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DIST. 7 REGION

W.P. No. 167-80-01

CONT. No.

W. O. No.

STR. SITE No.

HWY. No. 2

LOCATION HWY2 AND REID RD.

JUST WEST OF THE TOWN OF NEWTONVILLE

SLOPE STABILITY INVESTIGATION

=====

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:



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ANN CATAFORD - 5TH FLOOR (15575)

DOMINION SOIL INVESTIGATIONS INC.

104 CROCKFORD BLVD.

SCARBOROUGH, ONTARIO, M1R 3C6

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## **FOUNDATION DESIGN SECTION**

**foundation  
investigation and  
design report**

ENGINEERING MATERIALS OFFICE  
FOUNDATION DESIGN SECTION

WP 167-80-01

DIST 7

HWY 2

STR SITE -

Hwy. 2 and Reid Rd.  
Just West of the Town of Newtonville  
Slope Stability Investigation

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## FOUNDATION INVESTIGATION REPORT

For

Hwy. 2 and Reid Rd.

Just West of the Town of Newtonville

Slope Stability Investigation

W.P. 167-80-01

District 7, Port Hope

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### INTRODUCTION

This office was contacted on 92/07/10 by T. Lowe of the Geotechnical Section with regard to the stability of a roadway embankment for the widened Highway 2 at the above site required by the Planning and Design Office. Subsequent correspondence was through A. Cataford, Planning and Design who directly submitted the request and arranged for property clearance.

A foundation investigation was carried out at the above site consisting of two 18.4 m boreholes at Sta. 20+400 Lt. 33 m and Sta. 20+350 Lt. 21 m located at the crest of the natural slope, as shown on Figure 5. Laboratory testing is still in progress on the recovered soil samples. Thus the attached borehole logs will require confirmation on material classification. Completed borehole logs and laboratory test results will be submitted at that time.

### SITE DESCRIPTION AND GEOLOGY

The site is located at the north/east corner of Reid Rd. and Hwy. 2 approximately 1.5 Km west of the Town of Newtonville, Township of Clarke in the Regional Municipality of Durham. The existing roadway is an asphalt covered 2 lane winding road.

The topography of the area consists of rolling grass lands with farms and residential homes. A residential housing development is proposed between Reid Rd. and Ovens Rd. adjacent to the embankment. The surcharge loading of any structures placed near the crest of the slope could affect its stability, however as they will be at a distance away from the crest this is not considered a concern.

The site is located in the region known as the "South Slope". The characteristic deposit in the area under investigation consists of fine sands and silts underlain by clay tills with rock fragments. While not encountered in this investigation overburden is reportedly underlain by limestone bedrock.

#### SUBSURFACE CONDITIONS

The subsoil stratigraphy encountered at the site consisted of the following distinct layers. A 2.9 m thick deposit of sandy-silt, trace gravel, trace clay which contained traces of organics surficially down to 0.6 m. This layer was primarily very dense having a compact state of denseness within the surficial organics. Underlying the above was a 10.3 m - 11.3 m very dense, non-cohesive heterogeneous mixture of silt, sand and gravel with a trace of clay, containing occasional cobbles which can be categorized as having a glacial till composition. The above two deposits comprise the materials within the natural slope with the non-cohesive glacial till extending approximately 4 m below the existing grade of Hwy. 2 and 2 m below the bottom of the proposed drainage ditch. Underlying the above stratigraphy the material becomes cohesive classified as a heterogeneous mixture of clayey silt, sand and gravel with occasional boulders, a cohesive glacial till. This deposit was grey in colour having a hard consistency.

#### GROUNDWATER CONDITIONS

Ground water levels were obtained utilizing installed piezometers and observations

in open boreholes during the course of the investigation. Measurements taken two, five and seven days after installation found the depth of the water table in BH 2 to be at 12 m, 11.5 m and 11.75 m depths respectively. The water table in BH 1 appeared to be lower at 13.7 m. The dry cemented nature of the glacial till confirmed the recorded depths as the samples retrieved became wet upon approaching the cohesive till. For slope stability purposes the water table is estimated to be at an elevation of 158 m . All boreholes were placed immediately at the crest of the natural slope revealing the depth of the water table at these locations only. The water table further north away from the crest may rise following the grade of the natural ground surface.

Groundwater levels in general are subject to seasonal fluctuations and hence can vary from values given in this report.

## DISCUSSION AND RECOMMENDATIONS

It is proposed to widen Hwy. 2 requiring cutting into the existing 10 m high natural slope north between stations 20+300 to 20+500. A pavement elevation of approximately 160 m with and adjacent drainage ditch of 1.5 - 2 m will necessitate slopes of up to 11 m in this region. The toe of the proposed ditch is at an elevation of 158 m with the crest of the embankment at a maximum elevation of 169 m. The current natural slope is 10 m high with an approximate 2:1 slope.

