SOME NOTES ON THE STATE OF THE MELBOURNE WATER SUPPLY.

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IN view of the present very serious situation at Melbourne in regard to the water supply, it will doubtless be of some interest to members of the Engineering Section of the Royal Society to know from whence the water is derived and what is the reason for the present shortage.

Melbourne is served by (1) The Yan Yean, (2) The Maroondah, two separate systems which deliver the water into a distributing Reservoir at Preston, which is about 7 miles in a direct line from the G.P.O., and is at an elevation of 328 feet above sea level. Its capacity is 16 million gallons or 2 millions less than our Centennial Park Reservoir.

The Yan Yean System derives its supply from the drainage of the coastal range of mountains, the summit of which at this part is 2,630 feet above sea level, and about 29 miles in a direct line from the G.P.O. Here the River Plenty, Wallaby Creek, and Silver Creek take their rise, the former flows to the South of the range, and the two latter to the north. Small weirs intercept the drainage from the Wallaby and Silver Creek catchments, whose combined watersheds amount to 11,500 acres or 18 square miles, and divert it into an aqueduct which conveys it to a low place on the crest of the main dividing range, where the elevation is 1694 feet above the sea. From this point the water drops a height of 633 feet in a length of 683 feet through a series of shoots and artificial falls lined with

granite, discharging into Jack's Creek, which is one of the branches of the Plenty River. It then follows the bed of this creek for 3 miles and enters the Tooroorong Reservoir, which receives the combined waters of the Eastern Plenty, Jack's, Silver and Wallaby Creeks, from a total catchment area of 22,000 acres or 34·37 square miles.

The dam of this reservoir is 15 chains long with a puddle wall; the inner slope is protected with granite pitchers. The area is 36 acres, and the storage capacity 60 million gallons. The water from the reservoir is conveyed by a "clear water channel," $4\frac{3}{4}$ miles in length, lined with granite pitchers, having a carrying capacity of 120 million gallons per day, and discharges into the "old Plenty Aqueduct," which connected the Plenty River with the Yan Yean Reservoir. The Yan Yean Reservoir is formed by the construction of an earthen bank, 49 chains long, 30 feet high, 20 feet wide on top, inside slopes of 3 to 1, outer slope of 2 to 1. The by-wash is 5 feet below the top of the bank and is at a level of 602 feet above low water at Hobson's Bay. When full the water covers an area of 1,360 acres, with an average depth of 18 feet and maximum depth of 26 feet. The total capacity being 6,400 million gallons, of which 5,400 million gallons are available for consumption. From the reservoir the water enters an open aqueduct 7 miles long, which delivers into a small reservoir 14 feet deep and holding 3 million gallons, which serves as a pipe head, and is at an elevation of 485 feet over sea. The delivering capacity of the aqueduct to this point is 33 million gallons per day. From the pipe head reservoir three large mains viz., a 27 inch and two 30 inches lead the water to Preston Reservoir a distance of 7 miles. This reservoir as before stated, is 328 feet above sea level and holds 16 million gallons. This system served Melbourne for a considerable time, but the increasing population and

demand for water requiring an additional supply resulted in the selection of the Maroondah or Watts' system being brought into operation in the year 1891.

Maroondah System.—The water from this system is obtained from the tributaries of the Yarra arising from the flanks of Mount Juliet, Mount Monda and Mount Riddell, whose altitudes are 3,651, 2,974, and ——[1] feet respectively. The completed Maroondah scheme includes a storage reservoir with a dam 105 feet high, calculated to store 2,000 million gallons. This dam has not yet been constructed, as up to the present the natural flow of the creeks with the storage in the Yan Yean reservoirs have proved quite capable of providing all the water at present required for Melbourne, equal to about 44 million gallons per day summer service. The watershed of the Maroondah system embraces an area of 35,500 acres or 55·46 square miles.

A temporary weir has been constructed of Portland cement concrete across the Watts' River, from which the water is led in an aqueduct 41 miles long to the Preston Reservoir. On this length there are 25½ miles of open contour channels, 12 tunnels aggregating 6½ miles, three of which are about one mile long, and 14 inverted syphons totalling 9¼ miles. The open conduit is lined with cement concrete or brickwork in cement, the cross section being a quadrant of 3 feet 10 inches radius, with 1 to 1 slopes, and a fall of 1 foot per mile. The channel as now completed, is capable of delivering 25 million gallons per day, while the tunnels are of this capacity lined where necessary with brickwork or cement concrete.

