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COMMONWEALTH OF AUSTRALIA.

FEDERAL CAPITAL ADMINISTRATION.

REPORT

OF THE

ROYAL COMMISSION.

(6.) WATER SUPPLY, POWER, AND MISCELLANEOUS.

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ROYAL COMMISSION ON FEDERAL CAPITAL ADMINISTRATION.

REPORT.

6. WATER SUPPLY, POWER, AND MISCELLANEOUS.

To His Excellency the Right Honorable SIR RONALD CRAUFURD MUNRO FERGUSON, *a Member of His Majesty's Most Honorable Privy Council, Knight Grand Cross of the Most Distinguished Order of Saint Michael and Saint George, Governor-General and Commander-in-Chief of the Commonwealth of Australia.*

MAY IT PLEASE YOUR EXCELLENCY:

1. The question as to water supply to be dealt with in this final part of the Report includes charges of default in design of the works now in progress, not only in respect of particular matters included in the scheme, but also because it has been alleged that the whole scheme of water and power supply was misconceived, and that in place of the pumping system that has been designed, a gravitation and hydro-electric scheme should have been adopted. Two such schemes were described in evidence and each must be compared with the scheme now in construction, for decision as to their relative merits must precede any decision upon the charges of want of skill in design made against the responsible officers. As to the production of power, it is charged that the present system is and always must be very costly, and that power more than sufficient for all the needs of the Capital City could have been obtained at very small cost by using the Cotter River flow for its production, and that the difference in cost is such that the power house should be discarded and a hydro-electric scheme adopted.

CHARGES OF DEFAULT.

2. It will be convenient to deal with the matter by examining first of all the charges of default in construction of the water supply works that have been made against the officers, and then to consider the larger and more important question whether the projects put forward by Mr. C. E. Oliver and Mr. J. G. Starr are so far superior to the pumping scheme, that one of these should have been adopted originally. Briefly described, the present scheme includes a concrete overshot dam at the Cotter River near its junction with the Murrumbidgee, 100 feet high and impounding 1,400,000,000 gallons of water, the supply being carried by pipes from the dam to the pump-house which is on the right bank of the Murrumbidgee just below the junction of the two rivers. From thence the water is pumped through a rising main to a pipe head reservoir on Mt. Stromlo, and thence by pipe line is taken by gravitation to a reservoir on Red Hill near the Capital site, and is intended to be distributed by mains connecting with the Red Hill-Stromlo pipe line at a point near the foot of Red Hill and within the city area. The main charges of faulty design and wasteful expenditure in carrying out the existing works, are, first, that it was a waste of money to make a tunnel for the pipe line

from the Cotter River to the Murrumbidgee in place of carrying it on the surface, and second, that there was a similar waste in carrying the pipe line in a tunnel under the Murrumbidgee rather than along the river-bed or upon the bridge which has been erected at this spot; and third, that the reservoir at Red Hill is wholly unnecessary; and fourth, that excessive provision for storage at the Cotter Dam has been made. Many other charges of less consequence than these four were made, and will be dealt with in their order.

3. With regard to the first charge of waste of money in making a tunnel for the pipe line through the hill between the dam and the pump-house, it appears that the total length of pipe from the dam to the pump-house is 3,967 feet. For the first 1,200 feet from the outlet of the dam, the pipe is laid on a bench cut on the left bank of the Cotter, then there is a tunnel 1,965 feet long to the left bank of the Murrumbidgee just below its junction with the Cotter; from there the pipe goes 67 feet down a shaft, 668 feet in a tunnel under the river, and 67 feet up a shaft on the other side. The total cost of this work was £25,210. The cost of the first 1,200 feet was £1,333, including pipe, being at the rate of £1 2s. 2d. per foot. The tunnel section, 1,965 feet, cost £17,815, or £9 1s. 4d. per foot. It was at first intended by Mr. Hill that the pipe from the dam to the Murrumbidgee should be in tunnel throughout: but Colonel Owen's decision was that the first 1,200 feet should follow the line of the Cotter. The charge made against this work is that the pipe could have been carried much more cheaply if it had followed the contour of the Cotter throughout its whole length, and that the tunnel was unnecessary. Before comparing the estimates of cost of the work if carried out in one way or the other, it is necessary to consider points raised by the officers as to certain incidental advantages of their scheme over the other. It is urged that there is very great advantage in having the pipe in tunnel as it is not then liable to be damaged by falling rocks or by floods; further, that when it is necessary to lay a second pipe line, this will involve nothing more than the cost of the pipe and labour if it is laid in the tunnel, but that if it is to be added to another pipe already on the bench, a fresh bench will have to be cut, or the existing bench extended. Another point not made by the officers, but seeming to me to be of some consequence, is that if a supply of water is required greater than could be carried in the existing 18-in pipe the tunnel which has been lined with concrete and is fully adapted to, and designed for the purpose, may be used as a closed aqueduct, and 1,965 feet of pipe line thereby saved. These points are of weight, and a further point was urged in favour of the tunnel on account of its having a straight pipe line as compared with the pipe following the contour which necessarily must have many curves and bends. Mr. Dixon, who gave evidence on this point, estimated that the friction resulting from these curves and bends would involve an extra cost of pumping amounting to £160 per annum on a supply of 2,400,000 gallons per day, which, capitalized at 6½ per cent., amounts to £2,460. Mr. Starr estimates the cost of pipe line from the dam to the Murrumbidgee, 8,200 feet, that is 1,200 feet to the tunnel mouth, and 7,000 feet on the contour line thence to the Murrumbidgee, at £9,215; Mr. Hill's estimate for 7,000 feet is £9,480; and assuming that figure to be correct the cost for construction only would have been £8,335 less than that involved by the tunnel, or if Mr. Starr is correct, the difference is £8,600 plus £1,333, the cost of the extra 1,200 feet. But Mr. Hill's contention is that the tunnel is the better expedient, because as soon as an additional pipe is required, the cost of laying that pipe 7,000 feet on the contour line will be £8,480, whereas the cost of laying that additional pipe in the tunnel line will be only £1,391, and that therefore the difference in construction cost will be greatly diminished as soon as a second pipe is required. As I have already suggested, I do not see why the extra cost of a pipe in the tunnel need be allowed for, and its cost £1,391 could, I think, be deducted. Making this deduction, the relative costs of the alternative methods when a second pipe became necessary would be £17,815 for the tunnel route, and £17,960 for the contour line.

4. So far in this comparison, I have not noticed Mr. Dixon's factor of extra cost of pumping capitalized at £2,460, and the further detriment which he mentions of probably cavitation in the pipes at the suction end resulting from the pressure there falling below atmospheric pressure. The calculation as to increased cost of pumping was based upon a plan of the supposed line, showing bends which admittedly would cause friction, and Kutter's formula was used in calculating the amount of such friction. Assuming the formula to be correct, the calculation was not questioned, but the contest turned upon the necessity of bends in the pipe line and the correctness of the formula. As to the first point, it was, I think, proved that by tunnelling in

