1892.
NEW ZEALAND.

DRAINAGE AND RECLAMATION OF LAKE ELLESMERE

(REPORT ON), BY J. M. HARDY JOHNSTON, M.INST.C.E.

Return to an Order of the House of Representatives dated the 7th July, 1892.

Ordered, "That a report on the drainage and reclamation of Lake Ellesmere, transmitted by the Akaroa County Council to the Minister of Lands, be forthwith printed and laid before this House."—(Mr. TANNER.)

SIR,— Christchurch, 10th July, 1878.

In compliance with an agreement entered into with the Lakes Ellesmere and Forsyth Reclamation and Akaroa Railway Trust, dated the 8th day of January last, to furnish a report upon the best means of draining Lakes Ellesmere and Forsyth, to be accompanied by survey-plans and approximate estimated cost for a line of railway from a point on the Southbridge branch railway to Akaroa Harbour, I have now the honour to submit to you the following final report upon the above-mentioned proposed works.

Having signed my agreement with the Trust at its meeting, which was held in the Beach Arms Hotel, near Lake Forsyth, on the date already mentioned, and having made a hurried reconnaissance of the mouth of Lake Forsyth, I returned the following day to Christchurch, when preparations were immediately made for carrying out a detailed survey of the estuary of Lake Ellesmere at Taumutu, which I personally commenced on the 15th January and completed by the 1st February.

Meanwhile, previous to making any arrangement for commencing a work of such magnitude as that of a survey of the whole lake, required to be completed in the short space of three months, and which could only be intrusted to very competent surveyors, I had learnt that a survey-plan of its shores, showing accurately the line of ordinary flood-height, and plotted to a scale of 20 chains to an inch, had within the last two or three years been made by direction of the late Provincial Government. Deeming it advisable, therefore, to make full inquiries as to whether such plan could be made available for our purpose, and thus be the means of greatly expediting the work, I applied at the Government Survey Office, where every facility was courteously afforded me by the Chief Surveyor for making tracings from the plans in question and collecting other information bearing upon the subject; but I regret to say that, after nearly a month's labour had been expended in procuring tracings and endeavouring to compile a complete plan of the lake, the work had to be abandoned owing to the unfinished state of the original plans and the difficulty of compiling a sufficiently accurate plan from surveys plotted to different scales.

It was therefore not until the beginning of March that the general survey of Lake Ellesmere was actually commenced, and with the aid of two surveyors I was enabled to complete the whole of the field-work by the first week in May, as mentioned in my progress report dated the 8th of that month.

The survey of the estuary of Lake Forsyth, extending from the sea-coast to a distance of nearly a mile along both shores, including soundings within the estuary, was also completed by the date above mentioned.

The survey of the proposed line of railway from Lincoln to Akaroa Harbour, a distance of 31 miles 25 chains, was not commenced till near the end of February, owing to some unaccountable delay on the part of the surveyor engaged to assist me in this work; and it was not until the 13th ultimo that I received the plans, when I discovered they were in an unfinished state.

The plans, therefore, to be referred to in this report may be summarised as follows:—

1. General plan of Lakes Ellesmere and Forsyth. Scale, 20 chains to an inch.
2. Plan of the estuary of Lake Ellesmere, showing proposed works. Scale, 1 chain to an inch.
3. Cross-sections (eighteen in number) of the estuary of Lake Ellesmere. Horizontal scale, 1 chain to the inch. Vertical scale, 20ft. to the inch.
4. Detailed drawings (six in number) of proposed works. Scale, 5ft. to an inch.
5. Plan of the estuary of Lake Forsyth, showing proposed works. Scale, 1 chain to an inch.
6. Plans and sections of proposed line of Railway to Akaroa Harbour, 31 miles 25 chains. Scale, 4 chains to an inch.

As it will be necessary to explain some of the investigations which the above survey-plans have enabled me to make, with the view of arriving at the object aimed at—namely, the best means of draining the lake—I shall now endeavour to do so in as comprehensive a manner as possible.

