

REMARKS: _____

FILE COPY



Ministry
of
Transportation

FOUNDATION DESIGN SECTION

**foundation
investigation and
design report**

**ENGINEERING MATERIALS OFFICE
FOUNDATION DESIGN SECTION**

CONT 96-49

WP 61-86-00A DIST 52
HWY 11 STR SITE

Hwy. 11 and Muskoka Road #37 Interchange
Connection 'A' and the EW-N Ramp

DISTRIBUTION

P. Furst (1)
J. McDougall (2)
R. Mantha (2)
S. Wilson (2)
M. Holowka
J. Robinson
E.A. Joseph
O. Ramakko (Cover Only)
F. Bacchus (Cover Only)
File

GEOCRES 31E-116

DATE

MAY 23 1995

FOUNDATION INVESTIGATION REPORT
for
Hwy 11 and Muskoka Road #37 Interchange
Connection 'A' and the EW-N Ramp
W.P. 61-86-00A
District 52, Huntsville

INTRODUCTION

This report summarizes the results of a foundation investigation carried out at the proposed Connection 'A' and EW-N Ramp alignments of the Hwy 11/Muskoka Road 37 Interchange. The investigation was carried out upon the request of the Northern Region Geotechnical Section. The main purpose of the investigation is to determine the bedrock profile in this area which will govern the construction method and ground support scheme for the proposed road formation.

The field work was carried out between 95 02 13 and 95 02 27. The work consisted of ten (10) sampled boreholes and three (3) probe-holes advanced between Sta. 10+530 and 10+620 of Connection 'A' and Sta. 11+200 and 11+320 approximately. Bedrock was cored in eight (8) of the boreholes.

SITE DESCRIPTION

The site is located to the east of Highway 11, between the highway and Latvian Road. It is situated just to the north of the existing Hwy 11/Muskoka Road 37 intersection in the Township of Bracebridge, District of Muskoka.

Physiographically, the site is located in a region known as Number 11 strip, after Chapman and Putnam (1984). It typically consists of bare rock ridges and glacial deposits of sand, silt and clay.

At the site location, Hwy 11 and Latvian Road are separated by an existing slope. The height of the slope ranges from 4 ±m at the south end (Sta. 11+200) to 11 ±m around Sta. 11+400. The composition of the slope material also varies. Between Sta. 11+200 to 11+305 approximately, the slope comprises rock fill overlying bedrock. The area at the toe of the slope is heavily wooded. From Sta. 11+305 to Sta. 11+375 approximately, it is primarily composed of sand and silt. The slope surface is grassed. From Sta 11+375 on, massive bedrock outcrops can be found on the slope face. The slope angle varies, but typically at 2H:1V for the soil slope and steepens up for the rock fill and bedrock outcrops. The slope above Latvian Road comprises mainly bedrock outcrops. The existing slopes and roadways appeared to be in good shape with no obvious sign of distress.

The site is bounded by Hwy 11 to the west and Latvian Road to the east. There is no major land use except a snowmobile trail runs along the toe of the slope.

INVESTIGATION PROCEDURES

Soil data and inherent properties were obtained by insitu and laboratory testing. The procedures employed are discussed below:

Field

The field investigation work was carried out between 95 02 13 and 95 02 27 and consisted of ten (10) sampled boreholes advanced to a depth ranging from 3.9 to 17.4 m. In addition, probing was done by augering to refusal at shallow depths (0.6-0.8 m) at three (3) locations.

Two track mounted auger machines were mobilized to speed up the progress. The boreholes were advanced using conventional hollow/solid stem augering techniques with continuous flight augers. The sampling program consisted of disturbed samples taken by split spoon sampler in accordance with Standard Penetration Test (ASTM D1586). Standard Penetration ('N') values were recorded for assessment of the denseness of the non-cohesive material encountered. Bedrock was cored at eight (8) hole locations. Wire line rock coring techniques were employed in one of the machines to retrieve rock core samples for rock quality determination and classification purposes. Standard N size core barrel and casings were used. Conventional rock coring was carried out in the other machine with B size core barrel and casings. All subsoil samples were identified in the field and returned to the laboratory for further examination and appropriate testing.

Ground water level was monitored in the boreholes during the investigation. All boreholes were backfilled upon completion of the field work.

Borehole locations and elevations were provided by Northern Region Planning and Design Section. The proposed borehole locations were staked out in the field. No drilling was carried out on the existing slope as the slope gradient is too steep for the machines. Boreholes offset from the original stake locations were tied in by our field staff upon completion of the field work.

Laboratory

The laboratory testing on selected soil samples consisted of the following:

- Grain Size Distribution
- Natural Moisture Content
- Organic Content Determination

Laboratory results are given in the following section of this report and are illustrated on Record of Borehole sheets included in the Appendix.

SUBSURFACE CONDITIONS

General

The Record of Borehole sheets in the Appendix illustrate the subsurface conditions at the borehole locations. The locations of the boreholes are shown in Drg. No. 618600A-A.

A series of boreholes were advanced along Latvian Road with rock coring carried out on most of them to prove bedrock (except BHs 2, 8 and 10). The bedrock surface was found to be undulating with depths varying from 1.4 to 5.6 \pm m. The overburden comprises mainly granular/rock fill or sand and gravel with boulders. Boreholes were also advanced at the toe of the existing slope. At BH 12 location, bedrock was deeply seated at 15.4 m depth with native silty sand and non-cohesive glacial till material overlying it. At BH 11 and 11A locations, bedrock was encountered at 5 and 6.7 \pm m respectively.

Following are the specific descriptions of the materials encountered in the investigation.

Fill

Granular fill is generally contacted at the ground surface for all the boreholes advanced along the existing Latvian Road (BHs 1 to 10). This fill layer is about 0.6 to 0.8 m thick and consists of sand and gravel. At BH 7 and BH 9, the fill layer extend to 2.6 and 2.1 m respectively and consists of boulders and rock fragments, probably pushed in during construction of the road. Some organic inclusions were found in BH 9. Laboratory tests carried out on a sample retrieved from BH 7 indicate moisture content of 10.5% and Grain Size Distribution of 47% gravel, 45% sand and 8% silt & clay. A sample retrieved from BH 9 was also selected for testing. The results indicate moisture content of 20.5%, organic content of 4% and Grain Size Distribution of 26% gravel, 62% sand and 12% silt & clay.

Sand and Gravel with Boulders

This non-cohesive soil stratum was encountered at BHs 1, 3 to 6 and 9 below the fill layer, overlying bedrock. It consists of sand and gravel with boulders and the thickness of this stratum varies from 0.6 to 5.0 m. Due to the bouldery nature of this deposit, Standard Penetration Tests carried out typically encountered refusal on boulders. Laboratory tests carried out on a sample retrieved from BH 5 indicate moisture content of 13% and Grain Size Distribution of 27% gravel, 61% sand and 12% silt & clay. A sample retrieved from BH 9 was also selected for testing. The results indicate a moisture content of 13% and Grain Size Distribution of 18% gravel, 71% sand and 11% silt & clay.

Silty Sand to Sandy Silt

This is a major deposit contacted in the boreholes advanced at the bottom of the existing slope (BHs 11, 11A and 12). The thickness of this non-cohesive layer varies from 3.8 to 12.8 m. It is described as silty sand to sandy silt with isolated sand layers, silt zones as well as clay pockets. Standard Penetration 'N' values range from 9 to 63 blows/30 cm indicating compact to very dense state of denseness. Three (3) samples were selected for laboratory testing and the results indicate natural moisture contents of 7.5, 24.5 and 33.5%, and Grain Size Distribution of 0-8% gravel, 16-89% sand and 3-84% silt & clay.

Heterogeneous Mixture of Sand, Silt and Gravel (Glacial Till)

This non-cohesive layer was contacted in BH 11 and BH 12 overlying bedrock. Numerous boulders and cobbles were encountered in BH 12. Based on the SPT 'N' values (60 blows/30 cm and 54 blows/28 cm), the material is very dense. Laboratory testing carried out on two representative samples indicates natural moisture contents of 11±% and Grain Size Distribution of 18-28% gravel, 48-55% sand, 22-25% silt and 2% clay.

