PAPER
PREVENTION AND MITIGATION OF FLOOD DAMAGE.
By Mr. J. T. Noble Anderson (Past President).

Introductory.

The present paper can only set out the chief arguments in this great subject—a subject of the most vital importance to the future of our great continental island. The Institute has done well to bring it forward just when we have passed through one of those unusual seasons which the public vainly imagines will not recur. Only last year the snow in Rome, and the earthquakes, which two thousand years ago inspired the "Annus Mirabilis" of Horace, were repeated; and,—so little do we to-day remember the past,—it was authoritatively given out that snow had never before fallen in Rome.

Unfortunately, the fatuous public is only too easily persuaded, when the immediate smart of the last losses is mollified, to believe a recurrence of the damage is so remote that half measures are justified. And economic actuarial figures can always be used to support this view, which, though specious, will not stand critical analysis. But that show of economic engineering which helps popularity, and plays into the hands of temporising politicians, again and again gets the vitally important work postponed.

Recurrence of Floods.

In our case here, added to the fact that our records of eighty years alone make it rash to assume that peak floods may not be repeated "once in a hundred years"; the last most damaging flood* which has visited us since 1870, would have been much worse had it not been that the tidal and wind conditions which aggravated former floods were entirely absent. The fact remains that, like so many instances of the past, where civilisation ruthlessly invades virgin country, it brings about its own destruction. Every new channel opened up for drainage or navigation, or for ill-advised attempts to prevent flooding, or to reclaim land from bay or lake, aggravates the incidence of floods to those below. Our bridge engineers have incidents of bridges washed away by having too narrow waterway between them, which have been replaced by wider, and those by again wider, and yet all washed away. In one case in Southland, New Zealand, in less than fifty years one bridge had to be replaced five times. Also, on the recurrence of floods, much has already been given before

*5th December, 1934.
this Institute, and records of floods apparently as severe are as follows:—Three prior to 1870; and, since the 1891 flood, which precipitated the widening of the Yarra above the Falls Bridge, there have been three floods in Northern Victoria, and one on the Yarra, 1923, which have rivalled the great 1870 flood, each in their own particular district.

In Victoria the flood experiences between 1854 and 1871 all were mainly due to two causes—the clearing of timber land and the blocking of waterways by fallen timber. So serious did the matter seem that the Victorian Railways, to prevent disastrous recurrences, constructed all their bridges with more than ample waterways. Luckily, timber was still very cheap in those days, and many of these, such as the Yarra Glen Bridge, over 1½ miles long; the Tallangatta Bridge (Mitta Mitta River), and the Tarwin Bridge, on the Great Southern Railway, are now, when the timber is gone, being replaced by shorter spans.

The first voice raised against the extravagance of this panic was due to a joint investigation by Professors W. C. Kernot (Melbourne) and Warren (Sydney), when Professor Kernot read a paper before this Institute showing how, in a rough rule of thumb adaptation of the then celebrated Colonel Dickens formula for maximum flood discharge:

\[
\text{Discharge in cusecs.} = \frac{\text{Constant (arbitrary)} \times M}{L^{3/2}}
\]

Where \( M \) = square miles
\( L \) = river length in miles.

For simplicity, Kernot assumed a velocity of five or six feet a second, which is a normal river flood velocity, and gave the very simple formula—

\[
\text{Area of waterway} = 40 \times M^{3/4}.
\]

Obviously this would not well apply to rivers running in narrow gorges, nor in tropical countries, where the rainfalls correspond to the cloudbursts which occasionally, on a small stream, upset all calculations, but he showed that not one single bridge out of more than a hundred cases investigated in Victoria would have failed if even so small a constant as 40 had been used in his formula. Hence, as a rough approximation, I have always used this formula, and where the area has been less than one square mile, increased the bridge clearance area from 50 to 100 per cent., according to the relative steepness of the watershed and of the channel where the culvert is situated. Working with this rule of thumb as a check on other calculations, in

*Any bridge of less than 20-feet span I prefer to call a culvert.*
several hundred cases, I have only known half-a-dozen where the bridges have washed away, and in every single one of these my proposal had been rejected as too expensive, and I had passed on the work to other engineers to prevent my earnestness being doubted.

The Chief Cause of Loss.

Great as the trouble due to the dislocation of transport from the washing away of bridges and banks undoubtedly is, every engineer knows that this is only a very small destruction compared with devastation of arable lands, and the consequential permanent damage to all the meteorological and physical characteristics of the country.