Lake Ellesmere is situate to the west of and adjoining Banks Peninsula, in the Provincial District of Canterbury. It lies between 44° 8′ and 44° 18′ south latitude, and 172° 23′ and 172° 41′ east longitude. Its greatest length along its southern boundary, by the shingle-bank which divides it from the ocean, is 17 miles—*i.e.*, from Taumutu to Birdlings—and its greatest breadth, measured at right angles from a point half-way along the shingle-spit to the small bight a little to the east of L2 River, is 10 miles. Its circumference at flood-line may be taken roughly at 60 miles, but the length of the traverse chained in ascertaining accurately the flood-line measured 97 miles. The area within the flood-line is computed as follows:—

	Acres.
Submerged during ordinary flood	73,195
Points of land in lake not submerged	592
Sand-hills in lake not submerged	135
Total area of lake	73,922

	Acres.
Area of land submerged, April, 1878	49,435
Area of land not submerged and lying between level of lake April, 1878, and flood-line.	24,487
Total area of lake	73,922

Much speculation has been entered into by theorists relative to the origin of Lake Ellesmere, and the changes that have taken place "in some remote period" as to the course of the larger rivers in the neighbourhood that now flow directly into the sea north and west of the peninsula, such as the Waimakariri and Rakaia, which are alleged to have at one time discharged their waters into the site now occupied by the lake. As nothing could be gained by attempting to unravel intricate questions of this kind even were there reliable data to work upon, I shall simply confine myself to the matter-of-fact evidence as gathered from the survey-plans attached to this report.

The area of the basin which is drained into the lake is about 750 square miles, and the principal channels are the Rivers Selwyn, Hart's Creek, L2, Halswell, Irwell, and Kaituna, besides several other minor creeks and rivulets, situated chiefly along the peninsula border of the lake.

The quantity of water discharged into the lake by each of the above several rivers and creeks (the Selwyn excepted) is continuous, and almost uniform throughout the year. The reason of this is that they are not greatly influenced by heavy rainfall, but almost entirely by springs, contributed most probably by percolations from the larger rivers.

Although the drainage-area of the Selwyn alone may be taken at two-thirds of the whole basin drained into the lake, yet its discharge during the year is not so great as that of Hart's Creek, or even the L2 River.

In order to arrive at an approximate estimate of the quantity of water accumulated in the lake during an average year, I will take the flood-line as 4ft. above high water of sea-level, which gives 13,939,000,000 of cubic feet, or nearly 2,000,000,000 less than calculated by Mr. Bray, M.Inst.C.E., in his report of the 10th April, 1875, addressed to the late Provincial Government.

As, however, there is reason to believe that upon the lake being let out, as has been the custom annually for several years past, and the mouth again becomes closed by the action of the waves breaking on the beach, the water in the lake having attained and preserved for some time a lower level than that of an ordinary high tide of the ocean, it would seem that Mr. Bray's figures as to the quantity of water accumulated in the lake during the year, namely—15,900,000,000 are approximately correct.

The question now arises as to the best means to be adopted, not only for draining the lake of this vast accumulation of water, but to prevent for all time any accumulation whatever above high water of sea-level in the estuary and not within 2ft. of that height in the upper half of the lake, as will presently be shown.

Having given the subject my best consideration I feel confident that, by permanently opening the mouth of Taumutu in the manner I am about to propose, the height of the lake-waters will be reduced throughout its upper compartments to at least that of half-tide of sea-level, as the full influence of the flood-tide will not have time to spread itself over so large an area and at so great a distance from the comparatively narrow entrance at Taumutu before the ebb commences.

This being the case, and taking the height of the ordinary flood-line throughout the lake at 4ft. above high water of sea-level, as already stated, the permanent reduction made in the height of the lake-waters would amount to between 6ft. and 7ft. below ordinary flood-line—*i.e.*, 2ft. at least below high water of sea-level.

The approximate area of land that would thus be reclaimed, judging by the few soundings that have been taken, would amount to between 30,000 and 35,000 acres; but how much of this will be suitable for pasturage and how much for agricultural purposes it is impossible to say until the land is reclaimed.