Bedrock

Bedrock was cored in BHs 1, 3 to 7, 9 and 12. It is a slightly weathered to unweathered igneous/metamorphic rock of the Grenville Province. The rock retrieved from BHs 1, 3 to 7 and 9 advanced from Latvian Road is a strong Hornblende-Biotite Gneiss. Core Recovery (CR) obtained generally varies from 66 to 100%. The CR is exceptionally poor in BH 6, ranging from 5 to 100% with a void between 5.41 and 5.72 m depths. Rock Quality Designation (RQD) varies widely from 0 to 100%. The rock retrieved from BH 12 at the toe of the slope consists of a medium strong Amphibolite overlying strong Granite. CR obtained ranges from 87 to 100% and RQD ranges from 36 to 89%.

Rock cores from the field were examined and classified by MTO petrographer, D. Williams. Detailed descriptions of the rock are attached in the Appendix.

Groundwater

During the time of the investigation, the boreholes along Latvian Road (BH 1 to 10) were dry before water was pumped in for rock coring. The holes caved in immediately when the casings were extracted after completion of drilling and no measurements were made. The ground water level measured in BHs 11, 11A and 12 at the toe of the slope was generally close to the ground surface, at El. 274 \pm m in BHs 11 and 11A and El. 272 \pm m in BH 12. Seasonal fluctuations in water levels are expected.

retaining wall at the toe of the slope. This scheme will require a temporary slope be formed to the full height of the existing slope. This will involve major earthwork and the temporary cut will encroach into the existing Latvian road. Reinforced earth wall construction will have the same problem. Unless Latvian Road can be temporarily reduced in width or relocated, this scheme is not feasible.

2. Figure 7 illustrates a caisson wall scheme that does not require temporary cut slopes. Either a cantilevered continuous caisson wall socketed into bedrock or tied-back caisson wall can be employed. However, this scheme will be costly and are not warranted for a project of this size.
3. Figure 8 illustrates a permanent shoring scheme in the form of tied back soldier pile wall with concrete lagging, that does not require temporary cut slopes. Again, this scheme will be quite costly to construct. In addition, boulder obstructions are expected and there will be difficulties in advancing the soldier piles.

For the above-mentioned schemes, additional field investigation will be required to determine the soil conditions along the retaining wall alignment. Since the alignment is on the existing slope, either an access ramp will have to be constructed or individual platforms will have to be built on slope for a diamond drill to facilitate the operation.

4. A more feasible and cost effective solution is soil nailing. Figures 3 and 4 illustrate this method schematically. Details of the method is given in the following paragraph.

Recommendations

It is recommended to reinforce the existing slope by means of 'soil nails' and form a steep cut for the construction of the proposed ramps. Soil nailing is a practical technique in stabilizing slopes by reinforcing the ground with relatively small, fully bonded steel bars. These are introduced into the soil mass, the face of which will be stabilized by shotcrete and act to produce a zone of reinforced ground. This zone then performs as a homogeneous unit to support the unreinforced ground behind in a manner similar to a gravity retaining wall. Some of the benefits in using this method on this site are summarized as follows:

1. In contrast to classical reinforced soil structures, soil nailing proceeds downwards from the existing ground surface. The construction procedure typically involves three basic steps: excavation, nail installation and facing placement. Excavation is made in stages with each bench being 1 to 1.5 m deep. No major temporary cut is therefore required. Typical construction procedures are illustrated in Figure 9.

2. Construction equipment for nail installation and shotcreting are relatively small scale and mobile which is ideal for a small site like this.
3. Soil nailing can proceed rapidly and the excavation can be shaped easily. It is a flexible technique, readily accommodating variations in soil conditions as excavation progresses. This is beneficial in this case since the investigation results indicate that the bedrock profile can change rapidly over a short distance. The scope of work can therefore be readily adjusted as excavation proceeds.
4. Nailing is applied at the earliest possible time after excavation and in intimate contact with the cut soil surface. This minimizes the disturbance to the ground. Furthermore, nails are installed at high density (typically one per 1.5 to 3 m²). The consequences of one unit failure are not necessarily so severe. In addition, the constructional tolerances of installation need not be so high, given their overall interactive mode of operation.
5. The finished slope surface will be shotcreted. However, like a reinforced earth wall, a face wall can easily be constructed with precast wall panels. Planter boxes can also be built in and specially selected plants such as creepers can be planted and developed to cover the entire slope to provide a natural outlook.
6. In general, soil nailing is 10 to 30% cheaper than other conventional retaining system.

The soil nailing design should be carried out by a specialist contractor. The following design considerations should be accounted for:

1. The nailed slope is considered as a composite mass, and failure criteria for the soil, reinforcements and interaction between the soil and the inclusions must be satisfied and considered in the analysis. Failure surface may lie entirely within the reinforced zone. Failure surface may also lie partially outside of the reinforced zone. Both internal and external stabilities should be considered. Internal failure modes include pull-out of the bars, tensile failure of the bars and local instability at each level of nails. External failure modes include global instability of the nailed mass and surrounding ground with respect to a rotational or translational failure along potential sliding surfaces. Since the excavation will be carried out in stages, the stability of the cut at each stage of construction should be analyzed. This governs the angle of the soil nailed slope and hence the height of the overall cut. Based on a slope angle of 1H:1.5V, the cut slope height is in the order of 7 to 9 ±m. The slope above the soil nailed cut should be smoothed out to a flatter gradient as illustrated in Figures 3 and 4.
2. For the design of soil nails, an appropriate skin friction value between soil and

grout has to be assumed. This value should be verified in the field by pull-out tests in advance of the installation of permanent nails. The design should be modified accordingly, if necessary. In some cases, as shown in Figures 3 and 4, some nails might be socketed into bedrock. A different skin friction value should be used and the required nail length can be adjusted accordingly. For preliminary design purpose, the following design parameters may be employed:

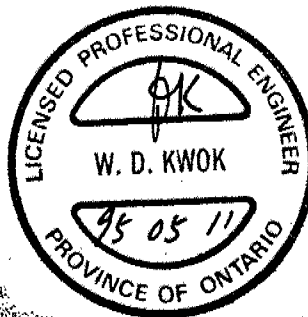
$$\begin{aligned}\phi &= 30^\circ, & C &= 0, & \gamma &= 19 \text{ kN/m}^3 \\ \text{Grout/Soil Skin Friction} &= 75 \text{ kPa} \\ \text{Grout/Bedrock Bond Capacity} &= 500 \text{ kPa}\end{aligned}$$

3. Since this is a permanent system, considerations should be given to the corrosion aspect of the nails. All soil nails should be hot-dip galvanized bars. A minimum grout cover of 20 mm all round should be provided. In addition, depending on the design life of the system, a sacrificial thickness may be required to allow for steel loss with time.
4. Shotcrete is the conventional facing for soil nailing slopes. However, the long term performance of shotcrete facings has not been fully demonstrated particularly in areas subject to freeze-thaw cycles. Although the base ground water table is generally close to the slope toe, increases in nail stresses due to freeze effects under transient conditions should be accounted for. Alternatively, freeze effects may be minimized or eliminated by provision of insulation layers between the shotcrete surface and a concrete or stone facing.
5. Although the ground water table was measured to be close to the slope toe, a drainage system is still advisable in case of seasonal fluctuations and transient flow conditions. In general, weepholes can be provided to prevent built up of hydrostatic pressure behind the shotcrete face. Spacing at 3 m centres is probably adequate in this case.
6. Since this is the first time that soil nailing techniques are employed in MTO projects, the performance of the system should be monitored during construction. Our office can provide technical support throughout the project. It is recommended that at least two (2) slope inclinometers be installed in advance of the excavation to monitor the ground movement during construction. In addition, some monitoring points can be set up at each level of excavation to monitor the surface movement as excavation proceeds down to the lower levels. Locations and details of the site instrumentation will be provided when the soil nailing layout is available. The soil nails are different from anchors on design principles and no stressing of the bars is necessary. However, if excess movement takes place, the constructed nails can be stressed up to reduce the movement.

