. | .. | .. | .. | .. | Bombay Government Resolution. |
| (6) I.D.R. 11 | .. | .. | .. | .. | Drawing No. 11 of Irrigation
Development and Research Circle. |
| (7) I.D.R.N. 20 | .. | .. | .. | .. | Note No. 20 written by the Super-
intending Engineer, Irrigation
Development and Research
Circle. |
| (8) S.I.D. 213 | .. | .. | .. | .. | Drawing No. 213 of Special
Irrigation Division. |
| (9) S.I.D.N. 12 | .. | .. | .. | .. | Note No. 12 written by the
Executive Engineer, Special
Irrigation Division. |
| (10) I.D.R.F. or S.I.D.F. 30. | .. | .. | .. | .. | File No. 30 in Irrigation Deve-
lopment and Research Circle or
Special Irrigation Division. |
| (11) I.D.R.N.* 15 | .. | .. | .. | .. | Note either under preparation or to
be written by Superintending
Engineer, Irrigation Development
and Research for which data has
been collected or experiments
are in progress. |

Subject.	Reference.
A	
Aeration of Sewage	I.D.R.N.* 20.
Afflux—Method of calculating at Malegaon Cut	T.P. 20.
Agricultural side of irrigation	T.P. 17 and 21; I. D. R. No. 9; evidence before Royal Agriculture Commission, Vol. II, Part I.
Alkali—Removal of	T.P. 24.
—Composition of	Do.
Alkaline soils	T.P. 24.
American Bridge—for estimating “total salt” in water	I.D.R.N.* 17.
Do. do. - N in effluent	Do.
Analysis—of effluent and other manures—	T.P. 17.
—Chemical — of soils	Do.
—Physical — of soils and sub-soils	Do.
Anemometer readings—Chart for	I.D.R.N.* 21.
Anna Valuation of cane crops—accuracy of —	T.P. 21.
—valuation of soils on Revenue .. ..	.....
Department basis (Bhaganna)	S.I.D.N. 4.
Appreciation in land values due to the advent of canals	S.I.D.N. 2.
Aqueducts—Modification in design to turn them into S.W.F.S.—	S.I.D.F. 195.
—Modification in Pier design to reduce afflux	I.D.R.N.* 22.
Area—Classification of — showing suitability of various crops	T.P. 16.
Atki —Chart of gul rates per (of 200 lbs.) in Baramati	T.P. 21.
Augers—Post hole and screw — for sub-soil surveys	I.D.R.N.* 10.
B	
Baffle—boom design for stilling water below falls	T.P. 15.
Baffles of Gibb's Modules—	I.D.R.N. 3.
Barrage—Silt experiments	I.D.R.N.* 24.
—Silt experiments	I.D.R.N. 11.
—Afflux experiments	I.D.R. No. 11.
“Base” —“Duty”	B.E.C. 30.
“Bell-mouth” —for — pipe outlet	S.I.D. 116-c.
“Biff-wall” for stilling—below falls	T.P. 15.
Bitumen lining (Mexphalte)	S.I.D.N. 7.
Block formation—Cost of —	I.D.R.N.* 12.
—Principles of —	Do.
—Procedure in connection with —	Do.
—Rules regarding —	Do.
Block plans of Nira Left Bank Canal	S.I.D. 301.
Do. do. Right Bank Canal	S.I.D. 302.
Block plans of Godavari Right Bank Canal	S.I.D. 288.
Do. do. Left Bank Canal	S.I.D. 288.
Block plans of Pravara Left Bank Canal	S.I.D. 289.
Do. do. Right Bank Canal	S.I.D. 289.
Block system of irrigation	T.P. 16.
Brass—Corrosive effect of effluent on —	S.I.D.N. 1.
Brix readings of sugarcane juice (to indicate ripeness)	T.P. 17 and 21.
C	
Canal Irrigation Northern and Deccan Types compared and basic differences explained	T.P. 19 and 25.
Canal losses—Percolation and absorption	B.E.C. LXVIII.
Canal capacity required	B.E.C. XXX.
Canal weeds	T.P. 19 and 25.
Cane—Cost of cultivation of —	B.E.C. LXVIII.
—Crushing and Manufacturing cost per Palla of gal	T.P. 17.
—Maturity of — in relation with Brix reading and soil types	T.P. 21.
	T.P. 21.

Subject.	Reference.
C—contd.	
Cane area—Effect of restriction of in canal tracts ..	T.P. 21.
Capacity co-efficient of canals	B.E.C. XXX.
	T.P. 25 and 19.
Capillary rise of water in various soils	I.D.R.N. * 16.
Catchment area—Correlation of — with maximum run-off and rainfall.	I.D.R.N. * 25.
Causes that lead to deviation from the ten days standard interval of watering.	S.I.D.N. 3.
Cement—Effect of addition of Na ₂ Co ₃ —on quick setting of —..	S.I.D.N. 8.
Cess Irrigation—to standardise demand for water ..	T.P. 25.
Channel—Approach—design for Standing Wave Flumes ..	T.P. 15.
Chemicals useful in leaching out salts from soils ..	I.D.R.N. * 18.
Chemical analysis of soils and sub-soils ..	I.D.R.N. * 17.
—effluent	Do.
Co-efficient of correlation, standard deviation and probable error of — for outturn of cane as compared to anna valuation of crop.	T.P. 21.
Concrete pipes. “Hume”—	I.D.R.N. 2.
Conductivity of water — used to determine salt content ..	I.D.R.N. * 17.
Contouring Surface — by cross section method ..	Pa. 9.
Core wall Limited usefulness of—in preventing losses from canals	I.D.R.N. 4.
Corrosive effect—of effluent on metals	S.I.D.N. 1.
Cost of—Pipe drains and open drains	I.D.R.N. * 10.
—Standing Wave Flumes	T.P. 15.
—Canals, Distributaries, dams, etc.	S.I.D.N. 13.
Cost of Distributaries, limit of 'justifiable expenditure in construction	T.P. 19.
Critical velocity for small depths	I.D.R.N. * 24.
Crops—Delta for different—	B.E.C. 30.
—Suitable in alkaline soils—	T.P. 21.
—Duty and Duty ratio of —	B.E.C. 30.
Crop ratios	T.P. 25.
Cumulative curves of run-off	I.D.R.N. * 14.
Current meters for measuring velocities. Rating of— ..	I.D.R.N. * 15.
Curves—Evaluation of — by graphical and mathematical methods	S.I.D.N. 12.
D	
Damage to land—Origin, etc., of —	T.P. 14 and 24.
Damaged lands—Evaporation of sub-soil water from the surface of —	T.P. 24.
Deflocculation of soils. Causes leading to —	I.D.R.N. * 16.
Delta— Δ —total depth of water applied to crops, in a stated period or 'base'	T.P. 17 and 21.
Demarcation of Blocks—Desirability of — How cost to be met	G.R. 1556 of 8-2-26 and
	I.D.R.N. * 12.
Dethridge meter. Experiments for calibrating— ..	S.I.D.N. 10.
Dilution of effluent. Calculations for working out— ..	S.I.D.N. 6.
Dionic water tester for measuring salt contents, etc. ..	I.D.R.N. * 16 and * 17.
Disc readings. White—	S.I.D. Register and I.D.
	R.N. * 21.
Discharge formula—for flumes of various types ..	T.P. 15.
Discharges. Proportional—	T.P. 15.
Discharges of Open channels. Methods of observing— ..	T.P. 15.
Discharges of various trenches of Baramati Salt lands ..	T.P. 24.
Discharges of nalas—	S.I.D. Register.
Discharge formulas. Comparison of—by Kutter's and Manning's formulas	T.P. 20.
Discharge curves. Evaluation of—graphically and mathematically	S.I.D.N. 12.