Based on an evaluation of the subsurface conditions at the site, stability analysis was carried out to evaluate the overall and internal stability of the cut slope. An effective stress analysis was applied for calculations of slope stability of the embankment fill using the limit equilibrium method of stability developed by Sarma (1973 and 1979). A minimum factor of safety of 1.3 was incorporated for the analysis. It should be noted that all stability calculations were made for the static condition only.

The design parameters, subsurface geometry and ground water level used in the analysis will be discussed as follows:

For a maximum slope height of 11 m (STA. 20+400)

<u>Thickness (m)</u>	<u>Soil Type</u>	<u>Cu (kPa)</u>	<u><math>\phi</math> (degrees)</u>	<u>KN/m<sup>3</sup></u>
3 m	Sandy-Silt	0	30°	20
10 m	Non-cohesive (Glacial Till)	0	30°(35°)	22
12 m	Cohesive (Glacial Till)	0	37°	22

\* Water level is at a depth of 1 m below the bottom of the proposed ditch.



Based on the analysis, the slope is stable up to 8 m in height provided it is constructed with MTO current standards of 2H:1V slopes. It is recommended that the road embankment with a maximum height of 11 m should be constructed with a 2.0 m wide midheight berm utilizing the 2:1 slope (See Figures 2 and 4 in the appendix). As the material is very dense deep seated failures are not a concern, however surficial sloughing could occur at slopes exceeding 8 m, as confirmed in the slope stability output results attached. The addition of a 2 m berm will prevent against this possibility (See Figures 1 and 3 in the appendix). The proposed slope design of a maximum height of 11 m together with a 2 m midheight berm and a second 1 m berm at the toe would thus have an adequate factor of safety from internal stability considerations.

#### CONSTRUCTION CONSIDERATIONS

For erosion protection purposes, the embankment slopes should be covered with a layer of topsoil and properly seeded in order to enhance adequate vegetation cover in accordance with OPSD 218.01. Interception ditch at the crest of the slope should be designed according to MTO practice.

Any cut material removed from the existing natural slope would be acceptable for use as fill material, as defined in OPSS 215.05.

#### MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of M. Michalek, Jr. Foundation Engineer utilizing equipment owned and operated by Dominion Soils Investigations Limited.

The project was carried out under the general supervision of T. Kim, Senior Foundation Engineer. The report was written by M. Michalek, reviewed by T. Kim, P. Eng. and approved by M. Devata, Chief Foundation Engineer.

Please find enclosed, in the appendix the borehole log sheets together with slope stability results.



*MARTIN MICHALEK*

M. Michalek, P. Eng.  
Jr. Foundation Engineer

*M. Devata*

M. Devata, P. Eng.  
Chief Foundation Engineer

## APPENDIX

# RECORD OF BOREHOLE No 1

1 OF 1

METRIC

W.P. 167-80-01 LOCATION Sto. 20 + 350 Lt. 21 m ORIGINATED BY M.M.  
 DIST 7 HWY 2 BOREHOLE TYPE Solid Stem Auger COMPILED BY M.M.  
 DATUM Geodetic DATE 92/11/16 CHECKED BY T.K.

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>	
166.8	Ground Surface														
0.0	Trace Organics														
	Sandy Silt		1	SS	56	156									
	Trace Gravel														
	Trace Clay		2	SS	93										
	Very Dense														
163.9			3	SS	90	/25cm									
2.9			4	SS	100	/13cm									
			5	SS	100	/15cm									
			6	SS	100	/10cm									
			7	SS	147	/28cm									
	Heterogeneous Mixture of Silt, Sand and Gravel Trace/Some Clay														
	Occasional Cobbles (Glacial Till)		8	SS	80	/10cm									
	Very Dense		9	SS	87	/15cm									
			10	SS	83	/15cm									
			11	SS	127										
			12	SS	70	/8cm									
152.1	Brown														
14.7	Grey		13	SS	93										
	Heterogeneous Mixture of Clayey Silt, Sand and Gravel														
	Occasional Boulders (Glacial Till)		14	SS	70	/10cm									
	Hard														
148.4			15	SS	80	/15cm									
18.4	End of Borehole * Water Level not stabilized														

# RECORD OF BOREHOLE No 2

1 OF 1

METRIC

W.P. 167-80-01 LOCATION Ste. 20 + 400 Lt. 33 m ORIGINATED BY M.M.  
DIST 7 HWY 2 BOREHOLE TYPE Hollow Stem/Solid Stem Augers COMPILED BY M.M.  
DATUM Geodetic DATE 92/11/16 CHECKED BY T.K.

