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REPORT

by

W. G. VAN LIENDEN

on

UMFOLOSI FLOOD CONTROL

and

POLDER RECLAMATION WORKS.

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JANUARY 1958

W. G. VAN LIENDEN

S Y N O P S I S

THIS REPORT deals with flood damage caused by the Umfolosi and Umsindusi Rivers to cane lands between the S.A.R. Bridge near Mtubatuba and the St. Lucia Estuary, and in order to improve conditions, recommends the normalisation of the Umfolosi River over its entire length from this bridge to the sea, allowing floodwaters occurring with certain frequency, to flow over improved floodways, contained between embankments at a certain distance from the normal riverbed, and allowing excess floodwaters from floods of a higher magnitude, to flow along the Umsindusi River.

THE REPORT discusses the possibility of improving the Umfolosi River by shortening its length by nearly a quarter: by cutting off two riverloops and going through a low hill.

THE UMSINDUSI RIVER is to be improved under a long term development programme.

THE REPORT recommends the early reclamation of certain swamplands in order to facilitate the financing of the recommended flood control works, and points out the possible additional benefits which could be achieved by the construction of a harbour for coastal traffic near the mouth of the Umfolosi, together with industrial development.

I N T R O D U C T I O N

I would like to start with two quotations which in my opinion are guiding principles in the working out of the Northern Route.

Firstly, I quote from the classical flood embankment description by Lacey, in his 1923 Paper - "Some problems connected with the Rivers and the Canals in Southern India."

"When a river brings down a vast quantity of material either in suspension or rolled along its bed, which may consist of particles of clay, sand, shingle, or boulders, and when such a river spills its banks, its velocity is checked as it debouches from the hills into the plains and the boulders, stones and shingle are spread fanwise over the country, the point of the fan being the point of debouchment.

The River generally occupies a channel on the ridge of the fan, the valleys on either side of the fan being drained by smaller streams which discharge the spillwater of the river, and the local rainfall on their basins.

Similarly, when a river approaches the sea its velocity is checked; it spills over its margins and the silt and alluvium also form a fan-shaped deposit but this is not so pronounced as in the case of the boulder and shingle deposit.

As the flood spreads over the great alluvial plains, the farther it travels from the river, the less material is deposited, consequently the largest deposits occur in close proximity to the river which frequently occupies the highest ground.

The level of the river-bed is gradually raised and if its banks are not protected by levees the external spills cause a corresponding rise of the land on either side.

If levees are constructed the flood waters are confined between the marginal flood-embankments, and the land adjacent to the margin is deprived of its layers of deposit.

When these levees were constructed by early irrigation engineers it was considered that, by holding up the flood waters, the depth of the river would increase and that corresponding scour and lowering of the river-bed would result.

This, however, proved not to be the case.

In many rivers the effect of the levees was to raise the river-bed so that the flood-waters topped the levees, and as these were again raised, a corresponding rise of the river-bed took place, until in some places the river-bed rose above the level of the adjacent country."

Secondly, regarding the Flood Embankments along the Orissa Rivers, by Delta, written in 1858. - "About the Tidal Compartment and the Fluvitable Compartment of a River."

"If the Tidal Compartment is not capable of discharging the whole of the flood in a river and if the flood is confined within the fluvitable compartment by marginal flood-embankments, the flood line and bed of the river will be raised and the range of tidal influence will suffer diminution.

"The more the fluvitable compartment is worked beyond its capabilities, the more inefficient does it become owing to the rise of the river-bed.

If the tidal compartment is more than able to carry off the discharge of the fluvitable compartment, it will cause the fluvitable compartment waters to scour and improve this compartment in the lower stages of the flood and to increase the range of tidal influence.

The more efficient the tidal compartment the less will be the rise of the bed produced in the fluvitable compartment during high flood and the better able will the tidal compartment be, to reduce or annul the rise of the bed in the fluvitable compartment during the lower stages of the flood."

In the first quotation we have this cardinal point:-

"The riverbed may be raised by the floodwaters..."

Consequently, a flood protection scheme, using dikes for its protection, requires regular and perpetual maintenance of the riverbed and its floodways, to prevent this raising of the riverbed and to control this natural tendency.

This is the price which has to be paid for the beneficial use of the lands which encroach upon Nature's territory.

As described above, the river brings down a large quantity of silts and sands of various sizes, which want to settle in proportion to their coarseness, as the current slackens. Our principle should, therefore, be to assist the river in its natural tendency to deposit its silt load in the sea.

The river channels should therefore be planned in such a way that the bulk of the silt load is transported and deposited well into the sea by the floodwaters themselves, and that essential maintenance be done on cleaning up and preparation work throughout the year to ensure maximum flood transportation of silt during the next flood season.

The further this bedrun can be transported the smaller will be the essential maintenance and the lower the recurring maintenance costs.

DEGREE OF PROTECTION: It has to be realised that it is not reasonable and not economical to try to find 100% protection against the all-time flood, or even the flood which might only occur once in a century, as the lands are not inhabited.

We read in "The Behaviour and Control of Rivers and Canals" by Sir Claud Inglis (page 418 - Part 11. 1949):-

"In deciding what maximum flood to allow for, judgment must be used whether a risk may be taken or not. If a dam is to be built above a town, no risk can be taken, but if such damage as will occur - say once in a hundred years or more - can be easily rectified, it will often be unnecessary to design for a maximum flood. - A "breaching section" may be provided."

The all time peak flow of the Umfolosi is of the magnitude of some 250,000 cusecs or thereabouts.

Very large tracts of land would have to be occupied by embankments and floodways for this peak flow, and the construction costs of these works would be a multiple of the amount under consideration.

In view of the assets involved, I therefore consider it reasonable to protect the existing cane lands and the new proposed polder areas against a flood which might occur in the Umfolosi once in 50 years, in other words against a flood of a magnitude of approximately 100000 cusecs. ($Q_{2\%} = 100,000.$)

Any floodwaters in excess of this quantity of 100,000 cusecs, thus normally a relatively small quantity, will be allowed to flow via a breaching section A-A, or "safety valve", namely along the natural funnel over Lots 21 and 22, as it is doing at present already under flood conditions, and will flow through the existing Umsindusi and Wilson's Drain towards the sea near Mpelane.

SUMMERBED AND WINTERBED OF UMFOLOSI: The existing Umfolosi "summerbed" can take only approximately 16,000 cusecs in the S.A.R. Mill Bridge Section, after which spilling starts to take place.

Consequently, dikes, embankments of suitable strength and height will have to be constructed over considerable lengths and at a certain distance from the river, to contain this 100,000 cusecs flood within these dikes and to prevent spilling into the lands.

This land between the summerbed and the dike is called "winterbed" or floodway.

A freeboard of 4 ft. should be provided to allow for wave action and other effects and this freeboard also provides a measure of some extra discharge capacity, which amounts here to nearly 37%.

LONG TERM DEVELOPMENT SCHEME FOR UMSINDUSI:

It will be necessary to improve the Umsindusi River as well, and to regularise its bed. At present the river has no specific capacity - an unsatisfactory state of affairs - as with a catchment area total of about 190 square miles a flood of 21,000 cusecs can be expected once in 50 years. The Eteza Lake can only store part of this flow for a short time and therefore cannot act as a flood storage reservoir.