MISCELLANEOUS

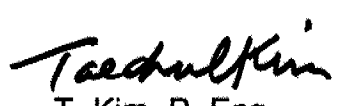
The field work for this investigation was carried out under the joint supervision of D. Kwok, Project Foundation Engineer, J. Crabb, Engineering Trainee and T. Hickey, Technical Trainee. The drilling machines and equipment were owned and operated by Dominion Soil Investigation Inc. and Canadian Soil Drilling. Bedrock was examined and classified by MTO petrographer D. Williams.

This report was prepared by D. Kwok, reviewed and approved by T. Kim, Senior Foundation Engineer.




D. Kwok, P. Eng.
Project Foundation Engineer




T. Kim, P. Eng.
Senior Foundation Engineer

APPENDIX

AREA-2
SOIL NAILING

AREA-1
ROCKFILL SLOPES /
ROCK CUTS

STA 11+340

STA 11+320

PLATE -1

Geocres No 31E-116
WP 61-86-00A



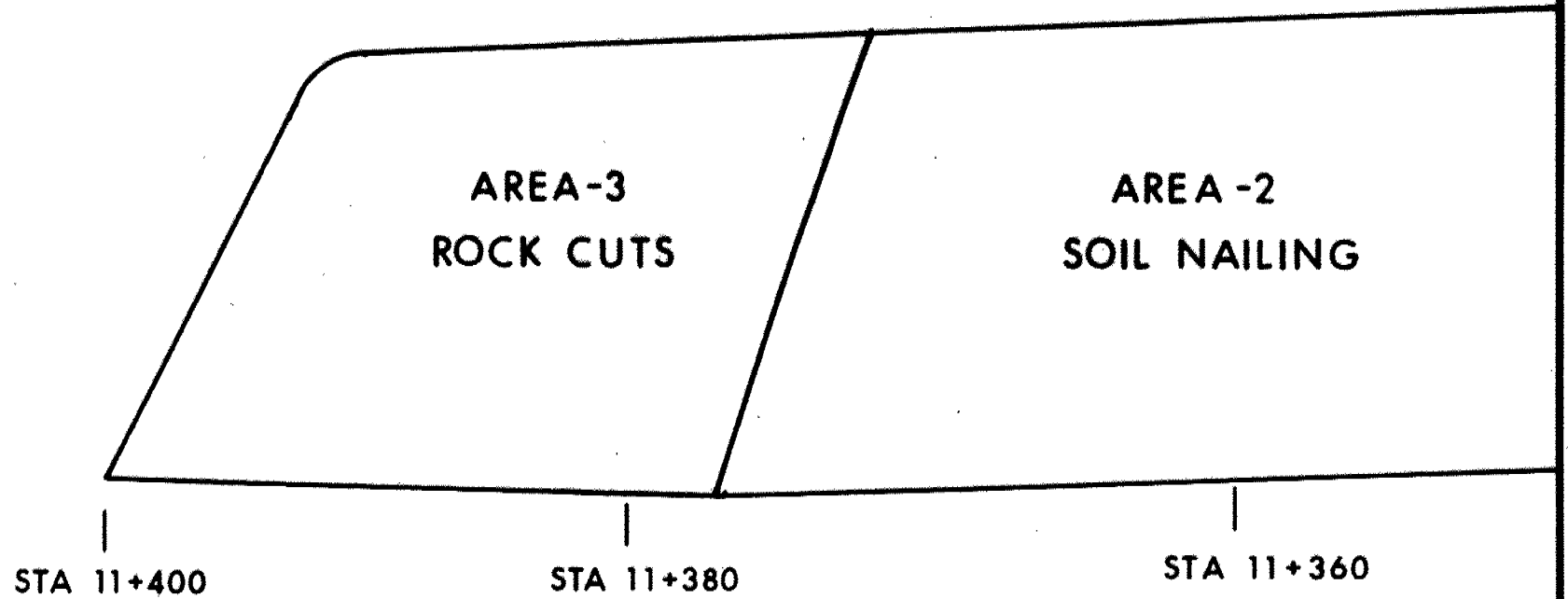
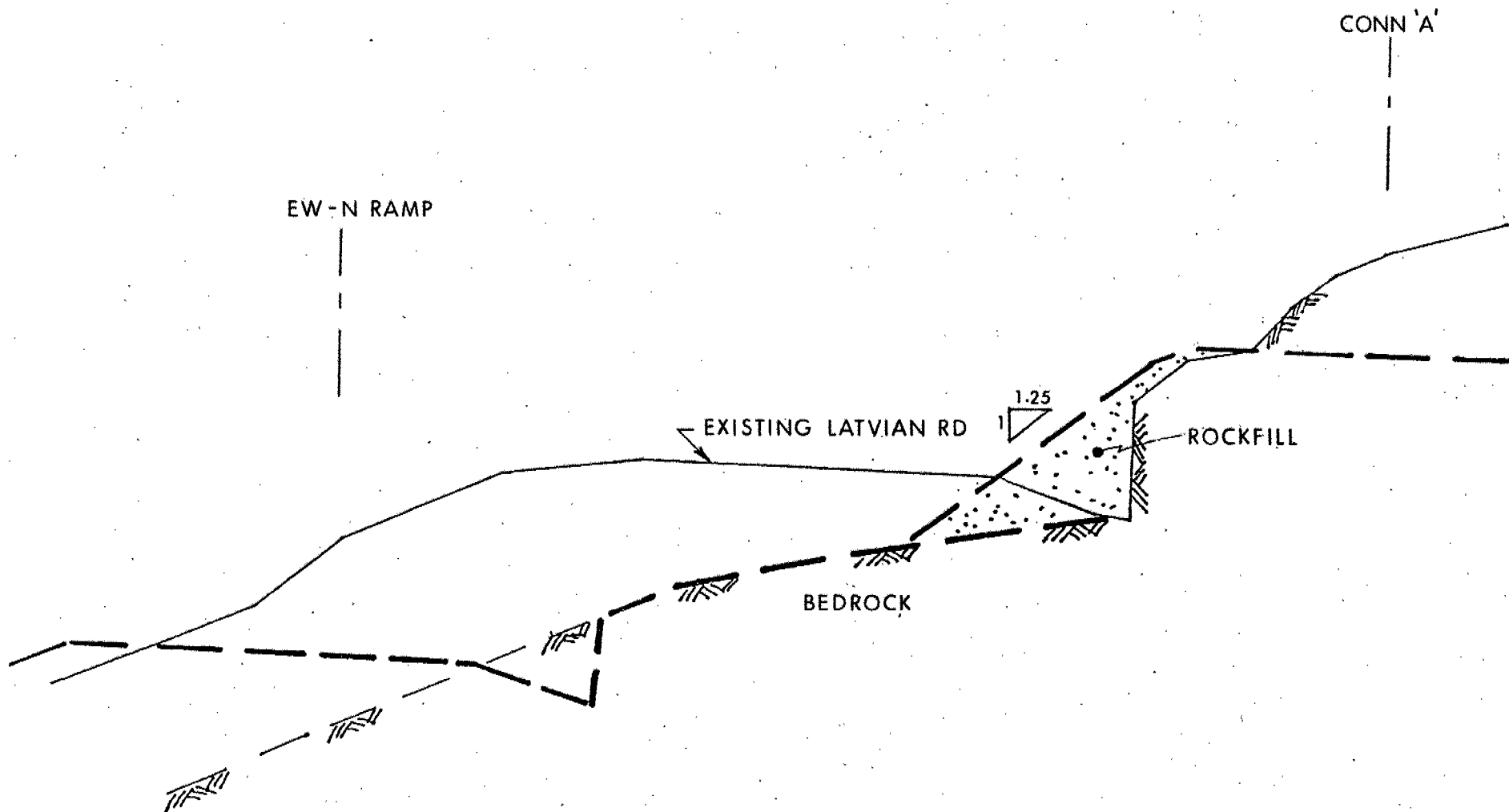


