

**FOUNDATION INVESTIGATION AND DESIGN REPORT
GWP 392-98-00
PROPOSED EMBANKMENT WIDENING
HIGHWAY 17 FROM STATION 11+725 TO 11+825
TOWNSHIP OF ROLPH**

**December 20, 2005
TG04221**

**Prepared For:
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1.0 INTRODUCTION

DST Consulting Engineers Inc. (DST) has been retained by JMC Transportation Group to conduct foundation investigations at nine locations for the proposed embankment widening for the passing lanes of Highway 17 and a culvert extension in the Townships of Head and Rolph. This report summarizes the factual information and provides recommendations for one of these sites.

Authorization to proceed with this work was received from JMC Transportation Group. This work was carried out as part of their Total Project Management Contract for the Ministry of Transportation of Ontario (MTO) under G.W.P. 392-98-00.

The project is located on Highway 17, from 6.2 km west of Renfrew County, Road 635, easterly 18.6 km. As part of this project, it is proposed to construct one new eastbound passing lane from Station 28+250 to Station 30+850, Twp of Head, one new westbound passing lane from Station 29+120 Twp of Head to Station 12+250 Twp of Rolph and to extend the Colton Creek culvert. Within the alignment for the passing lanes, Detailed Foundation Investigation and Design are required at nine locations for embankment widening and for a culvert extension. The specified locations for detailed foundation design are as follows:

Township of Head	Station 28+475 to 28+700
Township of Head	Station 29+175 to 29+350
Township of Head	Station 30+025 to 30+150
Township of Head	Station 30+450 to 30+600
Township of Head	Station 30+750 to 31+100
Township of Rolph	Station 10+400 to 10+675
Township of Rolph	Station 11+250 to 11+550

Township of Rolph	Station 11+725 to 11+825
Township of Rolph	Station 12+050 to 12+250

At the proposed passing lane locations, the through lanes and the passing lanes will be 3.75 m wide. Shoulder widths at the passing lanes will be 3.0 m on the side of the new passing lane and 2.3 m on the opposite side. The shoulder rounding on the side of the new passing lane will be 1.0 m.

This report addresses the field investigation, laboratory testing program and design for the proposed widening at the Township of Rolph, Station 11+725 to 11+825, as defined by the Ministry as the Foundation Investigation and Design Report.

2.0 SITE DESCRIPTION

Along this section of highway under investigation for the proposed widening, the existing embankment varies in height from approximately 2 m to 2.5 m within the proposed construction.

The existing ditch is grassed covered with cat tails and generally slopes downward towards the culvert located at approximate Station 11+800. The tree line is approximately 16 m from the highway centreline at mid site. No rock outcrops were evident within the study area.

A picture of the site taken from Station 11+850 looking west is shown below.



3.0 INVESTIGATION PROCEDURES AND LABORATORY TESTING

Site work was carried out between December 2 and 8, 2004 utilizing a track mounted CME 75 drill rig equipped for geotechnical drilling and operated by DST. Seven boreholes were put down to depths ranging between 6.75 to 10.8 m.

Borehole locations and a stratigraphic profile and section are shown on the Borehole Location Plan, Drawing No. 1. Boreholes 48 and 52 are located in the shoulder of the roadway while Boreholes 46, 47 and 49 to 51 are located between the toes of the existing and proposed embankments. The boreholes were advanced with hollow stem augers to a depth of 10.8 m or auger refusal which occurred in Boreholes 50 and 51 at a depth of 7.5 and 6.7 m respectively.

Soil samples were obtained from the auger flights and from the split spoon sampler used for the standard penetration test (SPT). The SPT involves driving a 50 mm diameter thick-walled sampler into the soil under the energy of a 63.5 kg weight falling through 760 mm. The number of blows required to drive the sampler 300 mm is known as the standard penetration blow count (N) which provides an indication of the denseness or consistency of the soil. Representative soil samples are obtained from within the sampler. Borehole Logs are presented as Enclosures 1 to 7.

Ground surface elevations at the borehole locations were surveyed by DST and referenced to the centreline of highway at Station 11+725. The elevation of the centreline was taken as 177.1 m from K Smart Associates Limited survey of the site.

The fieldwork was supervised on a full-time basis by DST personnel who located the boreholes in the field, supervised the drilling, sampling and in-situ testing, and logged the boreholes. The soil

samples were identified in the field, placed in labelled containers and transported to DST's laboratory in Thunder Bay for further analysis.

Classification and index tests were subsequently performed in the laboratory on samples collected from the boreholes to aid in the selection of engineering properties. Laboratory tests included natural moisture contents and gradation analyses. Laboratory test results are presented on the Borehole Logs and Enclosure 8. Where samples were non-plastic, grainsize analyses were carried out above the 0.075 mm sieve which is adequate for the purposes of soil classification and assessment of frost susceptibility. Other analyses of the finer fractions of non-plastic soils were not carried out given that soil permeability estimates were not required.

