12TH MAY, 1892.

THE GANGES CANAL, UPPER INDIA.

BY F. A. FRANKLIN, M.I.C.E.

THE object of this paper is to lay before you in a practical manner, with the assistance of illustrations, some of the most important works of this truly gigantic undertaking. The same system is adopted, on more moderate scales, all over India, in controlling and distributing the waters of the rivers, over the vast plains lying between them.

In the year 1884, the author being commissioned by the Government of New South Wales to examine and report on the works of the water conservation in Bengal and Upper India, and later, for $2\frac{1}{2}$ years as a Member of the Royal Commission on Conservation of Water, he was enabled to obtain much practical information, which he now intends, in this paper, to lay as clearly as possible before his fellow-members, with the hope that he may remove some of the doubts that exist as to the applicability of such like works here. The works about to be described are the most extensive in the world for the purpose of irrigation, and were designed for domestic purposes, cultivation, and general stock requirements of six millions of people; but the same principle of distribution may be applied here or elsewhere, on any scale as to dimensions and cost, commensurate with the population and demand.

Plate XVIII. represents a portion of the Holy City of Hurdwar, which is situated on a branch of the Ganges River, in the Dehra Doon.

On reference to the map of India, Plate XIX., on the north, you see the great range of Himalayas extending over a length, from east to west, of 2,000 miles, and rising into the region of perpetual snow, few of the passes being at a less altitude than 15,000 or 16,000 feet, and the highest summit yet measured being Mount Everest, 29,000 feet above sea-level.

The northern provinces of British India occupy a great plain which flanks the Himalaya along its entire length, and many parts are subject at times to severe drought, owing to an insufficient rainfall. The rainfall of the upper Gangetic plain is about 30 inches, but on the slopes of the Himalaya it is much greater. The source of the Summer rain or south-west monsoon, that is from May to October, being a continued stream of air highly charged with vapour which is poured over the land from the Indian Ocean, and infringing on the lofty faces of the mountain range, is driven upwards to the colder regions where condensation takes place and exceedingly heavy rainfall occurs, the drainage from which forms the many tributaries to the Ganges on its northern bank throughout its course towards the sea. It is at this point the pure water of the Ganges is intercepted and diverted in the manner hereinafter described. This place is known throughout India as The Hurkee Pyree or sacred bathing place. Hurdwar is commonly called the "Gate of Vishnu," and is a celebrated place of Hindoo pilgrimage, situated in the Saharunpore district, about 110 miles from Delhi, but it can now be approached to within 50 miles, by railway. The city is most pleasantly situated at the foot of a range of low hills which are again backed up by the monarchs of the Himalayas. The whole line of water frontage is occupied by mosques, temples and bathing ghats or stairways.

The Ganges River immediately above this city, rolled down from the mountains in a succession of lengths of open stream,

and heavy rapids, over beds composed of rocks and boulders; during rainy seasons, those alternate reaches and rapids developing into a continuous mass of rolling cataract, therefore the first work undertaken was the training and controlling of the turbulent and erratic stream into a permanent and well-defined branch channel whose capacity should be at all times equal to the supply estimated as necessary for the projected canal—or about 8,000 cubic feet per second.

The fountain head of this great river is at the foot of the gorgeous pile of perpetual snow known as the Gungootree Mountain in the Himalayan range. The supply is, of course, perennial, and this fact has been the cause of creating doubt in many minds that the dealing with rivers, whose discharges are of an intermittent character, cannot prove effective; this doubt is, however, set at rest by the great practical successes achieved under such conditions in many parts of the world.

Before dealing with the sacred waters of the Ganges in the wholesale manner designed, there were naturally many great prejudices to be first overcome, as every drop of this stream is venerated by the natives along its course of 1,514 miles to the sea. Hurdwar holds an annual fair to which devotees flock, to the number of 200,000 or 300,000, from the most distant parts of India, not only for religious purposes but for the exchange of wares from Cabul, Cashmere, and other parts of Northern India, for the manufactures of Delhi, Lucknow, and all Hindustan. At another great festival, held every 12 years, the estimated attendance has been computed at not less than a million. Formerly the fairs did not pass off without bloodshed, but since the place came under British rule precautions have been taken, and now all passes off quietly and orderly, to the astonishment of the crowds who visit it.

