



Digital MEMS Inclinator System with Android App Instruction Manual

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1 INTRODUCTION

RST's Digital MEMS Inclinometer System represents a breakthrough in inclinometer system technology, providing unprecedented accuracy, efficiency, and ease of use. The system is comprised of a digital inclinometer probe, cable system, reel with battery power, and the Digital Inclinometer app that functions as a readout, analysis, and data storage device.

The digital inclinometer probe incorporates cutting edge micro electro-mechanical systems (MEMS) technology providing high precision and durability. A highly accurate survey of the inclinometer casing is used to establish the initial position of the casing. Any subsequent deviations in the casing from this initial value or baseline reading, represent changes occurring in the subsurface. The Digital MEMS Inclinometer System can accurately measure the rate, depth, and magnitude of these deviations.

The Digital MEMS Inclinometer System measures lateral movement of earthworks or structures, landslides, and embankment fills. It can be used to monitor stability adjacent to excavations or underground workings and deflection of piles, piers, abutments or retaining walls.

1.1 INTENDED AUDIENCE

This guide is for the service personnel responsible for installing and maintaining the Digital MEMS Inclinometer System. This manual provides steps and examples of how to take readings and interpret the data. This manual also contains care and maintenance recommendations that will help extend the life of your inclinometer system. For more information on the installation or other questions, contact RST Instruments Ltd.

1.2 ICONS AND CONVENTIONS USED IN THIS GUIDE

This guide uses the following icons to call attention to important information.



WARNING: This icon appears when an operating procedure or practice, if not correctly followed, could result in personal injury or loss of life.



CAUTION: This icon appears when an operating procedure or practice, if not strictly observed, could result in damage to or destruction of equipment.



CHECK: This icon appears to remind you of quality-related features.



NOTE: This icon appears to highlight important, non-safety related information.

2 SYSTEM OVERVIEW

2.1 PARTS AND COMPONENTS



Figure 1: Parts and components

- | | |
|---|---|
| 1. Soft shell case | 7. Device accessories |
| 2. Digital inclinometer probe with protective end cap | 8. USB cable for Android device |
| 3. 70mm/2.75" outside diameter (OD) cable grip | 9. AC adapter for Android device |
| 4. 85mm/3.34" OD cable grip | 10. AC adapter for reel battery charger |
| 5. Android device | 11. Cable reel with wireless communication system |
| 6. Silicone lubricant for use on connectors | 12. Reel carrying case |
| | 13. Micro-fiber cleaning cloth |

3 PROBE TYPES

The new digital probe resembles that of the traditional analog probes sold by RST. The digital inclinometer has the smallest package available for a given wheel spacing, with the best ability to track deformed casings. This means that the digital probe can handle greater bends in the casing without becoming stuck.

The metric probe can negotiate a radius of 1.88m (74") in 70mm (2.75") OD inclinometer casing. The digital inclinometer will continue to provide readings past the limit for other probes on the market.

