FIRST SOIL MECHANICS REPORT

ON

SITES PROPOSED FOR FISHING HARBOURS

25·2·

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

This report is the first in a series prepared for internal Project use 'by Consultant Mr.. R B.. Lundstrom. The conclusions and recommendations given in the report are those considered appropriate at the time of its preparation. They may be modified in the light of furthe knowledge gained at subsequent stages of the Project.

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1• INTRODUCTION

This report is based on Soil Investigations performed by the Project staff and Laboratory Analysis performed by Scandiaconsult in Sweden. Soil samples have been sent to Krishnarajasagar Laboratory Mysore, India, concerning Kakinada harbour site butthe test results are still not available.

A visit was made to Chandbali, site headquarters for he site investigations at Chandinipal, on the 18th of Tfovmber, 1970 and to Nizampatam site on the 21st of November, 1970 by Mr Rune B. Lundstrom, Mr. David :Bayne and Mr. Krishnamurthy.

Recommendations for the soil mechanics design and further investigations are given as follows:-

2. hIZAJ:1IPATAi\1

2.1 Investigations:-

Site investigations, weight and hammer soundings, sampling and vane testing, have been performed along the southern river bank a.s briefly shown on Drawing No.SU-50-23. Laboratory tests of soil samples have been performed by Scandiaconsult in Sweden. The results from tho investigations ,and the tests are shown in Drawings Nos.:-

50-7	Plan			
50-8	Sections	of	Boreholes	1 to 9.
50-9	"	"	n	10 to 13.
50-10	"	it	"	14 to 16 and 2L
50-11	"	"	If	16 to 20.

and in Scandiaconsult report on Daboratory Tests dated 6th August.. 1970,

A harbour site has been proposed on the northern bank of the river close to the connection of the river with the. recently excavated channel to the sea. The minimum water depth at this site at MLiS is about 2.5 m. The harbour site is well protected.

2.2 Description of soil c0nditions:

The soil conditi,Jns at the proposed harbour site are poor. The top soil is dark organic clay with root-fibres. Down to a depth ranging between four to si.x: metres the soil consists of a highly plastic silty clay with moisture conent between 45 to 95% and a sheer strength on average of 0.5 t/m • Organic mixture is found in the upper part of the cla;y layer. The compression index is about *0.8.* Under this layer in Boreholes Nos. 18 and 20 is found less plastic silty clay with strata of silt and sand which at a depth of 4 to 7 m has changed to sand. In Boreholes Nos. 16, 17 and 19, however, this sand is not found.

Below a depth of about 7 m the soil is mainly consisting of silty clay with strata of silt and sand. The clay is in some levels highly plastic. The moisture content varies between 34 and 66%.

The sher strength of the clay increases from a value of about 1o3 t/m at a depth of 7 to 8 m to 3.5 t/m^2 at a depth of 15 m. The compression index is in general lower than in the upper very soft clay and varies around 0.35 and 0.45. In some layers higher figures are, however, found.

2.3 _Stability conditions:

The natural river bank has 2' factor of _Eafety of about 1.2 at LLWo If a fill of 0.9 m is put on the surfacG and a live load of 1 t/m2 is utilized, the factor of safety will be lower than 1.0 which means that a slip failure will occuro To make the harbour area safe it is necessary to consi.dsr special measures which are described under the heading "Recbmm;:mdations" o

2.4 Settlements:

If the fill and the live load is applied upon the ground surface disregarding the difficulty of the stability the total settlement is calculated to V::l ry between 50 and 65 cm. The vari2,tio.1s would result from the irregulirities in the soil stratification. The upper soft soil to a deph of 4 - 6 m gives as much as 30 - 45 cm. in settlement. A common method to get a quick consolidation is to drive vertical sand drains at a spacing of 1.2 to 2.0mo In this soft upper clay it seems, however, not possible to use this method because there is a risk that the sand-drains cannot be held in position by the soft clay cind consequently fail to work properly.

2.5 Recommendations for const_ ctio,_Y.?.

2.5.1 Land area:

To be able to utilize the propoaed site two alternative ways of constructing the h'lrbour farea are discussed,

The best altenative seems to be to remove the upper soft soil down to the sand layer or the firmer clay to a maximum depth of about 5 to 6 m below the Gx:isting ground surface. The refill shall consist of granular soil c:.nd can be placeci to a height of O.7 m above the existing ground surfac8. The settlements of such a fill will be about 20 to 30 cm. and a 1ather big portion (25 to 301) will occur during the construction psiod.

All buildings o.n the fill are recommended to be founded on piles. The length of Hie piles is estimated to "be about 25 m, Pre-fabricated concrete piles of 30 ems, square are est mated to carry a live load of maximu8 25 tonnes,

The other alternative 6f construction is o r0vid a concrete deck founded on piles over the whole areo,, This alte.r:..::..c:C -.; is, however, estimated to be more e:in:;<=>nsive than the first mentionecl alternative.

Regarding the extensive measures it seems reasonable to consider utilizing the opposite river.bank as the site for the harbour. Borings have not been performed at that location but during the site inspection it was ooserved that the rather high sand-dunes could be cut down to suitable level to get the harbour area in a convenient way. The buildings could possibly be founded on slabs. It is, however, necessary to perfo.:rm bor:irigs to get this possibility confirmed.

To be able to utilize the opposite (south) river bank it may be necessary to construct a bridge over the river at a suitable location. The cost for uch a bridge hasp of course, to be considered when comparing the two sites. The location on the south river bank has the advantage that future expansion is facilitated.