The valleys are crossed by wrought iron syphons 50 to 53 inches diameter, with falls of 7½ or 4 feet per mile respectively. These syphon pipes are ¼ inch or ⅜ inch wrought iron plate, in some places carrying a pressure of 100 lbs. per square inch. With the exception of the Plenty

[1] This height cannot be supplied.

River, which is crossed on a wrought iron girder bridge, all the syphons are laid under the beds of the streams. At each of the charging and discharging basins, provision is made for connecting a duplicate syphon. Each of the syphons is provided with a scour pipe large enough to take the full flow of the aqueduct, enabling the water to be directed down any of the natural water courses when it becomes necessary to empty any lengths of aqueduct for cleansing and repairs. The tunnels are constructed to carry 50 million gallons per day, but the aqueducts and syphons are only now arranged for 25 million gallons, but by constructiug the duplicate syphons, and raising the side slopes of the open channels the necessary increase to 50 millions can be readily obtained.

Preston Reservoir.—Both the Yan Yean and Maroondah systems unite in the Preston Reservoir where the water is distributed to the central parts of the Metropolis. This reservoir is constructed partly in excavation, partly in bank, and is lined with bluestone pitchers, the side slopes being $1\frac{1}{2}$ to 1. It is 20 feet deep, and holds 16 million gallons.

The Yan Yean reservoir with a by-wash level of 602 feet governs the whole Metropolitan area by gravitation. The Maroondah system only delivers into Preston reservoir at 328 feet.

Average daily consumption for each month from 1891 to 1903:

	January.	February.	March.	April.	May.	June.
Average	33093436	34666704	30185718	25211126	22520842	21287286
Maximum	37821998	41630304	33610839	28562900	27147129	25689700
Minimum	28306891	28498814	25008731	21280987	19412690	17036021
	July.	August.	September.	October.	November.	December.
Average	21321399	22127792	22664674	25067122	29339076	33101834
Maximum	34349226	26580548	27135736	29047355	34956667	38276258
Minimum	17273423	18110390	19534740	21836103	25177922	28575041

The demand for water increased from 32 gallons per head in 1877 to 41 in 1887, but as soon as the Maroondah system became available the use of water rapidly increased. In 1888 it was 49, rising in 1894 to 61, then dropping to 52 in 1896, rising to 61 in 1898.

The total quantity of water that can be sent into Melbourne by the existing works is—

Yan Yean system	33	million	gallons	per	day
Maroondah	25	,,	,,	,,	
High level main	9	,,	,,	,,	
Total possible daily supply ...	67	,,	,,	,,	

NOTE.—The above description of the Melbourne Water Supply is extracted from the Engineer-in-Chief's Report of 1903.

It will be seen from what has been stated, that Melbourne is supplied practically from the daily flow of the streams, and the quantity received from these sources has been so good that it is only on occasions when the rainfall is considerably below the average, when the demand for water is in excess of the combined stream flow that the Yan Yean reservoir has been called upon to make up the deficiency. Owing to the long continued drought the draft upon the reservoir has been so continuous as to reduce it to a level never previously experienced, and very great anxiety is felt as to the result should the dry spell continue.

It will be remembered that I drew attention in my address on May 20th, 1908, to the fact that there had been a persistent decline in the rainfall from the year 1875 to 1898 as shown by the Melbourne residual mass curve diagram, and that although a slight rise had occurred for the six years following to 1904, another persistent decline had set in which has continued to the present time when the ground water would probably be found to be at a lower level than it had ever attained before.

That the conditions which have existed since the year 1875 are having the effect I anticipated may be judged from the following extract from a report by Mr. E. G. Ritchie, the Melbourne Engineer for Water Supply, published on July 1st, 1908. The report is as follows:—

"Lest too much reliance be placed upon the results from the rainfall of the past few days, and the warning of the drought be soon forgotten," Mr. Ritchie points out, "From 19th to 24th inst., we have had the splendid rainfall of 516 points at Wallaby Creek, making 736 points for the month up to 24th. This is a record of total rainfall for June which during the past 18 years has been exceeded only upon five occasions. Nevertheless, the total intake to Yan Yean reservoir has not exceeded a rate of 30 million gallons per day. Under normal conditions of saturation I should have expected nearly three times the rate of intake from such a rainfall as that of the past few days showing how great have been the demands from the absorbent soil. I might mention that the carrying capacity of the intake channel is 120 million gallons per day. The net gain in depth of the Yan Yean reservoir from this rainfall has only been about 8 inches to date. There is no doubt of course that the daily volume of the streams will be fortified for some time, but the fact remains that the larger portion of this splendid rainfall has gone to make good the losses incurred by the failure of the last autumn rains. The results may be further improved by phenomenal rainfalls, but I do not think we are at all justified in expecting such. The possible exhaustion of the reservoir which I have predicted may be to some extent averted by further drastic economies, which will amount—possibly to restriction—at least to greatly reduced pressure. Even if the latter course only be resorted to, it must mean deprivation to the residents of the Metropolis, less water for gardens and a great loss in revenue to the board which can ill be faced. Further it will mean increased peril by fire."