Formerly the public ghat or stairway leading to the general bathing place was very narrow and confined, not allowing for more than four persons to pass abreast. This contracted area for the passage of an immense crowd occasioned a dreadful tragedy

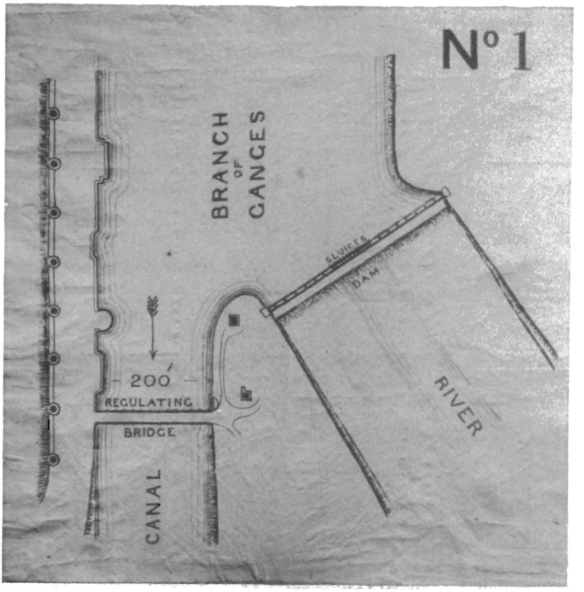
in 1819, when in consequence of a rush made by the pilgrims, to gain precedence in bathing, 430 persons were squeezed to death. The Government immediately constructed the extensive ghat which has ever since fully answered all purposes and prevented a recurrence of such accidents.

The first conception of the Ganges canal was due to Colonel Colvin, in 1836, 56 years ago, but it was not seriously considered until the occurrence of the great and disastrous famine of 1837-38 when the whole question was re-opened and finally a proposal by Colonel Cautley, R.E., in 1840, to construct works to supply 6750 cubic feet per second, and to command 1,473,000 acres at a cost of £722,000 was accepted, and work commenced in a small way in 1842, but it was not until 1845 that the entire project was fully designed, approved and fairly commenced, and the contemplated works comprised a main line of canal from Hurdwar to Allyghur, whence two branches were to bifurcate to Cawnpore and Jar, navigable throughout, giving a length of main canal 380 miles, branches 465 miles, equal to 845 miles; on the main line were 9 escape channels, and 3 on the branches. All preliminary work being completed Government ordered a fair commencement of the work in 1847, and in 1854, seven years later, the water was for the first time admitted into the canal, and irrigation commenced the following year. After opening the works it was found necessary to duplicate a portion of the main canal, from Roorkee, in order to ease the current and prevent erosion of the banks, as also to make separate provision for navigation from same point, for a distance of 165 miles. On completion, the aggregate length of distributaries constructed was 3,346 miles, and estimated expenditure at £2,155,000.

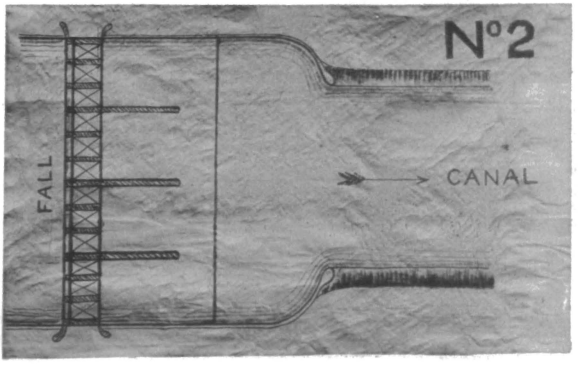
It is generally admitted that the headworks are placed too high up the Ganges, and caused the treatment of the drainage of the country between Hurdwar and Roorkee to be dealt with in the elaborate and expensive manner to be hereafter described.