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT 7 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	20	40	60	80	100	W <sub>P</sub>	W		
169.4	Ground Surface															
0.0	Trace Organics Compact		1	SS	13											
	Sandy Silt		2	SS	63	XXXX										
	Trace Gravel		3	SS	117											
	Trace Clay		4	SS	123											
166.5	Very Dense		5	SS	120	/20cm										
2.9	Heterogeneous Mixture of Silt, Sand and Gravel Trace/Some Clay Occasional Cobbles (Glacial Till) Very Dense		6	SS	123	/8cm										
			7	SS	120	/8cm										
			8	SS	120	/10cm										
			9	SS	120	/8cm										
			10	SS	120	/8cm										
			11	SS	120	/8cm										
			12	SS	120	/10cm										
156.2	Brown															
13.2	Grey		13	SS	141											
	Heterogeneous Mixture of Clayey Silt, Sand and Gravel Occasional Cobbles (Glacial Till) Hard		14	SS	129	/25cm										
			15	SS	133											
151.0			16	SS	120	/8cm										
18.4	End of Borehole															
• GROUND WATER CONDITIONS																
PIEZO NO.	Date	GROUND WATER ELEVATION (Metres)														
1	92/11/16	12														
	92/11/19	11.5														
	92/11/23	11.75														

## EXPLANATION OF TERMS USED IN REPORT

**N VALUE:** THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS  $\bar{N}$ .

**DYNAMIC CONE PENETRATION TEST:** CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

**CONSISTENCY:** COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH ( $c_u$ ) AS FOLLOWS:

$c_u$ (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

**DENSENESS:** COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

**RECOVERY:** SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

**MODIFIED RECOVERY:** SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

**JOINTING AND BEDDING:**

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	> 3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE

### MECHANICAL PROPERTIES OF SOIL

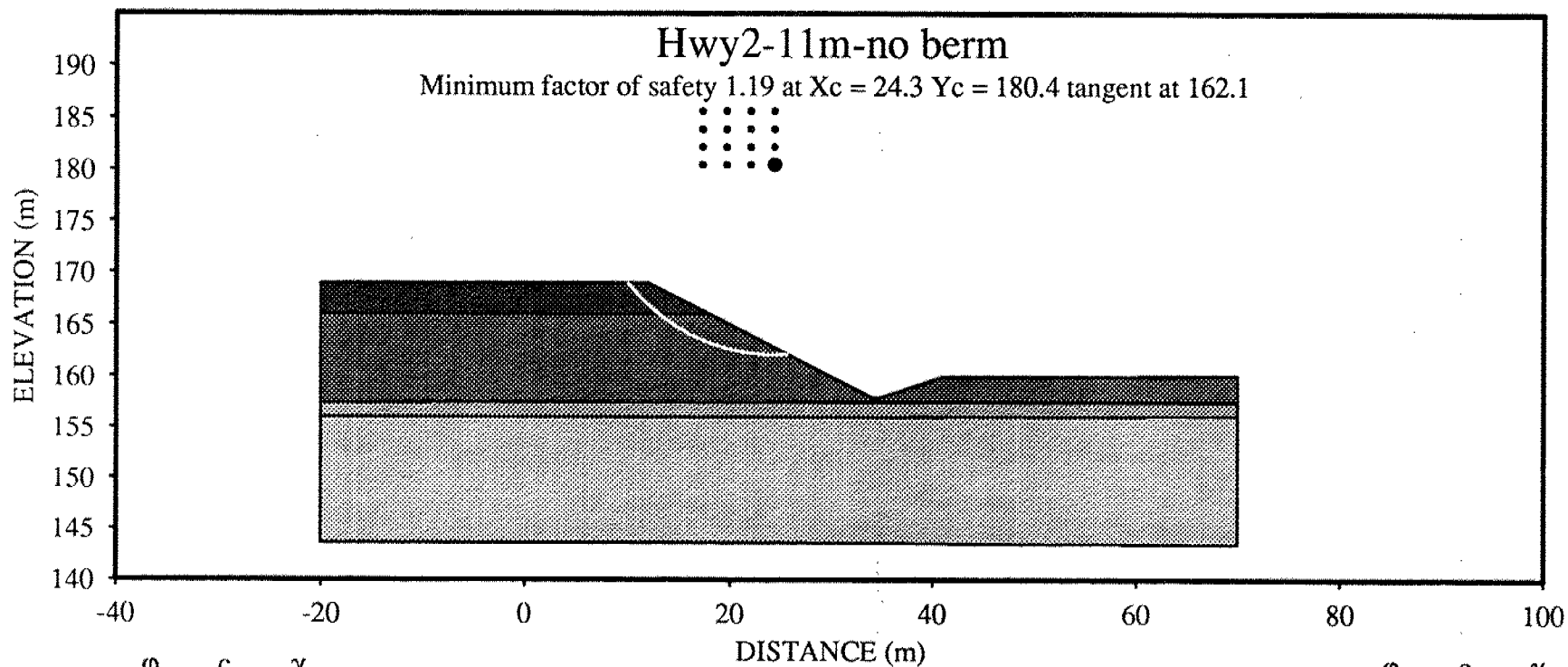
$m_v$	$\text{kPa}^{-1}$	COEFFICIENT OF VOLUME CHANGE
$C_c$	1	COMPRESSION INDEX
$C_s$	1	SWELLING INDEX
$C_\alpha$	1	RATE OF SECONDARY CONSOLIDATION
$c_v$	$\text{m}^2/\text{s}$	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
$T_v$	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
$\sigma'_{v0}$	kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$	kPa	PRECONSOLIDATION PRESSURE
$\tau_f$	kPa	SHEAR STRENGTH
$c'$	kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$	°	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$	kPa	APPARENT COHESION INTERCEPT
$\phi_u$	°	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$	kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$	kPa	REMOULDED SHEAR STRENGTH
$S_i$	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

