TcpGPS for Android

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1 Introduction

TcpGPS is an Android application (available both for mobile phones and tablets) that allows the user to carry out field work on measurements of farms, roads, crops, etc., in a simple way.

In addition, after carrying out the survey or importing a file of measured points, it is possible to proceed to the staking out of these points, offering tools for quick and easy location of these points on the ground.

Finally, the data obtained can be exported to a range of different formats (TXT, GML, KML, etc.) and synchronized with Google Drive to make them instantly available on any other platform.

TcpGPS app is available for any Android device with a version 6.0 or above, for both smartphone and tablet. In this document the screenshots were taken in a smartphone in order to show functionality independently.

1.1 Installation

Installing TcpGPS Android application requires a device with Android OS and Internet connection. The recommended requirements are shown in the following table:

Feature	Recommended
Android OS	V6.0 or above
RAM	2GB
Connectivity	Data connection Bluetooth Internal GPS
Sensors	Magnetometer and accelerometer
GPU	High performance

From Google Play Store you can find and install the application, named **TcpGPS**.

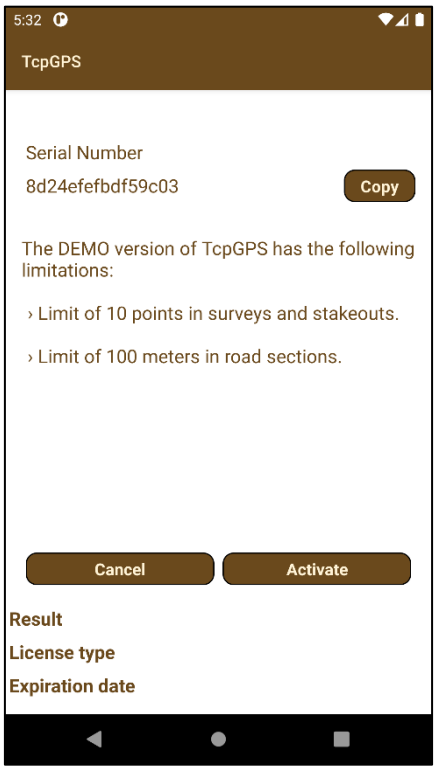


Figure 1. License request

The application requires a set of permissions:

- **Bluetooth** for connecting to external GNSS receivers.
- **Internet** for downloading ESRI maps, synchronizing to Google Drive and using NTRIP and WMS services.
- **Location** for getting position from the internal GPS.
- **Camera** for making photos and use augmented reality.
- **Microphone** for recording voice notes.
- **Storage** for accessing files and storing results.

These permissions will be requested to accept after installing the application.

The first time the application is started, the user will be required to fill the data information fields for requesting a license. Two different license versions are available for TcpGPS Android.

1.2 Demo license

Once the application has been downloaded and installed, you can request a **demo license** with a limit of 10 points by entering your email and your country. If you have already purchased your permanent license, you can enter the activation code and start working in the unlimited mode.

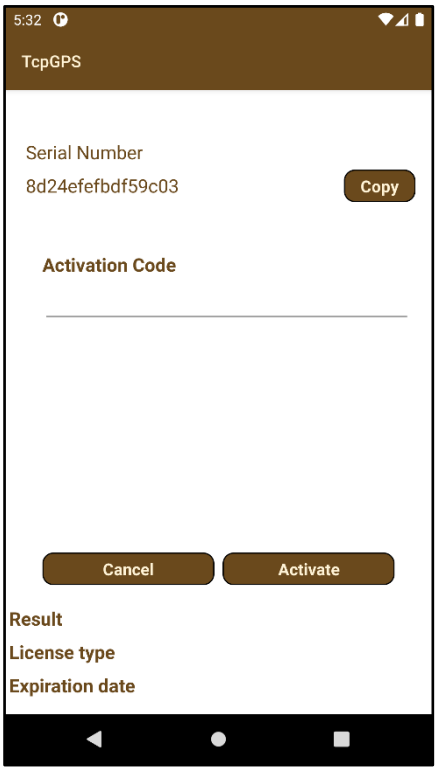
1.3 Full license

At the application start, if you do not have a license, you may type an activation code (see **Figure 1. License request**) you can get sending an email to **sales@aplitop.com**.

If you already have a **demo** license you can also type the activation code to upgrade your license from **demo** to **full**.

For more details, you can find the technical note for licenses here:

https://www.aplitop.com/subidas/Products/TcpGPS%20Android/support/en/tcpgps_android_en_v21_001_licencia.pdf



1.4 Application data

In section **Menu > Application > About us** is possible to find information about:

- **License agreement.**
- **User information** associated to license**.**
- **System and application information**: version and device, list of sensors, etcetera.

2 Session wizard

When the application start-ups, it displays a wizard for configuring the GNSS receiver and the project to be used in the working session.

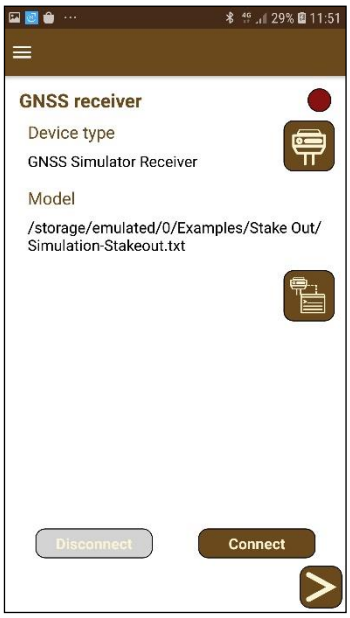


Figure 2. GNSS receiver connection assistant

Figure 3. GNSS receiver working mode assistant

Figure 4. Project configuration assistant

2.1 GNSS receiver connection assistant screen

On this screen (Figure 2), the user can connect and configure the GNSS receiver he wants to use or both receivers if a base-rover configuration is needed. These are the options available:

- **Receiver**: The last receiver and model used in the last session are shown here. It allows to connect to a new receiver or model , or connect/disconnect to the last one.
- **Console:** It is possible to access to a terminal for checking what is the app receiving from the receiver by clicking .

Once the receiver is connected (or not), by clicking on **Next** the user continues to the next wizard screen:

2.2 GNSS working mode assistant screen

This screen (Figure 3) has available four options for configuring the working mode on our GNSS receiver:

- **Rover**. GNSS rover configuration for collecting data.

- **Base**. GNSS base configuration for sending corrections to all GPS connected as rover to that base.
- **Static**. It allows to configure the GNSS to start and stop a static measurement of the current point.
- **Constellations**. It allows to select the constellations you want to use in your measures.

Depending on the features and available resources of each GNSS model, these options will be enabled or disabled.

2.3 Project assistant screen

On this screen, the user can configure the project he wants to work on. He can create a new project or select one of his previous for continuing the job. The following is the list of options for setting up the project:

- **Project**: A list of the projects created by the application is presented, placing it in the last used project. You can choose another project from the list or create a new one on the button .
- **Coordinate system**: The coordinate system of the current project can be changed in the case of an error. A notice will notify the user of the risk of using this option, since it only affects the points captured by the application and it may affect other points or cartographies.

Once the settings have been established, you can start working by clicking on the button .

3 GPS connection

TcpGPS allows you to use two data sources: the *device's internal GPS*, if it has one, or an *external GPS connected via Bluetooth*.

In **GNSS receiver connection assistant** screen or **Device > Connection** section are available the needed options for selecting and configuring the different types of GPS receivers:

- **GNSS Internal Receiver**: Use of the device's internal GPS. Some new devices have the possibility to use the NMEA format to manage locations. In that mode, the device's internal GPS and the NMEA format will be used. Additionally, a set of models of different brands is available for connecting with these receivers that needs an external application for receiving the GNSS data.
- **GNSS External Receiver (Bluetooth)**: It allows to connect to GNSS receiver through Bluetooth connection.
- **GNSS Simulator Receiver**: This mode uses a file of coordinates in WGS84 to simulate the locations in the application.

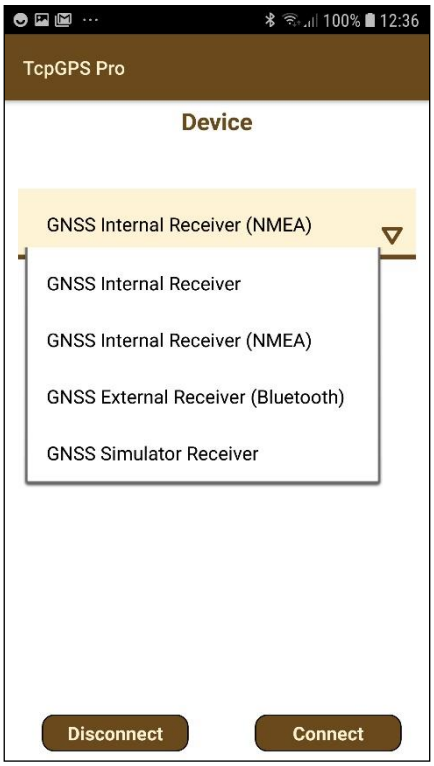


Figure 5. Selection of the receiver

Once the type of receiver is selected and the needed configuration is completed, the communication will be established by pressing **Connect**. With **Disconnect** button the application is disconnected from the current receiver.

3.1 Connection to the internal GPS

In this case, only the device's GPS must be enabled. The application will automatically connect to it and receive the data. Also, the internal GPS with **NMEA** output can be selected if the device provides this feature.

These options have the possibility to connect with receivers that needs an application as a bridge between GNSS and TcpGPS.

3.2 Connection to an external GPS

In this case, the Bluetooth connection of the device must be enabled to establish communication with the external GPS (which must also be compatible with this type of connection).

When this mode is selected, the options for connecting with the external device will be shown. *Brand* and *model* must be selected using the spinners. The brands and models in the list have a basic configuration that is sent from the application in order to make easier to start working.

If a different configuration is needed or the model is not in the list, *GENERIC* option allows to connect with any device that is configured previously.

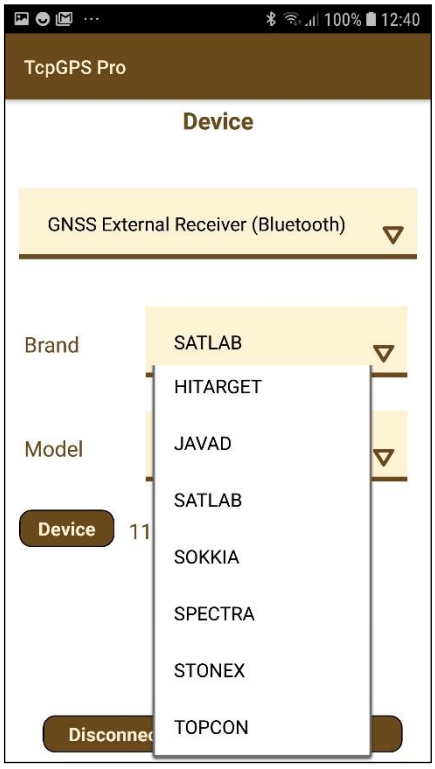


Figure 6. Brand and model selection

Figure 7. Search of a GNSS device

The application stores the information of the last GPS configured, but if no one was used before, a GNSS can be found by pressing the button **Device**.

In this screen, **Search** button will start the searching of near Bluetooth devices. When the ID (or the MAC if the receiver has no ID) is shown in the list, it could be selected.

3.3 Configuration of the external receiver

Once the app is connected to the receiver, it can be configured by setting its parameters in **Device > Set up receiver**.

Each supported brand and model have a set of specific forms where modifying these parameters and send the configuration to the receiver.

Usually, GNSS receivers can be configured in two modes: **base** or **rover**, and each one can establish different types of **data links**, depending on the capacities and hardware available.

3.3.1. Base configuration[1]

This option enables the user to configure the receiver in RTK mode, what allows the rover receivers to work with centimetric precision.

Firstly, the position where the base is located must be set. It can be introduced by two ways:

- **Getting the position for the receiver**, by using the **GPS** button. This location will be taken with the receiver in autonomous mode, what can be ideal when a local system is going to be created, then the location of the base is not important, or it will be placed in a different location in each session.
- **Using a point from the current project**. This option is only available once a project is loaded.
- **Typing the location manually.** It allows to configure the base introducing the values manually. The distance between the current location and the location introduced must be less than 100 meters.

The user can use projected or geographic coordinates in all cases.

Next step is to choose the type of **data link**. When clicking **Next**, the screen for configuring the data link will be displayed. This screen depends on the brand and model of the receiver and the set of parameters will change. Check the technical notes available in our website (https://www.aplitop.com/documentation-technical-notes) for detailed information about the configuration of different GNSS brands and models.

[1] In this section are described the common options to configure the GNSS. However, these options can change, not to be available or to be needed additional parameters depending on the receiver.

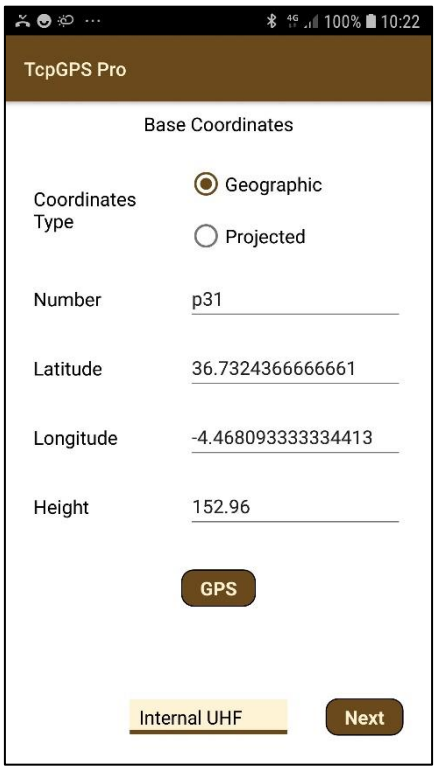


Figure 8. Base configuration

3.3.2. Rover configuration

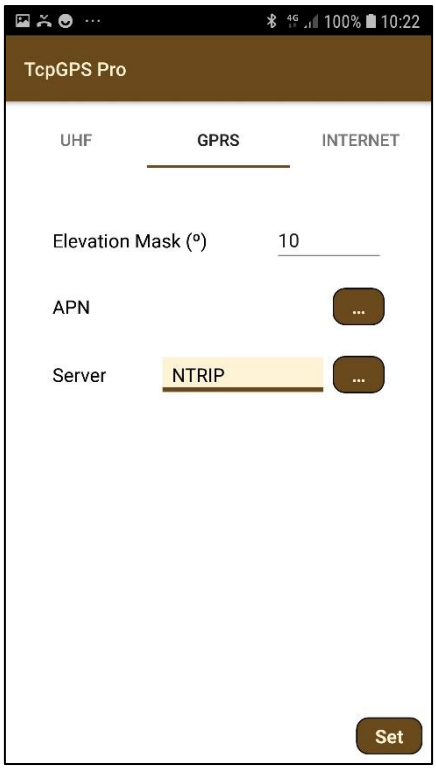


Figure 9. Rover configuration

This option configures the rover receiver for getting RTK corrections via radio, GSM or GSM, or DGPS corrections with SBAS u OMNISTAR (not all these configurations are available in every receiver, even some receivers could offer other types of configurations).

The configuration will be sent to the receiver by pressing **Send** button.

Check the technical notes available in our website for detailed information about the configuration of the different GNSS brands and models supported by the software (https://www.aplitop.com/documentation-technical-notes).

3.4 Static

Some devices allow the user to record data in static mode, for postprocessing. In this case, the option **Static** will be present in the menu.

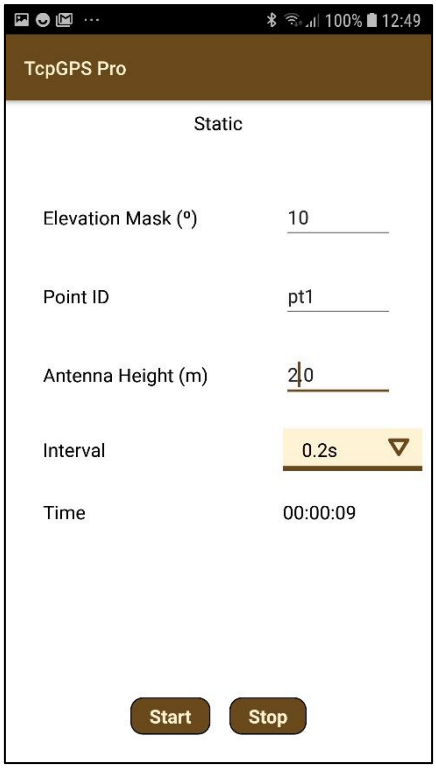


Figure 10. Static recording configuration

After setting the parameters, the recording will be initialized by pressing **Start** button and finished using **Stop** button.

3.5 Terminal

A terminal is available for advanced users who wants to know what the receiver is sending, where is shown the frames and messages received. This terminal is accessed from **Device > Terminal** or in the button in the **GNSS receiver connection assistant screen**. This terminal has the following options for interacting:

- **Pause/Continue:** The user can pause and continue receiving data into the terminal. However, while the reception is paused, the messages received will be discarded by the terminal.
- **Record:** Store the messages to a log file.
- **Clean:** Remove all the frames shown in terminal.
- **Hex output:** The messages are shown with hexadecimal values.

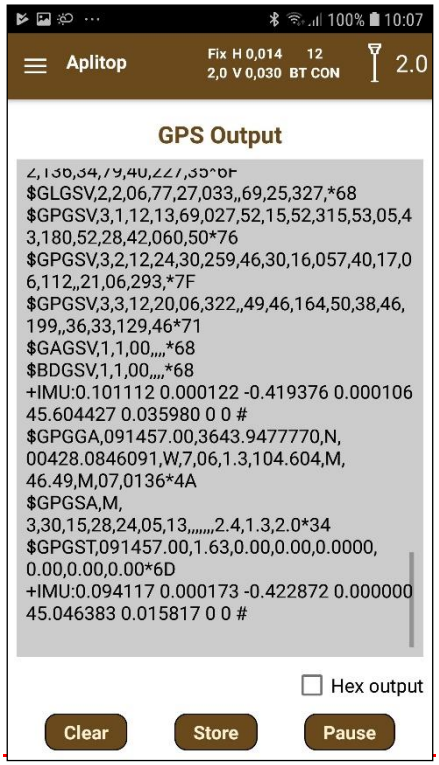


Figure 11. Monitor of the messages received from the GNSS

3.6 GPS status

It is possible to consult the GPS status by opening the **GPS status** section, pressing on the **communications toolbar**.

In this section, you can find information on both GPS (Figure 12) and available satellites (Figure 13). The arrows in the **options menu** can be used to navigate between one view and another.

In the following table are described the parameters shown in the numerical screen of this section:

UTC Time	Current UTC time.
Satellites	Number of satellites used in the measurements.
Position Type	Position type of the measurements.

Latitude/ Longitude/ Ellipsoidal Height	Coordinates of the current position in WGS84.
H. Prec/ V.Prec	Horizontal and vertical precisions of the current measures (meters).
PDOP (Position Dilution of Precision)	Empirical and dimensionless indicator of the quality of the measure. The lower it is the higher is the quality.
Age	Real Time Age of the corrections received by the GNSS.
Easting/ Northing/ Orthometric Height	Coordinates in the coordinates system used in the project (shown above these parameters).

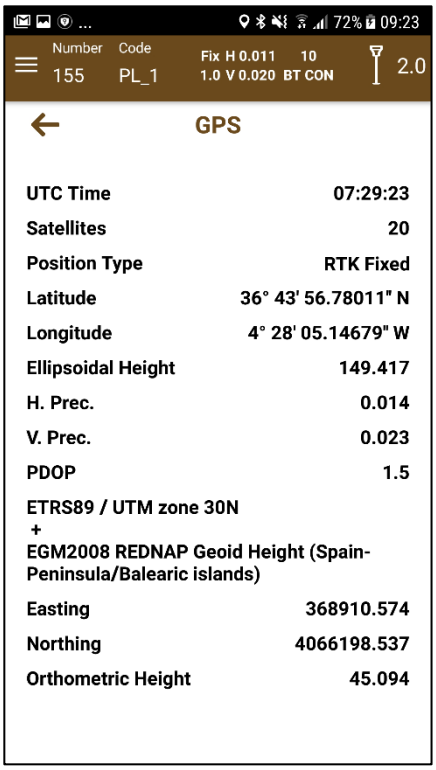


Figure 12. GPS status

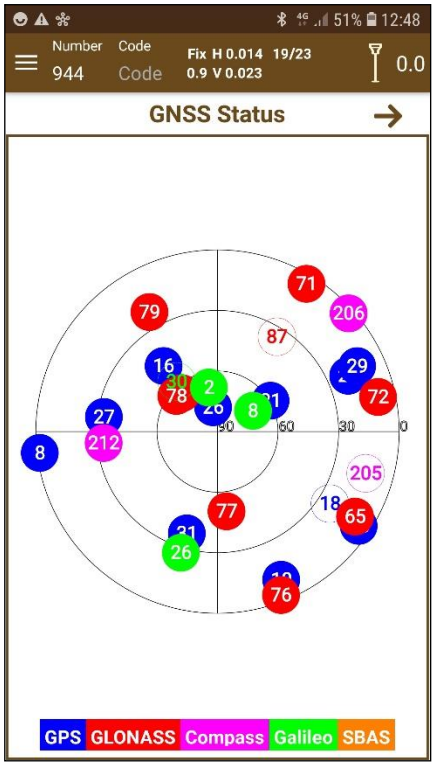


Figure 13. Satellites constellation

4 Preparation of the project

From the **Session** screen at the start of the application or the main menu in **Menu > Project**, the user can create a new project o select one of the previously created.

