February 4, 1868.

CHARLES HUTTON GREGORY, President,
in the Chair.

THE following Candidates were balloted for and duly elected:—JOHN WOLFE BARRY, JAMES CRAIG, CHARLES HENRY DENHAM, and DAVID REID EDGEWORTH, as Members; FRITZ BERNARD BEHR, RICHARD BROOME, WILLIAM HENRY COCK, FREDERICK CHARLES DANVERS, EDWIN WILLIAM DE RUSSETT, CHARLES WILLIAM DIXON, WILLIAM FREDERICK FAVIELL, ALFRED FRANCIS JOHN FISHER, JOHN HENRY GREENER, JOHN TUNSTALL HAVERFIELD, Captain, Royal Marines Light Infantry, WILLIAM ROBERT JOHNSON, Captain, Madras Staff Corps, JAMES OUCHTERLONY MACDONALD, THOMAS BOUSTEAD NELSON, LIONEL HENRY SHIRLEY, ARTHUR TELFORD SIMPSON, HENRY EDWARD THORNTON, and THOMAS WALKER, as Associates.

It was announced that the following Candidates having been duly recommended, had been admitted by the Council, under the provisions of Sec. IV. of the Bye-Laws, as Students of the Institution:—JOHN HOPWOOD BLAKE, JOSEPH CASH, RAYMOND EDMISTON, MALCOLM GRAHAM, CHARLES EDWARD JONES, JAMES VERCHILD LEY, MORTON KELSALL PETO, WILLIAM HERBERT PETO, CHARLES EDWARD ROBINSON, ARTHUR TOULMIN SMITH, EDWARD HERBERT STONE, and FRANK NAPIER THOROWGOOD.

No. 1,186.—“Floods in the Nerbudda Valley: with remarks on Monsoon Floods in India generally.”¹ By ANDREW CASSELS HOWDEN, Assoc. Inst. C.E.

ONE of the chief wants experienced by the Civil Engineer in India arises from the scantiness of information regarding the periodical monsoon floods, to which the rivers especially and the country generally is subject. Much valuable information probably exists in the hands of the Engineers now engaged upon the numerous public works throughout the country, but, as it has never been collected for reference in any tangible form, it is for all practical purposes comparatively useless.

The observations contained in this Paper are necessarily incomplete; the limited extent of the district under review, and the difficulties inherent in a new, and to some extent unknown country, render this unavoidable. But if the Author succeeds in eliciting

¹ The discussion upon this Paper was taken in conjunction with the preceding one, and occupied portions of four evenings, but an abstract of the whole is given consecutively.

the views of others, who may have had better opportunities of observation, a service will have been rendered to Indian engineering.

The Nerbudda Valley is bounded on the north by the Vyndhya Mountains, and on the south by the Sautpoora range. (Plate II, Fig. 2.) It consists principally of what is known as black cotton soil, and is renowned for its fertility. The immediate drainage of the valley supplies nearly the whole volume of the waters of the Nerbudda River, which traverses it in a direction nearly due east and west. The total length of the river is 800 miles; it takes its rise from a pond on the elevated plateau of Amarkantak, in the Vyndhya Mountains, at an elevation of 3,500 feet above the sea; its fall to Jubbulpore, 190 miles distant, is 10 feet per mile, and from this point to the Gulf of Cambay the fall may be estimated at about 2 feet per mile.

The width of the river at its source is a yard, while a little above its confluence with the Towah, 360 miles down stream, it is 900 yards, and at its mouth it exceeds a mile. The river rises between 30 and 40 feet in an ordinary monsoon, but it has been known to rise nearly 60 feet and to overflow its banks.

Perhaps few rivers of similar magnitude and length receive so few tributaries. The principal of these are, the Herrun, the Shair, the Towah, the Gunjal, and the Suktha or Chota Towah.

Midway between the river and the Sautpoora Mountains, the valley for a length of about 270 miles is traversed by the north-eastern extension of the Great Indian Peninsula Railway, which thus crosses all the tributaries that fall into the river on its southern bank, and it is the floods to which these feeders are liable, rather than the Nerbudda River itself, that will form the subject of the present Paper.

The floods of this region may be divided into two classes, viz. :

1st. Those affecting the plains.

2nd. Those affecting the rivers.