As I pointed out before the Institute in 1913, there are many other causes besides deforestation which operate. Every civil engineer must have sufficient knowledge of the Pleistocene and Paleolithic periods, as well as the modern physical geology, to know that far the greatest factors in "laying low the mountains and filling the valleys" have been floods and droughts. My hope is that these papers may give occasion for so earnest a discussion on these matters that the possibility of not only preventing the destruction from floods, but also the certainty that such desolation may not follow our educated civilisation as wiped out at least half-a-dozen prehistoric civilisations between China and Northern Africa through ignorance of the results of their own actions. In recent times the dwindling of Spain's prosperous twenty million people to one-third in 100 years in the sixteenth and seventeenth centuries followed the wholesale devastation of forests, and the loss of millions of Chinese lives in the last 100 years was due to indiscriminate piling up of river levee banks. These are outstanding lessons for us.

An example that every country engineer should point out to the farmers in hilly and undulating country is the manner in which plough furrows, if not run across the line of fall of the paddocks, tend to create fresh channels for the storm water to flow. This storm water, encountering broken soil, which readily scores out and creates deeper channels, which ultimately deepen and broaden out into deep gullies, not only damaging arable value by breaking the paddock into isolated smaller areas, but draining out the subsoil. This subsoil is the natural water reservoir, without which half of Australia would be a desert.

The critic may plead that this reservoir will be tapped by so many fresh springs, and that the river beds below will have an improved summer flow. This, if it occurs at all, as seems likely,
means that ultimately, when prolonged droughts occur, the subsoil water, being lower than ever before, rivers which were never dry before would run dry. This has occurred in the Goulburn twice in the twentieth century.

Comparison of Australian and Northern Climates.

The perfectly valid objection to assuming that our conditions are at all parallel with those cited from the Northern Hemisphere, where the summer half of the year is seventeen days shorter than our winter half, and where, in consequence, the earth’s surface has aged many millions of years less than our antipodal parts of its surface, means that, instead of our learning from them what is likely in the future to happen here, it is for them, studying our condition, to find what will happen there.

This is true, but the evidence is that, while we are less subject to seismic damage, we are far more subject to devastating droughts, with their companion floods. The late Professor David and others have attempted to link our periodicity with sun spots, and the 34.5 year periodicity of the Nile, the Caspian Sea and the Danube; but, on the discussion of a paper I read before this Institute, the late Mr. Barachi (Victorian Government Astronomer) gave, as a result of exceptionally close analysis, that the only thing certain about our climate was that it would not follow any certain periodicity.

All this is aside from the present problems because the great forces of nature, the laws of gravitation, and the organic chemistry of matter are universal. And we are confining our attention to the influence of an element (water) which is the main cause of the damage to as well as the building up of our material wealth. And its action is assumed to obey these laws of nature everywhere.

Historically, for us much may be learned from the digging of the Americans with the late Lawrence of Arabia on the Tigris and Euphrates, where they exhumed records of civilisations wiped out by two things—the silt of floods, in one case at Ur, measuring thirteen feet deep, and the shifting of river beds from their original channels. Scott Moncrieff’s work was mainly to restore with modern silt-scouring schemes. Giekie warned the American people that the Gulf of Mexico annually receives over six million cubic yards of the richest soil of their continent. Happily, to-day, this is one of the most important cares of the military engineers of that country.

Reference has frequently been made to the futility of levee banks alone. These, to be effective, should be accompanied by

§There is, however, a close general sequence between mean annual temperature in both hemispheres—which obviously is due to extra terrestrial influences.
reservoirs in the hilly and undulating countries above, from where the silt is primarily borne. The case of the Colorado River will be dealt with in greater detail in a later paper. In the meantime, however, mention must be made of the great Roosevelt Dam, just completed, the largest structure of its kind yet erected, at a cost of one hundred and sixty million dollars. Its capacity will be large enough to save the country below from flood damages, and it is expected to show a working profit from the sale of irrigation water and the one million electric horse power it is to develop. It is of the greatest interest to record that the siltage up within level banks below this river, which from Yuma to the Californian Gulf forms the international boundary between the United States of America and the United States of Mexico, shifted that boundary 22 miles, thus annexing, it was claimed, valuable Mexican territory to the U.S.A. Happily, the dispute was submitted to the impartial arbitration of Canada, our sister Dominion. Thanks to this immense reservoir, in which the provision for silt deposition is such that it can never cause trouble, this problem is finally settled. There is perhaps, not even excepting India, no river where greater storage capacity for irrigation and flood control had been already developed than this Colorado River. Already the storage from dams directly on the river and its main tributaries aggregate the enormous total of fifty million acre feet, equal to say fifteen times the annual discharge of the Murray River at Mildura, and it is worthy to record that to Mr. Elwood Mead, as much as anyone else, is due the credit that the joint Governments found the money for the great works on the Murray River.