4.1 Project options

The **Project** submenu can be found on the side menu, which allows you to choose one of the following options:

Figure 14. Main menu

- **Information**: On this screen you can consult the properties of the project (the name, author, coordinate system, etc.). In addition, it is possible to change the coordinate system, although this option is recommended to be used with extreme caution since, when applied, only the points saved in the project will be affected, not the cartographies or other elements added, so undesirable results may be obtained in these cases.

- **New project**: Allows a new project to be created, as it is described in section **Creation of a new** project**.**
- **Open**: Allows you to choose another project to work on.

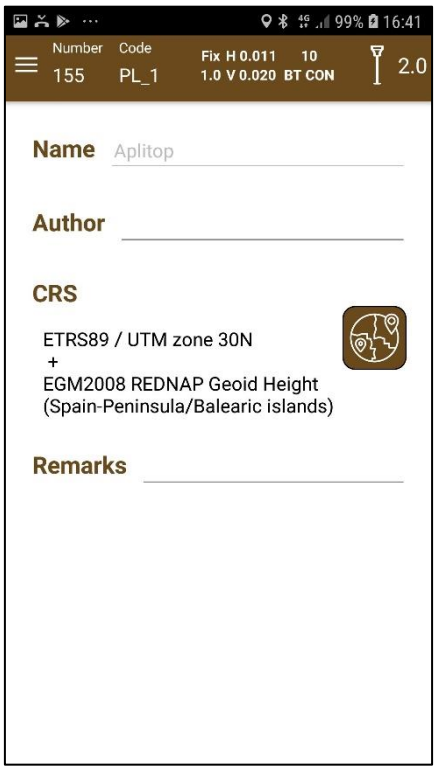


Figure 15. Project information screen

4.2 Creation of a new project

If the option to create a *new project* is selected, the application will display the screen shown in the Figure 16. It will request:

- The **Project Name**
- The **Author** of the job.
- **Project information** with the last update date and the number of points.
- Descriptive, informative **comments** or relevant project data.
- A **Coordinate system** that will be used for the job.

Once all the data has been entered, the project will be load and the application will be entered in **Survey** mode.

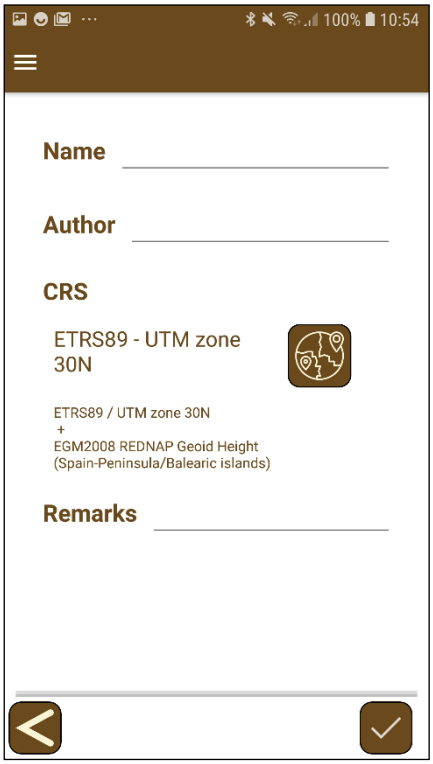


Figure 16. Project creation

4.3 Selection of coordinate system

ISO Standard 19111, **Geographic information - Spatial referencing by coordinates**, defines the conceptual scheme for the description of spatial referencing through coordinates. Describes the necessary data to define the reference systems of one, two- and three-dimensional coordinates as well as the information needed to convert coordinates from one system to another.

According to this Standard, a coordinate reference system is composed of a coordinate system and a datum. Of the different types of datums that distinguish the Standard, the **Geodetic Datums** and the **Vertical Datums** are the ones that will be used in this module. The former requires the description of an **Ellipsoid** and the latter do not.

Based on this classification, two groups of coordinate reference systems have been created: Geodetic **SRC and the Vertical SRC**.

The **Geodetic** SRCs are divided into different types. Based on the classification of **ISO 19111** and the classification made by the **EPSG (European Petroleum Survey Group, www.epsg.org,** http://www.epsg.org/now the **OGP**, **International Association of Oil & Gas Producers**) in its database, we will distinguish: the **SRC Geographical, the SRC Geocentric and** the **SRC Projected**.

To start working on a project, it is essential to define in which coordinate system the points and geographic data will be represented.

Clicking on the button displays a list of coordinate systems that have previously been configured in the application in other projects (Figure 17).

If you want to add a new one, click on .

Once the coordinate system is selected from the list, it will be assigned to the project by clicking on the button .

The coordinate system could be also deleted using the button .

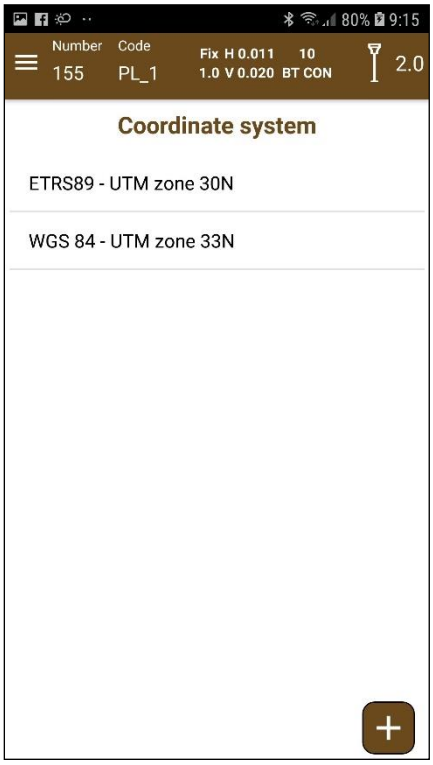


Figure 17. Coordinates system list

Figure 18. Configuration of a new coordinates system

If you use a coordinate system frequently, it can be set as your default coordinate system of your new projects by selecting it from the list and pressing the button .

Aplitop is continuously improving its applications and service. One of them is the coordinate system service. By pressing the button the user can check if new

updates of the coordinate system database are available to always have the latest versions and systems[2].

When a new coordinate system is created, the **continent** and the **country** in which it will be worked will be established, and then the **coordinate systems, datum transformations** and available geoids (Figure 18) in that region **will** be listed in this region:

- **Coordinate systems**: List of projected coordinate systems used in the selected country.
- **Datum transformations**: List of datum transformations for the area that has been selected in the coordinate system.
- **Geoids**: List of geoids that can be used to calculate orthometric heights.

Clicking on the button creates the new coordinate system settings with the name that was assigned to it.

[2] If you have a coordinate system that you use and do not see in the list, either because it is local to your area or created by you, you can contact Aplitop at soporte@aplitop.com to study if it is possible to add it to our database data.

5 User data

TcpGPS is also able to collect user data for GIS kind works. As will be seen later, each project layer (punctual, lineal and polygonal) can define a data set to be attached to the entities associated to them. These data are editable and configurable, as can be seen in the section …

Once the data are defined, the user can check and modify by entering in the screen …

Finally, this information is exported together geographic data of the entity in Shape format, and can be consulted in any software that allows work with this type of format, for example, QGIS, as shown in the following image:

Figure 1. User data associated to an entity

6 Workspace

Figure 19 shows an image of the workspace as presented at start-up. The following parts are distinguished:

1. **Map**: The map is the main working element, since it is where the points and information about them are displayed.
2. **Map menu**: Various options for working with the map are displayed in the map menu, such as accessing the layers presented in the map, zoom extension, GPS tracking, and map mode.
3. **Working menu**: Options for carrying out work regarding surveying, staking out, points, etc. are displayed in this menu, depending on the section being accessed.
4. **Application menu**: Options to browse through the different sections of the application are displayed in this menu, such as surveying, staking out, or project.
5. **Status toolbar**: Information regarding the GPS and Bluetooth status. Additionally, fields for setting the number, code and antenna height of the receiver are available.
6. **Navigation controls**: This menu has buttons to change the working mode in those templates that are allowed, as well as additional options, also depending on the template.
7. **Data panel**: This space is used for showing information and data needed in the current working section.

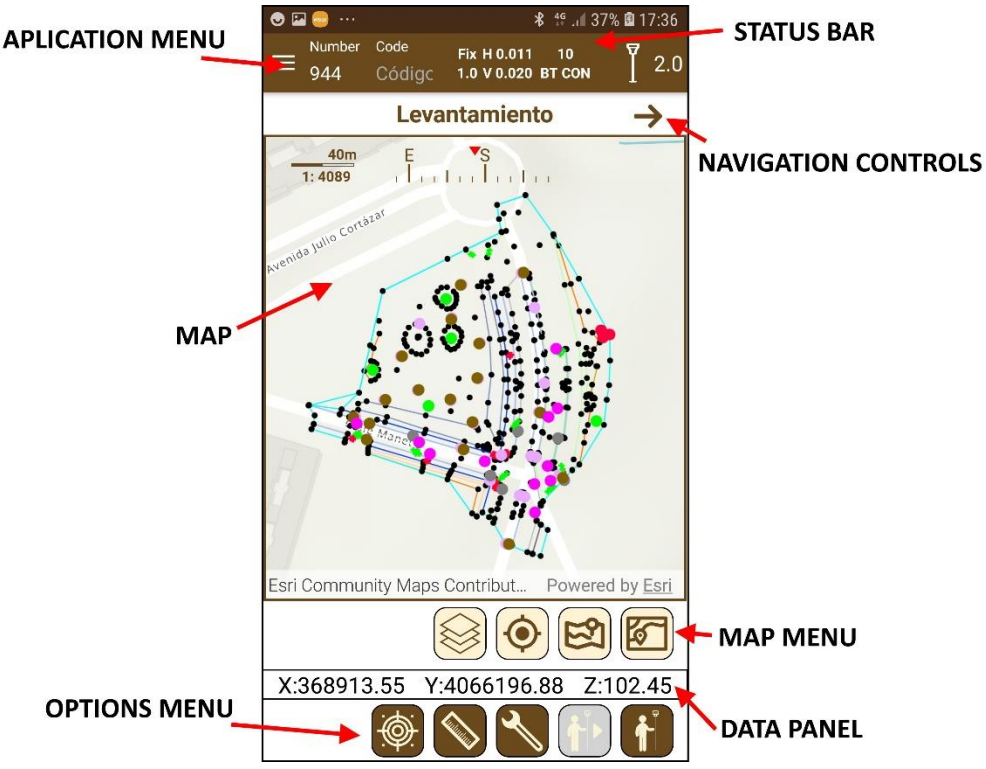


Figure 19. Workspace

Each of these parts will be described below, and the information and elements that are presented in will be shown in each section.

6.1 Map menu

In sections where the map is used, a floating menu appears inside the map window containing options for interacting with it. Some options are shown only in some sections. In the following table are described all the available options:

	Access to **Layer management** section.
	Zoom the map showing all the elements of the project.
	Enable/disable the GPS tracking.
	Change the base map type: **topographic**, **streets** or **satellite**.

6.2 Status toolbar

In the status bar you have access to the Application **Menu,** as well as to the information on the current status of the receiver that is being used. In Figure 20 you can see in detail the content of the menu bar.

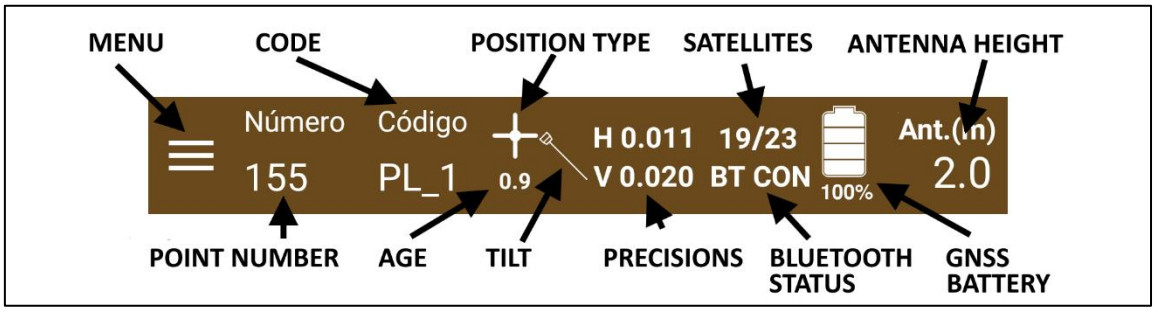


Figure 20. Status toolbar

- **Application menu**: Described above, it gives access to the different templates of the application.
- **Antenna height**: Set the antenna height in the project (meters).
- **Type of position**: Position that the GPS is currently capturing. It can be **FIX** (fixed), **DGPS** (differential), **FLOAT** (floating) or **AUTO** (autonomous).
- **Age**: It refers to the age in real time, in seconds. The latency of the corrections that are received from the reference base.

- **Tilt**: Those receivers where tilt option is supported, this icon will show the status of it. The possible icons are:

Tilt not connected or error.

Need to calibrate. Please, follow the steps provided by the manufacturer.

Keep the receiver vertically.

Tilt limit exceeded.

Ready for measurement.

- **Precisions:** The vertical and horizontal precisions in which the receiver is currently working in, in meters.
- **Battery:** Those receivers whose battery state is supported, it will be shown here together the remaining charge.
- **Satellites**: Number of satellites currently used to perform the measurements.
- **Bluetooth status**: Icon that shows the current status of the Bluetooth connection to the external receiver (if this receiver option is being used). The following messages are used for describing the status of the Bluetooth:
    - **BT ICX**: Initializing connection.
    - **BT CRC**: Creating connection.
    - **BT CTN**: Connecting with GNSS.
    - **BT CON**: Connected to GNSS.
    - **BT ND**: No data from receiver.
    - **BT EC1**: Connection error 1.
    - **BT EC2**: Connection error 2.
    - **BT DSN**: Disconnecting from receiver.
    - **BT CLC**: Closing connection.
    - **BT DSC**: Disconnected from receiver.
    - **BT EXC**: Connection exception.
    - **BT EXD**: Disconnection exception.

7 Configuring the workspace

The **Settings** option can be found in the **Application** submenu. This option leads to the **Settings** section, where a set of parameters for the workspace is available (Figure 21). These options are described in the table below:

Surveying and Staking Out	
Item categories	Item categories to be considered for GPS data
Minimum Number of Satellites	Minimum number of satellites for obtaining GPS data
Real Time Age	Maximum difference in time between corrections that will be considered to validate the position received.
Horizontal and vertical precisions	Minimum precisions that will be considered to validate the position received from the GPS in meters
PDOP	Empirical and dimensionless indicator of the quality of the position received (Position Dilution of Precision). The lower the value, the higher the quality.
Height of the Antenna	Default antenna height to be used during the Project (in meters)
Observation Time	Time interval in seconds when the epochs for defining the current point will be taken.
Codes separator	Character used as reference for codes separation in multicodes (see **Point code management**)
Measuring shortcut	Allow to select a physical key in the device to make measures easily[3].
Codes file	Allow to choose a file with a list of predefined codes for points.

[3] It is not recommended to use the home, volume or power keys because they have a function into the device. This option should be used if the device has extra keys that can be configured for other purposes.

Voice measure keyword	In those working sections where the icon is present, the measure by voice can be enabled. The word defined here will be the one interpreted as the keyword to measure.

Staking Out	
Staking Out Mode	Staking out mode used (north, movement, or most recent point staked out)
Horizontal Tolerance	Horizontal tolerance to take the point as having been reached (in meters).
Vertical Tolerance	Vertical tolerance to take the point as having been reached (in meters).
Distance Target Mode	Distance at which to change to target mode (in meters).
Next Point	Automatic stepping to the next point to be staked out according to the number of the point or by proximity to the current one.

Augmented Reality	
Text Size in AR	Size of the text used for showing the id of the points.
Distance for displaying texts	This distance is used for displaying only the texts of the points that are at this distance as maximum.
Stick configuration	The user can configure the length and the color of the highlighted stick.

Application	
Orientation	Allows to choose the screen orientation (portrait or landscape).
Sound Mode	Switch between sounds or voice indications.
Use Clustering	Enable the clustering of points when zooming.
Cluster Tolerance	Level of point clustering.

Minimum Observation Scale for Cluster	Scale level from which point clustering will be applied.
Minimum Observation Scale for Point Data	Scale level from which the point data will be displayed on the map.
Activate floating button	Allows to use a floating button that can be set at any place of the screen for measuring points.
Floating button size	Sets the size of the floating button.
Activate log	Allows the activation of the logger for generating log files of the current session.
Activate compass	Activation of the compass over the map.
Activate scale	Visualization of the map scale.

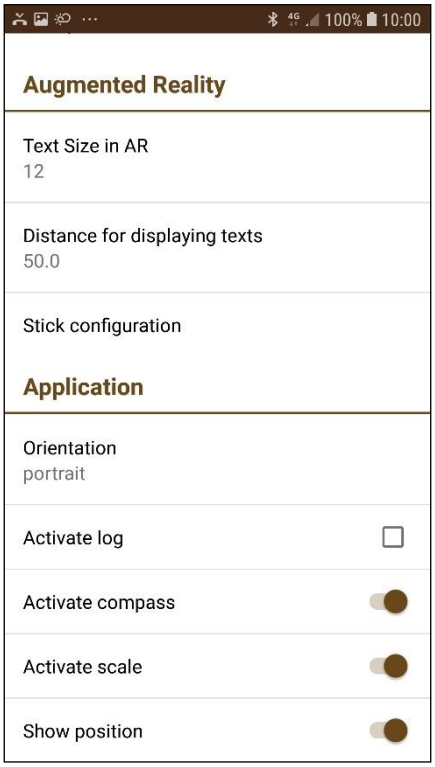


Figure 21. Configuration section

8 Local system

In this section the user can create, apply or remove a local transformation by adding or modifying control points. Available transformations are **2D/3D Displacement** and **2D/3D Helmert**. **Appendix A.** Transformations contains detailed information about these transformations.

Figure 22 shows the main screen for creating a local system. It shows the map of the area and the current GPS position. In addition, if points have been taken in surveying, that are shown in the map to be selected as control points.

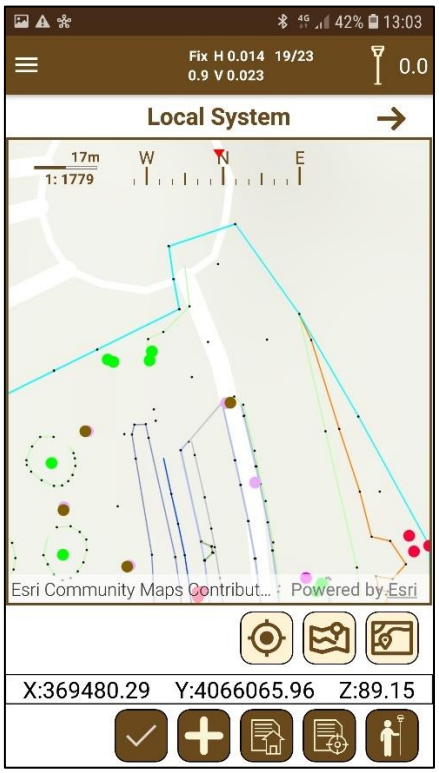


Figure 22. Creation of a local system

On the menu of this template are the buttons for the different options that allow the insertion of control points, in addition to being able to select these directly on the map if there are points previously taken. These are outlined below:

	Manually insertion of the origin and target of the control point
	Import a file with points that could be used as origin of control points.

	Import a file with points that could be used as target of control points.
	Use the current GPS position as origin of the control point.

When manually insertion, point capture or map selection are used, a dialogue is displayed to allow the user to edit the information of the control point. This dialogue has options for typing the point coordinates, using the GPS position or selecting targets from list containing previous imported points (Figure 23).

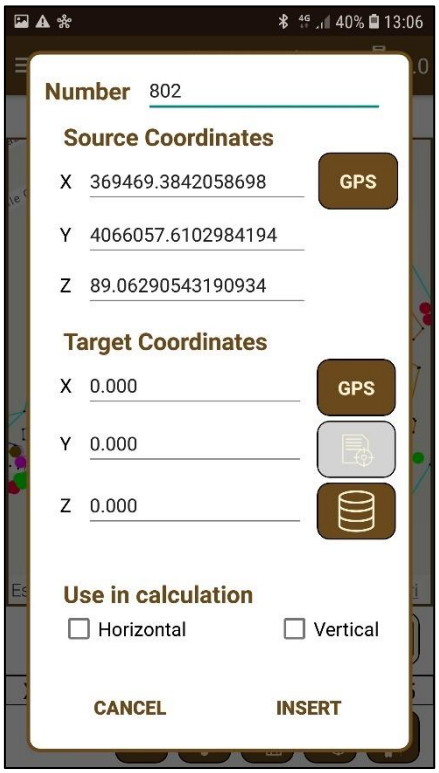


Figure 23. Dialog for edition of a control point

Once control points are selected, the numeric screen shows detailed information about the transformation, the points used, leftovers and errors.