Subject.	Reference.
D—contd.	
Distributaries. Justifiable expenditure in constructing — for rabi, perennial and monsoon areas	T.P. 19.
Distributaries. Old and new designs for Deccan	T.P. 19.
Distributary Head Regulators. Design of —	T.P. 19.
Distributaries. Tail—a drag on finance	T.P. 19.
Distribution in Northern India and Deccan compared	T.P. 19.
Distribution. Proportional—	T.P. 19 and 25.
Distribution of water—Alternative system of —	T.P. 25.
—Difficulties in the way of —	S.I.D.N. 17, 19 and 20.
Distribution of velocities	I.D.R.N. * 26.
Distribution of water. Basic principles of —	T.P. 25.
Drainage costs	T.P. 14.
of land in the Deccan	Ag. Journal I.S.C. 1919.
Drainage Schemes—Preparation of —	I.D.R.N.* 10.
—Construction of —	Do.
—Maintenance of—	Do.
Drainage waters.—Salts contained in —	T.P. 24.
Utilization of — for irrigation	I.D.R.N.* 10.
Drains—Pipe and open—where suitable	I.D.R.N.* 10.
—Pipe—, cost of —	Do.
—Open—, cost of —	Do.
—Effect of intercepting —	Do. and T.P. 24.
—Discharge of open and pipe	Do.
—Intercepting and relief—	Do. and T.P. 24.
Duties of irrigation water in the Deccan	B.E.C. XXX.
Duty. Increase in — due to modules	T.P. 25.
Duty. Canal, Definition of and figures for—	B.E.C. 1918.
E	
Effluent analysis	I.D.R.N.* 17.
—Comparison of — with local manuring	T.P. 17.
—Corrossive effect of — on soil — deflocculation	T.P. 17.
—Effect of — on the growth of various garden and	T.P. 17.
fodder crops	T.P. 17.
—Effect of — on local biennial rotation	T.P. 17.
—Value of nitrogen in the normal dose	T.P. 17.
—Variation of 'N' and denitrification of 'N' in — in	I.D.R.N.* 20.
passing through septic tanks	T.P. 17.
—When—should be cut off in the case of cane	T.P. 17.
Effluent distribution Difficulties in the way of —	S.I.D.N. 6.
Effluent irrigation. Total area suitable for — on D3—D6	S.I.D.F. 133.
M. R. B. C.	S.I.D.N. 6.
—June—October Plantation—	S.I.D.N. 6.
—Conditions and arrangements necessary before in-	S.I.D.N. 6.
troducing—	S.I.D.N. 6.
Effluent Scheme. Original Project and history of — since	S.I.D.F. 133.
1916	T.P. 15.
Erosion below Falls and rapids	S.I.D.N. 16.
Evaporation of water from tanks	T.P. 24.
from damaged lands	T.P. 24.
of sub-soil water from damaged lands	T.P. 24.
F	
Falls—Old and new design of —	T.P. 15.
—Comparative cost of the old type fall and flume meter	Do.
fall	Do.
—Design of dissipators of Standing Wave Flume	I.D.R.N. 8.
Field irrigation	I.D.R.N.* 10.
Financial aspect of land drainage	T.P. 15.
Floats—Velocity measurement errors using	T.P. 15.

Subject.	Reference.
F—contd.	
Flood absorption—by tanks (lakes)	I.D.R. N. 14.*
Floods—Maximum—in Deccan	I.D.R.N. 25.
—Relationship with rainfall	I.D.R.N. 7.
—duration of —	I.D.R.N. 25.
Flooding of lands to leach out salts	T.P. 24.
Flume—Crump Standing Wave Flume	T.P. 15.
—meter fall	Do.
—Modular limit of S.W.	Do.
—Formula	Do.
—Narrow throated S.W.—	Do.
—Theory of long crested —	Do.
—Principles of design of S.W.—	Do.
Flumed masonry works	I.D.R.N. 22.*
Fluming. Reduction of afflux due to —	Do.
Flumed regulator. Effect of — on silt draw	T.P. 26.
G	
Gates—Automatic — at Lake Fife	I.D.R.N 23.*
—Model experiments to ascertain discharge coefficient of—	
Gauge. Float—	S.I.D. 270/A.
Gibb module—Conditions where suitable	T.P. 26 and I.D.R.N. 3.
—Original and general formulas for —	I.D.R.N. 3.
Godavari Canals—Damage in — tract; soil classification maps	
of —	S.I.D. 288.
—Areas suitable for various crops on —	S.I.D. 286.
—Hydro-isobath maps of —	S.I.D. 284.
—Block maps of —	S.I.D. 288.
Grasses. Utilising — for prevention of scour in open trenches	I.D.R.N. *10.
Gul rates per palla for 1918 to 1926 in Poona	T.P. 17 and 21.
Gul and sugar rates—Chart showing — for years 1890 to 1927.. .. .	S.I.D. 186.
Gul and sugar rates—Relationship of —	S.I.D.N. 21.
H	
Hand weed sickle. Effect of — on removing weeds from	B.E.C. LXXIV.
canals	T.P. 15 and 20.
Head—	Do.
—Error in measurement of loss of —	Do.
—Friction—	Do.
—Velocity—	Do.
Headwalls for pipe drains	I.D.R.N. *10.
Headwalls Humped—in distributaries	T.P. 25.
Headwalls for perennial sections of distributaries	T.P. 19.
for non-perennial section	Do.
Holdings—Consolidation of small — on Deccan Canals	S.I.D.F. 171.
Hume concrete pipes—Graph showing discharges and cost	
for different sizes of	I.D.R. 11.
Hume concrete pipes—Cost of carriage and laying	I.D.R.N. 2.
Hump—Design of—	T.P. 15.
Hydraulic gradient—	T.P. 20.
—Mean radius	T.P. 20.
Hydraulic jump—Adaptation of — for quantity measurements	B.E.C. LXXIV.
—Theory and formula of —	T.P. 15.
Hydro-isobaths of Deccan Canals, i.e., lines of equal depths of	
water below ground surface.	
—Godavari R.B.	S.I.D.N. 15 and
” L.B.	S.I.D. 284.
—Pravara R.B.	S.I.D. N. 15 and
” L.B.	S.I.D. 285.
—Nira L.B.	S.I.D. 290
” R.B.	S.I.D. 291.
Hydro-isobaths of various years in Baramati Salt lands	T.P. 24.

Subject.	Reference.
I	
Impact losses—	I.D.R.N. 11.
Import duty of sugar—Conversion of — into an effective protective duty	S.I.D.N. 21.
Inlets—On open trench in land drainage	I.D.R.N. *10.
—Design of —	Do.
Intensity of irrigation to be allowed before drainage	Do.
—Of irrigation to be allowed after drainage	Do.
Intercepting drains—Utility of —	T.P. 24.
Irrigation—Depth of waterings in —	T.P. 25.
Irrigation from river flow and storages	S.I.D.N. 20.
Isobaths—Murum— of Deccan Canals	I.D.R.N. *10.
Isohyets—Maps showing	I.D.R. 65
J	
Jump-Hydraulic—	B.E.C. LXXIV.
K	
K. Recuperation coefficient	Agricultural journal.
Definition of —	I.S.C. 1919.
Kennedy gauge outlet	B.E.C. XLVIII.
L	
Land drainage—Cost of — on basis of area protected	I.D.R.N. *10.
—Financial aspects of —	Do.
—How to meet the cost of —	Do.
—Importance and necessity of —	Do.
—Maintenance cost of —	Do.
Land values in irrigated tracts. Enhancement of —	S.I.D.N. 2.
Leaching of salts by chemicals	S.I.D.N. 18.
Lindley Standing Wave Flume. Modular limit of —	T.P. 22.
Lining—Effect of weeds and percolation on question of —	B.E.C. LXVIII.
Lining in deep cuttings	I.D.R.N. 4.
Lining,—Where — is suitable —	B.E.C. LXVII I & I.D.R.N. 4.
Liquid soils	I.D.R.N. *10.
Liquid Solid friction	I.D.R.N. 27.
Losses—Absorption—	B.E.C. LXVIII.
—Percolation—	Do.
—Methods to reduce—	I.D.R.N. 4.
—from canals in the Deccan—	B.E.C. LXVIII.
—from distributaries and small channels in the Deccan	T.P. 19.
M	
Malegaon Cut. Effect of partial lining on afflux in —	T.P. 20.
Manholes—Type design of —	I.D.R.N. *10.
Manning's formula—Nomogram for —	S.I.D. 239.
Manning's and Kutter's formulas for "N"—rugosity coefficient	T.P. 20.
Manures—Analysis of —	T.P. 17.
Manures—various—Cost of — in years 1915 to 1927	S.I.D.N. 18.
Measuring devices on D/8, Nira Left Bank Canal	T.P. 15, 25.
Measurements of water—Tank—	B.E.C. LXXIV.
Meter—Standing Wave Flume—Falls	T.P. 15.