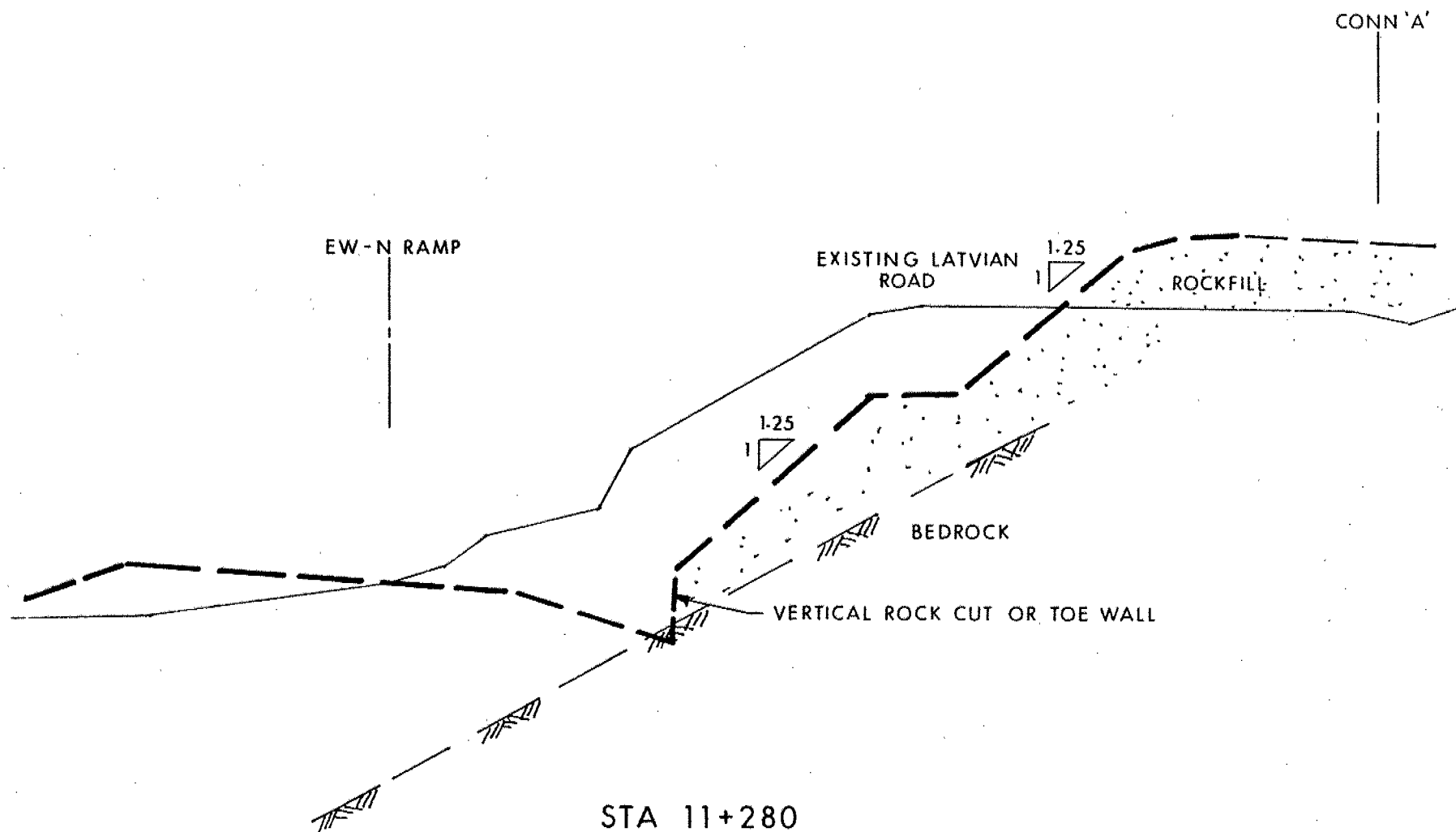
PLATE - 2

Geocres No 31E-116
WP 61-86-00A

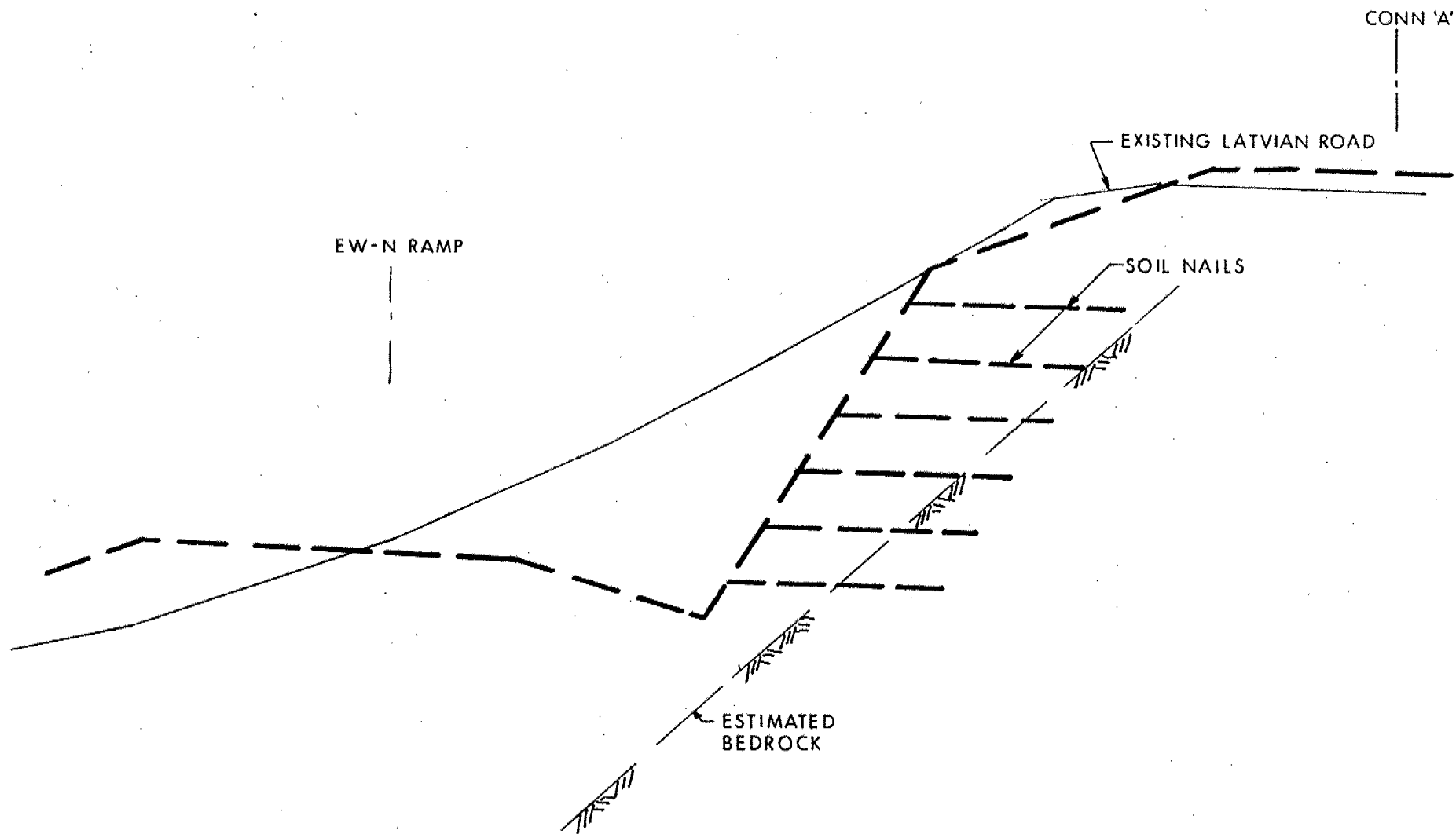




WP 61-86-00A
Fig-1



WP 61-86-00A
Fig -2

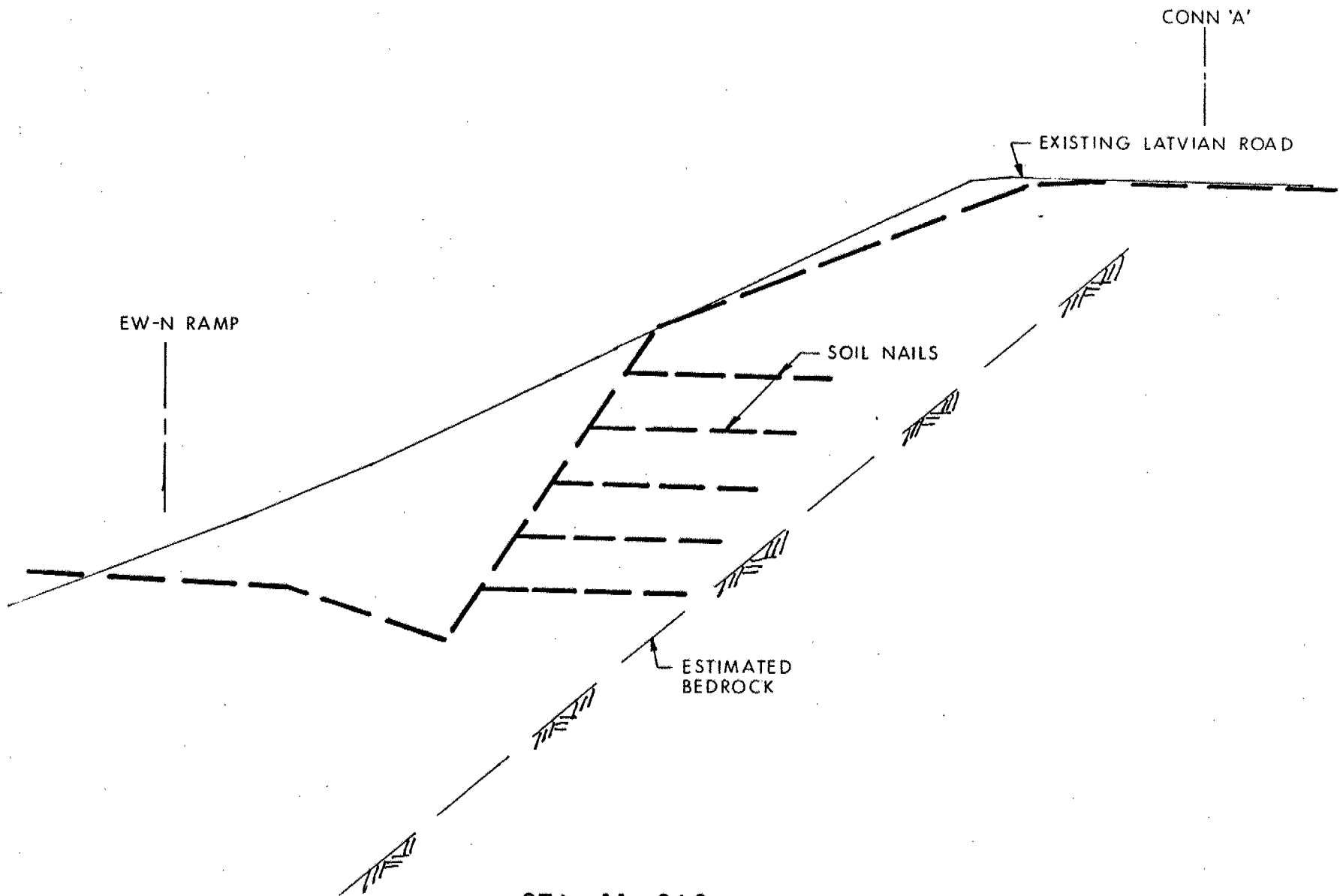


STA 11+320
SOIL NAILING SCHEME

NTS

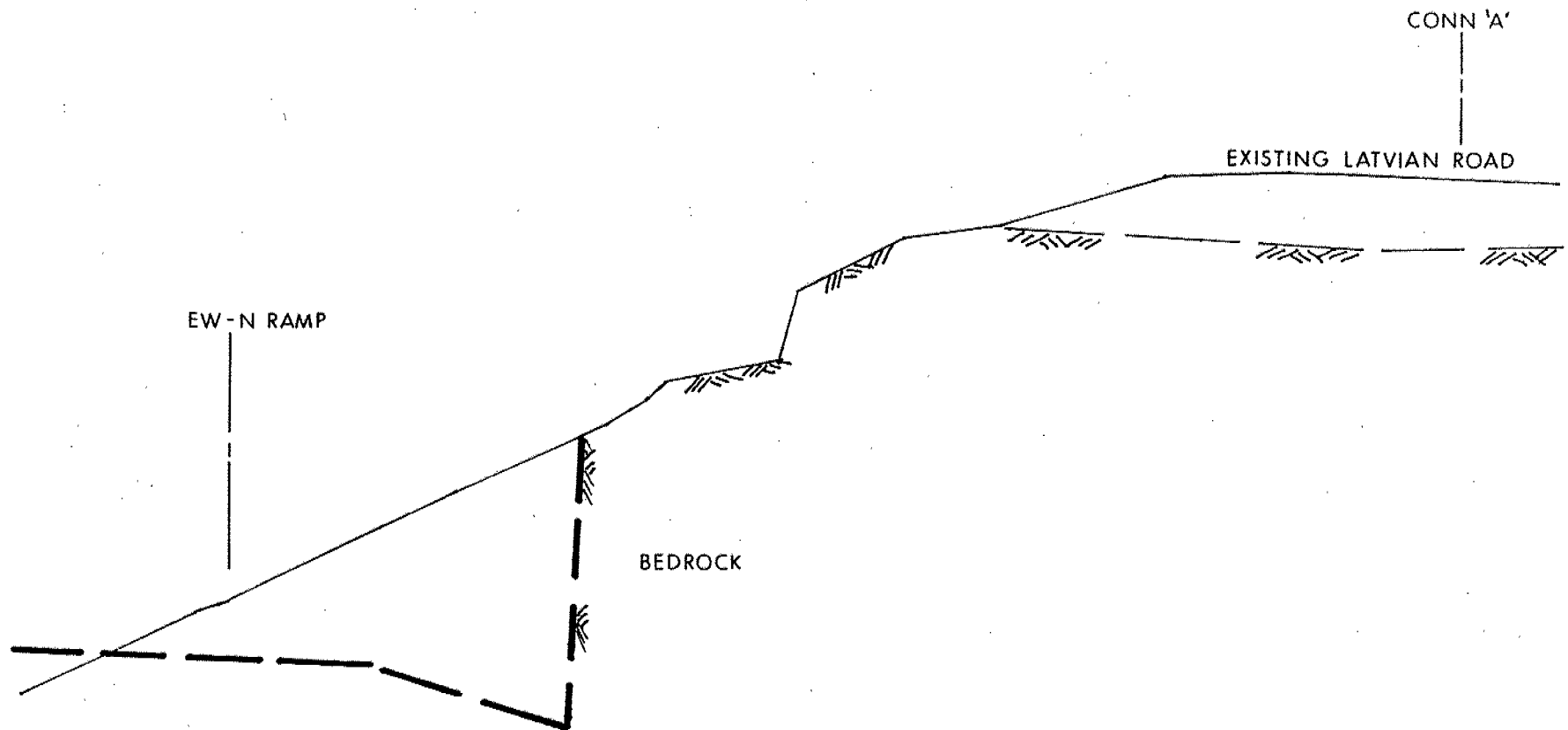
WP 61-86-00A

Fig -3



STA 11+360
SOIL NAILING SCHEME
NTS

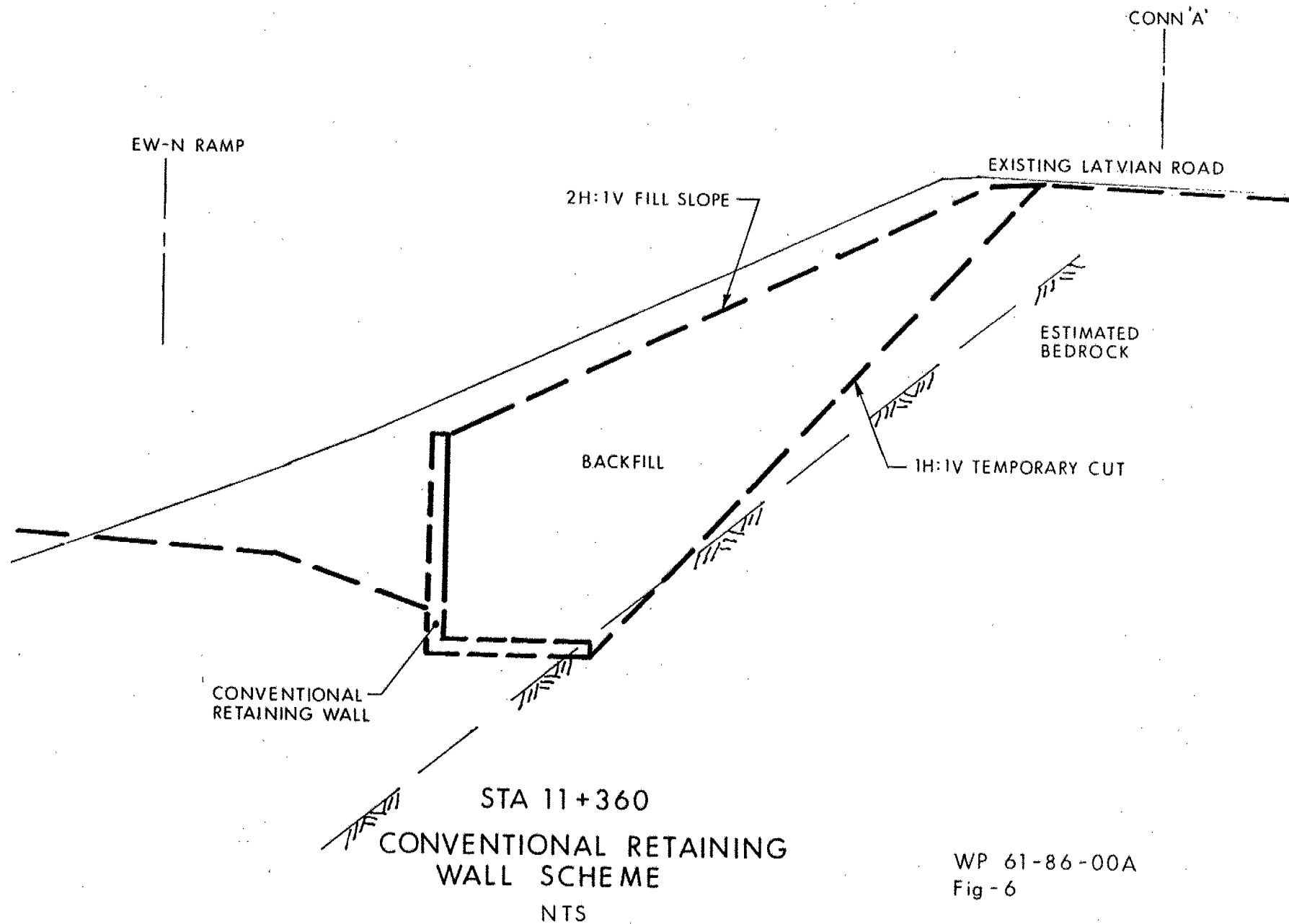
WP 61-86-00A
Fig - 4



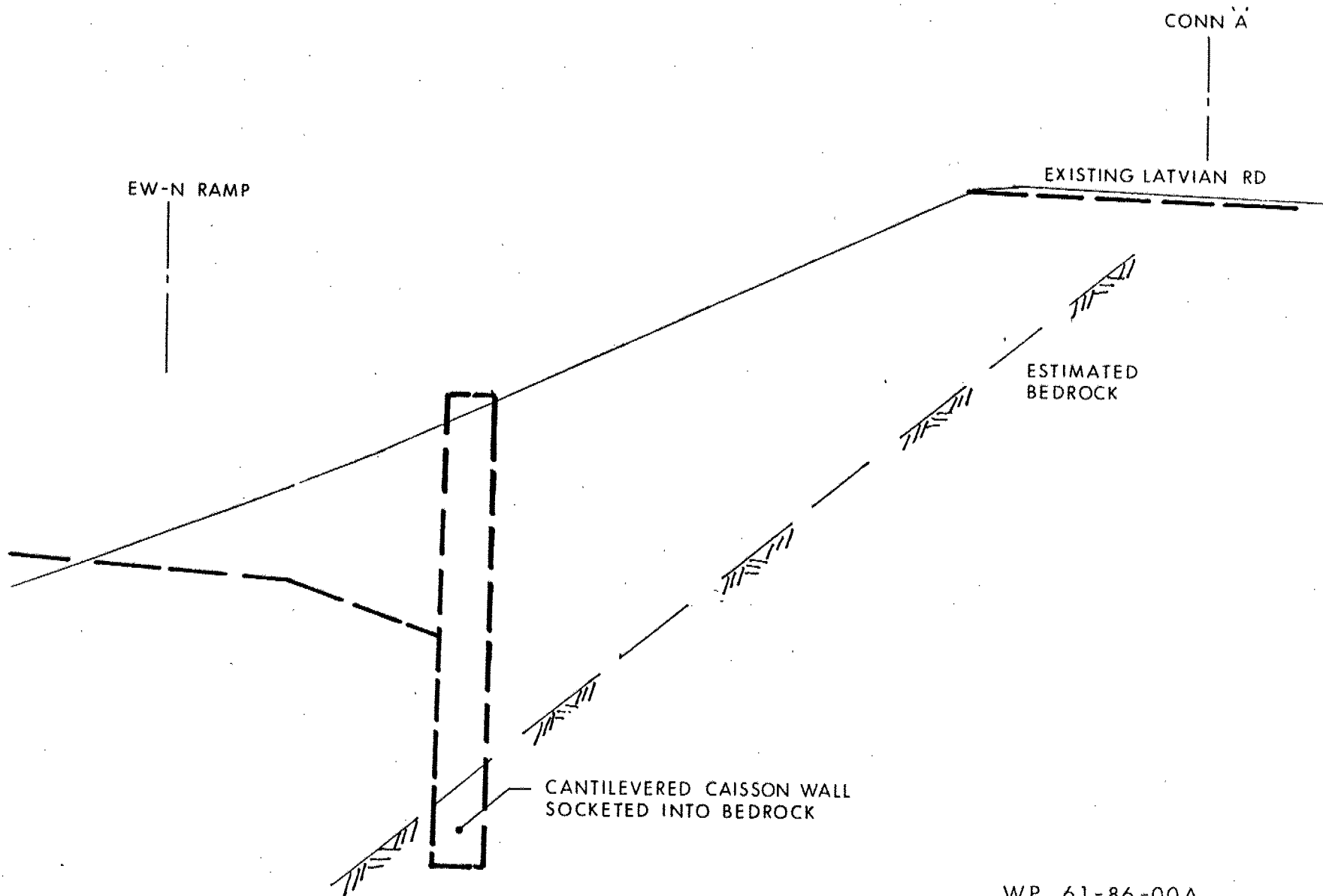
STA 11+390

NTS

WP 61-86-00A
Fig -5

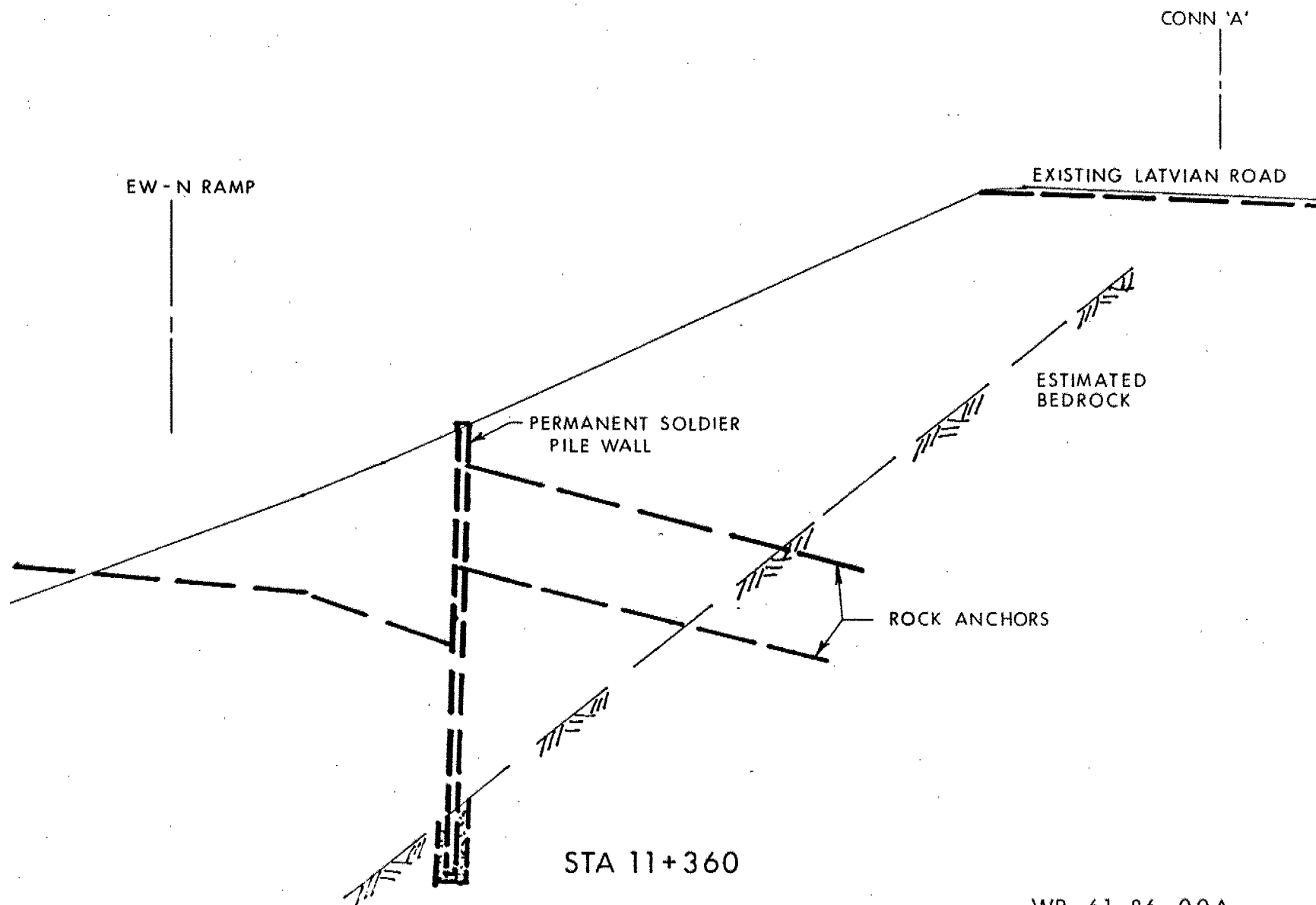


WP 61-86-00A
Fig-6



CAISSON WALL SCHEME
NTS

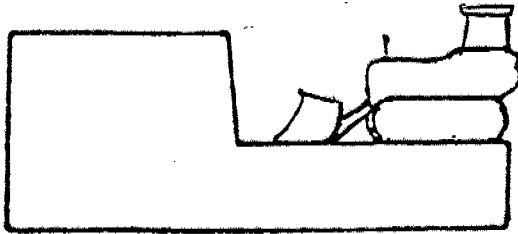
WP 61-86-00A
Fig -7



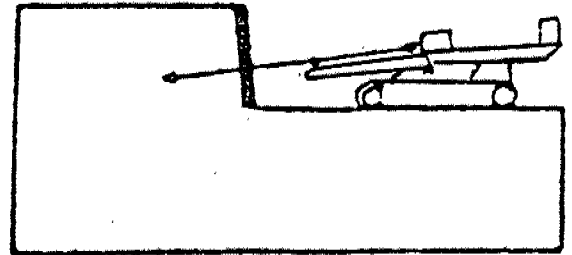
PERMANENT SOLDIER PILE
WALL SCHEME

WP 61-86-00A
Fig - 8

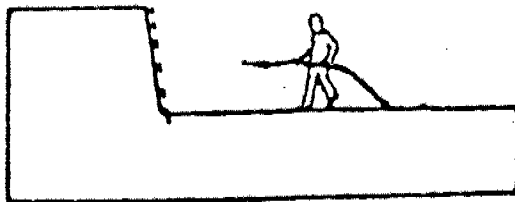
1. Excavation



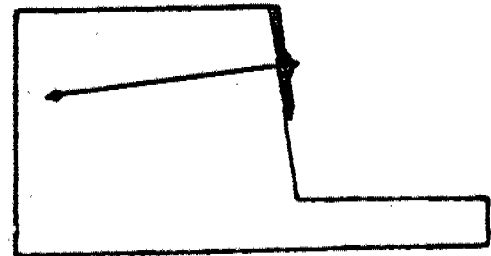
2. Nailing



3. Reinforced Shotcrete



4. Further Excavation



1. The soil is excavated in layers of 1 to 1.5 m.
2. Holes are formed by percussive or rotary drilling. Soil nails consisting of galvanized steel bars are installed into the holes and the annular space between nails and soil is grouted. Casings will be required if the hole does not stay open. The head of the nail is connected to a steel plate on the slope face.