But, as regards the quality of the submerged lands, it is very evident that the greater portion of that which is laid bare by the periodical opening of the mouth is of such a character as to offer great encouragement for the prosecution of any works at a reasonable cost that would secure its permanent reclamation, as there can be no question of its becoming in a short time a highly remunerative undertaking.

Unfortunately there is no reliable record of the changes that have taken place in the bed of the lake beyond what can be gathered from the earliest settlers, which does not extend much beyond a quarter of a century of time, and cannot be said to throw any light upon the subject. Whatever also may have been gleaned from the Natives is extremely vague, and of no value as evidence by Mr. Bray's report, already alluded to.

It is very certain, however, that the silt and alluvium brought down by so many channels, and distributed at almost equal distances around the upper shores of the lake, has created a deep deposit of rich soil throughout the greater part of its area.

This accretion to the bed of the lake admits of being measured by ascertaining the amount of detritus held in suspension in a given quantity of its water in time of heavy freshets; and to show that this would be by no means inconsiderable, I may state it to be a well-established fact that there are few rivers of the drainage-capacity of the Selwyn that do not discharge into the sea many thousand tons of detritus annually. To compare great things with small, I may also further mention that, from observations made regularly for ten years—from 1862 to 1871, both inclusive—at one of the three great mouths of the Danube—the Kilia—it was ascertained by the Engineer to the European Commission for the improvement of that river that 426,000,000 tons of solid matter had been discharged into the Black Sea during that time—as the author states, equal to the excavation of three Suez Canals, or a mound 20ft. high covering fourteen square miles of surface.

I am therefore inclined to think that the natural process of raising the bed of the lake by the deposit of detritus brought down by the several rivers and creeks already named is more rapid than is generally supposed, and will be greatly accelerated by opening the mouth permanently at Taumutu, as nearly the same amount of detritus will then be deposited over little more than half the area than at present, although no doubt a considerable portion will escape seaward through the mouth, to be cast ashore along the shingle-bank or settle down in the ocean-bed.

The peculiar formation of the lakes, lagoons, and river estuaries along the coast of New Zealand is mainly due to the medium rise and fall of the ocean-tide, averaging about 6ft., which is not sufficient of itself to maintain a permanent channel between them and the ocean unless assisted by a constant superabundant land-flood or by the art of man.

Hence nothing of a similar description is met with on any other coast, that I am aware of, where the ordinary rise and fall of the ocean-tide reaches to even 9ft. or 10ft.

The southern portion of the Malabar coast bears the greatest analogy in its leading physical features to this coast that perhaps can be found, especially in reference to the estuaries of its mountain-torrents, terminating in numerous deep lagoons or backwaters for a distance of two hundred miles along its coast, with which I had so much to do a few years since, and which must be my excuse for alluding to the subject as an illustration in the present instance.

Although the tidal rise and fall of the ocean along the Malabar coast is only 3ft., as has just been stated, and one of the largest of the numerous lakes referred to—namely, that of Cochin—is only about the same area as Lake Ellesmere, yet, owing to the large volume of water it receives from several mountain-rivers, together with the flux and reflux of the sea, the mouth of the lake at Cochin remains permanently open, and a channel is maintained sufficiently deep to allow vessels drawing 18ft. to enter the lake, where they load and discharge their cargoes alongside a wharf in perfectly smooth water. The result is that no land is flooded above high water of sea-level surrounding the backwater of Cochin, whilst in all the others many thousand acres of otherwise valuable land is inundated during the greater part of the year, and it entails a large annual expenditure on the Government of the country in periodically opening the several bars to assist the escape of the flood-waters to the sea.

Wherever there is no perceptible rise and fall of tide, as for instance in the Mediterranean, the Black, and Caspian Seas, lagoons in the true sense of the term abound along their shores, and at the deltas of rivers, covering extensive areas, with only a few inches, or it may be a foot or two at most, in depth of water, and yet the submerged lands are beyond the means of reclamation—at all events as a remunerative work—for the simple reason that they are flooded by tideless seas.