places some of the acuter bends could be avoided, but such an expedient would necessarily increase the cost of construction. As to the proper formula, Mr. Dixon admits (16755) "The question of loss of head through curvature is in a very uncertain state. Different formulæ give different results", and there was in evidence a conflict of highly technical evidence, based upon differing opinions of engineering authorities. The points raised are not, I think, necessary for decision, because in the present case it must be assumed that the dam as designed would always be full, or within a very few feet of its crest, even if 5,000,000 gallons per diem were taken out, and as there would be water pressure of 42·8 lbs. in the suction pipe, the friction resulting from curvature becomes negligible. In the pipe line at the Murrumbidgee tunnel there are now four right-angle bends, and these are not alleged to be detrimental. Therefore I do not in the comparison of cost allow any part of the capitalized sum of £2,460 to debit of the contour pipe line. The comparison therefore is, taking the cost of the work done, and Mr. Hill's estimates of work not done: Tunnel line for one pipe £17,815; for two pipes £19,206; contour line for one pipe, £9,480; two pipes, £17,960; a difference for one pipe of £8,335, and for two pipes, £1,246 in favour of the contour line. If I am right in assuming that the tunnel could have been used as an aqueduct from the first, the result would be to make a difference in favour of the tunnel line in the figures stated of £1,391 for one pipe, and £2,782 for two pipes. The summary of the whole matter is that for a population of fewer than 12,500 persons the contour pipe line would be the cheaper; for a city exceeding that population, the tunnel line would be preferable, the incidental advantages more than off-setting the excess of cost if any. On the whole I do not think that the extra cost of the tunnel was justified, but in justice to the officers it must be remembered that five years ago it was anticipated that population at the Federal Capital would increase much more rapidly than is now deemed probable.

5. The charge of wasteful expenditure with regard to the tunnel for the pipe line under the Murrumbidgee seems to me to be completely established. The cost of this work was £6,061 plus £250 to £450 required for its completion and more than £5,400 of that expenditure would have been avoided by the simple expedient of carrying the pipe line along the left bank of the Murrumbidgee to the bridge of steel girders on concrete piers that has been built there, carrying it along the up-stream side of the bridge, thereby strengthening that structure, and then bringing it along the right hand bank of the Murrumbidgee about 150 yards to the pump-house. What possible reason there was for constructing the river tunnel I am quite unable to see. The river just at this place is shallow, and there is no reason why the pipe line should not have been taken straight across the river in a concrete bedding, if for any reason none was suggested in evidence it was inadvisable to take the pipe along the bridge. That alternative certainly would have been cheaper and better than the expedient that has been adopted. Evidence was given to show that in some instances in Australia, pipes had been carried under a river or swamp in a tunnel; but it is evident that, although this may sometimes be done, it is an expedient that would only be resorted to if no other way of carrying the line were possible. A further objection to the tunnel under the river is that silt would rest in the pipe, and there would be no possible way of clearing it out, as the water could not be discharged into the tunnel. To meet this objection it was urged that no sludge could be deposited in the pipe because the flow of water two and two-fifths feet per second—would be sufficient to carry away pebbles and even pieces of stone, but even if that is so in the ordinary cases of flow, there may be, and would be, times when the water being still, the sediment would settle. Also it was said that the pipe and tunnel could be cleared by releasing its contents of water and then pumping it out of the tunnel. This does not seem a convenient or effective expedient, and I think that the objection as to possible silting up of the pipe is one that has considerable force; but it is of minor importance contrasted with the main objection to the work. This is not, I think, a case where engineers might be expected to have differing opinions as to the proper method of carrying the pipe across the river. The expedient of crossing the river by tunnel is one so exceptional and undesirable if it can be avoided, that it is upon the engineers here to show that no other means of carrying the pipe was possible. They have wholly failed in this, and have not shown any reason for spending £6,061 upon a work that should have been better done for £500.

6. As to the reservoir at Red Hill, Mr. Hill in his evidence (26248) describes this as a "stand-by." Mr. Starr condemns it as unnecessary (5896), Mr. Oliver supports that opinion (36828). I think they are right. The idea of having a reservoir at that

site was first recommended by a Water Supply Commission, whose members visited Canberra in 1910 in order to formulate a scheme for the City, and this recommendation was adopted by Colonel Owen. The reservoir cost £13,828, and in the documents it is usually described as a "service reservoir." It was not in fact intended for that purpose: Colonel Owen (25661) says that it was always intended that the take-off should be from the pipe at the foot of Red Hill. It has a capacity of 3,000,000 gallons and was intended only as a means of temporary supply in case of any stoppage on the pipe line from the Cotter Dam to the point where the service mains were intended to connect near the foot of Red Hill. The works were designed for a supply of 1,286,000 gallons per day, so that assuming any stoppages in the supply from Stromlo, there would be less than three days' supply available from Red Hill. The reservoir at Stromlo cost £11,877, and was of similar capacity. In the event of any stoppage between the Cotter River and Stromlo, this latter supply would have been available to consumers, so that the Red Hill reservoir could only be of any effective service in case of a break between Stromlo and the City mains: and it is difficult to conceive of any substantial damage that could occur along that line, the pipe traversing lands where no extensive break that would take more than 24 hours to repair might be expected, or that could occur, except upon the rarest occasions. At the least, the Red Hill reservoir would appear to be an excessive precaution against an event very unlikely to occur. If it had not been constructed the cost of a considerable length of pipe line could also have been saved, and it may, I think, fairly be assumed that the reservoir is responsible for about £16,000 of expenditure. Incidentally it may be mentioned also that £13,800 seems an excessive amount to pay for this work, as this represents more than £4,500 per million gallons a figure that is out of all proportion to the ordinary cost of such work. This cost is in part accounted for by the fact that the area of the reservoir has been obtained entirely by excavation, and that the material excavated was solid rock throughout, and the work has also to bear the cost of the aerial rope-way. Whether another site where the excavation would have been in more tractable material was available, or whether the reservoir could have been more cheaply constructed if part of the capacity had been obtained by elevated concrete walls, there is no evidence to enable me to determine.

7. The charge that those responsible for the present scheme of water supply have made excessive provision for storage has in my opinion, been fully proved. The capacity of the pumping plant is 1,286,000 gallons in the 24 hours, intended to provide for a population of 21,433, on a consumption of 60 gallons per head per day. The capacity of the dam if finished as intended would be 1,400,000,000 gallons, in round figures, three years supply. During the time that records of the flow of the Cotter River have been kept, the minimum flow for any one day was 1,334,000 gallons: but in the month in which this occurred the average per day was 1,896,000 gallons. The supply from the Cotter would, Mr. De Burgh states, (B.206) "be more than sufficient for Sydney or Melbourne." It is quite true that the data as to rainfall on the watershed, and as to the Cotter River flow are even now insufficient for accurate estimate, and were still less reliable at the time that this dam was designed, and the designers must be credited with an intention to secure the City against water famine as far as this could possibly be done, and also to provide for the growth of its population. Even assuming that the dam was intended to provide for an ultimate supply of 20,000,000 gallons per day, that is for a city of 200,000 people, and a consumption of 100 gallons per head per day, this would still give 70 days' supply. As I stated in Part 3 of this Report, paragraph 37, the intention to store such an enormous body of water was no part of the original design, but resulted from the discovery when the work was well on towards completion, that by adding 10 feet at a cost of £3,000, 560,000,000 gallons would be added to the capacity of the dam. The original intention was that 856,000,000 gallons should be provided for, and even this compared with the capacity of the pumps and mains must, I think, be regarded as altogether excessive. The Honorable W. H. Kelly had intended that in lieu of a dam 90 feet high as designed, the dam should only be carried up to 40 feet, and new plans to provide for this were accordingly drawn, but for some reason the original design was afterwards restored. One justification for incurring the cost of this enormous storage is strongly urged by Mr. H. A. Dixon (Assistant Engineer, mechanical, in the Home Affairs Department), on the ground that it is necessary that there should always be a positive pressure greater than the atmospheric on the suction side of the pump, and that this would be provided if the dam were carried to the full height, which is 1,657 feet above sea-level. His calculation is that this positive pressure would reduce the cost of pumping

by £440 per year, but capitalized by 5 per cent., this would only amount to £8,800, a sum that represents a mere fraction of the cost of the extra height of the dam. In justification of Mr. Dixon's calculation it must of course be considered that a dam conserving 1,400,000,000 gallons might be reasonably expected to be always full; whereas a dam conserving say 50,000,000 gallons might—I doubt if it would—be liable to fall at times below the crest. I cannot think that this matter of maintaining positive pressure at the suction inlet was an element of consideration at the time of the original design, or that a city of 200,000 people requiring to be supplied with water was then in contemplation. I think rather that the one object was to afford a supply of water that would never fail, and in doing this the designers have provided for an unjustifiable amount of storage. It is true that Mr. Oliver in his evidence admits that the rainfall records of the last three years have compelled engineers to reduce their estimates of rainfall and run-off by as much as one-third, but even allowing for this reduction the excess is still unreasonable. Nor can the officers responsible justify their action under these reduced estimates for the dam was designed before this newer knowledge of probable supply was available.

