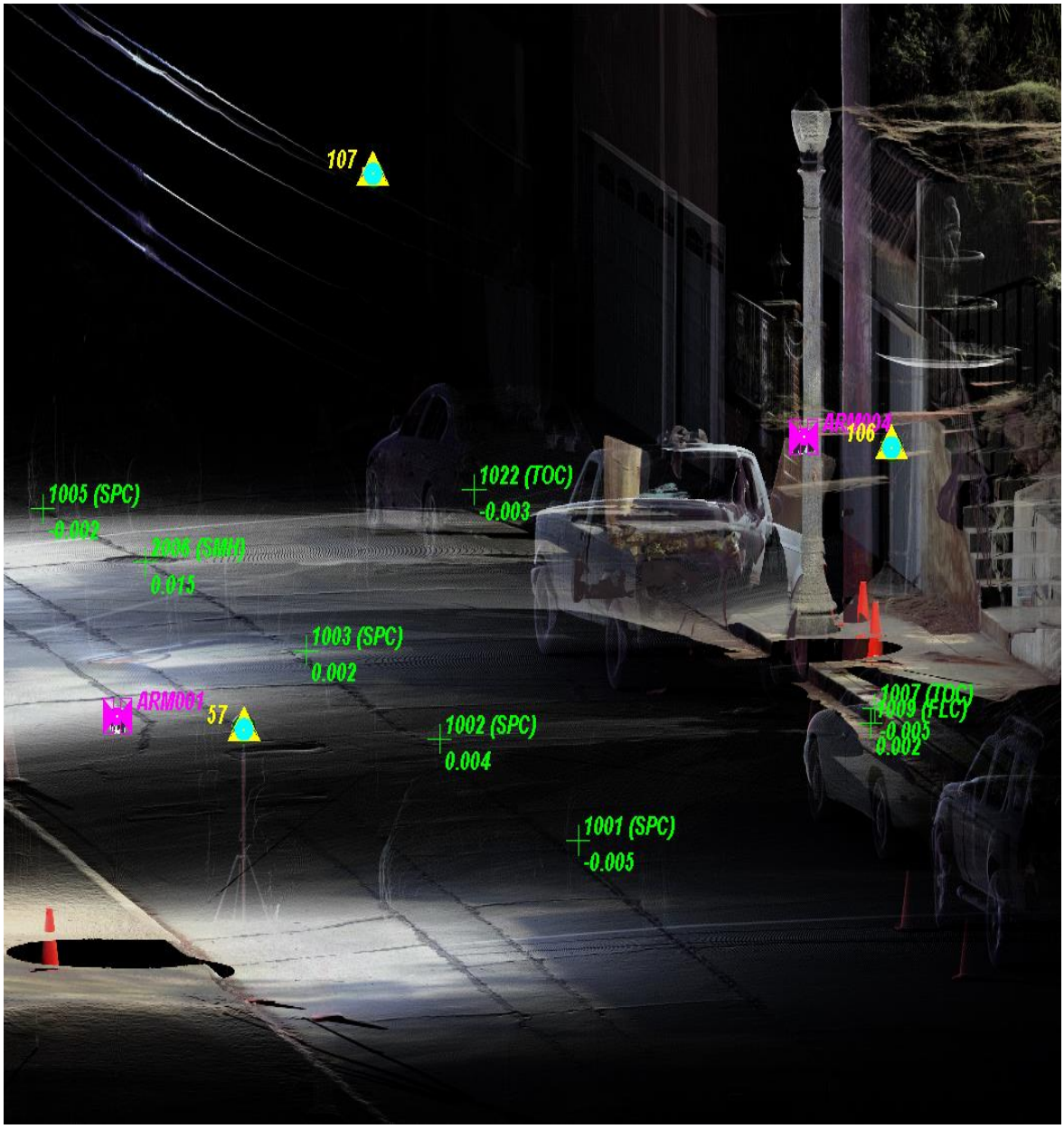

EQA4SCENE

Elevation Quality Analysis for FARO Scene

User Manual

Revised: 12/31/2016

CONTENTS

INTRODUCTION

Welcome to Elevation Quality Analysis for Scene (EQA4SCENE), a plug-in app for FARO Scene that makes it easy to verify the accuracy of point clouds.

WHAT IS EQA4SCENE?

Elevation Quality Analysis for Scene (EQA4SCENE) is a complete and easy-to-use solution to verify the accuracy of a point cloud registered with a FARO Scene.

EQA4SCENE provides a variety of tools to validate the registration results of 3D laser scans by comparing the vertical aspect (Elevation or Z) of 3D point cloud data with the data obtained by conventional survey methods. Advanced statistics are provided on point cloud uniformity. Additionally, "cloud-to-control" and "cloud-to-cloud" analysis is implemented in a simple, easy to understand format. Extensive built-in reporting will satisfy even the most demanding requirements. This is a must have application for any scanning project.

LEARNING RESOURCES

Point Cloud Spatial Solutions offers several approaches to help you learn how to use EQA4SCENE. There's this User Manual that you are reading now and an online support website, http://www.pcss.xyz/support/.

The User Manual explains how to use EQA4SCENE, giving an overview of the product's purpose and highlighting various workflow options. Details are provided about each and every feature that the software offers, explaining its purpose and usage. It's a great resource to help you get the most out of your EQA4SCENE experience.

In addition to the User Manual, additional learning materials are available at http://www.pcss.xyz/support/. There you'll find workflow tutorials and answers to frequently asked questions. If you have a question or issue that you don't see addressed in the tutorials or FAQ, please contact our support team and we'll be happy to help answer your questions.

SYSTEM REQUIREMENTS

EQA4SCENE works with version 5.2 or above of SCENE or SCENE LT. Verify that your computer meets the minimum system requirements for your operating system and

hardware as specified by FARO documentation for SCENE or SCENE LT. Visit the FARO Technical Support Center http://www.faro.com/en-us/support for more details.

INSTALLING APP IN SCENE

Open SCENE or SCENE LT (version 5.2 an above). Use the App Manager to install the downloaded app. The App Manager is available under Tools → Apps:

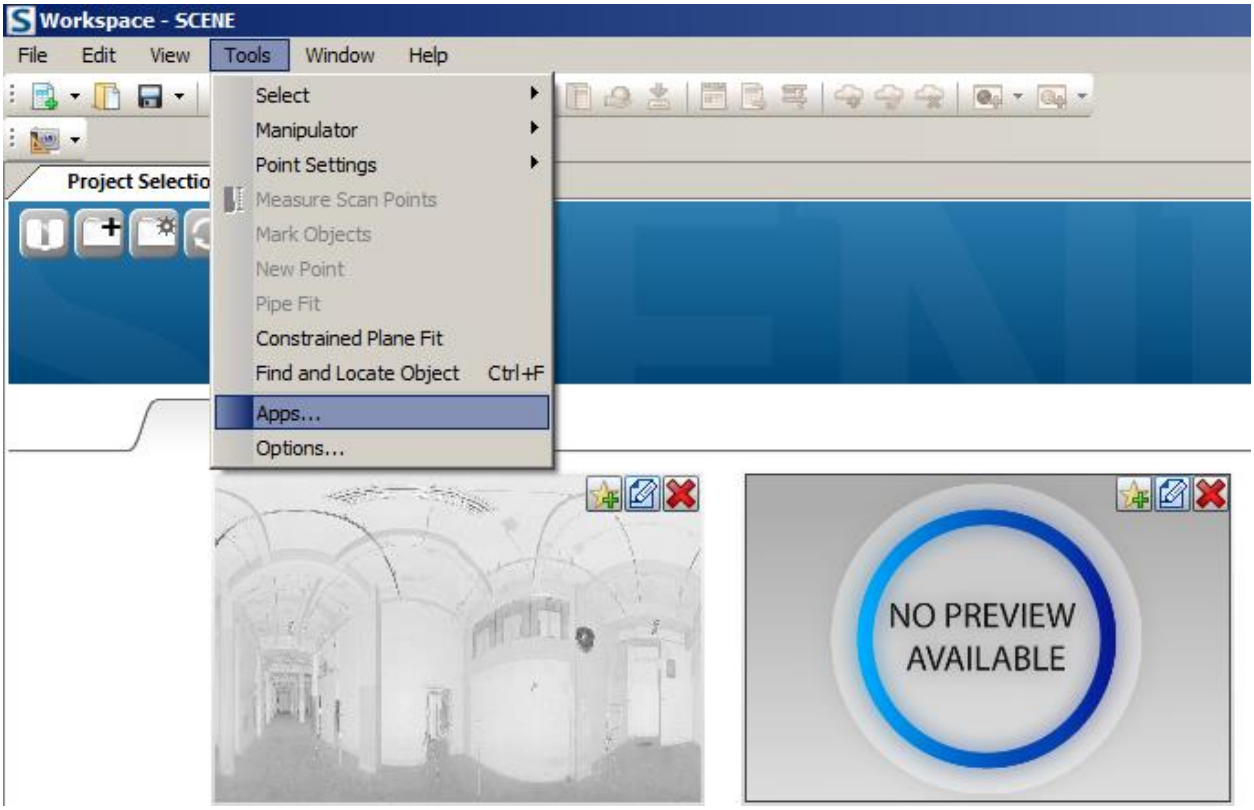

Figure 1: FARO SCENE Tools Menu

After App Manager starts, click the **Install** button.

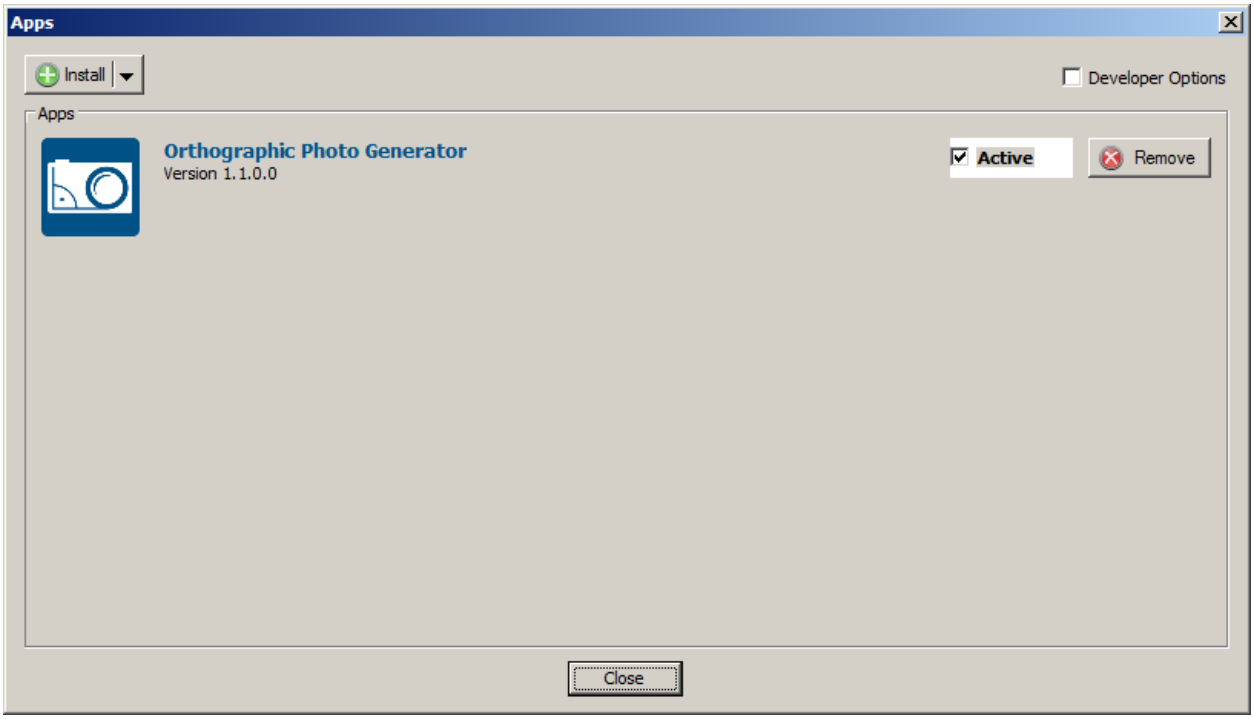

Figure 2: FARO SCENE Apps window

When the file system browser opens, browse to select saved EQA4SCENE_1.0.fpp and click the **Open** button. The following window will appear:

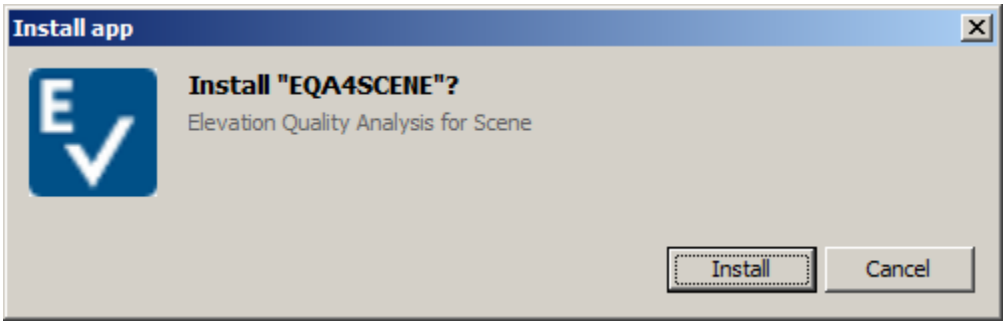

Figure 3: FARO SCENE Install app window

Click the **Install** button. Once installed, click the OK button:

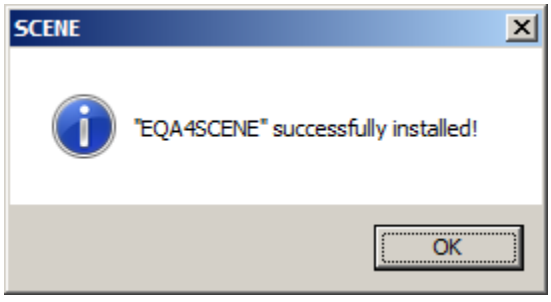

Figure 4: EQA4SCENE successfully installed message window

The following icon should be added to the SCENE toolbar: 

STARTING THE SOFTWARE

After successful installation, click the  icon on a SCENE toolbar. This will start the EQA4SCENE app.

