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Geotechnical Software

CLiq User's Manual

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CLiq v.1.7

Liquefaction assessment software from CPTU measurments

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by GeoLogismiki

CLiq is software for the assessment of soil liquefaction using CPT/CPTU data. CLiq was developed in collaboration with Gregg Drilling & Testing Inc., a leading company in site investigation and CPT, and Professor Peter Robertson, author of the method used in the software.

CLiq provides users with an easy to use graphical environment specifically tailored for CPT and CPTU data. This new software addresses advanced issues such as cyclic softening in clay-like soils and thin layer/layer transition zone detection. CLiq provides results and plots for each calculation step, starting with the basic CPT data interpretation through to final plots of factor of safety, liquefaction potential index and post-earthquake displacements, both vertical settlement and lateral displacements. CLiq provides consistent output results by applying the state-of-the-art methods (e.g. Youd et al, 2001) along with the calibrated procedures for post-earthquake displacements (e.g. Zhang et al 2002 & 2004).

CLiq User's Manual

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2 Introduction

CLiq is software for the assessment of soil liquefaction using CPT/CPTU data. CLiq was developed in collaboration with Gregg Drilling & Testing Inc., a leading company in site investigation and CPT, and Professor Peter Robertson, author of the method used in the software.

CLiq provides users with an easy to use graphical environment specifically tailored for CPT and CPTU data. This new software addresses advanced issues such as cyclic softening in clay-like soils and thin layer/layer transition zone detection. CLiq provides results and plots for each calculation step, starting with the basic CPT data interpretation through to final plots of factor of safety, liquefaction potential index and post-earthquake displacements, both vertical settlement and lateral displacements. CLiq provides consistent output results by applying the state-of-the-art methods (e.g. Youd et al, 2001) along with the calibrated procedures for post-earthquake displacements (e.g. Zhang et al 2002 & 2004).

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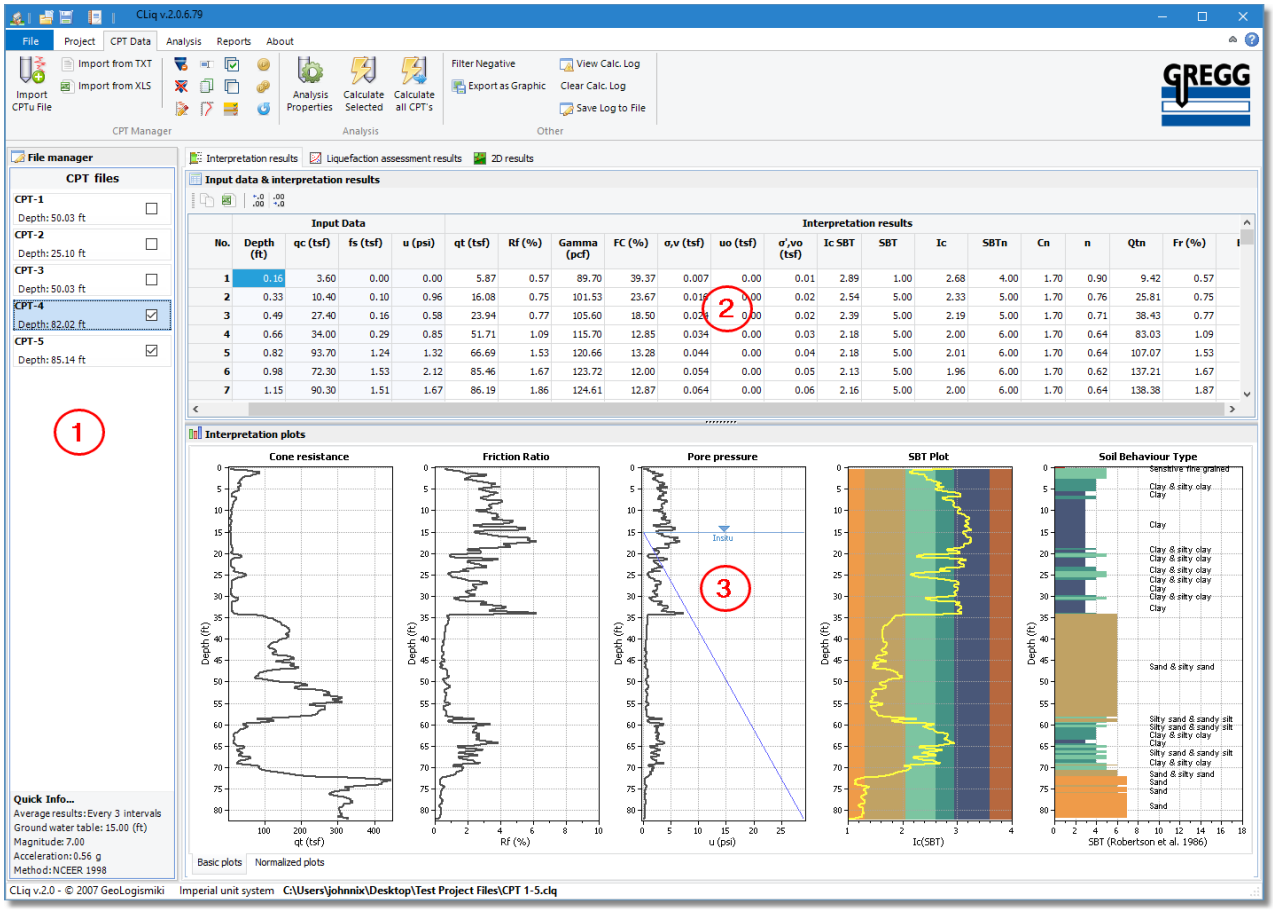
3 Overview

The software's main window is divided into two areas. In the left area, under the title ***File manager*** (marked as "1" in the figure below), it displays a list with the available CPTU data for the current working project. Inside the right area CLiq will display input and calculation results in both tabular and graphic format. This way you can always have an instant preview of your data and liquefaction assessment results for quick reference.



CLiq main window

The right hand side of the main window shows tabular output in the top half (marked as "2" in the figure above) and plots in the lower half (marked as "3" in the figure above). The top half has three (3) tabs, one for *Interpretation Results*, one for *Liquefaction assessment results* and one for the presentation of *2D results*. A short description of what these tabs show is presented below:

When the *Interpretation results* tab is activated, the table shows the measured CPT input data and basic interpretation results as a function of depth. The lower half shows the various plots in two tabs.

Basic plots: This tab displays plots of the corrected cone resistance, q_t, friction ratio, R_f, penetration pore pressure, u (with reference hydrostatic profile based on user input GWT), 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.

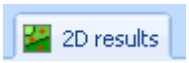
When the *Liquefaction assessment results* tab is activated, the table shows input data and calculation results as a function of depth. The lower half shows the various plots in three tabs.

Intermediate results: This tab displays plots regarding the steps needed to calculate the clean sand equivalent normalized cone resistance (needed for the $CRR_{7.50}$ calculation).

Cyclic Liquefaction Plots: This tab presents the summary of the calculation procedure by presenting plot of the Cyclic Stress Ratio (CSR), Cyclic Resistance Ratio (CRR), Factor of Safety, Liquefaction Potential Index and estimated displacements (vertical and lateral) over depth.

Analysis summary: This tab presents an overall summary of the liquefaction assessment, in terms of the normalized SBT_n and the plot of CSR versus clean sand equivalent normalized cone resistance with each CPT data point displayed.

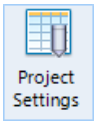
Check for strength loss: This tab presents a summary related to "Flow Liquefaction" and the resulting "liquefied strength ratio", depending on the method selected by the user.



This tab contains all the necessary commands to create and print 2D results for the LPI or vertical settlements.

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 CLiq 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 *Project* tab and click on the 

button. The following dialog will appear:

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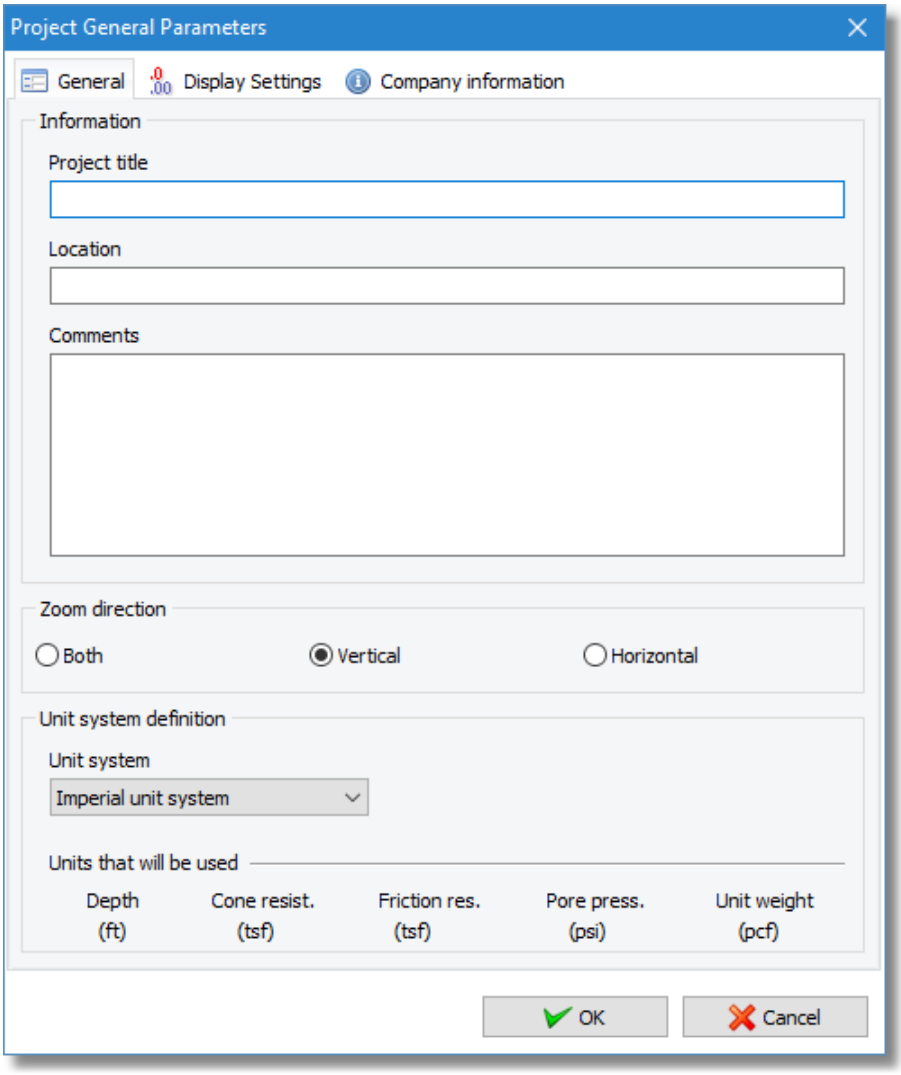

Project information dialog

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 resistance**	**Friction resistance**	**Pore pressure**	**Unit weight**
SI	meters (m)	Megapascal (MPa)	Kilopascal (kPa)	Kilopascal (kPa)	Kilonewtons per square meter (kN/m³)
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 CLiq will assist you in order to convert your input data to meet the above units.

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 generated reports.

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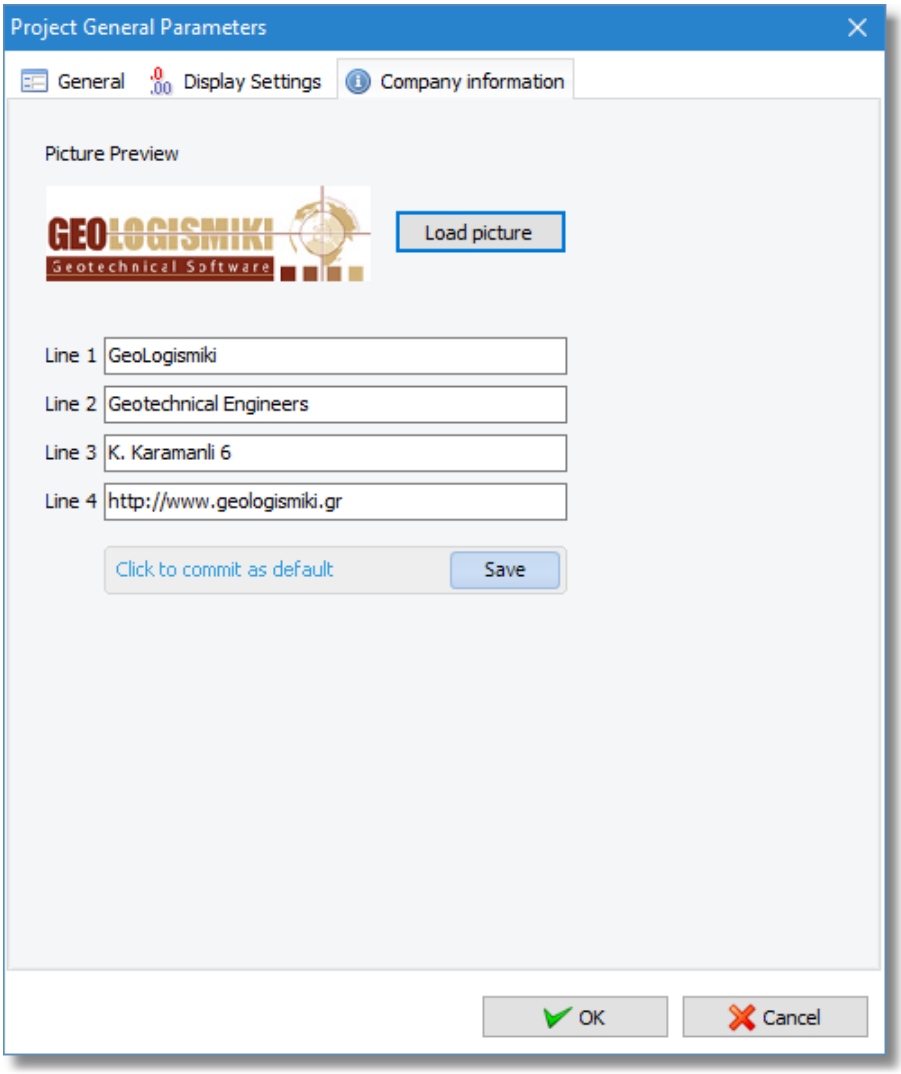

Company Information

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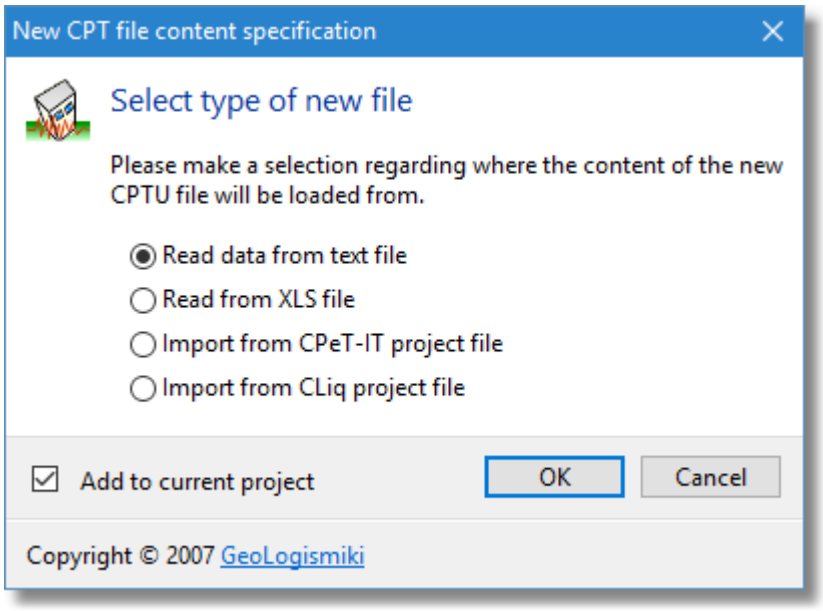
3.2 Importing CPTU data

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 *CPT Data* tab and selecting the *Import CPTU file* command. The following dialog will appear:



CPTU file type selection

By default, CLiq will prompt you to read data from a text file. If you are a licensed CPeT-IT user you may import CPTU files from a CPeT-IT project file as described here. If you wish the new data files to be included in you current working project the *Add to current project* check box must be checked (applies only when importing data from CPeT-IT projects). Click *OK* to continue. The import data dialog will appear:

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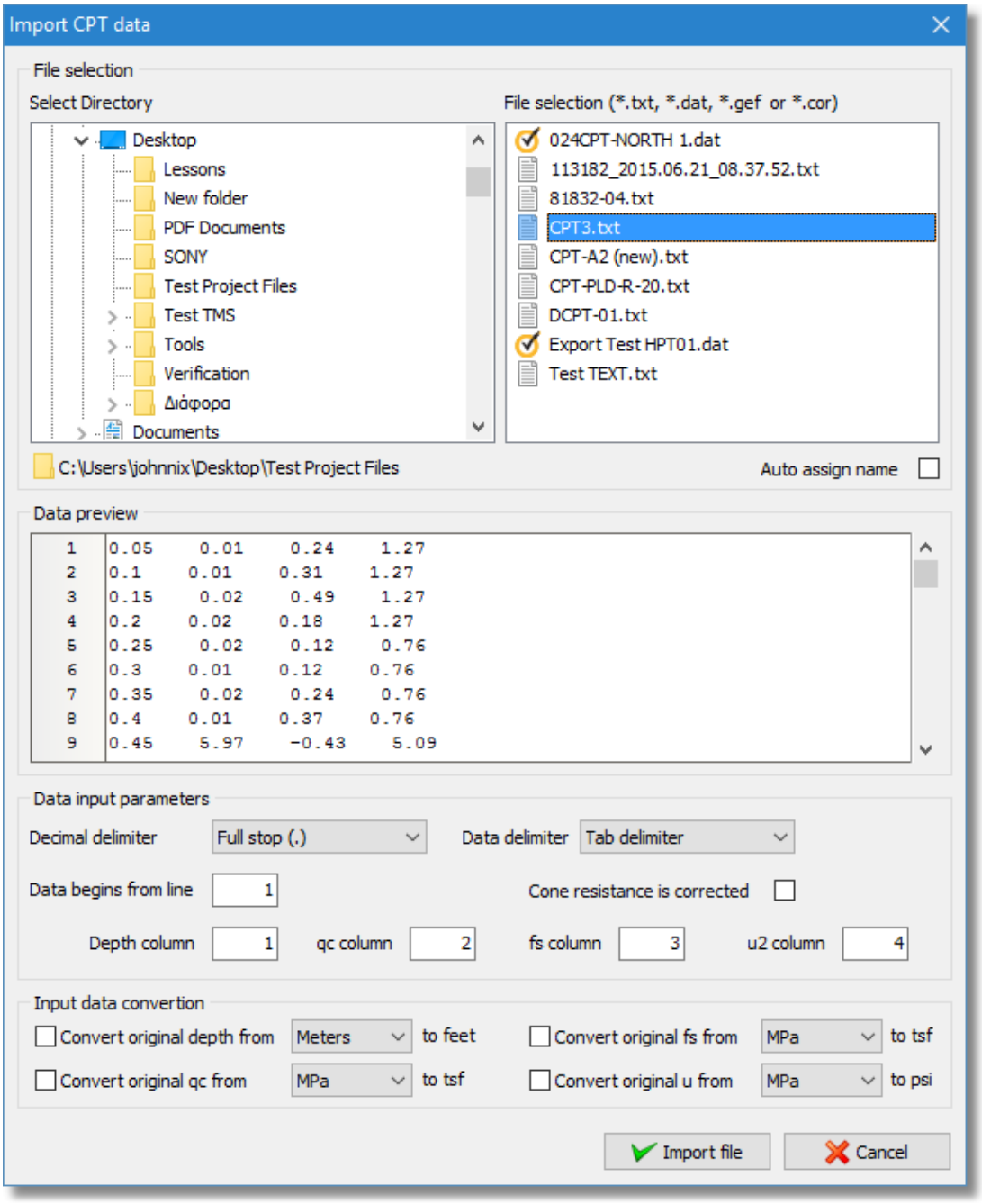

Import CPT file dialog

CLiq can read data that are stored in an ASCII file with extension .txt, .data, .cor and .gef. 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. Each CPT file will be given a new file name, starting with CPT-01. The file name can be changed to match the actual file name if the *Auto assign name* check box is not checked. You may also select multiple files by holding down the CTRL key on your keyboard while selecting files.

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). If other columns exist in the data file the software will ignore them.

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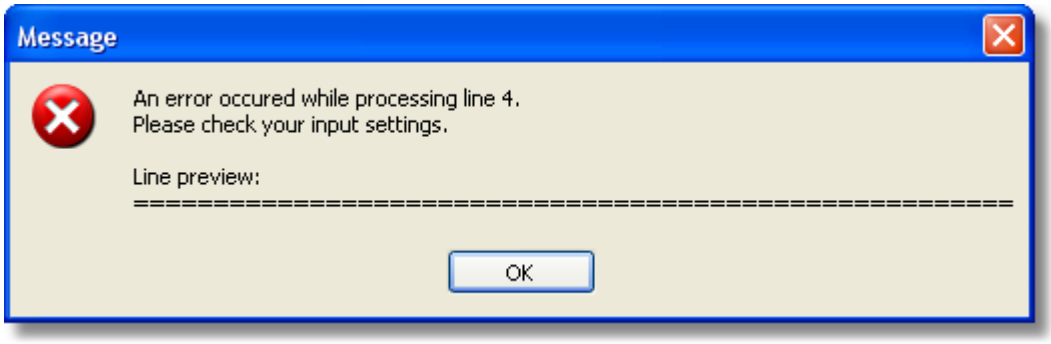
Based on the data preview and type of file you selected, you must provide the software with additional information regarding the data structure inside the file. CLiq needs to know what character is used as a decimal delimiter, what character is used as a data delimiter (separation character between column 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 for all selected files otherwise the import procedure will fail to read all files.