At the point shown in the illustration the branch of the Ganges is about 300 feet broad. This channel is maintained

GANGES CANAL, UPPER INDIA.



PLAN MYAPORE DAM.



BAHADOORABAD FALLS.

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by a system of temporary crib-weirs and spurs placed at its junction with the main river, so that the supply of water to the headworks below is evenly maintained.

DESCRIPTION OF THE WORKS.

THE MYAPORE DAM AND REGULATOR.

The headworks at Myapore, Plate XX. consist of an overshot weir or dam built across the branch of the river already referred to, at three-quarters of a mile below the city of Hurdwar. The approaches to the canal on either side are protected by massive rivetment walls carried along the canal to protect the flank of the regulating bridge; along these walls are arranged extensive stairways for bathing purposes.

The dam across the channel is 517 feet in width between its flanks, and is provided in its centre with 15 openings of 10 feet each, fitted with sluice gates, having the sills 2 feet 6 inches above the level of those in the openings of the regulating bridge. The regulating bridge is provided with ten openings, 20 feet wide and 16 feet high from the sills, each bay being filled with gates and the necessary appliances for regulating them. Diagram No. 1.

The canal supply is regulated at this point with extreme nicety, any surplus water being conveyed through or over the weir to the main river below. During heavy floods the water is entirely shut off, and supply to the canal, at those periods, is regulated by side sluices in the flank walls. As a protection to the flanks of the canal entrance, the embanked and rivetted approaches are provided on the up-stream side with open wells for the escape of the lateral drainage into the river below.

There is a large amount of detail in connection with this work with which it is impossible to deal at this time. The work of the canal from this point, for 17 miles, is in cutting and in its course is bisected by four rivers crossing at varying

levels. On reference to the map it will be seen that the canal takes a direction nearly at right angles with the Ganges and consequently somewhat parallel with the foot of the lower range of hills. Of course this drainage had to be provided for, and the works adopted for this purpose are without rival in any part of the world.

THE ASUFNGGUR FALLS.

In determining the slope of the canal bed it was found necessary to dispose of the superfluous fall by artificial means. The illustration, Plate XXI., shows a masonry fall adopted along the main line of the canal, by means of which the longitudinal section is laid out in a series of steps, the length and height being determined by the profile of the country. Diagram No. 2.

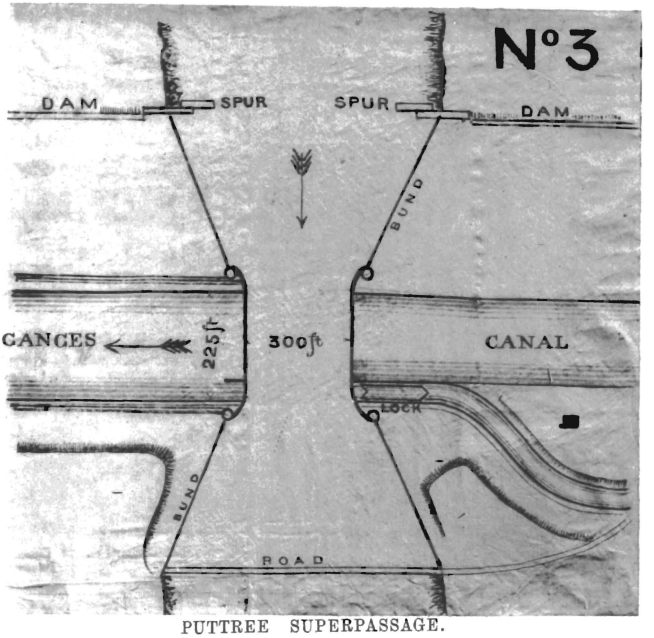
The falls consist of bridges varying in width according to the waterway required. To the down-stream ends of alternate piers are attached, training walls, 84 feet long, dividing the water into chambers of 54 feet each in width, Plate XXI Below these walls the canal bed is floored with boxwork and filled with stone to prevent scour, and the sides are retained by walls. There are fourteen such falls in a distance of 165 miles.