2.5.2 Approach Road:

The road to the site can be built up on cross-laid fascines, assuming the same conditions as found on the harbour site; the width of the fascine-mat should be about 28 m. On this mat there should first be piled up layer of 0.5 m and after that the road embankment with a width of 5 ur 6 m up to a total fill height of 1.3 m. The slopes of the embankment are recommended to be 1:.3. The settlement of the embankment will be considerable and amounts to about 70 cm.

2.6 Recommendations for, further site investigations:

The hitherto performed site investigations have given a good picture of the conditions t the site. Before detailed final design is undertaken, it is recommended, in order to mc:..ke the best use of existing soil conditions and possibly to reduce required remedial measures, that further investigations as shown in Drawing Ifo. S0-50-22 are carried out.

3. NARASAPUR

3.1 Investigations:

It is planned to build the harbour on the southern bank of the Godavari River about 6 km. downstrGam of the town of Narasapur.

IJo records from current measurements in the river are available except some spot measurements performed by the survey party at the site. It is, however, estimated that the current can reach about 3 metres per second during floods.

Weight-soundings, sampling (undisturbed samples) and vane-borings have been carried out at the site. 'I·he samples have been tested by Scandiaconsult in Sweden.

The results from the investigations are shown on Drawings lfos":

52-11	Plan	
52-4	Section of boreholes	1i2 and 3u
52-5	" " "	4,5,6 and 7.
52-6	" " "	8 and 9.

and in Report on Laboratory ':'esting dated 2nd Novemli er 1970.

3.2 Description of soil conditions:

Down to a depth of 6 to 9 m, the s.oil consists of silty clay with strata of non-plastic silt and sand. The clay has an average bulk density of 1.65 t/m3. The moisture content, which varies widely because of the fifferent quantities of silt and sand, has been recorded from 51 to 80%. The shear strength varies also because of the mixture of silt and sand, but as an average can be given a figure of 1.0 t/m2 in the upper layers which increases to 1.7 t/m2 at a depth of 9 m.

In general, it seems that the soil conditions improve somewhat, with increased distance from the river bank.

Below the silty clay, sand is found mainly with mixture of silt and clay. One layer of silty clay has also been found in the sand deposits. The borings have been carried out to a depth of around 21 m.

3.3 Recommendations for the design of the harbour:

In a preliminary design it.was proposed that the landing quay should be constructed in a recess cut in the river bank. This would make landing considerably easier as the current immediately in front of the quay would then be less than out in the river.

It was considered that the land.area of the harbour should be brought up by sandfill to a level of +2•75, so that the area would. not be inwidated during the floods than can normally be expected each year.

Records from continuous observations of water levels in the river over a long period indicate, however, that extreme floods have occured in the past and on those occasions the water-level has surpassed the above recommended level of +2.75.

To protect the fill of the harbour land ar«3a from such floods it is recommended that it should be surrounded by a dike. This ike should at least reach the level of the fill and have a width at the top of 1 metre. The dike couli be constructed of impermeable soil. In order to ensure stability)f the cut along the river it is necessary that the slope towards the water should not be steeper than 1 in 3.

The <;'bove mentioned fill may further not be placed closer than 17 m from the top edge of the cut slope. The level of the land between the fill and the water level :h:Juld not be higher than +1.10.

The fill will settle almost 30 cm, but due to the stratification of silt and sand it is estimated that the settlements will to a large degree (50j) occur durin,g the first two years.

All he.avier buildings (load exceeding 2 t/m2) in the harbour area should be founded on piles if t.hey .a.re constructGd within 25 m from the top edge of the cut-slope. If sqµare piles with 30 ems. sides are used, it is recommended that the piles should be driven down to a depth of about 25 m. A maximum live load of about 25 tonnas can be applied on each pile.

Lighter buildings (Load not exceeding 2 t/m2) can possibly be founded on a raft foundation of reinforced concrete. The slab should in any case have a width of at least 0.6 m. The rc:cft or·slab foundations sholild not be construct.ed within one and a half years after the fill has been placed. The settlement of the lighter buildings founded as described above can be estimcted to be about 15 to 20 cm. To decrease the settlement of the buildings it is recommended that at extra mt;tre of sandfil1 be placed within the area for the planned buildings. This fill should then be removed when the foundation work will com1nence.

3·4: ?,.::.com1aend11tions for further site investigations:

The present investi'<;ations give a general picture of the soil conditions. To check that no worse soil conditions can exist inside the harbour area and also to give possibilities to improve the above recommended design, it would be necessary to perform complimentary investigations as shown on DrawinG lfo.S0-52-13 enclosed to this report.

4. KAKilir.ADA

4.1 Investigations:

The fishinc harbour is situated on the opposite side of the channel to the State Port Office. The site investigated is aloneside the fishing harbour where an extension of the present facilities is planned.

Site investigations have been performed bl means of weight and hammer soundines, sampling (undisturbed samples) and vane tests in situ. The samples have been tested by Scandiaconsult in Sweden,

The results from the investieations are shown on Dre.wine; Nos.:

51-1	Plan
51-2	Section of Eoreholes 1 to 6
51-3	" " 7 to 10.

and in Scandiaconsult Report on Laboratory Testinc: dated 25th September, 1970.

4.2 Description of soil conditions:

The soil consists of clay, silt and sand both in layers and in mixture. In many of the samples brown grey silty clay is found. In some samples, the clay has some strata of silt. The moisture content in the clay varies between 51 and 94'%, the bulk density from 1.43 to 1.71 t/mj at a depth of 10 m. The figures of the shear strength given are average values from triaxial tests, fall-c.one tests and vane-test results. The vane bore results show a great variation from one depth to another.