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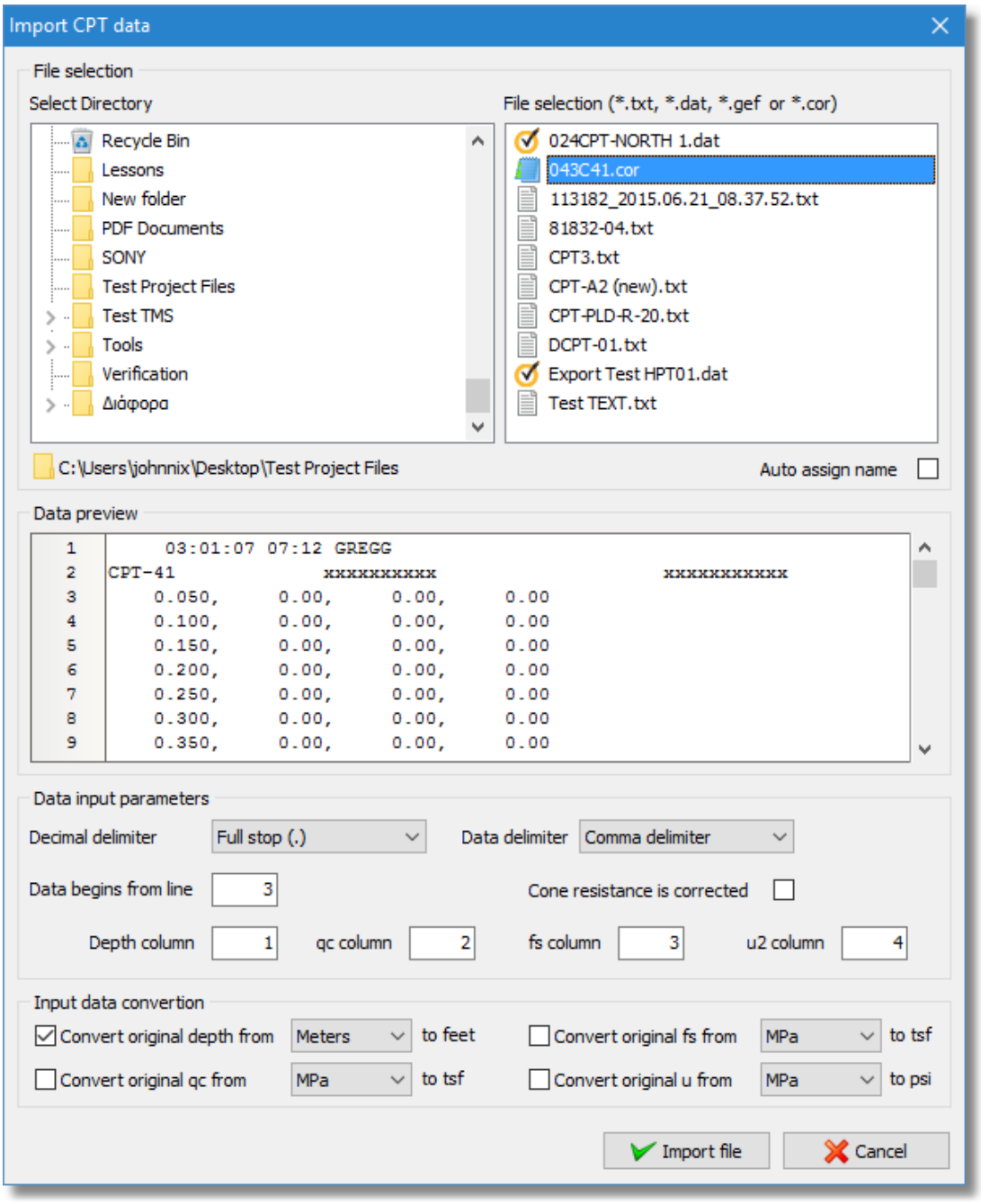
3.2.1 Importing .cor files

Gregg Drilling Inc., provides its customers with an ASCII text file containing the basic CPTU field measurements. This file has an extension .cor and when selected the software will make the appropriate selections for the various data input parameters and conversions 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.



Importing .cor files (for a project with units in SI)

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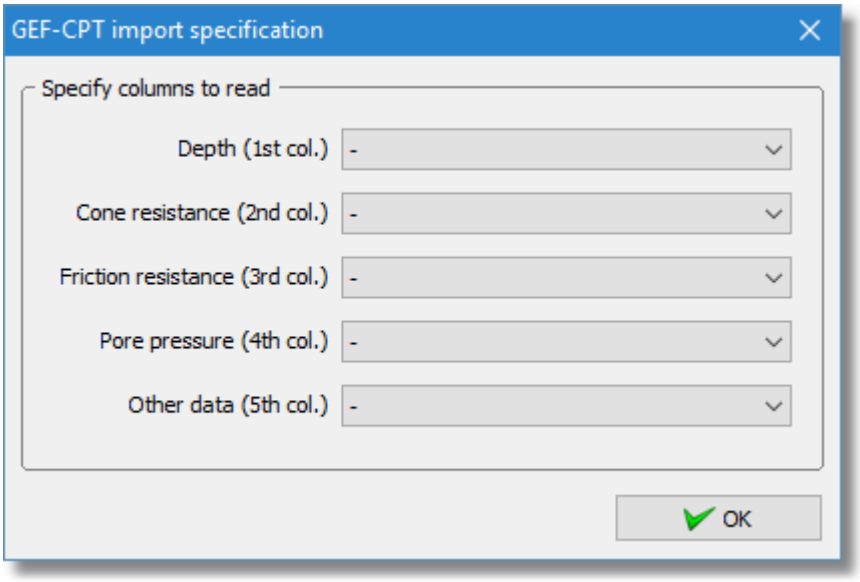
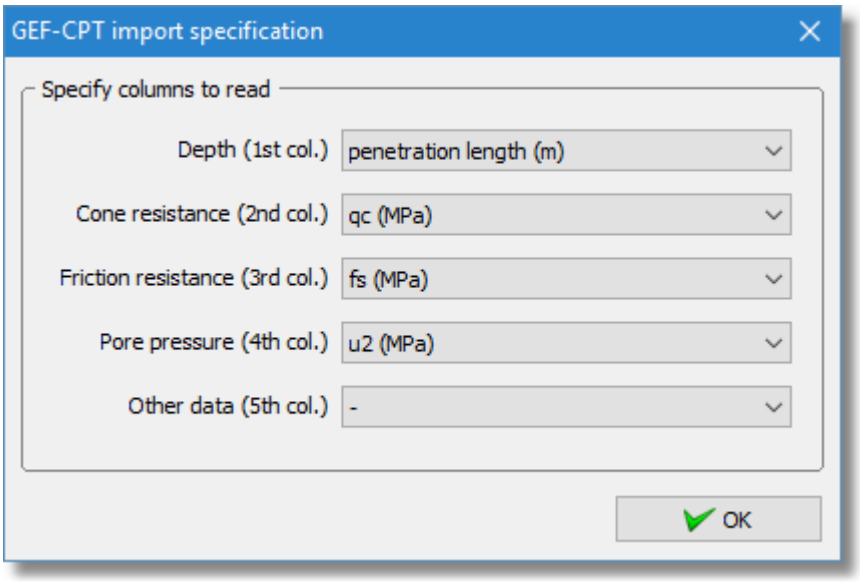
3.2.2 Importing .gef files

GEONET, the central Dutch website on Geotechnics, developed the Dutch national GEF-standard on geotechnical data-exchange. CLiq provides support for importing data from a GEF CPT data file. When you select the .gef file the following dialog will appear:



GEF import file dialog

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:



Selected columns to import from a GEF file

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. Please notice that the *Data delimiter* should be set to *Tab delimiter.*

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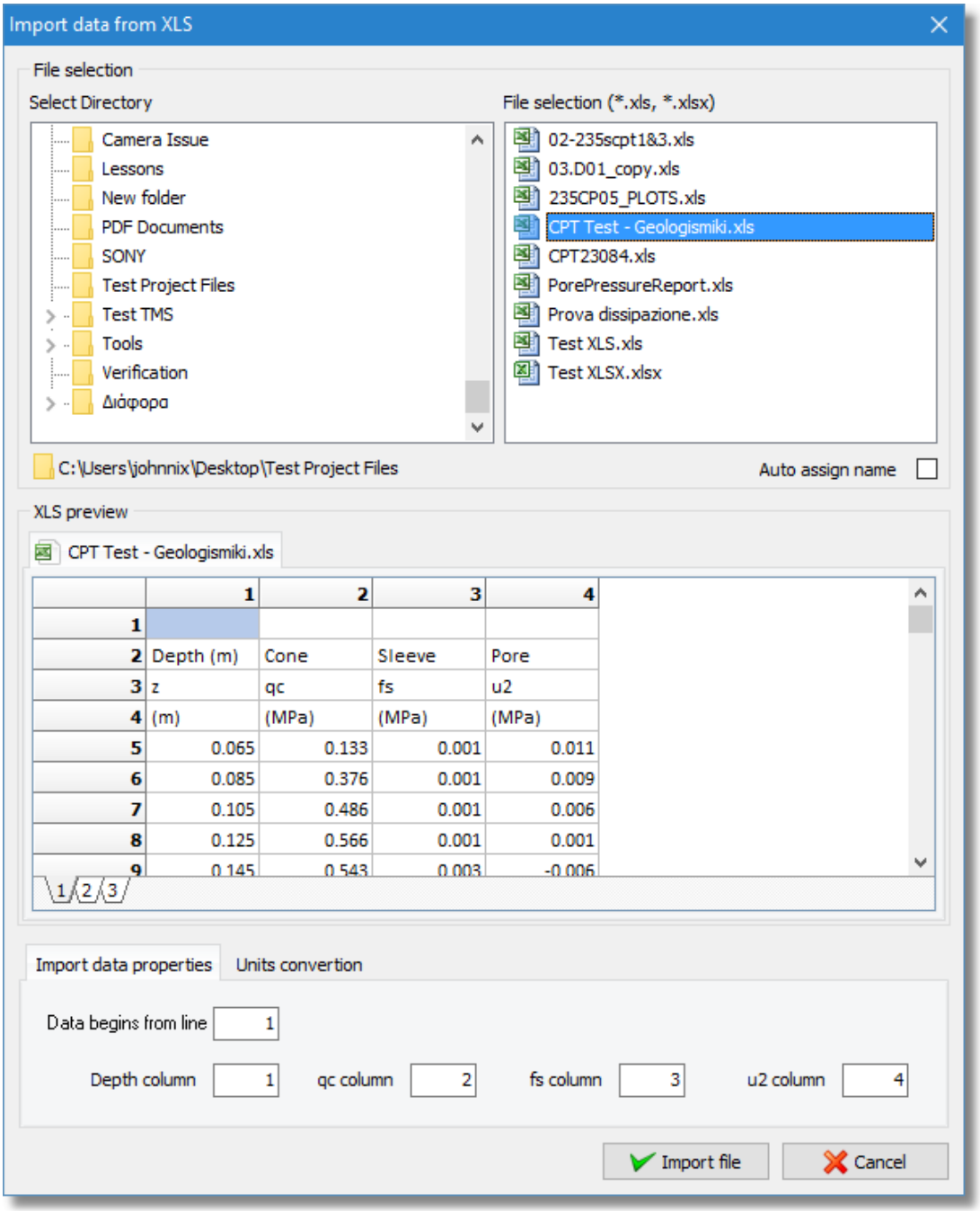
3.2.3 Importing XLS files

Importing data from an XLS file is very similar to the importing procedure described above. After you have selected *Read from XLS file* CLiq will display the following dialog:



Importing XLS file (for a project with units in SI)

Browse to the directory where the XLS files are and click on a file. CLiq will try to read the file and load its contents into the *XLS preview* area. Depending on the size of the XLS file, this procedure may take some time. You may browse into the preview of the XLS file and switch between sheets in order to locate the sheet which holds the data. In case that the data in your file do not meet the units specification, click on the *Units convertion* tab and 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.

Click *Import file* to create the new CPTU file.

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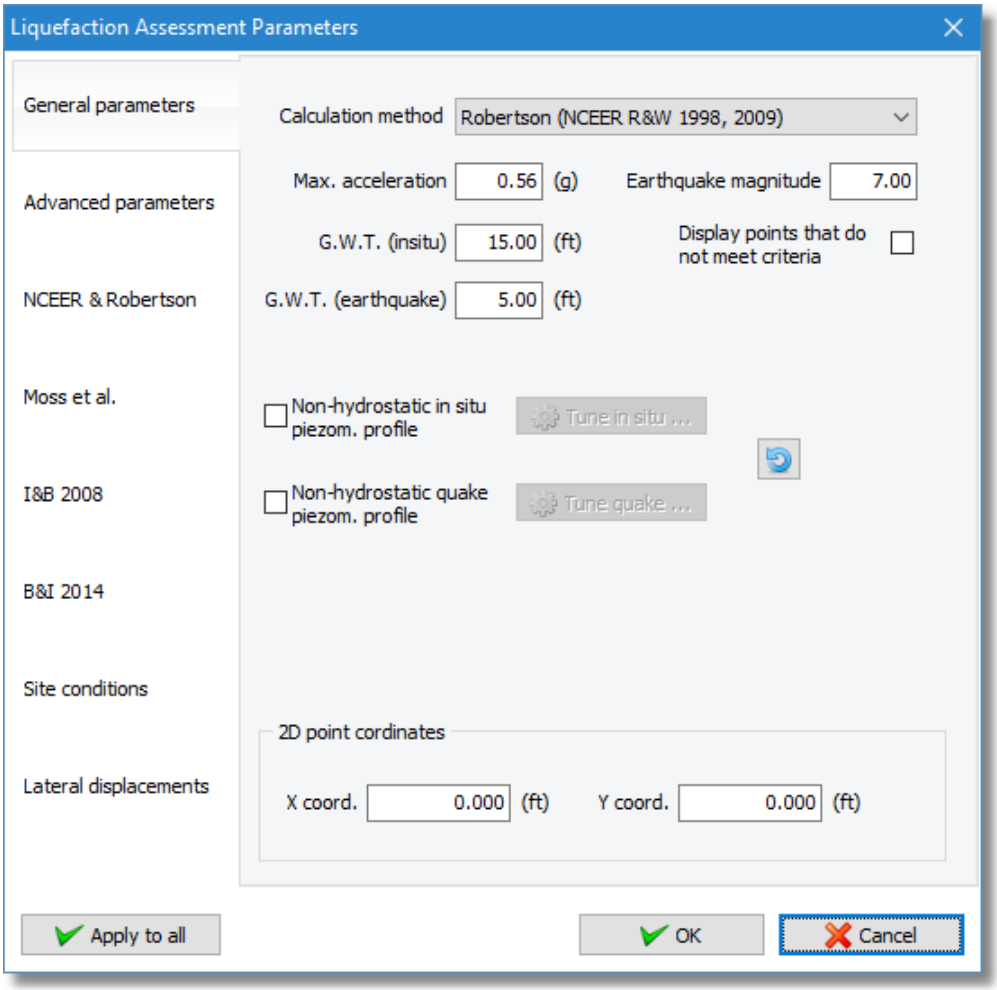
3.3 Defining CPT and liquefaction calculation parameters

CLiq uses established empirical correlations to estimate geotechnical parameters for basic data interpretation. It also allows the user to modify constants that are essential for the liquefaction calculation procedure. These input parameters are applied to each single CPTU file in the current project, giving the ability to perform analysis with different set of parameters for the various files. In order to preview and/or modify the calculation parameters, first select a CPTU file and then from the *CPT Data* tab select the *Analysis properties* command. The following dialog will appear:



Liquefaction assessment parameters dialog

The dialog presents various sections where the user may alter calculation parameters. For more details click on the section name are presented below:

1. General parameters
2. Advanced parameters
3. NCEER & Robertson
4. Moss et al.
5. I&B 2008
6. B&I 2014
7. Site conditions
8. Lateral displacements

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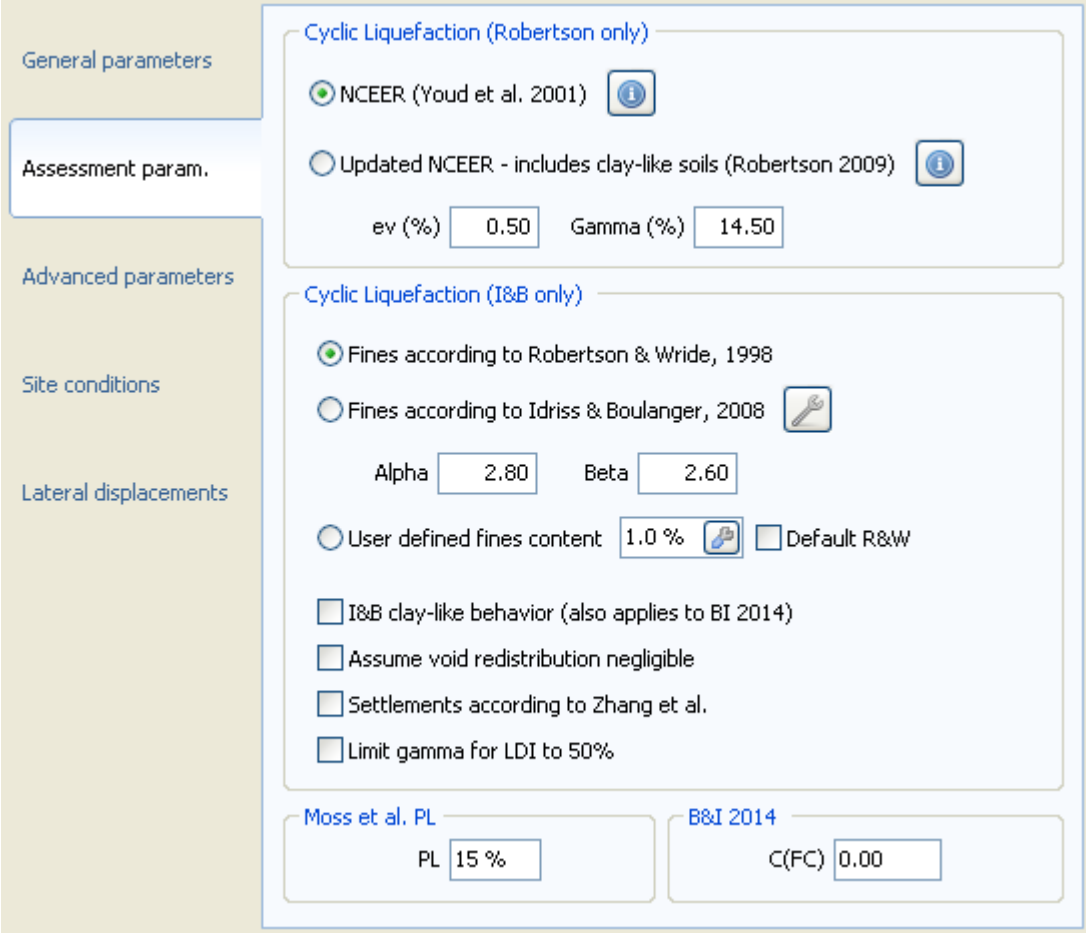
Assessment parameters



Assessment parameters

-
-
- **Moss et al. PL**: The deterministic CRR formula provided by Moss at al. makes use of the probability for liquefaction. This portion can be altered with the default value set to 15%
- **B&I 2014 (C_{FC})**: Fitting parameter for the estimation of apparent fines content.

Advanced parameters

Site conditions

In this section the user may specify final site conditions that is the expected condition of the site during the earthquake.

Lateral displacements

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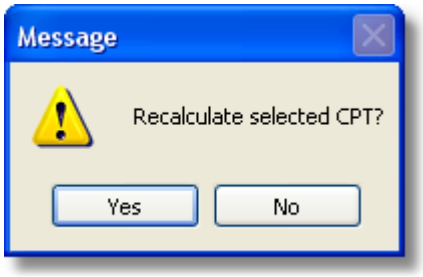
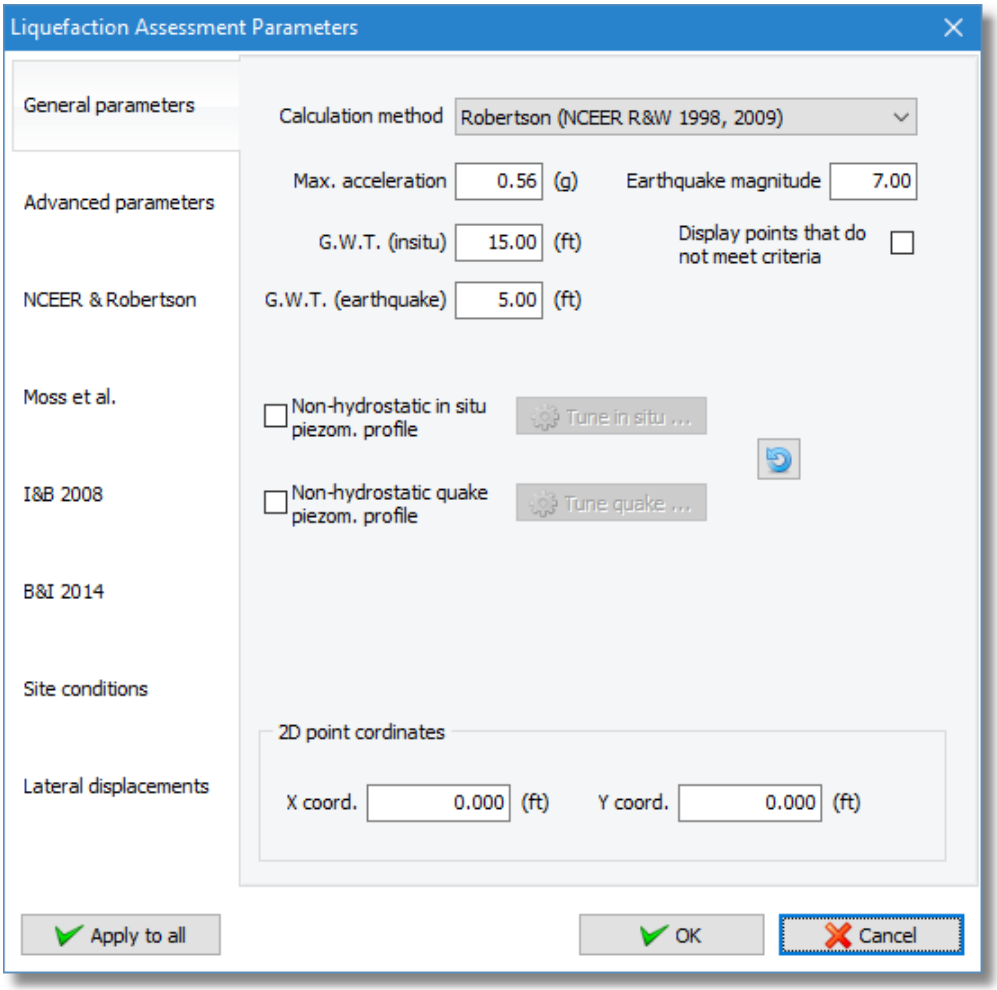
If you need to set these parameters to all CPTU files in the current project, click on the *Apply to all* button (this will result the dialog to close and CLiq will recalculate all CPTU files). When done click on the *OK* button to close the dialog. Please notice that the software will try to automatically recalculate the selected CPTU file and will prompt for an answer:



Calculation of a CPT file

Answer *Yes* to the above dialog if you must recalculate the basic interpretation of the CPTU file e.g. if you have altered the cone area ratio or the thin layer detection algorithm. If you answer *No* the software will use the current interpretation to perform the liquefaction calculation. If you are not sure about your answer always click on the *Yes* button. If your answer is *Cancel* then no calculation will be performed but the changes made to the liquefaction calculation properties will not be lost.