4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 Published Engineering Geology

The Quaternary and bedrock geology of the area under investigation as reported by John F. Gartner and P.F. VanDine in the Northern Ontario Engineering Geology Terrain Study 103, Deep River Area (NTS31K/SW) District of Nipissing and County of Renfrew consists of a discontinuous veneer of ground moraine till over the bedrock. During deglaciation, a number of glaciofluvial deposits were formed (Chapman 1975). Precambrian rocks of the Grenville Structural Province underlie the Deep River map area. The oldest and most abundant rocks of the metamorphic complex are metasediments derived largely from siliceous sandstone and siltstones. These metasediments consist of a variety of gneisses and can be found throughout most of the map area.

The mapping associated with the above report indicates that the soil, landform, topography and drainage generally consist of sand and gravel outwash plain with moderate local relief and dry.

4.2 Field Observations

The generalized stratigraphy of the site based on the borehole locations off the highway consist of a thin layer of organics overlying a sand. Auger refusal occurred in Boreholes 50 and 51. The refusal material was not confirmed by diamond drilling techniques, therefore could be boulders or bedrock.

The highway fill, as identified by Boreholes 48 and 52, consists of granular fill up to 2.0 m in thickness. A trace of organics was found in the split spoon sample at 1.5 m in both boreholes. Below the granular fill a sand exists to the depth of penetration to depths up to 10.5 m.

4.3 Embankment Fill

The fill in the highway embankment consists of sand and gravel. The sand and gravel comprises the base and subbase materials. The base materials vary in thickness from 0.3 to 0.35 m. The subbase varies in thickness from 1.5 to 1.65 m. The bottom of the fill varies between elevations 174.9 m and 175.0 m at the borehole locations.

The Standard Penetration Test (SPT) results generally indicate loose to compact state of denseness (N values vary from 8 blows/0.3 m to 11 blows/0.3 m).

Gradation analyses (Enclosure 8) conducted on samples from Boreholes 48 at 0.75 m and indicate 13.0% fines, 72% sand and 15% gravel.

4.4 Organics

An thin organic layer is present at surface in all boreholes located off the Highway varying from Elevation 174.9 m to 177.1 m. The organic layer varies in thickness from 0.25 m to 0.4 m. The organic layer consists of topsoil. At Borehole 50 only, a layer of peat, 0.2 m in thickness was present below the topsoil. Peat layers may be present at other locations outside the highway embankment between borehole locations.

A trace of organics was also found in the split spoon sample from Boreholes 48 and 52 beneath the road fill at a sample depth of 1.5 m.

4.5 Sand

From beneath the fill and/or organics noted above, a sand exists with varying silt content to the

extent of the boreholes. Gradation analyses conducted on representative samples retrieved from the field investigation at Boreholes 46, 48 and 51 indicate 0% gravel content, 48% to 92% sand and 8 to 52% silt (Enclosure 8).

The Standard Penetration Test (SPT) results generally indicate a very loose to compact state of denseness (N values vary from 2 blows/0.3 m to 22 blows/0.3 m).

4.6 Groundwater

The groundwater levels taken on completion of drilling are noted on the Borehole Logs, Enclosures 1 to 7. The groundwater level noted during our field investigation varied between 0.7 m and 2.9 m below existing grade. For design purposes, the high groundwater level should be taken at the natural ground surface outside the embankment.

Groundwater levels may fluctuate seasonally and in response to climatic conditions.

5.0 DISCUSSION

DST Consulting Engineers Inc. (DST) has been retained by JMC Transportation Group to conduct a foundation investigation for proposed westbound passing lane of Highway 17 in the Township of Rolph between Stations 11+725 and 11+825. It is understood that no significant change in grade is expected. The existing embankment width (shoulder to shoulder) is understood to be 12.1 m. With the addition of a new passing lane and the proposed modifications to the lane and shoulder widths, it is understood that the new embankment width from end of shoulder to end of shoulder will be 16.55 m. With a 1.0 m rounding proposed for the passing lane side of the embankment, the distance from existing centerline to end of rounding on the passing lane side will be 11.5 m (3.75 + 3.75 + 3.0 + 1). Along the proposed passing lane side, the existing height of the embankment varies from 1.4 to 2.8 m with side slope grades between 4.0 and 6.8 horizontal to 1 vertical.

The subsurface conditions below the existing embankment shoulder consists of up to 2.2 m of granular fills overlying sands and silts. The lower 0.1 to 0.6 m of sand fill contains trace amount of organics. In general, the subsurface conditions beyond the existing toe of the embankment were found to consist of up to 0.3 m topsoil overlying sands and silts except at Borehole 50 where 0.2 m of peat was encountered beneath the topsoil.

