SESSION II.

1921.

NEW ZEALAND.

WAIMAKARIRI RIVER

(REPORT OF RIVERS COMMISSION ON).

Presented to both Houses of the General Assembly by Command of His Excellency.

REPORT.

To His Excellency the Right Honourable John Rushworth, Viscount Jellicoe, Admiral of the Fleet, Knight Grand Cross of the Most Honourable Order of the Bath, Member of the Order of Merit, Knight Grand Cross of the Royal Victorian Order, Governor-General and Commander-in-Chief in and over His Majesty's Dominion of New Zealand and its Dependencies.

MAY IT PLEASE YOUR EXCELLENCY,—

The Governor-General's Commission, dated the 8th April, 1919, directed us to inquire into certain matters in respect of the Clutha, Orari, Rangitata, Waimakariri, Ashley, and Maerewhenua Rivers, and such other rivers as might be added thereto from time to time. The Governor-General's further Warrant, dated the 22nd July, 1919, added to the Commission the Waihi, Wairau, Waiau-uha, Taieri, and Aparima Rivers. The present report deals only with the Waimakariri River. The reports upon the Maerewhenua, Clutha, Aparima, Taieri, Rangitata, and Wairau Rivers have already been presented; the reports upon the remaining rivers will be submitted in due course.

The time within which we were required to furnish our reports was extended by the Governor-General to the 7th June, 1920, further extended to the 7th December, 1920, and still further extended by Your Excellency to the 7th March, 1921.

The Governor-General's Commission directed us, in respect of each river,—

"(1.) To inquire into the cause or causes of the silting-up of the channel, the flooding of the adjacent lands by the said river, the erosion of its banks, and the damage to the surrounding country;

"(2.) To ascertain the nature and extent of the damage done to the lands adjacent to the said river, and what area of land is affected by such floods or erosion, or both, and whether it is practicable at reasonable expense to prevent such flooding or erosion, or both, either wholly or partially;

"(3.) To ascertain the best method of providing for the control of the said river and its tributaries so as to safeguard the lands affected, and to provide for the effective control and improvement of the said river and its banks;

"(4.) To ascertain the nature and extent of any drainage-works that may be required, and the best method of carrying out such works;

"(5.) (*a.*) To furnish estimates of the cost of such remedial measures as you may recommend should be taken for the effective control and improvement of the said river and its banks;

"(*b.*) To report what area or areas of land should be constituted a district in respect of which a rate may be levied to secure and pay the interest on and provide a fund for the repayment of any loan that may be raised to carry out any river-improvement works which you may recommend should be undertaken;

"(*c.*) To report your opinion as to what matters, if any, should be adjusted by legislation; and

"(*d.*) Generally, to report your opinion on all matters arising out of or touching the premises, including the question as to whether or not one or more competent authorities shall be appointed to control the whole or any portion of the said river, and what statutory powers should be possessed by such authority."

The Governor-General's Commission also required us to report separately in respect of each river.

Investigations made.

Sittings, Evidence, and Inspections.—After examining the various rivers in Otago and South Canterbury upon which your Commissioners were directed to report, they arrived in Christchurch on the 13th July, 1919, and on the following day proceeded with their investigations of the Waimakariri River.

In company with Mr. J. E. McEnnis, Resident Engineer, Public Works Department, Christchurch, your Commissioners visited and inspected the following points in the district: Kaiapoi, Stewart's Gully, the Main Drain, the Eyre, and the Cust. Also, accompanied by the Chairman of the Kaiapoi Harbour Board and the Harbourmaster, your Commissioners made an inspection by launch of the Waimakariri River below Kaiapoi towards the mouth of the river.

On the 16th and 17th July the Commission held sittings at the Courthouse, Kaiapoi, and received evidence from nineteen witnesses. On the 18th July a sitting was held at the Departmental Buildings, Christchurch, when nine witnesses were examined.

River Nomenclature.

In the following report the different portions of the main river and its branches, &c., will be referred to as follows:—

The "old north branch" refers to the channel leaving the main river opposite the top end of what is now known as Coutt's Island. It picks up the drainage from the Eyre, the Cust, and the Cam before flowing through Kaiapoi Township and rejoining the main river below. From observations made on the ground your Commissioners have arrived at the definite opinion that the so-called "old north branch" is not, and possibly never has been, in reality a branch of the river under normal conditions of flow, and that it is only during floods that the channel forming the "old north branch" comes into active use as a flood-overflow channel, having numerous subsidiary smaller overflow-channels of its own running off in the direction of Kaiapoi. It is not until this so-called "old north branch" picks up the drainage from the Eyre and the numerous small springs discharging into it that it becomes a definite river-channel joining the main-river outlet near Kaiapoi.

The "new north branch" refers to the existing branch, originally formed by artificial means, but which is now the main branch of the river, flowing on the north side of Coutt's Island, and between this latter island and Kaiapoi Island, rejoining the south branch just above the Empire Bridge to form the main river again. This new north branch is frequently referred to in the evidence and elsewhere as "the cutting."

The "south branch" refers to that portion of the river flowing on the south side of McLean's, Templar's, and Coutt's Islands.

The "main river" refers to the portions of the river above McLean's Island and below the junction of the new north and south branches just above Empire Bridge.

"Stewart's Gully" refers to that portion of the present main river about one mile below Empire Bridge and about one mile in length. The old south branch lies to the west of Stewart's Gully, and is now a subsidiary channel only.

"The Gorge" is situated at the point where the railway-bridge on the Sheffield–Oxford line crosses the Waimakariri River.

"Coutt's Island" is that portion of Kaiapoi Island which has been cut off from the latter by "the cutting" referred to elsewhere.

Physical Characteristics.