3.3.1 General parameters



Liquefaction assessment parameters dialog

- **Calculation method**: A list with the available calculation methods, by default the software uses the NCEER (Youd et al. 2001) method (i.e. Robertson & Wride, 1998)

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- **Max, acceleration**: This field holds the value of the peak ground acceleration that will be used for the calculation of Cyclic Resistance Ratio.
- **Earthquake magnitude**: This field holds the earthquake magnitude that will be used for the determination of Magnitude scaling factor. This factor is used to convert the analysis to an equivalent earthquake of a magnitude of 7.50 .
- **G.W.T. (insitu)**: This field holds the absolute depth of water level relative to the ground surface (e.g. a value of 1.00 meter means that ground water level is located one (1) meter below the ground free surface). The value of the insitu G.W.T. will be used for the determination of in-situ stresses needed for the calculation of the basic CPT interpretation and Cyclic Resistance Ratio.
- **G.W.T. (earthquake)**: This field holds the depth of water level during the earthquake and it will be used for the calculation of the Cyclic Stress Ratio (CSR). When a fill is present G.W.T. during earthquake measures from top of the fill. This means that if the insitu G.W.T. is at 2.00 meters and you place a fill of 1.50 meter height then to preserve the G.W.T. during earthquake in the same level you must enter a value of 2.00 + 1.50 = 3.50 meters.
- **Display points that do not meet criteria**: During the liquefaction assessment calculation the software excludes points by applying a large value (equal to 4.00) on the CRR portion based on some criteria. CSR calculation is normally performed for these points hence they can be plotted in the CSR vs $q_{t1N,cs}$ plot. Unchecking this option will instruct the software not to plot points that belong in a transition layer or measurements above the ground water level that internally are excluded from the liquefaction procedure, hence having a default FS value equal to 2.00.
- **Non-hydrostatic piezom. profile**: Non-hydrostatic piezometric profiles can be defined for both in situ and during earthquake conditions. Checking the appropriate check box the corresponding tune button will be enabled. Clicking the button will popup the following dialog:

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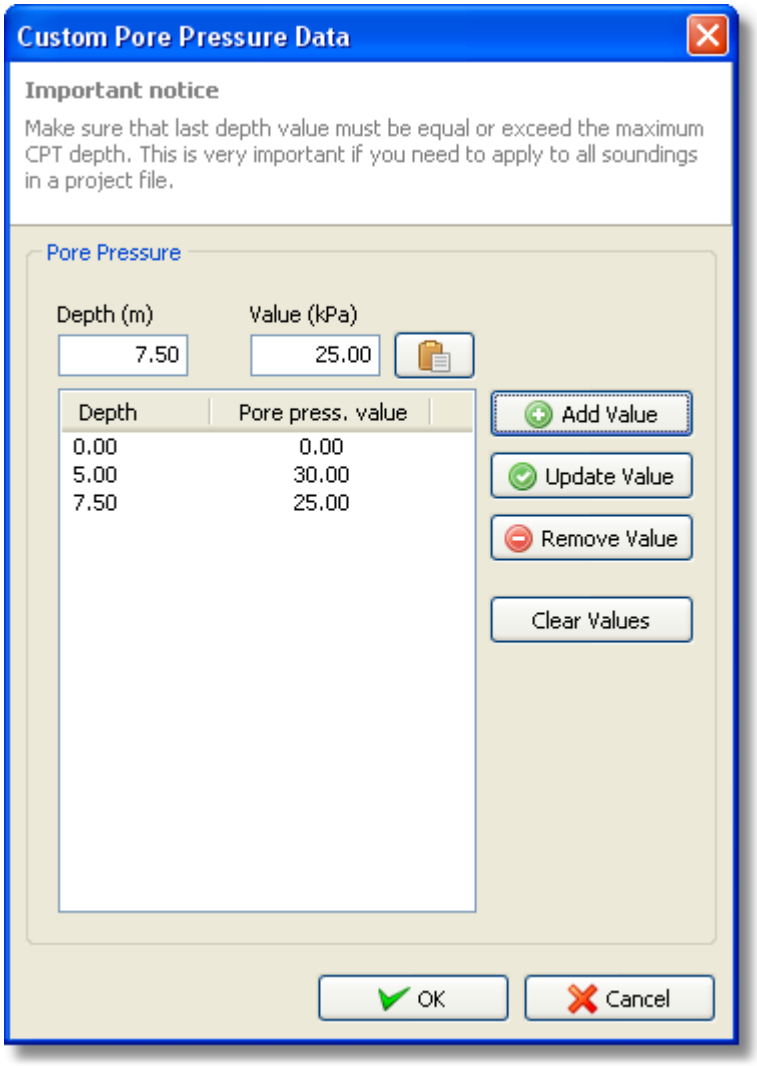

Definition of non-hydrostatic piezom. profile

The values required are pairs of depth and pore pressure and values in between are calculated with simple linear interpolation.

- **X coord. and Y coord.**: These fields hold a pair of numbers that represent the coordinates of the CPT. The default value for both fields is 0.000 and can be altered when using the 2D feature. The X, Y coordinates are referenced to some reference point at the site, not latitude or longitude.

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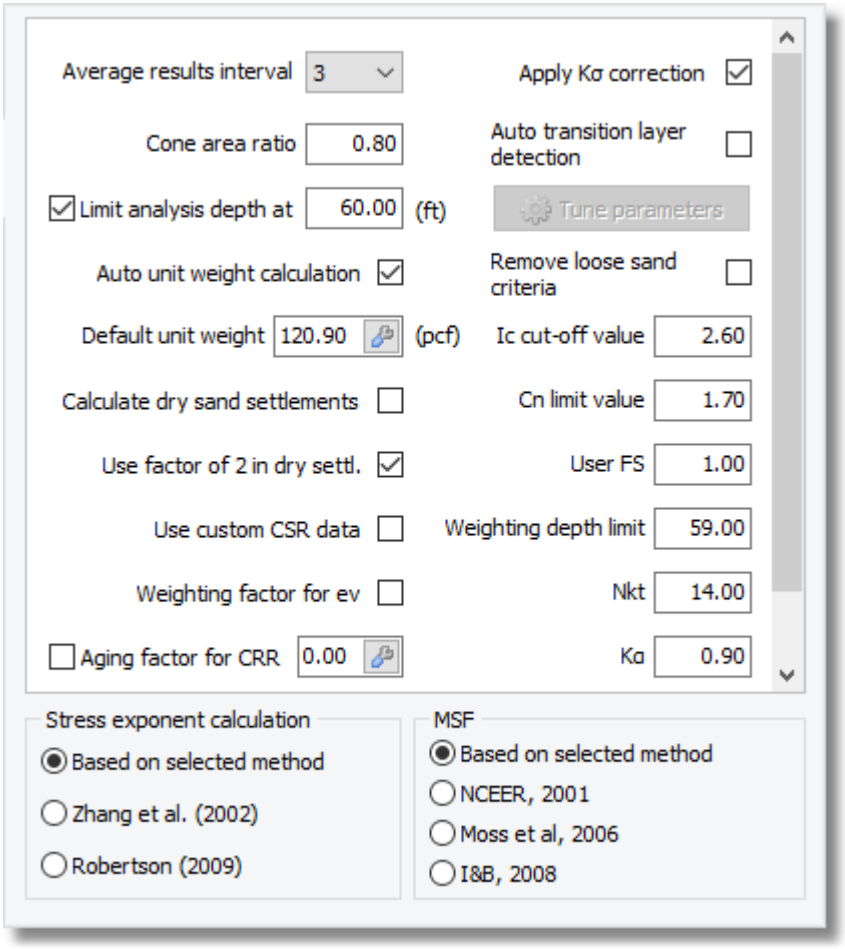
3.3.2 Advanced parameters



Advanced parameters

- **Average interval**: Available selection is 1, 3 or 5. The number denotes how many depth increments will be used in order to produce averaged results. If 1 is selected there is no averaging on input data. The function used for averaging data is the simple running average algorithm so there is no volume reduction on the original data.
- **Cone area ratio**: The net area ratio for the cone (default value to 0.80). This value is used for the determination of the total cone resistance q_t.
- **I_c cut-off value**: According to Robertson and Wride (1998) soils with a Soil Behavior Type Index (I_c) greater than 2.60 are characterized as clay-like soils and likely not susceptible to cyclic liquefaction. Data points (sounding points) that meet that criterion are excluded from the liquefaction calculation procedure. User may alter this value accordingly to engineering judgment and samples. Default value is 2.60.
- **Limit analysis depth at**: Experience has shown that the 50-foot (15 m) depth may be adequate for the evaluation of liquefaction potential in most cases, however, there may be situations where this depth may not be sufficiently deep (from SP117). Hence, the software provides a user option to ignore any cyclic liquefaction below a user input depth, where 20 m (or 60 ft) is the default value if the user selects this option (check box checked).
- **Default gamma value**: This field holds the default value of soil unit weight that will be used for the determination of stresses. By clicking the small button next to the default unit weight box the user can input a table of soil unit weight values as a function of depth.
- **Auto unit weight calculation**: If checked the software will try to estimate the unit weight automatically. If not checked then it is assumed that the soil has a constant unit weight over depth, equal to the value entered in the *Default gamma value* field.

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- **Apply K_σ correction**: If unchecked CLiq will not apply a correction due to overburden stresses. For Moss et al. method this option will make no difference as the calculation procedure assumes K_σ=1.00
- **Auto transition layer detection**: If checked the software will try to locate and eliminate (exclude from liquefaction calculation) points that belong to transition layers. Detailed information on this procedure can be found here.
- **Remove loose sand criteria**: For Robertson methods, when calculating grain characteristics factor K_c, if checked the software will not set K_c=1.00 when 1.64 < I_c < 2.36 and F < 0.5%
- **Calculate dry sands settlements**: When this option is checked the software will estimate vertical settlements due to the compaction of sand above GWT during earthquake based on Robertson & Shao, 2010.
- **C_n limit value**: For CPT points close free ground surface normalized CPT resistance can get quite high so a limit on the stress normalization factor can be used. Default value from Youd et al. 2001 is 1.70
- **Use Custom CSR data**: Custom CSR data can be imported to the software be clicking the button on the main toolbar. Notice that overburden correction factor will apply to the custom CSR data. Magnitude scaling factor will only apply if CSR data are not adjusted to M_w=7.50
- **User FS**: A custom safety factor that can be applied on the liquefaction FS calculated. In general it is recommended to leave this to the default value of 1.0. If a value FS > 1.0 is selected, the program will modify the CSR by a that factor (i.e. if FS = 1.2, the CSR will be increased by a factor of 1.2, resulting in a more conservative calculation).
- **Weighting factor for e_v**: Cetin et al (2009) suggested a simple linear weighting factor that will weight the volumetric strain (e_v) with depth. This reduces the impact of any volumetric strains at large depth. The weighting starts from 1.00 at the ground surface and equals to 0.00 at the weighting limit depth. Cetin et al 2009 suggested a depth limit of 18m, but can be user defined based on engineering judgment.
- **Aging factor for CRR**: Researchers (e.g. Arango et al 2000) have suggested that the cyclic resistance ratio (CRR) increases with geologic age of the deposit. By selecting this feature, the calculated values of CRR7.5 are increased by the input factor (i.e. if the aging factor is 1.2, the CRR7.5 values are increased by a factor fo 1.5).
- **N_{kt} (Undrained shear strength factor)**: When the user has selected to include clay-like soils (under Assessment param.), this value of Nkt is used to estimate the peak undrained strength (S_u) for the clay-like soils (i.e. soils with I_c > I_c cut-off) to calculate the $CRR_{7.5}$ for cyclic softening.
- **P_L based volumetric strain**: For every CPT point the software calculates the probability for liquefaction, if this option is checked then the volumetric strain calculated at each point is reduced by the portion of the estimated probability e.g. if P_L=30% then volumetric strain will be e_v*30%
- **K_α (Static Shear Stress Correction Factor)**: Idriss and Boulanger (2008) showed that the CRR for cyclic softening of clay-like soils is reduced when there is an existing initial static shear stress present. When the user has selected to include clay-like soils (under Assessment param.), this value is applied as a reduction factor to the $CRR_{7.5}$.
- **Stress exponent calculation**: Each CPT-based method uses different methods to normalize the cone resistance as a function of vertical effective stress using a stress exponent. It is suggested to allow the software to use the recommended method based on the selected liquefaction assessment method. However, the user has the option to select either the Zhang et al (2002) or Robertson (2009) methods as an alternate normalization. The default is "Based on the selected method"

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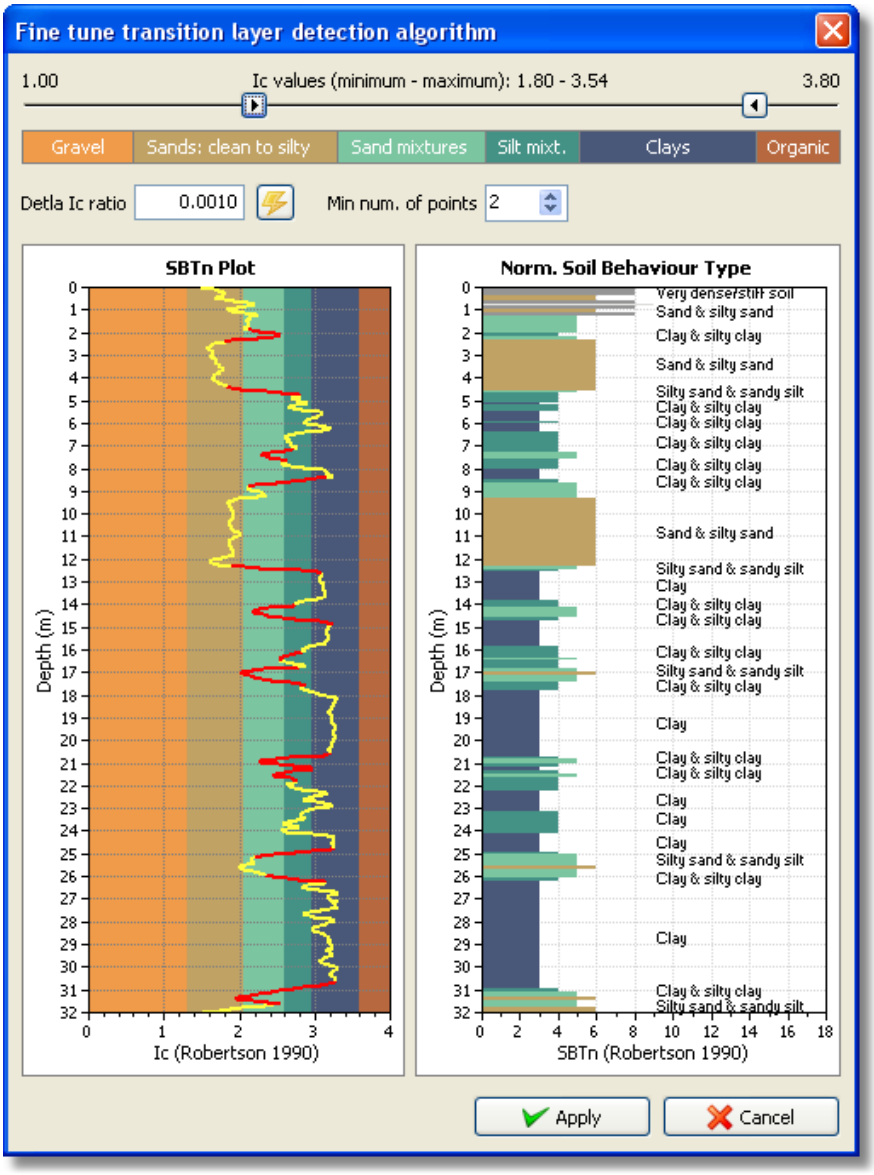
- **MSF (Magnitude Scaling Factor)**: Although the software offers the flexibility to use any of the available MSF methods it is strongly recommended to use only the suggested MSF for each method. The default is "Based on the selected method".
- **Delta Ic (scroll down inside the dialog box to see this feature)**: When vibro-compaction is carried out the horizontal stresses are often modified significantly resulting in a change in SBT I_c. The 'delta I_c' feature provides an option for the user to modify the I_c values to match pre-improvement conditions to better capture the grain characteristics (e.g. fines content).

3.3.2.1 Transition layer detection

When the user selects the *Auto transition layer detection* the *Tune parameters* button becomes available. When the user clicks on the *Tune parameters* button the following dialog box is shown:



Tune transition detection algorithm dialog

The software will delete 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

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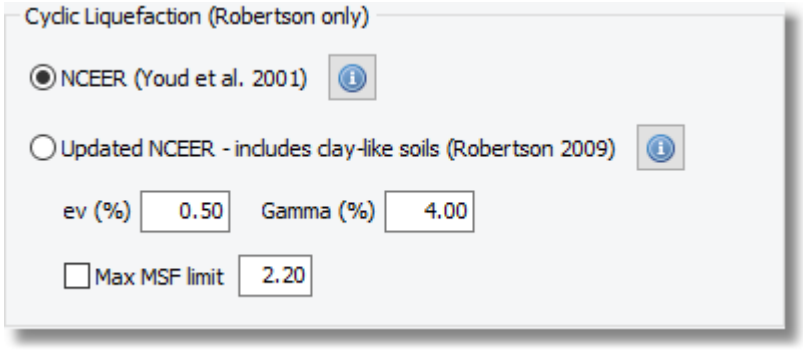
value in the box and input an alternate value, then click on the button to see the new red sections that will be deleted. The user can also move the sliding scales above to modify the range of I_c to define the transition. User judgment is required to optimize the amount of data that will be deleted. 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 CLiq will recalculate the layers automatically.

Click on the *Apply* button to see the resulting change in the liquefaction analyses. It is best to have the main page set to show *Liquefaction assessment results* and *Analysis plots* to see the effect of the results. Click on the *Calculate* button to implement the re-calculation using the user input transition layer correction.

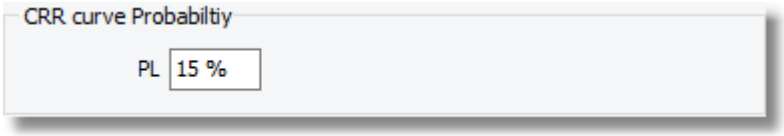
3.3.3 NCEER & Robertson



NCEER & Robertson calculation properties

- **Cycling Liquefaction (Robertson only)**: Options in this area apply only to Robertson & Wride 1998 and Robertson 2009 assessment method by specifying the actual calculation method to be used either NCEER (Youd et al, 2001) or Robertson (2009). For Robertson (2009) e_v and Gamma boxes contain the maximum values for post liquefaction volumetric strain and shear strain for clay-like soils, respectively. When checked *Max MSF limit* will use the input value as a maximum.

3.3.4 Moss et al.



Moss et al. calculation properties

- **CRR curve Probability**: Values of probability P_L to be used for the calculation estimation of CRR (default value is the one suggested by the authors)

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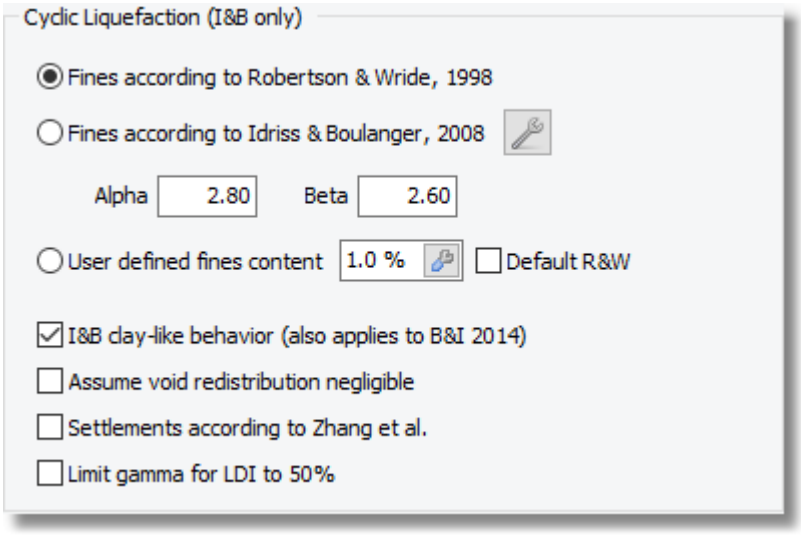
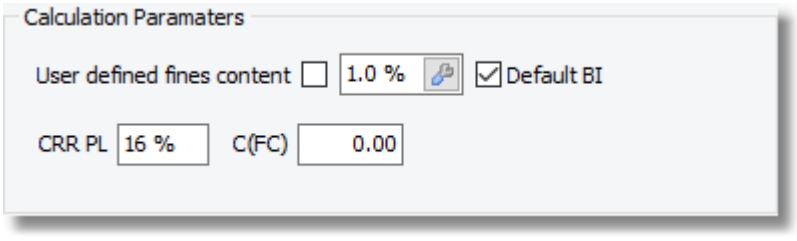
3.3.5 I&B 2008



I&B 2008 calculation properties

- **Cyclic Liquefaction (I&B only)**: For the Idriss & Boulanger (2008) calculation method a set of options are available. For the determination of the apparent fines content the default method is the use of the R&W formula. The second option is the use of the formula I&B proposed on their 2008 publication and a last option where the user can define a custom fines profile. For the I&B formula further customization can be fone by clicking the wrench button.
- **I&B clay-like behavior**: When checked the software will perform the cyclic softening calculation for clayey soils (CPT points with $I_c > I_c$ cutoff value) otherwise only sand points will be tested for cyclic liquefaction. This option is also used for the Boulanger & Idriss 2014 method
- **Assume void redistribution negligible**: Idriss & Boulanger (2008) provide two curves to estimate liquefied strength ratio. When this option is checked, the curve based on negligible void redistribution is used
- **Settlements according to Zhang et al.**: If check the software will make use of the Zhang et al. (2002) formulas for settlements estimations rather than the one proposed by I&B (2008)
- **Limit gamma for LDI to 50%**: According to I&B limiting shear strain can be reduced to 50% when performing LDI calculation

3.3.6 B&I 2014



B&I 2014 calculation properties

- **User defined fines content**: If checked the software will use custom FC data input instead of using the formula from B&I 2014. If the *Default BI* is checked then for CPT points that no custom data is available the software will use the value form the B&I 2014 formula instead of the default value input

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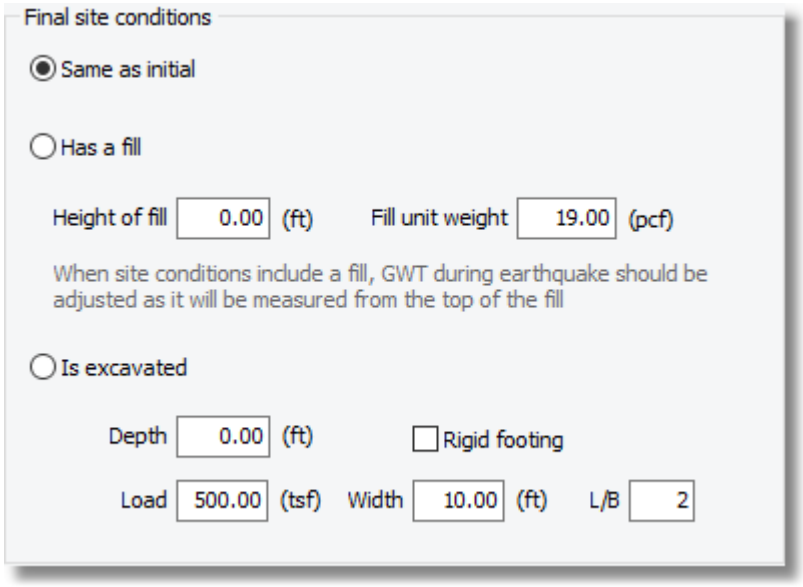
3.3.7 Site conditions



Site conditions parameters

- **Same as initial**: Select this option if the final site conditions (conditions during earthquake) are the same as the initial conditions (when CPT was performed), i.e. no fill or excavation.
- **Has a fill**: Select this option if the final site conditions where changed by applying a fill. The *Height of fill* input box holds the value of the height of fill and the *Fill unit weight* input box should hold the unit weight of the material used to construct the fill. These two parameters will be used to calculate the geostatic stresses during earthquake.
- **Is excavated**: Select this option if there will be an excavation before the earthquake. CLiq will not perform CSR calculations from depth 0.00 down to the value entered at the *Depth* field while CRR will be given a large value of 4.00. The *Width* field is the width of the foundation (foundation is assumed to be of a rectangular shape) and the *L/B* input box hold the value of the length to width ratio of the footing (e.g. a value of 1.00 means the footing is square and a value of 10 means that the footing is strip). Calculations of the load stresses distribution below the footing are performed based on the Boussinesq theory for a point under the middle of the footing. If the *Rigid footing* is checked the formula for a rigid footing will be used. Note the GWL (earthquake) must also be adjusted to reflect the added fill.