Engineering properties for embankment fill have been estimated as follows:

- Unit Weight, $\gamma = 20 \text{ kN/m}^3$
- Drained Angle of Internal Friction, $\phi' \geq 30^\circ$
- Drained Cohesion Intercept, $c' = 0 \text{ kPa}$

Engineering properties for the organic materials have been estimated as follows based on the

highest measured moisture content of 58%:

- Void Ratio (e) varies from 1 to 2.
- Compression Index (C_c) varies from 1.0 to 1.5.
- Secondary Compression Index (C_{α}) varies from 0.1 to 0.15.
- Unit Weight (γ) = varies from 12 to 13 kN/m³
- Large Strain Drained Angle of Internal Friction, $\phi' \geq 30^\circ$
- Drained Cohesion Intercept, $c' = 0$ kPa.

Engineering properties for sand have been estimated as follows:

- Unit Weight, $\gamma = 20$ kN/m³
- Drained Angle of Internal Friction, $\phi' \geq 28^\circ$
- Drained Cohesion Intercept, $c' = 0$ kPa

Based on the findings of the field and laboratory programs preliminary engineering assessment of various construction alternatives were carried out to identify the most feasible construction option. The results of this preliminary assessment have been discussed in Section 5.1, Preliminary Assessment of Construction Alternatives. Assessments for stability and settlement have been carried out for static conditions and are reported in subsequent sections of this report for the preferred option.

As indicated in the Draft Supplemental Pavement Design Report, G.W.P. 392-98-00, carried out for this project by Golder Associates Ltd., it is understood that are no settlement areas identified within this section of the highway.

5.1 Preliminary Assessment of Foundation Alternatives

Based on the findings of the field investigation works and engineering assessment, the following table has been prepared summarizing and comparing various foundation alternatives. Through this exercise of comparing the various foundation alternatives, DST has selected a preferred option.

DST recommends subexcavation and replacement of the topsoil and any peat below the proposed embankment widening (Foundation Alternative 2 in the following table). Given relatively shallow and variable organic thickness found below the proposed widening, removal is recommended to avoid potential differential and long term embankment settlements. As the topsoil/peat thickness is generally less than 0.4 m costs associated with its removal are considered to be relatively small given the much improved settlement performance. The subsequent sections of this report address this foundation alternative in detail.

Foundation Alternative	Advantages	Disadvantages	Costs	Risks/Consequences
1) Fill placement without peat excavation	Lowest cost alternative.	Poor settlement performance with differential and short and long term settlements. Within the embankment widening, maximum settlements due to primary consolidation of the peat has been estimated at less than 100 mm, most of which will occur over a period of 1 to 2 months (regrading will be required to account for settlement during this period). Additional settlement due to secondary consolidation of the peat over a 25 year period has been estimated to be in the order of 25 mm. Side slopes flatter than 1.25:1 for rockfill and 2:1 for earth fill would likely be required. Possible peat displacement during fill placement at localized areas; however this risk can be reduced through the use of a geotextile. Typically, staged construction may be required where embankment fills over peat exceed 1.2 m which could add to construction delays.	Lowest cost for construction. Some additional construction costs associated with geotextile and staged construction may be warranted to avoid peat displacement. Highest long term maintenance costs.	High risk of poor settlement performance (both short and long term). Instability and displaced peat will need to be addressed during construction. Zones where peat has been displaced can lead to more severe differential settlements. Risk of higher long term maintenance costs associated with settlements.
2) Fill placement with peat sub-excavation	Short and long term settlement below widening associated with primary and secondary consolidation of the peat is mitigated. Settlements associated with native soils below peat are expected to be negligible. Conventional fore slopes of 1.25:1 for rockfill and 2:1 for earth fill will likely prove adequate.	Excavation of the peat will likely be required in the wet with subsequent fill placement. Fill placement below water will require the use of rockfill or 19 mm stone and a geotextile separator.	Costs associated with topsoil/peat excavation are considered are expected to be minimal given the topsoil/peat thickness is generally less than 0.3 m and up to 0.4 m at one location (as indicated on the test hole logs). It is expected that excavation can be carried out without utilizing specialized equipment such as a drag line. Long term maintenance costs will be reduced given improved settlement performance.	It will be important to ensure all peat is removed especially where excavation in the wet is required. Where zones of peat are left in-place localized areas of differential settlement can be expected. Should peat be found at depths deeper than expected special measures may be required for subexcavation. Potential instability and/or settlement on existing embankment due to adjacent subexcavation and fill placement for widening.

