CPeT-IT User's Manual v.1.4

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Table of Contents

1 License Agreement

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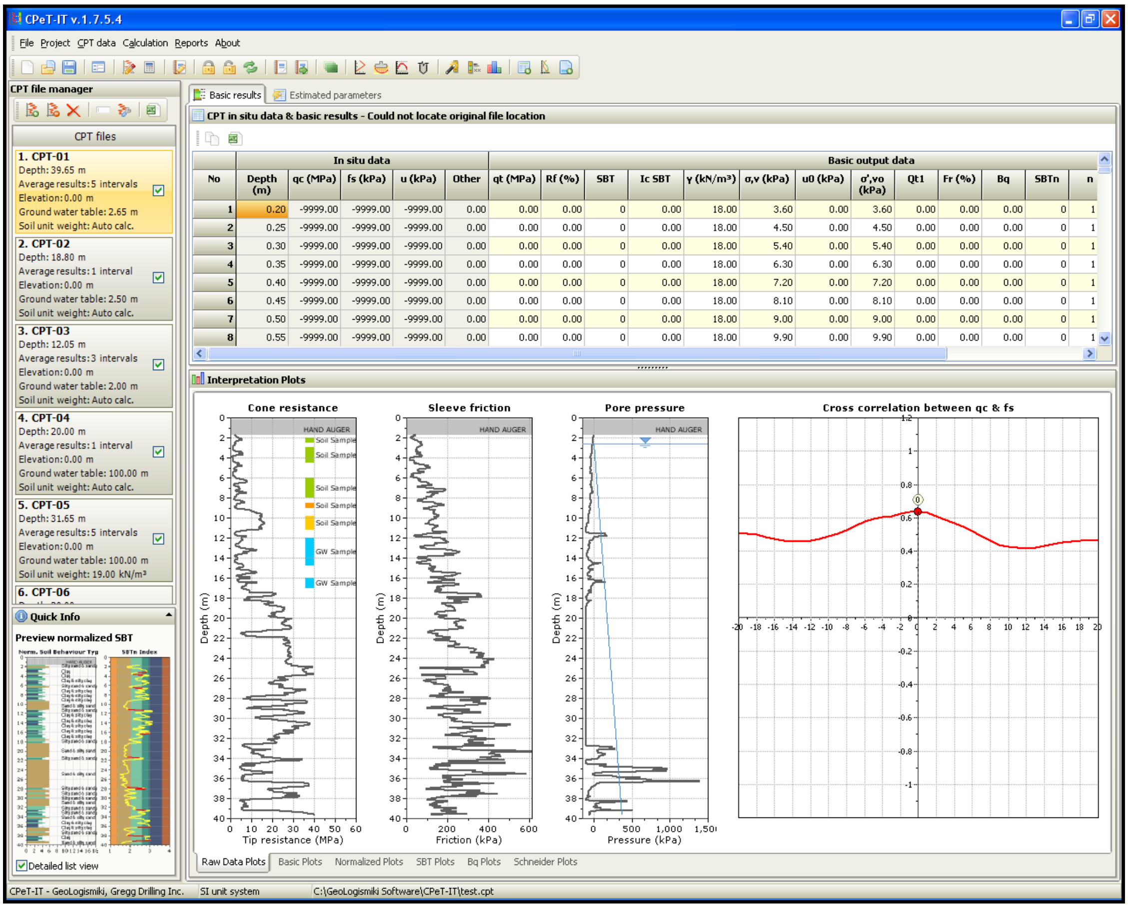
2 Introduction

CPeT-IT is software for interpretation of CPTU data. CPeT-IT was developed in collaboration with Gregg Drilling & Testing Inc., a leading company in site investigation and CPT, and Professor Peter Robertson, co-author of the comprehensive text book on the CPT.

CPeT-IT takes CPT data and performs basic interpretation in terms of Soil Behaviour Type (SBT) and various geotechnical soil and design parameters using current published correlations based on the comprehensive review by Lunne, Robertson and Powell (1997), as well as recent updates by Professor Robertson. The interpretations are presented only as a guide for geotechnical use and should be carefully reviewed. Either GeoLogismiki or Gregg Drilling Inc., does not warranty the correctness or the applicability of any of the geotechnical soil and design parameters interpreted by the software and does not assume any liability for any use of the results in any design or review. The user should be fully aware of the techniques and limitations of any method used in the software.

3 Overview

The software's main window is divided into two areas. In the left area, under the title ***CPT file manager***, it displays a list with the available CPTU data and in the large right area CPeT-IT will display input and output results in both tabular and graphic format. This way you can always have an instant preview of your data and estimations for quick reference.



CPeT-IT application window

The right hand side of the main window shows tabular output in the top half and plots in the lower half. The top half has two tabs, one for *Basic Results* and the other for *Estimated Parameters*. The relative size of the top and lower windows can be adjusted by clicking and dragging the horizontal dividing bar.

When the *Basic Results* tab is activated, the table shows the measured CPT input data and basic output data as a function of depth. The lower half shows the various Basic Results - Data Plots.

Data plots

At the base of the main window, the *Raw data plots* are displayed along with tabs to show, *Basic plots*, *Normalized plots* and *SBT plots*.

Raw data plots: This window displays plots of measured, cone tip resistance, q_c, sleeve friction, f_s, and penetration pore pressure, u, and cross correlation between q_c and f_s. A hydrostatic pore pressure line is also shown on the CPT pore pressure plot to act as reference and is determined based on the user input of ground water level (GWL). The cross correlation plot is a comparison between the q_c and f_s profiles. Since the center of the friction sleeve is physically several centimeters behind the cone tip (actual distance will depend on cone size, e.g. 10 cm^2 or 15 cm^2), most contractors offset the data so that both the tip, friction and pore pressure are shown at the same depth, rather than the same time. The cross correlation plot provides a check to evaluate if the offset has been fully effective or to determine if the data set has not been corrected for the physical offset. If the data has been fully offset, the cross correlation should show a maximum values at zero offset. In highly interbedded profiles, the cross correlation may not always show a clear maximum value.

Basic Plots: This window displays plots of corrected, q_t, friction ratio, R_f, penetration pore pressure, u (with reference hydrostatic profile based on user input GWL), normalized SBT_n I_c, and non-normalized SBT.

Normalized Plots: This window displays plots of normalized CPT parameters, normalized tip resistance, Q_{tn}, normalized friction ratio, F_r, normalized pore pressure parameter, B_q, normalized SBT_n I_c and normalized SBT_n.

SBT plots: This window displays the CPT results on both the non-normalized and normalized CPT Soil Behaviour Type (SBT and SBT_n) charts suggested by Robertson et al., 1986, and Robertson, 1990. When the cursor (with "SHIFT" key pressed) is moved over the CPT data, the depth of the data point is displayed and the associated line of data are highlighted in the table above.

Bq plots: This window displays the CPTu results on both the non-normalized and normalized CPT Soil Behavior Type charts based on normalized pore pressure parameter, Bq.

Schneider Plots: This window displays soil classification plots suggested by James Schneider et al. based on normalized excess pore pressure.

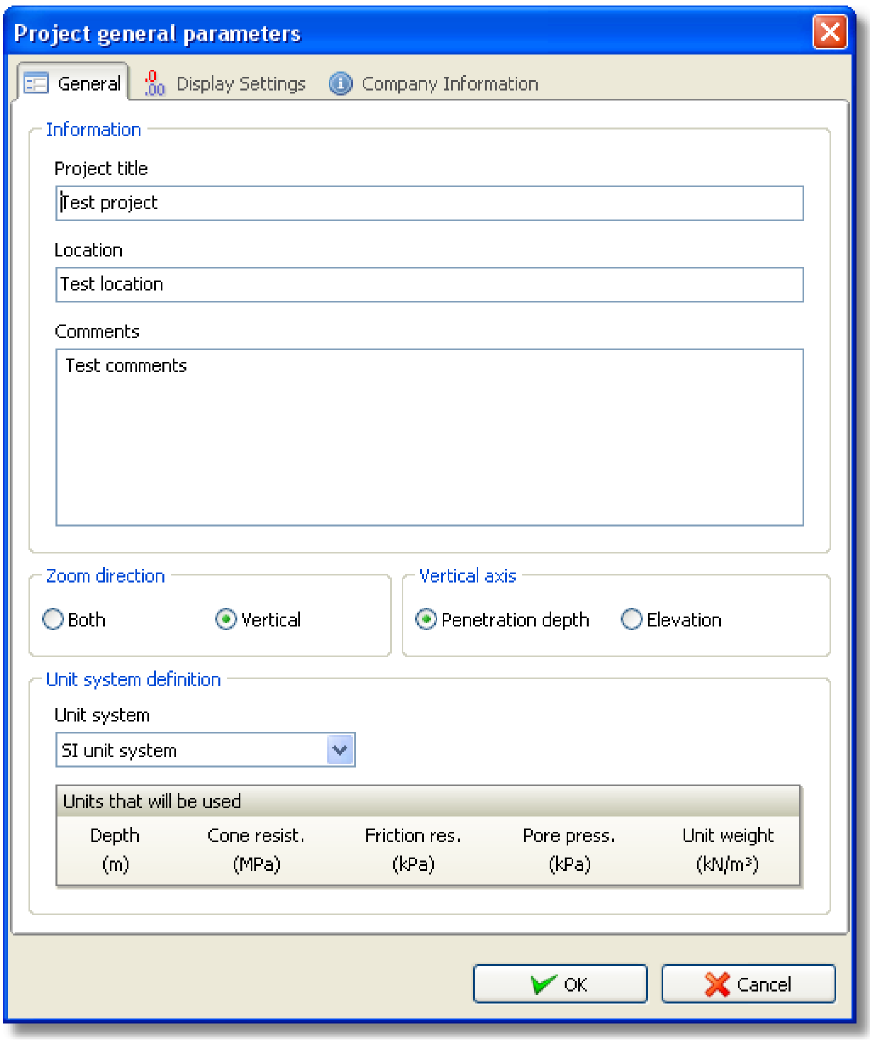
When the *Estimated Parameters* tab is activated, the table shows the calculated geotechnical parameters based on the user input constants. The lower half shows plots of estimated parameters versus depth under three tabs, *Estimated Plots 1, Estimated Plots 2* and *Estimated Plots 3*.

As with all plots the scales can be adjusted (see Customizing plots).

3.1 Starting a new project

When the software starts it will always display a new empty project. In order to begin entering CPTU data you must first define the unit system that you wish to use. By default CPeT-IT uses the SI unit system. Defining the unit system prior to inserting any data will allow you to easily switch between the supported unit systems, applying automatically all required transformations.

In order to define the unit system, click on the menu *Project* and select the *Project parameters* command (alternatively you may click on the  button located on the main toolbar). The following dialog will appear:



Using the above dialog you can insert or modify settings regarding the project's general information. For example, you can enter the Project Title and the Test Location (both not to exceed 150 elements, since they appear on the Plots). Comments will not appear on the Plots. When the dialog opens it will display any previous data entered before. From the *Unit system* drop down list you can specify the unit system you wish to use. Below the drop down list the software will display the units that will be used for data importing and interpretation. These units are:

Unit System	Depth	Cone resistnace	Friction resistance	Pore pressure	Unit weight
SI	meters (m)	Megapascal (MPa)	Kilopascal (kPa)	Kilopascal (kPa)	Kilonewtons per square meter (kN/m^3)
Imperial	feet (ft)	Tons per square foot (tsf)	Tons per square foot (tsf)	Pounds per square inch (psi)	Pounds per cubic foot (pcf)

The units used are fixed and cannot be changed in any way thus your input data must fully comply to this specification. During the import procedure CPeT-IT will assist you in order to convert your input data to meet the above units.

Zoom direction is used to specify how the software will handle zooming inside the plots (by left click and drag inside the plots area). Setting this option to *Both* will instruct the software to try and fit left and bottom axes according to the rectangle drawn during the click and drag mouse movement. *Vertical* direction (selected by default) will only adjust the left axes of the plots.

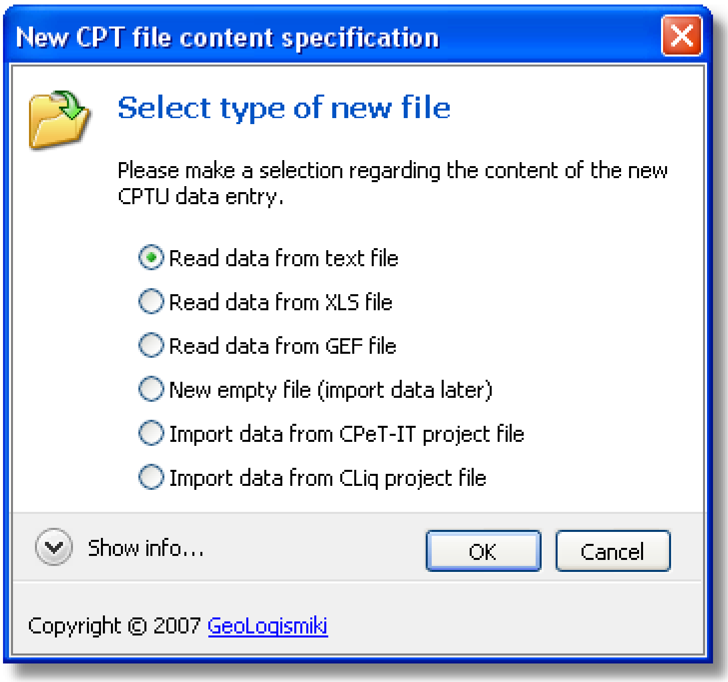
Vertical axis of a plots can be set to display depth data as a function of the penetration depth or elevation. If you have previously fixed the vertical axis scale changing this option may result to an empty plot so make sure you check Y axis scale (min and max values) prior to any change. Elevation data are only visible to plots where all calculation data and results will appear displaying the penetration depth of each CPT point.

To commit any changes made you must click on the *OK* button. If you click on the *Cancel* button no changes will be made.

Use the Company Information Tab to input your company logo, name and address, which will appear on all future reports.

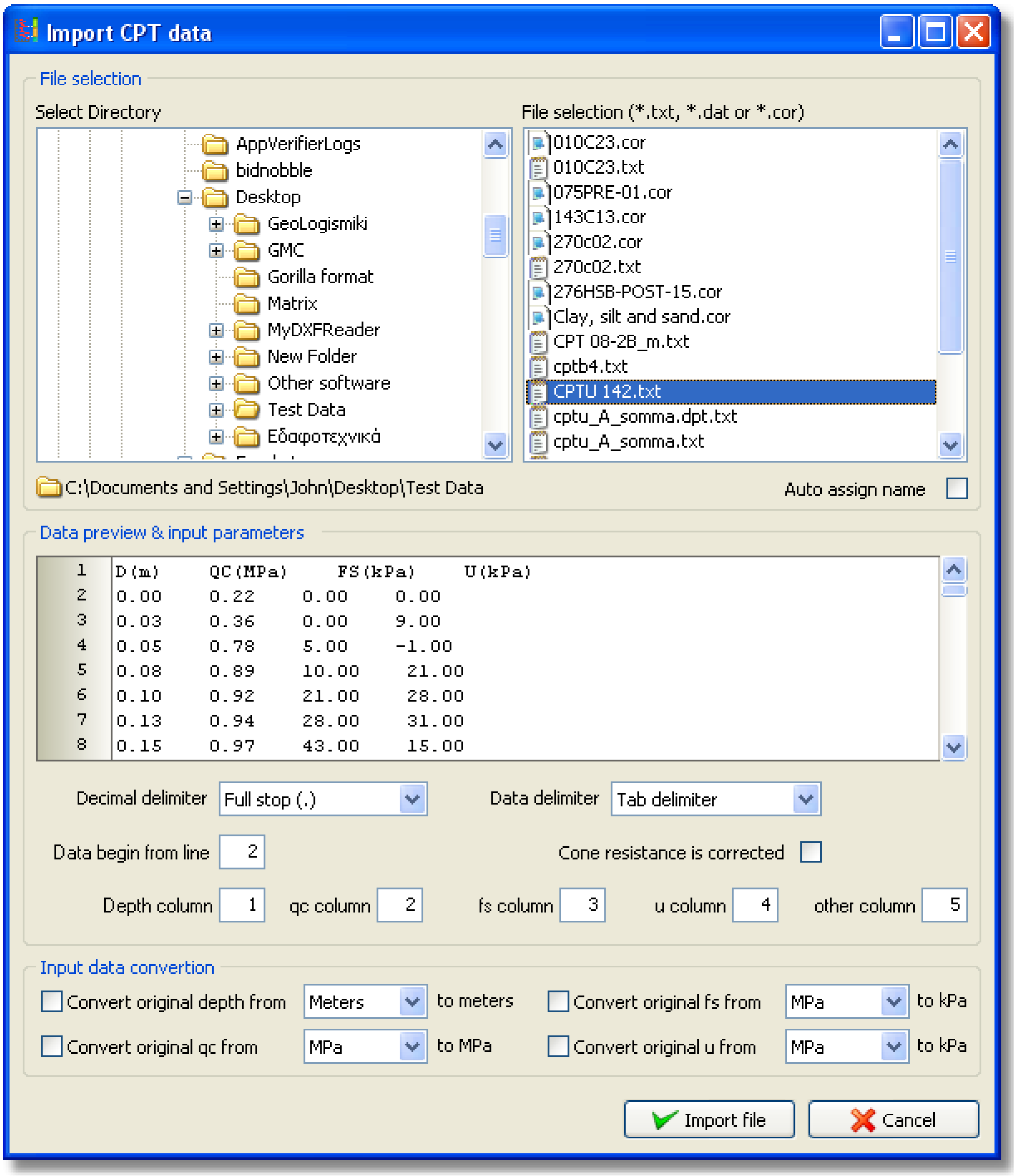
3.2 Importing CPTU data

After you have specified the unit system for the current project you can import CPTU data from an ASCII data file by clicking on the menu *CPT data* and selecting the *Import single CPT file* command (alternatively you may click on the button located on the CPT file manager toolbar). The following dialog will appear:



New CPT file options

By default, CPeT-IT will prompt you to read data from an ASCII file. Click *OK* to continue. The import data dialog will appear:



Data import dialog

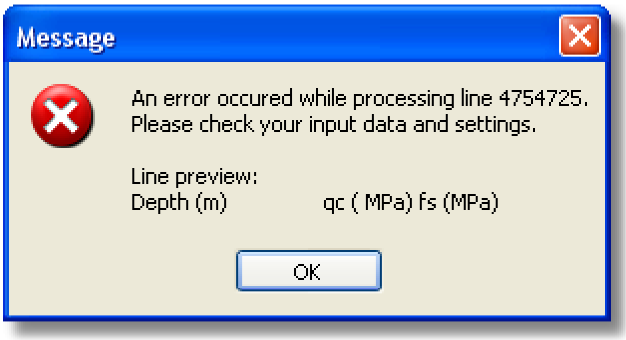
CPeT-IT can read data that are stored in an ASCII file with extension .txt, .dat, .cor. While browsing to your hard drive you will see all files that match the above extensions in the *File selection* list box located at the top right area of the dialog. Clicking on a file will instruct the software to load the contents of the file and present them inside the *Data preview* area. In this way you may browse to the contents of the file prior on inserting it into the software. The preview area will also provide you with additional information you may need in order to import the file correctly e.g. the line number from where the actual data begin. If the *Auto assign name* checkbox is checked each CPT file will be given a new file name, starting with CPT-01 otherwise the CPT file will be named after the associated file name without the file extension (e.g. .cor). The file name can be changed to match the actual file name by using the *CPT data – Rename CPT* feature when a file is highlighted. You may also select multiple files by holding down the Ctrl key on the keyboard while clicking on the file names.

As a general rule, the data file must contain at least 4 columns of data in the following order, depth - cone resistance - friction resistance - pore pressure (where pore pressure is the penetration pore pressure u measured behind the cone e.g. u2). Additionally the program will look for a fifth column which may contain any other data such as electrical resistivity or UVIF. If other columns exist in the data file the software will ignore them.

Based on the data preview, you must provide the software with additional information regarding the data structure inside the file. CPeT-IT needs to know what character is used as a decimal delimiter, what character is used as a data delimiter (separation character between column data), from which line the actual data start (after any header information) and if the data file contains the raw cone resistance measurements (there are cases where your CPT contractor may give you a file containing the corrected cone penetration resistance q_t instead of the raw field value q_c). Making the right selections inside the *Data input parameters* is very crucial for a successive completion of the import procedure.

Finally, in case that the data in your file do not meet the units specification you can select the corresponding check box for the value you wish to convert e.g. if your data file contains depth measurements in feet and your project's unit system is set to SI then you should check the *Convert original depth from* checkbox and from the drop down list select feet.

In order to import the file click on the *Import file* button. If an error while reading the data file occurs, the software will display a message stating the line number where the error appeared. All data prior to that line will be included in the imported data. Such an error may occur when there are blank lines in your original data file. In any case you can preview the imported data and decide whether to keep them or edit the original file to fix the error and reimport. (A common error would be not to set the data delimiter to the correct character and so the software will not import any data as an error will be raised from the very first line).



Error message from data import procedure

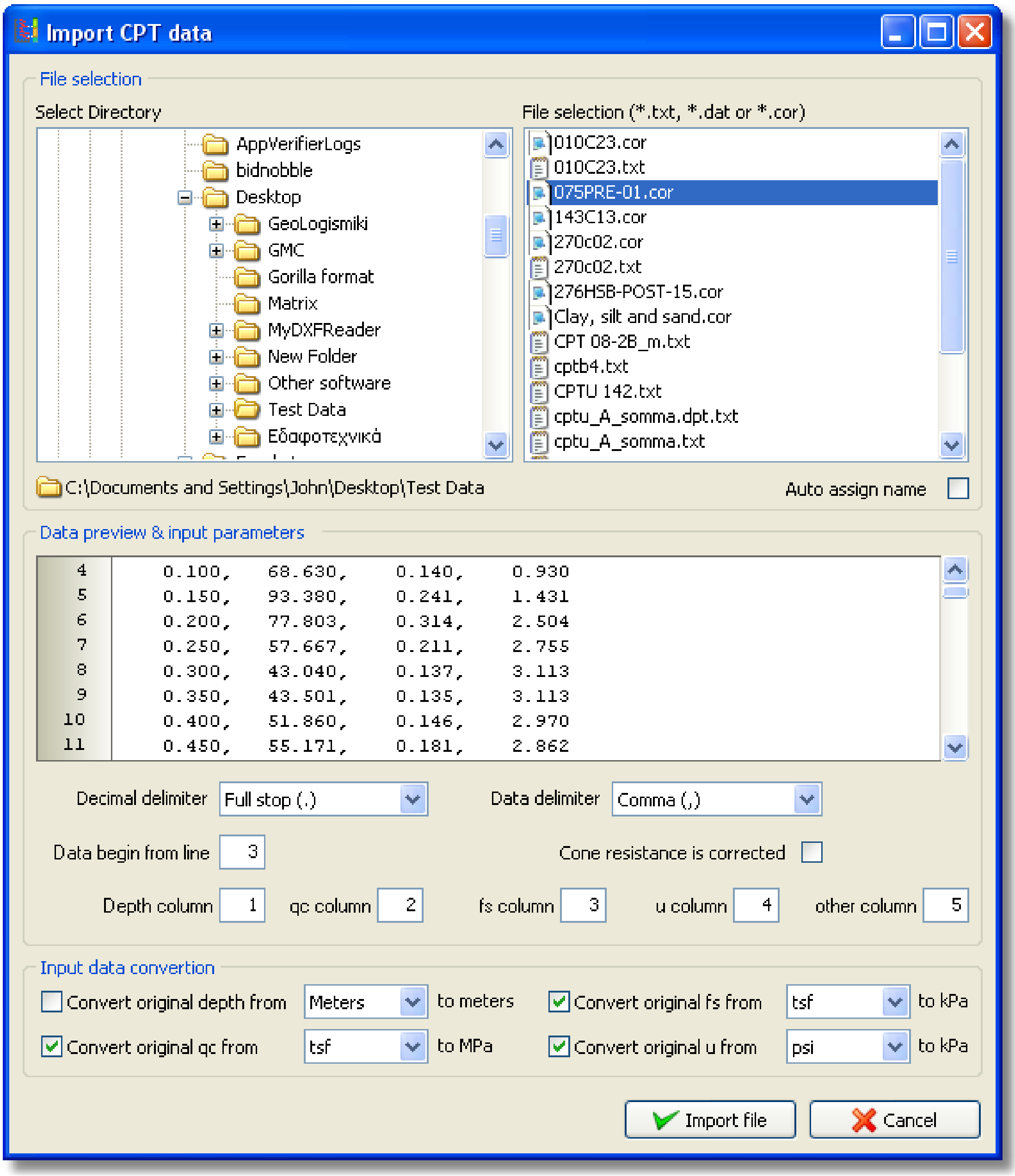
Note

If there are multiple files in your selection

> you must make sure that the file structure is common to all selected files otherwise the import procedure will fail to read all files

3.2.1 Importing .cor files

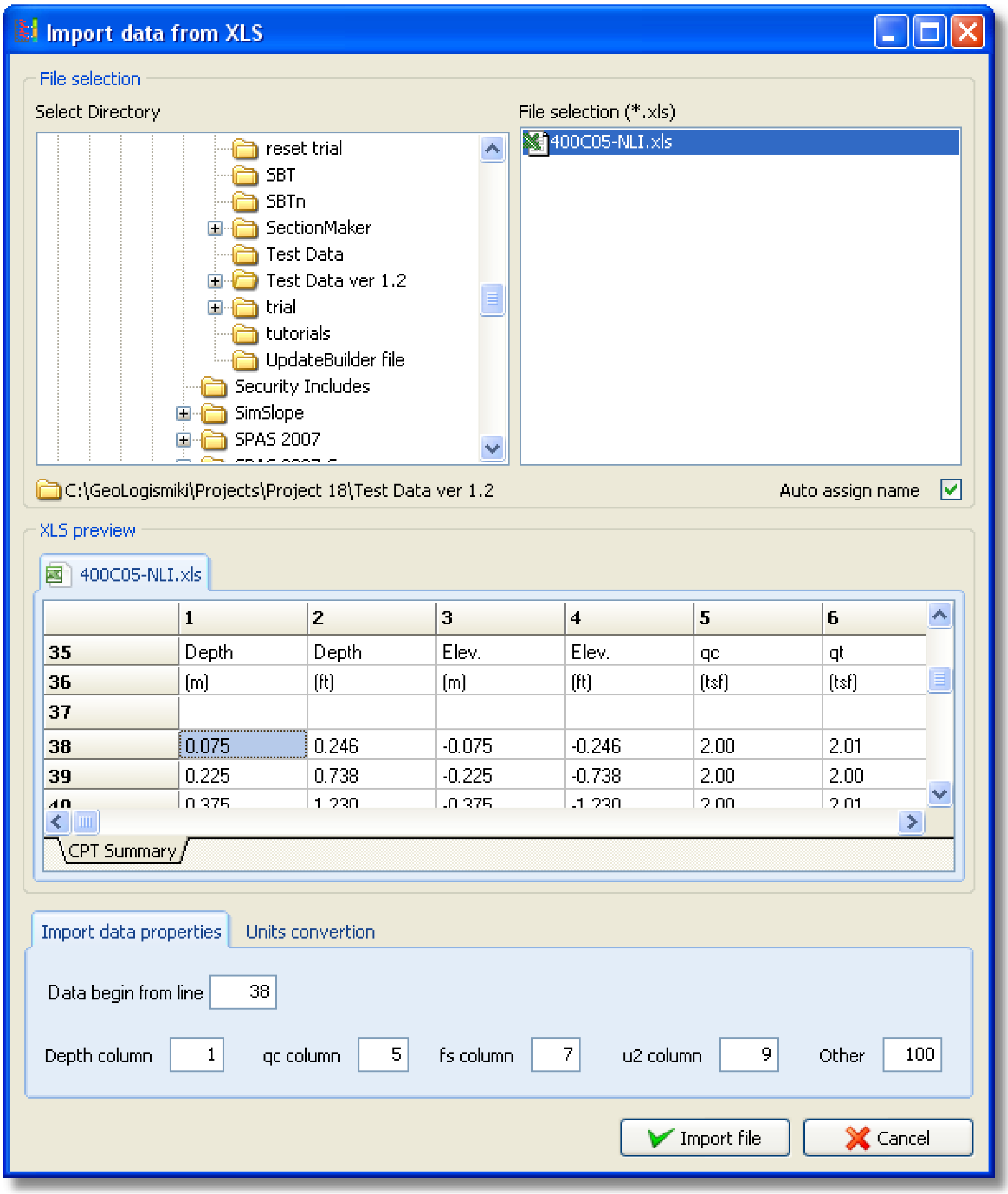
Gregg Drilling Inc., provides its customers with an ASCII text file containing the raw CPTU field measurements. This file has an extension .cor and when selected the software will make the appropriate adjustments for the various data input parameters and convertions automatically. After selecting such a file just click on the Import button to let the software read and import the data to your new CPT entry.



.cor file selection for SI project units

3.2.2 Importing .xls files

Importing CPT measurements from a Microsoft Excel® file is similar to the procedure to import data from an ASCII file. Just browse to the directory where the file is stored and select it. A preview of the file contents will be displayed in the *XLS Preview* portion of the dialog. CPeT-IT will include all Sheets in the preview area but will import data only from the selected one.



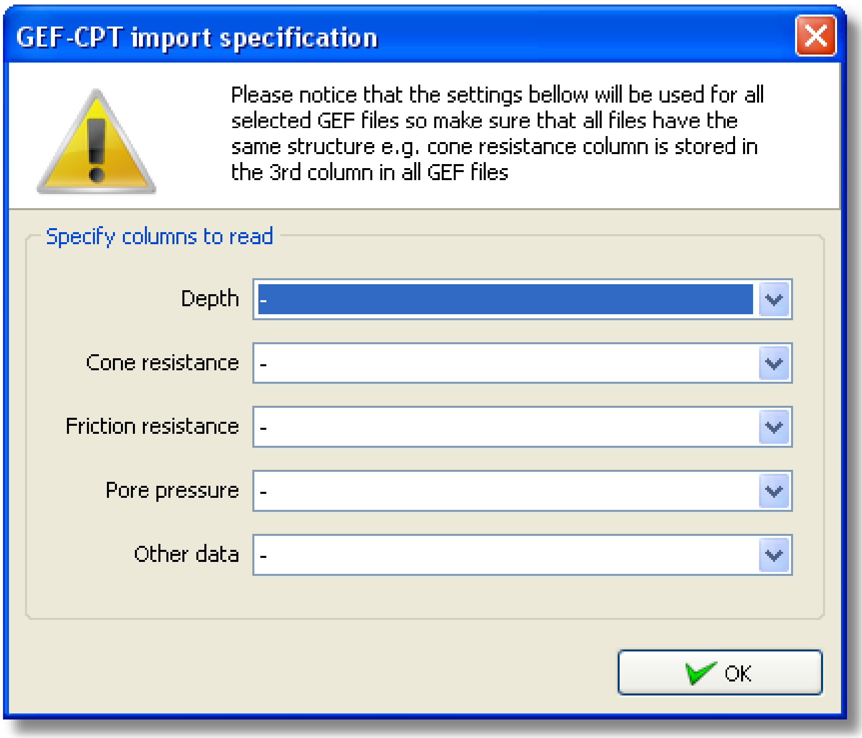
XLS import dialog

Make sure that all the import properties are entered correctly and click on the *Import file* button to create the new CPT file.