Subject.	Reference.
Metals—Corrosive effect of effluent on —	S.I.D.N. 1.
Mixture of effluent with water—Ratio of —	S.I.D.N. 6.
Module—Crump adjustable—proportional semi-module	I.D.R.N. *13.
—Gibb—	T.P. 25.
—Modular limit of Gibb's—	I.D.R.N. 3.
—Partial running of Gibb's—	T.P. 25.
—Rateable Gibb—	T.P. 25.
—Principles and formulas of	I.D.R.N. 3.
Modules and Semi-modules—	B.E.C. VIII & XLVIII.
Modular limit of Standing Wave Flumes	T.P. 15 & 22.
Motion—Stream line—	T.P. 15.
—Vortex—	I.D.R.N. 3 & 5.
Murum isobaths—Cost of showing—	I.D.R.N. *10.
—Significance of — on Deccan Canals	I.D.R.N. *10.
N	
Nitrogen—in effluent—	I.D.R.N. 17.*
—Relative value of — in effluent and other manures	T.P. 17.
“N”—rugosity coefficient in Manning's formula and Kutter's	T.P. 20.
—formula	T.P. 20.
Nala—discharge in different catchments	S.I.D. Register.
—Gradual silting of —	T.P. 24.
—Surveys	I.D.R.N. *10.
Nomogram for Manning's “N” for different values of “R”,	S.I.D. 239 & T.P. 20.
—“S” and “V”	T.P. 15.
Notched fall—Comparison with Standing Wave Flume Fall	T.P. 15.
O	
Obstructions to drainage—	I.D.R.N. *10.
Observation tubes in land drainage Schemes	I.D.R.N. *10.
Offtakes of Pazar channels	Do.
Open trenches—Design of —	Do.
Orifice outlet—Standing Wave—	S.I.D.N. 11.
Outfall—for drains	I.D.R.N. *10.
Outlet—Standing Wave Pipe—Design of —	T.P. 23.
—Recovery of head of Standing Wave Pipe—	T.P. 23.
—Capacity	T.P. 19.
Outlets—for non-perennial section	T.P. 19.
—for perennial section	T.P. 19.
—On Distributary 8, Nira Left Bank Canal—Method	T.P. 25.
—of rotating—	T.P. 21.
Outturn—Effect of irrigation interval on —	T.P. 21.
Outturn and profits from cane	T.P. 21.
Outturn of sugarcane—Effect of the quantity of Nitrogen	T.P. 17.
—applied on —	T.P. 17.
P	
Pajhar channels—Design of —	T.P. 19.
—Percolation losses from —	I.D.R.N. 4.
Permeable strata—Discharge through —	I.D.R.N. 17.*
Physical analysis of Soils, Subsoils and Effluent	I.D.R.N. 11.
Pier cut and ease water designs at Barrage	Do.
—Effect of — on afflux	I.D.R.N. *10.
Pipe—drains in land drainage—Where to use—	Do.
—Cost of —	Do.
—Discharge of —	Do.
Pipes. Hume concrete—whether cost can be justified in Irri-	I.D.R.N. 2.
—gation work	

Subject.	Reference.
Pipe outlets—Standing Wave—	T.P. 23.
—Discharge coefficient of —	Do.
—Effect of projection into a channel of —	Do.
—Effect of adding a bell-mouth to —	Do.
—Effect of adding a hood at the downstream end of —	Do.
—Modular limit of —	Do.
—Type design of —	Do.
Pit at Pimpra, Nira Left Bank Canal—Experiments to find out losses from bed and sides in —	
Pitching—Objections to —	B.E.C. LXVIII.
Pit work in soil survey	I.D.R.N. 4.
Pitot tube	I.D.R.N. *10.
Plane table—Tacheometric—Note on how to use	Pf./8 and I.D.R.N. *24.
Porosity of various strata	S.I.D.N. 5.
—Measurement of —	Ag. Journal.
Posthole Auger—Working of —	I.S.C. 1919.
Profits—Effect of state of land on —	I.D.R.N. *10.
—Effect of fragmentation or smallness of holdings on —	T.P. 21.
—Effect of amount of oil cake applied on —	T.P. 21.
—Effect of skill of the cultivator compared to condition of lands on —	T.P. 21.
—Comparison of — in 1908 and 1914-1918	T.P. 21.
Puddle core—Limits of usefulness of —	T.P. 21.
in porous banks	I.D.R.N.4.
Pumping experiments at Baramati to reduce damage	Do.
—Effect of — on the salinity of subsoil water	T.P. 24.
	T.P. 24.
Q	
Quantity tests—How carried out at the Hydrodynamic Research Station ..	B.E.C. LXXIV.
R	
Rainfall—Calculations of mean — by different methods	I.D.R.N. 7.
—Maximum and minimum — in Deccan catchments..	I.D.R.N. 7.
Rainfall in Deccan Canal tracts	T.P. 21.
Rain-gauges	S.I.D.N. 22.
Raised sill—Design of —	
—Effect of — on afflux	I.D.R.N. 11.
Rates for oil cake—	T.P. 21.
Rates of "gul" in Poona Market	T.P. 17 & T.P. 21.
Rateability of modules and semi-modules	I.D.R.N. 3.
Recovery of head of Standing Wave Flumes	
—of Standing Wave Pipe outlet	T.P. 15, 22 & 23.
—of Lindley Standing Wave Flume	
Recuperation—	Ag. Journal I.S.C., 1919.
Reclamation—various methods of —	T.P. 14 & T.P. 24.
—Economic	
—Plants and crops for —	T.P. 24.
Relief drain	I.D.R.N. *10.
Remodelling of distributaries—	T.P. 25.
Rentals of lands in the Deccan	S.I.D.N. 2.
Resistance of water in electrical bridge in determining Nitrogen in effluent and total salts	I.D.R.N. 17.*
Retentivity of soils	I.D.R.N. 16.*
Retrogression of levels—Effect of —	I.D.R.N. 11.
—Scour due to —	Do.
Return of Canal water to river by seepage	I.D.R.N. 15.*