Foundation Alternative	Advantages	Disadvantages	Costs	Risks/Consequences
3) Lightweight fills without peat excavation	Can be used to mitigate/reduce potential settlement issues.	Unless costly rigid foam type insulation is considered for lightweight fill, settlement reduction will be negligible. Foam type insulation is not recommended below the water level. Some fill will be required above and below the insulation which will lead to primary and secondary consolidation of the peat. For up to 1.0 m of fill placement primary consolidation in the order of 50 mm can be expected with secondary consolidation settlements in the order of 25 mm over 25 years. Regrading will be required during the period of primary consolidation.	Construction utilizing rigid foam type insulation is likely cost prohibitive and <u>not warranted</u> . Some increased long term maintenance cost may be realized to address some differential settlement due to secondary consolidation of the peat.	Black ice formation is a known problem where rigid foam type insulations are used.
4) Preload with or without surcharge or wick drains	Preloading without wickdrains may be considered to reduce/mitigate primary consolidation of the peat.	Given the relatively small settlements expected, preloading is not considered feasible. Wickdrains would not prove economical to accelerate preload duration. Light surcharge loads may be considered.	Additional cost associated with additional regrading required after preloading and for construction delays. Long term maintenance cost will be higher than that of peat removal given some long term settlement can be expected due to secondary consolidation (unless a surcharge is considered). Displacement of the peat may be incurred during construction.	Preload may not prove adequate in eliminating all long term consolidation of the peat which can be highly differential leading to increased maintenance costs.
5) Retained Soil System	Can be useful to permit construction with steeper than conventional slopes. However, given embankment toes are expected to be within existing ROW, an RSS is <u>not warranted</u> .	High costs, <u>not warranted</u> . Would likely require peat removal to provide necessary foundation capacity and improve settlement performance.	High cost, <u>not warranted</u> .	A retained soil system does not improve settlement performance, <u>not warranted</u> .

5.2 Stability Analysis For Proposed Passing Lane

The grade of the proposed new passing lane and associated shoulder will approximately match the height of the existing roadway (approximately 1.4 to 2.8 m height) and be 6.75 m in width. The existing side slope is constructed at a slope of 4.0 to 6.8 H:1V utilizing granular fill. At this time it is not known if the proposed new widening will utilize rockfill (if available), or granular fill. As such, recommendations for both construction materials have been provided. Peat subexcavation is proposed by DST as per OPSD 203.030, or OPSD 203.020 (Appendix 'B') with a side slope of 1.25H:1V for rockfill, or 2.0H:1V for granular fill. The peat subexcavation is to be extended as per Note 1 of these standards.

The above noted configurations provide a minimum design target factor of safety of at least 1.3 for end of construction and final long term (drained) conditions.

Under OPSD 203.020, the existing side slope is specified to be temporarily cut at a slope of 1 horizontal to 1 vertical starting at the existing shoulder. This is done to facilitate the removal of more peat possibly located below the existing side slope. It should be noted that sloughing of the 1 horizontal to 1 vertical slope may be experienced during construction. The degree of sloughing will be largely dependant on the duration in which it is left to stand. Backfilling of the slope to design levels should commence immediately after excavation. We recommend rapid excavation and backfilling methods be utilized. The temporary slope should be visually inspected as construction progresses. Should excessive sloughing become problematic, the temporary cut slope angle may be revised to 1.5 horizontal to 1 vertical. However, additional settlements may be incurred below the proposed new shoulder and rounding.

5.3 Settlement of Proposed Passing Lane

Maximum settlements induced by the proposed passing lane fills due to primary and secondary consolidation of any peat remaining below the existing embankment and side slope have been estimated based on two scenarios as follows:

1. During peat subexcavation, the existing side slope is maintained, as per OPSD 203.030.
2. During peat subexcavation, the existing side slope is cut at 1H:1V, as per OPSD 203.020.

The following table indicates the settlements calculated for construction as per OPSD 203.030.

Location	Primary Consolidation of Peat (mm)	Secondary Consolidation of Peat Over 25 yrs. (mm)	Total Settlement After 25 years (mm)
C/L Existing Roadway	N/A	N/A	N/A
Existing Shoulder	<5	25	30
Midpoint Passing Lane	<5	25	30
Passing Lane Shoulder	<25	25	50

The following table indicates the settlements calculated for construction as per OPSD 203.020.

Location	Primary Consolidation of Peat (mm)	Secondary Consolidation of Peat Over 25 yrs. (mm)	Total Settlement After 25 years (mm)
C/L Existing Roadway	N/A	N/A	N/A
Existing Shoulder	<5	25	30
Midpoint Passing Lane	<5	25	30
Passing Lane Shoulder	N/A	N/A	N/A

Estimated settlements due to consolidation of organic soils for the above scenarios have been presented in the following tables. The settlements have been calculated for a passing lane embankment constructed to the same grade as the existing highway shoulder over the thickest deposit of peat found below the proposed embankment widening. Settlements have been calculated at the existing centerline, existing shoulder, approximate midpoint of passing lane, and the approximate shoulder of the new passing lane. It is expected that most of the primary

consolidation of the peat will occur over a period of 1 to 2 months. For a 2 month construction period, we expect that at least 90% of the primary consolidation will have occurred (actual degree of primary consolidation during construction will depend on fill placement methods and scheduling). Secondary consolidation has been calculated over a 25 year period.