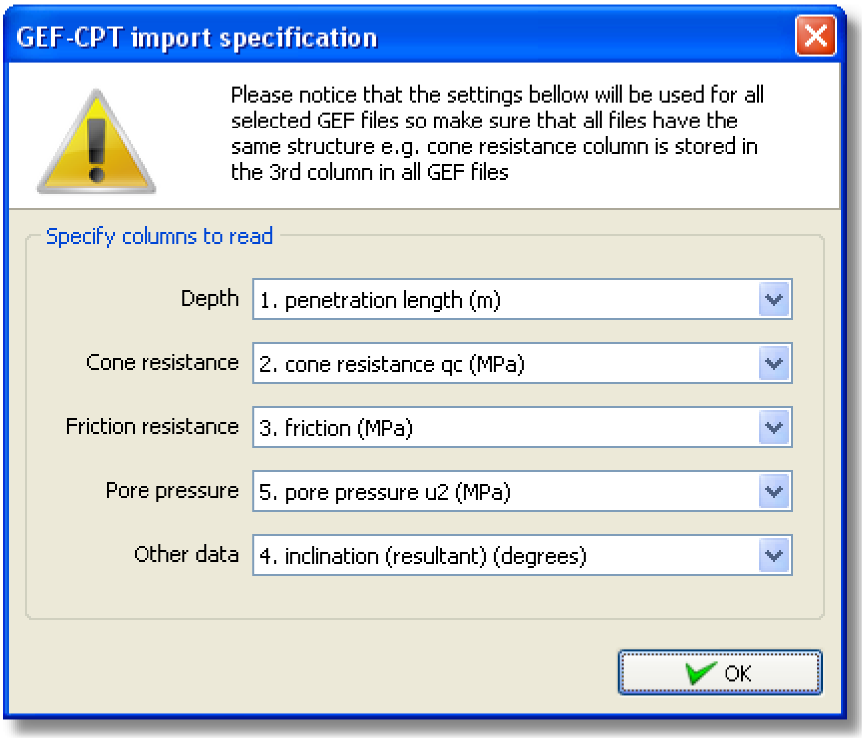
3.2.3 Importing .gef files

GEONET, the central Dutch website on Geotechnics, developed the Dutch national GEF-standard on geotechnical data-exchange. CPeT-IT provides support for importing data from a GEF CPT data file.

Browse to the directory where your .gef files are stored and select one so that you can specify the structure of the file. When you select a .gef file the following dialog appears:

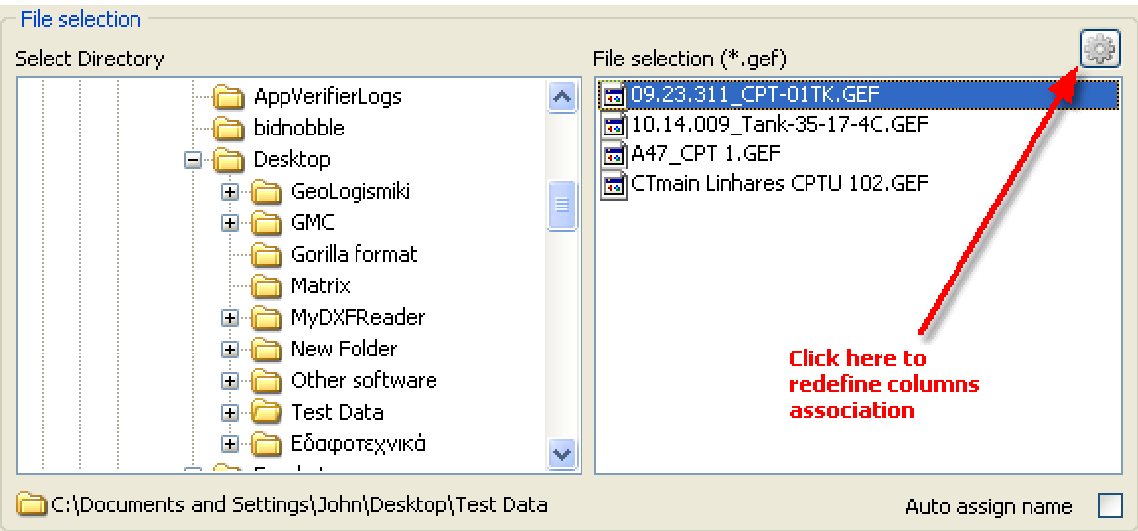


The software will read the file and fill the drop down lists with the information that is included in it. You must make the appropriate selections keeping in mind that you must provide information for at least four columns. The dialog then can look like this:



You can see that the measured pressures are all in MPa so you will have to make the appropriate conversions. Click ok the OK button to close the dialog. Now the data are visible in the *Data preview* area. The *Data delimiter* should be set to *Tab delimiter.*

The columns association defined in the above dialog will be used for all selected .gef files in the *Files selection* list box. If you wish to redefine columns, just click on the small button located above and to the right of the file list.



3.3 Defining CPT parameters

CPeT-IT uses established empirical correlations to estimate geotechnical parameters. Many of them have constants that have a range of values depending on soil type, geologic origin and other factors. The software uses default values that have been selected to provide, in general, conservatively low estimates of the various geotechnical parameters. These default values are assigned to every new CPTU data you import automatically.

The following empirical correlations have been used to calculate parameters:

Input:

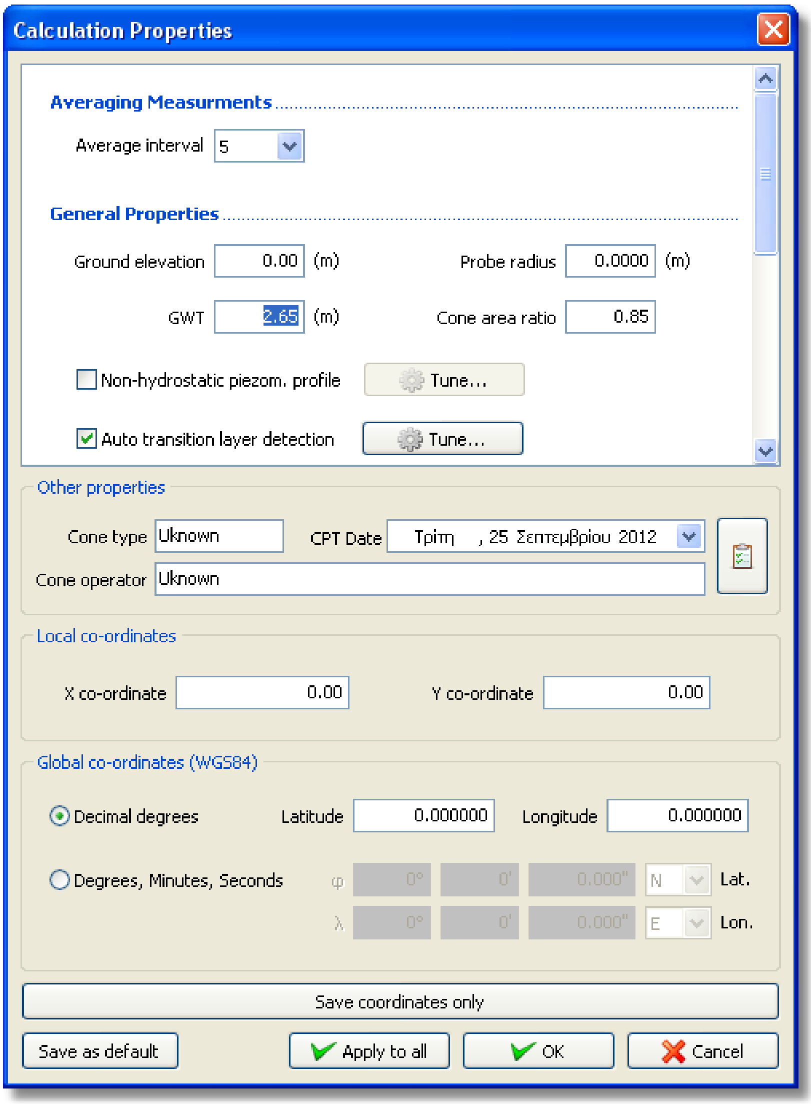
- Units for display (Imperial or metric) (atm. pressure, pa = 0.96 tsf or 0.1 MPa)
- Elevation of ground surface (ft or m)
- Depth to water table, z_w (ft or m) – input required for each CPT sounding. Equilibrium water pressures are assumed hydrostatic relative to the input GWL
- Net area ratio for cone, a (default to 0.80)
- Relative Density constant, C_{Dr} (default to 350)
- Undrained shear strength cone factor for clays, N_{kt} (default to 14)
- Over Consolidation ratio number, k_{ocr} (default to 0.33)
- Unit weight of water, (default to g_w = 62.4 lb/ft³ or 9.81 kN/m³)
- Probe radius (default to 0.0183 m)

Output:

Total cone resistance, q_t (tsf or MPa)	$q_t = q_c + u \times (1-a)$
Friction Ratio, R_f (%)	$R_f = (f_s/q_t) \times 100\%$
Soil Behavior Type (non-normalized), SBT	see note
Unit weight, g (pcf or kN/m³)	based on SBT, see note
Total overburden stress, s_v (tsf)	$s_{vo} = g \times z$
Insitu pore pressure, u_o (tsf)	$u_o = g_w \times (z - z_w)$
Effective overburden stress, s'_{vo} (tsf)	$s'_{vo} = s_{vo} - u_o$
Normalized cone resistance, Q_{t1}	$Q_{t1} = (q_t - s_{vo}) / s'_{vo}$
Normalized friction ratio, F_r (%)	$F_r = f_s / (q_t - s_{vo}) \times 100\%$
Normalized Pore Pressure ratio, B_q	$B_q = u – u_o / (q_t - s_{vo})$
Soil Behavior Type (normalized), SBT_n	see note

SBT_n Index, I_c	see note
Normalized Cone resistance, Q_{tn} (n varies with I_c)	see note
Estimated permeability, k_{SBT} (cm/sec or ft/sec)	see note
Equivalent SPT N_{60}, (blows/ft or blows/30cm)	see note
Estimated Constrained Modulus, M	see note
Estimated Relative Density, D_r, (%)	see note
Estimated Friction Angle, f', (degrees)	see note
Estimated Young's modulus, E_s (tsf or MPa)	see note
Estimated small strain Shear modulus, G_o (tsf or MPa)	see note
Estimated Undrained shear strength, s_u (tsf or kPa)	see note
Estimated Undrained strength ratio	s_u/s_v'
Estimated Over Consolidation ratio, OCR	see note

In order to view or edit these constants select a CPTU sounding and from the menu *CPT data* click on the *CPT Properties* command (alternatively you may click on the  button located on the *CPT File Manger* toolbar). The following dialog will appear:



CPT calculation properties dialog

The calculation properties are:

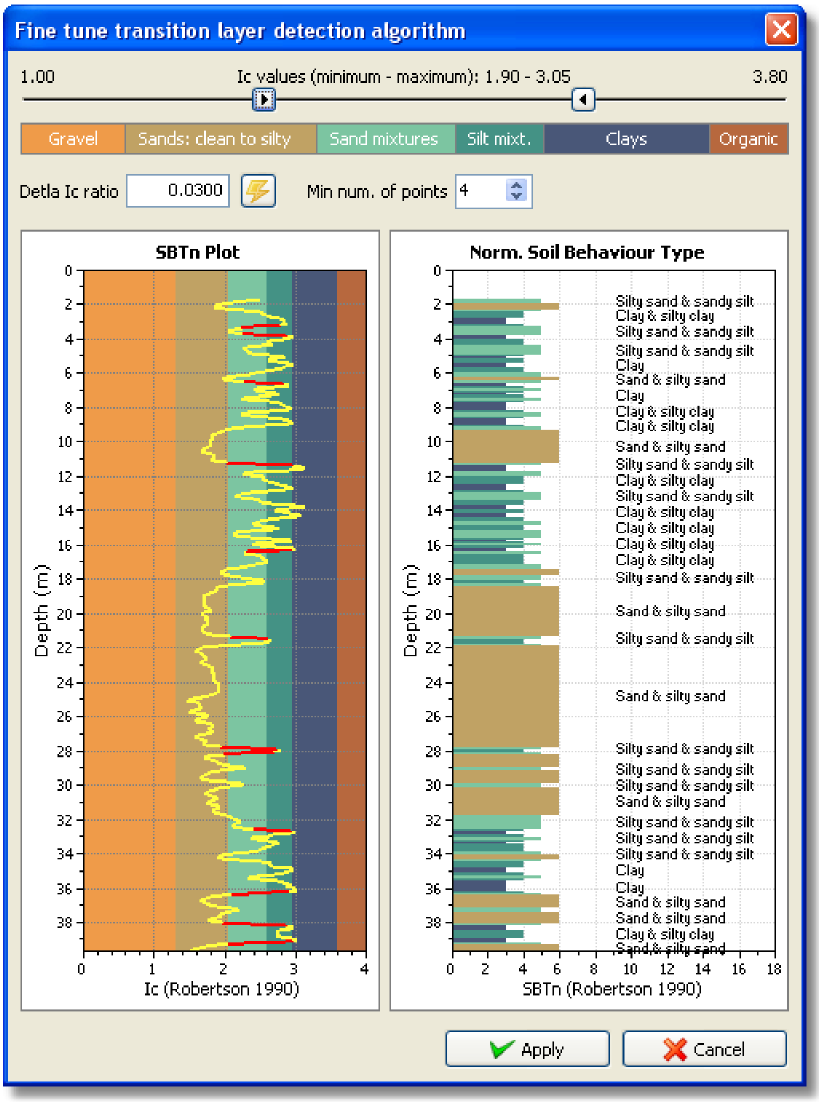
- Average interval: Available selection is 1, 3 or 5. The number denotes how many values will be used in order to produce averaged results. If 1 is selected there is no averaging of data. When either 3 or 5 is selected, the data are averaged every 3 or 5 intervals and presented as a rolling average.
- Ground elevation: Elevation of the free ground surface. This value can be entered for each CPT file or applied to all files.
- GWT: Ground water table below the free ground surface starting from zero value at the surface. For over-water projects, a negative value should be provided to identify that the water level is above the ground surface. For over-water CPT it is often common that zero load CPT base line measurements are taken at the mudline and in these cases the GWT should be input as zero, since the total weight of the water above the mudline has been removed in the baseline measurements. For over-land projects, this is typically the depth below ground surface.

- Probe radius: Radius of the cone used for the calculation of c_h in the dissipation module.
- Cone area ratio: The net area ratio for the cone (default value to 0.85).
- Non-hydrostatic piezom. profile: When checked a custom profile of pore pressure values may be defined and used.
- Cone resistance is corrected: When checked the software will assume that imported raw cone resistance q_c is already corrected and equal to q_t
- Unit weight of water: Unit weight of water (default value to 9.81 kN/m³ or 62.40 lb/ft³).
- Auto unit weight: When checked the software will use a built-in function to estimate unit weight based on q_t and R_f. If unchecked then a list of custom values can be used or apply the constant value entered in the edit box.
- Auto OCR number: When checked the software will try to estimate over consolidation ratio number, k_{ocr} for every CPT point. If unchecked then a custom constant value is used (default value to 0.33).
- Auto N_{kt}: If checked then undrained shear strength cone factor for clays, N_{kt} will be estimated by the software at every CPT point otherwise a constant value will be applied (default value to 14).
- D_r constant: Relative density constant, C_{Dr} (default value to 350).
- C_n cutoff: At very low penetration depths (close to the free ground surface) normalization factor n may take large values resulting to large Q_{tn} values. Enabling this option will set a maximum to the calculate C_n (default value is 2.00)
- N_s: This is a constant used for the calculation of soil sensitivity (ranges between 5.0 to 10.0 with an average value of 7.10)
- Calculate SPT: Selection to choose between the estimation of corrected N_{60} SPT values or normalized corrected SPT values $N_{1(60)}$
- Auto transition layer detection: When checked the software will try to detect data that are in transition from either clay to sand or vise-versa. Data belonging to transition zones will not be plotted in the estimations plots and will not contribute to average values used in the Geotechnical Section module. Click on the *Tune* button to fine tune the detection algorithm.

In order to apply any changes made to the selected CPTU just click on the *OK* button. If you wish the changes made to be the default values for every CPTU that you will create click on the *Save as default* button. If you click on the *Apply to all* button, all values entered in this dialog will be applied to every CPTU sounding in the current project. *Save coordinates only* button will cause the dialog to close applying the changes made to coordinates only.

Closing the above dialog will not cause any recalculation of the estimated properties. To do so you will either need to recalculate all CPTU soundings or just the selected one. Click on the *Calculation* menu and select the appropriate command. Alternatively you may click on the button in order to recalculate all CPTU soundings.

3.3.1 Transition layer detection



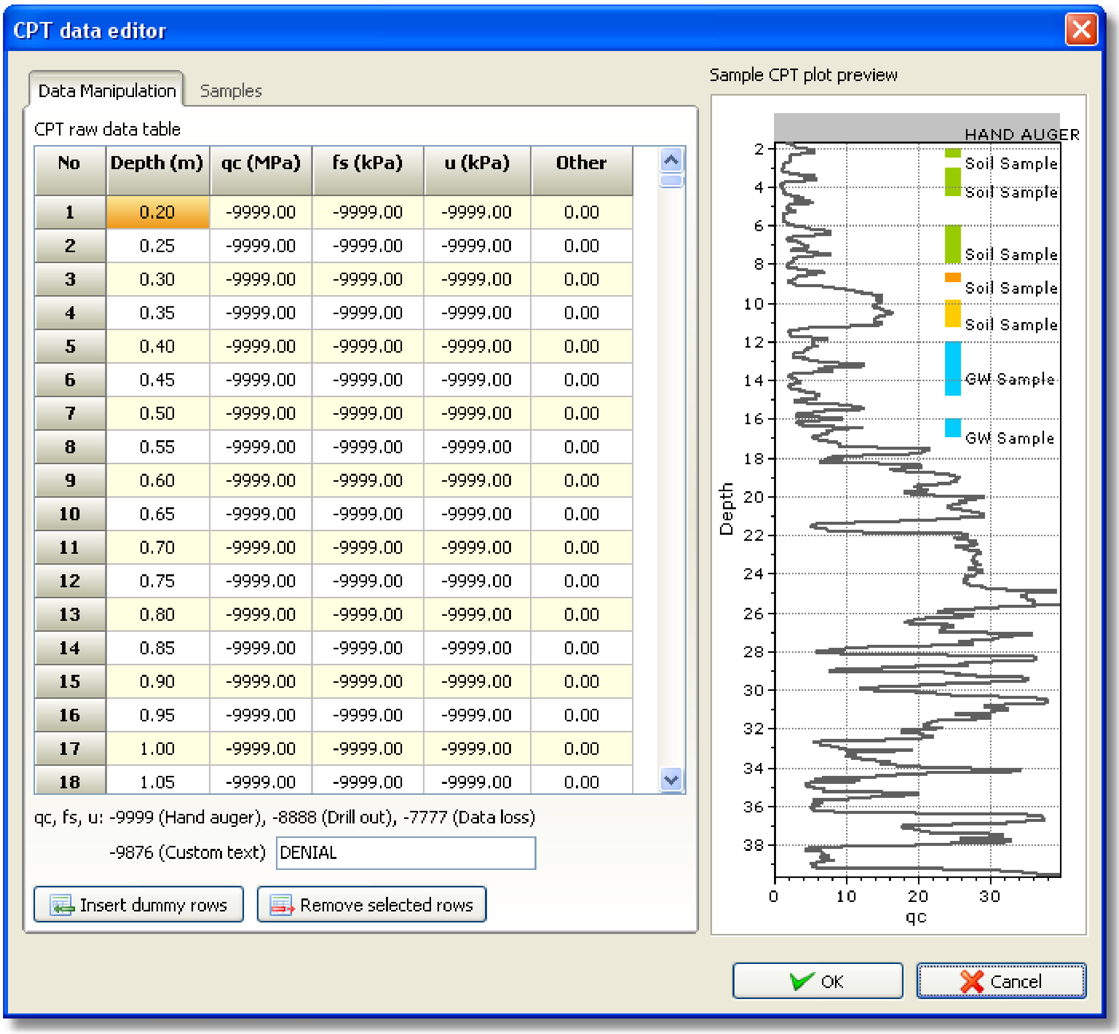
Transition detection dialog

The software will ignore data when the cone is in transition from either clay to sand or vise-versa. To do this the software requires a range of I_c values over which the transition will be defined (typically somewhere between 1.80 < I_c < 3.0) and a rate of change of I_c. Transitions typically occur when the rate of change of I_c is fast (i.e. delta I_c is small). The user can modify both the range (using the sliding scale) and the rate of change of I_c (delta I_c) and observe which parts of the cone profile will be deleted from the liquefaction assessment (deleted sections are shown in red on the I_c plot below). To change delta I_c, move the cursor over the current delta I_c value in the box and input an alternate value, then click on the button to see the new red sections that will be deleted. The user can also move the sliding scales above to modify the range of I_c to define the transition. User judgment is required to optimize the amount of data that will be deleted. Finally, using the *Min num. of points* edit box you may instruct the software to keep detected transition layers with a minimum number of CPT points according to the number entered. Using the up and down arrows CPeT-IT will recalculate the layers automatically.

Click on the *Apply* button to accept changes made.

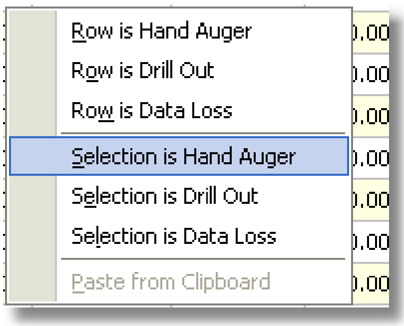
3.4 Editing CPT data

It is a common practice to hand auger the first centimeters before inserting the cone to the ground. Also, during the test, the cone can meet refusal on a soil layer that cannot penetrate and special treatment should be made, allowing the cone to continue after the hard layer has been drilled out. To include such information in your CPTU data and be able to present it in the raw input plots, select a CPTU element and from the menu *CPT data* click on the *Edit CPT data* command. The following dialog will appear:

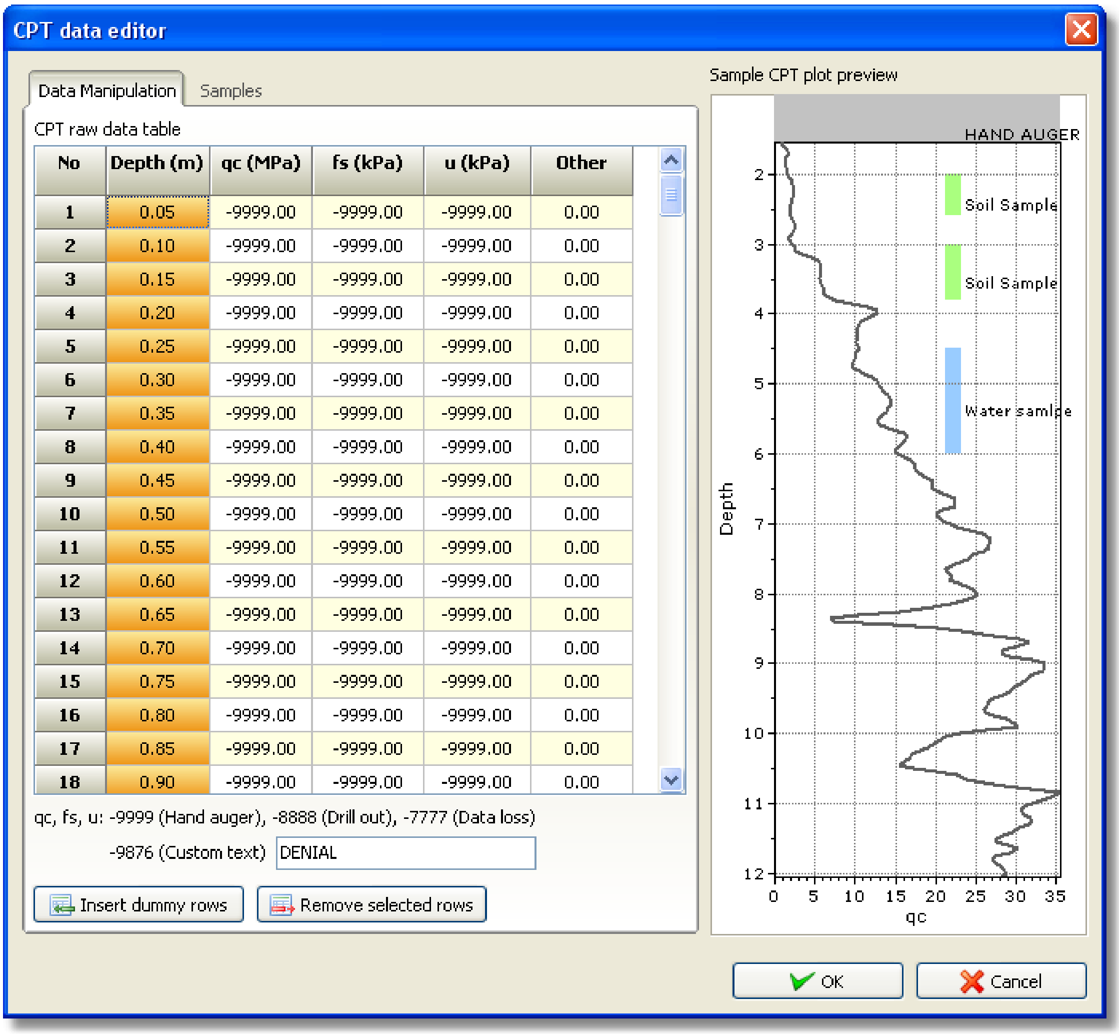


Edit CPT data dialog

It is possible that the contractor of the CPTU created a file where for the first 1.50 meters all recordings are set to zero for the reason that no measurements where taken since this depth was hand augured. The software in general, will omit values equal to zero and this is why on the sample plot at the right displays the q_c value starting from a depth of 1.55 meters. In order to display the area where soil has been hand augured or drilled out you need to change the measurement values to a value of -9999 for hand auger or -8888 for drill out or -7777 for Data Loss. To do so just select the cells in depth column that need to be altered using the mouse (or using the arrow keys holding down the SHIFT key on your keyboard) and right click on the selection. A pop up menu appears:

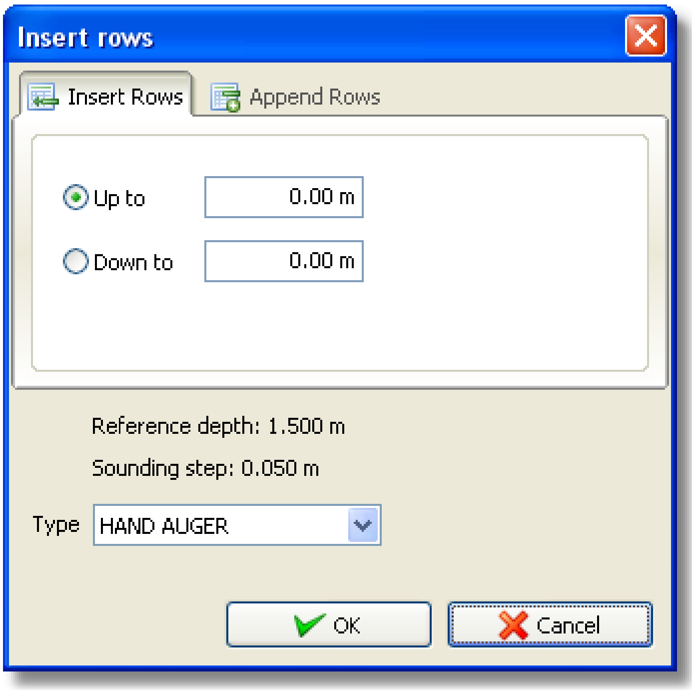


Select the *Selection is Hand Auger* command and the software will fill the appropriate cells with the value -9999. Immediately you will see the changes made in the sample plot.

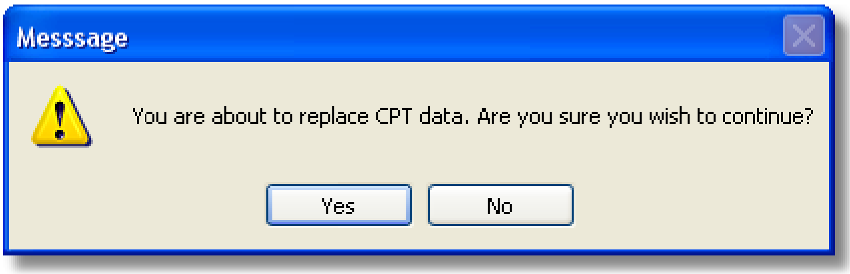


Results at a start depth > 0.00 m

There can also be the case where the CPTU data file includes only the soundings. In this case, data could start directly form depth 1.55 meters so you will need to insert dummy measurement values from depth 1.50 up to 0.0 meters. Select the cell where you want to append rows and click on the *Insert dummy rows* button. The following dialog will appear:



The dialog displays the reference depth which is actually the start depth for the insertion operation. Sounding step displays the data step that will be used for the inserted rows (the sounding step is the average step calculated from the original data file). Select *Up to* if you want to insert rows before the reference depth or *Down to* if you wish to insert rows after the reference depth. In the associated edit boxes insert the end depth value. From the *Type* drop down list select the type of data to be inserted (Hand auger or Drill out). Click on th *OK button* to commit the changes to your data. Since the changes cannot be undone the software will ask you if you wish to continue with data replacement.



If for some reason, data points from your CPT are missing you can use the *Append Rows* section to "inject" the values missing in the correct place using the same technique as described above.

3.4.1 Direct edit raw CPT data

Sometimes it may be useful to edit a few raw measurements in order for example to fix peaks in qc profile due to rod change. The software provides a quick and easy way to locate and fix these values without the use of the CPT data editor. The procedure is described below:

1. Enable the direct edit mode by clicking on the button on the main toolbar or from the *CPT Data* menu select the *Enable Direct Edit Raw Data* command. The icon on the toolbar will remain pressed (highlighted) to visually inform that the feature is enabled.

2. By holding the SHIFT key on your keyboard locate the value you wish to fix.

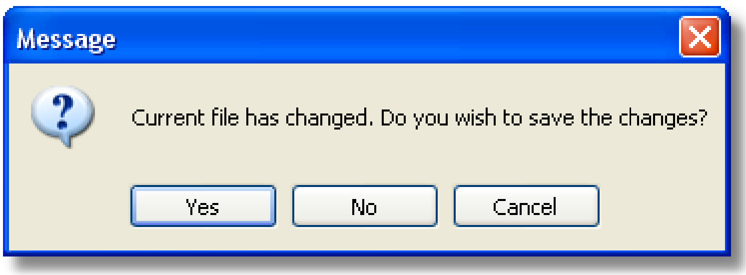
3. Click on the corresponding cell and edit the value. Press *Enter* on your keyboard to commit the change or just click anywhere outside the cell. The plot will be updated automatically but no calculations are performed during this step.

4. Disable the feature by clicking on the highlighted icon (in order to avoid any accidental changes in raw data) and recalculate your CPT.