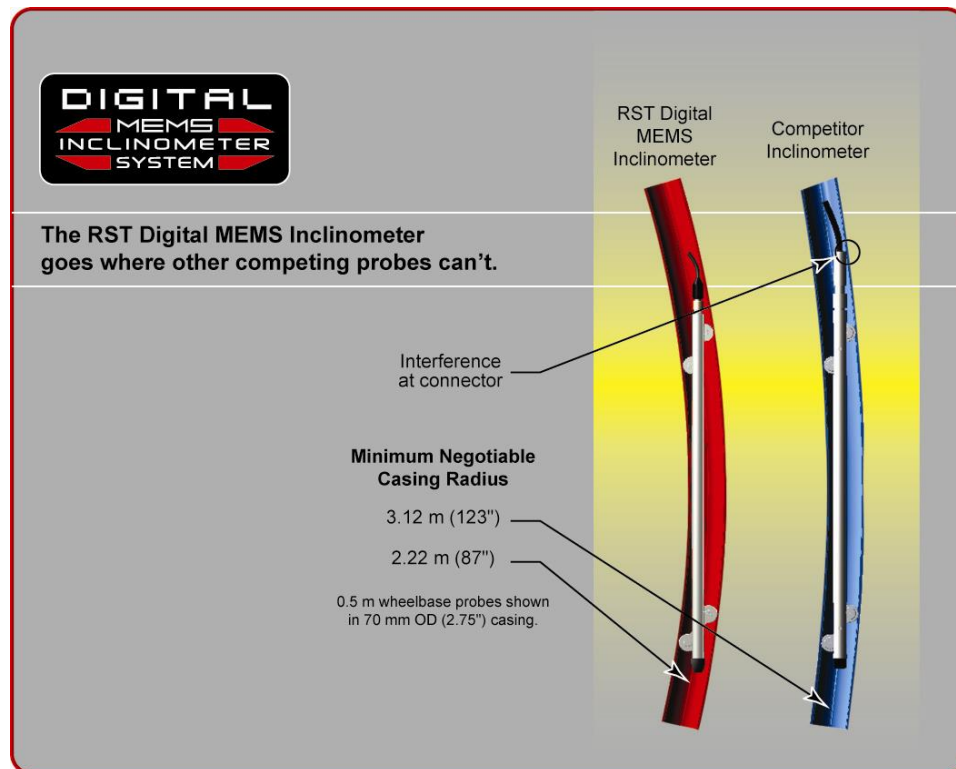


Figure 2: RST Digital MEMS Inclinometer digital probe sizing vs. competitor inclinometer

The connectors, wheels, and wheel carriages are the most precise and durable in the industry. The probe wheels are made of high-grade hardened and heat-treated stainless steel. These are extremely durable and the most robust on the market.



CAUTION: The digital probe also uses shear pins on the wheel assemblies. If the probe gets stuck in the inclinometer casing, apply a force of approximately 300 lbs to shear pin to prevent damage to the probe or cable. Contact RST Instruments Ltd. for instructions on retrieving a probe that is stuck in a hole and replacing the probe shear pins.

3.1 VERTICAL PROBE

Vertical probes collect data in the A and B axes and are the most used probes. Readings taken from an inclinometer probe are deviations from the vertical over the distance between the upper and lower wheels. When the probe is passed through the inclinometer casing, a reading is taken every 0.5m (or 2 feet). When the probe is at rest, the MEMS accelerometers sense the inclination of the access tube in two planes. This inclination in terms of angular deviation (recorded at that depth) appears on the handheld device's screen.

3.2 SPIRAL PROBE

The RST Digital Spiral Probe is designed to complement the Digital MEMS Inclinometer System. In situations where excessive spiral is present in the inclinometer casing, it becomes important to correct for the spiral to have the correct magnitude of displacement in the A and B axes. A spiral sensor is used to determine the true azimuth of inclinometer casing after installation.

The spiral sensor is connected to the digital inclinometer reel just like a standard RST digital inclinometer probe. The Digital Inclinometer app automatically senses the digital spiral probe. The probe is then lowered to the base of the borehole and the survey is performed in 0.5 metre (or 2 feet) intervals depending on whether a metric or imperial system is being used. Readings are displayed on the handheld device in degrees. Device recommendations are discussed in section 6.2.

After data is collected, it can be imported into the RST Inclinalysis™ Software. A spiral correction can then be applied to the digital inclinometer data and plots of the corrected borehole data can be created.



NOTE: For information on the Inclinalysis™ Software, contact RST Instruments Ltd. or visit our website at <http://www.rstinstruments.com>.

3.3 DUMMY PROBE

Dummy inclinometer probes for use in testing in boreholes are available for purchase from RST. RST encourages customers to try the new digital dummy probe in existing holes where the competitor's probes do not work. If the dummy probe passes through all areas of the casing, the RST Digital MEMS Inclinometer System will work. Therefore, the existing hole will still be viable, and a new hole will not need to be drilled.