The Waimakariri River has its source in the high lands near Mount Rolleston, and, with its principal tributaries the Bealey, Poulter, Esk, Kowai, and Broken River, drains an area of approximately 1,000 square miles. In former years many thousands of acres in the upper portion of the watershed were heavily covered with bush; these hills are now bare, and shingle-slides discharging their debris into the tributaries are increasing both in number and extent. Although this river is to a certain extent snow-fed, the influence of the melting snow on the flood-discharge is not very great, and the big floods in the lower reaches of the river are mainly due to heavy rains coming from the West Coast. These westerly rains do not appear to extend east below the Cass and Mount White on the Esk; and, although no rainfall records are available, it is well known that these downpours are not only extremely heavy and prolonged, but are also fairly frequent, with the result that the Waimakariri may be flooded many times in one season. This latter fact is important as having a distinct bearing on the travel and deposition of shingle in the lower reaches of the river, as will be referred to later on.

The Waimakariri River, the total length of which from its source to the sea is about eighty-five miles, has the following approximate fall: From its junction with the Bealey down to its junction with the Esk, twenty-one miles, at 23 ft. to the mile; between the Esk and the Kowai, seventeen miles, at 33 ft. to the mile; between the Kowai and the top of Coutt's Island, thirty-two miles, at 29 ft. to the mile; from the top of Coutt's Island (old north channel intake) to Empire Bridge the slope rapidly flattens out, until from the Empire Bridge down to the sea, a distance of five miles, the slope is less than 1 ft. to the mile.

From the rapid flattening-out of the river-slope between the top end of Coutt's Island and the Empire Bridge, with the subsequent flat gradient down to mean sea-level at the estuary, it will be seen that the Waimakariri River differs from most of the other Canterbury rivers, which continue their steep gradients more or less down to their outlets, and consequently that the Waimakariri River is in a more advanced stage of river-development as compared with rivers like the Rangitata, for instance. This in a great measure may be due to the presence of Banks Peninsula, which, acting as a groyne protection against the influence of the heavy south-east seas, would thus assist in the more speedy formation and extension of the low-lying delta at the river-outlet. The existence of beds of gravel and small shingle underlying the river-deposited alluvium, at depths ranging from 100 ft. near the coast to 35 ft. on Coutt's Island, would seem to indicate that the extensive river-flat or flood-plain had been originally laid down on a sinking shore, and that this had subsequently been raised to its present level. The river below the tidal limits has all the characteristics of a "delta river," with the tendency to form numerous branch outlets to the sea. The river for the last five miles or so has cut down to what is known as the "base level of erosion." Any future development of this portion of the river must inevitably be in the direction of gradually raising its bed-level from Coutt's Island down, the ultimate effect being to do away with the present rather sudden transition from a sharp to a flat river-gradient. Although it may take very many years to effect this alteration in the bed-gradient, it must be remembered that the causes operating to bring about this result are constantly at work, and are being augmented by protective works and other human efforts to control the river. Consequently it may be that the advancing toe of shingle below Empire Bridge, and the accretion of sand and shingle in both the north and south branches—but more especially in the latter—are evidences that the above-mentioned phase in the development of this river is now in progress.

In common with most delta rivers, the Waimakariri has in the past scoured out various overflow-channels in the endeavour to discharge its pent-up flood-waters across the low-lying country to the sea. Of these the old north channel, the overflow-channel at Chaney's into the Styx, the diversion of the south branch (known as Stewart's Gully), and the well-defined channels which leave the river higher up and run down to Lake Ellesmere and the Avon and through Christchurch, are the most important.

It is probable that a portion at least of the river-discharge did at one time flow down through the low lands now occupied by Christchurch, and empty into Lake Ellesmere, but that a local elevation of the land—of which there is reported to be evidence at Banks Peninsula—diverted the waters to the north. Wind-borne sand deposited in these old channels may also have assisted in raising their beds somewhat, but nevertheless they still stand at such a low level as to be a source of danger to Christchurch during abnormal floods. The danger lies not so much in possible damage to property in the city and suburbs, through breaching of the present protective works, as in the possibility of an abnormal flood taking charge of these old channels and forming permanent branches of the river in this direction, or at least scouring out the channels to such an extent as to make further protective works both difficult and very costly.

Regimen, Past and Present.

Past Regimen.—An old provincial map of uncertain date (plan No. 1) shows the Waimakariri River at a point about ten miles from the coast bifurcating into what is known as the old north branch—which, in our opinion, as already stated, is a flood-overflow channel only—flowing through Kaiapoi Township, and picking up on its way the drainage from the Eyre, Cust, and Cam swamp-outlets; the other, or south branch, flowing past Belfast and Chaney's, and rejoining the north branch just below Kaiapoi Township, the combined river then flowing down the estuary out to sea. The south branch was the shorter of the two, and from all appearances must have been the principal discharging branch of the river. At that time the south branch did not flow down Stewart's Gully. The map also indicates an overflow-channel from the south branch flowing into the Styx and discharging into the estuary near its outlet. At that time (probably 1860) Kaiapoi Island was bounded by these two branches, and the western extremity appears to have tailed out as a shingle-spit opposite the old north-branch intake. It may be noted that neither McLean's nor Templar's Islands, together with several smaller islands, are indicated on this map, although it is probable that they existed as shingle-banks at that time. In about the year 1863–64 the Provincial Government made two 12 ft. cuttings, half a chain apart, from the old north-branch overflow intake, following an easterly direction along the line of old flood-overflow channels down past Section 19907. At this time the flood-waters used to pond up at the old north-branch intake and flow over a portion of Kaiapoi Island into the south branch lower down; and it would appear as the most reasonable explanation—which is one also borne out by some of the evidence—that the object of the Provincial Government in making this cut was to prevent, or at least mitigate to some extent, the flooding of Kaiapoi Island. The result of this action, however, was finally, through the scouring action of successive floods, to divert the greater portion of the river-flow through this new channel and down into the south branch opposite Chaney's, thus cutting Kaiapoi Island in two, the western portion of which is now known as Coutt's Island. This new north branch rapidly became the main branch of the river, as it is in evidence that after the 1868 flood more water flowed in it than in the south branch. The old north overflow branch at its upper end is now silted up and overgrown with vegetation. About the year 1882 the main river—or, rather, what was then known as the south branch—took a new course through Stewart's Gully, rejoining the old north branch at a point farther down below Kaiapoi Township. Stewart's Gully has increased in width during the past twenty years, and is now the main-river channel.