As the canal was designed for navigation in addition to its more important object of irrigation, throughout its length it is adapted to this purpose. It is therefore evident that wherever over falls occur special works become necessary to compensate for these sudden differences of level.

At these places a small navigable channel 20 feet in width has been made to form a loop on one side, commencing about three-quarters of a mile above the site of the fall and re-entering the canal at about the same distance below.

On these channels, locks, at the point corresponding with the situation of the falls, on the main line have been constructed for the purpose of delivering the boats at the different levels which the bed assumes.

GANGES CANAL, UPPER INDIA.



PUTTREE SUPERPASSAGE.

DHUNOWREE WORKS—PLAN.

At each of these locks turbines are fixed, and corn mills have been erected worked by water power. In nearly all cases settlements have sprung into existence.

THE PUTTREE SUPER-PASSAGE.

The term super-passage is applied to this particular kind of construction, Plate XXIII., and differs from the ordinary aqueduct, inasmuch as owing to the rapid slope of the torrent beds above them it is only during and for a limited time after rain storms it acts as a watercourse; at other times it is available and is freely used for general traffic.

The river bed approaching this passage is confined within well-defined banks, having at its near approach protecting bands and spurs to direct the stream to the axis of the artificial channel, the level of bed which corresponds with that of the river on the opposite or down-stream side, which is also protected in its flanks by bands, as shown on Plate XXII.

The catchment area of this torrent is 80 square miles in extent, having a length of 16 miles by an average width of 5 miles running direct from the Sewalik hills.

This structure consists of eight arches of 25 feet span each for the passage of the canal supply, a ninth arch of the same dimensions being devoted to navigation.

The width of waterway over this super-passage is 300 feet in the clear, the parapets being 14 feet high, of very massive construction, and has at all times proved ample for the purpose designed, at times of highest flood. This work is situated at the tenth mile from the head works. A somewhat similar work is placed at four miles above it to carry the Ranipore torrent, which has a catchment basin of 45 square miles. It is but 200 feet between the parapets on account of the smaller body of water brought down by its torrent. These two works cost £78,000.

Plate XXII. and Diagram 3, show the Puttree super-passage on the up-stream side with the arrangement of the navigation

canal lock and mode of departure from the main canal. In order to obtain sufficient headway for the passage of the canal traffic the inverts of the super-passage main canal arches are arranged as an ogee fall of 9 feet depth. The lock shown provides for this difference of level.

Plate XXIV. shows the type of bridge used for cross communication. These bridges are situated at intervals of 3 miles throughout the whole length of the canal, and each one is provided with bathing ghats extending up and down stream of their abutments, thus enabling the population on each side to gain easy access to the water of their beloved Ganges.

THE DHUNOWREE WORKS.

These Works, Plate XXV., are situated at the 13th mile from Hurdwar, where the canal encounters the Rutmoo torrent. This river has a catchment area of 126 miles, and is from the foot hills 26 miles in length, a width of 6 miles, with a slope of bed 8 feet per mile, at its intersection; its natural bed is on the same level as the canal, into which it is freely admitted over a masonry inlet. Opposite this inlet is a masonry dam outlet, consisting of forty-seven ground sluices of 10 feet width, separated by piers 3 feet 6 inches thick as shown; each opening is provided with a moveable sluice-gate, and slotted chambers for the insertion of sleeper shutters at any time required for readjusting the sluice-gates after floods; these gates are held up by chains, to confine the water within the canal bed, but are so arranged and connected, that, when it is necessary to open them simultaneously, the removal of a simple cottar or pin at once releases them.

On reference to Diagram No. 4, it will be seen that in addition to the traffic bridge, with its projecting flank walls, there is below the dam another regulating bridge of the same character as that described at the headworks, the distance along the canal between the two structures being 800 feet, the whole

of which space at varying levels being available as an overshot weir, beside the sluice openings for the discharge of this torrent which is often of a most violent character.