OTHER CHARGES OF FAULTY DESIGN AND CONSTRUCTION.

8. Numerous objections to other matters of design and construction of works in connexion with the water supply were raised by one or other of the engineers called by Mr. Webster. Mr. Starr (5776l) said that from his observation of the dam, he came to the conclusion that "as regards its strength it is a little bit weak in the outer toe"; (5772), "in working it out by moments it showed a slight weakness at the outer toe"; but later, (5774) he admits that it "was not dangerous, and the weakness he mentioned was a thing that he would not take notice of even if he had the designing of it himself." Later (7083) he states that "the dam is perfectly safe, but if there is a weakness it is at the toe." This charge therefore collapsed. Then it was asserted in evidence that there had been extravagance in constructing the dam inasmuch as its thickness throughout, and especially at the outer toe, was excessive. Certain theories based upon engineering constructions were advanced in support of this charge, but I find that it also fails.

9. Another objection with which it is unnecessary to deal at length was that raised by Mr. Starr as to the need of a by-wash to the dam so that surplus water could be led away by a side channel, and not allowed to flow over the notch at the top of the dam as at present. The objection to the flow of water through the notch was stated to be that the water at great velocity striking the concrete near the foot of the dam would in time cause some injury to the structure. The design of the dam was stated to be faulty inasmuch as no steps had been provided to break the force of the water flowing down from the notch, and that no water cushion had been provided. It was admitted that a water cushion would obviate any possible detriment or danger, and it was proved that upon the original plan for this dam a water cushion had been provided for by an intended low-level dam below the main dam, making a pool 15 feet in depth. Therefore this objection was fully answered. Mr. Starr's by-wash was estimated by him to cost £1,000. The dam to provide a water cushion could be erected for less than £500, and on the score of cost alone the latter expedient is to be greatly preferred to Mr. Starr's alternative. Seeing the quality of the rock at each end of the dam and its grade, I am inclined to believe that the cost of Mr. Starr's by-wash would be at least three times, if not five times, as much as his estimate of £1,000. Mr. Connell (18054) thinks it would probably cost £7,000.

10. Another objection to the work taken at a very late stage of the inquiry was that there would be water hammer in the pipe in the pump-house, and in the rising main, and that this would imperil the pipes and pump. I cannot see in the evidence any scientific basis for this suggested danger, nor do I find any cause of apprehension as to the sufficiency of the pipes or valves. Another charge of a character conflicting with that just mentioned, was that there had been extravagance in the work, inasmuch as the pipes at the pump-house end of the rising main were of excessive thickness, and therefore of excessive cost. Mr. Stair "would not be surprised if one-third of the cost of rising mains could have been saved" by putting in lighter pipes, but admitted (5868–77) that this was "only a guess." This latter charge in my opinion, also fails.

11. A charge of excessive cost was also preferred in respect of the Stromlo and Red Hill reservoirs. These are each divided into three compartments by two equidistant concrete walls, and it was contended that one wall making two compartments would have been enough; that the walls were unnecessarily thick, especially at the base; and that the concrete lining of the sides of the reservoir was excessive in thickness. As to the question whether there should have been two compartments or three, I see no reason why two should not have sufficed, nor was any explanation offered in evidence as to the reason for providing three. Each compartment can only hold 1,000,000 gallons, and there seems no reason why two compartments each holding 1,500,000 gallons should not have served all necessary requirements. The work of scouring and cleaning the compartments could as easily be done with one partition in the reservoir as with two. With regard to the thickness of the walls, it does seem that the charge of excess has been established. Of course, the walls had to be built sufficiently strong to resist pressure on either side, because the only test of strength would come when one compartment was empty, and the other full; but on the weight of evidence, I am of opinion that 6 feet of solid concrete were not required at the base, and that there is unnecessary thickness in the wall throughout. In support of the charge of excessive thickness in the lining, it was stated that concrete where it is upon rock, is not required for strength nor to prevent the percolation and escape of water. Concrete is not water-proof, and its purpose where it is upon solid rock, is merely to provide an even surface upon which the rendering, which is waterproof, may be put. As to the lining, it was assumed by the witnesses called to support this charge of excess, that it was 18 inches throughout in the case of each reservoir. Upon Mr. Connell's evidence this is not so: the thickness in Stromlo being 18 inches, but at Red Hill only 9 inches. Mr. Starr estimates the excess expenditure from excess of concrete for walls and lining for these two reservoirs at £6,258. This is based on the assumption that there is 18 inches of concrete lining in each reservoir, and in his report on the matter (5878) he stated, "If the excavation is made with reasonable care a bed of concrete of an average thickness of 6 inches is ample to receive the rendering." Further on in the same report he states that in constructing such a work "all the inequalities in the rock should be brought to a straight even face and battered with concrete to receive the rendering. A foot thick of concrete is generally allowed for that." Upon these inconsistent statements as to the concrete necessary for lining I cannot find that 9 inches was excessive. Even discarding the second statement by Mr. Starr as to a foot being necessary, the question whether 6 inches or 9 inches should be allowed is one on which there might be a reasonable difference of opinion between equally eminent engineers. So in the Red Hill reservoir, except as to the unnecessary wall, I do not find any excess in the work. As to Stromlo reservoir, Mr. Connell, who designed this work and supervised its construction, states that the necessity for 18 inches of concrete in that case was that the floor to a great extent consisted of rotten granite, so that the concrete was not merely required to make an even surface for the rendering, but was necessary for strength. The nature of the rock at Stromlo, is the justification for the extra depth of concrete, and this extra concrete was I think a reasonable precaution taken to avoid a very probable danger. Except as to this reservoir being in three compartments instead of two, I cannot see any evidence of want of skill in design or construction. The cost of the second wall in each case was not given in evidence; Mr. Starr's estimate of £6,258 was based solely on excess excavation and lining, and as to these items I find that there is no excess.