### STRESS AND STRAIN

$u_w$	kPa	PORE WATER PRESSURE
$u$	1	PORE PRESSURE RATIO
$\sigma$	kPa	TOTAL NORMAL STRESS
$\sigma'$	kPa	EFFECTIVE NORMAL STRESS
$\tau$	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
$\epsilon$	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
$\mu$	1	COEFFICIENT OF FRICTION

### PHYSICAL PROPERTIES OF SOIL

$\rho_s$	$\text{kg}/\text{m}^3$	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	$e_{\min}$	1, %	VOID RATIO IN DENSEST STATE
$\gamma_s$	$\text{KN}/\text{m}^3$	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	$I_D$	1	DENSITY INDEX = $\frac{e_{\max} - e}{e_{\max} - e_{\min}}$
$\rho_w$	$\text{kg}/\text{m}^3$	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
$\gamma_w$	$\text{KN}/\text{m}^3$	UNIT WEIGHT OF WATER	$S_r$	%	DEGREE OF SATURATION	$D_n$	mm	n PERCENT - DIAMETER
$\rho$	$\text{kg}/\text{m}^3$	DENSITY OF SOIL	$w_L$	%	LIQUID LIMIT	$C_u$	1	UNIFORMITY COEFFICIENT
$\gamma$	$\text{KN}/\text{m}^3$	UNIT WEIGHT OF SOIL	$w_p$	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
$\rho_d$	$\text{kg}/\text{m}^3$	DENSITY OF DRY SOIL	$w_s$	%	SHRINKAGE LIMIT	q	$\text{m}^3/\text{s}$	RATE OF DISCHARGE
$\gamma_d$	$\text{KN}/\text{m}^3$	UNIT WEIGHT OF DRY SOIL	$I_p$	%	PLASTICITY INDEX = $w_L - w_p$	v	$\text{m}/\text{s}$	DISCHARGE VELOCITY
$\rho_{\text{sat}}$	$\text{kg}/\text{m}^3$	DENSITY OF SATURATED SOIL	$I_L$	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
$\gamma_{\text{sat}}$	$\text{KN}/\text{m}^3$	UNIT WEIGHT OF SATURATED SOIL	$I_C$	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	$\text{m}/\text{s}$	HYDRAULIC CONDUCTIVITY
$\rho'$	$\text{kg}/\text{m}^3$	DENSITY OF SUBMERGED SOIL	$e_{\max}$	1, %	VOID RATIO IN LOOSEST STATE	j	$\text{KN}/\text{m}^2$	SEEPAGE FORCE
$\gamma'$	$\text{KN}/\text{m}^3$	UNIT WEIGHT OF SUBMERGED SOIL						



$\phi$	c	$\gamma$
--------	---	----------

30.0	0.0	20.0
------	-----	------

30.0	0.0	22.0
------	-----	------

Sandy Silt

Het. Mix. CL.SL.SA.GR.

Het. Mix. CL.SL.SA.GR.