At times of sudden flood the mode of operation is to open the ground sluices and drop the gates of the regulating bridge in which there are ten openings of 20 feet in width each, by which means the flood is forced through the sluices down the natural channel of the Rutmoo River. As soon as the flood is passed the regulating bridge is again opened and the dam sluices closed, which allows the canal supply to run in its ordinary volume.

As these floods may occur at any hour of the day or night it is of the utmost importance that strict supervision be kept, as the duty is very heavy in the rainy season, and it is imperative that the appliances of this immense safety valve should be worked with the greatest expedition, as the safety of the lower works is dependent on the complete control of this system. The cost of these works was £52,600.

Plate XXVI., represents another type of over-bridge of larger dimensions, which is also provided with bathing ghats, and shows how minor streams are admitted into the canal. This heavy class of bridge is necessary as another result of keeping the canal on too high ground and consequently necessitating cutting in approaching the edge of the basin of the Solani River.

THE GREAT SOLANI AQUEDUCT.

The author has already explained how two rivers are conveyed over the canal by super-passages, and one in the plane of the canal bed itself. Plate XXVII. shows how the Solani River conveyed under the canal, The valleys of each of these rivers are separated by a ridge of land, the ridge between the Rutmoo and Solani being high, and two miles wide, through which the canal is carried at a maximum depth of cutting of 37 feet, and

terminates on the northern bank of the Solani River valley which at this point is 11,680 feet, or nearly $2\frac{1}{4}$ miles, in width, to its opposite bank at Roorkee. As the canal enters the valley it is carried in an earthwork embankment or platform, raised to an average height of 16 feet 6 inches above the bed of the Solani, having a base of 350 feet and breadth on top of 290 feet. On this base the retaining banks of the canal are formed, 30 feet wide on top and 12 feet deep. These banks are lined throughout, on the inner side, with masonry walls, formed in steps, extending along the whole length, or nearly $2\frac{1}{2}$ miles north of the Solani.

The river itself is crossed by the masonry aqueduct shown in the illustration, which but faintly conveys an idea of the magnitude of this great structure, which is one of the most remarkable works of its kind in the world.

The total length of the aqueduct proper is 920 lineal feet, giving a clear river waterway of 750 feet, in 15 arches of 50 feet span each. The length of each arch from face to face is 192 feet, and thickness, in concentric rings of brickwork, 5 feet, with a rise of 8 feet segmental arch.

The foundations are laid on cubes of masonry 20 feet wide, pierced with 4 wells each and sunk to a depth of 20 feet in the bed of the river, in the manner common in India of under sinking by internal excavation. The amount of masonry so used in foundation is scarcely less than that visible above the surface. The total height of the aqueduct above ordinary water level is 38 feet. It is therefore not so imposing when viewed from below in consequence of this deficiency of elevation, but as viewed from above, when its immense breadth is observed with its line of masonry channel nearly 3 miles in length, the effect is most striking.

The waterway over the masonry aqueduct is formed in two separate channels each 85 feet in width, leaving 22 feet at side for traffic. The side walls are 8 feet thick and 12 feet deep, with a depth of 10 feet of water when the canal is running full.

After passing the aqueduct a continuation of three-quarters of a mile of embankment connects the masonry work with the high land at Roorkee, and brings the canal to the end of its greatest engineering difficulties.

ROORKEE.

We have now arrived at Roorkee, Plate XXVIII., a town which has sprung into great importance since the canal works were commenced, and it is now one of the most attractive and busy stations in the North-west provinces. Situated on the high land above the Solani, it was the point selected for starting the gravitation lines of the main canal through the hitherto dry lands between the Ganges and the Jumna, and also for forming the workshop establishment for the requirements of the whole system.

The workshops are used for the purpose of constructing all the detail work beyond the capabilities of ordinary native workmen located along the line of canal and for maintenance work.

The establishment consists of foundry, fitting, smiths', pattern and carpenters' shops, and forms one of the finest establishments of the kind, either public or private, in India. 1,500 native workmen are employed in the various branches, including mathematical instrument making, under the supervision of two Europeans.