3. The whole face is then protected by a skin of shotcrete reinforced with a wire mesh.
4. A new layer of soil may be excavated.

Note: Steps 2 and 3 can be switched if it is considered necessary to protect the cut face with shotcrete right after the excavation for erosion control or stability reasons.

Figure 9 Construction Procedures

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 63.5 kg, 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 / 0.3 m)	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	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_a	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	e_{\min}	1, %	VOID RATIO IN DENSEST STATE
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{\max} - e}{e_{\max} - e_{\min}}$
ρ_w	kg/m^3	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m^3	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kN/m^3	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m^3	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	e_{\max}	1, %	VOID RATIO IN LOOSEST STATE	j	kN/m^2	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						

RECORD OF BOREHOLE No 1

1 OF 1

METRIC

W.P. 61-86-00 LOCATION Sta 10+822.5 o/s 2.3 m Lt.C.L. Conn. 'A' ORIGINATED BY DK
 DIST 52 HWY 11 BOREHOLE TYPE H.S. Augers, NQ Core Barrel COMPILED BY TH
 DATUM Geodetic DATE 95 02 13 - 95 02 15 CHECKED BY TK

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100					
283.6	Ground Surface															
0.0	Sand & Gravel (Granular Fill)		1	SS	50 /Bcm	DRY *										
0.8	Sand and Gravel with Boulders		2	RC	REC	100%										RQD 38%
282.2			3	RC	REC	85%										RQD 0%
1.4			4	RC	REC	100%										RQD 38%
	Bedrock		5	RC	REC	100%										RQD 31%
279.2			6	RC	REC	100%										RQD 74%
4.4	End of Borehole															
	* 95 02 13															

RECORD OF BOREHOLE No 2

1 OF 1

METRIC

W.P. 61-86-00 LOCATION Site 10+603 e/s 2.0 m Lt C.L. Conn.'A' ORIGINATED BY TH
DIST 52 HWY 11 BOREHOLE TYPE S.S. Auger COMPILED BY DK
DATUM Geodetic DATE 95 02 24 CHECKED BY TK

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ KN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	SHEAR STRENGTH kPa								
						○ UNCONFINED + FIELD VANE * QUICK TRIAXIAL * LAB VANE 20 40 60 80 100					WATER CONTENT (%)					