LICENSING THE SOFTWARE

The first time EQA4SCENE is launched the Software License Agreement appears.

Figure 5: EQA4SCENE Software License Agreement window

Please accept the terms and click the **Close** button. The Product Activation window will pop up.

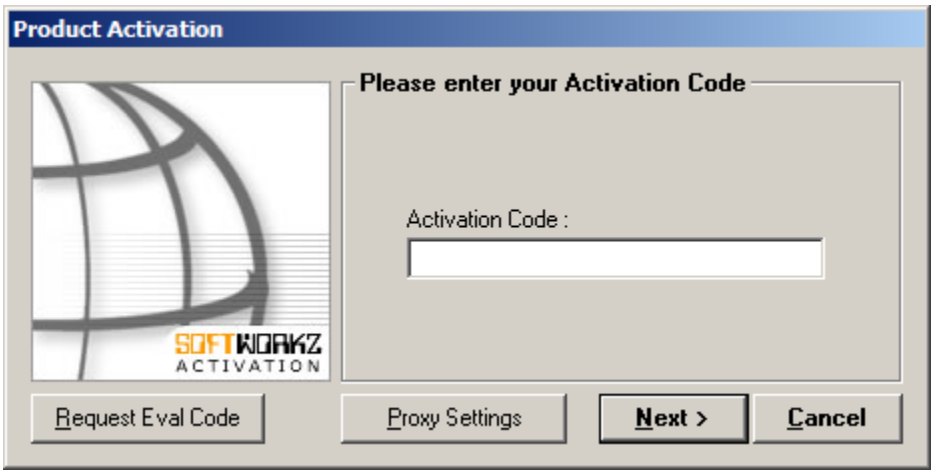

Figure 6: EQA4SCENE Product Activation window

Enter the Activation Code exactly as provided in the registration email you received from FARO and click **Next**. The Activation Information window will appear.

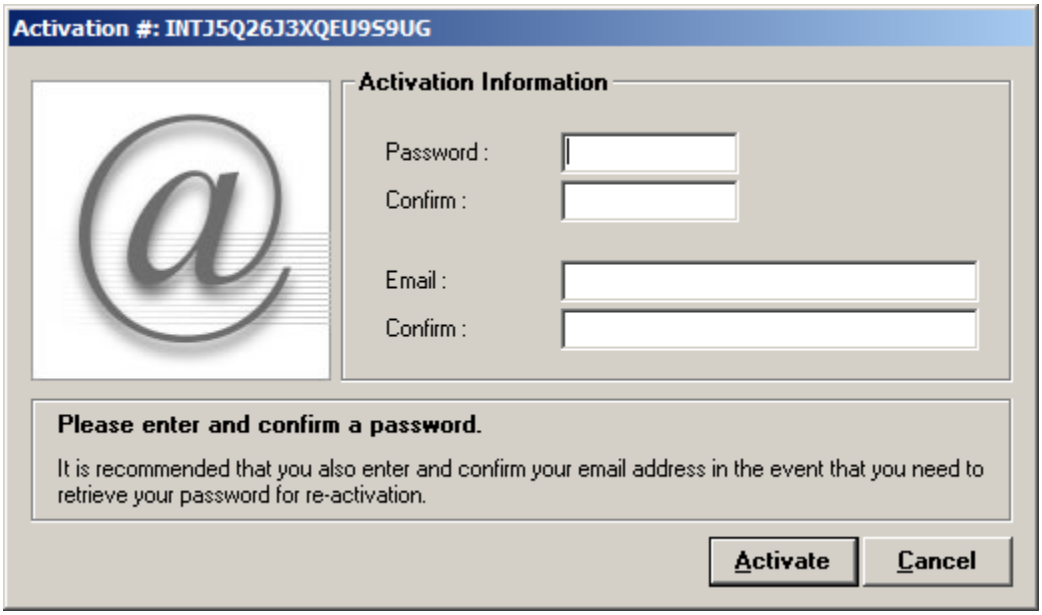

Figure 7: EQA4SCENE Activation Information window

Enter and confirm your password and email address. The License Code password is needed when re-installing or re-activating the software, and when accessing the myLicense Portal http://www.softworkz.com/myLicense/. The email address is used to send information to the user, such as a "Send Lost Password" email.

QUALITY CONTROL –THE BASICS

Quality Control (QC) is defined as a process that evaluates output against a standard and takes corrective action when the output doesn't meet that standard. Quality Control is an extremely important aspect of any engineering or construction project. When delivering, acquiring or utilizing your own point cloud data, proper quality control and validation procedures help to ensure that your point cloud data is accurate.

Validation Quality Control reports are often required by agencies as a part of a final deliverable package. If point cloud data is intended for delivery to agencies that require proof of compliance, please carefully follow the necessary validation procedures.

EQA4SCENE is designed to facilitate a point cloud Quality Control process by offering two quality analysis methods. The "Cloud-to-control" method, also known as "Ground Truth," which compares point cloud elevation (Z) values to the data collected by survey methods, and "Cloud-to-cloud" analysis, which provides information on how point cloud elevations from different scans compare in overlapping areas.

Quality Control (Validation) points are usually located during the field mission when surveyors develop survey project control. Once point cloud registration is completed, an operator imports validation points collected by a surveyor in the field to compare elevation (Z) values of the supplied points to the corresponding values of the cloud points. An Elevation Quality Analysis Report is generated as a result of this process.

TYPICAL VALIDATION WORKFLOW

MISSION PLANNING

Normally validation workflow starts at the planning stage of a project when a detailed mission plan is prepared. While planning the placement of the scanner setups, targets and control points, locations of the validation points are identified and marked on the mission plan. The mission plan is very important, especially when land surveying tasks are subcontracted.

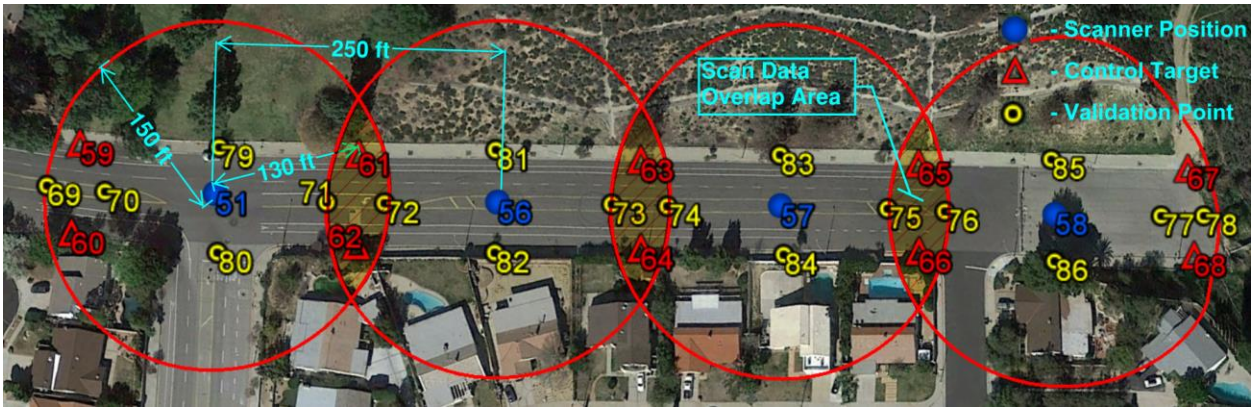

Figure 8: Sample mission plan. Background image is a courtesy of Google Earth Pro

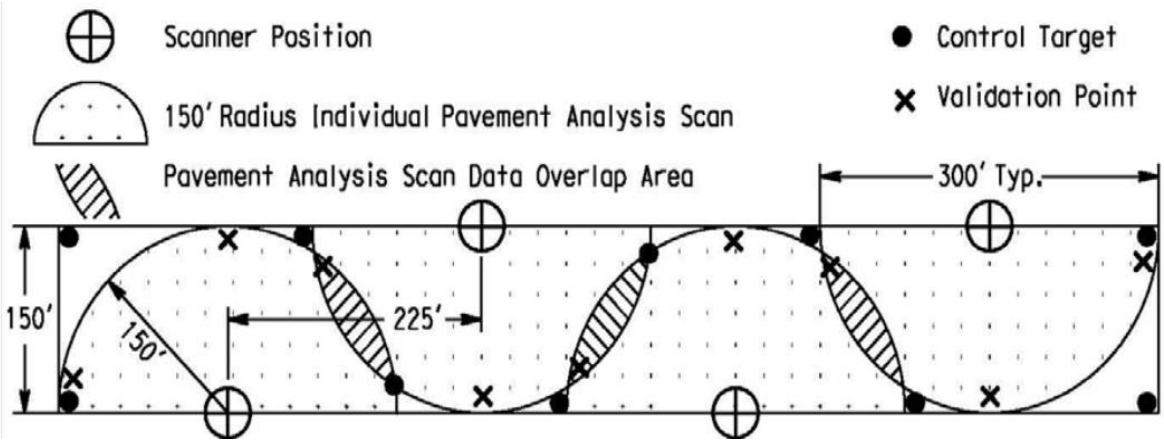

Figure 9: Sample mission plan. Image is a courtesy of Caltrans

SELECTING LOCATION FOR QUALITY CONTROL (VALIDATION) POINTS

EQA4SCENE produces analysis results for any validation point located within the analyzed point cloud. The positions of such points are vital for a successful validation process. Carefully chosen locations for the validation points produce better validation

results and will save time generating the Elevation Quality Analysis (EQA) Report. Here are some tips that have proven useful when selecting validation point locations.

Reduce the number of validation points and obtain more statistical data by placing validation points within overlapping areas of the scan data. Areas with the most overlaps are best for placing validation points. For validation points within overlapping areas of the scans, in addition to the "Cloud-to-control" analysis, EQA4SCENE will also provide "Cloud-to-cloud" analysis data showing information on how point cloud elevations (Z) from the different scans compare in overlapping areas.

Validation points located near leveled areas provide better data for the elevation quality analysis than points located on sloped surfaces.

Figure 10: Validation point located on slope or on leveled surface

Vertical or near-vertical planes are not suitable for placement of validation points. Avoid faces of buildings, structures, walls, fences and poles when locating validation points.

Avoid areas next to vertical planes or grade breaks. When selecting a location for a validation point, maintain a distance from a vertical plane larger than the search zone radius to ensure that cloud points on the vertical surface are not included into the Search Zone.