1st. The floods affecting the plains:—

The average rainfall in the valley for the last fifteen years has been 45·97 inches per annum distributed over the four monsoon months, from June to September; but the maximum amounted to 64·05 inches, while the minimum was 30·5 inches. Taking the average of the mean fall, it would give about 11·5 inches per month, a quantity which the natural watercourses are sufficient to provide for; but as 10·50 inches have been known to fall during eighteen hours (as was the case in August, 1864), these have been found inadequate, and the result has been sudden and disastrous floods.

TABLE of RAINFALL in the NERBUDDA VALLEY.

Year.	Inches.	Locality.	Year.	Inches.	Locality.
1852	49·35	Hoosungabad.	1860	40·10	Hoosungabad.
1853	48·20	Ditto.	1861	50·45	Ditto.
1854	35·30	Ditto.	1862	52·20	Ditto.
1855	31·75	Ditto.	1863	52·19	Rampoor.
1856	63·35	Ditto.	1864	43·39	Hurda.
1857	64·05	Ditto.	1865	41·20	Ditto.
1858	48·45	Ditto.	1866	39·06	Ditto.
1859	30·50	Ditto.			

The first eleven years were kept by Surgeon Trimmell, of the 1st Regiment M. N. I., at Hoosungabad; the last four years by Messrs. Hood, Winton, and Mill, Contractors. Contract 16, G. I. P. Railway.

The greater part of the Nerbudda Valley traversed by the railway is almost a level plain, with only a slight fall towards the rivers, and intersected with few natural watercourses. This being the case, the railway embankments form an artificial bund or dam right across the country, intercepting the natural flow of surface water, and causing floods, which without this obstruction would not exist. This tendency seems to have been underrated, when the gradients were first laid out, and probably a too great leaning to economy may have contributed to the same result; but wherever this has occurred, the rail level has had to be considerably raised, and additional waterway provided.

Floods of this description took place near the town of Hurda in 1864 (said by the natives to be the highest known for thirty years), washing away completely several miles of shallow embankment, and even tearing large holes in the seat, and leaving the permanent way twisted upon the cess. This portion of the line was raised 6 feet, and double 30-foot girder bridges built where 2-foot culverts formerly existed.

Near the village of Tamurnee also, in 1864-5, the embankments were cut through in several places, and much damage done, necessitating the raising of the gradients for upwards of 5 miles, and the provision of a large amount of additional waterway. For the whole of this distance there was not a single well-defined watercourse. Other districts of the Great Indian Peninsula Railway have also suffered, more especially portions of Contract No. 17, and in the Concan. In 1866 about 75 miles of the Scinde Railway, and 30 miles of the Bombay, Baroda, and Central India Railway were for all practical purposes rendered useless. The East Indian Railway also suffered considerably. A full discussion of the causes and means of prevention of these and similar disasters is of the utmost importance. The lessons to be learned are many and obvious.

In carrying a railway across plains of the description referred to, great attention must be paid to the rainfall of the district, and ample provision must be made for carrying off the maximum amount speedily, without causing it to dam up, as few embankments (especially those formed of black soil) can withstand the immense pressure then brought upon them, although the period of danger may not exceed twelve hours during the year; and should an opening once be formed, the scour is such that the embankment speedily melts away. Black soil embankments, from the dry state of the material when put together, will frequently shrink to the extent of from 25 to 40 per cent. They are also subject to extensive cracks and fissures in the dry season. Great care should therefore be taken in closing in behind the abutments of bridges as the work proceeds, thus ensuring the earth being well trodden down, instead of, as is frequently the case, being filled in afterwards with loose and dry material. Those portions subject to backwater and scour should be protected by retaining walls and pitching. Embankments of this description, however, are of so treacherous a nature that, even after every precaution, the water will frequently force its way through, and leave the bridge isolated. The Chief Engineer of the Bombay, Baroda, and Central India Railway, mentions in one of his reports a case in which a black soil embankment adjoining the Keem Bridge on that railway was pushed bodily over 18 inches, bending the permanent way to that extent. A case also occurred with a shingle embankment on the Great Indian Peninsula Railway, near Bhosawul, at the Sookee Nuddee, the waters of which rose during the night of the 26th of June, 1867, and washed away a length of 50 feet of bank behind the abutment, when, unfortunately, several lives were lost.

An Engineer new to India, and with only European experience, would be surprised to see in many cases bridges in an open plain, with neither road, river, nor water for miles. Should he, however, revisit the spot during a monsoon flood, the cause would be apparent: he would then see the dry plain transformed into a lake, and the water rushing through the openings with the force and rapidity of a mill-race.

