GEOKON

GK-604D | *aos*
Inclinometer Readout
Application

User's Manual

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1. Introduction

The GK-604D is made up of three components:
- The Readout Unit, consisting of a smart phone or other Android device running the GK-604D|aos Inclinometer Readout Application (see Figure 1 and Figure 5).
- The GK-604D Remote Module, housed in a weather-proof reel enclosure containing the cable that directly connects to the inclinometer probe (see Figure 1).
- The inclinometer probe, either analog or digital. See Figure 1 (digital, 6100D-X) and Figure 6 (analog, 6100-1X).

Figure 1 – Model GK-604D, Digital Inclinometer System

The Android readout unit and Remote Module components communicate wirelessly using Bluetooth®, a reliable digital communications solution. This simplifies the handling of the system in the field as well as simplifying the transfer of data to your PC workstation for final analysis.

1.1 Features

Readout based on an Android device:

- Users will feel familiar with the Android operating system that is common to many smart phones.
- Long battery life, easily charged with micro USB cable.
- Ease of use.

Lightweight and simple Remote Module:

- Lithium battery (8+ hours of continuous use).
- One button operation; automatic power down when Bluetooth connection is dropped or after several minutes of inactivity.
- Rugged and weather resistant.
- Reliable connection to standard inclinometer probes (Figure 1) is accomplished via model 6000-2 control cable. This cable features a lightweight, polyurethane jacket, is less than 7 mm in diameter (see Figure *2*) and contains a central Kevlar® strand with a breaking strength of 150 kg.

Figure 2 - Model 6000-2 Control Cable (top)

Pulley Assembly

A pulley assembly is used to grip the control cable. This ensures that the cable markers are not dislodged from the cable as they might be using cable holds. The pulley assembly is shown in Figure 3 and the cable holds (now discontinued) in Figure 4.   The pulley style places no stress on the cable markers and removes any tendency for markers to slip over the cable as when using cable holds.

Figure 3 - Pulley style cable grip

Figure 4 - Cable holds (obsolete)

1.2 GK-604D | aos

The "GK-604D | aos" inclinometer readout application installs on devices running a minimum Android version of 4.0.3 (see Figure 5) and is designed to communicate via Bluetooth with Remote Modules connected to analog or digital probes (Figure 1 and Figure 6), both MEMS and force-balance type. For digital probes the Remote Module is fully contained within the reel as depicted in Figure 1.

For users with existing analog probes that are connected through an interface unit, GK-604-4 (see Figure 7), or via the GK-604-3 reel system, the GK-604D | aos application will continue to read this discontinued hardware.

Figure 5 – Android Field Device running GK-604D|aos

Figure 6 - 6000/6100 type probe

Figure 7 - GK-604-4 Interface

1.2.1 Compass Probes

In addition to standard inclinometer probes, the GK-604D|aos can also be used with Geokon's Compass Probe. See Appendix G for more information on these probe types.

1.3 Before using the GK-604D|aos

The readout software runs as an application under Android operating system (minimum of 4.03) installed on a smart phone or other Android device.

- The user should familiarize themselves with Android and the device running it.

- It is assumed in the instructions below that the user can launch applications on the Android device (including file manager applications) and manage Bluetooth settings.

- It is assumed that the user can use the on-screen keyboard to enter text and numbers.

- Check out the Maintenance requirements in Section 6.

2. Installation and Operation

The steps described in section 2.1 are an attempt to guide the user through the process of launching the GK-604D|aos, connecting to the probe and taking a survey. The steps below attempt to cover all cases and refer the user to the appropriate section of this manual when more information is needed.

NOTE: Always make sure that the inclinometer probe is attached to the reel before attempting the quick start sequence below.

2.1 Initial Quick Start Sequence

The following steps are a guide to the typical operation of the "GK-604D|aos" and, if followed, should result in a successful "hole" survey being taken:

A) If the Remote Module has not been previously connected to the Android field device or if a new Bluetooth pairing is needed, please see section 2.2 (Establishing Contact with the Remote Module).

B) Launch the GK-604D|aos by tapping on the "Apps" icon from the main screen of the Android device, then tap the "GK-604D aos" icon. If the GK-604D|aos application has not been installed, please see section 2.3 (Installing the GK-604D|aos).

GK-604D aos

C) If the screen shown in Figure 17 is displayed instead of the Main Screen (see Figure 25), please refer to section 2.4 (Starting the GK-604D|aos app for the first time) before continuing to step D.

D) If the Inclinometer System is a digital system (probe model numbers 6100D-E and 6100D-M), any new "probe" will be discovered upon connection to the Remote Module (covered in later steps).

E) At this point the "Main" screen should be displayed (see Figure 25), a "Project" and "Hole" should have been created and/or selected.

If connecting to an digital system for the first time, please select "UNKNOWN" for the hole parameter, "Probe Name:". If not the first-time connecting, skip to step H.

If connecting to an analog system for the first time, a "Probe" should have already been created in the Probe Library and the Probe's name selected for the current hole's "Probe Name:" parameter. If not the first-time connecting skip to step H.

F) If one is not selected already, select a hole by tapping on one of the holes listed in the main screen, then tap "Select" from the resulting pop-up menu.

G) Insure that the correct Bluetooth pairing is selected by tapping on "APP" then "System Configuration". From the System Configuration screen, make sure that the "Bluetooth Connection" parameter matches the current Remote Module to be connected to. If the Remote Module does not appear as a selection in the "Bluetooth Connection" "picker control, please refer to section 2.2 for more information regarding Bluetooth pairing. Dismiss the System Configuration screen.

H) Press the button labeled "POWER ON (BLUETOOTH)" on the Remote Module. A blue light should come on and start to blink, signifying that the Remote Module is waiting to connect to the android device.

I) From the "Main" screen (see Figure 25), tap the "APP" button. Start the connection process by tapping on the "Live Readings" button. Tap on "OK" from the resulting reminder prompt (see Figure 27). If the Remote Module fails to connect with the Android device, then the screen shown in Figure 28 will be displayed, indicating that either the Remote Module is no longer trying to connect (timed out), that the Bluetooth pairing is associated with another device or Bluetooth is disabled. Make sure that the proper device is selected in the System Configuration settings, then try to connect again.

After a few seconds, the blue light on the Remote Module should change to a steady state blue (lit but not flashing).

If connecting to an analog system, or to a digital system that's been previously connected to, the Live Readings Screen will be displayed (see Figure 30). Skip to step J.

If connecting to a digital system for the first time (or the probe has changed):

a. If the window shown in Figure 8 is displayed, then the probe has not been previously detected by the GK-604D | aos. In this case, tapping "Yes" will cause the probe to be added to the Probe Library and the Probe Settings screen shown in Figure 9 to be displayed. This allows an opportunity to give the newly detected probe a user friendly name and description. See section 4.2, Probe Configuration for more information on probe settings. When satisfied with the settings, tap "<" in the upper-left corner of the screen to exit (and save) the Probe Settings screen (see Figure 9).

Because the Probe Name parameter was set to "UNKNOWN" in step E, the window in Figure 10 will be displayed, allowing the name of the probe just

found to be saved into the current hole configuration.

b. The Live Readings Screen will be displayed (see Figure 34).
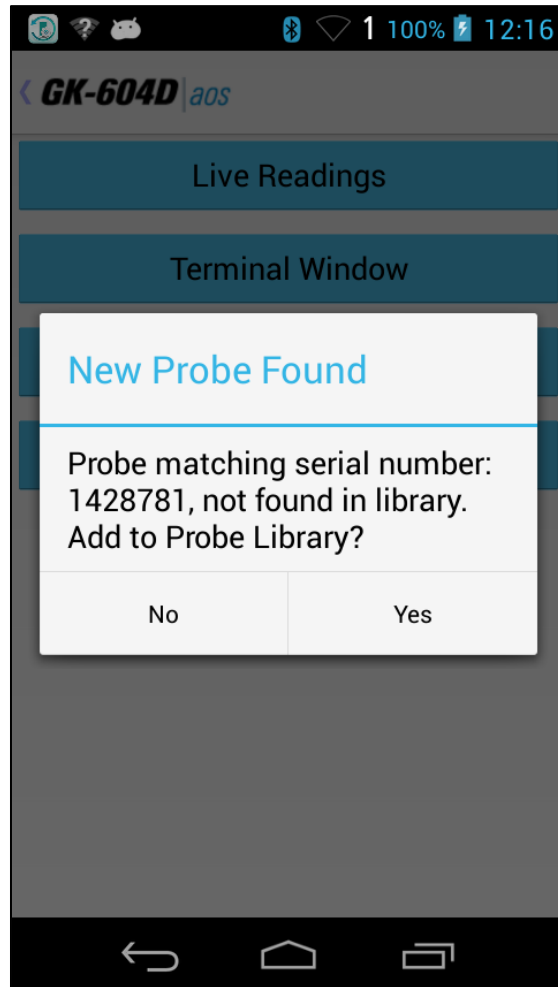
Figure 8- New Probe Found

Figure 9 - Initial Probe Settings
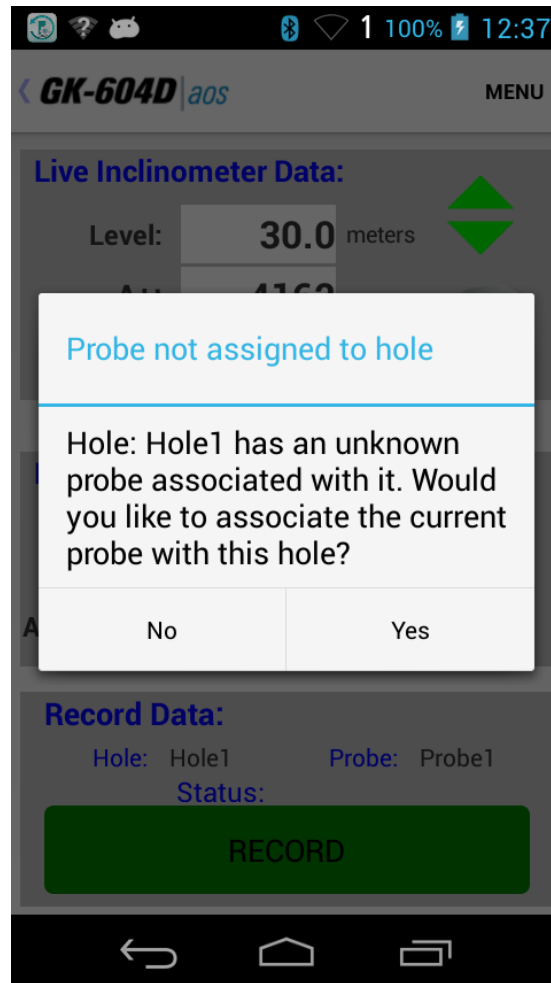
Figure 10 - No Probe Association Screen

J) Refer to section 3.3.1 for more information about taking a survey using the Live Readings window. Also refer to section A.2 for information regarding the mechanical process of taking a survey.

K) After performing a survey, any saved data corresponding to a particular hole survey may be reviewed and/or reports generated by tapping the "File" menu then "View Data". See section 3.3.3 for more information about the View Data option.

L) Raw data files may be exported to a file system folder of the user's choosing by tapping on "File" then "Export data to file". See section 3.3.1.1 for more information regarding data export options.

M) To close the GK-604D | aos, tap on the Android "Recent Apps" button, then dismiss the GK-604D | aos application.

2.2 Establishing Contact with the Remote Module

The procedure below should be done once for each Remote Module that the Android device will be communicating with. Follow the steps below to ensure the 'partnership' with the Remote Module is established before using the readout application:

1. Enter the Settings screen of the Android device (see Figure 11). Insure that the slider next to the "Bluetooth" parameter is set to "ON". Tap "Bluetooth" to begin setting up a Bluetooth "partnership" (**Note**: For some Android versions the Bluetooth On/Off control may only appear on the Bluetooth Pairing screen (see Figure 12).
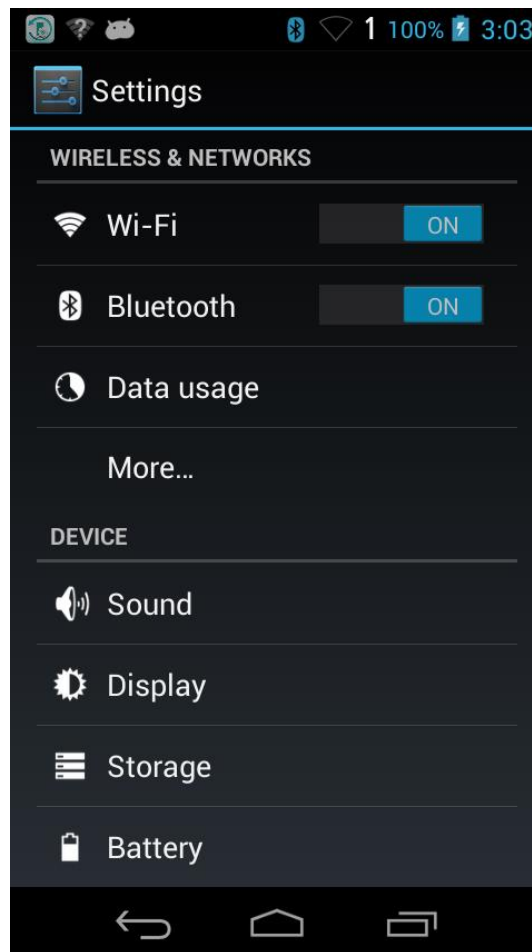
Figure 11 - Android Device Settings Screen

2. Press the button labeled "POWER ON (BLUETOOTH)" on the Remote Module before tapping "SEARCH FOR DEVICES" from the Bluetooth Pairing screen (see

Figure 12) to instruct the Android device to begin searching for available Bluetooth devices to pair with.
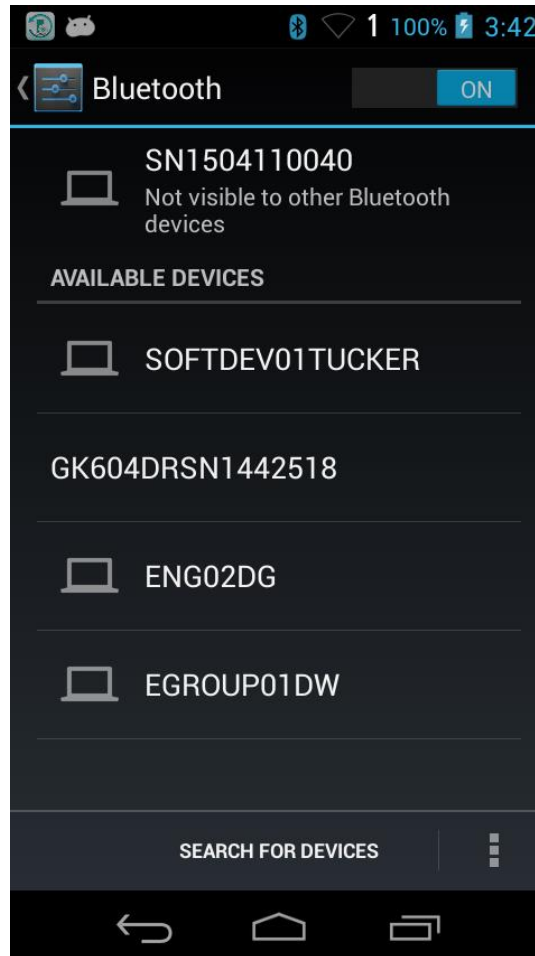
Figure 12 - Bluetooth Pairing Screen

3. Geokon Remote Modules typically have device names that start with "GK604DRSN" followed by the serial number of the reel. As shown in Figure 12 there is an available device called "GK604DRSN1442518". Tap on the device to begin the pairing process (see Figure 13). Where requested, enter the PIN "default" and tap "OK". If the device pairing is successful then the new paired device will be displayed under "Paired Devices" in the Bluetooth setting screen as shown in Figure 14.
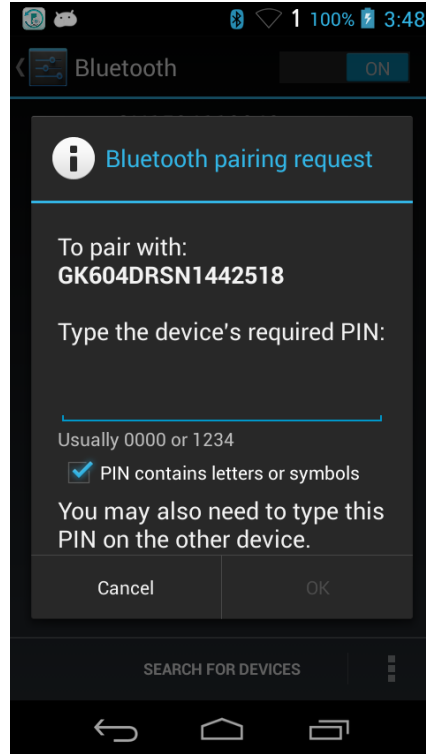
Figure 13 - Bluetooth Pairing Request Screen
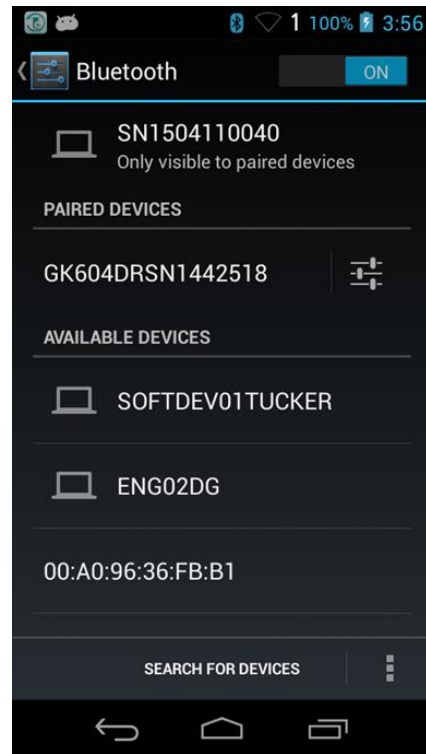
Figure 14 - Paired Devices

2.3 Installing the GK-604D | aos Application

The installation of the GK-604D | aos Application requires the following:

- Android device with cell phone capability (and data plan) or wireless internet connection to allow access to Google Playstore. Alternatively, a USB connection from the Android device to a host PC, allowing file transfer of the application ".apk" install file.
- Android device with version 4.0.3 (Ice Cream Sandwich) or higher operating system.
- The Android device must have at least 50 Mbytes of free memory and be Bluetooth enabled.

2.3.1 Installing GK-604D | aos from Google Playstore

From the Android device, tap on the "Google Play Store" icon to launch Google Play application (see Figure 15).
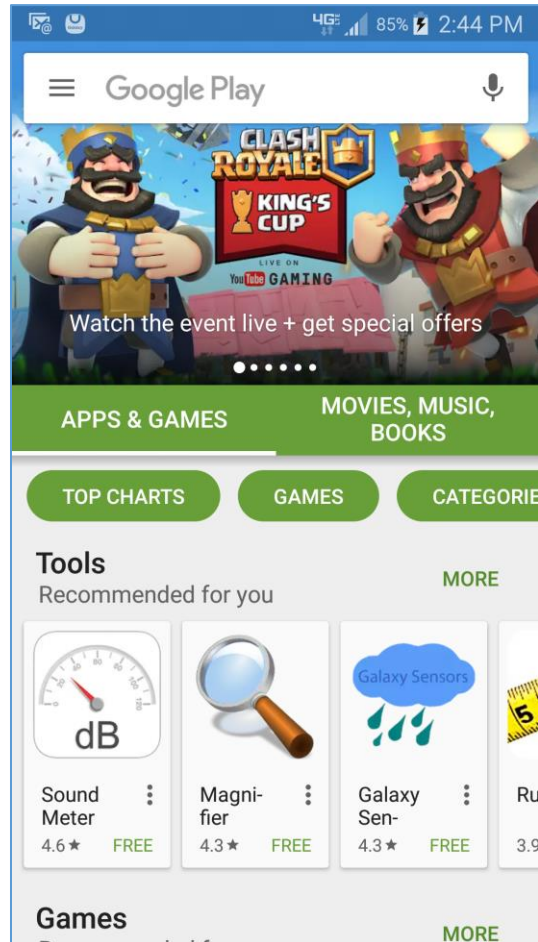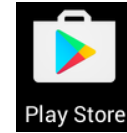
Figure 15 - Google Play Store Application

In Figure 15 above, enter the text, "GK-604D", into the Google Play search bar. Selecting "GK-604D | aos Inclinometer…" from the search results screen will display the "GK-604D | aos Inclinometer App" install screen (see Figure 16).