Subject	Reference
R—contd.	
Rise of water levels in irrigated tracts	S.I.D.N. 15 & S.I.D. 284, 285.
River Gauging at different gauging sites—Information regarding the —	I.D.R.N.* 13.
Rivers and nallas in the Deccan —. Movement of —	T.P. 24.
Run-off—Calculations of — from rainfall	I.D.R.N. 7.
—Maximum — from a — in the Deccan catchment	I.D.R.N. 25.
Run-off of past years—Rectification of — by velocity curves	I.D.R.N. 7.
S	
Sale of water by measurement	T.P. 25.
—at volumetric rates	Do.
Salt efflorescence—Composition of — predominance of particular salts in the soils at Baramati— —Intensity of —	T.P. 24.
Salt lands at Baramati—Previous history of —	T.P. 24.
Salts—Leaching out of — by chemicals	T.P. 24.
—Percentage of — injurious to crops	T.P. 24.
—Types of —	T.P. 14.
Scouring Sluice—Effect of —	I.D.R.N. 11.
Screw auger—Use of —	I.D.R.N.* 10.
Security sewer rods—Use of — in pipe drains	Do.
Seepage water—Return of—	I.D.R.N.* 15.
Septic tank—Changes in “N” while sewage passes through	I.D.R.N.* 20.
“Setting” of modules	T.P. 15 and I.D.R.N. 3.
Setting of cement—Effect of Na_2CO_3 on	S.I.D.N. 8.
Sill Barrage—Effect of different designs of the — on afflux —on scour	I.D.R.N. 11. Do.
Silt draw investigation	T.P. 26 & I.D.R.N.* 24.
Silty water—Conditions necessary to ensure —	B.E.C. LXVIII.
Soils, Deccan	Agri. Journal I.S.C., 1919.
Soils—Deterioration of — due to ratooning	T.P. 21.
Soil maps of Deccan Canals	S.I.D. 288, 289, 301, 302.
Soil series	T.P. 14.
Soils and Sub-soils—Relation of — in the Deccan	T.P. 13.
Soil survey—Rates for —	I.D.R.N.* 10.
Soil suitability	T.P. 16.
Soil suitability for crops for Nira Canals,—Discharge based on —	S.I.D.F. 14.
Soil texture—Effect of various coarse manures on the preservation of —	T.P. 17.
Soil types—Physical properties of —	T.P. 17.
Solid—Liquid friction	I.D.R.N. 27.
Standing Wave—Conditions under which — will form	T.P. 15.
Standing Wave Flumes—	T.P. 15.
Standing Wave Flumes—Cost of	T.P. 15.
Standing Wave Flume design —. Principles of—	T.P. 15.
Standing Wave Flume—Effect of fluctuating discharges on the design of — —Meter falls —Parts of — —Modular limit of —	Do. Do. Do. Do.
Standing Wave Flume Fall design with downstream divergences	Do.
Standing Wave Flume—Lindley type	T.P. 22.
Standing Wave orifice outlet—Experiments in connection with —	S.I.D.N. 11.
Standing Wave Pipe outlet	T.P. 19.
Stilling chambers for reading gauges	T.P. 15.
Stop gates	T.P. 25.

Subject	Reference
S—contd.	
Strata cut by canals—Charts for —	
—Godavari Canals	S.I.D. 293.
—Pravara Canals	S.I.D. 294.
—Nira Canals	S.I.D. 292.
Sub-artesian flow—Location of — in drainage trenches ..	I.D.R.N.* 10 & T.P. 24.
Sub-artesian flow—Effect of —	I.D.R.N.* 10.
Subsoil survey—Necessity of —	T.P. 24.
Sugar and “gul” rates—Chart showing — for years 1890 to 1927	S.I.D. 186.
Sugar and “gul” rates—Relationship of	S.I.D.N. 21.
Surface indications to denote subsoil strata	I.D.R.N.* 10.
Symbols used in Hydraulic Research	I.D.R.N. 1 (printed).
Siphon Spillways at Distributary No. 5 and Khadakvasla—Experiments re-priming, pressures, velocities, etc., with	I.D.R.N.* 5.
T	
Tacheometer Plane table—Instructions on use of	S.I.D.N. 5.
Tintometer readings for determining silt in water	S.I.D. Register and I.D.R.N.* 21.
Transition sections of canals	I.D.R.N. 4.
Transpiration ratio of sugarcane	I.D.R.F. 158.
Trenches—Cost of —	
—Design of open and pipe —	I.D.R.N.* 10.
—Discharge of—	
Turbines—Water—	S.I.D. 154 and T.P. 17.
U	
“ Udid ” green manuring—Effect of — on the outturn of cane ..	T.P. 17.
Unitisation of areas	I.D.R.N. 6.
V	
V Notch experiments	S.I.D.N. 9.
Vanes—Baffle — of Gibb module	I.D.R.N. 3.
Varieties of cane suited to effluent irrigation	T.P. 17.
Vegetables—Suitability of — to effluent irrigation	T.P. 17.
Velocity permissible in channels	T.P. 19.
—of approach—Theoretical and actual effect of—	T.P. 15.
Velocity measurements by current meters	I.D.R.N.* 15.
—by pitot tubes	I.D.R.N.* 24 and I.D.R.N.* 5.
Venturi module sluice on Distributary 8, Nira Left Bank Canal.	T.P. 25.
Viscosity formula	I.D.R.N. 27.
Vortex flow—Free —	I.D.R.N.* 5.
W	
Water cushion	T.P. 15.
Water levels of wells in Deccan Canal tracts	S.I.D. well registers.
Water level recorders—Bore-hole and Stevens —	Pf/3 and Pf/6.
Water requirement experiments	T.P. 17.
Water restriction—Potential advantages of	T.P. 25.
—Difficulties of	T.P. 25.
Watercourses—Capacity of—	T.P. 25.
Waterings in the hot season—Irregularity of —	T.P. 17.
Waterings—Variations from the standard 10 days —	S.I.D.N. 3.
Water levels—Causes of fluctuations and rise of — in wells	S.I.D.N. 15.

Subject	Reference
W—contd.	
Waterlogging—Causes of —	I.D.R.N.* 10.
Weeds—Charts for all canals	I.D.R.N.* 21.
—Closures of canals due to — and interval between closures on different canals	Do.
—Cost of removing —	Do.
—Ecology of —	Do.
—Effect of light as observed by tintometer tests, on — ..	Do.
—Effect of velocity of water on —	Do. & B.E.C. LXVIII.
—Effect of silt (as observed by white disc readings) on —	I.D.R.N.* 21.
—Factors affecting —	B.E.C. LXVIII.
—Rate of growth of — on Pravara canals	I.D.R.N.* 21.
—Types of — in the canals	Do.
Wells —Recuperation of —	Ag. Journal I.S.C., 1919.
—Rise of water in — after advent of canal irrigation ..	S.I.D.N. 15.
—Salt contents of water in wells	I.D.R.N.* 19.
in different sub-soils before and after advent of canals	I.D.R.N.* 28.
White disc readings—Object of —	I.D.R.N.* 21.
X—Nil.	
Y—Nil.	
Z—Nil.	

General Note :—

References in brackets are to Technical Papers : T. P. or Reports I. D. R. N. (see Index)



Salt lands, Baramati, before drainage and reclamation. (T. P. 24.)



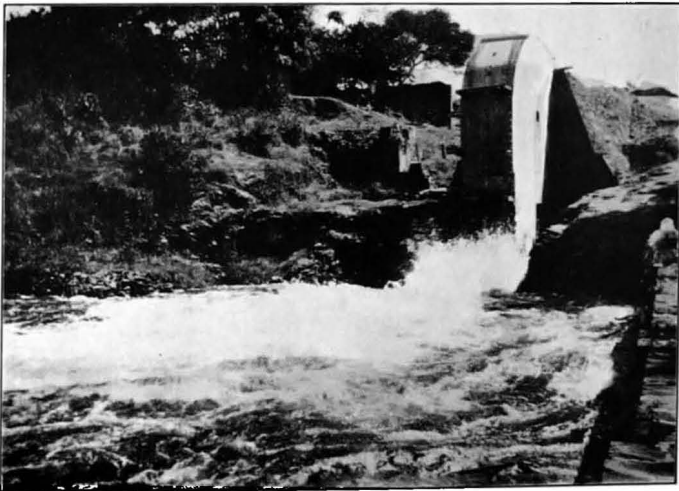
50 Ton Crop of Cane grown in reclamation land, Baramati. (T. P. 24.)