The second class of floods are those affecting the rivers.

The principal rivers crossed by the Great Indian Peninsula Railway, in the portion of the Nerbudda Valley to which this Paper refers, from Bhere to Bagra—a distance of 100 miles, are, the Towah, Gunjal, Matchock, Karlee Matchock, and Suktha or Chota Towah rivers, besides the Sconce Jamnee, Hurda, and other nullahs.

The greatest flood known for the last ten to fourteen years (the natives say thirty) occurred in 1864, and gave a favourable oppor-

tunity of watching its effect upon the rivers and nullahs before mentioned.

The largest and most important river is the Towah, which rises in the Sautpoora Mountains, and receives the watershed of between 500 and 600 square miles of country. Neempani, near one of its branches, is shown upon the only trigonometrical map extant as 2,700 feet above the sea, and Bagra, where the viaduct crosses, as 1,150 feet, giving a fall of 1,550 feet, in a distance of 50 miles, equal to the extraordinary fall of 30 feet per mile. This will account for the unusual features that occur during its floods. Beyond this, the fall (from calculation) is about 4.25 feet per mile. This will not, however, give the true velocity, as the immense impetus the water receives before reaching the plains must materially increase it. It will be seen from the Table (p. 224), that the calculated velocities for the Gunjal River fall short of the actual ones.

The Towah Viaduct, as originally designed, consisted of eleven spans of 74 feet each, with the rail level at a height of 74 feet above low water; but when the piers were partially built, an immense flood occurred, on the 15th of August, 1864, and the river rose 47 feet in a few hours and washed away piers 6 and 7, the former being 85 feet and the latter 39 feet in height. The aspect of the flood on this occasion presented several interesting features, and the Author is greatly indebted to Mr. C. J. Shaw, the Engineer in charge, for much valuable information regarding it.

No correct gauge was kept of the rain that fell, but in the great floods on the same occasion at Hurda 10.50 inches were gauged in eighteen hours, and it may be assumed that an equal quantity fell here. It appears that the level of the water at the west bank, or abutment No. 1, was 90.00; on the east bank, or abutment No. 2, it was 97.25, while at piers 6 and 7, it was 101.00; the cross section of the stream thus forming a curve (Plate 11, fig. 1); the obstruction caused by the piers damming back the river to this extent. No observations as to the velocity of the current were taken, but assuming it to have been the same as at the Gunjal River during the great flood of the same year, viz., 16.58 feet per second at the surface, then the fall per mile must have been about 4.25 feet, and the discharge 976,629 cubic feet per minute.

In the succeeding monsoon of 1865 several observations were taken by Mr. C. J. Shaw. Rain fell from the 16th to the 19th of July. The level of the river on the morning of the 19th was 86.00, and in the afternoon, at abutment No. 1, 90.00, the same as in the previous year. There was little backing up at 86.00, but it became alarming at an increased height of 4 feet, viz., when the river stood at 90.00. The side elevations of piers 8 and 9 (Plate 11, figs. 7 and 8,) show the action of the water. It will be seen that at the former there was a fall of 10 feet, and at the

latter 7·50 feet, from the cutwater to the back of the pier; whirlpools were formed at the down-stream end, and waves of from 6 feet to 10 feet in height both above and below the viaduct. On the morning of the 20th the river had fallen 12 feet and was tranquil, with no backing up.

The original piers of the Towah Viaduct were of nearly similar dimensions to those at the Gunjal, 12 feet wide to the first plinth, 11 feet to the second, and 10 feet above. After the disasters of 1864 Mr. R. W. Graham (M. Inst. C.E.), the then chief resident Engineer, resolved to convert the five centre spans into three, and to give an additional thickness to the four central piers of 3 feet 6 inches, carrying them up 13 feet 6 inches in width to the cutwater cap. Little was done during the season of 1864-65, when further observations on the floods were made. It was, however, determined by Mr. J. R. Rushton (M. Inst. C.E.), who succeeded Mr. Graham, to convert the three centre openings into two spans of 202 feet 6 inches each, with a massive elliptical central pier, built of solid block-in-course up to low-water level, and above that of the same description of work as the other piers, block-in-course face-work with rubble backing.