The user can display information about the points in the top spinner, where he can select:

- **Source points**: The coordinates of these points will be used as *origin coordinates*.
- **Target points**: The coordinates of these points will be used as *target coordinates.*
- **Leftovers**: Show the differences between each origin and target point. *Source points* and *Target points* are related by their number.

The number of control points will enable one or several transformations that can be selected in the spinner of the numeric screen.

Each transformation will be characterized by a set of parameters:

- **MSE 3D**: Medium Square Error in 3D.
- **MSE H/V**: Medium Square Error in horizontal and vertical.
- **Max**. **Res. X/Y/Z**: Maximum residue in X/Y/Z coordinates.

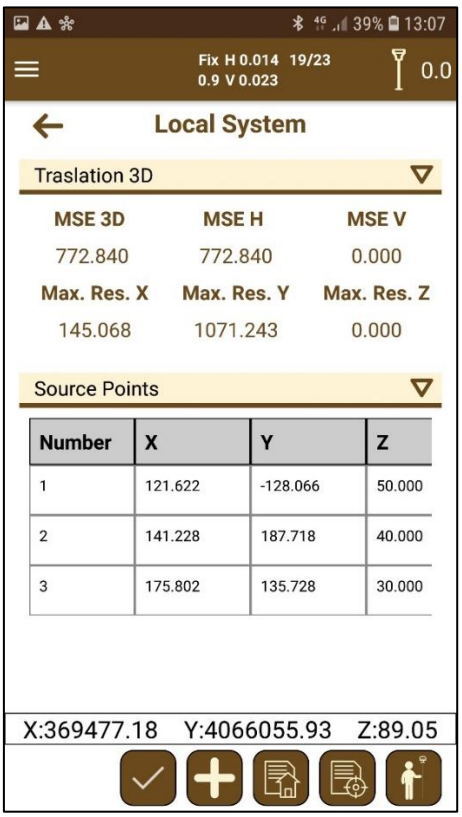


Figure 24. Transformation data

The user can store the transformation by pressing the icon . A name for the file will be requested and the transformation will be stored in a file with **.ntr** extension into the project folder, allowing to be used in other projects.

8.1 Apply a local system

Just after storing the transformation, the user is asked if he wants to apply it. But it is not needed to create a transformation to apply it. In **Menu > Local System > Apply**, the user can select a **.ntr** file in the device containing a transformation previously created and apply it to the current project.

It must be considered that when a transformation is applied to a project with points, cartographies and other elements, the transformation will only convert the points that has raw data associated. The other elements will not be affected.

8.2 Remove a local system

The user can stop using a transformation at any moment by clicking on **Menu > Local System > Remove**. The transformation will stop being used and the points will be converted to the original coordinates system of the project. As it has been said before, only points with raw data will be affected by this transformation. The transformation file is not deleted from the internal storage of the device.

9 Layer management

In the TcpGPS maps (both when surveying and staking out) a division into layers is carried out that are organized according to their nature (Figure 25).

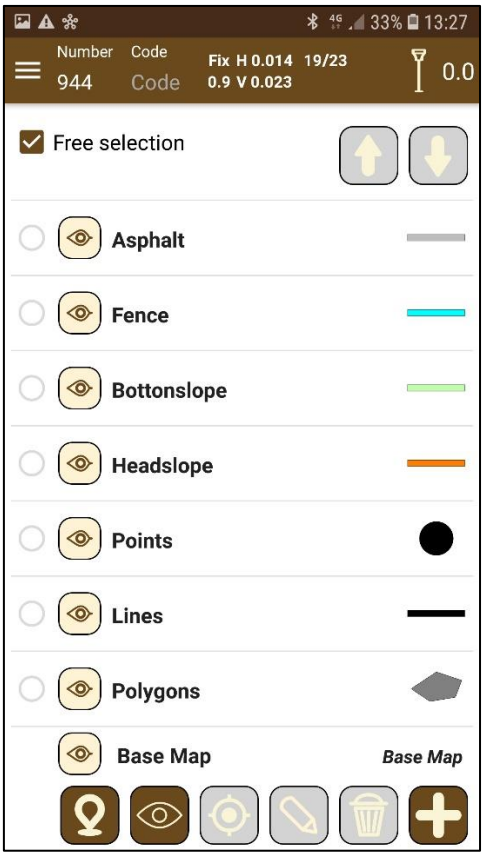


Figure 25. Layer manager

The following types of layer store points, lines and polygons created when working. These layers are associated to codes, and the same layer may be associated with different codes, but always of the same type:

- **Points Layers**: These layers divide the set of work points into different subsets separated by their code. When a new project is created, a layer of **points** is automatically created that will contain all the points that do not have a code, or the code has no layer associated.
- **Lines Layers**: These layers contain lines and polylines defined attending to the lineal code associated. When a new project is created, a layer of **lines** is created for those lines with no code or the code has no layer associated.
- **Polygons Layers**: These layers contain polygons defined attending to the polygonal code associated. When a new project is created, a layer of **polygons** is created for those polygons with no code or the code has no layer associated.

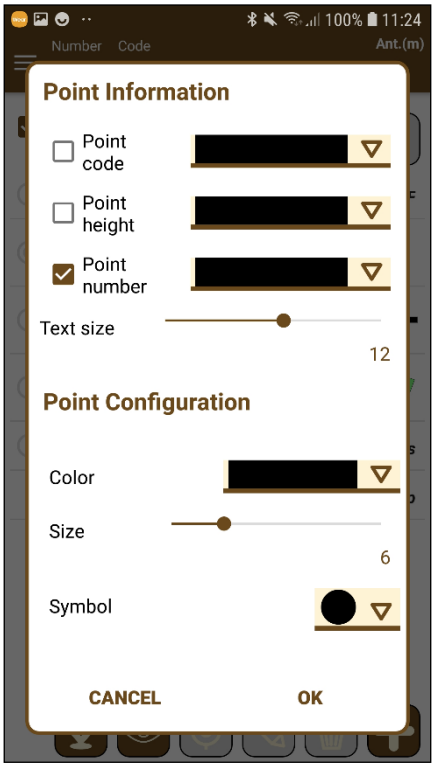
The types of layer below contain base maps or cartographies, which will be used as references, but also for other tasks as surface analysis:

- **Base Map layer**: This layer is created automatically when a new project is created and is unique.
- **DXF layer**: This layer contains a DXF map imported from a **.dxf** file.
- **DWG layer**: This layer contains maps imported from **.dwg** files.
- **Surface layer**: This layer contains a 3D Surface built by DXF 3D faces or LandXML. This layer is used in surface analysis (see **Surface analysis**).
- **KML/KMZ layer**: This layer contains a KML cartography. It also can be imported from compressed format with **.kmz** extension**.**
- **GML layer**: This layer contains a GML cartography.
- **Shape layer**: This layer contains a SHAPE map imported from a **.shp**[4] file.
- **WMS layer**: This layer allows a **WMS** service to be configured that will be displayed on the map.

The following commands can be executed on each of these layers:

- **Sort layers**: You can change the order of one layer with respect to another using the buttons to **raise** or **lower** the layer in the stack of layers.
- **Add layer** : Import a layer from a file or the cloud (Google Drive).
- **Edit the layer** : The settings window of the selected layer type is displayed.
- **Delete layer** : Deletes the project layer.
- **Center in map** : Center the map fitting the selected layer.
- **Display the layer** : Enables or disables the display of the layer on the map.
- **Basic point configuration** : Set the style and basic information to display of the points. The style will be applied only if the point has no code associated.

[4] As well as the **.shp** extension, the associated **.prj**, **.shx**, and **.dbf** files must be present.

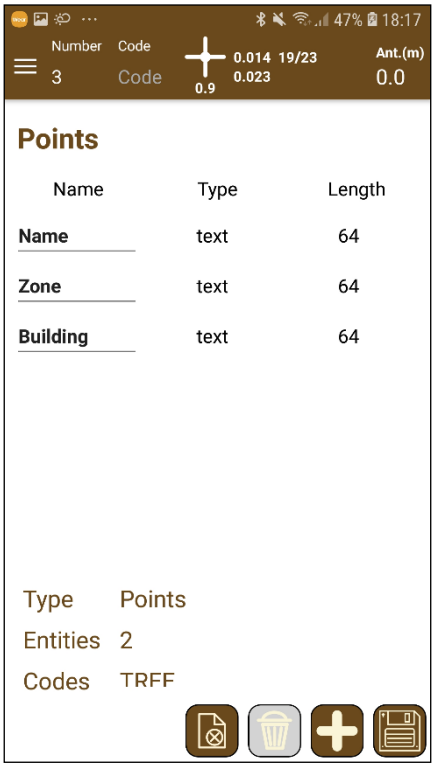


Additionally, each layer can be shown or hidden by clicking on button.

Each layer has a selector at left side for setting the current active layer. This active layer will be the reference for searching when clicking on the map. If you do not want to establish a single active layer and you want to perform searches in general, the **Free Selection** box must be activated.

9.1 Editing working layers: user data struct

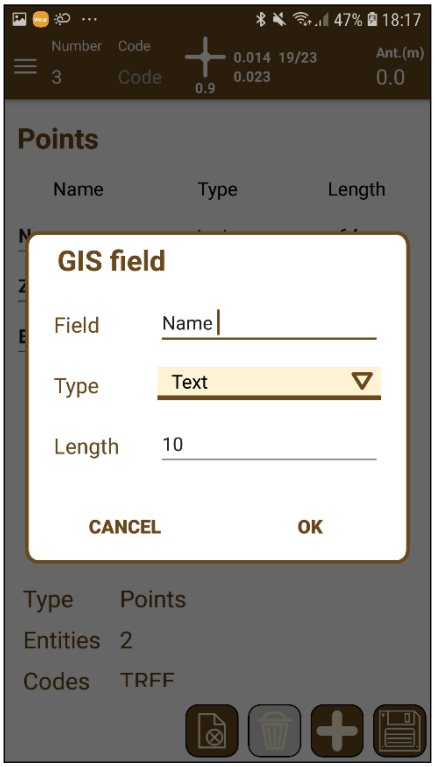
Working layers (**points**, **lines** and **polygons**) can define an **user data** struct to be filled in each entity whose code is associated to the layer.



Four types define the content of the field:

- **Text**: alphanumeric character sequence.
- **Integer**: integer value.
- **Real**: real value.
- **Date**: date formatted as dd/mm/yyyy.

The data struct can be modified to be adapted to the needs of the project. The fields can be deleted by pressing or its name modified. It is not possible to modify the type or the length of the field.



By pressing the button the changes made in the struct will be accepted. The information of the entities associated to this layer will be modified in the same way the data struct is modified in this section.

In section **Details of the points** there is an example of an entity with user data.

9.2 Editing the Base Map layer

This layer, like the **Points** layer, is a special layer that is created when a new project is created. Its purpose is to manage the base map that will be presented in the workspace. The properties that you can define here are (Figure 26):

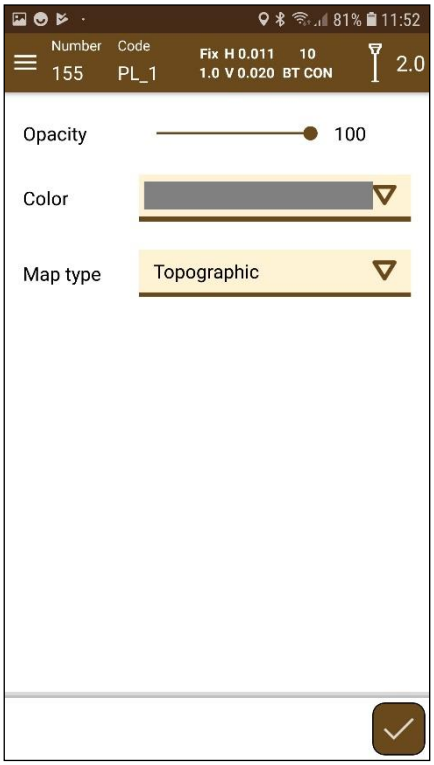


Figure 26. Editing the Base Map layer

- **Opacity**: Level of map transparency.
- **Color**: Background color when the map could not be loaded, or its visualization is disabled.

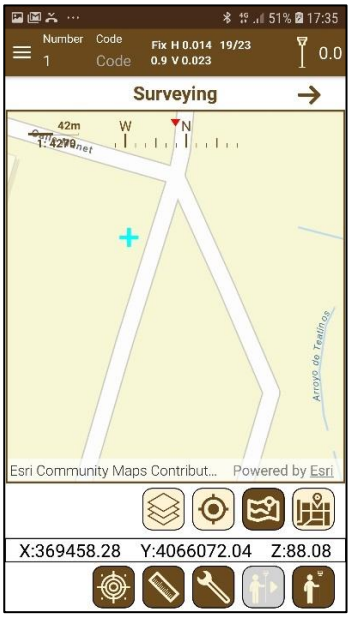


Figure 27. Street map

Figure 28. Satellite map

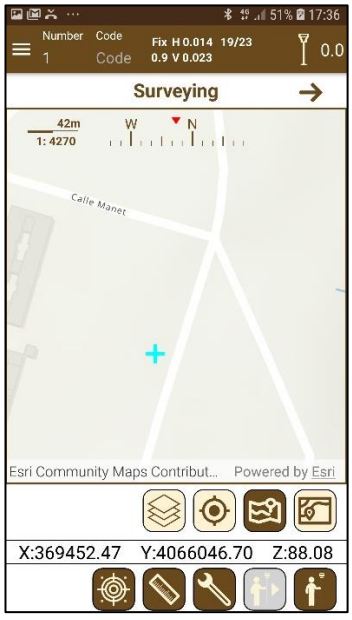


Figure 29. Topographic map

Apart from ESRI maps, the user can configure his own base maps using WMTS services. To do that the following options have been added:

- **Import WMTS service**: Allow to import a list of WMTS service from a file containing pairs **Name** and **Service URL**.
- **Add WMTS service**: Allow to add a WMTS service manually.
- **Edit WMTS service**: Allow to modify the WMTS information.

Delete WMTS service: Remove a WMTS service from the list.

9.3 Editing the shape layer

A **shape** layer manages a file of this type to be displayed in the workspace (Figure 30). In order to be able to load these types of files, it is necessary to have four different file types in the same folder:

- **.shp**: This is the SHAPE file with the information to be displayed.
- **.shx**: This is the associated index file.
- **.prj**: Projection file indicating the system on which the map was made.
- **.dbf**: Database with information associated with the points and geometries of the map.

Shape files containing punctual, linear or polygonal geometries, both 2D and 3D, are supported.

These files can be loaded from the internal storage of the device or download from a Google Drive account, if the user is logged in (see **Export of digital models**

If the project contains digital models generated, they can be exported to **DXF** format with 3D faces.

When this option is selected, a dialog will be displayed requesting the user the name of the file where the model will be stored and the model to export, selected from a list.

Google drive data synchronization). Clicking the button you will access the internal storage file explorer and clicking the button you will access the cloud services for downloading the shape cartography stored in the Google Drive account.

The properties to be defined for this layer are:

- **Layer name**.
- **Opacity**: Level of transparency of the layer.
- **Color**: Color for lines and dots on the map.

- **File**: File to be displayed.

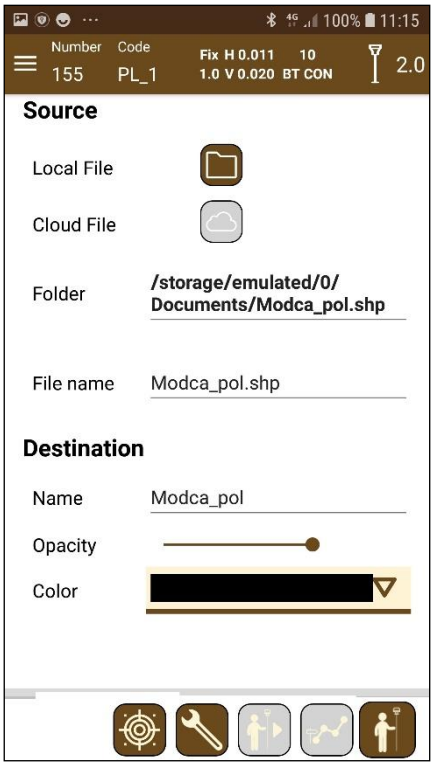


Figure 30. Editing the Shape layer

9.4 Edition of DXF, KML/KMZ, GML and DWG layers

The DXF, KML / KMZ and GML layers contain cartographies of these types, where all the information is inside those files. These layers share the form of editing since it will be their content that establishes the parameters of each one.

The properties that can be configured on this layer are:

- **Layer name**.
- **Opacity**: Level of transparency of the layer.
- **File**: File to be displayed.

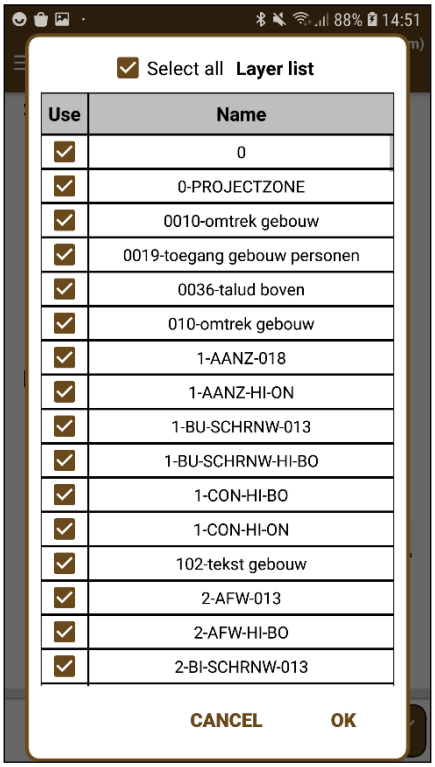
As with shape layers, files can be loaded from the internal storage of the device or downloaded from a Google Drive account.

8.4.1. DXF

The entities supported in DXF are:

- **ARC**: Arcs (2D and 3D).
- **CIRCLE**: Circles (2D and 3D).
- **POLYLINE / LWPOLYLINE**: Polylines (2D and 3D).
- **LINE**: Lines (2D and 3D).
- **POINT**: Points (2D and 3D).

- **VERTEX**: Vertices of polylines (2D).
- **TEXT**: Texts.



8.4.2. DWG

In this case, the entities supported by TcpGPS are **points**, **lines**, **polylines 2D** and **3D**, **arcs**, **circles**, **ellipses**, **splines** and **helices** as well as **single line texts**.

8.4.3. KML/KMZ

The following entities are supported with the indicated structures:

- **Points**

```
<Placemark>
   <Point>
      <coordinates></coordinates>
   </Point>
</Placemark>
```

- **Polylines**

```
<Placemark>
   <MultiGeometry>
      <LineString>
         <coordinates></coordinates>
      </LineString>
   </MultiGeometry>
</Placemark>
```

- **Polygons**

```
<Placemark>
      <Polygon>
         <outerBoundaryIs>
               <LinearRing>
                     <coordinates> </coordinates>
               </LinearRing>
         </outerBoundaryIs>
   </Polygon>
</Placemark>
```

8.4.4. GML

Geometry entities that contain the following structure are supported:

```
<cp:geometry>
      <gml:MultiSurface gml:id="" srsName="">
            <gml:surfaceMember>
                  <gml:Surface gml:id="" srsName="">
                        <gml:patches>
                              <gml:PolygonPatch>
                                    <gml:exterior>
                                          <gml:LinearRing>
                  <gml:posList srsDimension="" count=""></gml:posList>
                                          </gml:LinearRing>
                                    </gml:exterior>
                              </gml:PolygonPatch>
                        </gml:patches>
                  </gml:Surface>
            </gml:surfaceMember>
      </gml:MultiSurface>
 </cp:geometry>
```

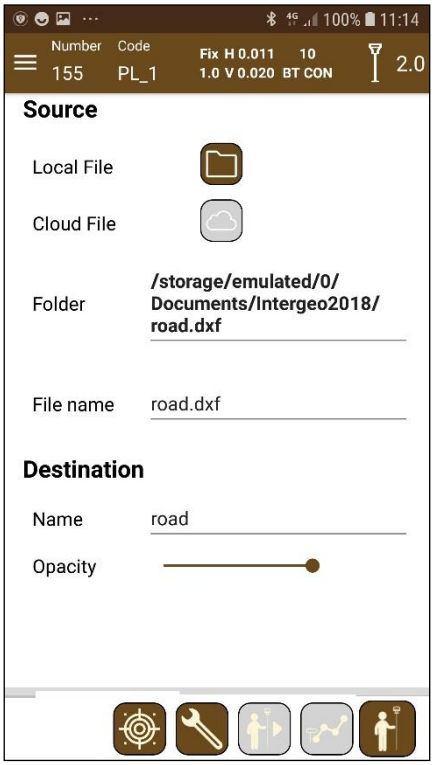


Figure 31. Editing the DXF, KML/KMZ or GML layers

9.5 Edition of surface layers

The surface layer manages a 3D surface imported from a DXF file that contains 3D face entities (**FACE3D**).