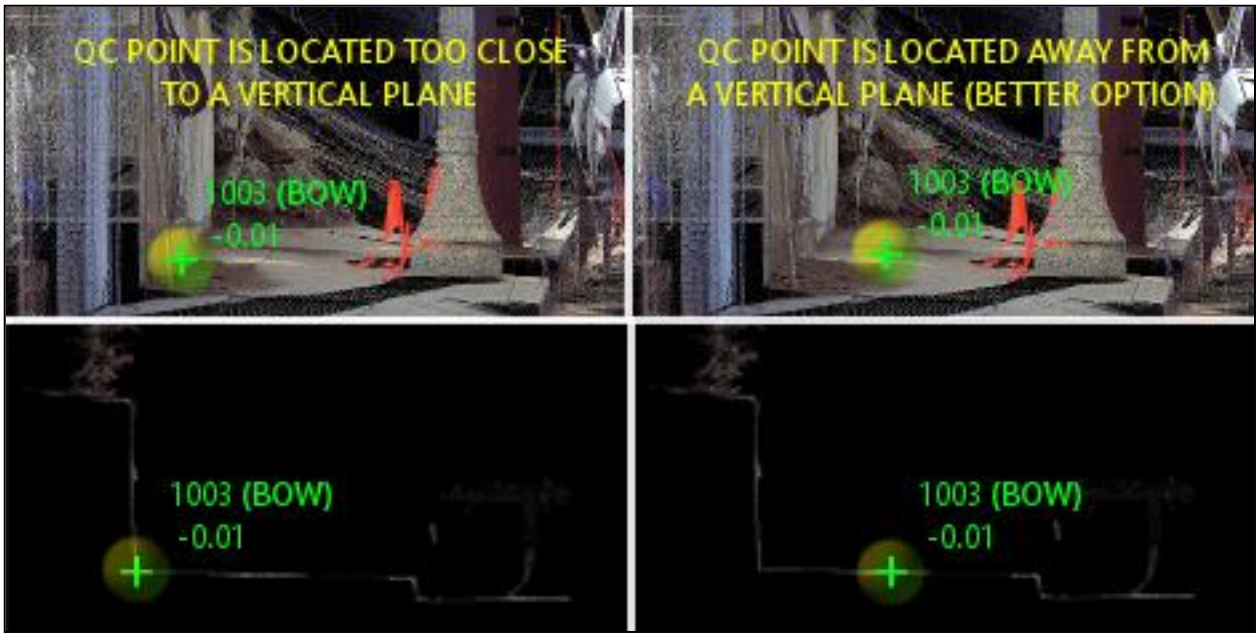

Figure 11: Validation point located near a vertical surface

A grade break can be defined as a line formed by the intersection of two sloping planes of different steepness. The best analysis results are achieved if the search zone contains cloud points from only a single sloping plane. Elevation quality analysis can be seriously compromised if a search zone includes cloud points from both sloping planes of a grade break. When selecting a location for a validation point, we recommend avoiding grade breaks such as a flow line, the top of a curb, edge of a walk, top and toe of slope, etc.

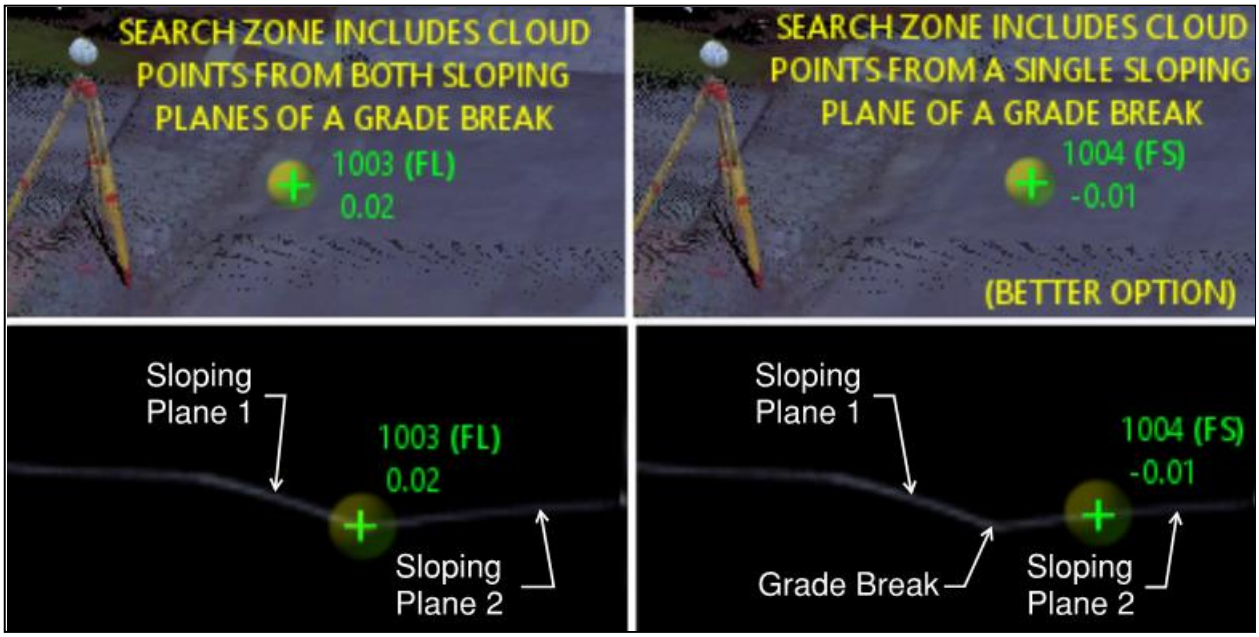

Figure 12: Validation point located near the grade break

For more information on Search Zone please see the *Selecting Parameters for Elevation Quality Analysis* chapter of this manual.

Uniform smooth surfaces are better suited for elevation quality analysis than rough surfaces. Concrete sidewalks, asphalt roadways, paved areas, and compacted dirt pads are good candidates for placing validation points. On the contrary, uneven surfaces like deteriorated pavements, grassy areas, areas covered with debris or gravel should be avoided when choosing validation point locations.

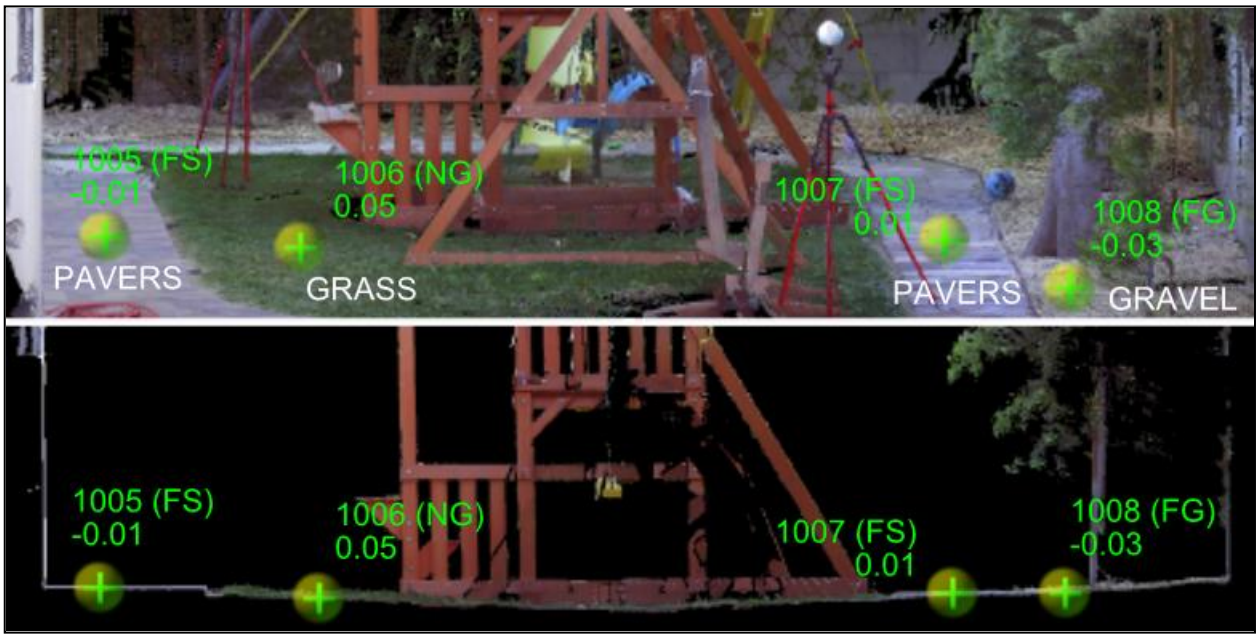

Figure 13: Validation point located on smooth or rough surface

Geometry is a very important factor for any geospatial network and should always be considered. The best results are typically seen when Quality Control points are distributed evenly throughout the project site. Points should not be located too close to the scanning locations or control targets.

FIELD WORK

Fieldwork normally starts with inspection of the site and adjustments of the mission plan to real site conditions. Scanner setups, scan targets, control and quality control (validation) points get their final locations and are marked on the ground. Survey measurements are taken to locate set points using proper GPS or conventional survey methods allowing one to achieve horizontal and vertical accuracy as required by the project's specifications. Field measurements are reduced and adjusted in the office to calculate resulting X, Y, Z coordinates for each control and quality control (validation)

point. Adjusted coordinate values are used to register and georeference scans to produce one uniform point cloud.

OFFICE WORK

Once raw data scans are downloaded, registered and georeferenced within the FARO Scene, registration results can be reviewed and compared to the project specifications. These registration results are either satisfactory or unsatisfactory. Any subsequent validation routine will help prove good registration results or can be used as a tool to detect registration blinders or weak elements.

EQA4SCENE offers an elevation quality analysis routine consisting of four basic steps.

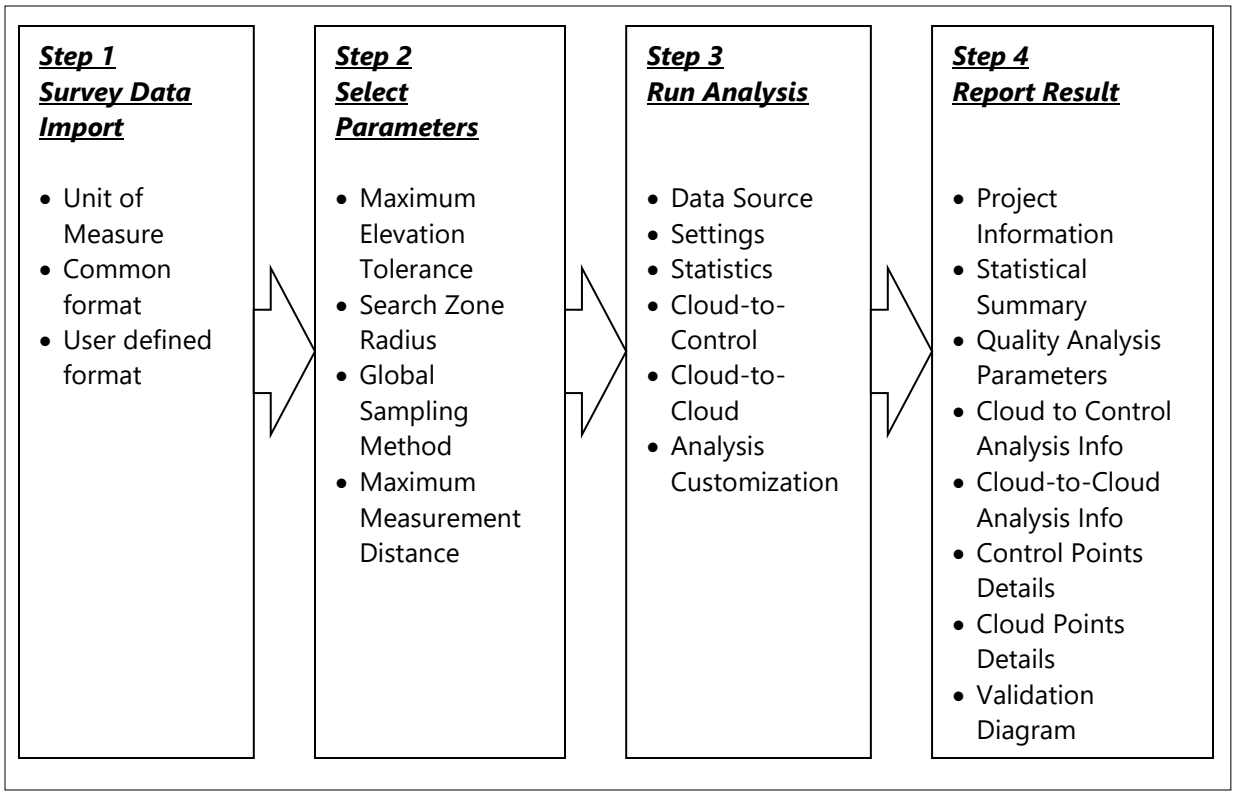

Figure 14: Four steps of the Elevation Quality Analysis routine

Step One is survey data import. At this step, an appropriate file and data format should be selected to import validation points. Survey data should be presented in the form of an ASCII file. EQA4SCENE will accommodate a variety of different file extensions and data formats described in detail later in this manual, however, at a minimum, a survey

file should contain point number, northing, easting and elevation for each validation point. Successful import will populate the Analysis Preview Table *(see Figure 16)*.