After tapping on "Install" the app will begin the install process. Follow the on-screen instructions to finish the GK-604D | aos application
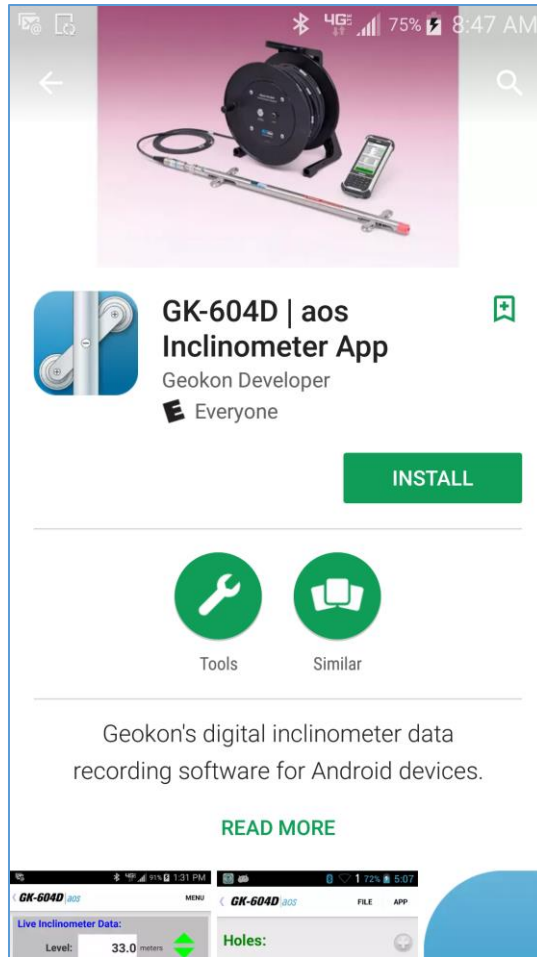
Figure 16 - Geokon GK-604D | aos Install Screen

2.3.2 Installing GK-604D | aos via USB link to Host PC

The GK-604D | aos application can also be installed by copying an Android Application Package (.apk) file to the Android device from a host PC. The process is as follows:

1. Download the zipped installer from Geokon's software download web-page. File is called: "com.geokon.GK_604Daos-Aligned.zip ".

2. Open a Windows Explorer window and unzip the downloaded GK-604D | aos installer.

3. Copy this installer (com.geokon.GK_604Daos-Aligned.apk) to a directory on the Android device that can be easily accessed from the device's internal File Manager such as "Card" or "External Storage".

   Note: directory names can vary with different versions of Android as well as different manufacturers of Android devices.

4. Disconnect the USB cable from the PC to the Android device.

5. Using an Android file manager application, find the file copied from the PC and tap on it to start the install process.

6. If asked, select "Complete action using Package Installer".

7. Follow the on-screen instructions to finish the install.

2.4 Starting the GK-604D | aos for the first time

The readout software is launched by tapping the Android "Apps" icon followed by the "GK-604 aos" icon from the "Apps" screen.

When starting the GK-604D | aos application for the first time, the screen shown in Figure 17 will be displayed. The GK-604D | aos uses "Workspaces" as the primary storage for "work". In the case of the GK-604D | aos, "work" consists of individual "projects" where hole configuration and data are stored.

Much like "Workspaces", "Probe Libraries" are where probe configurations are stored. Initially no workspaces or probe libraries have been defined.
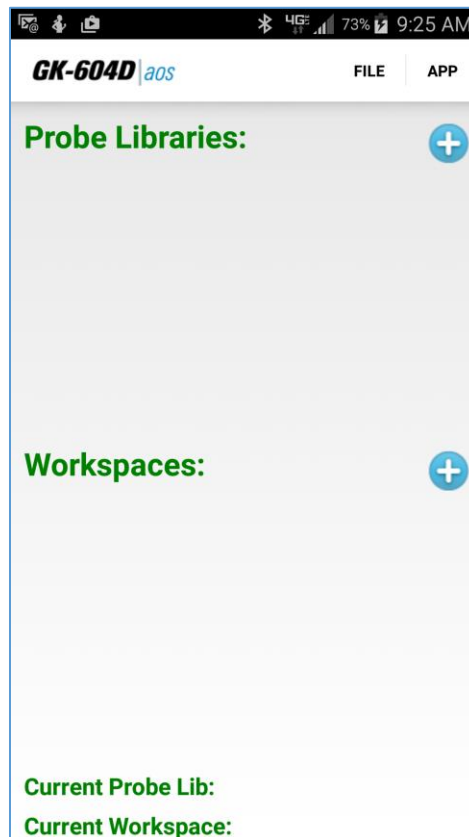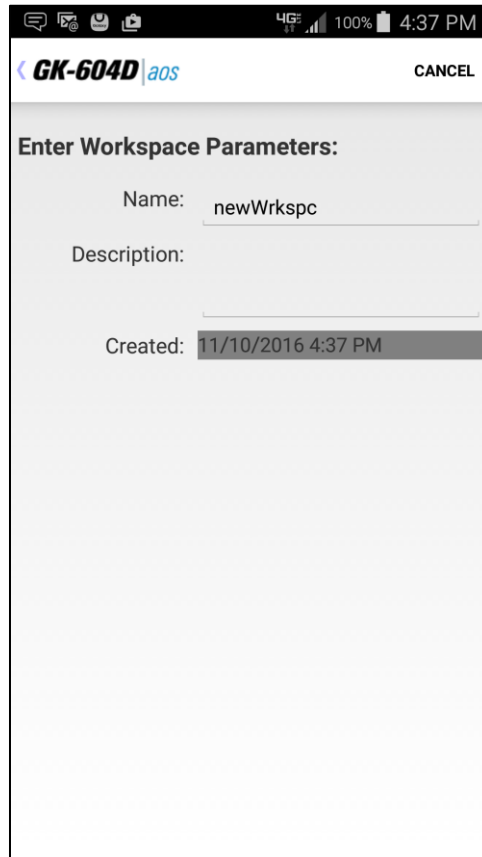
Figure 17 - Initial Screen

A new workspace can be created by tapping the "+" sign immediately to the right of the green "Workspaces:" label. Doing so causes the Workspace Settings screen to be displayed (see Figure 18). The workspace name parameter can be any combination of letters and numbers, should be descriptive in nature and is the only

required parameter for a workspace. After creation, this name will be displayed in the "Workspaces" list. Any number of workspaces can be created. The Workspace Settings screen is saved and dismissed by tapping the "<" symbol in the upper-left hand corner of the screen.

Figure 18 - Workspace Settings Screen

After the workspace has been created, a probe library should be created in a similar fashion to the workspace. The Probe Library Settings screen is shown in Figure 19. Just as with the workspace, only the probe library name is a required parameter. The Probe Library Settings screen is saved and dismissed by tapping the "<" symbol in the upper-left hand corner of the screen. After creation, this probe library name will be displayed in the "Probe Libraries:" list.

With both workspaces and probe libraries, the name parameter must be unique.

Figure 19 - Probe Library Settings Screen

For Analog Inclinometer Systems only: A probe should be created in the new probe library at this time. Tapping on the new probe library's name in the "Probe Libraries" list causes a pop-up menu to be displayed. Tap "Select" from this menu to cause the Probes screen to be displayed. See section 4.2 for more information about probe configuration.

After the initial workspace and probe library are created (see Figure 20) the new workspace should be selected to advance the program flow to the Projects screen. Select a workspace by tapping on a name in the "Workspaces:" list. Tap "Select" as shown in Figure 21, causing the Projects screen to be displayed (see Figure 22).

Figure 22 shows the Projects screen with the newly created workspace and probe library displayed as "Current Workspace:" and "Current Probe Library:" respectively. Notice that there are no projects in the "Projects" list and no "Current Project". New projects can be added to the current workspace by tapping on the "+" sign to the right of the green "Projects:" label. As with workspaces and probe libraries, the only

required parameter for projects is "Name". The Project Settings screen is saved and dismissed by tapping the "<" symbol in the upper-left hand corner of the screen.
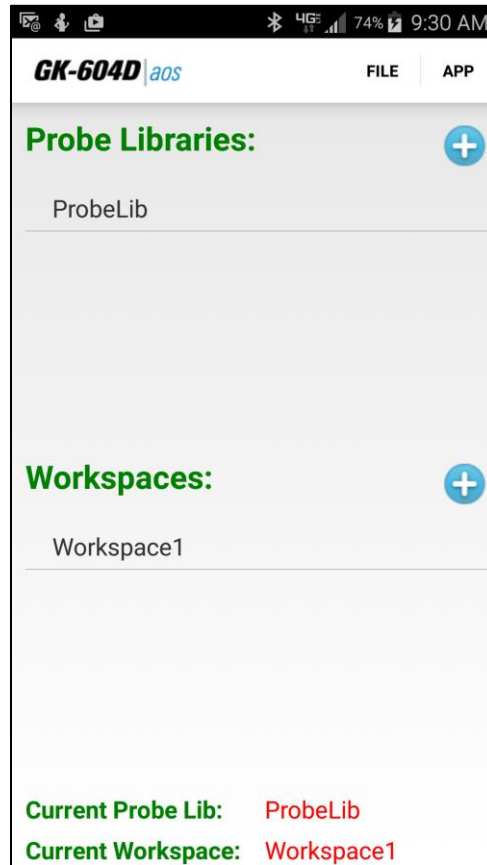
Figure 20 - Workspace and Probe Library Created

After dismissing the Projects Settings screen, select the new project by tapping on the new project name in the "Projects" list. Tap on "Select" from the resulting pop-up menu to cause the Holes screen to be displayed (see Figure 23).

New holes can be added to the current project by tapping on the "+" sign (to the right of the green "Holes:" label), causing the Hole Setting screen to be displayed (see Figure 24). Unlike workspaces, probe libraries and projects, most hole parameters are required. See section 4.1 for more information about hole configuration.
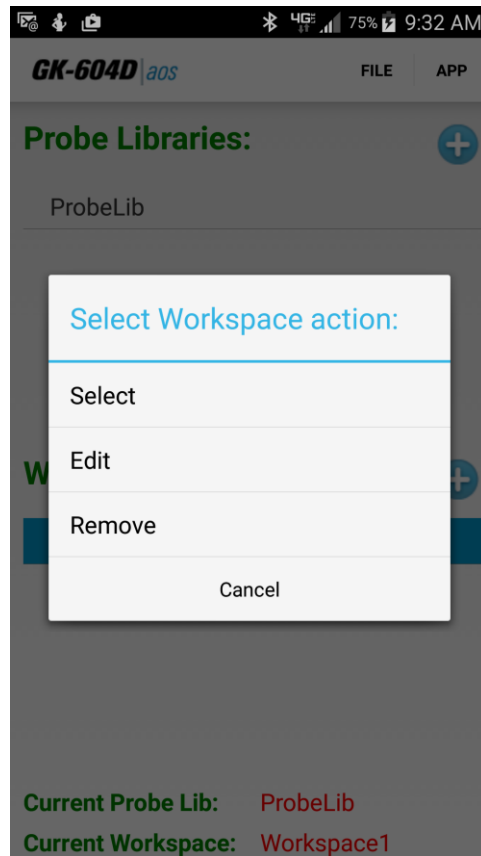
Figure 21 - Select Workspace

After saving and dismissing the Hole Settings screen, the GK-604D | aos application is nearly ready to take live readings. Please refer to section 2.1 (Initial Quick Start Sequence), starting with step "D".
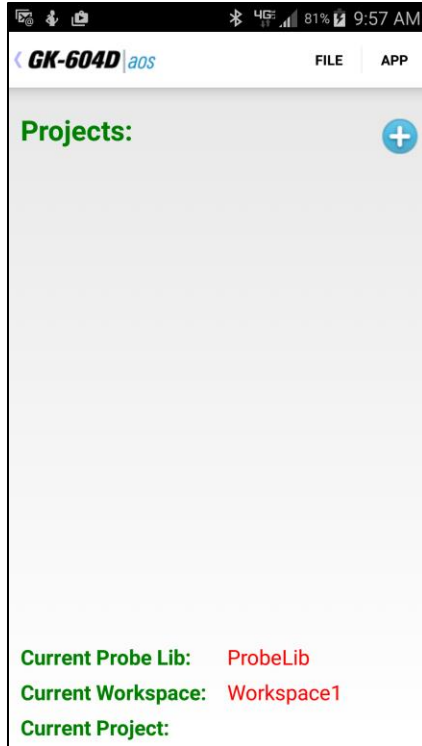
Figure 22 - Projects Screen

Figure 23 - Holes Screen

Figure 24 - Hole Settings Screen

3. User Interface

3.1 Overview

The GK-604D | aos user interface contains a number of navigation controls designed to make the job of selecting application elements and functions easier. These navigation controls present an organizational view of the active workspace, inform the user about the state of the application, and provide the user with tools to configure and control Geokon devices.
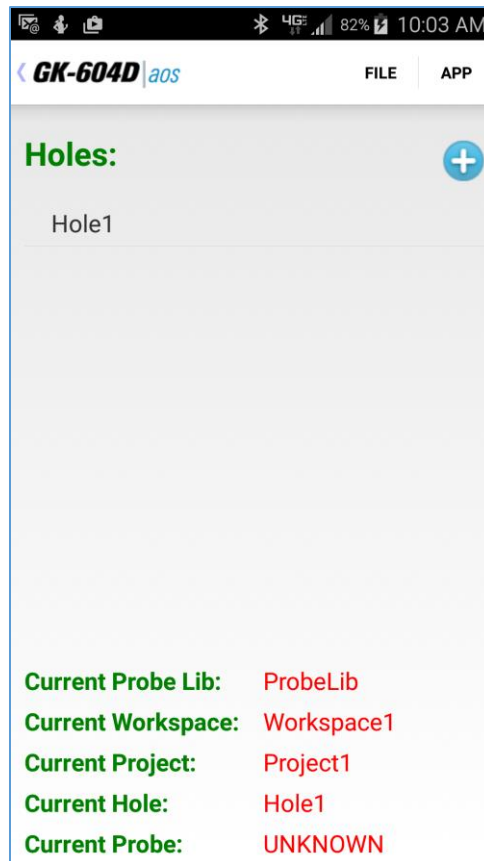
Figure 25 – Main Screen

The GK-604D aos User Interface is comprised of the following components:

"APP" Menu   Allows display of live readings, a debug terminal, installed application status and system configuration.

"FILE" Menu — Data exporting, importing and deletion. Data view/reporting options.

Status Area — Displays the currently selected hole and probe, project, workspace and probe library.

‹ GK-604D | *aos* — Navigation "back" button, also save any pending edits.

A more detailed description of the "APP" and "FILE" menu appear below:

3.2 APP Menu

The GK-604D | aos "APP" menu provides access to high level application functionality. It is located in the upper-right corner of the main window screen (see Figure 25). Tapping on the "APP" menu causes the screen shown in Figure 26 to be displayed. The APP menu sub-items are further described in the sub-sections below:
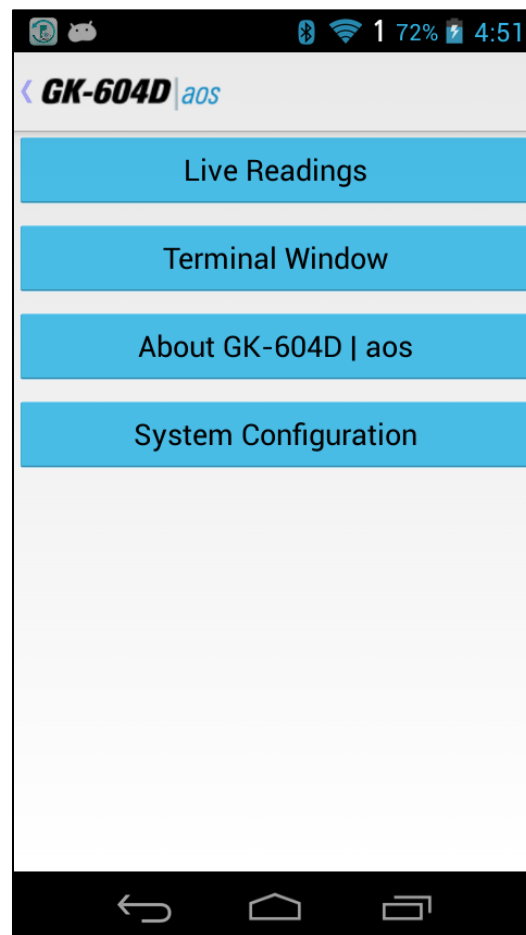
Figure 26 - APP Menu

3.2.1 Live Readings

Tapping on this menu item initiates the Remote Module connection process and after a successful connection, the Live Readings screen will be displayed (see Figure 30). Should the connection attempt fail, the window shown in Figure 28 will be displayed. The usual problems are: no pairing between the Remote Module and the Android device and/or Bluetooth is not enabled on the Android device.

