PART I.

The future growth of population and civilization will depend to a very great extent on the storage of water. This is essential, not only for irrigation, but for power. Because other resources, such as the best unirrigated lands and the natural fuels, will fail to meet the steadily growing demands.

Water storage consists of two kinds—"Surface storage," which admits of being readily increased and rendered available for use by artificial means, and "ground storage" (perhaps more accurately called underground storage), also readily made available for use by artificial means, but, so far, little increased by any human efforts.

Turning first to artificial surface storages—

In the past there have been marvellously great reservoirs. But few, however, of these efforts of past civilizations were sufficiently permanent to remain in use at the present day.

The reservoirs of the past with the greatest capacity were shallow, and have either been breached from neglect to maintain their immense lengths of embankment, or have been silted up. And here it may be stated at the outset that even with the extraordinary cheap rate that silt can be removed with modern suction dredge methods, it would never be profitable to obtain storage by the laborious method of excavating or removing silt. Such reservoir sites must be abandoned and others sought.

The beginning of the twentieth century sees immense storage reservoirs in contemplation—reservoirs of such capacity as to dwindle all past efforts into insignificance. Of these the most noteworthy are:

I. Works to increase India's irrigation and electric power development.
II. Works to enable the basin irrigation methods of Egypt to be almost entirely replaced by perennial irrigation.

III. The regulation of the Mississippi River, to mitigate floods and improve navigation.

It is gratifying to us, and a hopeful augury for our future, that all three of these enterprises are in the hands of our own race, and while others are squandering their substance on warlike preparations, our Empire and the great American Republic are steadily preparing for greater works of peace, which will bring triumphs—not only more renowned than war, but of such an enduring and prolific character as will bring untold benefits to the world for all time.

Of these, unfortunately, Indian problems are so different from our Australian problems that, attractive though the subject is, it must be passed over for considerations of problems which have more in common with our own.

The Egyptian problems, though almost equally alien, are yet so simple and so widely known that they are worthy of a passing glance, so that we may gather stimulus from the example of the wonderful boldness and resourcefulness of our brother British engineers who are shaping the scheme.

What is aimed at is the replacing of the present basin irrigation by a perennial system. The first step was taken in the Great Dam at Assouan and the diversion Barrage at Asyut.

The former was in everybody's mouth, and, judging by the comparisons of our Burrinjuck dam, and the American high dam in Arizona, called after President Roosevelt, with the capacity of the Assouan dam, it would appear that the popular idea is that this Assouan dam is noteworthy on account of its great storage.

Certainly, as intended by its designers, with a capacity of over 2,000,000 acre feet, this dam would have been remarkable, but, as carried out, owing to the religious or sentimental regard for the Temple at Philae, it has only 40 per cent. of its proper storage, and is by no means a record-breaker for size. What has made it remarkable and a classic work in engineering history was the stupendous engineering difficulties overcome, and the pluck that encountered and grappled with these, on what would seem entirely inadequate preliminary investigation.
At Asyut, it is true, something was known of the difficulties to be tackled. Two structures had already been unsuccessfully attempted there by our French predecessors. At Assouan, on the other hand, the attempt was very much a leap in the dark.

The dam had to be made across a river bed, 14 miles wide, where, in places, a rushing flood torrent of 60 feet deep ran at an enormous speed. To use the language of the late Sir Benjamin Baker—"It was impossible to tell the nature of the bottom of the river. Divers could not be sent down into a river running at fifteen miles an hour. All the information that could be obtained by probing and in other ways was that the material was the same below as on the bank." Under these circumstances it is not wonderful that a contract let for one and a half million pounds (£1,500,000) involved nearly a million pounds of extra payment.

The wonder is at the great heart of the contractor, Sir John Aird, who, to use his own expression, "let" himself "in for such a job," and who not only carried it through, but did so to the entire satisfaction of the engineers and in the time he promised.

Before such enterprises one feels that almost any apparently impossible feat in dam construction can be achieved. The rotten bed foundation and the ingenious means found to plug the under springs were features to be studied, and eliminated or avoided, by those wishing to tackle similar works in future, and hoping to keep within reasonable cost.

It is hardly likely that the Assouan dam will now ever be raised to the full height originally intended, because, in accordance with the now accepted views, the more valuable storages are those obtainable in the highlands or the tributaries. For instance, one of the storage reservoirs most famous is Lake Tsana, in Abyssinia, which is to have an available capacity of 33 million acre feet, and where the first rise of 15 inches will give more storage than the whole of the great Assouan dam.

Some idea of the Nile floods may be gathered from the fact that in twenty-four hours more water has passed down the river than would completely fill the Assouan dam. Owing to the wide differences in the rate of fall and rate of flow in the different tributaries the flood period is spread over nearly six months by the time the floods have reached Assouan. The works contemplated are, as has been already explained, to replace the present basin
irrigation by flooding on flat lands during flood times, by the more prolific method of perennial irrigation, and also to increase the irrigable areas. Incidentally, the river will be improved by the increased depositing of silt in the great lakes, and by a regulation which will make it better for transport.

Considering how immense are the works which would be needed to regulate floods in one of these greater rivers, it is not to be wondered at that even our American cousins have paused to count the cost before further proceeding with their great project to regulate the Mississippi—a project which will liberate a region destined to carry tens of millions of people in affluence.

The works first constructed effected the partial control of the Upper Mississippi River, above St. Louis. These, with a capacity of considerably over two million acre feet, have been carried out successfully, and in permanent concrete (reinforced) material at the surprisingly low figure of 35 cents per acre foot—less than one-tenth of the cost of any of our Australian reservoirs.

Emboldened by this success the projectors of the Ohio River regulating dams set out on a system to cost one billion dollars (£200,000,000). However, a halt was called, and so far practically nothing has been done in the way of appropriations, and an immense amount of desultory work has been done in conjecturing exactly how these works will effect the floods. Two things have contributed to delay the initiation of the works. First, great though the estimates are, they are generally regarded by engineers as being quite under the mark; and, secondly, apart from the general improvement expected to all the lands awash from the Mississippi floods, a considerable revenue was expected from the sale of power to the great manufacturing centres in Ohio and for transport; power to the extent of one million horse power was reckoned on. The question was then how far are these two uses—flood regulation and storage for power purposes—compatible. Clearly, if the whole capacity of the reservoirs is to be available to prevent floods, they must, before the usual flood season sets in, be entirely emptied. And, consequently, there may be considerable periods when they will be able to develop little or no power. In view of this, a district like Ohio, which is already supplied with exceptionally cheap fuel, is little likely to be a good customer for such an unreliable power supply—or if customers are found, the power sent would be a very low one,
since the tenants would have to maintain auxiliary engines, to tide them over the drought period.

At this juncture the various uses of stored water come forward for review.

The irrigation regulation of rivers and channels naturally, to some extent, can be worked in along with the control of floods, especially if some system of levees is also maintained. By the same regulation, abstracting the surplusage of ordinary floods, and paying it out in a steady increased dry weather flow, navigation can also be greatly improved, and, in fact, in many of the larger irrigation systems in India, navigation is a recognised adjunct of the irrigational canal business. On the other hand, up to now, it has been generally regarded that storage for power purposes does not go hand in hand with any of the other uses. Here, again, not only are there exceptions to the rule, but the increased steadiness of the regimen of a river fitted with a number of storage reservoirs, even for power purposes, has a beneficial effect on floods and on low draughts. If the floods are at times as large as ever, they obviously will be less sustained in duration, and the dry weather flow must be greatly augmented.

To obtain a clearer idea of the inter-dependence of these things, and also an insight into a method whereby power uses may be made to keep step with irrigation uses, a short general analysis of a river which is familiar to us all—the Goulburn—will suffice.

Taking the river above the Goulburn weir—Fed by a catchment of about 4000 square miles, the flow varies from 660,000 acre feet in a year to nearly 4,000,000 acre feet in the same period; and when considered in detail it will be found that to equalize the yearly flow which, for more than eighteen months, has been known to aggregate less than a third of its average discharge, and has gone for five consecutive years at a time with an annual discharge of less than three quarters of its average, it will be necessary to store something more than a single average fifteen months' discharge, and, allowing for losses by evaporation, this will mean an aggregate storage of above two and a half million acre feet.

This, then, represents the ultimate storage to utilize every drop of the Goulburn's water for irrigation, stock and domestic purposes. Assuming meteoric conditions to remain unchanged, this would be the irrigation use limit—giving over two million
acre feet of water a year, or sufficient to irrigate, say, seven hundred thousand acres of intensely cultivated land.