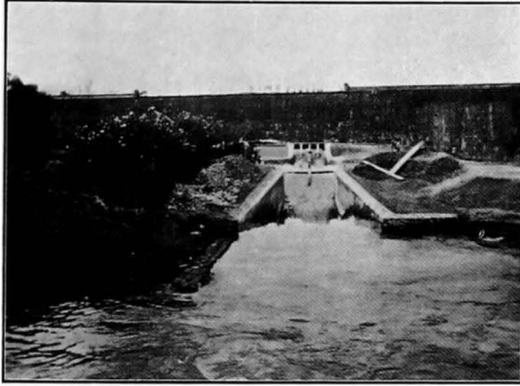
Khadakvasla Siphon Spillway, Siphon just at the point of full priming. ($Q = 150$ Cs.) (I. D. R. N. 5.*)



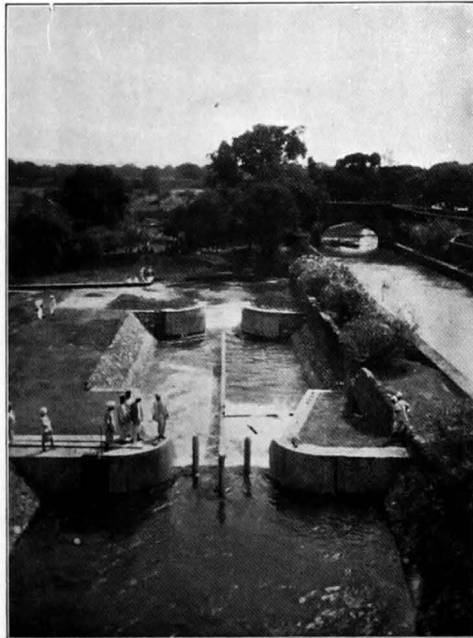
Siphon Spillway at Khadakvasla showing Siphon failing to prime as a result of triangular cut water giving ingress of air, through vertical water diaphragm. $Q = 150$ Cs. (I. D. R. N. 5.*)



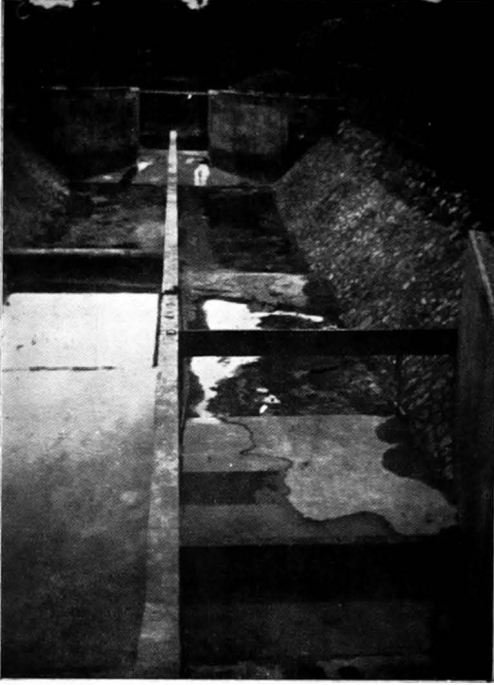
Siphon Spillway at Khadakvasla showing Siphon fully primed, discharging 500 Cs. (I. D. R. N. 5.*)



General view of Khadakvasla ; Hydrodynamic Research Station showing Standing Wave Flume in foreground. Baffle boom dissipator fall in middle distance and Khadakvasla Dam in back ground. (I. D. R. N. 26.*)

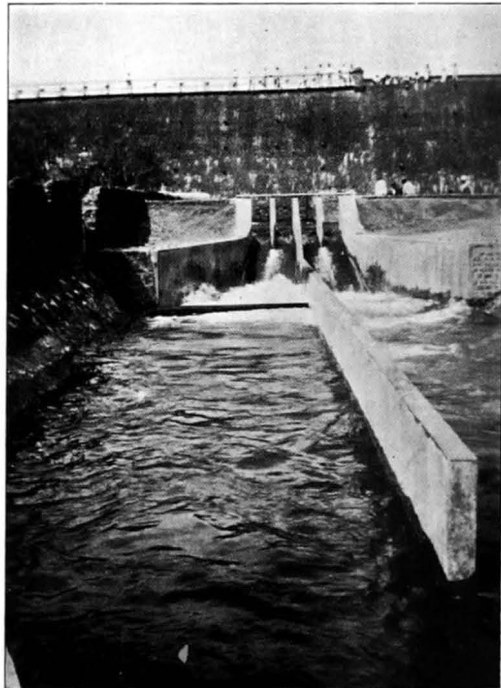


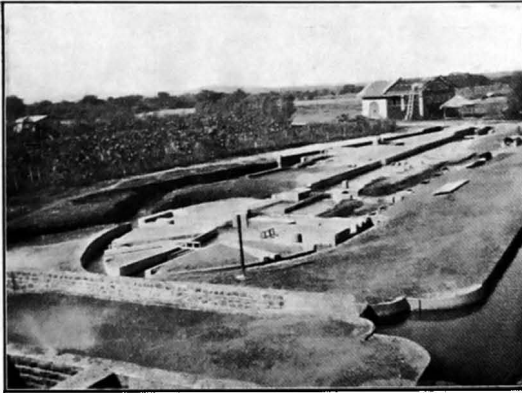
Looking downstream from top of Dam fall in foreground with baffle boom dissipator on right and biff wall dissipator on left. Standing Wave Flume in back ground. Mutha Right Bank Canal on right. (I. D. R. N. 26.*)



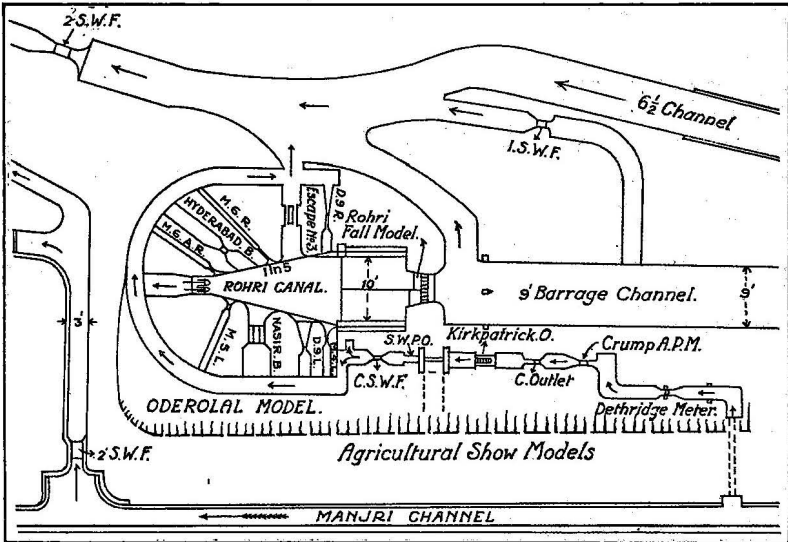
Right side baffle $h_b = 15''$,
 $L = 4'6''$. Boom at 18 feet
 (floating). Left side "Biff
 wall" $C = 1.7$ for 200 Cs.;
 $h_b = 1'65''$, $L = 46$ feet.
 (I. D. R. N. 26.)*

$Q = 170$ Cs., $D_1 = 3.15$.
 Baffle $h_b = 15''$ at $4'6''$ boom
 at 18 feet. Biff wall $h_b = 1'65''$
 at 46 feet. Heave at side due
 to boom not reaching bank.
 (I. D. R. N. 26.)*

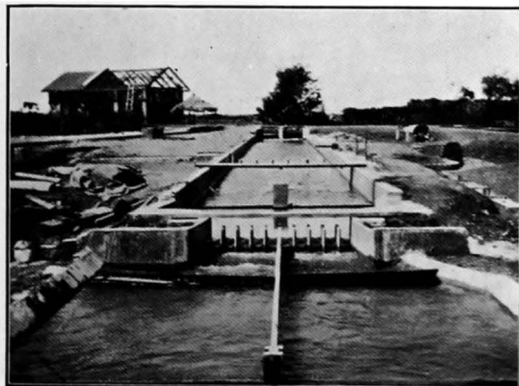


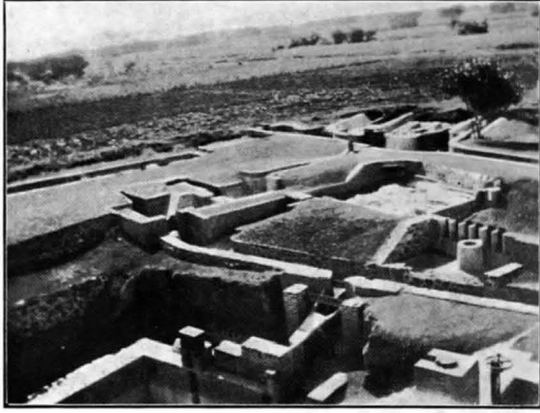


Bird's eye-view of the Hydrodynamic Research Station of downstream showing Oderolal model, Barrage model 9' and 6½' Channels, Pot culture house in the back ground. (For Plan vide Plate I. Drawing No. 62 of I. D. & R. C.)

