1896.

QUEENSLAND.

FLOODS IN BRISBANE RIVER, AND SCHEMES FOR ABATEMENT OF THEIR DISASTROUS EFFECTS.

(REPORT ON)

(WITH 10 MAPS AND 3 DIAGRAMS.)

Presented to both Houses of Parliament by Command.

TO THE HONOURABLE THE TREASURER.

Water Supply Department,
Brisbane, 10th June, 1896.

Sir,—In accordance with your verbal instructions, received about the end of 1893, directing me to investigate and report upon—

1. The causes and the extent of the floods of February, 1893 ; and
2. The means which may be taken for the abatement of the disastrous effects of future floods—

I have taken into consideration the situation in the Brisbane River valley as affected by abnormal floods which overflow the river banks, and the losses resulting thereby ; the conditions out of which such circumstances have arisen ; and the possibility of adopting some comprehensive scheme of protection of the general interests involved. Having, further, given every opportunity to those taking an interest in the subject to communicate their views, to describe their schemes for relief, and to take me over the ground, and having considered their suggestions, I have now the honour to submit, for your consideration, the following report, in which I have endeavoured to briefly place before you such information bearing upon the subject as I have been able to collect, as well as the inferences to be reasonably drawn therefrom, and to give an outline of some of the relief schemes brought under my notice and of those which I would recommend. This report, however, should not be treated as a final one, because there are valuable supplementary data bearing on the subject yet to be acquired, and which, if you desire, I will continue to procure—not that I think it probable their acquisition would cause me to alter the conclusions arrived at and shortly expressed herein, but because such additional information may be of use in working out the details of whatever scheme may be approved supposing one of those herein recommended be adopted.

In 1894 and in 1895 I had the honour to furnish you with interim reports on the subject, in which I hinted that probably relief from inundations would be found in widening, deepening, and regulating the river below the city, and this view has received further confirmation from subsequent inquiries.

The floods of 5th and 19th February, 1893, which will be assumed to be without parallel in the history of Queensland as far as can be determined by authentic and recorded observations, must be regarded as a general calamity of a very serious nature, but the most serious and important aspect of the case affects the future. While for many years to come we may not have a recurrence of such floods, yet the danger exists, and it cannot be denied that they may occur at any time. The excesses of Nature are sure to be repeated sooner or later, and the obvious lesson to be learned is the necessity for carrying out some comprehensive scheme of protection. In my opinion, however, the magnitude of the task places it beyond the means of local governing bodies, particularly at the present time, and thus, I may be permitted to add, makes it the special duty of the State to undertake the work, say, on the "betterment" principle. Legislation would doubtless be necessary in order to deal with the subject properly, but Government, recognising the serious responsibility, might safely undertake a scheme for dealing generally with the Brisbane River, if not with other large rivers of the colony which are seriously affected by floods. At all events, in view of the widespread distress and loss consequent on floods, it might be well to seriously consider the means that could be taken to diminish, if not to altogether prevent, their ruinous effects in future. Perhaps it may be thought that in making these remarks I am trenching upon policy. If you are of this opinion, or should think them otherwise out of place here, I beg you to be so good as to excise them from this report or to give me an opportunity of doing so.

As it seems to me that the misery and the loss attributable to the terrible visitations of February, 1893, aggravated by a painful uncertainty that apparently exists as to whether the heights of floods in the Brisbane River are progressively on the increase, when and to what extent abnormal floods may recur, and a belief that obvious remedies and the question of relief works generally have been neglected,

C. A. 43—1896.

have given rise to some natural irritation on the part of a section of the public, I deem it proper to state that there is not the slightest ground for such reflections. The questions involved are of so intricate a nature as to demand patient and thorough investigation and consideration, which of course occupy much time; and these matters have had my best attention as continuously as the numerous duties pertaining to my office would admit. In connection with floods and remedial measures, perhaps it may not be amiss to add—not as a suggestion that no action should be taken for ameliorating the evil effects of inundations, but by way of showing that Brisbane is not singularly situated in respect to floods—that, as far as the memory of man goes back, other Queensland rivers and some in the neighbouring colonies—and it may be said in Britain and foreign countries also—have proved to be a source of deep anxiety and trouble to dwellers on or near their banks, and also to those who have control over them. In many cases scheme after scheme has been proposed by able engineers for averting the disastrous effects of floods, but often nothing has been done, and matters remain as before, possibly because of the great cost such works involve.

In searching for data regarding floods in the river previous to 1893, I am much indebted to the columns of the Press, to Mr. J. J. Knight (the author of "In the Early Days,") to the author (the late Mr. Nehemiah Bartley) and editor (Mr. J. J. Knight) of "Australian Pioneers and Reminiscences," to Mr. A. Meston's paper on "Floods and Droughts," and to a paper entitled "Notes on Floods in the Brisbane River" by Mrs. C. Coxen (Trans. Royal Society, Queensland, 1893) for much of my information; had it not been for the valuable records, evidently carefully collected and well preserved, I could not have prepared the annexed diagram marked A. This diagram shows in graphic form for easy reference the heights above low-water datum, Brisbane River, and the sequence of all "big" floods from 1840 of which I could obtain any knowledge; and it also shows the respective level to which a flood in the river, of similar height to that of the 5th February, 1893, would be lowered by the execution of any of the schemes I recommend further on in this report.

CAUSES AND EXTENT OF THE FLOODS OF 5TH AND 19TH FEBRUARY, 1893.

The primary causes of these floods were:—(*a*) Heavy and continuous rains for several days on the drainage basin of the river; (*b*) The rapid discharge of the rain waters into the river, and the insufficient size of its ordinary channel, to carry off the waters poured into it—a condition aggravated by natural and artificial obstructions to the discharge into the sea, such as rocks, jetties, wharves, and other retarding objects on the river banks, and vessels berthed at the wharves or moored in midstream. Some of the retarding objects mentioned may not occupy much space, and it may be thought would exercise but little influence on the discharge of flood waters, but it must be remembered that each is the cause of eddies, cross currents, and surging of the waters, and these conditions have a marked effect upon the rate of discharge.

The floods were severely felt along the whole course of the Brisbane and Stanley Rivers, as well as those of their principal affluents and of their tributaries. Large portions of the low-lying lands adjacent to these streams, of the townships of Fernvale, Laidley, and Goodna, of the town of Ipswich, and of the city of North Brisbane and the municipality of South Brisbane were submerged to varying depths; and loss of life, great destruction of property, and much distress were the consequences. I have been unable to collect such information as would allow me even to conjecture the value of the property destroyed and damaged in and around the city and the municipality of South Brisbane, and in the country; but it must be represented by a very considerable sum, probably over a million sterling, although some writers have put it at double that amount.

From personal observation and sketches made during my inspections of the Brisbane River valley, I form the following estimate of some of the largest submerged areas:—

(*a*) 135 square miles = 86,400 acres of good agricultural and grazing lands along the banks of the Brisbane River, between Colinton and the city;
(*b*) 1,040 acres in Ipswich;
(*c*) 860 acres in South Brisbane;
(*d*) 317 acres in North Brisbane; and as it is probable that not less than 60 square miles of low-lying lands, situated along the banks of the Stanley and the Bremer Rivers, and Lockyer Creek, and the tributaries to these streams were inundated, the total area of land submerged by the flood of the 5th February, 1893, cannot be less than 198·464 square miles = 127,017 acres.

It may be pointed out that the rich alluvial lands on the banks are in every case the first to be submerged when a river escapes beyond its banks.

EXTENT, GEOLOGY, AND TOPOGRAPHY OF THE BASINS OF THE BRISBANE AND STANLEY RIVERS.

Excluding the basins of Norman and Breakfast Creeks, whose waters flow into the river below the city, the respective catchment areas of the Brisbane and Stanley Rivers are about 4,585 and 600 square miles, but if the Brisbane and Stanley valleys be regarded as a single basin its effective area may be fairly set down at 5,185 square miles. On the north-west this basin is bounded by the Cooyar Range, which reaches to an altitude of some 1,334 feet above sea level near Nanango, and 2,449 feet at Mount Cooyar; on the north it is bounded by the Mary Range, having an altitude of 1,570 feet near Conondale; on the east by the D'Aguilar Range, in places 1,000 feet; thence by another range, unnamed, which taking its rise near Sunnybank, on the South Coast Railway, stretches southerly until it joins the Main Range near Mount Nelson, 2,643 feet; and on the south-west and west by the Main Range, which has an altitude of 3,751 feet at Mount Mitchell, 2,319 feet at Picnic Point, Toowoomba, and 2,695 feet at Mocatta.

Dividing the basin by the line of the northern watershed of Lockyer Creek, in order to satisfy the topographical and geological conditions, the well-timbered area of the northern portion contains about 38 per cent. of the whole area of the basin, and the southen portion contains the remaining 62 per cent. The northern portion includes the upper reaches of the Brisbane River and the whole length of the River Stanley. The country, especially in the higher reaches of both rivers, is mountainous and extremely rugged. The mountain spurs are steep; their crests maintain high altitudes, and they are flanked by precipitous ridges. The valleys are deeply eroded, and these portions of the drainage basin present admirable conditions for arresting and condensing vapour-laden cyclonic winds. As will be shown later on, their steepness is eminently favourable for the rapid discharge of rain-waters.

Probably 1,292 square miles in the upper regions of the northern portion of the basin are occupied by granite, slates, and other older and impermeable rocks; while the lower country is occupied by the Ipswich Coal Measures, a considerable portion of whose component strata is more or less sandy and permeable. The Coal Measures rest on the primary rocks at probably no great depth, as here and there the latter rise to considerable elevations above the former. The steepness of the country, however, must greatly diminish absorption, owing to the rapidity of the rush of flood waters across the outcrop of the permeable beds.

Omitting the watershed on the Main Range, the southern portion of the basin does not attain the altitudes reached in the northern portion. It is comparatively flat to the foot of the range, a few spurs from which intrude themselves and, with considerable height, run in various directions through it. This portion is also occupied by the Ipswich Coal Measures, which lie upon comparatively impermeable slates, schists, quartzites, and granite of older date at a considerable depth below the surface.

It should be noted that within the areas occupied by the Ipswich coal formation exceptions to the permeability of the strata are to be found in the regions occupied by the outcrop of contemporaneous clays, shales, and igneous rocks, and that the permeable beds are undoubtedly continuous, both above and below the impermeable; hence, as will be mentioned at greater length later on in this report, the flatter slope of the southern portion of the basin and of its streams, and the more permeable character of the strata that prevail therein, are less favourable to the discharge of rain-waters than is the case in the northern portion, so the streams of the southern portion will flow less impetuously than those of the northern; and unless the swollen condition of the streams in the former is due to heavy rains that have fallen two or three days earlier than the fall of similar rains on the latter, it is probable that a flood wave from the northern portion would pass the junctions of the Lockyer Creek and the Bremer River before the maximum discharge from the Lockyer and Bremer could reach the Brisbane River, and this circumstance would, of course, have a marked influence on the height of a flood wave lower down.

The length of the Brisbane River is some 200 miles. It takes its rise in the Cooyar Range. At 174 miles from the city the river bifurcates, one branch of which is called the eastern and the other the western. At the head of the eastern branch the Rivers Mary and Burnett also take their rise and flow to the north. The principal affluents of the Brisbane River are the Stanley River, about 60 miles long; Cooyar Creek, 64 miles; Emu Creek, 66 miles; Lockyer Creek, 70 miles; and the Bremer River, about 56 miles long; and each affluent has tributaries of no small capacity and discharge during a flood.

The following are the respective distances above the city, as scaled from the map, and the summer levels of the river water above low-water datum, as determined by levelling, of various well-known points on the river:—

—	Scaled Distance above Brisbane.	Altitude above Low Water Datum.
	Miles.	Feet.
Junction of the Bremer River	30	25
Lowood (near)...	65	79
Junction of Lockyer Creek...	68	88
Caboonbah	110	172
Junction of the Stanley River	115	179
Cressbrook	129	246
Colinton ... ... —	146	317
Junction of Wallaby Creek	148	343
Junction of the east and west branches of the River Brisbane	174	489 (barometric)

Woodford, on the Stanley River, is 36 miles (scaled) above the junction of that river and the Brisbane River, and its altitude is 353 feet above low water datum as determined by levelling.

