

(Paper No. 2734.)

“The Water-Supply of Jeypore, Rajputana.”

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(Abridged.)

THE city of Jeypore was founded in the year 1718 A.D. by Maharajah Sewaie Jey Singh. It is situated in a small valley 5 or 6 miles long, surrounded, except on the south, by hills. The soil between the hills and on the plain is drift sand, interspersed here and there with beds of kunkur, or limestone nodules, which are found generally a few feet below the surface. A small stream called the Amani Shah, Fig. 1, Plate 4, which rises in the hills north of the city and flows past it about  $1\frac{1}{2}$  mile to the west, was evidently at one time dammed or “bunded” and diverted to the city.

That the supply obtained from this stream, supplemented by wells in the city, proved insufficient for the needs of the inhabitants is indicated by traces that are found of attempts having been made to bring water from a river called the Brandi, about 25 miles to the west. These works, however, appear to have been unsuccessful, and surveys made lately show that there was no gathering-ground which could have been depended upon for a proper supply, nor any site suitable for a storage-reservoir. The slope of the Amani Shah is about 16 feet in a mile, and as the soil is simply drift sand, it can readily be imagined how the bed was scoured by floods. This was not all—every year, when the reservoirs formed by the earthen dams across the stream were full, as there was no proper provision for discharging the waste water, the banks were overtopped and carried away—the bed being scoured to a considerable depth as a natural consequence. The expense and labour involved by the repeated renewals of the earthen dams led at length to a masonry dam being constructed across the river.

OLD IMPOUNDING-RESERVOIR.

This dam was founded on wells, and appears to have been built of first-rate masonry; it was about 60 feet high and 300 feet in length, with a massive stepped apron to discharge the surplus

water. Masonry steps were built on the banks of the nullah at each end of the dam on the up-stream side to afford access to the water; and wells for irrigation were made along the banks of the storage-reservoir. A masonry conduit, 3 feet by 2 feet in cross-section, provided with vertical air-shafts at intervals of 400 feet, was constructed for a length of 3 miles to the city, where open reservoirs were built in the two public squares to receive the water. After the completion of the dam, the reservoir took some seasons to fill, but on the eve of the inauguration of the supply, the dam, which had cost  $4\frac{1}{2}$  lacs of rupees, gave way, and in a brief space of time the lake was emptied and the work was utterly ruined; affording, in the words of the late Maharajah Sewaie Ram Singh, who was an eye-witness of the catastrophe, "the grandest and most expensive spectacle he had ever seen."

In design and construction the work was sufficient for any site with a rock foundation. Its failure was due to a work of that character being built in a nullah with sandy bed and banks, and to the wings not being carried far into the banks. The water appears to have found a passage round the west end of the dam, and perhaps under the foundation also.

No further attempt was made to supply the city with water until, in 1873, the project described in this Paper was undertaken. After an exhaustive inquiry into the feasibility of other schemes, it was decided to obtain a supply from the Amani Shah nullah, the water of which was pronounced by the Government analyst at Calcutta to be "of excellent quality." An anicut or weir was thrown across the bed of the nullah at the site of the old broken dam (Fig. 2, Plate 4). This was a masonry wall 6 feet high and 3 feet thick, founded on rectangular wells of masonry 9 feet by 5 feet, sunk 6 feet deep and filled with concrete, with intervals of 6 inches between them, to prevent them from jamming against each other whilst being sunk. On the down-stream side broken material from the old dam and rubble were spread to form an apron sloping 1 in 12, reaching to within 2 feet of the top of the weir. It was further protected by a pavement of heavy schistose slabs, 10 feet to 12 feet long, connected together by a  $\frac{3}{4}$ -inch iron chain which is secured to the wings at each end.

A pumping-house was erected containing two pairs of 11-HP. horizontal rotative high-pressure steam-engines, with 12-inch cylinders of 24-inch stroke, each pair of engines driving two sets of  $9\frac{1}{2}$ -inch three-throw plunger-pumps, capable of delivering 36,000 gallons per hour to the city. Steam was supplied from two Root boilers. The flue, which had a sectional area 20 square feet, was

taken up the sloping bank to a masonry chimney at the top, the total height being about 86 feet. These works were completed in 1874, and answered all expectations; but the demand for water annually increased, until during May and June, 1881, the water in the stream was only just sufficient to meet the demand.