The Engineer-in-Chief Mr. Oliver, in his covering minute refers to the

" Remarkable and unexampled falling off in the streams supplying the Yan Yean for such a long period has reduced the stored water to a dangerous point. The fears expressed he adds are not based on mere conjecture, but on absolute results of intake and output."

The President of the Board, Mr. W. J. Carre-Riddell, in his report says :—

"Although there is only a possibility of the Yan Yean being completely exhausted during next summer (which is unpleasant to contemplate) there is a great probability of that reservoir being then reduced to such a dangerously low level that the supply for the following years may prove insufficient for domestic and sanitary purposes. It is therefore of the utmost importance that immediate steps be taken to prevent the exhaustion of the Yan Yean, and the only means available are the diversion of the Coranderrk Creek and the Acheron River. The former work will be put in hand at once, and the latter should be carried on simultaneously so that both streams may be contributing their waters to the supply of Melbourne early in the new year at the latest, when the supplies from the Watts' River begin to fall off. The work of raising the sides of the Maroondah aqueduct is rapidly progressing and will be completed towards the end of this year, so that it will be in readiness to receive and deliver the waters of the Acheron into Melbourne on the completion of the work of diverting that stream. Upon the completion of the Coranderrk and Acheron diversions all will have been done that is possible to secure a supply of water to the metropolis during the interval which must elapse before the O'Shanassy scheme is completed. Even with the aid of the Coranderrk and Acheron it will require the greatest care and economy in the use of water to tide over the time required to carry out the O'Shanassy works. In reference to the Acheron diversion it is proposed to construct an earthern channel capable of delivering 7 million gallons per day, but there is no intention to take that amount of water all the year round. For the greater part of the year the Watts' River and Coranderrk Creek will

suffice for the requirements of the lower levels, but when the daily consumption of water exceeds the supply from those sources the waters of the Acheron will be availed of to make up the deficiency. It is estimated that the full amount of 7 million gallons per day will only have to be availed of during periods of high consumption, and that during a considerable part of the year there will not be any necessity to take any water at all from the Acheron. In the summer provision can be made by means of compensation water to secure ample supplies for domestic purposes for those dependent on the Acheron."

The Coranderrk Creek drains an area of about 7 square miles to the south of the Watts' River watershed. It is proposed to divert the water from this area amounting to about 3 million gallons per day, by a pipe conduit 4 miles in length delivering into the Maroondah aqueduct. The walls of this aqueduct are now being raised and strengthened to enable it to carry from 28 to 30 million gallons per day. As the lowest parts have been raised first, the aqueduct now brings about 1½ million gallons more water daily to the Preston reservoir than ever before. The result is that up to 24 million gallons of water have come from the Maroondah system to meet the daily demands of the metropolis, and it has been necessary therefore to draw upon the Yan Yean reservoir to only a very slight extent. Recently the water flowing down the Maroondah aqueduct has been within two inches of the top of the bank.

The Acheron River takes its rise in the mountains north of the Watts' River and the stream ultimately finds its way into the Goulburn River. The mountains here attain an elevation of over 3,000 feet. It is proposed to divert the water of this river from an area of about 9 square miles, and lead it round to a low saddle in the dividing range separating the Acheron from the Watt's River catchment area where the altitude is 1,628 feet. The water being

discharged on the southern slope of the dividing range would thus find its way into one of the tributaries of the Watts' River and ultimately into the Maroondah aqueduct.

The O'Shanassy scheme referred to in the reports proposes to intercept the water draining from an area of about 59 square miles of mountainous country lying to the east of the Watts' River about 6 miles, and to lead the water by a channel to carry 25 million gallons per day at present, to a pipe head near Woori Yallock, from which point pipes 42 inches and 50 inches diameter would be laid to a storage reservoir near Mitcham. The estimated cost of the scheme is £675,000.

It will be seen from the extracts from the official reports which have been published, that the situation in Melbourne with reference to water supply is very disquieting. It will take at least three years to bring in the water from the O'Shanassy River, and in the mean time it is absolutely necessary to augment the present supply from the Yan Yean and Maroondah systems in the manner described. No objection seems to be raised to the diversion of the Coranderrk Creek into the existing aqueduct, but there is very strong opposition by the residents on the Acheron and Goulburn Rivers to the head waters of the former stream being tapped for the supply of Melbourne.