The RST dummy probe has the exact same weight and dimensions as the standard probe. A ring is provided in place of the connector which allows the dummy probe to be lowered by a rope. Contact RST Instruments Ltd. to purchase a dummy probe.

4 VERTICAL DIGITAL PROBE

4.1 SIGN CONVENTION AND MEASURED DEVIATION

The vertical digital probe houses two MEMS accelerometers, which measure tilt in two axes. Proper installation of the inclinometer casing attempts to align one set of grooves in line with the axis of expected movement. This is called the A axis. The perpendicular set of grooves is the B axis.

When an inclinometer casing is surveyed for the first time (referred to as the “baseline reading”), it is necessary to select a fixed direction reference for the probe so that each time a survey is repeated, the probe will always have the same orientation in the casing.

For example, in an area suspected of landslide activity, the first set of readings should be taken by placing the upper wheels of the probe in the casing groove closest aligned to the downslope direction. Figure 3 illustrates an inclinometer casing installed with a groove orientation in the general downslope direction.

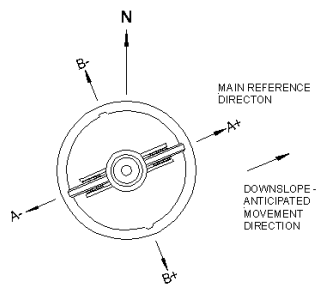


Figure 3: Probe orientation

In practice, it is often difficult to achieve exact orientation of grooves relative to some predetermined direction. The groove closest to the anticipated movement direction is usually chosen as the main reference direction. RST recommends that this direction (A+) be marked on the casing itself to ensure surveys are performed in the same manner each time.

The azimuth of this groove direction can be measured in a clockwise direction from the main reference direction (A+). All subsequent measured inclinometer movements would be referred to this direction.

Readings taken from the inclinometer probe are deviations from the vertical over the distance between the upper and lower wheels (see Figure 4), calculated as:

$$D = L \times \sin(\alpha)$$

Where:

D = Deviation, which is the lateral displacement in the direction of the axis of measurement

L = inclinometer probe length, typically 0.5 m for a metric probe or 2 feet for an imperial probe

α = inclination angle of probe from vertical axis

The Digital MEMS Inclinometer System uses the industry standard sign convention, where tilt in the direction of the upper wheels results in a positive deviation and tilt in the direction of the lower wheels results in a negative deviation as shown in Figure 4.

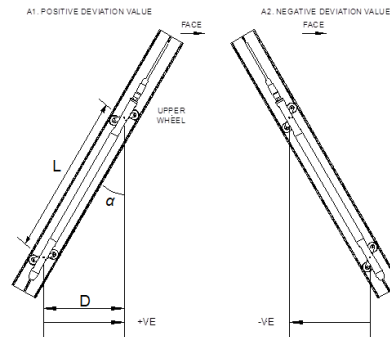


Figure 4: Sign convention in the A-axis and deviation measured by inclinometer probe

Figure 5 shows the sign convention for the A and B axis. Figure 6 shows markings on the probe.

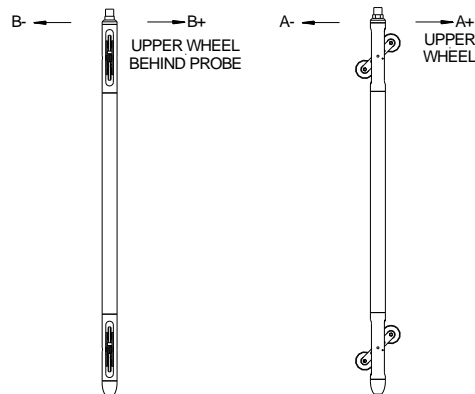


Figure 5: Probe axes

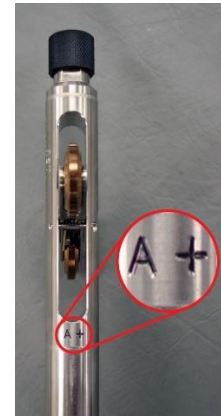


Figure 6: A+ marking on the inclinometer probe

5 INCLINOMETER CABLE AND REEL

The RST Digital MEMS Inclinometer System comes with a durable lightweight reel that is easy to handle. Since only a pair of conductors is needed in the cable, the weight and dimensions of the cable are drastically reduced compared to a traditional analog cable. The reel is battery-powered and houses the electronics used for wireless communication.