In 1883, the supply ran so short that an intermittent system of distribution had to be introduced. It was then decided to sink a well in the bed of the stream, near the engine-house, and to erect an auxiliary pump over it, with a view to tap the springs below when the surface-water failed. The well was of masonry, 20 feet in internal diameter, carried on a wrought-iron curb 4 feet high and 3 feet 8 inches wide at the top, filled with concrete. Eight  $1\frac{1}{4}$ -inch bolts were carried up from the curb in the middle of the masonry, and at every 20 feet there was a horizontal band of flat-iron, 3 inches  $\times$   $\frac{1}{4}$  inch, and with a band of iron outside to brace the structure together. Weep-holes 15 inches by 12 inches were left in the masonry about 8 feet apart horizontally and 2 feet vertically. These were closed with faces of dry bricks inside and outside, and the spaces between them were filled with sharp sand. The object of the weep-holes was to permit free infiltration of water through the sides of the well, and so to diminish the tendency of sand to blow up from the bottom. Owing to the approach of the hot season, sinking was stopped at 80 feet when there was 68 feet depth of water in the well, and a Davey pumping-engine was erected on the top, and was worked when required. Notwithstanding this, in 1884 it was again found necessary to restrict the supply to the city during May and June.

The necessity of removing once for all this trouble, and the fact that during the rains a large quantity of water flowed away, led to its being decided to store this surplus water for use in the hot weather. The obstacles which presented themselves in dealing with the proposal were: that the bed and banks of the river are composed of loose sand, and the difficulty of arranging outlet-works and an efficient and safe waste-weir. It must also be observed that the banks of the river are about 700 feet to 800 feet wide at the top and 61 feet deep; and any attempt to build a dam had to be completed in one season between the rains.

#### NEW IMPOUNDING-RESERVOIR.

A site was selected 750 feet above the pumping-station, where an embankment thrown across the river would impound 148 million cubic feet of water up to the 46-feet contour. The drainage-area

above this point is about 13 square miles. The mean rainfall is 24 inches, but considering the nature of the soil, it was not expected that more than 4 inches of rain, or about 120 million cubic feet of water, would flow off annually. If, however, from silting of the reservoir or any unexpected cause the water should ever reach the 46-foot contour, provision was made for its escape by cutting a channel 3,795 feet long at that level, leading to low ground on the west. The bed-slope of this channel was 1 foot in a mile, the bottom-width being 20 feet, and the side-slopes 1 to 1; and any overflow would pass away by it gradually, over the natural surface of the land. The experience which has been gained since the embankment was made has shown that only about one-sixtieth part of the rainfall flows off the catchment-area into the reservoir. This, no doubt, is largely owing to the absorbent nature of the soil, as one-tenth part has been found to be the average elsewhere in the district.

The embankment possesses some points of interest, in that it has no core-wall; that it is made of sand, resting upon sand and mud, the natural surface being merely dug up and coarse grass roots being removed.

Its dimensions are :—

	Feet.
Length at top . . . . .	680
Height . . . . .	61
Breadth at the top . . . . .	30
"    "    base . . . . .	390
Inner slope . . . . .	4 to 1
Outer " . . . . .	2 to 1

Work was begun on the 27th June, 1884. Light rails, 16-inch and 24-inch gauge, and double side-tipping wagons were ordered by telegraph from England, and, as soon as they arrived, the work was vigorously prosecuted. Sidings were laid down on each bank with a slight incline. Two men were placed in charge of each wagon, which, after being filled, was pushed along, and soon acquired sufficient momentum to run on to the site of the bund, carrying both the earth and the men also, who quickly jumped on to the wagon-frame when it started. As the embankment rose the rails were also raised, and the speed and economy with which the work was done were highly satisfactory. As many as 129 wagons were at one time employed, bringing about 30,000 cubic feet of sand daily from a distance of about 1,000 feet, at half the cost of manual labour. Extra men were employed to spread and ram the earth, and a few Raj elephants walked backward and forwards, morning and evening, over the work to consolidate it.