Clayey Silt(Till)

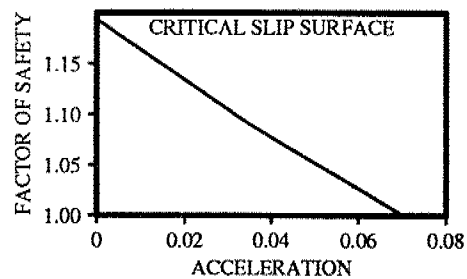
$\phi$	c	$\gamma$
--------	---	----------

30.0	0.0	22.0
------	-----	------

37.0	0.0	22.0
------	-----	------

#### CRITICAL ACCELERATIONS

0.299	0.244	0.186	0.121
0.293	0.235	0.173	0.105
0.287	0.226	0.160	0.088
0.281	0.215	0.146	<b>0.070</b>

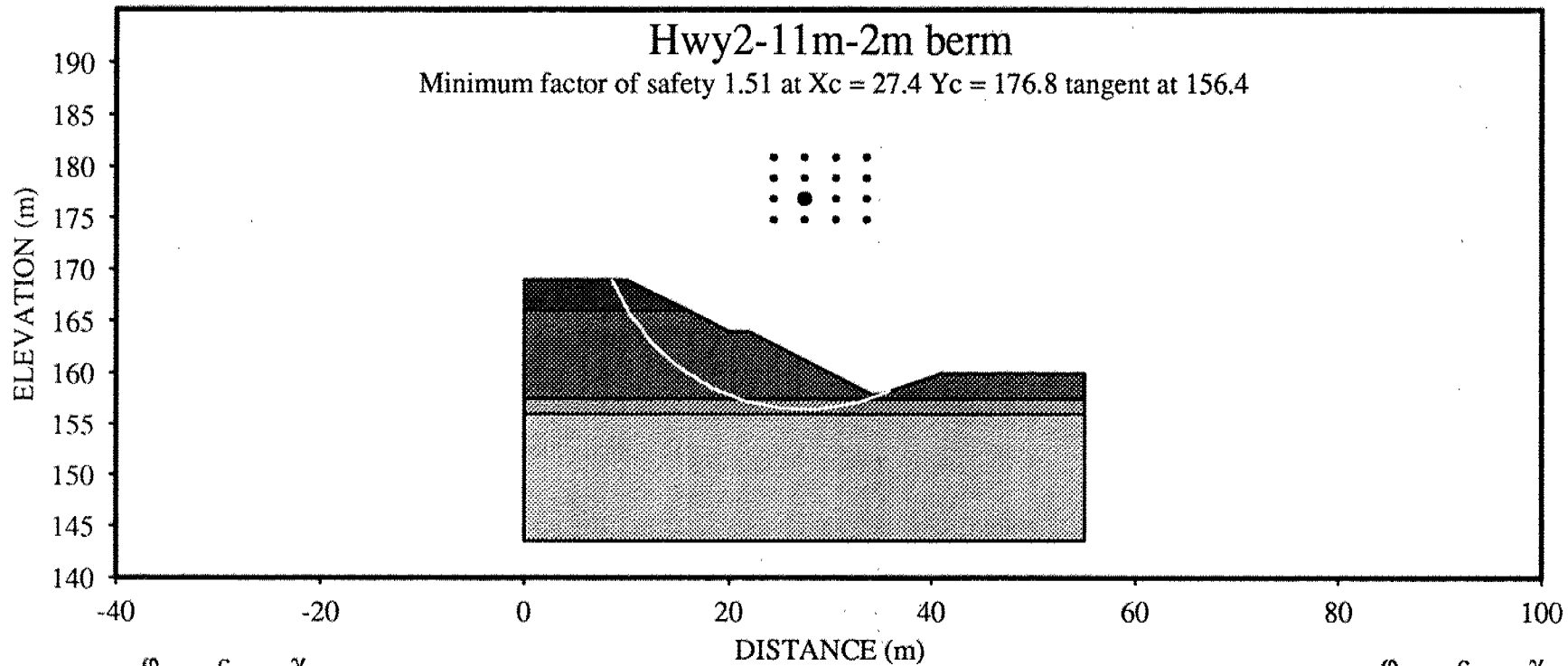


#### FACTORS OF SAFETY

2.387	1.977	1.644	1.370
2.321	1.910	1.582	1.311
2.253	1.842	1.517	1.249
2.182	1.767	1.452	<b>1.193</b>

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Fig 1



$\phi$      $c$      $\gamma$

30.0    0.0    20.0     Sandy Silt

30.0    0.0    22.0     Het. Mix. CL.SL.SA.GR.

Het. Mix. CL.SL.SA.GR. 