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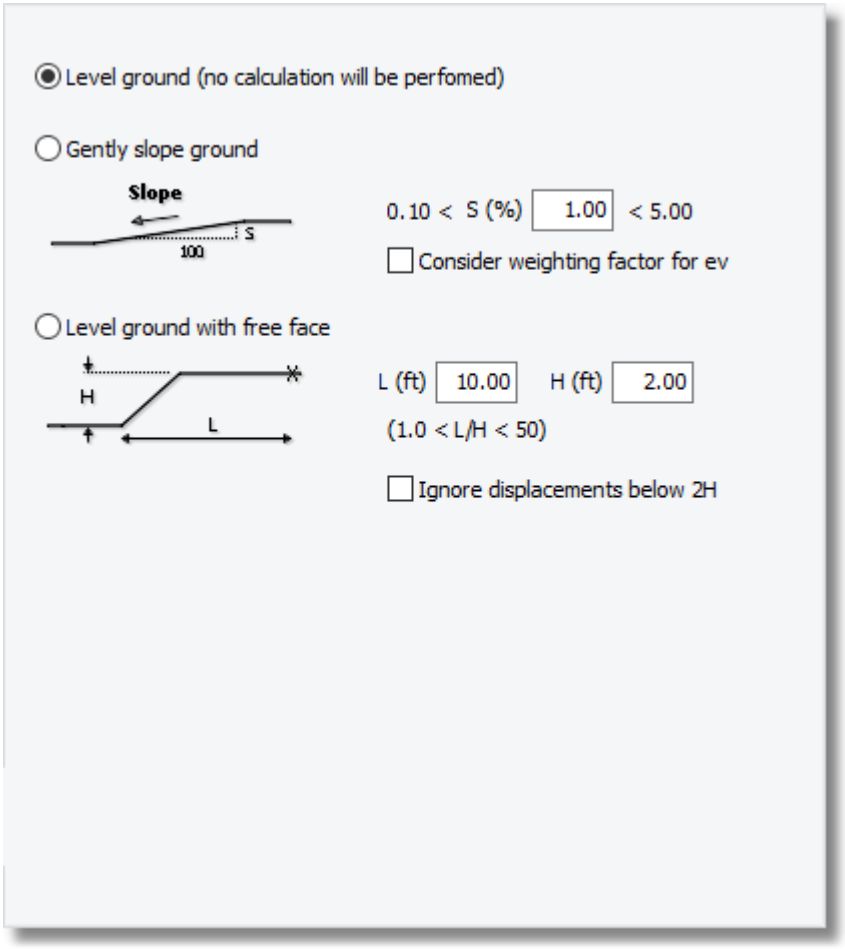
3.3.8 Lateral displacements



Lateral displacements parameters

- **Level ground (no calculation will be performed)**: When checked CLiq will not perform any calculation for the estimation of lateral displacements.
- **Gently slope ground**: This is the default selection. Lateral displacements will be performed based on the slope value entered (value must be larger than 0.20% and smaller than 3.50%). If liquefaction is calculated at large depth the resulting lateral displacement can be excessively high (since the program sums up all shear strains regardless of depth). The user has the option to apply a linear weighting factor to the shear strains (gamma) to avoid excessive lateral displacements. The linear weighting is similar to the weighting applied to vol. strains (e_v) and extends to a depth of 18m.
- **Level ground with free face**: When checked the software will estimate lateral displacements based on the geometry profile specified. *L* field holds the horizontal distance of the CPT from the slope toe, and *H* field holds the vertical height of the slope. When the *Ignore displacements below 2H* check box is checked, calculation of the estimated lateral displacements will not be performed for points that lay below a depth of 2xH from the ground surface (minus the fill height if specified).

3.4 Performing a calculation

The calculation procedure may be initiated for a single CPTU file or for all files in the current working project. To perform a calculation for the selected single CPTU file click on the *Data* menu and select the *Calculate selected CPT* command or you may click on the button located on the *File manager* toolbar. To perform an overall calculation for all CPTU files in the current project, click on the button on the main window toolbar. When performing an overall calculation the software will also perform the basic interpretation calculation.

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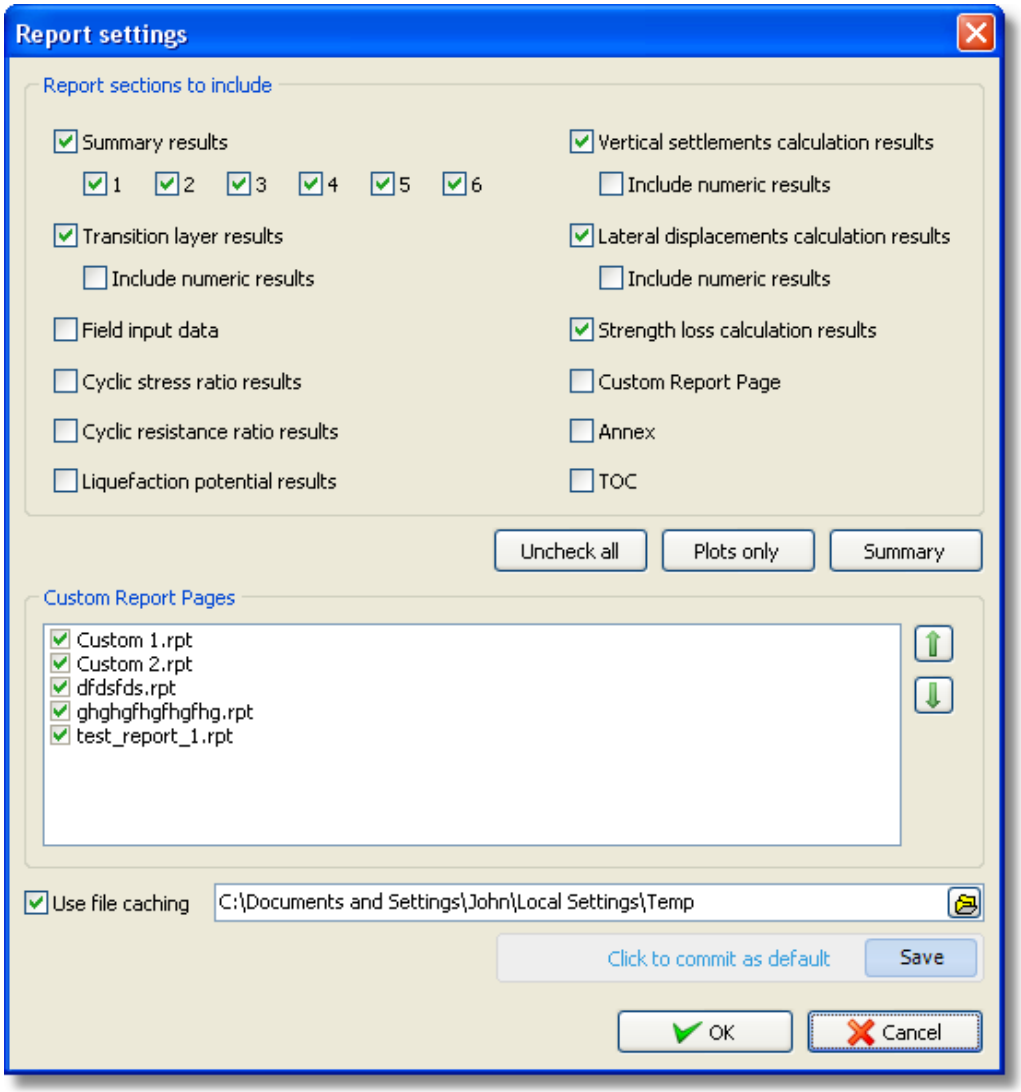
3.5 Preparing and printing a report

Preparing a report for a CPTU file is very easy. A full report contains pages with plots and tabular data for every calculation step, starting from in-situ measurements to settlements analysis. You may select the various sections of a report simply by clicking on the *Reports* menu and selecting the *Report settings* command. You may also click directly on the button which is located in the main toolbar. The following dialog will appear:



Report settings dialog

Check or uncheck sections that you wish to be included or excluded from the report and click on the *OK* button to commit the changes.

You can create reports for a single CPTU file or an overall report for all selected (checked) files in the current working project. To preview the report only for the selected CPTU file click on the *Reports* menu and select the *Single CPT report* command. Alternatively you may click on the button located on the *File manager* toolbar. To preview the report for all selected CPTU files click on the *Reports* menu and select the *Overall selected CPT report* command. Alternatively you may click on the button located on the *File manager* toolbar. The following dialog will appear:

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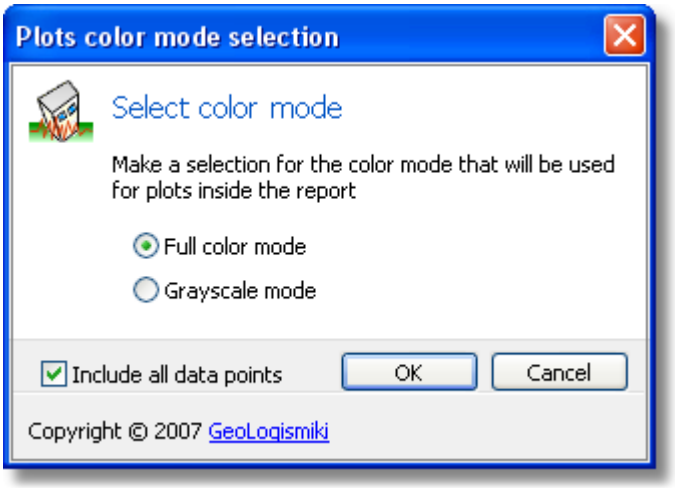

Plots' color mode

You have the option to crate a report using the colors used in the software or create plots using a grayscale mode which is very helpful when you must photocopy the report. Unchecking the include all data points will force the software to omit CPT points that do not meet the limitation depth criterion.

To proceed and create the report click on the *OK* button and a dialog will appear with the preview of the report that includes all sections that where selected.

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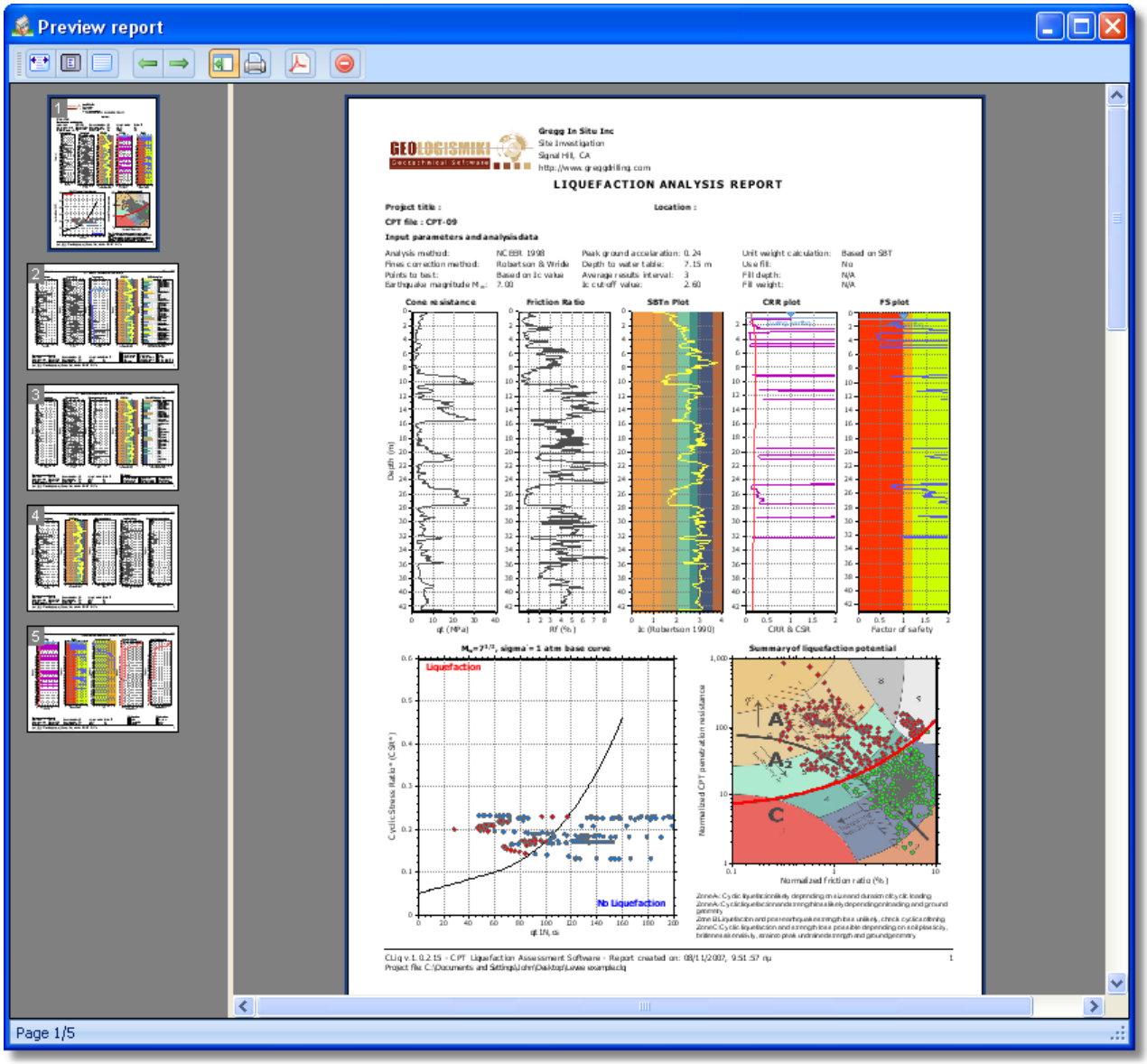

A sample report preview (summary results only in full color)

You may print the report by clicking on the button on the toolbar or you may export the report in a PDF file by clicking on the button.

All reports are designed to fit to an A4 page. If you wish to print the report on a different page without loosing any information, you may use the *Scale* feature (located inside the *Print mode* area) as shown below (i.e. need to print the report in a Letter size):

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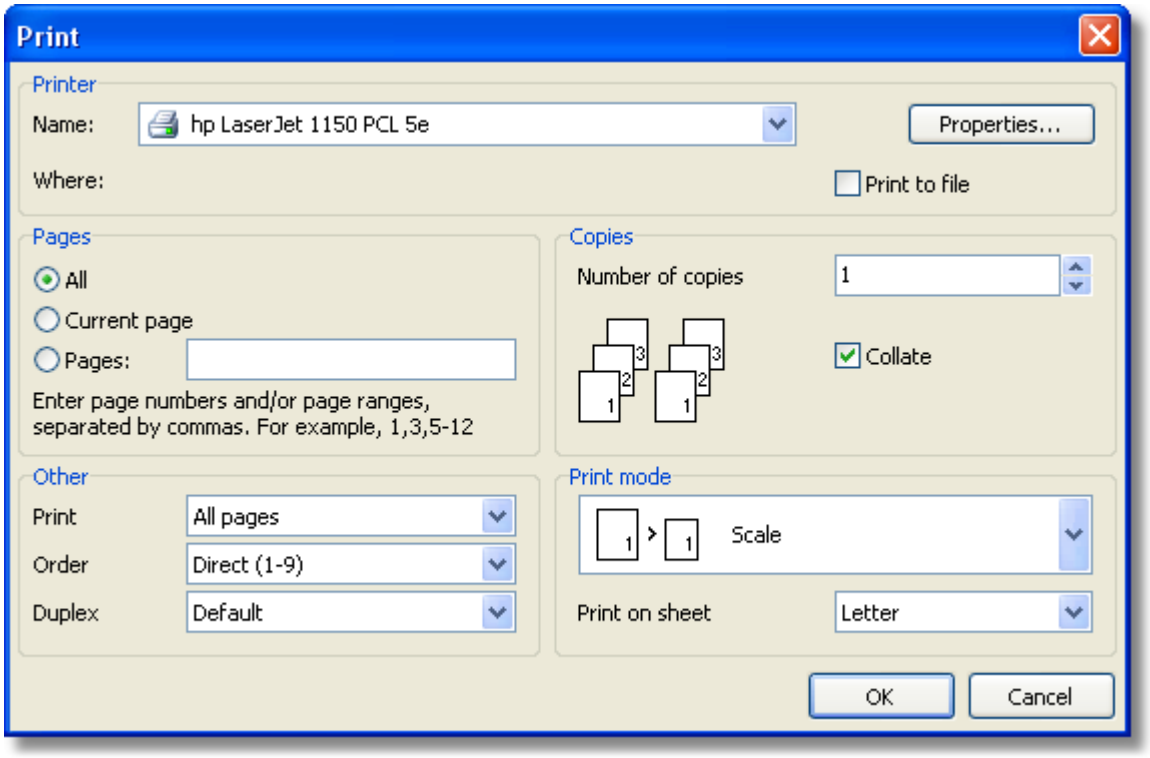

Print settings dialog

4 Advanced features

Some advanced features and techniques are presented below.

4.1 Creating a 2D plot

Performing various CPTU measurements at a site can be used to calculate overall results like LPI that refer to a single location. Combining the results of all CPTU files, CLiq can create a plain 2D map in plan view showing an estimated spatial distribution of LPI or vertical settlements. The accuracy of the map is based on the total number of CPTU files used.

The software by default creates an empty A4 page which will be used to insert the CPTU files and preview the map. At the bottom of the page there are some useful information regarding the position of the mouse over the page (in real world coordinates), page dimensions and the working layer. The origin of the coordinates is the bottom left corner of the page with associated coordinates of (0.00,0.00). The real world coordinates are calculated based on a custom drawing scale which by default is set to 1:50. For the default A4 page and SI unit system, a map scale of 1:50 means that the page top right corner will have the following coordinates: X = 14.85 (m) and Y = 10.50 (m). Using the toolbar button you may easily customize page setup and drawing scale.

You may add CPTU in 2 ways. If you have previously defined the coordinates of the CPTU files you can click on the button and the software will automatically place them inside the page. Another way is to click and drag to drop the CPTU files from the *File manager* into the page. Releasing the mouse button will display the following dialog:

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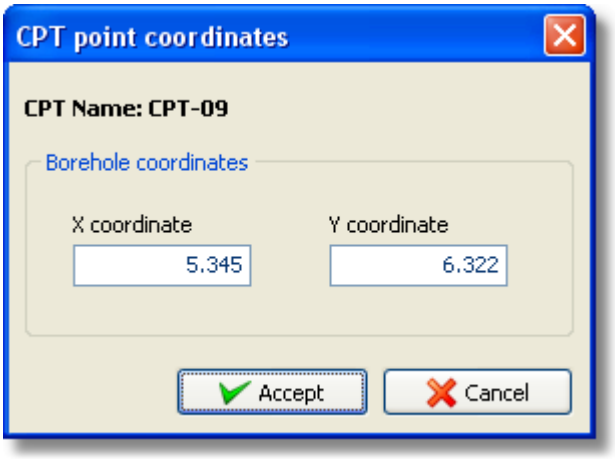
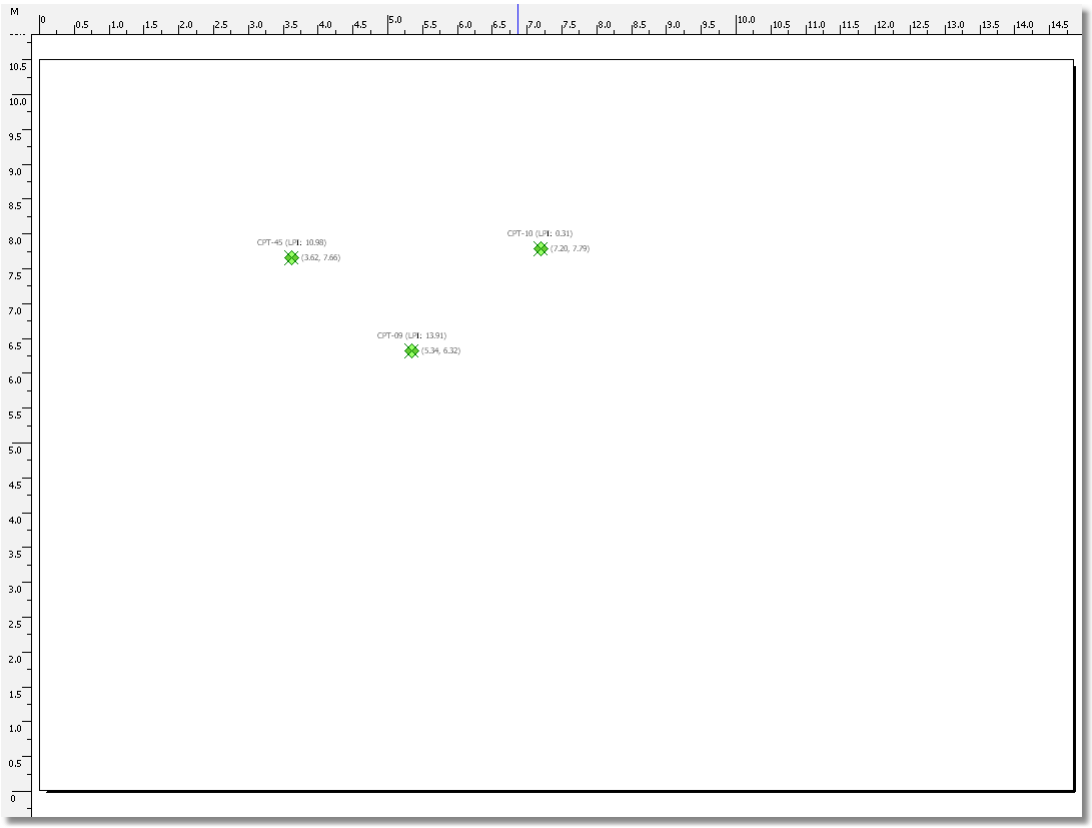


CPT point dialog

The *X coordinate* and *Y coordinate* fields will be filled with the coordinates of the point where you released the mouse button. Replace these coordinates with the real ones and click on the *Accept* button. The CPT point will be inserted and the page will look like the following image:



Page with CPT points

At the right of a CPT point CLiq displays the value of the variable to be processed (by default this is the LPI). To change the coordinates of a CPT point first make sure that the working layer is the *CPT points layer* (more information on how to change the working layer can be found here). Double click on the CPT point and the CPT point dialog will appear again.