Present Regimen.—From an engineering point of view the river need be considered only from below the Gorge. From a point eight miles below the Gorge down to the head of Templar's Island the fall in the river is fairly uniform, and

averages about 27 ft. to the mile. Below Templar's Island the gradient rapidly flattens out down to where the present north and south branches join above the Empire Bridge, at which point the mean bed-level of the river is practically the level of high-water mark. From here down to the estuary at its outlet the fall to mean sea-level is less than 1 ft. to the mile under normal conditions of flow. Plan No. 4 (plotted from cross-sections A to H, plan No. 3) shows approximately the existing condition of flood and low-water slopes with corresponding mean bed-levels in the present north branch between the west end of Coutt's Island and the Empire Bridge. From this it will be noted that there appear to be two well-defined shoalings or shingle-waves in that length. At the present time this new north branch is carrying the greater part of the water, both during normal flow and flood-flow. We have little doubt but that in the past the south branch was the principal channel, carrying most water, and that during the last forty or fifty years the conditions have been so changed as to have diverted the main river-current over towards the north bank and down this new north channel. This diversion of the main stream over towards the north has had a serious effect, inasmuch as it has resulted in a very considerable erosion of the north river-bank below a point opposite No. 12 groyne. (See plan No. 2.) Of the banks so eroded on the north side the portions up-stream above McLean's Island consist of high banks from 12 ft. to 16 ft. in height, while those lower down-stream are in most cases low, or just about flood-level, with level land at the back right away to the Eyre and Cust districts. The area of land so eroded and washed away since 1878 appears to have amounted to over 2,740 acres, in addition to some 1,000 acres eroded on the south side of the river; and it is therefore probable that, expressed in cubic measure, not less than 15,000,000 cubic yards of material has been eroded from both river-banks, partly to be carried out to sea and partly to be deposited in the river-bed lower down.

As to the cause of this swinging-over of the main river-current from the south side to the north side, three contributing factors, acting either singly or together—but more probably in combination—may be adduced. In the first place, it is a well-known fact that all shallow rapid rivers with shingly or gravelly beds change their channels alternately from one side to the other, gradually filling up existing channels with detritus and scouring out new channels elsewhere; and it may be that the regimen of the river had reached that stage when a gradual swinging-over of the main current to the north side had become a natural process in the life-history of the river. It may be noted in this connection that Mr. E. Dobson, C.E., in 1866 reported that the gradual accumulation of shingle in the south branch was diverting the great bulk of the water over into the (old) north branch, causing injury to Kaiapoi Island and Town.

In the second place, the construction of the numerous groynes on the south bank, with the consequent accretion of shingle, may have diverted the main current over to the north side, thus inducing it to cut out a new and defined channel for itself. Much evidence has been given in support of this theory, although in the nature of things such evidence must of necessity be unsupported by any direct proof that this alone has been the cause. In the third place, owing to the formation of the new and more direct channel for flood-discharge down the north side of Coutt's Island, the main current may have been, if we may so express it, "drawn over" to this side by reason of this new north branch forming a more suitable and rapid means of discharge. That the effect of the construction of the groynes on the south bank marked 1 to 12, but more especially the latter, has been more or less to divert the current over to the north side may, we think, be admitted; but, assuming the new north branch to have been non-existent, we think that the diverted current would again have swung over to the south channel through the subsidiary channels between McLean's, Templar's and Coutt's Islands. Seeing, however, that this new north channel had been formed some years prior to the construction of the groynes on the south bank, we are inclined to the opinion that the principal cause of the main current having been diverted to the north side has been the formation of the new north branch, and that the subsequent erection of the groynes has been a contributing factor in a minor degree only. What proportion of the total effect is to be ascribed to each contributing factor we consider it is quite impossible for any one to say.

The foregoing conclusions have been arrived at only after careful consideration, and the question has been discussed at some length in view of possible future contention between the controlling bodies on the north and south sides of the river as to responsibility for damage by erosion.

It will be noted on the longitudinal profile of the new north branch of the river (plan No. 4) that the river-gradient rapidly flattens out below the top of Coutt's Island, and for the last five miles of its course is flowing through the flood-plain on what is technically known as the "base level of erosion." Where such a condition exists the future development of the river must inevitably consist in a gradual building-up of its bed on the flatter portion, and at the same time a corresponding "corrosion" or erosion of its bed in the steeper portion, thus tending to equalize the gradient down to the sea, and to do away with the somewhat sudden transition from a steep to a flat gradient between the top of Coutt's Island and the Empire Bridge. The river-channel is already too constricted near the Empire Bridge to permit of the passage of a big flood-discharge on such a flat gradient, and consequently the flood-waters are ponded up at this point and tend to overflow the flood-plain. Should shoaling or building-up of the river-bed in this vicinity increase, the conditions causing ponding of flood-waters would, of course, be aggravated.

In regard to the deposition of silt, it is no doubt certain that the enormous amount of north-bank erosion, referred to elsewhere as being about 15,000,000 cubic yards, has greatly assisted in the shoaling of the river as it exists at present, although a great portion of it, being very fine material, may have been carried out to sea.