This possible storage will have a marked effect on floods. In considering what this would be, the first fact to be borne in mind is that for irrigation and such like uses the demand requires that at all times the reservoirs be kept as full as possible.

Consequently, there would be occasions when a severe flood, following a wet season, would find the reservoirs already full, and flowing over. Under such conditions, the apparently contradictory result may occur of the flood run off being greater than it would have been had there been no reservoirs at all.

The records of floods on the Upper Mississippi subsequent to the completion of the regulating dams, show that this has actually happened there, and the River Shannon, in Ireland, which drains an area nearly half of which is natural storage, lakes and bogs, affords the extraordinary record of, during a wet month, coming after a wet season, more water flowing off in the river than the rainfall record showed to have fallen on the whole watershed.

Taking these records, a casual observation would condemn the attempt to regulate a river by storage dams which cannot be controlled entirely for regulating purposes, but, turning again to our concrete instance of what would happen in the Goulburn River with 2½ million acre feet stored for irrigation, it will be found that such a condition would only have occurred, in our day, after the wet seasons 1909-10-11, which culminated in June, 1911; and to go further back would mean at least 25 years to 1887. Clearly, instead of being a constantly recurring damage, as it is at present, the damage of floods to the Goulburn flats becomes one which could be insured against as easily as an average life insurance at, say, 2½ per cent. of the total value of the damage. And the floods, being of shorter duration when they do come, would work less permanent harm. Put in figures, lands now worth £15 an acre, if so far protected, would become worth £35 an acre.

On an estimate of 100,000 acres of rich flat land, so far saved from the almost biennial flooding, such a storage provision would increase the value of the flats by two million pounds.

It is possible, though hardly likely, that ultimate developments of irrigation with the cooling and moderating effect not only of irrigated culture but the great areas of lakes and channels would
so modify meteorological conditions as to entirely remove all flood damage on the lower river.

This incidentally suggests how irrigated areas will ultimately grow beyond what it is now possible to figure on. Just as investigations in similar districts have shown that a proportion of the waters absorbed in irrigation are returned as ground waters to the river beds lower down, so also much of the water absorbed by irrigated vegetation is returned as light rains and dews; and much of the water apparently lost in evaporation from the surface of the dams goes to cool the atmosphere in the catchment and environs, with the result that the rainfall is more frequent, and especially the summer rainfall is improved.

These are anticipations which are not taken into account in any practical estimates for costs and expenditures. Omitting these, however, a rough estimate of the advantages of fully developing the irrigation possibilities of this river would be somewhat as follows:

Using values at Mildura and in the irrigated land of the western United States as a guide, it can be assumed that even if the high rate of 10s. an acre foot were charged for water, yielding, say, £700,000 a year from the irrigated area, the value of the irrigated lands would be fully £100 an acre. Without making any allowance for the vastly improved values to all the towns and adjoining lands, this alone represents an immense aggregation of wealth.

A very conservative estimate of the direct increase of wealth would be to take the unimproved land values. These would be somewhat as follows:

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of 700,000 acres at £100</td>
<td>£70,000,000</td>
</tr>
<tr>
<td>Deduct value of improvements in planting, grading, fencing, buildings, etc., say</td>
<td>35,000,000</td>
</tr>
<tr>
<td>Deduct total unimproved value, 700,000 acres before operations at, say, £8 per acre</td>
<td>5,600,000</td>
</tr>
<tr>
<td>Total deduction</td>
<td>£40,600,000</td>
</tr>
<tr>
<td>Nett increased value due to new works</td>
<td>£29,400,000</td>
</tr>
</tbody>
</table>
To this has to be added the moderating effects of this great storage, and the abstraction of so much water on floods.

This, as shown above, is 100,000 acres at £20—£2,000,000; while later on it will be shown that the value of electric power which can incidentally be sold will represent at least an addition of £1,000,000 to the capital value of the necessary storage and irrigation works.

Thus we get value of irrigation works ... £29,400,000

Improved condition of river flats ... 2,000,000

Value of electric power ... 1,000,000

Total value of scheme to fully use Goulburn £32,400,000

These are conservative and cold commercial figures, and are such as might be considered by a millionaire combine. This, however, must be borne in mind, that the Government of the country should regard all such projects from a far wider point of view.

This project has a wonderfully attractive promise—namely, the development of so vast an irrigation enterprise means a wonderful increase to the commercial and industrial stability of the country. This Goulburn River alone will be made to give the means to support, not 30,000 people, as has been estimated, but over 300,000, in ease and comfort not dreamt of by the unsettled population of a few thousands who live on a feverish gamble between the extravagant fat years and the cruel, ruinous years of drought.

Doubt will be expressed as to whether so great an aggregate as over 2,500,000 acre feet can be stored in the Goulburn Valley. The author has an intimate acquaintance with the district, and has no hesitation in giving the following as reliable facts.

First, flood storage reservoirs must be directly on the river, and such storage as the Waranga, though indispensable for the economical distribution of the water, can only be regarded as distributory storage, and not for increasing the quantity of water which can be drawn from the river.

To prove this it is only necessary to recite what actually happens at Waranga in flood times. The floods rise to over 30,000 cusees at the Goulburn Weir, whence is the channel to feed the Waranga Dam; but the capacity of the channel is only 1700
cusecs—a figure which is exceeded by the ordinary river flow during quite six months of the year. Clearly, then, unless some storage is provided on the river higher up, the Waranga scheme must allow all valuable floods to continue to waste themselves.

To enlarge the Waranga feed channel sufficiently to even catch half of the maximum flood, say, 17,000 cusecs, would mean to double its depth and treble its width, and incidentally raise the Goulburn Weir.

It has been stated that this scheme, which also would involve very expensive alterations in the Waranga reservoir itself, has been rejected by the State Rivers and Water Supply Commission, and the author considers it as too extravagant to warrant any consideration, except as showing the absurdity of such projects to catch large floods elsewhere than on the river where they occur.

On the other hand, granted that the reservoirs on the river above the offtake are sufficient to regulate the river flow, so that the least summer discharge is greater than the full capacity of the offtake, and it is obvious that the Waranga (or similar distributing dam) can be used to its full advantage. Thus, in the case of the Waranga channel, the 1700 cusecs, if directly feeding distributory channels, would not give the necessary regimen to serve one-third of the area it can command, when all the fluctuations of demand are met by a storage. For instance, while the inlet by this channel will, say, be kept at 1700 cusecs, continuously flowing for 365 days a year, the outlets may be increased to more than three times that capacity and draw the water during only the 120 days it is actually wanted for irrigation. The small quantity kept in the channels for the stock and domestic purposes will be found to be negligible. By considering these facts it will be realised what is the difference between the functions of these shallow basin reservoirs in the areas served, and the great river or lake reservoirs which form the main storage.

This, then, is the first fact, that, however useful are such reservoirs, they cannot be relied on to stop the waste of our flood waters.

At the same time it has been made public that the authorities contemplate increasing such offtakes from the Goulburn, and propose a further storage reservoir at Reedy Lake. No doubt such will ultimately be necessary, since the limit to what the present Goulburn Waranga Reservoir can supply would not, under the
best conditions, exceed 250,000 acres, and under its present conditions little more than half that quantity. But the question will be asked why these further distributing works should be gone on with before the large reservoirs on the main river—which must be made sooner or later—are constructed. And this question is the harder to answer seeing that neither the present Waranga scheme nor the new Reedy Lake scheme can be utilised to the full until the larger reservoirs are constructed.

An answer may be given that the proposed Tabilk weir will supply the want. This is not so. If it is to be a diversion weir to feed the Reedy Lake, then, like the Goulburn Weir, its storage value will be negligible, because it must be nearly full before the Reedy Lake channel can be fed; and, on the other hand, if it is to be a storage reservoir to the Waranga, its value for Reedy Lake will be very slight indeed.

Further, drawing off so shallow a reservoir is against all precedent. Shallow waters evaporate rapidly, and evaporation, which at present forms an appreciable loss in the case of hundreds of acres of distributory channels, will be a very serious loss indeed in thousands of acres of shallow, stagnant swamp waters.

The second fact, and a fact which seems to have been overlooked by the authorities, is that the Upper Goulburn Reservoir sites admit of the construction of deep hydraulic fill dams, and do not require the expensive masonry dams which apparently have been all that up to now have been figured on. On the Nexaca and Tescapa Rivers in Mexico this method is in use: There the foundations were so rotten that no masonry could have been used; and on the advice of the most eminent hydraulic engineers this new method was adopted. For a brief mention see Vol. VIII., pages 138-139, of Proceedings V.I.E. In the appendix to this paper a brief account of these reservoirs and how they have increased the available power value of the rivers by nearly double will be found.