After you placed all points inside the drawing area you must define a rectangle grid that includes all points. Click on the and move the mouse where the top left corner of the grid will be placed (notice that the mouse cursor now looks like a small cross) and click once. Move the mouse where the bottom right corner of the grid will be placed and click once more. The following dialog will appear:

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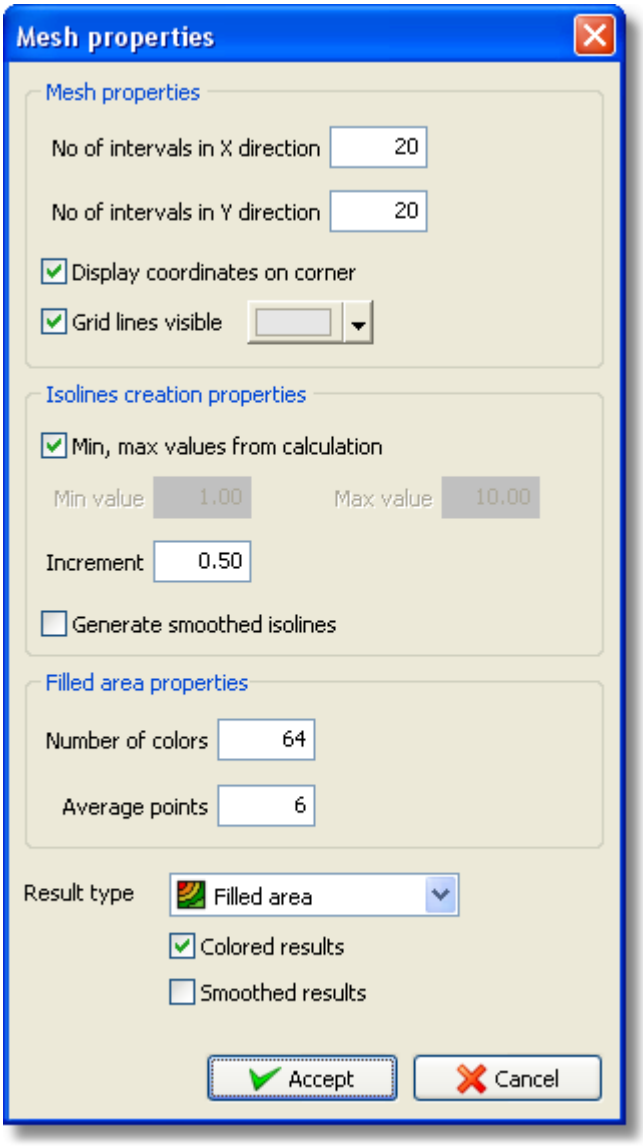

Grid setup dialog

Defining a dense grid may produce more smoothed results but it will also slow down the calculation process. The maximum *Number of colors* supported is 255. The *Average points* field holds the number of CPT points that will be used to estimate the value of the variable for each grid point. For each grid point the software will search for the closest *Average points* CPT points and if there not exist so many it will use the available number to calculate the estimation of the variable. Click *Accept* and the drawing area should look like the following image:

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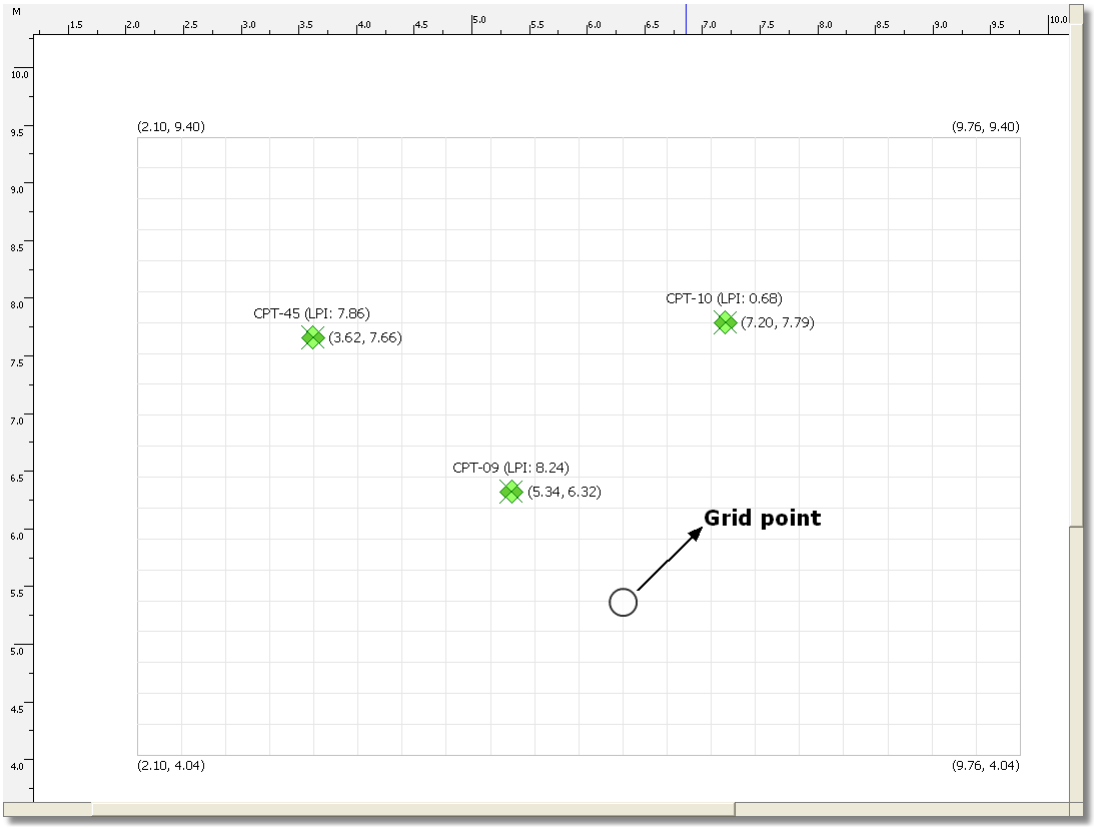
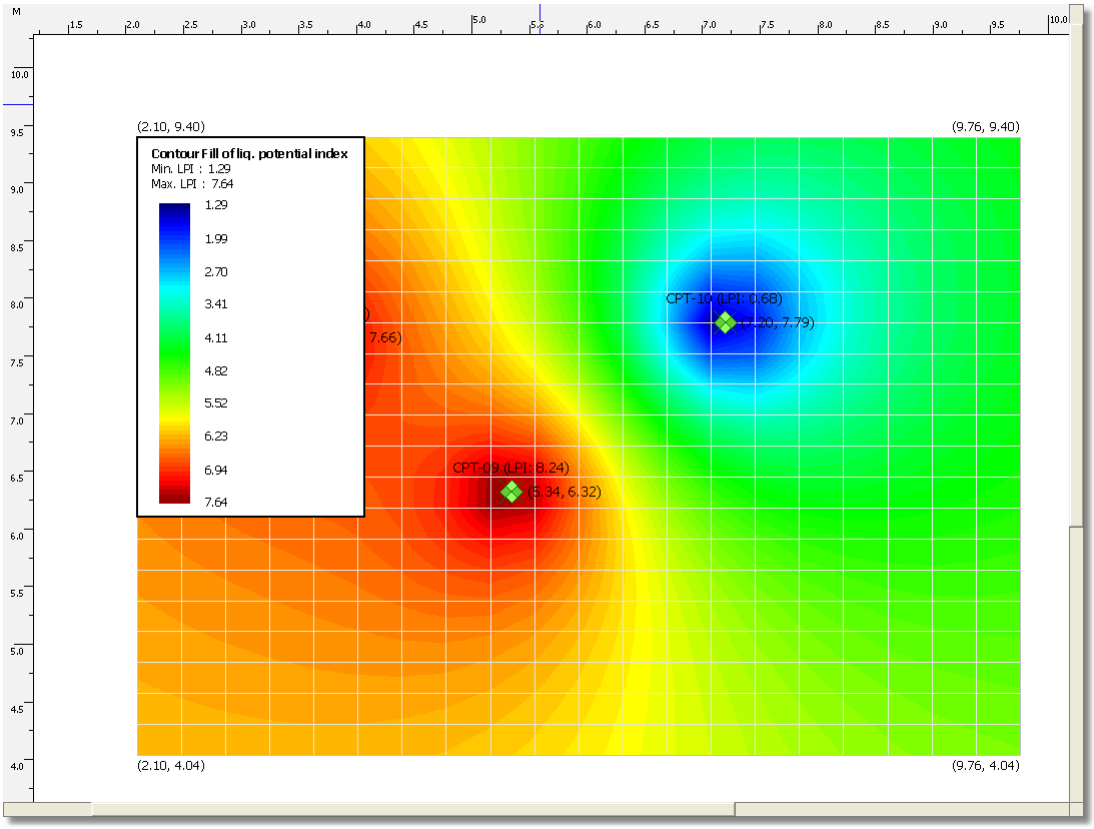


Page with CPT points and a grid

Final step is to create the map either by clicking on the button to visualize the LPI variable or the button to visualize the vertical settlements. The page will now look like this:



Page displaying a map

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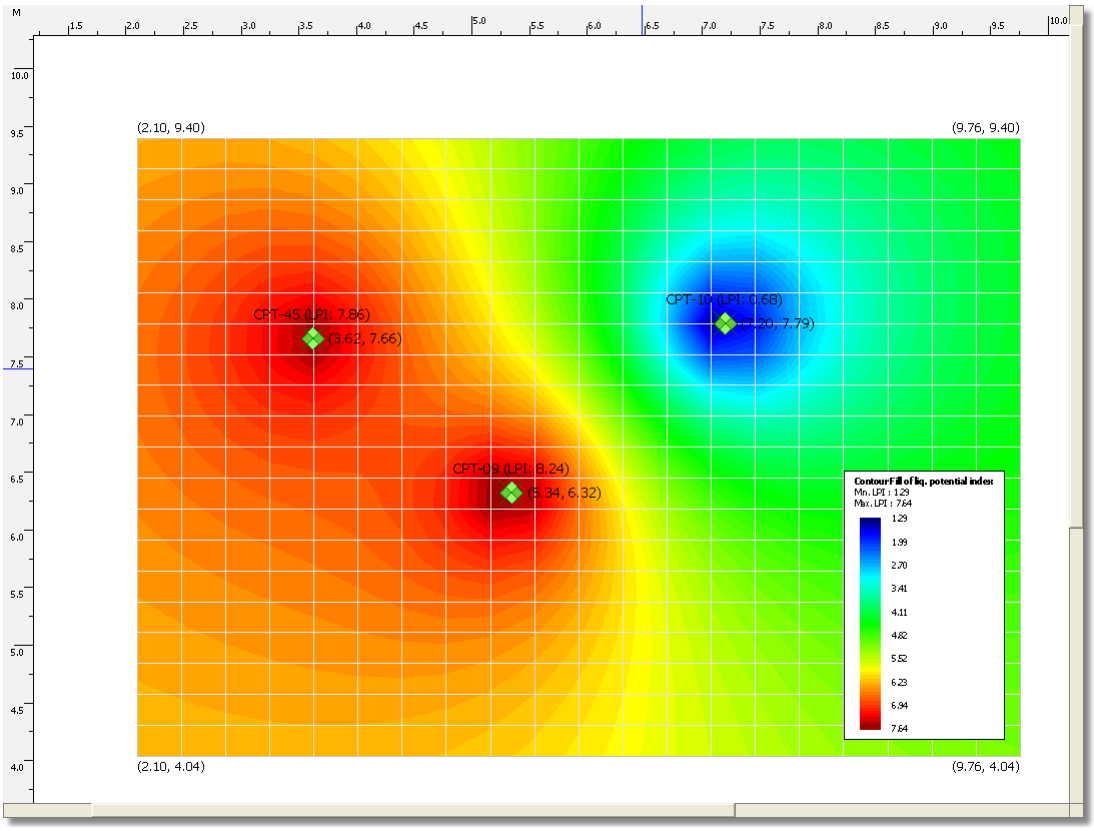
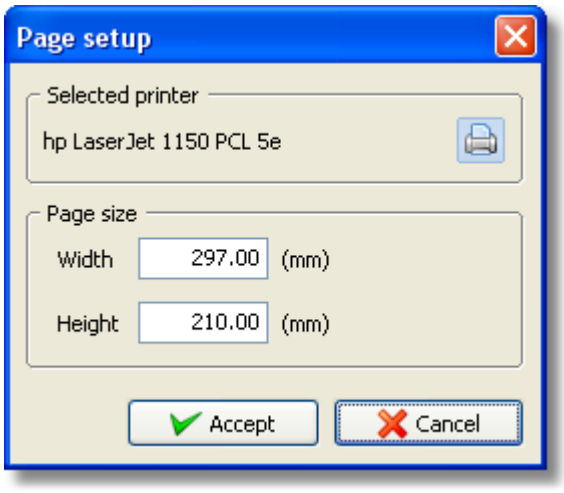
You may alter the position and size of the legend. Make the *Results layer* the current working layer and click and drag the legend in order to move it. You may click in any corner and drag to adjust its size.



Adjusted grid legend

4.1.1 Page setup

Click on the button on the toolbar. The following dialog will appear:



Page setup dialog

The dialog displays the current page dimensions. You may modify the *Width* and *Height* fields any way it is necessary but you may also select a different page based on the pages the default printer supports. Click on the printer icon and from the dialog that appears make any changes necessary. Click the *Accept* button to close the page setup dialog and commit any changes made.

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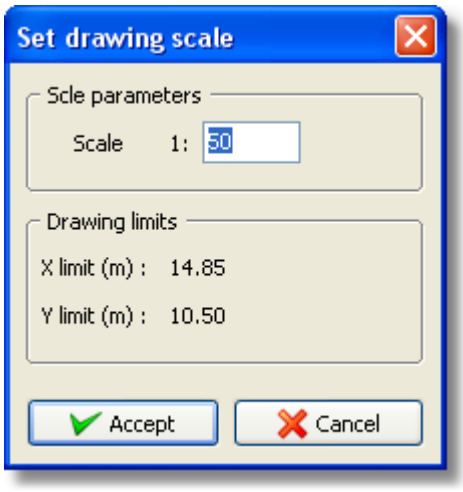
4.1.2 Drawing scale

Click on the button on the toolbar. The following dialog will appear:



Drawing scale dialog

In the *Scale* field you may enter the drawing scale you prefer to use. While changing the drawing scale you may preview the drawing limits inside the *Drawing limits* area. Drawing limits reflect the real world coordinates that the page can display. Click *Accept* to commit the changes.

4.1.3 Changing working layer

Objects inside the page (CPT points, grid and results) are placed in a separate layer so that the user can easily work with them. There are three (3) layers, the Grid area layer, the CPT point layer and the Results layer. The active layer name can be found inside the panel just below the bottom of the page. In order to change the working layer you can click on the arrow of the

button. A popup menu will appear and from there you may select the layer you wish. You may also right click in an empty region inside the page and the same popup menu will be displayed.

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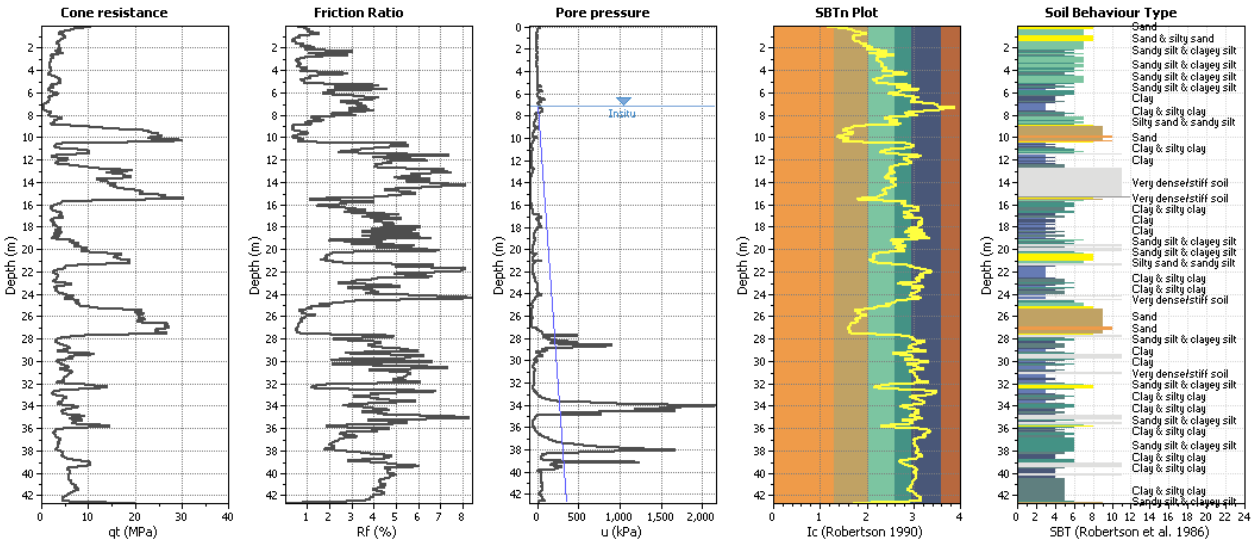
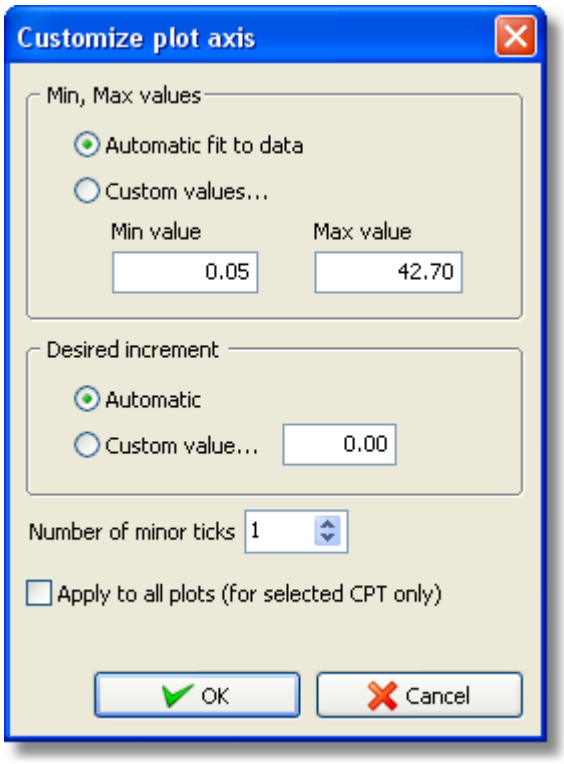
4.2 Customizing plots

By default, when importing CPTU data, all plots use an auto scale feature to fit the data in both vertical and horizontal axes. CLiq allows you to modify the scale of the axes by setting custom minimum and maximum display values. Changes to the scales can be made in the right hand window that show the draft graphic plots. Consider the Basic plots below:



Basic plots

It is clear that the vertical axis is not the same for all plots. In order to customize the vertical axis just click on anyone of them (e.g. click on the q_t plot vertical axis). The following dialog appears:



Customize vertical axis dialog

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

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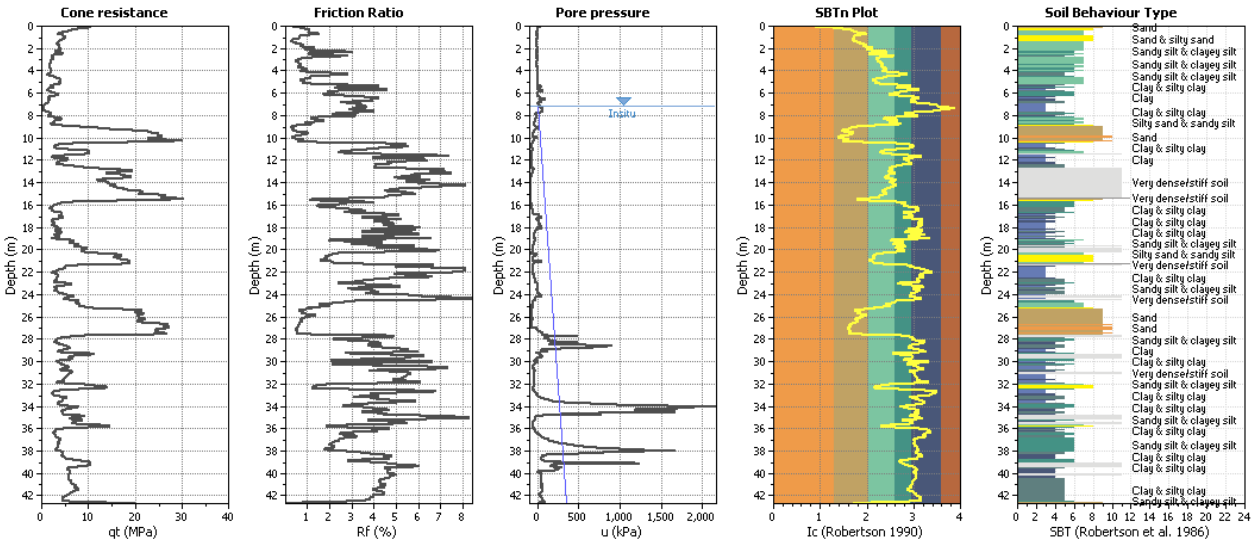
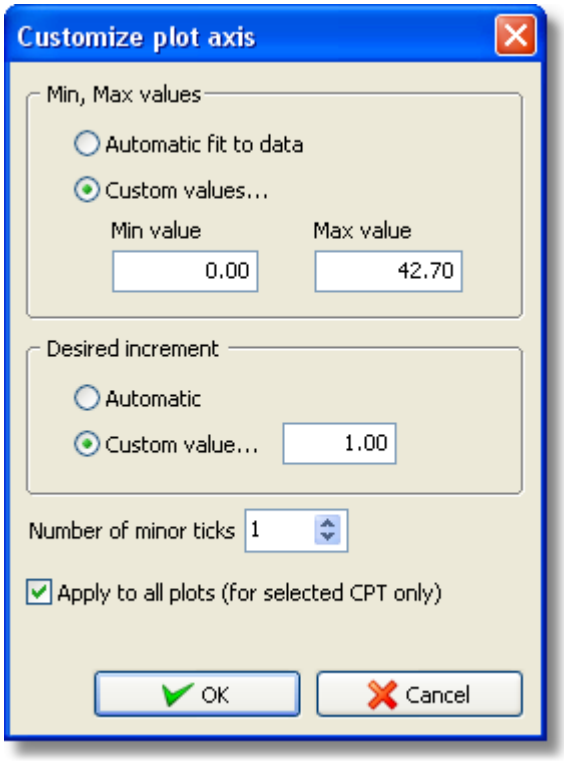
depth value every one meter so just enter 1.00 into the associated edit box. The *Number of minor ticks* should be an integer value which denotes the number of minor ticks between two depth increments.