											10	20	30			
284.2	Ground Surface															
283.8	Granular Fill	X	2			DRY	284									
0.6	End of Borehole	**														
	* 95 02 24															
	** Auger refusal on probable boulders															

RECORD OF BOREHOLE No 3

1 OF 1

METRIC

W.P. 61-86-00 LOCATION Sta 10+580 o/s 4.2 m Lt C.L. Conn. 'A' ORIGINATED BY DK
 DIST 52 HWY 11 BOREHOLE TYPE H.S. Augers, BQ Core Barrel COMPILED BY JC
 DATUM Geodetic DATE 95 02 14 - 95 02 15 CHECKED BY TK

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT 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 _p	W			W _L
284.1	Ground Surface																
0.0 283.3	Silty Sand with Gravel (Granular Fill)																
0.8 282.5	Sand and Gravel with Boulders																
1.6	Bedrock		1	RC	REC	100%										RQD 50%	
			2	RC	REC	87%											RQD 27%
			3	RC	REC	100%											RQD 90%
280.2																	
3.9	End of Borehole																
	• 95 02 14																

RECORD OF BOREHOLE No 4

1 OF 1

METRIC

W.P. 61-86-00 LOCATION Sta 10+565 o/s 8.2 m Lt C.L. Conn. 'A' ORIGINATED BY TH
 DIST 52 HWY 11 BOREHOLE TYPE H.S. Augers, NQ Core Barrel COMPILED BY TH
 DATUM Geodetic DATE 95 02 23 CHECKED BY TK

