WATER SUPPLY IMPROVEMENTS.

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Preliminary.

This paper concerns the considerations leading to the location of water wells, rather than the mechanical details in connection with drawing the water.

The three Cantonment supplies discussed have been chosen, in the case of Ambala, on account of the exceptional difficulties in obtaining large quantities of water in this area; and, in the case of Rawalpindi and Kohat, on account of the novel features presented.

The ordinary plains station, built on an alluvial formation with a flat and uniform surface, and containing various coarse water bearing sand beds at varying depths, does not present any particular difficulty with regard to well locations. Generally the wells can be placed anywhere, for there is no indication to suggest any particular point and one location yields just as much water as another. Strainer tube wells give quite the best results under these conditions.

Thus, although it is appreciated that strainer tubes are an excellent means of drawing off water from sand beds, the three cases cited below do not lend themselves to strainer tubes, and possibly for that reason are considered novel.

Unfortunately there are no general conclusions which can be drawn regarding the location of wells, and each area has to be considered independently.

AMBALA.

Present Source of Supply.

The water supply in this district is drawn from sand beds beneath the Tangri Nullah, and this is the only water in any quantity so far discovered.

A number of attempts have been made with tube wells up to 200 feet deep, and in 1871 the Military Works sank a tube 700 feet deep, but without success. The information obtained from all these wells is that the formation down to 700 feet consists of clay interspersed with layers of fine sand, but that along the bed of the Tangri Nullah there is a slightly coarser sand bed between level 48 to 70 feet. This Tangri sand bed is the one being tapped

by all the waterworks in this district. The city is slightly off it and probably for this reason gives the smallest proportional yield. There appears to be no surface indication favouring the position occupied by this waterworks.

Possible Alternative Sources.

These Tangri Nullah sand beds are not a good source of supply, owing to the fineness of the sand, but if this sand is not developed the alternatives are either the conveyance of water from the foot-hills or the Sirhind Canal; or the sinking of a well below 700 feet. It is not proposed to discuss the two former schemes as apart from the expense involved, considerable delay would inevitably result in obtaining agreement between all parties, and an improvement to the Cantonment supply is required at once.

A deep tube well is an expensive undertaking and results might be anything from an artesian well spouting water into the air to a dry hole; however, this much is certain, that in the clay and sand formation of this district it will be impossible to carry a pipe larger than 6" diameter below 1500 feet, and, taking the most optimistic view, the maximum yield of such a well would be as much water as could be passed through a pipe of that diameter, whether the water is forced up from below or sucked up by a pump from above. The geological report states that water might be struck at 2000 feet, but that it might not be fresh water. No fresh information would be obtained until the well reached 700 feet below the surface. Taking the above facts into consideration, the maximum yield of a deep well would be 300,000 gallons and the large expenditure and risk involved is not warranted for such a small return.

The tapping of the subsoil water a few feet below the bed of the Tangri is a possible source of supply, but presumably this is only an expedient, as the laying of a horizontal strainer below water level in running sand is a much more expensive operation than sinking a vertical one; at Bibyal the sand is too fine for a strainer to work satisfactorily; and water so near the surface is liable to serious pollution at odd times.

Tangri Nullah Sand Bed.

It is therefore proposed only to consider the best means of obtaining water from the Tangri Nullah sand beds, and in this connection the situation at Bibyal is considered.

The Cantonment supply at Bibyal is drawn from 16-14 feet diameter percolation masonry wells 315 feet apart, arranged on the circumference of a circle 2,200 feet in diameter with suction pipes from pairs of wells to a steam pumping plant in the centre. There is also one 30 feet diameter well in the river bed, 1800 feet from the pump house, connected to the system.

With a depression of 9 feet these wells normally yield about 250,000 gallons daily, whereas the estimated requirements of the Cantonment to-day are 700,000 gallons. Considering means of increasing the supply, the sand is too fine to admit of tube wells being a success, and the only remedy is more masonry wells. Taking a definite maximum water speed at which sand will not blow in a masonry well, then the yield is proportional to the total area of the bottoms of all the wells working. Thus the greater the number of wells and the larger the diameter, the greater will be the yield: and, although the maximum speed through the water sand at Bibyal is only $\frac{1}{2}$ inch per minute this will still be the cheapest method of improving the yield. In pursuing this policy, a 30 feet diameter well has just been sunk near the centre of the circle of wells, close to the pump house, and two preliminary tests have shown a yield of a little over 100,000 gallons per day with 7 feet depression. This location near the pump house was not the best from a water yielding point of view, but owing to trouble with the long suction pipes of the existing wells, and the necessity of an early increase to the supply, this well was sunk as an expedient. Locations in the bed of the river are better, owing to the surface loam on the river bank finding its way down into the water sand and clogging it, but such locations are too far away from the existing steam pumps to get a good grip on the water. The suction head is between 20 and 24 feet with the wells working at 9 feet depression.

It should be noted that with such a fine water sand there cannot be any general underground flow in one direction, and this sand is probably only fed by the local rains sinking down through holes in the various strata above the water sand. No doubt the actual water level decreases very much more than is shown by the standing water levels in the wells, owing to capillary attraction in such fine sand. This view is supported by the reduced recoupment of the Bibyal wells during the summer, with a given depression head. Probably the various surface subsidences which occur after the rains in various parts of Ambala Cantonment are due to the water finding its way to the lower sand beds, as mentioned above.

Subsoil Water Level.