12. One matter that was very strongly pressed by Mr. Webster as showing a want of foresight in the construction of the tunnel, was that when the time arrived when it should be necessary to put in three more 18-in. pipes, it would be impossible by reason of the dimensions of the tunnel to carry out this work. He succeeded in showing that the space was insufficient to enable the extra pipes to be placed in position or to be repaired after they had been so placed, but the difficulty is wholly artificial. If it should become necessary to increase the water-carrying capacity of pipes in the tunnel this could be done, not by putting in more 18-in. pipes, but by putting in a 27 or 36 in. pipe. This expedient did not in evidence occur to Mr. Hill, and the matter as between him and Mr. Webster was contested on the point whether the tunnel could carry four 18-in. pipes. The difficulty raised by Mr. Webster can be still more easily met. The tunnel is lined with concrete from end to end, and it was intended that ultimately the tunnel should itself be an aqueduct, and the pipes be dispensed with. This of itself is a sufficient answer to Mr. Webster's charge of negligence in failing to provide room for four sets of pipes. The point was not raised during the inquiry, but upon later consideration, I cannot see why the tunnel should not now be used as an aqueduct,- of course closed so as to maintain pressure. There may be a sufficient answer upon some engineering grounds to this suggestion, but for all that I can see at present, the tunnel ought to have been made an aqueduct from the first, and the expense of laying even one pipe should have been avoided. But as I have not had an opportunity of having this matter considered by an expert, I am unable to put forward my own view except as a suggestion.

13. Criticism was directed against the designers of the Cotter Dam, based upon the contention that the dam as built involves an unnecessary expenditure of fully one-third of the total cost. The present dam is a gravity dam built straight across the river, and it is contended that a curved dam, by reason of its greater strength, would have required only two-thirds of the quantity of concrete that has been used. Mr. Starr asserted that there would have been this saving, and that the dam should have been constructed in that form. He also stated that the site was admirably adapted for a curved dam, and that he would have built it in this shape. Assuming that a curved dam has the advantages stated, it is still clear from the evidence that two things are absolutely necessary to such a structure; it must have good abutments, and there must be rock or other solid foundation for the concrete to rest upon. Mr. Starr admits (5793) that he did not examine the bottom to see whether it was suitable for a curved dam, and Mr. Connell states (16970) the reasons why the gravity dam was found necessary. He shows upon the basis of calculations made by him that a curve of about 230 feet radius would be here required, and that the cost of driving into the rock at each side of the river in transverse section would be very much greater than going in on cross section as for a gravity dam, and that this difference would represent a very considerable sum. Further, from his evidence it appears that there is a good rock foundation for the gravity dam, but that on the up-stream side, and on the line where the curve would be, the rock falls away to deeper water, and so in order to get a foundation for a curved dam, 5 feet or more of concrete would have been required before the work would reach the level of the base of the gravity dam. Every phase of the matter seems to have been fully considered by Mr. Connell, and his evidence and my view of the site, satisfy me that the proper decision was arrived at. The cost of securing the abutments of a curved dam was really much greater than had been estimated by Mr. Connell in his calculations, for by reason of faulting in the rock at the right-hand side of the river, it was necessary to cut into the bank 30 feet before solid rock was reached. Obviously the increase of cost in making a transverse section for the curved dam would have been very much greater than was assumed. Mr. Connell, in respect of this dam, appears to me to have done his work carefully and well. Much evidence was given as to other curved dams, but their superiority over gravity dams must still be taken to be doubtful. One of the standard books, *Wegman*, cited 7014, states that

> "The best way is to design a dam that will resist the water pressure by its weight, and to curve the wall as an additional safeguard. If a curve is erected, the material must crush before it can collapse."

This quotation does not support the proposition that a curved dam requires only two-thirds of the material of a gravity dam, although there are other authorities in support of that proposition.

14. Another objection raised to a part of the present scheme was that the reservoirs on Stromlo and Red Hill are at an excessive altitude, involving needless cost for pumping. The water is pumped from the pump-house at Murrumbidgee 820 feet to the reservoir at Stromlo, and there is then a fall of 20 feet to the Red Hill reservoir. Stromlo reservoir is 2,370 feet above sea-level and 530 feet above the lower part of the City area, this head giving a pressure of 227 lbs. at such levels. Colonel Owen called evidence to prove the desirability of having this pressure for the purpose of assisting the work of the fire brigades, and upon this evidence it was strongly contended that such a pressure was necessary in the interests of public safety. Mr. Webster's contention was that the pressure was altogether excessive, even for the purpose of fire-fighting, and that detriment to the water service would ensue by reason of excessive pressure upon the taps. I do not think that there is much force in the last objection, but the attack based upon extra cost has weight. Taking the cost of power at 1·3d. per kilowatt, Mr. Starr showed (5967) a saving of £3,200 per year for a lift of 550 as compared with 820 feet. This would not be the whole of the saving, because there would have been considerable saving in the

length of the pipe line if the water had not been taken to the tops of these two hills. It is not shown that these reservoir sites were the only ones possible, and that therefore there was necessity for carrying the water to the present height, and so the question is whether a right judgment was exercised in providing the present pressure. I am not able to say that there was error in taking the supply to the height stated. A lower pressure would have involved further pumping as the City grew, and its more elevated suburbs were built upon, and so the increase in future expense might well outweigh the present saving. This point must be again referred to in dealing with Mr. Oliver's gravitation scheme.

ALTERNATIVE SCHEMES OF WATER SUPPLY.

15. When Colonel Owen was employed in designing a system of water supply, he had available the reports of Mr. E. M. De Burgh, M.I.C.E., Chief Engineer for Rivers, Water Supply, and Drainage in the State of New South Wales, dated October 1908, dealing with the question of water supply for the Federal Capital, and for the production of hydro-electric power. He favoured a scheme of water supply from the Cotter River, and suggested three alternative systems. The first was a gravitation scheme, the plan being to impound 653,000,000 gallons at a point 11 miles on the air line above the junction of the Cotter and the Murrumbidgee; that is, about 10 miles in a direct line above the present dam, the distance between the two sites on the river line being about 15 miles. He estimated the daily average flow at the proposed site at 59,000,000 gallons, and the water-shed area at 110 square miles, and proposed to convey the water from this storage reservoir in a 27-in. pipe, approximately 45 miles in length to a service reservoir at Canberra. The cost of this gravitation scheme he estimated at £706,000 for the pipe line, £14,000 for a concrete dam, £14,000 for a service reservoir, and interest during one year of construction, £32,000: a total roughly of £850,000. The distance of 45 miles is apparently about 15 miles in excess of the real distance. He himself did not favour this scheme, because of the cost of the pipe line which he regarded as prohibitive. He suggested a second scheme of water supply by pumping: the dam in that case to be situate at the present site, and to be about 130 feet high, and to impound 2,688,000,000 gallons. He proposed to erect at that dam pumps capable of lifting 5,830,000 gallons per day, six days a week, through a rising main to an auxiliary service reservoir situate at a level of 2,100 feet, whence the water would gravitate to a service reservoir adjacent to the Capital at a level of 2,050 feet. The estimated cost of this scheme was £339,000 of which sum £94,000 was for a concrete dam, and £158,000 for a steel pipe 11 miles in length and 27 inches in diameter. Another alternative pumping scheme was intended to provide 1,000,000 gallons per day at a total capital cost of £185,000; the dam to be of the same height, cost and storage as in the preceding scheme, but the pipe to be 14 inches in diameter, and to cost £37,400 for its 11 miles of length. The pumps used under the second and third schemes were to be duplicate, one being worked by surplus water from the dam, and the other to be worked by steam when surplus water was not available. Colonel Owen also had access to a report by Mr. Corin regarding the Cotter supply of water and power, his suggestion being that there should be a dam in the Upper Cotter with "considerable storage." This scheme provided for a city of 50,000 inhabitants and was intended to supply 5,000 horse-power for electric lighting and power, and 2,000 horse-power for 30 miles of tramway route in the Federal city and suburbs. The route of the intended pipe line had been surveyed and marked. Colonel Owen seems to have come to the conclusion that the gravitation schemes were impossible. The scheme he adopted is the third alternative scheme of Mr. De Burgh with some variations. The pumps under the present system are worked not by surplus water, but by electric power, and the pipe is 18 inches instead of 14 inches. Another important variation is that Mr. De Burgh's proposed service reservoir was to be 2,050 feet, 300 fee lower than the reservoir that has been constructed at Red Hill. Mr. De Burgh's gravitation scheme provided for only one service reservoir, but his second and third alternatives provided for two at a cost of £29,000.