As the excess Umfolosi floodwaters, as mentioned above, might only come down once in 60 or more years, the Umsindusi will transport mainly its own floodwaters and therefore a long terms development scheme should be started for this river: starting with a cleaning out and widening programme working upstream from the new improved cut near Mpelane.

Any outcoming spoil from these operations should not be deposited close to the riverbank, but at a designed distance, forming low dikes where possible.

As the Umsindusi has a very unfavourable gradient over the larger part of its length, improvements will have to be found not so much in deepening as well, as in widening its present bed.

The stretch from the existing new cut to the Twin Drains should be given priority - other sections following in time.

The Umsindusi sections between K.79 and U.205 should be deepened as well to provide a better outfall for the Mkomane and Mavuya Valleys. The existing South embankment here should be made continuous and should be raised and strengthened, and the possibility of introducing outfall gates for these rivers, investigated, to prevent backflooding by the Umsindusi.

The works under this long term development programme for the Umsindusi should be done as part of the normal maintenance programme, for which purpose annually a sum should be set aside.

Thus, the cultivated lands being protected against large floods by the proposed dikes along the Umfolosi, together with the provision of safety valves, the inherent protection for the whole district increases year by year in proportion to the improvements effected to the Umsindusi under its long term development programme.

RIVER SURGERY: It will also be possible to improve the river gradient and to reduce the danger of spilling by applying some "river surgery"; by cutting out a few meandering loops (C. & E.) which reduce the river-length approximately 24,000 ft. from 112,000 ft. to 88,000 ft. or a reduction in length of nearly 22%, with a considerable saving in embankment construction and maintenance costs.

AREAS OCCUPIED BY DIKES AND WINTERBED: The areas occupied by the floodwaters when the river leaves its summerbed and fills its winterbed, amount to approximately 1,200 acres, which area cannot be used for cane growing.

Lack of accurate maps does not allow a better estimate at this stage.

Some selected areas might still be utilised in a minor way for sheep grazing or for the winning of hay, or the growing of lucerne, but only when permitted by the controlling authority. The floodway portions can best be given out on short leases, e.g. for 1 - 3 years, on certain conditions.

RE-ALLOTMENT OF LAND: Some present cane-growers will find their farm divided into two parts after completion of the major scheme, as the result of the above river surgery; one part say, lying South of the Umfolosi and the other part North of the river. From an economical point of view the best plan will be to re-allot those cut-off areas on each side of the river and to compensate for the areas lost to embankments and winterbed, with new land in the proposed new polders.

SEPARATION OF UMFOLOSI AND UMSINDUSI NEAR CONFLUENCE: I recommend to separate the Umfolosi from the Umsindusi at "X" by means of an extension to the Main South Umfolosi Dike, thus preventing most of the backing up of Umfolosi floodwaters in the Umsindusi.

This will also improve the location of the main gate at G.1. enabling the Polders to discharge directly in the Umsindusi, as close to the new cut as possible.

The above separating embankment or guide bank is, as it were, a part of the Umfolosi Main Dike, but of lesser dimensions and only a relatively short length is required.

TIDAL COMPARTMENT: The tidal compartment near the mouth of the Umfolosi will have to be improved by dredging.

The spoil can be dumped at selected localities, one of which is the large swamp area, marked "D", East and North East of Polder IV which area will provide a dumping ground for a period of over 40 years.

The Tidal Compartment must be able to receive a major flood of the order of 150,000 - 170,000 cusecs, without experiencing trouble.

MODEL: As the discharge of such large quantities into the sea, under influences of wind, currents and littoral sanddrift, etc., is a rather complex affair which might not even require any groynes, I recommend the expenditure of a sum for the construction and study of a model of the mouth of the Umfolosi, to find the exact requirements in this respect.

This would allay any fears which other parties might have and would provide a basis for agreement on this point.

An amount of £5,000 has been allowed in the estimates.

STABILISATION OF SAND DUNES: The widening and improvement of the tidal compartment near Mpelane will cause a few small scars in the local sand dunes.

For the stabilisation of these sand dunes I find recommended for the Zululand Coastal areas in the Annual Report of the Soil Conservation Board of 1956:-

Star Grass
Napier and Australian Wheat
Causuarina Equisitifolia
Osteospernum Moneferum }
Dadonea Viscera } in large quantities.

EXISTING NEW CUT NEAR CONFLUENCE: The existing new cut near the confluence should be enlarged over its full length and the Umsindusi section adjoining here, should be widened and deepened as soon as possible, as a preventive measure under preliminary maintenance; thus providing for the maximum possible reserve discharge capacity.

MAINTENANCE OF FLOODWAYS AND WATERWAYS: It is important to keep all floodways and waterways in the whole district free from obstructions such as trees, holes etc., and to maintain these well, e.g. by the introduction of the right type of grasses, by removing weeds and vermin etc.

Regular bi-annual inspections are necessary and a Board or Committee with statutory powers will have to be set up to deal competently with these matters.

Here the example of the system used in Holland could be followed, where regular inspections are carried out in early spring and late fall by the "dijkgraaf" and his officers in their respective polders, checking the state of the various waterways, dikes, sluices, bridges, etc., and taking measures if conditions so require. Some difficulty might be experienced by introducing such a system of controlled regular maintenance, as some people might feel that they are loosing part of their independence, and as the internal drainage system is not yet sufficiently in order.

However, the necessity of introducing controlled maintenance will be recognized as soon as the benefits, which fall to the community as a whole, are understood.

SHORT CUT THROUGH HILL NEAR ULOA BRIDGE: Just before the Uloa bridge the Umfolosi makes a large curve, from south, going south-east and then turning north, coming in Warners Drain, going around a low hill.

This curve caused many breaches just upstream of this bridge, and constitutes a danger to the southwards lying areas, from the Y-drain to the Umsindusi.

As a low saddle of approximately 60 ft. height at this hill could be traversed, a better routing would be achieved with a certain shortening of the length of the river and a slight

improvement to the gradient.

The material coming from this cut could advantageously be used for the construction of the dike lengths adjoining this cut, as the soil is of a better quality for dikebuilding than the material found in the neighbourhood, and this quantity would not have to be borrowed in the neighbourhood, which factor I consider a very great advantage.

BRIDGES: Regarding a National Road bridge over the Umfolosi or the Umsindusi, this Northern Route scheme leaves the Provincial Authorities completely free where to cross the rivers, and does not impose any particular route, thus avoiding protracted and difficult negotiations, which would cost much valuable time, and would not show any benefits.

The existing Mill bridge and the Uloa bridge however will be affected by the new winterbed, and a high level bridge, not hindered by the floodwaters will have to be built over the full width between the dikes.

The new Mill bridge will have to be designed to carry tramline traffic as well as road transport by trucks, etc., the new Uloa bridge only road transport, as for the area north of the Umfolosi North Dike (polder III etc.) the tramline could link up via a line along the Umfo North Dike and the new cut through the Uloa hill. As for the type of bridge: a Bailey type bridge could be used in both instances, which components are now available ex British Army surplus stocks, at prices considerably below the cost of new equipment.