An important part to any inclinometer casing survey is the repeatability of the depth measurements. It is extremely important that measurements be consistently within 5 mm (0.25") of one another between subsequent surveys. For accurate repeatability, two aluminum cable grips are provided with the system, for 70 mm (2.75") and 85 mm (3.34") OD casing respectively.

The cable grips provide a solid reference for the cable crimps to sit in. This results in reduced operator error, with checksums smaller and surveys more accurate.

The thin, strong cable contains a Kevlar® strength member, allowing a long length of cable to fit on a small reel with no stretch. The aluminum sleeved measure marks are precision swaged to the cable and are not subject to tearing when handling. The measure marks are spaced at 0.5 metre or 2 feet intervals. The cable is marked with a red measure mark and a label every 5 metres or 10 feet, depending on whether the metric or imperial system is being used. The urethane jacket is highly abrasion-resistant and maintains flexibility at low temperatures.



NOTE: Avoid running the cable over sharp edges and to periodically clean it with a soft cloth. Be sure to keep the protective cap on the connector whenever the probe is not in use and avoid dropping or banging the cable end. Always keep the connectors and threads clean by rinsing them with water and be sure to lubricate frequently. Exercise care when connecting and removing the cable from the probe. Make sure to only turn the connector ring, not the entire cable.

5.1 INCLINOMETER REEL BATTERY

The inclinometer reel has a green LED light that will flash to indicate battery status (Table 1). The LED light on the reel will flash when the power button is pressed. A full charge will last around 30 hours. Monitor the battery status. **Do not let the battery completely discharge.**

If the serial number of the reel is 2500 or above, the battery is contained inside the inclinometer reel. The inside of the reel is not accessible, and the battery is not removable. **Do not try to remove the battery.** See Section 15.1 for battery status and Section 15 for battery charging instructions.

If the serial number is 2499 or lower, the battery can be removed and recharged. Refer to Section 15 for instructions on removing and recharging the battery.

LED Flash	Battery Status
1 flash, reel does not power on	Completely discharged
2 flashes, reel does not power on	Discharged below level required to connect
1 flash, reel powers on	Discharged below 25%
2 flashes, reel powers on	Discharged below 50%
3 flashes, reel powers on	Discharged below 75%
4 flashes, reel powers on	At full charge

Table 1 Battery status LED

5.2 CHARGE THE BATTERY – REEL WITH SERIAL NUMBER 2500 OR ABOVE

→ **NOTE:** Do not follow these instructions if the reel serial number is under 2500. Refer to Section 15.

5.2.1 Reels with serial number of 2500 or higher

To charge the battery on a reel with a serial number 2500 or higher, locate the battery port on the side of reel. Turn the cap counterclockwise to unscrew. Plug the charger into the battery port and begin charging. After charging is complete, place the cap back and tighten.



Figure 7: Reel battery port



Figure 8: Plugging charger into battery port

5.2.2 Reels with serial number of 5000 or higher

The battery is recharged using a standard USB charger. The battery port may be accessed by unscrewing the cap on the outside of the reel. Refer to Figure 9 for the location of the battery cap. Turn the cap counterclockwise to unscrew. Plug the charger into the battery port and begin charging. The charging red LED will be on until charging completes. After charging is complete, place the cap back and tighten to ensure debris does not enter the battery.