The properties to be configured for this layer are:

- **Layer name**.
- **Opacity**: Level of transparency of the layer.
- **File**: File to be displayed.

Once the layer has been configured, by clicking the loading of the surface file starts and once it is completed it will return to the list of layers, where the newly created layer will appear.

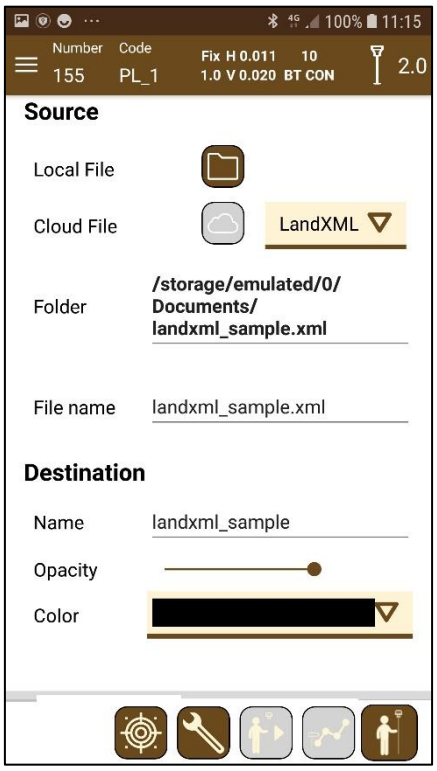


Figure 32. Editing the Surface layer

9.6 Edition of WMS layers

A **WMS** layer manages the connection with this kind of service for loading the information related to the current working area.

When you create a new WMS layer, what you must do is create a new entry to connect to the desired service or use one of those that have been used previously. You can add as many services as you want, in addition to being able to edit existing ones (if there is a change in the URL that connects to it) or you can delete them if they are not going to be used or they are no longer available.

The functions available to edit layers of this type are:

	Allow to import a list of WMS servers from a TXT file with the following format: **<Name>** **<URL>**
	Defines a new WMS service by entering the corresponding URL.
	It allows it to modify the URL of the WMS service, in case of error or if it has been transferred to another address or server.

It allows the deletion of a WMS service from the list, if it is not used or it is no longer available.

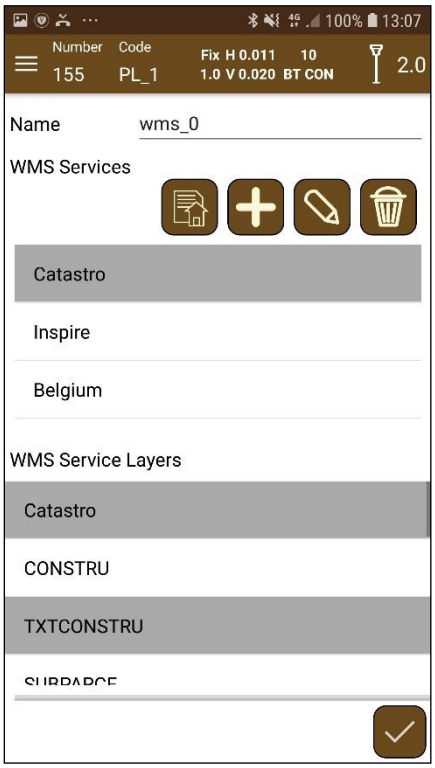


Figure 33. Editing the WMS layer

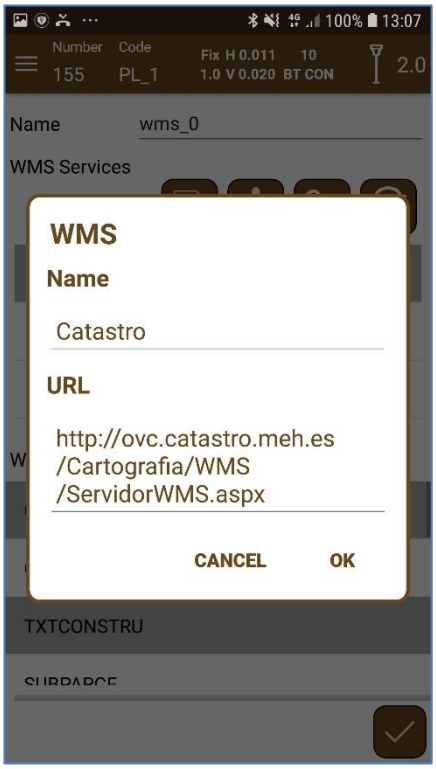


Figure 34. WMS service example

9.7 Loading layer from cloud

When you want to create a new layer, you have the option to Access Google Drive cloud services by clicking on the button . This button will give you Access to the Google Drive explorer for searching the desired file.

10 Survey

This is the first screen that appears for the user when they enter the application. Two modes are available: **map mode** (**Map surveying screen**) and **numerical mode** (**Numerical surveying screen**). For switching between both modes, these buttons can be used.

10.1 Map surveying screen

In the survey screen map mode are shown the points, cartographies and roads that compound the project.

Figure 35. Surveying map mode

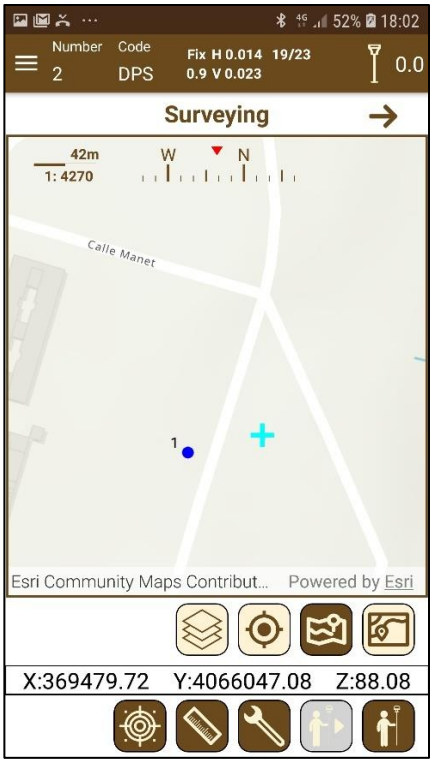


Figure 36. Example of point with its basic data

Figure 36 shows an example of a measured point with its basic information displayed around it:

- At top left of the point is shown the **number**.
- At right of the point is shown the **height**.
- At bottom right of the point is shown the **code**.

The floating menu below the map contains certain functions for interacting with the map. See **Map menu** section for detailed information about each option.

When you pick on a point, a dialog will be displayed showing his number. By clicking on the button , it possible to access the detailed information of the point (see **Details of the points**).

10.2 Numerical surveying screen

Several parameters associated with the points taken can be configured from the numerical surveying screen:

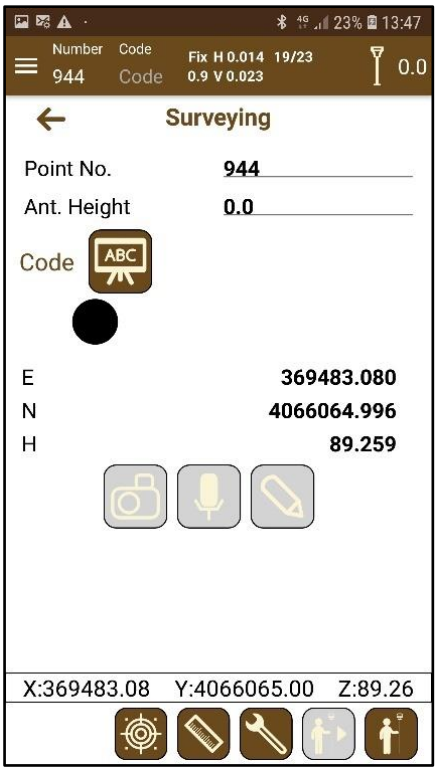


Figure 37. Surveying numerical mode

- **Point number**: Number of the next point that will be taken. This number will increase 1 in 1 as consecutive points are taken, from the given. The number of a point is an alphanumeric text that, in the case of numbering more than one point, it will add a suffix that will indicate the numbers taken with that same initial text. For example, if the number is decided to be **CRT**, the first point will be **CRT**, but the next one will be **CRT_1**, **CRT_2**, and so on.
- **Height of the antenna**: The height of the antenna at the moment the point was gathered. By default, the value defined in the **Settings** will appear, but if you

need to change this to a specific point or points, it is possible to define a new one here (this does not change the default value).

- **Code**: A code that will be associated to the point, which can be selected from a predefined list or a new code created (see **Point code management**).

The **numerical surveying** screen also displays the numerical information of the current GPS position.

10.3 Point survey

Using the button of the menu bar you can take the current point where the GPS is located. If the point does not comply with any of the restrictions established in the settings regarding the type of position, the number of satellites or the accuracy, the user will be notified of this situation and he will decide whether he wants to take it. It will be disabled when you are using the **Continuous survey.**

In the **numerical mode** screen, it is possible to configure the point before taking it by assigning different parameters, as it is explained in **Numerical surveying screen**.

When taking a point, the user can directly associate an *image* and a *voice note* using the buttons that appear in the numerical template of the survey . If detailed information about the point is required, it can be accessed by choosing the point on the map and clicking the **info** button (see **Editing points**).

10.4 Continuous survey

Using the button begins the taking of a series of consecutive points according to three criteria:

- **Continuous measurement by time interval**: A time interval is defined for the next point to be taken.
- **Continuous measurement by distance**: A distance is defined after which the next point will be taken.
- **Continuous measurement by gradient interval**: A difference in level is defined after which the next point will be taken.

Before starting the taking of the points, a dialog will request which criteria will be used to decide when to take a point.

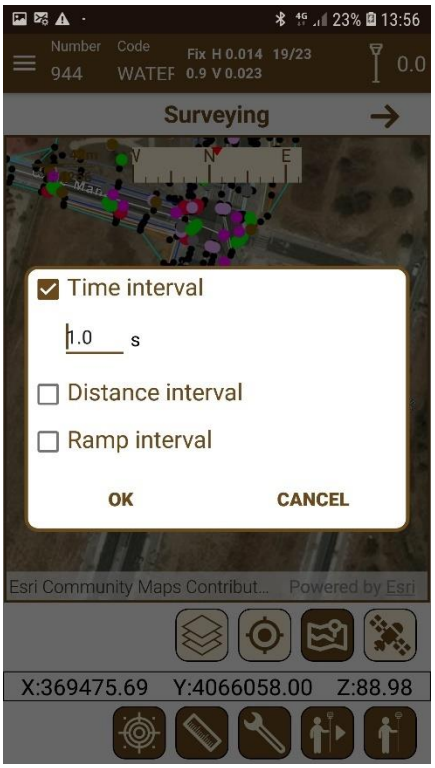


Figure 38. Dialog for setting up continuous surveying criteria

When points are taken continuously, the conditions to take them as valid will only be considered in the first one and for the rest of the points a voice will advise if the restrictions are satisfied or not and, in consequence, if the point is measured or not.

Once the taking starts, it can be stopped at any time by pressing the same button, that has changed its icon to .

This mode is very useful when measuring lines or alignments, where the points must be measured at certain distance.

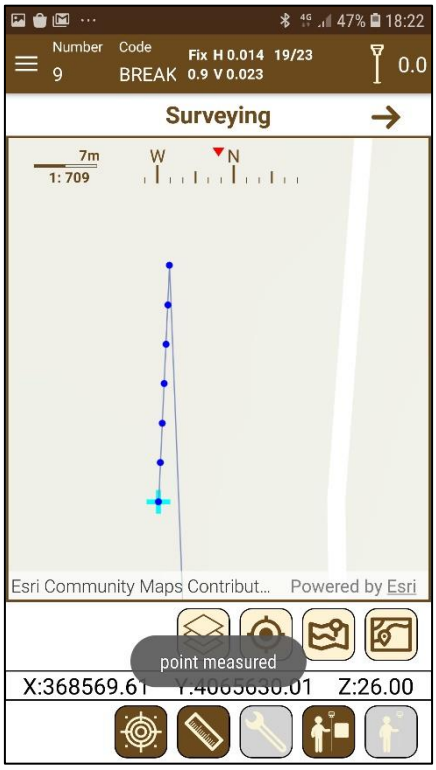


Figure 39. Continuous surveying

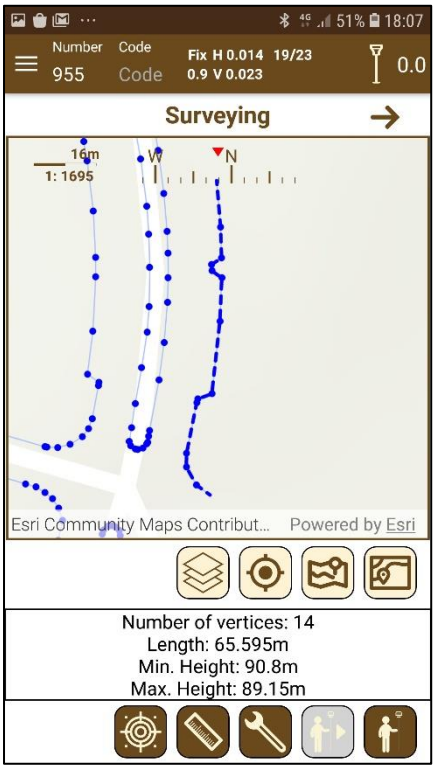


Figure 40. Line data

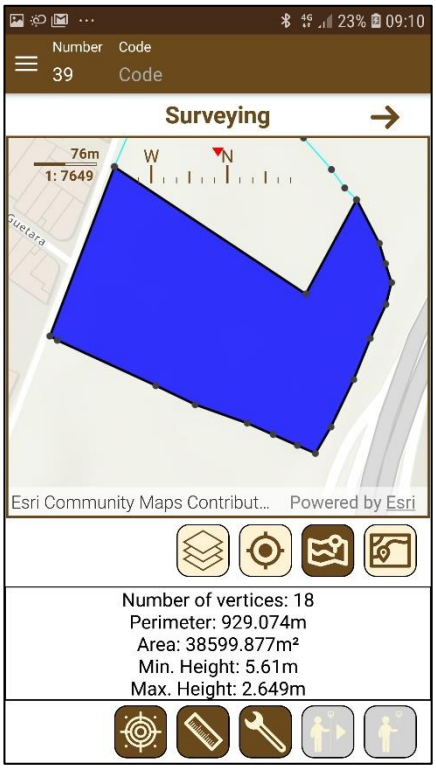


Figure 41. Area data

10.5 Point code management

To classify the points, it is possible to assign them a specific code that groups them and distinguishes them from the rest. This code may be composed by a set of codes of different type for identifying the point in a better way or to define different properties for the point. Some examples of codes are shown below:

TREE

SHOULDER,ASPHALT

MANHOLE,LP_1,PT_2

As you can see in the examples above, a **separator** character will be used for identifying each code of the multicode. To change this separator, see **Configuring the workspace**.

There are three types of codes in the application:

- **Punctual**: Used for defining singular points (TREE, MANHOLE, LAMPPOST…)
- **Lineal**: Define polylines. In this case, a sequence of points composes the polyline. The first point of the polyline will be attached the **s** suffix (start) and the last point the **e** suffix (end). Here you have an example:

  ASPHALT S

  ASPHALT

  ASPHALT

  ASPHALT E

- **Polygonal**: Define areas or parcels. As lineal codes, a suffix for the starting point (**s**) and another one for closing the polyline (**c**) are needed. For instance:

  PLOT S

  PLOT

  PLOT

  PLOT C,POST

In the numerical survey mode, the button

displays the code management dialog. It is also possible to access the code management screen by a long click over the **Code** filed in the status bar.

In Figure 42 dialog is shown with the list of codes available in the database of the application. This database is modified as new codes are inserted and existing ones are modified or eliminated. By clicking on the desired code and accepting the choice, the code starts to be used in the following taken points. Using this list, you can build your code or multicode (if you want to assign more than one code to the point) only by checking the **Use** checkbox beside each code.

Previously, it was said that a **separator** is needed to compose a multicode and it can be selected in **Configuring the workspace**. If you want to add a new code to your multicode, you must click the button to introduce the **separator** or type it if you know which separator is selected.

If the code is lineal or polygonal, you can add the **start** or **end** suffix for the line or the **start** or **close** suffix for the polygon, only clicking the corresponding button or typing it. This is important because when the application builds the lines or polygons it uses these suffixes as references.

In Figure 43 it the options to edit or create a new code are displayed. The codes can be punctual or linear (depending on whether they will represent independent points or points that will make up a line or a plot). In addition, a wide base of colors is available to assign to the points that contain this code.

Depending on the type of the code, you can configure the style of the elements that use this code. For points you can define the color, size and type of symbol. For lines you can set the color, width and style of line. For polygons, apart from the style of the contour line, you can define the fill color and the level of transparency.

It must be considered that if the code of the point is a multicode, the style for its representation over the map will be the style of the first code which associated layer is visible.

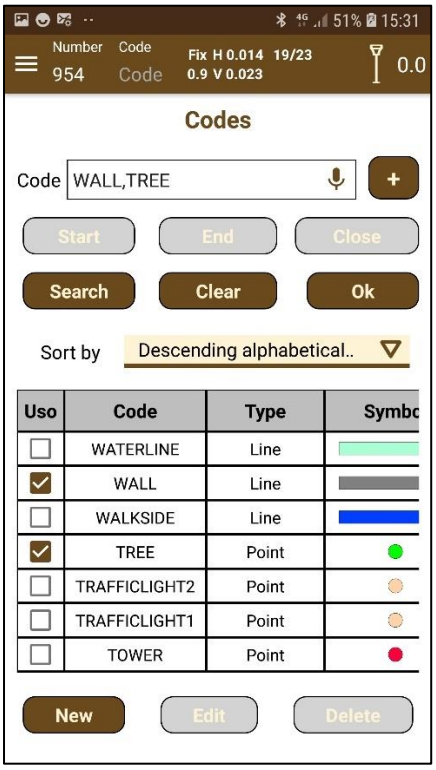


Figure 42. List of point codes

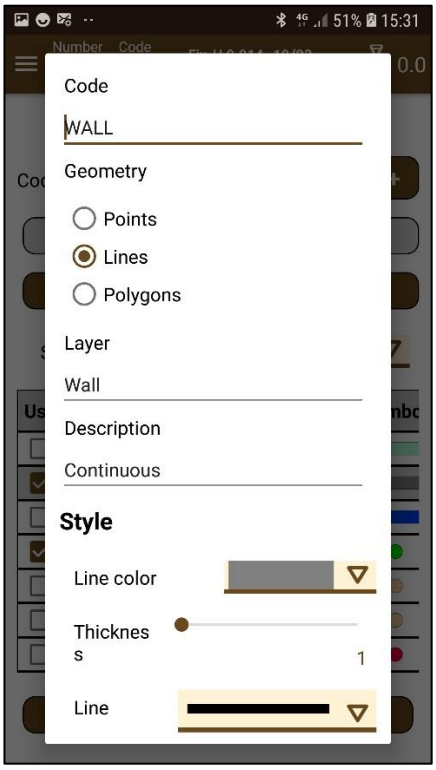


Figure 43. Edition and creation of codes

10.6 Observation time

As it was seen in the template of the **Configuring the workspace** it is possible to establish the **observation time** of a point. When the observation time is bigger than 0, by taking a point in an individual capture, as many captures will then be taken during the interval. When the measurement is finished, the list of captures taken and the differences with the average are displayed. If the measurements taken are considered acceptable, the point can be recorded or discarded for a new measurement.

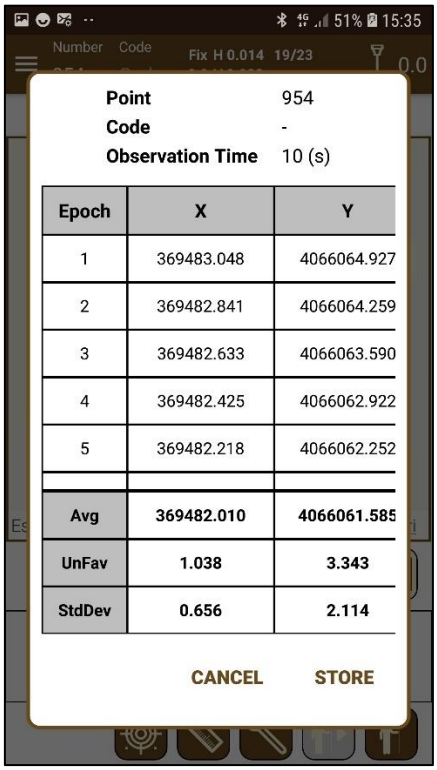


Figure 44. Epochs measured for a point

10.7 Distances and areas

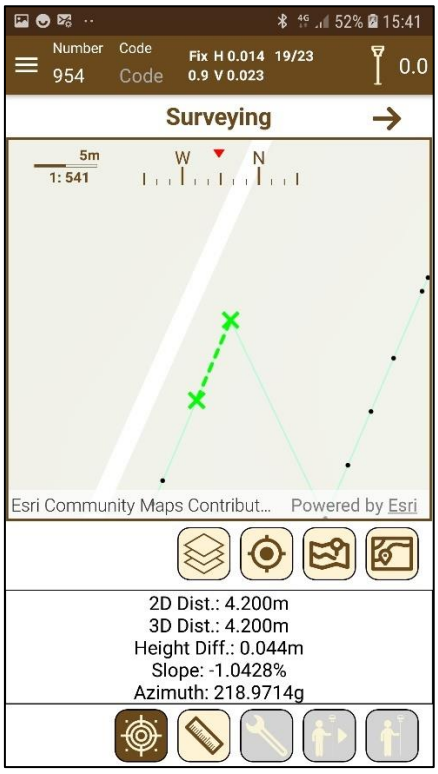


Figure 45. Measuring the distance between two points

In this mode, the map has an additional functionality: **distance and area measurement**.