An amount of over 30% has to be added to the cost however, due to ocean freight and high clearance charges.

It might be cheaper to construct the superstructure on the site in prestressed concrete. In both cases the bridges will have to be founded on caissons.

A tentative amount of £240,000,- has been included in the estimates.

DIKES ALONG THE UMFOLOSI. All dikes, as required along the Umfolosi, are relatively low embankments, with profile as shown on typical section; and can all be made either from excavation in loco, spoil coming from local Umfolosi widening, or regulation operations, or from new cut-off excavations, or from the cut through the Uloa hill.

Any surplus material can be spread in selected areas or used to fill in old river courses, and a few dumps could be made to provide for a reserve in case of emergencies.

The dikes are required to have a freeboard of 4 foot above the 100,000 cusecs floodlevel. Hereby has to be added a varying height due to the shrinkage of the surrounding ground, and a varying height due to the settlement of the construction fill.

As the soils vary according to their locality, it is difficult to decide on a slope for the embankments, in anticipation of the results of soil investigations.

Provisionally a slope of 1 in 4 has been assumed, for the calculation of the excavation quantities. If the quality of the spoil from the cut through the hill is as anticipated, the slope of the embankments made from this spoil might be reduced somewhat, depending on the foundation conditions.

DIKES ALONG WARNERS DRAIN AND FURTHER TOWARDS CONFLUENCE. The Umfolosi South Dike Embankment, from Drain No.4 embankment eastwards, is discussed in the Reclamation Report, as this dike protects the larger polder areas, together with the dike along the Umsindusi. The construction cost of these dikes has therefore been considered to fall under Polder development, and can be found in the estimates for those polders.

SAFETY VALVES: BREACHING SECTIONS: To prevent overtopping of the embankment during large floods, I consider that, in addition to the large natural safety valve A--A, which exists just downstream from the SAR bridge, towards Eteza, an extra safety valve or breaching section has to be provided in the new Umfolosi South Dike, as marked B--B on plan, just before the river enters the new cut through the hill.

Both safety valves could take the form of an "overlaat" section, namely a local lowering of the dikecrown to full 100,000 cusec floodlevel, thus omitting the 4 ft freeboard height. In this manner excess floodwaters would find their way via the prepared floodway between the North and South Twin Drain embankments towards the Wilsons Drain, which would have to be improved under the already mentioned long term Umsindusi development programme. These breaching sections will have to be protected by stone pitching and an apron, to prevent scouring and undermining of

the embankment.

A sum of £50,000,- has been included in the estimates.

RAISING OF EXISTING TRAMLINE: In this connection, the existing tramline, which crosses this floodway between the Twin Drain Embankments on two places, will have to be raised approximately 10 feet above the floodway, over a length of say 700 ft, for which works a sum of £5,000 - has been included in the estimates.

FUTULULU LAKE: The Futululu Lake, which is the natural drainage basin for some farms to the northwest of the Umfolosi, in that area, will require a gate to discharge into the new re-aligned Umfolosi, and to prevent backing up of Umfo water, for which works a sum of £25,000 - has been included in the estimates.

FLEXIBILITY OF EXECUTION: It is possible to execute the several components of this Northern Scheme separately, thus avoiding an elaborate organisation, and keeping the annual cost low.

I suggest to execute the various parts of the major scheme in such a way, that they do not clash or interfere with the reclamation works, but rather run concurrently with these works, which should start first.

The whole Northern Scheme can be separated into 5 major steps:

The first step should be the improvement of the tidal compartment, roughly from the end of Warner's Drain downstream towards the sea, by dredging and normalising the Umfolosi River and using the spoil as much as possible to form embankments, where these are designed.

The second step should be the construction of the main dikes along Warner's Drain, mainly the South dike first, and again the widening and normalising of the riverbed here. A part of this excavation benefits the enclosing polder dike here, as discussed in the reclamation report.

The third step should be the cut through the hill near Uloa, using the excavated soil for the construction of the main dike embankments; and the safety valve near the end of the Y-drain.

The fourth step are the river surgery works connected with the cutting out of a few meandering river loops: the construction of the new riverbed here, and corresponding dikes, and the construction of the required gate for the Futululu discharge.

The fifth step would be the rest of the dike works more upstream and the overlaat near the funnel towards Eteza Lake, as a keystone.

The two required bridges can be constructed quite independently from this programme.

Each of the above steps would increase the protection against floods, till the fullest possible protection is reached. Actually, the protection against floods increases in direct proportion to the amount of works being executed.

Various combinations are also possible:

(I) From a financial point of view, it would be possible to construct all the polder reclamation works only, and to do nothing else. This would give, after a short construction time, a certain amount of revenue, which would easily outweigh the losses sustained annually by uncontrolled flooding. And everything could be left at that.

(II) The next combination would be the construction of the polders coupled with improvements to the tidal compartment only, step 1. This would give revenue, but not much relief during floods.

(III) The third combination and better proposition already would be polder construction with steps 1 and 2.

(IV) From now on it is rather difficult to separate the various works, as e.g. the cut through the hill provides the spoil for the construction of the embankments in this area. At this stage the safety valve near the Y-drain should be completed, and, the Umsinduši should in a provisional way have been cleaned out and widened in the long term program for this river, as far as the Twin Drains, so that an uninterrupted floodway is provided during the works on the hill cut.

Another approach could be, if it were decided not to spend any funds on the polder reclamation works, to start with step 1, improvement to the tidal compartment, and then to go over to step 4, and do the river surgery, etc., as described, followed by the safety valve near Y-drain and floodway between Twin drains. This would not be a complete scheme, but the measures would give some relief.

The recommended method of execution however is to start with the Polder reclamation works, as described in the reclamation report, and as soon as the organisation herefore is under way, say after eight to ten months, to start with step 1, and step 2, as described, of the Northern Scheme, and then the various other steps.

ESTIMATE OF COST OF COMPLETE NORTHERN ROUTE.

1.	<u>CUT THROUGH HILL AT ULOA:</u> 3,034,000 cuyd ad 2/- cuyd	£ 303,400.-
2.	<u>UMFOLOSI SOUTH DIKE EMBANKMENT:</u> from Uloa Cut - No.4 drain embankment. 9,400 ft. normal profile 952 sq. ft. 331,400 cuyd ad 1/- cuyd	£ 16,570.-
3.	<u>UMFOLOSI NORTH DIKE EMBANKMENT:</u> from Uloa Cut - end polder III. 758,000 cuyd ad 1/- cuyd	£ 37,900.-
4.	<u>EXCAVATION RIVERBED (cut-offs):</u> bed 190' - top width 250' - 15' deep. 14,000' length. 1,710,000 cuyd ad 1/-	£ 85,500.-
5.	<u>UMFO DIKE EMBANKMENTS ADJOINING THIS EXCAVATION.</u> Standard dike sections, both sides of river. 14,000' 987,000 cuyd ad 1/6	£ 74,025.-
6.	<u>UMFO DIKES - both sides:</u> from SAR - Uloa cut less cut-offs. 64,200' length - standard profile. 2,264,000 cuyd ad 2/6.	£ 283,000.-
7.	<u>WIDENING RIVERBED:</u> Extra 110' - From Uloa Cut - end polder III. 20,000 ft. 1,222,000 cuyd. (half this quantity has been allowed for in polder est. for construction of polder embankment.) 611000 cuyd ad 1/-	£ 30,550.-