Generally stated, the profiles of the beds of the Brisbane and of the Stanley Rivers are curves of a parabola. The average fall of the Brisbane River from Wallaby Creek to the city is $\frac{H}{L} = \frac{343}{148} = 2{\cdot}\dot{3}\dot{2}$ feet per mile. Similarly, the fall of the Stanley River from Woodford to its junction with the Brisbane River is 4·83 feet per mile.

RAINFALL.

Although the amount of rain falling over the area of a river basin is not necessarily a measure of the discharge of a stream, and gives no clue to the law of sequence of dry and wet years or periods, if there really be any such law, yet an accurate knowledge of its amount and seasonable distribution is of the highest importance to the engineer entrusted with the design of water storage and drainage works. To him reliable rainfall statistics are especially necessary as supplying data upon which he may safely design and construct his works. But, notwithstanding that of all meteorological observations the determination of the quantity of rain which has fallen within a given area and time is the simplest of all such work, and the rain gauge is, perhaps, the least expensive, most simple, and least liable to derangement of all meteorological instruments, yet the number of recording stations, and their situations, and the measurement and recording of the rainfall, as far as the Brisbane River basin is concerned, was sadly neglected until four or five years ago, as will be evidenced by reference to the annexed table, marked B. This table contains all the information regarding rainfall on the basin which I have been able to collect, although neither time nor trouble has been spared in the matter, and the figures given are understood to be correct. As I am under an impression that this compilation of the records of rainfall on the basin is the first that has been made here, I think it well to place it on record, as it may be of some value hereafter.

In studying the characteristics of a river it is also important to ascertain as accurately as possible what has been the greatest and the least rainfall on the basin in a given time, and the seasons of maximum and minimum precipitation and their extent and duration, as the discharge depends much upon these among other elements. The whole of the rainfall over a river basin does not find its way into the main stream; some of it is lost by evaporation, and still more by percolation. Efforts have been made to ascertain by means of formulæ what proportion of the rainfall finds its way into the river and is discharged; but all attempts of the kind have ended in failure, because the configuration and geological characteristics of the basin and other undeterminable elements affect the results. Hence the only correct mode whereby the flow-off can be approximately ascertained is that of gauging the streams. The geological nature of the strata occupying a basin exerts a marked influence on the discharge, and is one of the most important causes of the varying characteristics of floods. Rain falling on steep and comparatively impermeable strata is rapidly discharged; the river rises speedily to a great height during heavy rains, and on the cessation of the rains it falls nearly as quickly; but when the strata are flat and permeable the river rises slowly to a less height, the duration of the flood is increased, and the river falls less quickly. In a river basin of varying steepness and occupied by strata of different degrees of permeability, like that of the Brisbane River, there is much variation in the volume discharged and in the speed with which the water flows off different portions of the catchment area; and these elements, combined with those of distribution, intensity, and duration of the rains, are the cause of irregularities in the height and duration of floods in large basins.

The accompanying coloured lithograph maps, marked No. 1 and No. 1A respectively, show the distribution and the amount of the rainfall on the Brisbane River basin during five days from 31st January to 4th February, 1893, and during four days from 14th to 17th February of the same year, and which caused the floods of the 5th and 19th of that month at Brisbane. The coloured lithograph maps, numbered 2 and 2A, are respectively designed to graphically show the relative daily rainfall observed at sixteen recording stations on the basin during the same periods. From these maps it may, perhaps, be possible to trace the track of the respective storms.

The annexed diagrams, respectively marked C and C^1, show the respective curves of rainfall over the basin during the periods mentioned in the preceding paragraph. The curves have been plotted from the rainfall observations registered at sixteen stations, the positions of which are given on the lithograph maps No. 1 and No. 1A before mentioned. Under each rainfall curve is also plotted the curve of the computed discharge of the river at Brisbane. The true position of the discharge curves would be later than the rainfall curves, but the former are plotted directly under the latter to show more distinctly and conveniently the difference which represents the losses by retention of water in the upper channels, evaporation, and absorption.

These curves show that the computed discharge of the river at Brisbane was some 64 per cent. of the rainfall of the period between 31st January and 4th February, 1893, and about 85 per cent. of the rain that fell on the basin during the period between 14th and 17th February of the same year.

PAST FLOODS IN THE BRISBANE RIVER.

Although only the remarkable floods of 1841, 1845, 1852, 1857, 1863, 1864, 1867, 1870, 1873, 1875, 1879, 1887, 1889, 1890, and 1893 are specially noticed here, there can be no doubt that smaller floods productive of great inconvenience, if nothing more, intervened between those mentioned. As far as I can learn, the highest floods that have occurred since 1840 were those of 1841 and 1893; next in the order of height comes the flood of 1890; then those of 1887, 1864 and 1889, as will be observed by reference to the annexed diagram marked A. For compiling the diagram much time and trouble have been expended in obtaining the data, and as I believe this is the first compilation of the kind with respect to Brisbane River floods, I desire to place it on record for future use. Here I would take the opportunity of urging that hereafter all reference to the height of floods in the river should, for the sake of uniformity, convenience, and comparison and the avoidance of confusion, be referred to low-water datum, at all events to high-water ordinary spring tides, which might give the public a better idea of the height of a flood, as, either given, the other may easily be found. The Press could give great assistance in bringing this suggestion into general use.

The earliest flood in the Brisbane River of which, so far as I can learn, there is any authentic record is that of September, 1825, but, unfortunately, I can learn nothing regarding its height, so it could not be shown on diagram A. The next one that can be traced is that of January, 1841. This flood is said to have been the highest on record, and it is mentioned by Mr. Knight, in his work "In the Early Days," that the late Mr. John Petrie always spoke of it as "the great flood of 1841;" be this as it may, as it seems to have been an exceptionally high one, I took some trouble to ascertain its height, and that which is given in diagram A has been arrived at in the following manner:—It is mentioned that in the account Captain Wickham, the first P.M., gave of it he stated that the flood waters rose to a height of 20 feet where Finney Isles and Co.'s shop now stands. From levels given on two plans of Brisbane respectively dated 1840 and 1842, checked with the levels taken by the Harbours and Rivers Department over twenty years ago in connection with the city drainage, I find that the level of the creek which then existed on the site where Finney, Isles and Co.'s new building in Edward street now stands was 10 feet 7 inches above low-water datum, and 20 feet added to this=30 feet 7 inches, the height above low-water datum of the 1841 flood. Thus, if the accounts mentioned are correct, this flood was 3 inches higher than the flood of 5th February, 1893, which reached the level of 30 feet 4 inches above the same datum. But in considering the flood of 1841, and the causes which led to its great height, it should not be forgotten that the conditions of the river were then very different from what they now are. In 1841 the low-lying lands adjacent to the river would doubtless be covered with dense scrub, the river banks would be fringed with mangroves, and the channel was probably more tortuous and contained many shoals. These conditions, combined with that of a bar having only 4 feet of water on it at low water, would materially check the rapid discharge of flood waters. Had the river then been under similar conditions to those which now exist very likely the 1841 flood would have been some feet lower than it was even had the rain waters had the same facilities as now for draining into the upper reaches of the river.

As all the information available regarding the heights of floods from 1840 to the present year is given in diagram A, it is perhaps unnecessary in this place to enlarge upon the subject further than to mention that I have been unable to learn the height of the flood of 1852. The only information I can find regarding this inundation is that in March of that year the river rose; that the waters, after crossing Stanley street, subsided and rose again a fortnight later, when they "came tumbling down, bringing with them casks of tallow, wool, produce, &c.;" that the waters reached up Albert street to a point above

Elizabeth street, and finally reached the corner of Adelaide and Albert streets, having crossed Queen street lower down; and it is also stated that this flood was in some respects similar to the flood of 1893. The 1863 flood was "heralded in by a terrific cyclone." The flood of April, 1867, damaged the new Victoria Bridge, and the flood of 1889 caused several vessels in the river to break adrift. The floods of 1890 and of 1893 are too well remembered to be commented on.

MAXIMUM RATE OF DISCHARGE TO BE DEALT WITH IN DEVISING WORKS FOR THE ABATEMENT OF FLOOD DAMAGE.

In devising means to prevent or to mitigate the evil effects of floods the first aim of an engineer would naturally be to arrive at an approximation of the maximum volume of the flood discharge, say from velocity observations of the flood waters. In the absence of such observations the engineer would have to fall back upon flood marks, determine from these the surface inclination of the stream as accurately as such a mode will permit, and then compute the discharge therefrom; but as there is no formula for this purpose applicable to rivers in general it is preferable to depend upon velocity observations, even if these are of an ordinary kind, provided they have been quietly and patiently made in fairly favourable reaches of the stream. Fortunately, in the case of the flood of 5th February, 1893, there are available several surface velocity observations made under moderately favourable conditions with apparently suitable objects presenting little aërial surface to the winds and at the same time floating, deeply immersed, in mid-current when the height and the velocity of the flood-waters were about their maximum. From these observations the discharge has been computed on the supposition that for this case the mean velocity may fairly be taken as ·85 of the maximum surface velocity. The computed results arrived at in this way from these observations agreed pretty well and their mean value has been adopted as approximately correct: anyway nothing closer to the truth can possibly be obtained now. As a check in some measure, however, the results so determined were subsequently compared with two or three discharges computed by formula in which the surface slope of the flood-waters (obtained as accurately as possible by levelling between flood-marks) was a factor, and the agreement was remarkable. This confirmation of the results arrived at from velocity observations I look upon as a singular coincidence, because there are so many varying conditions which affect the flow of water in natural channels that all hydraulic formulæ give mere approximations to the truth, and therefore it may be said that all determinations of the discharge of large rivers depending upon the inclination of the surface slope are more or less unreliable, while the problem is complicated by variations in the cross-sectional areas, curvature, &c., producing local irregularities on the surface. For these reasons the true determination of the effective inclination is at best a tedious and very troublesome operation, even when accurate flood-marks are available, and is often uncertain, even if practicable, as the difference of level between two points in the surface of flood-waters is generally the mean fall—not the effective fall, and the most careful levelling falls short of what many cases demand.

Formulæ which are much in favour for computing discharges from surface velocity observations are those of Darcy and Bazin, and as further elaborated by Kutter; but all such formulæ are, as far as I am aware, resolvable into the general but simple form of Chezy:—

$$V = C\sqrt{RS}$$

In which V=the mean velocity in feet per minute. R=the hydraulic mean depth$\left(\frac{\text{sectional area}}{\text{wet perimeter}}\right)$ in feet. S=the sine of the inclination or surface slope of the water$\left(\frac{\text{fall}}{\text{length}}\right)$in feet; and C is a coefficient to be determined and applied in accordance with experience to the case under investigation, as the mean velocity of a current bears a varying ratio to the maximum surface velocity. The formula last mentioned in this paragraph is that which has been used in making computations for this report.

I would add, however, that it is not to be supposed that I am in a position to state positively that the maximum discharge arrived at is more than approximately correct, or to state what precise amount of relief would result from any scheme of improvement brought forward. But from the available data mentioned I can with more reasonable prospect of success deal with the subject than if no data whatever were at hand. Uncertainty must always attend attempts to regulate and control large rivers, and to look for exact results is out of the question. We can only expect approximation to accuracy.

It will be quite evident that, to obtain the relief desired, any works that are carried out with the object of giving such relief must provide for the control, within the areas of North and South Brisbane at least, of floods as high as that of 5th February, 1893, and for the rapid discharge of their waters into the sea.

The maximum rate of discharge of the river at Brisbane during the height of the flood mentioned in the preceding paragraph has been carefully computed at 24,000,000 cubic feet per minute, and therefore I am of opinion these figures represent the minimum volume that should be provided for in the construction of relief works—a volume so enormous that I think few people will realise its magnitude and the difficulties that must be encountered in controlling such a volume of water rushing down a river channel. But perhaps the magnitude of this volume will be better conceived if it be compared with the discharge of some other well-known large rivers in other parts of the globe. It is equal to the ordinary discharge of the Indus at Sukkar, India; very nearly equal to the maximum flood season discharge of the Nile at Cairo, a river that ranks amongst the first in the world in respect of length and catchment area; and, to come nearer home, it is nearly three times the maximum discharge of the 1870 flood in the Hunter River, near Maitland, New South Wales, a river which is frequently visited by floods that cause great loss and destruction of property and much misery. (There have been other floods in the Hunter since 1870, but I have no information regarding them.)