When we press the button the app asks the user for the kind of measure:

- If **distance measurement** is selected, we will be instructed to choose the first point; Once selected, the second point will be requested and then the information about the distance between the two will appear (Figure 45): *distance 2D* (without taking into account the dimension), *distance 3D*, the *height difference* and the *slope* between the two points.
- If **area measurement** is selected, you will select points over the map and the area will be built and updated each time a point is added. You must be careful because the order of the point will define the shape of the area. *Number of vertices*, *perimeter*, *area* and *maximum* and *minimum height* are the data shown.

10.8 Survey tools

Clicking the **tools** button displays a dialog box where you can find a set of tools to work with the points gathered. These tools correspond to the calculation of new points using intersections or reference points. There are three types of intersection: **line-line intersection**, **line-circle intersection** and **circle-circle intersection**. Two options are available for creating new points from reference points: **distance and azimuth** and **2 points and distance**.

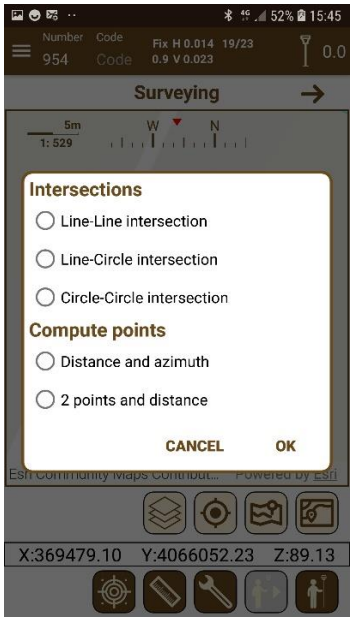


Figure 46. Surveying tools dialog box

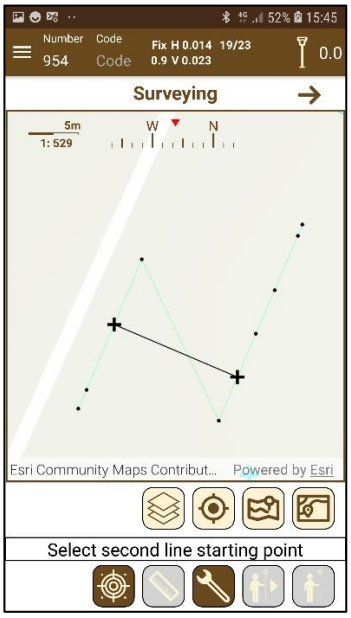


Figure 47. Selection of points for the intersection

Figure 48. Confirmation of the intersection solution

10.8.1. Line-line intersection

In this case, the point where two lines are cut is calculated. The application will ask the user first to click on the two points that will form the first line and then select the two points that will form the second. It will show immediately the two lines and the intersection between them. If the lines are parallel, there will be no cut off point. Next, it will ask for confirmation, if you want to save this solution.

Figure 49. Intersection of two lines

10.8.2. Line-circle intersection

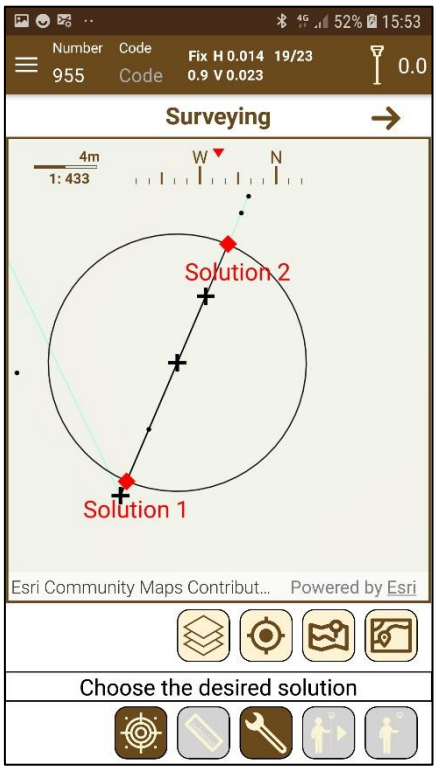


Figure 50. Line-circle intersection

The application will ask the user first to select the two points that form the line and, next, the point that will be the center of the circle, after which you must write the radius of it. In this case, it can happen that there is no solution if the line and the circle are separated; that there is only a solution if the line is a tangent to the circle, or that there are two solutions if the line cuts the circle. The application will show the line and the circle and the intersection between them and, if there is more than one, it will ask you to choose which of the two you want to record.

10.8.3. Circle-circle intersection

This case is like the previous one, and there may be none, one or two solutions. The application will request the user the center of the first circle and then the radius and perform the same operation for the second circle.

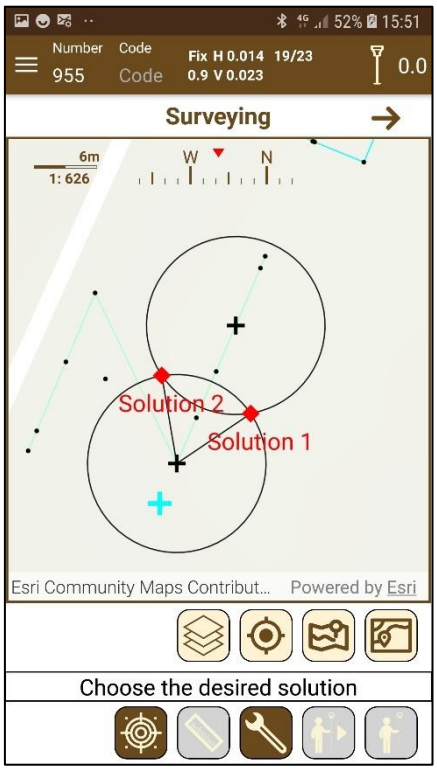


Figure 51. Circle-circle intersection

10.8.4. Distance and azimuth

In addition to using intersection, points can also be calculated from others using the **Distance and azimuth** tool. The application will ask the user to choose a point from those present in the work and then enter the distance and the azimuth of the point that will be generated, taking as reference the selected point.

Figure 52. Point calculated by distance and azimuth

10.8.5. Two points and distance

Whit this tool, the user can select two points a set a distance from the first point to calculate a new one, taking the azimuth between the selected points as the direction where apply the distance.

Figure 53. Two points and distance

11 Roads (Pro version)

When entering the road edition (**Menu> Edit> Roads**) a list of the roads that are currently in the project is presented.

Figure 54. List of roads

For the management of the list of roads, the following options are available:

	Adds a new road to the list. It can be imported from a **.eje** file (created using *TcpMDT*) or a *LandXML* file.
	Enter the road edition template where you can associate a vertical alignment and the cross templates to it.
	Remove the selected road and all the elements associated with it.

These roads are shown in the survey template of the application in blue and red which is currently the active road, selected on the list by clicking on the marker on the left.

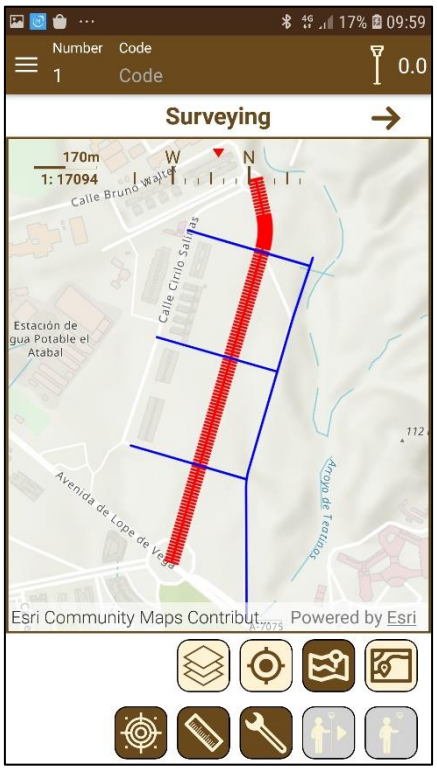


Figure 55. Roads in surveying

When the horizontal alignment of a new road has been loaded, you will go directly to the editing screen, where you can select a vertical alignment and make a list of files of templates that will be associated with that road.

The files that are supported are:

- **.eje files** that contain the horizontal alignment of the road.
- **.ras files** that contain the information of the vertical alignment.
- **.tra files** that contain the cross section of the ground or the road defined.

These extensions correspond to the native files created by the TcpMDT **application**, although it is possible to use the **LandXML format**, of which the entities supported are:

- **Alignment**: It contains the points that form the horizontal alignment of the road.
- **Profile**: It contains the vertical alignment data.
- **CrossSects**: It contains the data of the templates of the road.

Both the horizontal alignment and the vertical alignment and the construction of templates can be visualized in graphic mode and its data consulted on the button .

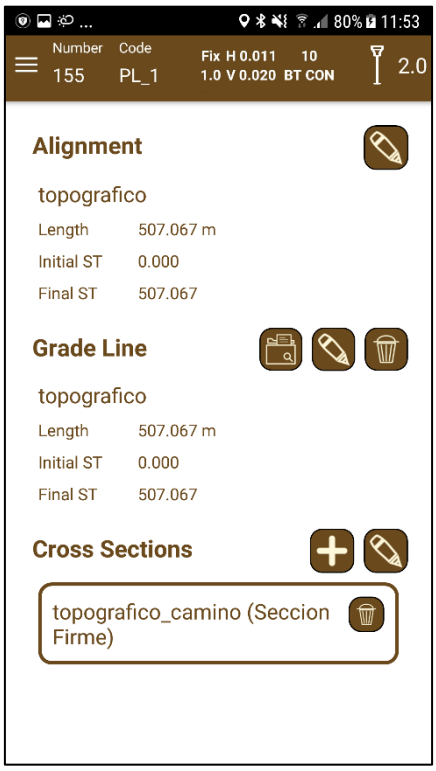


Figure 56. Editing a road

11.1 Horizontal alignment display

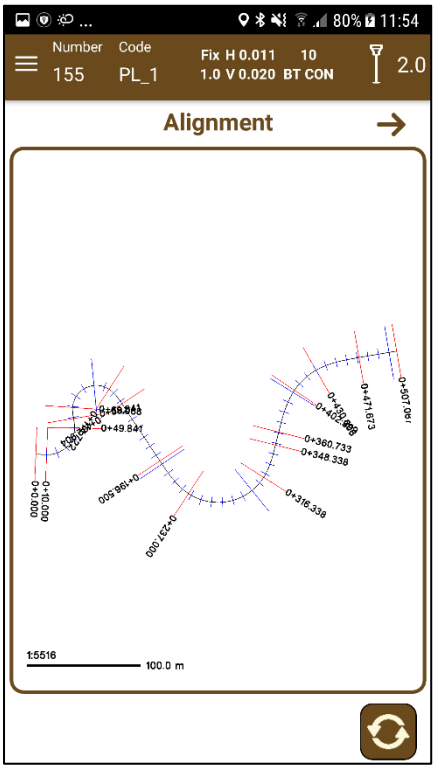
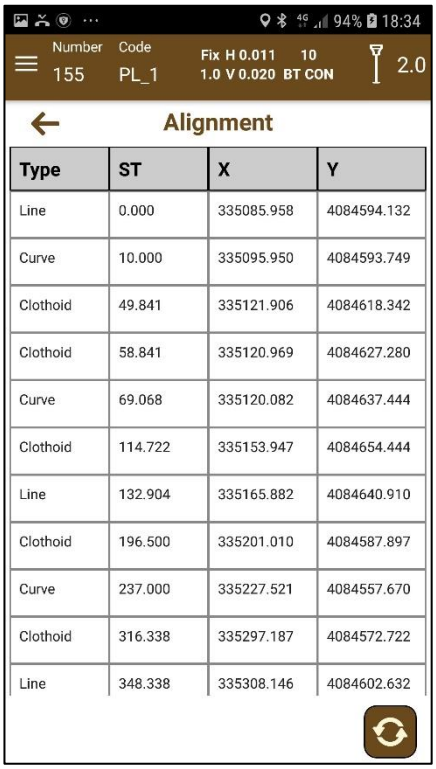


Figure 57. Top view of the alignment



Type	ST	X	Y
Line	0.000	335085.958	4084594.132
Curve	10.000	335095.950	4084593.749
Clothoid	49.841	335121.906	4084618.342
Clothoid	58.841	335120.969	4084627.280
Curve	69.068	335120.082	4084637.444
Clothoid	114.722	335153.947	4084654.444
Line	132.904	335165.882	4084640.910
Clothoid	196.500	335201.010	4084587.897
Curve	237.000	335227.521	4084557.670
Clothoid	316.338	335297.187	4084572.722
Line	348.338	335308.146	4084602.632

Figure 58. Numeric information of the alignment

The display of the horizontal alignment presents the vertical alignment and allows the rotation of the presentation for a better observation, especially if a smartphone is used.

In smartphones you can alternate between the elevation view and a table with data of the horizontal alignment and in tablets both screens are presented at the same time for a better study of the information. The button allows it to extend the plant of the horizontal alignment to full screen for a greater definition or to return to the two columns with the numerical information.

11.2 Vertical alignment display

The display of the vertical alignment presents it in elevation. As in the horizontal alignment, rotation of the presentation is allowed. In addition, in this case, a magnification factor can be applied to obtain a better definition of the vertical alignment in the button . This magnification is in the **x1 - x20** range.

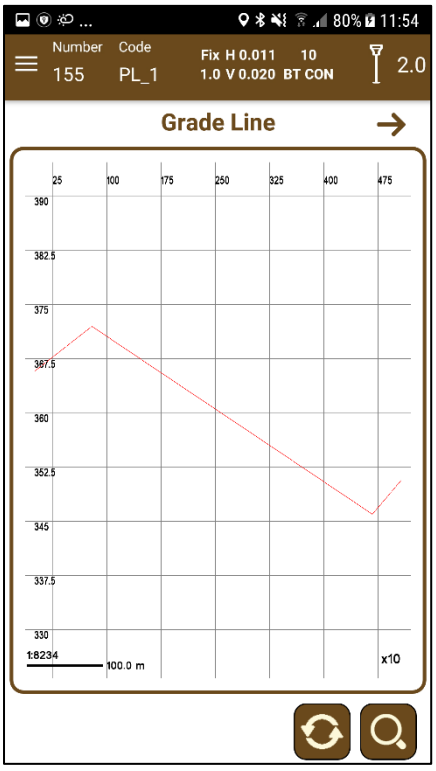


Figure 59. Vertical alignment view

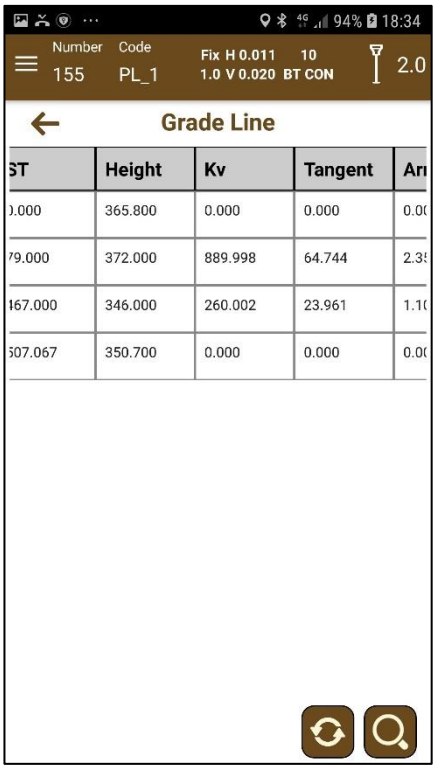
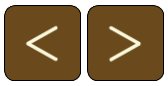


Figure 60. Vertical alignment numerical information

As in the horizontal alignment, on tablets the information of the vertical alignment and its elevation view is presented for a better analysis of it, as well as the possibility of hiding the column of data and extending the elevation of the vertical alignment.

11.3 Cross sections display

The display of the templates presents the template in the current station of each one of the transverse files contained in the list.

When you start the window, the application will immediately be placed in the template closest to the current position. With the buttons  you can switch from one station in the template to the previous one or the next one respectively. For templates, a magnification factor can also be applied to obtain a better definition.

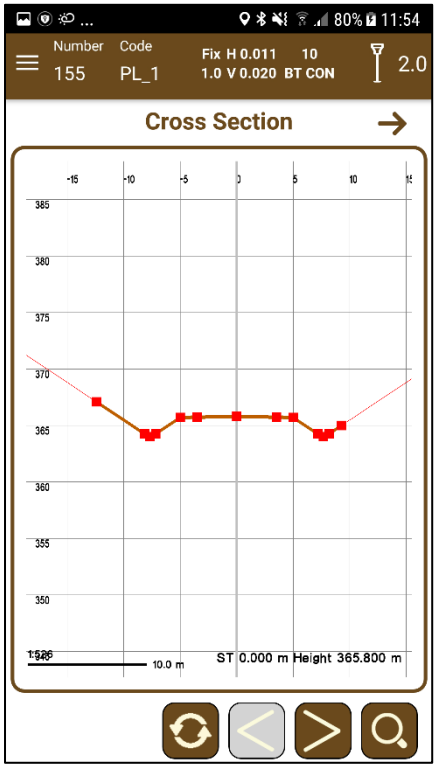


Figure 61. Cross section view

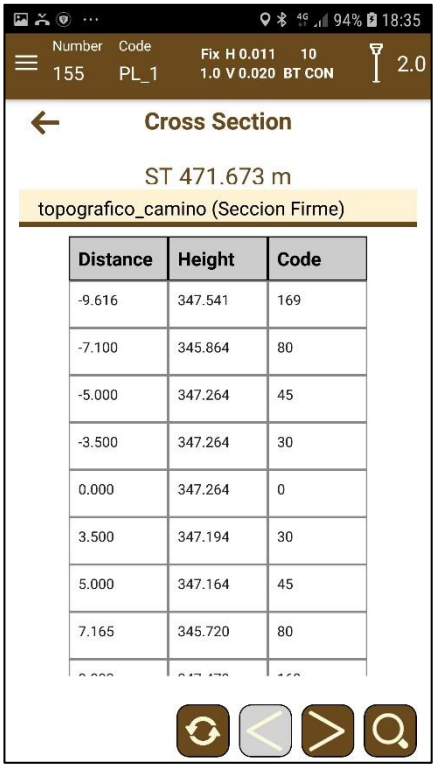


Figure 62. Cross section numerical information

In the numerical presentation of the data of the templates, the information of the points of the transverse file selected in the current station is shown. The template to be displayed can be chosen from the drop-down list, automatically updating the data, and, in the graphic view, the template with greater thickness of the line will be highlighted.

12 Digital model (Professional version)

In TcpGPS you can create digital models using the measured or imported points of the project. To access this option, click on the **Edit > Digital Model** submenu.

When you enter the screen, a map with the points stored in the project and usable for the digital model generation is shown, along with the digital models already created.

Two options are available in this screen:

- **Import** of a digital model.
- **Creation** of a digital model.

These models can be used in **surface analysis** (see **Surface analysis** section) for getting information about the difference of height between the digital model surface and the current terrain delimited.

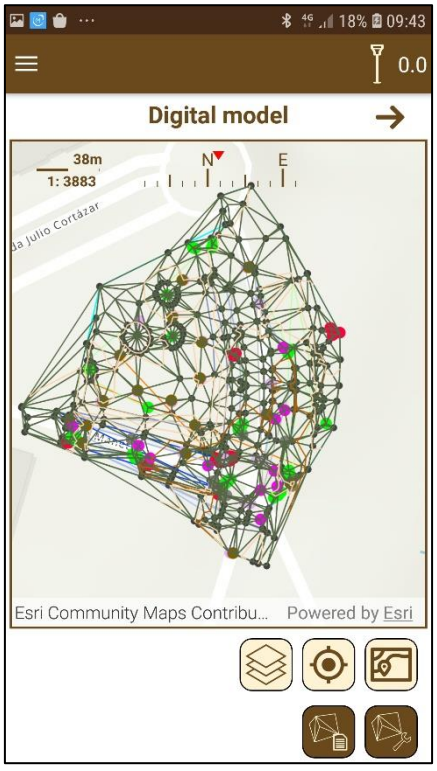


Figure 63. Digital model created

12.1 Import a digital model

This option allows the user to import a digital model from a **DXF** or a **LandXML** file.

In case of a DXF file, the entities **3DFACE** will be taken for define the faces or triangles of the digital model.

For **LandXML** the entity used for creating digital models is **Surface**.

12.2 Creation of a digital model

A digital model is created using a process called **triangulation** in which the points are turned into triangle vertices, generating an irregular mesh defining the terrain.