16. It is now contended that a pumping scheme should not have been adopted, as a supply by gravitation could have been obtained at less cost and in such quantity that a large proportion not needed for use in the city could have been applied to the production of electric power. The first of these schemes now propounded, is that set out by Mr Starr in Exhibit B.110, and explained in his evidence (6895–6933, 7120–7131) Briefly, his scheme is to have a storage dam at the upper site indicated

by Mr. De Burgh, to cost £120,000 and to impound 2,000,000,000 gallons. Instead of bringing the water down by a 27-in. pipe as proposed by Mr. De Burgh, his scheme is to bring it from the dam to a site on Black Hill, 13 miles away, and near the junction of the Cotter and Murrumbidgee, in open channel. He suggests a fall of 4 feet to the mile, and a width of 5 feet 6 inches, and a depth of 2 feet 9 inches for the channel, and estimates the cost of the channel at £6,000 per mile. His scheme provides for a reservoir at Black Hill, and a power-house situate there with Pelton wheels for the generation of hydro-electric power, 15,000,000 gallons of the proposed supply of 18,000,000 gallons being devoted to this purpose, the remaining 3,000,000 gallons being carried from Black Hill to a service reservoir in the city, costing £12,000. The whole cost of his scheme calculated to supply 18,000,000 gallons a day, is estimated at £294,144, and the power to be produced would be equal to 1,334 kilowatts delivered in the city, 2,000 kilowatts being generated at Black Hill at a cost of one-fifth of a penny per unit. Mr. Starr had not an opportunity of developing his scheme, and had made no survey of the route. His first item, the dam on the Cotter, to cost £120,000 is not approved by Mr. Oliver, who estimates the cost of a dam to provide storage for a daily supply of 20,000,000 gallons at £500,000. Mr. Oliver has had the advantage of careful survey of the whole locality and of estimates of cost made by Mr. Percival, surveyor, an officer of considerable experience in such work, and I accept his estimate as being a more accurate approximation than that of Mr. Starr of the cost of the dam. If Mr. Oliver's calculation of cost of the dam is correct, £380,000 for this item alone must be added to Mr. Starr's total of £294,000. Mr. Starr's proposition is not closely calculated, and is subject to very material revision in respect of items besides the one already mentioned. Mr. Oliver having had greater opportunities for consideration of the matter, has been able to put before the Commission a more closely calculated and definite scheme. His proposal is to have a storage dam at Mr. De Burgh's gravitation site, 200 feet high built of concrete, and a channel down the left bank of the Cotter; Mr. Starr's proposal was for a channel on the right bank, Mr. Oliver's preference for the left bank being that he "would thereby get 830 feet head as against 600 feet on the left-hand bank." If he is right in this, Mr. Starr's scheme is impracticable for Mr. Oliver's service reservoir is only 50 feet higher than Capitol Hill. The estimated cost of this channel to carry 20,000,000 gallons is £6,000 a mile, and in its course it would take up the waters of the Lee and Condor Creeks, tributaries of the Cotter, and would lead to a reservoir at Mt. McDonald, thence by a pipe-line across the Murrumbidgee the water would be carried to the present pump-house, and through the pipes of the present system for some distance towards the reservoirs which Mr. Oliver proposes, one at Black Mountain, and one at Mt. Russell, of 3,000,000 gallons each. The service reservoir would be on Southland Crescent, also to contain 3,000,000 gallons. The total cost of this scheme is stated at £694,000. In this total no allowance is made for the cost of that part of the present pipe-line that would be used, and I find no item to include the cost of the reservoirs at Mt. McDonald, at Black Mountain, at Southland, or at Mt. Russell. Mr. Hill estimated the cost of Mt. McDonald reservoir at £86,000, but Mr. Oliver while asserting this total to be wholly erroneous, does not himself supply an estimate of its cost. His figures must, I think, be amended by addition of the cost of each of the reservoirs indicated. Upon evidence before the inquiry, £2,000 for each 1,000,000 gallons of contents would be an average cost. Assuming that Mt. McDonald is to be of 30,000,000 gallons contents and the others to be of 3,000,000 gallons each, the cost would be about £60,000 for Mt. McDonald and £18,000 for the three others; £78,000 in all. Mr. Oliver's figures of cost are worked out on a basis of supply of 1,250,000 to 20,000,000 gallons of water per day, the latter quantity being sufficient for a population of 200,000 persons, and he neither takes credit for the value of the power that could be produced, at Mt. McDonald, nor debits the scheme with the cost of plant necessary for its production. Upon his figures (B.114) for a daily supply of 1,500,000 gallons the expenditure would be £107,000 beyond the £262,000 already expended on the pumping scheme. He debits the whole of this latter expenditure to his scheme, although he would use the work only so far as it represents £111,000 of the total, and so charges his scheme with the £151,000 worth of works not used, and brings out the cost of the water so supplied at 12·6d. per thousand gallons. If he had debited his scheme only with the £111,000 of work used and £107,000 of new work, upon this total of £218,000, the cost per thousand gallons would be reduced from 12·6d. to 7·4d. Supplying 2,500,000 gallons the total cost of the new works required for that supply being increased from £107,000 to £256,000, and adding the whole sum of £262,000 already expended, the water would cost 7·8d. per thousand gallons, and this cost upon provision for 5,000,000 gallons would be reduced to 4·9d., and for 20,000,000 gallons would stand at 2·01d. The scheme is progressive to provide ultimately for 200,000 persons and like other gravitation schemes (the capital cost of these being usually high as compared with pumping schemes, and the annual cost being low)—the reduction of the cost of water when the scheme is used to its full capacity, is constant and considerable. In considering these figures, however, it must be remembered that the cost of service reservoirs has not been allowed for, and that no charge is made for maintenance. Mr. Starr's estimate of £1,500 per year may probably be taken as sufficient for the latter item.