Note: When attempting to connect to the Remote Module, please ensure that the "Power On" button on the Remote Module has been pressed (blue light will be blinking) before tapping on the "Live Readings" menu item. Figure 27 shows a reminder to turn on the Remote Module before connecting.
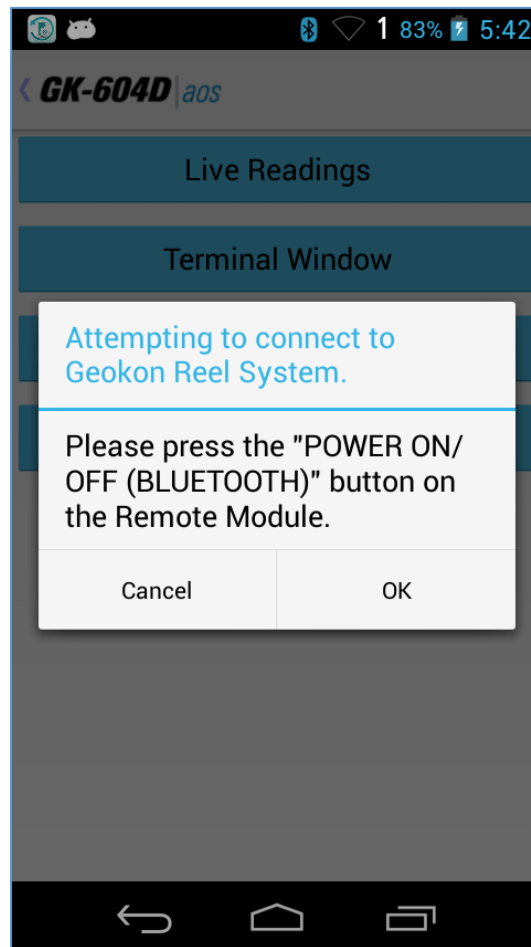
Figure 27 - Remote Module Power-On Reminder
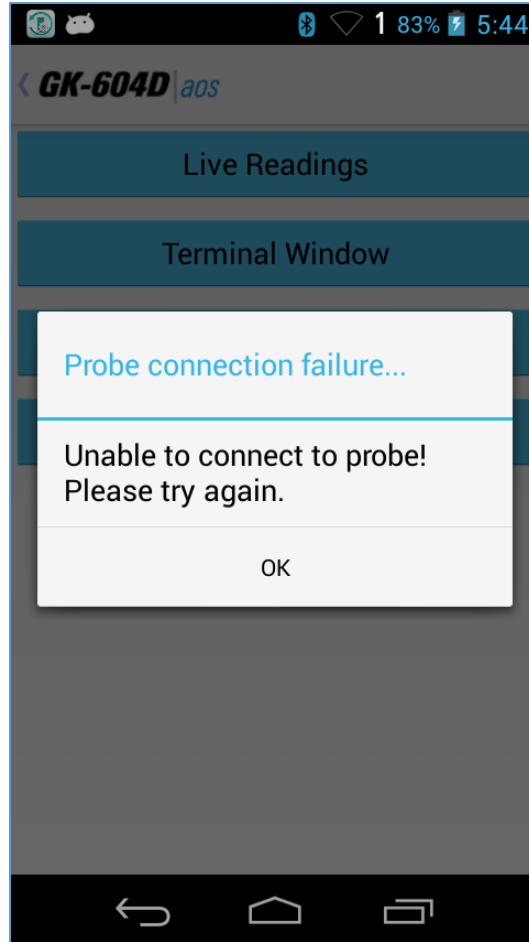
Figure 28 - Remote Module Connection Problem

After the Remote Module successfully connects to the Android device, the blue "POWER ON" indicator will transition from blinking to steadily lit and one of two possible screens will be displayed:

1. The "Live Readings" screen is displayed (Figure _30_).

2. Figure 29 shows the message displayed if the GK-604D | aos detects temporary data left over from a previous survey that wasn't saved. Tapping "Yes" loads the temporary data and then displays the Live Readings (see Figure 30). Tapping "No" displays the Live Readings (see Figure 30)
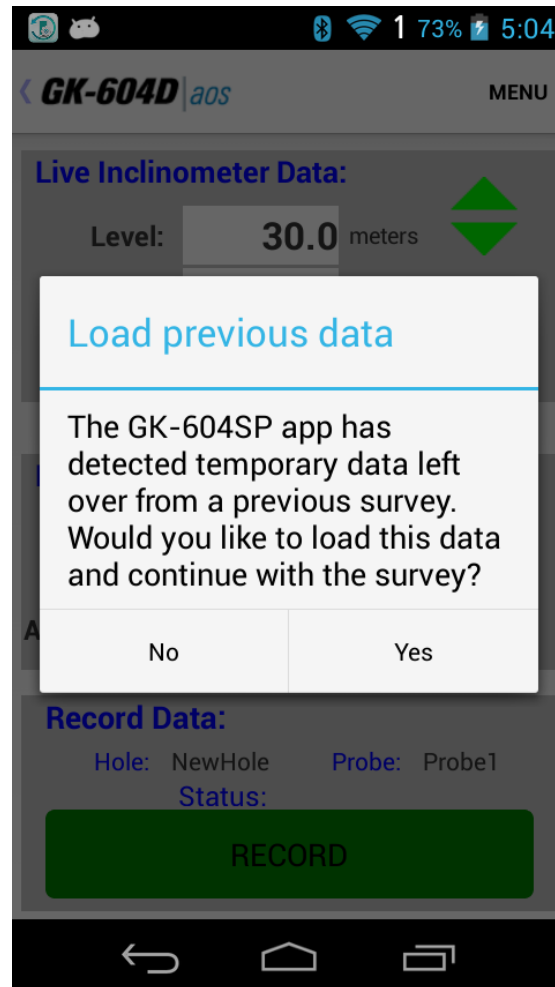
Figure 29 - Temporary File Data Prompt
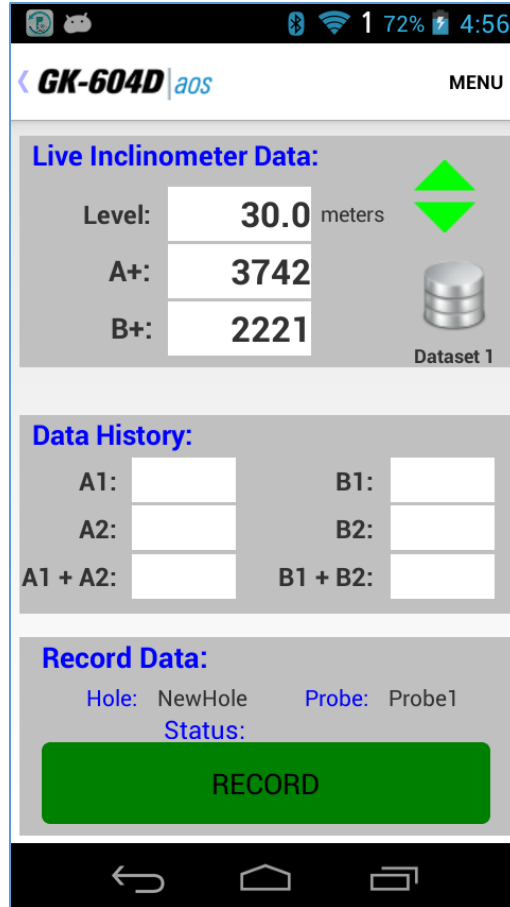
Figure 30 - Live Readings Screen

The Live Readings screen (see Figure 30) is where all survey data points are read from the probe and stored in application's database. Readings are continuously updated from the Remote Module. The data set always starts with 'Dataset 1' but can be switched at any time to 'Dataset 2' (after rotating the probe 180 degrees).

- At the start of a survey, the 'Level' is set to the "Starting Level" configured for a particular hole. Tapping the large green "Record" button (with a finger or tap of the stylus) records the displayed set of A and B values and automatically changes the 'Level' (on screen) by the amount based on the hole configuration "Interval" value (see section 4.1).

- A sound may be heard when the "Record" button is tapped, depending on the Android device's settings, confirming that the reading has been stored. If no beep is heard, press the "Up Volume" control at the top right or left side of the Android device to adjust the volume.

- Be sure to move the probe to the new level and wait for the readings to stabilize before recording the next reading.

- At any point you can scroll the 'Level' using the green up and down arrow buttons on the screen and view data stored and checksums ("Data History:" section of the screen). When done taking readings, tap "< GK-604D|aos" to dismiss the screen. The application will detect **‹ GK-604D** *aos* if readings have been recorded and if so, an opportunity to save the readings (see Figure 31) will be presented to the user.

  o Even if "No" is selected from the Unsaved Data Prompt (see Figure 31), the readings will be saved to a temporary database table and can be restored the next time "Live Readings" is entered (see Figure 32 and Figure 33).

  o If "Yes" is selected from the Unsaved Data Prompt (see Figure 31), then the readings will be saved to the database and the survey will be saved with the name given to it in the Survey Metadata Settings (see section 3.2.1.1, Survey Metadata topic). If no name was entered in the Survey Metadata Settings, the survey will saved using a 3-digit numerical suffix combined with the "Hole" name. For example if there was 4 previous surveys saved for a hole with the name of "HL123_Dam75", the new survey would be named: "HL123_Dam75_005".
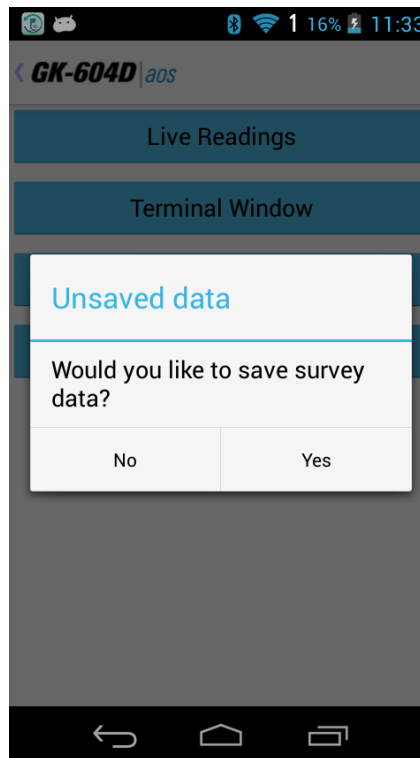
Figure 31 - Unsaved Data Prompt
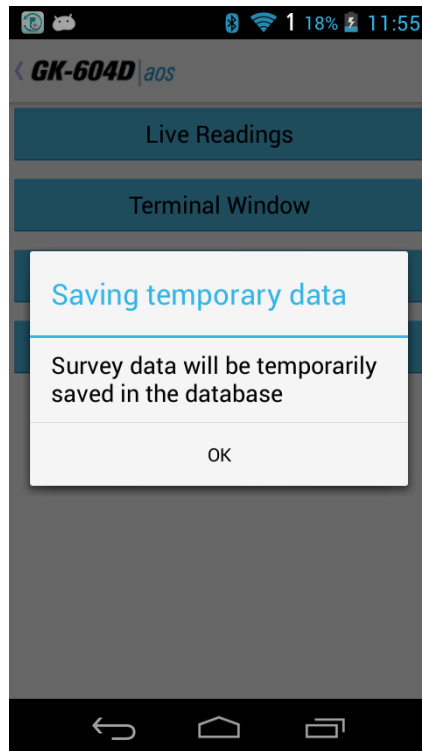
Figure 32 - Saving Temporary Data
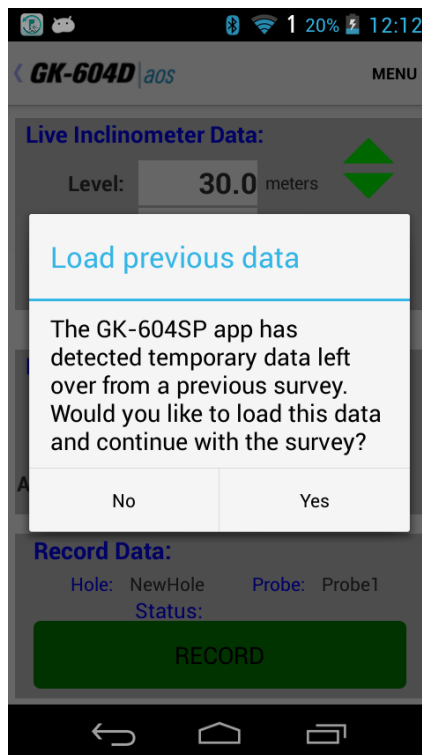
Figure 33 - Load Previous Data Prompt

See section 3.3.5 (System Configuration) for more information about options that affect Live Readings and taking surveys.

3.2.1.1 Live Readings Screen Menu Options

Figure 34 shows the available options from the Live Readings "Menu" item when a Digital Inclinometer/Compass probe is detected. These options are described below:
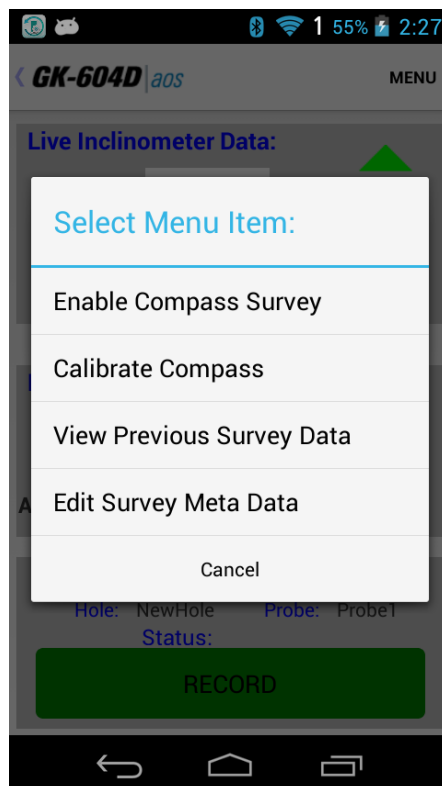
Figure 34- Menu option (Live Readings screen)

Enable /Disable Compass Survey

For GK-604D systems with a reel firmware version of V2.7 (or greater) AND a probe firmware version of V2.7 (or greater), capability exists to take a Compass Survey of the selected hole at the same time as the inclinometer survey. This menu item is only shown if a compass probe is detected. See Appendix G for a complete description of the integral Compass portion of the inclinometer Probe. Tapping this menu item will enable the digital compass, dismiss the menu and cause a message the message, "Compass enabled, survey will take longer", to be displayed. Tapping the Live Readings "MENU" icon with the compass enabled yields the menu options shown in Figure 35.
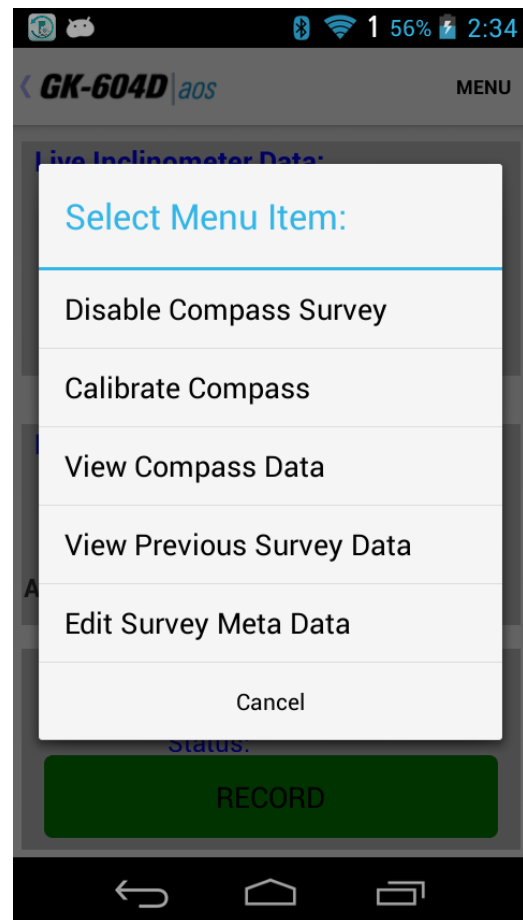
Figure 35 - Live Readings Menu Options (Compass Enabled)

Calibrate Compass   Tapping this item causes the Compass Calibration dialog to be displayed where a procedure to calibrate the Digital Inclinometer/Compass probe can be followed. This menu item is only shown if a compass probe is detected. See Appendix G for a complete description of the Compass Calibration procedure.

View Compass Data   When a compass survey is enabled, this menu item is enabled and allows the compass heading to be displayed in place of inclinometer "A" data. This item toggles between "View Compass Data" and "View Inclinometer Data" depending on the data currently being viewed (see Figure 36 and Figure 37). This menu item is only shown if a compass probe is detected. See Appendix G for a complete description of the Compass Probe.
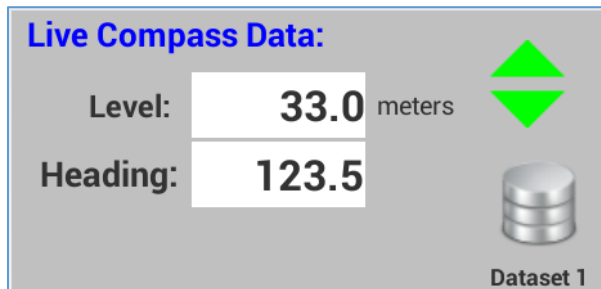
Figure 36 - Viewing Compass Data
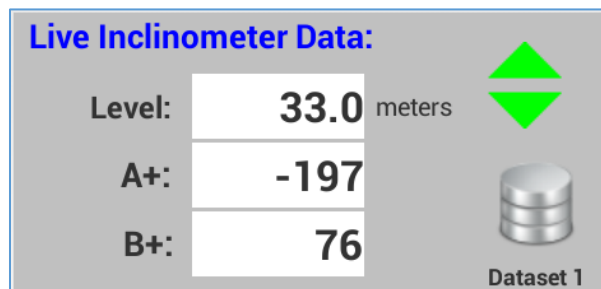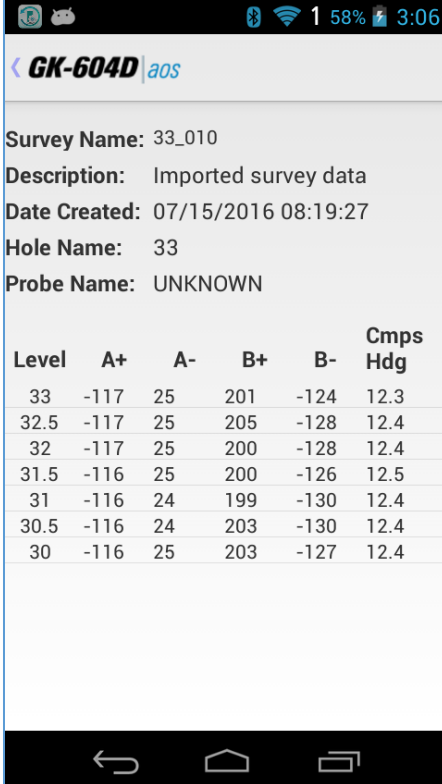
Figure 37 - Viewing Inclinometer Data

View Previous Survey Data

Allows viewing (and loading) of previous survey data. When tapped, the user must first select the previous survey to view. After selecting a survey, the screen shown Figure 38 will be displayed. After dismissing this window by tapping "<", a prompt is displayed asking the user if they'd like to load this survey. Tap "Yes" to load the data or "No" to continue with the current survey.

Figure 38 - View Previous Survey

Edit Survey Meta Data

When tapped, the application will display the edit screen shown in Figure 39. The Meta Data Editor allows a survey to be named and a brief description added. Optionally a picture can be selected/taken of the site and saved to the Android file system. Buttons to take and select photos (from the gallery) are off the screen when this editor is first launched and must be scrolled down to (see Figure 40).
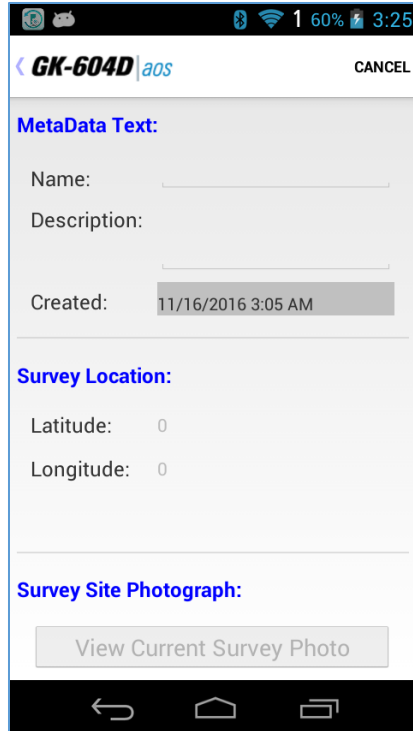
Figure 39 - Meta Data Editor
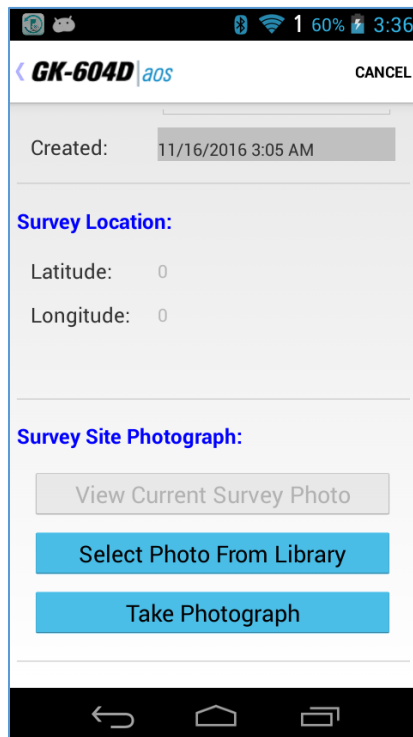
Figure 40 - Meta Data Editor (Screen 2)

3.2.2 Terminal Window

This feature requires an active connection to a Remote Module and will attempt to connect when invoked. If a connection cannot be made, the window shown in Figure 28 will be displayed.

If a connection can be made, the window shown in Figure 41 is displayed. Using the "Terminal Window" requires the use of the on-screen keyboard to enter simple one or two character commands to the Remote Module. See Appendix D for more information regarding the Remote Module command structure.