The practice of reclaiming land, as carried on upon the shores of the British Isles, or upon other coasts where there is a considerable rise and fall of the ocean-tide, is diametrically opposite to what is required to be done either upon the shores of India or those of New Zealand, where the object is not to reclaim land from the sea, as in England or Holland, but from the periodical land-floods, whose natural outlet to the ocean is barred by the action of the waves breaking upon a sandy beach, as in India, or upon one of loose shingle of considerable depth and extent, as in New Zealand. These land-floods being thus locked up till their accumulated waters have inundated large tracts of land by rising to a level of several feet higher than the ocean, either periodically force a passage through the sand- or shingle-bank to the sea by their own weight and volume, or are assisted to do so from time to time by temporarily removing a portion of the obstruction which the sea has caused, or by works of art establishing a permanent channel.

In order, therefore, to prevent the periodical accumulation of river-floods forming into lakes and lagoons along the seaboard, as just described, the simple and only remedy is to establish a permanent channel between them and the ocean at a point which presents the most favourable site for the purpose.

To effect this desirable object at Taumutu at a reasonable cost and in a comparatively short time there can be no risk of failure whatever, provided the work herein proposed be well and faithfully executed.

With a rise and fall of 6ft. in the ocean-tide, coupled with the daily influx of the river-waters draining into the lake, it is estimated that about 5,000,000,000 of cubic feet of water will pass through the mouth from seaward into the lake, and 5,025,000,000 of cubic feet of water outwards to seaward twice in every twenty-four hours. With so powerful and constant a scouring agent there would be no risk of injury being done by shingle lodging in the channel, but should it be found that shingle had any tendency to collect behind either pier to such an extent as might endanger its being carried round the heads into the channel by the backwash of the waves—and this would be ascertained during the progress of the works—then it might be advisable to extend the piers a short distance further into deeper water; but I apprehend that this will not be required, for some years to come at all events.

As will be seen by the general plan (Drawing No. 1), the mouth of Lake Ellesmere is situate at the western extremity of a deep estuary, three-quarters of a mile in length by an average width between high-water line on either side of about 15 chains, and through which the drainage of the lake passes on its way to the sea when the mouth is open.

Referring to the enlarged plan of the estuary (Drawing No. 2), it will also be seen that the soundings marked in black figures show the depth of water in feet below high water of an ordinary spring-tide, and that it ranges throughout the deep-water channel of the estuary at from 12ft. to 23ft. for an average width of about 6 chains. The soundings outside to seaward show a depth of 15ft. at a distance of only 1½ chains from the line of high water on the beach at the mouth, and as much as 25ft. at a distance of 3 chains from the same line, which depth is also pretty uniform along the coast on either side of the proposed entrance. These soundings, both inside the estuary and outside to seaward, together with the character of the substratum, as ascertained by actual borings as shown on the plan, and by a series of eighteen cross-sections (Drawing No. 3), present most favourable features for establishing a permanent and deep channel at the point indicated upon the plan.

The works, therefore, that I have to recommend are shown in pink colour in the plan under consideration (Drawing No. 2), and consist mainly of a western and eastern pier or mole each extending from inside the estuary and through the shingle-bank to seaward beyond low-water mark.

The western pier extends in a direct line north and south at right angles with and through the shingle-bank. Including the wingwalls, the work is divided into four sections, each different in transverse dimensions and also slightly in design.

The first or sea sections of the pier from A to B is 300ft. in length, and is to consist of a strong timber framing of round totara or ironbark piles filled with massive concrete blocks set in courses within the framework and protected by loose blocks placed at random to seaward.

The whole of the hearting within the pile-framing to be carried up to 6ft. above high water provisionally, and when perfectly consolidated the superstruction can be added when deemed necessary.

The second section, B to C, being for the most part within the estuary, and backed up by firm ground, will consist of a timber framing similar to that just described, but of less dimensions, and filled with concrete blocks set in courses as shown by the transverse sections on Drawing No. 4 (details of design), which are common to both piers as regards the description of work.

The length of the wing or wharf-wall, CD, is 600ft., and varies in sectional dimensions and strength in proportion to the resistance necessary to be given to the strong ebb-current at this part, and also to the sea entering the channel between the piers. The wing-wall, BN, is 490ft. in length on plan, and is intended to protect and retain the high bank of shingle behind the piers; but it is doubtful whether it will be required, as I apprehend that after the pier is built the shingle will have rather a tendency to accumulate than otherwise at this point. However, I have thought it safe to provide for 200ft. of this wall in the estimate.