After points are imported, the required parameters for analysis are selected in ***Step Two***. The key parameters that must be defined before executing the analysis are: Maximum Elevation Tolerance, Search Zone Radius, Global Sampling Method and Maximum Measurement Distance. Each parameter is described in more detail in the *Selecting Parameters for Elevation Quality Analysis* chapter of this manual.

In ***Step Three***, the user selects a data source (project point cloud or specific scans), defines settings, runs analysis, reviews results, identifies blinders and weak registration elements, makes adjustments to the dataset, re-registers the point cloud and runs the analysis again. This cycle repeats until user is satisfied with validation results and is ready to move to the next step.

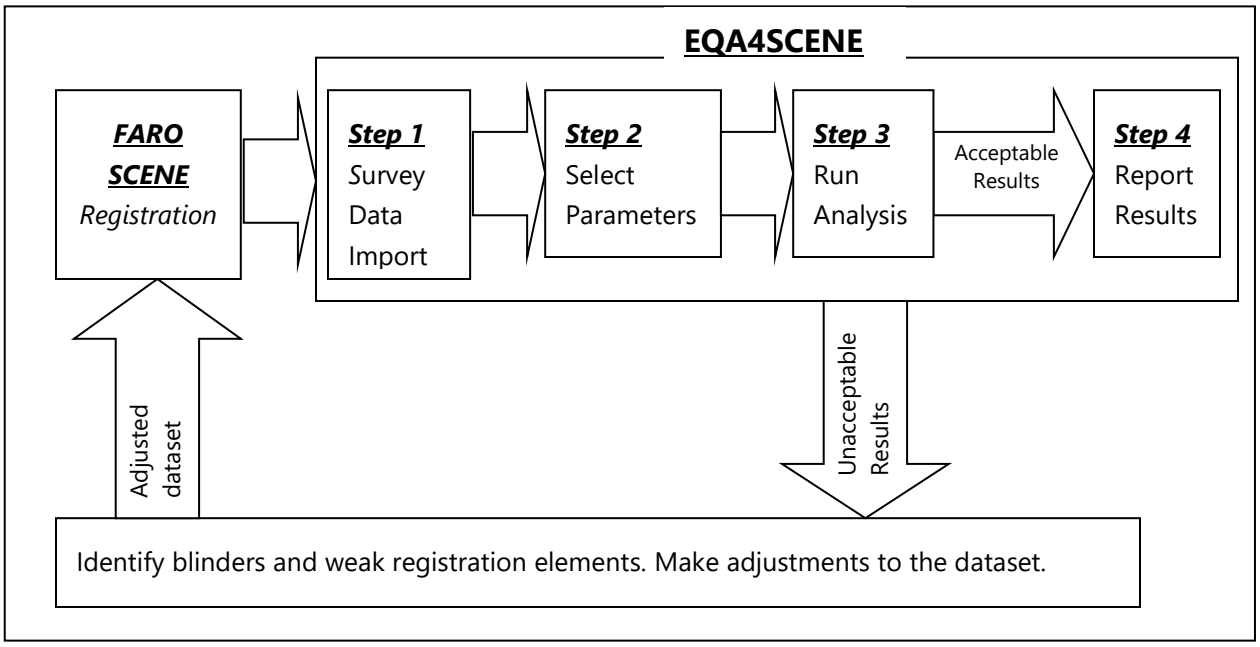

Figure 15: Quality Analysis and Data Registration Cycle

Step Four is the last step of the routine and reports Elevation Quality Analysis results. EQA4SCENE provides an inclusive, highly customizable reporting capability. Depending on the purpose and set requirements, a user can chose to report up to 12 different tables including Company Information, Project Information, Scanner Information, Quality Analysis Parameters, Statistical Summary, Quality Analysis Summary, Cloud-to-Control Analysis, Cloud-to-Cloud Analysis, Control Points Details, Cloud Points Details,

Abbreviations and Validation Diagram. Validation results can also be exported to Microsoft Excel for further use in custom calculations.

THE USER INTERFACE

EQA4SCENE window consists of six different panels as shown on *Figure 16* below.

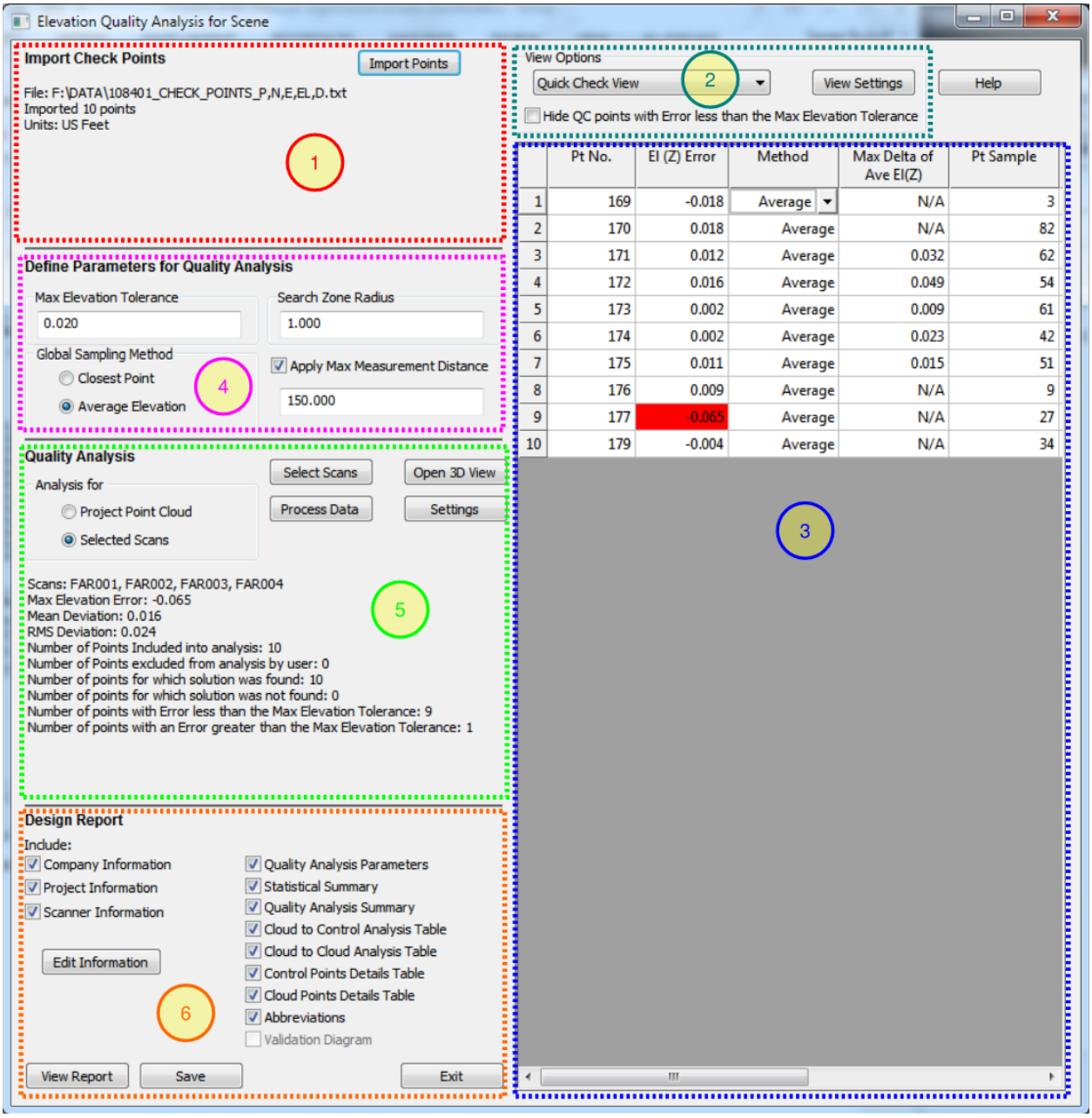

Figure 16: Composition of EQA4SCENE window

1. IMPORT PANEL

The Import Panel is used to import survey quality control (validation) points and display information on the location of the source file, number of imported points and selected

units of measure. The **Import Points** button opens the Import Text/ASCII dialog window.

2. ANALYSIS PREVIEW SETTINGS PANEL

The Analysis Preview Settings Panel helps to customize information displayed in the Analysis Preview Table. The View Options drop down menu allows for quick selection of preset table views.

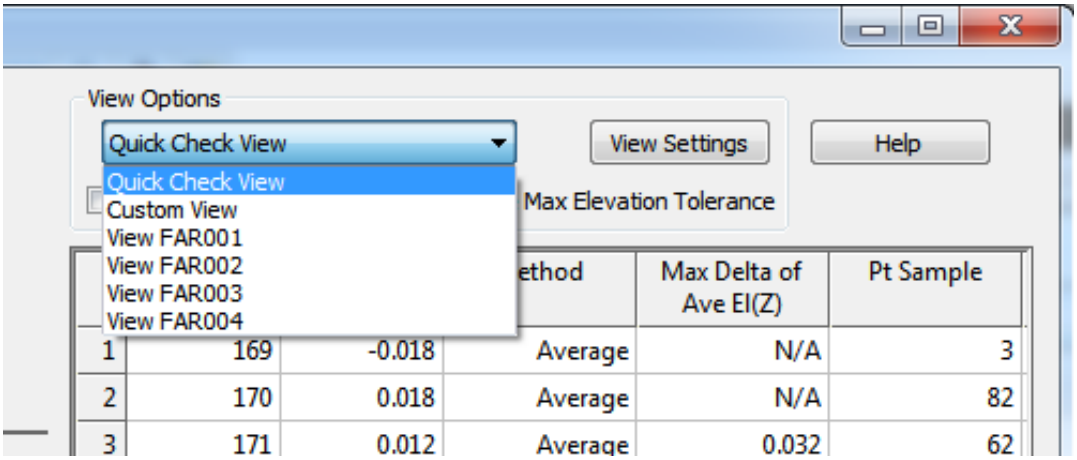

Figure 17: View Options of the Analysis Preview Settings Panel

When checked, the ***Hide QC points with Error less than the Max Elevation Tolerance*** checkbox hides information on all check points that met validation criteria and shows only out-of-tolerance observations that require attention. The 3D view window will behave in a similar manner.

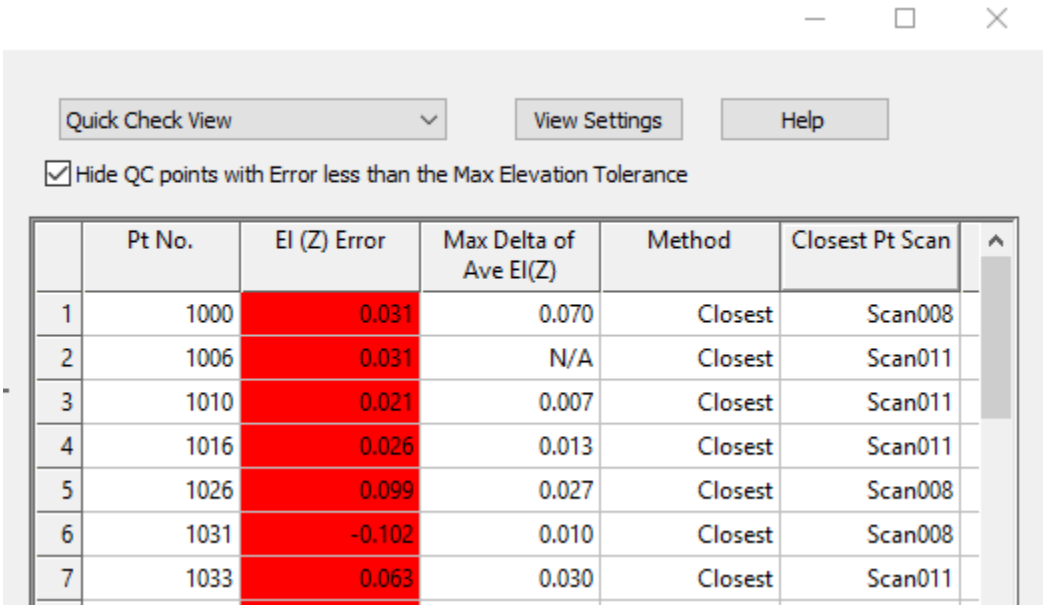

Figure 18: Hide QC points checkbox of the Analysis Preview Settings Panel

The **View Settings** button opens the Custom Table Settings dialog window.