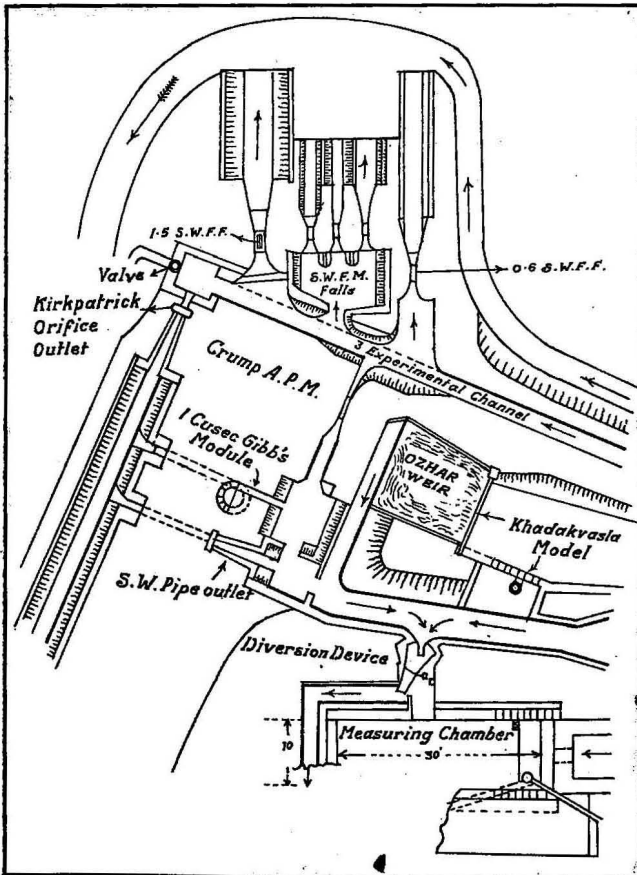


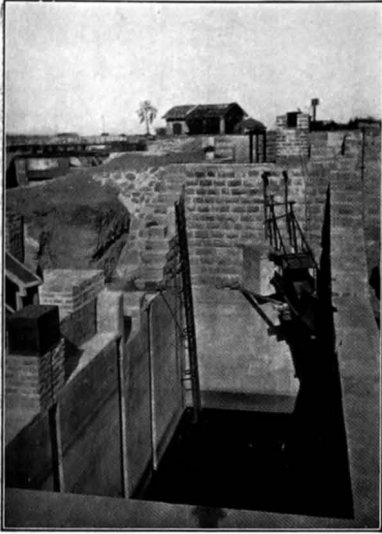
Hydrodynamic Research Station at Distributory No. 6, Rohri Fall model. Barrage model in 9' Channel in the back ground.



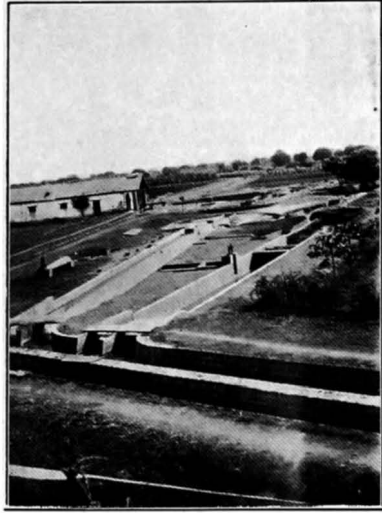


Bird's eye-view of the Hydrodynamic Research Station at downstream showing model of automatic gates at Khadakvasla, Horizontal Diversion Device, Ozhar Weir model and Flume Falls. Crump A. P. M., Gibb Module and S. W. P. O. (Vide Plate I. Drawing No. 62.)

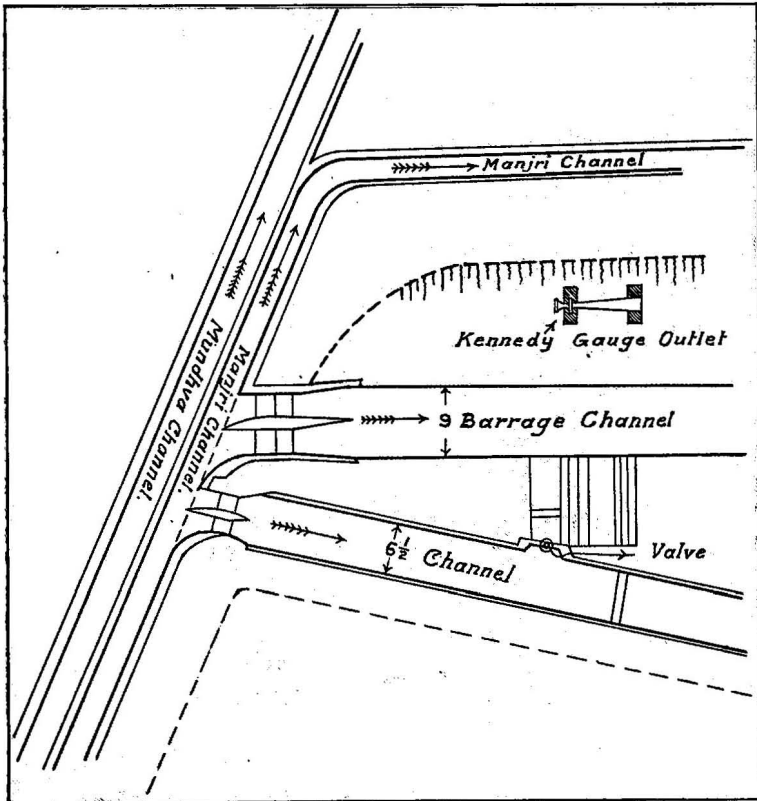




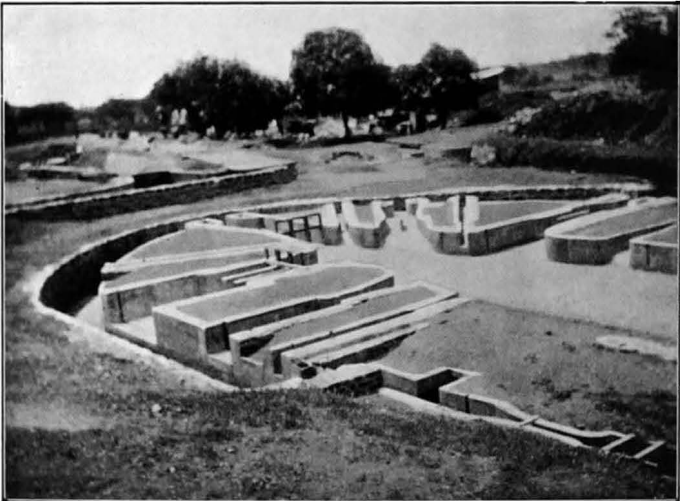
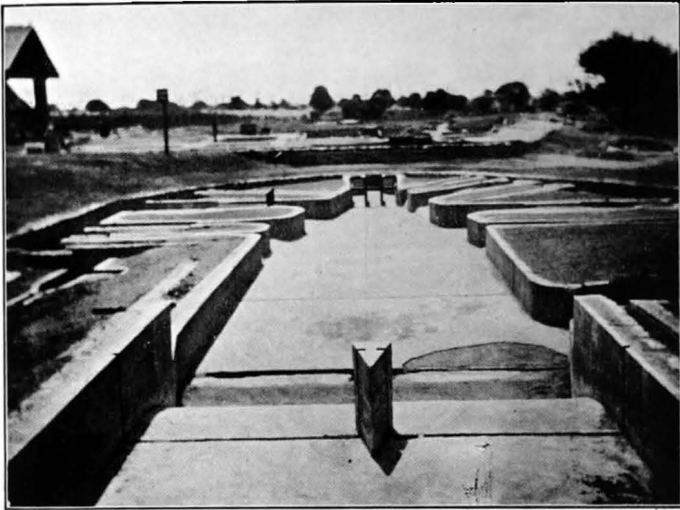
Measuring Chamber showing Hydraulic jump device which deflects water for measurement in a fraction of a second without affecting upstream conditions.
(Vide sketch in sheet No. 6.)