The work of the east pier, including the retaining-walls within the estuary, is divided into five sections. The two sections EF and FG, forming the pier, bisect the shingle-bank on a curve of 8 chains radius, so as to direct the current freely through the channel-mouth, and thus contract it to a width of 330ft. between the pier-heads, which form is the best the configuration of the locality will admit of so as to concentrate the scouring-power of the ebb-tide to the greatest advantage, also to act as a wave-trap within the entrance.

The seaward section, EF, is 300ft. in length, and that of the spit section, FG, 400ft. Both sections are the same in transverse dimensions as the corresponding sections of the western pier, as shown on the sheet of detailed drawings No. 4. The retaining-wall may be said to extend from G to J, the several sections GH, HI, and IJ increasing in transverse dimensions and strength as the work approaches the pier, those of the two first named being the heaviest, and their length is 300ft. respectively. The remaining length of this wall is 800ft., and is simply a retaining-wall to prevent the shingle being washed into the estuary by heavy seas breaking over the shingle-bank, which, although very rarely happening at this part, the work may nevertheless be required. It can be formed either with round and sheet piling or with fascines.

Apart from the works of the western and eastern piers, and the walls in connection with them, as already described, the walls KL and KM are necessary, not only as a protection to that part of the north shore of the estuary opposite the entrance against the erosion which would be caused by the heavy seas that will at times roll in through the new channel between the piers, but also to direct both the strong ebb-tide of the estuary and that of the creek towards the mouth.

The wall KL is necessarily of great length, measuring 1,100ft. on the plan, and KM is 400ft., but they need not necessarily be very expensive works, as will be seen by the estimate; and I am of opinion that the greater part of the walling within the estuary might be formed of good fascine work with great rapidity and economy.

The detailed drawing No. 4 is intended to show the description of the work as completed, but it will not be necessary that they should be carried out otherwise than provisionally for the first two or three years after the mouth is permanently opened, in order to allow of the hearting of the work between the close piling to thoroughly settle down and become consolidated by the action of the waves and the scour through the channel before the superstructure shall be carried up to the required height.

The approximate estimated cost of the provisional works is therefore as follows:—

Western pier—	£	£
To 300 lineal feet of pier, A to B	12,375	
To 300 " " B to C	7,575	
To 600 " of wharf-walling, C to D	3,150	
To 200 " " B to N	600	
		23,700
Eastern pier—		
To 300 lineal feet of pier, E to F	12,240	
To 400 " " F to G	11,760	
To 300 " of wharf-walling, G to H	6,750	
To 300 " " H to I	3,375	
To 800 " of reclaiming-wall, I to J	2,400	
		36,525
North shore and creek-walls—		
To 1,100ft. of walling, K to L	2,200	
To 400ft. " K to M	900	
		3,100
		£63,325
To contingencies, 10 per cent. on £63,325		6,332
Total cost of provisional works		£69,657

It will therefore be seen that the total estimated cost approximately of the whole work when completed will amount to £88,093; but it will not be necessary in the first instance to expend more than what will carry out the works provisionally, which will amount to £69,657, as already shown, and which would not occupy more than two years to complete in order to secure a permanent open channel of at least 24ft. in depth at high water and 18ft. at low water. I may add that the estimate is a liberal one; and I have every reason to believe that, in the event of the works herein recommended being required to be carried out, that a closer study of the subject would enable me to modify many portions of the design by which a considerable reduction in the estimate could be effected.

Lake Forsyth.

As several projects have from time to time been proposed for draining Lake Ellesmere besides that at Taumutu, the only one appearing at all worthy of notice is that through Lake Forsyth, by means of a canal connecting the two lakes and opening the mouth of the latter. I have been at some pains to investigate the cost of this scheme, together with its merits and prospective value, as may be seen by the plan (Drawing No. 5), which has been carefully prepared for the purpose.