The strata of sand and silt can be regarded more or less as a type of reinforcement.

Below a depth of about 10 m, . the 1:3oil seems to improve faster than i.n the layers above that depth . At a depth of about · 18 m, the soundings show a sudden increase in the penetration resistance.

The borings have not been performed to greater depths than about 20 m.

It should be observed that the soil in some layers has a sulphate content so that sulphate resisting concrete may be requieU if foundation on concrete piles has to be performed.

4.3 Recommendations for Design:

In a preliminary design it is proposed that th0 quay should be built up by hollow concrete blocks having a weight by volume of 0.88 t/m3 *in* dry and 0.50 t/m3 in water. The bottom of the basin is planned to be at a level *bf* -20 and the quay deck at a level of +2.4. The quay deck is designed as a concrete slab on beams.

The front part of the quay would give a lQad of 3.'20 2 t/m^2 on the ground. To this should be added the live load of 1 t/m

The load of the soil at present overlaying the level on which the bottom concrete blocks should be placed is 4.40 t/m^2•

The utilised shear strength of a load of 4.2 t/m^2 uniformly distributed over an area is 0.18 x 4.2 = 0.75 t/m2 . The reorded shear strength at a level of about -2.0 is equal to 1.5 t/m . The factor 9f safety is consequently equal to 2.0.

The settlements of the constructions are theoretically nil. When soil is removed the 3oil left will always swell to some extent. This swelling effect will give settlements when a new load is placed on the excavated area. T:ie settlements are estimated to be less than 10 cm it./hich could be comp:msated. by raising the quay desien level by 10 cm, specially the qiay front.

From soil mecha_1.ics point of view, the proposed design is well fitted to soil conditions . It is possible to decrease the proposed width of the c[U.df by 2 to 4 m if required which means that the width could be 7 m. 3elow the two front rows of blocks, a concrete slab. is recommen.i.ed to bridge over uneven settlements.

Inside the harbour basin, it has been sugested that the berthing could be done tc dolphins or to floating structures with bridge connections to land. with such a solution for the berthing, an ordinary quay is not necessary. It is also required that the slope from the harbour plane shoulcl not be steeper than the natural slope of the material. Th sbil conditions allow a slope of 1 in 1.5 with a live load of 1 t/m^2 to the edge of the slope. The slope should be protqcted by filter material which can withstand the waves from the boat traffic and also the effect of the tidal variations .

Lighter buildings not exceeding 2 to 3 t/m^2 can be founded on slabs. Settlements wi:..l occu.r up to 10 - 15 cm. :Buildings exceedine 1 t/m^2 fou.nded on slabs cannot be constructed closer to tho slope edge than 10 m.

The figures above eive an idea of the possibilities for the founcla.tions.. For each planned building$_8$ it is recommended to perfor soundings at least in each corner of the building and sampling in the centre of the building.

The existing buildings in the area should be studied with regad to types of foundation and noticeable settlements; the condition of the buildings should be investigated.

Heavier buildings (in excess of 2 t/m2) should be founded on piles. If concrete piles of 30 cm square are used, a live load of about 30 tonnes could be applied on a 25 m long pile. For heavier buildings where pile-foundations are to be used, hammer borings in at least each corner of the building is recommended to a depth of 40 m or where the resistance goes up to 300 blows per 20 cm penetration.

5.. TRAINING OF SOIL lVIECH.AlHCS EtWiliIE}!;RS .AND PERSONlEL

To get good experience in soil mechanics$_1$ it is essential that the engineer should take part in all the various phuses of site investigations, :field work, laboratory tests, preliminary and final evaluation of the obtained results. He should also eet practice in making calculations of stability, settlements, earth pressure, etc. and in the selection of types of foundations and finally he should get op:i;iortunity to follow construction works as a controlling engineer or supe.xvisor.

The field work should be continued for a period of about one year with various types of borings on land as well as off-shore borings on rafts or piled platforms.

If the project finds it of interest to set up a limited soil mechanics laboratory, the following tests are recommended to be performed:-

Bulk Density determination
Moisture content with liquid and plastic limit
Sieve analysis
Visual examination of samples
Shear strength analysis of clay by fall-cone test
Settlement analysis by oedometer tests.

The counterpart engineers should also be informed about thG foundation design of the various projects, for which they have taken part in the site investigations and laboratory tests.

Through the above mentioned contacts with the various phases of the soil mechanics work, an engineer interested in soil mechanics will get experience of and feeling for different types of soil and their characteristics. He will also get experience in plannin future investigations with proposals for investigation methods to be used in the field, time required for performing the field work and the costs for the invcstigtions.

After the first year, the engineer should go over to design work more and more but not leave the investigation part entirely.

It is impona.nt for a soil mechanics engineer to be in good tcvu.ch with constrl.l.ctio work. He should have opportunity of visiting construction sites where structures of. his design are being undertaken. A young Qnginecr should in the beginning work under the supervision of an cxperionced ·engineer.

The above mentioned points of views on how an engineer can get knowledge and experience Ln soil mechanics are applicable mainly to engineers with university degree.

Parallel to this training, there should be developed a staff of other engineers and boring foremen. 4o should 5et training in the field and laboratory works and .also geii training in design work as fw.r as it is possible and suitable. It is a great advc::.ntage if an engineer is fully familiar with more. than one phase of the soil mechanics work. A sil mechanics division with engineers trained in more than one phase of the work is capable of avoiding bottlenecks in the daily work.