A temporary outlet, consisting of two 12-inch sluices, was built 5 feet above the river-bed at one side, and the nullah was closed on the 26th October, with the object of impounding as much water as possible for the ensuing hot season. In the meantime the permanent outlet-well and culvert were taken in hand. The difficulty of laying the foundations was increased owing to the water, which by this time had risen to a height of 13 feet. The foundations were laid on hollow wooden frames, the outside dimensions of which were 13 feet by 8 feet, on which masonry walls were built 6 feet high and 1 foot 6 inches thick. When these were thoroughly set, they were sunk, and the internal spaces were then filled with concrete (Fig. 3, Plate 4). An interval of about 1 foot was left between each pair of frames to prevent jamming during the process of sinking. These were afterwards filled with concrete, and the whole surface was covered with slabs of stone.

The outlet-well, Fig. 3, is of masonry, oval in plan, 11 feet 6 inches by 9 feet 6 inches inside, carried down about 12 feet below the ground and built to a height of 40 feet above it. Wing-walls are provided on the water-side, with cross-walls to counteract any thrust. In these cross-walls are large openings over which movable iron gratings are fixed. The water passes through these gratings to two 12-inch outlet valves, which have gun-metal faces and are raised or lowered by vertical iron rods, worked from cast-iron pillars at the top of the well. A flight of stone steps outside gives access to the top of the well, which is covered with a wooden floor protected by a handrail round it. A masonry staging is built above the sluices, carrying a travelling crab-winch from which a dredger can be worked to remove any silt that may accumulate in front of the inlet-valves; stone slabs are fixed inside at convenient distances to form a staging for a light iron ladder to be placed when required, to allow of descent and access to the valves. Inside the well are two sluice-valves similar to the two outside it. These admit the water to two 12-inch flanged pipes, which are laid through the culvert side by side. In order to prevent sand from blowing up inside, the bottom of the well was closed with a wedge-shaped mass of concrete. The outlet-culvert, a cross-section of which is given in Fig. 4, is of masonry, 7 feet wide and  $7\frac{1}{2}$  feet high. At the end and half-way, air-shafts are built for purposes of ventilation.

It was feared that when the reservoir filled, water might creep along the culvert; and to prevent any chance of this, slabs of sandstone, 3 inches or 4 inches thick and about 8 feet long, were built in the masonry of the culvert, projecting 6 feet all round it,

forming collars at every 50 feet along the length of the culvert, against which the earth was well rammed, so that any leakage should be prevented from creeping along the surface of the masonry.

A common source of weakness in earthen bunds occurs at the toe of the outer slope, where the earth often weeps with leakage and the slope of the bank becomes a hollow curve. To obviate this in small embankments, the natives often drive in stakes, and weave about them a wall of thorns or coarse grass to prevent earth from coming away with the leakage. In the present case, the following course was adopted :—Next to the earth a layer of sharp sand, about 10 feet wide and 5 feet deep, was placed; outside this a similar layer of small broken stone; and finally a similar mass of large rubble. This was carried along the toe of the outer slope. It was anticipated that the whole of this material might sink and disappear in the first year, and that it might be necessary to renew it more than once; but that when it did stand, it would act as a filtering medium, keeping back the earth, but allowing water to percolate out free from silt. It has answered better than was anticipated, but little settlement has occurred, and it has not had to be renewed. There is less leakage than was expected, and the water passes away quite clear. Springs occur even at the foot of the side banks of the nullah, 200 feet or 300 feet below the site of the dam, showing how porous the soil is. Another danger in large earthen bunds is that the rain-water which falls upon the surface of the embankment often drains towards some low point, and then, running down the slopes, cuts deep gutters. To prevent this the following plan was adopted: On the top of the dam a low bank of earth was made on both sides, and the top was rammed with kunkur. This formed a footway along each side, the centre portion being left unmetalled; and any water which falls upon the top of the embankment during the rains sinks quietly into it and disappears without doing any harm. The inner slope is covered with a 9-inch layer of broken stone up to high-water mark; above this and on the outer slope coarse grass is planted.

The work was completed in September, 1885. The greatest flood occurred on the 1st August, 1885, when the water rose 5 feet 10 inches in twenty-four hours. On the 1st September, the level of the water was 24 feet 4 inches, and on the 31st December 23 feet 11 inches. The water generally reaches its highest level in December or January, showing that the reservoir is fed by springs. The highest level yet attained is  $31\frac{1}{2}$  feet.