Figure 9: Reel battery port



Figure 10: Plugging charger into battery port

5.3 TURN ON WIRELESS COMMUNICATION

Press the power button to the left of the battery port. A solid green light appears to indicate power is on. The reel automatically broadcasts its device name and continues to broadcast for up to five minutes. During this five-minute window, the Digital Inclinometer app must establish Bluetooth connection with the reel. If the app unable to connect to the reel, the reel powers down to reduce battery consumption.

The reset (power) button has a green light that indicates the reel's status. **No light** indicates reel power is off. **Solid light** indicates power is on, but the reel is not connected to the Digital Inclinometer app. **Blinking green** at one second intervals mean the reel is connected to the Digital Inclinometer app.

5.4 CHECK REEL AND PROBE STATUS

On the bottom of Digital Inclinometer app are the reel, probe, and battery status icons. You can tap these icons to display reel, probe, and battery status.

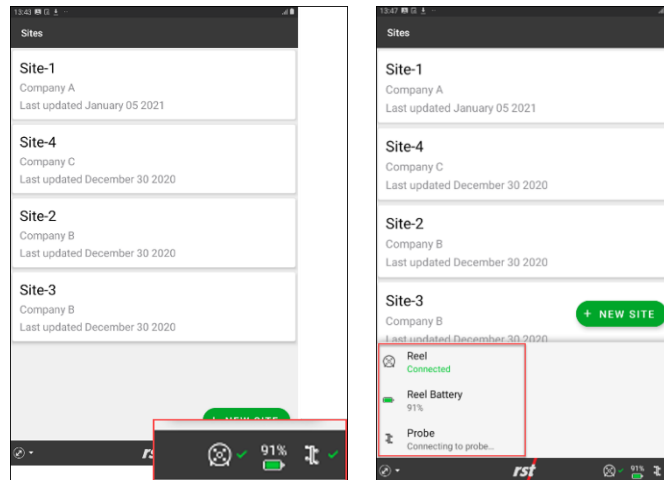


Figure 11: Status icons Figure 12: Expanded status



The statuses provide diagnostic information as shown in Table 2.

Device	Status	Description
Reel	Disconnected	App is searching for a Bluetooth connection to the reel. This status stays until the app is disconnected
Reel	Connected	App has Bluetooth connection to the reel
Reel	Updating reel battery state...	App is connected to the reel and updating battery status
Reel Battery	Percentage	Battery level
Probe	Disconnected	App is not connected to the reel
Probe	Connected	App has a Bluetooth connection to the probe
Probe	Connecting to probe...	App is connecting to the probe

Table 2 Diagnostic information for the reel and probe

5.5 DEVICES LIST

The app retrieves reel and probe information every time it tries to connect to the devices. You will need this info when contacting RST for help.

To see the list of devices connected to the app, tap **MEASURE**  on the bottom of screen and then tap **DEVICES** . Connected devices appear under MY DEVICES and AVAILABLE DEVICES.

MY DEVICES show reels within Bluetooth coverage of the app and that were connected in the past. When you launch the app, it will automatically try to connect to devices in this list. Tap **FORGET** opposite the device to remove it from the list.

AVAILABLE DEVICES show reels within Bluetooth coverage of the app but have not yet connected to the app. The app does not automatically connect to these devices. Tap a device from this list to move it to the MY DEVICES list.

The reel ID appears as DRxxxx, (“DR” stands for Digital Reel) with xxxx as the last four digits of the serial number. Always make sure the serial number on the reel you want to connect to the app is what appears on the screen. If the connected reel is not what you want, tap the one you want from the list to connect and display its information.

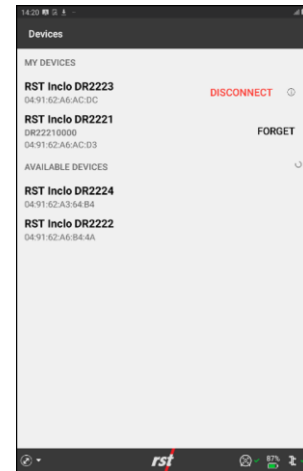


Figure 13: Sample Devices screen showing reel is disconnected

5.6 REEL AND PROBE INFORMATION

The app extracts information from the connected reel and probe. Tap the **Information** icon for the connected device to see information about it.