RELIEF SCHEMES BROUGHT UNDER NOTICE.

Some who witnessed the disastrous effects of the inundations of 1893 in the Brisbane Valley have imagined schemes of relief which they believe would, if carried out, avert such destruction and misery in future; but all of the suggested works appear to me to be either impracticable or to involve expenditure quite disproportionate to the useful effect expected from them, so I refrain from commenting otherwise than briefly on the most plausible of the schemes suggested, with the object of showing that they have not been brushed aside without due consideration.

DIVERSION CANALS.

In connection with the question of flood relief works there appears to be a popular idea—in fact, a prevailing belief—that without difficulty a canal could be formed from some point on the river to the sea by means of which floods below the canal entrance at the river end would be wholly averted.

It will be evident that if a costly canal is to be formed, so extensive a work would not be justified by any result short of total relief to the districts which it is intended should be benefited. The question then is how much water should be drawn off the river when in flood to achieve the object desired without injuring the navigable conditions of the river below; and the answer to this is, all water above high water ordinary spring tides, therefore the capacity of such a canal must be at least 24,000,000—4,000,0000=20,000,000 cubic feet per minute to afford relief from such a flood as that of 5th February, 1893.

A personal inspection of the country between the river and the sea, particularly along the suggested canal routes, together with such data as are afforded by trial surveys, discloses the impracticability of such works, except at a cost so enormous as to prohibit their execution; and, further, the results of my examinations of the country generally and of my investigations of the subject convince me that no canal can be cut which would produce results commensurate with the magnitude and the cost of the undertaking. Moreover, without the construction of a massive weir across the river bed at the entrance to the canal, I could not answer for the results, as the tendency of streams is to follow the channel having the greatest hydraulic mean depth, which, of course, without the weir would be the river channel. But the building of such a weir would not only necessitate the construction of a lock for the passage of up-river traffic, but the existence of a weir in the situation mentioned would be detrimental to the river channel lower down, as it would greatly diminish the tidal flow; and this would be inimical to the maintenance of the river channel for navigation purposes, for it should not be forgotten that the volume of tidal flow is generally an excellent measure of the navigable conditions of a river.

Another matter to be kept in view is that, even with a weir across the river, there would be at the canal entrance considerable loss of head; and this would seriously affect the volume that would enter it and the velocity of the water once in the canal; hence there can be no doubt that a large proportion of the flood water would still flow down the river, unless a dam were placed across it, which is not to be thought of. The relief that would be afforded by a canal is therefore very problematical.

From trial sections taken along the routes of two of the canals suggested—sections which I obtained the better to satisfy the advocates of this mode of dealing with floods—Drawings No. 7 and No. 8 have been prepared, and the following conclusions have been arrived at:—

Drawing No. 7 is a plan showing the route of each of the proposed canals, and Drawing No. 8 is a longitudinal section of the country along each route. The plan shows one canal leaving the river at Oxley, and the other leaving the river at Yeronga, and that both canals have a common outlet to the sea at the mouth of Tingalpa Creek. For convenience and brevity the canal leaving the river at Oxley will be distinguished by the prefix "upper" (upper canal), the other canal by the prefix "lower" (lower canal).

The outlet of each canal would extend well into the bay, but with the view of keeping down excavation to the lowest limit, the dredging to be done in forming it would shoal gradually as the flood waters would spread over the sea. Doubtless a bar would form at the outlet of either canal, hence dredging would be required after every fresh in the river to keep the channel open notwithstanding tidal flow, which in the case of the upper canal would be 770,000 cubic feet per minute, or 184,800,000 cubic feet each spring tide, and proportionately less during other tides. The velocity of the current would be 30 feet per minute, which is insufficient to prevent the deposition of sand. The slope and the section of one canal would be different from those of the other, but the slope and section of each individual canal would be uniform throughout its length. The dimensions of each have been computed by the formula already mentioned.

A glance at the sectional Drawing No. 8 shows that the maximum depth of cutting from the bed of the upper canal would be about 252 feet, and that for a length of some 8½ miles the average depth would be about 120 feet. Similarly, the maximum depth of cutting in the lower canal would be about 170 feet, and for a length of some 6 miles the depth would average 100 feet. Both canals would, therefore, have colossal dimensions; the depth of excavation in each, if not the other dimensions also, would rival the respective depths and dimensions of some of the largest canals in the world; the volume of earthwork in each of the suggested canals would be enormous, a large proportion of the cuttings would be in solid rock, and it is difficult to realise their magnitude and to arrive at a fair estimate of the probable cost of either scheme.

Either canal would involve the purchase of much land, the construction of two expensive railway bridges, three or more large road bridges, revetting and other works for the protection of the slopes of the embanked portions, and finally an inlet weir; but taking into consideration at present only the excavation involved in the execution of each canal, it is estimated that at the very moderate rate of 1s. 3d. per cubic yard the upper canal would cost some £9,523,194, and the lower one about £7,138,000, estimates which if taken alone will, I think, place these schemes out of the question.

Before leaving the subject of diversion canals, however, I would add that the remarks made in respect of the schemes just considered are, generally stated, equally applicable to the proposal to cut off and divert flood waters from the basin of the Stanley River immediately above Woodford, by means of a canal which would discharge into the Six-mile or some of the other creeks on the east slope of the D'Aguilar Range, and thence into the sea. The carrying out of such a scheme would cut off only about 93 square miles of the basin, and less than 10 per cent. of the rainfall which caused the flood of 5th February, 1893. It would demand the construction of a large and expensive dam near Woodford, a canal of large dimensions, heavy masonry or concrete works, a costly railway bridge, road bridges, and a heavy outlay in training the waters in the channels between the Range and the sea.

As no fitting site presents itself near Woodford for the construction of a concrete dam across the river, an earthen dam must be built. Such a work would not, however, be safe, and it would always be a menace to the lower country, unless it were furnished with a waste weir or by-wash of such dimensions as would safely pass the waters of the largest possible flood, and such "waste" works would most likely cost as much if not more than the dam itself. This is not an ideal view. Then the canal would discharge over the steep escarpment on the east side of the range, and here most massive "drop" works of masonry and concrete would be demanded to prevent the channel scouring back to and completely altering the course of the river, and carrying down and covering the country below with sand, sludge, &c. The addition of a large volume of water to the streams in the flat district around Caboolture (streams that have enough to do to carry off the waters of their own basins) would only transfer many of the evils to that district, would most probably inundate the country between the D'Aguilar Range and the sea, and would doubtless give to owners of lands situated on the river banks below Woodford, and also to the east of the range, grounds on which to base claims for compensation for loss of water on the one hand, and for damage caused by inundating their properties on the other.

Taking into consideration all the circumstances in connection with this mode of dealing with floods, I have no hesitation in advising that their further consideration be abandoned.

COMPENSATING OR REGULATING RESERVOIRS.

As beforementioned, inundations take place in the valley of the Brisbane River whenever the waters gathered on the higher grounds come down at a greater rate than the river channel can carry off. If the excess of the waters above what the channel can safely discharge were held back by means of natural or artificial reservoirs in the higher reaches of the river and its affluents, and were allowed to escape gradually after the heavy rains have ceased and before the advent of a second flood, no inundation would take place: for instance, the great North American lakes are important and effective natural regulators, and the filling up of low-lying marshes and hollow lands along the course of a river has to a greater or less degree the same effect.

It is upon this principle that the French engineers have been endeavouring to deal with the flood waters of the Rhone, which some years ago occasioned such extensive inundations. If such a system of preventing floods were practicable here another great advantage claimed by advocates of this method would be that the waters might be stored at the end of a wet season and be made available for a general system of irrigation. A very little consideration, however, has convinced me that except at enormous cost nothing of the kind is practicable in the Brisbane River valley, which lacks natural reservoirs and lakes or other depressions that could be improved and formed into storage basins; and which is also singularly destitute of good sites for large reservoirs, with masonry dams, such as would, in the aggregate, hold back a volume of water equal to that which caused the floods of 5th February, 1893, less the allowance mentioned below. Therefore, if the storage system of averting floods were to be adopted, numerous small but comparatively costly reservoirs of the aggregate capacity suggested must be formed by the construction of high masonry or concrete dams. Sites for small reservoirs present themselves here and there in the valley, but unfortunately not always accompanied by the conditions demanded by the construction of such dams.

But assuming the features of the valley and the disposition of the rocks and other geological conditions to be favourable for the formation of storage reservoirs of an aggregate capacity equal to that suggested, and for the construction of high concrete dams, what volume of storage would it be necessary to provide for holding back a single flood such as that mentioned in the succeeding paragraph?

The computed discharge of the Brisbane River during the flood between the 2nd and the 8th of February, 1893, both days included, was 118,049,000,000 cubic feet; but supposing, for the purpose of placing this mode of dealing with flood waters in the best possible light, that a volume equal to that of the 1887 flood—namely, 38,049,000,000, could be allowed to pass down the river without causing inconvenience, the volume that should be stored would be 118,049,000,000 cubic feet, less 38,049,000,000 = to 80,000,000,000 cubic feet, a volume which may be better imagined if mentioned in figures probably more familiar to the mind: thus it would occupy an area 11½ miles by 10 miles = to 115 square miles or 73,600 acres 25 feet deep.

Clearly, the distribution of the reservoirs necessary for dealing with this volume of water would depend upon the drainage area each should command and other circumstances; and the capacity of each would be determined by local conditions, such as the features of the country, the inclination of the stream, and the height of the dam, &c. But, supposing this volume to be equally distributed and held back by, say, 100 reservoirs, each with a mean depth of 25 feet, the high-water surface of each would equal 736 acres; and as in large reservoirs favourably situated the ratio of the mean to the maximum depth may be set down at 3 to 1, the maximum depth or the height of the concrete dam for each reservoir would be 25 × 3 = 75 feet; and the safety of such a dam would demand a solid rock foundation of the hardest description. Earthen embankments would be out of the question in such a position as here contemplated, unless provided with waste weirs or by-washes that would fully and quickly discharge the whole volume of a maximum flood within the time of its duration—works that would be enormously massive, and which would in each case cost quite as much if not more than the dam itself.

From opportunities of which I have availed myself to closely examine the Brisbane River valley, I have little hesitation in stating that it is extremely doubtful whether good reservoir sites could be found, even in the tributary valleys flanking the main stream, in situations where they could be made available for the purpose mentioned by filling them with water conducted from the river in channels which might be cut with a rising grade from them to the river; and considerable experience in the construction of such channels enables me to say that they would be costly not only in first construction but in maintenance.

The question of the cost of this mode of dealing with flood waters now comes to be considered. To base an estimate upon the cost of reservoirs already formed in the colonies is scarcely satisfactory, because such reservoirs having been formed chiefly for water supply purposes their sites were no doubt chosen where everything was favourable for the storage of a maximum volume at a minimum of cost. It is very different, however, in the case under consideration, in which the choice of sites is limited; still, in the absence of working drawings and bills of quantities, the best materials at hand must be applied, so that the estimate formed shall be as nearly correct as possible.

Taking the capacity and the cost of some dozen storage reservoirs, some particulars of which are before me, I find that their volume varies from 24,000,000 to 1,732,000,000 cubic feet and their cost from £30 to £1,623 per million of cubic feet stored; but, taking all the circumstances of the Brisbane valley into consideration, I would not like to base a preliminary estimate of the kind I now give upon less than £100 per million cubic feet; so, at this rate, the cost of storing 80,000,000,000 cubic feet would be 80,000 × £100 = £8,000,000, exclusive of the cost of land, engineering expenses, and outlet works, the latter of which would probably cost from a quarter to half as much as the dams and other works. No better estimate can be made unless a detailed survey of each site and working drawings for each reservoir are prepared, so that the estimate named and the method of arriving at it are merely given for what they are worth, although I should add that I am of opinion that an estimate based upon the additional data suggested would not be less than that given. It may be of some interest to mention that the estimate of an English engineer for storing a volume equivalent to 3 inches of rainfall over the river Thames basin—5,162 square miles in extent—is £15,000,000.

It may now be well to consider what would be the effect of storing 80,000,000,000 cubic feet of water in the river valley, and how it would be dealt with.