Here I venture to predict that a beginning has only now been made; but I forecast an expenditure of £20,000,000, though at the time Mr. Elwood Mead (1912) limited the request to the Parliaments at £4,500,000. To-day that sum has been almost trebled, and when all the subsidiary works are completed it will be found that £40,000,000 will have been well spent. On the Goulburn I was taken to task for an estimate of £1,500,000 for Reservoirs directly on the river bed to give a capacity of 700,000 acre feet. One reservoir alone has cost already more than this sum, and the total storage on the river is only half that estimate.

The Value of River Silt.

In all great problems there are two sides to be considered. It is not always that the lower flats are damaged by the deposition of infertile mud, or deep banks of river gravel over their surface; e.g., in the valley of the Po, in Lower Egypt, in many parts of China, and in the lower Ganges. In these places the two great
fertilisers, hot sun and irrigation, have combined to give tenfold the benefit that the erosion either in the hills or among their own fertile flats has ever destroyed. To a large extent all these depend on the deposition of solid organic matters to supplement their other efforts to fertilise the soil. The jealousy of the modern state of Egypt at the British efforts to supply Upper Egypt, Dongola and the Sudan with irrigation water from reservoirs is one of the large factors in disturbing international policy to-day. An immense amount of the richest silt coming to Egypt comes from the Blue Nile (Abyssinia), while the White Nile, flowing slowly through hundreds of square miles of morass, brings little flood water, and can easily be maintained at its dry weather flow by water diverted from the floods of the Blue Nile, thus robbing Lower Egypt, it is claimed, of much of the Nile’s fertilising value.

In 1911—see Vol. XIII. of our Proceedings—I gave the estimate for raising Lake Tzana as giving a storage of 33 million acre feet. Since then political reasons have abandoned this scheme, and estimates are given of 4½ million acre feet, drawing off flood water by lowering and widening the outlet, and not appreciably altering the flood level.

"Darn the Rivers and Blast the Rocks."

The value of dams to control floods was a problem which first came into modern engineering when navigation and industry, under the stimulus of rapidly increasing populations in the latter half of the eighteenth century, incurred great increases of population in the great cities such as London, Bristol, Paris and Hamburg owing to later transport over canals. Not only had the river flats to be protected, but the canals introduced a new engineering problem—often having to draw their water from reservoirs.

The full force of their progress was first really felt in "the hungry forties," when the railways superseded the canals, which most of them ultimately bought out. Such great flood prevention works as on the Rhine and the Rhone owe their fruition to this period, and a toast popular seventy or eighty years ago in the Institution of Civil Engineers was something like this: "To the Civil Engineers: May they dam the rivers and blast the rocks!" Epigrammatically this gives the only prescription for flood control.

Flood Mitigation.

This subject is, if possible, more important than flood control; and, because it is more subtle, it is less understood. Everyone seems satisfied that reafforesting was the proper panacea. Like
all panaceas, it should only be adopted under the most skilful expert advice. The late Col. Chittendon, U.S.A. reclamation service, first raised a protest against the view that reafforesting would benefit the rainfall, and cited many startling incidents to the contrary. His officers, with twenty-five years' subsequent experience, have made out a good case from irrefutable experiments in the western States of U.S.A. Against this, the persistence of "Dew Ponds" throughout droughts is undoubtedly due to the adjoining trees. Personally, I have, from my own experience in the past twenty years, confirmed the American view so far, at least, as the spring run-off from pine forests is concerned, but then only in their first twenty or twenty-five years of growth, when the heavy carpet of pine needles prevents most ordinary rainfalls from reaching the ground beneath.