The opinion has been expressed in various quarters that the subsoil water level in Ambala is dropping. The record of the levels at Bibyal since 1907 does not show any decrease beyond the ordinary annual fluctuations due to rainfall. The level of water in the wells supplying the Kheyra duct—which was constructed as a gravity supply possibly 60 years ago—also does not show any marked decrease. The level of the water this year after a severe drought was still one foot above the outlet pipe before the

rains, but no records of the levels of these wells have been kept. There appear to be no just grounds for assuming that the levels are dropping seriously enough to warrant the abandoning of this Tangri Nullah sand and the reason for the supposed drying up is probably due to mud being drawn into the wells causing a decreased yield. In any case electric pumping offers considerable latitude with regard to a drop in the water level.

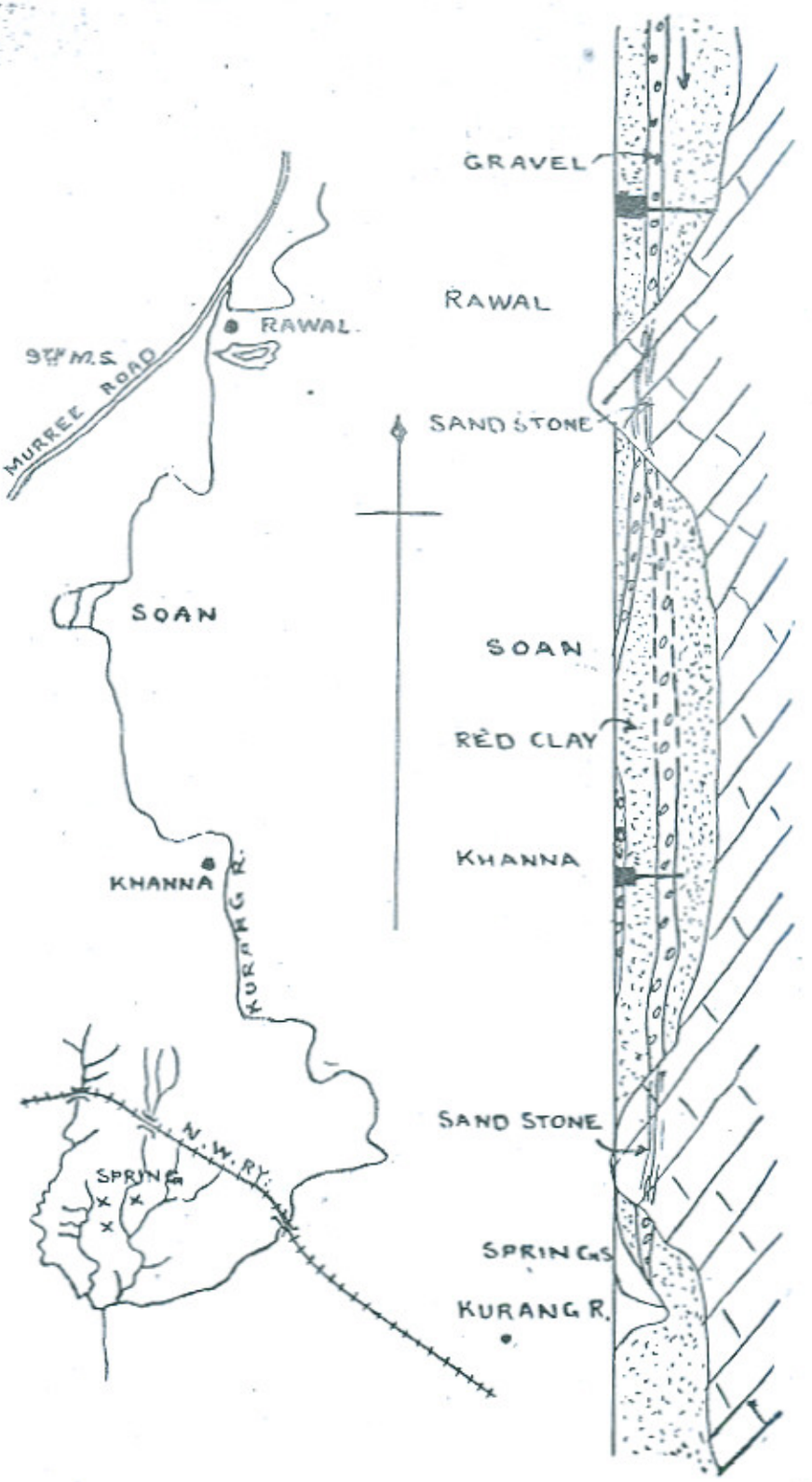
Masonry Wells.

It is anticipated that each 30 feet diameter well in the river bed, pumping 24 hours, will deliver 100,000 gallons daily without blowing. It has been found impossible to keep the sand level in the existing wells stationary below 10 feet above the bottom of the curbs, and in the new wells this is being anticipated by filling in with coarse sand up to that level, to avoid disturbing the strata of clay overlying the water sand on the outside of the wells. The new well has been given a solid brickwork steining, but it is proposed to make the lower 10 feet of the other wells of dry brickwork with a view to increasing the yield. This Bibyal pumping station will be electrified in conjunction with the Cantonment electrification scheme, each well being fitted with an auxiliary electric motor pumping into a central sump. In this manner it will be possible to scatter the wells at liberty along the river bed, 200 yards being the minimum distance between wells.

RAWALPINDI.

Existing Source.