Figure 64. Creation of a digital model (1)

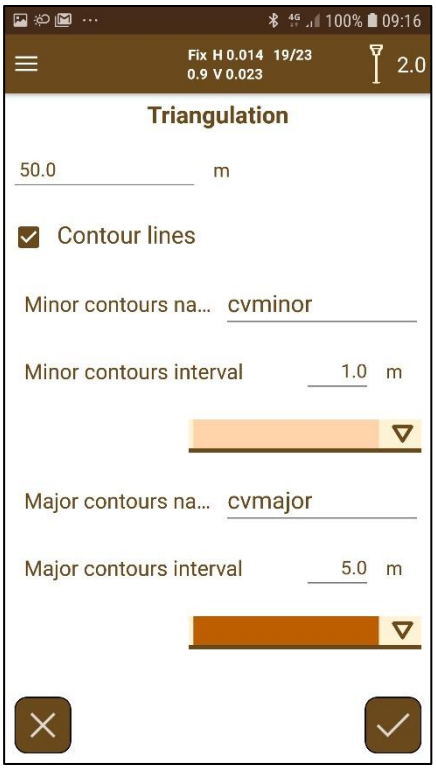


Figure 65. Creation of a digital model (2)

The following parameters will be required in the screen for configuring the digital model:

- **Name** of the digital model.
- **Color** for drawing the digital model.
- **Break lines**. If this option is enabled and the project contains lines or polylines, a list of them will be displayed for selecting those you want to use as break lines. These lines, either by the characteristics of the terrain or by the peculiar way of seeing it, will be obligatory lines (in advance) in the formation of the digital terrain model. It is not mandatory to define them, but it is highly advisable for the work to have validity and precision, since through these lines the relief is defined by following the existing slope changes.
- **Maximum distance**. It defines the maximum length for the edges of the triangles. If a triangle has an edge with a higher length than this value, it will not be created.
- **Contour lines**. By enabling this option, contour lines can be generated from the generated digital model. There are two types of contour lines:

- **Minor contours**.
- **Major contours**.

Each type of contour is defined by its **name**, **color** and height **interval** between each of them.

By clicking on the accept button, the triangulation process will start. When it is finished, one or several layers will be added to the project:

- **Digital model layer**. This layer manage the visualization of the digital model and it can be used in **surface analysis**.
- **Contour lines layer**. If the contour lines option was selected, two layers will be added, with the names typed, that manage each type of contour lines.

You can generate as many models as you desire, but if the names of the models or the contour lines match with any other present in the project, it will be replaced by the new one.

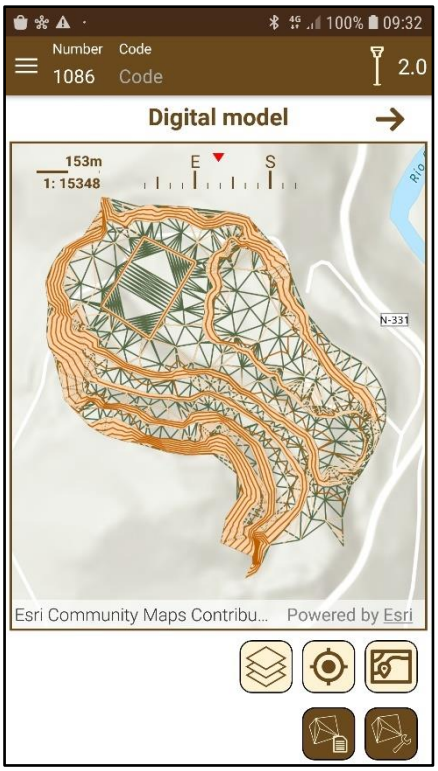


Figure 66. Digital model triangulated with TcpGPS

13 Setting out

In the side menu, the **Staking out** submenu can be found, which gives the option to choose one of the different modes, depending on the type of work that the user will perform:

- **Setting out of points**: Performs a setting out of the points contained on the project database.
- **Setting out of lines**: It allows to stake out lines formed by the union of two existing points in the database of the project.
- **Setting out of polylines**: The setting out is performed on polylines or polygons defined in a DXF, KML / KMZ, shape or GML cartography.
- **Surface analysis**: Analyze the difference in dimensions between the current position of the GPS and the 3D surface loaded.
- **Road Setting out**: It allows you to stake out a set of points configured on a road.
- **Slope control**: The current state of the land is analyzed according to the theoretical template that has been loaded into the project.

13.1 Setting out modes

When setting out, the reference to get the indications for reaching the points can be the **north**, the **movement** or the **last staked out point**.

13.1.1. Setting out to the north

In this case the indications are referred to the **north** direction, so it is recommended to be oriented to the north when using this mode.

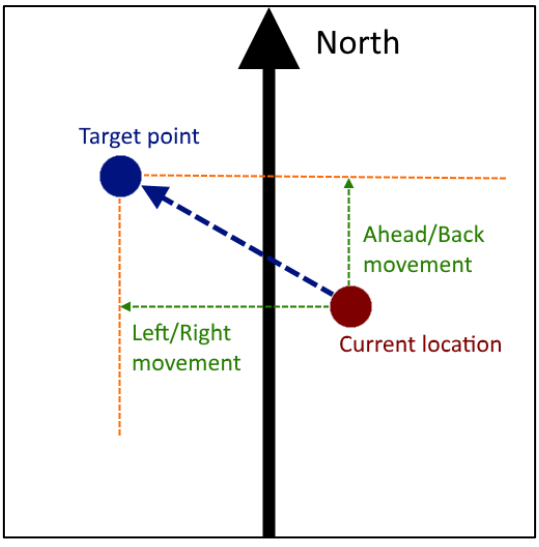


Figure 67. Example of setting out to the north

13.1.2. Setting out to the movement

In this case the last movement of the user is taken as reference for indicating the next movement he should do to reach the target point. In this mode, a new movement will be recognized when at least the location has change in 50 centimeters of distance.

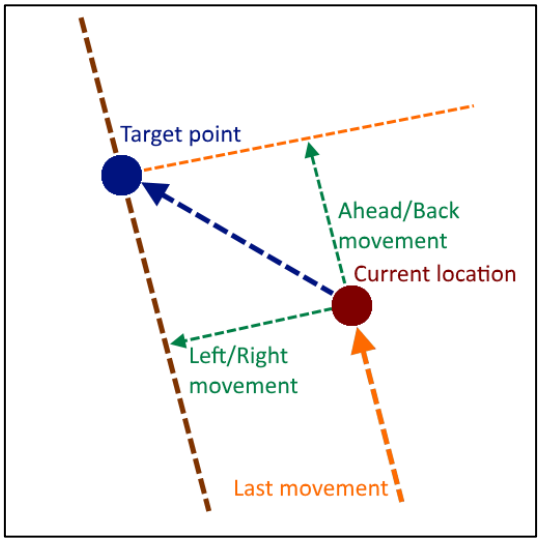


Figure 68. Example of setting out to the movement

When the position reaches the limit configured settings named **Target Mode Distance** (see **Configuring the workspace**) the last move the user did is taken as reference and it does not change anymore, in order to avoid continuous changes due to the small distance to the point.

13.1.3. Setting out to the last point

In this case, the line from the last set out point to the target point is taken as reference.

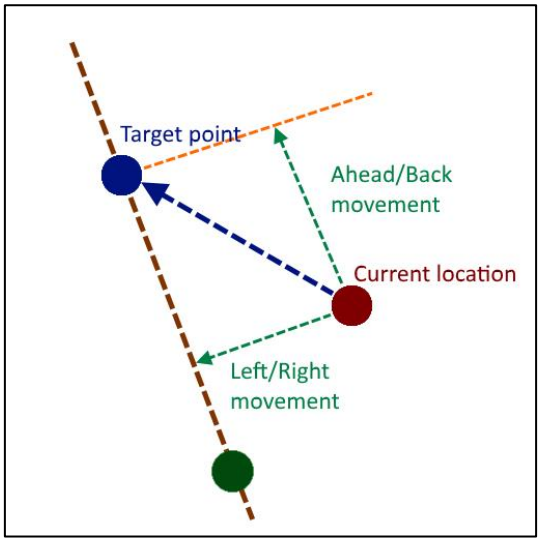


Figure 69. Example of setting out to the last point

13.1.4. Setting out to the sun or shadow

This mode is like setting out to north, but in the case the reference is the sun. The user must have the sun at his back and a good guide is his own shadow.

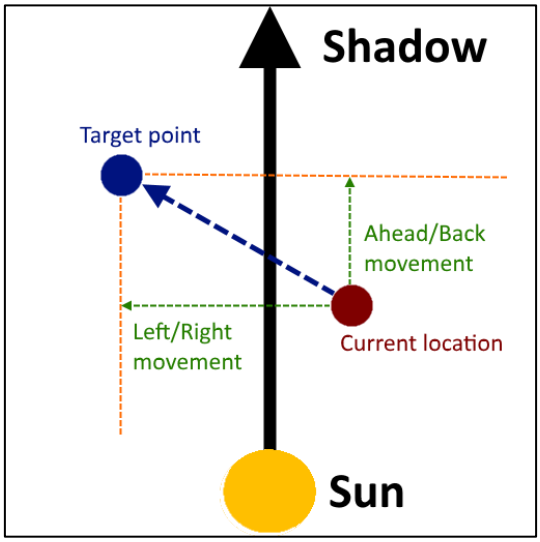


Figure 70. Setting out to the sun

It is very important to know that the reference will change depending on the hour and the day.

When using stake out to the shadow the direction is the inverse, i. e., the user must leave the sun behind him to obtain the reference. In this mode, the cast shadow can be a great help when it comes to orienting himself.

13.2 Set out points

In this section, individual points are staked out. To make the job easier, TcpGPS incorporates various modes for staking out.

13.2.1. Map mode

In this mode, a map is displayed showing the available points for setting out and the current position of the GPS. You can select the point to set out simply by clicking on it. A signal indicating the point and a line between the current position and this one will serve to advance towards it in the correct direction. Over this line is shown the distance to the point.

Figure 71. Map staking out mode

The map is always pointing north, unless the reference is set to the movement, which will be pointing to the current direction in which the user is moving. In addition, at the top there is numerical and visual information about the movements to be carried out with the distance that must be travelled.

When a point is stored it is marked with a green symbol as the last set out point, for identifying it in case to be using **Setting out to the last point**. The other set out points change their symbol to . Once the points are staked out, the user can check the differences between these points and the original points in the section **Edit > Points**. (Check section **Staking out data**).

13.2.2. Compass mode

In this mode, the direction in which the point is relative to the north from the GPS position will be indicated. It is a mode that is recommended to locate points at a long distance, since in the vicinity of the point the measurement of the angles can be erratic. To use it, the device must have a magnetometer.

In the compass, three lines are highlighted:

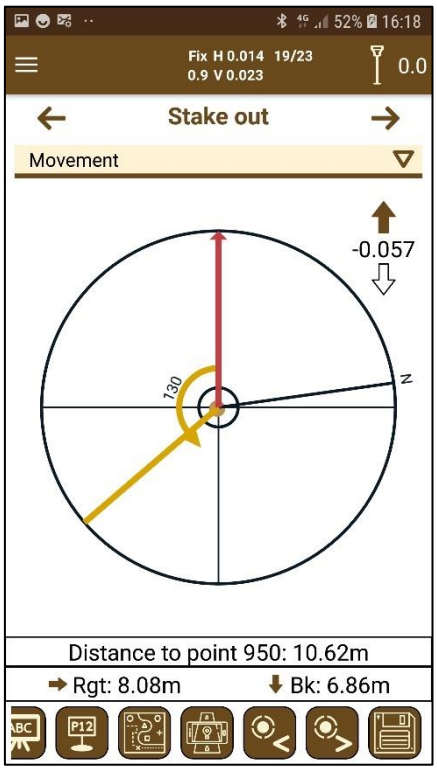


Figure 72. Compass staking out mode

- The **red line** is fixed and indicates the current direction the user device is pointing. This line changes its color to **green** when the line indicating the point to be set out matches with her.
- The **black line** indicates the direction of the north.
- The **orange line** indicates the direction to the point to be staked out.

Between the red line and the orange line is indicated the angle the user must turn to face the point.

On top of the compass is indicated the **distance** to reach point.

13.2.3. Target mode

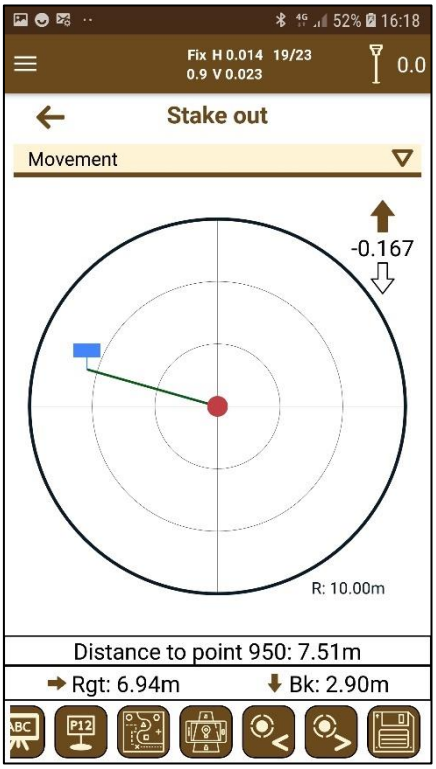


Figure 73. Target staking out mode

In this mode, the current position of the GPS (in **green**) is shown in relation to the center of a target that marks the point to be set out (in **red** at center of the dartboard). The position of the GPS within the target will be determined by the movements to be made depending on the selected setting out mode. In this mode, a greater precision is obtained when locating the point, so its use is recommended in the vicinity of the point to be set out.

On top of the dartboard are shown the movements the user should make to reach the point: left or right for lateral movements and forward or backward for advance movements.

13.2.4. Augmented Reality mode

In the setting out of points and setting out roads, there is a way of **setting out in Augmented Reality** that can be accessed on the button once a setting out has been selected. This mode is a way to visualize on the real terrain the layout of the points to be set out so that they are easy to locate. In the screen the user can see the image captured by the camera and overlapped to it a set of points that the user is staking out

(represented as red sticks), with the current point to be staked out highlighted. The user can configure the aspect of the highlighted point in **Menu > Settings > Augmented Reality > Stick configuration** (see **Configuring the workspace**).

Augmented reality mode needs the *magnetometer* and *accelerometer* sensors of the device for getting the orientation of the camera. The quality of the experience will be affected by the sensibility of these sensors. Interferences in the magnetic field can decrease the quality of the visualization.

For reducing the interferences and improve the experience of the user this mode has available a set of controls that allows to adjust the camera view. These controls let the user to modify the *angles of the camera* (pitch, roll and yaw) and the *distance offsets* (X, Y and Z).

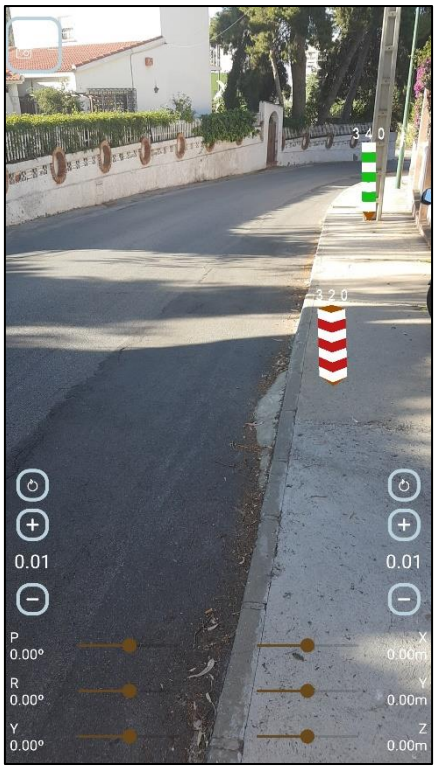


Figure 74. Augmented Reality staking out mode

In addition, clicking in button, a dialog is displayed for setting the offsets of the camera relative to the point the GNSS receiver is measuring, in centimeters. This measuring point will depend on the height of the pole configured in the application. In **Figure 75** is shown an example where the antenna pole height is 0 and the point measured is the base of the GNSS.

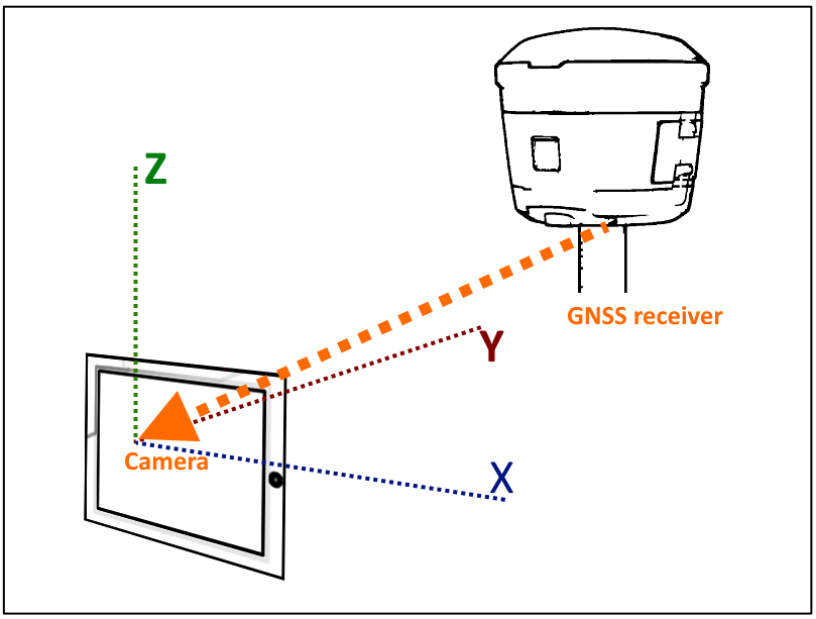


Figure 75. Offsets of the camera relative to the GNSS measuring point

13.2.5. Changing the staking out mode

To change the mode, the controls will be used will be used. In addition, when the minimum distance to the point configured in the application is met, the target mode is automatically passed to obtain more precision in setting out.

When the current location is at a distance lower than the set in **Menu > Settings > Stake out > Target Mode Distance**, the application will display the target mode automatically.

13.2.6. Staking out options

The following options are provided for working with **staking out of points**:

- **Staked out point** : Saves the point staked out in the database by recording the current GPS data. This data is shown can be checked in the **Editing points** section by selection the **stake out** list. In this list are shown the differences between the original point measured in the surveying process and the current set out point.
- **Next** **/previous** **point**: They allow you to select the point to be staked out by scrolling through the list of points according to their numerical order.
- **Select code** : Allows you to select a specific set of points according to their code. Another option is associated with this one to allow you to return to the full list of points .

- **Point selection** : Allows the user to select a point by entering its number.

In each setting out mode, help is provided in the form of voice prompts to mark the movements to be made or the remaining distance to reach the point.

13.3 Stake out lines

In this template we will work on setting out a line (Figure 76**¡Error! No se encuentra el origen de la referencia.**) that will be established between two selected points.

When you want to stake out a line, the application will ask for the first point (selectable in the map) and then for the second. Once the two points are selected, a line will join them on the map and the following information will be presented:

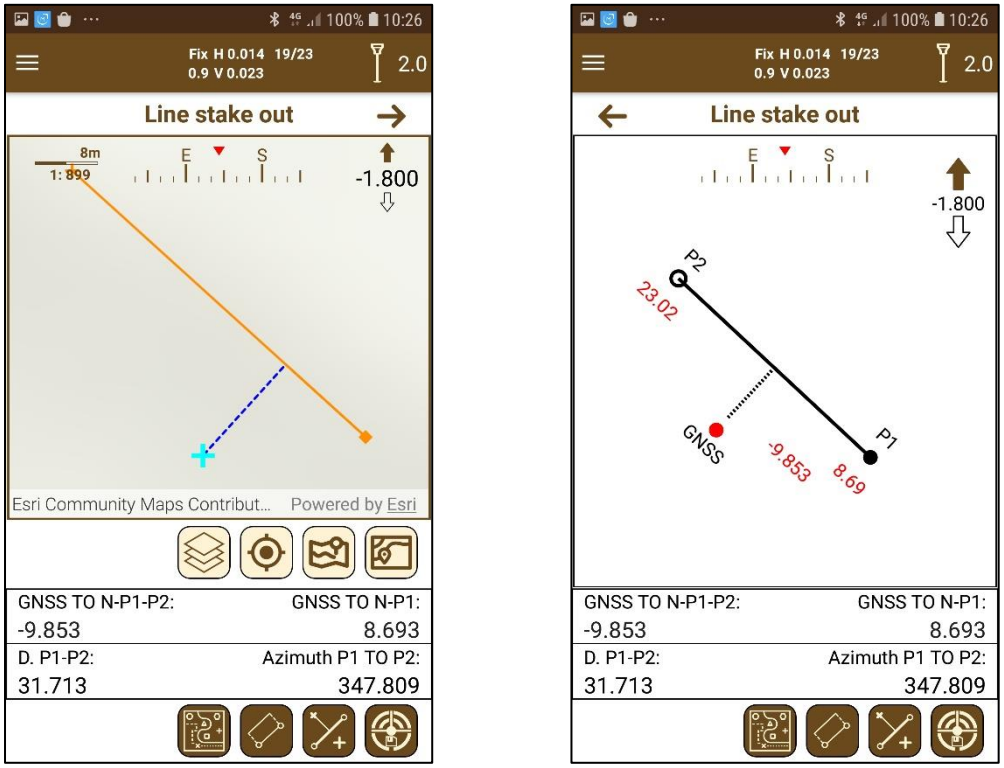


Figure 76. Line stake out

- **GNSS TO N-P1-P2**: Distance from the current point to the line in perpendicular fashion. If the perpendicular falls outside the line, an extension of it will be drawn for its representation.
- **GNSS TO N-P1**: Understanding the origin as the first point chosen, this distance is the distance from the current point projected on the line, to the origin.