This method of construction is amazingly cheap, and, following as it does the method that nature has adopted in making many of the embankments for natural lakes, gives the surest promise of permanency to the structures. It is far superior in its nature to ordinary earthen dams, or even the best designed masonry or concrete structures. It is true that the flood spill ways or outlets are made in reinforced concrete, often with tunnels
lined with steel; but these are in every case founded on solid rock and at such levels as will preclude undermining by water.

To give some idea of what has been done in this way: the Nexaca dam is 200 feet high; the sill of the overflow is set 20 feet lower, and in all the effective depth for storage is 176 feet. This dam contains over two million cubic yards of materials, and has been built for less than a quarter of a million pounds.

The foundations certainly, as seen by the author five years ago, offered far greater difficulties than are likely to be met at Trawool; but though there is far superior material for the rock work at Trawool, that and the labour will be far dearer, consequently comparing like with like, the author considers that a similar dam of similar height (say 40 feet higher than has yet been proposed at Trawool) can be made for three-quarters of a million pounds.

In neither of these cases are the values of lands resumed included, nor the railways displaced; but it is worthy of mention that the Mexican Power Company had to pay heavy land compensation, it is understood averaging 300 dollars an acre.

Returning to the Goulburn sites, there are two places where vast storage can be obtained. The lower, already made public by the Trawool proposal, would flood some 20,000 or 30,000 acres of the flat land which extends up the river from Trawool to Thornton, and includes the lower Acheron flats. Possibly there are other sites better than that at Trawool. One very likely site would be at Molesworth railway station. The upper site, which some of the local residents have named the "Goultite site," is situated below the junction of the Goulburn and the Delatite. Here there can be no question about the relative cheapness of the dam. Nowhere has the author in this country seen a site better suited for constructing an hydraulic fill dam of giant dimensions. The stiff clay is within economic reach and in great quantities, and suitable rock for the outer walls can be got at a minimum of cost.

Probably such a dam as the celebrated Nexaca dam, 200 feet high, could be made for the same cost. The only thing which would be bigger than the Nexaca would be the flood water provision. At a very outside estimate the author considers that £400,000 would at this site give a storage of 600,000 acre feet. This, added to the Trawool or similar dam, at, say, Molesworth, should secure all the storage needed to give a fully regulated
supply for diversion weirs further down the river, and with the incidental addition of such storage provisions as the Waranga. There should be a storage provision of well over the two and a half million acre feet estimated on.

While land resumption should be made above Trawool from the moment the Goulite Dam is commenced, so as to discount the rise in values due to its moderating effect on floods, there can be no doubt but that from an economic point of view the Goulite Dam should be put in hand at once, and the leakage in interest until the work was completed would be less felt this way than in any other. To begin with, so soon as the rock fills were completed to, say, 30 feet above the river bank the river could be turned into the outlet tunnels, and these would be at such a level as to secure from that time the advantage of some storage. Then the progress payments or contracts aggregating, say, £350,000 or £400,000, would not be relatively heavy, and the interest to be paid for the land resumptions would be nearly met by the releasing of those lands on short time leases. Here would be an admirable opportunity for initiating new settlers, because on the leased farms, from their proximity to large works in progress, a fair start can be made by the active man with little or no means.

The accompanying photographs, supplied by a local resident, shows the river at the proposed site.

One fact, however, in connection with hydraulic fill dams must not be lost sight of—namely, that there is no form of construction which grows more slowly, and the process cannot be rushed. When the Nexaca dam had been nearly four years under construction the gradually narrowing slime centre seemed to have set before it had sufficiently set to be solid, and the result of too rapid construction was a slip of some hundreds of thousands of cubic yards and consequent delay.

This obviously is an argument to confirm the view that this Goulite dam should be put in hand at once. The other argument is that all the works lower down the river will immediately be able to be used to almost their full advantage. The value of the Waranga basin to meet the rapidly growing demands will be nearly doubled without any Tabilk storage, and the Reedy Lake diversion, if undertaken, could be held back till the larger storage at, say, Trawool is put in hand.
So far the third advantage of the large reservoirs on the upper river, namely, by the development of electrical power, have not been touched on.

Approximately irrigation demands extend from the end of October to the beginning of June, and during this period the power which could be developed will vary from 20,000 horse power to over 30,000 horse power; but between these seasons the power would fall to perhaps 3000 horse power (effective). There is a ready mode of remedying this defect—namely, that the many waterfalls and rapids on the rivers which are fed from that highland area lying between the Goulburn and the Yarra, though of little account during the summer months when the maximum power is being developed in the storage reservoir outlets, is yet of considerable extent in the winter months, and by an electric circuit of less than 200 miles half a dozen stations, each of which could develop over 3000 horse power, can be harnessed and connected with Melbourne and the reservoirs.

By this means probably 25,000 horse power can be obtained at all seasons. This is worth, say, £2,500,000; and the cost of the installation would not exceed £1,500,000. Hence, the £1,000,000 assumed as the value of the reservoirs for power purposes.

The aggregate cost of the total works to irrigate over 700,000 acres of land and add a quarter to the population of Victoria would probably be well under ten millions, spent somewhat as follows:—

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td>Store dams on the Goulburn (this includes land re-</td>
<td>£1,500,000</td>
</tr>
<tr>
<td>sumption)</td>
<td></td>
</tr>
<tr>
<td>Distributory dams, and channels to the irrigated</td>
<td>5,500,000</td>
</tr>
<tr>
<td>areas, say</td>
<td></td>
</tr>
<tr>
<td>Sundry works on the river, and relocation of roads,</td>
<td>1,000,000</td>
</tr>
<tr>
<td>railways, etc., on whole area, say</td>
<td></td>
</tr>
<tr>
<td>Contingencies of all kinds (25 per cent.)</td>
<td>2,000,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>£10,000,000</strong></td>
</tr>
</tbody>
</table>

It has been shown the direct benefit from these works will aggregate £32,400,000. Clearly, it is worth while to embrace the opportunity of dealing with the question on the largest and broadest lines. To do otherwise will cramp development, and continue the period when the State's prosperity will remain sub-
ject to the cruel vicissitudes of droughts, and when at one month we are clamouring for immigrants and at the next are at our wits ends to find employment for our own people. The figures may seem startling to those who have not made themselves familiar with what has been done and is contemplated elsewhere.

No more wholesome example of the bravery which wins success can be given for such than the cost of reclaiming the Dutch polders, in most cases reaching £200 an acre, exclusive of the heavy annual charges to be met for pumping. But, apart from the great cost of reclaiming land, a precedent may be found in the big cities. In New Zealand the larger cities—Wellington, Auckland, Christchurch and Dunedin—though not aggregating as large a population as this scheme should support, have spent a far larger sum on their streets, tramways, harbours, water supply and sewerage than the outside amount which this will produce, and most of these are unremunerative expenses; whereas the irrigation works when once well started are most remunerative, and really will only require the loan of Government Credit to start them. The Government irrigation works in India, though not run primarily for profit, yield 6½ per cent. per annum on the capital expenditure, and it can be easily shown that with moderate irrigation charges, not exceeding, say, 7s. 6d. per acre foot, not only can all interest on these Goulburn works be paid, but the works themselves maintained and steadily improved.

DISCUSSION.

The President said Mr. Anderson had treated them to an interesting paper. He was sure few of them would be prepared to enter into a critical discussion of the author's views without the opportunity of a closer study of his reasoning and figures. In due course the lecture would be published and distributed to members, and he was sure that no one would more welcome a critical discussion than the author himself. He ventured to think many of the suggestions had been given for the purpose of provoking discussion. However, he would be glad if anyone present was prepared to make observations on matters presented by Mr. Anderson.
Mr. A. W. CRAVEN said he had listened with great interest to the paper. He took a great interest in those things. He had had a lot to do with the Goulburn Weir, having laid out most of the channel himself; and afterwards, when he became associated with the Railways Standing Committee, the question of the water supply of the Mallee came up, and they threw themselves into the question of bringing the Murray River down and tapping it. The idea was to tap it somewhere about Albury and bring the water down with a view to carrying it on to the Mallee. He had at that time worked out a lot of rough contours that he got from the ordinary railway time table, and roughly sketched out a design which culminated in the Waranga basin. At that time a tremendous amount of levelling had been done. The Railway Committee requested the Water Supply Department to give it more details with regard to the carrying out of channel work to the Mallee, and, if possible, to connect it as far as Lake Albacutya. However, they soon saw that it would become a great project indeed, and he himself ran out about 266 miles of levels from the Mitta Mitta to the parish of Waggaronda. Later on he was connected with the Royal Commission on Water Supply in connection with the terrible mess the country got into with regard to the water trusts. Things would have to improve a great deal from the beneficial point of view before they could deal with the big problems. Although they must look to the Goulburn River for a large amount, still they would have to go eventually to the Murray for a great deal of the water. Most of the members would be familiar with Cambaroona—the country below was Tregono. If they built that reservoir that country would all be submerged. That reservoir would absolutely destroy the Murray valley as a means by which they could locate a lot of farmers on the land.