The water supply for this district is obtained from 2—16 feet diameter masonry wells 30 feet deep at Rawal, at the 9th milestone on the Murree Road, and is conveyed by gravity in a masonry duct to the City and Cantonment. The maximum capacity of this duct is 1,800,000 gallons per day and normally this flow can be maintained throughout the year without pumping ; but during the recent drought the level of water fell below the outlet pipe and only 500,000 were pumped daily. The Cantonment supply was augmented curing this period by an artesian well at Khanna delivering 400,000 gallons daily into the duct, and it is proposed to investigate the occurrence of the gravel beds tapped by this new well. The medical authorities do not look with favour on the masonry duct for a drinking water supply ; and from an engineering point of view it has collapsed at various points on one or two occasions in the past. So long as it is impossible to get inside and examine its condition it will always be viewed with suspicion. Thus improvements to the water supply naturally first took the line of a secondary supply nearer the reservoirs to tide over any period of failure of the duct, rather than installing pumps and a long length of pipe line from Rawal.



RAWALPINDI.

SCALE 1/2" = 1 MILE.

New Sources.

Considering the location of new wells in this district, the formation is red and yellow clay overlying sandstone, and from the evidence of a number of test bores sunk at various times to a depth of 200 feet, this formation is quite useless for water supply purposes. It has, however, one redeeming feature in that the clay contains very coarse gravel beds passing through it at various points, and a well striking one of these gives an excellent yield. Thus the finding of water in this district resolves itself into the finding of gravel beds, for there is such a small resistance to the flow of water through these beds that water only flows along the surface after these beds are flowing to their full capacity. These gravel beds are simply ancient river beds beneath the surface, kept open by a flow of water from the hills. They are not more than a couple of hundred yards or so wide in most places, or more than 4 feet thick. The Rawal wells, and in all probability the N.-W. R. well in the Leh Nullah, are tapping such gravel beds, and it is proposed to follow up the direction taken by the Rawal bed after leaving Rawal. No information is available regarding its position above Rawal, except that it is being brought to the surface by the Rawal outcrop.

Rawal Gravel Bed.

The gravel bed at Rawal is 30 feet from the surface, about 250 yards wide and 4 feet thick, and is broken by an outcrop of sandstone immediately after leaving the wells. The water passes through fissures in this outcrop beneath the surface, but continues again in a gravel bed in the other side following more or less the course of the Kurang Nullah. At Soan, 3 miles below Rawal, a rise in the strata brings this gravel bed to the surface, and the Kurang Nullah, which is normally dry between Rawal and Soan, has perennial water from Soan onwards. Continuing downstream to Khanna, 3 miles below, there is here a gravel bed on the right bank 10′ from the surface and 3′ thick ; a second gravel bed 90′ from the surface 3′ thick ; while there was also a flow of 3,000,000 gallons down the Kurang Nullah at this point at the worst period of the recent draught. It should be mentioned that the existence of the 90 feet gravel would not have been suspected but for a trickle of water coming from a tube sunk by a zamindar in this district, and upon the strength of this information a test bore was sunk which afterwards developed into a very successful water-yielding well. From Khanna onwards the Kurang makes a detour to the left and passes into rocky country, but by continuing across country 3 miles to the south, two tributaries of the Kurang are reached. These tributaries have cut a channel about 80 feet deep in the clay formation and have exposed sections of gravel beds which are discharging 2,000,000 gallons daily all the year round. It is therefore assumed that the springs in these tributaries are the outlet for the water in the 90′ gravel

bed at Khanna. A constant flow of water in a gravel bed is a prime condition, as otherwise, surrounded by loose clay as they are, they would silt up in a very short time and the water would not again force a passage. Returning again to the Khanna well, the next point to be considered is the direction from which the lower gravel bed reaches Khanna. The first supposition was that a deeper gravel bed existed all the way along to Rawal, and a test bore was put down in an unused well at Rawal with the object of tapping it. This bore however passed only through red clay and struck limestone and sandstone at 117′ from the surface. Later however, the results of pumping during the summer appeared to indicate that this gravel bed was drawing its supplies from the water running in the gravel beds near the surface, immediately down stream of the Rawal outcrop. Pumping 400,000 gallons daily from the Khanna well for four months, did not result in permanently lowering the water level half an inch, while the Rawal wells steadily decreased $\frac{1}{2}$″ and $\frac{3}{4}$″ daily throughout the drought, and it is difficult to assume that the water was being drawn from such a large stationary source that this pumping, coupled probably with the water overflowing at the tributaries, made no effect upon it.