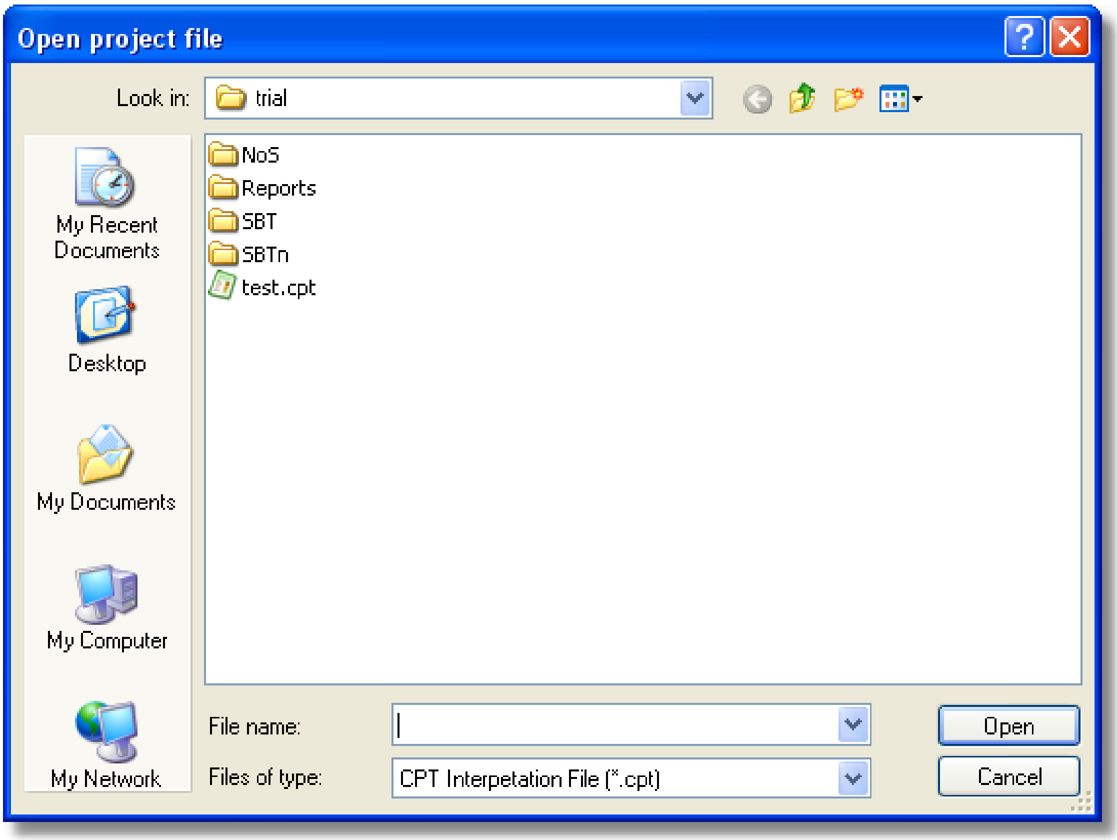
> **Note**
>
> Direct edit mode allows changes to depth, q_c, f_s and u_2 values only.

3.5 Loading a project

To load a previously saved project file, click on the *File* menu and select the *Open Project...* command (alternatively you may click on the button located on the main toolbar). The software will prompt you with a question regarding saving the current project first.



Unless you click on the *Cancel* button the standard Windows load dialog will appear:

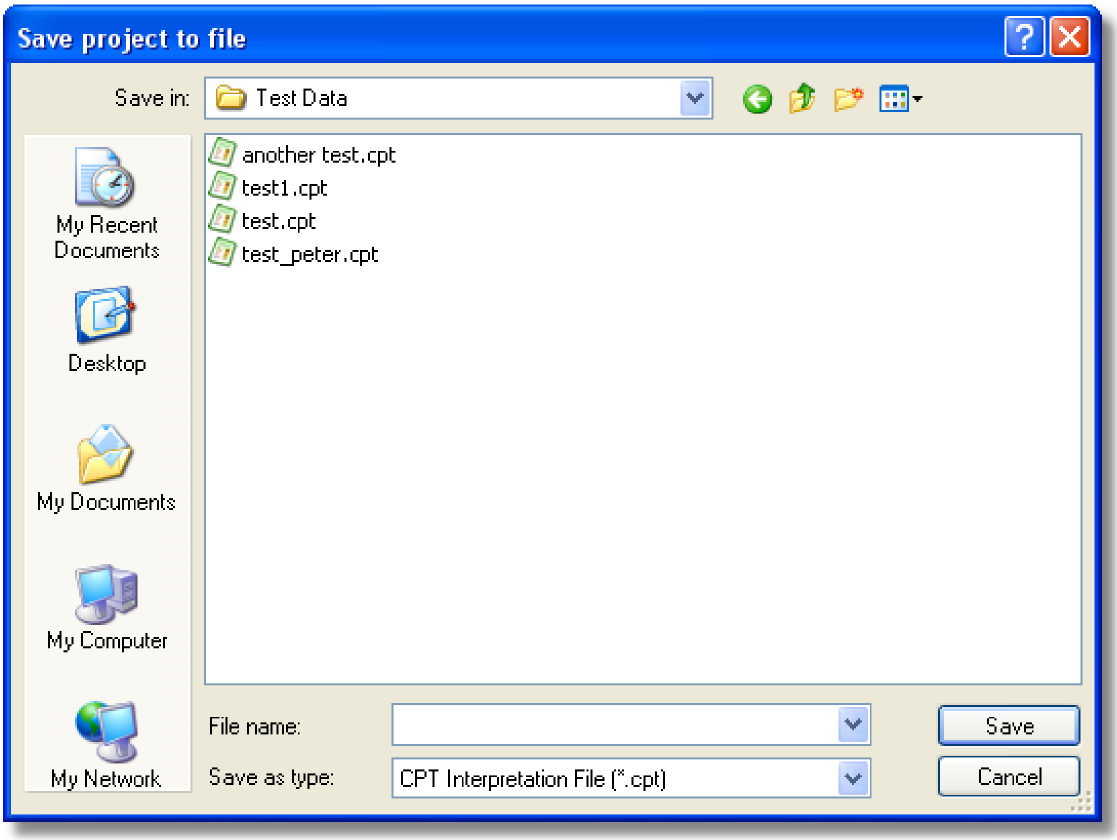


Open project file dialog

Browse to the directory where your project file is located, select it and click on the *Open* button.

3.6 Saving a project

To save a project and all the CPTU data entered just click on the menu and select the *Save Project* command (alternatively you may click on the  button located on the main toolbar). The standard Windows save dialog will appear:

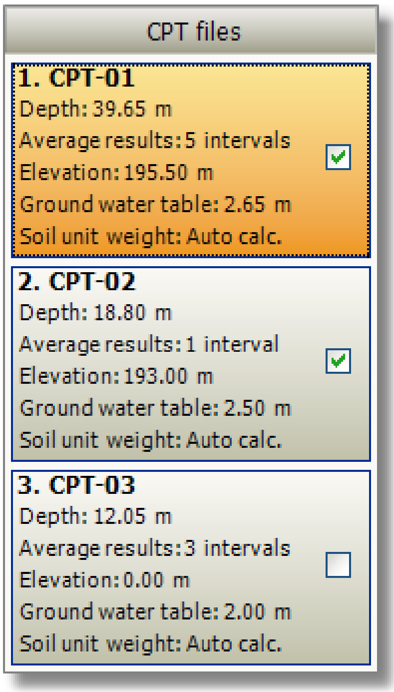


Save project dialog

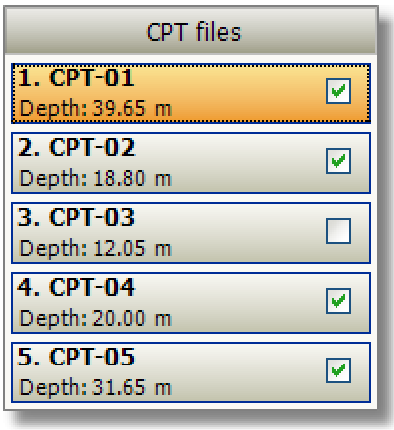
Browse to the directory you wish to save the file. Enter a name on the *File name* field and click on the *Save* button. The above dialog will be displayed only once, the first time you try to save a new project. If you need to rename a previously saved project select the *Save As...* command form the *File* menu. The above dialog will appear again and you can now define the new name and location of the project file.

3.7 Printing results

CPeT-IT can create single reports for every level of interpretation or an overall report for every CPTU in the project. Batch reports can also be created for the selected CPTU (a selected CPTU for batch printing is identified by a tick mark).

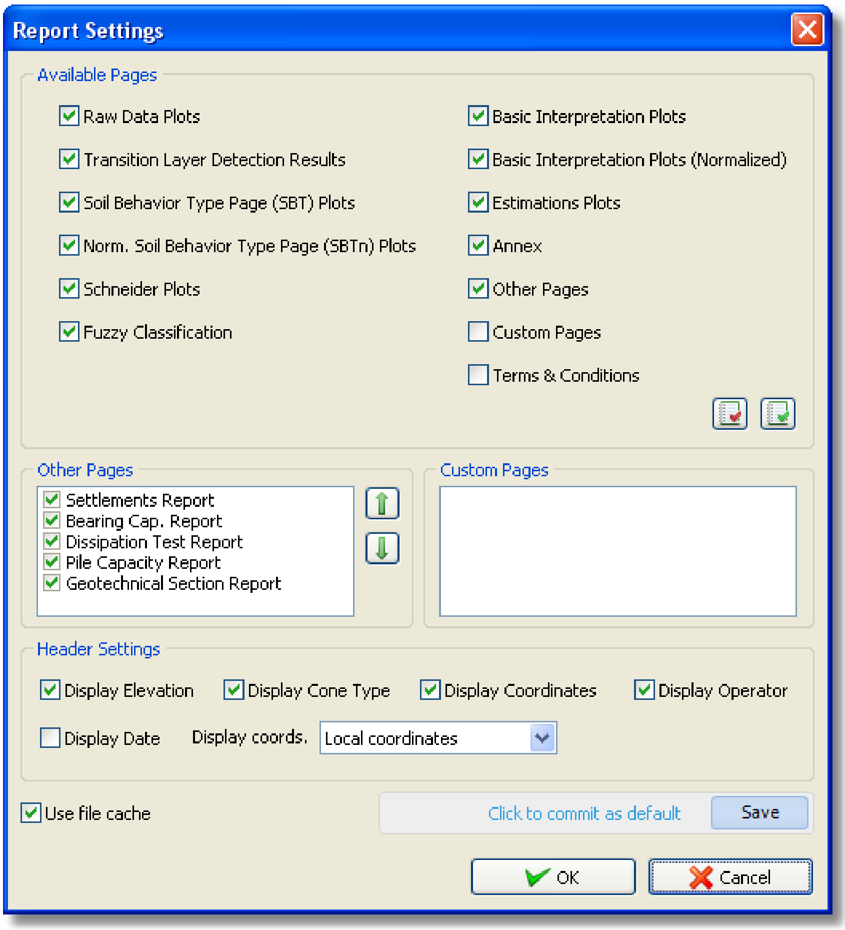


Selected CPTU for single report



Ticked entries will be included in the batch report

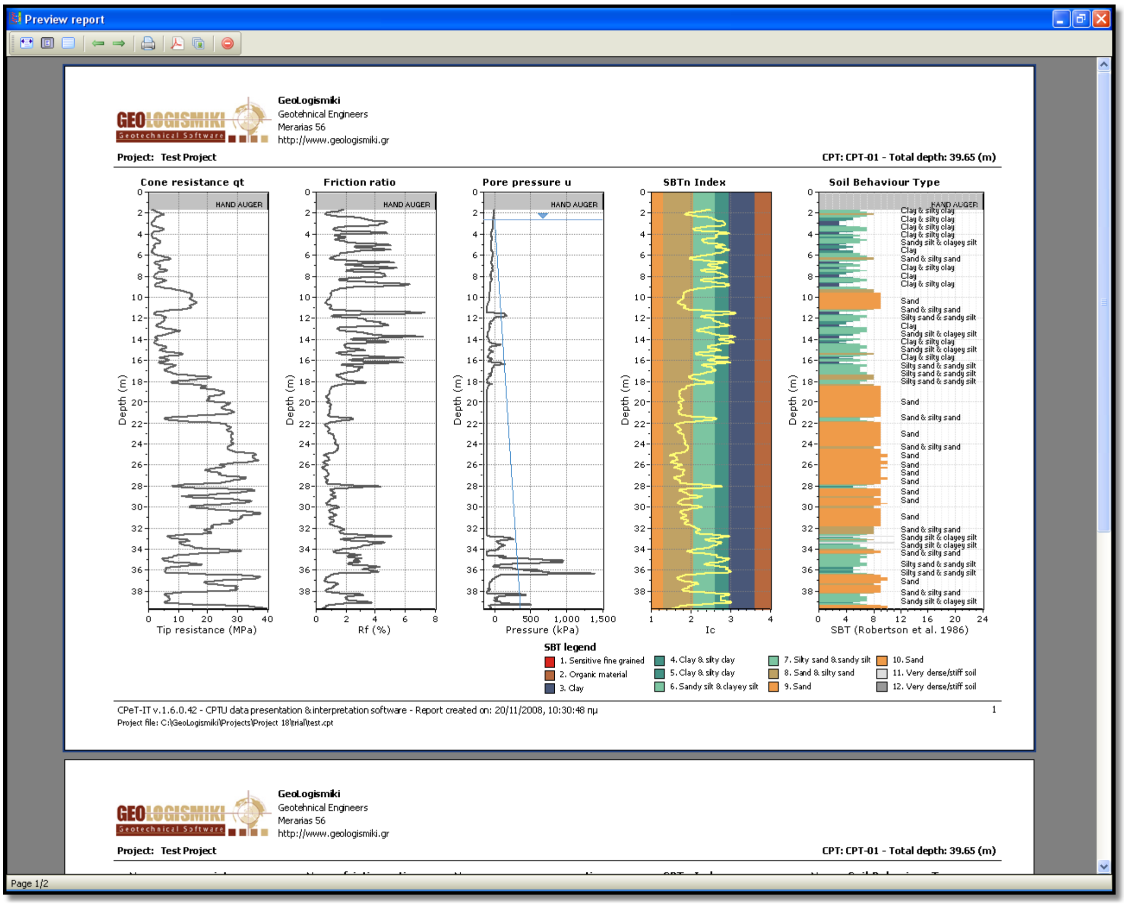
The software provides seven (7) single reports that may be included in any combination in the final generated report. From the *Reports* menu select *Report Pages Settings* or alternatively click on the  icon of the main toolbar. The following dialog appears:



Report pages

Check the pages needed in the report and click the *OK* button to accept the changes. Next time a single report or an overall report is created will include only the pages selected from the previous dialog.

In all report pages the header will display data defined from the *Project parameters* command



Sample basic report

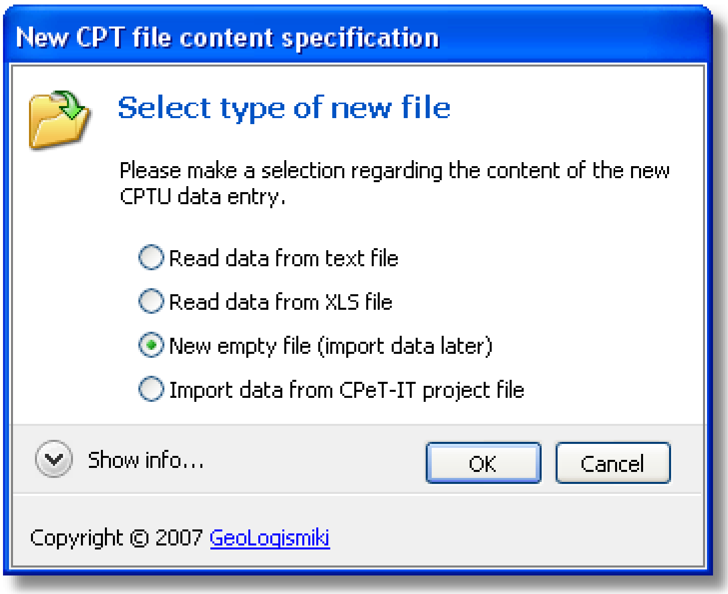
From within the report dialog you may export pages directly to a PDF file or image files.

4 Advanced features

Some advanced features and techniques are presented below.

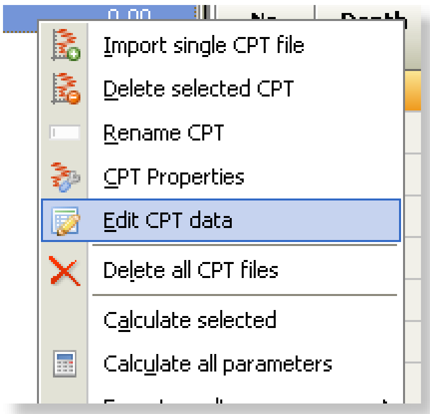
4.1 Importing data from other applications

It is not always necessary to provide the software with an ASCII text file in order to import data. You may use the standard copy and paste procedure between any application that can handle tabular data and CPeT-IT, simply by editing an empty data file. From the content specification dialog click on the *New empty file* radio button.

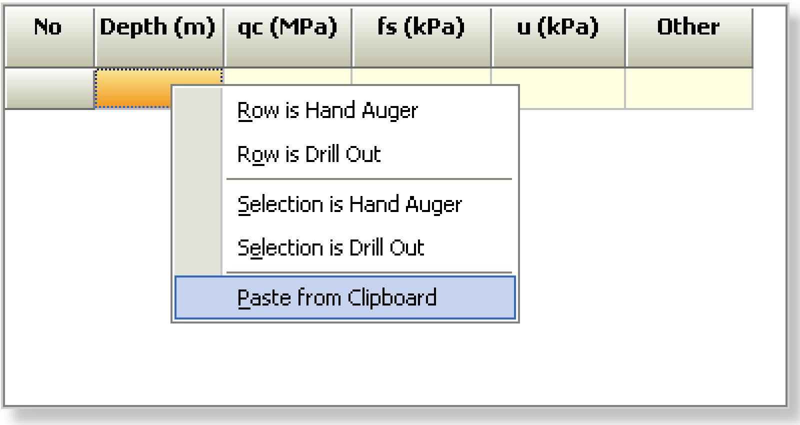


Create a new empty CPTU file

A new empty CPTU entry will be added in the list. Right click on it and from the pop up menu select *Edit CPT data*.



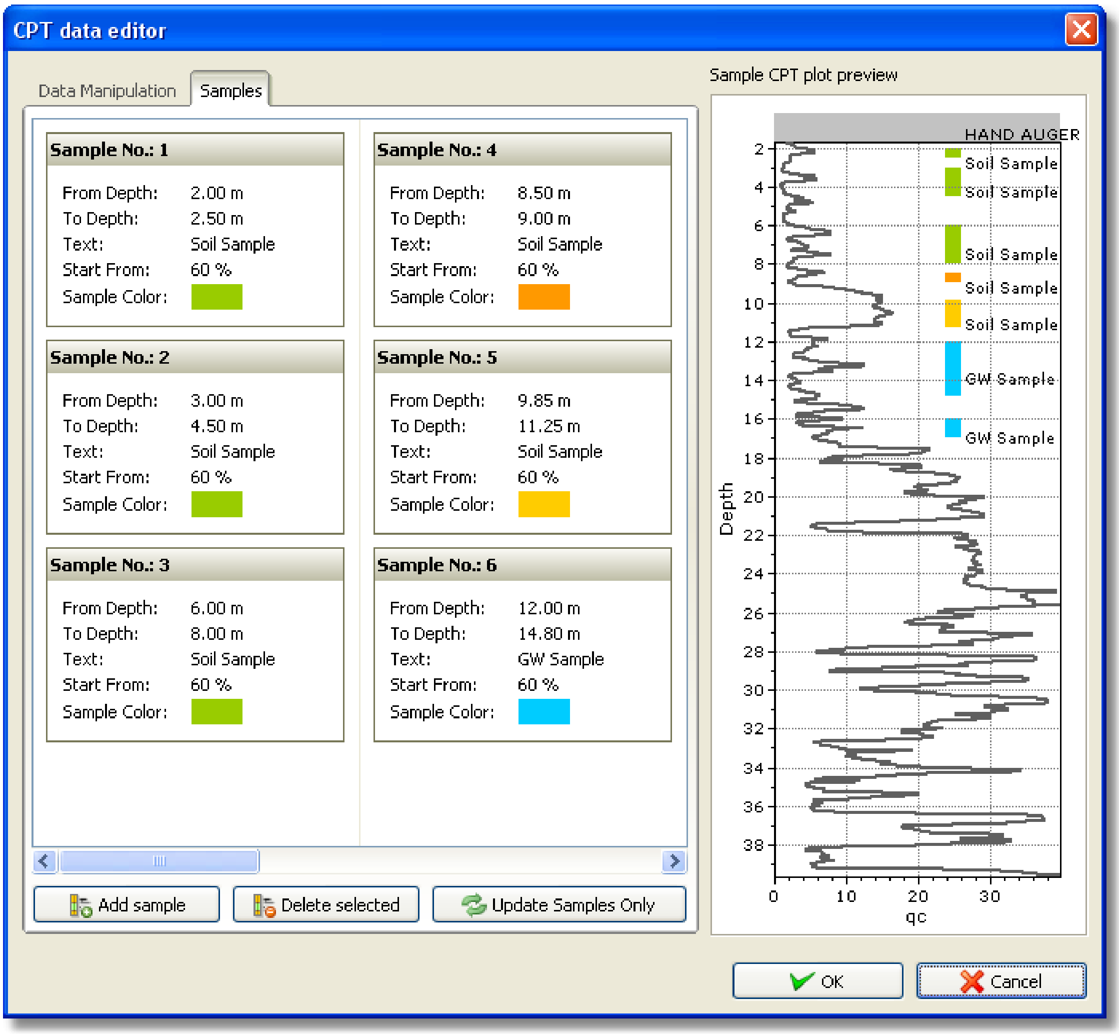
From your spreadsheet application select the data that contain depth values and copy them. In the *CPT data editor* dialog right click on the first empty cell in the depth column and from the pop up menu select *Paste from Clipboard*.



The software will create as many rows as needed to fit all the data from memory. Repeat the same procedure for other values (cone resistance, sleeve friction an pore pressure). You must always have in mind to paste data that comply with the project unit system.

4.2 Adding sample data

Since it is possible to collect small diameter, disturbed soil samples with the same CPT pushing equipment immediately after the CPT, you may need to display this information inside the raw cone resistance plot. Select a CPTU data and open the Edit CPT data command and click on the *Samples* tab located at the top of the dialog.



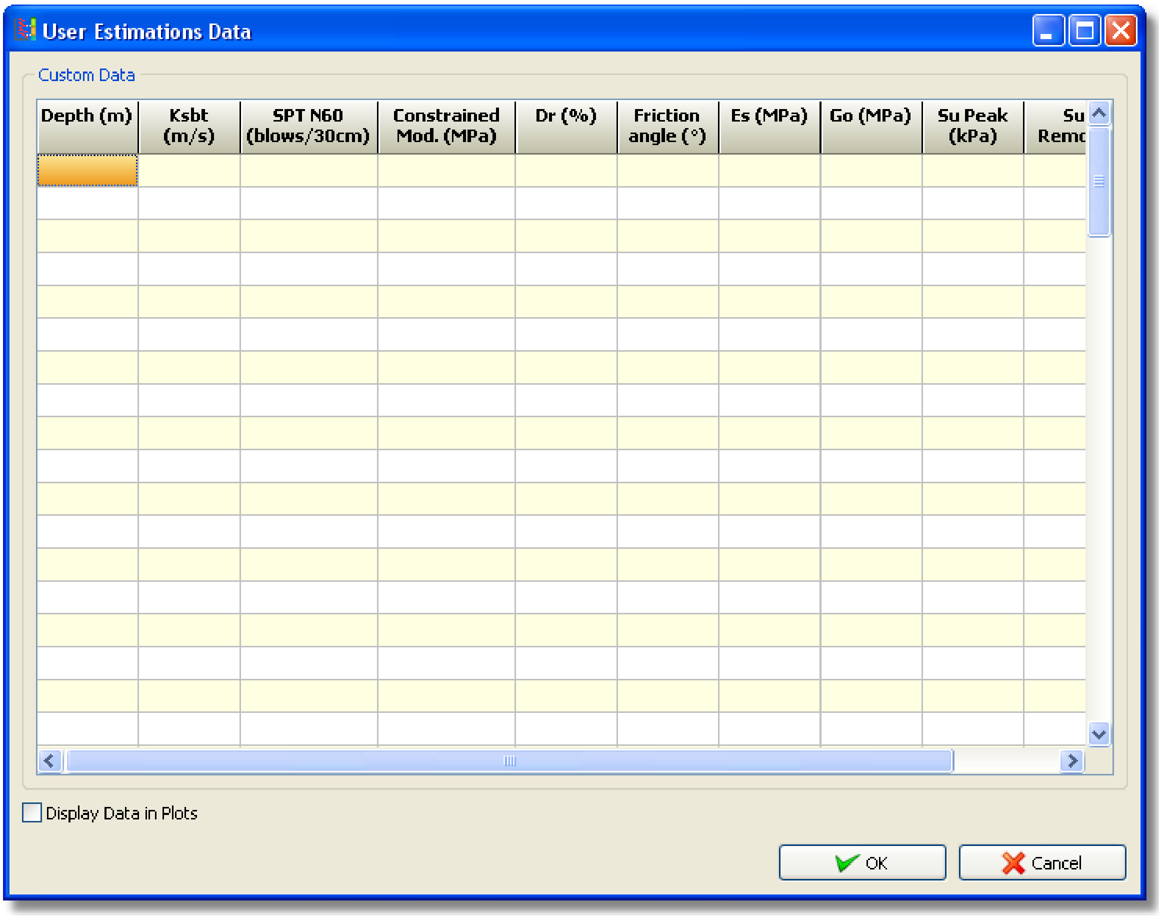
Samples tab in the CPT data editor

To insert a soil sample just click on the *Add sample* button and a new sample entry will appear at the end of the samples list. In the *From* edit box enter the depth from where the sampling procedure began. In the *To* edit box enter the depth where the sampling procedure stopped. In the *Start From* edit box you may enter a value which denotes the relative distance to the plot width from where the sample will appear. Click on the color box to define a custom color for the sample.

To delete all samples from the current CPTU click on the *Clear all* button. To delete only the selected one click on the *Delete selected* button. Clicking on the *Update Samples Only* button will close the dialog and save only the samples information.

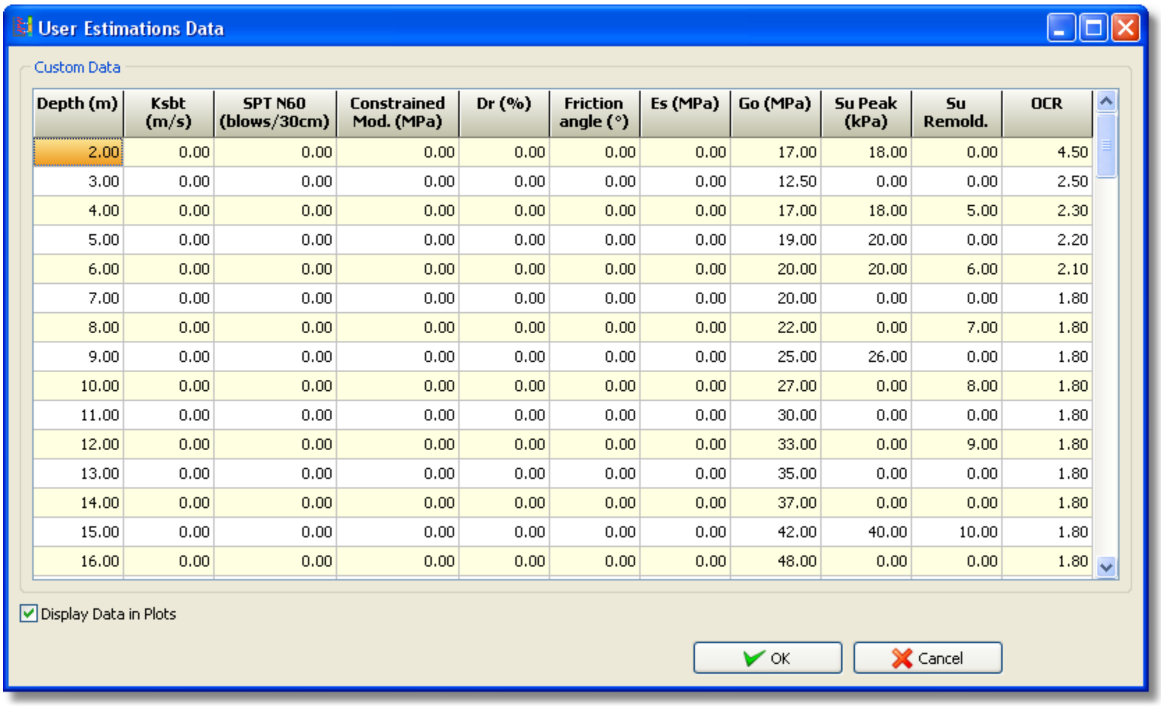
4.3 Adding custom estimations data

It is possible to plot soil parameter data measured by other means like laboratory tests, over the estimations plots from CPTu. Click on the  icon located at the far right of the top toolbar and the following dialog will appear:



Custom estimations input dialog

Using the above displayed table enter depth and soil parameter values. When finished check the *Display Data in Plots* checkbox and click the *OK* button. Custom estimations data will now be plotted over the CPTu estimations plot in red dotted line.