After typing in a command, tapping the "Send (CR)" button will cause the command to be sent to the Remote Module. Figure 41 shows the response to a Firmware Version command (4).
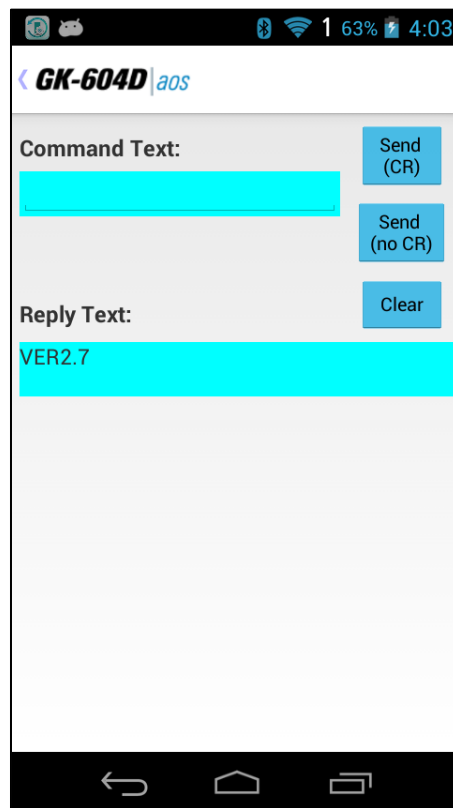
Figure 41 - Terminal Window

Alternately, tapping the "Send (no CR)" menu gives the user the ability to send a character to the Remote Module without a Carriage Return (CR) appended to the character string. This is useful when a confirmation character is required (such as for the calibration routine) but no carriage return.

3.2.3 About GK-604D

This displays an information panel giving copyright information as well as the application version (see Figure 42). Tapping on the "Remote Module Status" button will display another screen reminding the user that a probe must be connected to a Remote Module and the Remote Module ready to connect (blue light blinking) (see Figure 27).
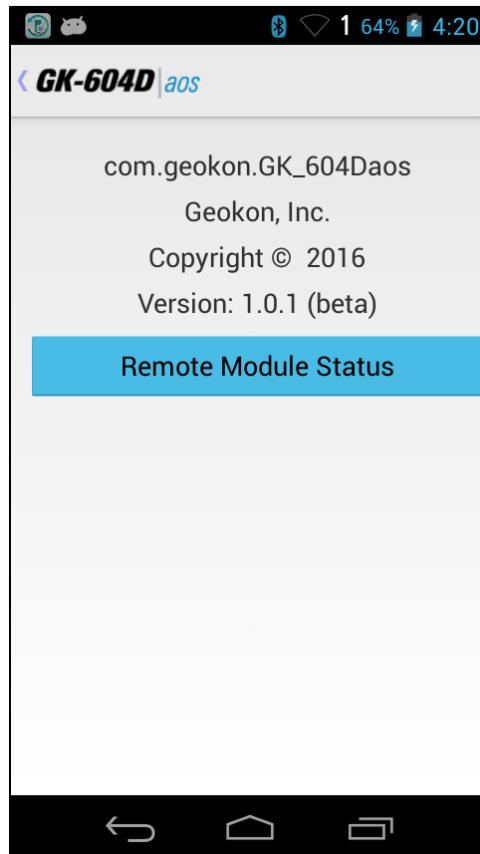
Figure 42 - About GK-604D IRA

Tapping on the "OK" icon from the reminder prompt causes the GK-604D | aos app to initiate the connection process with the Remote Module. If the connection is successful then the screen shown in Figure 43 is displayed, giving status about the Remote Module and probe.
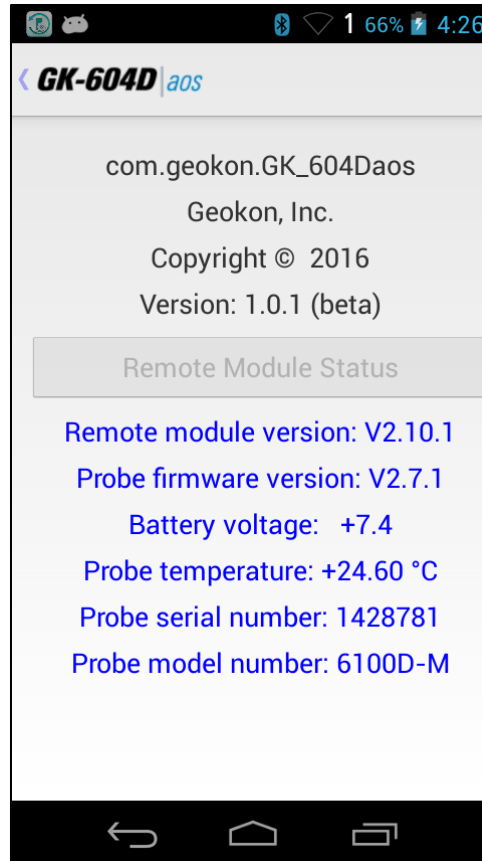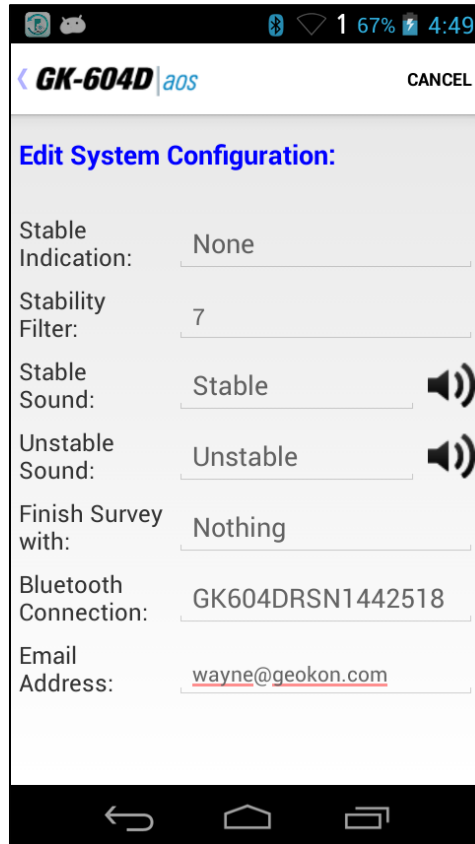
Figure 43 - Remote Module/Probe Status

Figure 43 depicts the status available for a digital Remote Module and probe. For analog systems, only the Remote Module version and battery voltage is listed.

3.2.4 System Configuration

This screen allows selecting options that affect how the system works and how surveys are taken (see Figure 44). The sub-sections that follow describe each parameter in detail.

Figure 44 - System Configuration

3.2.5.1 Stable Indication:

Valid choices for this selection include:

None　　　　On the Live Readings Screen, the only indication of stability will be to monitor the A and B readings (see Figure 30).

Visual Only　　When this stability indication is selected the "Record" button is displayed on the Live Readings Screen in the color green if the reading is stable (Figure 30) or in the color red if the reading is unstable (see Figure 45).

Visual/Audible　When this stability indication is selected, in addition to the "Record" button colors described above, an audible indication is played indicating readings stability or instability (see Figure 44 and Figure 45, as well as sections 3.2.5.3 and 3.2.5.4).
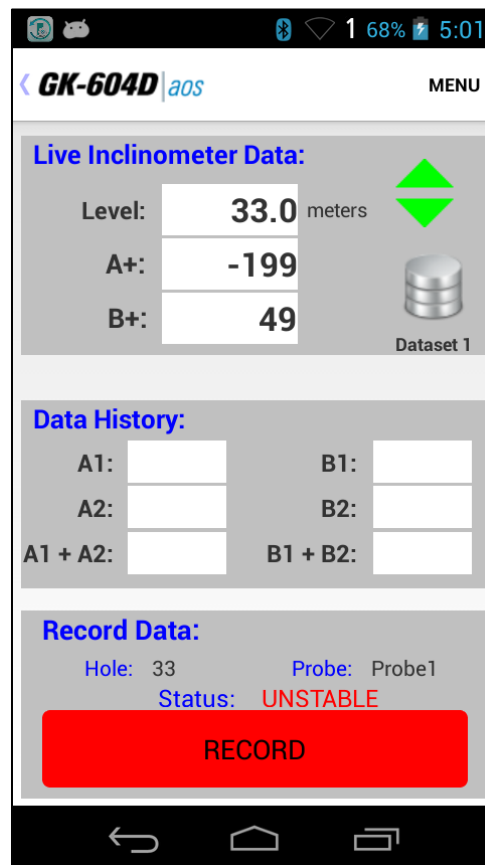
Figure 45 - Unstable Indication

3.3.5.2 Stability Filter:

If the "Stable Indication" (see section 3.2.5.1) selection is set to something other than "None", this parameter will be enabled and an integer number can be entered. This number is used to determine readings stability (a value less than 10 is recommended).

When taking live readings, if the difference between two subsequent readings of the A **and** B channels are less than or equal to the "Stability Filter" then the reading will be deemed stable and, if enabled, the "Stability Indication" icon (see Figure 30 and Figure 45) will be set accordingly.

3.3.5.3 Stable Sound:

If the "Stable Indication" (see section 3.2.5.1) selection is set to "Visual/Audible", this parameter will be enabled and a drop-down list will display the choices of "sounds" that the HHD can make when a stable reading is achieved in the "Live Readings" screen (see Figure 30).

Tapping on the icon to the right of the "Stable Sound" selection plays a preview of the actual sound heard.
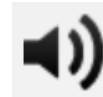
3.3.5.4 Unstable Sound:

If the "Stable Indication" (see section 3.2.5.1) selection is set to "Visual/Audible", this parameter will be enabled and a drop-down list will display the choices of "sounds" that the HHD can make when the readings achieved in the "Live Readings" screen are determined to be unstable (see Figure 45).

Tapping on the icon to the right of the "Unstable Sound" selection plays a preview of the actual sound heard.

3.2.5.5 Finish Survey with:

This parameter deals exclusively with "unfinished" survey data files. A survey is unfinished if readings were not taken at each level from starting up to the zero level. Many surveys may not completely finished because the geometry of the probe will not allow the last reading or two to be taken while the probe is still in the casing.

NOTE: Surveys MUST start at the "Starting Level" and continue in a contiguous manner until the survey is ended (by tapping on "<"). Readings **cannot** be skipped at the beginning or in the middle of the survey, only at the end.

Valid choices for this selection (see Figure 44) include:

Nothing   The survey will not be filled in and will remain unfinished. "READINGS" will be modified to reflect the actual number taken.

```
        :
        :
        :
 #READINGS:5
 FLEVEL,    A+,     A-,     B+,     B-
     5.0,    45,     12,    -87,     81
     4.5,    46,     12,    -84,     81
     4.0,    44,     12,    -85,     82
     3.5,    46,     13,    -85,     82
     3.0,    44,     13,    -86,     82
```

NaN(s)   Each missing level "row" of the survey will be filled in with "NaN(s)" which is the floating point representation of a non-numerical value. NaN is an abbreviation for "Not a Number".

```
        :
        :
        :
 #READINGS:11
 FLEVEL,    A+,     A-,     B+,     B-
     5.0,    32,     25,    -81,     82
     4.5,    33,     24,    -81,     82
     4.0,    30,     24,    -81,     82
     3.5,    30,     24,    -80,     81
     3.0,    29,     24,    -80,     81
     2.5,    29,     24,    -81,     81
     2.0,    30,     24,    -83,     81
     1.5,   NaN,    NaN,    NaN,    NaN
     1.0,   NaN,    NaN,    NaN,    NaN
     0.5,   NaN,    NaN,    NaN,    NaN
     0.0,   NaN,    NaN,    NaN,    NaN
```

Blanks   Each missing level "row" of the survey will be filled in with blank characters

```
        :
        :
        :
 #READINGS:11
 FLEVEL,    A+,     A-,     B+,     B-
     5.0,    46,     17,    -86,     80
     4.5,    46,     17,    -86,     82
     4.0,    46,     14,    -86,     81
     3.5,    42,     19,    -86,     80
     3.0,    50,     18,    -86,     80
     2.5,    45,     12,    -86,     80
     2.0,      ,       ,       ,
     1.5,      ,       ,       ,
     1.0,      ,       ,       ,
     0.5,      ,       ,       ,
     0.0,      ,       ,       ,
```

3.2.5.6 Bluetooth Connection:

This parameter must be a previously paired Bluetooth device that is selected from a list of known Bluetooth devices.

NOTE: A survey will not be performed and no connection will be possible to the Remote Module if this parameter is not set correctly. Please see section 2.2 (Establishing Contact with the Remote Module) for more information regarding Bluetooth pairing.

3.2.5.7 Email Address:

This parameter allows entry of an email address so that the Android device can export a data file as an email attachment.

3.3 FILE Menu

The GK-604D | aos "FILE" Menu provides access to importing and exporting features along with data viewing and report generation. It also is used to fully delete previously "hidden" configuration elements. It is located in the upper-right corner of the main window screen (see Figure 25). Tapping on the "FILE" menu causes the screen shown in Figure 46 to be displayed. The FILE menu sub-items are further described in the sub-sections below:
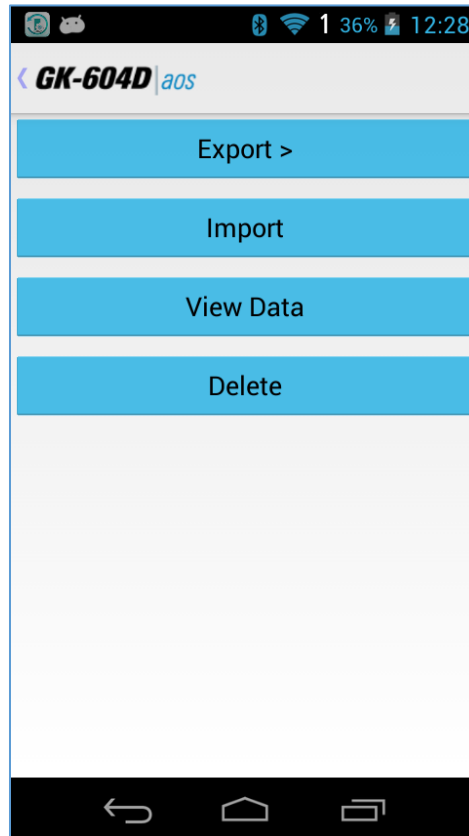
Figure 46 - File Menu

3.3.1 Export Menu

The Export menu is used to export hole data element settings to a folder of the user's choosing. Hole data can also be exported as an email attachment. Figure 47 shows the export options and the sub-sections below describe them in more detail:
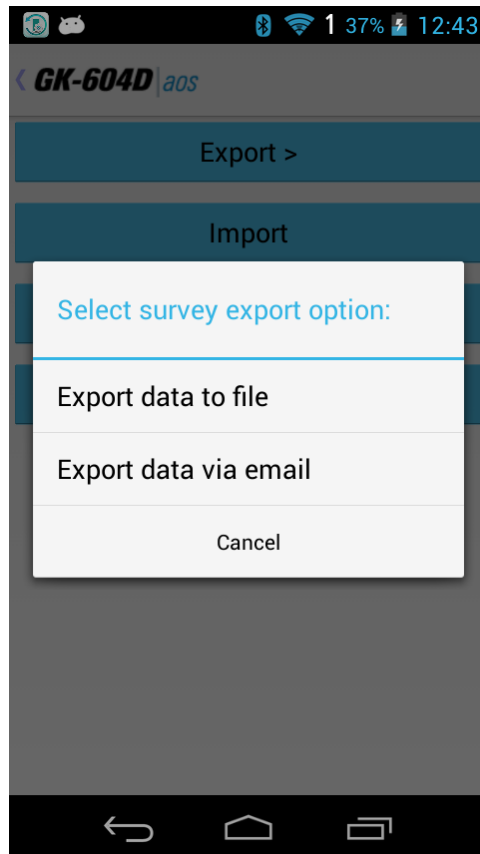
Figure 47 - Survey Export Options

3.3.1.1 Export Data To File

The "Export Data to File" menu allows exporting of data from the current hole (as listed in the status area) to a "raw" data file. Figure 48 shows the surveys available for hole "33". A survey is selected from the scrollable list by tapping on the survey name.

When a survey is selected the "Export Folder Selection" screen (see Figure 49) is displayed. Tap on a folder icon to navigate to sub-folders. When the desired folder is selected, tap "Select" from the menu bar to export the survey data to a ".gkn" file containing the raw data from the survey. See Appendix B for more information regarding ".gkn" data file format.
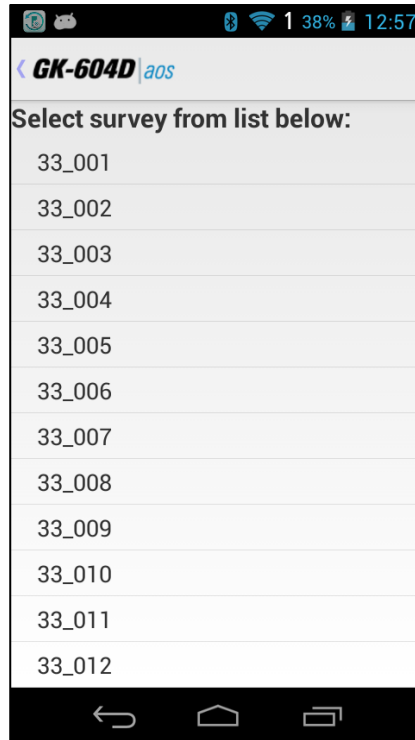
Figure 48 - Survey List
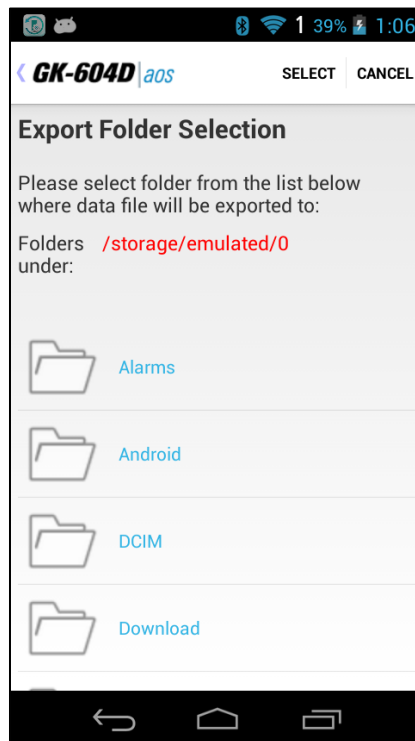
Figure 49 - Export Folder Selection

3.3.1.2 Export Data Via Email

The "Export Data Via Email" menu allows exporting of survey data from the current hole (as listed in the status area) as a "raw" (.gkn) data file. This file (or files in the case of an enabled digital compass) is compressed into a "zip" file, "GK_Attachment.zip", and becomes the email attachment. Figure 48 shows the surveys available for hole "33". A survey is selected from the scrollable list by tapping on the survey name.

When a survey is selected the "Share Via" screen (see Figure 50) is displayed. Tap on the "Email" icon to begin the export process and to display the email message screen shown in Figure 51. Note that the hole survey file (.gkn) has been compressed, renamed and attached to the email, a default message has been included and the email is pre-addressed to the email recipient that was entered for the System Configuration Email Address parameter (see section 3.2.5.7 for more information regarding the setting of this parameter). The email (with attachment) can be sent at this point.

Note: After the first data file has been exported as an email attachment, the Android device typically remembers which application it used to send the email so the "Share Via" screen (Figure 50) may not be displayed again.

See Appendix B for more information regarding ".gkn" data file format.
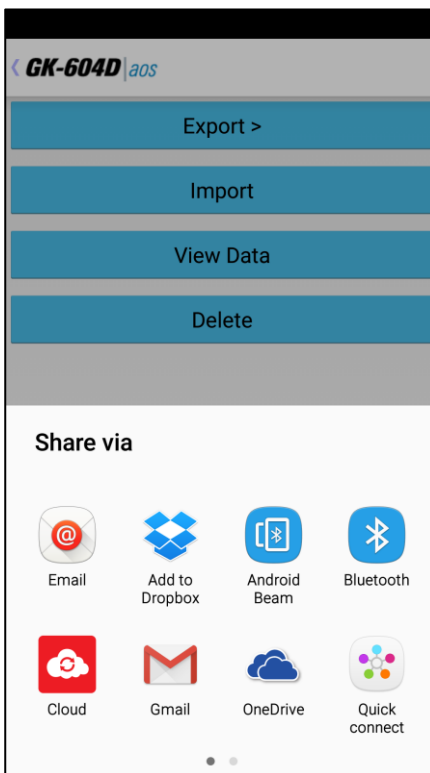
Figure 50 - Share Via Screen
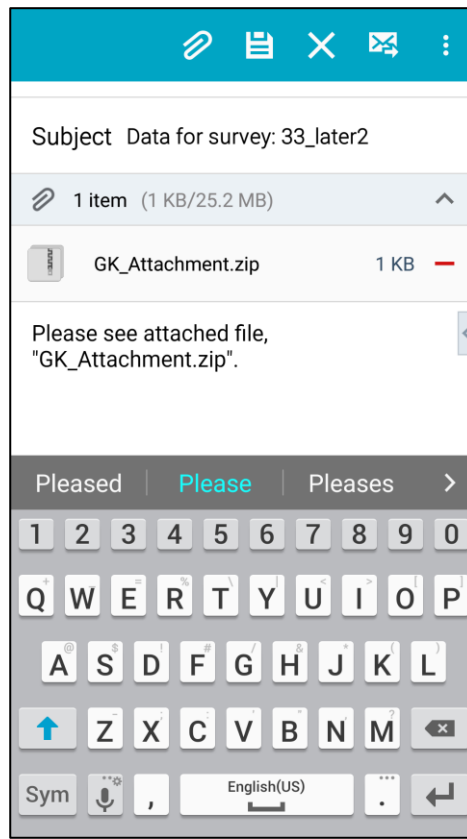
Figure 51 - Email Message Screen

NOTE: Sending data files as an email attachment requires an active data plan or access to a WIFI connection!