The Minister for Water Supply Mr. Swinburne, says:—

"I am very strong in my attitude, and I will never give way on this point, that the waters of the Acheron belong to the northern areas. The northern people must not have taken from them water they require in order to save the Melbourne people expense. What the Board wants is equal to $\frac{1}{50}$ of the total summer flow of the Goulburn, and the Acheron waters are among the most assured sources of supply."

The Cabinet has arrived at the following conclusions as published in the press of 11 July :—

"The Cabinet recognising that the water of the Acheron is part of the Goulburn system and is required for the development of agriculture in the northern areas where the supply of water is already inadequate, is extremely reluctant to even temporarily divert any flow that will affect those localities, and the more so as assured and ample water supply for the metropolis can be obtained from other sources. In view, however, of the Board's contention that danger of the most serious character to the inhabitants of the metropolis, may arise, unless the Board has during the next three years the opportunity of supplementing its water supply by a diversion from the river, the Cabinet is prepared to grant the concession on the following general conditions, which if approved by the Board will be later incorporated in an agreement :

(*a*) That the Board guarantee to the satisfaction of the Minister of Water Supply, that it will proceed with and complete within three years from the date of the signing of the agreement, an adequate scheme for the improvement of the water supply of the metropolis from the O'Shanassy River, or some other source than a tributary of the Goulburn.

"(*b*) That the works necessary for the temporary diversion be designed and constructed to the satisfaction of the State Rivers and Water Supply Commission which may itself either carry out the whole or part of the works, or may require the Board to do so. The Board in either case is to pay the total cost of the works, and also all the subsequent cost of maintenance and management.

"(*c*) That while the various districts dependent on the Goulburn system of water supply have received the quantities of water at present, or that may from time to time be allotted to them, the commission may apportion, divert, and supply to the Board from the available remainder, such quantities as the Commission may decide.

"(*d*) That the Board pay to the Commission for the water so diverted by the consent of the Commission at the rate of 1d per 1,000 gallons, such payments to be made every three months."

The press states that this communication will be considered at a meeting of the Water Supply Committee, and it will probably come before the Board at the meeting to be held on Tuesday week. In the meantime members of the Board are being confirmed in their opinion that it is not equitable for them to be called upon to pay for the water at its source, in view of the fact that about £36,000 worth is given to the Government free every year for use in Government departments. That sum does not include either water for flushing channels, watering the streets, supplying gardens under the control of the Government, nor what is used in extinguishing fires, for all of which no charge is levied.

* * *

It will be seen that these conditions are very stringent, even at one million gallons per day so diverted from the Acheron into the Watts' River watershed, the cost will be for the necessary works £6,000, and for water at 1d per 1,000 gallons £4 3s. 4d. Very little is known about the Acheron, and as to what quantity is available. The area above the point of interception of the water is only about nine square miles, and the long continued drought has no doubt affected that stream in a similar manner to the Wallaby and Silver Creeks, which Mr. Ritchie has already stated are diminishing quickly. In view also of the ground water in the Watts' River catchment area being at a lower level now than ever before, since records have been made of the rainfall, it appears to me that only a small proportion of the Acheron water discharged over the mountain side will find its way to the aqueduct situated at the lower levels. The probability is that a considerable part of the water will be absorbed on the way down, and although it will not be actually lost inasmuch as it will be stored underground to ultimately assist in feeding the stream, it will take a long time to gravitate to the point where it is now so much needed.

Seeing that there is such opposition to the diversion of water from the Acheron River, and that if proceeded with it will be exceedingly costly for the small amount of water likely to be derived thereby, which also may be seriously diminished before it reaches the intake to the aqueduct by losses such as I have described, it will be well to consider whether the money proposed to be expended on the Acheron scheme would not be more advantageously applied to the extraction of the additional water required from the saturated beds adjacent to the streams on the Watt's River watershed, and at the same time commencing works for the development of that system, by conserving as much as possible the underground water.

Notwithstanding the protracted drought the Maroondah catchment area appears to yield still a very large quantity of water, I think something like 17 million gallons daily is now flowing into the aqueduct for the needs of Melbourne. How long it would continue to discharge at this rate if the dry season continues it is impossible to say. The stream fluctuates of course with the rainfall. Every shower that falls upon the area contributes its quota to the stream and also to the underground supply or water table. If the water table is low, the immediate "run off" will be very much diminished as has been already proved on the Wallaby and Silver Creeks. That portion of the rainfall which is absorbed by the soil and goes down below the limit of evaporation (which is estimated by competent authorities at 2 feet) continues to sink until it joins the water table.