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 plots. This feature is only available when editing a vertical axes.

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



Basic plots with custom scales on vertical axis



Custom scale settings used

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:

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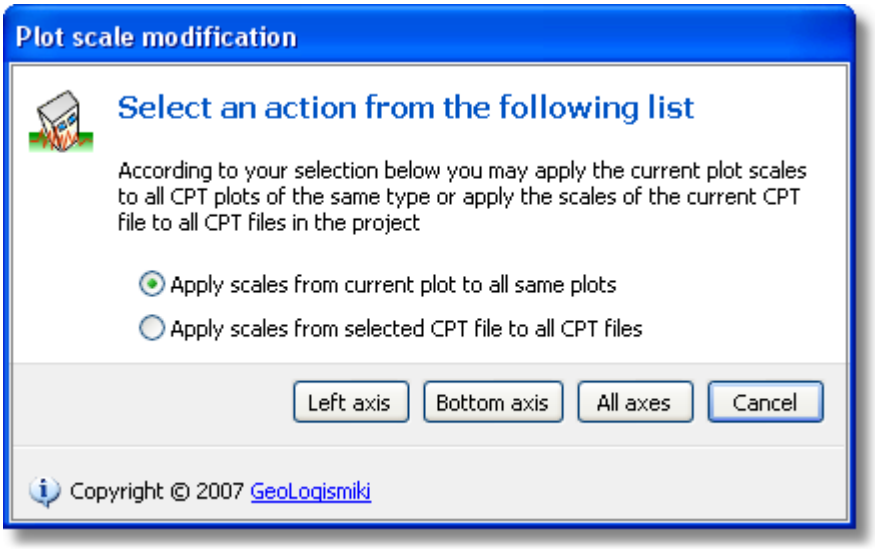

Plot scale modification dialog

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 plots 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.

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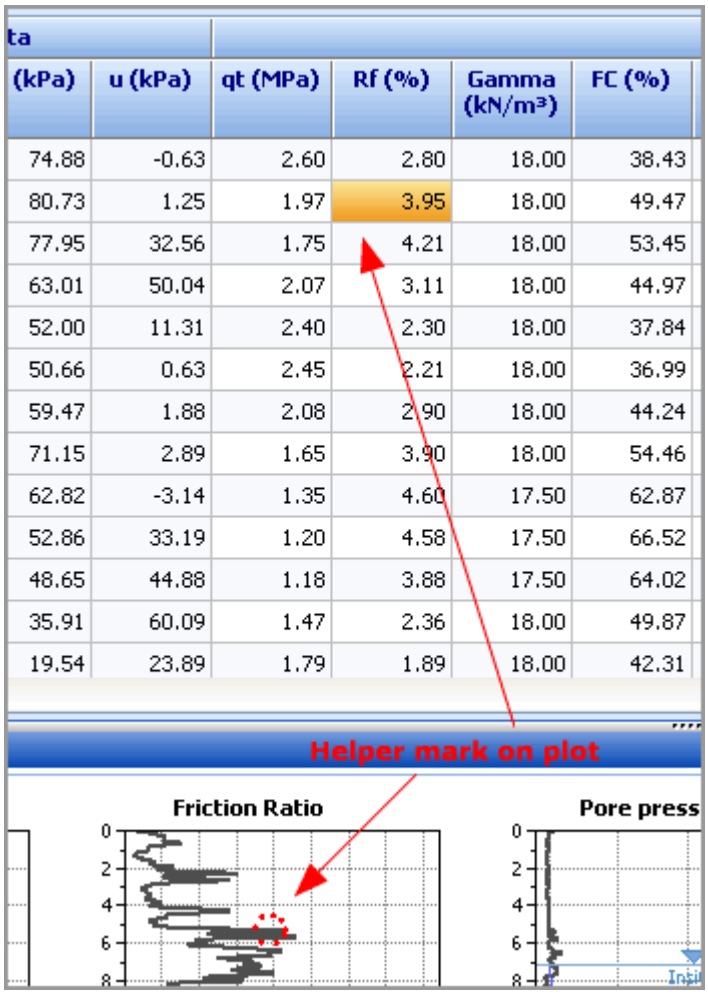
4.2.1 Navigation helper tool

If you need to locate numeric data (input data or calculation results) 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.



4.3 Exporting plots as graphic files

CLiq offers the ability to export plots in a graphic file format like .png, .gif or .jpg. Exporting individual plots in a graphic file may be useful if for example you need to place some plots on a presentation.

Select a CPTU file from the file manager and from *Data* menu select the *Export plots as graphic* command. Alternatively you may use the right mouse button on the CPT file and from the pop-up menu that will appear select again *Export plots as graphic*. The following dialog will appear:

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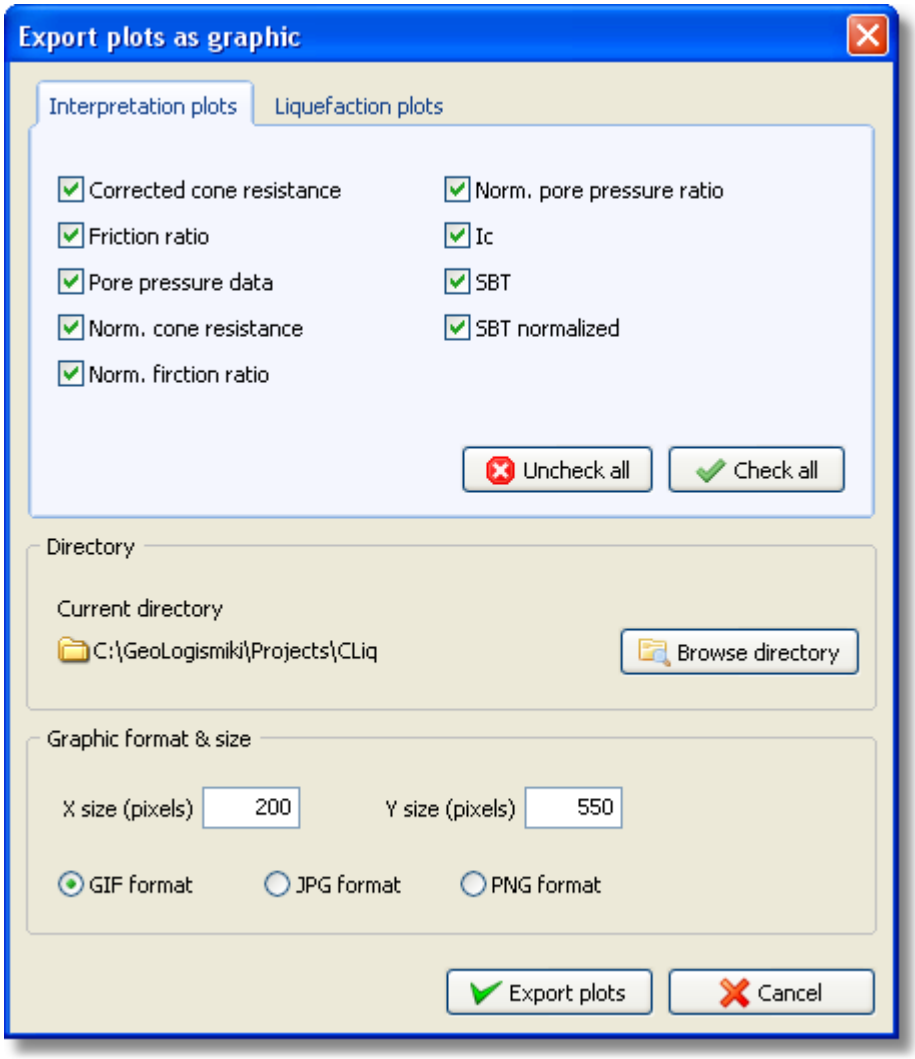

Export plots dialog

There are two (2) tabs on top of the dialog. The *Interpretation plots* tab which includes all plots associated with the basic interpretation procedure and the *Liquefaction plots* which includes all plots regarding the liquefaction assessment analysis. CLiq will export only the plots that are selected that is their associated check box is checked.

In the *Directory* area the software will display the current directory where the files will be saved. If you need to change this folder you can easily do so by clicking on the *Browse directory* button. You will see the following dialog:

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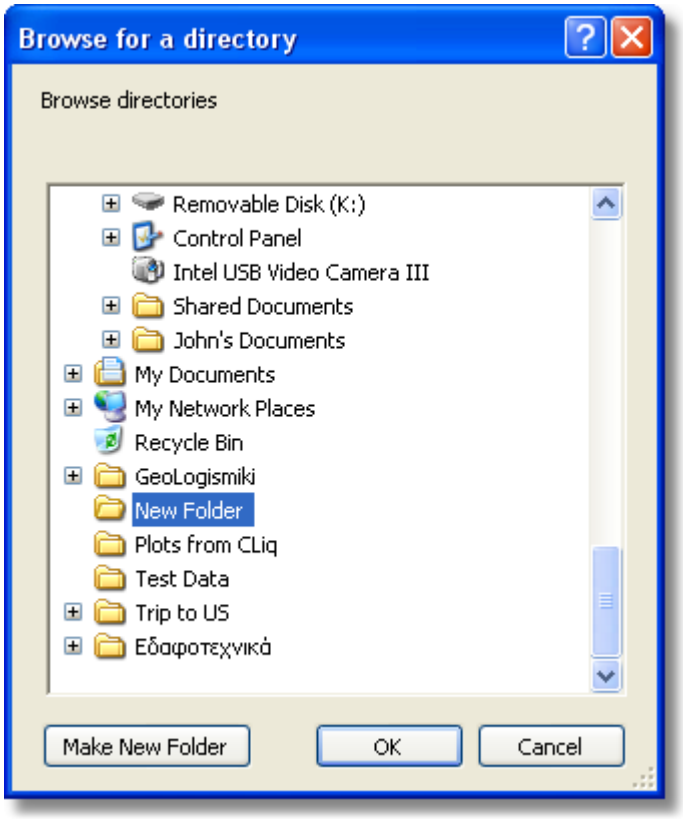

Browse directory dialog

Browse for the directory you wish to use or click on the *Make New Folder* to create a new folder under the selected directory. Click *OK* when finished and your new selection will now appear under the *Current directory* label.

You may use the *X size (pixels)* and *Y size (pixels)* to customize the size of the exported plots. You may also choose between various file formats as GIF, PNG and JPG. Click on the *Export plots* to close the dialog and complete the export procedure.

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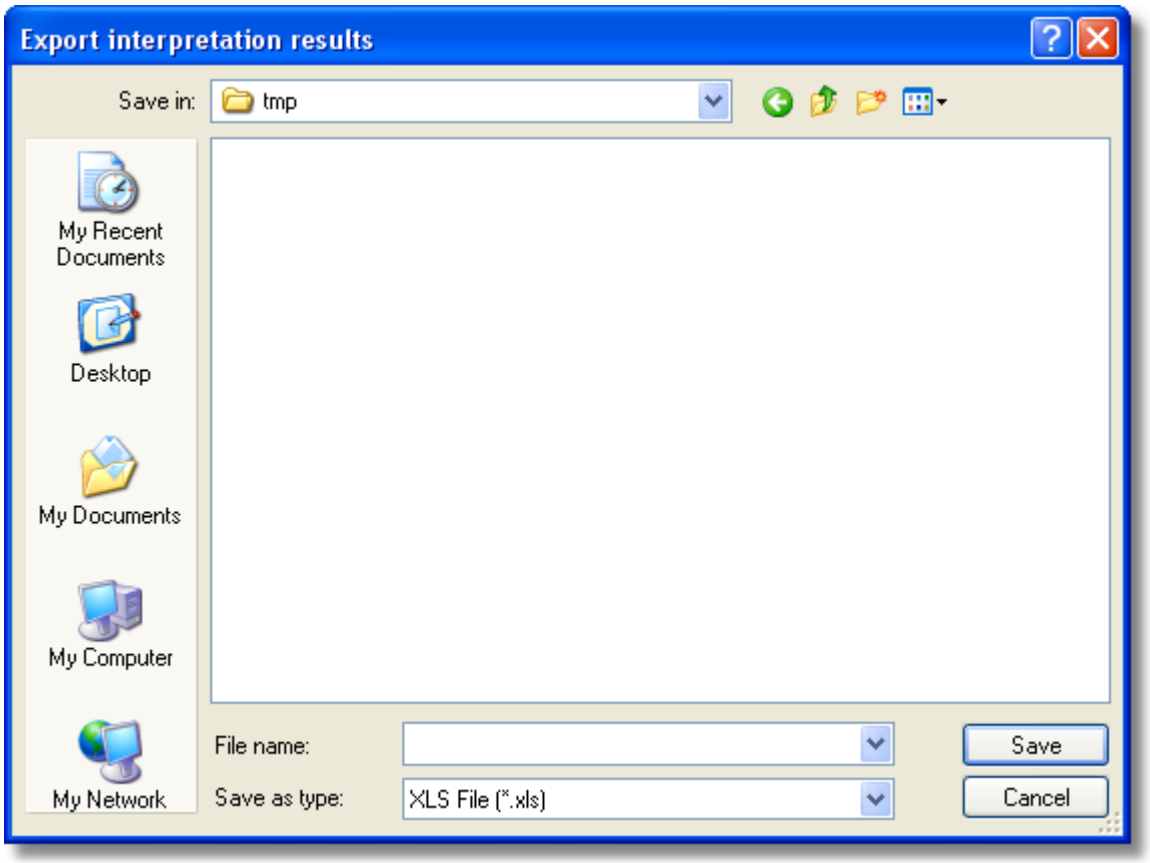
4.4 Exporting tabular results

CLiq allows the user to export tabular results in an Excel® file for further manipulation. You may export tabular results for both interpretation and liquefaction assessment simply by double clicking the button on the toolbar above the tabular results (or double click anywhere inside the tabular results). The following standard Windows dialog will appear:



Export tabular results dialog

Navigate to the directory where you wish to save the results. Type a name in the *File name* field at the bottom of the dialog and click the *Save* button.

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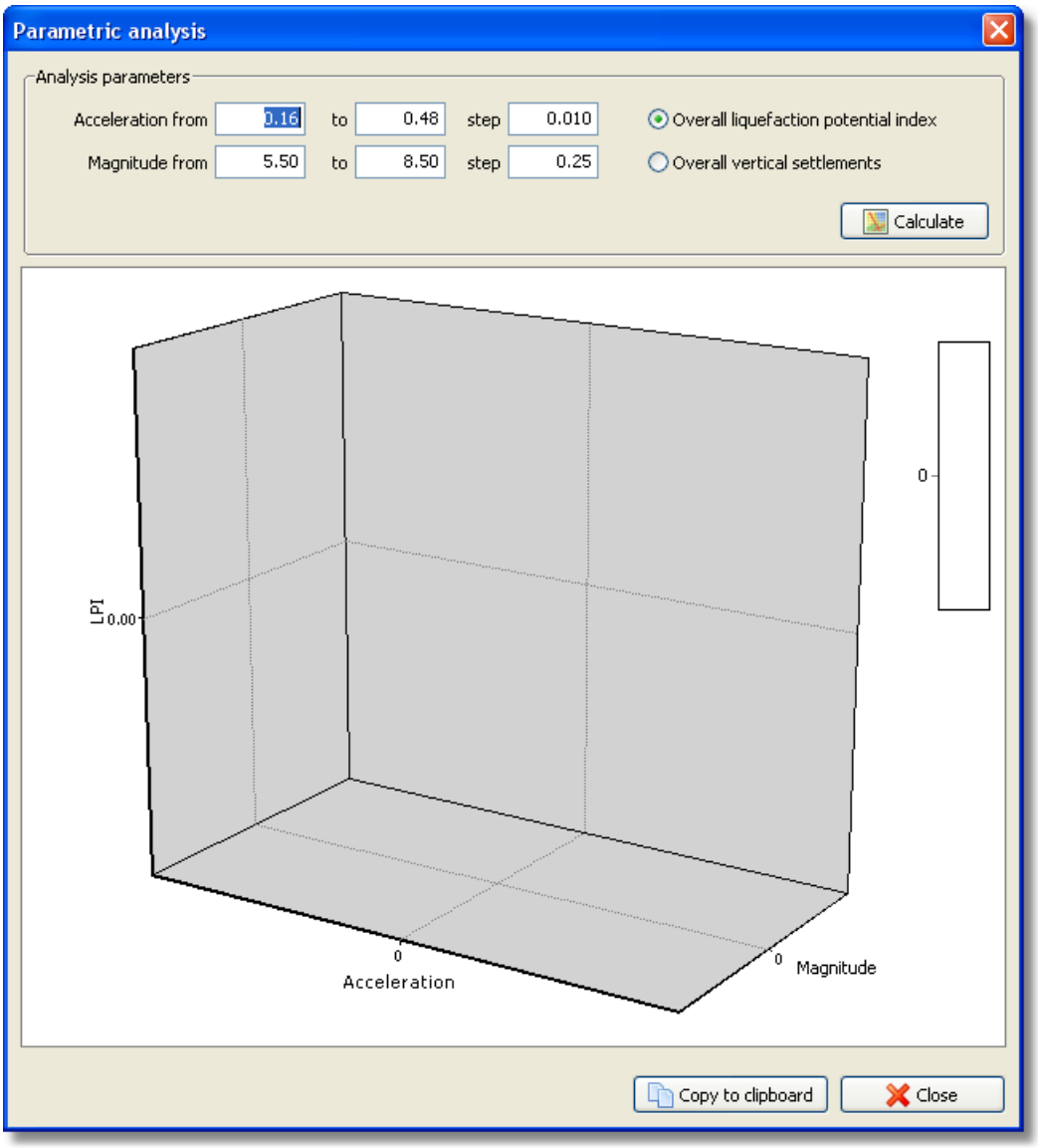
4.5 Parametric analysis

You may test the sensitivity of your analysis based on a range of values for both earthquake magnitude and peak ground acceleration. Click on the button located at the main window toolbar and the following dialog will appear:



Parametric analysis dialog

Enter the desired range for acceleration and magnitude and select the result you wish to visualize, LPI or overall vertical settlements. Click on the *Calculate* button and CLiq will create a surface plot of your analysis (for the selected CPTU file).

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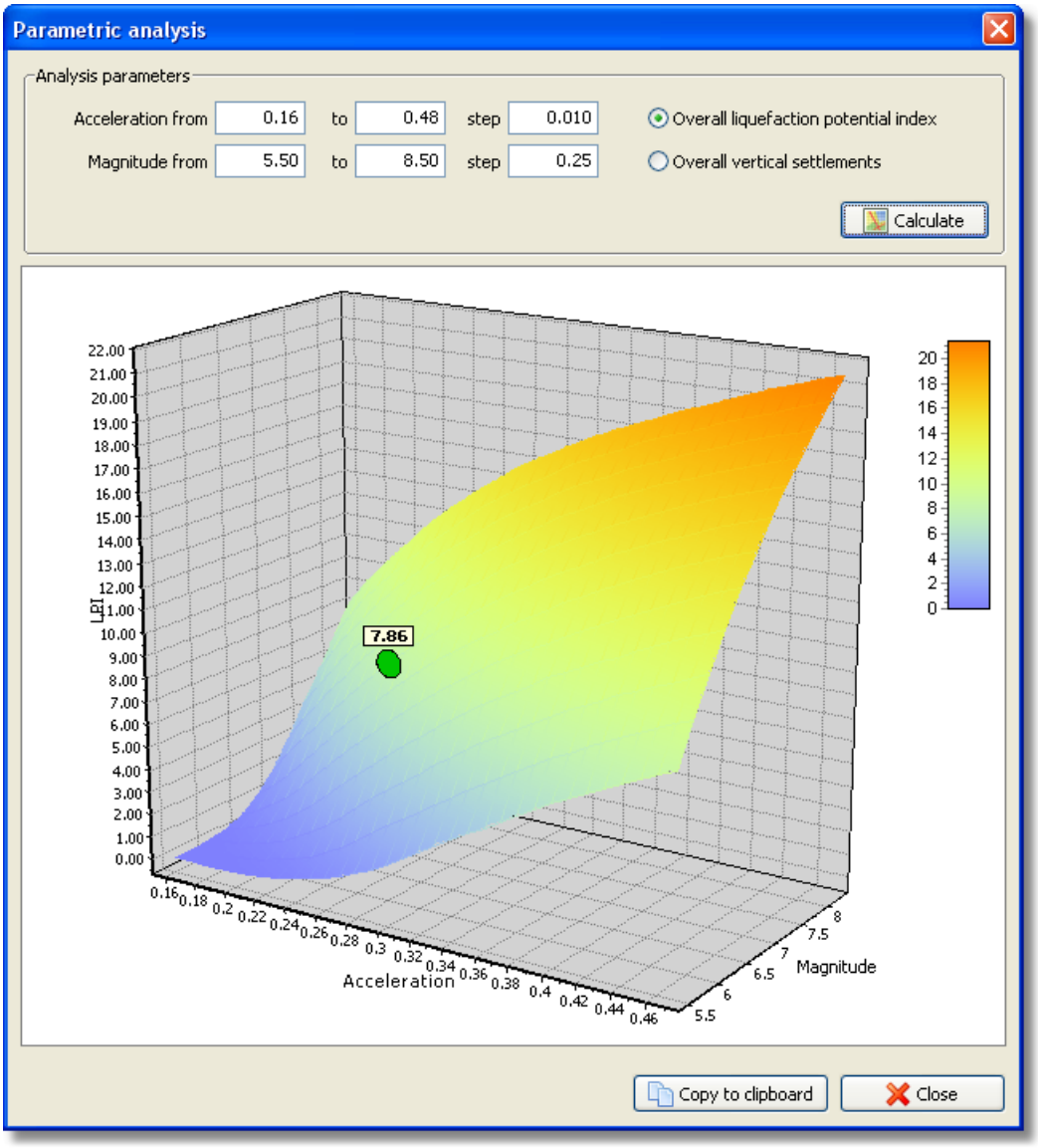

Parametric analysis plot

The green circle represents the result for your current CPTU file liquefaction properties. You may rotate the plot by clicking and dragging the mouse around the plot area. Click *Copy to clipboard* to copy the plot in order to paste it as an image in other applications.