Mr. ANDERSON said the Murray was even worse for flooding than the Goulburn.

Mr. CRAVEN said further up there was what was known as the Talmalmo scheme. There they put a lot of bores down and found bottom at 140 feet. That precluded that site. Further up was Towong. There was a proposal by a New South Wales engineer to construct a reservoir from the two ranges that came in from Towong. It would be practically an enormous inland sea. It would submerge and destroy all that country. That scheme
would cost an enormous amount of money, but a proper estimate was never made. Further on again there was what was called the Geehi. What would be submerged there would not matter much. It was an ideal place, because it was right below the snow mountains. On the Mitta Mitta River there were several sites, but each of these he could see plainly would displace a large number of farmers from the land.

However, he thought they could not say much about the paper until they saw it in print. It would take them some time to study the various views that Mr. Anderson had promulgated. He was glad to have had the opportunity of being present, and felt certain that the paper they had heard would read very well indeed, and be a valuable contribution to the journal of the Institute.

Mr. JAS ALEX SMITH said he thought he was quoting the author correctly in saying there would be an expenditure in works of £32,000,000. That would mean, on the assumed population served, that an annual tax per head of about £3 10s. would be required to meet the interest charges.

Mr. ANDERSON said the works would only cost £10,000,000. The value accruing would amount to £32,000,000.

Mr. SMITH said in that case an annual tax of £1 3s. 4d. would cover the cost of the works. That would mean that a very small increment indeed in the productivity of the land would under the condition assumed more than cover the cost of the work. Mr. Anderson had mentioned the irregular production of power. Certainly less water was coming down during the five summer months than during the seven winter months. But had Mr. Anderson taken into consideration that that power might be largely used for the production of electrical products—aluminium, carborundum, calcium carbide, etc., and the power stored in chemical form?

Mr. ANDERSON said they had not elsewhere any outlet for their power as profitable as direct electrical supply.

Mr. SMITH: But if the power is not immediately so required, then an irregular supply when the demand was regular had a lesser value, since it did not obviate the necessity for the provision of capital for a stand-by steam plant.

Mr. ANDERSON said when they were using the water for irrigation there was little power available in the hills.

Mr. SMITH said the point he was making was that even with irregular production of power they could still make use of it if
they used for the production of electrical products the power in excess of that directly transmittable at payable rates.

Mr. Anderson said if they took, for example, carbide, they could not get more than £8 or £9 per ton for it. A steady horse power for 24 hours a day cost £8 or £9. Take 25,000 h.p. in the reservoir for six months, and it would equal £100,000.

Mr. Smith said there was one other point. Mr. Anderson was taking the horse power value as £10 per annum. He thought that was rather high. It would not cost £10 per annum per horse power with modern installations dealing with 30,000 h.p.

Mr. Anderson thought in a place like this it would.

Mr. Smith said, assuming a modern power installation, it would cost about 30s. for fuel. It would be at most not more than £2, and the other costs would not go to £8. But even greatly reducing Mr. Anderson's estimate of £10 there was a great deal indeed in the scheme. He would like to have an opportunity of going into the matters he had noted. He was sure there were many points in regard to which, although they might criticise, the criticism would only lead to further light being thrown on the subject by the author.

The President said he would like to make a few observations, especially upon a remark of Mr. Craven's that the scheme was going to cost a terrible lot of money. They heard a great deal about that. He wanted to impress and spread the gospel that was so prevalent in America. It did not matter how much a project cost if it returned a proper interest on the investment. The more it cost the better. There had been one or two statesmen in Australia who had recognised that. One was Sir John Forrest. He made the observation to support what was half humorously referred to as revelling in millions. One must be quite prepared, in the development of this country, to face the expenditure of millions. He must not be deterred by the fact that the projects would run into millions. If he had understood the main purport and tenor of the paper, it seemed to him that the main purpose was to briefly outline a scheme for a deep reservoir on the higher reaches of the River Goulburn. And, personally, he agreed with Mr. Anderson as to the advantage of going up stream and making a deep reservoir. He would like Mr. Anderson to give more technical information on the question of rock-filled dams. He thought the question was little understood, and the whole ques-
DISCUSSION—WATER STORAGE.

The discussion of water storage had very properly been brought before the profession.

The tendency was to say that water storage was the affair of the Water Supply Commission; but at least the broad principles and problems that affected the community ought to be the subject of concern to every engineer, just as he should have some idea of the railway policy of the country. Mr. Anderson had suggested the various functions of water storage, or the purpose of river regulation, power, flood regulation, irrigation and navigation. He had dealt most fully with flood regulation and irrigation. He thought the paper had been successful in showing that these were inconsistent, and that it was difficult to provide successfully for flood regulation requirements and irrigation, and still more so for irrigation and power. Mr. Anderson had several times said, "Let us use this river to the last drop." He thought that was absolutely wrong. They must not use their rivers to the last drop. They must leave sufficient to let the river exist as a river. And he put this broad view to them, that the day would come, and must come, when the whole of the surplus waters would be conserved in deep storage reservoirs high up in the hills. Stored water would serve to feed irrigated lands, and canalised rivers would serve as main arteries of transport to the seaboard. He had over and over again heard it said, "What is the good of preserving a dying interest?" He said the industry of navigation was not paltry; it was not dying; and it was worth preserving. Again, it was said irrigation must be supreme over all considerations. He said that that scheme which was best for irrigation was also best for conserving the river as a natural highway for transportation. He had taken into consideration railways and also American experience. He was delighted that the subject had been brought before the Institute, and hoped they would discuss the whole matter very closely.

Mr. A. W. Craven said, as to what the President had said concerning the conserving of the rivers, he believed Geehi was the one place that would fulfil the conditions mentioned. It was right in the snow, and they would not submerge a lot of the finest of the country. It would be up in the mountains, and would always keep the Murray River a navigable stream.

Discussion adjourned.
pregnant paper which he had delivered, but also for the entertaining slides which had illustrated the matter brought forward.

The vote of thanks was carried by acclamation.

Mr. J. T. N. Anderson, in acknowledging the vote, said he was indebted to members for the way in which they had listened to him. He felt there were a great many imperfections in the matter. It was by no means a complete dealing with the subject, which was an exceedingly difficult one to deal with. The problems were not dealt with in a popular way, but his audience did not require that. A hint to his audience was almost enough to point out what he meant, consequently he had not elaborated some of the points, especially that of conserving not only the monthly flow, but the annual flow in the river.

At 10 p.m. the meeting closed.

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PAPER.

WATER STORAGE.

By J. T. N. Anderson
(Past President).

PART II.

STORAGE ON SURFACE AND UNDERGROUND.

Few people realize what immense stores of water are always latent in the surface and the subsoils. Approximately it may be assumed that the voids in sands and gravels average forty per cent. of their total volume. Assuming on the average only half this quantity in the upper seven feet, and the surface evaporation to abstract during the summer the equivalent of the contents of the upper two feet, then the effective storage of this surface crust is equivalent to one acre foot per acre. Such vegetation as can tap this reservoir is drought-resisting. At the same time it must not be assumed that all soils, or even a small proportion of soils, are saturated to within two feet of the surface, or that soils so saturated will sustain vegetation. On the contrary such soils as are completely saturated to this level are fatal to most forms of vege-
What does happen, is that the moisture, which is assumed here as half what would suffice to completely saturate the subsoil, is in a state of continual circulation; a portion, when the surface is drying under summer heats and dry winds, rising to supply the loss, while the great bulk is continually passing down towards the bedrock, and the soil, in a sponge-like state, contains also quantities of air. The storage in the porosity of the lower rock gradually finds its way by fissures to the surface or the deeps below sea level. The quantity of water so held in suspension varies from the limestones and sandstones, where it may reach to, perhaps, fifty per cent. of the total volume down to less than one per cent. in the more compact igneous rocks. It has been assumed, vide Vol. IX. "Proceedings, Victorian Inst. Engineers," pages 98 and 107, that there is less loss by this seepage here in Australasia than the average in other countries. The run-off of our rivers, where recorded, hardly bears' out this view, and the very large area of forests in the Australasian coastal lands certainly should help to feed the underground waters. The factors which make for penetration of water to the depths are chiefly those which retain the moisture longest on the surface, so that it has time to soak in, and of course the absence of stiff clays between the surface and the bed rocks.