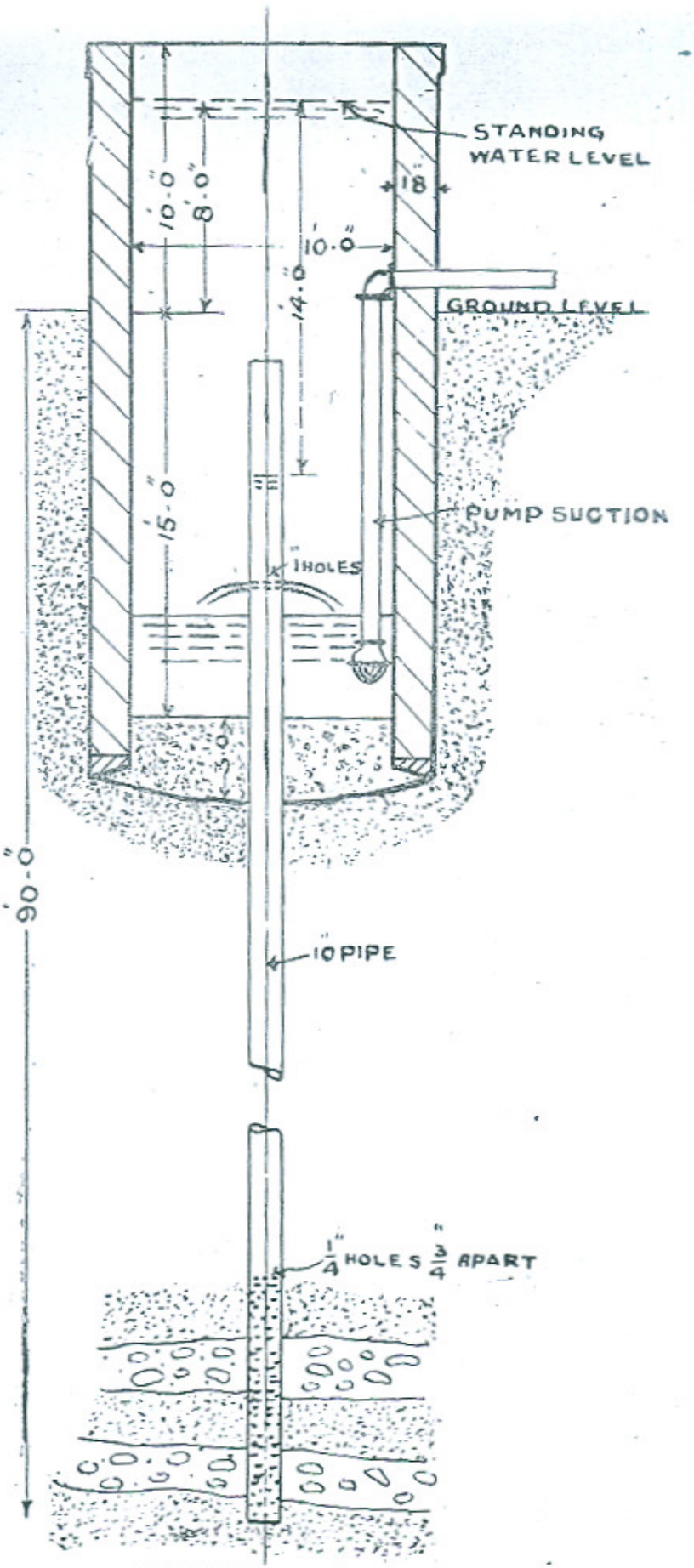
It is therefore concluded that all the water passing down that Kurang Nullah, the water in the upper gravel bed at Khanna, and the water from the artesian well and springs in the tributaries, is all escaping over the Rawal outcrop, and without including the water in the upper gravel bed at Khanna, the quantity so escaping at the worst period of the recent drought was measured at over 5,000,000 gallons daily.

Origin of gravel bed water.

Regarding the source of such a large quantity of water after more than twelve months without any rainfall beyond a few thunderstorms, the record of the levels at Rawal show that local storms only affect the supply temporarily in the form of spates and that the main source must be large underground reservoirs. The probable solution is that the limestone ridges in the Murree area originally started their existence with fissures running through them, and that rain and snow water, turned into a dilute acid be CO_2 from the atmosphere, has desolved away the limestone in these fissures during the ages, until large underground caverns have been formed.

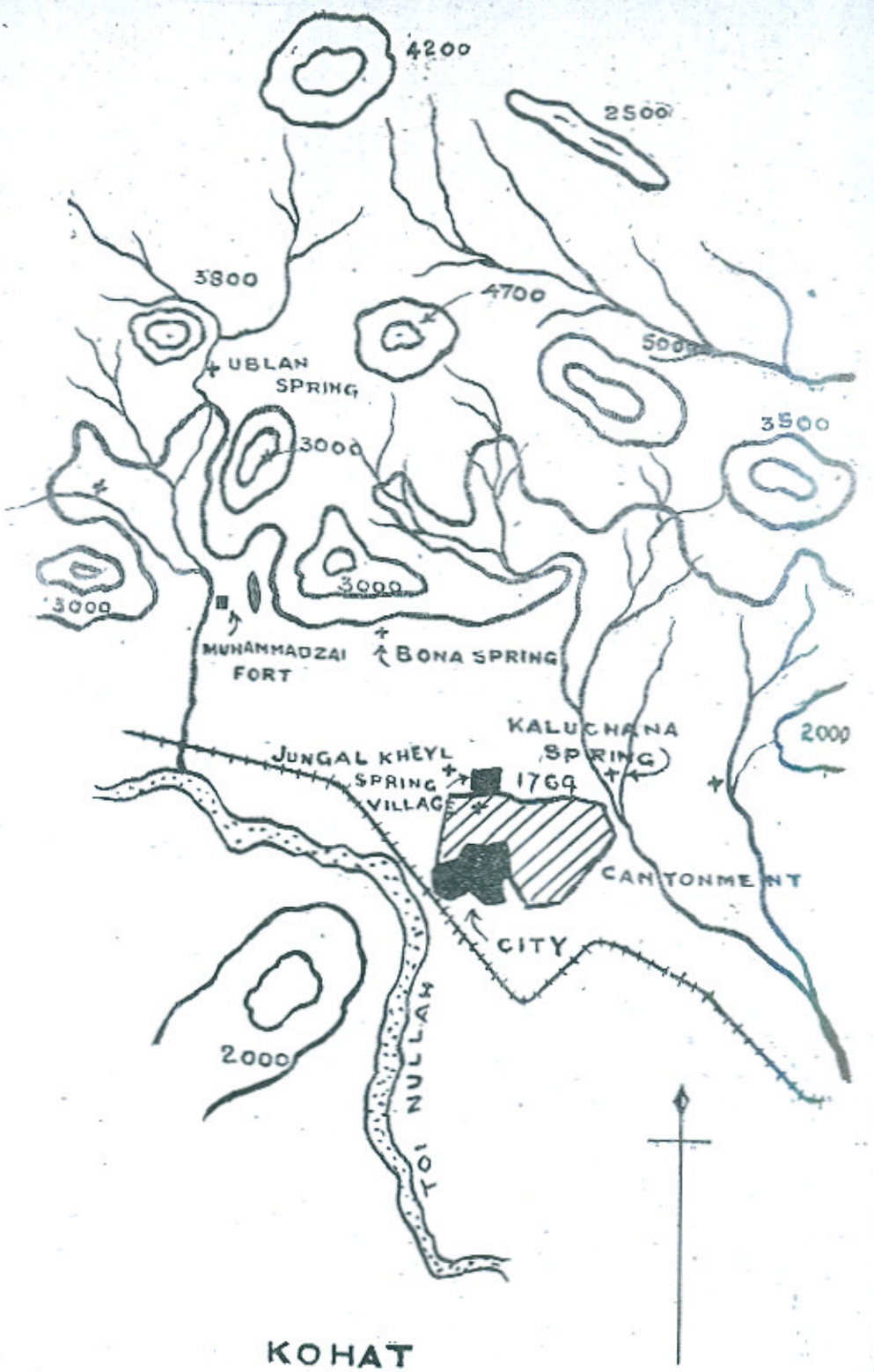
Khanna well.