User Estimations Data

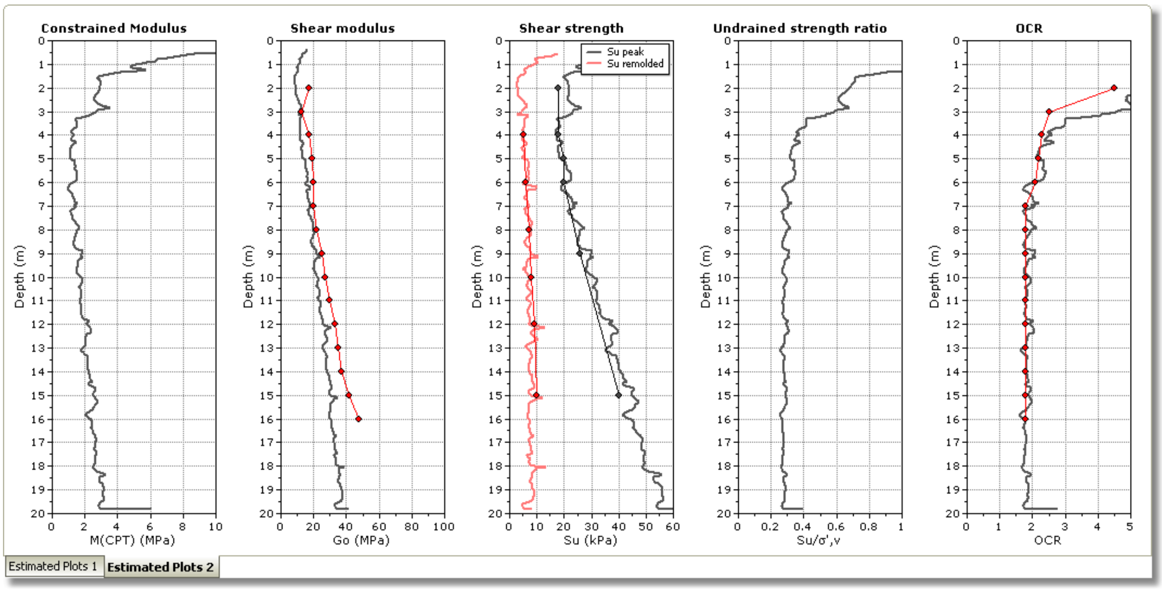
Custom Data

Depth (m)	Ksbt (m/s)	SPT N60 (blows/30cm)	Constrained Mod. (MPa)	Dr (%)	Friction angle (°)	Es (MPa)	Go (MPa)	Su Peak (kPa)	Su Remold.	OCR
2.00	0.00	0.00	0.00	0.00	0.00	0.00	17.00	18.00	0.00	4.50
3.00	0.00	0.00	0.00	0.00	0.00	0.00	12.50	0.00	0.00	2.50
4.00	0.00	0.00	0.00	0.00	0.00	0.00	17.00	18.00	5.00	2.30
5.00	0.00	0.00	0.00	0.00	0.00	0.00	19.00	20.00	0.00	2.20
6.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	20.00	6.00	2.10
7.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	0.00	0.00	1.80
8.00	0.00	0.00	0.00	0.00	0.00	0.00	22.00	0.00	7.00	1.80
9.00	0.00	0.00	0.00	0.00	0.00	0.00	25.00	26.00	0.00	1.80
10.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00	8.00	1.80
11.00	0.00	0.00	0.00	0.00	0.00	0.00	30.00	0.00	0.00	1.80
12.00	0.00	0.00	0.00	0.00	0.00	0.00	33.00	0.00	9.00	1.80
13.00	0.00	0.00	0.00	0.00	0.00	0.00	35.00	0.00	0.00	1.80
14.00	0.00	0.00	0.00	0.00	0.00	0.00	37.00	0.00	0.00	1.80
15.00	0.00	0.00	0.00	0.00	0.00	0.00	42.00	40.00	10.00	1.80
16.00	0.00	0.00	0.00	0.00	0.00	0.00	48.00	0.00	0.00	1.80

Display Data in Plots

OK Cancel

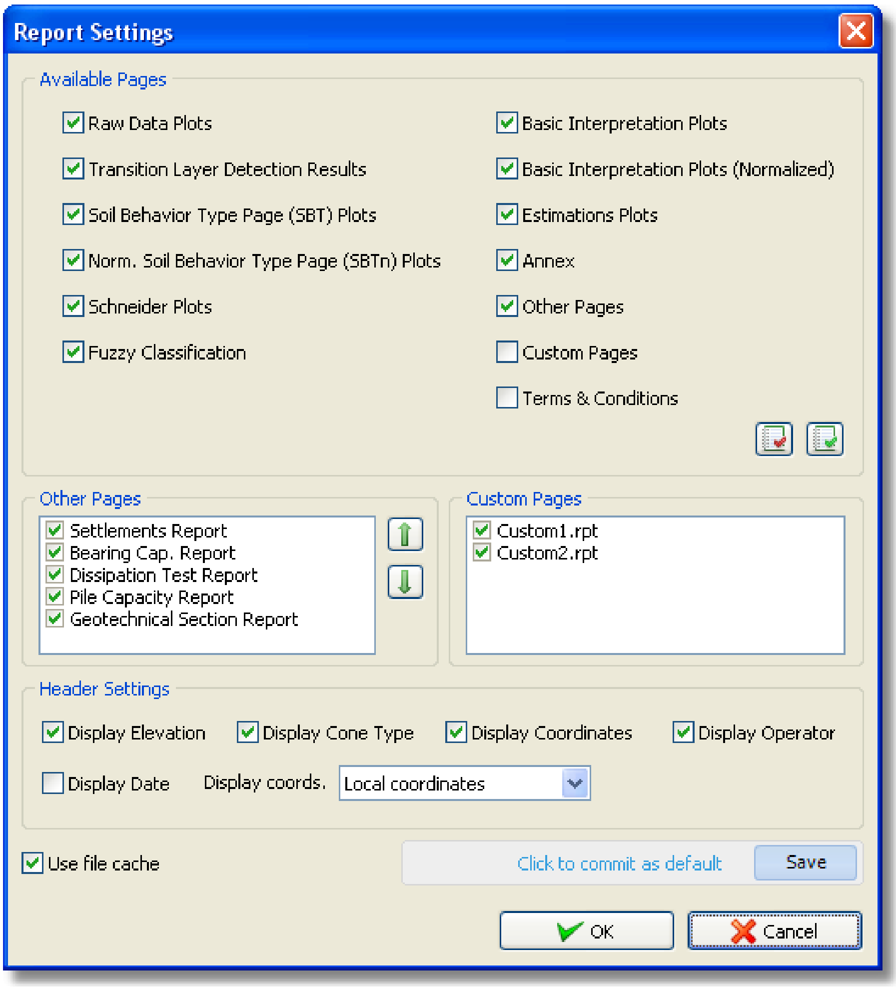
Custom estimations data



Estimations plots with custom data

4.4 Customizing Reports

To customize the interpretation report generated, click on the *Report Pages Settings command* under the *Reports* menu or alternatively click on the button on the main toolbar. The following dialog will appear:



Report settings dialog

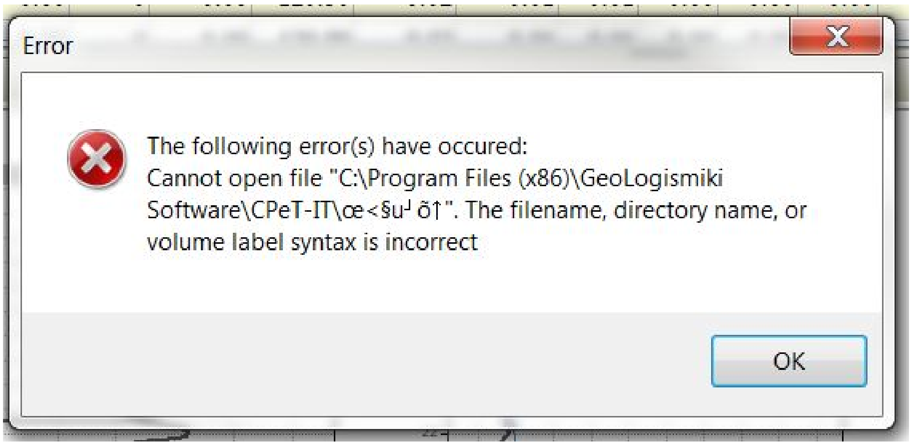
From *Available Pages* section you can select which pages you would like to be included in the report. Click on the  button to deselect all pages or  to select all.

From *Other Pages* section you can select additional pages generated from the various software modules. The selected pages will appear after the interpretation pages and in the order that appear inside the list. To rearrange the list use the   buttons to move the selected entry up or down respectively.

From *Custom Pages* section you can select the custom report pages you wish to appear on the report. The pages will appear only if you have previously checked the *Custom Pages* check box inside the *Available Pages* section.

Finally, from *Header Settings* you can select the information you wish to appear inside the header of each report page.

In some Windows® 7 systems, strict user security settings do not allow the software to create some temporary files needed from the creation of a report, so an error message appears when trying to create a report which looks like the following:

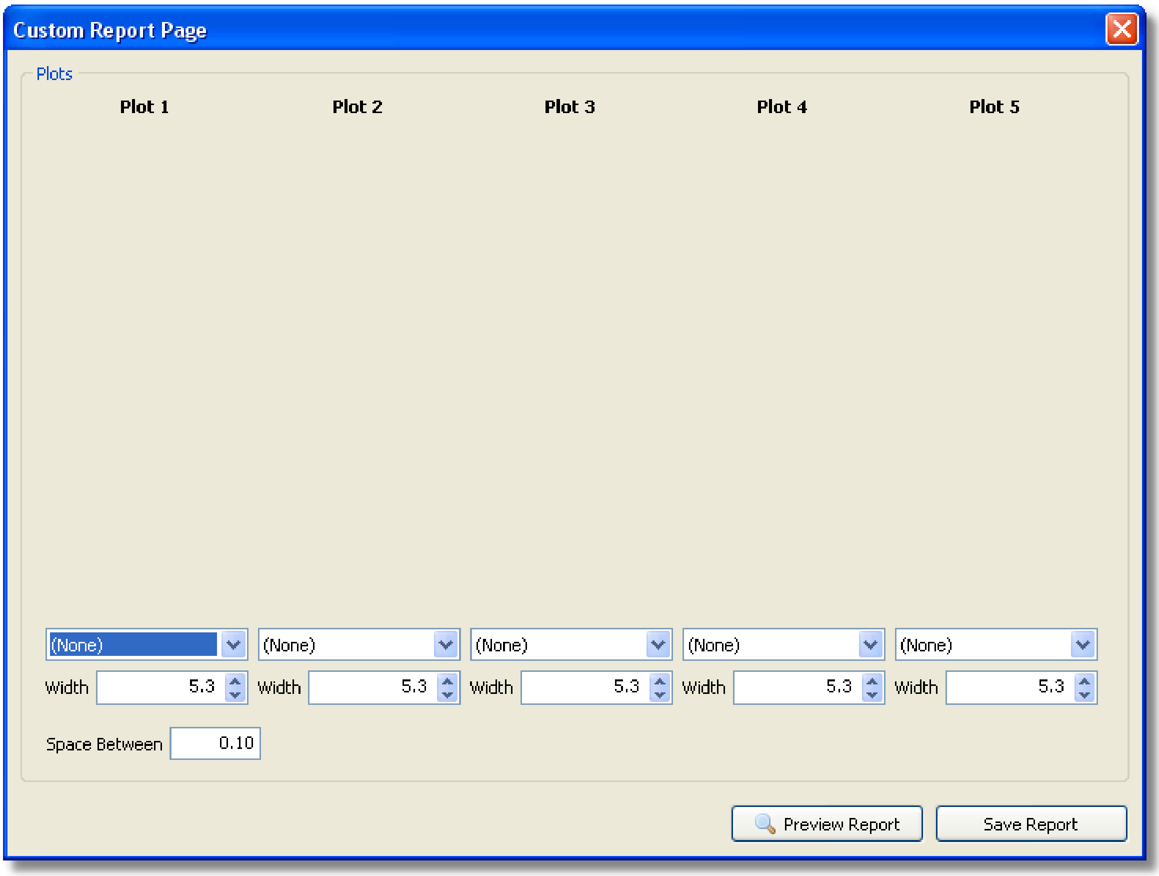


Error message when trying to create a report

To avoid this error make sure to uncheck the *Use file cache* check box.

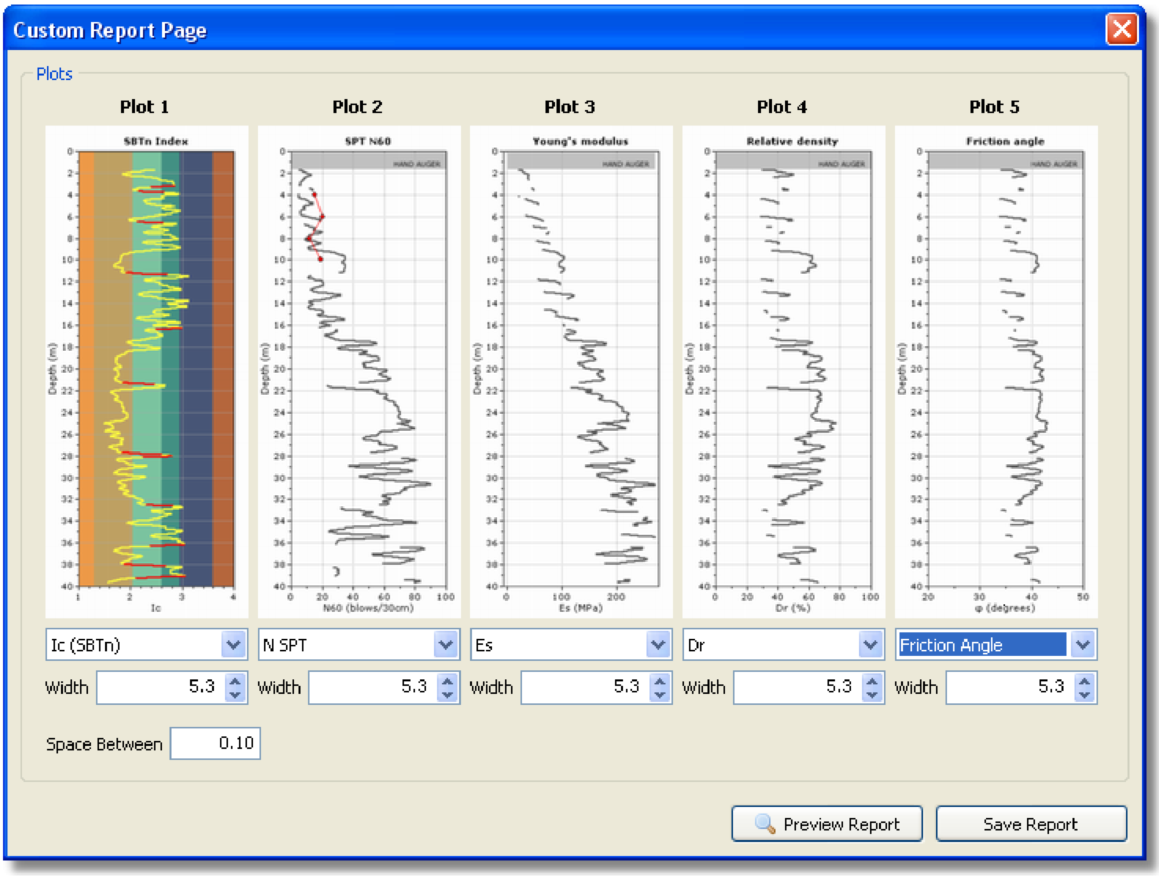
4.4.1 Custom Report Page

A custom report page can be created by calling in order to present any of the interpretation plots available. Click on the  button on the main toolbar or select the *Custom Report Page* command from the *Reports* menu.



Custom report page dialog

You may use up to 5 plots that will be presented on the page (the page layout will be in landscape). Width of the plots and the distance between them can be edited using the according *Width* edit boxes and *Space Between* edit box.

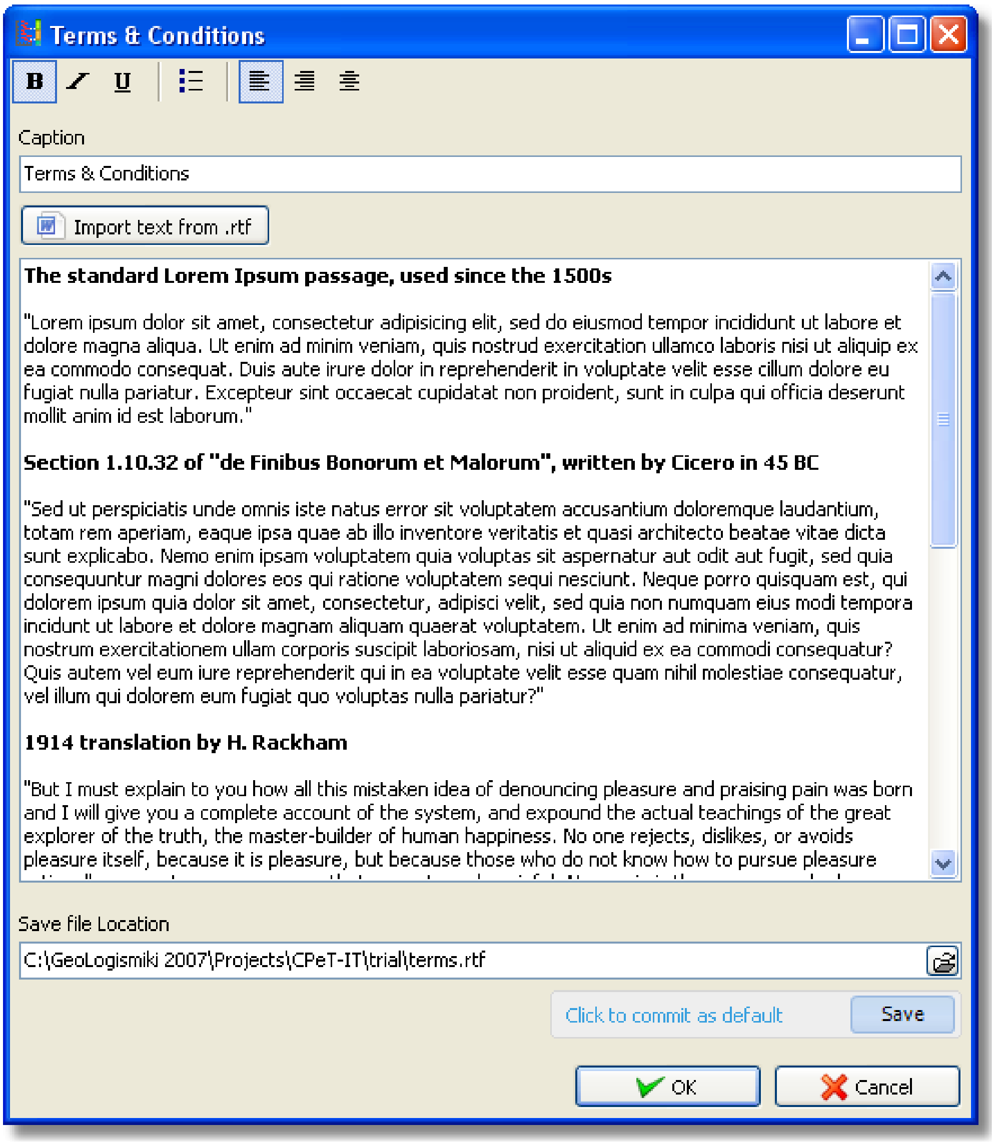


Custom report page dialog with plots selection

Click on the *Save Report* button to save the custom report. The report file should be placed on a specific directory inside the *Reports* directory of the software. In case the directory does not exist the software will ask you to create it so you will need to allow that operation.

4.4.2 Terms & Conditions

A special report page can be presented at the very end of the generated reports that most commonly will contain the terms and conditions or privacy terms for the generated estimations.

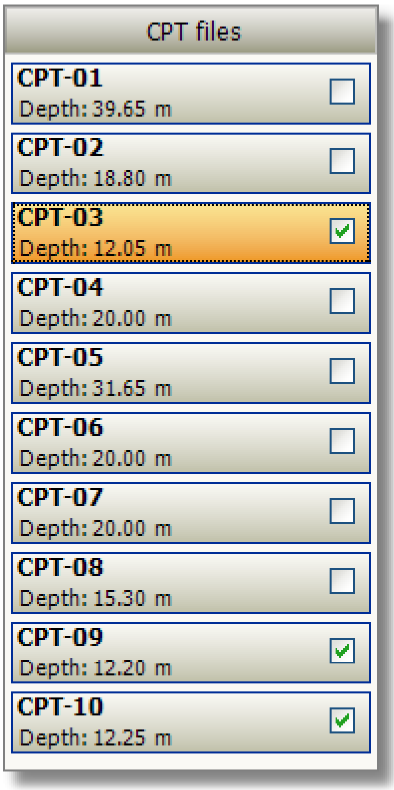


Terms & Conditions dialog

Click on the *Import text from .rtf* button to import text from an RTF file or alternatively you may copy and paste the file contents from your word processor application into the text area. The software needs to know the file name to use when displaying this page so the *Save file location* area needs to be filled with the appropriate information.

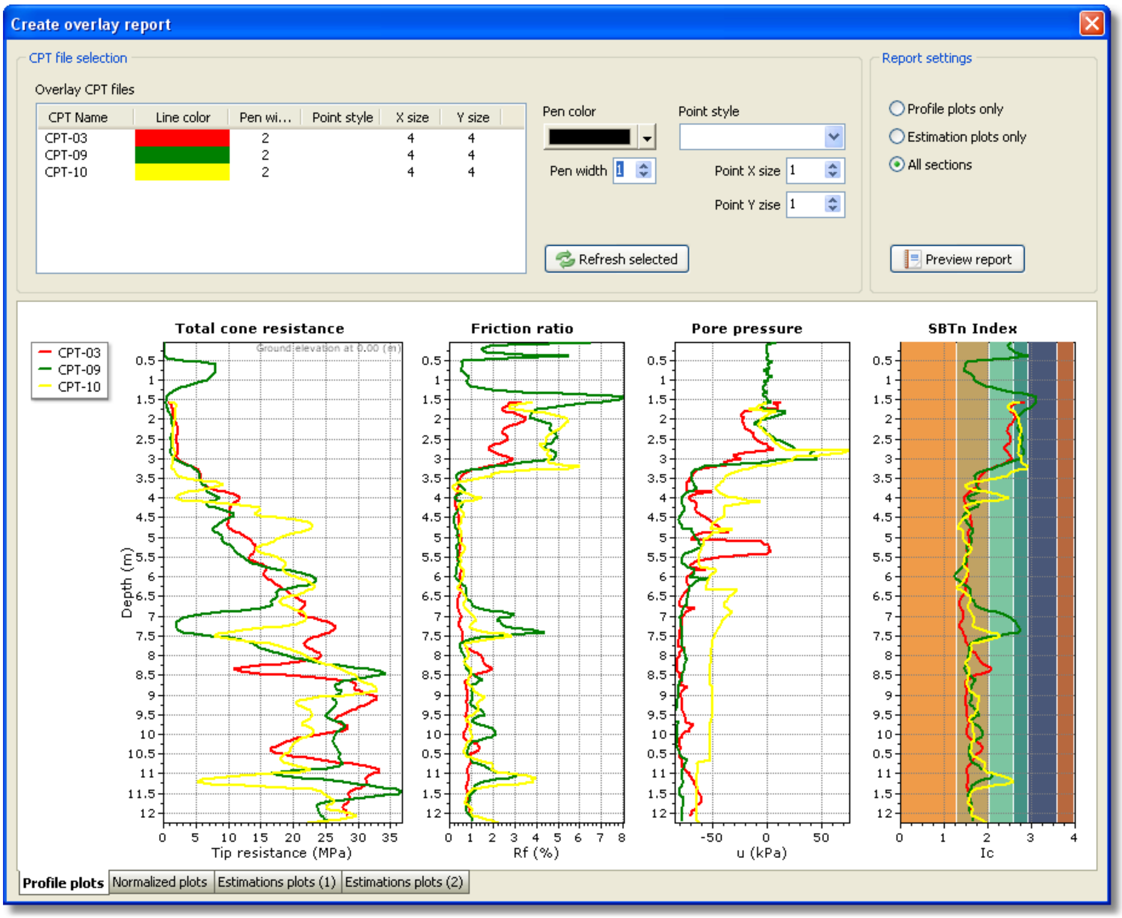
4.5 Creating overlay report

Overlay reports provide a visual mean of comparing CPTU data over depth. In order to initiate the creation of an overlay report you must first check any CPTU file inside the list.



Selected CPTU files will be included in overlay report

Click on the *Reports* menu and select the *Create overlay report* command. The following dialog appears:



Overlay report dialog

The software will create all necessary plots using default settings regarding the color of line used, point style for each line, plot scales etc. You may customize plot scales in a way similar to the one described here. If you wish to alter the way each CPTU file is plotted you must first select the file from the *Overlay CPT files* list box. CPeT-IT will display the visual properties of the selected CPTU file. You may alter the following attributes:

1. Pen color: From the *Pen color* drop down box you may define a different color for the plot line of the selected CPTU file.

2. Point style: The *Point style* drop down list contains point styles that you may apply to the selected CPTU line.

3. Point size: Using The *Point X size* and *Point Y size* spin edit boxes you may alter the dimensions of the points.

4. Pen width: The number inside the *Pen width* spin edit box defines the thickness of the CPTU plot line

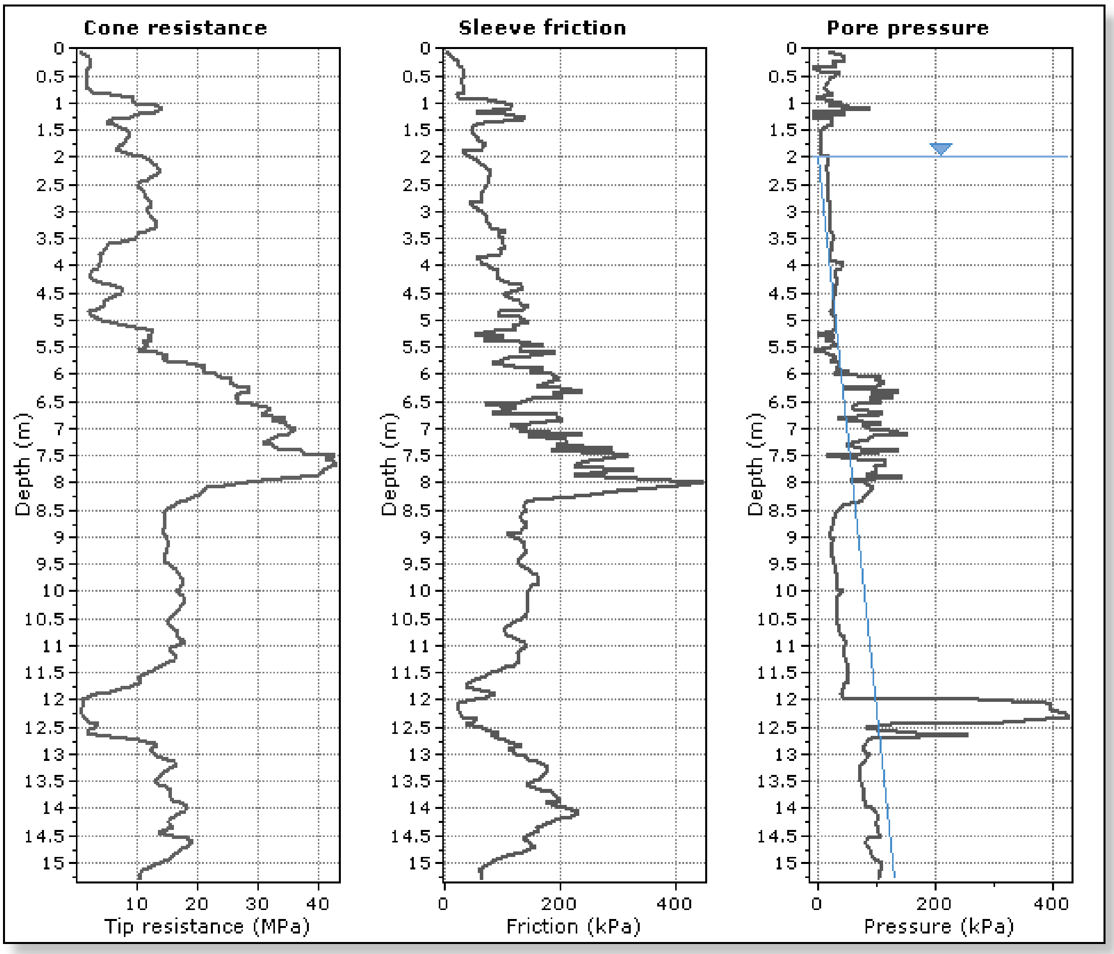
To apply the changes made you must click on the Refresh selected button. Immediately the selected CPTU file will appear eoth the newly entered properties.

To preview and print an overlay report just click on the *Preview report* button. According to the radio button that is checked the report can display the profile plots only, the estimation plots only or profile and estimation plots.

4.6 Working with plots

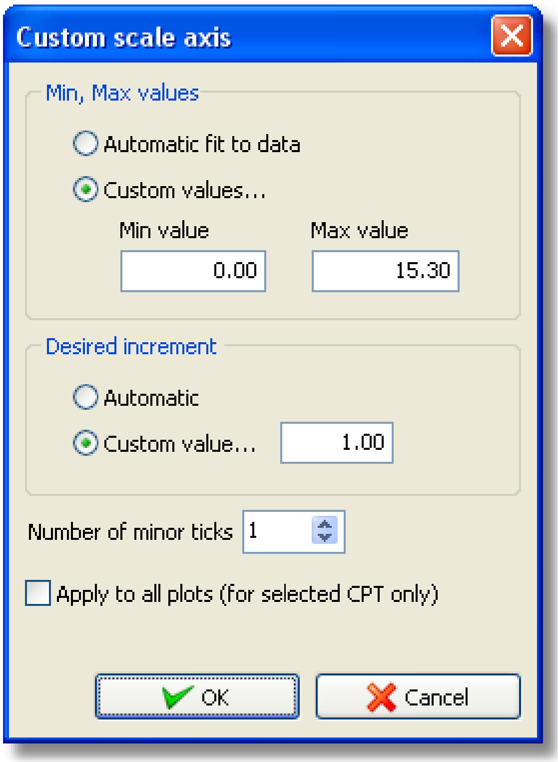
4.6.1 Customizing plots

By default, when importing CPTU data, all plots use an auto scale feature to fit the data in both vertical and horizontal axes. CPeT-IT allows you to modify the scale of the axes by setting custom minimum and maximum display values. Consider the raw input plots below:



Sample raw data plots

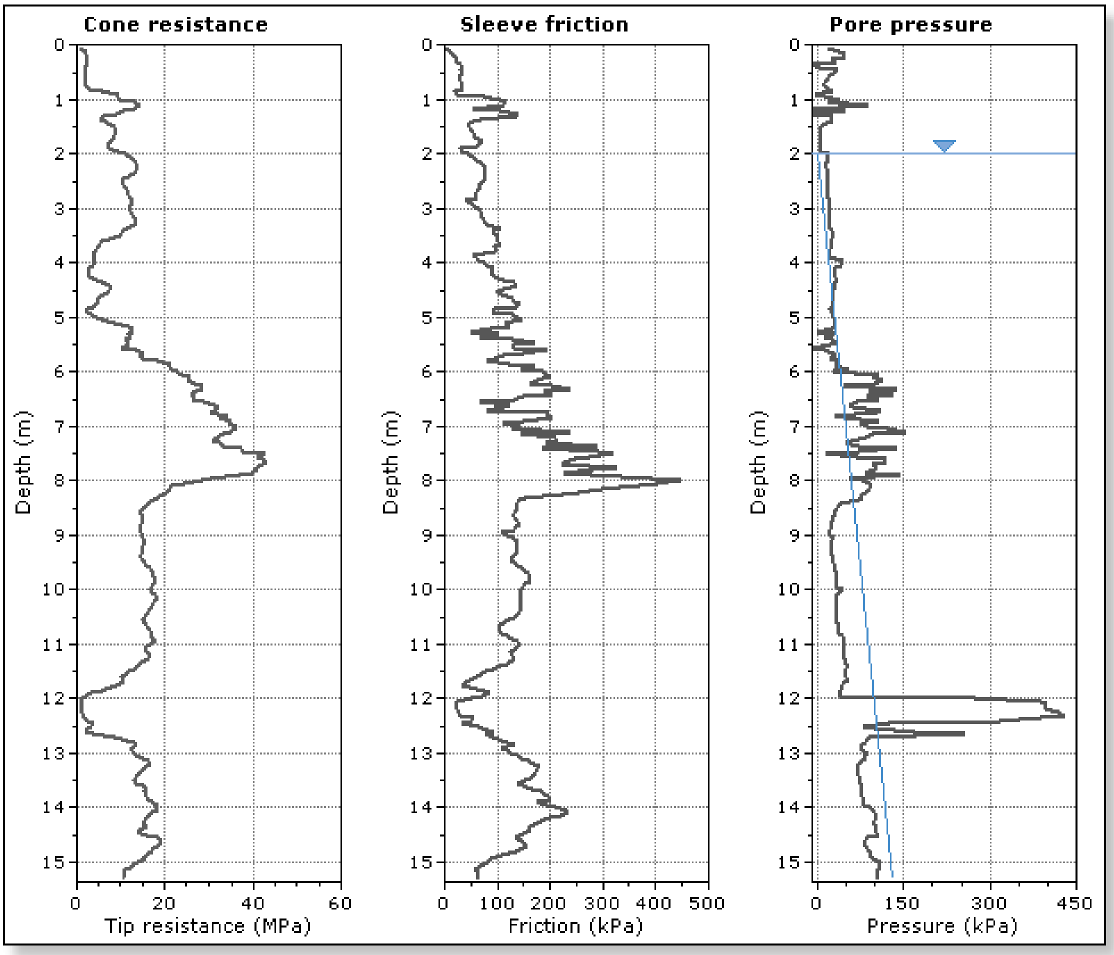
In order to customize the vertical axis just click on anyone of them. The following dialog appears:



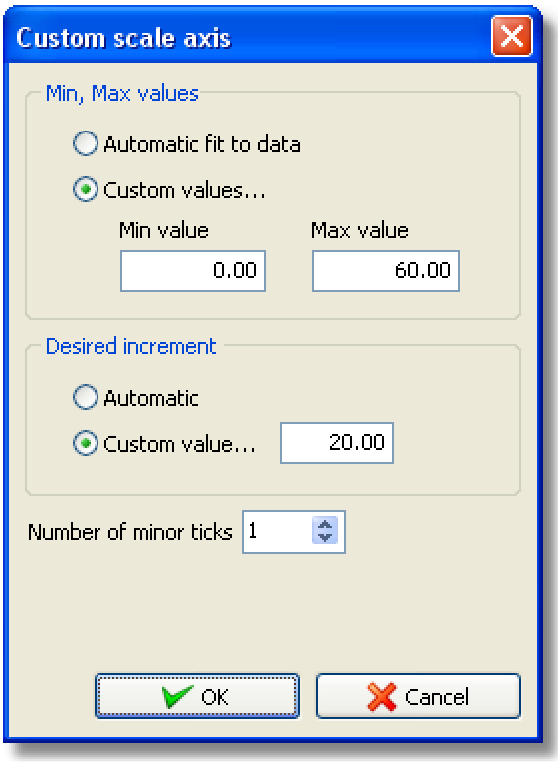
The dialog will display the current axis scaling values, which are set to Automatic by default. You may alter the minimum and maximum values that the axis can display by entering data on the *Min value* and *Max value* edit boxes. Entering a custom value in the *Desired increment* area the plot will try to display a label using this value as a step. For example you may need to display the depth value every one meter so just enter 1.00 into the associated edit box. The *Number of minor ticks* should be an integer value which denotes the number of minor ticks between two depth increments.