Of these factors all the forestry exponents claim that the forests give the best ground water spring flows, while the majority of engineers seem to regard the effect of forests on run-off as negligible. The views held on both sides have been so forcibly put, and are so conflicting that a brief consideration here may not be out of place.

The engineers, while admitting that forest denudation is invariably followed by the scouring out of ravines and gulches by the storm-water, where formerly little or no water channels existed, and the consequent necessity to enlarge the smaller culverts on roads and railways, yet point out that the maximum flood records on the large streams and rivers are usually found in the periods before the forests have been denuded, and gather from this that forests have practically no effect in moderating floods, and consequently in conserving water to be given off in the drought seasons. They point to the fact that the areas which give the best drought flows are the bare mountain sides, where the snow lies in deep drifts, and persists almost throughout the whole summer. The regions within the perpetual snow-line do not come
within the consideration of Australian engineers, and in any case, owing to the great evaporation at those high levels, where surface tension is low, the flow-off is seldom so great as from such elevations as are found in the Dividing Range in Victoria and New South Wales from, say, 2,000 to 7,000 feet above sea level. Such a range is much more favourable to a moist climate than the Rockies, or other snow-clad mountains, where the coastal winds are effectually dried of their moisture before reaching the continental side. In our case, then, the conflicting theories of the engineers and the foresters are easier of solution. Here we have mountains such as those from Healesville to Baw-Baw, thickly covered with forests, and having practically the same rainfall as mountains at the Buffalo, where there is less timber and more snow-drifts, and yet the former give the better summer run-off.

Briefly, as will be seen from the accompanying views, the snows that fall in timber country are evenly spread, and lie melting for a sufficient time to give off most of the snow-water to the ground beneath, while in the bare rocky country, a vast quantity of the snow disappears by evaporation direct into the atmosphere. Then, too, the efficiency of forests as breakwinds will have a most remarkable effect in keeping the surface of the ground moist long after it has dried off on the cleared lands. It is perfectly true that trees abstract an immense amount of moisture from the soil, which is continually rising in the summer as sap, and gets dissipated by evaporation from the leaves. To this even more than the shade must be attributed the cool temperature of forests in the summer. In the primaeval forests in Gippsland of a summer morning, an hour or two after sunrise, a beautiful effect is often seen. The trees up to 80 or 100 feet from the ground are practically bare trunks; at that level they spread out, and are well covered with leaves. These leaves catch the moist air rising from the ground—the dew that has just evaporated—and hold it half condensed again in the shape of a horizontal gossamer wreath of beautiful white cloud.

This illustrates one of the most marked benefits of the forest country. Whatever else its effects may be on winter rains or on torrential equinoctial rains, there can be no doubt but that they are a most effective condenser to catch and hold summer rains.

This can any summer be noticed on the range mentioned above, from Healesville to Baw Baw, the Yarra watershed of which has been marked off for Melbourne’s water supply. Here a repeated
experience is to find frequent showers above the 1,500 foot level often sufficiently heavy to even influence ground flow during summer months, when below that level on the cleared lands there has been no rainfall.

If these forest ranges are not conserved for water supply, and if the irrigationists work on the lower Goulburn only, then in process of time the fruitgrowers will find that it is cheaper to clear the rich forest lands, where there is sufficient natural rainfall, to save their charges of 10/- an acre foot for irrigation, and so the fruitgrowing areas in the upper Goulburn, in spite of the cooler climate, will ultimately outvie those in the irrigation areas, with the consequent result that the forests will, before the pressure of population, be infringed, and gradually denuded to the ultimate heavy damage of the whole country.

There can be little doubt but that much of the desolation which swept away the irrigation works in North Africa and in Asia Minor came from similar causes to this. The solution to this difficulty is met by the modern method of appropriating all the mountain valleys for reservoir sites. Then not only will it be unprofitable to use the forests for anything except regulated saw-milling, but the climate will be so far chilled that there will be little temptation to embark on agriculture or dairying. Without such preventives it is hardly possible that these forests will long stand before the pressure of increasing population, and popular clamour to get on the good lands.

One word more on ground waters. It has been remarked that the proportion of rainfall that finds its way into our rivers points to the fact that there is a very considerable proportion of ground water in Australia. In most countries at the same latitude, or rather with similar isothermals, spring water of a perennial character, is found within five hundred feet lower elevation than the top of the range feeding it. Here in the part of the country mentioned, forming the watershed of the Goulburn and the Yarra exactly the same is found, and at the higher elevation, say 4,000 feet and upwards, where barometric pressures are lighter, and the atmosphere is cooler, with frequent rains, these perennial springs are found close to the summit. Elsewhere in Victoria, unless the slope of the range be very flat indeed, such springs are in existence, but do not come to the surface. This continent, being almost the oldest in the world since its formative eruptions, has a greater depth of alluvial and aerial deposits than are found else-
level of the water, and the water had sunk in the sands and gravels so deeply, that, even after a heavy rain, it had sunk quite to the bottom of the small wells. At Ballarat, and Maryborough, and Rutherglen, the alluvial fields, it was only necessary to quote the Ballarat and Maryborough, or the Rutherglen alluvial fields, to satisfy the enquirer on this point, and elsewhere in Australia, not only stock and domestic uses are served from our wells, but they also supply water for irrigation.

The future will see far more use made of such ground storages than the past, when it becomes realized that if a horse-power cost one penny an hour, sufficient water to irrigate one acre one foot deep can be raised from fifty feet at a cost of only 4½, or less than any of our irrigation trusts charge per acre foot for water from their gravitation channels. The trouble that the bulk of our ground storages contain too much alkali is one which often corrects itself with constant pumping.

The author is aware that in passing over the question of natural surface storage he has neglected what is perhaps the most important of all the aspects of the water storage question. Its bearing on the whole irrigation, as well as water supply questions, of the Murray, Murrumbidgee, Darling country, is too important and too complicated to be adequately dealt with in a general paper on water storage. But there is one aspect of the question too prone to be lost sight of, namely, the effect on the health of the community of the large shallow basins. In the mountains, and surrounded by eucalypt forests, no evil effect need be feared. But shallow surface basins in irrigated areas with the consequent hot, moist summer atmosphere, and the sanitation of an agricultural or horticultural community, are veritable fever beds.

Mr. J. T. N. Anderson submitted a copy of "The Engineer," of November 8, 1907, containing illustrations of rock-filled dam construction in connection with the Necaxa Power Works, Mexico.
DIAGRAM.

Showing Proportions of the Flow of the Goulburn River diverted and used, year 1910.

Total flow at Goulburn Weir 2,151,000 acre feet.

- Volume diverted . . . 136,000 acre feet.*

- Volume used (approx) 40,000 acre feet = 2%.

*The greater part of this volume was diverted to fill Waranga Reservoir, and was subsequently allowed to flow to the Murray, by way of the Campaspe.

Taken from the Annual Report, 1911, of Water Supply Commission.
Fig. 1.

VALLEY OF THE NECAXA AND ITS TRIBUTARIES
Showing Reservoir Sites.

Fig 1a.

VALLEY OF THE GOULBURN AND ITS TRIBUTARIES
Showing Reservoir Sites Suited for Flood Abatement
Fig. 3.
FIRST REGULATOR ON WARANGA CHANNEL

Fig. 4.
INTAKE OF WARANGA BASIN.
Fig. 5.

Sugar Loaf Hill.
Right Shoulder of Embankment Proposed—below Junction of Goulburn and Delatite Rivers.

Fig. 6.

Mount Pinniger.
The Left Shoulder of the Proposed Embankment below the Goulburn and Delatite Rivers.
Fig. 7.
JUST BELOW SITE OF PROPOSED RESERVOIR, LOOKING UP Goulburn Valley.

Fig. 8.
SITE OF PROPOSED RESERVOIR.
Looking up Delatite Valley.
STORAGE ON THE UPPER MISSISSIPPI.

Fig. 9.
LEECH LAKE DAM.

Fig. 10.
LAKE WINNIBIGOSHISH DAM.
Fig. 11.
PINE RIVER DAM.