Hydrodynamic Research Station at downstream showing 9' Barrage and 6½' new Channel. In the foreground are seen Mundhya and Manjri branches of downstream; in the back ground on the left is seen the Cane Crusher Shed.

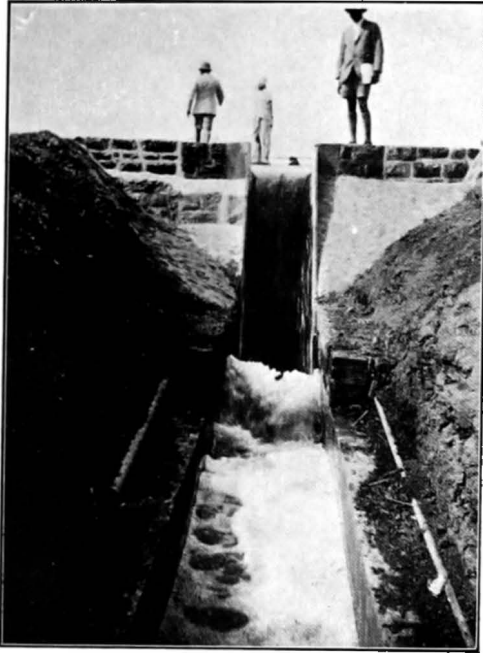


MODEL OF ODEROLAL FLUMED REGULATOR WITH SEVEN OFFTAKES.



Advantages :—

- (i) Compactness and cheapness of design.
- (ii) Excessive silt draw of offtaking channels obviated.
- (iii) Loss of head negligible. (T. F. 26.)



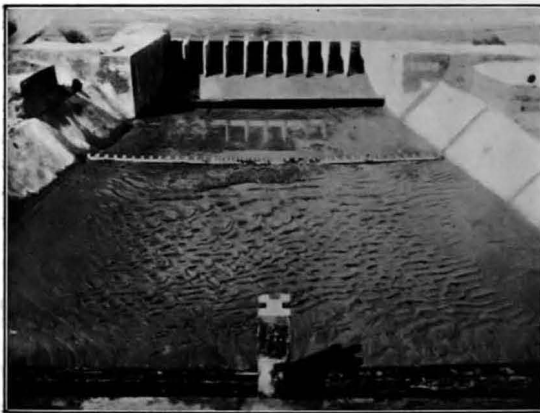
Baffle fall in action ; looking upstream. Drop 6' in Mundhva channel.
(T. P. 15.)



Small models of Flume Fall at Distributary No. 5, Mutha Right Bank Canal.
(I. D. R. N. 26.)*



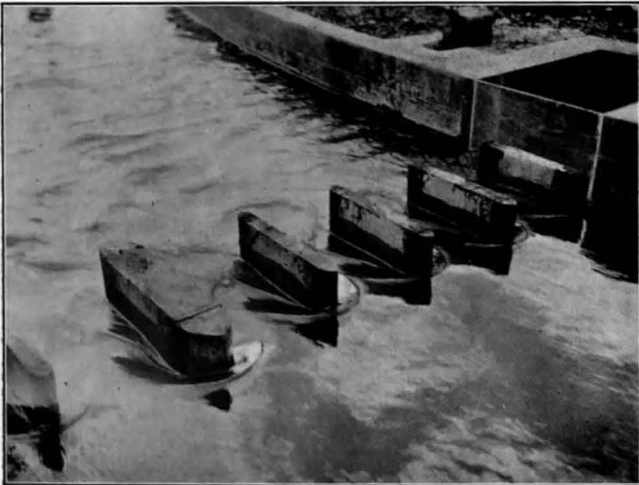
Model of Baffle-boom dissipator (Left) compared with biff wall dissipator (Right) from above fall. (I. D. R. N. 26.)*



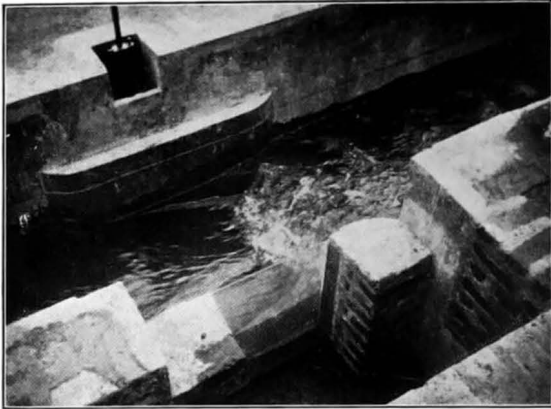
Rohri Fall Model—Series X. Silt spread in the bed ; bed was deepened in the middle.
Shows no scour in the bed beyond 125 feet (actual) from toe of fall if Rehbock 1" high is placed at 100 feet (actual) in addition to baffle and boom.
(I. D. R. N. 26.)*



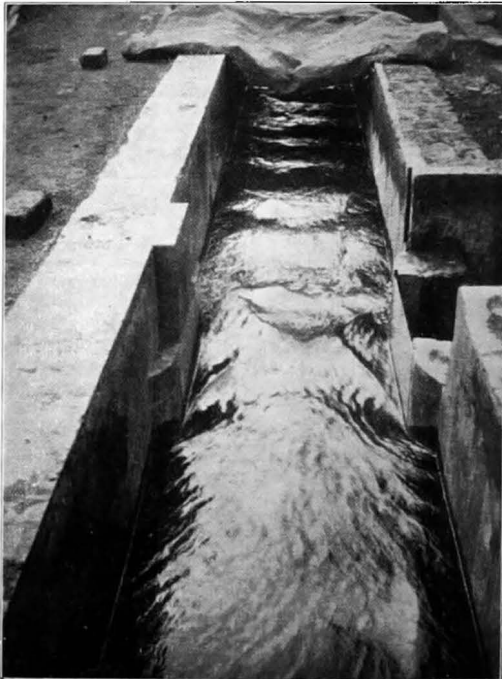
Pointed pier 1 in 5 upstream ; 1 in 10 downstream. (Looking downstream.) (I. D. R. N. 11.)



Pier equilateral arcs of circles. (Looking downstream.) (I. D. R. N. 11.)



Sill experiments: Loss of head = 0.034. Original sill level raised 1 foot.
 R. L. 177 with 1 in 5 slope upstream from 177 to 176.0 and 1 in 10
 slope downstream from 177.0 to 171.0. (I. D. R. N. 11.)



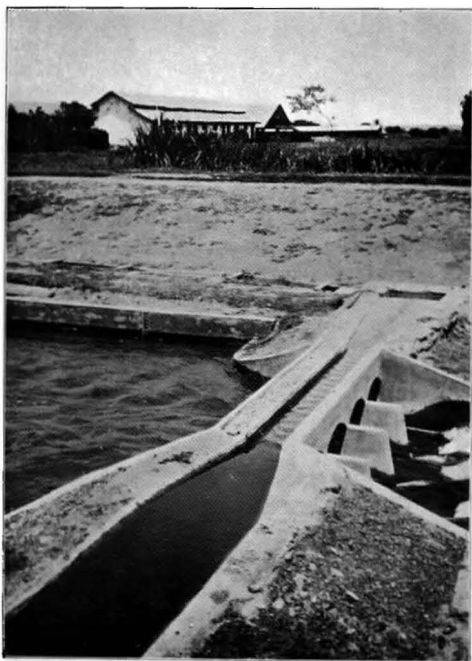
Sill experiments: Loss of head = 0.021. Sill, R. L. 177.0, 1 in 3 upstream
 and 1 in 5 up to 174.7 and 1 in 70 to R. L. 174 downstream.
 (Looking downstream.) (I. D. R. N. 11.)