Clayey Silt(Till)  37.0    0.0    22.0

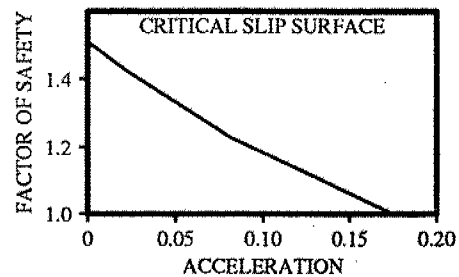
$\phi$      $c$      $\gamma$

30.0    0.0    22.0

37.0    0.0    22.0

#### CRITICAL ACCELERATIONS

0.231	0.187	0.215	0.303
0.226	0.179	0.214	0.314
0.223	<b>0.175</b>	0.212	0.326
0.222	0.179	0.206	0.336



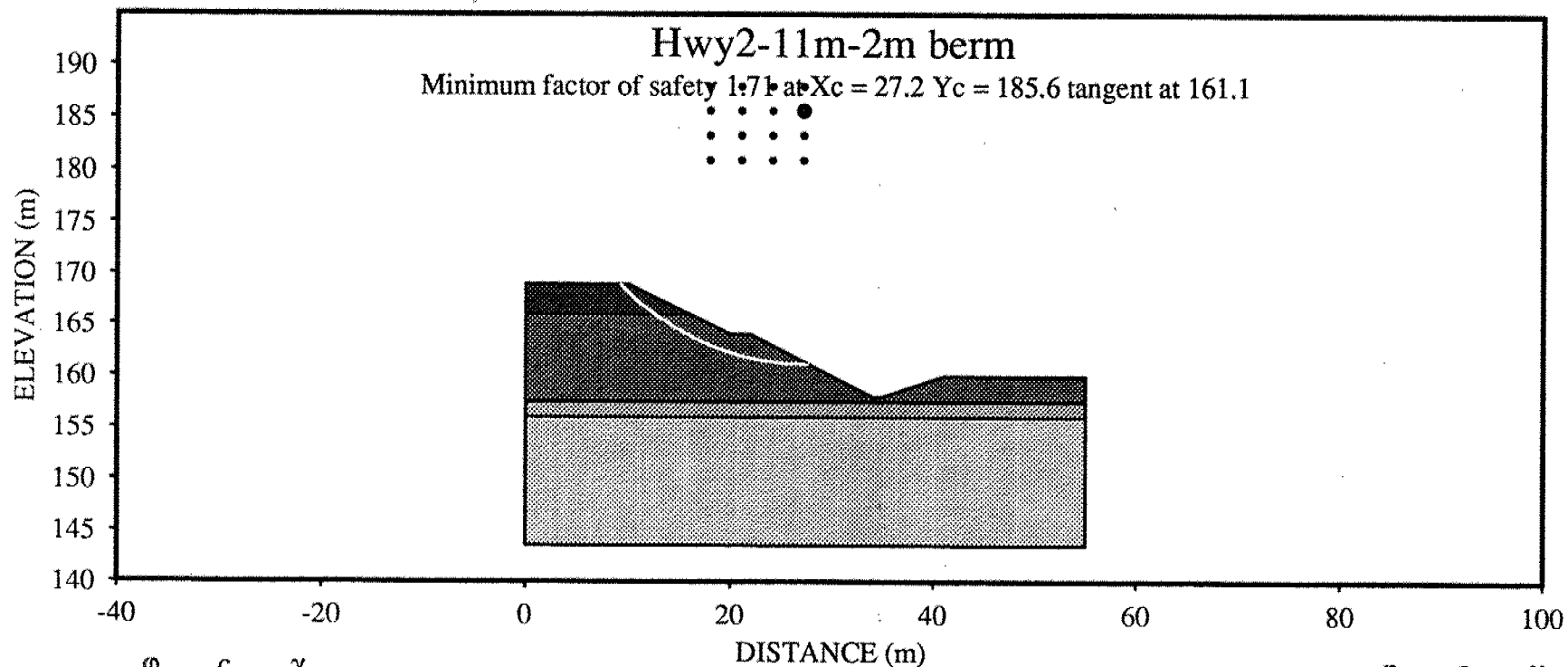
#### FACTORS OF SAFETY

1.764	1.572	1.685	2.196
1.727	1.533	1.678	2.266
1.694	<b>1.510</b>	1.671	2.337
1.670	1.518	1.650	2.387

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Fig 2





$\phi$	c	$\gamma$
--------	---	----------

30.0	0.0	20.0
------	-----	------

35.0	0.0	22.0
------	-----	------



Sandy Silt

Het. Mix. CL.SL.SA.GR.

Het. Mix. CL.SL.SA.GR.