Supposing the water to have been stored, to let it off slowly after a flood had reached its maximum height would be to keep the river in flood and prolong its destructive effects. On the other hand, to retain it until the river fell within its banks would be highly dangerous. As we know by experience, there is always the risk of a second flood occurring shortly after the first; in such a case the second flood would find the reservoirs full, and the flood would pass on down the valley and inundate the low-lying lands, the towns, and the city as before, if nothing worse happened. This is no ideal picture, as, unfortunately, it will be too well remembered that in February, 1893, two serious floods, with an intervening one of less height, happened within a fortnight, and high floods had previously happened in quick succession in the Brisbane valley. To insure the full benefits of a storage system of relief, the waters must be run off as quickly as practicable, and this would involve serious difficulties of a practical nature; since to control and discharge 80,000,000,000 cubic feet would undoubtedly be a heavy undertaking, requiring the services of probably two or three men at each reservoir, who would receive their instructions through a telegraph system specially constructed for the purpose.

If the river basin were divided by natural boundaries into 13 sections, each having an important affluent and its tributaries to deal with, and if each section received an equal volume of the flood waters of the basin—a supposition scarcely realisable, but given to illustrate what follows—then each division would receive 80,000,000,000 ÷ 13 = 6,153,846,153 cubic feet; and the lowest of the reservoirs of its series must pass this volume within a reasonable time—say, 7 days—so that the reservoirs would be empty and be ready to receive another flood; and to admit of this discharge from a reservoir 75 feet deep at the dam would require 6 outlet pipes, each 8 feet in diameter (assuming that this is the largest size desirable, and on which to place controlling valves).

Referring to the floods of February, 1893, with these reservoirs the case would have stood thus:—The first flood would have filled them. About the time to commence running off the water a small flood took place, and kept the river so high that it would have been most undesirable to run off any; hence the waters of the second flood would have gone down the river as before, but, before the waters of this flood had fallen low enough to admit of running off those of the first flood, a third flood of serious height took place, and the reservoirs being still full it would also have passed down the river and caused a destructive inundation. Hence to secure the full benefits by means of storage reservoirs it would be indispensable that, in the aggregate, they should be large enough to store at least two such floods as that of 5th February, 1893; and as the estimate given is for works to store only the waters of a single flood, it must be doubled for works of twice the capacity.

Important considerations regarding the working of reservoirs for the combined purposes of storing flood waters and regulating the flow in wet seasons, as well as for irrigation in dry seasons, will now be referred to. For the former object water must be released from the reservoirs as quickly as practicable, so that the storage basins may be empty to receive the next flood; but for the latter purpose the waters must be stored against a dry period. Hence, on a first flood filling the reservoirs, by whom and how is it to be decided whether the water should be retained or released? If it be retained, and a second or third flood takes place, the valley, with reservoirs designed for a single flood, will be devastated exactly as if no reservoirs existed, and the officer in charge will be greatly blamed; if, on the other hand, the waters are released, and no second flood takes place, there will be no water for irrigation purposes. Crops may then suffer, and the consequences may be disastrous, and the controlling officer will be censured. In either event the outlay incurred in forming the reservoirs will have been of no avail.

Sufficient has now, I think, been said to show that the dual benefits expected from this mode of dealing with flood waters in the Brisbane Valley are not likely to be realised; that in any case the cost of such works would be prohibitive, and that the idea ought to be abandoned.

The construction of innumerable cheaply-built, small, rough rubble weirs, rough bush timber and stone "crib," "hollow frame," and "rip-rap" dams in the smaller gullies, creeks, and streamlets would form in themselves, without the débris they would catch, effective obstructions to the rapid discharge of rain-water into the larger creeks and the river.

EMBANKMENTS OR LEVEES.

Levees on a large scale along the low-lying banks of a river are not to be recommended for several reasons, some of which may be mentioned. They raise the height of flood waters within their banks and their tendency is to raise the bed of the river channel, so that the embankments have to be correspondingly raised, and it is a fact that their effect has been, in some instances, to raise the river bed above the level of the adjacent country. They are also highly dangerous, as a breach involves widespread disaster among those who have been lulled into a state of false security, and are unprepared for an inundation. They are, moreover, expensive in first cost and in maintenance, and are not now so much in favour among engineers as they were at one time. I have mentioned them briefly, however, to indicate that they have not been altogether overlooked.

WORKS RECOMMENDED FOR CONSIDERATION.—ALTERNATIVE SCHEMES.

I am now brought to the question: Can anything be done at reasonable cost to give relief from the destructive effects of floods in the river commensurate with the outlay? The reply to which is an emphatic yes, especially if the relief works are designed to go hand in hand with and to form part of permanent harbour and river improvements of no small order, and this has been my aim since I came to the conclusion that within the Metropolitan and South Brisbane areas, on the low-lying lands on the river banks below the city and for some distance upwards, no relief can reasonably be expected at moderate cost, except by widening, deepening, and regulating the river so that it shall have sufficient capacity for the rapid discharge of the greatest known flood without overflowing the banks of the river to any destructive extent. In this direction the works hereinafter recommended have been designed, and I have no hesitation in stating that the flood relief and river improvements which each scheme is calculated to effect will be approximately secured by the execution of one or other of them, although it may be added that if river improvement alone (with which I have nothing to do) were the object it would be quite possible to effect improvements meeting all the demands of river navigation for years to come at less cost. In determining the character and scope of the respective schemes the rapid discharge of high upland floods at a minimum of cost has been constantly borne in mind as being of the first importance.

The first question to be determined was the necessary dimensions of a river channel, with the slope available, for carrying off, in the manner already mentioned, floods equal to that of 5th February, 1893—viz., 24,000,000 cubic feet per minute, without permitting the level of the waters to be more than 14·50 feet above low-water datum (in other words, 1 foot 6 inches below the planking of the Norman Wharf).

Careful computations show that a channel of the capacity given must carry a depth of 26 feet at low water for a width of 1,500 feet at Victoria Bridge, that the width must gradually expand to 2,480 feet at Doughboy Creek, and that the depth of 26 feet at low water ordinary springs must be maintained out to sea; but as a channel of the width of 1,500 feet in the city would be impracticable, the question resolves itself into that of providing for the discharge of the greatest volume of water possible by means of the widest river channel practicable, which is limited to 950 feet by the relative position of the city and South Brisbane. The result of further computations there anent is the submission of the alternative schemes now suggested, all of which have been designed to secure the same object, but in different degrees and have been planned upon the same engineering principles and on similar data.

For convenience the schemes are distinguished by the letters A, B, and C, and the salient points of each will now be briefly described without entering into technical details, which have demanded and received careful consideration.

SCHEME A.

This scheme provides for deepening, widening, and otherwise regulating the present channel of the river by cutting off the corners at Garden Point, Kangaroo Point, New Farm Point, Norris Point, and Bulimba Point, so as to form a channel carrying from Victoria Bridge to the sea the full depth of 26 feet at low water ordinary spring tides, and having a width of 942 feet at the bridge, extra width at bends, and a section gradually increasing in width downwards to the mouth of the river in such a ratio that it will have a uniform discharge of 24,000,000 cubic feet per minute with the surface inclinations shown on the accompanying longitudinal section.

The total quantity of all materials to be removed in this scheme is some 114,750,000 cubic yards, of which about 1,167,000 cubic yards may have to be removed by aid of blasting, or by Lobintz rock breakers, or other suitable means; the remaining 113,583,000 cubic yards would be excavated by dredging; but as in dredging work it is customary to speak of tons, it will be more convenient to follow this practice and to convert cubic yards of dredging into tons—so 113,583,000 cubic yards $=\frac{27}{21}=$ 146,035,286 tons.

The dredged materials would be deposited behind retaining walls to be built along the lines shown on the general plan. The area of the land that would be reclaimed in this way would be about 1,304 acres, and the quantity of dredgings that would be disposed of in reclaiming this area to a height of 6 feet above high water ordinary springs would be about 64,000,000 cubic yards=82,285,715 tons, or about 56 per cent. of the computed total quantity of materials to be excavated from the river bed, points, &c.

An additional area of about 2,000 acres of low-lying land, now covered by high spring tides, could also be raised to a level of 6 feet above H.W.O.S. tides; and this would require and would thus dispose of another 28,000,000 cubic yards or 36,000,000 tons of the dredgings, and the surplus 27,749,571 tons could be utilised in raising any other low-lying lands along the river banks to such heights above the flood grade A as might be desired, or it could be carried to and be deposited at sea.

All rock excavated from the river would be used in the construction of the retaining-walls before mentioned. The aggregate length of walling required would be about 13 miles, and about 1,500,000 cubic yards of stone would be required in their construction.

Although, if the necessary materials for protecting the river banks were available from the cuttings, it might be advantageous so to dispose of them, yet no special protection of the banks exposed by cutting away the points, corners, &c., would be absolutely required beyond what may now be necessary, as the greatest velocity of the waters in the new channel would be some 25 per cent. less than the velocity attained by the flood waters on 5th February, 1893, which, generally stated, did not have any marked effect in respect of the erosion of the river banks.

As this scheme does not provide for lowering the level of flood-waters of equal volume to that of the flood of 5th February, 1893, below a point 19·28 above low-water datum—in other words, below a point 3 feet above the floor of the Queen's Hotel, equal to 3 feet 3 inches above the level of the floor of the Norman Wharf, it provides, by means of walling, for the exclusion from the city and also from South Brisbane of all flood-waters which would inundate the parts of these areas which are below a level equal to 1 foot lower than the flood of the 13th March, 1890; in other words 19·42 feet above low-water datum.

The walling would be built of concrete along the lines shown on Drawing No. 6, and where the walls would abut on existing permanent structures watertight joints would be formed and arrangements would be made for strengthening and fitting the river fronts of these structures in such a manner that, while flood-waters would be kept in the river channel, the least inconvenience possible would be caused to the respective owners and occupiers. Openings in the buildings and in the walls, at the positions shown on the drawings, for giving ingress and egress to and from the wharves, &c., would be furnished with watertight flood-gates for the exclusion of flood-waters from the city and South Brisbane. These gates would be closed only when warning was received from the upper reaches of the river of the coming down of a flood considerably higher than that of 1890, a condition which reference to the annexed diagram A will show is of rare occurrence. Compliance on the part of private property-owners with the order to close the flood-gates would have to be enforced by strict legislative enactment. The average height to which the walling in the city and South Brisbane would have to be built, supposing the summit of the walling to be 3 feet above the the computed highest flood-level, would be 9 feet. In the city some 1,130 lineal yards would be required; and in South Brisbane about 1,280 lineal yards, in addition to two earthen embankments, would be necessary, as shown on drawing.

The beneficial effects to be expected from the execution of this scheme may be briefly stated as follow:—

(*a*) The lowering of the level of a flood equal to that of the 5th February, 1893, to the grade line shown on Drawing No. 4; in other words, to a height of 19·28 feet above low-water datum, equal to 3 feet over the floor of the Queen's Hotel or 3 feet 3 inches over the planking of the Norman Wharf.

(*b*) The opening of the river to the largest class of merchant steamship at nearly all states of the tide.

(*c*) The reclamation of at least 3,300 acres of land, having a river frontage of 13 miles to a depth of 26 feet at low water, the value of which I am not competent to appraise but leave to experts in this line to decide, but which in the near future must be great and should be credited against the cost of the scheme.

(*d*) The rapid discharge of such a flood as that of March, 1890, without any other inconvenience than that of clearing the lower wharves of perishable goods, and the quick discharge of all floods such as those of 1845, 1857, 1864, 1887, and 1889 without any other inconvenience than is now caused by a "fresh" in the river.

(*e*) The complete exclusion of floods from the city and South Brisbane by aid of the walling previously mentioned.

(*f*) The reduction of the velocity of the current in the river during a flood such as that of March, 1890, to less than five knots per hour, which would not prevent steam ferry traffic; nor, taking into consideration the increase in the width of the river at bends, would steam navigation traffic up and down the river be interrupted thereby.

It is computed that the volume of water which passed off through the Boat Passage during the maximum height of the flood of 5th February, 1893, was about 2,500,000 cubic feet per minute—a volume so small, when compared with the flood discharge of the river at the same time, that its exclusion from the latter would scarcely interfere with the scouring action of the flood-waters in the river, so that it is not thought desirable to interfere with existing conditions by closing this passage.