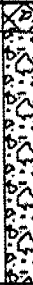
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa									
							20	40	60	80	100						
283.7	Ground Surface																
0.0	Sand & Gravel (Granular Fill)					DRY											
0.6	Sand and Gravel with Boulders																
280.7																	
3.0	Bedrock		4	RC	REC	100%											
			5	RC	REC	100%											
			6	RC	REC	100%											
			7	RC	REC	100%											
			8	RC	REC	100%											
277.6			9	RC	REC	100%											
6.1	End of Borehole																
	95 02 23																

RECORD OF BOREHOLE No 5

1 OF 1

METRIC

W.P. 61-86-00 LOCATION Sta 10+550 o/s 7.2 m Lt C.L. Conn. 'A' ORIGINATED BY JC
 DIST 52 HWY 11 BOREHOLE TYPE H.S. Auger, BQ Core Barrel COMPILED BY JC
 DATUM Geodetic DATE 95 02 15 - 95 02 17 CHECKED BY TK


SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa												
								20	40	60	80	100						WATER CONTENT (%)		
						○ UNCONFINED + FIELD VANE														
						● QUICK TRIAXIAL × LAB VANE														
283.2	Ground Surface																			
0.0	Sand & Gravel (Granular Fill)					DRY *														
0.8	Silty Sand and Gravel with Boulders						282													
							280													
277.5			1	WS	-											27 61 (12)				
5.6	Bedrock		2	RC	REC 100%											RQD 100%				
274.5			3	RC	REC 97%	276										RQD 97%				
8.7	End of Borehole																			
	• 95 02 15																			

RECORD OF BOREHOLE No 6

1 OF 1

METRIC

W.P. 61-86-00 LOCATION Sta 10+530 o/s 9.5 m lt C.L. Conn. 'A' ORIGINATED BY JC
 DIST 52 HWY 11 BOREHOLE TYPE H.S. Auger, NQ Core Barrel COMPILED BY TH
 DATUM Geodetic DATE 95 02 20 CHECKED BY TK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								20 40 60 80 100										10 20 30		
282.5	Ground Surface																			
281.8	Sand & Gravel (Granular Fill)		1	SS	6	DRY •	282													
0.7	Silty Sand with Gravel and Boulders							280												
279.1			2	RC	REC		69%	278												
3.4	Bedrock		3	RC	REC		73%													
	--- fractured zone ---		4	RC	REC		80%	276												
275.1			5	RC	REC	100%														
7.4	End of Borehole • 95 02 20																			

RECORD OF BOREHOLE No 7

1 OF 1

METRIC

W.P. 61-86-00 LOCATION Sta 11+200 e/s 3.7 m Rt C.L. EW-N Ramp ORIGINATED BY TH
 DIST 52 HWY 11 BOREHOLE TYPE H.S. Auger, NO Core Barrel COMPILED BY TH
 DATUM Geodetic DATE 95.02.16 CHECKED BY TK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
280.3	Ground Surface																
0.0	Sand and Gravel, Trace Silt with Cobbles and Boulders (Fill)		1	SS	43	DRY /15cm	280										
			2	SS	44	/15cm											47 45 (8)
277.6			3	SS	61	/13cm	278										
2.6	Bedrock		4	RC	REC	100%											RQD 79%
			5	RC	REC	100%											RQD 82%
			6	RC	REC	100%	276										RQD 87%
			7	RC	REC	100%											RQD 82%
274.5	End of Borehole																
5.8	• 95.02.16																

RECORD OF BOREHOLE No 8

1 OF 1

METRIC

W.P. 61-86-00 LOCATION Sta 11+221 o/s 6.5 m Rt C.L. EW-N Ramp ORIGINATED BY TH
 DIST 52 HWY 11 BOREHOLE TYPE S.S. Auger COMPILED BY DK
 DATUM Geodetic DATE 95 02 24 CHECKED BY TK

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL * LAB VANE 20 40 60 80 100					W _p	W		
280.8	Ground Surface															
280.8	Granular Fill					DRY										
0.6	End of Borehole • 95 02 24 •• Auger refusal on probable boulders or rock fill															

RECORD OF BOREHOLE No 9

1 OF 1

METRIC

W.P. 61-66-00 LOCATION Sta 11+240 o/s 8.5 m Rt C.L. EW-N Ramp ORIGINATED BY TH/KC
 DIST 52 HWY 11 BOREHOLE TYPE H.S. Auger, NQ Core Barrel COMPILED BY TH
 DATUM Geodetic DATE 95 02 17 - 95 02 20 CHECKED BY TK

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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	W _P W W _L	SHEAR STRENGTH kPa			WATER CONTENT (%)				
281.3	Ground Surface																
0.0	Silty Sand with Gravel Some Rock Fragments (Fill) Boulders with topsoil inclusions		1	SS	50	DRY 13cm	280										
279.2			2	SS	50	13cm											
278.6	Silty Sand, Some Gravel		4	SS	90	23cm											
2.7	Bedrock		5	RC	REC	87%	278										
			6	RC	REC	100%											
			7	RC	REC	89%											
			8	RC	REC	95%	276										
275.7	End of Borehole																
5.6	+ 95 02 17																

RECORD OF BOREHOLE No 10

1 OF 1

METRIC

W.P. 61-86-00 LOCATION Sta 11+261 o/s 10.5 m Rt C.L. EW-N Ramp ORIGINATED BY JH
 DIST 52 HWY 11 BOREHOLE TYPE S.S. Auger COMPILED BY DK
 DATUM Geodetic DATE 95 02 24 CHECKED BY TK

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			*N* VALUES	SHEAR STRENGTH kPa								
281.2	Ground Surface															
0.0 280.4	Granular Fill					DRY *										
0.8	End of Borehole * 95 02 24 ** Auger refusal on probable boulders	**														

1 OF 1

METRIC

W.P. 61-85-00 LOCATION Sta 11+280 o/s 0.2 m Rt C.L. EW-N Ramp ORIGINATED BY JC
DIST 52 HWY 11 BOREHOLE TYPE H.S. Auger, BO Core Barrel COMPILED BY TH
DATUM Geodetic DATE 95 02 23 CHECKED BY TK

+3, x5: Numbers refer to Sensitivity

RECORD OF BOREHOLE No. 11A

1 OF 1

METRIC

W.P. 61-86-00 LOCATION Sta 11+280 o/s 3.2 m lt C.L. EW-N Ramp ORIGINATED BY JC
 DIST 52 HWY 11 BOREHOLE TYPE H.S. Auger COMPILED BY JC
 DATUM Geodetic DATE 95 02 27 CHECKED BY TK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa									
							20	40	60	80	100						
275.8	Ground Surface																
0.0																	
	Silty Sand to Sandy Silt																
269.1																	
6.7																	
	Probable Bedrock																
265.1																	
10.7	End of Borehole																
	• 95 02 27																
	** Auger hit rock surface and slided down the rock face at an angle																

RECORD OF BOREHOLE No 12

1 OF 1

METRIC

W.P. 61-86-00 LOCATION Sta 11+321.5 e/s 7.5 m Lt C.L. EW-N Ramp ORIGINATED BY DK
 DIST 52 HWY 11 BOREHOLE TYPE H.S. Auger, BQ core barrel COMPILED BY JC
 DATUM Geodetic DATE 95 02 20 - 95 02 22 CHECKED BY TK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ KN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
273.3	Ground Surface																
0.0			1	SS	23		272										
	Sand, Trace Silt Compact to Dense		2	SS	37												
			3	SS	18												
	Silty Sand		4	SS	9		270										0 71 15 14
	Occasional Clay Pockets		5	SS	12												
	Compact		6	SS	12		268										
			7	SS	13		266										
	more silty		8	SS	15		264										0 16 (84)
			9	SS	19												
			10	SS	17		262										
260.5																	
12.8	Heterogeneous Mixture of Sand, Silt and Gravel Numerous Boulders and Cobbles Very Dense (Glacial Till)		11	SS	60		260										18 55 25 2
257.9																	
15.4	Bedrock		12	RC	REC	93%	258										RQD 65%
255.9			14	RC	REC	89%	256										RQD 36%
17.4	End of Borehole																
	• 95 02 20																