The arrangement of the Khanna artesian well is as follows. A string of 10″ wrought iron pipe forms the tube, and the bottom 10′ of this pipe, corresponding to the gravel bed, is perforated with $\frac{1}{4}$″ diameter holes spaced $\frac{3}{4}$″ apart. A 10 feet diameter plugged steining 15′ deep has been sunk round the 10″ pipe; and



KHANNA . WELL

SCALE 1/8 = 1 INCH.



KOHAT

SCALE $\frac{1}{2}$" = 1 MILE

sufficient 1" diameter holes 10' below ground level have been drilled in the 10" pipe to give a flow of 4 lakhs per day with the water in the steining pumped down below these holes. The standing water level in the 10" pipe is 8' above ground and 400,000 gallons was obtained with 14' depression. The site of this well is approximately 50' below the Rawal wells. The Rawal masonry wells deliver 1,800,000 gallons with a depression of 4 feet.

KOHAT.

Preliminary.

The supply in this district is drawn from the Bona springs, 1½ miles north of the Cantonment. The normal yield of these springs is 1,200,000 gallons daily, but during the recent drought it decreased to 700,000 gallons. Under an old agreement with the cultivators, the Cantonment is allowed to take one-twelfth of the water from these springs on condition that payment is made of half the expenses of maintaining the Toi Channel. This Toi Channel is an open earthwork channel diverting water from the Toi Nullah, and it more or less compensates for the water taken from the Bona Springs. In considering means of improving this supply, any attempt to use water visible to the inhabitants would immediately result in large claims for compensation; thus although it might be possible to arrange for a larger percentage of the Bona Spring water in return for the construction and upkeep of another channel; a good well, if it could be found, would be much cheaper and more satisfactory. It is therefore proposed to consider the best location for a well.

Water finding.

The formation is yellow clay overlying massive limestone and the outstanding feature is that the Jangal Kheyl springs inside the Cantonment were giving a flow of six million gallons daily towards the end of the recent drought. This water flows through the Cantonment in roadside channels and is afterwards used by cultivators. It is evident that springs of this calibre, giving such a large flow after the complete failure of last year's monsoon, and having had to draw upon their own resources for over a year, must be drawing their supplies from very large caverns in the limestone ridges to the north. There is no other direction from which such a large quantity of water could be drawn. The ridges to the east are not high enough; and to the south the ground falls away to the river Toi. There are good local wells in Jangal Kheyl village immediately north of the springs, and these wells no doubt account for the reported pollution of the water from time to time.

At any rate it is certain that the pollution must occur close to the springs, as water purifies itself very quickly, and this is the only source of pollution if it is admitted that this water comes

from the north. Considering the exact point at which the water issues from the limestone ridges, the first possibility is that the Jangal Kheyl springs are simply the overflow from the Bona springs as the latter issue from the limestone on a level with the plain and it is quite possible that only a part finds its way to the surface at Bona. Against this theory however, it is stated that the Bona water is harder than the Jangal Kheyl water. The next possibility is the point at which the stream one mile east of the Bona Springs flows out on to the plain. This would be a good position for a test bore as there is also a small spring, the Kalu Chana, in the bed of this stream 1½ miles downstream, brought to the surface by a rise in the strata. It is probably the same rise in the strata which brings the Jangal Kheyl water to the surface. The third possibility is near Muhammadzai Fort, 1½ miles to the west of the Bona Springs. The Ublan spring is situated in the same valley three miles above this Fort, the water issuing from the limestone and disappearing again underground almost immediately. This spring is situated in very unsettled country on the border of independent territory and compensation would have to be paid for using water from it. It should be understood that the three points mentioned above are only the most likely places at which the water is issuing and it might actually be issuing from any point between these two extremes, but there is no indication to suggest other points. The limestone hill rising to 3,000 feet behind the Bona Springs, is no doubt the source of the Bona water ; and the Jangal Kheyl water is also either coming from the same hill, or is coming from similar hills behind and being conducted round one side or the other of this hill.