Touching the important question of the tidal capacity and flow of the river—which, regarding the Brisbane River, I have not hitherto seen or heard referred to—the following figures may be of some value. The area of tidal water above Luggage Point is—

Above Victoria Bridge, some	100,316,800	square feet.
Below „ „	195,450,000	„
Total, some...	295,766,800	„

And the volume of tidal water in these areas, when the tidal range is 7 feet, is—

Above Victoria Bridge, about	446,914,300	cubic feet
Below „ „	1,368,150,000	„
Total, about	1,815,064,300	„

So that the volume of tidal water which passes Victoria Bridge each 7-feet spring tide is 446,914,300 cubic feet, which passes over the sectional area of the river with a mean velocity of 87 feet per minute. The maximum surface velocity is slightly over 1 knot per hour.

The volume of tidal water passing Luggage Point each 7-feet tide is 1,815,064,300 cubic feet. The mean velocity is about 253 feet per minute, or 2·5 knots per hour. The maximum surface velocity is some 300 feet per minute, equal to 2·9 knots in the same time. The velocity and volume increase gradually from Victoria Bridge downward to Luggage Point.

The net reduction in the tidal capacity that would be caused by the reclamation of land by depositing the dredgings as shown on Drawing No. 3 would amount to about 49,790,000 square feet, equal to 348,530,000 cubic feet, or 19 per cent. of the total capacity; but this reduction of the volume flowing into and ebbing out of the river would be compensated by the increased grade consequent upon the shortening of the channel by rounding off bends, by fairing up the river generally, and by the increased hydraulic mean depth of the new channel, and the consequent increase of tidal flow in reaches above the bridge. Hence it is not thought that any loss of scouring effect would result from the improvements recommended.

I estimate the approximate cost of this scheme, exclusive of land, engineering expenses and plant, as follows:—

Excavation in River—		
Dredging		£1,747,134
Rock excavation		525,000
Retaining walls for reclamations		187,500
Total estimated cost of river improvements		£2,459,634
Walling, including flood-gates in road-openings, and in openings in buildings—		
North Brisbane	£23,800	
South Brisbane	26,250	
Embanking South Brisbane	14,000	
		£64,050
Pumping installations for local drainage behind walling, including necessary drainage works and valves on existing outfalls—		
North Brisbane	£43,700	
South Brisbane	131,250	
		£175,000
Total estimated cost of Scheme A		**£2,698,684**

SCHEME B.

This scheme provides for a short cut through Kangaroo Point, and for another cut through New Farm, as shown in close-dotted hatching on the general plan, and for deepening, widening, and otherwise regulating the present channel of the river, as in Scheme A, excepting those portions between the entrance to and exit from each of the proposed cuts. The cuts and the river channel would carry a depth of 26 feet at low water ordinary springs, their width would expand, and they would have a uniform discharging capacity of 24,000,000 cubic feet per minute with the surface inclinations shown on the longitudinal section of the river, all as in Scheme A.

Most of the materials to be removed from the cuts would most probably be in hard volcanic tuff, and it is computed that of this material about 10,000,000 cubic yards would have to be removed. The bulk of these excavations would be kept comparatively dry by leaving at each end of the cuts a "berm," having its top level with high-water spring tides. Good working faces could thus be had, the materials would be excavated and removed under the most favourable conditions, and on the completion of the intermediate portions of each cut these "berms" would be removed. Steam excavators, waggons and locomotives on lines of rails would be used in carrying on the works.

As mentioned in describing Scheme A., a minimum quantity of 1,500,000 cubic yards of rock would be required for retaining walls. The length of these walls, and therefore the quantity of rock that would be required for their construction, could with advantage be largely increased. The cuts at Kangaroo Point and New Farm would furnish all the stone that would be wanted for this purpose, and also enough for facing and protecting the whole of the banks of the river, between the city and Moreton Bay, from the wash of steamers if such works were subsequently found to be necessary.

All the remarks regarding disposition of dredgings, area of land reclaimed, &c., in respect of Scheme A apply to this scheme also.

The advantages that may certainly be expected from the execution of this scheme are as follow:—

The lowering of the level of a flood equal to that of 5th February, 1893, to the grade line shown on drawing No. 4—that is, to 17·28 feet above low-water datum, equal to 1 foot over the floor of the Queen's Hotel, or, say, 1 foot 3 inches over the planking of Norman wharf, instead of 19·28 feet, 3 feet and 3 feet 3 inches respectively, as in Scheme A. Thus the cuts would shorten the length of the river between Victoria Bridge and Luggage Point by about 2 miles, and would reduce the level of floods in the city and South Brisbane 2 feet more than Scheme A would. The execution of this scheme would also permit a reduction of 2 feet in the height of the concrete protecting walls in the city and South Brisbane—that is, from 9 feet to 7 feet average height, and would make it unnecessary to close the flood-gates therein unless warning were received of a flood 10 per cent. greater in height than that of March, 1890, coming down the river.

The two cuts mentioned would form two islands, one at Kangaroo Point, the other at New Farm. The severed parts of the river would form convenient docks free from perceptible tidal current with quayage space on the North Brisbane side of the Kangaroo Point dock of 7,500 lineal feet, and on Kangaroo Point Island of 3,500 feet; on the South Brisbane side of the New Farm dock of 12,000 lineal feet, and on the island 8,500 feet. The total net length of quayage space which could be added by the cuts would be 7,500 lineal feet, or in the gross 11,000 feet. The cuts would be excavated to the exact dimensions necessary for the rapid discharge of floods, and therefore their efficiency should not be reduced by wharves projecting into the stream.

The areas of the Kangaroo Point and New Farm Islands would be about 38 and 385 acres respectively, and they would form excellent sites for bulk stores and other business premises.

I estimate the approximate cost of this scheme, exclusive of land, engineering expenses, and plant, as follows:—

	£	£
Cutting through Kangaroo Point and New Farm ...	1,073,575	
Excavation in River—		
Dredging and rock excavation	2,043,066	
Retaining walls for reclamation	37,500	
Total estimated cost of river improvements ...		3,154,141
Walling, including flood-gates in road openings and in openings in buildings—		
North Brisbane...	17,000	
South Brisbane...	18,750	
Embankments—		
South Brisbane	10,000	
		45,750
Pumping installations, including necessary drainage works and valving existing outfalls—		
North Brisbane	43,750	
South Brisbane	131,250	
		175,000
Grand total estimated cost of Scheme B		£3,374,891

SCHEME C.

Scheme C. is submitted as an instalment of Scheme A. It provides for the regulation of the river in the same way as the latter. The widths, depth, and inclinations of the channel would ultimately be the same, but in the meantime only the central 500 feet width would be 26 feet deep at low-water spring tides, and the remainder of the full width would be only 16 feet deep (see general plan). Finally, the whole channel would be dredged to 26 feet, so that in the end the result would be Scheme A. In the meantime, however, until the completion of the scheme to its ultimate full dimensions, the portion now submitted as Scheme C. would yield all the advantages claimed for Scheme A, but to a less degree, inasmuch that the height of the floods in the city and South Brisbane would rise some 2 feet 2 inches higher than would be the case if Scheme A were carried out at once; so the average height of the protecting concrete walls would be 11 feet 6 inches high instead of 9 feet; the earthen embankments in South Brisbane would of necessity have also to be raised proportionately, and it would be necessary to close the flood-gates in these walls, and in the riverside walls of the buildings, when a flood of somewhat less height than that of March 1890 was expected.

This scheme if given effect to would, by the facilities afforded for the more rapid discharge of high floods of upland waters, give very substantial relief to the city and South Brisbane, and, while the more complete scheme was being carried out, it would also relieve, to a very considerable degree, navigation of many of the disabilities now experienced in the river. The factor of river navigation, however, is one with which, I repeat, I have nothing to do: it is simply mentioned here, as a matter of duty, for your information.

I estimate the approximate cost of this Scheme exclusive of land, engineering expenses, and plant, as follows:—

	£	£
Excavating in river—		
Dredging	1,236,610	
Rock excavation	350,000	
Retaining walls for reclamation of land	187,500	
Total estimated cost of river improvements		1,774,110
Walling, including flood-gates in road openings and in openings in buildings—		
North Brisbane	37,000	
South Brisbane	41,000	
Embankments in South Brisbane	20,000	
		98,250
Pumping installations, including necessary drainage works and valves on existing outfalls—		
North Brisbane	43,750	
South Brisbane	131,250	
		175,000
Grand total estimated cost of Scheme C		£2,047,360

None of these schemes show any work above Victoria Bridge, but if any of them were carried out it would be desirable to round off the point near the north end of Montague road, and perhaps some of the others, for a little way further up stream.

The first effect of lowering the flood surface at Victoria Bridge would be a steep grade above, and the resulting increase of velocity would scour out the river bed until the grade became so flat that further scouring would cease. This lowering of the grade would also materially relieve the flooding to which Milton and Toowong have been exposed, and the beneficial effects would be felt for many miles up the river, though it is impossible to say to what extent, in the absence of detailed surveys and other data. The flood relief works which are now proposed for the benefit of the city, South Brisbane, and the districts lower down the river could be extended upwards in future, should it be considered that the results would be commensurate with the cost.

If it be thought that the estimated cost of any of the schemes recommended is prohibitive, it should be borne in mind that some years must necessarily elapse before the completion of improvements so extensive could be accomplished; hence the expenditure would be distributed over many years; consequently the raising of the necessary funds would not, I think, be a difficult matter, nor would the tax that would be necessary to provide for a sinking fund and interest be severely felt by the districts benefited, and the final results would—exclusive of the increased value conferred upon property—fully justify the expenditure.

But should it nevertheless be considered inexpedient to carry out any of the schemes suggested, concrete walling furnished with flood-gate openings and embankments might be built in the city and in South Brisbane as recommended for Schemes A, B, and C, except that in this case their average height must be 20 feet at least. Provision would also be required at the south end of Victoria Bridge to prevent flood waters from gaining admission into South Brisbane by that way. The execution of these works alone would, in my opinion, be but a "make-shift," but they are mentioned to show the least that could be done under force of circumstances. The effect of the walling and of the embankments would be to slightly raise the level of high floods at Brisbane and for a little way above the bridge; they would have no beneficial effect upon the river or upon navigation, rather otherwise, and the only advantage that would accrue would be the exclusion of flood waters from the city and South Brisbane.

I estimate the approximate cost of this arrangement, exclusive of land and engineering expenses, as follows:—

Walling, including flood-gates in wall-openings and in openings in buildings—		
North Brisbane	£85,800	
South Brisbane	118,800	
Embankments, South Brisbane	40,000	
		£244,600
Pumping installations, including necessary drainage works and placing valves on existing outfall sewers—		
North Brisbane	£43,750	
South Brisbane	131,250	
		£175,000
Total		£419,600

In the meantime, until some scheme of river improvement can be put in hand, I would strongly advise that steps be immediately taken to prevent the erection, on low-lying flooded lands along the river banks below the city, of buildings of every kind, and also of all other structures that would retard the flow of flood waters. Of course owners would require compensation, but by adjusting river frontages in some cases I presume the amount that would be involved would not be very large; any way, it should be borne in mind that land values increase as years roll on, and possibly land could not be obtained cheaper than now.

Admitting that a period of ten years would not be too long to allow for the execution of either of the Schemes A and B, the quantity of dredged materials to be annually dealt with would be that stated on page 9—namely, 146,035,286 tons÷10=14,603,528 tons.

Working two twelve-hours shifts daily, a well-found modern dredger of average size of the Von Schmidt type would lift and discharge 1,000,000 tons per annum if furnished with an ample number of steam hopper barges, &c., so 14,603,528 tons÷1,000,000 tons indicates that fifteen of such dredgers would be required,* and the entire dredging plant necessary would probably cost £500,000.†

Of all the suggested schemes, B would most certainly, in my opinion, produce the best and most satisfactory results. Scheme A stands next, then C, and finally the walling and embanking alone.

I scarcely favour Scheme C, unless it were decided to enlarge it until it finally became Scheme A. The merits of this scheme are less first cost, and considerable improvement of the navigable channel. Its defects are that in the shallow parts on each side of the navigation cut the velocity of the tidal waters will be retarded; during flood tide they will be filled from the deeper central or navigation cut, and during ebb tide this will be reversed, when they will empty back again into it; but of course if Scheme A or B is beyond the combined means of the districts to be benefited, Scheme C might be carried out as an instalment of A or B.

The channels and other works recommended are of sufficient dimensions, but not more than enough to relieve, in the manner already mentioned, the city and South Brisbane from disastrous results of floods in the river, and should either of the schemes, A, B, or C, be carried out, it is essential that the works should be commenced at the lower end, and completed upwards towards the bridge.