The settlements along the longitudinal profile of the passing lane will vary and be roughly proportional to the thickness of the peat deposit below the embankment.

Settlements attributed to the native sands below the proposed widening have been estimated to be less than 25 mm and are expected to occur during construction.

6.0 RECOMMENDATIONS

A new westbound passing lane is proposed from Stations 11+725 to 11+825 in the Township of Rolph. The existing highway embankment is approximately 1.4 to 2.8 m in height and is to be widened to facilitate the construction of the new passing lane and shoulder. The existing native soils at the site consist of up to 0.4 m of topsoil/peat overlying sands and silts.

The additional load of the proposed passing lane does not adversely affect the stability of the existing highway embankment, nor the passing lane itself. In general, the ground level is similar on both sides of the embankment. The construction of the passing lane can therefore proceed without special considerations for stabilizing the embankment. It is recommended the passing lane be constructed in accordance with OPSD 203.030, Embankments Over Swamp, Existing Slopes Maintained. There is negligible improvement in settlement performance to warrant the additional costs associated with construction in accordance with OPSD 203.020, Embankments Over Swamp, Existing Slope Excavated to 1:1.

It is expected that at least 90% of the primary consolidation settlements within organic soils, as provided in Section 5.3, will occur during construction. The remaining long term settlements will begin during fill placement for the passing lane and will continue at a decreasing rate. As such, some minor long term maintenance of these areas may be required as the new fills continue to settle. This may involve occasional grading/filling of shoulders and patching of asphalt.

Benching of earth slopes should be carried out in accordance with OPSD 208.010, Benching of Earth Slopes. The existing organics and deleterious material beneath the proposed widening should be excavated to the native sand which will be in the order of 0.2 to 0.4 m deep as indicated

as discrete borehole locations. The width of swamp excavation should include the additional excavation as indicated in Note 1 of OPSD 203.030.

The native sand subgrade will likely be wet and easily disturbed through site traffic of any type. Water ingress into the excavation will need to be controlled and granular fill should be placed and compacted immediately following excavation. Where dewatering cannot be accomplished, excavation of the peat and fill placement in the wet should be considered. The use of self compacting rockfill or clear stone (such as 19mm stone) should be used below the water level.

Where the embankment material will consist of rockfill, a side slope of 1.25H:1V can be constructed. Voids on the top of the rockfill embankment should be chinked with rock fragments and spalls to form the subgrade as per OPSS 206.07.08, Rock Embankments.

Where the embankment material consists of Granular 'B', Type 1 fill in accordance with OPSS 1010, a side slope of 2:1 should be constructed. The embankment fill should be placed in lifts to the required subgrade level and compacted to a minimum 95% of standard Proctor maximum dry density. The slope should be initially overbuilt and cut back to the design slope in order to achieve the specified compaction to the slope face.

Where rockfill and/or clear stone fill is used to replace the excavated peat, a non-woven geotextile (OPSS 1860.07.05.02 Class II) should be placed between the native subgrade and fill to prevent the migration of fines into the void spaces of the fill.

6.1 Construction

The construction methodology must be in accordance with all relevant Ministry guidelines. The contractor's methods and equipment must be suitable for the site conditions and materials used.

Equipment and worker traffic over the subgrade soil should be avoided and the first lift of fill should be placed and compacted immediately after excavation to provide a working surface and protection for the subgrade. Given the current ground water level is at or near the surface of the peat, advanced dewatering methods may be required during excavation of the peat to permit excavations in the dry. It may prove more economical to carry out peat subexcavation and fill placement in the wet. Where construction in the wet is considered, tight quality control will be required to ensure adequate subexcavation has been achieved and to ensure adequate fill placement to above the water level.

7.0 LIMITATIONS OF REPORT

A description of limitations which are inherent in carrying out site investigation studies is given in Appendix "A", and this forms an integral part of this report.

For DST CONSULTING ENGINEERS INC.

Prepared by:

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APPENDIX 'A'
LIMITATIONS OF REPORT

LIMITATIONS OF REPORT

GEOTECHNICAL STUDIES

The data, conclusions and recommendations which are presented in this report, and the quality thereof, are based on a scope of work authorized by the Client. Note that no scope of work, no matter how exhaustive, can identify all conditions below ground. Subsurface and groundwater conditions between and beyond the testholes may differ from those encountered at the specific locations tested, and conditions may become apparent during construction which were not detected and could not be anticipated at the time of the site investigation. Conditions can also change with time. It is recommended practice that DST Consulting Engineers be retained during construction to confirm that the subsurface conditions throughout the site do not deviate materially from those encountered in the testholes. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the testhole locations and should not be used for other purposes, such as grading, excavation, planning, development, etc.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with details stated in this report. Since all details of the design may not be known, we recommend that we be retained during the final stage to verify that the design is consistent with our recommendations, and that assumptions made in our analysis are valid.