Conclusion.

The line of least resistance for improving the water supply would be to sink wells immediately north of Jangal Kheyl village, and the only object in keeping further north is to risk failure for the chance of obtaining water without pumping or compensation.

With a little industry it should be possible by sinking test bores along the foot of the limestone ridge, to locate the water channel leading to the Jangal Kheyl springs and considerably improve the gravity water supply to this area.

The above theories have not yet been tested by boring.

DISCUSSION.

MR. W. CATHROW said that a certain amount of work had been done since writing the paper.

At Rawalpindi, three test bores had been sunk close to the Railway, with a view to tapping the gravel bed between Khanna and the springs. The third bore struck sandy gravel at 90 ft., and between 107 and 114 ft. the gravel was quite clean and free of sand. Water level was 20 ft. from the surface, and although a proper pumping test could not be made, baling with a 10-foot bailer made no impression on the water level. He thought it would be agreed that this was conclusive evidence of the connection between Khanna and the springs west of Topi. The position of this bore was slightly west of the line between Khanna and the springs.

At Kohat, one test bore near the Bona springs had been sunk 110 ft. through hard white clay and the work was proceeding. There were no results up to the present, but a chemical analysis of the water from the Bona and Jangal Kheyl springs showed them to be one and the same water. The result of the chemical analysis made him feel particularly confident of this area, but it might be necessary to drill into the limestone below the yellow clay in order to strike the water channel.

The new well near the pump house at Ambala was awaiting the result of a trial with a reverse filter, as recommended in a pamphlet written by Mr. Temple some time ago. The object of the experiment was to decide whether grading with sand ranging from fine at the bottom to coarse at the top, would be likely to give better results than simply filling in with coarse sand, as recommended in the paper.

In the meantime the well was being pumped slowly up to a maximum of 50,000 gallons per day.

The author mentioned at the end of his preliminary remarks, that there were no general conclusions regarding the location of wells, but on further consideration there appeared to be just this one conclusion, namely, that COARSE SAND and LIMESTONE were the only two formations in Northern India which were capable of storing sufficient water to give a supply during dry years and during the hot months of the year, and these were the only two formations worth considering in connection with a well location. This statement might require modification later, but he had been privileged to report on a fairly large number of water supplies and so far it held good.

Put in another way it might be accepted that all perennial springs on the frontier were drawing their supplies from limestone and with this information it was generally possible to come to some conclusion as to the direction of origin of the water.

MR. F. C. PAVRY said he would like to make a few remarks about water supply at Ambala as the North Western Railway had a similar problem to deal with there. Recently he had to investigate the possibility of increasing the Railway supply and the conclusion he came to was the same as the author's—*viz.* that the only practicable and economical way was by tapping the 14 ft. thick sand stratum near the Tangri by open wells giving the necessary percolation area. The Railway had four 12 ft. wells and a new 20 ft. well not yet connected up. In sand of such poor quality a few large wells would obviously be much more effective and economical than a number of small wells ; and he proposed to put down 30 ft. or 40 ft. wells here when the Railway had decided on its total requirements.

It would appear from pages 111 and 112 that 250,000 gallons and 100,000 gallons respectively were obtained by 24 hours' pumping from the set of sixteen 14 ft. wells and the 30 ft. well. If this was so the discharge per sq. ft. of floor area per hour was only 4 gallons for the former and 6 gallons for the latter. The Railway was more fortunate as its wells gave a corresponding figure of 12 gallons which itself was considerably lower than the average in the Punjab.

If these wells had actually been pumped continuously for a prolonged period it would be interesting to know if the author had any data showing the effect of such pumping on the level of the water table and the discharge. The Railway Engineers tried to keep down the pumping to 8 hours a day where possible for various reasons including that of allowing the wells to recuperate. As an instance of such recuperation the discharge from the 12 ft. wells at 16 ft. head pumped 22 hours a day equalled that from the new 20 ft. well at 9 ft. head pumped 8 hours a day.

The author's proposal on page 112 to fill the lower 10 ft. of the new wells with coarse sand seemed to be much more promising than the shallow graded sand and stone filters used so far for keeping down fine sand. The sand would, the speaker thought, be more certain in its action than the stone filters. The Railway had the latter in some of its 12 ft. wells and also in the 20 ft. well. They allowed pumping up to a head of at least 16 ft. in the former but only 10 ft. in the latter without blowing.

On page 112 the author proposed to make the lower length of 10 ft. of steining of dry brickwork to increase the yield. Railway experience in this respect at the Tangri might perhaps interest him. The sand bed here was only 14 ft. thick. The lower

7 ft. of the 20 ft. well was made in dry brickwork starting from 4 ft. above edge of curb. Due to slight error in sinking and possibly subsequent settlement under test pumping the curb was now only a few inches above the underlying clay. In future railway wells at the Tangri the speaker therefore proposed to make the steining solid throughout and bed the curb just below top of the sand stratum. He did not think the small extra discharge from the dry brickwork justified one in risking the total failure of the well.

MR. D. A. HOWELL remarked that the same difficulties which the author mentioned regarding the Cantonment supply had been ecperienced with the supply to Ambala City. In the Handesra Scheme for Ambala City which had originally provided a supply of over 200,000 gallons per day the present yield was only about 80,000 gallons per day. The diminution in yield was due to the "clogging" of fine material washed by the water round the wells which thus prevented the inflow of water.