NORMAN AND BREAKFAST CREEKS.

The abatement of the evil effects of inundations on the low-lying areas of these creeks, caused by back-waters from the Brisbane River when it is in flood, has not escaped attention. The necessity or otherwise for constructing at the mouth of each creek relief works quite distinct from the river works already mentioned in this report has been carefully considered, and the effect which the execution of either of the schemes for improving the river channel would have in ameliorating the disastrous effects of such inundations on these creeks has had attentive consideration.

It is computed that the execution of Scheme A would lower the waters of such a flood as that of 5th February, 1893, to such an extent that they would not reach to a higher level in Norman Creek than about the high-water level of the 1887 flood; nor in Breakfast Creek to a higher level than about 6 inches below that attained by the flood of March, 1890; therefore I do not feel warranted in recommending additional special flood relief works for either creek, especially as I understand that with the exception of a short length of road between the junction of Ann and Wickham streets and Forsyth's corner on the Breakfast Creek road the 1890 flood-waters were nowhere deeper than some 18 inches on the road between the junction mentioned and the Hamilton; that the flood of 1890 did not do much damage at Breakfast Creek, and that the flood of 1887 did not cause much inconvenience on Norman Creek. Moreover, the areas drained by Norman and Breakfast Creeks being large—about ten and a quarter and thirty and a-half square miles respectively—a separate relief scheme for each creek would involve large expenditure in each case for flood-gates, intercepting drainage channels, very heavy earthworks, and costly pumping plant.

In this report I have endeavoured to place before you, as briefly as the magnitude of the questions involved would admit, all the salient features of each scheme brought under my notice, as well as of those which I would recommend, and also the principal data, and the basis upon which I have arrived at the conclusions set forth. If I have succeeded in some measure in doing so, I shall feel satisfied; but should you desire further information upon any points which you think obscure, or which may have been omitted, I shall be pleased to have an opportunity of affording you any further information in my power,

I have, &c.,

J. B. HENDERSON, M. Inst. C.E., &c.
Government Hydraulic Engineer.

---

* If desirable a greater number of dredgers, or dredgers of much greater capacity, could be employed. Recent official trials of a hydraulic suction dredger for navigation improvements in the Mississippi River show an average result of over 5,000 cubic yards, or, say, 6,430 tons per hour=154,320 tons per diem. If such a dredger were to work only half time, or, say, 160 working days per annum, it would deal with 24,691,200 tons.

† Of course, at the end of the job the plant would be an asset of considerable value. Part would be kept for maintaining the river channel, while the remainder could be otherwise disposed of.

Table B.

TABLE of RAINFALL at METEOROLOGICAL STATIONS on the BRISBANE RIVER DRAINAGE BASIN from 1870.

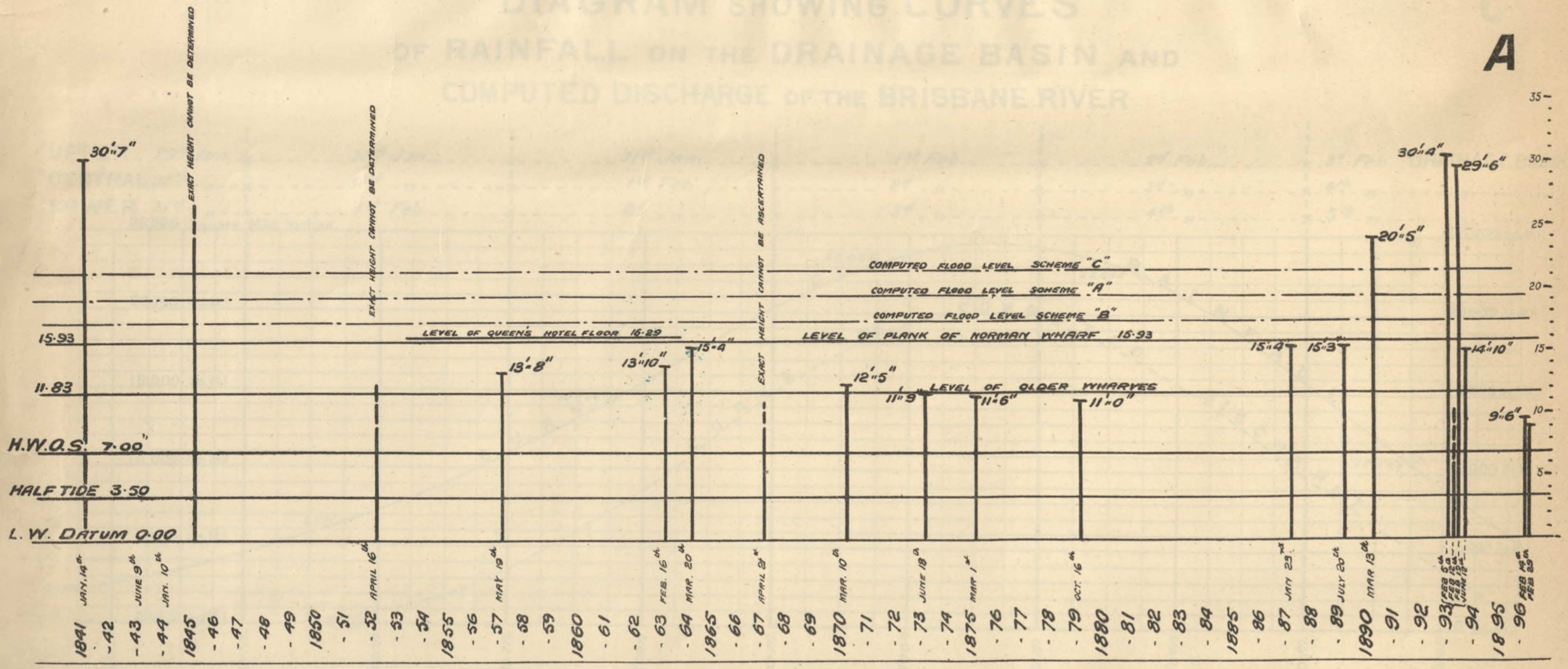
YEAR.	Corinda.	Cressbrook.	Crohamhurst.	Enoggera.	Esk.	Fassifern.	Franklyn Vale.	Goodna.	Helidon.	Ipswich.	Kilcoy.	Laidley.	Lowood.	Marburg.	Nanango.	Woodford.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1870	...	...	...	88·64	...	...	...	73·12	...	66·84	...	...	...	...	...	
1871	...	...	...	43·39	...	...	...	41·31	24·18	40·23	...	...	...	...	...	
1872	...	...	...	45·10	...	...	...	39·56	26·93	37·98	...	...	...	...	...	
1873	...	...	...	63·84	...	...	...	45·50	44·23	53·44	...	...	...	...	...	
1874	...	...	...	34·10	...	...	...	29·28	31·72	27·49	...	...	...	...	...	
1875	...	...	...	61·85	...	...	...	53·07	34·77	53·42	...	...	...	...	...	
1876	...	...	...	42·01	...	...	...	31·08	32·38	37·42	...	...	...	...	...	
1877	...	...	...	20·95	...	...	...	22·08	11·30	19·75	...	...	...	...	...	
1878	...	...	...	46·68	...	...	...	36·42	21·83	28·17	...	...	...	...	...	
1879	...	...	...	68·08	...	...	...	48·91	41·06	59·77	...	...	...	...	...	
1880	...	...	...	44·78	...	...	...	33·19	22·21	38·49	...	...	...	...	...	
1881	...	...	...	25·84	...	...	...	17·70	21·02	24·25	...	...	...	...	...	
1882	...	...	...	37·85	...	...	...	28·05	18·86	34·86	...	...	...	...	34·86	
1883	...	...	...	32·09	...	...	...	21·78	...	23·11	...	...	...	...	24·37	
1884	...	...	...	44·90	...	...	...	34·96	...	32·57	...	...	...	...	31·70	
1885	...	...	...	25·47	...	...	25·28	24·43	22·13	21·52	...	...	...	...	19·85	
1886	...	...	...	50·84	..	...	34·12	42·80	30·35	38·36	...	...	...	...	39·16	
1887	...	...	...	30·52	55·39	56·61	50·81	57·63	18·99	48·32	...	...	...	...	44·63	97·48
1888	...	...	...	33·65	28·71	23·81	...	35·50	...	22·39	..	...	26·20	...	22·91	35·96
1889	...	41·35	...	48·52	37·01	37·87	...	36·37†	...	35·75	...	...	38·32	...	42·07	63·06
1890	67·57	45·67	...	50·64	49·57	47·95	56·65	36·81	...	55·07	...	56·46	56·87	...	53·05	81·60
1891	39·49	37·29	...	37·56	37·07	37·13	38·76	29·98	27·71§	28 57	45·82	31·46	33·40	...	30·13	47·79
1892	61·32	48·40	...	61·21	48·58	54·63	48·27	51·63	40·51‖	47·11	59·96‖	48·57	51·47	...	39·47	59·73
1893	85·73	80·58	201·64*	90·59	85·26	56·44	60·30	35·34‡	46·09‖	70·64	38·84‖	64·86	...	...	53·55	115·19‡
1894	42·34	39·70	94·25	44·19	44·02	37·36	19·65	36·83	28·50	38·67	40·73‖	38·02	40·30	34·82	30·53	59·93
1895	46·83	28·34	71·22	46·41	33·66	36·13	34·58	39·24	29·63	33·24	32·20	37·42	29·00	38·67	29·16	43·75

*Of this quantity 107·6 inches fell in February, 1893. † Approximate. ‡ Flood covered gauge in February, 1893 § Doubtful; ten months' rainfall only. ‖ Doubtful.

Price 10*s.* 6*d.*]

By Authority: EDMUND GREGORY, Government Printer, William street, Brisbane.