- **D P1-P2** is the length of the line.
- **Azimuth P1 TO P2** is the azimuth of the line following the direction P1 to P2.

Line stake out mode displays the line to stake out with the points at both sides and the current position of the user respect to the line.

If the user is out of line ahead (beyond the destination point) or behind (before reaching the point of origin) a dotted line will inform us of this situation.

All the stakeout data is presented on the representation.

If you want to set out another line, just press the button .

Additionally, it is possible to stake out a parallel line to the defined in the map by clicking on the button <imagen>. A dialog will be displayed asking for the distance in meters where the parallel line will be set. If the distance is positive, the new line will be set to the right of the first one, and if it is negative to the left.

13.4 Set out polylines

In this case, we work on maps of type *DXF*, *KML / KMZ*, *GML* or *shape* that contain elements formed by an indeterminate number of points of the polylines or polygons (closed polylines) type and also the polylines and polygons measured in surveying.

When a polyline is selected, this is staked out by PK. The movements shown in the screen are the ones needed to reach the line.

If you want to stake out the vertices of the polyline, you can switch to vertex mode with the button and back to PK mode with the button .

In **vertex mode**, the vertices corresponding to the points that form it are automatically marked. It takes, by default, the vertex closest to the current one, being able to change the vertex with the buttons .

When you want to store the information of one of the setting out points, press the button . In this case, since the points of the polyline are not saved as project points, both the polyline vertex information and the setting out point information are stored in vertex mode, and the projected point in the polyline and the setting out point if it is in PK mode.

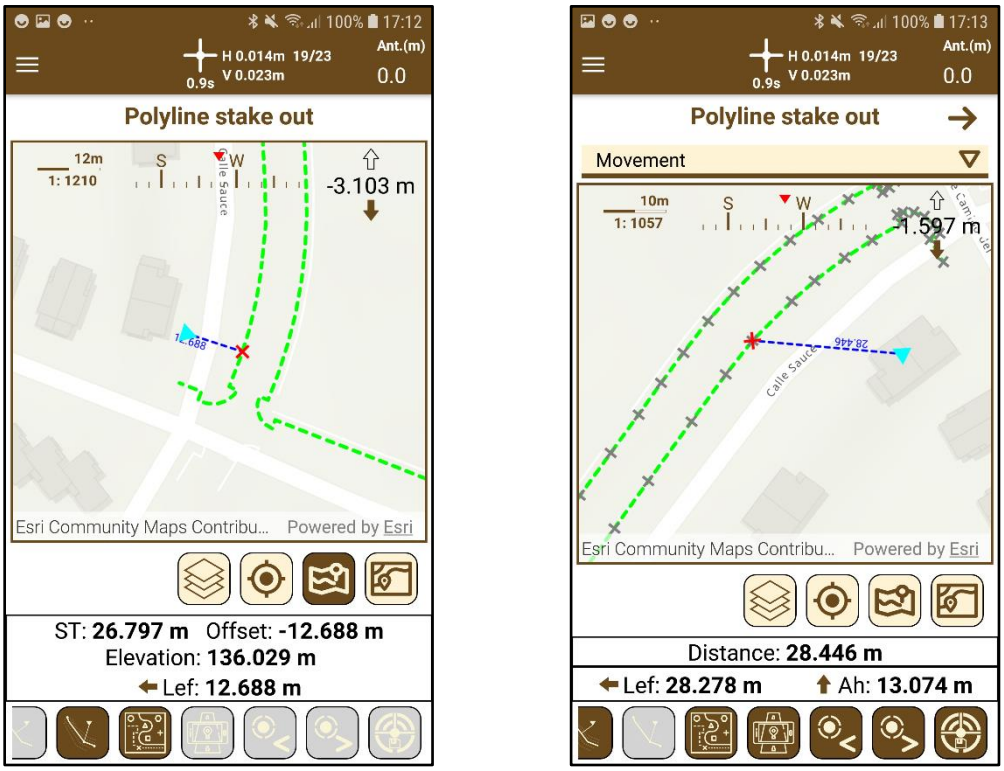


Figure 77. Polyline stake out

13.5 Surface analysis

This template is intended to check a 3D surface imported from a DXF file containing *3D faces* or a LandXML containing *surfaces* entities. To carry out this check, the dimension defined on the surface will be compared with the elevation measured by the GPS and the difference will be shown. In addition, the face on which the GPS is located at each moment is highlighted.

In the **Layer management** section is possible to change the active layer in case the project contains multiple surface layers. The active surface layer will be the one taken for making the analysis.

The information shown is:

- **Height**: Current height of the GNSS receiver.
- **Height diff.**: Difference of height between the GNSS height and the current selected surface.

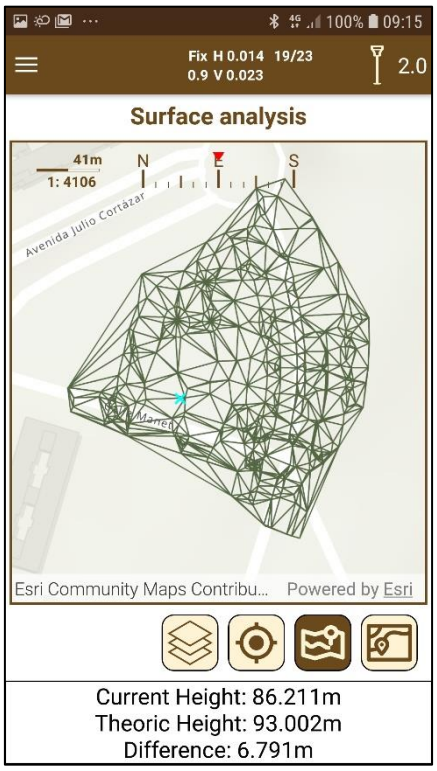


Figure 78. Surface analysis

13.6 Roads stake out (PRO version)

13.6.1. Stake out settings

In the setting out of roads, the points referred to the horizontal alignment of the road are set out. To do this, first you must configure the point or the set of points you want to set out.

If you want to set out a single point, just indicate it in the *Initial* Station.

If what is desired is to stake out a set of points along the horizontal alignment or parallel to it, the option *Interval* should be activated, and an *Initial Station* indicated from which the following points of the interval will be created. Then you can modify the interval between the points that will be taken. In addition, if this option has been selected, a drop-down list with the ordered set of interval points helps the user to choose the point to be set out.

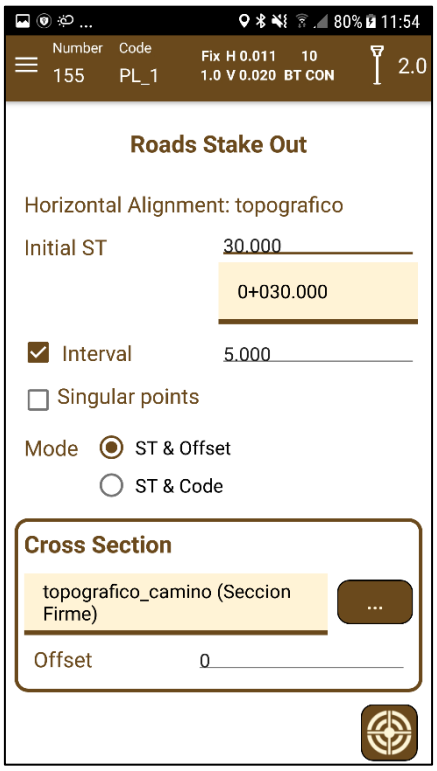


Figure 79. Road stake out settings

As an additional option, you can stake out, alone or next to the points defined in the interval, the singular points that form the horizontal alignment, marking the *Singular Points* option. These points are also added to the list of drop-down points and begin with an **[S]**.

If no other option is configured, all points will be located on the horizontal alignment. However, it is possible to set out points that are at a distance from the horizontal alignment, parallel to it. To do this, you can select if you want a list of points parallel to *the horizontal alignment at a certain distance (Setting out by Station and Displacement*) or to use a selected point of one of the vertices of the cross templates associated with the road, defined by a code (*Setting out by Station and Code*).

If there is no cross section selected, only the option of setting out by *Station and Displacement* will be available, indicating the displacement in meters that the points will have on the horizontal alignment. If the distance is positive, they will be placed to the right of the horizontal alignment and if it is negative to the left.

When a cross section is selected from the list associated with the horizontal alignment, the setting out option for Station *and Code* is activated, in this case you can enter a code manually or select it from the cross-template view on the button

.

Once the list of points to be set out has been configured, the setting out of the button starts .

13.6.2. Stake out display

The setting out screen has two modes: setting out *of a plant* and setting out *in elevation*. The latter will be shown if a cross section has been selected and if the road has a vertical alignment associated with it. To switch between both views, the navigation menu buttons are used .

The information displayed on the elevation is the following:

- **The** Station and the current **displacement**.
- Move **forward / backward** from the current station to reach the point.
- Movement **in / out** of the horizontal alignment to reach the point.
- Current **elevation and movement up / down to reach the slope.**

In the plant, the information of the current position marked with a celestial cross is shown.

If you have selected a range of points to set out, with the buttons

you can change the point to set out within the list.

Figure 80. Road stake out (top view)

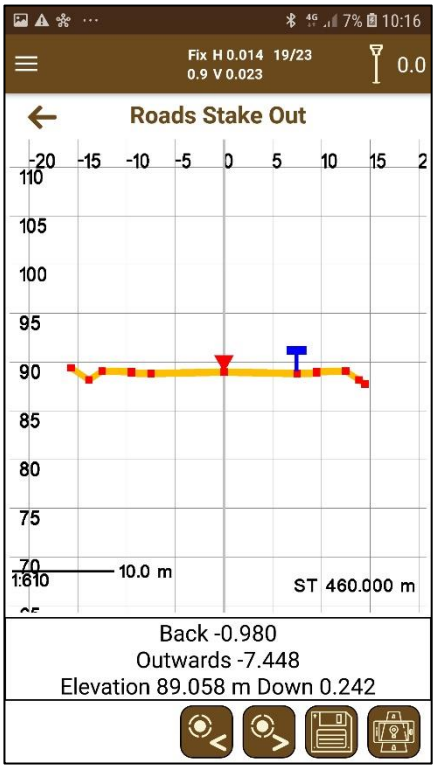


Figure 81. Road stake out (front view)

When the setting out point has been reached, it can be saved using the button . In this case, two points will be saved in the project database: the original point calculated in the list of points to be set out and the point that has been marked as set out.

13.7 Slope control (PRO version)

13.7.1. Slope control configuration

In the control of slopes the verification of the state of the terrain is made according to the road. In order to carry out slope control, the road must have a vertical alignment and at least one cross section.

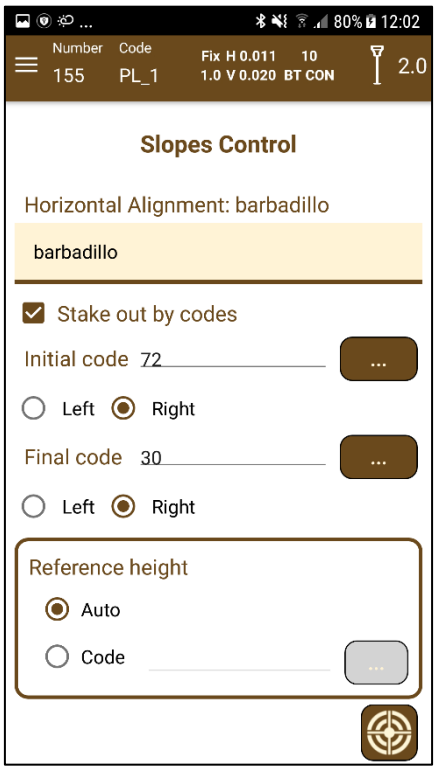


Figure 82. Slope control configuration

The first step to configure the slope control that you want to perform is to select the cross section to be used in the process. Once this is done, the following options will be activated:

- **Setting out through codes**: If you want to set out according to a certain segment template of the template, you can select the codes of the points in each end of a certain template. In this way, the control will be referred to the vector that defines the stretch and its extension in space. If this option is not selected, the control will be done according to the entire selected template.
- **Height dimension**: If the height dimension is taken automatically, the control will be referred to the current template dimension. If a point of the template is selected as the reference dimension, it will be determined by entering the code of that point or selecting it from the template itself.

To select the codes in each case from the selected template, press the button . In this way, the template closest to the current position will be displayed or you can travel between the template to look up the required code directly on the models.

13.7.2. Slope control display

In the slope control display screen, the elevation of the template closest to the current position of the GPS and the information related to the movements to be made to reach the position in said slope is presented.

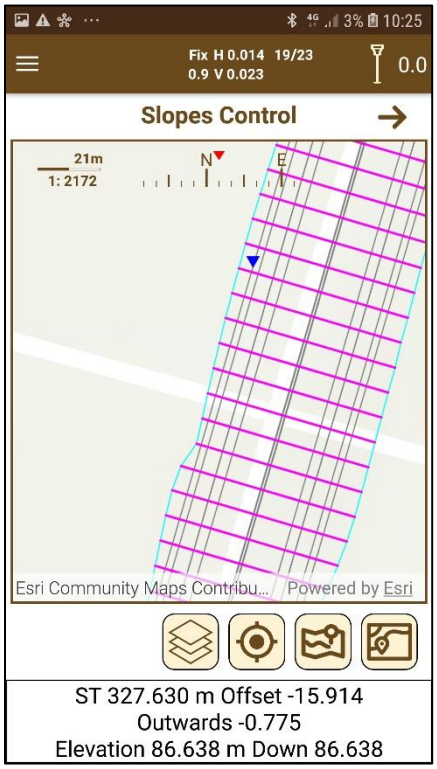


Figure 83. Slope control display (top view)

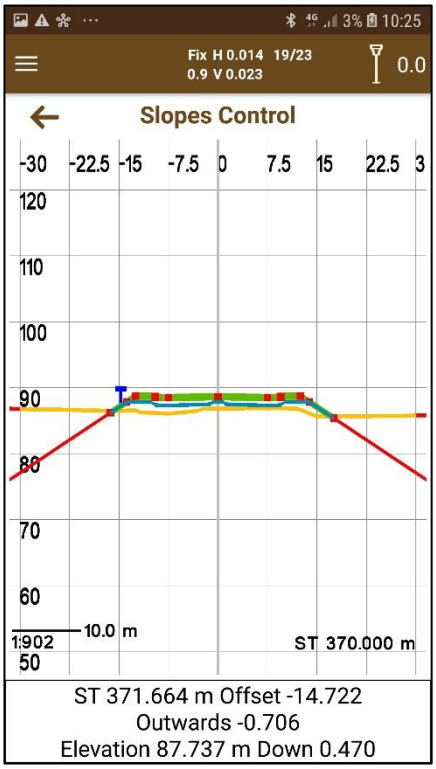


Figure 84. Slope control display (front view)

The information displayed is the following:

- **The Station** and the current **displacement**.
- Movement **in / out** of the horizontal alignment to reach the slope.
- Current **elevation and movement up / down to reach the slope.**

14 Working with the data

Once the surveying data has been gathered and/or the staking out work performed on them, a range of tools are available in order to be able to work with the data.

14.1 Importing points

It is possible to import points previously taken in other platforms or from other projects made with TcpGPS using files of the following type

- **TXT** or **PUN**: The format of the points in these files must be:

  <point id> <X> <Y> <Z> <point code>

  For example:

```
1 324177.421 4041653.935 0.85 SURV
2 324177.436 4041653.925 0.62 SURV
3 324177.422 4041653.937 0.63 SURV
4 324177.418 4041653.932 0.75 SURV
5 324177.432 4041653.942 0.55 SURV
6 324177.433 4041653.928 0.49 SURV
7 324177.414 4041653.939 0.65 SURV
8 324177.416 4041653.935 0.77 SURV
9 324177.427 4041653.919 0.76 SURV
10 324177.412 4041653.941 0.81 SURV
```

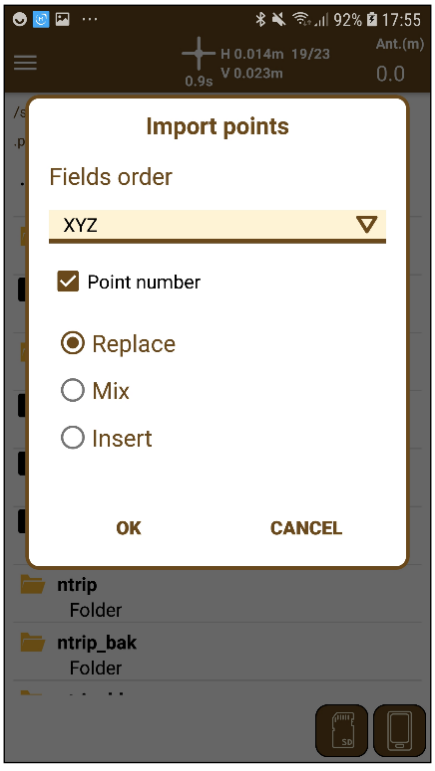


Figura 85. Import points

- **DXF**: The **POINT** entities contained in the file will be taken.
- **KML / KMZ**: **Point** entities will be taken as valid points.
- If the application is synchronized with **Google Drive** services, you may import these files from the cloud.

Selecting the file with the desired points will open a dialog with the following options to import these points:

The default option is **Replace**, that will erase all the points in the drawing and replace them with the imported points.

Insert adds the points at the end of the list of existing ones. The ordinal of the points of the file to be imported is ignored, and the new points will be imported from the initial number specified in the dialog.

Finally, the **Mix** option considers the point names, adding from the new file only those points whose number does not already exist in the point cloud.

14.2 Exporting points

Points gathered in TcpGPS can be exported to the following formats: **KML**, **PUN**, **CSV**, **TXT**, **DXF**, **Shape** and **GML**. A special type of exportation is included, called, **MDT**, where a **.pun** and a **.gps** files are generated to use them into *TcpMDT*.

Figure 86. Point export menu

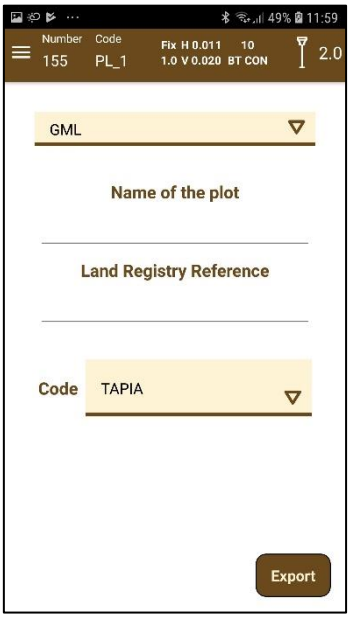


Figure 87. Export to GML format dialog box

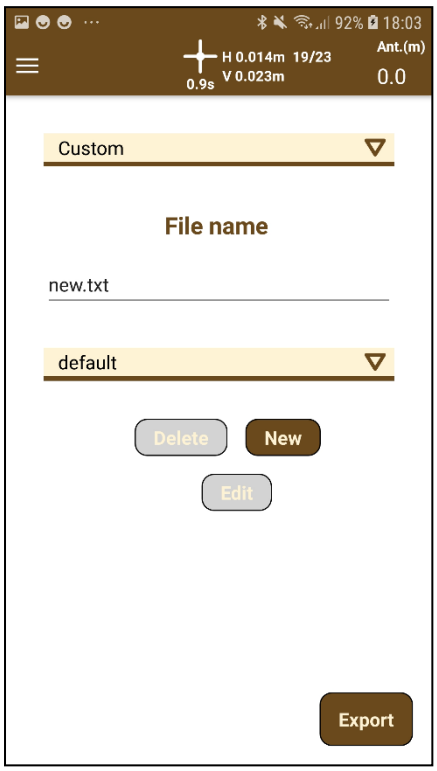
Figure 88. Export to TXT, DXF and KML formats dialog box

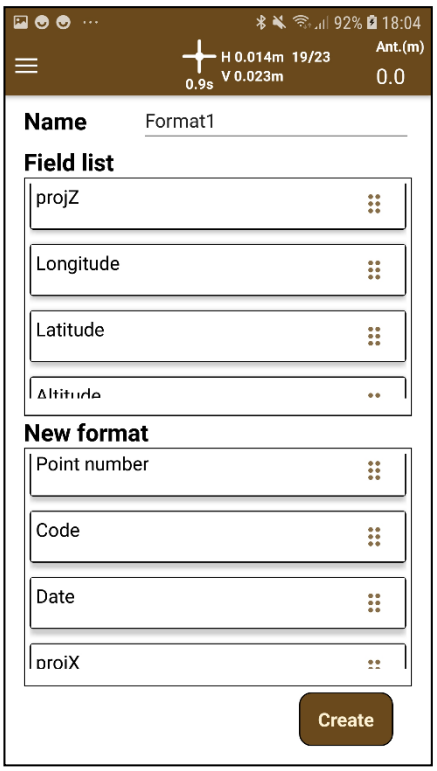
Additionally, the option to design custom formats has been implemented by selecting the **Custom** option, which we can be used to customize the attributes and types of data

that the file will contain, adding to the name the extension with which we want to save the file.