The Punjab Public Health Department had had borings made on the Tangri with the result that the strata had been proved to be as follows :—

Surface—

7½ ft. thick clay.
13 ft. thick stiff clay.
17 ft. thick fine sand.
9½ ft. thick yellow sand.
20 ft. thick coarse sand.

Clay beds.

This agreed very nearly with the results obtained by the Military Authorities mentioned by Mr. Cathrow.

A 40 ft. diameter well was about to be sunk into the coarse sand bed. Past experience in this district had shewn that although wells yielded a fair supply of water at first their yield rapidly diminished. This diminution was attributable to the fact that the water entering the wells which had been generally pumped to a depression head of 7 or 8 ft. had such velocity that it carried with it fine particles of sand which were deposited around the well thus choking up the strata surrounded the well and obstructing the inflow of water. To obviate this effect as far as possible it had been arranged to make the well of very large diameter, and also it had been proposed to pump only to a depression head of

about 4 ft. by which means it was hoped to obtain a supply of about 120,000 gallons per day of 24 hours. Of course it remained to be seen whether the desired effect would be produced by adopting this course which appeared from past experience a reasonable one to take.

After the well had been at work for some time useful data would be forthcoming.

Mr. Pavry had remarked that the North-Western Railway were pumping their wells at Ambala to 9 ft. depression head. He had come to the conclusion that at Ambala at any rate this was not safe as not only was the clogging action of the water entering the wells increased velocity of flow, thereby causing the yield to be diminished more rapidly, but also the structure of the wells was endangered due to blowing taking place.

R. B. AMAR NATH NANDA remarked that the Headworks for the Ambala City water supply was situated about one mile from the Tangri and within an angle formed by this nullah on one side and the line of flood spill, taking off from it a few miles above, on the other. The advantages of this site were :

1. Safety of the headworks from the damaging effect of the Tangri during flood.

2. Replenishment of the subsoil storage of this area from two sides.

As regards tapping of subsoil water a few feet below the bed of the Tangri, the Sanitary Engineering Department had successfully laid a horizontal strainer 100 ft. long and 10 inch in diameter at an average depth of 6 ft. below spring level. Yield obtained was 9,000 gallons an hour under a depression head of 8 ft. and the total cost including cost of 100 ft. strainer and 80 ft. plain pipe came to Rs. 8,000.

The yield from this tube in 24 hours working was nearly equivalent to that actually obtained from all the 27 wells of the old headworks at Handesra.

It must, however, be admitted that water so near the surface was liable to pollution, and this, as remarked by the author of the paper, was a point for consideration at Bibyal when there were habitations above the headworks.

Regarding subsoil water level, this was gradually falling at Handesra. In 1895 when the city water-works were built the rising main served as a falling main and water passed down it by gravity. Later on due to drop in water table the suction limit was exceeded and the pumps were lowered by 9 ft.

Similarly the water supply feeding the Khera duct was originally a gravity supply lent since several years past due to drop in water level pumps had been installed for lifting the water into the duct.

Lastly he thought that filling the bottom 10 ft. of the new wells at Bibyal with sand for anticipating "blow" of sand was not a sound remedy. What was required was the putting in of graded material as a reverse filter in the bottom of the well on Mr. Temple's principle. This had been tried on well No. 4 at the Handesra headworks and found successful in stopping "blow" of sand.

MR. FOY said that the information about Ambala was interesting to him as he had lived there for six years, the last three years of which were the exceptionally dry ones of 1918, 1919 and 1920 in which he had the mortification of seeing every rose bush in a good garden die because even the masonry duct was unable to give a single drop of water to the garden cistern. In this period he had many opportunities of discussing the water situation with the officers of the P. W. D. and Military Works, and it had always surprised him that every scheme contemplated further tapping of the Tangri Nullah basin while no one seemed to try the equally promising valley of the Ghaggar which was only three miles from the city against the seven or eight miles to Handesra for military water supply. What the conditions of the Ghaggar sub-soil near Ambala were the speaker did not know, but certainly it should be possible to get water in very large quantities from Mubarakpore and though the distance seemed great this was not an insurmountable difficulty to modern engineering. With regard to the Handesra water supply, in 1915 a committee decided to lower the cut from the Tangri referred to by Rai Bahadur Amar Nath in order to fill large tanks near the Handesra wells in the hope of raising the water table. The lowering of the Regulator in the Bund and the cut from it was done by the Irrigation Branch in the winter of 1915-16, but so far the speaker had been unable to find out what the result had been.

Two years ago an officer of the Military Works informed the speaker that they intended to put a horizontal wired tube of the tube well sort in the Tangri near the Bibyal wells, but whether this had been done the speaker had never found out. It was therefore interesting to hear Rai Bahadur Amar Nath's account of such a tube put in near the Handesra wells.

The speaker took this opportunity of urging on the authorities the necessity for a bold policy of breaking away from tapping the already overtaxed Tangri Basin and search for suitable water bearing strata in the Ghaggar Basin.

RAI BAHADUR LALA GANGA RAM said that the proper scheme to adopt in the case of the Ambala water supply was the boldest, which would be to bring water from Pinjore in a gravitation conduit of reinforced concrete. Twenty cusecs of water were available at Pinjore and the fall available was about 800 ft.

MR. J. A. R. BROMAGE stated that he was very interested in Mr. Cathrow's paper as his own department had been conducting boring operations to the North of Rawalpindi with a view to finding a suitable source for an extension to Rawalpindi City supply. Water had been found at a higher level in the Sohan River and a water bearing gravel bed of considerable thickness had been struck. An experimental well was now going to be sunk with a view to finding the field of the gravel bed.

