

ConeTec Interpretations as of April 8, 2014

ConeTec's interpretation routine provides a tabular output of geotechnical parameters based on current published CPT correlations and is subject to change to reflect the current state of practice. The interpreted values are not considered valid for all soil types. The interpretations are presented only as a guide for geotechnical use and should be carefully scrutinized for consideration in any geotechnical design. Reference to current literature is strongly recommended. ConeTec does not warranty the correctness or the applicability of any of the geotechnical parameters interpreted by the program and does not assume liability for any use of the results in any design or review. Representative hand calculations should be made for any parameter that is critical for design purposes. The end user of the interpreted output should also be fully aware of the techniques and the limitations of any method used in this program. The purpose of this document is to inform the user as to which methods were used and what the appropriate papers and/or publications are for further reference.

The CPT interpretations are based on values of tip, sleeve friction and pore pressure averaged over a user specified interval (e.g. 0.20m). Note that q_t is the tip resistance corrected for pore pressure effects and q_c is the recorded tip resistance. Since all ConeTec cones have equal end area friction sleeves, pore pressure corrections to sleeve friction, f_s , are not required.

The tip correction is:
$$q_t = q_c + (1-a) \cdot u_2$$

where: q_t is the corrected tip resistance
 q_c is the recorded tip resistance
 u_2 is the recorded dynamic pore pressure behind the tip (u_2 position)
 a is the Net Area Ratio for the cone (typically 0.80 for ConeTec cones)

The total stress calculations are based on soil unit weights that have been assigned to the Soil Behavior Type zones, from a user defined unit weight profile or by using a single value throughout the profile.

Effective vertical overburden stresses are calculated based on a hydrostatic distribution of equilibrium pore pressures below the water table or from a user defined equilibrium pore pressure profile (this can be obtained from CPT dissipation tests). For over water projects the effects of the column of water have been taken into account as has the appropriate unit weight of water. How this is done depends on where the instruments were zeroed (i.e. on deck or at mud line).

Details regarding the interpretation methods for all of the interpreted parameters are provided in Table 1. The appropriate references cited in Table 1 are listed in Table 2. Where methods are based on charts or techniques that are too complex to describe in this summary the user should refer to the cited material.

The Soil Behavior Type classification charts (normalized and non-normalized) shown in Figures 1 and 2 are based on the charts developed by Dr. Robertson and Dr. Campanella at the University of British Columbia. These charts appear in many publications, most notably: Robertson, Campanella, Gillespie and Greig (1986); Robertson (1990) and Lunne, Robertson and Powell (1997). The Bq classification charts shown in Figures 3a and 3b are based on those described in Robertson (1990) and Lunne, Robertson and Powell (1997). The Jefferies and Davies SBT chart shown in Figure 3c is based on that discussed in Jefferies and Davies, 1993.

Where the results of a calculation/interpretation are declared ‘invalid’ the value will be represented by the text strings “-9999” or “-9999.0”. In some cases the value 0 will be used. Invalid results will occur because of (and not limited to) one or a combination of:

1. Invalid or undefined CPT data (e.g. drilled out section or data gap).
2. Where the interpretation method is inappropriate, for example, drained parameters in an undrained material (and vice versa).
3. Where interpretation input values are beyond the range of the referenced charts or specified limitations of the interpretation method.
4. Where pre-requisite or intermediate interpretation calculations are invalid.

The parameters selected for output from the program are often specific to a particular project. As such, not all of the interpreted parameters listed in Table 1 may be included in the output files delivered with this report.

The output files are provided in Microsoft Excel XLS format. The ConeTec software has several options for output depending on the number or types of interpreted parameters desired. Each output file will be named using the original COR file basename followed by a three or four letter indicator of the interpretation set selected (e.g. BSC, TBL, NLI or IFI) and possibly followed by an operator selected suffix identifying the characteristics of the particular interpretation run.