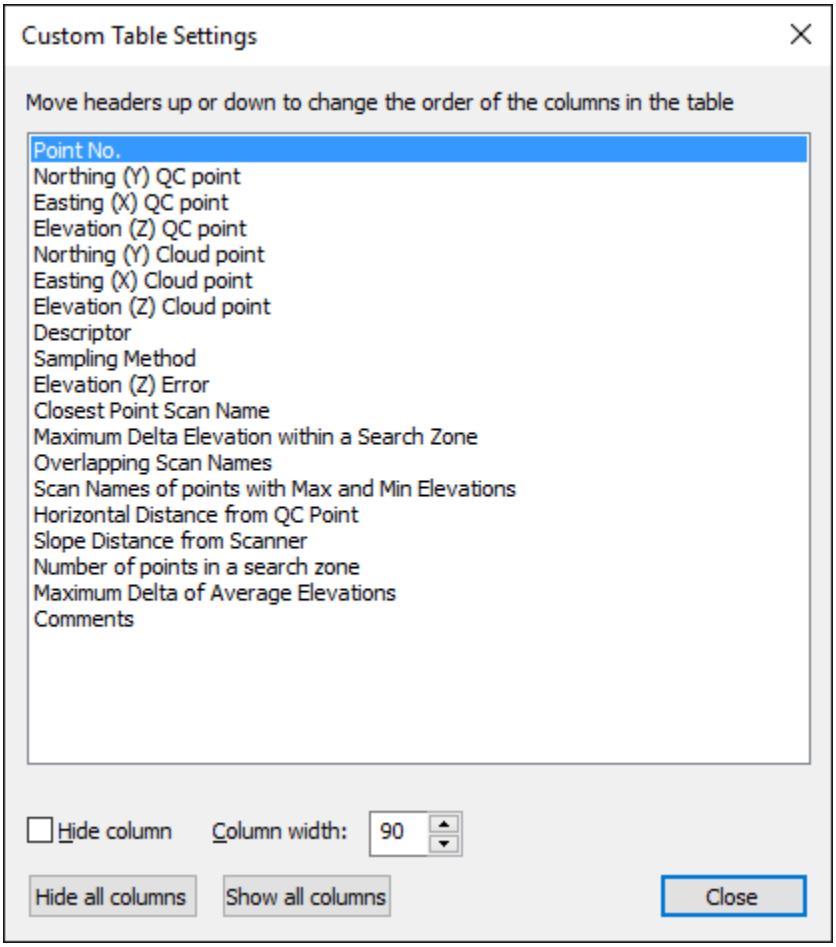

Figure 19: Custom Table Settings dialog window

3. ANALYSIS PREVIEW TABLE

The Analysis Preview Table displays information on a current analysis session. The information in the window can be viewed, sorted and tuned to fit goals and user preferences. The visibility of specific columns can be controlled through the Custom Table Settings dialog *(see Figure 19)*. The following information is available for preview:

Point No. is a number or name of the Quality Control Point, sometimes also referred to as Validation Point in this manual. Once a point is imported, it also becomes a name for the corresponding search zone. The name can be numeric or alphanumeric.

Northing (Y) QC Point is a coordinate of a Quality Control Point whose value is determined by measuring parallel to a north or Y-axis of the project horizontal datum.
Easting (X) QC Point is a coordinate of a Quality Control Point whose value is determined by measuring parallel to an east or X-axis of the project horizontal datum.
Elevation (Z) QC point is a coordinate of a Quality Control Point whose value is determined by measuring the vertical distance from a project vertical datum.
Northing (Y) Cloud Point is a coordinate of a Cloud Point whose value is determined by measuring parallel to a north or Y-axis of the project horizontal datum.
Easting (X) Cloud Point is a coordinate of a Cloud Point whose value is determined by measuring parallel to an east or *X*-axis of the project horizontal datum.
Elevation (Z) Cloud Point is a coordinate of a Cloud Point whose value is determined by measuring the vertical distance from a project vertical datum.
Northing (Y), Easting (X) and Elevation (Z) of the Cloud Point described above are for points selected by the Closest Point sampling method only. Average Elevation sampling method will return N/A (Not Applicable) for the coordinate values of the Cloud Point.
Descriptor is a feature description of the Quality Control Point given by a field surveyor. Knowing what kind of feature that a validation point represents will help in selecting an appropriate sampling method and radius of the search zone. For more details, see the Chapter *Performing Elevation Quality Analysis* of this manual.
Sampling Method is a selection technique for a subset of points used in elevation quality analysis calculations. EQA4SCENE currently offers Closest Point and Average Elevation sampling methods. Cells of the Sampling Method column in Analysis Preview Table can be used to set “Closest Point,” “Average Elevation,” or a “Do not Use” option for each individual Quality Control point.
Elevation (Z) Error is the difference in elevation between a Quality Control Point and the closest found Cloud Point within the analysis zone. This statement is valid when the Closest Point sampling method is selected. For the Average Elevation sampling method, this column returns a difference in elevation between a Quality Control Point and the average elevation of all points within a search zone.
Closest Point Scan Name is the name of the scan containing a Cloud Point closest to the center of a search zone. Proximity calculations are performed for X-Y plane.
Maximum Elevation Difference Scan Names shows the names of two overlapping scans having points with the largest elevation difference within the search zone. Where there is no overlap in a search zone that includes cloud points that belong to the single scan, a N/A (Not Applicable) message is displayed.

Horizontal Distance to QC Point is the shortest distance in X-Y plane from the center of the search zone to the closest found Cloud Point.
Horizontal Distance to Scanner is the shortest distance in X-Y plane from the center of the scan containing the closest found Cloud Point to the center of the search zone.
Number of points in a search zone (Pt Sample) shows the total number of Cloud Points found in a specific search zone.
Maximum Difference of Average Elevations shows the maximum vertical distance between the average elevations of the overlapping scans. This statistical characteristic is a part of the Cloud-to-Cloud Analysis. Unlike Maximum Elevation Difference, Maximum Difference of Average Elevations allows to estimate vertical separation of the overlapping point clouds for the Quality Control Points located on considerably sloped surfaces.

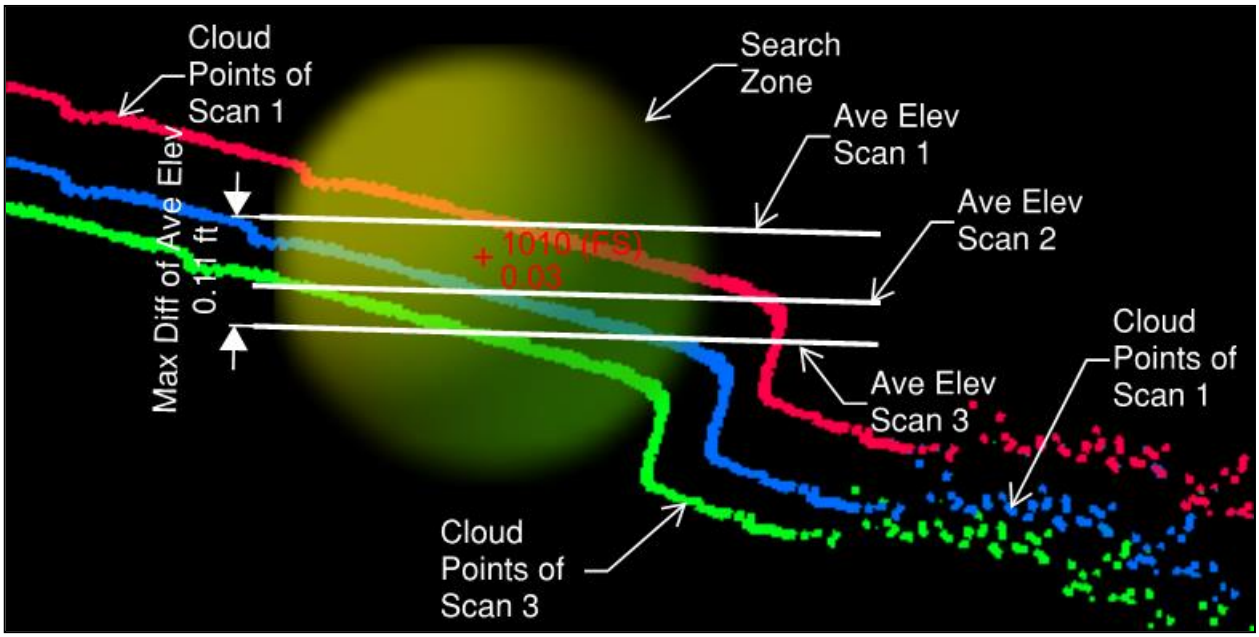

Figure 20: Maximum Difference of Average Elevations

Comments is an editable column where a user can add any comments related to the specific search zone.

4. QUALITY ANALYSIS PARAMETERS PANEL

The Quality Analysis Parameters Panel allows a user to define various parameters for the current elevation quality analysis session including Maximum Elevation Tolerance,

Search Zone Radius, Global Sampling Method and Maximum Measurement Distance. For more information on Quality Analysis Parameters, see the Chapter *Selecting Parameters for Elevation Quality Analysis* of this manual.

5. QUALITY ANALYSIS LAUNCH PANEL

The Quality Analysis Launch Panel provides tools to select the data source (project point cloud or specific scans), to control settings and to run quality analysis. It also displays a Statistical Summary of the current analysis session.

When the ***Project Point Cloud radio button*** is selected, EQA4SCENE runs a quality analysis for the entire project point cloud. Since a unified project point cloud does not contain information from the single scans, this selection will only provide Cloud-to-Control analysis. The **Select Scans** pushbutton is greyed out and the scan selection option is not available when the Project Point Cloud radio button is selected.

When the ***Selected Scans radio button*** is selected, both Cloud-to-Control and Cloud-to-Cloud analysis methods are available. The **Select Scans** pushbutton opens a Select Scans dialog window showing available scan data and provides tools to select specific scans or all available scans for analysis.

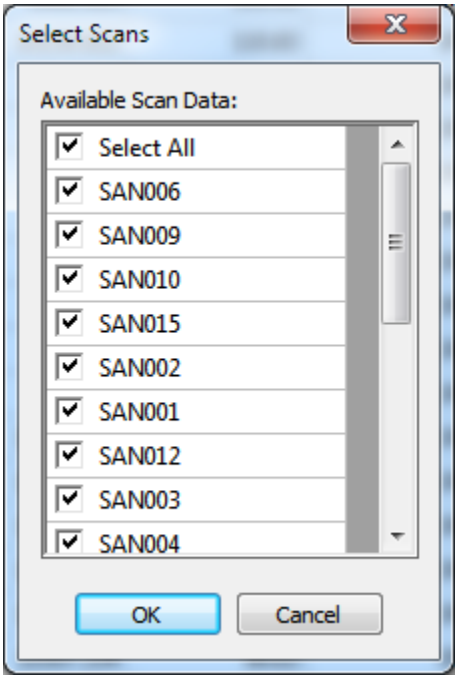

Figure 21: Select Scans dialog window

Open 3D View opens a new 3D view of the project that can be configured to show elevation differences, validation point information, scanner positions, targets and validation point locations.

Settings opens a dialog box that contains a number of configuration settings described further in Chapter *Settings* of this manual.
Process Data starts the analysis process. After the analysis process is completed, the Quality Analysis Launch Panel also displays a basic statistical summary.

6. DESIGN REPORT PANEL

The Design Report Panel provides a set of tools for Elevation Quality Analysis Report customization. EQA4SCENE offers 12 different tables to report information on company, project, scanner, parameters, statistics, etc. For more information on reporting see the Chapter *Reporting Results* of this manual.

The **Edit Information** button opens a new dialog where a user can enter and save information on company, project and scanner.