MR. CATHROW replying to the discussion said that with regard to Mr. Pavry's remarks, the Bibyal wells were normally pumped 16 hours, but when the water levels were very low it was generally only possible to pump 3 or 4 hours and then they were obliged to allow the wells to recoup. A tell-tale well, which was not pumped, gave the standing water level, but the pumped wells never recouped to the level in the tell-tale well.

This applied particularly to dry periods when water levels were low and when in his opinion, capillary attraction began to counteract the force of gravity, and slowed down the rate of recoupment.

Records of the levels of the Bibyal wells had been kept since 1907, but up to the present no useful information appeared to be obtainable from them. The last three years had been comparatively dry and levels had dropped on an average of 2 or 3 feet. Given good rains again, the levels should again become normal.

He quite agreed that the well curbs should be set in the clay strata above the sand. Difficulty was experienced at Bibyal owing to the curbs sinking and breaking the suction pipes. It was hoped, however, that the 10 ft. of coarse sand inside the well would remedy this to some extent. The object of the dry brickwork staining was to tap the sand above the clay bed.

Replying to Mr. Howell, the author said that the result of the test bore for the new city well at Handesra confirmed previous experience of boring in the Tangri Nullah, *viz.*, that a coarse sand strata existed between 48 and 70 feet. The principle of not depressing this new well more than 3 or 4 ft. was sound, but it would probably prove a counsel of perfection. The yield at Bibyal would be very small indeed with such a depression head.

He was interested to hear the reasons given by Rai Bahadur Amar Nath Nanda for choosing the particular site occupied by

the city waterworks. With regard to the water levels at Ambala, he was not yet definitely convinced that the water levels were genuinely dropping, for in such fine sand a comparatively steep gradient was required to make the water move into the wells at all. As pumping proceeded, the area from which the supply was drawn had to be increased, and the water level in the wells had to be lowered to give the necessary water gradient required for the larger area. In this way the working water level in the wells finally adjusted itself to the required yield, and this was probably the reason why the pumps had to be lowered at one period. The final working water level would be considerably lower than the water level at the time the pumps were installed.

In reply to Mr. Foy, the possibilities of the Ghaggar Nullah had not been investigated by the Military, principally owing to economic reasons in connection with the existing pumping installations. There is no reason to suppose that conditions there would be any better than the Tangri Nullah, even supposing that an ancient river bed of coarse sand existed below this nullah, similar to that below the Tangri. The author had no information regarding the formation below this nullah, but it might be stated as a general case, that if there was no coarse sand, there would not be water in sufficient quantities to warrant the installation of a pumping station. The location of a well in this district depended upon locating coarse sand which would store up water in the spaces between the grains of sand ; and at Ambala, the only place at which such coarse sand could be found was below the bed of the Tangri Nullah. This accounted for all the water works being located along the line of this nullah.

Regarding the overtaxing of the Tangri Nullah, this was no doubt true ; but the geographical position of the city, rather than the cantonment, lent itself to the use of the Ghagar Nullah. One test bore in the bed of this Ghaggar Nullah opposite the city, and another at Mubarakpore, should give all the information necessary for drawing up a completely independent scheme for the city. The surface indications were good at Mubarakpore, and if the necessary coarse sand existed that area would make a good source of supply.

Regarding the horizontal strainer, a start was certainly made on one at Bibyal, but owing to the fineness of the sand, which simply passed right through the strainer, it was proposed to lay ; the possibility of pollution due to its closeness to the surface, and the practical certainty that the medical authorities would insist upon chlorination ; and finally owing to the very great difficulty in excavating in running water-logged sand, the idea was abandoned in favour of masonry wells.

In reply to Rai Bahadur Ganga Ram regarding the adoption of a scheme for conveying water from Pinjore, this was purely

an economic question and so far the military authorities would not consider it. The author would not personally support the idea of a masonry duct unless the internal section was at least 5 ft. square. The ordinary small duct in India was impossible to keep in proper repair, because the size was not large enough to admit of a man getting inside and inspecting it. Generally the only evidence of leakage was a patch of green vegetation on the surface. The Rawalpindi Duct was in comparatively good condition, but the water became polluted in passing through it. The pollution in this case however was not serious.

The author had not personally investigated the Pinjore source, but since there was a large volume of water available, and being in the hills it would probably be fairly pure ; provided there was no heavy compensation to pay for water rights, it would probably be quite a sound proposition to construct a large size duct to Ambala.

Various speakers had mentioned the necessity of taking the boldest policy, and the result of this discussion appeared to be either a pipe line from Mubarakpore, a large duct from Pinjore, or a pipe line from some of the larger springs in the foot hills. It was a question which would require careful investigation and involve a large amount of money, and if the various bodies concerned were prepared to pay the piper, then a great improvement over the present masonry wells would be obtained.

The author agreed with Mr. Bromage that the new bore one mile north of Rawalpindi City had struck a gravel bed similar to the one discussed in the paper, and a well in that position should give quite a good yield.

Mr. W. P. Sangster, in closing the discussion, reminded the Congress that on the previous day, in his address, he had mentioned the development of the Attock oil-fields as a striking testimony of the importance of geology as a hand maiden of industry. In Mr. Cathrow's paper they had another example of the utility of geological science, and it had been shown there how a knowledge of geology was of the greatest value, in discovering source of water supply. With these examples before them he took the opportunity of advising members to bring the study of geology within their engineering range.