Carried forward £ 830,945.-

	Brought forward	£ 830,945 - -
8.	<u>TRIMMING AND EGALISING</u> <u>EMBANKMENT SLOPES:</u>	
	122,000 linft ad 2/6d per linft.	£ 15,250 - -
9.	<u>DREDGING TIDAL COMPARTMENT:</u>	50,000 - -
10.	<u>FUTULULU GATE INTO UMFOLOSI:</u>	25,000 - -
11.	<u>STONE PITCHING - BREACHING</u> <u>SECTIONS IN UMFOLOSI DIKES:</u>	
	(a) near S.A.R. Bridge 17,000 sq. yd. ad £1/sq. yd.	17,000 - -
	(b) near "Y" Drains 33,000 sq. yd. ad £1/sq. yd.	33,000 - -
12.	<u>LIFTING TRAMLINE</u> crossing floodway between Twin Drain Embankments	5,000 - -
13.	<u>MODEL MOUTH UMFOLOSI:</u>	5,000 - -
14.	<u>NEW BRIDGES</u>	240,000 - -
		<hr/>
		£ 1,221,195 - -

Say £1,222,000 - -

Above estimates show that for the total Northern Scheme a quantity of 4.3 million cubic yard is required for fill in profile, and that about 6 million cubic yard is available in cut.

Allowing 20% for settlement, consolidation, etc. this brings the required fill quantity to 5.4 million, or a surplus of cut over fill of say half a million cubic yards, which amount can easily be spilled in increased profile, old riverbeds, holes, etc.

The unit prices used are not unreasonable, and have been paid for similar work elsewhere. Besides this material from cut is again charged when used in fill.

FINANCES:

The amount of £ 1,222,000,- for the total Northern Scheme would require £ 88,600 - per annum for redemption of capital and interest in 30 years ad 6%.

Likewise £ 21,750,- p.a. would be required for the Polder construction costs of £ 300,000 -, as follows later on in this report, or an annual total of £ 110,350,- for both schemes together.

Against this amount of £110,350 - we have to consider the amount at present annually lost to floods, say a conservative figure of £ 100,000,- besides the income from new polder areas.

This income is a variable amount, estimated to start with say £ 72,000,- after the first $1\frac{1}{2}$ -2 years after the start of the reclamation works, increasing to £ 904,000 - after 6 years from start, for 11,300 acres ad £ 80.- per acre.

It would thus appear to be not too difficult to finance the schemes in the light of the benefits which will accrue from increased safety to flooding and new reclaimed lands.

EQUIPMENT AND STAFF:

It has in principle been assumed that all works will be done by your Company with your own machines and your own staff. As you already have a competent organisation dealing with labour and the organisation thereof, it did not seem necessary to allow for large overheads in this respect.

At some stages of the works, in order to speed up seasonal work, or to reduce risks, or in order to prevent the buying

of too much machinery or plant, it might be advisable to give out some minor parts of the Scheme to subcontractors. For instance, the construction of the two new bridges, or possibly part of the cut through the Uloa hill.

In general, in the type of work under consideration, the smallest unit-costs are usually obtained with the largest dredgers and the smallest draglines, achieving efficiencies of 70% for $\frac{3}{4}$ cy draglines (% actual digging hours to total hours worked, sustained performance) and 75% for dredgers.

As the quantities of excavation in the Northern Scheme do not warrant the use of very large dredgers, it has been considered a wiser policy to use a few units of the same, moderate size, thus simplifying the training of operators, the maintenance, the spare parts supply, and the pipe yard position. I would therefore recommend all suction cutter dredgers to be of the 16 inch type.

The same applies to the $\frac{3}{4}$ cy draglines, which should all be of one or two types only.

If a construction time of 6 years is taken as a basis for the Northern Scheme, the following plant is recommended as main equipment:

<u>No.</u>	<u>Type</u>	<u>Remarks</u>
2	16" Suction Cutter Dredgers	one of which could possibly be the s.c. dredger recommended for the Polder Recl. Wks. for long distance throws
1	booster station	
	16" steel pipes and couplings	
4	$\frac{3}{4}$ cy draglines, with min. 40' boom and swamptracks	
2	D-7 bulldozers	} general work, clearing up, opening up, etc. compacting work etc.
1	motor grader	
3	15 cy scraper units	15 cy struck capacity
2	work boats for dredgers	resp. 1, if one dredger, see above.
	optional 2- 10 ton sheepsfoot rollers	
	1- ripper attachment	
	a survey boat, which can be shared with the Polder construction works.	

For some stretches of dike work, it might also be possible to make use of some of your Loco's and rails together with cocopans.

One dragline could keep 3 a 4 trains of 20 cocopans busy, depending on the situation.

This is only a provisional list of recommended plant: the actual requirements might be slightly different when the quantities of excavation, etc., are more accurately known.

For major overhaul of plant and major repairs, which can not be done under field conditions, it is assumed that use could be made of the existing repair- and mechanical workshop facilities attached to the Mill in Riverview.

Similarly in all matters concerning Staff, workmen, accountancy, correspondence, etc. it would be possible to make use of the existing facilities of your Company.

The following Staff is suggested:

<u>Europeans</u>		<u>Natives</u>	<u>Can be combined with Polder Wks.</u>
			<u>xx</u>
1	Civil Engineer		
1	Assistant Civil Engineer		
1	Worksforeman		
1	Surveyor		
1	Draughtsman		
2	Dredger operators	4 oilmen	
		4 deckhands	
	Dragline operators	4	
		4 oilmen	
	D-7 Bulldozer operators	2	
	Grade operator	1	
4	Gangers	100	2 gangs levelling, egalising, etc. 2 gangs at 16" pipes discharge ends.
1	Servicing mechanic	2) field unit xx
1	Blacksmith/Storekeeper	3	
	Surveyboat	1	xx
(1 optional)	Workboats	2 a 4	
3	Scrapers		
	Timekeeper	1	
<hr/>			
Total 16 Europeans		128 a 130 Natives.	

COMMUNICATIONS: As the distances between the various parts of the works and to the Riverview offices and Workshops are large, it is recommended to install two-way radio communication sets on the dredgers, in the field servicing/ repair shop, in the workboat and the surveyboat, and in the Engineer/Foreman's office.

MACHINERY FOR MAINTENANCE OF DIKES, RIVERS AND FLOODWAYS:

For the underwater section of the River and Tidal Compartment:-

The 16" Suction Cutter Dredger.

The 60 Liter Vloeimolen, which is also used in the Polders,
and on some places one of the $\frac{3}{4}$ cy. draglines.

For the grass and scrub eradication and weed-control of dikes
and floodways:-

A John Deere Model P.107 Gyramor Rotary Cutter and/or

A Marden Medium-sized Duplex Brushcutter.