On the other hand, our own experience in the Yarra watershed seems conclusive that most of our eucalypts yield a very high percentage of the total annual rainfall in their run-off, which has been diminished where ferns have replaced the eucalypt trees. The whole question is most complicated and intricate, and calls for the closest observation. There cannot be any doubt but that the existence of the immense sand and gravel deposits of Australia, due to its immensely greater relative age than any northern country, have more to do with the small volume of our perennial streams. Here, in sub-tropical regions, we find vast river beds and lakes which, unlike the Arabian and Persian "wadys," do not flow annually, but only once for a year or so in a generation. Great as will be the future when our irrigation has been fully developed from large water conservation, the chief resource of the major part of Australia must depend on its subterranean waters.

Subsequent papers relating to this subject will be—
1. Works for Flood Control.
2. Works and Measures to be Taken for Flood Mitigation.
The President said it was evident, from Mr. Anderson's talk, that it was not sufficient merely to alter drains, but it was necessary to obtain a permanent scheme for the prevention and mitigation of floods at their source. He could quite understand Mr. Anderson's statement that he could not deal exhaustively with the subject in one lecture. There was a wealth of information to be gained on various phases of the subject, and they would certainly be looking forward to hearing Mr. Anderson elaborate the various points of his address in the very near future. The matter was of great interest to Melbourne and the surrounding country. The present was the time to put forward ideas that were not snapped judgments, but the results of thought and experience gained from similar occurrences in other countries during hundreds of years.

Mr. G. G. Robert, commending the paper, said he looked forward to further amplification of the paper. He compared the steady outward flow of the broad stream of fresh water from the mouths of the Rio Grande and the Amazon with the tidal rush up the estuary of the Severn.

The President said the Mississippi certainly was an example of Mr. Anderson's point. They had provided for a great deal of irrigation, and yet, with all their provision of levees, floods were very disastrous. It certainly was a trouble that had to be remedied at its source.

Mr. R. J. Bennie said he wished to express his appreciation of Mr. Anderson's paper. It was a matter of great importance, and it was extremely valuable that Mr. Anderson had brought forward the major factors that were responsible for floods, and had suggested in brief the natural lines, not necessarily expensive, and that might even be revenue-producing, for mitigating floods. The best way to mitigate floods was to prevent the occurrence of them, and, although that was not entirely possible, yet the suggestion put forward in the paper for the proper ploughing of the ground and the conservation of the forests were points of extreme importance. Anyone having the misfortune to travel along the Grand Ridge Road in South Gippsland would see the result of deforestation in that district. There was one little valley left at Bulga to show what magnificent forests had been destroyed. The rest had all been cleared, and the soil was also rapidly being denuded away, and the bare rock was becoming visible. Such land, under wiser control, would be reafforested. He looked forward with great interest to the second part of Mr. Anderson's paper, and to seeing the
first part in extenso in print. It would be of great value if
the public were educated in the value of such matters, for it
was questions of that type that would make or break a nation.
Because the damage being done was so insidious, it was some-
times not appreciated, perhaps for generations. If it were
allowed to go on indefinitely, the damage would be beyond
reparation.

Mr. W. H. Cumming said the problem had been attacked by
Mr. Anderson in a very able manner. It was a problem that
was puzzling many people to-day. He was particularly inter-
ested in the fact that Mr. Anderson had gone back to the
fountain-head of our flood difficulties—the fact that much of
the flood damage was due to our forest country having been
wasted. Another point Mr. Anderson had stressed was the
importance of the situation of settlements in forests. He did
not know that the case of Germany was quite parallel with
Australia, because one reason why they had fewer bush fires in
Germany was that they had a heavy rainfall. Forest settlements
were also a good thing, because when a person’s life and property
depended on his care in the matter of fire, the result was fewer
forest fires. He had read some years ago that as a result of the
levee banks of the Yangtse River being continually built up,
they were now about six feet higher than the surrounding land,
and, with a country with a crowded population such as China,
one could easily imagine what the result of a break in the bank
would be. The reference to ploughing reminded him of an
instance he had read, of arid country where every creek was
dammed. Those dams were assisted beyond the normal rainfall
by diagonal furrows running back from the dams and up the
hill sides. He understood the amount of water collected in
that way was surprising. He also remembered noticing illus-
trations of rice fields in Java which were all in terraced country,
and horizontal furrows were used. Another point in connection
with forest settlement was that it had been proved in older
countries that the number of people that could be supported per
square mile was considerably greater in forest country than by
agriculture. That had been substantiated by figures in Germany
especially. He was very glad to know that Mr. Anderson was
going to continue the subject, and he would look forward to
some very interesting material.