Fig. 12.
HYDRAULIC FILL DAM

Fig. 13.
LOOKING UP STREAM AT SITE OF DAM NO. 2, AT NECAXA, SHOWING STRIPPED ABUTMENTS FOR THE DAM ON EACH SIDE.
Fig. 14.

**Liquid Earth being Deposited through Pipes on Outer Slopes of Dam No. 1, Tenango River.**

Fig. 15.

**In the Rubicon Forest, Upper Goulburn.**

View showing vegetation undisturbed by any clearing; and snow melting without any appreciable surface run off.
Fig. 16.

**IN THE RUBICON FOREST, UPPER GOULBURN.**
View showing snow sheltered by vegetation, and only giving run off where cleared. See tramline.

Fig. 17.

**SNOW DRIFTS AS STORES OF WATER,**
DISCUSSION.

The President said the whole subject was now open for discussion, and he sincerely hoped the discussion would not be closed that night. He felt sure a number of members who were unable to be present would like to address themselves to the subject.

Mr. J. A. Smith exhibited several slides, which illustrated the latter section of Mr. Anderson's paper.

The President said he would like to make a brief contribution. He remembered as he spoke a few interesting facts about the Riverina, whilst he did not claim that his recollection was good enough to give precise figures. A very large amount of the flow of the Riverina streams disappeared by soakage. Take the Murrumbidgee, for instance, at three points near Naranda, Hay, and at the junction with the Murray. At each of those points there was a steady diminution of flow. At the time at which he had investigated the matter there was at Narandra a flow of 200 cubic feet per second; at Hay 100 cubic feet; and at the junction something less than 50 cubic feet. All that water disappeared, but only a very small fraction could have been due to evaporation. It disappeared by soakage, and did not make its re-appearance in that region. But the most remarkable instance was the Lachlan. Most of them would be familiar with the map showing the Lachlan as flowing into the Murrumbidgee, but when one visited the locality one found there was no such junction in reality. There was no definite channel from the one river merging into the other. Under normal flow the Lachlan waters did not on the surface reach the Murrumbidgee at all. At flood time the country at the junction became an enormous lake, covering many square miles, and that was the way the two rivers met. Furthermore, it had been his experience that in all the Riverina creeks and rivers when the water ceased to run on the surface, they had only to dig three, four, five, or six feet, in order to get a subterranean flow. The whole subject deserved to be investigated very closely in order to see its significance.

Mr. Anderson's address was full of matters upon which members might hold contrary opinions. The author's purpose was to bring about an active debate, in which members might bring forward conflicting theories or otherwise, as shown by their own experience, or by their reading. Mr. Anderson had thrown down
the gage, and had enunciated theories which gave ample scope for diverse opinions. Personally, he thought some of the deductions were very bold. One which was in direct conflict with preconceived ideas was that the flow from forest lands was greater than from denuded country. But Mr. Anderson had brought forward a mass of evidence to support his view, and if he was correct it was a deduction of great importance to the constructional engineer. The generally accepted theory was that as the country became denuded the flood flow increased, but Mr. Anderson had arrived at the exact opposite conclusion.

The discussion was then adjourned to the next meeting.

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**EXHIBIT.**

**A PARTICULAR CASE OF CORROSION.**

By Wm. Chas. Rowe,

(Vice-President.)

The exhibit submitted is a suspension link and pivots from a weighbridge laid down some nine years ago, subject to continual vibration due to road traffic, subject also to continual state of wetness in the weighbridge pit, and to the action of gases discharged from accumulated road sweepings in the pit.

The link is situated at the ends of the main transfer levers immediately under the hanging or connecting rod, by which their action is transferred to the weighing steelyard.

The link is of mild steel.

The pivots are of hardened tool steel.

When new the pivots are turned to a comparatively sharp point, and are provided with a square collar to enable a spanner to be used to remove them from the beams. They engage into a very shallow countersunk recess in the link not more than about one-eighth of an inch in depth.

The weighbridge main transfer levers are of cast iron.

The exhibited link shows that the steel pivots have by the action of corrosion sunk so far into the link that, instead of a countersunk hole of circular form, as originally, the corroded hole
DISCUSSION—WATER STORAGE.

The President considered that in so far as Mr. J. T. N. Anderson's first paper constituted an argument for extended storages on the River Goulburn, and particularly in its upper reaches, a good case had been made out. The author had shown that lateral storages like the Waranga basin could not operate to materially mitigate floods, but so far as he was aware that had not been contended, nor did he see how such a contention could be sustained. It was quite clear that no such storages could operate in such a way. No doubt the ultimate aim of the engineer must be to store the whole of the natural flow in such a way as to intercept the whole of the flood waters, to the double end of preventing the damage caused by floods, and of preventing the serious loss of valuable water. While this was the desirable aim on general principles, it remained for much closer enquiry and much
more minute analysis than had been bestowed upon the question by the author to determine to what extent and at what rate the large expenditure necessarily involved would be justified. In this regard, it must be confessed that the author's estimates were somewhat shadowy, and served only to show that the figures involved were enormous. He thought that the author could, with advantage to members, supplement his papers by a more detailed description of the hydraulic fill dams which he had mentioned, of their mode of construction, of their cost, and of the conditions which were favourable to that type of construction.

The Author's second paper was mainly an argument against extended shallow surface storages, and with this he was also disposed to agree very heartily. On a relatively small scale, but in a multiplicity of instances, this wasteful practice had come frequently under his notice in connection with the attempts of the Riverina pastoralists to store domestic and stock supplies. The practice was to dam the shallow creeks, thus lifting the water to the banks, where it lay, covering thousands of acres to depths of three or four feet, the bulk of the water being thus gradually dissipated by evaporation, while the flocks of down-stream proprietors perished from drought.

The Author was to be complimented upon presenting to the Institute so complete a contribution upon a subject of such vital importance to our rural development, and he trusted that it would result in stimulating the interest of the profession in this direction.

Mr. JAS. ALEX. SMITH desired to know whether Mr. Anderson could inform them as to the latest American experience and opinion in regard to hydraulic fill dams, when the material was wholly clay, not rock-fill.

Mr. J. S. DETHRIDGE said the members of the Institute were certainly indebted to Mr. Anderson for his paper on such an important and interesting subject. To the speaker as one of the Commission whose duty it was to deal with works for the supply of water for irrigation, the paper was of special interest. He was not in a position to discuss proposals for further storages or questions of policy, because these were matters at present receiving consideration by the Government. His remarks would be devoted principally to showing the wide difference between the actual revenue obtainable from the works of the Goulburn scheme
and that which might be inferred to be obtainable from the figures of Mr. Anderson stating the nett increased value due to new works at £29,400,000.

A brief review of the history of irrigation in Victoria would help to explain the position. The construction of irrigation works on a large scale in Victoria was commenced about 1886. Within the next six years the expenditure on them, together with accrued interest, amounted to about £2,000,000. During the early nineties there were several very wet years, in which there was small need for artificial watering. Financial depression told against the payment of interest and other charges, and a general feeling of want of confidence in irrigation spread. This feeling was intensified by the adverse tone of the report of a Royal Commission on the subject in 1896. In 1900, by Act of Parliament, not less than £1,500,000 of the expenditure on irrigation works was either written off or made free headworks; that is, works in respect to which no charge is made on the lands supplied for interest, maintenance, or management.

The great drought of 1902, when in many parts of the State the seed wheat did not sprout for want of rain, and stock died by tens of thousands for want of food and water, created a great wave of feeling in favour of water conservation and distribution. The Waranga Storage Works were commenced, and in 1905, under the guidance of the Hon. George Swinburne, an Act was passed making all natural waters the property of the Crown, and embodying the principle that districts supplied with water for irrigation should be made to bear the cost of the works for their supply. Since the passing of this law there had been active progress with works and settlement under the Goulburn Waranga scheme. There was, however, much leeway to be made up before the annual revenue, which now amounted to about £30,000, would meet the annual charges. On the present capital debit the return would be about 3 per cent. If, however, the free headworks and written-off capital be taken into account the return was only about 1½ per cent. The frequent protests in the Press bore witness to the fact that there was no lack of effort on the part of the authorities to collect the revenue to which the State was entitled.

Now the point for serious consideration was this—even with all the advantage of the natural flow of the river and free headworks the revenue was not yet sufficient to save the general taxpayers
having to pay part of the annual charges involved, and the bill for interest, maintenance, etc., that would result from the construction of storages must involve a higher price for water than that now charged.