If the rainfall is sufficient in quantity and rate of fall to maintain the level of the water table, the hydraulic gradient underground will remain constant, and the streams will continue to flow in undiminished volume. We know, however, in the case of the catchment areas on which Melbourne relies for its supply, that the stream flow has very

seriously fallen off, and must therefore conclude that the water table must be low and is still falling.

The Melbourne rainfall diagram (*Plate 3*) shows that there has been an accumulated loss of rain below the mean at that place since the year 1875, amounting to 47·94 inches, or 1·8 years mean rainfall, and although a much higher rainfall is experienced on the catchment areas (probably nearly double that of Melbourne) it is reasonable to suppose that the same influences which have resulted in the decline at Melbourne, have affected those areas in a similar manner and the water table there is in all probability at a lower level than ever previously known.

In view, however, of the large quantity of water still running from a comparatively small area like the Watts' River catchment, viz., 55½ square miles, it is evident that there must be an enormous underground storage, either in the upper or lower portions of the area, probably in the latter. It would thus appear to be feasible, in order to maintain the supply in the aqueduct, or to augment it if necessary, to drain the water out from the saturated beds by making cuttings or trenches into the hill sides, or by constructing drains to be laid in trenches and parallel to the creek beds, properly protected with broken stone surrounding the pipes in order to arrest the sand while permitting the water to enter the joints or perforations. In this manner no doubt as much water as may be required could be liberated from the saturated ground by extending the drains. While this system would no doubt be very effective in keeping up the supply, it would assist in lowering the level of the water table in those areas where the operations were carried on, and it would therefore be necessary to construct works in suitable places in the upper portions of the catchment area to impound water resulting from heavy rains, which would exceed the discharging capacity of the aqueduct and would consequently run to waste.

Dams of the "rock fill" class could be quickly and economically built in the beds of the principal streams, or crib dams of rough timber logs could be erected, which would retard the flow of water during freshets and pass it off slowly. The water could also be diverted from the creek beds and conveyed by shallow channels contouring the hill sides, distributing the water in such places where there are thick deposits in which it would be quickly absorbed, thus artificially irrigating the soil for the purpose of storing up the water underground.

The building of the Maroondah dam should not be neglected any longer. It should certainly form part of the scheme for conserving the water, *by preventing the escape of the underground water, and impounding it*, together with the surplus water of freshets beyond the capacity of the aqueduct. This reservoir is estimated to contain 2,000 million gallons of surface water, but the dam being over 100 feet high would raise the level of the ground water at the back and sides over a very considerable area, thus conserving a very large underground supply.

Enough has been said to show how the scheme for conserving water above, and underground, could be developed to such an extent that a very large proportion of the water which fell as rain would be stored, and if the same treatment be extended to the Yan Yean system it would probably be sufficient to obviate the necessity for going further afield in search of new sources of supply for very many years. Silting up in the retarding reservoirs would probably take place in time, but it should be remembered that this can not be regarded as a total loss, for the reason that even if they filled up completely with sand they would still conserve in the interstices between the grains of sand about one third of their mass in water which would drain off slowly. Being of such cheap construction, others could be built

readily to replace them. The silting up of the Maroondah dam would be deferred indefinitely by the construction of these retarding dams on the upper part of the catchment area, but the débris carried down by storms from the thickly wooded area would be arrested and prevented from passing into the aqueduct, and the water having undergone a process of sedimentation in the big reservoir would be supplied to Melbourne of better quality than at present.

DISCUSSION.

THE WATER SUPPLY OF SYDNEY, PAST, PRESENT AND FUTURE.

By T. W. KEELE, M. Inst. C.E.

17th June, 1908.

Mr. NORMAN SELFE said, in the first paragraph of Mr. Keele's most interesting paper he states that the subject will no doubt afford ample scope for discussion. While it is not the general rule to discuss the addresses of retiring chairmen, it was certainly true that in the present case, the author had opened up a subject on which there was very much in addition to be said and in danger of being forgotten. He therefore, proposed rather to supplement than to discuss if the meeting was agreeable. As the paper opened with the history of the tanks and Tank Stream he (Mr. Selfe) thought it might not be generally known that among the many pictures of early Sydney, there was one published in London, at the beginning of the last century, which actually showed these tanks, and he had intended to bring it in to the meeting, so that members