By default, the app shows a profile named "Default", but we will have the possibility of creating our own custom formats with the supported attributes, in order to export the points with those characteristics added to those profiles.

The exported files will be saved in the local application file in the folder **tcpgps/project /custom**.





14.3

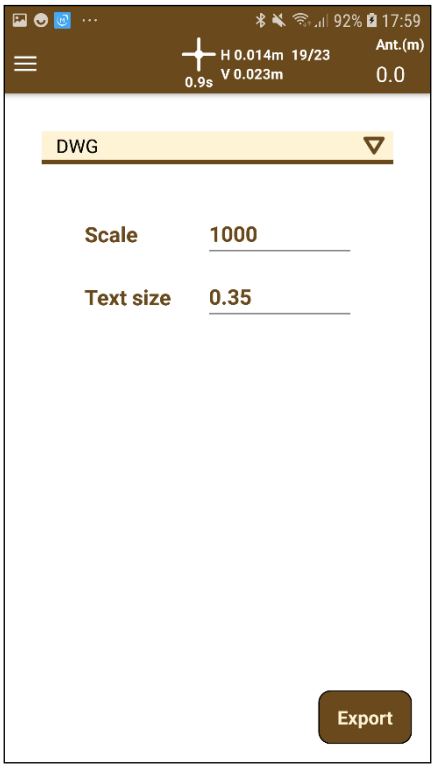
In addition, if geographic coordinates are included in the file, you can choose their format:

- Decimal degrees
- Degrees and decimal minutes
- Degrees, minutes and seconds

14.3.1 Exporting DXF y DWG

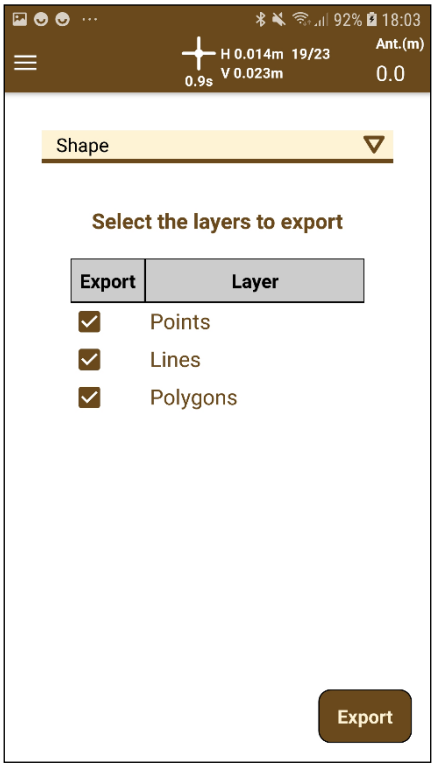
In this case, options for setting the size of the texts represented in the file are available:

- **Scale**: scale for adjusting the size of the text to the map.
- **Size**: size of the text for the scale defined previously.



14.3.2 Exporting to Shape

When export to Shape is selected, the user can select the layers he wants to export. A shape file is generated for each layer depending on the type of entities the layer contains.



14.3 Exporting raw data

The raw data contained in the application associated with points taken during a survey can be exported to **.gps** format, which looks like this:

Type	Source	Date	Time	-	Point	Lat	Lon	Alt	Antenna Hei	Pdop	UsedSats	Position Typ	Horizontal Pi	Vertical Prec	Code	-	Position Typ	Age	Observation	Base Distance
P	Surveying	14/06/2020	11:20:50	-	1	3.635.948.858	-433.648.465	205.379	0.000	3.1	16	8	0.022	0.040	BANCO	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:22:19	-	2	3.635.947.568	-433.650.197	205.379	0.000	3.1	16	8	0.022	0.040	-	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:22:56	-	3	3.635.945.200	-433.649.831	203.102	2.000	3.0	17	8	0.036	0.050	ARBOL	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:23:12	-	4	3.635.946.500	-433.641.541	203.341	2.000	3.0	15	8	0.050	0.090	ARBOL	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:23:44	-	5	3.635.947.793	-433.646.731	203.350	2.000	3.0	17	8	0.058	0.100	CAMINO	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:23:53	-	6	3.635.948.819	-433.647.196	203.310	2.000	3.0	16	8	0.036	0.060	CAMINO	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:24:03	-	7	3.635.951.294	-433.647.773	203.315	2.000	3.0	15	8	0.036	0.070	CAMINO	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:24:10	-	8	3.635.952.949	-433.648.413	203.333	2.000	3.0	15	8	0.036	0.070	CAMINO	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:25:45	-	9	3.635.947.987	-433.647.475	203.306	2.000	3.0	17	8	0.036	0.070	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:25:48	-	10	3.635.947.923	-433.648.352	203.355	2.000	3.0	16	8	0.036	0.060	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:25:50	-	11	3.635.947.593	-433.648.991	203.351	2.000	3.0	17	8	0.036	0.060	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:25:51	-	12	3.635.947.008	-433.649.307	203.328	2.000	3.0	17	8	0.036	0.060	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:25:53	-	13	3.635.946.354	-433.649.195	203.301	2.000	3.0	16	8	0.036	0.060	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:25:54	-	14	3.635.945.803	-433.648.661	203.344	2.000	3.0	16	8	0.036	0.060	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:25:56	-	15	3.635.945.541	-433.647.866	203.297	2.000	3.0	17	8	0.036	0.060	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:25:57	-	16	3.635.945.450	-433.647.180	203.307	2.000	3.0	16	8	0.028	0.050	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:25:59	-	17	3.635.945.515	-433.646.502	203.322	2.000	3.0	16	8	0.028	0.050	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:26:00	-	18	3.635.945.527	-433.645.801	203.334	2.000	3.0	15	8	0.028	0.050	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:26:02	-	19	3.635.945.528	-433.645.017	203.315	2.000	3.0	15	8	0.028	0.050	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:26:03	-	20	3.635.945.766	-433.644.331	203.339	2.000	3.0	15	8	0.028	0.050	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:26:05	-	21	3.635.946.326	-433.643.896	203.325	2.000	3.0	15	8	0.028	0.050	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:26:06	-	22	3.635.946.933	-433.643.826	203.337	2.000	3.0	14	8	0.036	0.060	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:26:08	-	23	3.635.947.463	-433.644.140	203.313	2.000	3.0	15	8	0.036	0.060	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:26:10	-	24	3.635.947.818	-433.644.862	203.307	2.000	4.0	15	8	0.036	0.060	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:26:11	-	25	3.635.947.758	-433.645.542	203.308	2.000	3.0	16	8	0.036	0.060	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:26:13	-	26	3.635.947.641	-433.646.220	203.303	2.000	3.0	16	8	0.036	0.060	PISCINA	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:26:44	-	28	3.635.948.256	-433.649.435	203.310	2.000	3.0	17	8	0.028	0.050	XXX	-	RTK Fixed	1.0	0	0
P	Surveying	14/06/2020	11:30:15	-	29	3.635.951.311	-433.649.229	205.661	2.000	2.8	16	8	0.022	0.040	EPOCAS	-	RTK Fixed	1.0	10	0

Figure 89. GPS file example

Two files will be generated when exporting raw data, both with **.gps** extension:

- The first one with observation basic data (or the average of the observations if the point was taken using more than one epoch), for instance *"Example.gps"*.
- The other one is a detailed file with all observations of each point, for instance *"Example_Details.gps"*.

Two types of lines exist in this format. Lines starting with **#** contains project information:

- **Projected SRC**: Projected reference coordinates system.
- **Geodesic T. Datums**: Transformation of geodesic datums.
- **Vertica SRC**: Vertical reference coordinates system.
- **Vertical T. Datums**: Transformation of vertical datums.
- **Local system**.
- **dX, dY, dZ**: Additional offsets applied to local system.

Lines starting with **P** or **B** contains information about the measured points:

- Base (**B**) or Point (**P**).
- Source.
- System date.
- System time.
- Name of the reference base. If "-" is shown, the base was configured in other working session. When working using NTRIP server, the name of the node is added.
- Point name.
- WGS84 Latitude.
- WGS84 Longitude.
- WGS84 Altitude.
- Antenna height. Offset is not included.
- PDOP.
- Number of used satellites.
- Position type identifier.
- Horizontal precision.
- Vertical precision.
- Point code.
- File where the point is stored.
- Position type description (Fixed, Floating, Autonomous, etcetera).

This format is compatible with **Aplitop**'s **TcpMDT** office **software**, so that the points are drawn automatically in CAD, being able to also consult all the raw data, as well as the linked images and voice notes. It also has numerous tools to create digital terrain models, generate contour lines, draw profiles, calculate volumes, etc. See https://www.aplitop.com/applications-topographic.

14.4 Export of digital models

If the project contains digital models generated, they can be exported to **DXF** format with 3D faces.

When this option is selected, a dialog will be displayed requesting the user the name of the file where the model will be stored and the model to export, selected from a list.

14.5 Google drive data synchronization

Figure 90. Google Drive login

In ***Application*** menu, you will find the option Cloud services. Clicking on it you will access to the Google Drive synchronization service.

Once you are in the cloud services screen, you may start the synchronization. Clicking on ***Login*** button, a dialog showing the list of accounts configured in the device will be displayed. You can select one of these accounts or connect with a new one. If the process is successful, you can import files into your project from Google Drive and export your project to the cloud.

14.6 Project synchronization with Google Drive

Inside the submenu **Export** of the main menu you can find the option **Synchronize**. In the screen, the current project is selected with its local root folder to export and the folder **TcpGPSProjects** where the project will be stored in Google Drive. The **Upload** button will not be enabled if you did not login to your Google Drive account in the **Cloud Services** section (see **Export of digital models**

If the project contains digital models generated, they can be exported to **DXF** format with 3D faces.

When this option is selected, a dialog will be displayed requesting the user the name of the file where the model will be stored and the model to export, selected from a list.

Google drive data synchronization).

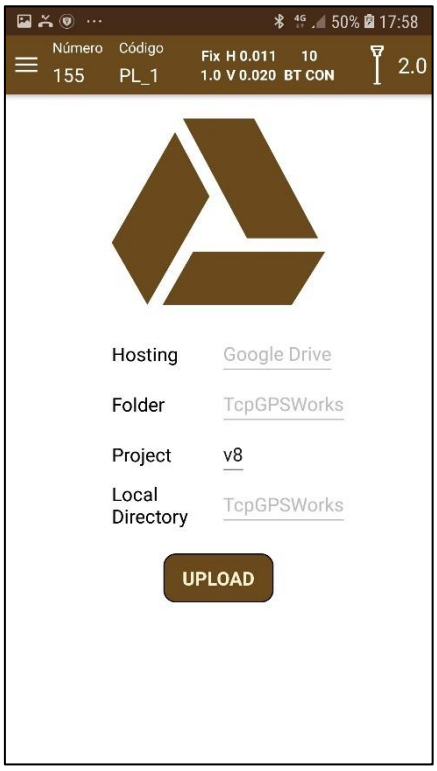


Figure 91. Uploading a project into Google Drive

In the mobile device where the TcpGPS application is executed, a directory structure will be created in the main memory of the device, which has the following structure:

```
+ Internal storage
     + aplitop
          + tcpgps
               + projects
                    + project_1
                         + img
                              - index.txt
                         + snd
                              - index.txt
```

The index.txt *files* present in the **img** and **snd** folders containing images associated with points and voice notes respectively, contain the relationship between said images and

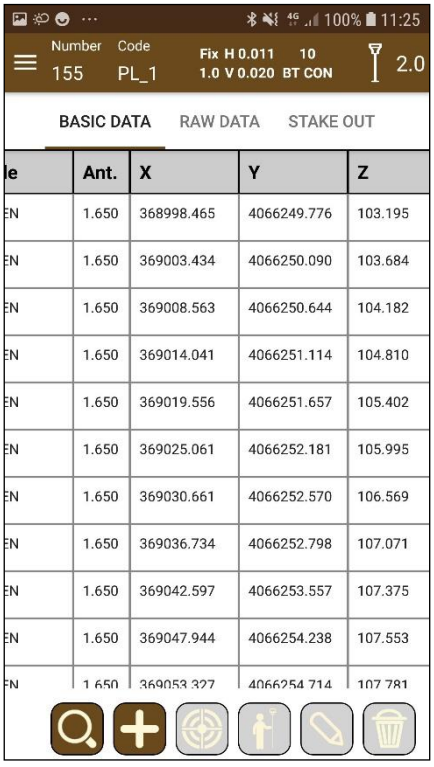
voice notes and the points to which they are associated, so that each line appears first the number of the point and then the name of the image or associated voice note.

14.7 Editing points list

Points gathered using TcpGPS are stored in the database associated with the project. The stored data can be viewed in the **List of points** in the **Edit** section (Figure 92).

14.7.1. Basic data

General information of the point as it was gathered, also considering the coordinate system used. Other information like whether the point has attached an image or a voice note is shown in that list in the form of icons.



le	Ant.	X	Y	Z
EN	1.650	368998.465	4066249.776	103.195
EN	1.650	369003.434	4066250.090	103.684
EN	1.650	369008.563	4066250.644	104.182
EN	1.650	369014.041	4066251.114	104.810
EN	1.650	369019.556	4066251.657	105.402
EN	1.650	369025.061	4066252.181	105.995
EN	1.650	369030.661	4066252.570	106.569
EN	1.650	369036.734	4066252.798	107.071
EN	1.650	369042.597	4066253.557	107.375
EN	1.650	369047.944	4066254.238	107.553
EN	1.650	369053.327	4066254.714	107.781

Figure 92. Basic data list

14.7.2. Raw data

Complete information of the point for later processing. Stored raw data fields are *date* and *time*, *source* from where the point was stored, *antenna height*, *latitude* and *longitude*, *height*, *position type*, *horizontal* and *vertical precisions* and *number of satellites*.

Figure 93. Raw data list

14.7.3. Staking out data

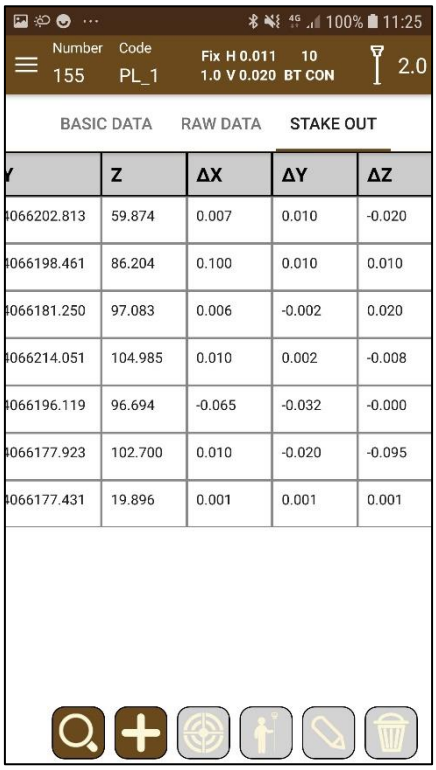


Figure 94. Stake out data list

Information for points that have been staked out. In this list are shown the differences between the point measured originally and the point got in the staking out process. The last staking-out performed on a point is only shown if it has been done several times.

14.7.4. Options

On these lists, you can search for specific points by their number or by their code, options are available in the button .

It is also possible to select a point from any list and select from a range actions to perform on it:

	This takes the user to the surveying section by centering the view on the selected point.
	This takes the user to the staking out section with the selected point ready to start the operation.
	This takes the user to the **Details of the point** section, from where information about the point can be viewed.
	Allow the user to add a point by typing its geographic or projected coordinates.
	Allow to remove the selected point.

14.7.5. Details of the points

This provides detailed information about the point, not only with respect to its numerical data, but also making it possible to associated multimedia information such as photos and voice notes with it. Additionally, it is also possible to edit the user data defined by the layer associated to the code of the point (see **Editing working layers: user data struct**).

This section is accessible from the **list of points** in **Editing points** section or by selecting a point in the map working mode and clicking the icon of information.

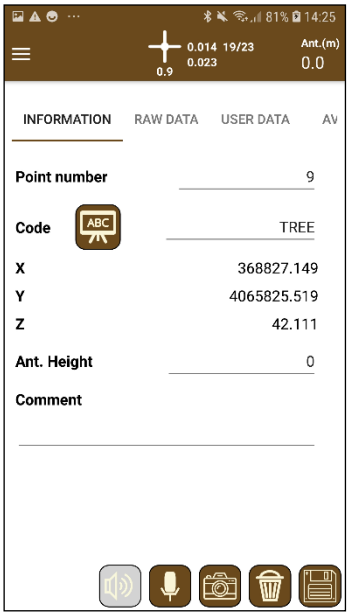


Figure 95. Basic point information

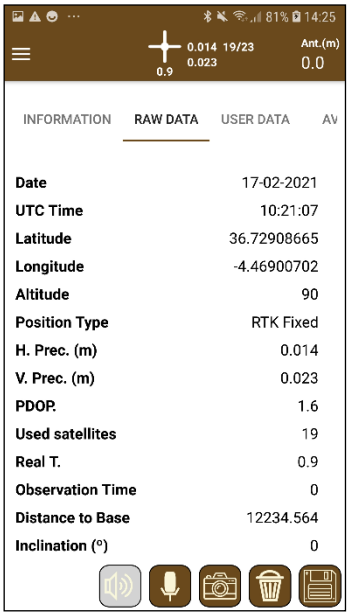


Figure 96. Raw point data

Figure 97. Information and multimedia data associated with the point

14.7.6. Details of the polylines

Like point features, polylines and polygons created in the survey may also have user data associated with it depending on the layer their code is associated with.

Appendix A. Transformations

In local systems you can define four types of transformations: **2D / 3D translations and 2D / 3D Helmert**. Below is the mathematical development of each of these transformations.

2D Displacements

Calculate the displacements x and y through the Arithmetic average of the differences between the origin and the destination. Only a couple of points are necessary.

Formulas:

$$x' = x + T_x$$

$$y' = y + T_y$$

where:

x ', y' = x, y transformed coordinates.

x, y = Original x, y coordinates.

Tx = Translation x.

Ty = Translation y.

Helmert 2D

It is also known as ***a 4-parameter similarity transformation***. The transformation process includes 3 steps: scaling, rotation and translations.

The first two are defined by a parameter each and the translations include 2. At least two pairs of points are necessary.

Formulas:

$$x' = (S \cdot \cos\theta) \cdot x + (S \cdot \sin\theta) \cdot y + T_x$$

$$y' = -(S \cdot \sin\theta) \cdot x + (S \cdot \cos\theta) \cdot y + T_y$$

where:

x ', y' = x, y transformed coordinates.

x, y = Original x, y coordinates.

S = Scale.

Θ = Angle of rotation.

Tx = Translation x.

Ty = Translation y.

3D Displacements

This type of transformation calculates the displacements x, y, z through the Arithmetic mean of the differences between the origin and the destination. Only a couple of points are necessary.

Formulas:

$$x' = x + T_x$$

$$y' = y + T_y$$

$$z' = z + T_z$$

where:

x ', y', z ' = x, y, z transformed coordinates.

x, y, z = Original x, y, z coordinates.

Tx = Translation x.

Ty = Translation y.

Tz = Translation z.

Helmert 3D

It is also known as ***the 7-parameter transformation***. The parameters involved are: three rotations, three translations and a scale factor. The rotation matrix is constructed by three consecutive turns around the x, y, z horizontal alignment. It is necessary to have at least 3 pairs of points.

Formulas:

$$x' = S \cdot (m_{11} \cdot x + m_{12} \cdot y + m_{13} \cdot z) + T_x$$

$$y' = S \cdot (m_{21} \cdot x + m_{22} \cdot y + m_{23} \cdot z) + T_y$$

$$z' = S \cdot (m_{31} \cdot x + m_{32} \cdot y + m_{33} \cdot z) + T_z$$

where:

x ', y', z ' = x, y, z transformed coordinates.

x, y, z = Original x, y, z coordinates.

S = Scale.

Tx = Translation x.

Ty = Translation y.

Tz = Translation z.

m11 ... m33= Coefficients of the rotation matrix.

Glossary

Datum Concept that describes the relations of position, orientation and scale of the ellipsoid reference with the Earth.

DGPS. Differential GPS code.

Ellipsoid Three-dimensional object generated by the rotation of an ellipse around the polar horizontal alignment of the Earth.

Epoch. Time at which a measurement is made by the receiver.

Geoid. Surface with a constant gravitational force.

GNSS Global Navigation Satellite System.

NMEA. Standard protocol for transmitting data from the GPS receiver to a computer (National Marine Electronics Associations).

NTRIP Networked Transport of RTCM via Internet Protocol.

RTK. Real-time kinematics.

SRC. Coordinates' reference system

URL Uniform Resource Locator.

WMS Web Map Service (Web Map Service).