Evidence goes to show that the toe of shingle deposit (not sand) in the river-bed, which formerly tailed out some distance above the Empire Bridge, now extends down below the bridge; also that the south branch from Templar's Island down has been building up its bed, until now it carries very little water as compared with the new north branch. It is also in evidence that the shingle has been accumulating in the new north branch during the past thirty-five years, and is now of considerable depth. As an explanation of this fact the general opinion has been expressed that a greater quantity of shingle is coming down the river from the higher reaches than formerly. In our opinion this conclusion may be a totally wrong interpretation of the facts. The movement of shingle—as distinct from sand—in the bed of a river depends wholly on the bottom velocity of the current, the shingle being either rolled and dragged along the bed or else lifted by vortex or eddy-action and carried a short distance down-stream, or until the force of gravity deposits it again on the bed. This bottom velocity increases—other things being equal—with the depth of water, so that it is mainly during freshes or floods that there is any tendency to disturb or transport any but the very lightest form of detritus. Under ordinary river conditions the transportation of shingle by freshes and floods is comparatively small; were it otherwise we should find a heavy shingle accretion deposited during falling floods right down to the river-outlet, instead of which we find in the present case no shingle deposit much below the Empire Bridge. An extension down-stream of either shingle or sand deposits may be due simply to the number of freshes or floods within a given period being much above the average number, or the normal number of floods may have been of greater intensity or of longer duration; any one of these three causes would extend the shingle-toe to some extent, and would also, probably, on the average, shift the whole surface bed of the river a little farther down-stream. On the other hand, it is possible for sand or small gravel to be disturbed and transported a greater distance with a much less bottom velocity of current; and no doubt the shoaling of the river referred to by witnesses is mainly due to this form of material, and not to shingle. In some respects the accretion of fine material forming sand and gravelly shoal-banks is worse than if formed of heavier shingle, since the former when exposed at low-water stages becomes a ready habitat for vegetation of all kinds, thus making the shoal-banks more stable and non-erosive by subsequent floods. We therefore consider that the present shoaling of the bed already referred to is not due to any excess of rock material thrown into the upper reaches of the river, and which might take a thousand or more years to work its way down to the lower reaches, but we are inclined to attribute any increased shoaling of the river-bed in the vicinity of Templar's and

Coutt's Islands more to material introduced into the river through erosion of the banks, augmented possibly by an increase in the number of small floods within recent years, or since the drainage area has been denuded of bush and vegetation. Apart from this cause, however, there must inevitably be—as has been already pointed out—a tendency for the river to gradually shoal with sand and fine gravel and to build up its bed in this vicinity, where the gradient rapidly flattens out; and there is no doubt but that the present shoaling is an indication that this process is at present in active operation, and that it has been greatly augmented by material from the erosion of the river-banks.

From about three miles above McLean's Island right down to Coutt's Island the bed of the south branch is thickly overgrown with gorse and other vegetation. Evidence was given showing that north-east winds deposited a considerable quantity of air-borne dust and sand in the south branch; if this were the case it would materially assist in the rapid growth of vegetation. Winds from the south-west, by causing wave-action in the north branch, accelerate the undermining and erosion of the north river-banks.

The calculated mean velocity of flood-water is between 7 ft. and 8 ft. per second just above the Empire Bridge, in which case the bottom or bed velocity would be about 4½ ft., and it is improbable that any shingle greater than 2½ in. average diameter would be moved or transported under such conditions.

Bridges.

The bridge known as "Coutt's Bridge," connecting Coutt's Island with Kaiapoi Island, is 360 ft. long. The capacity for discharge underneath the bridge, based on a flood-slope of 1 in 1,200, is about 29,000 cusecs (cubic feet per second) with the flood-level 2 ft. below the bridge-decking. During floods the bulk of the water flows round the west end of the bridge and across the approach road.

The Empire Bridge is 550 ft. long, and the discharge capacity, with flood-level 2 ft. 9 in. below decking, is about 60,000 cusecs.

The railway-bridge crossing Stewart's Gully (main river-channel) is 811 ft. in length, and the railway-bridge crossing the old south branch is 386 ft. in length. This latter bridge was originally much longer, but was shortened when the river shifted to Stewart's Gully.

Floods.

The earliest recorded serious flood in the Waimakariri occurred in 1865, when the overflow from the river flowed down the old channels and flooded Christchurch, causing considerable damage.

The highest recorded flood in the river appears to have been in February, 1868, when the whole of the Canterbury rivers were heavily flooded. The Eyre and Cust Rivers were also in flood at the same time, and, assisted by the overflow from the Ashley River and the backwater from the Waimakariri overflow, seriously flooded Kaiapoi Township and the surrounding country. It was this flood which was mainly responsible for the scouring-out of the cutting made by the Provincial Government in 1863–64 through Kaiapoi Island, and making it the present north branch.

Another big flood occurred in 1888, and this flood also overflowed the banks on the south side and found its way via the old river-channels down to Christchurch.

Other big floods in the Waimakariri occurred in 1905 (next in size to the 1868 flood), 1913, 1915, and recently in November, 1920. The 1905 flood burst through the railway-line at Chaney's and flowed down the old overflow-channel there and into the Styx.

In addition to these floods, Kaiapoi has been inundated by local floods coming from the Eyre and Cust Rivers, and also by flood overflow from the Ashley River. As a rule, floods in the Eyre and Cust do not synchronize with floods in the Waimakariri, but this happened in 1868 and 1905. Since 1913 there have been no floods in the Eyre.

The cause of the principal floods in the Waimakariri appears to be severe rains coming from the West Coast; but, unfortunately, scarcely any information is available as to rainfall and other conditions conducing to floods. It is to be

noted, however, that on account of the frequent heavy and prolonged rainfalls from the West Coast the Waimakariri may be flooded several times in the year. It is in evidence that the Waimakariri during the past four years averaged two or three small floods each year.

Maximum Flood-discharge.—Owing to the absence of reliable records and sufficient data, and also to the fact that so much of the flood-waters escape over the river-banks and spread across country, we have found it difficult to arrive at even an approximate estimate of a big-flood discharge in the main river just below the Gorge. The cross-sections of the river (A to H) plan No. 3, with levels of a recent fairly big flood, show that in the main river-channel just above the Empire Bridge the discharge has been approximately 60,000 cubic feet per second; but, as this does not represent an exceptional flood, we are inclined to the opinion that, taking the drainage area and other factors into account, a big flood may be estimated as discharging at the Gorge not less than 80,000 cubic feet per second.

Whilst two floodings of Christchurch due to the overflow of the Waimakariri down the old river-channels are on record, there have been several occasions on which the flood-waters have risen dangerously near to the tops of the protective works erected to close up these old channels. From 4 in. to 5 in. between flood-level and top of stop-banks does not appear to provide much margin of safety, considering the interests at stake.

A reference to plan No. 5, showing the contour lines of ground-levels from 5 ft. to 100 ft., and also to plan No. 3, showing the flood-levels at cross-sections A to H, will make clear the ponding-action that takes place in the vicinity of the east end of Coutt's Island. This shows that while at cross-sections H, G, F, and E the flood-waters are bank high and possibly higher, below cross-section D the water is dammed up by the constricted outlet, until at Coutt's Bridge the flood-level is some 5 ft. to 6 ft. above the general ground-surface. This points to the necessity either for a greatly enlarged discharge-channel down to the estuary, or else for a flood-overflow channel of much shorter length with corresponding increase in gradient down to the sea.