Table 1
CPT Interpretation Methods

Interpreted Parameter	Description	Equation	Ref
Depth	Mid Layer Depth <i>(where interpretations are done at each point then Mid Layer Depth = Recorded Depth)</i>	$Depth (Layer Top) + Depth (Layer Bottom) / 2.0$	
Elevation	Elevation of Mid Layer based on sounding collar elevation supplied by client	Elevation = Collar Elevation - Depth	
Avgqc	Averaged recorded tip value (q_c)	$Avgqc = \frac{1}{n} \sum_{i=1}^n q_c$ <i>n=1 when interpretations are done at each point</i>	
Avgqt	Averaged corrected tip (q_t) where: $q_t = q_c + (1 - a) \cdot u$	$Avgqt = \frac{1}{n} \sum_{i=1}^n q_t$ <i>n=1 when interpretations are done at each point</i>	
Avgfs	Averaged sleeve friction (f_s)	$Avgfs = \frac{1}{n} \sum_{i=1}^n f_s$ <i>n=1 when interpretations are done at each point</i>	
AvgRf	Averaged friction ratio (Rf) where friction ratio is defined as: $Rf = 100\% \cdot \frac{f_s}{qt}$	$AvgRf = 100\% \cdot \frac{Avgfs}{Avgqt}$ <i>n=1 when interpretations are done at each point</i>	

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Interpreted Parameter	Description	Equation	Ref
Avgu	Averaged dynamic pore pressure (u)	$Avgu = \frac{1}{n} \sum_{i=1}^n u_i$ $n=1$ when interpretations are done at each point	
AvgRes	Averaged Resistivity (this data is not always available since it is a specialized test requiring an additional module)	$Avgu = \frac{1}{n} \sum_{i=1}^n RESISTIVITY_i$ $n=1$ when interpretations are done at each point	
AvgUVIF	Averaged UVIF ultra-violet induced fluorescence (this data is not always available since it is a specialized test requiring an additional module)	$Avgu = \frac{1}{n} \sum_{i=1}^n UVIF_i$ $n=1$ when interpretations are done at each point	
AvgTemp	Averaged Temperature (this data is not always available since it is a specialized test)	$Avgu = \frac{1}{n} \sum_{i=1}^n TEMPERATURE_i$ $n=1$ when interpretations are done at each point	
AvgGamma	Averaged Gamma Counts (this data is not always available since it is a specialized test requiring an additional module)	$Avgu = \frac{1}{n} \sum_{i=1}^n GAMMA_i$ $n=1$ when interpretations are done at each point	
SBT	Soil Behavior Type as defined by Robertson and Campanella	See Figure 1	2, 5
U.Wt.	Unit Weight of soil determined from one of the following user selectable options: 1) uniform value 2) value assigned to each SBT zone 3) user supplied unit weight profile	See references	5
T. Stress σ_v	Total vertical overburden stress at Mid Layer Depth. <i>A layer is defined as the averaging interval specified by the user. For data interpreted at each point the Mid Layer Depth is the same as the recorded depth.</i>	$TStress = \sum_{i=1}^n \gamma_i h_i$ where γ_i is layer unit weight h_i is layer thickness	
E. Stress σ_v'	Effective vertical overburden stress at Mid Layer Depth	$Estress = Tstress - u_{eq}$	
Ueq	Equilibrium pore pressure determined from one of the following user selectable options: 1) hydrostatic from water table depth 2) user supplied profile	For hydrostatic option: $u_{eq} = \gamma_w \cdot (D - D_{wt})$ where u_{eq} is equilibrium pore pressure γ_w is unit weight of water D is the current depth D_{wt} is the depth to the water table	
Cn	SPT N_{60} overburden correction factor	$Cn = (\sigma_v')^{-0.5}$ where σ_v' is in tsf $0.5 < Cn < 2.0$	
N_{60}	SPT N value at 60% energy calculated from qt/N ratios assigned to each SBT zone. This method has abrupt N value changes at zone boundaries.	See Figure 1	4, 5
$(N_1)_{60}$	SPT N_{60} value corrected for overburden pressure	$(N_1)_{60} = Cn \cdot N_{60}$	4
$N_{60}lc$	SPT N_{60} values based on the lc parameter	$(qt/pa) / N_{60} = 8.5 (1 - lc/4.6)$	5
$(N_1)_{60}lc$	SPT N_{60} value corrected for overburden pressure (using $N_{60} lc$). User has 2 options.	1) $(N_1)_{60}lc = Cn \cdot (N_{60}lc)$ 2) $q_{c1n} / (N_1)_{60}lc = 8.5 (1 - lc/4.6)$	4 5