S U M M A R Y

1. The Tidal Compartment of the Umfolosi River is most important and should be improved mainly by dredging.
2. The Umfolosi River should be provided with a summerbed from the Mill Bridge as far as the end of the proposed Umfolosi South Dike and should have floodways designed to pass floods of a magnitude which might occur once in 50 years. The lands should be protected by dikes against such floods. To provide a fast routing of the floods the proposed river cut-offs and the cut through the Uloa Hill should be made.
3. The Umsindusi River should be improved under a long term development programme, being ultimately capable of passing any excess flow of floods, larger than the once in 50 years flood.
4. A Board with Statutory Powers should be set up for the district, charged with the organisation of controlled maintenance and funds should be set aside for this special purpose.
5. It will be possible to achieve the benefits of the scheme within the reasonably short construction time of about 6 years with the aid of Suction Cutter Dredgers, Draglines and Scrapers as the major tools.
6. It is recommended to start with the Polder Reclamation works, as further on described, and as soon as these works are underway and some experience has been gained, to start with the various steps as proposed, beginning with the tidal compartment.

AREAS WHICH CAN BE RECLAIMED:

POLDERS. There are several tracts of Crownland which are periodically flooded by the Umfolosi and Umsindusi Rivers, and by high tides from the sea.

As these areas are above Mean Sea Level they could be reclaimed at an economical cost.

The most direct and immediate method of reclaiming and safeguarding these areas against various adverse influences is by the construction of Enclosing Embankments or Dikes of sufficient height, thus forming a Polder, whereby the rainfall is collected in and transported by Canals which discharge via Sluiceways into the river near the sea.

I recommend for reclamation as Polders:

1. The Swamp Area East of No.4 drain, surrounded by the Umfo and Umsu, in extent about 10,830 acres gross, which contains the Polders 1a, 1b, 1c, 11a and 11b. See Plan - P-1.
2. The Swamp Area formed by the proposed new Umfo North River Dike, along Warner's Drain and the old Umfo River loop, in extent about 1150 acres gross, marked Polder 111.
3. The Swamp Area just East of Polder 111 and North of the Umfo North Dike, in extent about 400 acres gross marked Polder 1V on plan.
4. The large Swamp Area North from the Umfo and East and North-east from Polder 1V as far as the St. Lucia Estuary in extent about 2,000 acres, marked "D" on plan.

The Polders 1, 11, 111 and 1V could be used for the growing of sugar-cane, providing a total gross area of 12,380 acres of new land.

The area North of the Umfo, as per No.4 above is partly intended as a spoil area, namely to deposit the annual maintenance dredgings from the river mouth and adjoining river areas.

This dump area will be sufficient for a considerable time; I estimate that, if dredgings were deposited at the rate of 1 million cu yds per year and 15 ft. high, there would be space for over 40 years.

Industrial Area and Harbour for Coasters. The area could be developed into a small harbour for coasters, with annexes such as sheds, warehouses, light-industry etc., and with a few cranes for the shipping of timber etc., and roads could be developed linking up with Mtubatuba and Riverview, inland as well as along the Umfo North Dike as a direct link.

POLDERS 1 AND 11:

KAVELS. The individual "Kavels" in the Polders have been made approximately 40 acres each where possible, as the most economical unit in planting, cutting, etc., in terms of access, transport, drainage, supervision and maintenance.

Where possible each kavel has been given a largest dimension of not more than 2500 ft. and the short dimension 750 ft., arranging a group of kavels in such a way that there is always a main-canal or canal draining the respective kavelsluits which form the boundary of each kavel.

Each kavel has access to the tram system on one of its sides.

Care has been taken not to cross the canals with the tram-rails, in order to avoid bridges. Only in two cases was it found necessary to cross the canals and well in Polders 11a and 11b.

If found necessary after one or two seasons after completion of the respective kavelsluits to further improve the local drainage of a kavel, additional kavelsluits or ditches may be provided by further subdividing of the kavels.

TRAMLINE SYSTEM: Polders 1a, 1b, 1c, 11a and 11b are all connected to the existing main line system which enters the new areas at 2 points. Firstly where the No.4 Drain Embankment touches the Umfo Dike. This line serves the part of Polder 1a to the North of the main canal A and Polder 1b. Secondly where the existing tramline crosses the No. 4 Drain North of Mr. Woolmore's Farm. This line branches off, serving the various parts of Polders 1c, 11a, 11b and the Southern part of Polder 1a.

Both these main lines are through connected via the loop near the sluiceway - G.1.

The Polders 111 and 1V require a line which will go through the proposed cut near the Monzi Bridge, linking up with the Lots 82 and 83 etc., in the area North of the Umfo Dike.

In connection with the River surgery proposed in the Northern route some re-arrangements in the tramline system would have to be made here.

DIFFERENT POLDERLEVELS: The Eastern portion of Polders 1 and 11 is just above MSL and consequently not fully safe against river floodwaters and high sea tides, but on the other hand large areas more towards the West have a considerably higher level and it has, therefore, been found necessary to divide the Polders 1 and 11 in the areas as shown on plan, each with different water drainage level, or 'polderlevel'. This will greatly facilitate the normal drainage control and water management.

The subdivision of the Polders 1 and 11 is now as follows overleaf:

Polder	approx. gross area in acres	total gross area in acres	prelim. suggested polderlevel
1a	4960	7120	+ 15 and + 13
1b	690		+ 10
1c	1470		+ 10
11a	2070	3710	+ 13
11b	1640		+ 9
and for the Polders 111 and 1V			
111	1150		+ 18
1V	400		+ 14

The areas 1a, 1b, 1c, 11a and 11b must be able to drain via the gate at G.1. on the Umsindusi.

The areas V1, 1a and 11a can also drain via G.2. on the Umsindusi.

Area 11a, including 11b for that matter, can also drain independently on the Umsin via Gate G.2. when Gate G.3. between Polders 1 and 11 is closed.

I suggest that gate G2 be considered as a reserve gate, with capacity to drain 11a and 11b only. G2 thus would provide a reserve drainage capacity.

Gate G5 can refuse area V1 to drain via Polder 1 etc., depending on conditions in 1 and 11. Area V1 will then drain via No.4 drain southwards.

The above sub-division of the areas determines the capacities and dimensions of the various sluices, canals and main canals and pumps in this preliminary layout.

ROOTZONE OF CANE: As for favourable development, at least 2ft of well drained soil has to be available in order to provide the conditions whereunder cane can grow; this depth of 2 ft. has been adopted as the upper limit of the water table.

DIMENSIONS OF MAIN CANALS AND CANALS: With a view to construction and future maintenance I suggest to adopt dimensions for the main canals and canals which allow a 16" suction cutter dredger to be used for the initial rough excavation and thereafter a 60 liter vloeimolen to be used for the initial deepening and finishing of these canals and for the following maintenance.

Only the kavel-sluits are to be made and maintained by dragline or similar equipment. The excavations for these kavel-sluits, however, are considered to fall under "development" and are, therefore, not included in my estimates for Polders.

It is considered that in view of the soil encountered a maximum underwater slope of $1:2\frac{1}{2}$ may be allowed; however, it may be necessary to adopt even flatter slopes depending on the results of soil investigations.

In this connection it is recommended to excavate these canals only 'in the wet' and to provide the required capacity by making the canals wide and not deep.