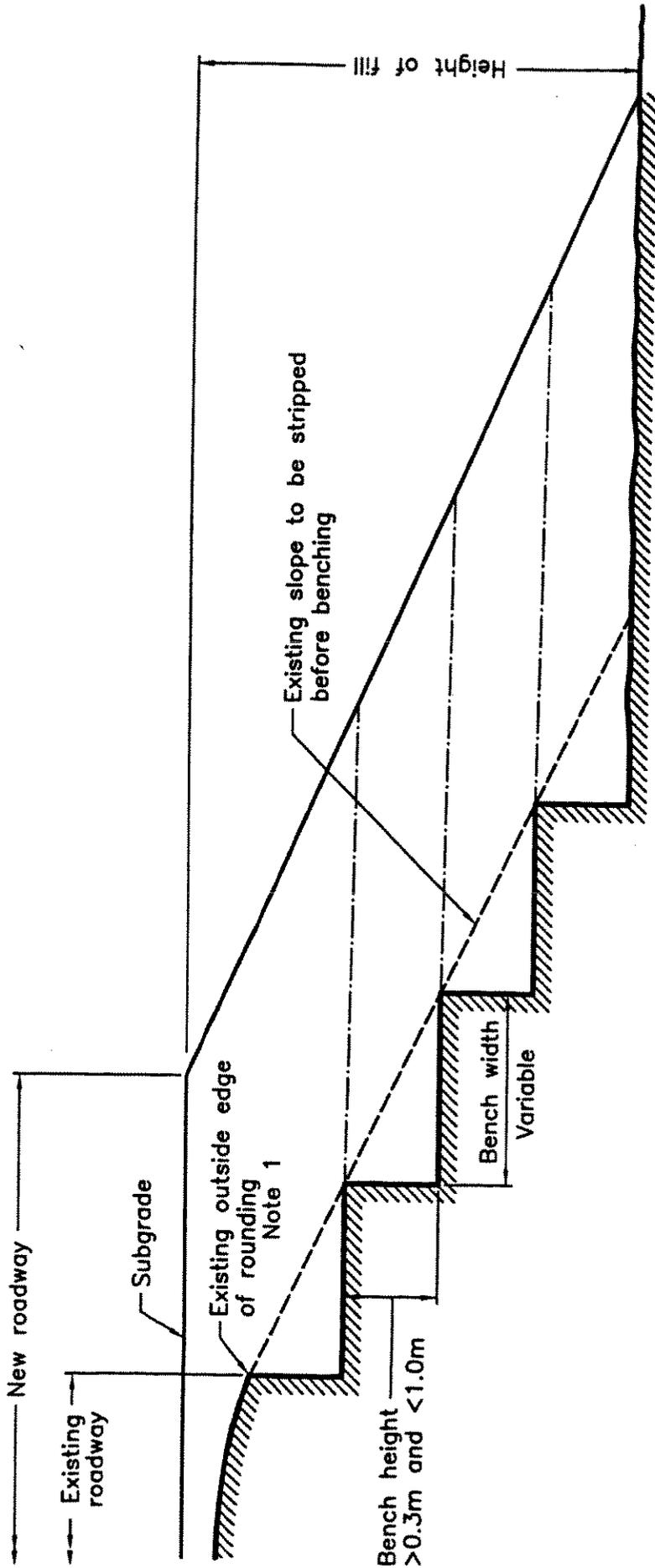
Unless otherwise noted, the information contained herein in no way reflects on environmental aspects of either the site or the subsurface conditions.

The comments given in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of testholes may not be sufficient to determine all the factors that may affect construction methods and costs, e.g. the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusion as to how the subsurface conditions may affect their work.

Any results from an analytical laboratory or other subcontractor reported herein have been carried out by others, and DST Consulting Engineers Inc. cannot warranty their accuracy. Similarly, DST cannot warranty the accuracy of information supplied by the client.

A P P E N D I X ' B '