3.3.2 Import Menu

The Import Menu is used to import configuration element settings (see Figure 52) that were previously exported using the Windows Mobile version of the GK-604D Inclinometer Readout Application.

Tapping on "Import" from the "File Menu" (see Figure 46) causes the "Import File Selection" screen to be displayed (see Figure 52). As with the "Export Folder Selection" screen (Figure 49), the "Import File Selection" screen (Figure 52) is initially displayed showing the Android device's "External Storage Directory". This directory varies from device to device and between different Android versions but is generally considered to point to the "SD Card".

Unlike the "Export Folder Selection" screen, the "Import File Selection" screen's list may contain both files and folders. Tapping on a folder icon will cause that folder's contents to be displayed in the next screen. There are 4 types of files that are importable: Hole Export files (.lvhe), Project Export files (.lvpe), Probe Export files (.gkpe) and Probe Library Export files (.gple). Selecting any one of these 4 types of files will cause the "Importing…" screen (Figure 53) to be displayed along with all of the configuration element types that were found in the selected file. Tap "Start Import" to begin importing. The subsections below describe each file type in detail:
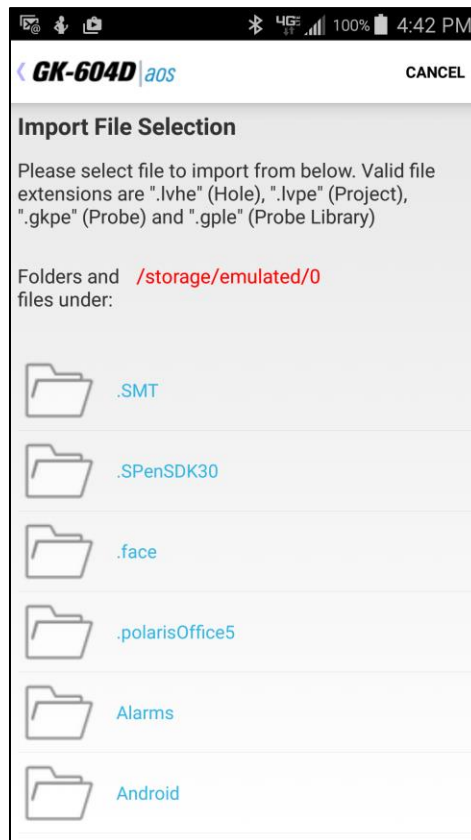
Figure 52 - Import File Selection
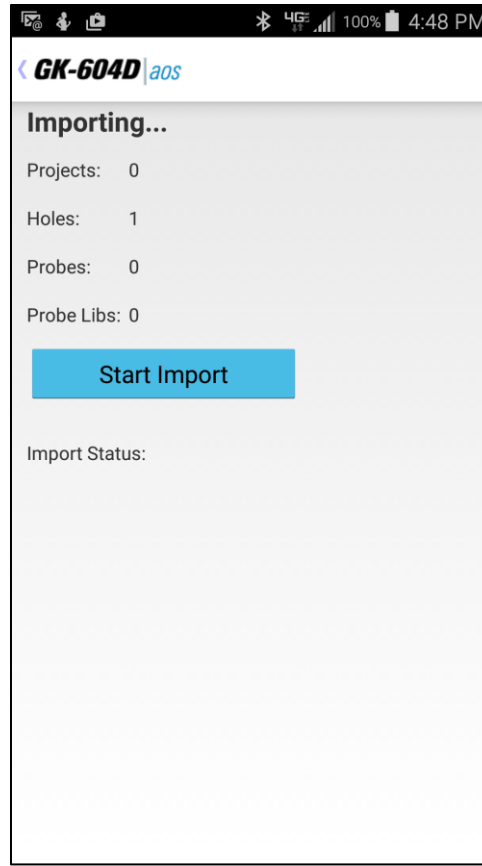
Figure 53 - Importing Screen

3.3.2.1 Hole Export File (.lvhe)

A Hole Export File contains all configuration parameters for a given hole as well as all survey data from all previously taken surveys. After the import is complete, a new "Hole" will be created in the currently selected project. If a hole with the same name already exists in the currently selected project a message will be displayed and the hole import will be cancelled.

3.3.2.2 Project Export File (.lvpe)

A Project Export File contains all configuration parameters for a given project along with all holes that were associated with this project **and** their survey data. After the import is complete, a new "Project" will be created in the currently selected workspace. New "Holes" will also be created as necessary. If a project with the same name already exists in the currently selected workspace, a message will be displayed and the project import will be cancelled.

3.3.2.3 Probe Export File (.gkpe)

A Probe Export File contains all configuration parameters for a given probe. After the import is complete, a new "Probe" will be created in the currently selected probe library. If a probe with the same name already exists in the currently selected probe library, a message will be displayed and the probe import will be cancelled.

3.3.2.4 Probe Library Export File (.gple)

A Probe Library Export File contains all configuration parameters for a given probe library along with all probes that were associated with this probe library. After the import is complete, a new "Probe Library" will be created. New "Probes" will also be created as necessary. If a probe library with the same name already exists, a message will be displayed and the probe library import will be cancelled.

3.3.3 View Data

When the View Data Menu is clicked the screen displayed in Figure 54 is shown. The Select View Options screen is used to select a report type (see Figure 55), survey and report options to view as a graphical or tabular report.

Figure 54 - Select View Options Screen

The survey or surveys are selected from rolling lists (similar to the report type in Figure 55) and, depending on the report type selected, requires the selection of one or two surveys. Deflection reports or plots require two surveys to generate the report or plot (see Figure 56).

The available report or plot options are shown in the sub-sections below:
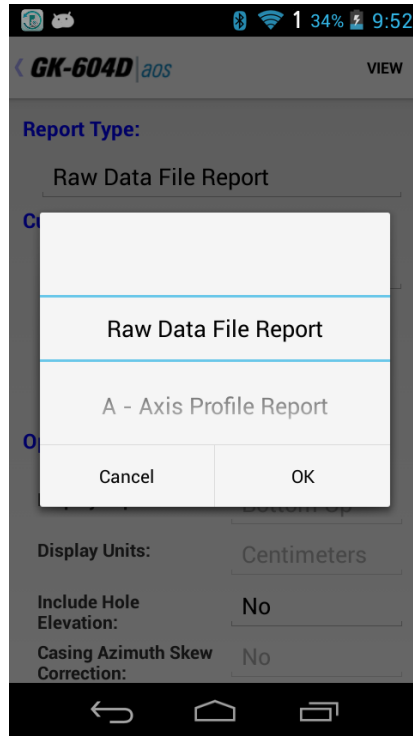
Figure 55 – Report Type List
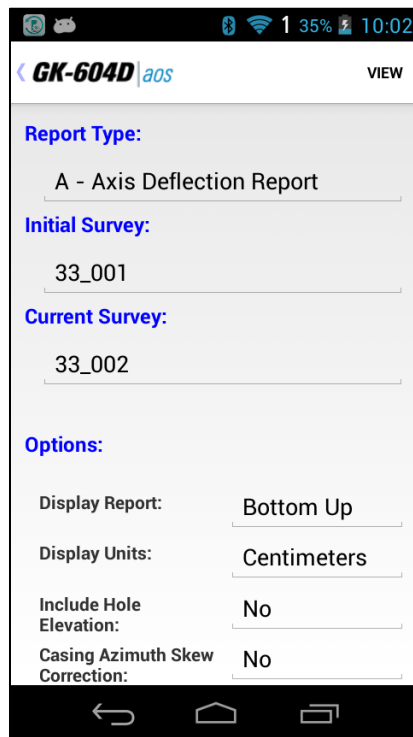
Figure 56 - View Options Screen (Selecting 2 Surveys)

3.3.3.1 Raw Data File Report

This selection will cause the selected "hole" raw data to be displayed in tabular form. Figure 57 shows the report as viewed on an Android device. The column and row data will scroll left and right and up and down so that all rows and columns can be seen.

Figure 57 - Raw Data Report

3.3.3.2 Axis Profile Report

Selecting this option allows viewing or saving hole profile data for the A or B axis. The profile is calculated from the magnitude of the readings at each level (see Figure 58). This report lists the profile of the casing as calculated from the bottom of the casing upward or from the top down (see the Options Screen in Figure 56). See Appendix C for an example of a profile report saved in text form. Tabular reports may also be saved in comma-separated value (.csv) format.

Figure 58 - Axis Profile Report

3.3.3.3 Axis Deflection Report

Selecting this option allows viewing or saving hole deflection data for the A or B axis. Deflection is determined from the accumulated change in deflection between the two selected data files at each level. This report lists the deflection of the casing as accumulated from the bottom of the casing upward or from the top down (see Figure 59). See Appendix C for an example of a deflection report saved in text form. Tabular reports may be saved in comma-separated value (.csv) format.

Figure 59 - Axis Deflection Report

3.3.3.4 Axis Profile Plot

Selecting this option allows a graphical view of hole profile data and is useful for visualizing the actual installed characteristics (inclination, couplings, anomalies, etc.) of the casing. Figure 60 shows a typical profile plot. "Screen-shots" of plots may be saved in ".jpg" format.
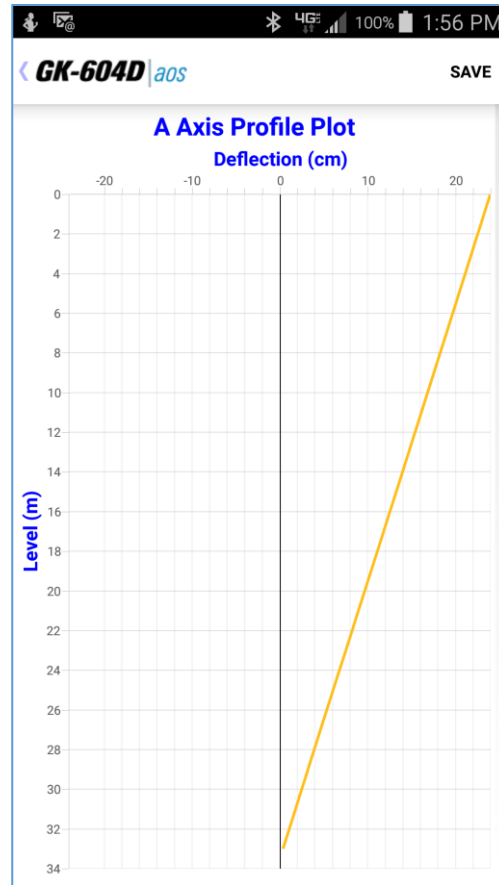
Figure 60 - Axis Profile Plot

3.3.3.5 Axis Deflection Plot

Selecting this option allows a graphical view of hole deflection data for either axis and is useful for visualizing magnitude and direction of any movement of the borehole (see Figure 61). "Screen-shots" of graphical reports may be saved in ".jpg" format".

In addition to saving reports and plots to the Android file system, each report or plot can also be emailed as attachment to the email address specified in section 3.2.5.7. Much like when exporting data via email (see section 3.3.1.2), the plot or CSV file is compressed into a "zip" file named "GK_Attachment.zip" and then sent via email as an attachment (see Figure 51).
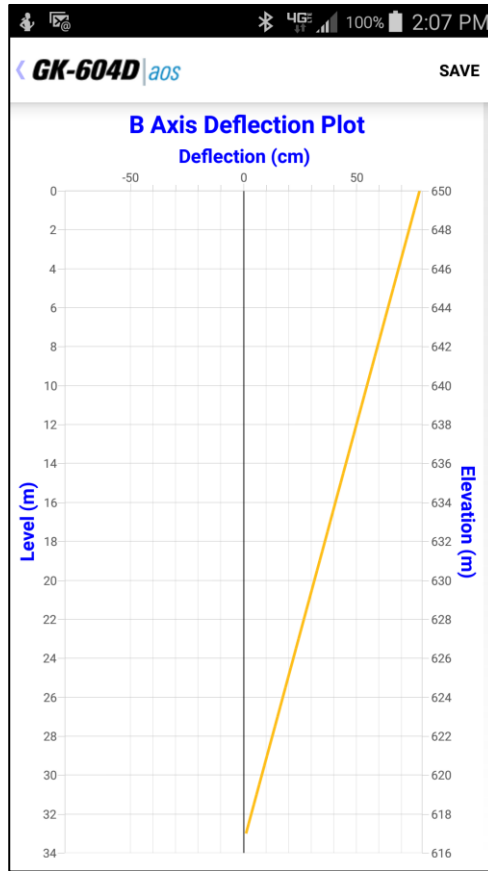
Figure 61 - Axis Deflection Plot

3.4.4 Delete

This menu item allows configuration elements to be permanently deleted from the system database. Tapping "Delete" acts on the currently selected item from the configuration element screen that was displayed before pressing "File". For example, if the "Holes" screen (see Figure 23) was displayed when the "File" menu button was tapped, the only candidate for deletion will be the currently selected hole. As can be seen in Figure 62, a warning prompt is displayed before an element is deleted.

WARNING: Selecting "Delete" will permanently delete the selected element and later restoration will **NOT** be possible.
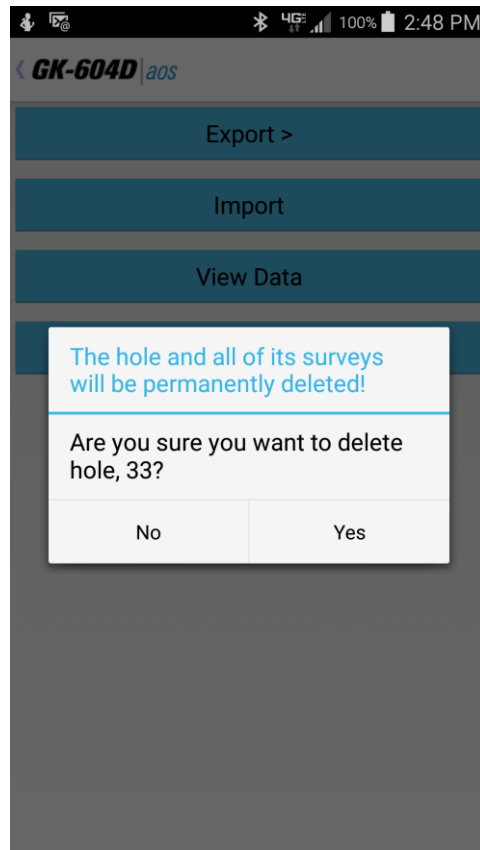
Figure 62 - Delete Warning Message

4. Configuration Elements

Each configuration element has settings that can be entered/modified. For some, like Workspace, Probe Library and Project the settings consist only of a name and description. Elements such as Holes and Probes require more configuration parameters such as English/metric units, initial level, and gage factors. These settings can be adjusted to meet the user's needs and the specifications of the probe. The software currently supports 2 different probe types and as many probe and hole configurations as the Android device can store in memory. All these can be adjusted using the Edit Settings option from the configuration element context menu.

4.1 Hole Configuration

Figure 63 depicts the Hole Parameters screen. The parameters that are visible are described below:

- **Hole name**
  Tap on this parameter to bring up the on-screen keyboard. Use it to enter a unique and descriptive hole name.

- **Description**
  Optional parameter. Using the on-screen keyboard, enter a brief description pertaining to the hole's location and purpose.

- **Created On**
  Read-only date and time value, generated when the hole was created.

- **Probe Name**
  Select the Probe Name from the drop down list. This associates a hole with a particular probe. Select "UNKNOWN" if the probe has not yet been "found" by the GK-604D | aos system.

- **Hole Units**
  The units for the hole level, interval and starting level. Select either meters or feet from the drop-down list (**must match probe!**).

- **Starting Level**
  Using the on-screen keyboard, enter a value for the initial level of the survey for this hole.

- **Interval**
  Enter an interval to be used for the survey. This value is dependent on Hole Units and is typically .5 meters or 2 feet.

- **GPS Status**
  Gives a status of the Global Positioning Satellite hardware on board the Android device.

- **Top Elevation**
  This optional parameter corresponds to the elevation at the top of the hole.

- **Latitude**
  Double floating point value corresponding to the "Y" location of the hole to be surveyed. This parameter can be entered directly if the GPS hardware is disabled or unavailable.

- **Longitude**
  Double floating point value corresponding to the "X" location of the hole to be surveyed. This parameter can be entered directly if the GPS hardware is disabled or unavailable.

- **Get GPS Coordinates**
  This parameter may be "hidden" below the screen of the Android device. Scroll up to expose the last two parameters (see Figure 64). This button is enabled if the "GPS Status" (above) displays "GPS Available". If the button is enabled, tapping it will cause the application to access the GPS hardware, read the current location and populate the Latitude and Longitude parameters (described above).

- **Azimuth Angle**
  This optional parameter allows correction of any casing deviation from the appropriate A+ direction (see Figure 64).

When done editing, the settings can be saved by tapping the "<" beside the application title. Tapping "CANCEL" will exit the screen with nothing saved.

Figure 63 - Hole Parameters (Screen 1)

Figure 64 - Hole Parameters (Screen 2)

4.2 Probe Configuration
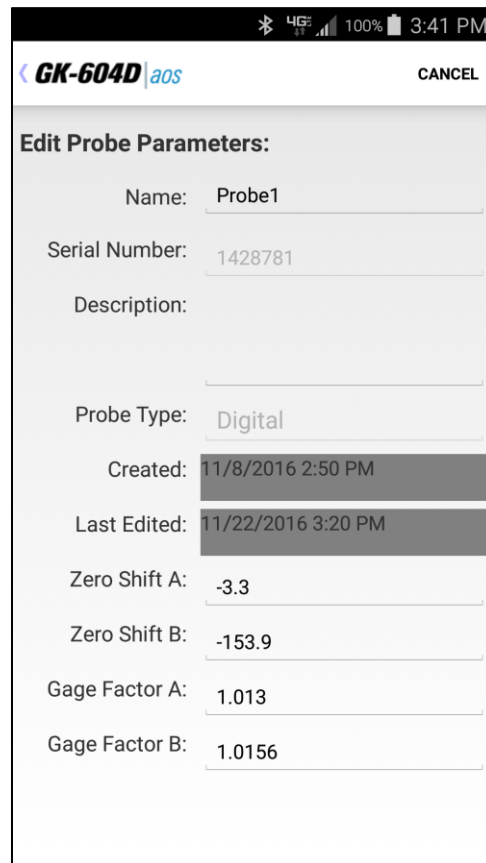
The Probe parameters (see Figure 65) identify and configure the analog or digital probe that is connected to the Remote Module. These parameters are described below:

- **Probe name**
  Use the on-screen keyboard to enter a unique and meaningful name for the probe. This name will be used to associate the hole to the probe.

- **Serial number**
  Read-only parameter for digital inclinometer probes, read/write parameter for analog and compass probes.

- **Description**
  Optional parameter. Enter a brief description pertaining to the probe

- **Probe type**
  Select a probe type from drop-down list. Choices are: **Analog** and **Digital**.

- **Date created**
  Read-only date and time value, generated when the probe was created.

- **Last edited**
  Read-only data and time value, updated whenever the probe settings are modified.