Summary of Conclusions regarding Physical Features, Regimen of River, Floods, etc.

The following is a brief summary of your Commissioners' conclusions with regard to the above matters:—

(*a.*) The main discharge of river was formerly in south branch; now down new north branch.

(*b.*) The diversion is due partly to natural causes, but is mainly due to the cut made by the Provincial Government in 1863–64 resulting in the formation of the new north branch, assisted by groynes and the growth of shingle-banks on the south side.

(*c.*) The so-called "old north branch" is blocked up at the southern end by a stop-bank, and now provides no relief for flood overflow; its only function is to carry discharge from Eyre and Rangiora swamp lands.

(*d.*) Owing to the low banks on the north side it is possible for floods to cut into the back of groynes and other works now protecting the entrance to the old north branch. This certainly should be prevented.

(*e.*) The south-branch bed has been building up for years past, greatly due to the south-bank groynes and also due to the diversion of the main stream north. The south-branch bed is badly overgrown with vegetation, and now carries little water.

(*f.*) The new north branch is now in process of building up its bed, thus tending to increase the height of flood-level, with consequent danger of bank-overflow.

(*g.*) The river-channels are considerably restricted in the neighbourhood of O'Callaghan's Road, Coutt's Bridge, and Empire Bridge. This in combination with the flattened river-slope leads to ponding-up of water at the east end of Coutt's Island.

(*h.*) The river-channel below Coutt's Island is inadequate for a flood-discharge of 80,000 cubic feet per second, estimated as a big flood.
(*j.*) The erosion of the river-banks is excessive, and mainly responsible for the silting-up of the channels lower down.
(*k.*) The margin of safety is insufficient for the protection of Christchurch from big floods.

Existing Flood-protection Works.

So far the greater part of the protective work has been carried out on the south or right bank of the river, and the object in view has been the prevention of flood overflow down the beds of the old channels leading to Christchurch City—the Avon and the Styx. These works consist in the main of groynes, stop-banks, and willow-planting. The groynes, as a rule, are of a substantial character and well carried out, either in massive concrete blocks or in netted stone (gabion work). The stop-banks cutting off the old overflow-channels to the south-east are, however, in many places too low, and do not offer a sufficient margin of safety against the risk of big floods finding their way down to Christchurch. All this work on the south side has been carried out by the South Waimakariri River Board. This Board has, since 1869, taken steps which on the whole have been adequate for the protection of the south side of the river, and to assist them they have had the revenue derived from large endowments. Your Commissioners understand that it is claimed by the South Waimakariri River Board that these endowments were given for the protection of Christchurch, and that the revenue derived from them could only be expended on the south bank of the Waimakariri. A careful search of old records convinces us that the endowments were intended for the protection of the banks of the Waimakariri, no stipulation being laid down that either bank was to have preference. Although the South Waimakariri River Board was asked to produce evidence in rebuttal of this conclusion it was unable to do so. As at a later stage in this report—under reference No. 5—your Commissioners will recommend that both banks of the river should be placed under the control of one body, and this body will be either the South Waimakariri River Board or its successor, it will be a perfectly simple matter to have the revenue from the endowments made available for expenditure on either bank in the future, as necessity may require. These works were started in 1859, but the main work was not carried out until twelve or fifteen years later.

On the north side of the river much work has been done, chiefly in the direction of stop-banking along the low-lying river-banks opposite Templar's Island. Some of this work has been done by the Eyreton Road Board and the Eyreton County Council, but the most of it has been carried out by private enterprise. The Government has subsidized the work to some extent. No information is available as to the total amount of expenditure incurred in the past on protective works.

In connection with the responsibilities of the South Waimakariri River Board there is one aspect of the Board's action—or, rather, inaction—which requires comment, and that is their failure to keep the south branch clear of gorse and other vegetation, and thus—either wilfully or negligently—allowing the south branch to get into such a condition as to have now made the north branch practically the only branch of the river. This may have resulted in great benefit to the settlers on the south side of the river, but has been, and will be, very harmful to those on the north side. This is one more instance of the folly of placing the two sides of a river under separate control. Your Commissioners are of opinion that every endeavour should be made to reopen the south branch so that it may carry its fair proportion of the normal and flood flow. This is impossible until the existing mass of vegetation is cleared off the river-bed.

Damage by Floods.

Erosion of Land.—This, by recent survey, is estimated to be about 3,740 acres, of which about 2,740 acres has been eroded on the north side of the river and 1,000 acres on the south side. The capital value of this land may be put down as

averaging £30 per acre, making a total value of, say, £112,000. The total area of land between Kaiapoi and Rangiora affected by floods is estimated to be 7,500 acres, the value of which would average £45 per acre. It is claimed that immunity from floods would have the effect of appreciating 1,000 acres of this land by from £10 to £15 per acre.

In addition to the loss by erosion there are the manifold damages of other kinds usually resulting from floods, such as loss of crops, damage to settlers' houses and effects, damage to roads and railway-line, stoppage of traffic, &c., on which, owing to lack of sufficient data, it is impossible to put a money value.

Port of Kaiapoi.

The Kaiapoi Harbour Board owns endowments in Kaiapoi to the value of £6,000. The Board has no rating-power, and depends entirely on port dues for its revenue. Since 1914 practically no shipping has been done, but prior to that date a fair amount of trade was carried on for some years by boats carrying about 200 tons on a shallow draught. The bar has been shoaling for some years past, and now has a depth of only 6 ft. at high water. A proposal was made some nine years ago to spend £20,000 on a scheme of harbour-improvement, which it was claimed would, if carried out, deepen the bar so as to permit of the regular trading of boats having an 8 ft. draught. A table showing the imports and exports (by water) to and from Kaiapoi between June, 1910, and May, 1914, is attached hereto.