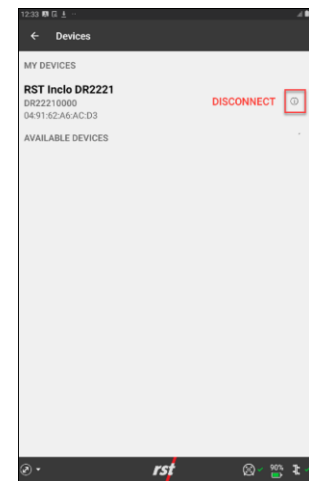


Figure 14: Information icon

5.6.1 Reel Information

Information on the Reel screen includes the following:

- Status – reel connection status
- Model – RST Digital Inclinometer Reel
- Serial Number – reel's serial number
- Battery Voltage – battery level
- Firmware – reel firmware version
- Run Time – number of minutes the reel has been connected to the app

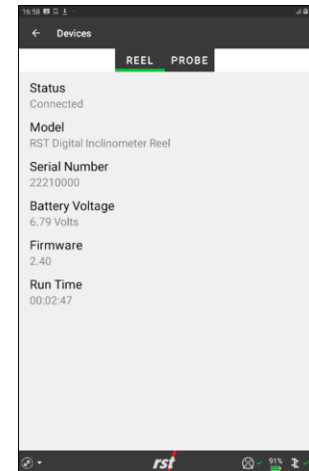


Figure 15: Reel information

5.6.2 Probe Information

Information on the Probe screen includes the following:

- Status – probe connection status
- Model – RST Digital Inclinometer Probe
- Serial Number – probe's serial number
- Firmware – firmware version
- Run Time – number of minutes the probe has been connected to the app
- Calibration Date – date when the calibration was last performed on the probe

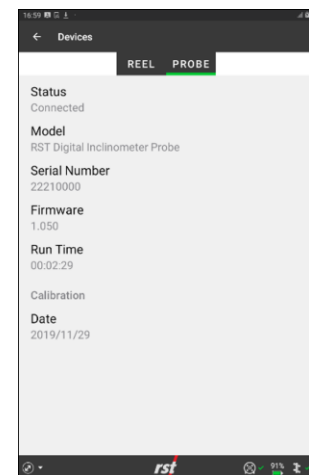


Figure 16: Probe information

6 DIGITAL INCLINOMETER APP FOR ANDROID DEVICES

The Digital Inclinometer app runs on most Android devices running Android version 5.1 or higher. The Android device connected to the app works as a readout and data storage device. You can perform a data reduction on site as soon as the survey is complete to display data in a form that you can be translate and use the visualization features to confirm data accuracy.

6.1 REQUIREMENTS

For the Digital Inclinometer app to run on an Android device, the device must:

- have Android version 5.1 or higher
- be Google Mobile Services certified and have pre-installed apps such as Google Play and Gmail
- have Bluetooth to connect to legacy and latest generation inclinometer systems

Other wireless networking capabilities such as Wi-Fi and cellular are recommended to remotely update collected data using email.

6.2 DEVICE RECOMMENDATIONS

Collecting data at the borehole expose devices to harsh environmental and field conditions. RST recommends rugged Android devices that can withstand the harshest environment, such as the Caterpillar CAT S42.