17. Mr. Oliver (Exhibit B.114) contrasts this cost with the cost of pumping 820 feet under the present system, and upon his figures, for a supply of 1,250,000 gallons, debiting power at 2d. per unit, the cost for that item is 8d. per thousand, and for interest and sinking fund at 6½ per cent. on capital expended, is 8·9d., making 16·9d. per thousand gallons. For 5,000,000 gallons the cost per thousand gallons for interest and sinking fund would decrease to 4·7d. and the cost of the water would be similarly reduced to 12·7d. He also considers the alternative scheme of pumping to 520 feet. Here a further addition would have to be made to the £262,000, the cost of the present work, for two new reservoirs at 300 feet lower level must be provided, and these with incidental expenditure, would cost about £22,000. The cost of pumping for 1,250,000 gallons would then be reduced from 8d. to 5d., and the total cost to 15·4d., while for 5,000,000 gallons the cost per thousand for pumping would increase to 7d., and the cost for interest and sinking fund diminish to 2·2d., making the total cost of 9·2d., but in these figures Mr. Oliver omits to add increased cost of work for the greater supply. Colonel Owen puts the cost of pumping at a very much lower figure, for in his estimate prepared on 17th June 1914, the scheme being then based upon a dam on the Cotter 40 feet high, and costing £50,000, the estimate, "exclusive of interest on capital," was for 750,000 gallons per day, 4·4d. per thousand gallons, and for 1,500,000 gallons 3·1d. per thousand gallons. The difference between Colonel Owen's pumping costs and the costs stated by Mr. Oliver is to be accounted for by the differing estimates of cost of power, Mr. Oliver assuming a cost of 2d. per unit and Colonel Owen calculating upon a basis of ·75d. or ·85d. Colonel Owen produced in evidence (C.82) figures stating the relative cost of the construction of works for a pumping scheme, £274,196; and of a gravitation scheme, £485,000, the latter total including only £95,000 for a storage dam at the Cotter. Upon these figures and in the case of pumping, allowing for power at the rate of ·75d., and interest and sinking fund at 6½ per cent., wages and maintenance, he shows an annual cost, on the basis of 1,060,000 gallons, of £24,329 for the power scheme and £32,569 for the gravitation scheme. Through all the 25 years of his comparison this cost of the gravitation scheme is invariable, the pumping scheme varying merely by the additional power required for the increasing quantity of water to be raised. According to his comparison during the 25th year, for an assumed population of 18,000, the annual cost of pumping would be £28,164, and the gravitation cost £32,569. Putting it on the basis of cost per thousand gallons, his estimate is that for 1,060,000 gallons daily, pumping would show a total cost of 1s. 3d., gravitation 1s. 9d., and in the 25th year that the cost of water pumped would be 10·3d., and of water brought by gravitation 11·9d. Summing up the matter in a separate return, his contention is that the saving in cost by pumping as compared with gravitation would in 25 years amount, with 3½ per cent. interest to £254,000. Two points, however, must be noticed in his calculations. One is that the whole cost of the completed gravitation scheme is debited at the outset, whereas Mr. Oliver proposes that the work should be progressive; the other point is that Colonel Owen's comparison only extends to a supply of 1,800,000 gallons per day. Even on his own figures if he had worked out the comparison on a basis of 26,800 population, the cost of water by gravitation and by pumping would be equal, and after that the gravitation cost would be less than the cost of pumping. Mr. Starr's estimate of cost is for pumping 1,250,000 gallons per day, £28,000 per year, and this rate is not much above Colonel Owen's estimate of the total cost of pumping 1,060,000 gallons. One difficulty arising on consideration of these figures is that no two of the calculators have adopted a common basis. For instance, Mr. Oliver's estimate of cost of power is 2d. per unit; Colonel Owen's is ·75d., and they also differ as to the storage to be provided, and on other equally essential points.

18. Before entering upon a close comparison of cost, some items in the calculations have to be considered, and the first is the proper sum for power to be charged against pumping. The cost of producing power at Canberra up to the present, is stated at

2d. per unit rising sometimes to 2·27d., and therefore Mr. Oliver was justified in using the lower of these costs for his present calculation; but with the very small requirement for power at the present time, it is obvious that this charge will be much reduced when the plant is used to an extent more nearly approaching its capacity. Colonel Owen's estimate (7466) is that the cost of power will be reduced to ·6d. per unit, and Mr. Oliver concedes that the reduction may be to ·8d. per unit, but does not think that it can be brought below that figure. Mr. Smith, electrical engineer, (16619), is confident that ·75d. will be reached, and he presses the contention that power used for pumping should not be charged at anything like the rate that is paid or estimated in respect of other services. This view seems to be very commonly adopted by companies producing and supplying power, and it rests upon a business basis. The plant must be equal to the peak load and this occurs usually between 5 and 10 p.m., when there is the greatest requirement for lighting and traction power. At other times in the 24 hours the load falls off very considerably, and the want of demand in the slack periods of the 24 hours reduces the load factor and makes for higher cost of producing power. When the load diminishes, the power not then required can be used for pumping, an operation that can be carried on during any part of the 24 hours. The advantage to plant in having such a demand at a time when there is no other use for the power, is shown by the facts in evidence that it is a common thing for a power company to charge 3d. or 4d. per unit for lighting and as little as ·6d. for power produced at times of lightest load. Mr. Smith therefore contends that if power can be produced at ·75d. the power applied to pumping should not be charged at more than ·5d. the cost of coal and wear and tear. I think that it would be a fair thing for the purpose of Mr. Oliver's comparison to accept the figure of ·75d., and then the cost for pumping is reduced from 8d. to 3d. per thousand gallons, and the total cost from 16·9d. to 11·9d., but on the other hand, to get at a fair comparison of what would have been the cost of water if Mr. Oliver's scheme had been carried out instead of that of Colonel Owen, one must deduct from the £369,000 the cost of the first stage of his scheme, the £151,000 of expenditure incurred upon the pumping scheme and not used in connexion with gravitation. Making that deduction the cost of water by gravitation per thousand gallons is reduced from 12·6d. to 7·44d. Making similar adjustments in respect of the larger quantities, 5,000,000 gallons pumped is reduced from 12·7d. to 7·7d., and by gravitation from 4·9d. to 3·78d. Making similar adjustments in respect of water pumped from the reservoirs 300 feet lower than those used under the present scheme, reduces the cost of pumping 1,250,000 gallons to 1·87d., and the total cost per thousand gallons to 12·27d.; the cost of pumping 5,000,000 gallons would also be reduced from 7d. to 2·6d. per thousand. Upon these figures allowing Colonel Owen's scheme the full benefit of the lower estimate of the cost of power, it would appear that the gravitation scheme, whatever the quantity supplied would produce water more cheaply than could be done by pumping: but there are two other matters affecting the comparison. The one item of estimated cost of Mr. Oliver's scheme that has been strongly contested is in respect of the race from the storage dam to Mt. McDonald. Mr. Oliver's estimate for this is £90,000 being 15 miles at £6,000 per mile; Mr. Hill estimated the cost of this item at £166,843, £11,120 per mile; and Mr. Oliver in reply produced detailed figures of costs and quantities showing a total of £88,267. This raised a very important question for decision, and at the desire of both parties I have visited, not only the Cotter River, following as nearly as possible the course of this channel, but also for the purpose of comparison, the greater part of the Maroondah line and the O'Shannassy, the cost of these completed works being used by Mr. Oliver to support his estimate for the Cotter line. As it is three years since the O'Shannassy line was constructed, and wages in the meantime have advanced, full weight must be given to this increment of cost, and Mr. Oliver asserts that he has allowed for it in his estimate. Mr. Hill has also taken into consideration the rate of wages now ruling and part of the excess of his figures over those of Mr. Oliver is accounted for by the fact that he has made more liberal allowance on this score than Mr. Oliver. Both in support of, and against Mr. Hill's estimates there must be considered the fact that Mr. Hill had in mind the cost—perhaps excessive cost—of other works carried out at Canberra, and allowed for this work on the same basis. In support of his estimates the distance of the route from the railway and the difficulty of obtaining the necessary supply of efficient labour must be allowed for. But the main question raised by the parties was whether the Cotter line is by reason of its ruggedness, quality of surface, and prevalence of rock and other difficulties impeding the construction of the line, a much more costly project than the Maroondah or O'Shannassy lines.