Since the vertical axis displays a common variable for all graphs (depth) checking the *Apply to all plots* checkbox will instruct the software to apply all changes made to all plots, except the SBT charts. This feature is only available when editing a vertical axes.

In a same manner you can alter the properties for the horizontal axis of each plot, making them look like:

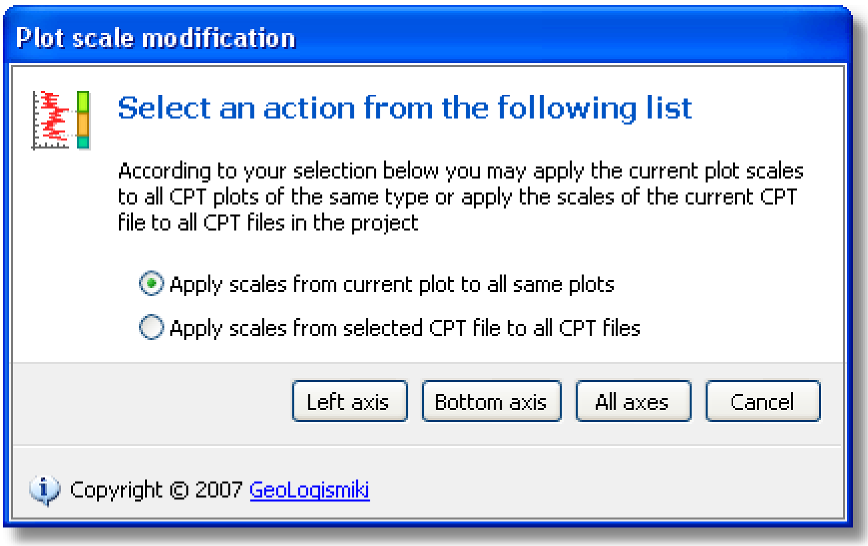


Sample raw plots with custom axes properties



Horizontal axes properties for the above Sleeve Friction plot

All the above made changes apply only to the current selected CPTU file. In order to apply the scales defined in one CPTU file to all CPTU files in the current project you must double click inside any plot. The following dialog will appear:



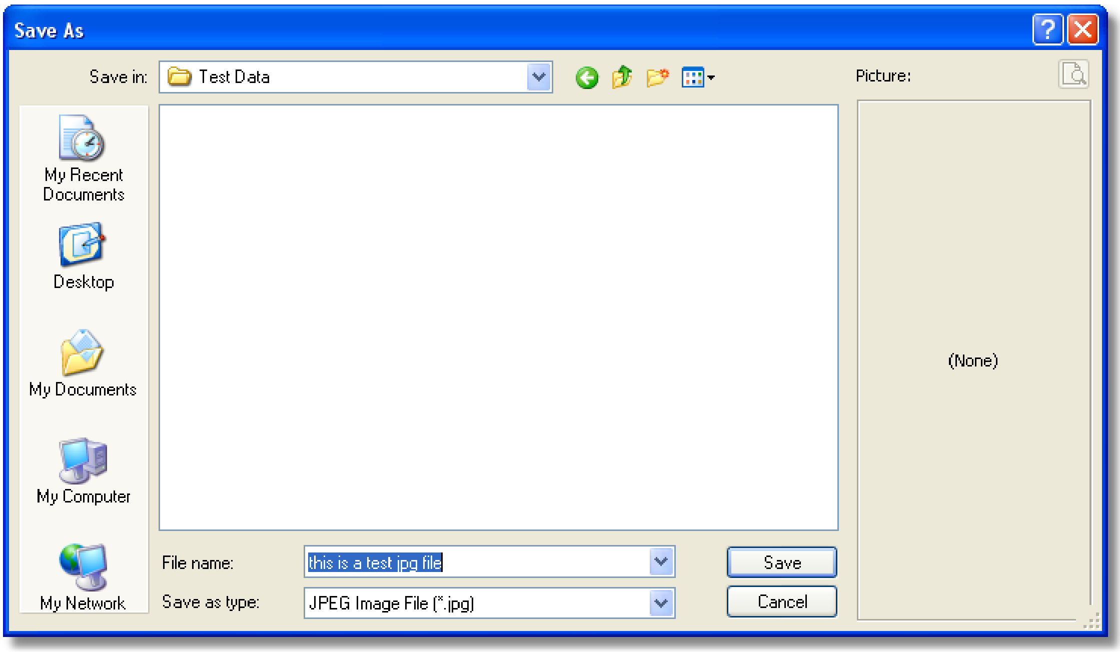
According to your selection you may apply the current plot scales (only for the plot where you double clicked) to all plots of the same type for all CPTU files or transfer the plot scales from all graphs in the selected CPTU file to all other plots for all CPTU files in the current project. You may also apply changes only for the left axes or bottom axes or all axes.

4.6.2 Exporting plots

You may export plots in different file formats (GIF, JPG or PNG) by right clicking on a plot. From the pop up menu select the *Export plot as graphic* command. The following dialog will appear:

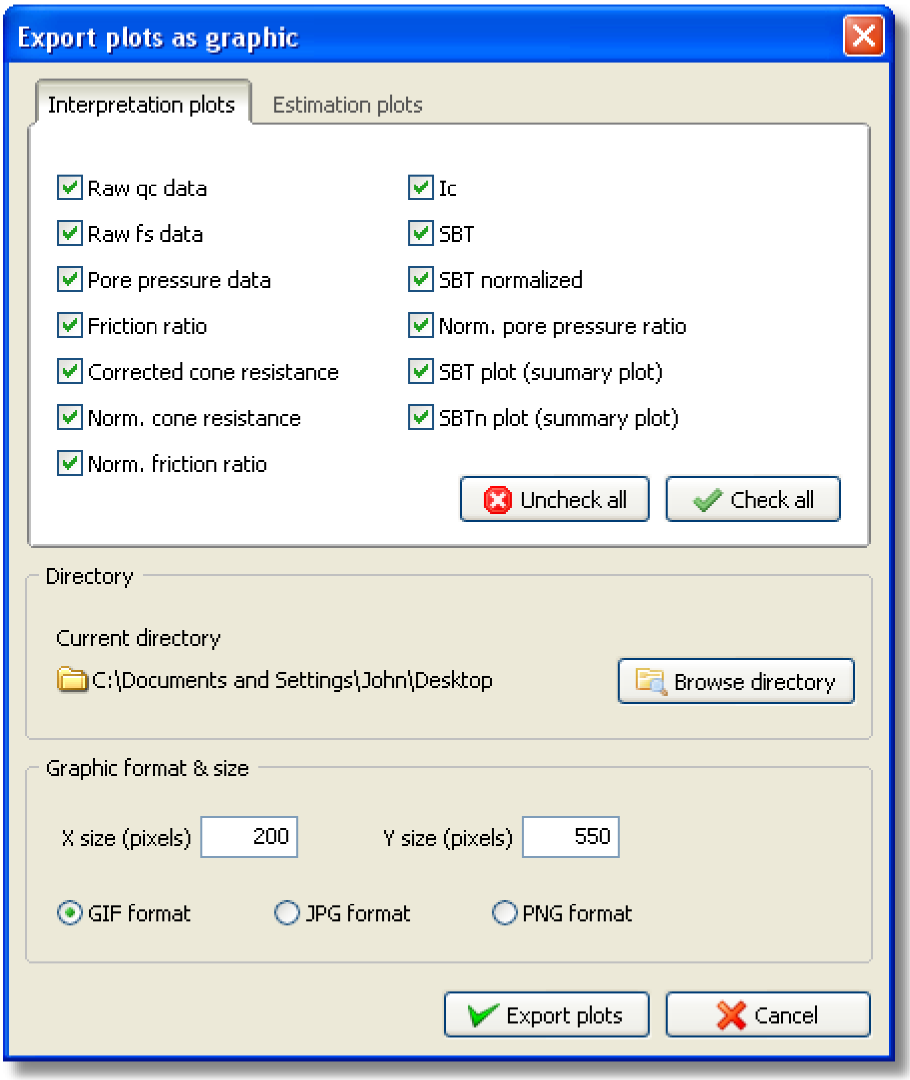
File format selection

Select the appropriate format of the graphic file you wish to create and click on the *OK* button. From the dialog that appears next, navigate to the directory you wish to save the file, enter the file name (without any extension) and click *Save.*



File save dialog

The above procedure exports the selected plot using the dimensions that are visible to the user. If you wish to export all plots using custom dimensions select the *Export plots as graphic* command from the menu *CPT data..Export*. The following dialog will appear:



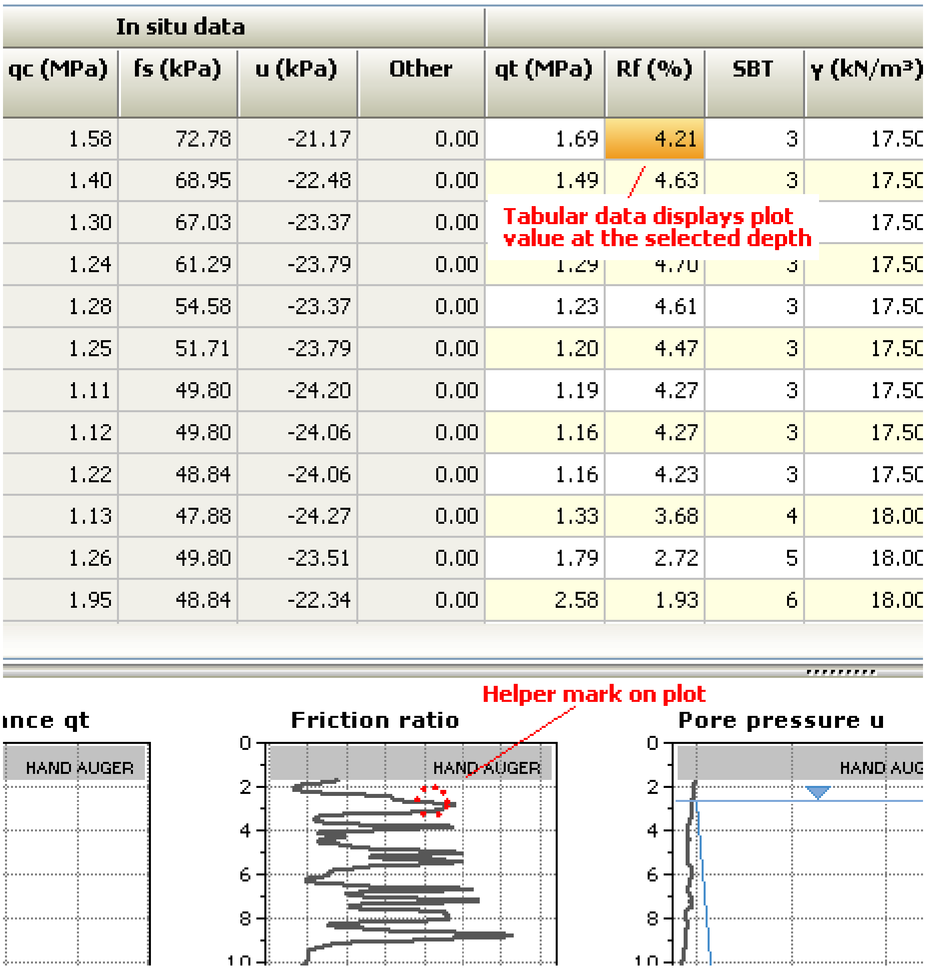
Export plots dialog

From the two (2) tabs you may select the plots you wish to export. Use the *Browse directory* button to navigate to the directory you wish to save the exported plots (the current directory is displayed under the *Current directory* label). Use the *X size (pixels)* and *Y size (pixels)* to define the size of the exported graphic file. After selecting the file format click on the *Export plots* button to complete this procedure.

> **Note**
>
> Plots are exported using fixed names. If you export plots to a directory where you previously exported plots from another project, old files will be overridden by new ones.

4.6.3 Navigation helper tool

If you need to locate numeric data (input data or estimations) for points from a plot, hold the SHIFT key on your keyboard while moving your mouse over the plot. There will be a red mark pointing to the closest CPT point and according to the plot, the tabular data will focus on the specified variable.



In situ data							
qc (MPa)	fs (kPa)	u (kPa)	Other	qt (MPa)	Rf (%)	SBT	γ (kN/m³)
1.58	72.78	-21.17	0.00	1.69	4.21	3	17.50
1.40	68.95	-22.48	0.00	1.49	4.63	3	17.50
1.30	67.03	-23.37	0.00	[illegible]	[illegible]	[illegible]	17.50
1.24	61.29	-23.79	0.00	1.29	4.70	3	17.50
1.28	54.58	-23.37	0.00	1.23	4.61	3	17.50
1.25	51.71	-23.79	0.00	1.20	4.47	3	17.50
1.11	49.80	-24.20	0.00	1.19	4.27	3	17.50
1.12	49.80	-24.06	0.00	1.16	4.27	3	17.50
1.22	48.84	-24.06	0.00	1.16	4.23	3	17.50
1.13	47.88	-24.27	0.00	1.33	3.68	4	18.00
1.26	49.80	-23.51	0.00	1.79	2.72	5	18.00
1.95	48.84	-22.34	0.00	2.58	1.93	6	18.00

4.7 Filtering CPT Data

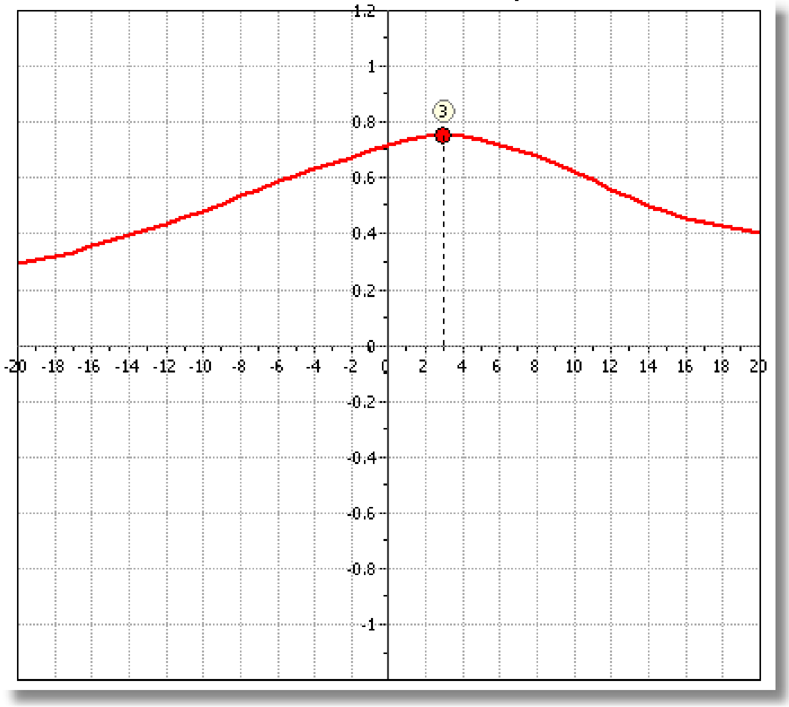
Sometimes, CPT data need some special processing to enhance the raw data values. The software provides the following filters:

- Cross Correlate
- Spike Filter
- Shift Raw Data
- Depth Correction

- Negative Value
- Convert u1 to u2

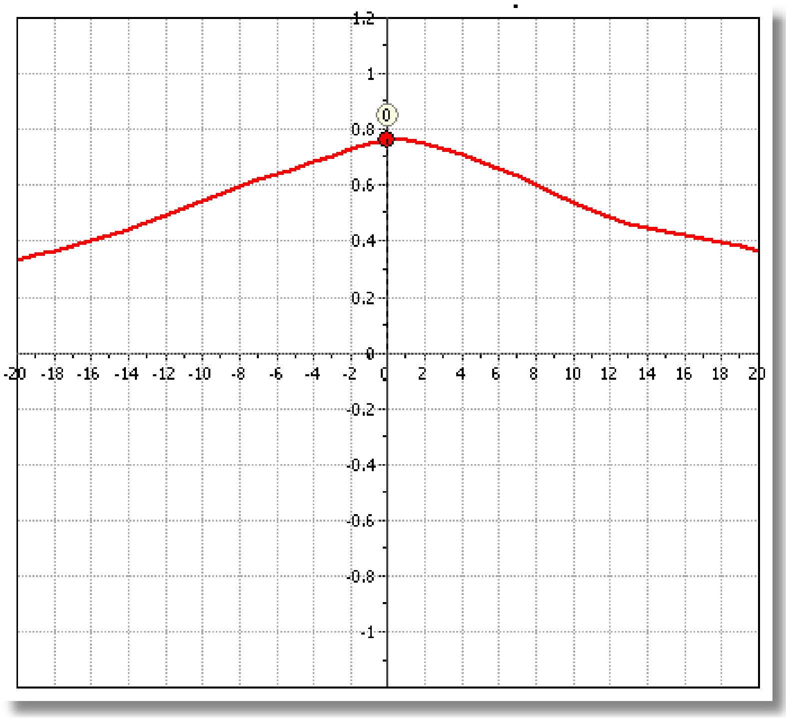
4.7.1 Cross Correlate

Since the cone tip physically is located at a distance below the center of the cone sleeve, the depth of a tip measurement is normally ahead from the sleeve measurement. The software uses the cross correlation function to analyze the relative position of qc and fs and proposes a shift value so that the two readings will "match".



Cross correlation plot

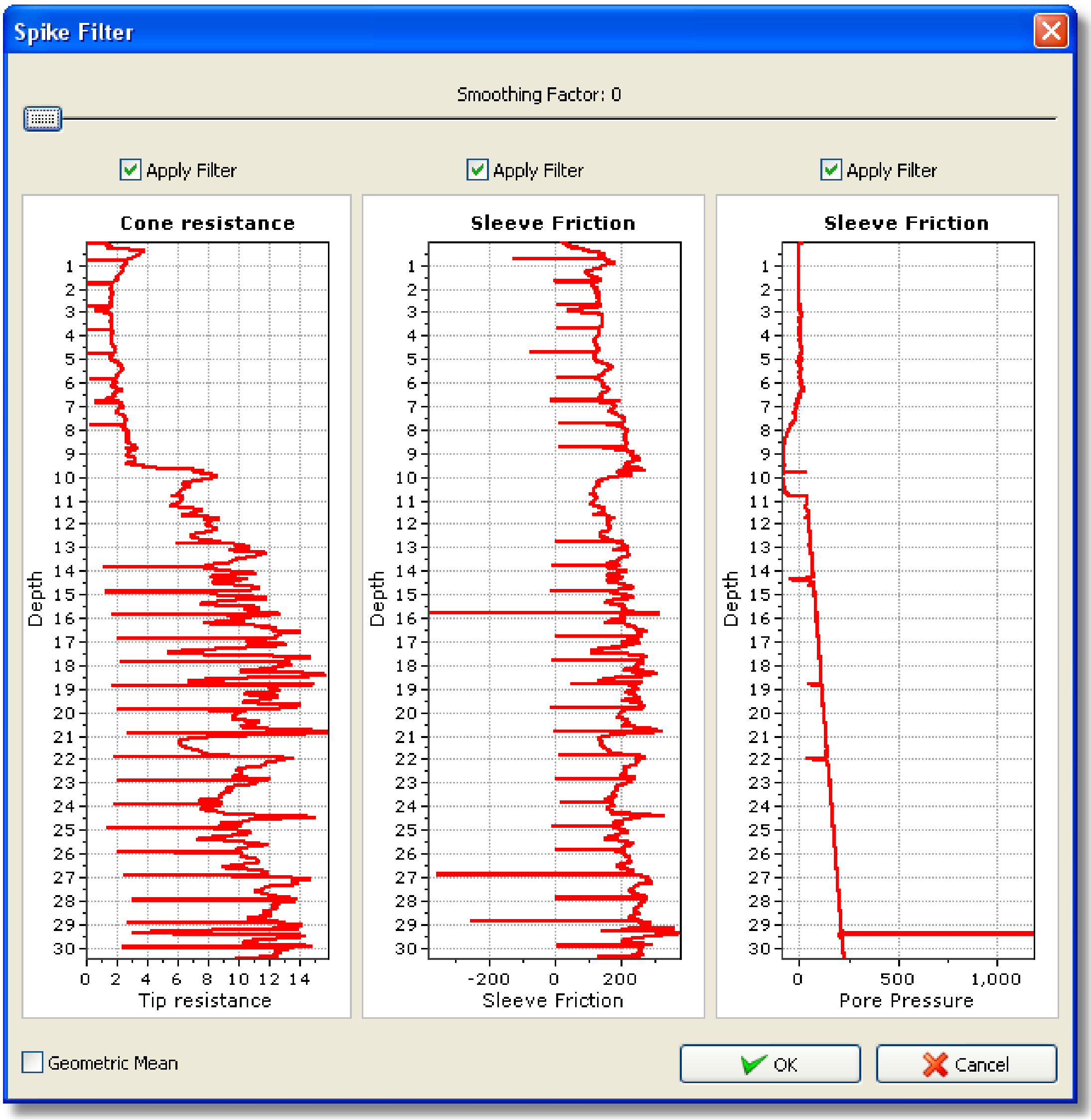
At the *Raw Data Plots* section the cross correlation displays a red dot with a number above it. When the value of the number is different than zero (0) then data need some processing. This value represents the lag number that is the interval steps needed to shift fs relative to qc (the interval step is defined as the distance between two successive CPT data readings). So, if the step interval is 0.05 cm and the lag number is 3 this means that the software estimates a relative shift of 15 centimeters. To apply the filter click on the cross correlate command and allow the software to proceed.



Cross correlation plot after the filter is applied

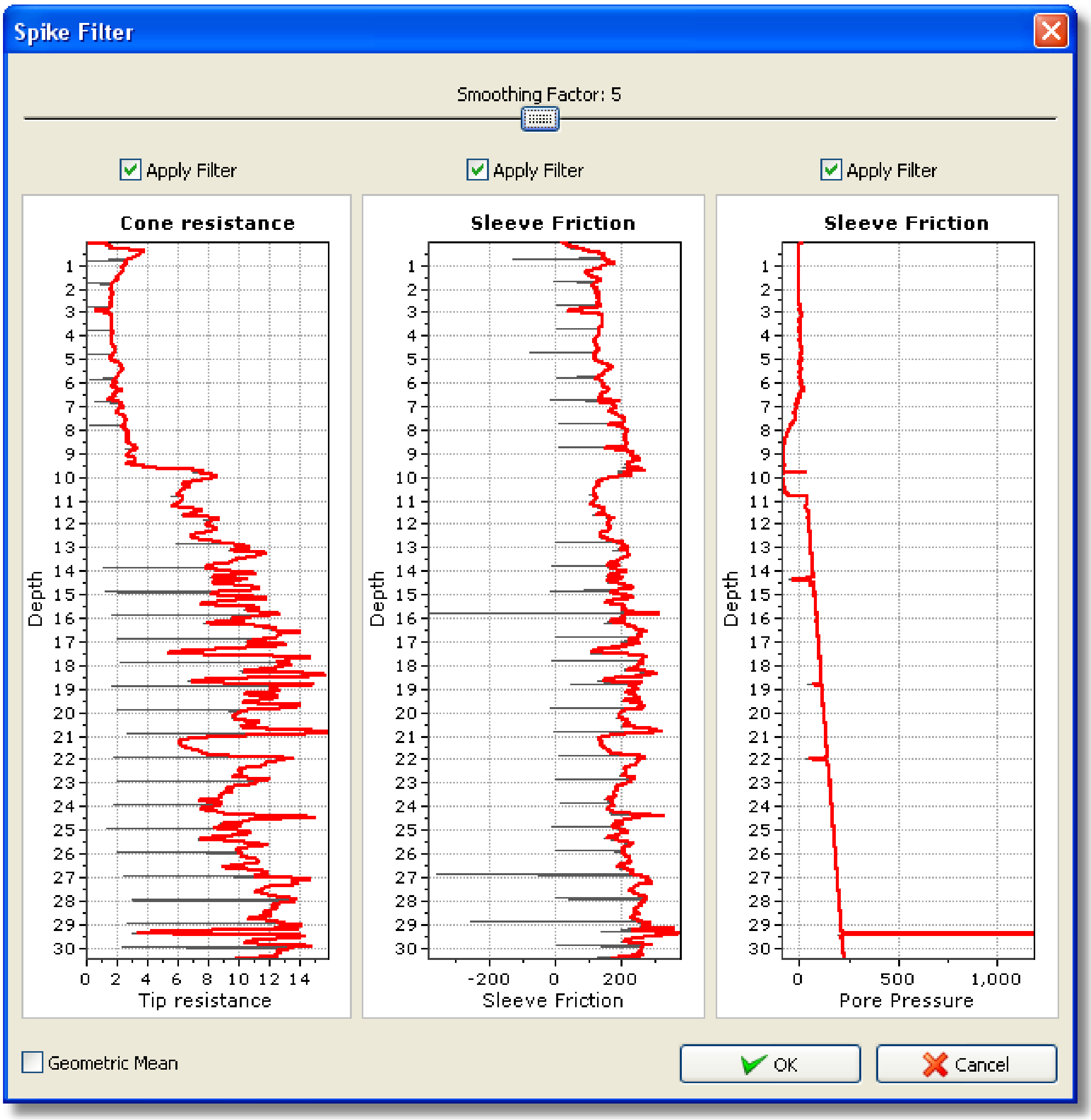
4.7.2 Spike Filter

During rod changing or when stopping for a dissipation test, qc and fs readings drop instantly and this results to spikes that can easily be removed using the spike filter. The filter dialog looks like the following:



Spike filter dialog

The red plot lines present the filtered values and the dark gray lines are the original raw values. The smoothing factor represents the nu,ber of times the filter will apply to the selected raw data (the *Apply Filter* check boxes should be checked in order for the filter to apply to the corresponding raw data).

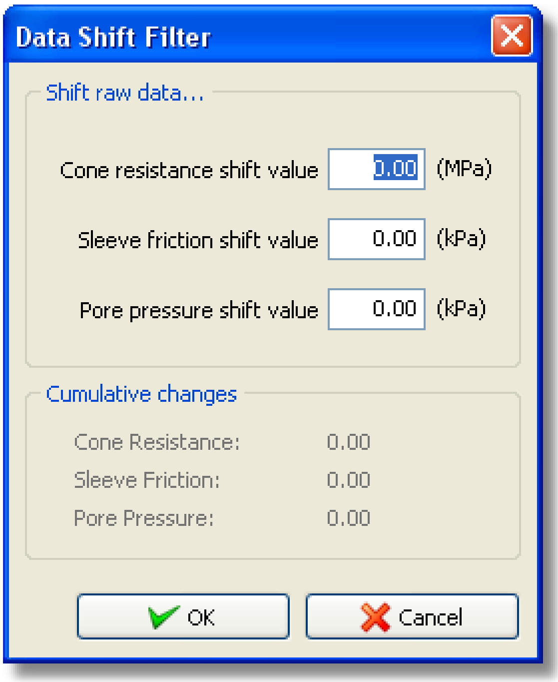


Filtered data preview

Filtered values are calculated based on the average values, by default the arithmetic mean is used but the geometric mean can be used if the *Geometric Mean* check box is checked.

4.7.3 Shift Raw Data

With the shift raw data filter you may add (or subtract) a fixed value from raw data. For example in cases where you penetrate a very soft soil and raw cone tip values are close to zero, most probably the interpretation will fail. Shifting qc to a larger value can help the interpretation processes.



Data shift dialog

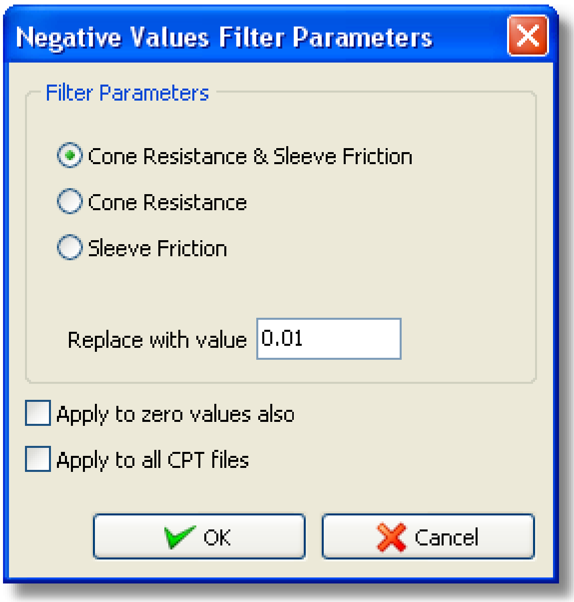
The software will monitor the changes made so that you can revert to the original values simply by entering the appropriate cumulative change.

4.7.4 Depth Correction

Depth correction is a simple filter that will adjust the penetration depth based on the inclination data. Inclination data should be imported in the "Other" data column in order for the filter to perform correctly.

4.7.5 Negative Values Filter

With this filter, negative raw data can be replaced with a custom value so that interpretation will not fail.