CONETEC CPT INTERPRETATION METHODS

Interpreted Parameter	Description	Equation	Ref
$(N_1)_{60cs}lc$	Clean sand equivalent SPT $(N_1)_{60lc}$. User has 3 options.	1) $(N_1)_{60cs}lc = \alpha + \beta((N_1)_{60lc})$	10
		2) $(N_1)_{60cs}lc = K_{SPT} * ((N_1)_{60lc})$	10
		3) $q_{c1ncs}/(N_1)_{60cs}lc = 8.5 (1 - lc/4.6)$	5
		FC ≤ 5%: $\alpha = 0, \beta = 1.0$ FC ≥ 35% $\alpha = 5.0, \beta = 1.2$ 5% < FC < 35% $\alpha = \exp[1.76 - (190/FC^2)]$ $\beta = [0.99 + (FC^{1.5}/1000)]$	
Su	Undrained shear strength based on q_t Su factor N_{kt} is user selectable	$Su = \frac{qt - \sigma_v}{N_{kt}}$	1, 5
Su	Undrained shear strength based on pore pressure Su factor $N_{\Delta u}$ is user selectable	$Su = \frac{u_2 - u_{eq}}{N_{\Delta u}}$	1, 5
k	Coefficient of permeability (assigned to each SBT zone)		5
Bq	Pore pressure parameter	$Bq = \frac{\Delta u}{qt - \sigma_v}$ where: $\Delta u = u - u_{eq}$ and $u =$ dynamic pore pressure $u_{eq} =$ equilibrium pore pressure	1, 5
Q_t	Normalized q_t for Soil Behavior Type classification as defined by Robertson, 1990	$Q_t = \frac{qt - \sigma_v}{\sigma_v}$	2, 5
F_r	Normalized Friction Ratio for Soil Behavior Type classification as defined by Robertson, 1990	$Fr = 100\% \cdot \frac{fs}{qt - \sigma_v}$	2, 5
Net q_t	Net tip resistance	$qt - \sigma_v$	
q_e	Effective tip resistance	$qt - u_2$	
q_{eNorm}	Normalized effective tip resistance	$\frac{qt - u_2}{\sigma_v}$	
SBTn	Normalized Soil Behavior Type as defined by Robertson and Campanella	See Figure 2	2, 5
SBT-BQ	Non-normalized Soil Behavior type based on the Bq parameter	See Figure 3	2, 5
SBT-BQn	Normalized Soil Behavior based on the Bq parameter	See Figure 3	2, 5
SBT-JandD	Soil Behaviour Type as defined by Jeffries and Davies	See Figure 3	7