19. My clear determination upon view of the Cotter is that it is much more costly country for channel construction than either the O'Shannassy or the Maroondah. I do not overlook the Donna Buang Tunnel on the O'Shannassy lines, nor the tunnels on the Maroondah, nor the quality of rock that they pierce, but the most important factor of increased cost on the Cotter, are the greater proportionate length of solid rock at the surface, and the steeper average slope of the hills upon which the channel is to be cut. The proportion of ploughable land on the Cotter is far below that of either of the other lines, and in some places sheer rock faces occur, which will involve very heavy cost whatever engineering experiment—flume, syphon, or tunnel, is adopted. The steeper average slope is very important as involving more extensive excavation, and on the steepest grades the country is usually solid rock to within 2 or 3 inches of the surface. At the dam site the country rock is sandstone, presently changing to granite, with very steep slopes where traversed by the surveyed line. Quartzite, sedimentary, and some plutonic rocks occur lower down the line, and wherever rock is at the surface, it is usually solid; sometimes "floaters" occur, but not often. Another item of cost is in the necessity throughout a considerable part of the route for side drains and flumes to carry storm-water clear of the channel. There is very little scrub or other vegetation, and the run-off would be rapid and charged with *débris*. Another important item is the distance from the railway, the nearest station, Canberra, being about 27 miles from the place where the route crosses the Urriarra road. Taking all these things into consideration, and also the fact that 1s. a day extra pay for work at the lower Cotter, has been paid, and would certainly be demanded for work on the upper Cotter, I think Mr. Oliver's estimate of £90,000 is too low; in arriving at this figure he takes the average on the O'Shannassy and adds 25 per cent.: £72,000 plus £18,000. I think 50 per cent., £36,000, should be added, bringing the cost to £108,000. I do not overlook the fact that both Mr. Percival and Mr. Oliver had had much experience in similar work, and that Mr. Percival has taken out quantities for the work, but all their calculations are based on an assumed similarity of the country along the two routes. I was asked to look at the two routes to see that they were comparable. I find that there is no comparison, but only contrast, and so I come to the conclusion that I have stated.

20. Therefore I think that Mr. Oliver's statement of relative costs should be amended; (1) by reducing the cost for power charged against the pumping scheme from 2d. to ·75d.; (2) by adding £18,000 to the estimate of cost of channel for the gravitation scheme for supply exceeding 1,250,000 gallons; (3) by adding to the cost of that scheme £60,000 for a 30,000,000 reservoir on Mt. McDonald for 2,500,000 gallons or more, as well as £6,000 for another 3,000,000 gallon service reservoir, and by deducting in each case £151,000 for cost of work not used; and (4) by adding to the gravitation scheme £1,500 per year for maintenance. If the latter item is excessive in case of the smaller supply, it is balanced by the omission of one of the reservoirs provided for in Mr. Oliver's scheme. The amended figures then compare as follows:—

PUMPING 820 FEET.

Million gallons per day	Cost of pumping at ·75d. per unit	Capital cost.	6¼ % Interest and Sinking Fund.	Cost per 1,000 gallons.	Total cost per 1,000 gallons.
	d.	£	£	d.	d.
1¼	3	262,000	17,030	8·9	11·9
2½	3	353,000	22,945	6	9
5	3	555,000	36,075	4·7	7·7

PUMPING 520 FEET.

Million gallons per day.	Cost of pumping.	Capital cost	6¼ % Interest and Sinking Fund.	Cost per 1,000 gallons.	Total cost per 1,000 gallons.
	d.	£	£	d.	d.
1¼	1·87	283,818	18,450	9·7	11·57
2½	2·25	374,018	24,310	6·39	8·61
5	2·6	576,848	37,495	4·9	7·5

GRAVITATION.

Million gallons per day.	Capital cost.	6¼ % Interest and Sinking Fund, and Maintenance, £1,500.	Cost per 1,000 gallons.
	£	£	d.
1¼	224,000	16,000	9·037
2½	395,000	27,175	7·15
5	595,000	40,175	5·28

21. From a comparison of these figures it is clear that if the gravitation scheme had been adopted, it would have been, even from the outset, cheaper than the pumping scheme. If it had been intended from the first to pump only 520 feet the cost might have been brought below the cost of gravitation, because the capital cost would then have been below the £262,000 that has been incurred, as a certain amount of pipe line up to and down from the higher altitude would have been saved. That comparison, however, is not now of importance. Colonel Owen must be judged by the pumping scheme that he has carried out, and not by the pumping scheme that he might have adopted, and the alternative of reducing the level by 300 feet, is not now of any value because it is clear that it would cost almost as much for the first 1,250,000 gallons to deliver water at 520 feet under an altered scheme as it now costs to deliver it from a point 300 feet higher. In justice to Mr. Oliver it was necessary in re-stating his figures for the purpose of making comparison between the cost of his scheme and that of Colonel Owen to deduct the sum of £151,000, which was no part of the necessary expenditure for gravitation, as the matter now stands the £151,000 having been expended and being a charge on water supply in the future, for the purpose of considering the present cost of carrying out a gravitation scheme, that amount must be taken into consideration. Adding 6¼ per cent. on £151,000 to the annual cost of supplying water under the gravitation scheme, 5·16d. must be added to the cost of £1,250,000 gallons, increasing this cost to 14·197d. per thousand gallons; 2.58d. must be added to 7·15d. making 9·73d.; and 1·29d. added to 5·28d. bringing that total to 6·57d. If I am right therefore, in my treatment of the figures, the cost of water supplied under the gravitation scheme would be greater than the pumping cost for any quantity under 5,000,000 gallons; above that quantity it would be less costly. Under all these circumstances it seems to me—(1) that a mistake was made in adopting a pumping scheme instead of gravitation; and (2) the money having been spent it will be less costly to supply the water by pumping than by gravitation; until the requirements of the Capital City exceed 5,000,000 gallons per day.

22. It is to be remembered with respect to Mr. Oliver's scheme that the delivery from the Southland reservoir would be at an altitude of 2,050 feet; this would be 50 feet above the surface of the Capitol Hill, and would (Exhibit B.114) "command 8,371 acres out of the 10,240 acres in the city block, or 82 per cent. of its area." The other 18 per cent. could not be reached from Southland, nor could some other very considerable areas of suburban land close to the city. The most desirable suburban lands are those on the slopes and ridges running down from Red Hill and the Mugga Mugga Mountain. These sites are perfectly sheltered from the west winds, and have a fine outlook over the Molonglo Valley, and although well within the reach of supply from Red Hill, could not be supplied from Southland. If the gravitation scheme were to be substituted for the pumping scheme, it would be necessary to provide an auxiliary pumping plant to supply these and other areas of similar altitude.

POWER-HOUSE AND PRODUCTION.

23. The power-house is stated to have cost for erection £39,596. As stated in Part 3 of this Report, it was valued by Mr. Hiscock at £20,125. In order to try and get some explanation of the contrast of these figures I have looked closely into the items of cost as supplied by Mr. Hill, compiled by Mr. Rolland (Exhibit C.36). The yearly totals of these are taken from the Authority book. In 1915–16 they do not agree with the figures stated in Exhibit B.60, as there is a sum of £49 in excess