- **A and B Channel Zero Shift**
  To compensate for any offset at zero enter appropriate values for the Zero Shift values (see the Inclinometer Probe manual and Calibration sheet for more information). Digital probes will likely have these values programmed at the factory.

- **A and B Channel Gage Factors**
  Using the on-screen keyboard, enter appropriate numbers for the 2 gage factors (see the Inclinometer Probe manual and Calibration sheet for more information). Digital probes will likely have these values programmed at the factory.

When done editing, the settings can be saved by tapping the "<" beside the application title. Tapping "CANCEL" will exit the screen with nothing saved.

If connected to a digital Remote Module and digital probe, Zero Shift and Gage Factor changes can be uploaded to the probe by answering "Yes" to the prompt

that's displayed when exiting the probe parameters screen (see Figure 66).

Figure 65 - Probe Parameters Screen
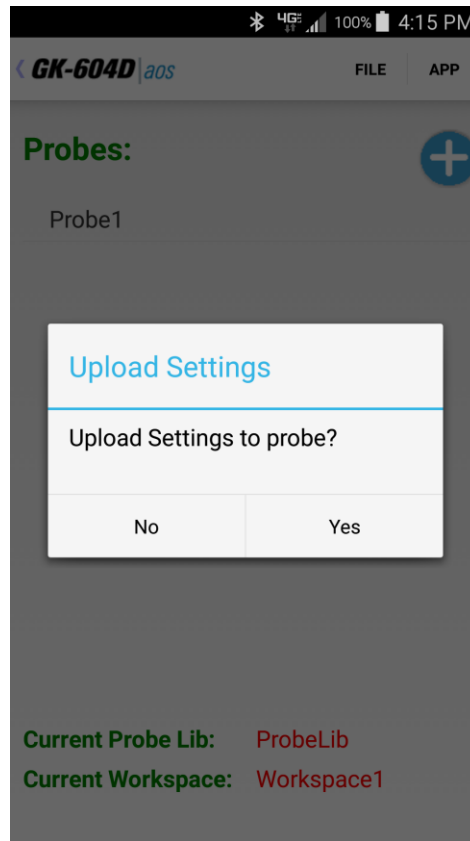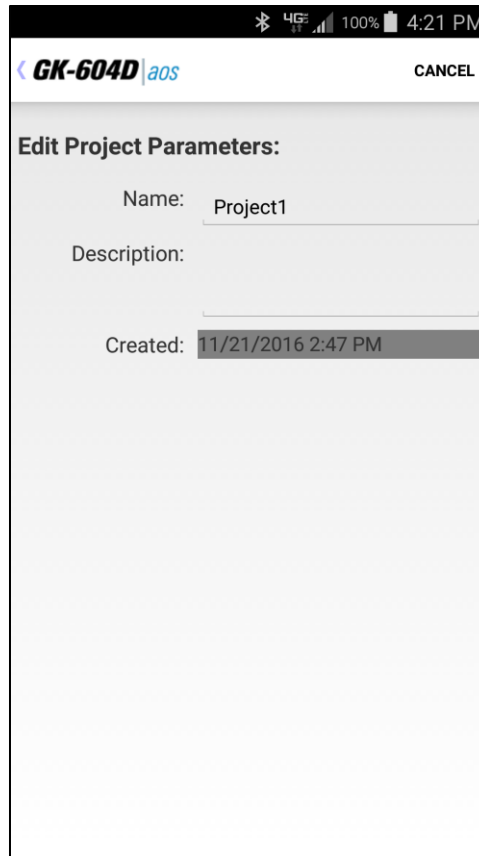
Figure 66 - Upload Settings

4.3 Project Configuration

The Project parameters (see Figure 67) identify the Project element. These parameters are described below:

- **Project Name**
  Use the on-screen keyboard to enter a unique and descriptive project name.

- **Description**
  Optional parameter. Use the on-screen keyboard to enter a brief description pertaining to the project.

- **Created On**
  Read-only date and time value, generated when the project was created.

When done editing, the settings can be saved by tapping the "<" beside the application title. Tapping "CANCEL" will exit the screen with nothing saved.

Figure 67 - Project Parameters Screen

5. Files, Folders and Transferring Data

The GK-604D | aos uses several types of files and dedicated folder locations to keep track of element configuration files as well as various repositories for reports and plots. The default locations and names for most of these appear in Table 1:

Purpose	Default Folder	Filename
GK-604D	aos backup database	Device storage/IncloData	IncloSQLite.db3
File system report storage	Device storage/IncloData/Reports	*.csv, *.jpg
Imported data repository	Device storage/IncloData/Import	*.lvhe, *.lvpe, *.gkpe, *.gple
Metadata picture repository	Device storage/Pictures	*.jpg

Table 1 – Folder paths and File Names

NOTE: Manual editing of any files or renaming folders above may result in data loss or unexplained operation and is strongly discouraged!

5.1 File Transfer

In general, the only files generated by the GK-604D | aos that might have to be transferred are the "hole" data files and/or reports. Connecting the Android device to a desktop or laptop PC using a USB cable (Type A to micro B) is straight forward and allows the user to view the Android devices storage as a flash drive on the desktop/laptop; you can then simply drag the files around to any folder on the desktop/laptop.

In general the only setting required on the Android device has to do with how the USB connection is used. Typically, selecting "File Transfer" for this settings allows files to be shared in both directions with a Windows PC.

6. Maintenance

Because the inclinometer probe is a totally sealed unit, field adjustments are not required.

6.1 O-ring

Maintenance of the 'O' ring on the connector requires that it be kept clean and free of cuts and nicks. Periodic greasing with 'O' lube is recommended. A worn or damaged 'O' ring should be replaced with a new one (five 'O' rings are supplied with each new probe).

6.2 Wheel assemblies

Wheel assemblies should be kept dry when in storage. They should be kept free of dirt by using a compressed air gun to blow away grit. **After every survey, spray the springs, pivots and axles with light oil**. This is very important and should not be neglected.

Geokon **recommends lubricating the wheel bearings after each use** as shown below. This practice forces out any water or contaminates that may be present thus extending the service life.

Figure 68 – Wheel lubricant (ADH-106 Belray Waterproof Grease Type 99540)
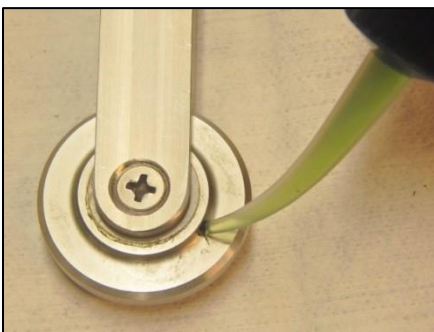
Grease wheels through the grease port in the wheel hub after each use.

Figure 69 – Greasing wheels

6.3 Water entry

One of the main problems encountered is failure to keep the cable and probe connectors dry. This is often caused by a failure to fully tighten the cable connector to the probe connector. This connection must be made up tight in order to compress the O-ring in the end of the probe connector. Periodically the pins of the probe connector **must** be sprayed with DEOXIT #DN5 spray contact cleaner and rejuvenator. A small spray can of this is supplied with each inclinometer probe. After each daily use always make sure that the connectors are completely dry before replacing the protective caps. Otherwise corrosion could result.

6.4 Zero shift changes

If the zero shift changes due to aging or rough handling this will not affect the quality or accuracy of the readings because the shift is removed by taking two sets of readings in the A+ and A− directions. However, if the zero shift changes by more than 5000 digits then the probe should be returned to the factory for repairs. Zero shift can be set to zero at any time using the software inside the GK-604 readout instrument (see section 4.2).

6.5 Self calibration check

It is good practice to have a piece of inclinometer casing permanently fastened to a fixed immovable structure in the laboratory. This casing is used as a periodic check on the calibration of the probe. Placing the probe in the casing should give a reading that does not change with time.

7. Troubleshooting

The sections below contain basic trouble-shooting information and are an attempt to solve the more common problems that may occur.

7.1 "Probe connection failure…"

Because this is the most common problem that will likely occur, this potential error deserves a section all to itself. When the GK-604D | aos is unable to establish connection to the probe (or the Remote Module) the error dialog shown in Figure 70 is displayed:
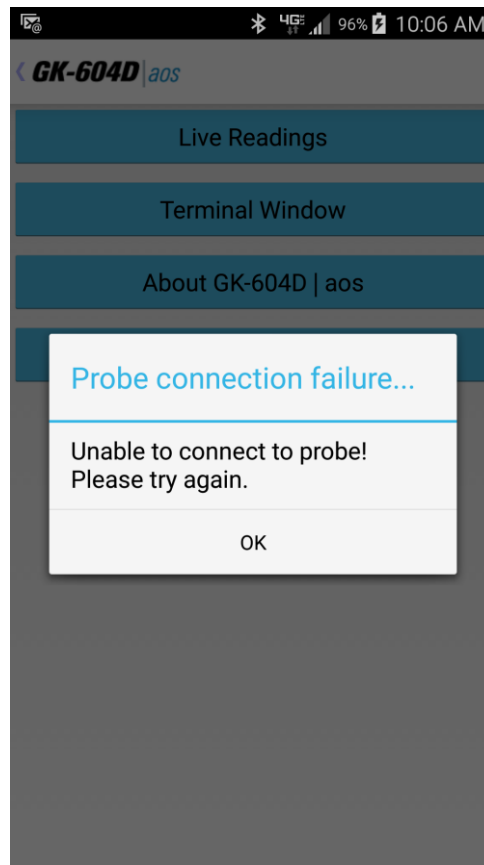
Figure 70 - Probe Connection Failure

If this error occurs, it's very likely that the problem lies with one of the following list of possible causes:

1) Bluetooth may not be turned on in the Android device settings. See section 2.2, Establishing Contact with the Remote Module (step 1), of this manual

2) The blue light on the Remote Module isn't blinking (see section 7.2)

3) The Bluetooth pairing is incorrectly selected in the System Configuration (see section 3.2.5.6, Bluetooth Connection)

4) The probe is disconnected from the Remote Module cable

5) The probe or cable may be damaged.

If the connection attempt fails multiple times after verifying the above steps, perform a full power down and restart of the Android device and attempt to connect again through the GK-604D | aos application.

7.2 Common Troubleshooting Solutions

Problem	Solution
Android device does not power up	Attach device charger for 2 hours then try again.
When launched, the "GK-604D | aos" app displays the Probe Library and Workspaces screen	Please refer to section 2.4, Starting the GK-604D | aos for the first time
When adding a "**Hole**," "**UNKNOWN**" is the only choice for "**Probe name**."	The "GK-604D | aos" app has not yet "discovered" the new probe or the probe was deleted from the probe library. Please refer to section 2.1, step E, of the GK-604D | aos User's Manual.
The blue indicator light does not blink when the "**POWER ON/OFF (BLUETOOTH)**" button is pressed on the Remote Module.	Attach Remote Module charger for 2 hours, then try again.
After tapping on "**Live Readings**" in the "APP" menu, the blue light never goes solid blue and a "**Probe connection failure**" screen is displayed.	Please refer to section 7.1 as well as section 2.2 of the GK-604D User's Manual.
The GK-604D | aos appears to be "hung" or "frozen" and will not respond to any key press.	This is highly unusual and may require that the Android device be powered down and/or a call to Geokon.
Blue light on Remote Module does not go off after Live Readings windows has been exited.	Press the "**POWER ON/OFF (BLUETOOTH)**" button on the Remote Module.

APPENDIX A. Inclinometer Theory

A.1. Inclinometer Theory

In the geotechnical field inclinometers are used primarily to measure ground movements such as might occur in unstable slopes (landslides) or in the lateral movement of ground around on-going excavations. They are also used to monitor the stability of embankments, slurry walls, the disposition and deviation of driven piles or drilled boreholes and the settlement of ground in fills, embankments, and beneath storage tanks.

In all these situations it is normal to either install a casing in a borehole drilled in the ground, to cast it inside a concrete structure, to bury it beneath an embankment, or the like. The inclinometer casing has four orthogonal grooves (Figure 71) designed to fit the wheels of a portable inclinometer probe (see Figure 72). This probe, suspended on the end of a cable connected to a readout device, is used to survey the inclination of the casing with respect to vertical (or horizontal) and in this way to detect any changes in inclination caused by ground movements.
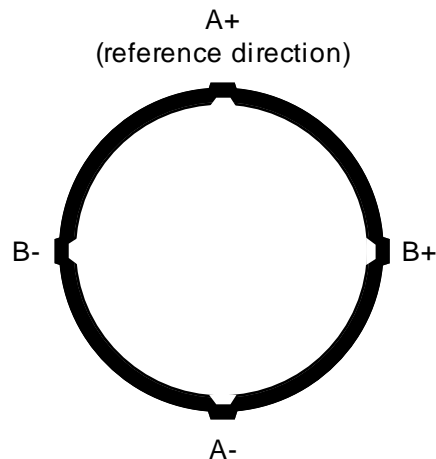
Figure 71 - Inclinometer Casing (end view)

The probe itself contains two MEMS, (Micro Electro-Mechanical Sensor), accelerometers, which flex when acted on by the force of gravity. Since the output voltage is proportional to the sine of the angle of inclination, the output is also proportional to horizontal deviation of the borehole (or the vertical deviation of a horizontal borehole).

In order to obtain a complete survey of the ground around the installed inclinometer casing it is necessary to take a series of tilt measurements along the casing. Typically an inclinometer probe has 2 sets of wheels separated by a distance of 2 feet (English system) or .5 meter (Metric system). A casing survey would begin by lowering the probe to the bottom of the casing and taking a reading. The probe

would then be raised at 2 foot (English system) or .5 meter (Metric system) intervals and a reading taken at each interval until the top of the casing is reached. The set of readings thus generated is called the A+ readings. Marks on the cable at 2 foot (English) or .5 meter (Metric) spacing facilitate the process. The probe is then removed from the casing, rotated through 180°, replaced in the casing, lowered to the bottom of the borehole and a second set of readings (the A− set) obtained as the probe is raised at the reading interval.
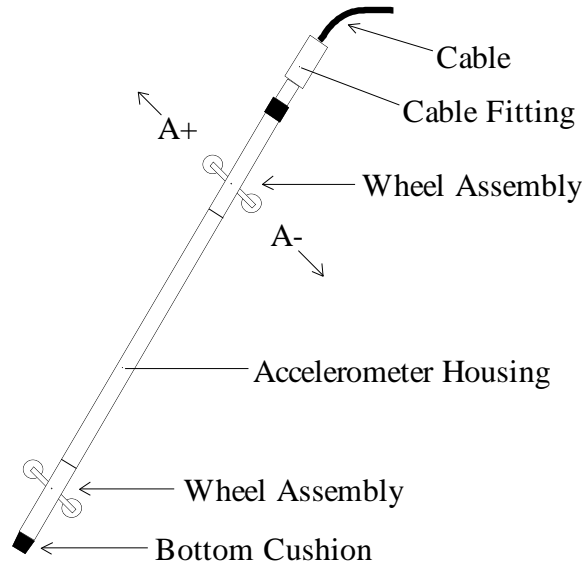
Figure 72 - Inclinometer Probe

Inclinometer probes usually contain two accelerometers with their axes oriented at 90° to each other. The A axis is in line with the wheels (Figure 72 illustrates) with the B axis orthogonal to it. Thus, during the survey, as the A+, A− readings are obtained, the B+, B− readings are also recorded.

During the data reduction these two sets of readings (A+, A− and B+, B−) are combined (by subtracting one set of readings from the other) in such a way that the effect of any zero offset of the force balance accelerometer is eliminated. [This zero offset is the reading obtained from the inclinometer probe when it hangs vertical. Ideally the offset (or bias) would be zero, but usually there is a zero offset which can change during the life of the probe due to drift of the transducer, wear and damage of the wheels or most likely due to a sudden shock to the transducer caused by dropping or allowing it to hit too hard against the bottom of an installed inclinometer casing.]

Subsequent surveys of the inclinometer casing, when compared with the original survey, will reveal any changes of inclination of the casing and locations at which these changes are taking place. Analysis of the change of inclination is best performed by computing the horizontal offset of the upper wheels relative to the lower wheels which has produced the tilting (θ) over the reading interval (L) of the survey (usually the wheel base of the probe, 2 feet for English systems, .5 meter for

Metric). At each position of the inclinometer the two readings taken on each axis (A+
, A− and B+, B−) are subtracted from each other leaving a measure of sineθ. This
value is then multiplied by the reading interval (L) and the appropriate factor to
output horizontal deflection in engineering units (inches for English, centimeters or
millimeters for Metric) (see Figure 73).
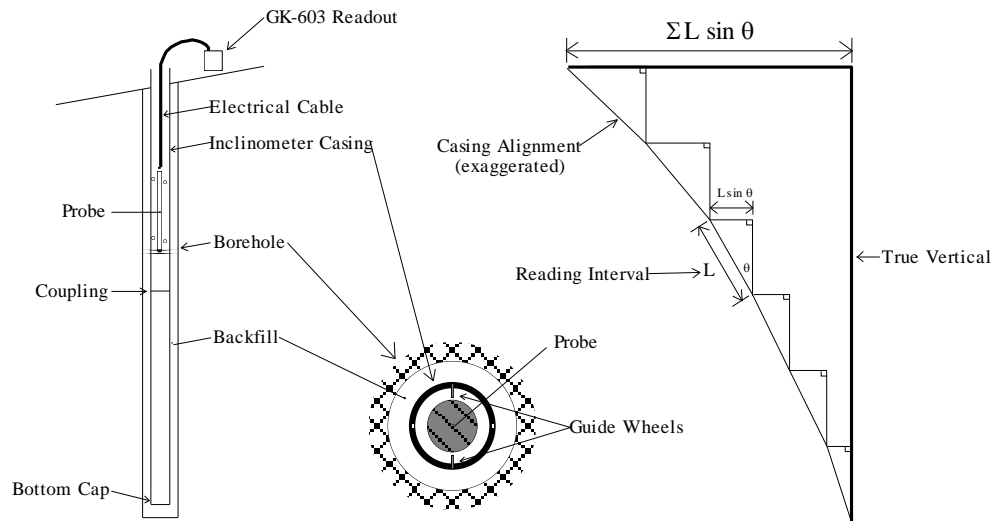
Figure 73 - Inclinometer Survey Description

When all these incremental horizontal deflections are accumulated and plotted
beginning at the bottom of the borehole the net result is to produce a plot of the
change in horizontal deflection between the time of the initial survey and the time of
any subsequent survey (see Figure 74). From such a deflection plot it is easy to see
at which depth the movement is occurring and its magnitude.
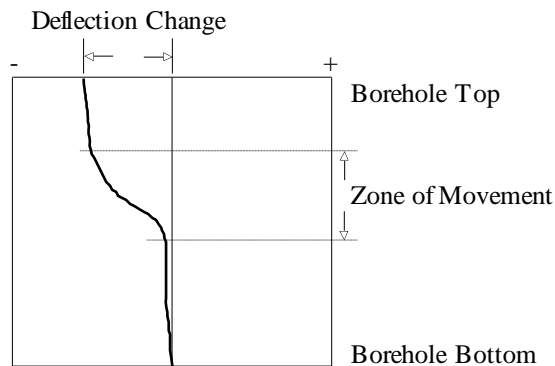
Figure 74 - Plot of Borehole Deflection

Other methods of analysis can be used but generally add little to the overall understanding of the situation. For example, using a single set of data, a profile of the borehole can be created. Also, a plot can be made of the actual change in reading (inclination) at each measurement depth increment. A plot of this nature reveals the depths at which movement is occurring. But this information can be obtained from the change in deflection curve with little difficulty.

One other analysis is the Check Sum (or Instrument Check) which can be used to measure the quality of the survey data. The quality of the data can be impaired by any or all of the following;

♦ Skipping over or duplicating a reading.

♦ Not allowing the inclinometer sufficient time to come to rest before taking a reading.

♦ Not allowing sufficient time to allow the probe to reach temperature equilibrium before commencing the survey.

♦ Malfunction of the probe, cable or readout device. This may be the result of shock, moisture, low battery conditions, opens or shorts in the cable or probe, etc.

♦ Carelessness in positioning the wheels so that the probe wheels do not rest on the same part of the casing from one survey to the next.