# PUMPS AND FILTER.

With the view of utilizing some of the surplus water, the two 12-inch pipes which are laid through the culvert were united and connected with a Schiele vertical turbine  $2\frac{1}{2}$  feet in diameter, which was placed in the deep well. By means of gearing, three 7-inch horizontal rams, of 15 inches stroke, are worked by it at 20 strokes per minute, delivering about 6,600 gallons per hour into the service-reservoir, 110 feet above it.

The average daily consumption of water had by the year 1890 increased beyond the capabilities of the pumping-engines that were erected in 1874; and in 1892 an additional engine and pump was erected, capable of raising 2,000,000 gallons per day. This machinery, which was made by Messrs. Easton and Anderson of Erith, is a compound beam-engine, the two bucket- and plunger-pumps being driven off the beam on either side of the centre. The sizes of the cylinders and pumps are :—

	Diameter.	Stroke.
	Inches.	Inches.
High-pressure cylinder . . . . .	$16\frac{1}{2}$	40
Low-pressure cylinder . . . . .	25	60
Bucket pumps . . . . .	$20\frac{1}{2}$	30
Plunger „ . . . . .	$14\frac{5}{8}$	30

The two 9-inch pipes which were laid down for the old engines were taken up, and a single 16-inch pipe was substituted for them, the delivery-pipes from the old engines being connected with this new main. Coal is obtained from mines near Calcutta and costs Rs.32 4 0 per ton delivered at Jeypore, an import duty of Rs.10 11 0 per ton being levied on it by the Jeypore Durbar. The boiler-house consists of merely a thatch roof, open along the ridge, carried by light iron trusses supported on masonry pillars, the sides being open. This is quite sufficient for its purpose.

The filter is supplied by an open masonry conduit from the anicut, Fig. 2, Plate 4, and, as soon as the water in it is 2 feet in depth, the surface is level with the crest of the anicut which serves as an overflow. The area of the filter is 160 feet by 80 feet; its section is thus composed (Figs. 5 and 6):—

	Feet. Inches.
Water . . . . .	2 0
Fine sharp sand . . . . .	2 0
Coarse sand . . . . .	0 3
Broken stone $\frac{3}{4}$ -inch to $1\frac{1}{2}$ -inch gauge . . . . .	1 0
Covering-slabs and drain . . . . .	0 6
	<hr/>
	5 9

The filtered water passes into a small covered tank, from which it is drawn by the pumps. The filter was designed to allow of sufficient water passing through, at the rate of 6 inches per hour, to keep the pumps supplied. The supply to the filter can be shut off at any time, and valves communicating with the river allow it to be emptied when it is required to clear it. A simple arrangement of valves on the suction-main renders it possible to draw the supply from the filter or direct from the river as may be desired.

#### SERVICE-RESERVOIRS.

The service reservoirs (Figs. 7, Plate 4), in duplicate, are placed on the highest ground in the neighbourhood, about 2,000 feet distant from the pumping-station. The floor of these reservoirs is 103 feet above the pumps and 36 feet above the city squares. Each reservoir is 150 feet by 100 feet at the bottom, by 15 feet deep, and contains 1,477,000 gallons. When the reservoirs were built they were open, but it was found that by exposure to the sun vegetable life was rapidly developed in the water. They were then covered by light masonry arches resting on masonry pillars. After that was done all signs of vegetable growth disappeared. The water is admitted from the 16-inch rising main into a sheet-iron vessel with one outlet, which can be turned round opposite to the reservoir into which it is desired to deliver water. One reservoir is in use for the supply to the city while the other is being filled; and by noting the depth of water daily, it is easy to calculate the consumption. The outlets are 12-inch screw-down valves with gun-metal faces, the mouths of the outlet-pipes being protected by large cages of finely perforated zinc, on iron frames which can be easily removed at any time.