It is of great value for a soil mechanics engineer to study abroad as it given him a wider view on the problems which will arise for him in the future. Studies in Scandinavia or England or in t.he States could be rcommended. The engineer taking up studies abroad should, however ii.ave had at least one year's experience from soil mechanics work in hif? own country. It would .give him a better backgrowid for evaluation of methods and theories•.

6. LIST OF DRAWINGS

NIZAMPAT.Ad!\i:

Title	Drawint:t No,
1. Location Map	SU-50-23
2. Borehole Plan -.Showing recommended borings	S0-50-22
3. Cross-Section - Slip circle calculations ..	so-50-21

NARASAPUR:

Title	Drawint:t No,
1. Borehole Plan - Showing executed and recommended borings	S0-52-13
2. Cross-Section - Slip circle calculations	so-52-8

KAKINADA:

Title	Drawint:t No,
1. Borehole Plan - Showing executed and recommended borings ...	S0-51-16
2. Cross-Section - S.lip circle calculations ..	S0-51-13

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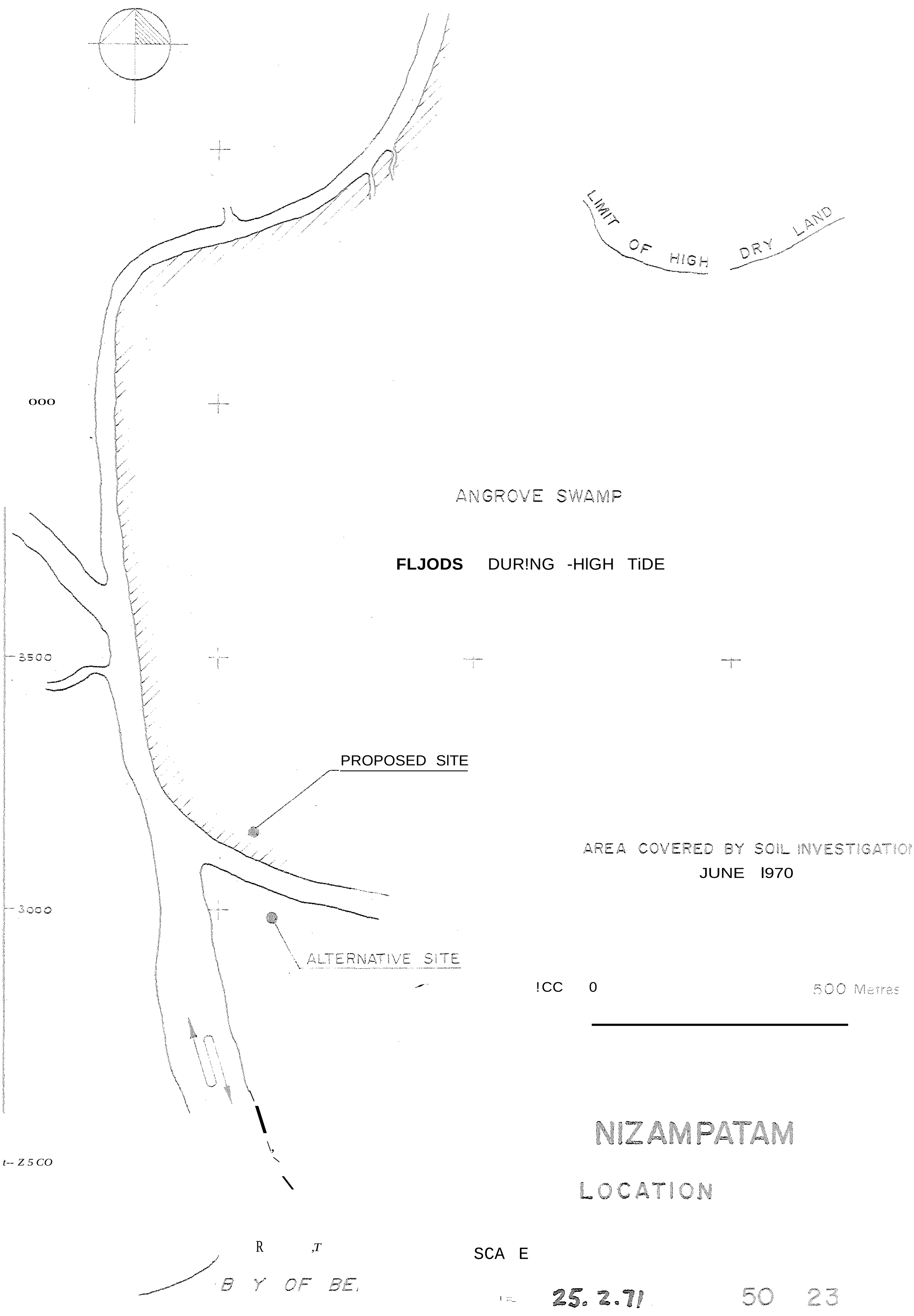