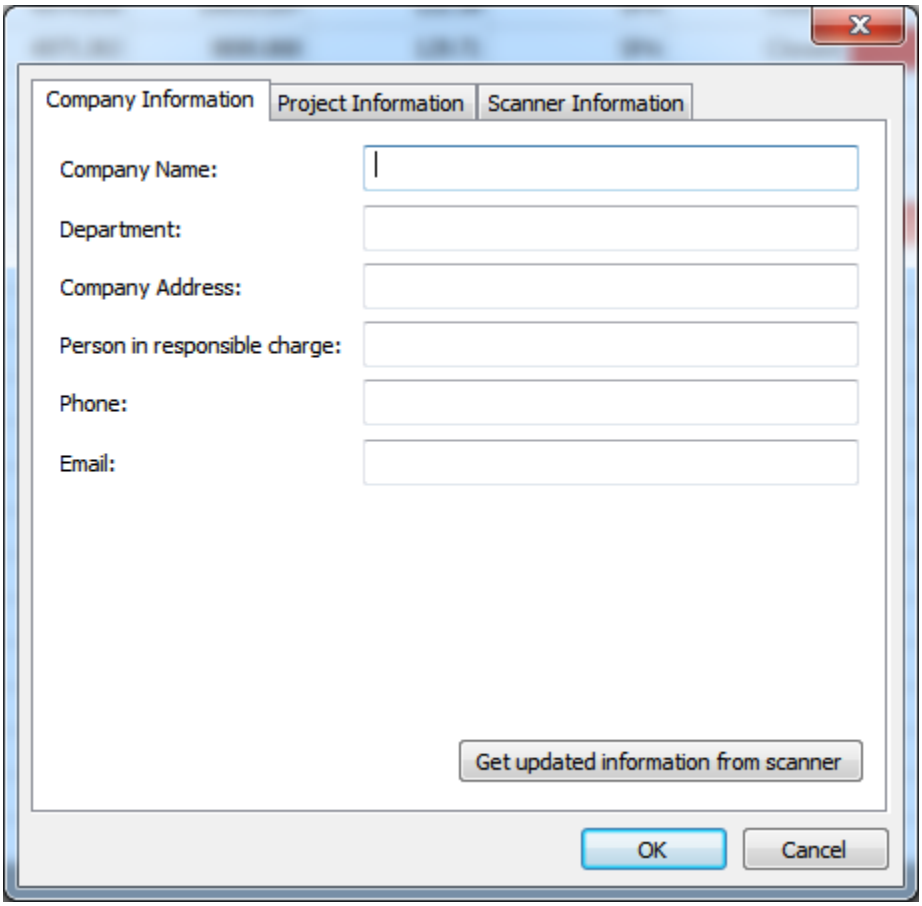

Figure 22: Edit Information dialog window

Get updated information from scanner will populate data fields with information entered by the scanner operator during the field phase of the project.

View Report will open a window showing a preview of the Elevation Quality Analysis Report in a text format showing information pieces selected on the Design Report panel.
Save opens a save file dialog window where a user can choose name, location and format of the report file. An Elevation Quality Analysis Report can be saved as TXT or XLSX.
Press the **Exit** button to close all EQA4SCENE dialogs.

IMPORTING QUALITY CONTROL (VALIDATION) POINTS

This dialog window imports Quality Control (validation) point data from an ASCII file into EQA4SCENE. Each line of the ASCII file can contain any combination of Point Number, Northing (Y), Easting (X), Elevation (Z), Description and other attributes. All point information should be on one line with the values separated by a comma, space or other delimiter. A user can choose from some common formats or a user defined format.

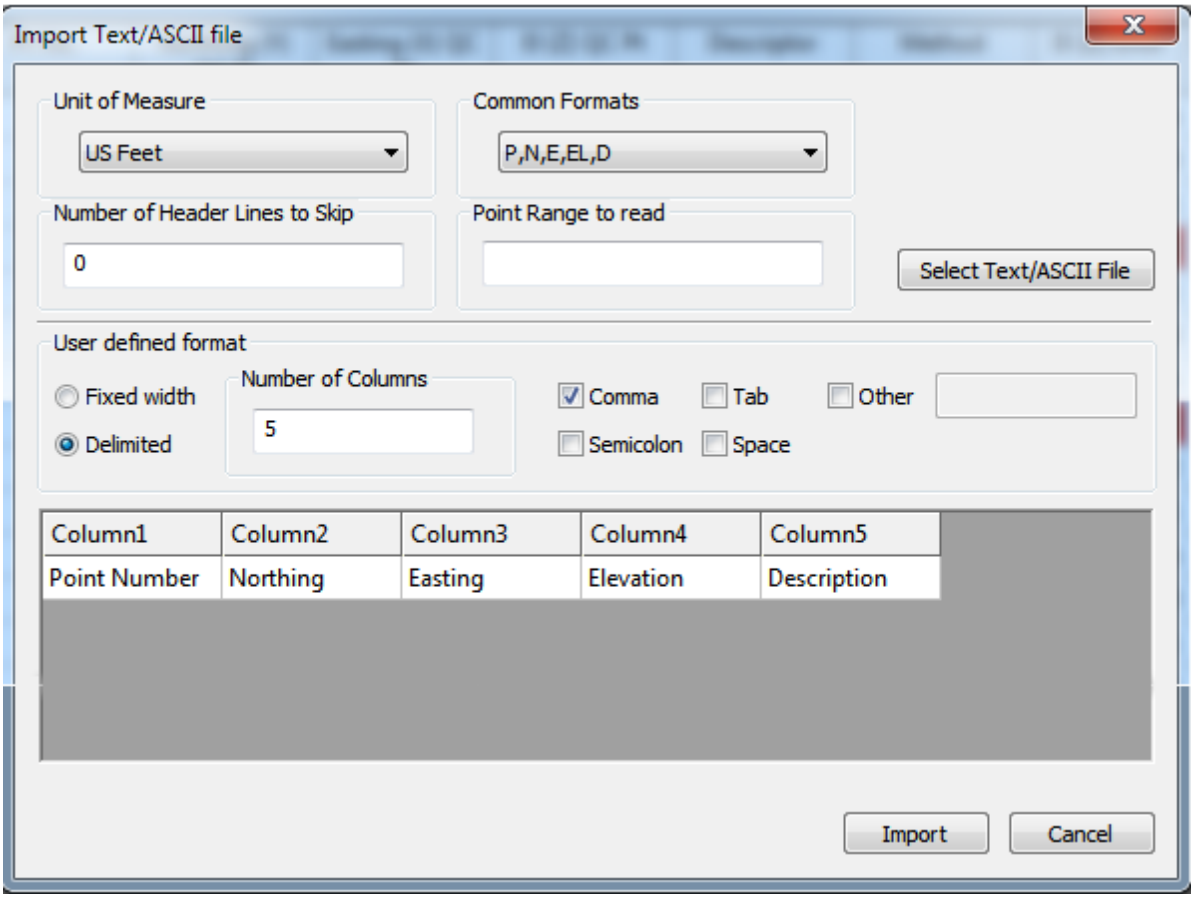

Figure 23: Import Text/ASCII file dialog window

Common formats can be selected from the Common Format List. EQA4SCENE offers 25 common file formats. Click the **Select Text/ASCII File** button and choose the file to read. A preview window will be populated with data contained in a selected file. Choose the desired common file format in the Common Formats dropdown list. All the lines in the ASCII file should contain point data in a specific order and separated by the delimiter matching the selected format shown in the common format box. Use the preview window to verify the content and coordinate order. If all data fields are filled

correctly, select the **Import** button to bring Quality Control (validation) point data into EQA4SCENE.

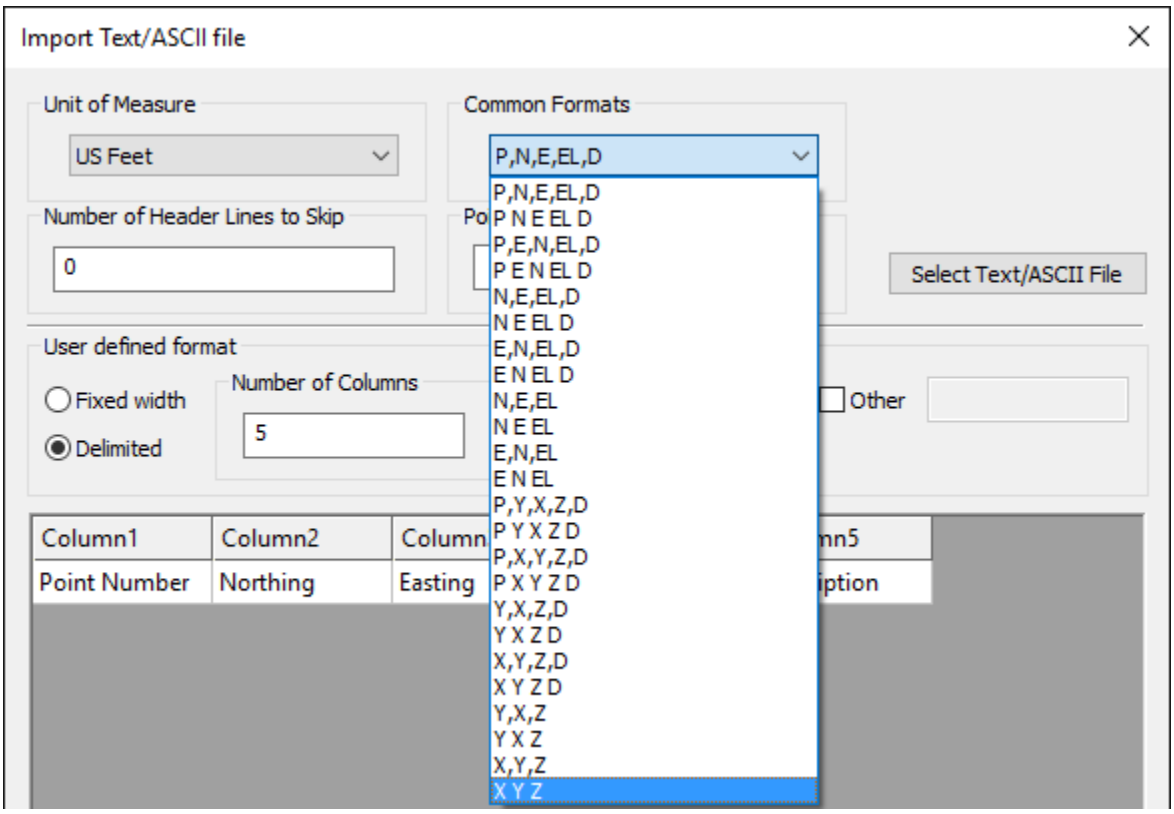

Figure 24: Import Text/ASCII file - Common Formats list

User defined format is designed to accommodate many different data types presented in a variety of forms. If items in the text file are separated by tabs, colons, semicolons, spaces, or other characters, select Delimited. If all of the items in each column are the same length, select Fixed width. Then specify the number of columns the data set contains.

To read the text file, pick the **Select Text/ASCII File** button and choose the file to read. The selected file is then displayed in the Preview Window as it will appear when it is separated into columns. The Preview Window is designed to help with selecting the desired data, organizing the data set and filling out the coordinate order.

For ***Delimited data***, select the character that separates values in your text file. If the character is not listed, select the ***Other*** check box, and then type the character in the box that contains the cursor. These options are not available if your data type is Fixed width.

For ***Fixed width data*** use the Preview Window to set field widths by moving edges of the column with your cursor. Start from the leftmost column and work your way to the right. When all columns in the Preview Window show desired data, select the **Import** button to bring Quality Control (validation) point data into EQA4SCENE.

For both common and user defined formats, header lines in a dataset can be skipped by defining the ***Number of Header Lines to Skip*** in the corresponding box.

Point Range to Read can also be defined for all formats. Use "-" to define the range of point numbers and "," to separate the ranges. For example, expression 1000-1021, 1050-1062 will import points with point numbers from 1000 to 1021 and from 1050 to 1062.

Units of Measure can be selected from the Units of Measure List. A user can choose from Meters, US Feet, International Feet or Inches. Units of measure should match the Units of the imported Northing (Y), Easting (X) and Elevation (Z) coordinate values.

SELECTING PARAMETERS FOR ELEVATION QUALITY ANALYSIS

Selecting correct parameters are critical for achieving realistic elevation quality analysis results. All parameters should be carefully considered before running quality analysis.

The ***Maximum Elevation Tolerance*** value is dictated by the purpose for which a point cloud will be used and is normally established by the end user. Most private companies or public agencies have a set of standards developed for each specific type of work that defines minimum accuracies and tolerances deemed necessary to meet specific objectives. Therefore, the Maximum Elevation Tolerance value for the specific project can be determined thru discussion with the point cloud end user or by studying corresponding company/agency standards.

Once a Maximum Elevation Tolerance value is determined and set in the corresponding box of the Quality Analysis Parameters Panel, elevation differences (or Errors) for all Quality Control points are compared to this value and any exceeding this parameter are displayed as underlined and highlighted in red in the Elevation Quality Analysis Report and Analysis Preview Table.