6.2.1 Caterpillar CAT S42

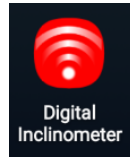
Operating system	Android 11
CPU	SMediatek MT6761D Quad Core
Memory	3 GB
Display size and resolution	5.5" 1440 x 720
Wi-Fi	802.11 b/g/n
Bluetooth	V.0 BLE
Cellular	4G LTE / GSM
Battery capacity	4200 mAh
Width, length, depth	161 x 77 x 13 mm 6.3 x 3.0 x 0.51 inches
Weight	0.22 kg, 0.50 lbs
Ingress protection	IP68 waterproof and dustproof
Certification	MIL-STD-810H (Shock and Drop)



6.3 INSTALL OR UPDATE THE APP

The Digital Inclinometer app is available for download from the Google Play Store. To find the app, search for “RST Inclinometer”. Updates are also available from the Google Play Store for app already installed on the device. This manual is for the Digital Inclinometer app version 1.2.7 and higher.

The app icon and name appear on the device once installed.



NOTE: The app is designed with compatibility in mind. The updates should maintain accumulated historical data. However, you should always export the accumulated data before updating the app version in case there is a compatibility issue. For information on exporting historical data, see Section 9.

6.3.1 App Pre-requisite Settings

The Digital Inclinometer app requires the following settings:

- Internet access using Wi-Fi, cellular, or both to allow the app to send emails collected borehole data to a recipient. Email is one of the available means to transfer data from the device to another computer.
- Voice call or text messaging – the Android device has capability to call a contact person. If this feature is required, an activated voice SIM card must be inserted and configured.
- Gmail account to allow the app to send collected data by email.
- Font size and screen zoom settings to allow the app to properly display and avoid truncated words and excessive word wrap. RST recommends initially setting the device with the smallest font size and zoom setting and increasing incrementally to the desired appearance.
- Screen timeout set to a large timeout value, such as 30 minutes. This setting specifies the time before the device enters sleep mode.
- Correct date and time setting as the app embeds this information in the data.

6.4 DIGITAL INCLINOMETER APP WORKFLOW

6.4.1 Screen Sections

The Digital Inclinometer app is designed to simplify workflow and allow the user to access functions with a minimal number of taps. The screen has three sections and layout is always in a portrait mode to display scrollable lists and graphical plots.

1. **Title bar** on the top, shows context-sensitive content. Additional controls, if applicable, are located at the left or right corner
2. **Middle screen** shows the context-specific content
3. **Status bar** on the bottom, shows connection status of the reel and probe, and other non-context specific content

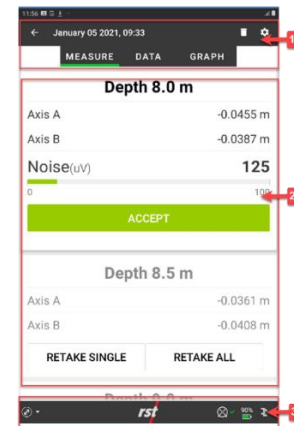


Figure 17: App screen organization

The icons are in different regions and provides context-sensitive functions as shown in Table 3 below.



















Top Title Bar Icons		
Icon	Short Name	Function
	Close	Close current configuration without saving
	Back	Return to the previous screen
	More	View more options
	Edit	Edit configuration
	Delete	Delete entry
Context-specific Content Icons		
Icon	Short Name	Function
	Zoom out	Display graphs in full screen mode
	Zoom In	Display graphs in partial screen mode
	Configuration	Configure graph options
	Info	Display information on the reel and probe
Bottom Status Bar Icons		
Icon	Short Name	Function
	Measure	Display measurement mode
	Devices	Display reel and probe information
	Transfer	Import or export data
	Help	Display Help functions
	Probe Disconnected	Probe is not available
	Probe Connected	Probe is connected and providing measurement data
	Reel Disconnected	Reel is disconnected from Bluetooth
	Reel Connected	Reel is connected to Bluetooth
	Battery	Reel battery level

Table 3: App icons and functions

6.4.2 Workflow Hierarchy

The app workflow follows a logical hierarchy that has four primary functions for users to access context-specific features.