The flood of 1864 was affirmed by the natives to be a most unusual one; but that of 1865 was of similar dimensions, and the flood of 1866 exceeded its predecessors both in force and magnitude, showing, that if floods of this description did not occur annually, at least they happened far more frequently than was desirable.

The central, or No. 4 pier, as before stated, was built of solid block-in-course up to low-water level, and above that with block-in-course face-work with rubble backing, and during the working season of 1865-66 the masonry was carried up to the cutwater cap bed. During the flood of August the 9th, 1866, the level of the water at abutment 1, was 93·75, and at abutment 2, 105·75. The top of the masonry of pier 4, on the east side, was not visible; but on the lower, or west, it was. The fall of water from the cutwater to the back of the pier was 15 feet.

The pier was unable long to withstand the force brought to bear upon it, and was speedily carried away to a depth of 3 feet below the top of the solid block-in-course foundation. Pier 5 (corresponding to pier 8 in the first design) went at the same time, and being only 13 feet 6 inches in width, and built of block-in-course face-work with rubble backing only, it broke off at a level 6 feet lower. Some idea of the force of the current may be formed from the mass of masonry washed away, viz. :—

From Pier No. 4, about 1,600 tons in weight;

„ Pier No. 5, about 1,000 tons in weight;

and of this mass of materials not a stone was ever recovered.

The question then presents itself, What are the greatest floods to be apprehended, and also what influence would the height of water in the Nerbudda River have? On the present occasion the level of the Nerbudda was about 20 feet lower than it has been known to be; would a simultaneous high flood in the latter cause a dangerous backing up? or would the fact of the Nerbudda being low, and thus causing an increased fall of from 6 to 8 feet per mile, increase the velocity of the Towah in a dangerous degree?

It has been found that the remaining piers and abutments were so shaken as to render it advisable to remove the whole and reconsider the design; and it has now been decided that the viaduct shall consist of three central spans, of 202 feet each, flanked on each side by one of 132 feet, and the rail level to be raised 6 feet.

The piers are to be elliptical, to be built of solid block-in-course throughout, set in cement; the face-stones not to be less than 4 feet in length, 18 inches deep, and 2 feet on the bed, with cement dowells, and tool-dressed on the face.

The next important river is the Gunjal, or more properly the Moorum, the two streams forming a junction about half a mile above the viaduct, and 14 miles from the confluence with the Nerbudda. The Moorum branch is nearly 70 miles in length, while the Gunjal is only 50 miles, and of much less volume: both rise in the Sautpoora Mountains. The fall from the mountains must be very considerable, somewhat similar to that of the Towah; the fall at the viaduct itself has been found, from actual levels, to be 3 feet per mile. The highest known flood occurred in July, 1864, when the river rose 46 feet above low water.

Observations were taken during two subsequent floods in the year 1866, and from the data then obtained, the velocity and discharge of the former has been calculated.

TABLE showing the VELOCITY and DISCHARGE of the GUNJAL and TOWAH RIVERS.

Name of River.	Date of Flood.	Height above Datum.	Fall per Mile.	Area.	Wetted Perimeter.	Hydraulic Mean Depth in Inches.	Mean Velocity in Inches per Second.		Discharge in Cubic Feet per Minute.
							From Observation.	From Calculation.	
Gunjal	Aug. 29, 1866	Feet. 73·00	Feet. 3·00	4,968	345	172·80	110·22	99·57	109,494
Ditto .	Aug. 8, 1866	95·00	3·00	15,549	500	373·08	153·68	147·00	477,820
Ditto .	July 22, 1864	103·84	3·00	22,032	557	474·60	..	166·14	732,123
Towah.	Aug. 15, 1864	101·25	4·25	29,390	1,108	318·24	..	166·14	976,629

Plate 11, Fig. 1, shows a plan of the river in the dry season; while Fig. 6 indicates the extent of backing up when the river stood at 95·00. No observations, as before stated, were taken when the river was at its highest, viz., 103·84; but it may be conjectured as having been much greater, the backing up increasing rapidly with every foot of rise in the river. The depth of water in the dry season ranges from a few inches to as many feet. The viaduct consists of eight spans of 85 feet from centre to centre (Fig. 4), and the rail-level is at 61·00 feet above low water. The piers are built of block-in-course face-work with rubble backing, with through plinth courses of solid block-in-course. The stone employed was sandstone of a superior quality. No difficulty was experienced in founding any, with the exception of No. 2 abutment, and all are on rock. Work was commenced in 1862, and the girders were fixed by the commencement of the monsoon of 1866, and the whole was completed and ready for inspection early in 1867.