For the smaller canals a minimum bottom width of 20 ft. is recommended. Some canals will, as a result of this requirement be oversized; this, however, will provide some extra storage capacity in times of heavy precipitation.

This recommendation to normalize the canal sections and dimensions in general will simplify the construction, the setting out and costing and will give some small extra storage capacity.

LINING OF PIPING CANALS B. and F. It may be necessary to line part of these main canals B and F with Gunite, Colcrete or Stone Rip Rap, or otherwise, if high velocities occur near the gates during sluicing or if rugosity has to be improved on account of flat gradients.

The main canals B. C. and F. will have no bottom gradient and will be level, in order to be able to use these canals in both directions as required. There will be a 'fall' when sluicing takes place. These canals have a bottom width of 42 ft.

Between Canal 18 in Polder 11a and Canal 20 in Polder 11b a gate G.4. could be provided in order to drain part of Polder 11a in a fast manner into Polder 11b in times of emergency or for other reasons.

PUMPS: The Polders 1b, 1c and 11b have too low a polder level to be able to drain by gravity on the main canals and require pumps to relieve these areas of precipitation and seepage.

The provisionally estimated capacities for the pumping stations P1. P2 and P3. are approximately 42, 89 and 105 cusecs with lifts of resp. 5 ft. 5 ft. and 6 ft.

In connection with canetrash and other flotsam driftwood I would recommend the use of Helicoid Screw Pumps which are not sensitive to vegetation etc., and do not clog up.

DIVISION BETWEEN POLDERS 1 AND 11: It will probably not be necessary to construct an embankment between Polders 1 and 11 as the old river course which forms the division approximately is slightly higher than the surrounding area, and only some small earthworks might be required to regularize the tram route as indicated.

EMBANKMENTS: All internal embankments, where necessary along the main canals and the canals are low dikes of approximately 6 ft. heights and can all be made from the spoil coming from the canal excavations.

Any surplus material can be spread over selected areas, as required, or a few reserve dumps can be made to provide for some stockpiling in case of emergencies.

The enclosing embankments along the Umfo and the Umsind are higher and require a crown height of at least EHW - Extra High Water, plus freeboard, which in the lower areas near Polders 1c and 11b amounts to about + 16 MSL plus 6 ft. freeboard = say + 22 MSL or an embankment of approximately 10 ft. above ground level here. Hereby has to be added the height due to shrinkage of the swamp floor and the over height due to shrinkage and settlement of the construction fill.

It is difficult to express an opinion about the slopes required for these main embankments as this depends so much upon the local type of soil, the height of the embankment and conditions of the sub-base encountered.etc.

It has been assumed, however, that normally a slope of 1 in 4 will be used and especially along the Umsind Swamp it might well be necessary to adopt slopes of 1 in 8 or even flatter.

In these areas the soil might have to be placed in lifts, allowing each lift to dry out and increase its bearing capacity before the next lift is applied. Again, regular soil investigations will give clarity on these points.

SETTLEMENT OF SWAMPFLOOR: As the drainage conditions improve and the water-table in general lowers, the swamp floor will settle. Amounts of 1 to 2 ft. can be anticipated and by the design of canal-inverts, pumping stations and gate sluices, this factor has to be taken into consideration.

SALINITY: It is possible that some lower areas of Polders 1a and 11a, at present inaccessible, when reclaimed will have a rather high accumulation of salts due to occasional flooding by sea-water.

Accumulation of salts in soils may have detrimental effects on crop quality as well as on crop yield. The effect on sugar cane may be an abnormal salt content in the milling juice.

Unfortunately it has not yet been possible to take watersamples for analysis in these lower swamp areas.

The sooner the lower land is leached out by precipitation and proper drainage, the sooner it can be brought under cultivation.

As experience has shown that it takes from one year to lower the salinity in sandy soils and from two to three years in clayey soils, an early construction of the canals and embankments in these areas is therefore imperative to reduce this leaching period.

POLDERS III AND IV: These areas are to the North of the new proposed Umfo winter dike, which dike protects the areas against river floods and against extra high water spring tides from the sea.

As the lands beyond the old river course are rising towards the North it will not be necessary to completely enclose the areas, as was discussed for Polders I and II.

Polder III Gross 1150 acres, Net approximately 1000 acres, discharges also the rainfall of a certain area U.178 and to the North thereof.

I suggest, therefore, to construct one main canal only, as shown on plan, which will serve above area and Polder III, together with a few small sluits, kavelsluits, spaced 1000 ft, discharging into the main canal; the main canal to be dredged by suction cutter dredger or vloei-molen, the sluits otherwise.

A pump at P 4. with capacity of approximately 60 cusecs will drain into the Umfo.

The tramline is proposed near the foot of the Umfo main dike to save the grade for the branchlines, passing the pump at P.4 and going into Polder IV as shown.

Polder IV. Gross 400 acres. Net approximately 250 acres, lying between the old river course and the new main dike, does not require any canals. A few sluits are shown, which will be sufficient to transport the rainwater to pump P.5 with a capacity of approximately 15 cusecs, which again discharges into the Umfo.

The old Umfo bed could stay in use as a gathering drain for the higher ground to the North.

GENERAL: It is generally recommended to dredge the main canals as early in the scheme as possible in order to initiate and increase the drainage towards the gates and to provide flotation, thus speeding up communications by water and land and accelerating the development of the various polders.

GRASSING OF EMBANKMENT AND DIKES: All embankments and dikes should be protected by grass.

MACHINERY FOR MAINTENANCE OF DIKES AND CANALS: For the underwater section of the main canal and canals a 60 liter Vloeimolen 6 bucket-dredger with 60 foot delivery chutes on each side is recommended.

For the grass and scrub eradication during the reclamation period and afterwards and for weed-control of the dikes and canal verges and small sluits - a John Deere Model P.107 Gyramor Rotary Cutter and/or a Marden Mediumsized Duplex Brushcutter are recommended.

All the cross sections of dikes and canals are designed to be mechanically maintained with the above machinery.

I do not have to explain the importance which is attached to a good functioning drainage system, with ditches and canals, as this is known in hundreds of Polders all over the world and especially in Holland. If these Polders were not regularly maintained, by dredging the canals or otherwise, the lands would revert to swamps in a very short time.

It may also be interesting to note that in the Mississippi River delta section of Louisiana (U.S.A.), an area which has an average rainfall of approximately 60 inches per year, the sugar cane area has approximately 1 mile of ditch to every 20 acres of land and in the cotton area 1 mile of ditch to every 50 acres of land.

RECOMMENDED PROCEDURE OF CONSTRUCTION:

Polders 1 and 11. From an economical point of view it will be most advantageous if revenue is derived from the polder areas at an early stage.

This would reduce the capital requirements for the construction of the Polders and would provide an all round increase in efficiency in the Mill production and distribution of transport and would provide compensation for the areas lost due to the main flood control scheme.

I would recommend to start with the dredging of the canals 1 and 2 in Polder 1a bringing the suction cutter dredger through the existing Umfo embankment in the head of proposed Canal 2, working down towards the main canal A and then dredging Canal 1. Then returning towards main Canal A, dredge this canal as far as Gate 4 (upstream) and then downstream as far as just downstream of the intersection of Canals 3 and 4 with main Canal A. After this the dredging of Canals 3 and 4 would follow, whereby canal 4 will come in temporary open connection with the Umfo to provide the necessary water requirements for the dredger.