LIMIT OF HIGH DRY LAND
OOO
ANGROVE SWAMP
FLJODS DUR!NG -HIGH TiDE
3500
PROPOSED SITE
AREA COVERED BY SOIL INVESTIGATIO
JUNE I970
3000
ALTERNATIVE SITE
!CC 0
500 Metres
NIZAMPATAM
LOCATION
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25. 2.71
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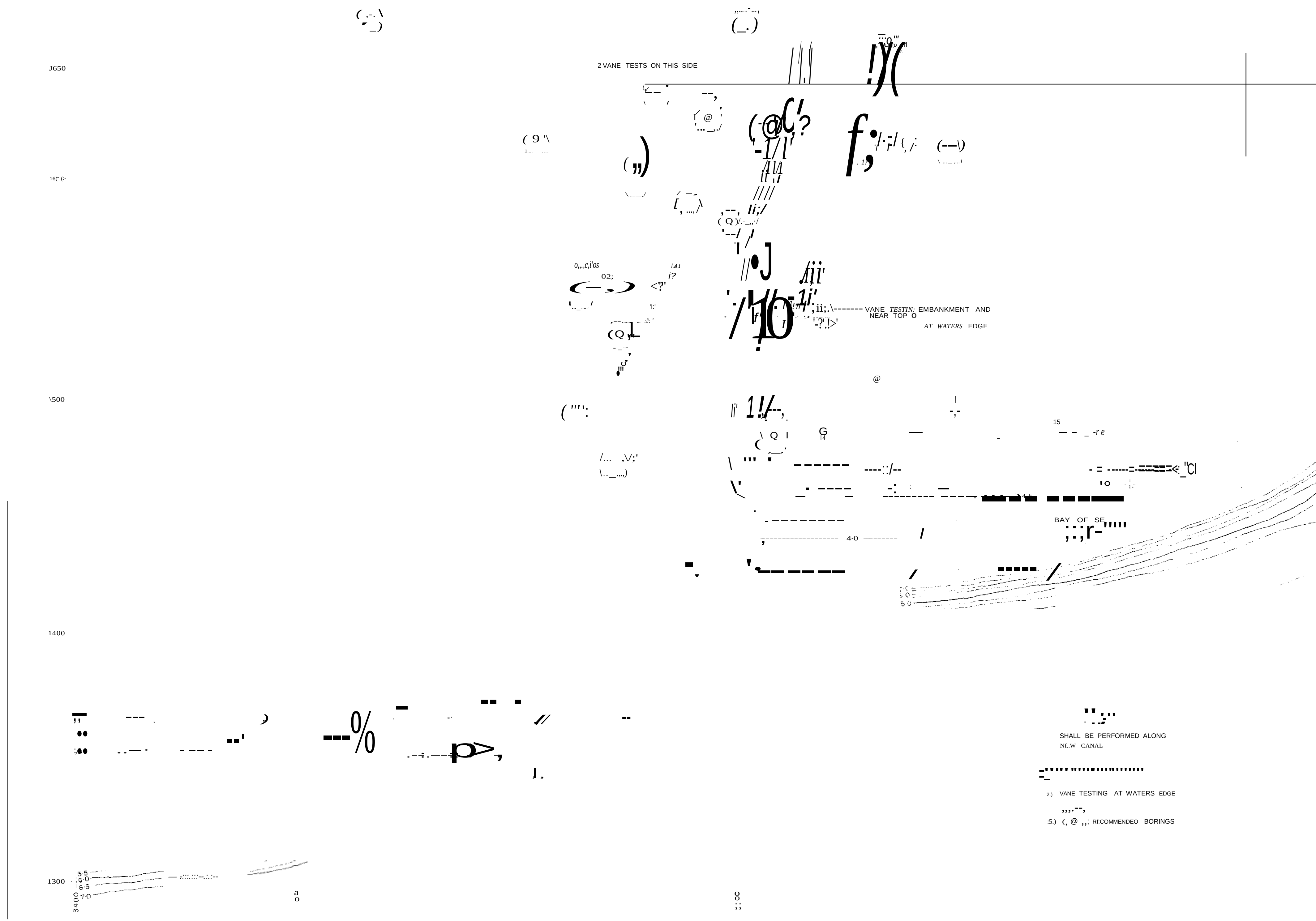
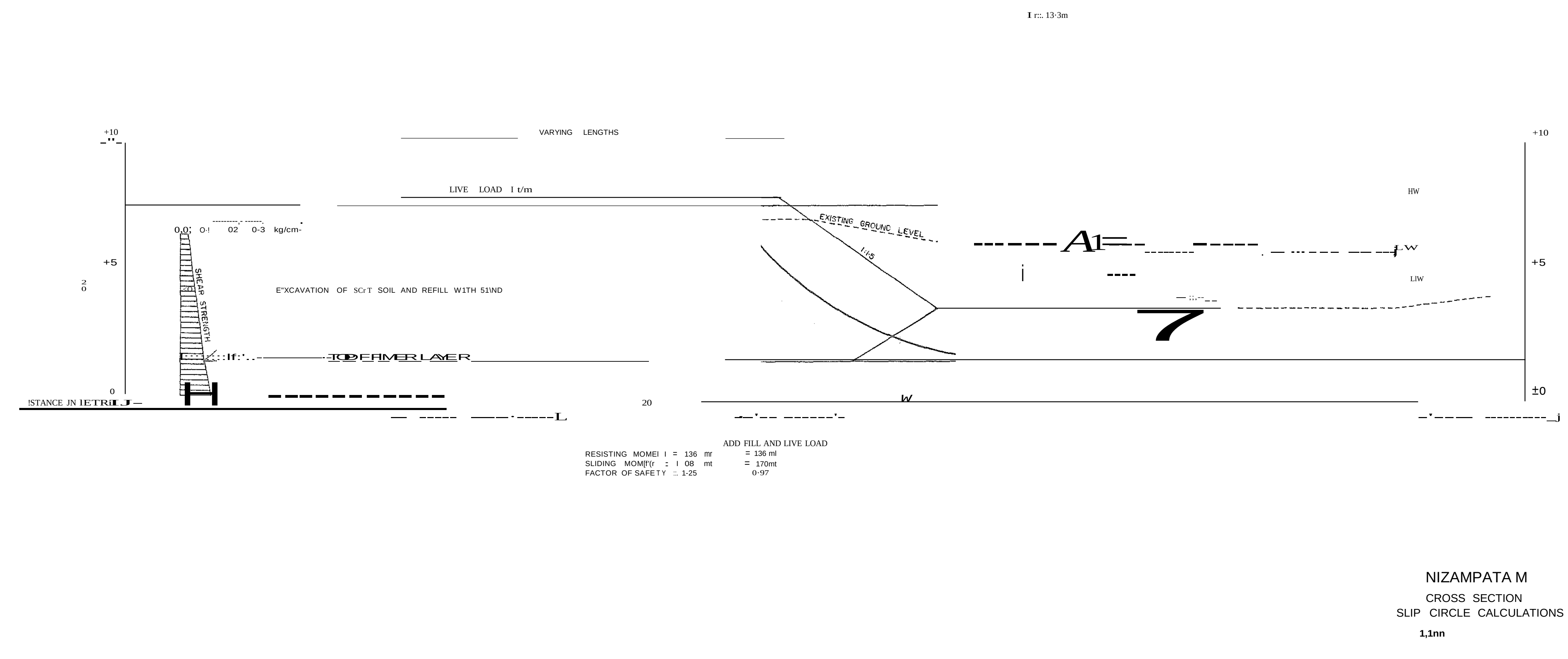
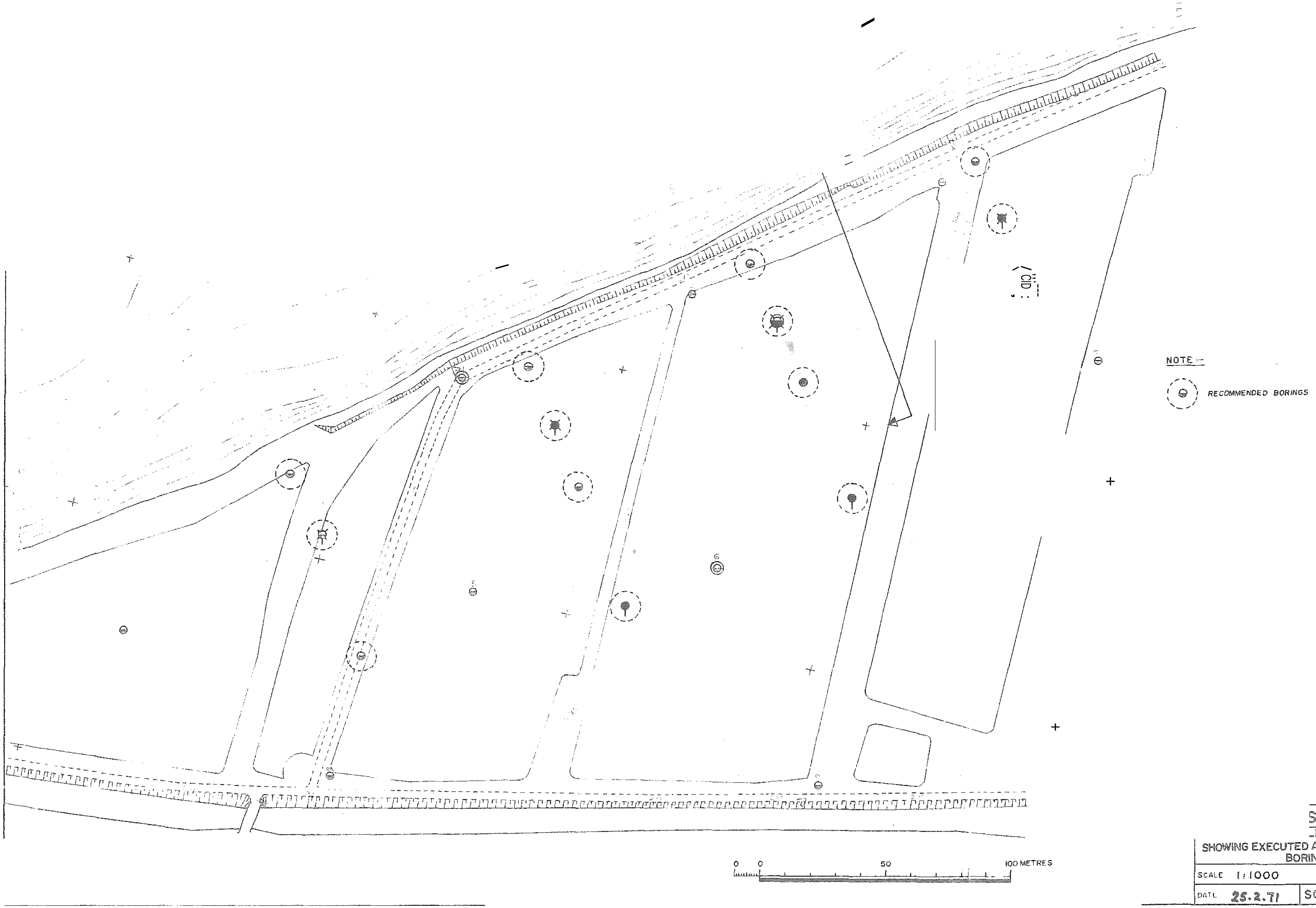