CONETEC CPT INTERPRETATION METHODS

Interpreted Parameter	Description	Equation	Ref
I_c	Soil index for estimating grain characteristics	$I_c = [(3.47 - \log_{10} Q)^2 + (\log_{10} Fr + 1.22)^2]^{0.5}$ <p>Where: $Q = \left(\frac{qt - \sigma_v}{P_a} \right) \left(\frac{P_a}{\sigma_v} \right)^n$</p> <p>And Fr is in percent P_a = atmospheric pressure n varies from 0.5 to 1.0 and is selected in an iterative manner based on the resulting I_c</p>	3, 8
FC	Apparent fines content (%)	$FC = 1.75(I_c^{3.25}) - 3.7$ $FC = 100$ for $I_c > 3.5$ $FC = 0$ for $I_c < 1.26$ $FC = 5\%$ if $1.64 < I_c < 2.6$ AND $F_r < 0.5$	3
I_c Zone	This parameter is the Soil Behavior Type zone based on the I_c parameter (valid for zones 2 through 7 on SBTn chart)	$I_c < 1.31$ Zone = 7 $1.31 < I_c < 2.05$ Zone = 6 $2.05 < I_c < 2.60$ Zone = 5 $2.60 < I_c < 2.95$ Zone = 4 $2.95 < I_c < 3.60$ Zone = 3 $I_c > 3.60$ Zone = 2	3
PHI ϕ	Friction Angle determined from one of the following user selectable options: a) Campanella and Robertson b) Durgunoglu and Mitchel c) Janbu d) Kulhawy and Mayne	See reference	5 5 5 11
Dr	Relative Density determined from one of the following user selectable options: a) Ticino Sand b) Hokksund Sand c) Schmertmann 1976 d) Jamiolkowski 1985 - All Sands e) Jamiolkowski et al 2003 (various compressibilities, K_o)	See reference Jamiolkowski et al 2003 reference	5 14
OCR	Over Consolidation Ratio	a) Based on Schmertmann's method involving a plot of $S_u/\sigma_v' / (S_u/\sigma_v')_{NC}$ and OCR where the S_u/p' ratio for NC clay is user selectable	9
State Parameter	The state parameter is used to describe whether a soil is contractive (SP is positive) or dilative (SP is negative) at large strains based on the work by Been and Jefferies	See reference	8, 6, 5
Es/qt	Intermediate parameter for calculating Young's Modulus, E, in sands. It is the Y axis of the reference chart.	Based on Figure 5.59 in the reference	5

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Interpreted Parameter	Description	Equation	Ref
Young's Modulus E	<p>Young's Modulus based on the work done in Italy. There are three types of sands considered in this technique. The user selects the appropriate type for the site from:</p> <p>a) OC Sands b) Aged NC Sands c) Recent NC Sands</p> <p>Each sand type has a family of curves that depend on mean normal stress. The program calculates mean normal stress and linearly interpolates between the two extremes provided in the Es/qt chart.</p>	<p>Mean normal stress is evaluated from:</p> $\sigma'_m = \frac{1}{3}(\sigma'_v + \sigma'_h + \sigma'_h)$ <p>where σ'_v = vertical effective stress σ'_h = horizontal effective stress</p> <p>and $\sigma_h = K_o \cdot \sigma'_v$ with K_o assumed to be 0.5</p>	5
q _{c1}	q _t normalized for overburden stress used for seismic analysis	$q_{c1} = q_t \cdot (Pa/\sigma'_v)^{0.5}$ where: Pa = atm. Pressure q _t is in MPa	3
q _{c1n}	q _{c1} in dimensionless form used for seismic analysis	$q_{c1n} = (q_{c1} / Pa)(Pa/\sigma'_v)^n$ where: Pa = atm. Pressure and n ranges from 0.5 to 1.0 based on I _c .	3
K _{SPT}	Equivalent clean sand factor for (N ₁) ₆₀	$K_{SPT} = 1 + ((0.75/30) \cdot (FC - 5))$	10
K _{CPT}	Equivalent clean sand correction for q _{c1n}	$K_{cpt} = 1.0$ for $I_c \leq 1.64$ $K_{cpt} = f(I_c)$ for $I_c > 1.64$ (see reference)	10
q _{c1ncs}	Clean sand equivalent q _{c1n}	$q_{c1ncs} = q_{c1n} \cdot K_{cpt}$	3
CRR	Cyclic Resistance Ratio (for Magnitude 7.5)	$q_{c1ncs} < 50$: $CRR_{7.5} = 0.833 [q_{c1ncs}/1000] + 0.05$ $50 \leq q_{c1ncs} < 160$: $CRR_{7.5} = 93 [q_{c1ncs}/1000]^3 + 0.08$	10
CSR	Cyclic Stress Ratio	$CSR = (\bar{\sigma}_{av}/\sigma'_v) = 0.65 (a_{max} / g) (\sigma_v / \sigma'_v) r_d$ $r_d = 1.0 - 0.00765 z$ $z \leq 9.15m$ $r_d = 1.174 - 0.0267 z$ $9.15 < z \leq 23m$ $r_d = 0.744 - 0.008 z$ $23 < z \leq 30m$ $r_d = 0.50$ $z > 30m$	10
MSF	Magnitude Scaling Factor	See Reference	10
FofS	Factor of Safety against Liquefaction	$FS = (CRR_{7.5} / CSR) MSF$	10
Liquefaction Status	Statement indicating possible liquefaction	Takes into account FofS and limitations based on I _c and q _{c1ncs} .	10