Much difference of opinion appears to exist among settlers as to the value or otherwise of a port at Kaiapoi, and as to what effect on the bar certain suggested flood-protection works might have if carried out. Many witnesses contend that the port is of very secondary importance compared with the saving of land and the prevention of flood-damage; with this opinion we most certainly agree. The district is well served by railway from Lyttelton; and, apart from the uncertainty involved in bar-harbour working, it is extremely doubtful if, in the matter of cost, sea-borne traffic could compete with railway carriage, except perhaps in a very few classes of goods, such as coal and timber; but even with respect to such possible exceptions as these the benefit would be confined mainly to Kaiapoi Township, and would not extend very far into the country districts along the railway-line.

Should works for the keeping-open of a permanent deep mouth be constructed in the future by the Harbour Board, the plans of these works should not be sanctioned by the Marine Department until they have been considered by the proposed board of control for the Waimakariri River, whose opinions should be given very careful consideration. Your Commissioners consider that the harbour-works can be constructed on such lines as will improve the harbour without hindering the discharge of flood-waters.

Local Bodies interested.

The local bodies interested in the control of the Waimakariri River are the Eyre County Council, the Kaiapoi Borough Council, the South Waimakariri River Board, the Waimakariri Harbour Board, the Rangiora and Mandeville River Board, and the Ashley County Council.

Land-tenure.

The greater part of the land affected by the Waimakariri River is freehold. All the land on the north bank is freehold, with the exception of two or three small reserves. On the south bank, reserves extend from a point approximately six miles below the Gorge to opposite Templar's Island, but most of the remaining land on this bank is freehold. Reserves and freehold land abut on the river in the vicinity of Kaiapoi. Most of the land on the islands in the river is freehold, but there are also reserves and Crown land in the river-bed.

REFERENCE No. 1.

To inquire into the cause or causes of the silting-up of the channels, the flooding of the adjacent lands by the said rivers, the erosion of their banks, and the damage to the surrounding country.

Your Commissioners attribute the silting-up of the river-channels to the natural tendency of the river to build up its bed on the flattened gradient in the vicinity of Coutt's Island. This is simply a phase in the life-history of the river, which must inevitably continue; but we are of the opinion that the amount of shoaling which under ordinary conditions would have occurred has been vastly increased by the amount of detritus emptied into the river through bank-erosion during the past thirty or forty years. A greater number than the average of small floods may have assisted to bring about the result. On this latter point we have no direct evidence, but it is quite possible that the destruction of large areas of bush and other growth in the upper drainage areas may have been the cause of a greater number of freshes and small floods, which, while insufficient to transport heavy shingle or gravel, might bring down a large quantity of finer material. We are also of opinion that failure to keep the river-beds clear of gorse and other vegetation has assisted in rendering any shoaling or sandbanks more stable and permanent.

The flooding of the lands adjacent to the river is in some cases due to want of proper stop-banks, or to stop-banks being of insufficient height. Towards the lower end of Coutt's Island, however, the flooding is, in our opinion, caused mainly by the ponding-up of the flood-waters due to inadequate channel-outlet on the flattened gradient below.

Flooding of Kaiapoi and the surrounding country is also caused in some cases by local floods in the Eyre and Cust, also by flood overflow from the Ashley River. The former is mainly due to insufficient height of stop-banks, coupled with inadequate outlet at the lower end near Kaiapoi, while the latter is due almost wholly to want of proper stop-banking on the south side of the Ashley River.

REFERENCE No. 2.

To ascertain the nature and extent of the damage done to the lands adjacent to the said rivers, and what area of land is affected by such floods or erosion, or both, and whether it is practicable at reasonable expense to prevent such flooding or erosion, or both, either wholly or partially.

The damage done by floods consists in—(i) Actual erosion of land on the river-banks; (ii) damage to crop and other improvements on the land; (iii) damage to house property and furniture, tradesmen's stock and fittings; (iv) damages to the railway-line, roads, and bridges; (v) damage due to loss of railway and road traffic, and also to general dislocation of business and farming operations, &c.; (vi) there is, in addition to actual damage, the ever-present risk of damage to Christchurch, and also to other portions of the district not hitherto flooded, due to the possibility, under existing conditions, of the river breaking through inadequate protective works and scouring out new overflow-channels, or of again reverting to old channels.

The area of land eroded amounts to some 2,740 acres on the north river-bank, and about 1,000 acres on the south bank, the estimated total value of which is £112,000.

With respect to the other kinds of damage done by floods we have insufficient data on which to form any estimate of the money value, and can only express the opinion that during the past fifty years the total amount would be very considerable.

Your Commissioners consider that it is practicable at reasonable expense to prevent to a considerable extent the erosion of the river-banks now taking place, and also to prevent—if not wholly, at least partially—the flooding of the lands in question.

REFERENCE NO. 3.

To ascertain the best method of providing for the control of the said rivers and their tributaries so as to safeguard the lands affected, and to provide for the effective control and improvement of the said rivers and their banks.

The remedial measures recommended by your Commissioners under this reference may be divided into four headings, viz.—(*a*) Works to safeguard Christchurch from flooding; (*b*) works to protect river-banks from erosion; (*c*) works to prevent or mitigate ponding-up of flood-waters near the lower end of Coutt's Island; and (*d*) works to prevent or mitigate damage by flooding from the Eyre and Cust.

With respect to (*a*) we recommend the strengthening, and raising to a height above flood-level sufficient to give a good margin of safety, of the principal stop-banks safeguarding the intakes to the old river-channels running down to the Styx, the Avon, and Christchurch. It is advisable that a margin of at least 2 ft. should be allowed between the top of stop-bank and the level of the highest recorded flood; also that the width at top should be not less than 4 ft.—preferably 6 ft.—with side slopes of not less than $1\frac{1}{2}$ to 1 on the river side, and on the opposite side up to 2 to 1, dependent on the height of bank. It would appear that the existing groynes are, so far, ample for the purpose intended, except that they should be raised to the same height as the stop-banks referred to immediately above; but the necessity for and the position of any additional groynes and stop-banks for the further protection of the old channels leading to the Styx, the Avon, and Christchurch is only to be determined by observation and experience during future floods.