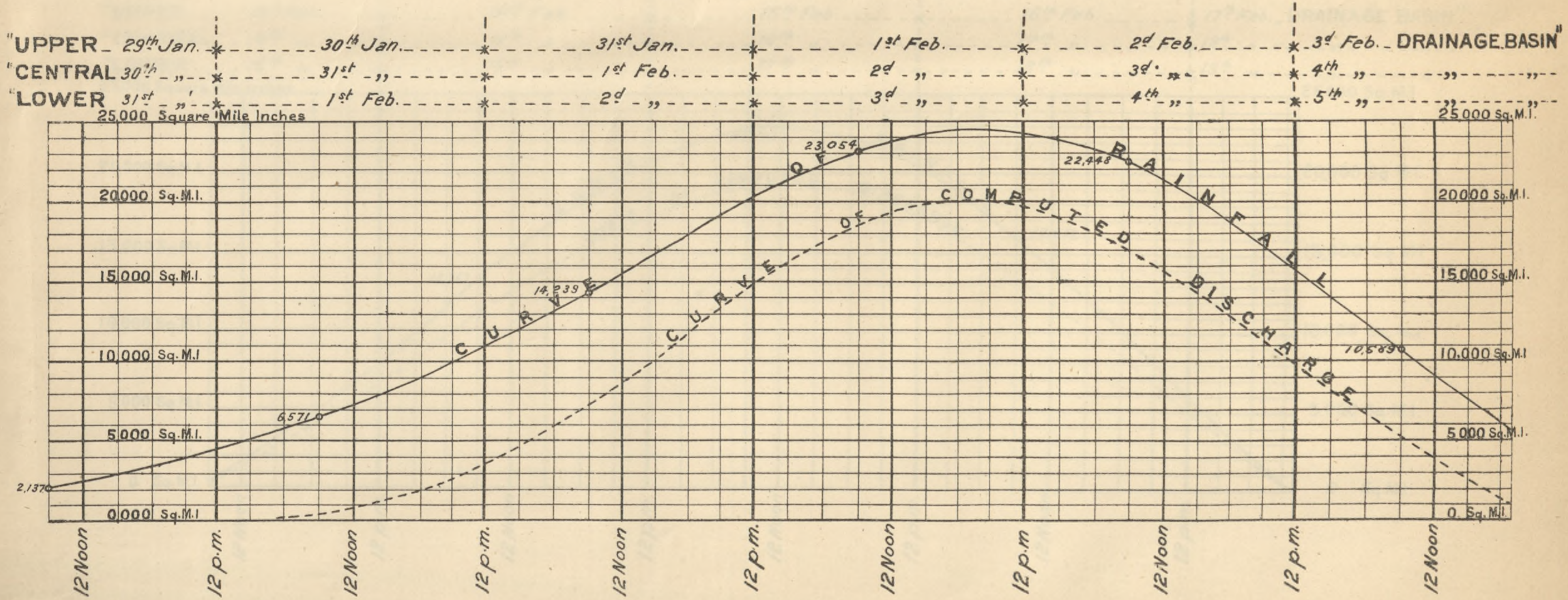
A



30'7"
EXACT HEIGHT CANNOT BE DETERMINED
EXACT HEIGHT CANNOT BE DETERMINED
EXACT HEIGHT CANNOT BE ASCERTAINED
COMPUTED FLOOD LEVEL SCHEME "C"
COMPUTED FLOOD LEVEL SCHEME "A"
COMPUTED FLOOD LEVEL SCHEME "B"
LEVEL OF QUEEN'S HOTEL FLOOR 16.29
LEVEL OF PLANK OF NORMAN WHARF 15.93
LEVEL OF OLDER WHARVES
15.93
11.83
H.W.O.S. 7.00"
HALF TIDE 3.50
L. W. DATUM 0.00
13'8"
13'10"
15'4"
12'5"
11'9"
11'6"
11'0"
15'4"
15'3"
20'5"
30'4"
29'6"
14'10"
9'6"
35
30
25
20
15
10
5
JAN. 14th
JUNE 9th
JAN. 10th
APRIL 16th
MAY 19th
FEB. 16th
MAR. 20th
APRIL 21st
MAR. 10th
JUNE 18th
MAR 1st
OCT. 16th
JAN 23rd
JULY 20th
MAR 13th
FEB 5th
FEB 12th
FEB 13th
JUNE 12th
FEB 14th
FEB 29th
1841
-42
-43
-44
1845
-46
-47
-48
-49
1850
-51
-52
-53
-54
1855
-56
-57
-58
-59
1860
-61
-62
-63
-64
1865
-66
-67
-68
-69
1870
-71
-72
-73
-74
1875
-76
-77
-78
-79
1880
-81
-82
-83
-84
1885
-86
-87
-88
-89
1890
-91
-92
-93
-94
1895
-96

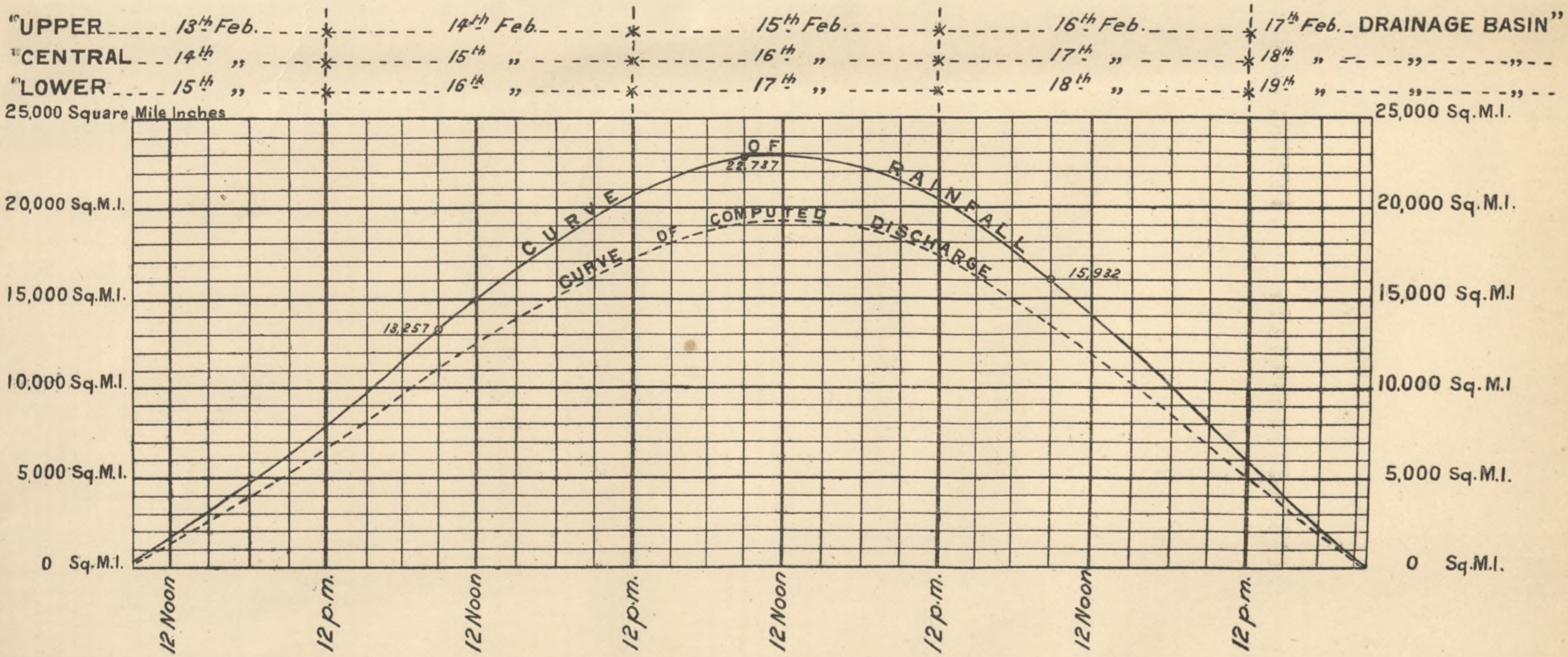
C

DIAGRAM SHOWING CURVES
OF RAINFALL ON THE DRAINAGE BASIN AND COMPUTED DISCHARGE OF THE BRISBANE RIVER



C'

DIAGRAM SHOWING CURVES OF RAINFALL ON THE DRAINAGE BASIN AND COMPUTED DISCHARGE OF THE BRISBANE RIVER



DRAWING No 7.

WATER SUPPLY DEPARTMENT

QUEENSLAND

PLAN SHOWING

SUGGESTED FLOOD DIVERSION CANAL

UPPER OXLEY TO TINGALPA CREEK,

LOWER S.B. CEMETERY TO TINGALPA CREEK.

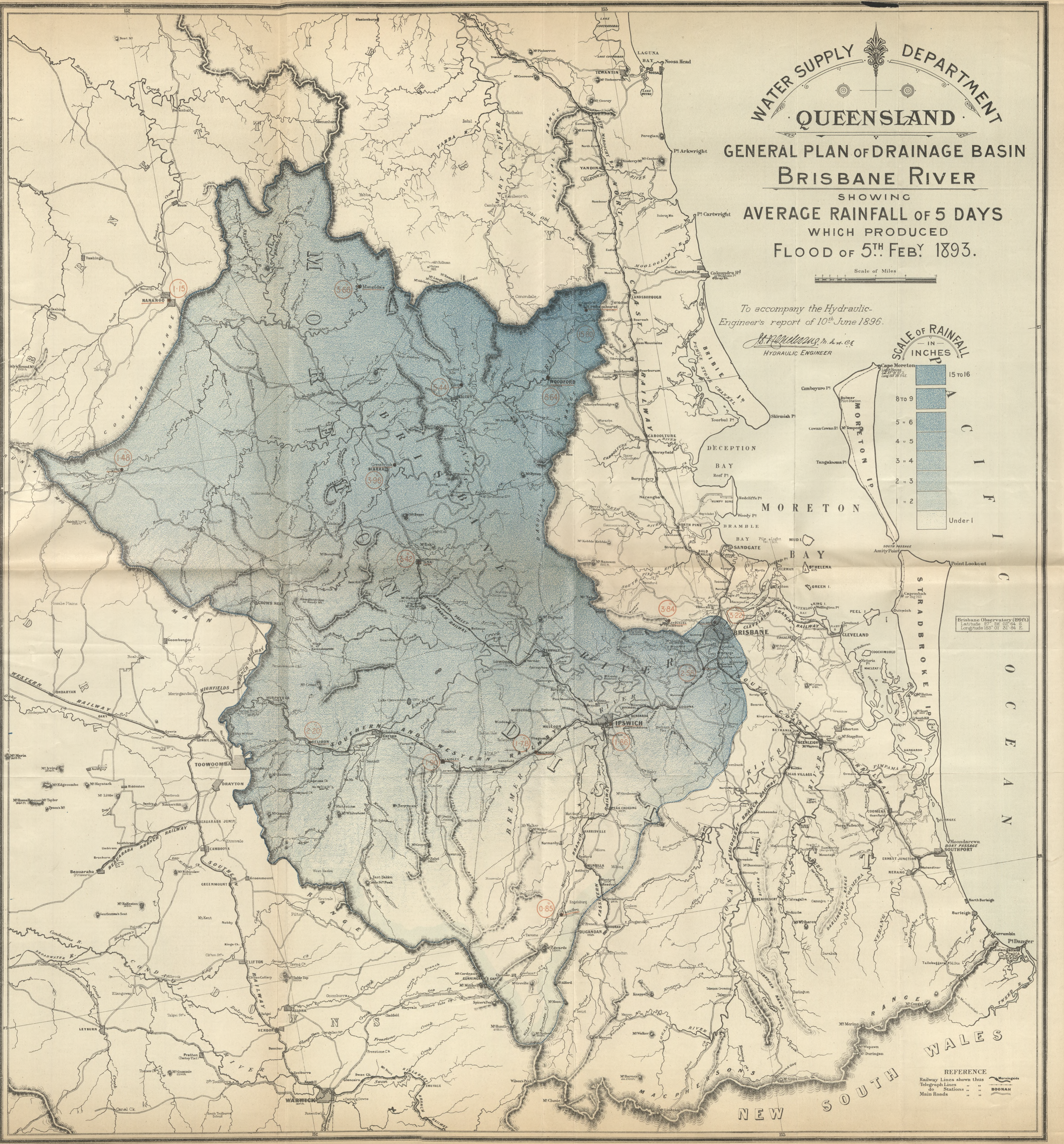
Seale, 40 Chains to an Inch.

To accompany the Hydraulic-
Engineer's report of 10th June 1896.

J.B. Henderson M. Inst. C.E.

HYDRAULIC ENGINEER.

DRAWING No 1.



WATER SUPPLY DEPARTMENT

QUEENSLAND

GENERAL PLAN OF DRAINAGE BASIN
BRISBANE RIVER
SHOWING
AVERAGE RAINFALL OF 5 DAYS
WHICH PRODUCED
FLOOD OF 5TH FEBY 1893.

Scale of Miles
4 3 2 1 0 4 8 12

To accompany the Hydraulic-Engineer's report of 10th June 1896.

J. B. Henderson M. Inst. C.E.
HYDRAULIC ENGINEER

SCALE OF RAINFALL IN INCHES

▨	15 TO 16
▨	8 TO 9
▨	5 " 6
▨	4 " 5
▨	3 " 4
▨	2 " 3
▨	1 " 2
▨	Under 1

REFERENCE

Railway Lines shown thus	Morningside
Telegraph Lines " "	
do Stations " "	BOONAH
Main Roads " "	

PRINTED AT THE GOVT. ENGRAVING & LITHOGRAPHIC OFFICE, BRISBANE, QUEENSLAND.