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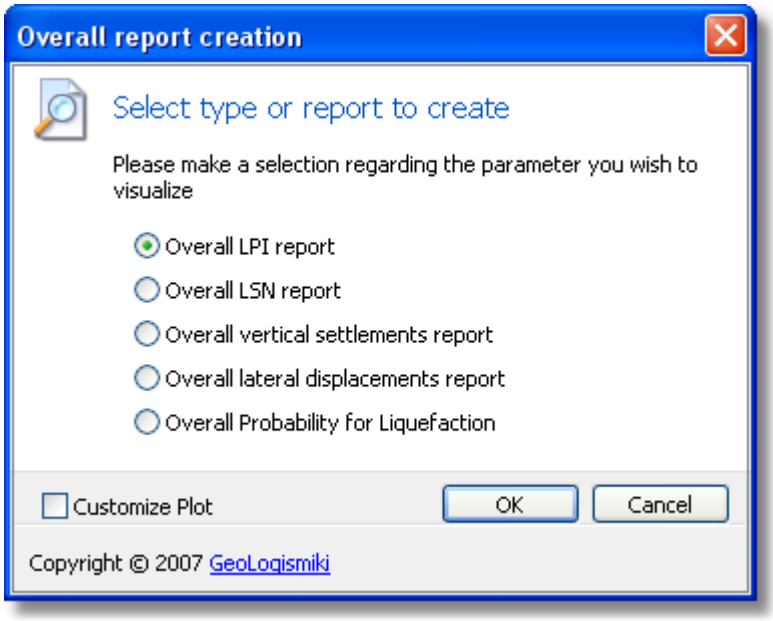
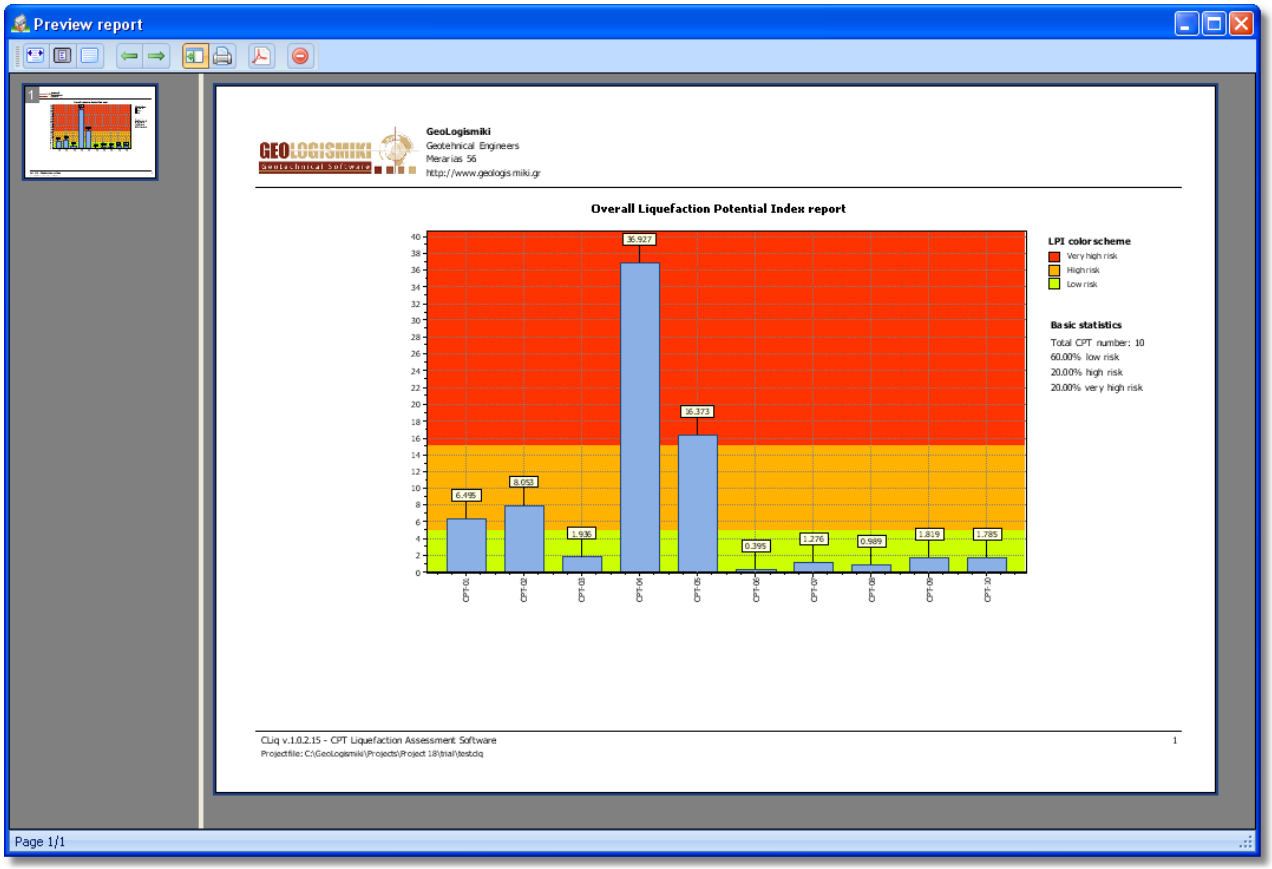
4.6 Overall summary reports

A summary report bar chart report of either LPI, LSN (Christchurch, NZ), vertical settlement, lateral displacement and LDI and Overall Probability for Liquefaction, for all selected (checked) CPTU file can be generated from the menu Reports and Overall summary report command. The following dialog will appear:



Overall summary report selection dialog

According to the selection made in the dialog shown above, CLiq will create a report (below is a report based on the LPI results). If the customize plot is checked a dialog will appear with several settings for the Y plot axis.



Overall LPI report

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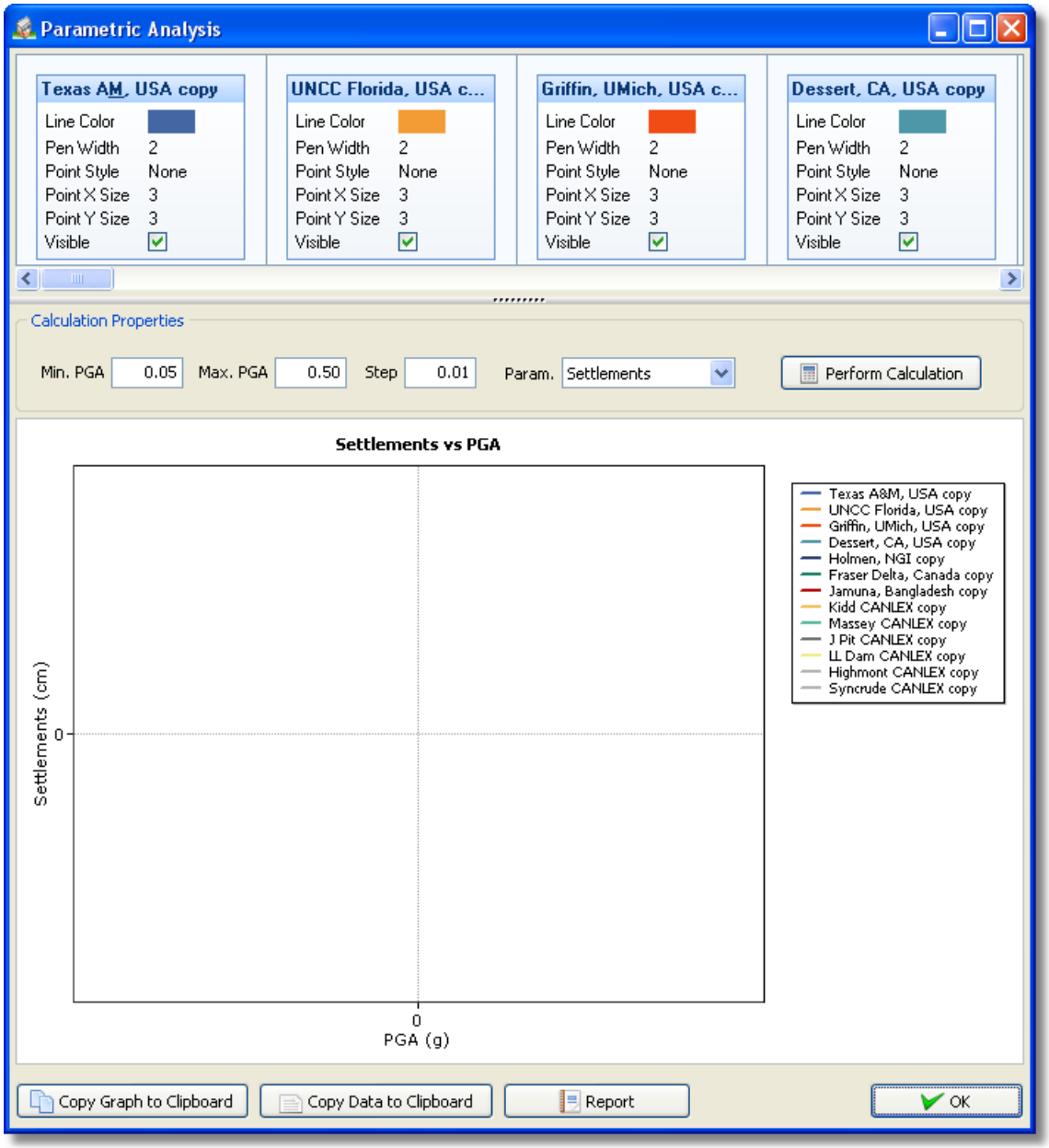
4.7 PGA Parametric Report

PGA Parametric Report is available from the main toolbar when hitting the button. The following dialog appears:



PGA Parametric dialog

The software will load all the selected CPT files into the new dialog and will assign default properties values like line color, pen width etc. After defining the desired calculation properties the selected parameter (settlemetns, LPI and LSN) the calculation is initiated by hitting the Perform Calculation button.

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PGA Parametric for LPI

As with all plots in CLiq, clicking on the axes brings up the dialog for defining custom parameter values.

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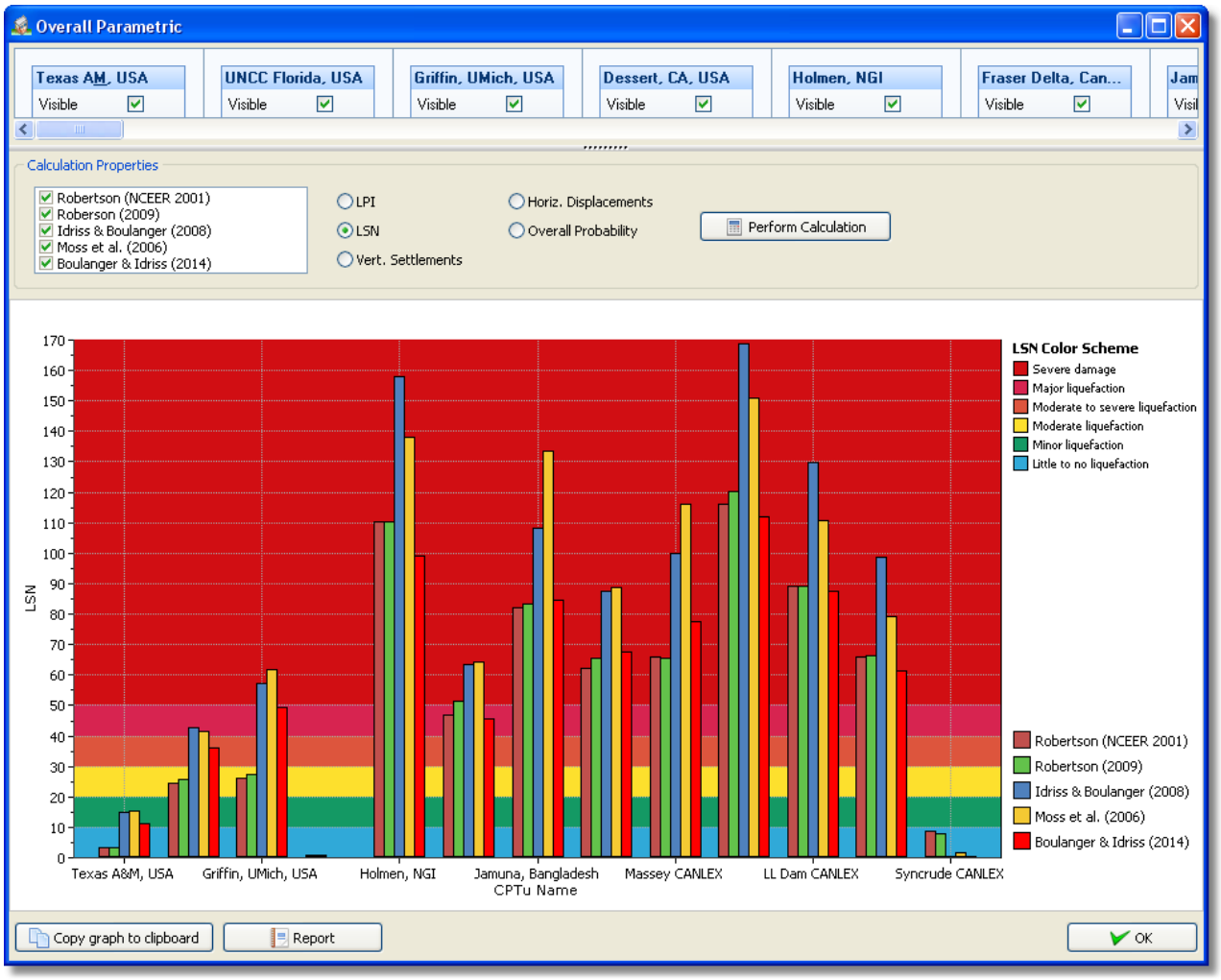
4.8 Overall Parametric

Hitting the button will bring up the overall parametric dialog. In this dialog the user can visualize any of the calculated parameters (LPI, LSN, settlements, displacements and probability) between the various calculation methods.



Overall parametric for LSN

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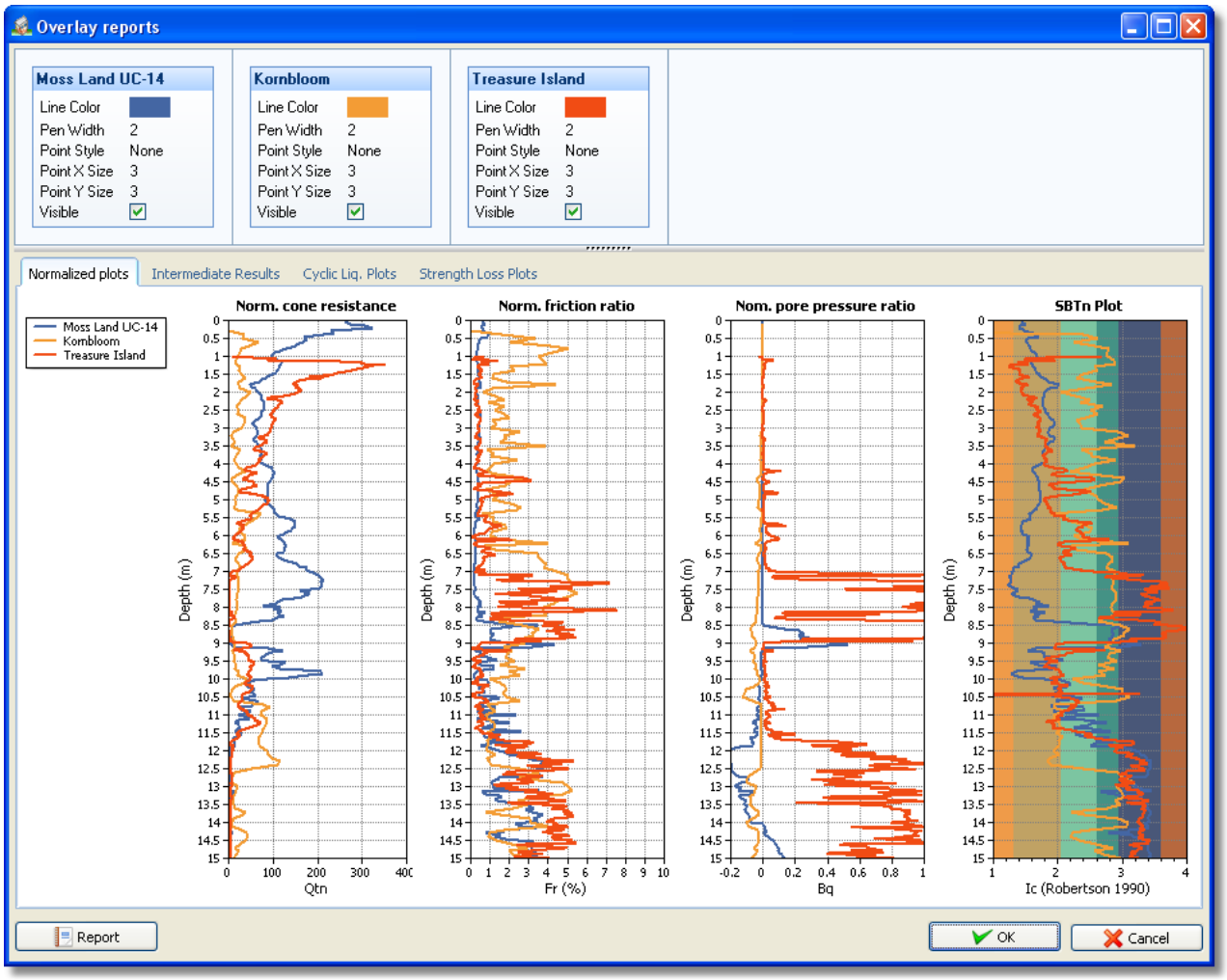
4.9 Overlay report

The overlay report module provides a quick way to quickly compare various calculation parameters between selected CPT files. By clicking the button on the main toolbar, the following dialog appears:



Overlay dialog

The various line properties can be altered by the user by clicking over the numeric values of each CPT file card at the top of the dialog. Plot axes can also be customized by clicking on any of them. The "Report" button will prepare and display a report of all the available plots

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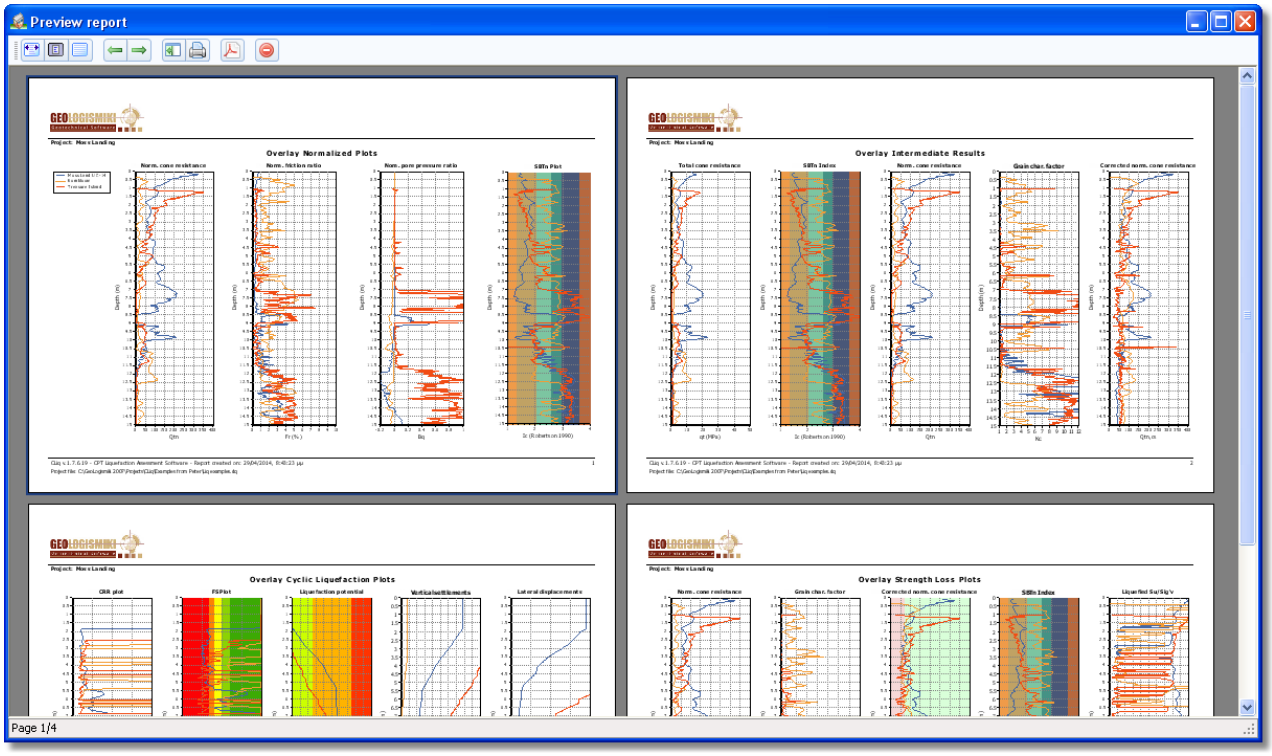
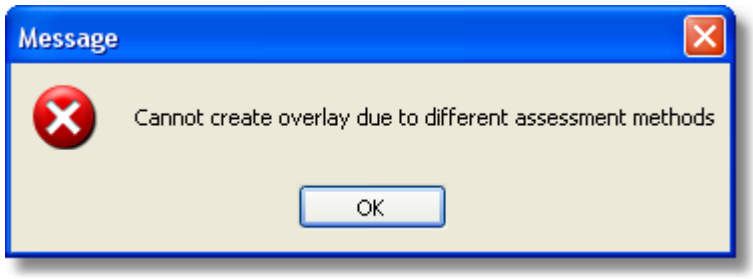


Overlay report dialog

The overlay module is only available when the selected CPT files share a common calculation method, in any other case the software will raise an error:



Overlay module creation error

4.10 Probabilistic settlements

Juang et al (2013) combined the deterministic model by Robertson & Wride (1998) for liquefactuon potential evaluation (in terms of nominal safety factor) and the probabilistic model by Ku et al (2012) for liquefaction probability. Together, these models provide a site-specific probabilistic liquefaction-induced settlement exceedance curve (right-hand plot) and a probability density curve (left-hand plot) for the predicted settlement. The method provides a conditional probability for a given (user input design values) ground shaking level represented by a pair of a_{max} and M_w values, along with the various design assumptions. The procedure consists of two models (based on case histories): Model A is applicable to the free-field conditions, and Model B is more applicable for estimation of liquefaction-induced building settlement. Model choice is made by selecting the appropriate box below the right-hand plot, the default is Model A - Free-field settlements. The scale for the Limiting Settlement is adjusted by modifying the "Maximum settle" value in the box below the plots.