On the opposite side of the station, situated on a gentle crest, is the Thomason College of Civil Engineering. Within its walls are educated all classes of public officers to the high state of efficiency necessary for their future positions in the service. The educational machinery of the college is as complete as that of similar establishments in Europe.

With a necessarily short notice of its two most interesting establishments, we may now leave Roorkee and proceed down the course of the canal to the southward.

The country through which the canal passes is admirably adapted for irrigation in many important particulars, but it presents some difficulties which required much careful thought to overcome. The great plain forming what is termed the Northern Doab is triangular in shape, its boundary on the north being the Sewalik hills, on the east by the River Ganges, and the west by the River Jumna; the base line of the figure therefore stretches from the head of the Ganges to that of the Eastern Jumna Canal, a distance of 45 miles. A line drawn across the Doab, 20 miles south of Meerut, shows the tract divided into two parts, presenting a marked and interesting contrast in the superficial character. North of the line, the notable feature is the rapidity of slope referred to, and the prevalence of undulating sandhills; to the south, the slope throughout is very gentle, falling about one foot per mile, and ultimately somewhat less, but broken at intervals by sudden and abrupt falls of several feet, so that the country is formed in a series of steppes, falling towards the south.

The course of the canal from Roorkee, southward, to Nanoon, is 180 miles; the slope of the bed is regulated by masonry falls wherever necessary, with loop navigation channels as before described. Bridges for cross communication are built at intervals of 3 miles, and to each bridge is attached the head of a Raghuba, or main irrigating channel, by which means the water is carried to the adjoining land and villages.

In addition to the ordinary discharge from the canal, for the purpose of irrigation, provision has been made for escape heads at suitable positions, by which means any surplus water may be discharged into the common drainage lines of the country passed through; these escapes occur at about every 40 miles, and consist of a certain number of sluices set under the roadway bordering the canal, so that free passage is open both to the water and road traffic.

The system of distribution by these Raghubas, or subsidary canals, is to carry them on elevated ground along the general

drainage lines of the adjoining country, so as to command all lands lying below. The length of minor canals, or distributaries, is about $5\frac{1}{2}$ times in length greater than the main line.

Along the lines of these branches outlets are fixed at carefully-considered points; these outlets are in some cases simple stoneware pipes inserted in the banks, which discharge into smaller or village channels; accurate measurement of the supply is registered, and charge made in accordance with the nature of the crop or area irrigated.

On both banks along the whole line plantations of useful trees have been formed, and the distances are clearly marked by milestones.

At Nanoon, the canal branches off into separate terminal lines, one direct to Cawnpoor, and the other to the River Jumna at Etawah

The Cawnpoor terminal line passes through that city, and in its course forms a pleasant esplanade lined with rows of handsome trees, and provided with bridges and bathing ghats, so as to be an ornament to the neighbourhood; its junction with the Ganges is effected by a series of locks for passing boats into the river.

The entire length of this line from Nanoon to the Ganges is 170 miles, and, owing to the number of off-lakes along its course, the sectional dimensions at the outlet is much diminished, the width at starting from the junction being 80 feet, and at Cawnpoor but 20 feet.

This completes a brief description of the Ganges Canal, and its advantages may be summarised as follows :—

RESULTS TO THE PEOPLE.

1. Certain in place of precarious irrigation.
2. Cheaper irrigation from the canal than by any other method.

3. Irrigation at moderate cost in localities where hitherto it was impossible.
4. Increase of produce from a given area.
5. Facilities for producing crops of a more valuable kind.
6. Increased value of property.
7. Increase of commercial facilities for transit.
8. The low price paid for the advantages of permanent water supply, the charges being not more than two shillings per acre.

The advantages to the Government may be briefly stated by the fact that

1. Security against the heavy demands for payment and remission required to alleviate famines, that of 1837-38 costing nearly as much as the works of the canal.
2. Increased land revenue consequent on the extension of the area irrigated and improved, with the ascertained return of 6 per cent. on the capital expended on the construction of the works.