With respect to (*b*), the works necessary for the protection of the river-banks from erosion lie chiefly on the north or left bank, and extend from a point about one mile above McLean's Island for a distance of about eight miles down-stream, although possibly only half this length requires urgent attention at present. The class of work which we recommend should be adopted for this north-bank protection consists in the construction of permeable (not solid) groynes of short length but at fairly close intervals, jutting out from the bank, the intervening bank between the groynes being protected by fascine work, or with trees laid with their branches down-stream and having their trunk ends secured by wire to pegs driven in the ground some little distance back from the edge. The groynes to be constructed of short piles (of *Pinus insignis* or other easily obtained timber) sunk a sufficient depth in the river-bed to allow for subsequent scour, spaced 5 ft. apart, with two walings—one at low-water level and the other at flood-level; the up-stream sides to be faced with branches of trees laid diagonally, with their trunk ends uppermost and secured by wire to the two walings. These groynes might be of varying length, extending from the bank, so that their outer ends would present a uniform line or curve to the river-current; they should average not more than, say, 30 ft. in length, and be spaced about 1 chain apart. The accompanying sketch (plan No. 7) shows the general design of work recommended; but the spacing and lengths of groynes necessary to ensure adequate protection, and the gradual aggrading or silting-up of the intervening spaces, is largely a matter to be decided by experiment. In addition to this, levees should be constructed some little distance back from the river at all places along the river-banks wherever the grade of the high flood when controlled would stand above the general level of the banks, and several rows of young willows should be planted in front thereof. It is anticipated that these permeable groynes placed at close intervals will, by reducing the current next the bank, have a greater and quicker effect as compared with solid groynes in inducing the deposit of sand and gravelly shoals in between, and so reducing the scour along the banks. When the silting-up between these temporary groynes has taken place the groynes may, if necessary, be slightly extended, and the intervening shoals should be planted with willows immediately in front of the river-bank. The entrance to the old north channel should be permanently closed by adequate stop-banking, and this channel should be used solely for drainage from the Eyre and Rangiora districts.

With respect to (*c*), in order to prevent ponding-up of the flood-waters in the vicinity of the lower end of Coutt's Island, and provide for the quicker discharge

of such, two schemes have been suggested, the idea being due in each case to Mr. E. Dobson, C.E. The first scheme (indicated on plan No. 5) is to construct a new relief-channel from a point on the new north branch about half a mile above Coutt's Bridge, and rejoining the main river above Stewart's Gully. The second scheme (also indicated on plan No. 5) is to construct, from a point just below the junction of the present north and south branches, a new river-channel across Irishman's Flat, right down to the estuary opposite the sea outlet. The objections which your Commissioners see to the adoption of the first scheme are, firstly, that it would tend to make the present north branch the permanent main river-channel; secondly, that, while certainly avoiding the constriction at Coutt's Bridge and the bad turn at the present junction with the south branch, it yet only reduces the total length of outlet to the sea by 10 per cent., and this in itself would not give increase in flood-slope sufficient to prevent ponding-up as at present. There also remains the difficulty in controlling the size and shape of channel, which in this case would pass through valuable land; and, finally, the scheme does not appear to offer any relief to Kaiapoi from flooding due to backwater from the existing channels. The second scheme, of cutting through Irishman's Flat, on the other hand, offers decided advantages. It shortens the present distance from Empire Bridge to the sea outlet by close on 50 per cent., thus increasing very materially the flood-slope and permitting of an augmented and quicker discharge of flood-waters. The land through which the suggested cut would be made is of very little value, and the ultimate size and shape of channel would be immaterial after it had crossed the railway-line. The danger of Kaiapoi Township being flooded by backwater from the Waimakariri would be practically avoided. By taking steps to induce scour of the existing channels between the north branch and the south branch, more especially those between McLean's and Templar's Islands and between Templar's and Coutt's Islands, the south branch might be made to again take its proper share of the river-discharge, thus greatly relieving the present scour of the north river-banks. Levels have been taken across Irishman's Flat, and from these a section has been plotted which shows that there are no great engineering difficulties to be overcome. This section, however, is not taken on the line of the suggested new channel, and before details of any scheme can be worked out it will be necessary to have a careful survey made in order to determine the best and cheapest route for such a channel. Alteration of the railway-line near Chaney's, with a new railway-bridge, also diversions of existing roads, and a road-bridge over the new channel would be rendered necessary under this scheme, but to what extent is contingent on the ultimate location of the new channel.

When the location of this proposed diversion has been finally fixed a strip of land between the river and the sea, not less than 20 chains in width, should be reserved and vested in the controlling authority. Both the new railway and road bridges should be of ample length, and have piers a sufficient depth to provide for subsequent scour of the new channel to what will probably be its ultimate depth and width. The length of bridging which may be ultimately necessary need not be erected at once, but the bridge may be extended from either end as required from time to time by the amount of scour taking place.

After careful consideration of all the points involved, your Commissioners consider that this scheme offers the only reasonable solution of the difficulty of flooding due to the ponding-up of the flood-waters in the vicinity of Coutt's Island.

With respect to (*d*), in order to relieve the lower end of the so-called old north branch in the vicinity of Kaiapoi Township from the flood-waters of the Eyre Main Drain, it has been suggested that the Eyre should be diverted at a point west of Harr's Road crossing, and, by a new main drain some two and a quarter miles in length, brought into the new north branch of the Waimakariri at a point west of the Education Reserve. While such a proposal, if given effect to, would no doubt relieve the portion of the old north channel referred to from excessive flooding, your Commissioners see many objections to such a diversion of the Eyre waters being made. The gradient of any diversion into the main river would be some 25 per cent. flatter than that of the existing channel, and might result in an accumulation of shingle near the point of diversion. The possible introduction into the main river of detritus from the Eyre drainage should be avoided, as the main river is already fully

loaded. The present channel-outlet into the old north branch is to all appearances sufficient for a fairly good flood-discharge, and it is highly probable that relief to Kaiapoi can be better and more cheaply obtained by judicious stop-banking to a sufficient height along both banks of the lower portion of the old north branch. These stop-banks should be kept a good distance back from the river-banks, so as to ensure ample width of waterway for flood-discharge. At the same time steps should be taken to remove all willows and vegetation from the channel.