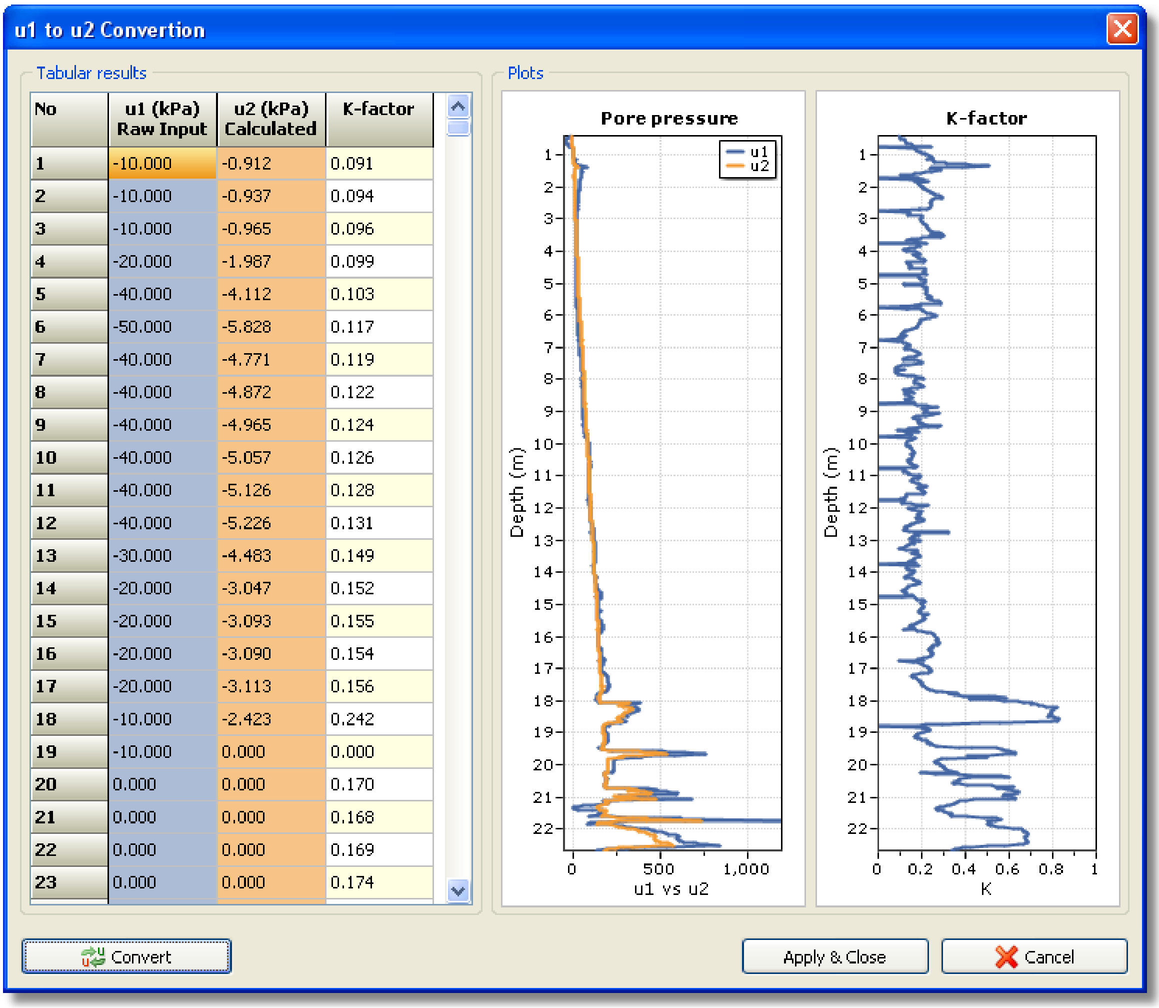


Negative filter dialog

The filter can be applied to negative values only or zero values (by checking the *Apply to zero values* check box). Checking the *Apply to all CPT files* will instruct the software to apply this filter to all CPT files currently imported to the project file.

4.7.6 Pore Pressure Converter

The software uses pore pressure measurements behind the cone tip u_2 for the interpretation but in case the pore pressure module is installed at the cone tip (u_1) this simple filter will try to make a conversion based on the work of J. Peuchen, J.F. Vanden Berghe and C. Coulais from Fugro.



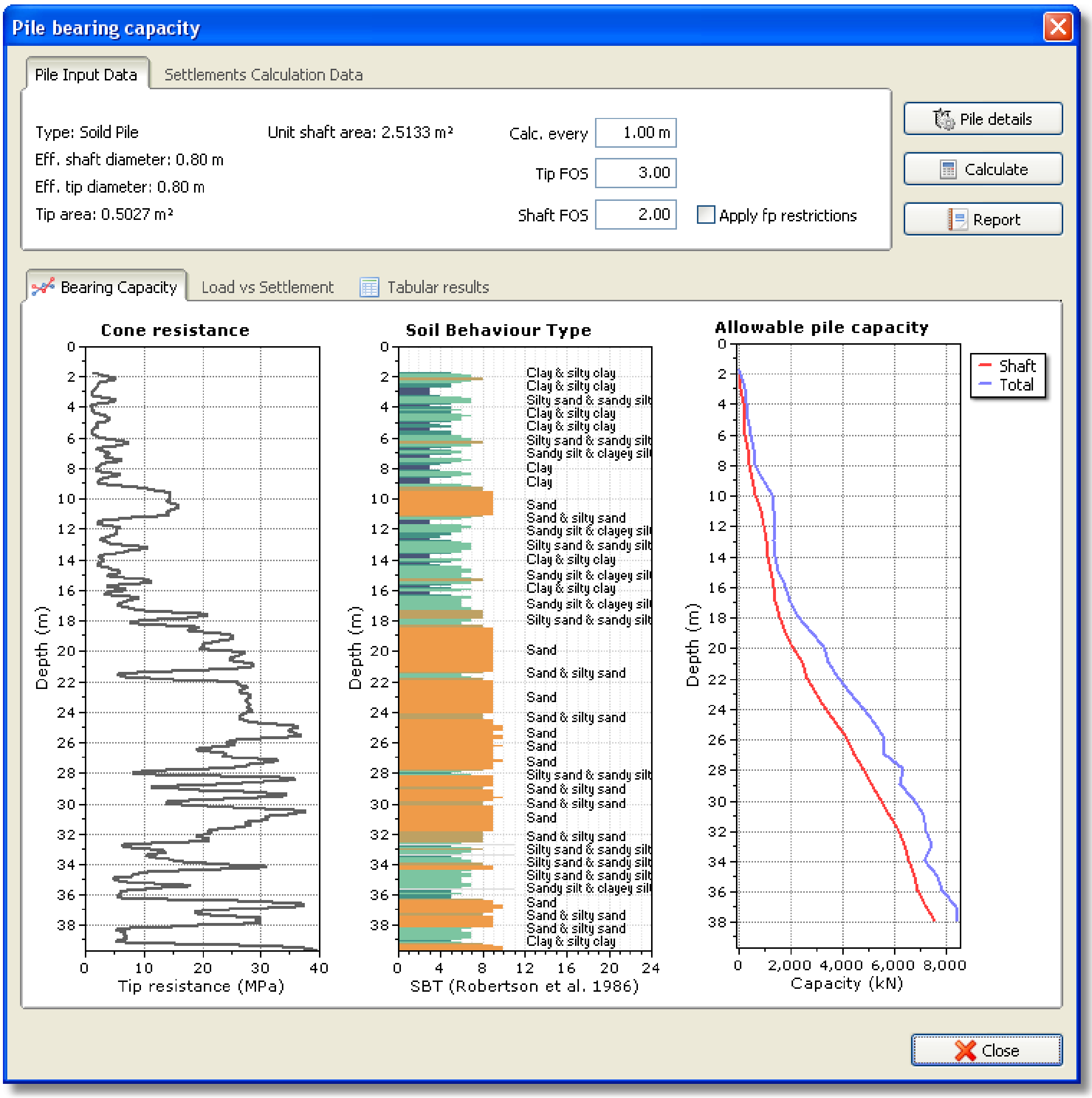
Pore pressure conversion dialog

Click on the *Convert* button to preview the conversion and the *Apply & Close* button to dismiss the dialog and apply the transformation.

4.8 Single pile bearing capacity

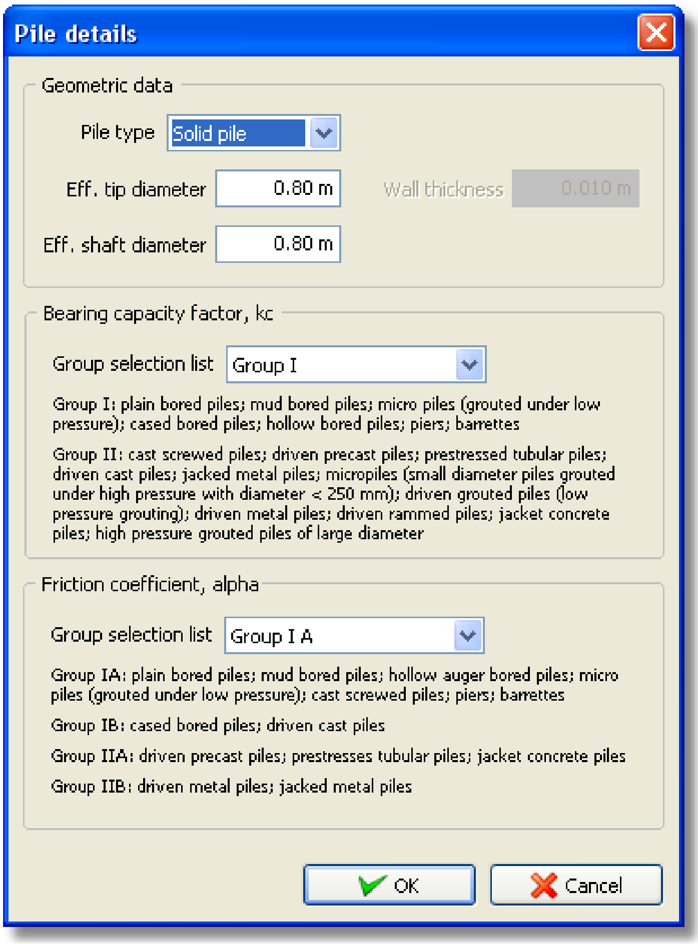
CPeT-IT can perform basic calculations regarding direct pile bearing capacity calculation form CPTU data, using the Bustamante and Gianaselli (1982) method (LCPC method). The LCPC CPT method is recommended since it provides simple guidance to account for different pile installation methods and provides good estimates of axial capacity of single piles. A more detailed description on the procedure can be found here.

After you have selected a CPTU file from the *CPT file Manager* click on the pile calculation tool button . The following dialog will appear:



Pile bearing capacity dialog

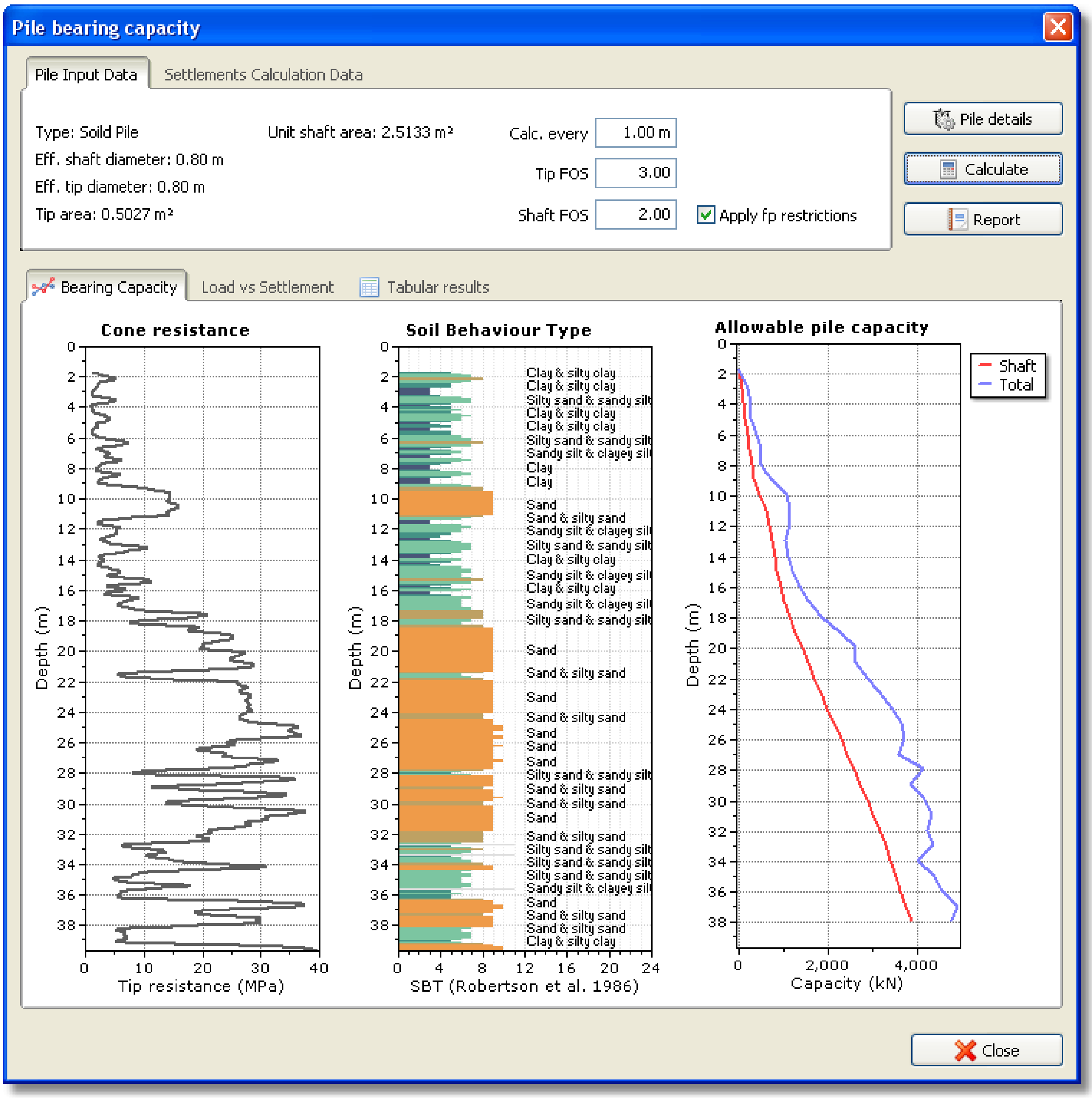
The software can perform the LCPC method using solid or pipe piles. Pile properties may be accessed by clicking on the *Pile details* button. The following dialog will appear:



Pile properties dialog

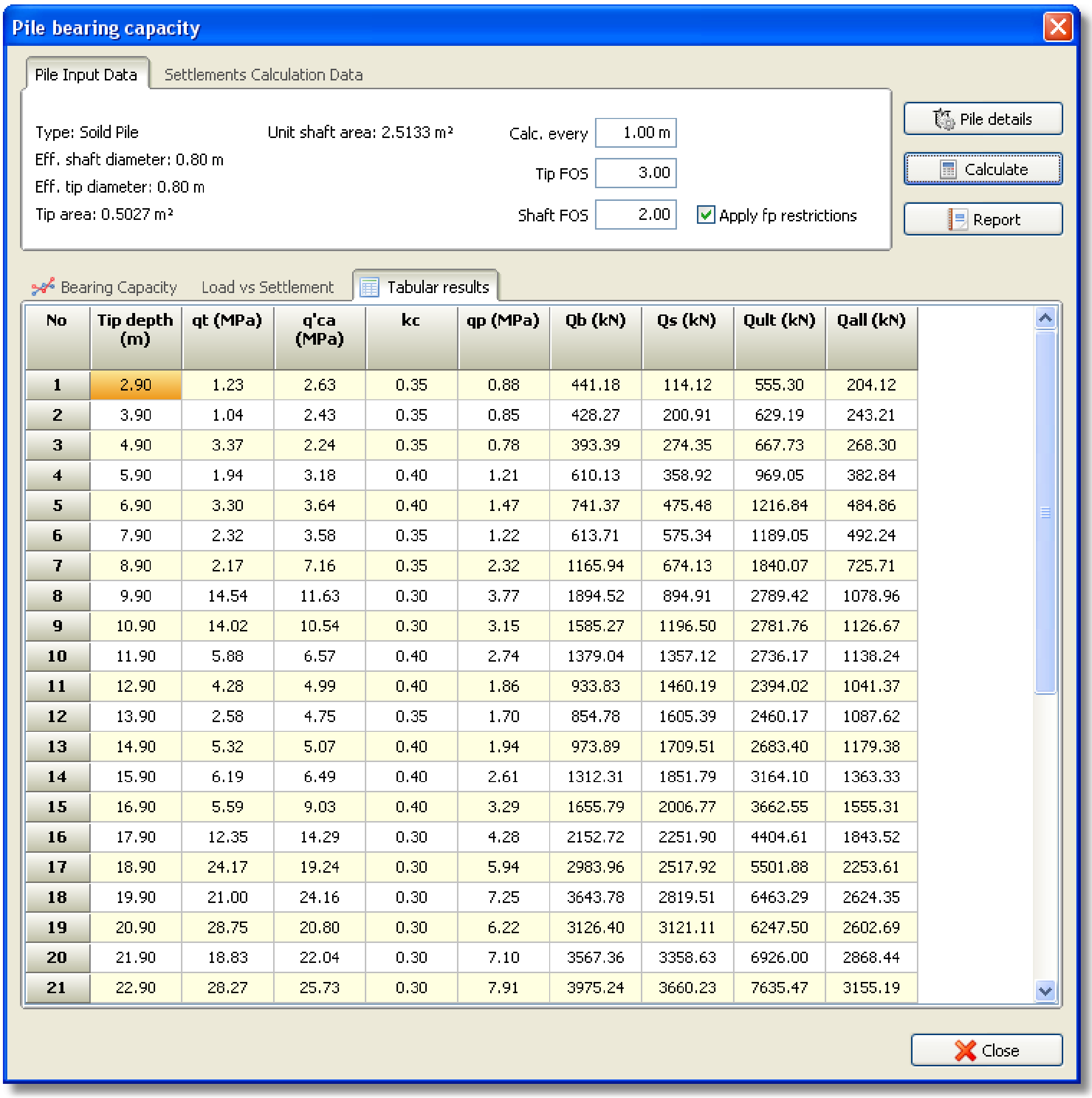
Pile type can be either solid or pipe. When a pipe pile is selected from the *Pile type* drop down list, the *Wall thickness* edit box will be enabled. According to the type of pile you must make the appropriate selections regarding the group of the pile for both bearing capacity factor and friction coefficient. Click on the *OK* button to commit the changes.

Calculations will be performed according to a depth step entered in the *Calc. every* edit box. The allowable capacity for the pile will be calculated based on the defined factors of safety for both the tip and shaft resistance. To perform the calculation click on the *Calculate* button. The results will be displayed as shown in the next pictures:



Calculation results (plots)

The bottom axis of the pile bearing capacity plot can be customized in a way similar to the one described here. The depth scales are the same as the ones used in the Basic plots for Tip resistance.

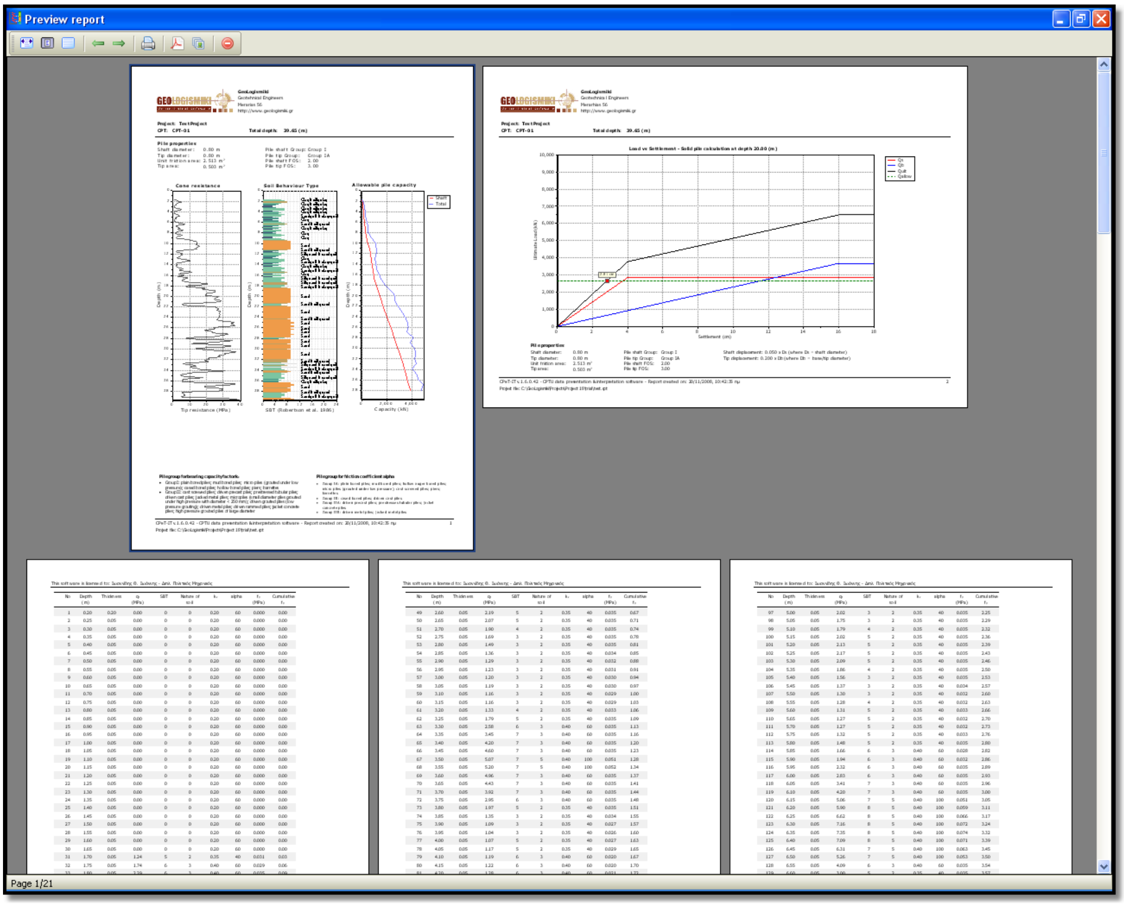


No	Tip depth (m)	qt (MPa)	q'ca (MPa)	kc	qp (MPa)	Qb (kN)	Qs (kN)	Qult (kN)	Qall (kN)
1	2.90	1.23	2.63	0.35	0.88	441.18	114.12	555.30	204.12
2	3.90	1.04	2.43	0.35	0.85	428.27	200.91	629.19	243.21
3	4.90	3.37	2.24	0.35	0.78	393.39	274.35	667.73	268.30
4	5.90	1.94	3.18	0.40	1.21	610.13	358.92	969.05	382.84
5	6.90	3.30	3.64	0.40	1.47	741.37	475.48	1216.84	484.86
6	7.90	2.32	3.58	0.35	1.22	613.71	575.34	1189.05	492.24
7	8.90	2.17	7.16	0.35	2.32	1165.94	674.13	1840.07	725.71
8	9.90	14.54	11.63	0.30	3.77	1894.52	894.91	2789.42	1078.96
9	10.90	14.02	10.54	0.30	3.15	1585.27	1196.50	2781.76	1126.67
10	11.90	5.88	6.57	0.40	2.74	1379.04	1357.12	2736.17	1138.24
11	12.90	4.28	4.99	0.40	1.86	933.83	1460.19	2394.02	1041.37
12	13.90	2.58	4.75	0.35	1.70	854.78	1605.39	2460.17	1087.62
13	14.90	5.32	5.07	0.40	1.94	973.89	1709.51	2683.40	1179.38
14	15.90	6.19	6.49	0.40	2.61	1312.31	1851.79	3164.10	1363.33
15	16.90	5.59	9.03	0.40	3.29	1655.79	2006.77	3662.55	1555.31
16	17.90	12.35	14.29	0.30	4.28	2152.72	2251.90	4404.61	1843.52
17	18.90	24.17	19.24	0.30	5.94	2983.96	2517.92	5501.88	2253.61
18	19.90	21.00	24.16	0.30	7.25	3643.78	2819.51	6463.29	2624.35
19	20.90	28.75	20.80	0.30	6.22	3126.40	3121.11	6247.50	2602.69
20	21.90	18.83	22.04	0.30	7.10	3567.36	3358.63	6926.00	2868.44
21	22.90	28.27	25.73	0.30	7.91	3975.24	3660.23	7635.47	3155.19

Calculation results (numeric)

By default the calculation of the friction coefficient performs a check for the restrictions defined by the LCPC method. If you wish not to include these restrictions during the calculation process uncheck the *Apply fp restrictions* check box.

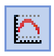
After the calculation is complete you may preview and print a report by clicking on the *Report* button.

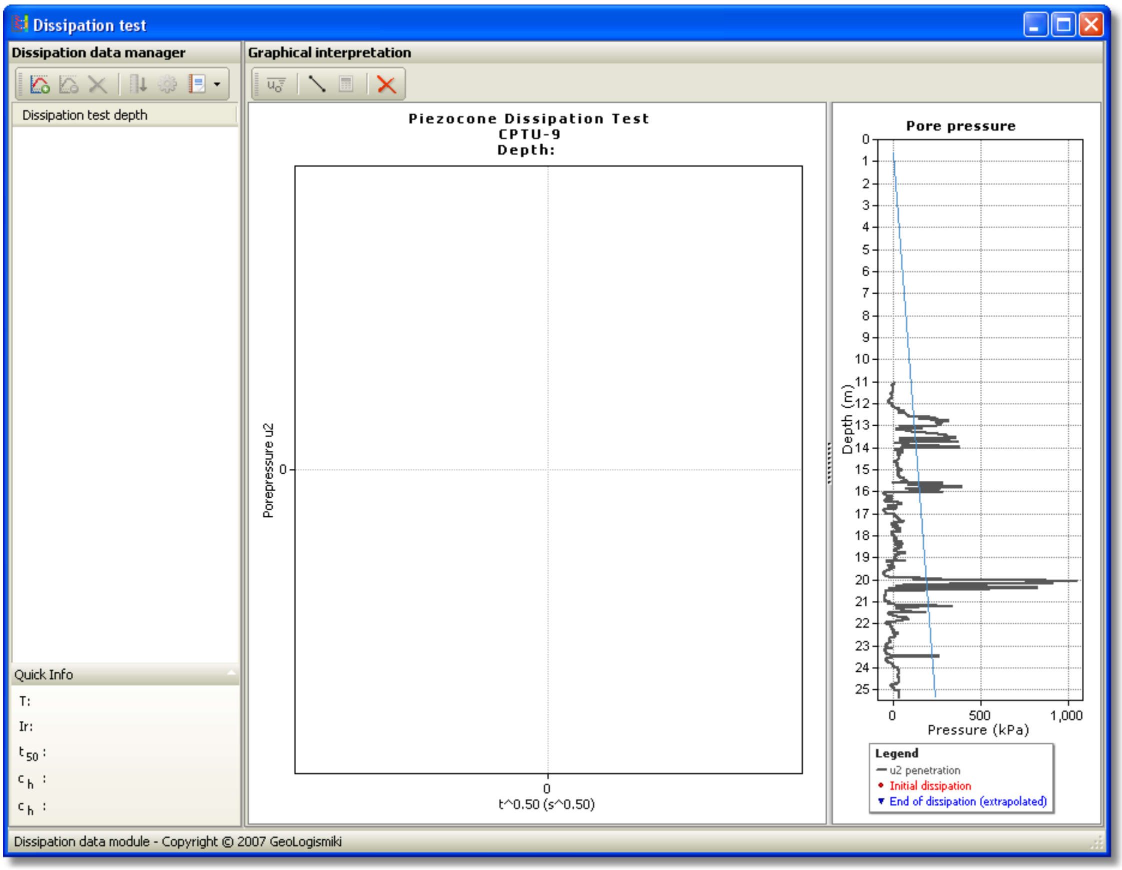


Pile bearing capacity report

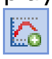
A single pile load-settlement plot can be generated by selecting the *Settlements Calculation Data* tab and providing the required user input variables. Clicking on the small *Calc.* button will refresh the settlement calculation based on the entered values.The load-settlement plot can be viewed by selecting the *Load vs Settlement* tab. Appropriate selection of the displacements to reach peak Qs and Qb is crucial in the calculation process.

4.9 Dissipation test interpretation

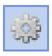
If a dissipation test has been carried out, the dissipation test results can be plotted and a value for the coefficient of consolidation in the horizontal direction, c_h, can be calculated. The 'Dissipation data module' can be activated by clicking on the  button located on the main toolbar. The following dialog will appear.

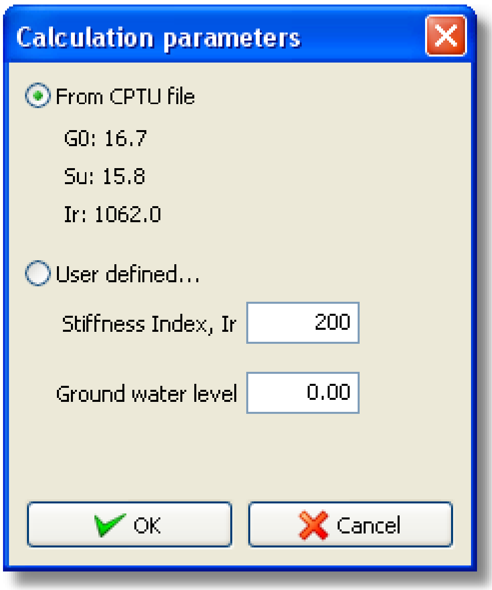


Dissipation module window

The *Dissipation data manager* will display any previously saved dissipation tests. If you need to import a new test press the  on the toolbar.

The calculation of c_h requires the time for 50% dissipation, t_{50}, i.e. the time for 50% of the excess pore pressure to dissipate. The dissipation results are presented on a plot of pore pressure versus square root of time. The plot will also display the calculated equilibrium pore pressure based on the user input ground water level (GWL). Houlsby and Teh (1988) showed that the theoretical dissipation on a square root time plot should have an initial linear portion then level off to the final equilibrium value. If the dissipation test has been carried out to equilibrium (i.e. 100% dissipation), the user can check the final equilibrium value against the assumed hydrostatic value calculated based on the user input GWL.

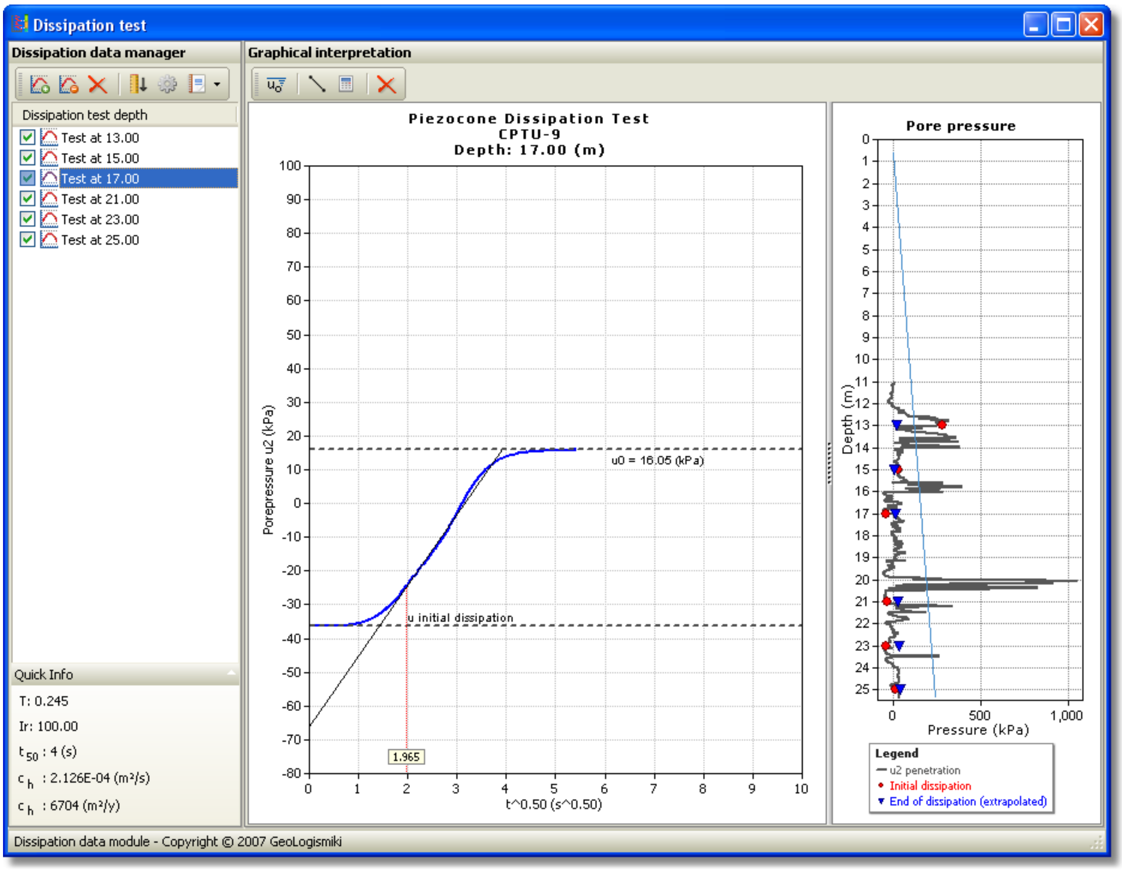
The user can use the  button to input a line over the linear portion of the measured data, then when the calculation button is clicked () the linear line is extended from time zero to the input equilibrium pore pressure and the t_{50} value calculated. The calculation of c_h requires a value for the rigidity index of the soil, I_r. The rigidity index is the equivalent elastic stiffness normalized to undrained shear strength, ($I_r = G/S_u$). The user can input or select the appropriate value for I_r by clicking on the calculation properties  button.