A dragline closes the gap formed in the dike by the entry of the dredger into Canal 2 immediately after the passage of the dredger and a temporary valve is put in for the above mentioned water requirements.

At the same time the spoil from the dredger is pumped through pipes to form the new embankments along the Umfo, in conjunction with draglines, which form the initial toes, etc., and bulldozers which do the general cleaning up work here and provide the required compaction.

If necessary, depending on the time of construction a part of the spoil coming out of Canals 3 and 4 can be temporarily dumped along the 3-4 Canal, to form a temporary low dike thus safeguarding this new area against backflooding by possible Umfo floods etc.,

In a similar manner the dredger continues in main Canal A towards Canals 5 and 6 etc.

Main Canal A continued in Main Canal B with embankments, should be first completed after which Main Canals C and F with adjoining embankments could be constructed.

At the same time the construction of the various gates and pumping stations should be in continuity with the dredging progress.

In this manner a first area of approximately 900 acres would be reclaimed in 6 to 7 months and be made available for immediate development which area would start to produce sugar cane after from 18 months to 20 months from starting, or say £72,000.

Similarly an area of approximately 5000 acres would become available after about $1\frac{1}{2}$ to 2 years which would produce say 5000×50 tons = 250,000 tons cane after three years from start, or about £400,000, and about 7000 acres under cane, yielding say 350,000 tons after four years from the start, completing the construction in the fifth year.

This is for the Polders 1 and 11, with as equipment one suction dredger for the rough work together with one 60 liter Vloeimolen (bucket dredger) with 60 ft. side chutes for the deepening and finishing off and five draglines $\frac{3}{4}$ cnyd, with 40 ft. standard boom and swamptracks and one D-7 bulldozer and a grader as main equipment.

One or two grabs on pontoons will be required to assist the suction dredger in the swamp area of the Umsindusi with the construction of the main dike. These are already in your Company's possession.

This is all in single shift.

If double shift is worked, in selected sections, at a later stage and if required, the construction time could be somewhat reduced. The lower Polders 1b and 1c and 11b however, will slow down the pace, as probably will the construction of the embankment along the Umsindusi where conditions are not so good.

Polder 111 does not provide construction difficulties. The main canal can be made either by suction cutter dredger or by vloeimolen.

QUANTITIES OF EXCAVATION: The quantity of spoil coming from the various canal excavations is larger than the amount required for the construction of the internal low dikes.

A large quantity can therefore be used in the construction of the enclosing embankments by piping the spoil from the suction cutter dredger, if necessary with a booster station, if distances become large.

Excavation canals	2,650,000 cuyd	Allowing 10% settlement.
Fill in internal low dikes	278,500 "	310,000
Fill in Umfo embankment	1,425,000 "	} 2,930,000
Fill in Umsu embankment	1,211,700 "	

Thus shortfall 2,930,000 - 2,340,000 cuyd = 590,000 cuyd to be found from local summerbed widening of Umfo.

ESTIMATED COSTS OF POLDERS 1 AND 11:

1. <u>Excavation canals</u>	2,650,000 cuyd ad 1/-	£ 132,500 - -
2. <u>Internal low Dikes</u>	310,000 " ad 1/-	15,500 - -
3. <u>Enclosing embankment along Umfo</u>	590,000 " ad 1/6 (Not included in Main Scheme Umfo)	44,250 - -
4. <u>Trimming and Deepening Canals</u>	160,000 linft ad 2/6	20,000 - -
5. <u>Pumping Stations P1. P2. P3.</u>		50,000 - -
6. <u>Sluice Gates G1. G2. G3. G4</u>		32,500 - -
7. <u>Lining part of Main Canals B. & F.</u>		5,000 - -
		<hr/> £299,750 - -
	Say	<hr/> £300,000 - -

ESTIMATED COST OF POLDER 111. The cost of the Umfolosi main dike embankment falls under the major Flood Control Scheme.

1. <u>Canal Excavation</u>	85,330 cuyd ad 1/-	£4,300 - -
2. <u>Trimming and Deepening of Canal</u>	8,000 ft. ad 2/6 p. linft.	1,000 - -
3. <u>Pumping Station say 60 Cusecs.</u>		7,000 - -
	Total Construction Cost	<hr/> £ 12,300 - - or

approximately £1 4 6 per acre - a very economical proposition.

YEARLY EXPENDITURE: This £300,000 at 6% interest over 30 years would require for interest and capital redemption an annual amount of £21,750 for a net area of 10,300 acres or £2 2 2 per acre per year.

Although not falling under this report, we have to add the amount to be expended by your Co-operative for the clearing of the lands itself and for the extension to the tramline system.

Assuming an amount of £12,200 for 12.2 miles of tramline, second hand (SAR), at £1,000 per mile, and 10,300 acres of land clearing at £7 10 - or £77,250 - -. this totals £89,450 or say £90,000 - - This amount at 6% interest and 30 years period requires for interest and redemption an annual amount of £6,525 - - or 12/8d per acre per year.

The full development cost per acre per year would thus be £2 2 2 plus 12 8d = £2 14 2 which amount is indeed a very economical one.

For purposes of comparison; on the Kafue Flats in Northern Rhodesia an estimate has been made by a team of drainage and agricultural experts for two large polders, enclosing 120,000 acres of agricultural land at a total expenditure of £80 per acre or £6 4 - per acre for interest capital repayment, maintenance etc.

POLDER IV: In view of the ultimate capacity of the Mill and the areas available for reclamation, it might not be necessary to reclaim the full acreage, but to leave out a section which per acre unit is more expensive to construct.

I think hereby of Polder IV, which with a potential of 12,500 tons cane in order to reclaim only 250 acres net, has to have an expensive Umfolosi dike, a small pumping station together with a rather long tramline access.

I therefore suggest not to reclaim Polder IV and not to construct the Umfolosi North Dike at this section until the possible yield of cane of this Polder becomes essential to the Mill.

MAIN EQUIPMENT REQUIRED: The main equipment required is thus:-

- 1 - 16" Suction Cutter Dredger
- 1 - 60 liter Vloeimolen (bucket dredger).
- 5 - $\frac{3}{4}$ cuyd capacity Draglines with 40 ft. boom and swamptracks.
- 1 - D-7 Bulldozer
- 1 - Grader
- 16" pipes with couplings etc.
- 1 - Workboat for the Dredger
- 1 - Survey Boat.

All this equipment can be used for the major flood control scheme at a later stage and for the maintenance of the Polders and the Major Scheme, upon completion of the Polder construction work.