Clayey Silt(Till)

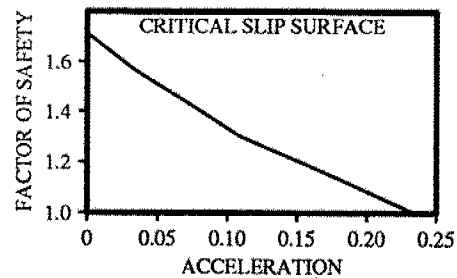
$\phi$	c	$\gamma$
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35.0	0.0	22.0
------	-----	------

37.0	0.0	22.0
------	-----	------

#### CRITICAL ACCELERATIONS

9.000	0.352	0.292	0.239
0.405	0.342	0.281	<b>0.235</b>
0.398	0.332	0.270	0.243
0.391	0.322	0.262	0.253

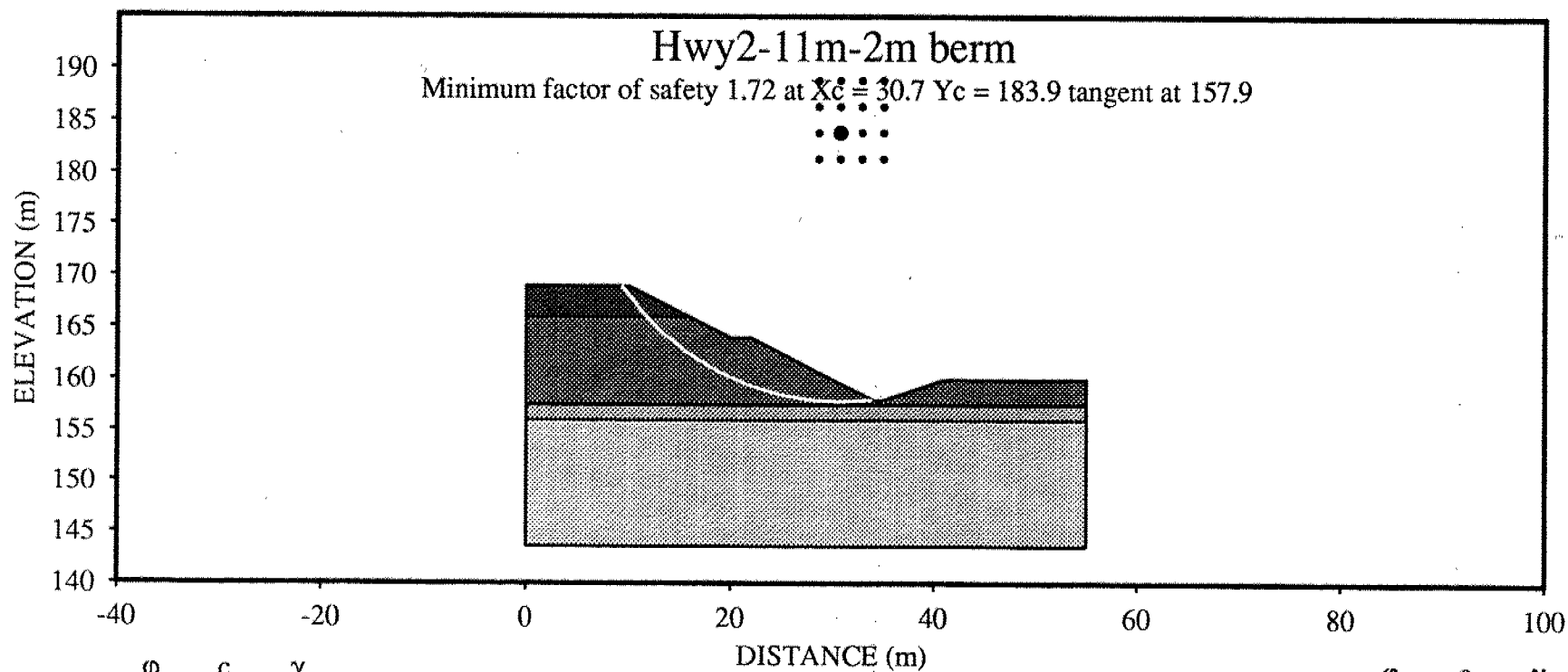


#### FACTORS OF SAFETY

9.000	2.361	1.994	1.733
2.733	2.273	1.921	<b>1.712</b>
2.637	2.185	1.850	1.744
2.539	2.099	1.802	1.761

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Fig 3



$\phi$      $c$      $\gamma$

30.0    0.0    20.0    Sandy Silt

35.0    0.0    22.0    Het. Mix. CL.SL.SA.GR.

Het. Mix. CL.SL.SA.GR.