Some idea of the force of the current in Indian rivers may be formed from the fact that when the Mulkapoor Viaduct, on the Nagpore extension, was washed away in 1864, some of the 30-foot plate-girders were carried 7 miles down stream, and this in comparatively a small river.

After the rivers, the effect of floods on the smaller streams, or nullahs, falls into insignificance, but, as this Paper has grown to larger proportions than was intended, mention of them has been omitted.

No absolute rule for the avoidance of accidents of this description can be given, nor will any attempt be made to do so on the present occasion; but a few of the more obvious precautions may be noticed.

First, wide spans are indispensable. The current in Indian rivers is so swift, and the rise of water so rapid, after a heavy fall of rain, that any contraction of the waterway causes a dangerous scour and backing up. In the nullahs referred to, crossed by 30-foot girders, about $\frac{1}{10}$ th of the waterway is occupied by the piers, and at the Gunjal, and the first design for the Towah, about $\frac{1}{10}$ th.

Secondly. Next in importance to having as few piers as possible, is the necessity of giving them the greatest strength by building them of solid block-in-course, set in cement. The chunam or lime of India, to ensure setting, requires to be freely watered and exposed to the air, necessitating the work being carried on slowly. In large works this is impossible. The mortar in the centre of the structure would require years to harden, and in its soft state it is quite unable to withstand the pressure that may be brought to bear upon it, probably during the first monsoon, and which, although it may not destroy, will so shake the work as to lead to its ultimate
[1867-68. N.S.]

destruction. In positions and under circumstances where perfect setting may be relied on, it would be quite able to withstand any force that might be brought to bear upon it.

An instance of the non-setting properties of this lime occurred near Hurda, where an abutment of the viaduct was removed to increase the waterway. The mortar in the top and outside courses was completely set, in fact nothing could be better. The greatest difficulty was experienced in demolishing the work with crowbars, &c., and in many instances the stones were fractured before the mortar gave way, whereas in the centre it was found in a plastic state. This masonry was upwards of three years old, and the lime used of the best description.

Thirdly. The face of the cutwaters of piers should always be tool-dressed to reduce the friction, the 'bush' frequently left on forming a great obstruction.

Fourthly. In cases where rubble-backing is used, care should be taken in suspending work to finish off below high-water level with a thorough bed of solid block-in-course, otherwise the water will penetrate the work, and speedily blow up the pier.

In discussing these failures great allowance should be made for the trammels with which the Civil Engineer in India is encumbered, and the limited means at his command. In the first place, economy compels the use of such materials as are found on the spot, and his skill is required to turn them to the best advantage. Unfortunately, the stone may be inferior and the lime worse, and unable to withstand the test of age and exposure.

The difficulties of transport form another impediment. The impossibility of conveying ironwork beyond a certain weight and bulk necessitates the adoption of smaller spans than would be otherwise advisable, while at the same time the structures are put to the severest test. If, therefore, failures occasionally happen, it is not to be wondered at, but rather that they are not of more frequent occurrence. As, however, civilization and improved means of transport increase, and the vicissitudes of the climate are better understood, failures will cease to be more frequent than in more favoured countries.

The Paper is illustrated by a series of drawings, from which Plate 11 has been compiled.

NERBUDDA VALLEY VIADUCTS.

APPENDIX.

CONTAINING EXTRACTS FROM VARIOUS SOURCES.

Floods on the Scinde Railway.

"Mr. John Brunton, M. Inst. C.E., in his pamphlet on the Scinde Railway, states the average rainfall—we believe throughout the whole length of the line to Kotree—for the five years, 1856-60, as 4·82 inches."—*Times of India*, Sept. 17, 1866.

RAINFALL BETWEEN KURRACHEE AND KOTREE.