By comparison with such sites as that at Burrenjuck on the Murrumbidgee, or the Roosevelt and Pathfinder dams in the United States, the sites on the Goulburn were not favourable. At Tabilk, Trawool, and Kerrisdale the rock was from 70 to 90 feet below the bed of the river. At the latter site a shaft was sunk, and a tunnel driven for a length of about 60 feet. The rock in the tunnel was a soft blue shale, fairly compact in situ, but when brought to the surface it soon decomposed. The foundation difficulty alone would probably not prevent construction in these cases, but in addition there were to be considered the great areas of river flats that would be submerged in all three cases; and in the case of Trawool and Kerrisdale the submergence of the important town of Yea, and many miles of the railway from Tallarook to Mansfield.

The Delatite Junction, or Sugarloaf site, had the advantages that the rock was practically at the level of the bed of the river, and the area of land that would be submerged was comparatively small. Attention was first drawn to this site by Mr. W. Greydon, a surveyor employed by the Water Supply Department in 1886; but many other surveyors had been impressed with its possibilities. The catchment area above the site was about 1,500 square miles, or two-thirds of the whole catchment above the Goulburn weir. Allowing for higher rainfall in the upper parts of the river, the run-off was probably about one-half of that at the weir. Mr. Anderson had stated the Goulburn flow at the weir as ranging from 660,000 acre feet in one year to nearly 4,000,000 acre feet in another. Granting that this was correct, there was the fact that the recorded gaugings showed that for a period of seven years commencing with 1890 the average flow was only about 1,500,000 acre feet. This period was usually taken as fixing the limit to the area of land that could be given an assured supply for irrigation.

As to the methods of construction. It was to be remembered that the presence of such important towns as Yea and Seymour in the valley below the site, precluded consideration of any method known to be attended by risk. The example of the failure of the Johnstown dam in America might be cited.
DISCUSSION—WATER STORAGE.

The behaviour of storages such as those suggested in preventing floods would depend very much on the time of occurrence of the flood. If this happened to be in the early part of the season when the storages were nearly empty, the moderating effect would no doubt be considerable, but if at the end of a wet winter, when the storages were full, their value for this purpose would be inappreciable.

In this discussion some mention had been made of the use of stored water for navigation. In a country where water had so high a value for irrigation as it had in Victoria, the use of stored water for navigation where such use meant flowing to waste was never likely to be favourably regarded. The construction of weirs and locks in the Murray would make navigation practicable without waste of water, but it was very doubtful whether the cost of such works would ever be warranted by the benefits obtainable. It was significant that river-side towns became comparatively indifferent to navigation when they secured direct communication with a capital or harbour by railway.

The President called upon Mr. Anderson to reply.

Mr. J. T. N. Anderson, in reply, said:—Concerning the earliest criticism from the President, that in proposing to use all the water to the last drop of the Goulburn River for irrigation, the great possibilities of inland navigation would be sacrificed, a few words of explanation were necessary. To compass such varied uses as irrigation, flood regulation, and water power, very considerable—in fact vast storages—were necessary, and to further retain the flow of the river for canalization might not be done without great expenditure and the sacrifice of some of the first-named interests. For a practical scheme to give returns that could be relied upon as safe to be realized, the lines adopted by the powers that be in the development of the country must be followed. This was along the lines of irrigation at the expense of other interests, and clearly this was the most natural and simple, as well as certain way to secure an early return in production for the money spent in the works.

Later on the navigation question would be returned to, but just here it was opportune to deal with Mr. Dethridge’s view that the storage capacity should be limited by the amount of storage that would be annually conserved during seven consecutive dry
years, such as those dating from 1896, and such would be only about one million acre feet for the whole Goulburn, and less than seven hundred acre feet for the proposed reservoir at the Sugarloaf Hill site.

It was evident, in the first place, that such storage unaugmented by further reservoirs would be quite insufficient to regulate floods. This Mr. Dethridge admitted with fact that the floods often occur in September. To the present audience it would be unnecessary to enlarge on the reasons why the bare irrigation storage would fail to have any practical effect on the mitigation of flood damages. Mr. Dethridge met this difficulty by saying that straightening the river and making levee banks would meet the flood trouble at an infinitely smaller expenditure. The author believed that his own experience was borne out by the best modern opinion, namely, that levee banks, to be effective, should accompany, not be in place of, flood regulating reservoirs, and this suggested a very serious aspect of the flood damage question, which, owing to the necessity of being brief, was not mentioned in the original paper, namely, the amount of riparian lands which were washed away, and absolutely disappeared after every heavy flood. Every such flood saw hundreds of acres of the very cream of the best lands in this State absolutely lost.

Mr. DETHRIDGE said there was no direct evidence of that.

Mr. ANDERSON, continuing, said, looking into the question casually, and comparing it with the other damages at the time it happened this did not seem so serious a disaster, because the observer only came on evidence of this damage piecemeal—here a rood or so on one side of the river, and there a few perches washed away on the opposite bank—perhaps seldom more than an acre in the aggregate over a mile of river. But when these damages were totalled over the hundreds of miles of rich river frontage on the Goulburn, it would be found that in many a winter far more than one hundred acres disappeared in this way. The bulk of the country a little way back from the Goulburn was of second class quality, and without the river flats, many comfortable farmers would be hardly able to make a living. The fact that the two classes of land could be worked together gave an altogether peculiar enhancement to the value of these flats—land that otherwise would not command more than £15 to £20 an
acre would often be worth far more than double that to the owner. Unluckily these lands were not numbered by as many thousands of acres as the other lands were by the tens of thousands, and the loss of a hundred acres of such land was far more serious than the loss of a thousand acres of land further from the river. Without going into the general question of whether levees, such as Mr. Dethridge advocated, could be satisfactorily constructed in all cases along the Goulburn and for the sum he assumed (£70,000), the author would point out that this feature of flood damage (bank erosion) would in no way be mitigated, since the levee banks must be above and beyond the river banks, and on the contrary, the effect of levees, in confining the flow of the heavier floods into a narrower water way might in many places actually aggravate the erosion damage. It would be found, as stated above, that most authorities now held the view that regulating reservoirs should go hand in hand with levee banks, and holding this view strongly the author had not hesitated to push to the utmost the wisdom of going far beyond the provision of reservoir capacity just enough to equalize even so long a period of light rainfall as the seven years which Mr. Dethridge had quoted. There were many reasons why reservoir capacity should be based on a long average—and why even if reservoirs should go over a period of more than seven years without once becoming brimful, they must not be considered wastefully large. The speaker had tried to show that irrigation uses could be made to go hand in hand with other uses, and obviously even in the case of hydraulic power this was hardly practicable except by very considerable reservoir capacity, and clearly reservoir capacity sufficient only to regulate the flow of the river, based on such years as the seven cited by Mr. Dethridge would utterly fail to give any effective flood regulation. The value of flood regulation, as the author had shown, in improving the condition of the river flats was £2,000,000. Now one item of expenditure the author omitted from his details, though it was covered by the large general provision for contingencies and unenumerated items, was the cost of the levee banks on the Goulburn. Except some 30 miles which he estimated for, he had no details of this, and was glad now to have Mr. Dethridge estimate that they could be constructed for £70,000. Deducting this £70,000 from the estimate of the benefit due to large flood regulating reservoirs, there was a sufficient balance left, viz., £1,030,000, to pay for the
excess cost of the larger reservoirs the author advocated. But apart from all other ancillary benefits such as this, having regard only to irrigation, the ultimate need to store the full quantity the author aimed at, would be seen so soon as the lands commanded by Goulburn irrigation were occupied to somewhat near their capacity. Then assuming that a dry cycle of years, such as the 1896-1903 cycle, should recur, the difference between the full reservoirs with which that cycle started, would represent one and a half million acre feet (2,500,000 by the author's proposal and 1,000,000 by Mr. Dethridge's). Assuming the water as economically husbanded, and this meant 200,000 acre feet additional available each year of the drought, but in any case it meant that during a period when irrigation would be in the greatest demand, and prices so high that a pound an acre foot would be gladly paid, there would be one and a half million acre feet available, owing to the extreme storage provision, worth £1,500,000 to the country. The author never contended that all the works he gave as the ultimate provision should be carried out at once. What he did plead for was that the foundations of the reservoirs should be made sufficiently wide and deep to carry the ultimately large-sized dams, and that sites for further extensions, such as the Trawool, should be purchased before their value was enhanced by the other works. Mr. Dethridge had done good service in showing how terribly hampered were all projects for large works by the statutory provision that each new work must show an immediate interest return.