Search Zone Radius is a parameter that defines the size of the subset of points involved in the Elevation Quality Analysis for the specific Quality Control Point. Once Quality Control Points are imported into EQA4SCENE, each point becoming a center of the search zone that is a sphere defined by the Search Zone Radius. All points that fall within this Search Zone become a part of the Analysis Zone named after the corresponding Quality Control point and are used in analysis calculations. Each Analysis Zone should contain enough points to provide the data for reliable statistical results. The point cloud density, number of the overlapping scans and search zone radius are the factors responsible for the number of points included into the specific Analysis Zone. Please consider these factors when choosing the size of the Search Zone Radius for your project. A denser point cloud with more overlaps requires a smaller Search Zone Radius.

EQA4SCENE provides considerable statistical information on each Analysis Zone. Statistical characteristics of an Analysis Zone like Maximum and Minimum Elevations (Z), Maximum Delta Elevation (Z), Average Elevation (Z), Maximum Delta of Average Elevation (Z), Point Sample and Distance from Scanner provide a user with additional information needed to estimate the validity of the calculated error.

Global Sampling Method is a selection technique for a subset of points used in elevation quality analysis calculations.

Scanners capture reality in a grid pattern. This method cannot guarantee an exact X,Y position of the Cloud Point over a QC Point located independently. Because of this, approximation methods have to be used to relate Quality Control and Cloud Points before elevation quality analysis calculations. EQA4SCENE currently offers two such methods: Closest Point and Average Elevation.

The ***Closest Point*** method selects a Cloud Point that is closest in the X-Y plane to the location of the imported QC Point and compares elevations (Z) of those two points. The search is performed within the subset of Cloud Points included into the Search Zone of the specific radius defined by the user. If no Cloud Points are found within the specified radius, a N/A (Not Available) message is displayed. This method is best suited for QC points located on smooth or sloped surfaces, near grade breaks or vertical planes.

The ***Average Elevation*** method averages Elevations (Z) values of all Cloud Points found within the Search Zone and compares resulting Elevation to the Elevation of the QC point. This method is best suited for QC points located on rough near-leveled surfaces.

Maximum Measurement Distance is a parameter that defines the horizontal distance from the center of the scan beyond which Cloud Points of this scan are not considered for elevation quality analysis calculations. This parameter helps to introduce the Useful Range of Scanning concept into analysis.

Modern laser scanners are capable of scanning features over long distances. However, the accuracy of the scan data diminishes beyond a certain distance. The Maximum Measurement Distance that can provide the desired accuracy of the final deliverables is defined as the Useful Range of Scanning. Extra care should be taken to ensure that the final dataset does not include any portion of point cloud data whose accuracy is compromised by measurements outside the useful range.

PERFORMING ELEVATION QUALITY ANALYSIS

Ones all parameters are set and the desired dataset is selected, Elevation Quality Analysis can be started by pressing the **Process Data** button. The analysis process will take some time, and when completed, Elevation Quality Analysis Results will be displayed in the Analysis Preview Table. At this stage, results can be reviewed and analysis can be fine-tuned by assigning a different Sampling Method for each individual Quality Control Point or by tweaking other parameters. When EQA4SCENE returns acceptable analysis results, the user moves to the final reporting stage of the analysis routine.

GENERAL CONSIDERATIONS

Please consider the following when performing Elevation Quality Analysis.

PROJECT POINT CLOUD AND SELECTED SCANS

EQA4SCENE provides tools to run Elevation Quality Analysis for Selected Scans or for an entire Project Point Cloud. Analysis for the Selected Scans option provides more statistical information, takes less time to execute and is the preferred analysis method for projects scanned with FARO scanners and registered with FARO SCENE. A Project Point Cloud is selected for analysis mostly when scan data is imported from sources other than FARO.

SAMPLING METHOD AND RADIUS OF A SEARCH ZONE

Knowing what kind of feature a Quality Control (validation) point represents will help in selecting an appropriate sampling method and radius of the validation zone. For example, if the Quality Control shot was taken at the top of a curb, a rapid change of the surface grade should be expected in close proximity to the shot. In this case, a small search radius in combination with the closest point sampling method would produce the best analysis results. For a Quality Control point that represents spot elevation on a flat, but rough asphalt surface, a large search radius and average elevation method are the best choices.

PROCESSING TIME

Depending on the hardware and software configuration of your computer, as well as the number of validation points, size of the point cloud, number of the selected scans as well as scan density, analysis time will vary from several minutes up to several hours. A progress bar will show the status of the calculations.

ASSIGNING SAMPLING METHOD FOR A SINGLE QUALITY CONTROL POINT

Start Elevation Quality Analysis by choosing a global sampling method that will utilize most of your survey dataset. Once the analysis process is completed and analysis results based on a selected global Sampling Method are displayed in the Analysis Preview Table, cells of the Sampling Method column can be used to further customize Elevation Quality Analysis by assigning the appropriate sampling method for each individual Quality Control Point. A Quality Control Point can also be excluded from the analysis by selecting the "Do Not Use" option in a corresponding cell of the Sampling Method column.

3D VIEW

Once Quality Control points are imported, the 3D View can be utilized to visualize a project site to show locations of scanner setups, control targets and Quality Control points. After analysis is completed, color-coded error values are also available for display.

To find a Quality Control point in the 3D view, select a row of the analysis preview table displaying a desired point, right click on the corresponding row header and select "Locate Point" from the dropdown menu. The 3D view window will center and zoom on the selected Quality Control Point.

If using the Validation Diagram option when Designing Report, please open the 3D view and position the point cloud on your screen as you want it to appear on a diagram, then press Save. Depending on your hardware and software configuration, it can take several minutes to create a report.

SETTINGS

The Settings window is used to define font, size and color of labels and symbols in the 3D View window. It also allows one to set the number of decimal places used in statistical calculations. See *Figure 25* for details.

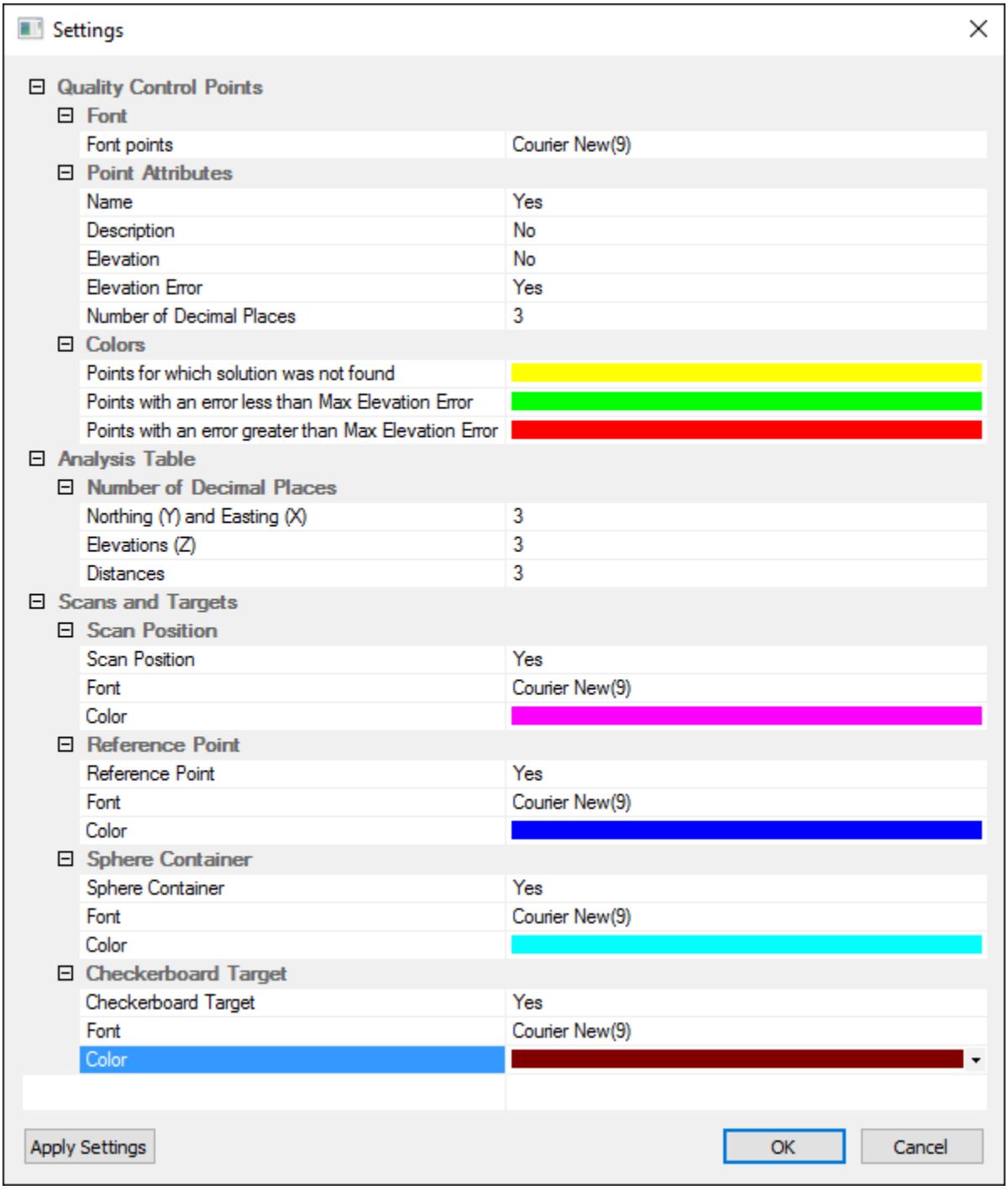

Figure 25: Settings window

Quality Control Points. The visibility of attributes can be controlled by selecting Yes or No from the drop-down list next to the corresponding attribute. Colors of the elevation error labels and number of decimal points displayed in 3D view can also be set in this section.

The ***Analysis Table*** section is designed to set a number of decimal places used in statistical calculations and is displayed in the Analysis Preview window and Statistical Reports.

The ***Scans and Targets*** section is designed to control appearance, font, size and color of the 3D View labels and symbols for Scan Positions, Reference Points, Sphere Containers and Checkerboard Targets.

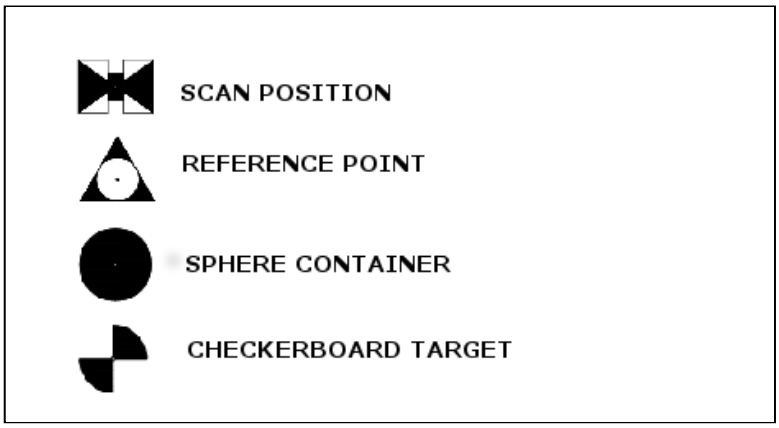

Figure 26: Symbols used in 3D View

STATISTICAL INFORMATION

When a dataset is processed, the following statistical information is displayed:

Scans – list of all scans involved into the Elevation Quality Analysis

Max Elevation Error – the largest absolute Elevation Error value in a dataset.

Mean Deviation = $\frac{\sum |Elevation\ Error|}{N}$

RMS Deviation = Root Mean Square Deviation = $\sqrt{\frac{\sum_{i=1}^{n}(Elevation\ Error)^2}{N}}$

Number of points included into analysis $= N$

Number of points excluded from analysis by user

Number of points for which solution was found

Number of points for which solution was not found

Number of points with Error less than the Max Elevation Tolerance

Number of points with an Error greater than the Max Elevation Tolerance

REPORTING RESULTS

The Elevation Quality Analysis Report can be designed by selecting required information pieces from the Design Report panel.

PROJECT INFORMATION TABLE

The Project Information section of the report provides Company data, Project specifics and Scanner details.

Company Information: Company Name, Department, Company Address, Person Responsible, Phone, Email.

Project Information: Project Number, Project Name, Project Description, Project Location, Project Datum, Field Work Authorization #, Survey Date, Field Operator, Office Operator, Additional Information.