Calculation parameters dialog

If the CPT indicates that the soil at the depth of the dissipation test is clay (i.e. SBTn of either 1, 2, 3, 4 or 9, see Note) the user can select I_r based on either the estimated values of small strain G_o and S_u from the CPT file or a user input value for I_r. The calculation properties dialog box also allows the user to modify the input GWL. I_r values typically vary from 100 to 500, with the higher values linked to low plasticity clays. If the soil is clay and there are estimated values for G_o and S_u, the calculated value for I_r maybe too large since the stiffness used is the small strain stiffness, G_o. However, the calculated values are provided as a guide.

The value of u_0 can also be entered manually by clicking and dragging the line plot on the chart or by clicking on the u_0 button on the toolbar. The user can check the initial and final pore pressures in the *Pore pressure* plot at the right of the dissipation dialog and make decide for any adjustments in these values.



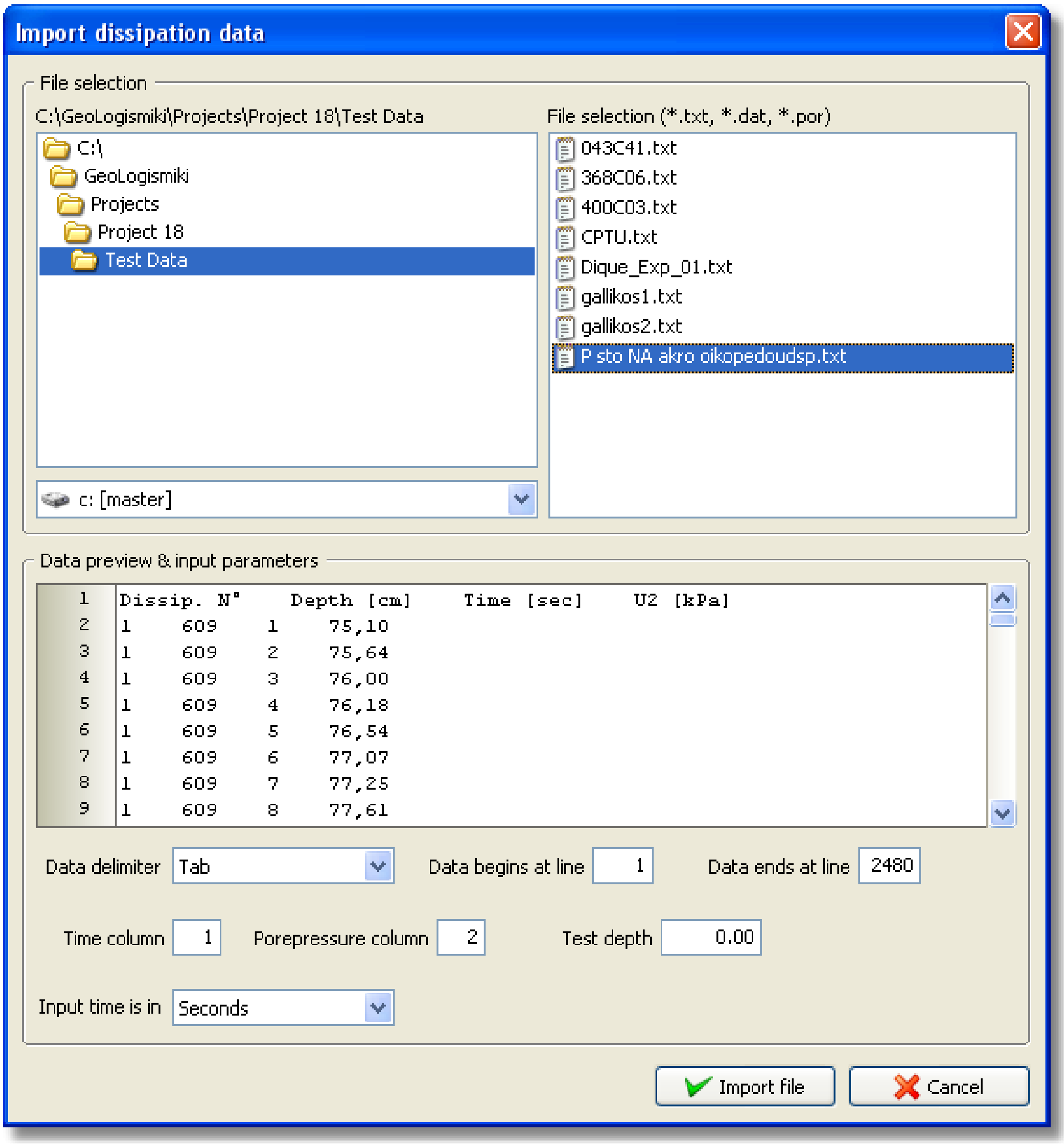
Calculation results in dissipation module dialog

The calculated value for c_h is shown in the lower left portion of the Dissipation Test dialog box, along with the theoretical time factor, T, the selected I_r and the calculated t_{50} from the dissipation test.

The user should ensure that the correct cone radius was provided in the general Calculation Properties dialog box, on the main window.

4.9.1 Importing dissipation test data

Dissipation data can be imported from any ASCII text file. The file must contain at least two columns of data, time and measured pore pressure. Clicking on the  button of the toolbar will bring up the *Import dissipation data dialog.*



Import dissipation data dialog

After browsing to the directory where the data file is stored, clicking on it creates a preview of the file. From the *Data delimiter* drop down list, select the character that is used to separate the columns. Since the file may contain more than one test readings, *Data begins at line* and *Data ends at line* edit boxes must contain the correct line numbers (in the above dialog the *Data begins at line* must be set to 2). *Time column* and *Porepressure column* edit boxes point to the data columns that the software will use to read the associated value (numbering of columns start from 1 for the leftmost column in the file). *Test depth* must contain the depth at which the test was performed and finally the *Input time is in* drop down list is used to instruct the software what unit is used for the time portion.

To import the test data click on the *Import file* button at the bottom of the dialog.

4.10 Settlements calculation

CPTu data can be used to directly estimate induced settlements due to an external load. CpeT-IT uses the following simple formula (based on 1-D consolidation) to estimate vertical settlements:

$$s = q \times \sum h \times \frac{I_z}{M_{CPT}}$$

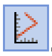
where:

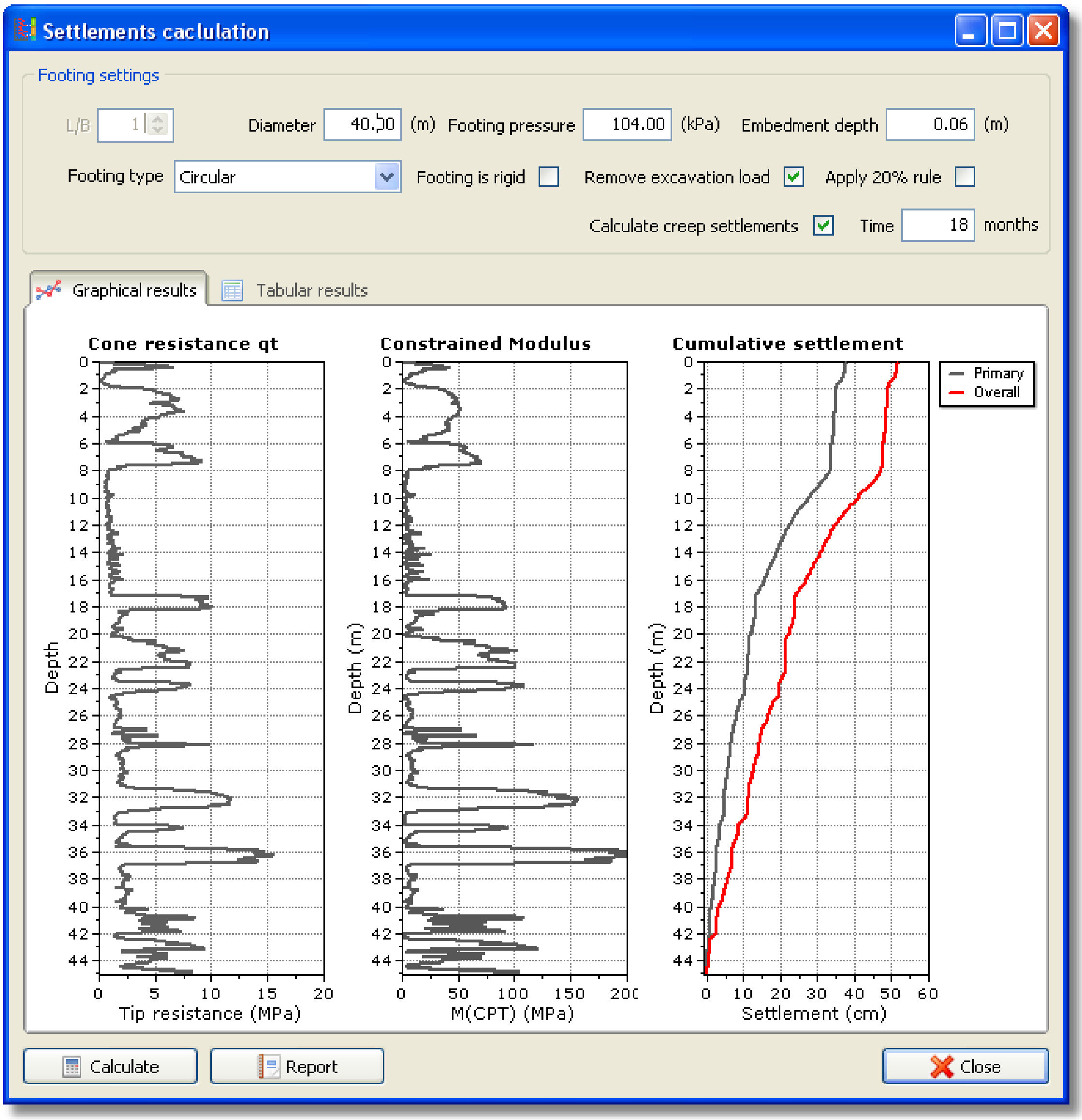
q: applied footing pressure

h: calculation layer thickness

Iz: stress reduction factor according to Boussinesq

M_{CPT}: Constrained modulus of soil layer

After you have selected a CPTU file from the *CPT file Manager* click on then settlements calculation tool button . The following dialog will appear:



Settlements calculation dialog

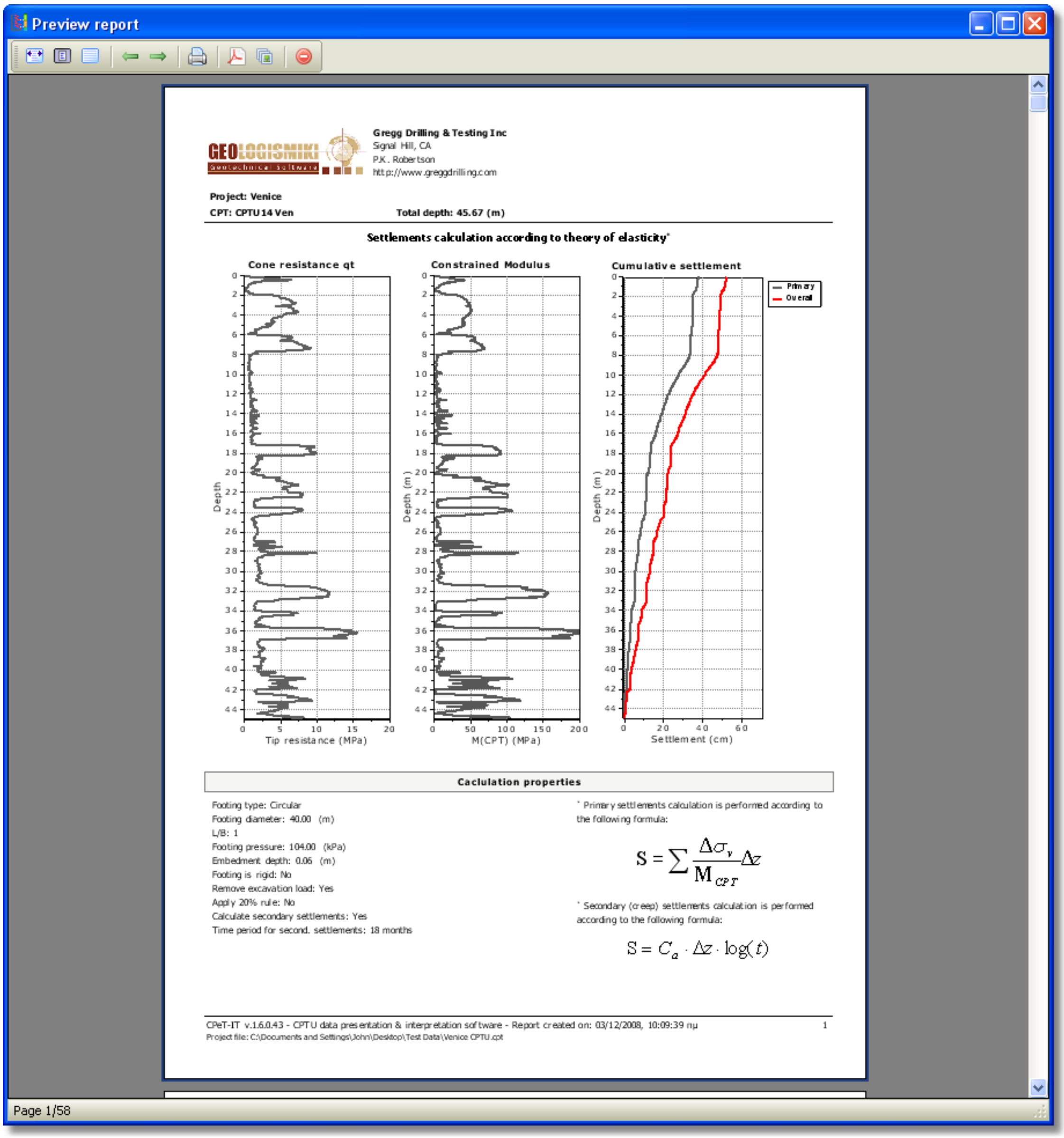
All properties used for the calculation can be entered on the fields that appear at the top of the dialog. When all input data are entered the calculation is performed by clicking on the *Calculate* button. The *Graphical results* tab will display the calculation results using the three plots available. The *Tabular results* tab displays the numeric calculation results inside a table as shown in the picture below:

No	Start depth (m)	End depth (m)	Thickness (m)	Calc. depth (m)	Iz	Delta sigma (kPa)	Eff. stress (kPa)	M (MPa)	Settl. (cm)
1	0.060	0.080	0.020	0.010	1.000	102.860	1.120	2.737	0.075
2	0.080	0.099	0.019	0.029	1.000	102.860	1.461	3.641	0.054
3	0.099	0.119	0.020	0.049	1.000	102.860	1.802	5.151	0.040
4	0.119	0.138	0.019	0.069	1.000	102.860	2.148	7.215	0.027
5	0.138	0.158	0.020	0.088	1.000	102.860	2.500	9.333	0.022
6	0.158	0.177	0.019	0.107	1.000	102.860	2.850	11.687	0.017
7	0.177	0.196	0.019	0.127	1.000	102.860	3.197	14.217	0.014
8	0.196	0.216	0.020	0.146	1.000	102.860	3.558	16.959	0.012
9	0.216	0.242	0.026	0.169	1.000	102.860	3.983	19.381	0.014
10	0.242	0.262	0.020	0.192	1.000	102.860	4.409	21.980	0.009
11	0.262	0.281	0.019	0.212	1.000	102.860	4.770	24.165	0.008
12	0.281	0.300	0.019	0.230	1.000	102.860	5.126	25.990	0.008
13	0.300	0.319	0.019	0.250	1.000	102.860	5.487	27.648	0.007
14	0.319	0.338	0.019	0.269	1.000	102.860	5.848	29.281	0.007
15	0.338	0.357	0.019	0.288	1.000	102.860	6.209	31.033	0.006
16	0.357	0.376	0.019	0.306	1.000	102.860	6.570	32.881	0.006
17	0.376	0.395	0.019	0.326	1.000	102.860	6.931	34.712	0.006
18	0.395	0.414	0.019	0.344	1.000	102.859	7.292	36.629	0.005
19	0.414	0.440	0.026	0.367	1.000	102.859	7.720	38.455	0.007

Numeric results of settlements calculation

Double clicking inside the table initiates the procedure to export the results in a XLS file format.

To preview the settlements report, click on the *Report* button.



Settlements report preview dialog

Creep settlements are estimated using the simplified approach suggested by Messi (1994) where:

$$C_a = 0.04 \times \left(\frac{C_c}{1+e_o}\right) \approx 0.1 \times \frac{\sigma_v'}{M}$$

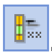
where M is estimated from the CPT.

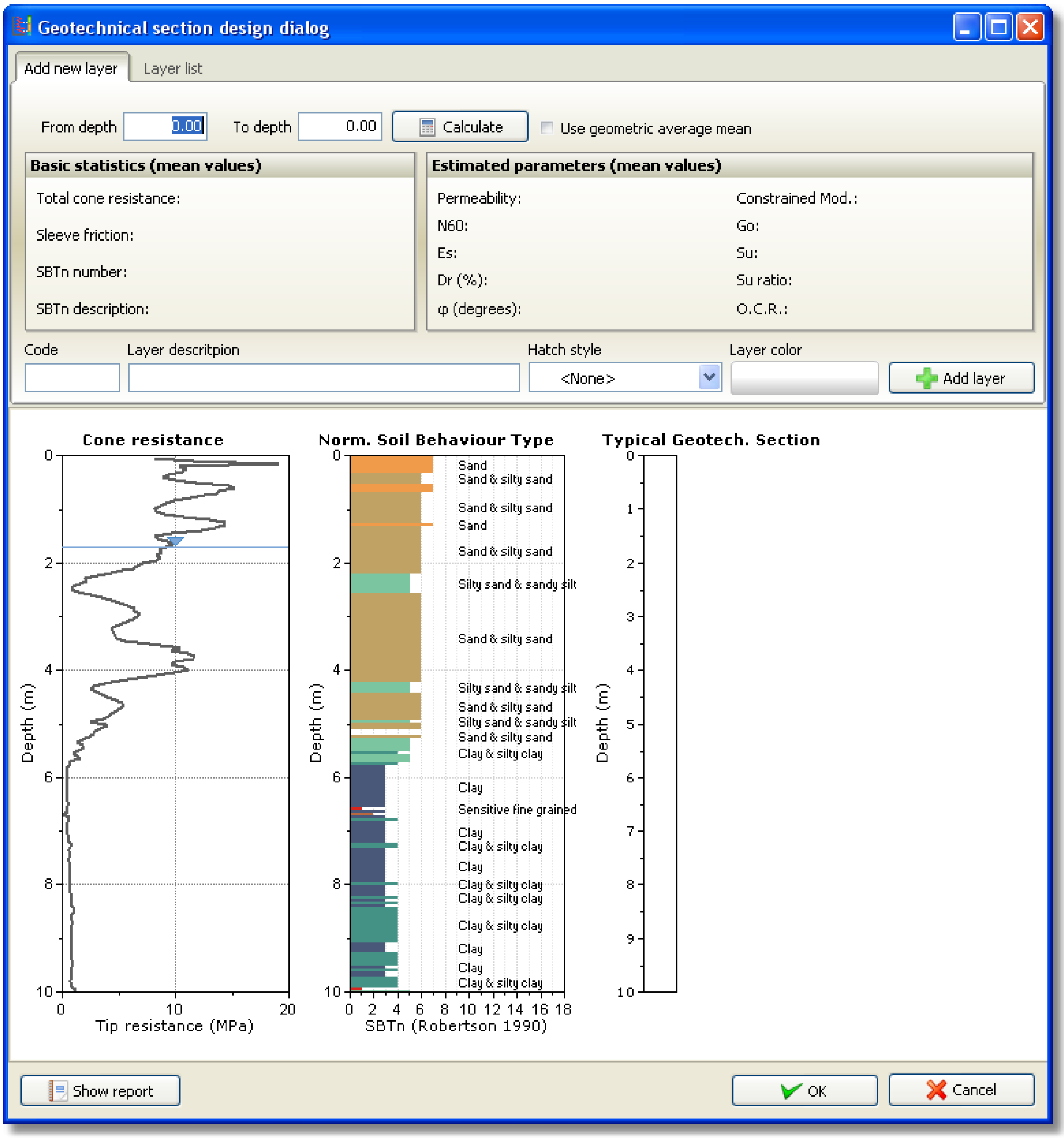
Note

The plots left axis scales used are taken from the *Cone resistance qt* plot in the

Basic plots tab of the main application window.

4.11 Geotechnical section creation

CPeT-IT offers a 2 modules for the creation of a typical geotechnical section, derived from the CPT data. A semi auto boundaries detection and a manual layers definition are available for the user. The description below refers to the manual layer definition module where using the mouse and/or keyboard the user can identify soil layers and calculate the average estimated parameters (a description for semi auto module can be found here). After you have selected a CPTU file from the *CPT file Manager* click on then settlements calculation tool button . The following dialog will appear:



Geotechnical section module dialog

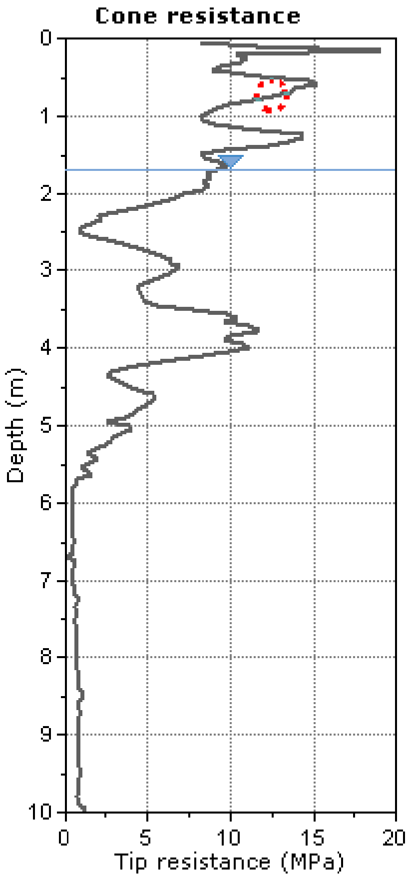
Soil layers are defined by selecting the start depth and end depth. The selection can be made either by entering the numeric values directly in the *From depth* and *To depth* edit boxes or by using the mouse pointer over the cone resistance plot. By entering the values directly to the edit boxes, the software will first try to locate the closest corresponding CPT points to that depth. Using the mouse pointer you may directly select these points as follows:

1. Hold down the SHIFT on the keyboard and while keeping it pressed move the mouse over the cone resistance plot. A red dotted circle will appear that snaps its center on the closest CPT point.

2. Move the cursor to the point that defines the start point of a layer and click the LEFT mouse button. The *From depth* will now be filled with the corresponding depth of

that point.

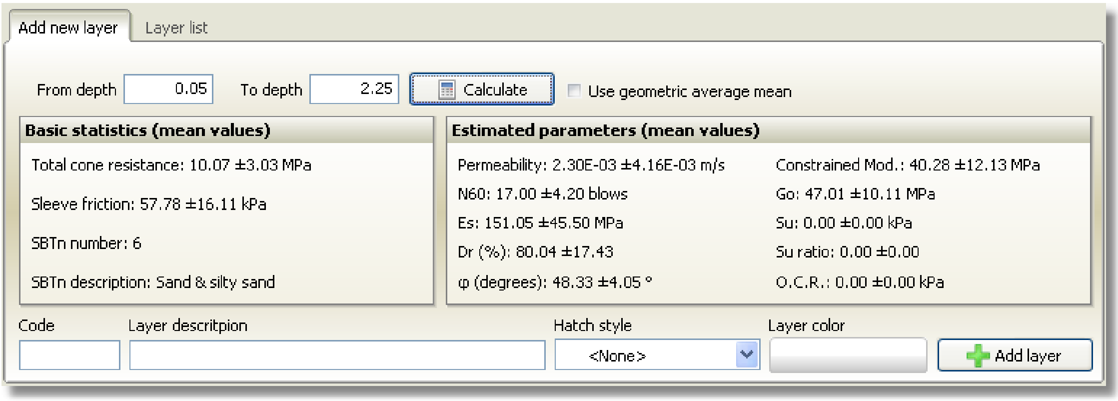
3. Move the cursor over the point that defines the end of the layer and press the RIGHT mouse button. Again the *To depth* edit box will display the depth of that point.



Selecting CPT points on the cone resistance plot

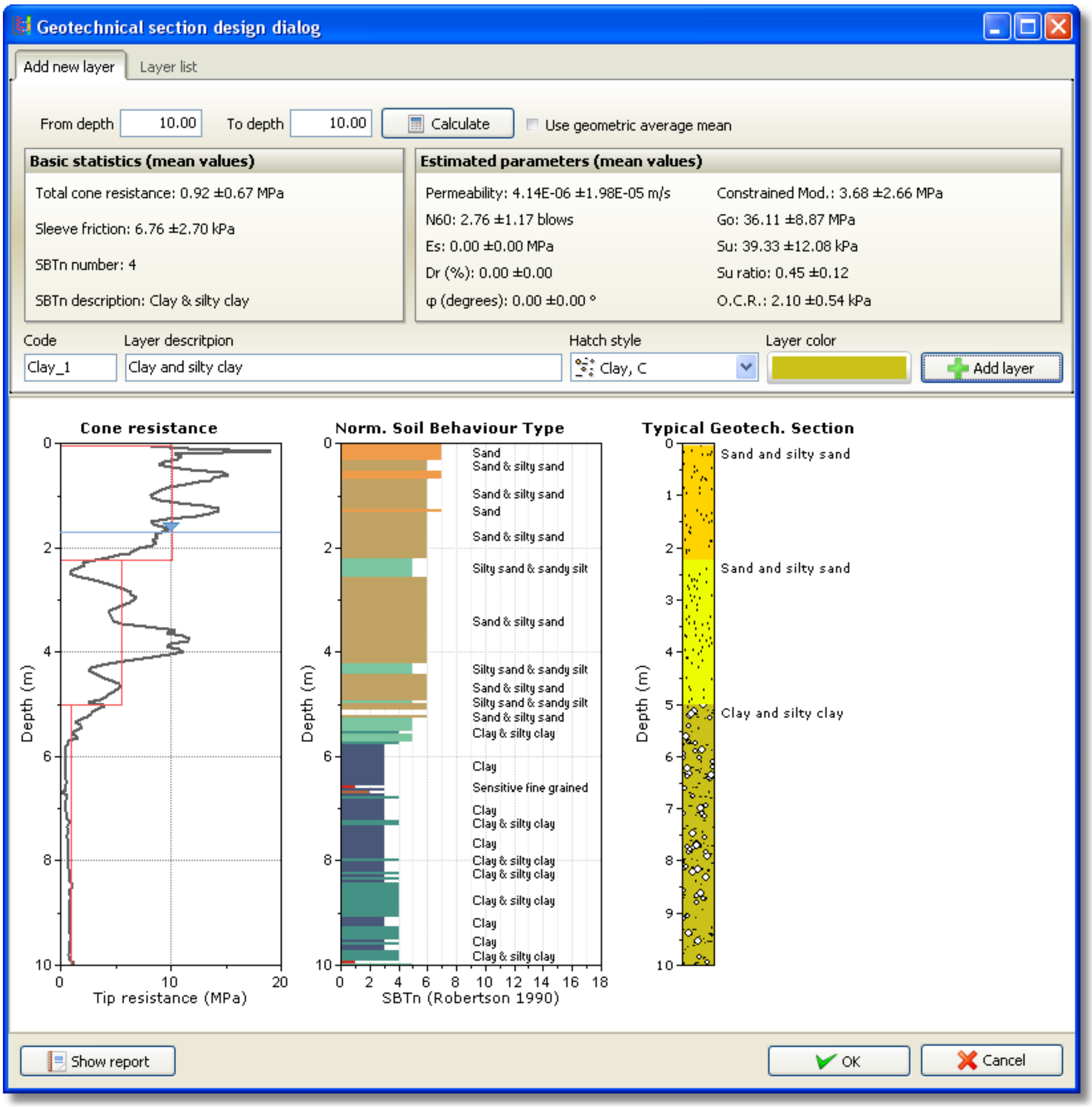
After you have successfully identified the starting depth and end depth of a single layer, click on the *Calculate* button to perform calculation regarding the average estimates for the selected layer. At this point no layer is added to the geotechnical section. The above procedure can be repeated until the calculation results satisfy the user.

When performing a calculation for a specific layer, the software may use the arithmetic or geometric mean based on the selection of the *Use geometric average mean* check box. When unchecked the software will use the "classic" average formula for the calculation of all parameters. In case the check box is checked, the geometric mean formula will be used instead. The geometric mean, in mathematics, is a type of mean or average, which indicates the central tendency or typical value of a set of numbers. It is similar to the arithmetic mean, which is what most people think of with the word "average," except that instead of adding the set of numbers and then dividing the sum by the count of numbers in the set, n, the numbers are multiplied and then the nth root of the resulting product is taken. The geometric mean is always smaller from the arithmetic mean due to the fact that it is not biased from very large values that may exist in a set. In order to produce a value greater than zero all of the numbers in the set should be greater than zero.



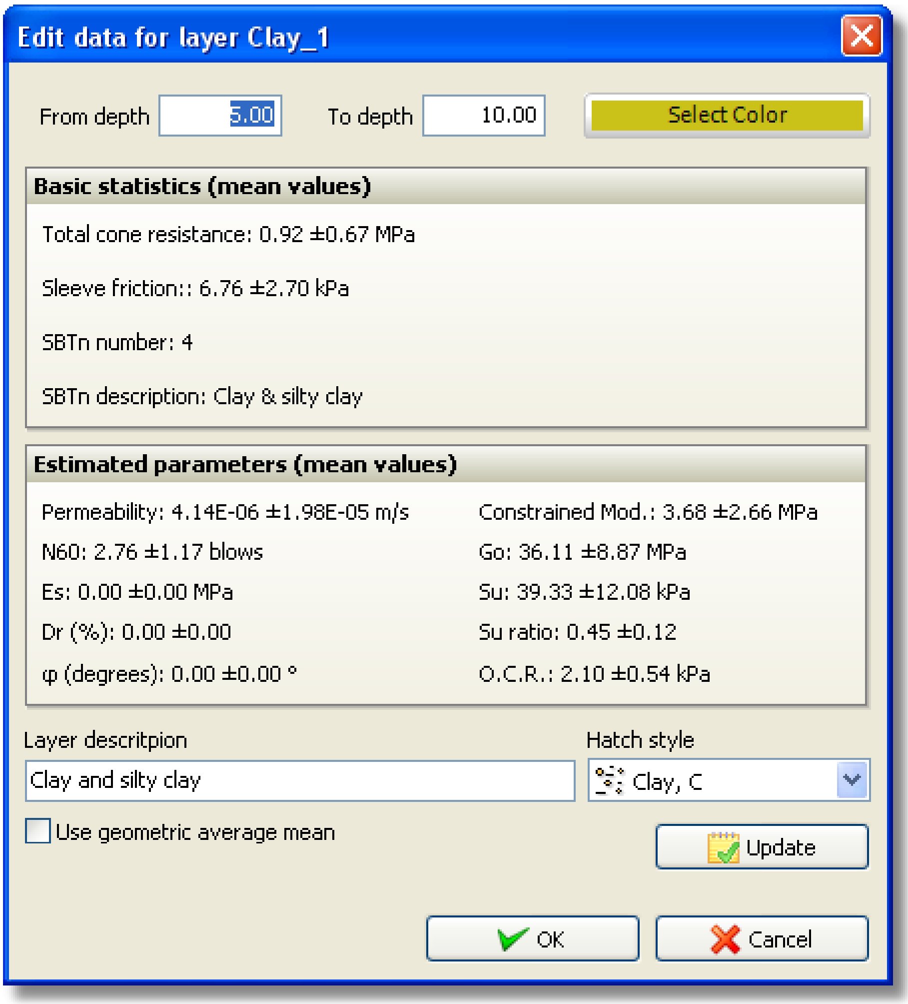
Calculations for the specified soil layer

In order to add a soil layer in the geotechnical section, the user must provide a short code, a description, a color and if needed a hatch style. The code can be any character but the length is restricted to 9 characters. Click on the *Add layer* button to insert the layer and preview it in the plots.