2 VANE TESTS ON THIS SIDE
VANE TESTIN: EMBANKMENT AND NEAR TOP O
AT WATERS EDGE
BAY OF SE
SHALL BE PERFORMED ALONG
2.) VANE TESTING AT WATERS EDGE
BORINGS
1500
1400
1300

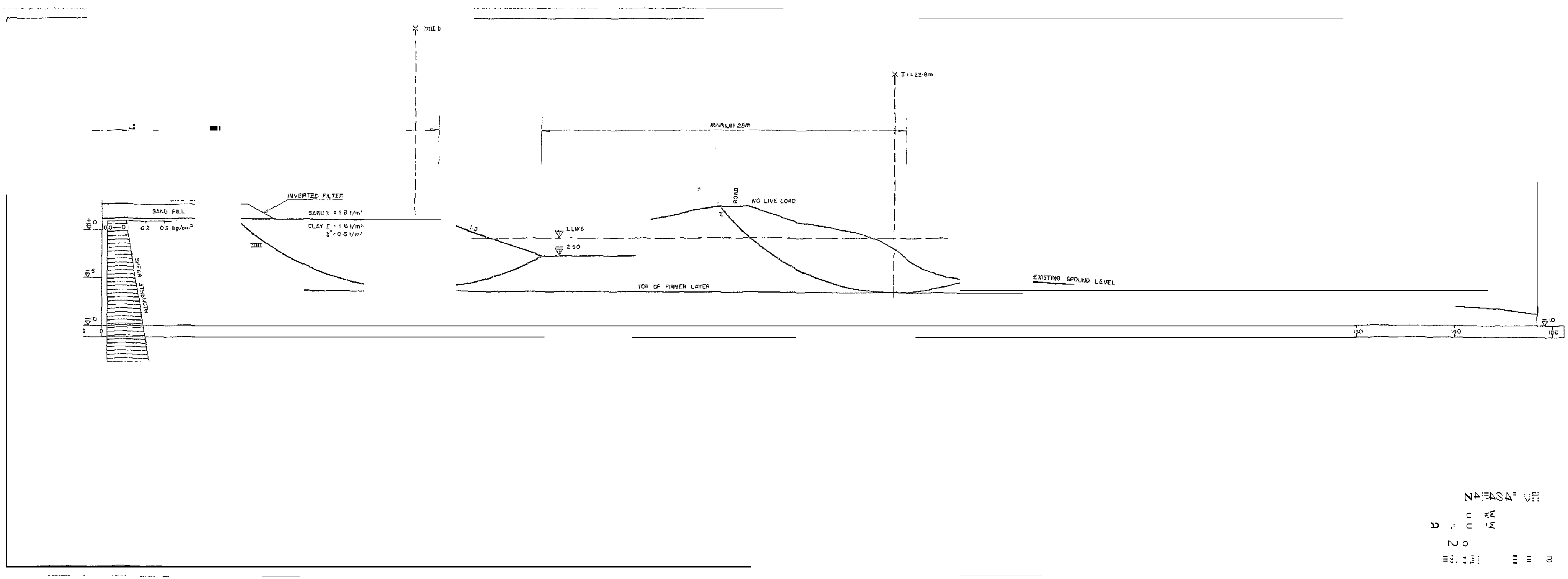


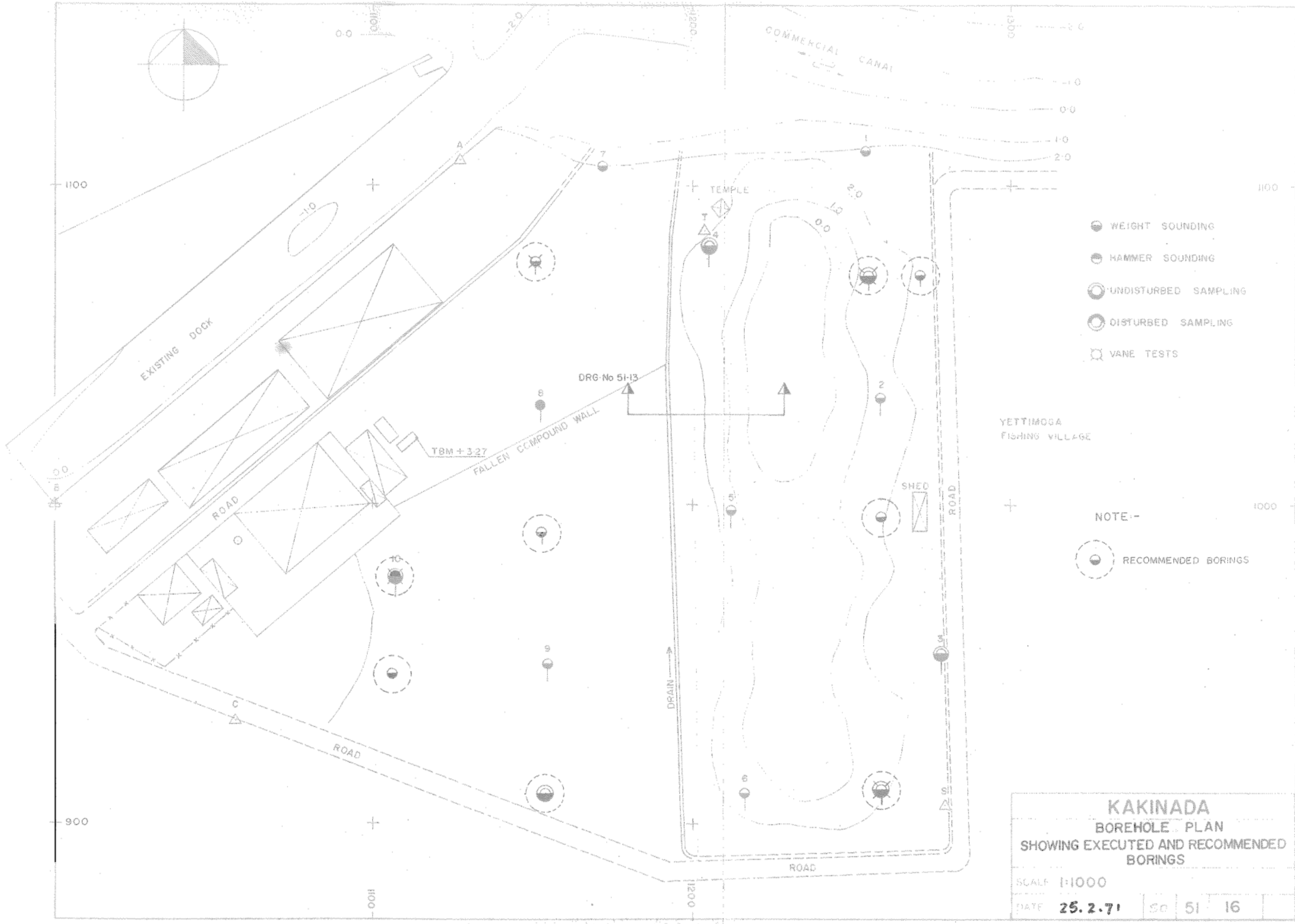
r = 13·3m
VARYING LENGTHS
LIVE LOAD 1 t/m
HW
EXISTING GROUND LEVEL
1:1·5
0·0 0·1 0·2 0·3 kg/cm²
SHEAR STRENGTH
EXCAVATION OF SOFT SOIL AND REFILL WITH SAND
TOP FIRMER LAYER
LW
LLW
+10
+5
0
±0
20
DISTANCE IN METRES
ADD FILL AND LIVE LOAD
RESISTING MOMENT = 136 mt = 136 mt
SLIDING MOMENT = 108 mt = 170 mt
FACTOR OF SAFETY = 1·25 0·97
NIZAMPATAM
CROSS SECTION
SLIP CIRCLE CALCULATIONS