The works I have to recommend for opening the mouth of Lake Forsyth, as shown in pink colour on the plan above named, consist of two piers projecting from inside the estuary through the shingle-bank and into deep water some 150ft. and 100ft. respectively beyond low-water line on the beach.

The western pier is carried the furthest to seaward, as is also the case at Taumutu, as some protection to the entrance against the south-west gales, which are the heaviest. It is divided into four sections, from A to E, including the walls within the estuary.

The eastern pier is divided into two sections, G to I, and the distance between the pier-heads is 350ft.

Both piers and the walls in connection with them have been laid out, after mature study of the configuration of the locality, in the best manner adapted to secure a permanent and deep channel-entrance, as also with reference to vessels making and leaving the channel in all states of the wind. I was unable to take soundings to seaward outside the shingle-bank, but I have every reason to believe that the water is of great depth close in shore.

The depth of water inside the estuary, as shown upon the plan, indicates a very deep channel, as much as 23ft. to 25ft. at high water of sea-level throughout the greater part of a mile in mid-channel from the mouth, which is perfectly sheltered from all winds.

The facility for carrying out works of the character herein proposed—viz., *pierres perdues*—is very great, having the best of rock stone for the purpose ready in inexhaustible quantity on the ground, and also timber close at hand. Hence the very moderate cost of the work, as shown in the following approximate estimate:—

For provisional works only,—

	£	s.	d.	£	s.	d.
Western pier—						
To 460 lineal feet of pier, A to B	14,820	0	0			
To 280 " B to C	2,688	0	0			
To 120 " C to D	1,200	0	0			
To 750 " D to E	3,700	0	0			
Eastern pier—				22,408	0	0
To 800 lineal feet of pier, G to H	19,200	0	0			
To 120 " H to I	1,820	0	0			
				21,020	0	0
				43,428	0	0
To contingencies, 10 per cent. on £43,428				4,342	16	0
Total cost of provisional works				£47,770	16	0

Additional cost of consolidating and completing the works,—

Western pier—							
To 460 lineal feet of pier, A to B	3,680	0	0				
To 280 " B to C	672	0	0				
To 120 " C to D	240	0	0				
				4,592	0	0	
Eastern pier—							
To 800 lineal feet of pier, G to H	4,800	0	0				
To 120 " H to I	580	0	0				
				5,380	0	0	
				9,972	0	0	
To contingencies, 10 per cent. on £9,972				997	4	0	
Additional cost of completion of works ...				£10,969	4	0	

The total approximate cost of the completed works is therefore £58,740, but to this there is to be added the cost of construction of 230 chains of canal, as marked upon the general plan (Drawing No. 1), which I estimate roughly from £95,000 to £100,000 at least; and this would bring the total cost of draining Lake Ellesmere through Lake Forsyth in round numbers to £160,000—*i.e.*, £72,000 over what it would cost to drain the lake more effectually at Taumutu.

In concluding this important subject, I may be excused if I mention a fact to prove the beneficial effect that is certain to arise in most similar cases by propagating the tidal wave into such estuaries of rivers and lakes on the coast that possess even a limited discharge of land-drainage compared to that of Lake Ellesmere, and in doing this I have only to state that at Kakanui, where the harbour-works are very incomplete owing to a want of funds, and the piers only extend as yet to low water-line on the seashore of the shingle-bank through which they have been carried, a channel has been scoured out and maintained to a depth of 16ft. But this is not all: in the lower compartment of the lagoon a deep deposit of offensive mud to the depth of a couple of feet at least has been scoured out, and the shores and that part of the bed of the lagoon left bare at low tide is now as pure and wholesome as any part of the sea-coast. Besides this, the whole of the lower part of the Township of Kakanui, to the extent of some 250 acres, had even been subjected to be inundated during every flood in the river to the depth of 2ft. or 3ft. previous to the mouth being opened, but now it is high and dry for all time to come, and the land has been greatly enhanced in value in consequence.

* * * * * * * * *

I have, &c.,

J. M. Hardy Johnston, M.Inst.C.E.

The Chairman, Lakes Ellesmere and Forsyth Reclamation and Akaroa Railway Trust.

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