♦ Positioning the wheels so that they fall right on top of a casing joint so that the reading is unstable or simply erroneous.

The Check Sum analysis is performed by adding the A+, A- readings and the B+, B- readings. When this is done the part of the reading due to the tilt is eliminated leaving only a value which is equivalent to twice the zero offset of the inclinometer transducer.

A.2 Conducting the survey

The following is a synopsis of the steps involved in taking a survey (see section 3.2.1 for more details):

1) Attach the cable to the probe making sure that the connector is clean and the O-ring undamaged. Tighten the connector to ensure that the O-ring is compressed and watertight.

2) Twist the probe so that the uppermost wheel fits into the casing groove that faces the direction of the anticipated movement, (In the case of a slope this would be downhill, or, in the case of a foundation wall in the direction of the opening. This guarantees that the measured deflections will be positive. Lower the inclinometer probe to the bottom of the casing. To avoid damage to the probe be careful not to let the probe strike hard against the bottom of the hole.

3) Select the size of pulley assembly, (or cable hold), that matches the inclinometer casing and place it inside the top of the casing. Lift the inclinometer until the first cable marker passes the clamps on the pulley assembly (or sits in the cable hold if a cable hold is being used)

4) Turn on the Android device, turn on the Remote Module (blue light blinking) then launch the GK-604D | aos application. Tap on the "Live Readings" button (from the APP menu) and verify that the Android unit has connected to the probe. The Live Readings screen should be displayed (Figure 30) and inclinometer readings can be observed. Wait until the probe temperature has stabilized and the reading doesn't change.

5) Make sure that the dataset indicator in the Live Readings screen (Figure 30) is set 1. Take the first reading, pull up on the cable until the next cable marker sits just above the cable grips on the pulley assembly, (or in the cable hold), and, after a short pause, take another reading.

6) Continue in this way until the top marker is reached, then remove the pulley assembly, (or cable hold), and pull the inclinometer out of the hole.

7) Twist the probe through 180 degrees then lower it to the bottom of the hole. Tap the "Dataset 1" button to select dataset 2.

8) Repeat steps 3 to 6.

9) Tap on the "<" icon to the left of the title to save the data.

A.3 Checksums and "Face Errors" on Inclinometer Probes

Many users have expressed concern about **checksums or "face errors"** on inclinometer probes. They are concerned with the effect of the "face error" on the accuracy of the readings. The purpose of this section is to show that under normal circumstances the effect of the "face error" or checksum is negligible even with checksums as large as 2000. **The only time a problem would arise is if the face error or checksum was to change between the two halves of a survey**. **This is why it is extremely important to not bang the probe on the bottom of the borehole between survey halves, and to not handle the probe roughly while out of the hole.**

The term "face error" comes from surveying terminology. It is normal for all theodolites to have a "face error" which is caused by imperfections of alignment of the collimation axis and other misalignments. These "face errors" are removed routinely by taking two readings of the theodolite: one angle is measured with the face of the vertical scale on the left of the theodolite and another with the face of the vertical scale on the right of the theodolite. The average of the two readings "face right" and "face left" gives the **true angle as the "face error" cancels out.**

Similarly with the inclinometer probe: the "face error" arises from the fact that the axis of the inclinometer probe is not parallel with the electrical axis of the internal, force-balance, servo- accelerometer transducer. Once again the "face error" is eliminated by taking two surveys of inclinometer readings one with the wheels of the inclinometer probe pointing in one direction and another with the wheels of the probe at 180° to the first direction. If the first set of readings are all too <u>large</u> by the amount of the "face error" then the second set of readings will be too <u>small</u> by the amount of the "face error" and the average or sum of the two readings will be a measure of the true inclination since the effect of the face error will be totally eliminated.

A.3.1 Effect of "Face Error" on reading accuracy

The "face error" or check-sum can only affect the accuracy of the readings if it affects the calibration of the probe. This is possible because the output of the probe transducer is proportional to the sine of the inclination from the vertical and the sine function is non-linear.

Imagine, for a moment, that the electrical axis of the transducer is five degrees away from being parallel with the axis of the inclinometer. This would give rise to a "face error" of 01743. (The inclinometer reader displays 20,000 sin$\varnothing$). So, one set of readings would be all too large by this amount and the other set of readings from a normal inclinometer survey would be too small by this amount, but the sum of the two readings would be accurate. The "face errors" having canceled out. However, if we assume that the hole is almost vertical then the transducer will be tilted at an angle of 5°. The difference in the slope of the sine function at any point is equal to the cosine of the angle at that point. The cosine of 0 ° is 1.0000 the cosine of 5 ° is 0.996 so that the effect of this "face error" on the calibration of the probe is to increase it by a factor of 1/0.996 = 1.004.

The practical implication of this would mean that if the apparent deflection of a borehole was 100 mm, the true deflection would be 100.4 mm. For practically all applications, in the real world, the difference is insignificant and is a lot less than the differences which normally occur from survey to survey i.e. a lot less than the <u>precision</u> of the inclinometer probe survey. (Lack of precision is caused by a failure to position the wheels of the probe in exactly the same place from survey to survey; failure to wait sufficiently long to allow the probe transducer to come to rest before reading; and random dirt in the inclinometer casing).

Note that the normal system accuracy of an inclinometer probe is ± 7 mm in 30 meters. By comparison it can be seen that the normal system accuracy or precision is very much larger than the calibration error caused by the "face error" and that for all practical purposes the "face error" is of no consequence

and can be completely discounted if it is less than 2000 digits.

(As another example, supposing the check-sum was as large as 5000 digits. This is equivalent to a gross angular error of misalignment of almost 15 degrees. The effect on the calibration would be a little over 3% so that the apparent deflection of 100 mm would be out by 3 mm which again is smaller than the normal data spread due to imprecision).

A.3.2 Measurement of "Face Error"

The "face error" is the reading shown by the inclinometer probe when it is perfectly vertical. In practice, the easiest way to obtain the "face error" is to run a normal inclinometer survey, with the two sets of readings at 180°, and then to run a profile or deflection report (see section C.2 and C.3, the column labeled "Diff"). Examination of the data will reveal the average checksum which is equal to twice the "face error."

A.3.3 Setting of the "Face Error" to zero

There are three ways of setting the "face error" to zero. None of them are necessary from the point of view of improving accuracy.

A.3.3.1 Mechanically

At the time of manufacture the electrical axis of the transducer is adjusted by means of shims etc., until it points parallel to the axis of the inclinometer probe. This method suffers from the disadvantage that if the "face error" changes due to wear and tear on the probe and rough handling, or shock loading of the transducer then the probe needs to be returned to the factory for dismantling and re-adjustment.

A.3.3.2 Electrically

Electronic circuitry can be included in the probe so that the output of the transducer can be adjusted to zero when the probe is vertical. The disadvantage of this method is that it introduces electronic components into the inside of the probe which may alter with time, temperature and humidity and which, if the "face error" changes due to wear and tear or rough handling, will require the probe to be dismantled and the electronic circuitry readjusted. Also, this form of correction only masks the "face error". It does not really remove it and if the "face error" is very large the calibration will be affected.

A.3.3.3 By software

The best way for setting the "face error" to zero is by applying an automatic correction to the measured readings using the software capabilities of the inclinometer readout box.

The procedure for setting the face error to zero is described in section 4.2 which covers the subject of "Zero shifts" which are the same as "face errors". The advantage of this method lies in its simplicity and the ability to set the "face error" to zero at any time without dismantling the probe. This is the method chosen by Geokon.

Another advantage of this method is that it is possible by judicious choice of the "face error" entered into the software program to make one probe give exactly the same digits output as another probe. This is sometimes thought to be desirable where probes are switched and unbroken continuity of the raw data is desired. It is not necessary for reason of accuracy as has already been explained.

The disadvantage of this method is that, if the probe is changed, the operator must remember to change the zero shift offset in the program to accommodate the "face error" of the new probe.

A.3.4 Conclusion

It has been shown that for most practical purposes check-sums of less than 2000 digits are of no consequence and can be completely ignored providing the inclinometer survey is conducted in the normal way. (i.e., 2 sets of readings at 180°) It has further been shown that the best method by far, for setting the "face error" to zero, is by means of the software capabilities in the inclinometer reader. This is the method chosen by Geokon.

APPENDIX B. Data File Format

B.1 Hole Data .GKN File Format

```
***
GK 604M(v1.0.1.0,01/13);2.0;FORMAT II
PROJECT  :myHoles
HOLE NO. :newHole
DATE     :01/02/13
TIME     :14:32:13
PROBE NO.:testProbe
FILE NAME:newHole_001.gkn
#READINGS:61
FLEVEL,     A+,     A-,     B+,     B-
  30.0,   1013,  -1052,   -380,    320
  29.5,    945,   -985,   -377,    315
  29.0,    946,   -981,   -346,    290
  28.5,    945,   -978,   -331,    276
  28.0,    995,  -1048,   -337,    278
  27.5,   1014,  -1050,   -318,    263
  27.0,   1034,  -1068,   -316,    265
  26.5,   1046,  -1078,   -348,    288
  26.0,   1037,  -1075,   -376,    326
  25.5,   1042,  -1075,   -415,    366
  25.0,   1079,  -1116,   -430,    366
  24.5,   1053,  -1087,   -440,    378
  24.0,   1027,  -1066,   -449,    385
  23.5,   1024,  -1061,   -477,    413
  23.0,   1020,  -1054,   -474,    422
  22.5,   1029,  -1063,   -500,    448
  22.0,   1099,  -1131,   -485,    437
  21.5,   1080,  -1116,   -503,    439
  21.0,   1047,  -1082,   -514,    462
  20.5,   1043,  -1075,   -518,    454
  20.0,   1042,  -1077,   -527,    469
  19.5,   1062,  -1096,   -542,    480
  19.0,   1074,  -1105,   -551,    487
  18.5,   1085,  -1118,   -553,    490
  18.0,   1104,  -1140,   -572,    513
  17.5,   1097,  -1128,   -541,    483
  17.0,   1090,  -1125,   -549,    500
  16.5,   1069,  -1105,   -545,    493
  16.0,   1103,  -1139,   -567,    497
  15.5,   1082,  -1129,   -566,    506
  15.0,   1065,  -1100,   -553,    495
  14.5,   1052,  -1086,   -529,    467
  14.0,   1009,  -1045,   -519,    452
  13.5,    956,   -991,   -534,    468
  13.0,    899,   -933,   -558,    492
  12.5,    841,   -874,   -557,    493
  12.0,    800,   -836,   -568,    499
  11.5,    778,   -808,   -547,    482
  11.0,    755,   -789,   -522,    464
  10.5,    752,   -785,   -489,    440
  10.0,    754,   -789,   -465,    409
   9.5,    766,   -802,   -433,    378
   9.0,    769,   -804,   -429,    371
```

```
8.5,    765,    -800,    -435,    372
8.0,    762,    -795,    -442,    379
7.5,    785,    -819,    -441,    386
7.0,    811,    -844,    -456,    388
6.5,    809,    -842,    -450,    394
6.0,    802,    -837,    -472,    414
5.5,    786,    -817,    -464,    398
5.0,    776,    -809,    -475,    412
4.5,    788,    -818,    -468,    404
4.0,    777,    -808,    -447,    381
3.5,    707,    -757,    -435,    375
3.0,    707,    -739,    -408,    354
2.5,    686,    -721,    -407,    359
2.0,    647,    -680,    -413,    356
1.5,    608,    -643,    -412,    357
1.0,    559,    -599,    -359,    298
0.5,    564,    -600,    -361,    300
0.0,    565,    -600,    -359,    300
```

APPENDIX C. Text Reports

C.1 Axis Profile Data Report (.CSV)

Shown as displayed in Excel, for clarity:

Report: A-Axis Change in Digits and Deflection in (cm) (Bottom Up)

Project Name:	Project1					
Hole Name:	33					
Top Elevation:	33					
Azimuth Angle:	324					
Hole Location:	Lat:	43.6465	Lon:	-72.2516		

Survey Name:	33_init1	
Reading Date:	10/27/2015	
Reading Time:	15:33:43	
Probe Name:	Probe1	
Picture Loc:	/storage/emulated/0/Android/data/com.geokon.GK_604Daos/files/Pictures/temp/IMG_20161123_092002.jpg	

Level (m)	A+ (dig)	A- (dig)	Sum (dig)	Diff (dig)	Diff/2 (dig)	Defl. (cm)
0	75	-211	-136	286	143	23.96
0.5	74	-211	-137	285	142.5	23.6
1	74	-211	-137	285	142.5	23.24
1.5	77	-211	-134	288	144	22.89
2	74	-209	-135	283	141.5	22.53
2.5	77	-209	-132	286	143	22.17
3	77	-210	-133	287	143.5	21.82
3.5	73	-208	-135	281	140.5	21.46
4	75	-208	-133	283	141.5	21.11
4.5	75	-211	-136	286	143	20.75
5	75	-211	-136	286	143	20.39
5.5	76	-211	-135	287	143.5	20.04
6	76	-208	-132	284	142	19.68
6.5	76	-208	-132	284	142	19.32
7	74	-211	-137	285	142.5	18.97
7.5	76	-212	-136	288	144	18.61
8	75	-212	-137	287	143.5	18.25
8.5	73	-211	-138	284	142	17.89
9	75	-208	-133	283	141.5	17.54
9.5	77	-212	-135	289	144.5	17.18
10	75	-212	-137	287	143.5	16.82
10.5	74	-212	-138	286	143	16.46
11	75	-211	-136	286	143	16.11

C.2 Axis Deflection Data Report (.CSV)

Shown as displayed in Excel, for clarity:

Report: B-Axis Change in Digits and Deflection in (cm) (Bottom Up)

	Project Name:	Project1				
	Hole Name:	33				
	Top Elevation:	33				
	Azimuth Angle:	324				
	Hole Location:	Lat:	43.6465	Lon:	-72.2516	

		--Initial Data--		--Current Data--	
	Survey Name:	33_init1		33_later2	
	Reading Date:	10/27/2015		10/27/2015	
	Reading Time:	15:33:43		15:38:11	
	Probe Name:	Probe1		Probe1	

Level	--Initial (digits)--			--Current (digits)--			Corr.	Defl.
(m)	B+	B-	Diff.	B+	B-	Diff.	Diff.	(cm)
33	264	-200	464	-199	271	-470	-934	78.05
32.5	264	-197	461	-199	270	-469	-930	76.88
32	265	-197	462	-198	270	-468	-930	75.71
31.5	265	-199	464	-198	271	-469	-933	74.55
31	265	-201	466	-198	271	-469	-935	73.39
30.5	264	-198	462	-197	271	-468	-930	72.22
30	265	-199	464	-197	271	-468	-932	71.05
29.5	265	-196	461	-197	272	-469	-930	69.88
29	265	-198	463	-200	272	-472	-935	68.71
28.5	263	-199	462	-200	272	-472	-934	67.55
28	266	-197	463	-199	272	-471	-934	66.39
27.5	265	-197	462	-197	272	-469	-931	65.22
27	264	-197	461	-198	271	-469	-930	64.06
26.5	265	-197	462	-198	271	-469	-931	62.89
26	266	-197	463	-198	271	-469	-932	61.73
25.5	265	-197	462	-198	271	-469	-931	60.57
25	264	-199	463	-198	271	-469	-932	59.4
24.5	264	-200	464	-198	273	-471	-935	58.24
24	264	-198	462	-198	273	-471	-933	57.08
23.5	265	-198	463	-197	272	-469	-932	55.91
23	264	-198	462	-197	272	-469	-931	54.74
22.5	263	-200	463	-197	272	-469	-932	53.58
22	262	-198	460	-197	273	-470	-930	52.42

APPENDIX D. Remote Module Command Structure

COMMAND	FUNCTION	SYNTAX	RETURN VALUE
0	TAKE VA READING	0	(+/-)#####
1	TAKE VB READING	1	(+/-)#####
2	TAKE BATTERY READING	2	\<sp>\<sp>+#.#
3	TAKE -12V READING [1]	3	\<sp>-12.0
4	FIRMWARE VERSION [4]	4	VER#.#
5	(see Note 2)	5	\<CR>
6	(see Note 2)	6	000\<sp>\<sp>\<sp>
7	TAKE +12V READING [1]	7	\<sp>+12.0
8	TAKE +5V REFERENCE READING	8	\<sp>\<sp>+#.#
9	TAKE 3.3V READING [1]	9	\<sp>\<sp>+3.3
D	LOAD PROBE DEFAULTS [3]	D	See Example D
G	DISPLAY GAGE PARAMETERS [3]	G	See Example G2
G	ENTER GAGE PARAMETERS [3]	G70A/(LorP)/#/#/# or G70B/(LorP)/#/#/# See example G below	See Example G1
T	PROBE TEMPERATURE (°C) [3]	T	(+/-)##.####
V	FIRMWARE VERSION (Remote Module) [3]	V	VER #.#
#	DISPLAY PROBE SERIAL # [3]	#	See example #
#sn	ENTER PROBE SERIAL # [3]	#sn(16 alphanumeric characters or symbols)	See example #sn

Notes:

1. These commands exist only for GK-604 analog systems and are included in the digital system for compatibility.

2. Like Note 1 but are for internal use only.

3. These commands exist only for GK-604D digital system.

4. Firmware Version (Command 4) returns the Remote Module version for analog systems and the probe firmware version for digital systems.

Example 1: <u>LOAD PROBE DEFAULTS</u>

Loads probe default gage parameters (calibration factors):

<u>Command:</u>   `D<CR>`

<u>Response:</u>   `GT:70A ZR:0.0000 GF:1.0000 GO:0.0000 GT:70B ZR:0.0000 GF:1.0000 GO:0.0000`

<u>Channels VA and VB:</u>   Linear Conversion
Zero Read Offset = 0
Gage Factor = 1
Gage Offset = 0

Results in digits display = 2500(Vout)

Example 2: <u>Enter Gage Parameters:</u>

Enter and store gage parameters for each axis:

<u>A axis:</u>   Linear conversion
Zero Read Offset = 0
Gage Factor = .62
Gage Offset = 0

<u>Command:</u>   `G70A/L/0/.62/0<CR>`

<u>Response:</u>   `GT:70A ZR:0.0000 GF:0.6200 GO:0.0000 GT:70B ZR:0.0000 GF:1.0000 GO:0.0000`

<u>B axis:</u>   Linear conversion
Zero Read Offset = 0
Gage Factor = 1.005
Gage Offset = 0

<u>Command:</u>   `G70B/L/0/1.005/0<CR>`

<u>Response:</u>   `GT:70A ZR:0.0000 GF:0.6200 GO:0.0000 GT:70B ZR:0.0000 GF:1.005 GO:0.0000`

Example 3: <u>Display Gage Parameters:</u>

Display gage parameters stored in the probe:

<u>Command:</u>   `G<CR>`

<u>Response:</u>   `GT:70A ZR:0.0000 GF:0.6200 GO:0.0000 GT:70B ZR:0.0000 GF:1.005 GO:0.0000`

Example 4: Display Probe Serial Number:

Display the serial number that is stored in the probe:

    Command: `#<CR>`

    Response: `6001-E,126543`

Example 5: Enter Probe Serial Number:

Enter and store probe serial number. Up to 16 alphanumeric characters and symbols may be stored.

    Command: `#sn6001-E,126543<CR>`

    Response: `6001-E,126543` [1]

NOTES:
1. The GK-604D IRA uses the serial number to determine the inclinometer probe units (metric or English) by reading the model number portion of the serial number string (the part to the left of the comma). If the model number does not contain an "-E" or a "–M" then unpredictable results may occur.