STAFF REQUIRED:

<u>Europeans</u>		<u>Natives</u>
1	Civil Engineer	
1	Workforeman	
1	Surveyor/Draughtsman	
2	Ganger with gang	60
1	Suction Dredger Operator	2 Oilmen 2 Deckhands
1	Vloeimolen Operator	1 Oilman 1 Deckhand
	Dragline Operators	5 5 Oilmen
1	Servicing Mechanic	2 helps
	Bulldozer Operator	1
	Grader Operator	1
	Workboat	2
	Survey Boat.	1
<hr/>		
Total - 8 Europeans		<hr/> 83 Natives <hr/>

RECAPITULATION OF POLDER DATA:

Polder	Approx. Gross Area in Acres		Net area in Acres	Prel. Proposed Polderlevel
1a	4960			+ 15 and + 13
11	690	7120		+ 10
1c	1470		10,830	+ 10
11a	2070	3710		+ 13
11b	1640			+ 9
111	1150		1,000	+ 18
1V	400		250	+ 14

Total reclaimable
Area 11,580 acres

Total economical
reclaimable areas
11,330 acres

SUMMARY:

1. The object of land drainage is to evacuate surplus water from the land in order to prevent the waterlogging of the soil, which leads to lack of fertility. Often the lower lying lands which are most in need of drainage give the best yields when adequately drained.
2. The yields of sugar cane from the areas adjoining the proposed Polders have emphasised the value of this land and no land should be allowed to lie unproductive for want of drainage.
3. It is possible to reclaim the areas proposed at an economical cost and render them safe against major floods to a very large extent; at least against floods which would occur once in 100 years.
4. It will be possible to do so within a reasonable short construction time with the aid of a suction cutter dredger, a vloeimolen and draglines as the major tools.
5. It would be possible to shorten the construction period by working double shift with the recommended equipment or by using more equipment. This would, however, cause the difficulties to multiply as well and it is felt that the extra effort will not yield a proportionally larger benefit under the given conditions.
6. The returns which can be anticipated from the growing of sugar cane in these areas are expected to wipe out the complete construction cost within approximately 3 to 3½ years from the start, so that moneys would be available for contribution towards the capital expenditure of the major flood control scheme.
7. It is estimated that the full construction time of the new polder areas will be approximately five years, so that six years from the start the whole area could be in full production; 11,300 acres yielding 50 tons per acre or say 565,000 tons cane, or ad £80 per acre, an amount of £904,000.

ESTABLISHING MEAN SEA LEVEL AT MOUTH OF UMFOLOSI: No local Mean Sea Level (MSL) was available at the mouth of the Umfolosi for comparison with Trig. Stations, Irrigation Department plans and SAR plans and as the computation of a rigorous tidal datum requires tidal observations extending over a long period in order that seasonal changes in level, and changes of longer period in both level and range may be eliminated, it was considered that an approximate method could be applied to obtain a good determination of the local MSL in a short time.

This was obtained by the "Challenger" method in two days by taking nine observations properly distributed so as to subdivide both solar and lunar days into not less than three equal parts.

In the mean of the nine results the lunar and solar semi-diurnal and diurnal inequalities were all four eliminated.

It was found that the MSL was approximately plus 10 against the value of the Trig. Station Pelana Hill, near the mouth and checked with the values of the Irrig. Dept. plans which were also based on the local Trig. Stations.

For the present we have adopted, therefore, a MSL of + 10 in our deliberations. In the future this result has to be verified by taking more observations.

TIDAL DATA: The times of the tides occurring near St. Lucia Estuary are considered to be reasonably equal as compared with Durban.

St. Lucia Bay lags 7 minutes in comparison to outside tides on HW, and lags 10 minutes on LW.

The double lunar tide (M.2 tide) is approximately 1.80 ft.

The double solar tide (S.2 tide) is approximately 1.0 ft.

The eccentricity tide (K.1 tide) is approximately 0.2 ft. or a total of 3.0 ft. against the average tide. 3.0 ft.

(Met. Office Louis Botha Airport - Durban)

PREVAILING WINDS: The maximum wind forces of the St. Lucia Estuary are of the order of 40-45 miles per hour with occasional thrusts of higher values.

Consistent winds come from the North East quarters but are of less force. The stronger winds come from the SW to SE quarters but are of lesser duration.

These winds (SW - SE) are reduced by the topographical features of the coastline such as Mpelane Hill, the coastal dunes etc.

The tidal compartment of the Umfolosi River lies in a NE - SW direction.

INFLUENCE OF DIRECT WIND ON HEIGHT OF EMBANKMENT: Let us assume a windforce of 65 miles per hour. This is a storm in the top category of the Beaufort Scale of Windforces, known as Windforce 11. Storm 56 - 65 miles/hour.

According to Dr. J. van Veen for shallow wide areas the following formula holds good:-

$$e = \frac{a V^2 L \cos \phi}{H}$$

wherein e = the extra direct rising of the sea level caused by the wind.

For a windforce of 65 miles per hour and a fetch of 1.63 miles, the approximate distance of the sea to the confluence and a water depth of 12 ft. we find a rise e of 8 inches and for a H = 3 ft. we find e = 2.73 ft.

Thus at LW or + 7 MSL say, we may expect under these conditions a rise of say 2.7 ft. bringing the water level to + 9.7 MSL and at EHW or + 16 MSL say, we may expect a rise of 8 inches, bringing the water level to + 16.75 MSL.

The extra Construction Height required due to wind-effect for the dike embankment near the confluence and Gate 1 is thus approximately 8". This height has already been discounted, however, in the free-board as recommended : 6 ft. above EHW or approx. + 22 MSL so that no extra height has to be allowed for due to the influence of direct wind.

RAINFALL: It has been found in the various records kept in the district, and in the collected data, that independent of the duration of a rainstorm the maximum rainfall for a series of days is of the order of 15 inches.

The maximum rainfall per 24 hour is about 10 inches with only one exception in 34 years.

The capacity of the canals, pumping stations etc. have therefore, provisionally been based on a drainage module of $1\frac{1}{2}$ inch per acre per 24 hours, assuming that a maximum rainfall of 15" must be drained in 10 days, in connection with the survival chance of cane.

As an illustration a short list is attached of the 10 storms of high rainfall intensity recorded in the 34 years period 1919 - 1953 at Station Hlabisa Hill 70 (Mr. S. Norris), the station closest to the polder works.

This list shows rainstorms with a rainfall of either more than 5" per 24 hours, or more than 10" per period.

LIST OF STORMS & PERIODS
FROM SEPTEMBER 1919 - OCTOBER 1953.

SHOWING SERIES OF RAINFALL DAYS OVER 10" FOR PERIOD AND
24 HOUR MAXIMUM OVER 5"

Date	Period	Series Days	For Period inches	Maximum 24 hours inches
Feb. 25	1 - 15	15	15.72	10.37
Mar. 25	9 - 27	17	37.88	10.00
Jan. 30	15 - 18	4	8.33	5.36
Feb. 32	19 - 22	4	12.16	8.41
Apl. 32	21 - 30	14	12.42	7.80
Mar. 40	12 - 24	10	10.63	2.55
May 40	4 - 7	4	14.55	7.72
Nov. 40	7 - 13	7	10.46	4.70
Mar. 43	4 - 13	9	11.20	5.91
Apl. 49	28 - 30	3	10.44	9.16

C O N C L U S I O N

The Northern Route flood control scheme and the Polder Reclamation Works, as described - with the flexibility and possibility to tackle these in small units, each of which contribute to the general security and prosperity - offer great practical and financial advantages.

I feel confident in recommending these schemes to your Company as the solution to the flood problems.