#### AQUEDUCT AND DISTRIBUTION-SYSTEM.

A 12-inch cast-iron spigot-and-socket pipe conveys the water to the city, Fig. 1, Plate 4, where it is distributed by pipes of smaller dimensions to the palace, the streets, the public gardens, and some of the public buildings. A 6-inch main supplies the Imperial Service Jeypore Transport Corps, and thence a 3-inch pipe is laid to the State Cotton Press. Another 6-inch main is laid direct to the private residence of H.H. the Maharajah. Scour-valves are placed at the lowest points on the line of pipes and at all dead-ends, and these are opened about once a week to clean out the pipes. All pipes above 3 inches in diameter are of cast-iron, those



of smaller size for house-connections being of galvanized wrought-iron. There is a stop-valve for every street. Stand-posts have been erected at the corners of all streets which intersect the main line of pipes. These are placed generally about 20 feet distant from the main, and a stop-valve is fixed on the branch so that the stand-post can be disconnected at any time. Self-closing ball stand-posts were tried at first, but were found to be unsuitable for drinking purposes for natives. The stand-post which is found to answer best here is a 4-way cast-iron post; two  $\frac{3}{4}$ -inch taps are provided for filling vessels, and two others for drinking purposes. The latter are fitted with diaphragms in which are small holes which allow the water to escape as fast as a man can conveniently drink. A stone step at the base allows one foot to be raised, so that a water-vessel can be rested on the knee whilst being filled.

No water-rate is levied on the city; the cost is met from funds provided by His Highness the Maharajah as a free gift to the people. Only those persons pay who have water laid on to their houses. To these the following rates are charged :—

	Rs.	a.	p.	
For the first tap . . . . .	1	0	0	per month.
If used for watering cattle . . . . .	2	0	0	„
For the second and every other tap . . . . .	0	8	0	„
For a drinking-tap <i>pro bono publico</i> . . . . .	5	0	0	„

Rs.5 is the highest charge made. For this, the payer can have as much water as he wants, except for garden purposes, for which it is not allowed to be used. The water is not allowed to be used in watering the streets, as these can be watered at less cost with water drawn from the existing wells at the road-sides. The average daily consumption has increased steadily from 263,988 gallons in 1877-78 up to 897,884 gallons in 1892 (Appendix). In order to ascertain the amount of water used per head, all sources of supply were watched simultaneously on one day, and the amount thus taken showed, on the basis of the 1891 census, an average daily consumption per head of 7·6 gallons, at a cost, excepting charges for interest and depreciation, of about  $2\frac{1}{2}$  annas per 1,000 gallons.

The cost of maintenance, from the returns for the year 1892, is :—

	Rs.	a.	p.
Establishment . . . . .	9,266	6	0
Fuel . . . . .	41,125	6	9
Sundries . . . . .	1,486	12	0

The establishment consists of a European engineer, a European assistant engineer, a mistri or foreman, three native drivers, a

smith, a boiler-foreman, six firemen, six oilmen, four men and ten apprentices. These men work in shifts of eight hours, as they have sometimes to work day and night.

The expenditure on the works to date has been—

	Rs.
Weir . . . . .	9,092
Pumps . . . . .	133,853
Buildings . . . . .	82,216
Boilers . . . . .	34,341
Supply wells . . . . .	65,765
Turbine . . . . .	7,500
Filter-beds . . . . .	19,615
Amani Shah storage-reservoir . . . . .	107,454
Service-reservoirs . . . . .	79,013
Pipes . . . . .	415,511
Miscellaneous . . . . .	43,249
Total . . . . .	<u>997,609</u>

The works were designed and carried out by Colonel S. S. Jacob, Assoc. Inst. C.E., of the Public Works Department, whose services were lent by the Imperial Government to the Jeypore State in 1867, and who has been employed there since that time. He has received assistance in consultation from Mr. J. W. Gray, M. Inst. C.E., Birmingham; from Messrs. J. C. and W. Lord, of Birmingham, who, from time to time, have been referred to, and have helped to carry out all the work required from England; and from Mr. J. Dominy, the Engineer of the Jeypore Waterworks, whose advice has been highly valued by the Author.

The Paper is accompanied by six tracings, from which Plate 4 has been prepared.

## APPENDIX.

### STATEMENT SHOWING AVERAGE DAILY CONSUMPTION OF WATER, 1877-1892.

Year	Average Daily Consumption in Gallons.	Year.	Average Daily Consumption in Gallons.
1877-78	263,988	1886	605,573
1878-79	310,512	1887	635,313
1879-80	359,364	1888	660,882
1880-81	416,694	1889	722,556
1881-82	384,858	1890	830,854
1882-83	483,371	1891	881,099
1884	518,002	1892	897,884
1885	560,890		

# THE JEYPORE WATERWORKS.

PLATE 4.

Fig. 1.