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Interpreted Parameter	Description	Equation	Ref
Cont/Dilat Tip	Contractive / Dilative qc1 Boundary based on $(N_1)_{60}$	$(\sigma'_v)_{\text{boundary}} = 9.58 \times 10^{-4} [(N_1)_{60}]^{4.79}$ qc1 is calculated from specified qt(MPa)/N ratio	13
Cq	Normalizing Factor	$Cq = 1.8 / (0.8 + ((\sigma'_v/Pa)))$	12
qc1 (Cq)	Normalized tip resistance based on Cq	$q_{c1} = Cq * q_t$ (some papers use q_c)	12
Su(Liq)/s'v	Liquefied Shear Strength Ratio	$\frac{Su(Liq)}{\sigma'_v} = 0.03 + 0.0143(q_{c1})$ Note: σ'_v and $s'v$ are synonymous	13

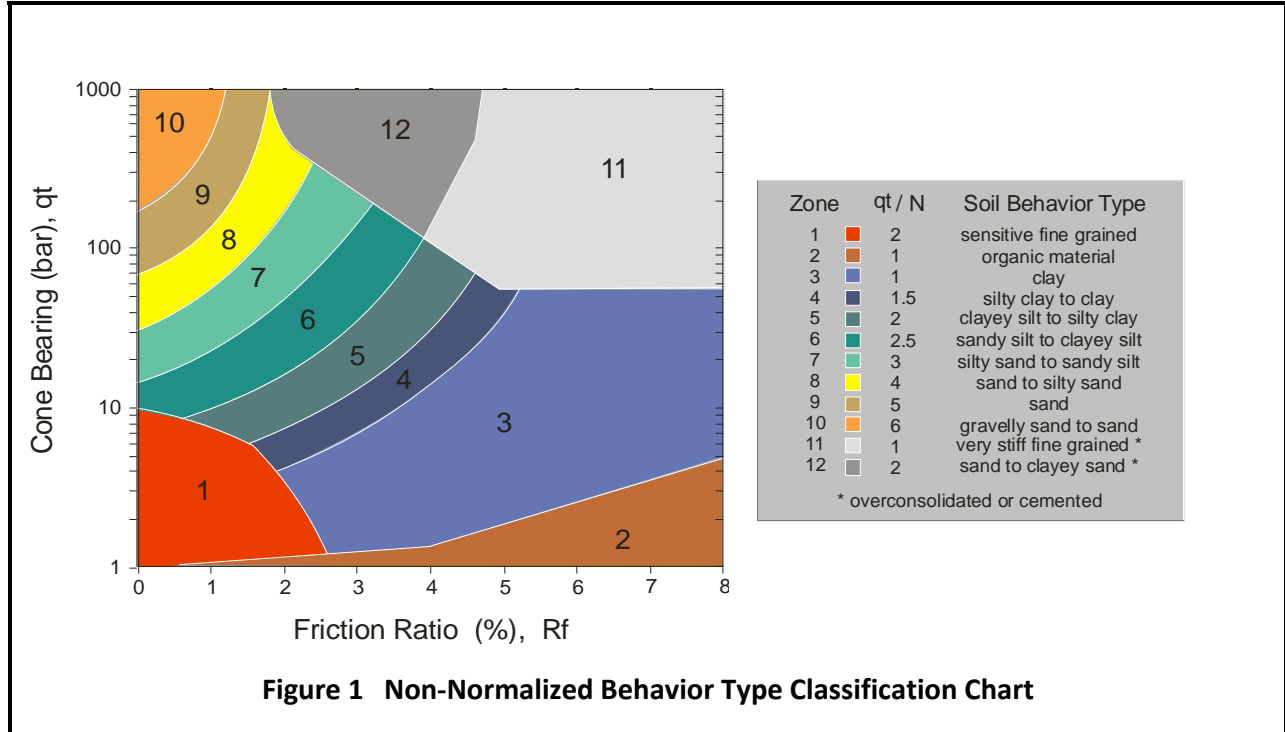