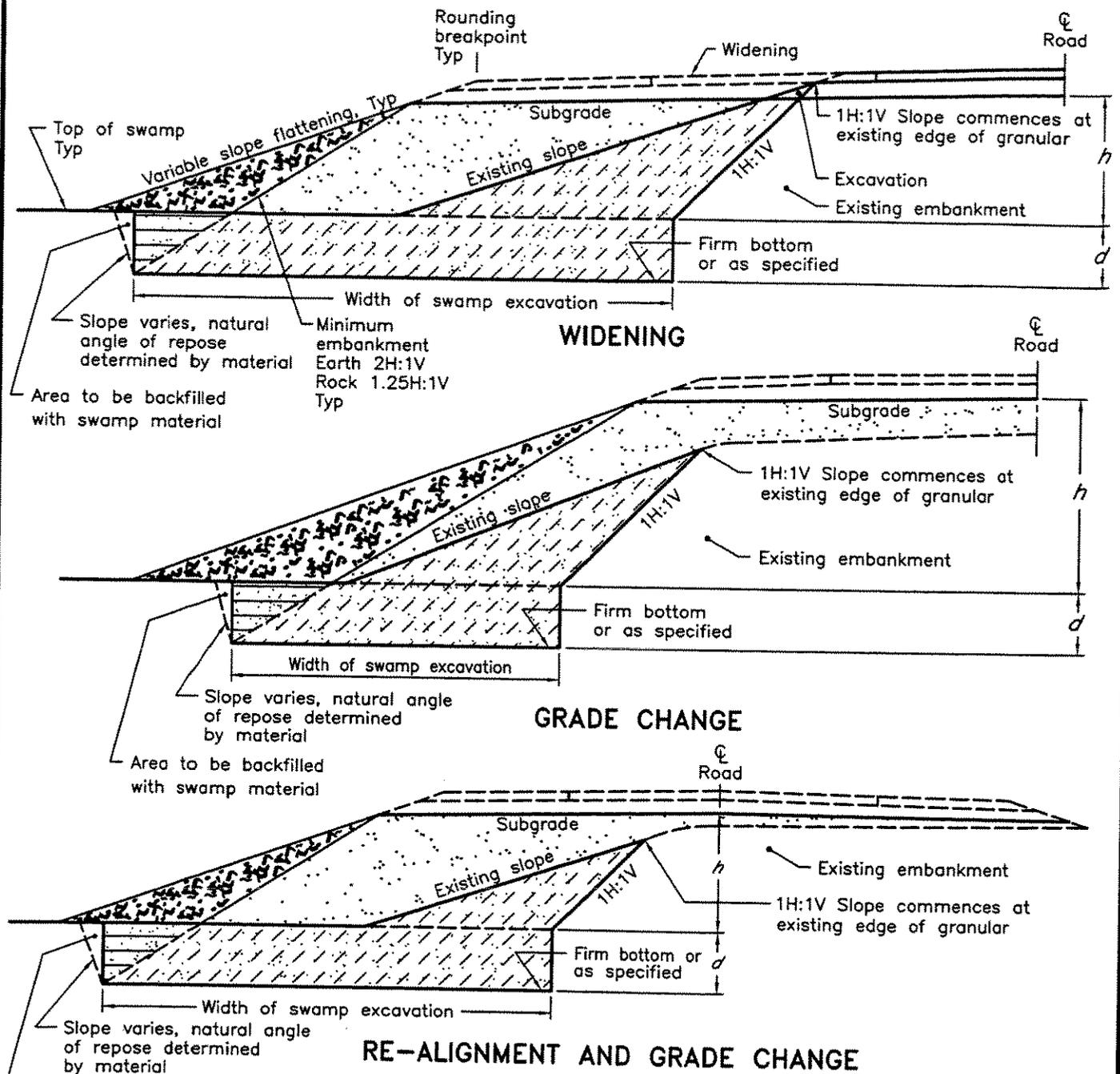
O P S D D R A W I N G S



NOTES:

- 1 When the subgrade is below the existing outside edge of rounding, benching shall be carried out below the point where the subgrade intersects the existing slope.
- A Benching is not required on existing slopes flatter than 3H:1V.
- B Benches are to be excavated one level at a time and the compacted fill brought up before the next benching level is excavated.

	Nov 2003	Rev 1	
<h2 style="margin: 0;">BENCHING OF EARTH SLOPES</h2>			
OPSD - 208.010			



NOTES:

- A For given limits of height $h \leq 4.5\text{m}$ and depth $d \leq 6.0\text{m}$, both requirements shall be met in order to apply.
- B Height of fill is the vertical difference between top of subgrade and top of swamp elevation measured at new road centreline.
- C Widening of existing earth embankments shall be benched according to OPSD-208.010.
- D All dimensions are in millimetres unless otherwise shown.

LEGEND:

- h - Height of fill
- d - Depth of sub-excavation
- Embankment materials as specified
- Excavated swamp material
- Excavate and backfill
- Excavate and backfill with swamp material