APPENDIX E. Data Reduction Formulas

E.1. Deflection Calculation

Label	Description
ZZ	Correction Angle (usually 0°).
RINT	Absolute Reading Interval in feet or meters.
IA+,IA−	Initial A Axis Data in Digits (2sinθ=10000 @ 30°, 2.5sinθ=12500 @ 30°).
PA+,PA−	Present A Axis Data in Digits (2sinθ=10000 @ 30°, 2.5sinθ=12500 @ 30°).
IB+,IB−	Initial B Axis Data in Digits (2sinθ=10000 @ 30°, 2.5sinθ=12500 @ 30°).
PB+,PB−	Present B Axis Data in Digits (2sinθ=10000 @ 30°, 2.5sinθ=12500 @ 30°).
SA	Calculated Digit Change for A Axis.
SB	Calculated Digit Change for B Axis.
M	Multiplier, where: Geokon probe Sinco Probe Probe configuration 2sinθ, 2.5sinθ. Metric units, millimeters, 0.05 0.04 Metric units, centimeters, 0.005 0.004. Imperial units, inches 0.0006 0.00048
CA	Deflection A (in inches, English units, not corrected). Deflection A (in centimeters or millimeters, Metric units, not corrected).
CB	Deflection B (in inches, English units, not corrected). Deflection B (in centimeters or millimeters, Metric units, not corrected).
DA	Deflection A (in inches, English units, corrected for angle). Deflection A (in centimeters or millimeters, Metric units, corrected for angle).
DB	Deflection B (in inches, English units, corrected for angle). Deflection B (in centimeters or millimeters, Metric units, corrected for angle).
cos	Cosine function.
sin	Sine function.

Table E-1 Data Reduction Variables (Deflection)

```
SA = ((PA+)-(PA-))/2 - ((IA+)-(IA-))/2

SB = ((PB+)-(PB-))/2 - ((IB+)-(IB-))/2
```

Equation E-1 Change in Digits Calculation (Deflection)

```
CA = M × RINT × SA

CB = M × RINT × SB

DA = (CA × cos(ZZ))-(CB × sin(ZZ))

DB = (CA × sin(ZZ))+(CB × cos(ZZ))
```

Equation E-2 Deflection Calculation

Note: Accumulate (Σ) DA and DB results at each depth increment (from the bottom up or the top down) to obtain the deflection change (Figure 59).

E.2. Profile Calculation

Label	Description
ZZ	Correction Angle (usually 0°).
RINT	Absolute Reading Interval in feet or meters.
A+, A−	A Axis Data in Digits (2sinθ=10000 @ 30°, 2.5sinθ=12500 @ 30°).
B+, B−	B Axis Data in Digits (2sinθ=10000 @ 30°, 2.5sinθ=12500 @ 30°).
SA	Calculated Digit Change for A Axis.
SB	Calculated Digit Change for B Axis.
M	Multiplier, where: Geokon probe Sinco Probe Probe configuration 2sinθ, 2.5sinθ. Metric units, millimeters, 0.05 0.04 Metric units, centimeters, 0.005 0.004. Imperial units, inches 0.0006 0.00048
CA	Deflection A (in inches, English units, not corrected). Deflection A (in centimeters or millimeters, Metric units, not corrected).
CB	Deflection B (in inches, English units, not corrected). Deflection B (in centimeters or millimeters, Metric units, not corrected).
DA	Deflection A (in inches, English units, corrected for angle). Deflection A (in centimeters or millimeters, Metric units, corrected for angle).
DB	Deflection B (in inches, English units, corrected for angle). Deflection B (in centimeters or millimeters, Metric units, corrected for angle).
cos	Cosine function.
sin	Sine function.

Table E-2 Data Reduction Variables (Profile)

$$SA = ((A+) - (A-))/2$$

$$SB = ((B+) - (B-))/2$$

Equation E-3 Change in Digits Calculation (Profile)

$$CA = M \times RINT \times SA$$

$$CB = M \times RINT \times SB$$

$$DA = (CA \times \cos(ZZ)) - (CB \times \sin(ZZ))$$

$$DB = (CA \times \sin(ZZ)) + (CB \times \cos(ZZ))$$

Equation E-4 Profile Calculation

Note: Accumulate (Σ) DA and DB results at each depth increment (from the bottom up or the top down) to obtain the profile.

E.3. GTILT Users

When using GTILT with the GK-604D | aos data files, use a Probe Constant of 10000 for both English and Metric "2.0sin" probes. For 2.5sin Units (Sinco) use a Probe Constant of 12500.

E.4. SiteMaster Users

When using SiteMaster with the GK-604D | aos data files, use a Probe Constant of 20000 for both English and Metric probes.

APPENDIX F. Technical Specifications

F.1. GK-604D Digital System Specifications

Standard Range	$\pm$ 30°
Sensors	2 MEMS accelerometers
MEMS Output	Differential $\pm$ 4 VDC
6100D Probe Output	Digital Data Stream
Probe Resolution	24-bit
System Resolution[1]	$\pm$ 0.025 mm/500 mm ($\pm$ 0.0001 ft/2 ft)
Accuracy	$\pm$ 0.05% Full Scale (F.S.)
Linearity	$\pm$ 0.02% F.S., up to $\pm$10°
Repeatability	$\pm$ 1 mm/30 m
Total System Accuracy[2]	$\pm$ 3 mm/30 m ($\pm$ 0.125 in/100 ft)
Temperature Range (Probe)	0°C to 50°C
Temperature Range (Remote Module)	-30°C to 50°C
Temperature Coefficient	0.002% F.S./°C
Wheel Base	0.5 m, 1m or 2 ft
Length x Diameter[3]	700 x 25 mm, 1200 x 25 mm or 32 x 1 in
Casing Size I.D.[4]	51 to 89 mm (2.0 to 3.5 in)
Weight (with case)	7.5 kg (16 lb)
Shock Survival[5]	2000 g
Battery (Remote Module)	Li-Ion, 7.4 V, 2600 mAh; >40 hours continuous operation per charge

Notes:

1. $\pm$ 10 arc seconds. This resolution is true only in the range of $\pm$ 5° from vertical. Beyond this, the resolution is diminished by the cosine of the angle from vertical.

2. Within 3° of vertical. This takes into account the accumulation of the error inherent with each reading and normal placement errors in positioning the probe inside the casing; also the effect of debris in the casing or casing damage.

3. The cable connector adds 150 mm to the length of the probe. The wheel diameter is 30mm.

4. The probe is designed for use in all standard inclinometer casing up to a maximum diameter of 89 mm (3.5 inches).

5. **The Inclinometer Probe is a highly sensitive device and should be treated with great care at all times in order to maintain calibration. In**

particular, the probe should be prevented from impacting the bottom of the casing with any force.

F.1.1 Compass Sensor Specifications

The following table contains specifications for the Digital Compass sensor embedded in digital inclinometer probes.

Compass Sensor	Anisotropic Magneto-resistive
MEMS Output[1]	± 4 VDC
Compass Sensor Resolution	12 bit
Remote Module Resolution	16 bit
Compass Sensor Accuracy	± 2 degrees
Operating Temperature	−30°C to 85°C (−22° to 185°F)

F.2. Analog Probe System Specifications

The following table contains specifications for the analog probe system which is comprised of a probe (6100-1M or 6100-1E) and the Remote Module. The Remote Module can be either a GK-604-3 (reel system) or a GK-604-4 (probe interface).

Probe Range (100% F.S.)	± 30°
Remote Module Input Range	± 8 VDC
Sensors	2 MEMS accelerometers
MEMS Output[1]	± 4 VDC
Probe Resolution[2]	.025 mm /500mm (.0001 ft/ 2 ft)
Remote Module Resolution	16 bit
Repeatability[3]	± 1mm/30m (± 0.05in/100ft)
Total System Accuracy[4]	± 4 mm/ 30 m (± 0.17 inch/ 100 ft)
Remote Module Accuracy	± 0.1% F.S.
Probe Temperature Range	−20°C to 50°C (−4° to 122°F)
Remote Module Temp. Range	-30°C to 50°C
Temperature Coefficient	<.0002% F.S./ °C (<.0002% F.S./ °F)
Wheel Base	0.5m or 1.0m (2 ft)
Probe Length x Diameter[5]	700 × 25 mm dia. (32 × 1 in dia.)
GK-604-3 Dimensions	*(L x W x H):* 380 x 280 x 490 mm
GK-604-4 Dimensions	*(L x W x H):* 160 x 75 x 75 mm
Weight (with case) (GK-604-1)	7.5 kg (16 lb)
Shock Survival	2000g
Battery (Remote Module)	Li-Ion, 7.4 V, 2600 mAh; >16 hours continuous operation per charge

Notes:

1. The probe outputs +/-4 volts at an inclination of +/-30° to the vertical. These parameters are referred to as full scale. Operation beyond this inclination is not possible with a standard MEMS probe.

2. The resolution shown in the table above is only true in the range of ± 5° from the vertical. Beyond this the resolution is reduced by a factor equal to 1/cosine of the angle from the vertical. For instance the resolution at 0 degrees from vertical is 10.3 arc seconds and the resolution at 15 degrees from the vertical is 10.3 x 1/0.966 = 10.7 arc seconds. The figures given assume that the readout box can detect a change of output of 0.0005 VDC.

3. The figure shown applies to the use of a single probe used repeatedly over a short space of time in a single borehole.

4. In practice, system accuracy is controlled mainly by the precision with which the inclinometer can be positioned at exactly the same depth, in the casing, from survey

to survey. Factors such as debris in the casing or casing damage also have an effect. The stated accuracy assumes that the surveys are conducted over a period of time in a proper manner and that the casing is within 5 degrees off the vertical. Accuracy is improved by allowing the probe to reach equilibrium at each depth level before taking a reading.

5. The probe is designed for use in all casing sizes up to 85mm ID (3.34in.). The wheel diameter is 30mm. The cable connector adds 150mm to the length of the probe.

F.3. Android Device Minimum Specifications

Operating System	Jelly Bean, 4.2 or greater
Bluetooth	Version 2.1 or greater
Wifi or Cell Phone capability	Required if email export and/or saving is used
GPS Hardware	Recommended
Camera	Recommended
Protective Case	Recommended

APPENDIX G. Compass Probe Operation

The GK-604D | aos supports Geokon's digital Inclinometer/Compass Probe (6100D-X, Firmware Version V2.7), requiring a GK-604D-X Digital Reel System with a firmware version of V2.7 or higher.

The compass feature of the inclinometer probe is described in detail in the following sections.

G.1 Inclinometer/Compass Probe (6100D-X)

As of probe firmware version V2.7, coupled with the GK-604D reel assembly (also V2.7), all digital inclinometer probes now include a 3-axis, magneto-resistive, compass sensor survey (see Figure 75). The compass sensor coupled with 2 axes of MEMS, allow a spiral survey to be performed **at the same time** as the inclinometer survey.

Figure 75 – Digital Inclinometer/Compass Probe (6100D-X)

Follow the steps below to perform a compass survey with the Digital Inclinometer/Compass Probe:

1. Connect the 6100D-X probe to the Remote Module and ensure that a Bluetooth pairing exists between the Remote Module and the Android device. See Section 2.2 for more information regarding Bluetooth pairing.

2. Launch the GK-604D | aos application.

3. If one does not already exist, create a hole to represent the physical hole, shaft or well where the inclinometer/compass survey is to be performed. If a probe configuration exists for the Inclinometer/Compass probe, then select the name of the probe to be assigned to this hole, otherwise set the "Probe" to "UNKNOWN". Set the "Azimuth Angle" parameter to "0" then save settings.

4. Press the "POWER ON (BLUETOOTH)" button on the reel and ensure that the blue light is blinking.

5. From the main screen (Figure 25), tap the "APP" menu (Figure 26) then "Live Readings" (Section 3.2.1). If the probe serial number matches a probe configuration serial number from the Probe Library then the "Live Readings" screen will be displayed (see Figure 30). Proceed to step 6.

   If the probe has never been detected before, a screen similar to the one in Figure 8 will be displayed. Tap "ok" to continue and the GK-604D | aos will display a probe editing screen to allow the probe to be named (see Figure 9). After entering a name, tap the "<" to the left of the title. If the hole to be surveyed has an "UNKNOWN" probe assigned to it then the GK-604D | aos will ask if this newly discovered probe should be assigned to this hole (see Figure 10). Selecting "Yes" will cause the GK-604D | aos to display the "Live Readings" screen (Figure 30).

6. If the GK-604D | aos has detected an inclinometer with the integral compass, tapping the "MENU" option will the display the menu shown in Figure 34. Tapping the menu option, "Enable Compass Survey", will display the message shown (in red) in Figure 76 for approximately 5 seconds and will enable the compass survey option. This message informs the user that, with the compass enabled, an inclinometer survey will take approximately 30% longer.
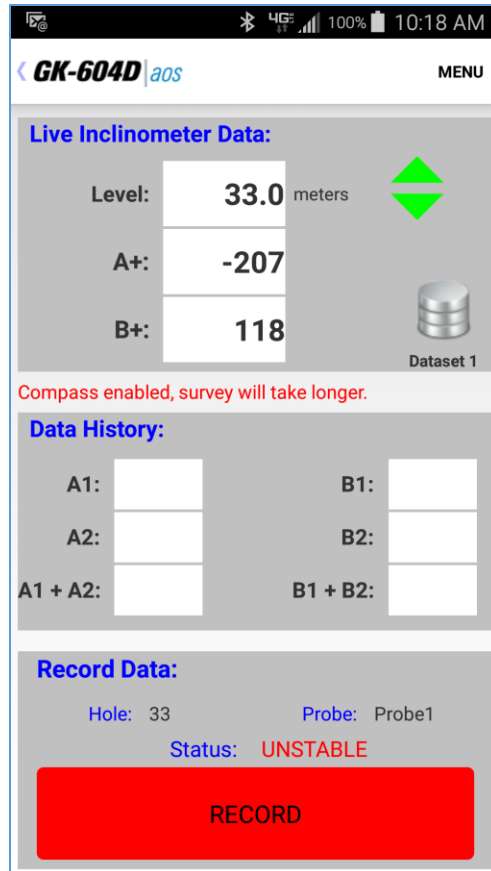
Figure 76 – Compass Enable Message

7. With the compass enabled, a survey is performed as normal (see Section 3.3.1) and the compass heading can be displayed at any level by tapping on "MENU->View Compass Data", displaying the screen shown in Figure 77.

8. While live compass data is being shown, "Live Inclinometer Data" can be re-displayed at any time by tapping on "MENU->View Inclinometer Data".
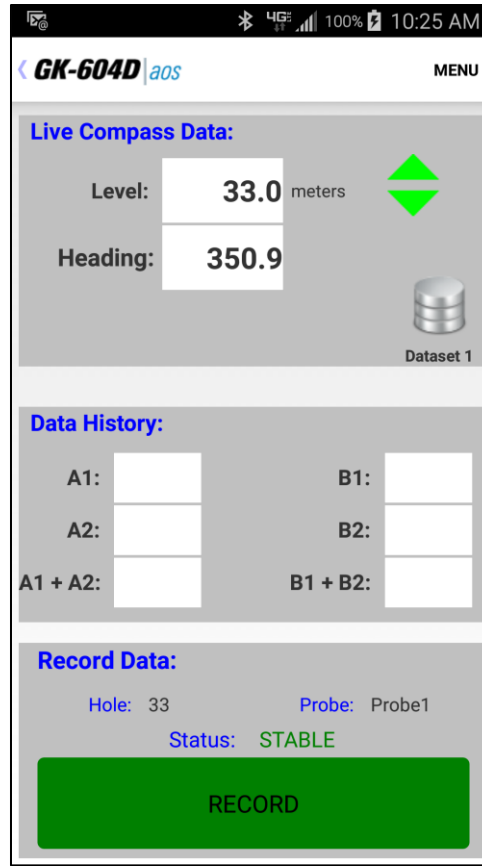
Figure 77 - Live Compass Data

9. When done the survey, tap the "<" to the left of the title and the "Unsaved data" prompt (see Figure 31) will be displayed. Tap "Yes" to save the inclinometer/compass survey data.

10. When exporting inclinometer surveys, data is saved into a ".gkn" file as normal while the compass survey data is saved into a ".gks" file. The ".gks" file format is supported by SiteMaster inclinometer analysis software and is very similar to standard inclinometer survey data with the following exceptions:

   - **A+** data is always in degrees.
   - **A-** and **B-** are always zero (0)
   - **B+** data is always 90 degrees greater than **A+**

11. For surveys with the compass enabled, compass data is included in the "Raw Data Report" as an additional column of data labeled "Compass Hdg (deg)". Compass data can also be exported for later use in analysis using "FILE-> Export". See Section G.2 for an example ".gks" file.

G.1.1 Calibrate Compass

For optimum accuracy, the digital inclinometer/compass probe should be calibrated for each site. The GK-604D | aos provides a dialog to facilitate this (see Section 3.2.1.1 and Figure 34). A compass survey does not need to be enabled to perform the calibration.

While the GK-604D | aos is connected to the probe and displaying the "Live Readings" screen, tap on "MENU->Calibrate Compass" to display the initial calibration screen (see Figure 78).
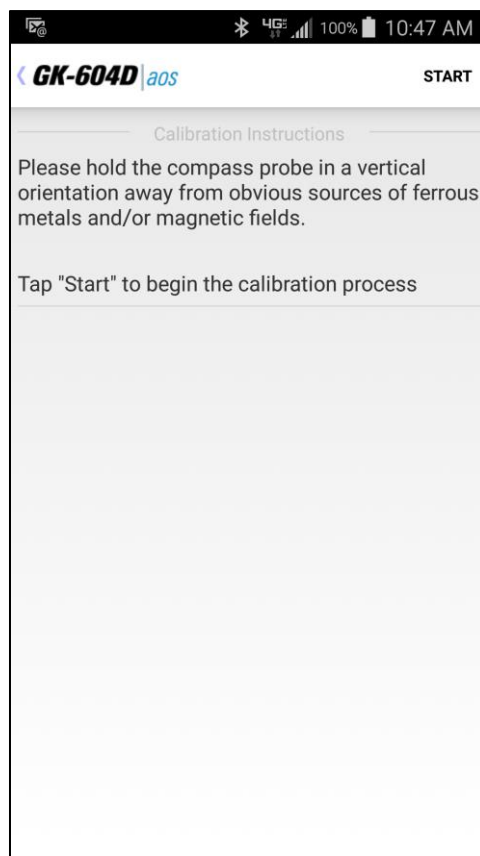

Figure 78 - Initial Calibration Screen

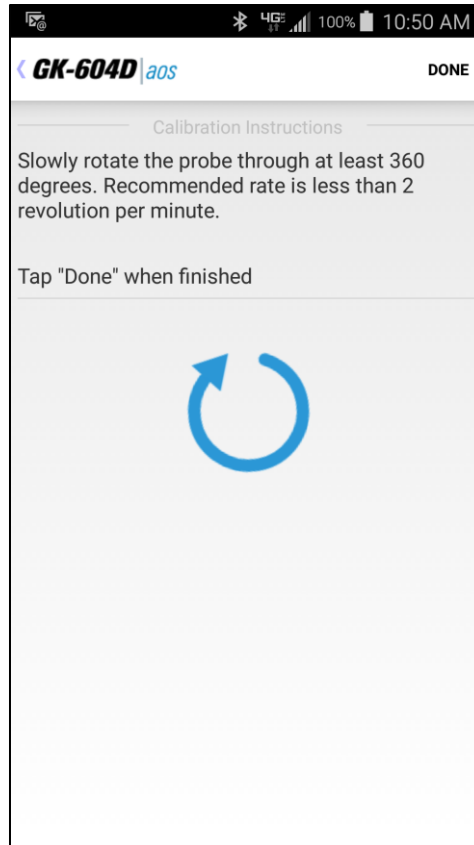Tapping "START" begins the calibration process (see Figure 79).

Figure 79 - Calibration Routine

As the instructions state, the probe should be held in an upright position and slowly rotated through at least 360 degrees. The large rotating blue "arrow" serves 2 purposes: one, it indicates to the user that the probe should be turned and two, it provides feedback that the calibration routine is still running. Tapping "DONE" sends a command to the probe that calibration is finished and the Live Readings screen is re-displayed.

G.2 Compass Survey Data

```
***
GK 604M(v1.2.0.0,07/14);2.0;FORMAT II
PROJECT  :testProj
HOLE NO. :testHole
DATE     :7/22/14
TIME     :11:30:57
PROBE NO.:incloCompass
FILE NAME:testHole_012_Compass.GKS
#READINGS:71
FLEVEL,    A+,    A-,    B+,    B-
  35.0,   164,     0,   254,     0
  34.5,   164,     0,   254,     0
  34.0,   168,     0,   258,     0
```