Figure 1 Non-Normalized Behavior Type Classification Chart

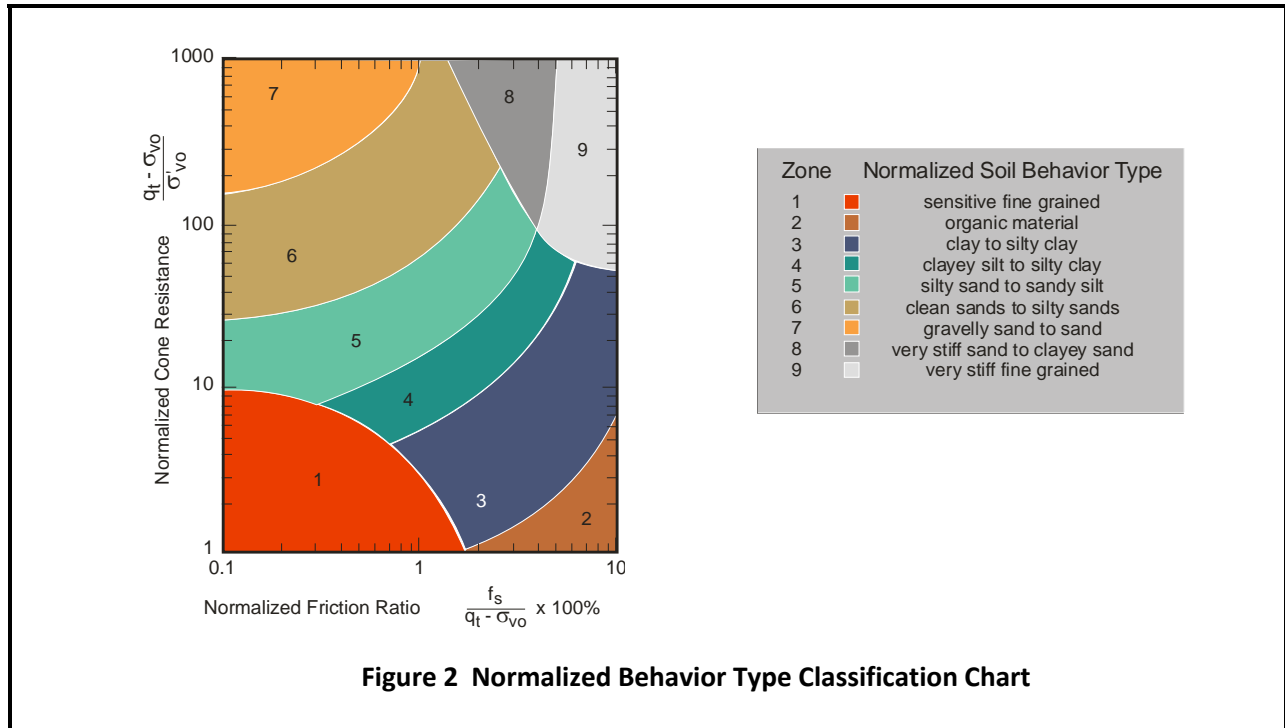


Figure 2 Normalized Behavior Type Classification Chart

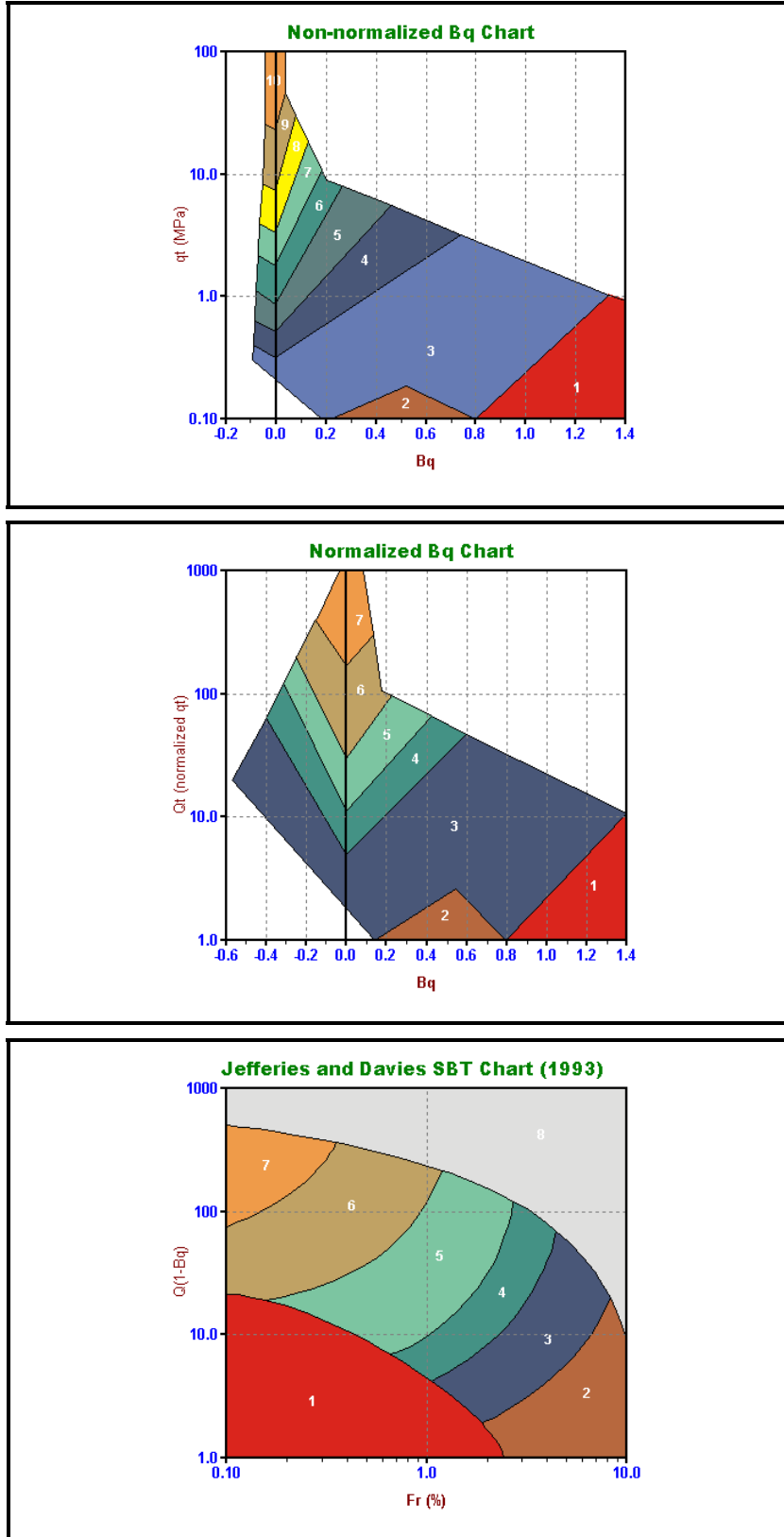


Figure 3 – Alternate Soil Behaviour Type Charts

Table 2 References

No.	References
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