Geotechnical section module dialog

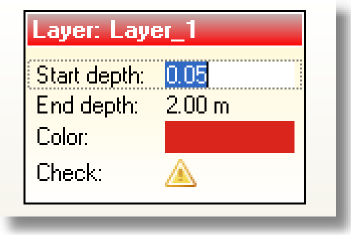
You may alter any soil layer by switching to the *Layer list* tab sheet where a list of the current soil layers is displayed. Double click on the layer you wish to modify and the following dialog will appear:



Edit soil layer dialog

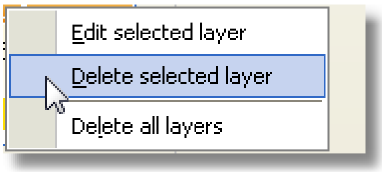
Click on the *Update* button first to perform the estimations calculation according to the new depth values entered. Click on the *OK* button to commit the changes for the current layer.

To quickly change start and end depth of a soil layer just click on the appropriate numeric value. Press *Enter* key or click anywhere outside the list entry to commit changes.



In place edit of depth parameters

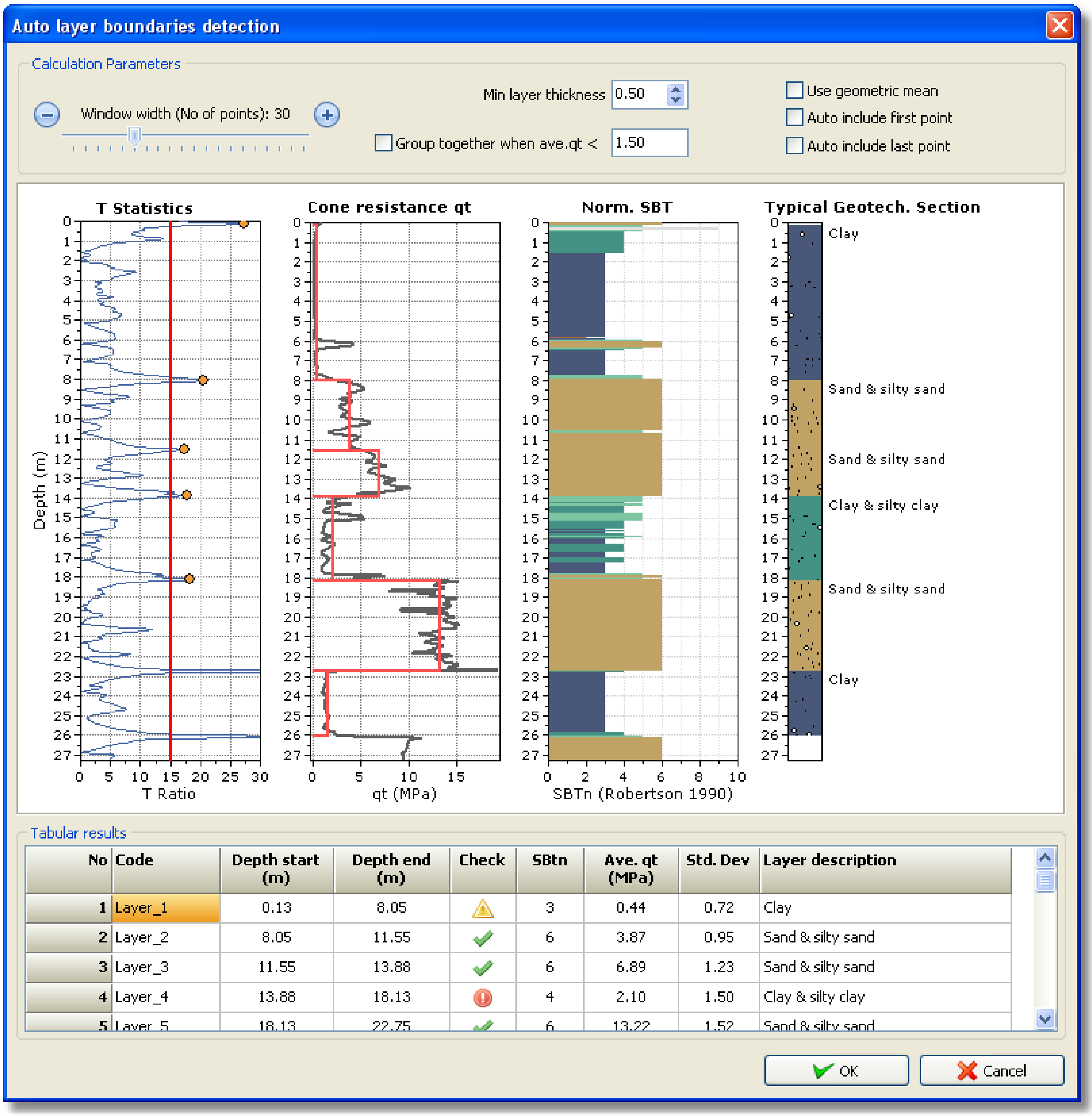
If you wish to delete a soil layer from the list, just select it and push the *Delete* button on your keyboard or right click on the selected layer and from the pop-up menu that will appear click on the *Delete selected layer* command.



Layer list pop-up menu

4.11.1 Semi auto soil layer boundaries detection

The semi auto soil layer boundaries detection is based on a simple univariate statistical analysis of the qt profile of the selected CPT. Clicking on the  button located at the toolbar the following dialog will appear:



Auto layers boundaries detection dialog

The software will try to locate soil layer boundaries based on the peaks of the T Ratio plot. The vertical red line in this plot presents a threshold value so that the application will know which peak values to peak. Peak values located to the right of the vertical line will be accepted and all others will be rejected. Obviously moving the line to the left of the plot more peaks will be included thus more soil layers boundaries will be identified. While moving the line the software will perform all the necessary calculations so the typical geotechnical section plot will always display the current soil stratigraphy.

Soil layers are filtered based on two (2) user defined parameters, minimum layer thickness and group together when average qt is less than a specific value. When group together is checked the software will check identical and successive layers if they meet this criteria and will present them as one.

The tabular results provide numeric results of the calculations along with a quick check that is based on the following rules:

- When less than 5% of the CPT points that form a layer have a SBTn number outside the overall SBTn of the layer, then this layer is considered to be ok (a green tick mark appears on the Check column)
- When 5% to 25% of the CPT points that form a layer have a SBTn number outside the overall SBTn of the layer, then this layer is considered to be less consistent (a yellow triangle mark appears on the Check column)
- When more than 25% of the CPT points that form a layer have a SBTn number outside the overall SBTn of the layer, then this layer is not considered to be ok (a red circle mark appears on the Check column)

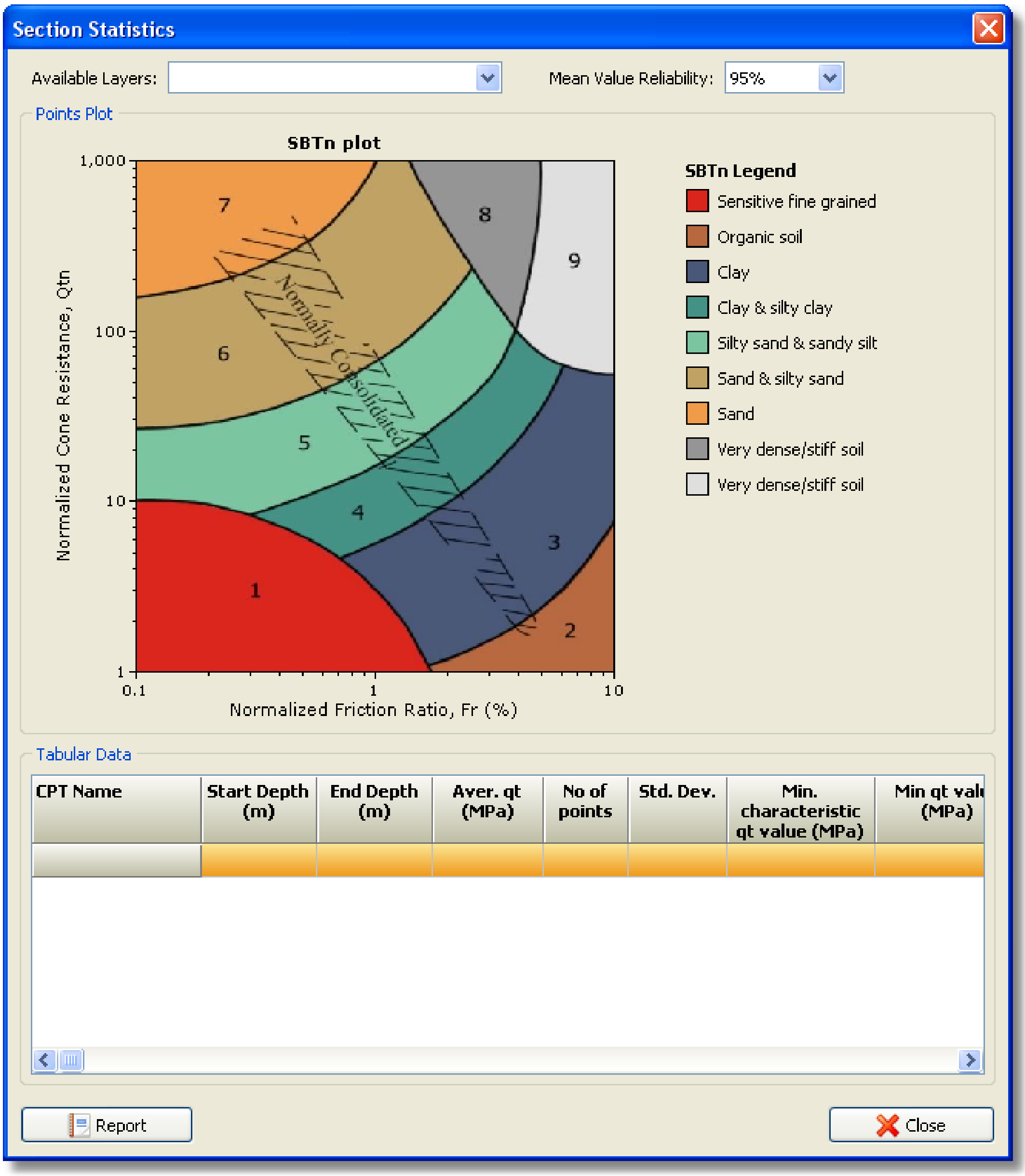
The Code column in the table is editable so the user can change the Code name if needed.

The statistical analysis is based on a window with a fixed width that moves from the top of the CPT profile to the bottom. The width is calculated based on the number of points (a default value of 30 is used) that can be changed using the track bar. Large number of points mean a smoother T Ratio plot, so less peaks will be displayed where less points result to a large number of peaks.

Clicking the *OK* button the software will ask if it should replace any previous geotechnical section with the current one. The user may review and make any changes using the manual geotechnical section design module at any time.

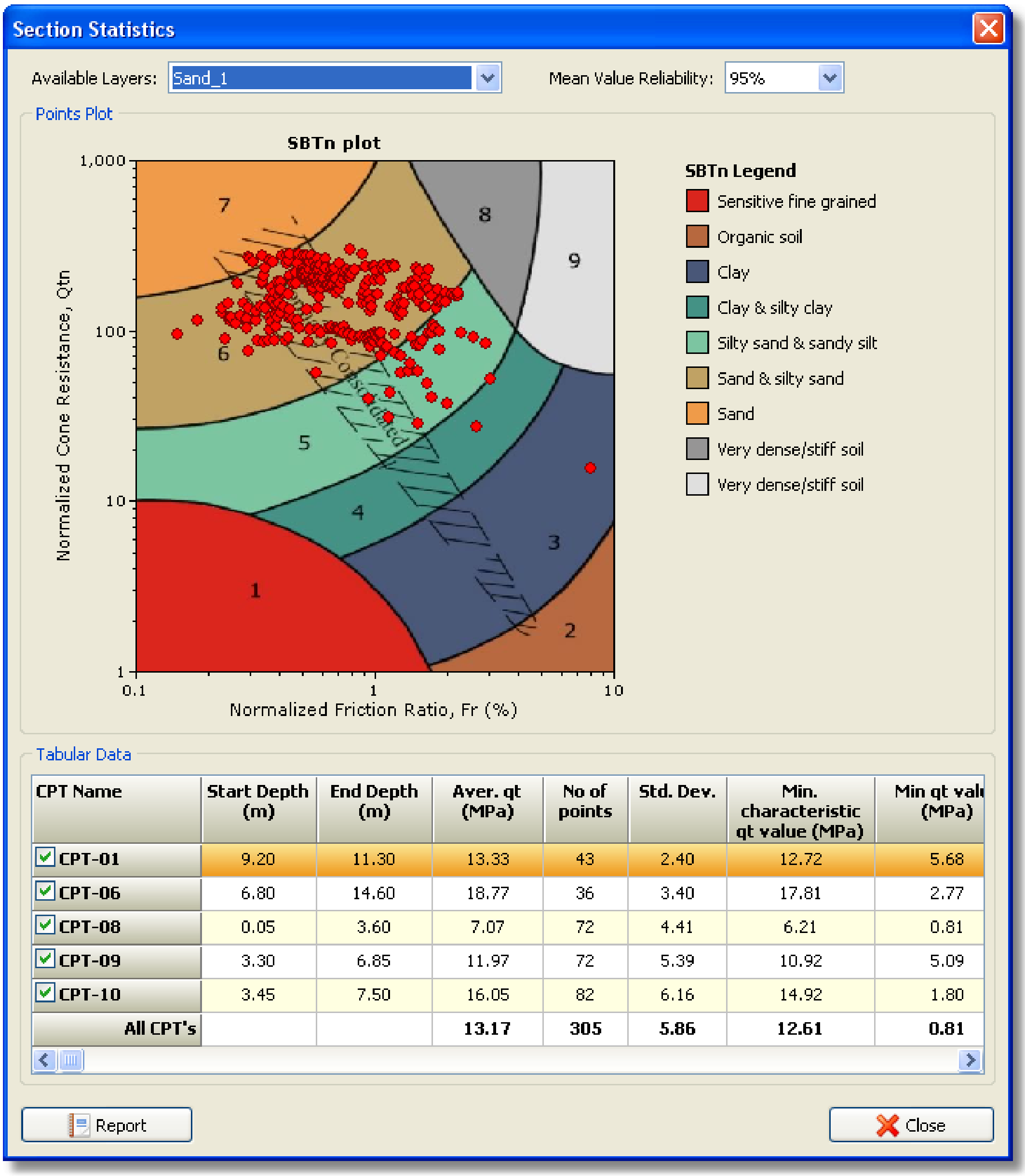
4.11.2 Geotechnical section layers statistics

Layers defined using the geotechnical section module may appear in several CPT files in a single project file. The user may review the statistical properties of each layer in terms of minimum characteristic values by clicking on the section statistics tool button . The following dialog appears:



Layer section statistics dialog

From the *Available Sections* drop down box select the section code name that you wish to preview. The software offers two (2) fixed values for the mean value reliability, 95% and 90% accessible from the *Mean Value Reliability* drop down box. After a layer is selected the software will display the calculated statistics:



CPT Name	Start Depth (m)	End Depth (m)	Aver. qt (MPa)	No of points	Std. Dev.	Min. characteristic qt value (MPa)	Min qt valu (MPa)
CPT-01	9.20	11.30	13.33	43	2.40	12.72	5.68
CPT-06	6.80	14.60	18.77	36	3.40	17.81	2.77
CPT-08	0.05	3.60	7.07	72	4.41	6.21	0.81
CPT-09	3.30	6.85	11.97	72	5.39	10.92	5.09
CPT-10	3.45	7.50	16.05	82	6.16	14.92	1.80
All CPT's			13.17	305	5.86	12.61	0.81

Statistics for layer code Sand_1

Characteristic values are calculated based on the following formula:

$$X_k = X_{mean} \times (1 - k_n \times V_X)$$

where k_n is a statistical coefficient and V_X is the coefficient of variation of the parameter X defined as:

$$V_X = s_X / X_{mean}$$

$$s_X^2 = \frac{1}{n-1} \times \sum (X_i - X_{mean})^2$$

where s_x is the standard deviation of the *n* sample test.

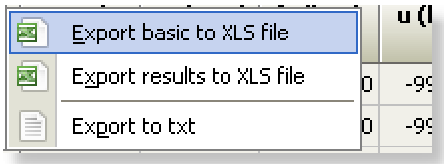
4.12 Exporting data

CPeIT-IT offers export capabilities for the following cases:

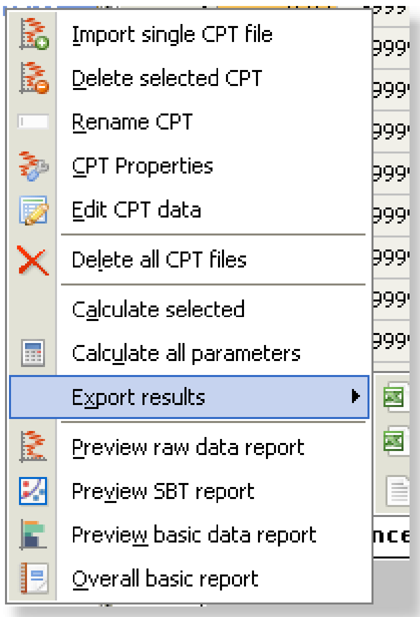
1. Export basic results or estimated parameters to XLS file
2. Export ASCII file for importing in to LiqIT

4.12.1 Exporting results to XLS file

In order to create a XLS file with the basic results or estimated parameters you must first select a CPTU entry from the *CPT file manager* list. Click on the *CPT data* menu and from the submenu *Export* make the appropriate selection.



Alternatively you may right click on the CPTU entry and from the pop up menu selected the Export results sub menu.

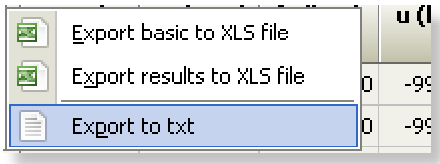


The standard Windows save dialog will appear. Browse to the directory where you wish the file to be saved, enter a valid name for the file and click on the *Save* button.

4.12.2 Exporting data for LiqIT

The software can create a Tab delimited text file which you can use to import data to LiqIT. This operation will create an ASCII file containing depth, corrected cone resistance, sleeve resistance, unit weight and apparent fines content data. It is recommended that prior creating the file you must set the average interval to 1 and perform a recalculation for the selected CPTU. This must be done due to the fact that input data are not averaged over depth.

Select a CPTU entry from the *CPT file manager* list. Click on the *CPT data* menu and from the submenu *Export* click on the *Export to txt* command.



The standard Windows save dialog will appear. Browse to the directory where you wish the file to be saved, enter a valid name for the file and click on the *Save* button.

5 Note

1. Soil Behavior Type (non-normalized), SBT Robertson (1990)

2. Unit weight, g either constant or based on Non-normalized SBT (Lunne et al., 1997 and table below)

3. Soil Behavior Type (Normalized), SBT_n Robertson (1990), using Q_{tn}

4. SBT_n Index, $I_c = ((3.47 - \log Q_{t1})^2 + (\log Fr + 1.22)^2)^{0.5}$

5. Normalized Cone resistance, Q_{tn} (n varies with I_c)

$Q_{tn} = ((q_t - s_{vo})/pa) \times (pa/(s'_{vo})^n$ and recalculate I_c, then iterate:

$$n = 0.381 \times I_c + 0.05 \times \left(\frac{s_{vo}'}{p_a}\right) - 0.15$$

Iterate until the change in n, $D_n < 0.01$

6. Estimated permeability, k_{SBT} (based on Normalized SBT_n) (Lunne et al., 1997 and table below)

7. Equivalent SPT N60, (blows/ft or blows/30cm) Lunne et al. (1997)

$$\frac{(q_t/p_a)}{N_{60}} = 8.5 \left(1 - \frac{I_c}{4.6}\right)$$

8. Relative Density, D_r, (%) $D_r^2 = Q_{tn} / C_{Dr}$

Only SBTn 5, 6, 7 & 8 '0' in zones 1, 2, 3, 4 & 9

9. Friction Angle, f', (degrees)

$$\varphi = 17.60 + 11 \times \log(Q_t)$$

Only SBTn 5, 6, 7 & 8 '0' in zones 1, 2, 3, 4 & 9

10. Young's modulus, E_s

$$E_s = \alpha_E \times (q_t - s_{vo})$$
$$\alpha_E = 0.015 \times \left[10^{(0.55 \times I_c + 1.68)}\right]$$

Only when Ic < 2.60

11. Constrained Modulus, M

$$M = a_M \times (q_t - s_{vo})$$
When $I_c > 2.20$ use:
$$a_M = Q_t \text{ when } Q_t < 14$$
$$a_M = 14 \text{ when } Q_t > 14$$
When $I_c < 2.20$ use:
$$a_M = 0.0188 \times \left[10^{(0.55 \times I_c + 1.68)}\right]$$

12. Undrained shear strength, $s_u = (q_t - s_{vo}) / N_{kt}$

Only SBT_n 1, 2, 3, 4 & 9 '0' in zones 5, 6, 7 & 8

13. Over Consolidation ratio, OCR = k_{ocr} Q_{t1}

Only SBT_n 1, 2, 3, 4 & 9 '0' in zones 5, 6, 7 & 8

14. Small strain shear modulus, G_o

$$G_0 = \alpha_M \times (q_t - s_{vo})$$
$$\alpha_M = 0.0188 \times \left[10^{(0.55 \times I_c + 1.68)}\right]$$

The following updated and simplified SBT descriptions have been used in the software:

SBT Zones		**SBT_n Zones**	
1	sensitive fine grained	1	sensitive fine grained
2	organic soil	2	organic soil
3	clay	3	clay
4	clay & silty clay	4	clay & silty clay
5	clay & silty clay		
6	sandy silt & clayey silt		
7	silty sand & sandy silt	5	silty sand & sandy silt

8	sand & silty sand	6	sand & silty sand
9	sand		
10	sand	7	sand
11	very dense/stiff soil*	8	very dense/stiff soil*
12	very dense/stiff soil*	9	very dense/stiff soil*

* heavily overconsolidated and/or cemented

Estimated Permeability (see Lunne et al., 1997)

SBT_n	Permeability (ft/sec)	(m/sec)
1	3×10^{-8}	1×10^{-8}
2	3×10^{-7}	1×10^{-7}
3	1×10^{-9}	3×10^{-10}
4	3×10^{-8}	1×10^{-8}
5	3×10^{-6}	1×10^{-6}
6	3×10^{-4}	1×10^{-4}
7	3×10^{-2}	1×10^{-2}
8	3×10^{-6}	1×10^{-6}
9	1×10^{-8}	3×10^{-9}

Estimated Unit Weight (see Lunne et al., 1997)

SBT	Approximate Unit Weight (lb/ft³)	(kN/m³)
1	111.4	17.5
2	79.6	12.5
3	111.4	17.5
4	114.6	18.0
5	114.6	18.0
6	114.6	18.0
7	117.8	18.5
8	120.9	19.0
9	124.1	19.5
10	127.3	20.0

11	130.5	20.5
12	120.9	19.0

6 LCPC method

The following text was taken from "Guide to cone penetration testing" by P. K. Robertson and K. L. Robertson. You may obtain a copy of the guide if you visit Dr. Robertson's personal web site at www.cpt-robertson.com or you may contact us directly and we will send you a copy.

Research has shown (Robertson et al., 1988; Briaud and Tucker, 1988; Tand and Funegard, 1989; Sharp et al., 1988) that CPT methods generally give superior predictions of axial pile capacity compared to most conventional methods. The main reason for this is that the CPT provides a continuous profile of soil response. Almost all CPT methods use reduction factors to measured CPT values. The need for such reduction factors is due to a combination of the following influences: scale effect, rate of loading effects, difference of insertion technique, position of the CPT friction sleeve and differences in horizontal soil displacements. The early work by DeBeer (1963) identified the importance of scale effects. Despite these differences, the CPT is still the test that gives the closest simulation to a pile. Superiority of CPT methods over non CPT methods has been confirmed in other studies (e.g. O'Neill, 1986). The main CPT method by Bustamante and Gianeselli (1982 - LCPC Method) is outlined below. The LCPC CPT method is recommended since it provides simple guidance to account for different pile installation methods and provides good estimates of axial capacity of single piles.

The method by Bustamante and Gianeselli was based on the analysis of 197 pile load (and extraction) tests with a wide range of foundation and soil types, which may partly explain the good results obtained with the method. The method, also known as the LCPC method, is summarized in the following figures.

Nature of soil	q_c (MPa)	Factors k_c Group I	Group II
Soft clay and mud	< 1	0.4	0.5
Moderately compact clay	1 to 5	0.35	0.45
Silt and loose sand	≤ 5	0.4	0.5
Compact to stiff clay and compact silt	> 5	0.45	0.55
Soft chalk	≤ 5	0.2	0.3
Moderately compact sand and gravel	5 to 12	0.4	0.5
Weathered to fragmented chalk	> 5	0.2	0.4
Compact to very compact sand and gravel	> 12	0.3	0.4

Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow auger bored piles; piers; barrettes.
Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250 mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of large diameter.

Figure 1. Bearing capacity factors, kc

		Category									
		Coefficients, α				Maximum limit of f_p (MPa)					
		I		II		I		II		III	
Nature of soil	q_c (MPa)	A	B	A	B	A	B	A	B	A	B
Soft clay and mud	< 1	30	90	90	30	0.015	0.015	0.015	0.015	0.035	
Moderately compact clay	1 to 5	40	80	40	80	0.035 (0.08)	0.035 (0.08)	0.035 (0.08)	0.035	0.08	≥ 0.12
Silt and loose sand	≤ 5	60	150	60	120	0.035	0.035	0.035	0.035	0.08	–
Compact to stiff clay and compact silt	> 5	60	120	60	120	0.035 (0.08)	0.035 (0.08)	0.035 (0.08)	0.035	0.08	≥ 0.20
Soft chalk	≤ 5	100	120	100	120	0.035	0.035	0.035	0.035	0.08	–
Moderately compact sand and gravel	5 to 12	100	200	100	200	0.08 (0.12)	0.035 (0.08)	0.08 (0.12)	0.08	0.12	≥ 0.20
Weathered to fragmented chalk	> 5	60	80	60	80	0.12 (0.15)	0.08 (0.12)	0.12 (0.15)	0.12	0.15	≥ 0.20
Compact to very compact sand and gravel	> 12	150	300	150	200	0.12 (0.15)	0.08 (0.12)	0.12 (0.15)	0.12	0.15	≥ 0.20

Category – IA: plain bored piles; mud bored piles; hollow auger bored piles; micropiles (grouted under low pressure); cast screwed piles; piers; barrettes. IB: cased bored piles; driven cast piles. IIA: driven precast piles; prestressed tubular piles; jacket concrete piles. IIB: driven metal piles; jacked metal piles. IIIA: driven grouted piles; driven rammed piles. IIIB: high pressure grouted piles of large diameter > 250 mm; micropiles (grouted under high pressure).
Note: Maximum limit unit skin friction, f_p: bracket values apply to careful execution and minimum disturbance of soil due to construction.

Figure 2. Friction coefficient, alpha

The pile unit end bearing, q_p, is calculated from the calculated equivalent average cone resistance, q_{ca}, multiplied by an end bearing coefficient, k_c (Figure 1). The pile unit side friction, f_p, is calculated from measured q_c values divided by a friction coefficient, α_{LCPC} (Figure 2).

$$q_p = k_c\, q_{ca}$$

$$f_p = \frac{q_c}{\alpha_{LCPC}}$$

Maximum f_p values are also recommended based on pile and soil type. Only the measured CPT q_c is used for the calculation of both side friction and pile end bearing resistance. This is considered an advantage by many due to the difficulties associated in interpreting sleeve friction (f_s) in CPT data.

The equivalent average cone resistance, q_{ca}, at the base of the pile used to compute the pile unit end bearing, q_p, is the mean q_c value measured along two fixed distances, a, (a = 1.5D, where D is the pile diameter) above (-a) and below (+a) the pile tip. The authors suggest that q_{ca} be calculated in three steps, as shown in Figure 3. The first step is to calculate q'_{ca}, the mean q_c between -a and +a. The second step is to eliminate values higher than $1.3q'_{ca}$ along the length -a to +a, and the values lower than $0.7q'_{ca}$ along the length -a, which generates the thick curve shown in Figure 3. The third step is to calculate q_{ca}, the mean value of the thick curve.

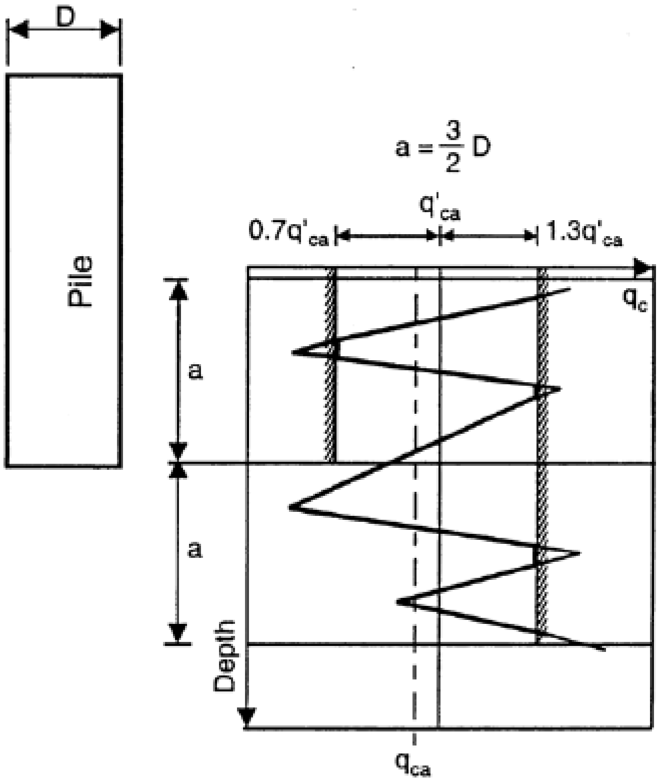


Figure 3. Procedure for qca calculation

7 References

- T. Lunne, P.K. Robertson and J.J.M. Powell, Cone Penetration testing in Geotechnical Practice, 1997
- Robertson, P.K., 2008, Guide to Cone Penetration Testing for Geotechnical Engineering
- Robertson, P.K., 2009, Interpretation of Cone Penetration Tests - a unified approach., Canadian Geotechnical Journal (in press)
- Designers' Guide to EN 1997-1, Eurocode 7: Geotechnical design - General rules, R Frank, C Bauduin, R Driscoll, M Kavvadas, N Krebs Ovesen, T Orr and B Schuppener

Back Cover