As to what ought reasonably be provided for in the Goulburn Valley, he was unable to follow the view that as nobody forty or fifty years ago could have anticipated the marvellous growth of Melbourne, so it was impossible to forecast what was in store for irrigation in the Goulburn.

On the contrary he regarded it as the business of the engineer statistician to so forecast, and in many instances the realization of such forecasts were largely due to the engineer himself. In making such forecasts, his wider outlook, and more intimate knowledge of the factors in the growth of the community he worked among, would make the engineer's estimate more reliable than those of the office statistician.

For examples of successful estimates of growth in population and wealth, it was not necessary to cite Bateman (Manchester), or
Bazalgette (London), but taking the city quoted, Melbourne, the author well remembered one of our own former members, the late William Thwaites. After in 1894 revising the estimates of Mr. James Manseigh, made while the effects of the land boom were still intoxicating, the statisticians drew up charts showing Melbourne’s probable growth, and these would, by comparison with subsequent census returns, be seen to be wonderfully close to the figures actually reached up to now.

The author had no hesitation in saying that unless its natural growth was unduly interfered with, Victoria must in between twenty-five and thirty years hence have a population of at least three millions, and going further, surely if irrigation was to realize all we looked for, the first and most favoured irrigation area, viz., the 2,500 square miles of the Goulburn and Campaspe Valleys, would carry at least a tenth of that population. When that happened, the anticipations of the speaker would be realized.

The consideration of works which must come long before this twenty-five years was spent, and which should be carried out piece-meal during the next, say, twenty years, was undoubtedly well within the scope of practical politics to-day.

The contemplation of the results of ample provision for unlimited irrigation growth within this period and the result—say seven hundred thousand (700,000) acres, occupied by 300,000 people, led back to the navigation question. To have estimated the value of the cheap water-borne traffic to this population had it been made, might perhaps have laid the author open to attack for trying to look too far ahead, consequently he had not anticipated the President’s suggestion to consider navigation, except to mention possible favourable conditions for navigation, which followed flood regulations. But what would happen could be forecast without going back to the history of water transport in Egypt, India, or China. We had the effect on irrigation lands in Mildura. Were it not for the river traffic the settlement would never have existed, and then when it was found that, sometimes, that traffic could hardly be relied on for more than five months in the winter, a season when only a part of the produce could be exported, the settlement languished until the railway reached it. Since then land values had more than doubled. The success of Mildura largely depended on its two means of traffic with the outside world.
To consider the case of the Goulburn Valley assumed that instead of paying 12/- or 15/- a ton by cartage on railway to reach their nearest markets, their produce could be transported by water at 5/- a ton, then, instead of being confined to produce only high-priced articles, such as fruits, cheese, butter, etc., they could profitably grow heavy crops of fodders, sugar beets, and such like, and the wealth of the district would be immensely increased.

The point was that instead of irrigation development destroying navigation, it opened up fresh possibilities for the growth of navigation. On the Goulburn itself there was not and never would be much real navigation, and after irrigation had diverted the water, it would be little more than a dry ditch. But the irrigation channels would extend through the heart of the most populous districts right on to the Murray River. The larger channels would be maintained at all times full, and the alterations necessary to make them navigable would not be sufficiently serious to prevent the natural demand from being given effect to.

The development of manufactures, and other profitable uses for the electric energy which the author estimated on, would bring further wealth to the district. Lord Bacon’s estimate that commerce brought opulence, manufactures wealth, and agriculture a competence, was still true. And in the proper development of this district there was room for all three. Therefore he saw no reason to abate his estimate that the irrigated lands would be worth £100 an acre. On the other hand he might enlarge this, and show that at least as much more of the contiguous lands would also increase greatly in value. Looking not only, as he did, at values at present in Mildura, but at values in every country where he had had occasion to know them, where population rose to 300 people in the square mile, he knew no place, neither in Great Britain, the Netherlands, or North America, where such lands would have a less value than £100 an acre, and that, notwithstanding the fact that in most of those countries money had a greater purchasing power than in Australasia. For instance, in Mexico wages were 1/9 a day. Finally turning to Mr. Smith’s statement that the rate of £10 per annum as the value of horse power working continuously was rather high, and that the coal costs alone would be only about £2 per annum. The author was prepared to accept the cost of £2 per annum as reasonable for coal per indicated
horse power. On an assumed 80 per cent. load factor, this worked out at only the pound of coal per indicated horse power per hour, and taking coal at 12/- a ton.

Mr. J. A. Smith said that with a large installation and producer gas it might be as low as .6 of a pound per hour, and the power would be produced when, and as required.

Mr. Anderson said: Granted, but the additional capital cost, and cost of renewing parts, and other charges made a great difference. The point, however, which the speaker had not brought out as he should have was that the estimate was for power delivered to the consumer, not for theoretically developed water horse power or indicated horse power. And taking the case of the Trawool Reservoir, assuming its variations of level at 130 feet head down to 30 feet head, and integrating the heads, and combining them with the volume integrals plotted from the area contours—

\[
\frac{4400}{8.8} \int \frac{h_2}{h_1} \int \frac{a_2}{a_1} \frac{dh}{dt} \frac{da}{dh}
\]

it would be seen that, taking this flow as 4,400 cusecs for the six months the reservoir would be discharging, the horse power would work out at 50,000. That was the limit, and meant over 30,000 horse power in electric leads in Melbourne. It would be noted that even when boosted up with the water powers available from the tributories, the author had limited his estimates to 25,000 horse-power.

For comparative purpose he would call attention to the fact that, making similar allowances for contingencies, such as losses in transmission and irregular load factors, the coal bill would be nearly doubled.

Rock-fills: In answer to Mr. Smith's question. The most recent hydraulic fill dams depended entirely on the clay hearting between stone and gravel to give the water-tight character not only to the embankment part, but to the foundation trench (puddle trench, as it used to be called).

He had at the preceding discussion promised to give as an appendix or supplement to the paper some further account of this type construction. Had the members, as he had, tested
a dam, the upper at Nexaca, known as the Tescopa, some 65 to 70 feet high, they would have had the same confidence in the method. The test had been arranged for Sir Scott Moncrieff, and some other eminent hydraulic engineers who had visited the site a week or so before him, and consisted in comparing the level of the crest of the dam with the original profile levels. The end profiles were in stone, and could not sink. It disclosed the fact that, though finished eighteen months, and quite full, the bank had not sunk more than a fraction of an inch. Anyone conversant with earthen dams made in the ordinary way would know that usually the sinkage in such a dam could be measured in feet, and the complete consolidation of the dam during construction must be conceded to be the best possible guarantee of its stability. He could not think that Mr. Dethridge when he spoke of the Johnstown dam disaster in Pennsylvania (1886), a dam which had been constructed without the usual precautions, and made in very little better style than an ordinary railway embankment, could have meant to infer that such a dam was of similar construction or comparable with a modern hydraulic fill dam.

Mr. J. S. Dethridge said that he had only mentioned that disaster incidentally as showing the damage that the failure of such a dam might effect.

Mr. Anderson, continuing, said that if properly constructed he would have almost as much confidence in allowing water to flow even over the top of an hydraulic fill dam as over a masonry dam, and that he knew of no records of failure of any properly made hydraulic fill dams.

As to Mr. Dethridge's remark about the recent flood having in places been as great a benefit as a damage to the riparian owners, he asked if this was not entirely exceptional, and owing to the very short duration of the flood, as well as the late season of the year when it occurred. Sufficient storage for floods could be left in reservoirs up to August, and for irrigation the September rains could be relied on to fill them, since flooding them was less damaging, but in any case no one reservoir could satisfactorily effect flood regulation. What was wanted was reservoirs of varying capacities in the different tributories, and these would so
far unequally check the rate of progress of floods, that a simultaneous rainfall over the whole watershed would fail to give synchronising effects on the main stream.

The subjoined diagram illustrated a typical hydraulic fill dam:

Discussion closed.

METALLOGRAPHY.

The President declared the discussion on Major R. Law’s paper on "Metallography" open, and invited visitors to take part therein.

Mr. A. J. Higgin said that Major Law had explained the subject of Metallography in an admirable manner. It was a very large subject, but Major Law had contrived to touch upon all the important points in a short space of time.

Without wishing in any way to detract from the value of the microscopic examination of metals, he would like to point out that there were limitations to its usefulness. There were, for instance, certain cases in which steel failed in the mechanical tests, but when examined under the microscope revealed no flaws. This seemed to be very mysterious, but it could be explained. When a mass of molten steel solidified it crystallized, and the divisions between the crystal grains could be seen under the microscope. The crystals would adhere, providing that nothing was