Clayey Silt(Till)

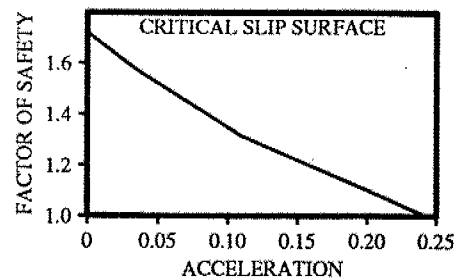
$\phi$      $c$      $\gamma$

35.0    0.0    22.0

37.0    0.0    22.0

#### CRITICAL ACCELERATIONS

0.283	0.253	0.283	0.354
0.274	0.246	0.285	0.370
0.267	0.243	0.287	0.386
0.262	0.248	0.285	0.399

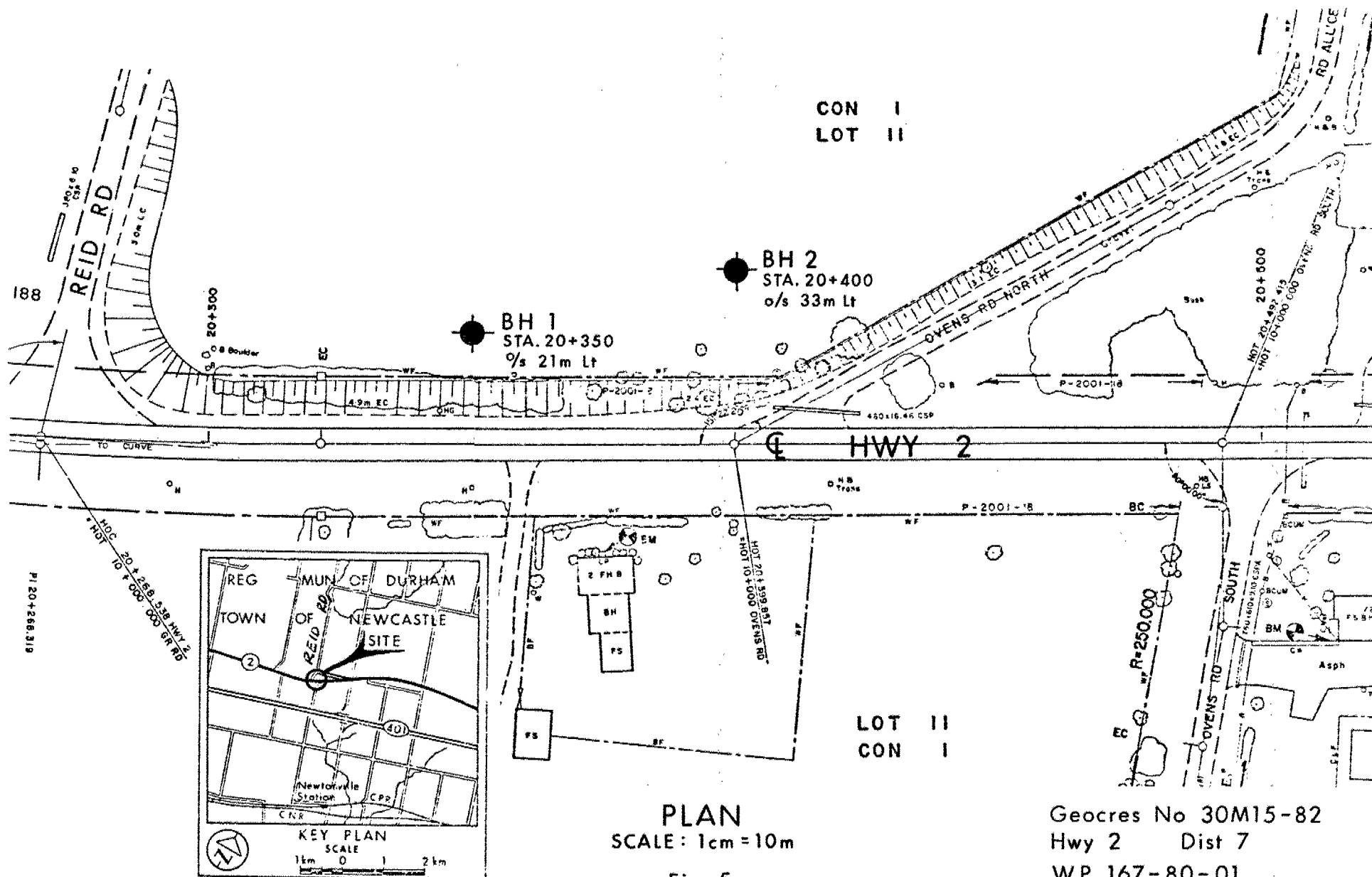


#### FACTORS OF SAFETY

1.920	1.777	1.920	2.337
1.859	1.738	1.930	2.444
1.813	1.721	1.949	2.555
1.781	1.737	1.945	2.640

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Fig 4



PLAN

SCALE: 1cm = 10m

Fig. 5