SAPUR
-E PLAN
SHOWING EXECUTED AND RECOMMENDED BORINGS

SCALE 1:1000			
DATE 25.2.71	SO	52	13


INVERTED FILTER
SAND FILL
SAND γ = 1·9 t/m³
CLAY γ = 1·6 t/m³
γ' = 0·6 t/m³
0·2 0·3 kg/cm²
SHEAR STRENGTH
MINIMUM 25m
Ir = 22·8m
LLWS
2·50
1:3
ROAD
NO LIVE LOAD
TOP OF FIRMER LAYER
EXISTING GROUND LEVEL
130
140
150



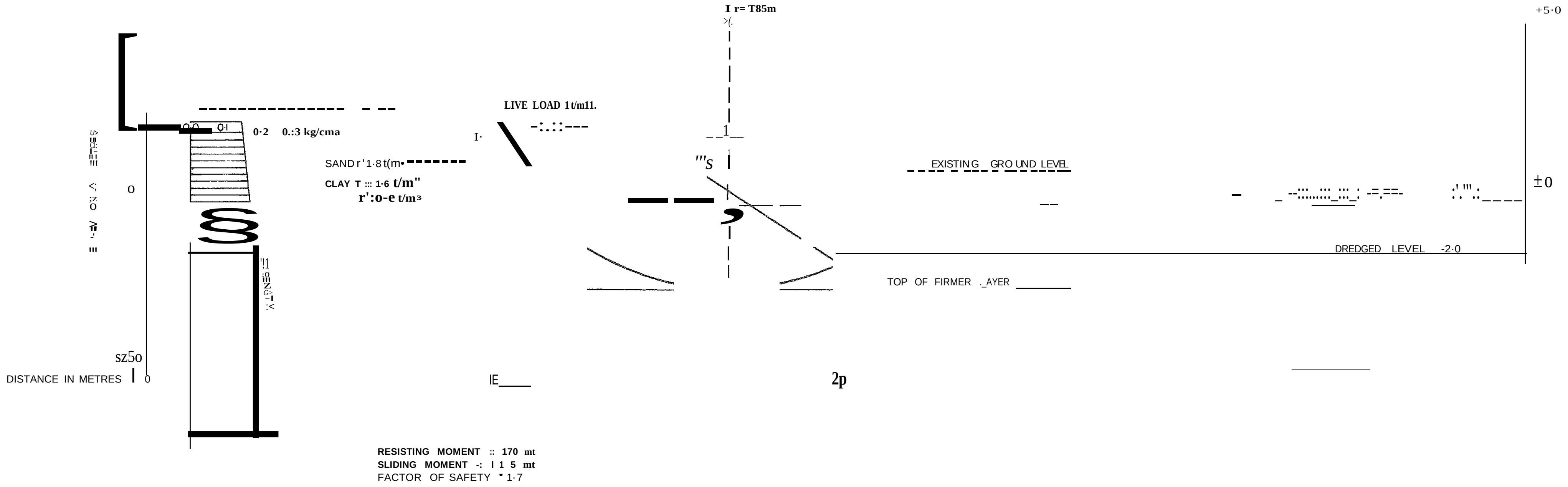
KAKINADA

BOREHOLE PLAN

SHOWING EXECUTED AND RECOMMENDED BORINGS

SCALE 1:1000

DATE 25.2.71 | So 51 | 16



KA

CROSS SECTION

SLIP CIRCLE CALCULATIONS

1=100

2s.-z.71 51 13