Scanner Information: Scanner Manufacture, Scanner Model, Scanner Serial Number, Calibration Certification #, Calibration Date, Owner, Scanner name.

STATISTICAL SUMMARY TABLE

The Statistical Summary Table reports the following:

QUALITY ANALYSIS PARAMETERS:

QC Point file – the path and name of the imported file containing Quality Control Points.

Scans - list of all scans involved into the Elevation Quality Analysis.

Units of Measure - units of the imported Northing (Y), Easting (X) and Elevation (Z) coordinate values of Quality Control Points. EQA4SCENE import supports Meters, US Feet, International Feet or Inches.

Max Elevation Tolerance – maximum Elevation Error value deemed acceptable by organization or agency for a certain task.

Search Zone Radius – reports the value entered by user in corresponding text box of the Quality Analysis Parameters Panel.

Max Measurement Distance – reports the value entered by user in corresponding text box of the Quality Analysis Parameters Panel. This parameter defines the horizontal

distance from the center of the scan beyond which Cloud Points of this scan are not considered for the elevation quality analysis calculations.

STATISTICAL SUMMARY:

Max Elevation Error - the largest absolute Elevation Error value in a dataset.

Mean Deviation = $\frac{\sum |Elevation\ Error|}{N}$

RMS Deviation= Root Mean Square Deviation = $\sqrt{\frac{\sum_{i=1}^{n}(Elevation\ Error)^2}{N}}$

Number of points included into analysis = N

Number of points excluded from analysis by user

Number of points for which solution was found

Number of points for which solution was not found

Number of points with an error less than the Max Elevation Tolerance

Number of points with an error greater than the Max Elevation Tolerance

QUALITY ANALYSIS SUMMARY TABLE

The Quality Analysis Summary Table provides the following information:

Pt No. – Point Number of the Quality Control Point and name of the corresponding Search Zone.

Method - Sampling Method selected by the user for a specific search zone.

El (Z) Error – Elevation (Z) Error is a difference in elevation between a Quality Control Point and the closest found Cloud Point when "Closest" Sampling method is selected. When the "Average" method is chosen, Elevation (Z) Error is calculated as the difference between Quality Control Point Elevation and Average Elevation of all Cloud Points within the corresponding search zone.

Max Delta El (Z) – represents the largest difference of the absolute elevation values in a specific zone. A large value is an indicator of a rough or sloped surface. A smaller value indicates a smooth or flat surface.

Description - Feature description of the Quality Control Point given by a field surveyor.

Comments - A column showing comments related to the specific search zone entered by the user.

CLOUD TO CONTROL ANALYSIS TABLE

Pt No. - Point Number of the Quality Control Point and name of the corresponding Search Zone.

El (Z) QC Pt – Elevation (Z) of the Quality Control Point

El (Z) Cloud Pt – Elevation (Z) of the closest found Cloud Point when "Closest" Sampling method is selected or Average Elevation (Z) of all Cloud Points within the corresponding search zone when the "Average" method is chosen.

Method - Sampling Method selected by the user for a specific search zone.

El (Z) Error - Elevation (Z) Error is a difference in elevation between a Quality Control Point and the closest found Cloud Point when "Closest" Sampling method is selected. When the "Average" method is chosen, Elevation (Z) Error is calculated as the difference between Quality Control Point Elevation and Average Elevation of all Cloud Points within the corresponding search zone.

HD – Horizontal Distance to QC Point is the shortest distance in the XY plane from the center of the search zone to the closest found Cloud Point. If "Average" Sampling Method is selected, this column will display N/A.

Closest Pt Scan – Closest Point Scan Name is the name of the scan containing a Cloud Point closest to the center of a search zone. Proximity calculations are performed for the X-Y plane.

CLOUD-TO-CLOUD ANALYSIS TABLE

Pt No. - Point Number of the Quality Control Point and name of the corresponding Search Zone.

Scan Name – Name of the single overlapping scan containing Cloud Points found within the Search Zone. For a line, containing unified information for all Cloud Points found within the Search Zone in all overlapping scans, "Zone" is displayed.

Max El (Z) – Maximum Elevation (Z) is the largest Elevation (Z) value for Cloud Points found within a search zone of the Scan displayed in a Scan Name cell of the same line. If "Zone" is displayed in a Scan Name cell of the line, than Max El (Z) represents the largest

Elevation (Z) value found within a search zone for Cloud Points found in all overlapping scans within a Search Zone.

Min El (Z) - Minimum Elevation (Z) is the smallest Elevation (Z) value for Cloud Points found within a search zone of the Scan displayed in a Scan Name cell of the corresponding line. If "Zone" is displayed in a Scan Name cell of the line, than Min El (Z) represents the smallest Elevation (Z) value found within a search zone for Cloud Points found in all overlapping scans within a Search Zone.

Max Delta El (Z) – Maximum Delta Elevation (Z) = | Maximum Elevation (Z) | - | Minimum Elevation (Z) |

Ave El (Z) – Average Elevation (Z) of all Cloud Point found within a Search Zone of the specific scan.

Max Delta of Ave El (Z) – Maximum Delta of the Average Elevations (Z) is a difference between highest and lowest average elevation values of the overlapping scans within a Search Zone. See *Figure 20.*

Pt Sample – Point Sample is a number of points found within a search zone for a specific scan or for all overlapping scans.

Dist from Scanner – Distance from Scanner is the shortest distance in the X-Y plane from the center of the scan to the closest found Cloud Point of the same scan. If the "Average" Sampling Method is selected, this column will display N/A.

CONTROL POINTS DETAILS TABLE

Pt No. - Point Number of the Quality Control Point and name of the corresponding Search Zone.

Northing (Y) - is a coordinate of a Quality Control Point whose value is determined by measuring parallel to a north or Y-axis of the project horizontal datum.

Easting (X) - is a coordinate of a Quality Control Point whose value is determined by measuring parallel to an east or X-axis of the project horizontal datum.

Elevation (Z) - is a coordinate of a Quality Control Point whose value is determined by measuring the vertical distance from a project vertical datum.

Description - Feature description of the Quality Control Point given by a field surveyor.

CLOUD POINTS DETAILS TABLE

Pt No. - Point Number of the Quality Control Point and name of the corresponding Search Zone.

Scan Name - Name of the single overlapping scan containing Cloud Points found within the Search Zone. For a line, containing unified information for all Cloud Points found within the Search Zone in all overlapping scans, "Zone" is displayed.

Method - Sampling Method selected by the user for a specific search zone.

Northing (Y) - is a coordinate of a Cloud Point whose value is determined by measuring parallel to a north or Y-axis of the project horizontal datum.

Easting (X) - is a coordinate of a Cloud Point whose value is determined by measuring parallel to an east or X-axis of the project horizontal datum.

Elevation (Z) - is a coordinate of a Cloud Point whose value is determined by measuring the vertical distance from a project vertical datum.

HD - Horizontal Distance to QC Point is the shortest distance in the X-Y plane from the center of the search zone to the closest found Cloud Point. If the "Average" Sampling Method is selected, this column will display N/A.

Dist from Scanner – Distance from Scanner is the shortest distance in the X-Y plane from the center of the scan to the closest found Cloud Point. If the "Average" Sampling Method is selected, this column will display N/A.

Pt Sample - Point Sample is a number of points found within a Search Zone of the specific scan.

ABBREVIATIONS

No. - Number

Ave - Average

Cloud - Project Point Cloud

Desc - Description

Diff - Difference

Dist - Distance

El - Elevation

Err - Error

Fd - Found

HD - Horizontal Distance

Max - Maximum

Min - Minimum

N/A - Not Applicable

Pt - Point

VALIDATION DIAGRAM

The Validation Diagram Option will place a screenshot picture of the current 3D view into your Microsoft Excel spreadsheet. When using this option, please open the 3D view and position the point cloud on your screen as you want it to appear on the diagram, then press Save. Depending on your hardware and software configuration, it can take several minutes to create a report.

TABLE OF FIGURES

APPENDIX A: SOFTWARE LICENSE AGREEMENT

Software License Agreement

License

1. Under this Software License Agreement (the "Agreement"), Point Cloud Spatial Solutions (the "Vendor") grants to the user (the "Licensee") a non-exclusive and non-transferable license (the "License") to use Elevation Quality Analysis for SCENE (EQA4SCENE) (the "Software").
2. "Software" includes executable computer programs and any related printed, electronic and online documentation and any other files that may accompany the product.
3. Title, copyright, intellectual property rights and distribution rights of the Software remain exclusively with the Vendor. Intellectual property rights include the look and feel of the Software. This Agreement constitutes a license for use only and is not in any way a transfer of ownership rights to the Software.
4. The Software may be loaded onto no more than one computer. A single copy may be made for backup purposes only.
5. The rights and obligations of this Agreement are personal rights granted to the Licensee only. The Licensee may not transfer or assign any of the rights or obligations granted under this Agreement to any other person or legal entity. The Licensee may not make available the Software for use by one or more third parties.
6. The Software may not be modified, reverse-engineered, or de-compiled in any manner through current or future available technologies.
7. Failure to comply with any of the terms under the License section will be considered a material breach of this Agreement.

License Fee

8. The original purchase price paid by the Licensee will constitute the entire license fee and is the full consideration for this Agreement.

Limitation of Liability

9. The Software is provided by the Vendor and accepted by the Licensee "as is". Liability of the Vendor will be limited to a maximum of the original purchase price of the Software. The Vendor will not be liable for any general, special, incidental or consequential damages including, but not limited to, loss of production, loss

of profits, loss of revenue, loss of data, or any other business or economic disadvantage suffered by the Licensee arising out of the use or failure to use the Software.

10. The Vendor makes no warranty expressed or implied regarding the fitness of the Software for a particular purpose or that the Software will be suitable or appropriate for the specific requirements of the Licensee.
11. The Vendor does not warrant that use of the Software will be uninterrupted or error-free. The Licensee accepts that software in general is prone to bugs and flaws within an acceptable level as determined in the industry.

Warrants and Representations

12. The Vendor warrants and represents that it is the copyright holder of the Software. The Vendor warrants and represents that granting the license to use this Software is not in violation of any other agreement, copyright or applicable statute.

Acceptance

13. All terms, conditions and obligations of this Agreement will be deemed to be accepted by the Licensee ("Acceptance") on installation of the Software.

Term

14. The term of this Agreement will begin on Acceptance and is perpetual.

Termination

15. This Agreement will be terminated and the License forfeited where the Licensee has failed to comply with any of the terms of this Agreement or is in breach of this Agreement. On termination of this Agreement for any reason, the Licensee will promptly destroy the Software or return the Software to the Vendor.

Force Majeure

16. The Vendor will be free of liability to the Licensee where the Vendor is prevented from executing its obligations under this Agreement in whole or in part due to Force Majeure, such as earthquake, typhoon, flood, fire, and war or any other unforeseen and uncontrollable event where the Vendor has taken any and all appropriate action to mitigate such an event.

Governing Law

17. The Parties to this Agreement submit to the jurisdiction of the courts of the State of California for the enforcement of this Agreement or any arbitration award or decision arising from this Agreement. This Agreement will be enforced or construed according to the laws of the State of California.

Miscellaneous

18. This Agreement can only be modified in writing signed by both the Vendor and the Licensee.
19. This Agreement does not create or imply any relationship in agency or partnership between the Vendor and the Licensee.
20. Headings are inserted for the convenience of the parties only and are not to be considered when interpreting this Agreement. Words in the singular mean and include the plural and vice versa. Words in the masculine gender include the feminine gender and vice versa. Words in the neuter gender include the masculine gender and the feminine gender and vice versa.
21. If any term, covenant, condition or provision of this Agreement is held by a court of competent jurisdiction to be invalid, void or unenforceable, it is the parties' intent that such provision be reduced in scope by the court only to the extent deemed necessary by that court to render the provision reasonable and enforceable and the remainder of the provisions of this Agreement will in no way be affected, impaired or invalidated as a result.
22. This Agreement contains the entire agreement between the parties. All understandings have been included in this Agreement. Representations which may have been made by any party to this Agreement may in some way be inconsistent with this final written Agreement. All such statements are declared to be of no value in this Agreement. Only the written terms of this Agreement will bind the parties.
23. This Agreement and the terms and conditions contained in this Agreement apply to and are binding upon the Vendor's successors and assigns.

Notices

24. All notices to the Vendor under this Agreement are to be provided at the following address:

Point Cloud Spatial Solutions
12440 Landale St.

Studio City, CA 91604

Or visit Point Cloud Spatial Solutions at http://www.pcss.xyz.