in that total. Where that amount comes from I cannot find out. Taking the figures of the total of £39,547 as supplied by Mr. Hill there must first be deducted the cost of the dam across the Molonglo erected to supply water for the circulating pumps. This work cost for material, £799 12s., and for wages £227 9s. 11d., making a total of £1,007 1s. 11d., so that deducting this sum, the cost of the power-house stands at £38,540. It is stated on Exhibit C.21 that there are in the power-house 4,705 cubic yards of concrete. This concrete was 1 in 8, or 1 in 10—evidence did not serve to establish the exact proportions,—and it was also stated that the cost per yard of the concrete could not be given because it varied from time to time. Concrete at Canberra was a very cheap item; sand and gravel could always be obtained conveniently and at little cost for labour, and an exceedingly advantageous contract for the purchase of large quantities of cement at 14s. 9d. per cask to be delivered over an extended period had been made. Concrete at the Cotter River dam 16 miles away, the men there receiving an extra rate of 1s. per day, is said to have cost from 26s. to 27s. 6d. per cubic yard. It should have been very much cheaper at the power-house. The cost of cement as shown in the particulars furnished, totals £3,490. At 26s. per yard the concrete in the building would have cost £6,116 10s. 3,221 cubic yards of concrete were in the foundations, 1,484 cubic yards in the walls. The concrete above ground was not required for strength, but merely as a sheathing for the steel structure already erected. It had been intended to sheath this structure with expanded steel, then brick was intended, and concrete finally adopted, partly because it was said to be cheaper. The total cost of cement in the concrete represents 14s. 8d. per cubic yard, leaving 11·4d. a yard for gravel, sand and labour. Other items of cost of erection are steel, £6,635, besides some £150 spent upon steel bars; and it is claimed that the expenditure on this item was £3,000 less than if the work had been done by contract. Materials are stated to have cost £16,834, and the amount charged to freight was £3,958 5s. 1d. That sum did not include freight on the cement, that cost being included in the total of £3,490 (16859), nor freight on piles. In 1913–14 the value of goods other than cement and piles debited was £6,979, and the freight is stated at £3,559 more than 50 per cent. on cost. Wages are stated at £15,820, and it is hardly conceivable that this amount was spent in labour on the power-house. If it is assumed that the difference between the cost of cement, £3,490, and the value of concrete, £6,116, is all represented by labour, that accounts only for £2,626, leaving £13,194 as the the cost of labour expended on the excavation, steel frame work, tile roof, and interior work. The work of bringing in the boilers and putting them on their beds was all done by the contractor: the cost of fixing other machinery is debited to "power-house plant." Mr. Hiscock's estimate of £20,125 includes overhead charges, and is at the rate of 5d. per cube. It will be seen according to the officers' figures that the wages paid amounted to within a fraction of 4d. per cube; the other charges represented a cost of 5½d. per cubic foot. As I have already mentioned, Mr. Hiscock was fully qualified to estimate the value of this building because as a member of the Malvern and Prahran Tramways Trust, he had had to do with the erection of a power-house of similar material and dimensions, and he also had been cognisant of the cost of erection of tramway sheds near Melbourne involving similar work, and also had knowledge of the cost of erection of a power-house at Geelong. His evidence was attacked on the ground that the plan of the power-house that he had seen did not show the full amount of concrete that was in the foundations, but he had been apprised of this fact and of the amount of the difference before he made his valuation. The contrast in the estimate of value and statement of cost is incapable of any reconciliation upon the evidence; even deducting all freights from the book cost of the building it still would stand at £34,000: that is, 8½d. per cube foot, and this considering the low cost of the concrete is beyond explanation at least none was suggested in evidence. I have closely looked at the items in the Authority book, but can find no evidence of any item having been wrongly charged. I accept Mr. Hiscock's valuation of £20,125 as being the reasonable cost of this building at Canberra, and therefore have to come to the conclusion that £18,000 of Commonwealth money has been unnecessarily paid away. What the cost of this building was according to the Works Branch accounts is not given in evidence, and I did not realise before the inquiry closed the possible importance of these figures in affording a solution of the mystery. Mr. Connell in his evidence relied entirely on the figures of cost stated in C.21 and C.36 to show the error of Mr. Hiscock's estimate, but as the question before me was what the building should have cost, his evidence and the figures of expenditure did not go far in furtherance of their intended purpose.

24. The plant at the power-house is stated to have cost £38,250, and the mains £32,365, giving a total cost of £110,211, for the entire work. Power is now supplied for light and heat to Acton and Duntroon, and is also used for motors employed in the construction of some of the works. With the very light load that the plant is now under, its efficiency cannot well be judged. Up to the present the cost of generation and supply has been about 2d. per unit, increasing on occasions to 2·27d., but with a more economic load factor when a greater amount of power will be required at the Capital, it is estimated by Colonel Owen that the cost will be reduced to ·75d. per unit, while Mr. Oliver's estimate is ·8d. Under Mr. Starr's hydro-electric scheme providing for 18,000,000 gallons of water to be brought from the Cotter River, 15,000,000 gallons to be used for the production of power, he charges power production with fifteen-eighteenths of the total annual charges, including interest, maintenance, and management, and upon his calculation the cost of delivering 1,334 horse-power at the Capital City would be ·2d. per unit. Mr. Oliver (36117) states the cost of producing power under his scheme at ·84d., a fraction above his estimate of future cost of power at the power-house. I cannot, for reasons already stated, accept Mr. Starr's estimate of cost of hydro-electric power. To supply hydro-electric power under Mr. Oliver's scheme would require so large an expenditure as to be unavailable for consideration for very many years to come, and would not be advisable unless it could be produced more cheaply than he anticipates. For these reasons, therefore, I think that the power-house is the best and cheapest source of supply.

25. No criticism was offered as to the cost of the plant or as to its efficiency. At the time it was purchased it was of the best type obtainable. The rapid progress of science in the development of electric power has enabled the production of power by means of turbines so superior to the present machinery that it must be counted as out-of-date, but not to such an extent as to justify its removal and replacement by machinery of a newer type.

26. Just at the close of the Inquiry it was suggested that the power-house would have cost less if expanded steel had been used instead of concrete as sheathing for the steel; but calculations were not available to show what the cost of such covering would be. On the evidence I cannot come to any determination against the officer responsible in respect of this contention. It was also urged that by another method of arrangement it would have been possible to obtain sufficient accommodation for all the plant with a reduction of 14 feet in the height of the walls. The evidence is insufficient to show that the present design for power-house and plant indicates any negligence or want of skill on the part of the officers responsible.

MISCELLANEOUS.

27. There are now only six questions of those stated at the first sitting of the Commission that have not been specifically dealt with in this Report. One is: "Was the site chosen for the purpose of the Small Arms Factory suitable?" As to this, I think there is no contention now by any one that either the No. 1 site or the No. 2 site were at all appropriate to the purpose of the Factory. A mistake was made undoubtedly in each case in selecting such sites, and there can be no question that the present site at Tuggeranong is infinitely preferable to either. Whether it will be found to be the best available is a question which I am not called upon to answer. Another unanswered question is: "Was the railway to the power-house built in accordance with, or contrary to, the decision of the Minister?" The answer is that it was in accordance with the ultimate decision of the Minister, the Honorable King O'Malley having determined that the railway should be up to the standard of New South Wales Government railways. No minute or record for this decision can be found, but there is no question that the decision was made and announced. Another question is: "Was the construction of this railway at a cost of £49,000 in lieu of a light railway or tramway justifiable expenditure of public moneys?" It is not alleged that there had been any waste or excess of expenditure upon this railway and whether the decision of the Honorable King O'Malley was right or wrong is a question not dealt with in evidence. As to the next question, "Was the expenditure on the railway in excess of the estimate, and if so, is any officer culpable in respect of the estimate, or in respect of the expenditure?" No evidence of any estimate of the standard railway was given and there is no evidence of any excess

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in the expenditure. Two further questions remain. They are: "Whether the facts with regard to certain buildings are as alleged by the Honorable William Webster in his speech reported in *Hansard*, pages 7965, 7969?" and, (2) "If there is any default in respect of any of these matters, upon whom does the responsibility rest?" No evidence has been given as to these buildings, and as Mr. Webster desires that inquiry as to these matters should be abandoned, I assume that I have Your Excellency's authority to refrain from proceeding further in respect of them.

I have the honour to be,

Your Excellency's most obedient servant,

WILFRED BLACKET,

Commissioner.

Melbourne, 17th April, 1917.

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