DRAWING No 1A

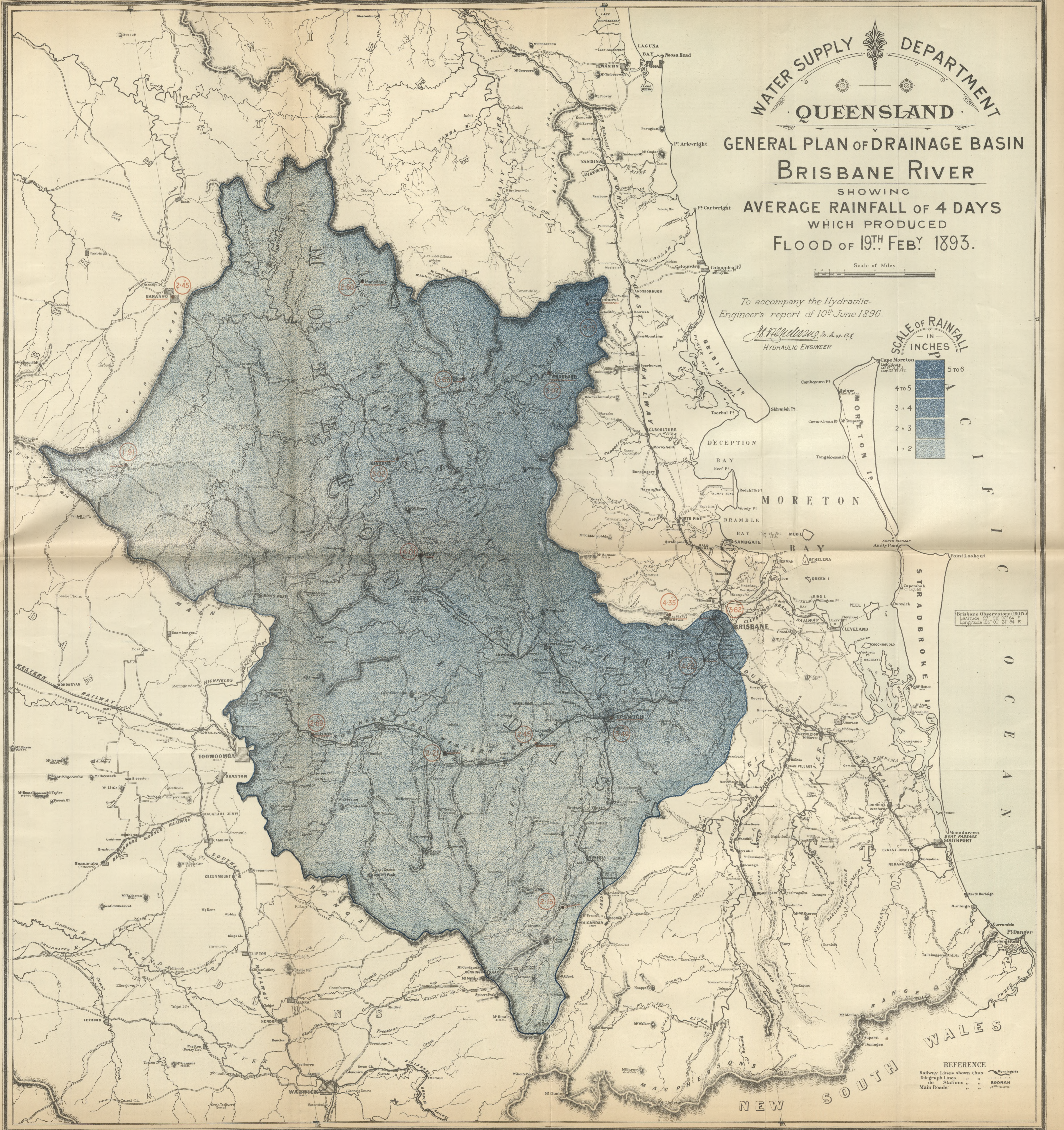
WATER SUPPLY DEPARTMENT

QUEENSLAND

GENERAL PLAN OF DRAINAGE BASIN
BRISBANE RIVER
SHOWING
AVERAGE RAINFALL OF 4 DAYS
WHICH PRODUCED
FLOOD OF 19TH FEBY 1893.

To accompany the Hydraulic-Engineer's report of 10th June 1896.

J. B. Henderson, M. Inst. C.E.
HYDRAULIC ENGINEER



DRAWING No 2.

WATER SUPPLY DEPARTMENT

QUEENSLAND

GENERAL PLAN OF DRAINAGE BASIN BRISBANE RIVER

SHOWING

AMOUNT OF DAILY RAINFALL WHICH PRODUCED FLOOD OF 5TH FEBY 1893

To accompany the Hydraulic-Engineer's report of 10th June 1896.

J. B. Henderson M. Inst. C.E.
HYDRAULIC ENGINEER

Printed at the Govt Engraving & Lithographic Office Brisbane, Queensland.

DRAWING No 2A

WATER SUPPLY DEPARTMENT
QUEENSLAND
GENERAL PLAN OF DRAINAGE BASIN
BRISBANE RIVER
SHOWING
AMOUNT OF DAILY RAINFALL
WHICH PRODUCED
FLOOD OF 19TH FEBY 1893

Scale of Miles

To accompany the Hydraulic-Engineer's report of 10th June 1896.

J. B. Henderson M. Inst. C.E.
HYDRAULIC ENGINEER

REFERENCE

Railway Lines shown thus — Morningside
Telegraph Lines „ „
do Stations „ „ — BOONAH
Main Roads „ „

PRINTED AT THE GOVT. ENGRAVING & LITHOGRAPHIC OFFICE, BRISBANE, QUEENSLAND.

DRAWING Nº 3.

WATER SUPPLY DEPARTMENT
QUEENSLAND

GENERAL PLAN
OF
BRISBANE RIVER
SHOWING
PROPOSED FLOOD RELIEF CHANNELS

SCHEMES A. B & C.

SCALE 1500 FEET TO ONE INCH

EXCAVATION OF DRY LAND SHOWN THUS ▨
FILLING " " ▨
DREDGING " " ▨

To accompany the Hydraulic-Engineer's report of 10th June 1896.

J. B. Henderson. M. Inst. C.E.
HYDRAULIC ENGINEER

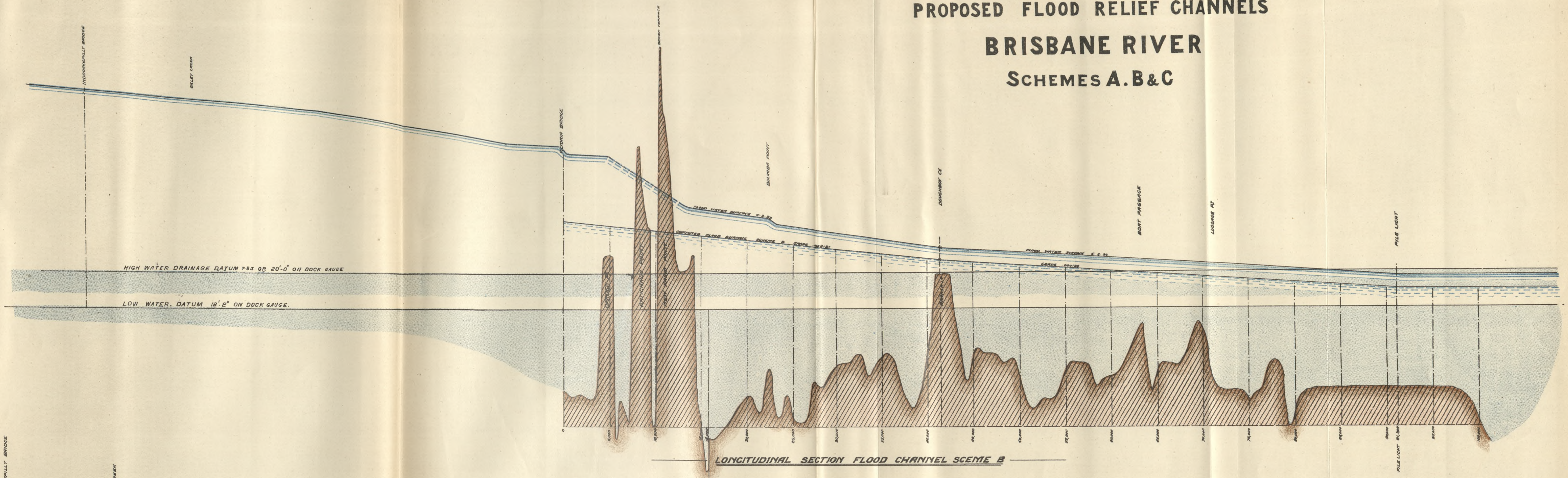
DRAWING No. 4

WATER SUPPLY DEPARTMENT
QUEENSLAND

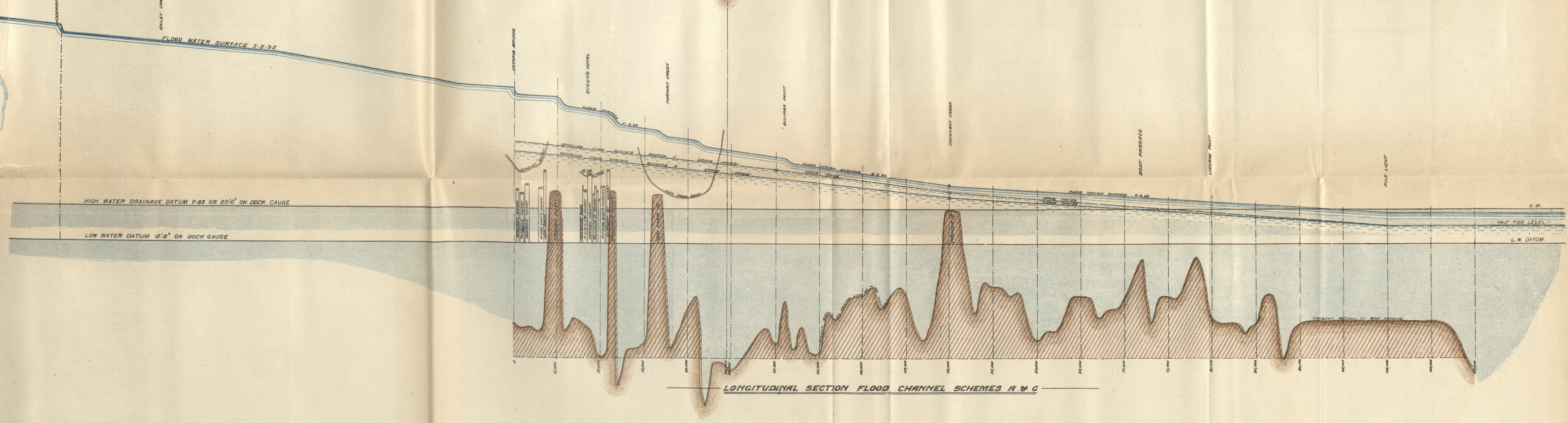
LONGITUDINAL SECTIONS
PROPOSED FLOOD RELIEF CHANNELS
BRISBANE RIVER
SCHEMES A. B & C

To accompany the Hydraulic-
Engineer's report of 10th June 1896.

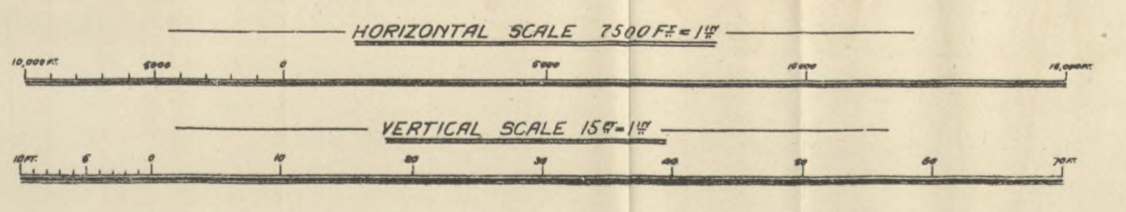
J. B. Henderson. M. Inst. C.E.
HYDRAULIC ENGINEER.



LONGITUDINAL SECTION FLOOD CHANNEL SCEME B



LONGITUDINAL SECTION FLOOD CHANNEL SCHEMES A & C



DRAWING No 5

WATER SUPPLY DEPARTMENT
QUEENSLAND

CROSS SECTIONS OF RIVER

SCHEMES A & C.

To accompany the Hydraulic-Engineer's report of 10th June 1896.

J.B. Henderson M.Inst.C.E.
HYDRAULIC ENGINEER

DRAWING No 6

WATER SUPPLY DEPARTMENT
QUEENSLAND

GENERAL PLAN
SHOWING
PROPOSED ALIGNMENT
OF
PROJECTED WALLS EMBANKMENTS &c
FOR PREVENTING INUNDATION IN N.& S. BRISBANE
SCHEME D.
AND IN CONNECTION WITH SCHEMES A. B.& C.

Another small Embankment about 1 Chain long required at Upper Melbourne Street.

SCALE.
FEET 200 100 0 200 400 600 800 1000 1200 1400 1600 1800 2000 FEET

PRINTED AT THE GOVT. ENGRAVING & LITHOGRAPHIC OFFICE, BRISBANE, QUEENSLAND.

To accompany the Hydraulic-Engineer's report of 10th June 1896.

J. B. Henderson. M. Inst. C.E.
HYDRAULIC ENGINEER