ONTARIO PROVINCIAL STANDARD DRAWING

Nov 2004

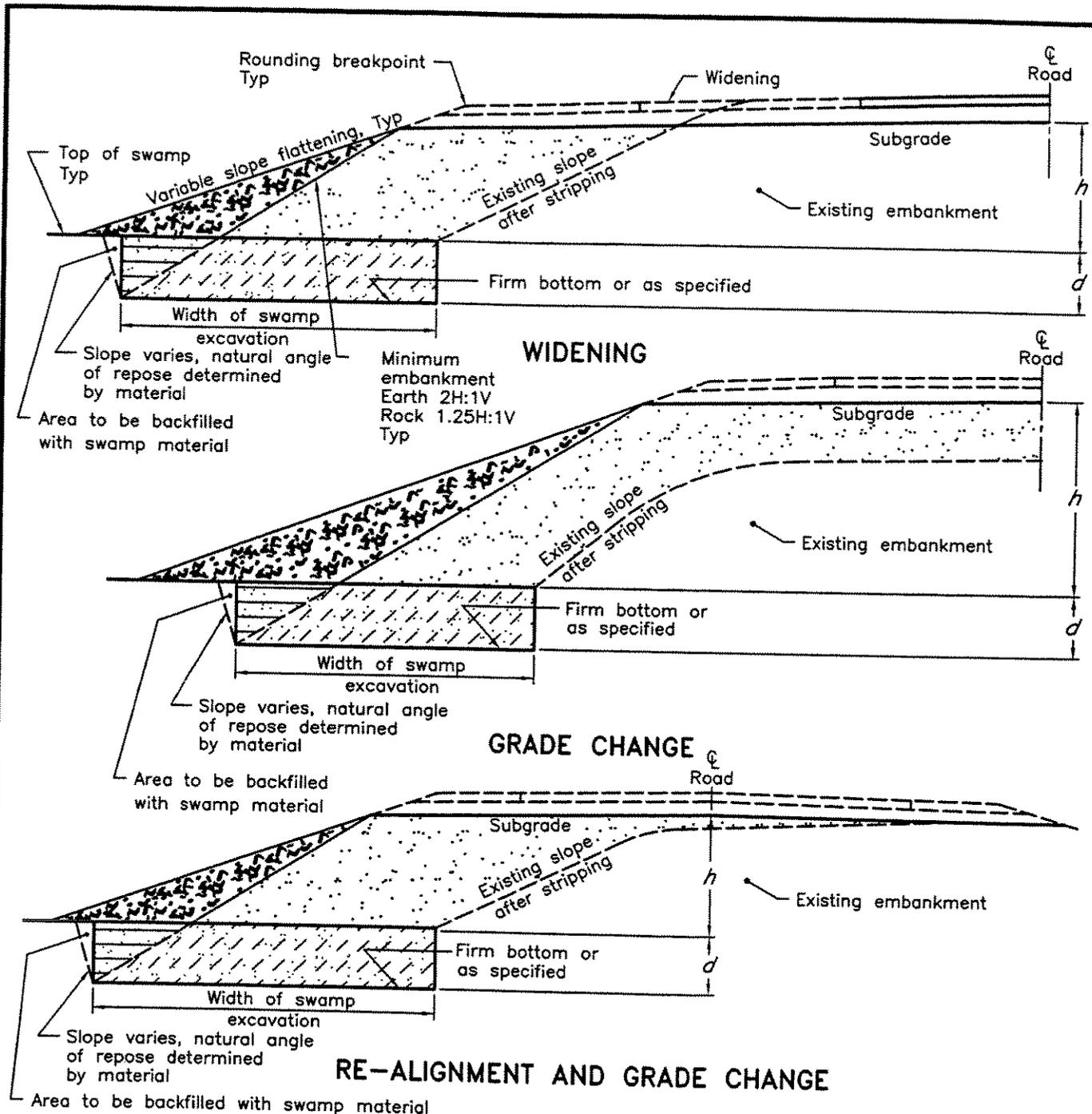
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EMBANKMENTS OVER SWAMP

EXISTING SLOPE EXCAVATED TO 1H:1V



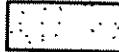
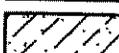
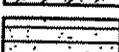
OPSD - 203.020



NOTES:

- A For given limits of height $h \leq 4.5\text{m}$ and depth $d \leq 6.0\text{m}$, both requirements shall be met in order to apply.
- B Topsoil shall be stripped from existing slopes.
- C Height of fill is the vertical difference between top of subgrade and top of swamp elevation measured at new road centreline.
- D Widening of existing earth embankments shall be benched according to OPSD-208.010.
- E All dimensions are in millimetres unless otherwise shown.

LEGEND:

- h - Height of fill
- d - Depth of sub-excitation
-  Embankment materials as specified
-  Excavated swamp material
-  Excavate and backfill
-  Excavate and backfill with swamp material

ONTARIO PROVINCIAL STANDARD DRAWING

EMBANKMENTS OVER SWAMP
EXISTING SLOPES MAINTAINED

Nov 2004 Rev 1



OPSD - 203.030

DRAWINGS

ENCLOSURES

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

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	FOIL SAMPLE

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

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	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 = $\frac{c_u}{\tau_r}$

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 = $\frac{w - w_p}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	e_{max}	1, %	VOID RATIO IN LOOSEST STATE	j	kn/m^3	SEEPAGE FORCE
γ'	kn/m^3	UNIT WEIGHT OF SUBMERGED SOIL						