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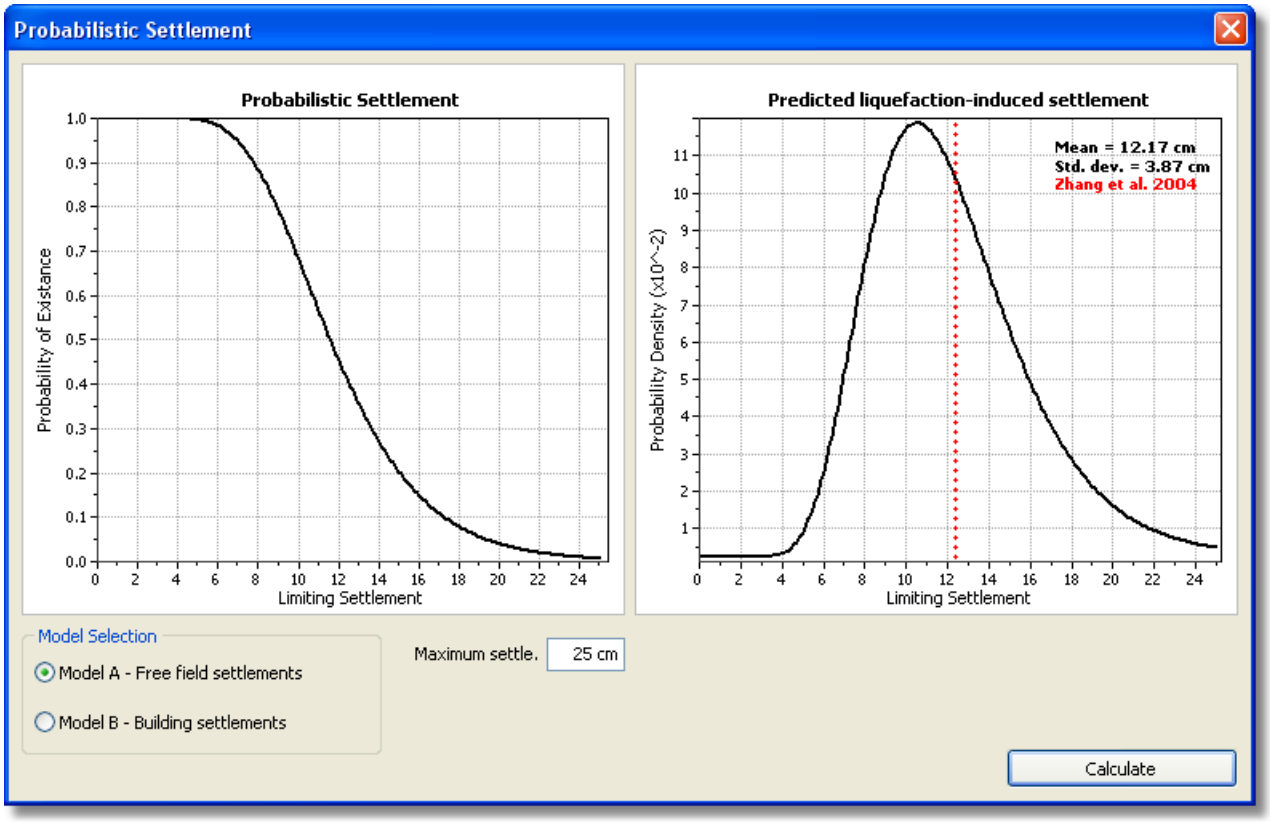

Probabilistic settlements dialog

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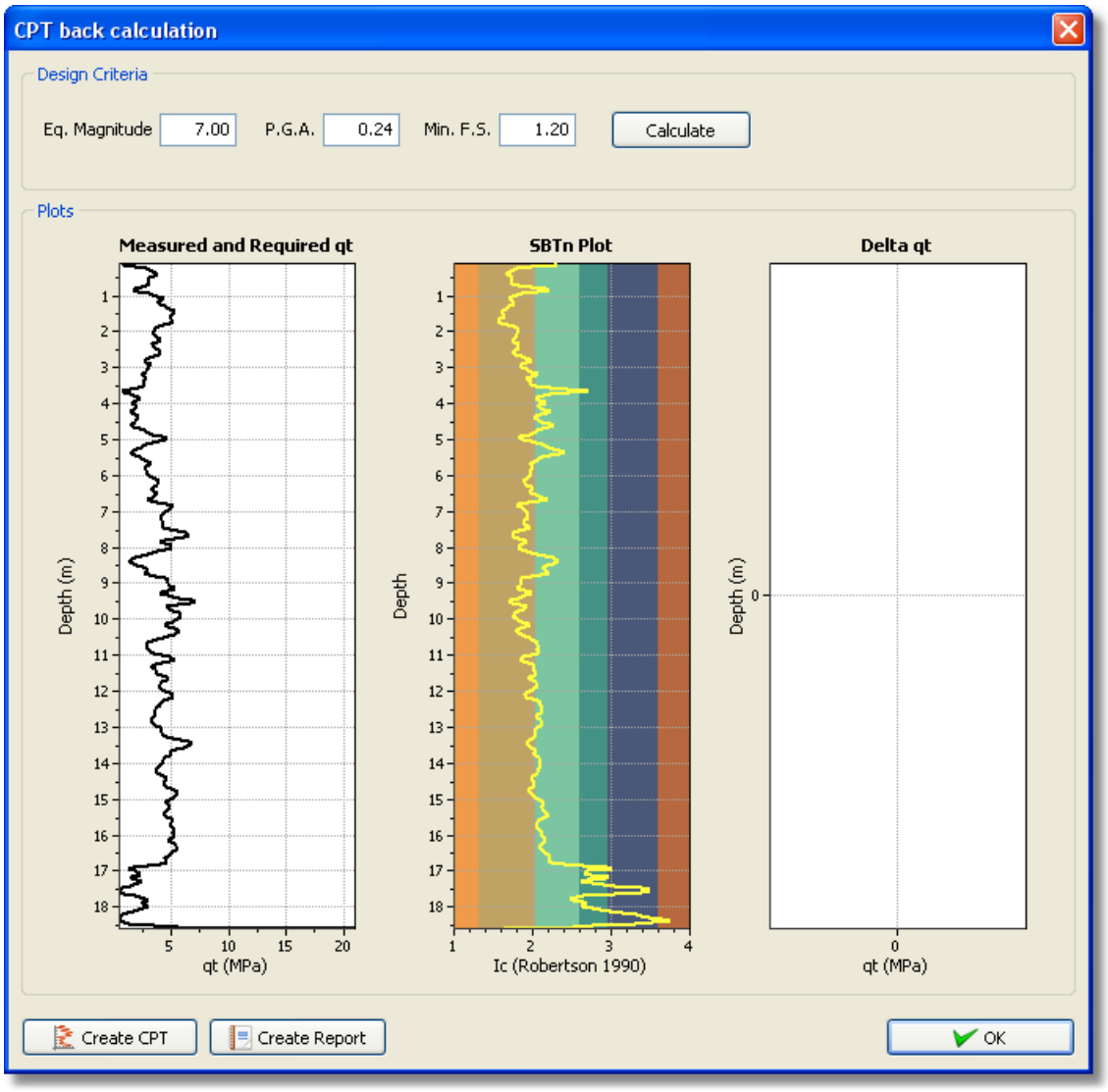
4.11 Gound Improvement Quality Control

The CPT is often used for quality control (QC) purposes after ground improvement (e.g. vibro-compaction, etc.). A ground improvement QC module is located by clicking the icon . The following dialog will appear:



CPT QC dialog

If ground improvement is used to improve the response of the ground against future design earthquake loading, the program will calculate a "design" cone resistance profile, q_c, based on a design earthquake (a_{max} and M_w) and required factor of safety (FS). The "design" cone profile is shown (in red) overlying the measured cone profile (shown in black). The program will also display (in the right-hand plot) the "Delta qc", which is the difference between the required 'design' q_c and the measured q_c in the zones where soils are susceptible to cyclic liquefaction (e.g. where I_c is less than the I_c cut-off value).

The module applies the Robertson and Wride (1998) method in reverse to calculate the required "design" q_c. The module icon will only be accessible when the Robertson (NCEER R&W1998, 2009) method is selected. The input FS can be used to minimize post-earthquake deformations, since volumetric and shear strains can occur when the FS > 1. The default FS is 1.2, but can be modified based on engineering judgment. By using the Robertson and Wride (1998) method in reverse, the program will apply all the user input settings in the 'Advanced parameter' settings (e.g. I_c cut-off value, transition layer detection, etc.).

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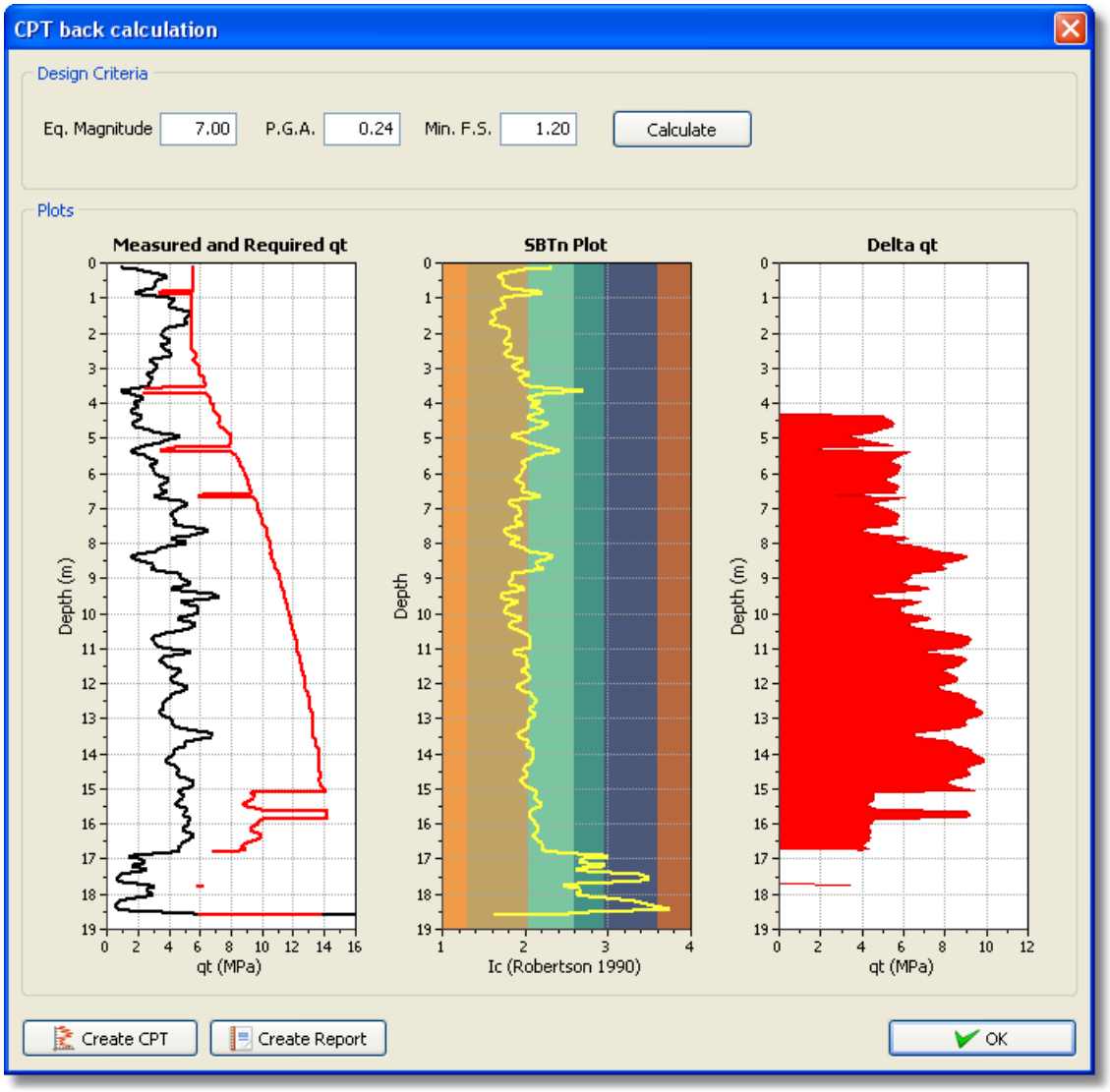

CPT QC calculation results

4.12 Complimentary calculations

CLiq offers two additional modules to evaluate soil liquefaction based on SPT and V_s methods. The calculation in both modules is limited to the estimation of the Factor of Safety (FS) profile. Each complimentary calculation is bounded to one CPT file and can be accessed by clicking the buttons or for SPT and V_s respectively.

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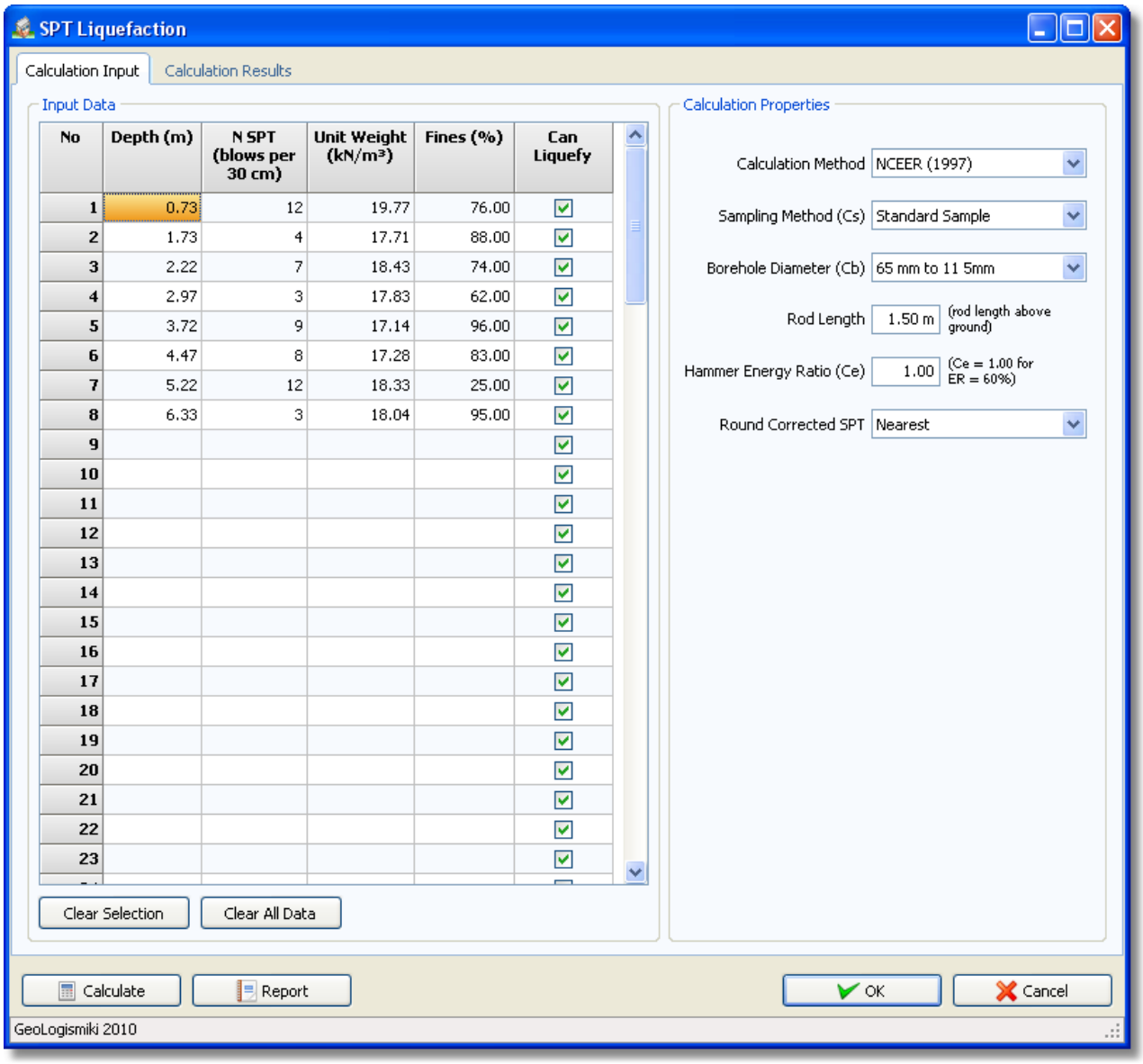
4.12.1 SPT based calculation module



SPT calculation module

In the calculation input tab the user can input the required field data and calculation properties. If the ENTER key is hit after input of a depth value the software will advance to the SPT cell and fill it with the value estimated from CPT data of that depth. SPT points can be excluded from the calculation simply by unchecking the "Can Liquefy" check box.

Calculation Properties

- Calculation Method: Calculation method can be one of the NCEER (1997), Seed et al. (2004) or Boulanger & Idriss (2004)
- Sampling Method (C_s): Correction factor for samplers with or without liners
- Borehole Diameter (C_b): Correction factor for borehole diameter
- Rod length: Specify rod length above ground surface to be used for the calculation of C_R (correction factor for rod length)
- Hammer Energy Ratio (C_e): Correction factor for hammer energy ratio (ER)

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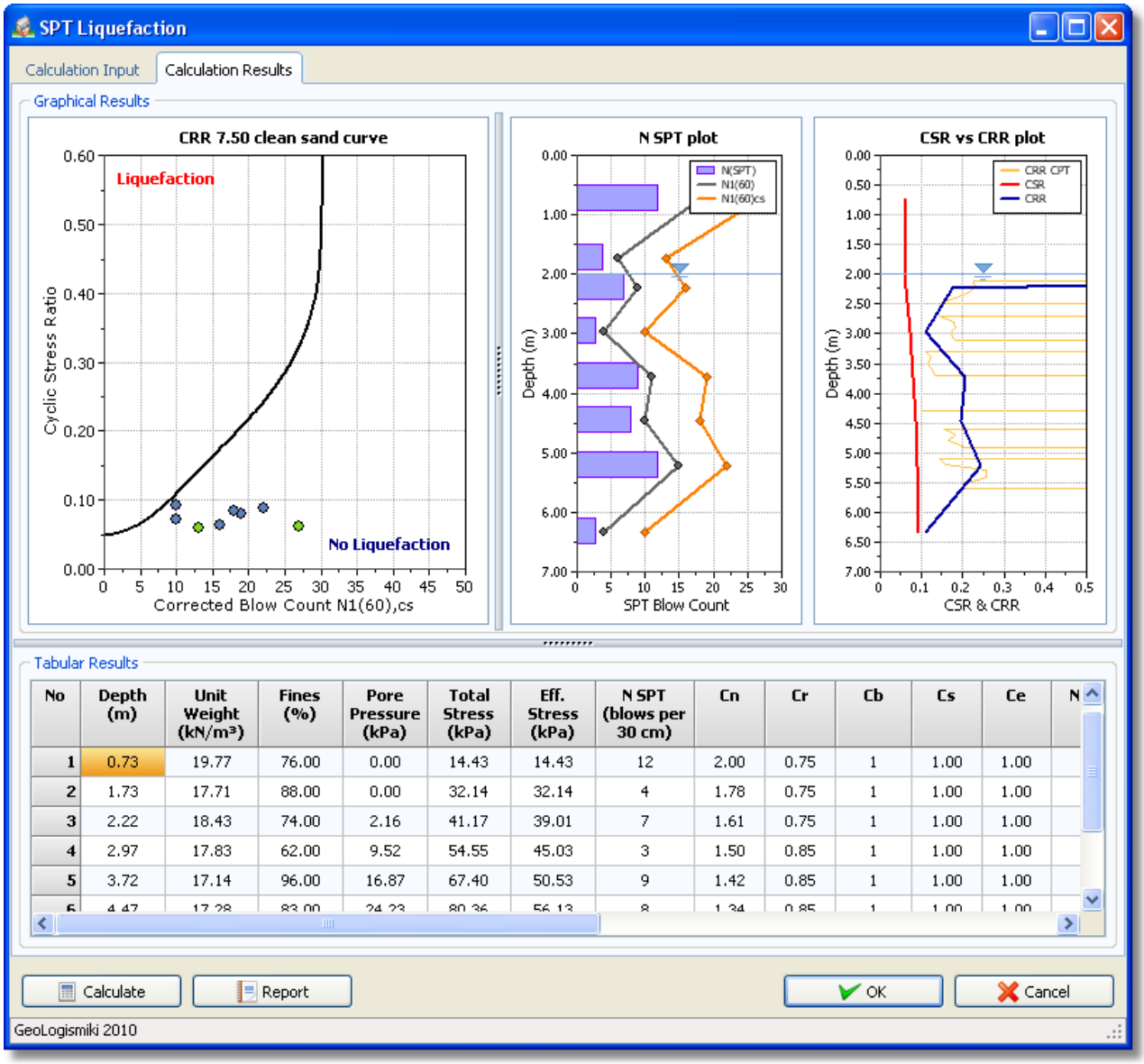
- Round Corrected SPT: A selection of options on how the software will manege calculated corrected SPT. Among the available options "Down" is the most conservative and "Up" is the less conservative

In the calculation results area the user can view plots and tabular results of the calculation.



No	Depth (m)	Unit Weight (kN/m³)	Fines (%)	Pore Pressure (kPa)	Total Stress (kPa)	Eff. Stress (kPa)	N SPT (blows per 30 cm)	Cn	Cr	Cb	Cs	Ce	N
1	0.73	19.77	76.00	0.00	14.43	14.43	12	2.00	0.75	1	1.00	1.00	
2	1.73	17.71	88.00	0.00	32.14	32.14	4	1.78	0.75	1	1.00	1.00	
3	2.22	18.43	74.00	2.16	41.17	39.01	7	1.61	0.75	1	1.00	1.00	
4	2.97	17.83	62.00	9.52	54.55	45.03	3	1.50	0.85	1	1.00	1.00	
5	3.72	17.14	96.00	16.87	67.40	50.53	9	1.42	0.85	1	1.00	1.00	
6	4.47	17.28	83.00	24.23	80.36	56.13	8	1.34	0.85	1	1.00	1.00	

SPT calculation results

4.12.2 Vs based calculation module

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Publications by Prof. Peter Robertson can be freely downloaded from http://www.cpt-robertson.com/pub.html

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