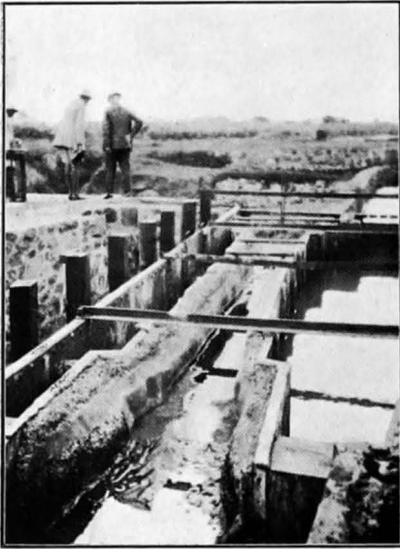
MODEL OF AQUEDUCT No. 23, NIRA RIGHT BANK CANAL.



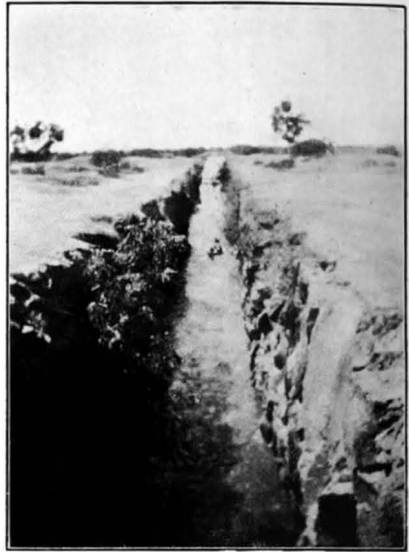
As originally designed
equivalent bed
width = 34'-8". (I. D.
R. N. 22.*)

As finally designed (Flumed)
equivalent bed width = 14 feet.
Loss of head = 0.106 feet.
(I. D. R. N. 22.*)

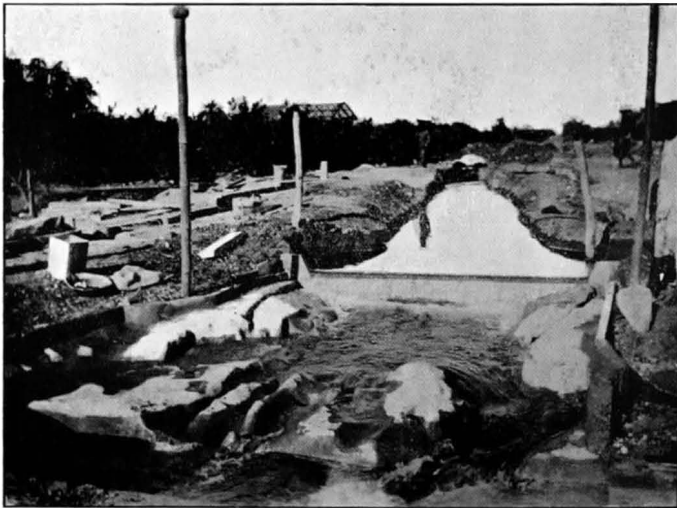




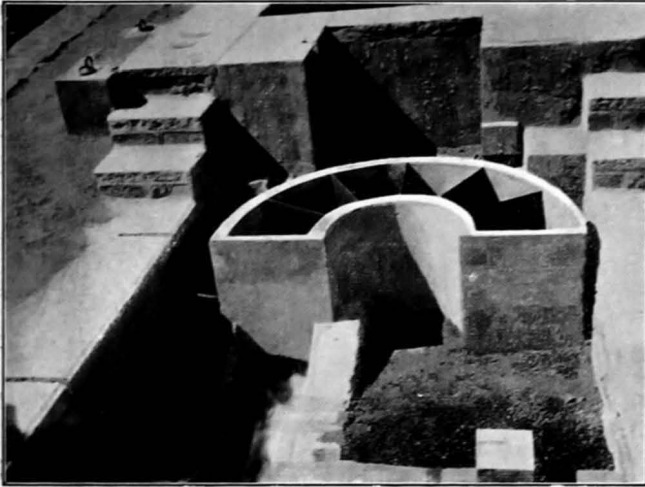
Model of same after lining; the relative effect of partial lining was ascertained. (T. P. 20.)



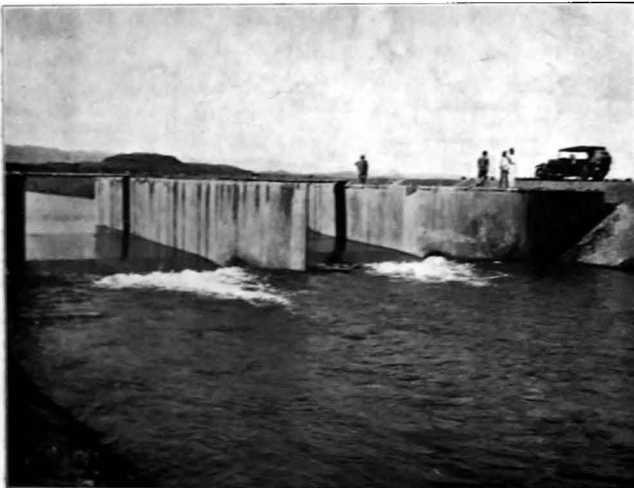
Malegaon rock Cut—30 feet deep, Nira Left Bank Canal, (T. P. 20.)



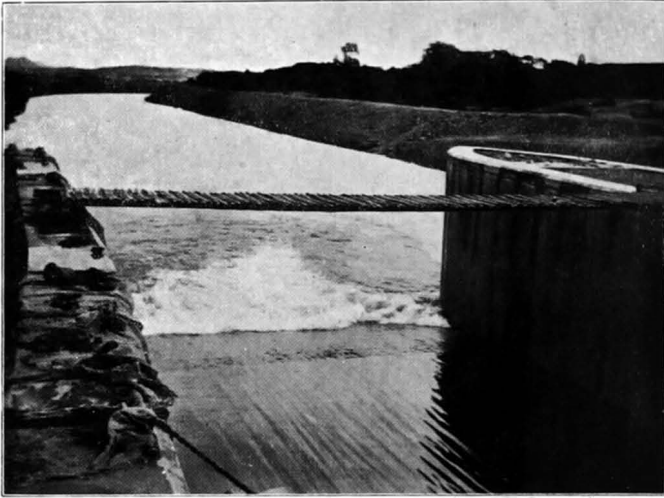
Model of Oshar Weir at Distributary No. 5. (I. D. R. N. 5.)*



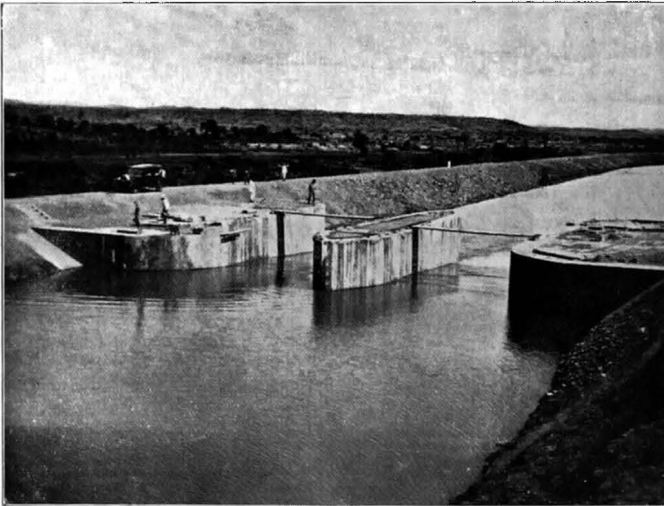
Three Cases Gibb Module in reinforced cement concrete fixed in chamber C of Hydrodynamic Research Station looking upstream. All cases except the last were working when upstream depth of water was 2-3 feet above module flow. (L. D. R. N. 3.)



Standing Wave Flume at head Nara Right Bank Canal designed to measure discharges up to 1,750 Cfs. (Looking upstream.) (L. P. 15.)



Standing Wave Flume at head of Nira Right Bank Canal. (Looking downstream.) (T. P. 15.)



Standing Wave Flume at head of Nira Right Bank Canal designed to measure discharges up to 1,750 Cs. (Looking downstream.) (T. P. 15.)