REFERENCE NO. 4.

To ascertain the nature and extent of any drainage-works that may be required, and the best method of carrying out such works.

Your Commissioners are of the opinion that, provided the main rivers Waimakariri and Ashley, also the Eyre and Cust, are controlled within definite channels, the existing system of drainage is, generally speaking, adequate, and only requires to be kept in repair and extended as circumstances require.

The exact nature and extent of any future drainage-improvement works which may from time to time be required should be defined by the controlling body recommended under reference No. 5 (*d*).

REFERENCE NO. 5.

(a.) *To furnish estimates of the cost of such remedial measures as you may recommend should be taken for the effective control and improvement of the said rivers and their banks.*

Your Commissioners estimate that the works herein recommended for the present effective control of the river and its banks will cost approximately the sum of £124,000.

(b.) *To report, in the case of each river, what area or areas of land should be constituted a district in respect of which a rate may be levied to secure and pay the interest on, and provide a fund for the repayment of, any loan that may be raised to carry out any river-improvement works which you may recommend should be undertaken.*

The area recommended to be constituted a district in respect of which a rate may be levied to secure and pay the interest on, and provide a fund for the repayment of, any loan that may be raised to carry out the river-improvement works recommended by your Commissioners is the whole watershed of the Waimakariri River and its tributaries up to the railway-crossing on the lower gorge, and including all the territory at present controlled by the South Waimakariri River Board: the whole as more particularly delineated on plan No. 6 attached hereto.

(c.) *To report your opinion as to what matters, if any, should be adjusted by legislation.*

Your Commissioners consider that the whole of their findings, as set forth in this report, should be enacted in special legislation to be called "The Waimakariri River Improvement Act."

(d.) *Generally, to report your opinion on all matters arising out of or touching the premises, including the question as to whether or not one or more competent authorities shall be appointed to control the whole or any portion of the said river, and what statutory powers should be possessed by such authority.*

Your Commissioners consider that there should be one River Board to control the whole of the area indicated under reference No. 5 (*b*), which Board should take over all the assets and liabilities of the present South Waimakariri River Board.

Your Commissioners consider that for the purpose of carrying out the works described generally in their recommendations under reference No. 3, and ensuring their proper maintenance in the future, also for the proper control of the river and for the better protection of the interests of the whole community, one controlling authority should be appointed. This controlling body should be called the "Wai-

makariri River Trust," and should consist of six local representatives elected from the district and also of two Government representatives called "River Commissioners" appointed for three years by the Minister of Public Works, one of the Government representatives being preferably a Stipendiary Magistrate or some person fully qualified and experienced in local-body work, and the other an engineer with expert knowledge of river-control.

Your Commissioners further recommend that the duties of this controlling authority be clearly set out as follows:—

(1.) To have detail surveys, plans, estimates, and specifications made for carrying out the works recommended above. These plans shall be approved by the Government nominees on the Trust.

(2.) To submit the proposals to the ratepayers and obtain their authority by poll to raise the necessary loan.

(3.) To carry out the necessary work, either by contract or direct labour, in as expeditious a manner as possible.

(4.) To maintain the works efficiently, and to do whatever extra work may be necessary to improve the regimen of the river and secure the fullest protection for the district from floods.

(5.) To take all necessary observations and keep records that will assist in the study of the hydrology of the river, changes in its regimen, heights and duration of floods, &c.

The Trust should have all the powers of a local body, and, further, should have absolute jurisdiction over the channel and banks of the river, inasmuch as proposals for all drains emptying into the river, all locks, tide-gates, bridges, ferries, wharves, &c., shall be submitted to and approved by the Trust before being carried out. No planting or cutting of willows should be done except by the Trust.

Government nominees: The River Commissioners may be appointed as Government representatives on any River Trust similarly constituted, and they shall report progress to the Minister of Public Works after each meeting of the River Trust. It should also be their duty to see that all valuable data are collected and forwarded to Wellington for embodying in the Government archives.

This our report, which has been unanimously adopted, we have the honour to respectfully submit for the consideration of Your Excellency, together with the transcript of the evidence taken by us in the course of our investigations, and the following plans (not printed) illustrating our report:—

Plan No. 1: Early map of Waimakariri River and district (date uncertain).

Plan No. 2: Recent survey and levels of Waimakariri River and branches, from the Sheffield–Oxford railway-bridge down to the sea. (Three sheets.)

Plan No. 3: Cross-sections A to H of river.

Plan No. 4: Longitudinal section of portion of river (plotted from cross-sections, plan No. 3).

Plan No. 5: General plan of lower portion of river.

Plan No. 6: Plan showing proposed rating-area.

Plan No. 7: Sketch of bank-protection proposed.

Also table showing imports and exports (by water) to and from Kaiapoi, June, 1910, to May, 1914.

Given under our hands and seals this 5th day of March, 1921.

F. W. Furkert, Chairman.
Ashley J. Hunter,
F. C. Hay, } Commissioners.

WAIMAKARIRI RIVER.—KAIAPOI HARBOUR BOARD.

STATEMENT SHOWING IMPORTS AND EXPORTS (BY WATER) TO AND FROM KAIAPOI, JUNE, 1910, TO MAY, 1914.

Imports.

Period.	Timber.	Coal.	Wool.	Cattle.	Sheep.
	Feet.	Tons.	Bales.		
June 1, 1910, to May 31, 1911	711,382	951	400	473	38,842
June 1, 1911, to May 31, 1912	1,200,055	200	422	684	24,381
June 1, 1912, to May 31, 1913	1,275,144	200	..	30	45,708
June 1, 1913, to May 31, 1914	422,554	70	..	465	36,334
Total imports for four years 1910–14 ..	3,609,135	1,421	822	1,652	145,265

Exports for Corresponding Period, 1910–14.

Produce	69,474 sacks.
General cargo	291 tons.
Cattle	265 head.

Approximate Cost of Paper.—Preparation, not given; printing (540 copies), £15.

By Authority: MARCUS F. MARKS, Government Printer, Wellington.—1921.

Price 6d.