"Measured by Scinde Railway Officials, from August 4th to 17th, 1866, or fourteen days, was as follows;—

	Inches.		Inches.
Kurrachee	10·10	Joongshaie	41·49
Landi	16·00	Hillgate	25·41
Guggur	32·00	Mayting	19·36
Dorbajee	40·24	Bolari	14·35
36½ miles, and at Kharaseer .	40·60	Kotree	11·57

"The rainfall of 1866 in Scinde, as also in Kattywar, will long be spoken of by the people of those provinces as a time to be remembered with dread. It is chronicled by whole villages overturned, fertile land devastated, roads rendered impassable, &c. The Mooktyear of Kurrachee has sent in a report of the destruction that has been ascertained, apparently from the flooding of the Mulleer alone." . . . "Ninety human lives have been lost; 4,359 grazing stock, and 158 draught animals have been swept away." . . . "The Mulleer Viaduct washed away is 12 miles from Kurrachee; the Bahrum about the same distance this side of Kotree." . . . "The first breach is between Kurrachee and Landi, 9½ miles from the former, and is 70 yards in width. At 12½ miles from Kurrachee is Bolton Road crossing; and from this road down to the Mulleer River, about a mile, the line has been almost destroyed; two culverts only remain, with the bank immediately over and adjoining them." . . . "At one place in this length the flood was strong enough to break the fish plates, and several rails have been carried 50 yards. The most important works that have suffered are the Mulleer Viaduct, the Joonshaie Bridge, and the Joolajee Bridge. Each of these will require six weeks to be repaired, provided no further rain occurs."—*Scindian*, Aug., 1866.

The following is extracted from the Report made by Mr. McNeill, acting agent of the Scinde Railway:—

"The Mulleer Viaduct was 1,800 feet long, in twenty-one spans of 80 feet each, built on stone piers, each pier consisting of two upright pillars, sufficient only for a single line. The foundations were of three kinds. Piers 1, 2, 5, 6, 7, and 8, built in brick wells; 3 and 4 in coffer-dams; the remainder had piles driven in the wells, and filled in with concrete. Two rivers meet the Mulleer above the viaduct, the Dumb about half a mile above, and the Sookhan quite close to the bridge. The sources of these streams are widely separated, and it would appear on the morning of the 5th, when the viaduct was carried away, that the streams were discharging themselves at different levels, causing great turbulence in the water passing under the viaduct."

"At daybreak on the morning of the 5th there was little or no water visible in the bed of the river, and at 8 A.M. it had almost reached rail level. At 9 A.M. the bridge was carried away. The water came down in a succession of bores, the largest of which, bringing down with it the ruins of a village about a mile and a half up the river, came down with immense force, rising above the level of the rails, and carrying away eleven spans of girders, with their piers, as if they had been straws. Some of the girders are within a few feet of the bridge, but two of them are at least half a mile down the stream; each span, with rails, &c., would weigh about 60 tons."

"The abutment at the Kurrachee side stood well."

"Mr. Newnham proposes to carry up the piers 6 feet higher than they are now, filling them up solid; and where the foundations are made, as in piers 3 and 4, for a double line, to build them up their full width, also solid." . . . "The Joolajee Bridge carried away consisted of nine openings, 20 feet each, semicircular; bed of river to crown of arch, 20 feet. The water rose within 3 feet of the level of the rails or crown of arch."

"The Joongshaie Bridge consisted of six openings of 40 feet span each, semicircular arches. One pier has given way, and the bridge must come down, and the waterway be considerably increased. The water rose to crown of arches."

"I may say 60 miles of the line are useless for regular traffic until the diversions (temporary) are completed.

(Signed) "DAVID MCNEILL,
"Acting Agent."

(From *Scindian*, Sept. 26th, 1866).

FLOODS, JUMNA RIVER.

(By Mr. G. Sibley, M. Inst. C.E., Chief Engineer East India Railway, N. W. P.)

"Lowest flood rises 30 feet above low-water mark.

Average	"	40	"	"	"	"
Maximum	"	50	"	"	"	"

"The year 1861 was remarkable not merely for the exceptional height, but also for the long duration of the floods—the river ran for eight days over 155·00, and for 4 days over 160·00. The maximum rate measured was rather more than 8 miles an hour, or about 12 feet per second (actually 950 feet in 81 seconds); for twelve days it ran over 10 feet per second.

"At the period of greatest discharge the mean surface velocity must have been 10 feet per second, and mean velocity of the whole stream upwards of 9 feet per second. The sectional area at that level being about 145,000 feet, it follows that the discharge per second must have reached the enormous amount of nearly 1½ million cubic feet."

RAINFALL IN GUJERAT.

"Average rainfall in Gujerat 25 inches, discharge of Taptee at the end of the month of February, amounts to 100,000 cubic yards per hour."—*Gujerat Metra*, March 17th, 1867.

[Mr. GREGORY,