- View site list shows list of all the created sites and allows a user to create a new site
- View borehole list shows list of all created borehole for a selected site, and allows a user to create a new borehole
- View readings list shows list of all collected readings for a selected borehole, and allows a user to add new readings and view combined plots
- View single reading shows list of the depth measurements and plot options for a selected reading

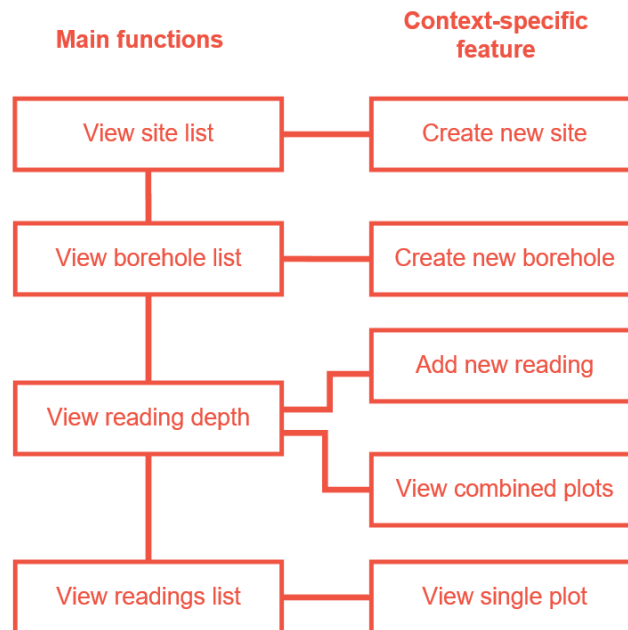


Figure 18: Workflow Hierarchy

6.4.3 View Site List

The View Site List is at the top of the workflow screen and displays the available sites sorted by site creation date. Items in the list shows the site name, company name, and when the site was created. Tap a site to view a list of associated boreholes.

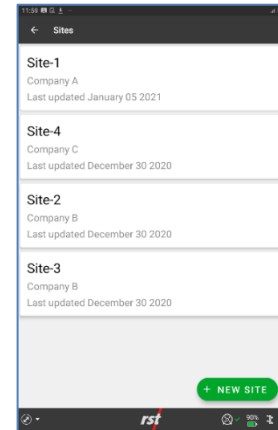


Figure 19: Sample site list

6.4.4 View Borehole List

The View Borehole List appears when the user selects a site from the Sites screen and shows a list of available boreholes sorted by borehole creation date. Items in the list shows the name and the depth of the borehole. Tap a borehole to see its readings. Tap **MORE** to call the contact person's phone number or edit the site information.

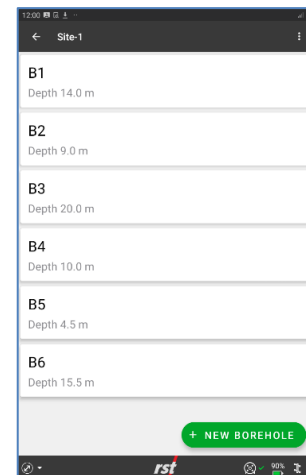


Figure 20: Sample borehole list

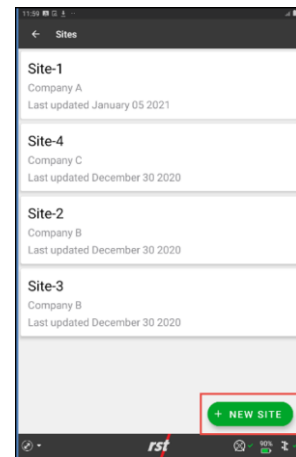
7 TAKE READINGS WITH VERTICAL PROBE

The app's primary function is to take readings at the borehole. To take a reading at the borehole, tap **Add Reading** from the Borehole Readings screen. The app ensures the reel and probe are functional and communicating with the app using Bluetooth. The app then performs integrity checks by verifying that the probe type is a vertical probe and the units in the probe match the borehole unit's configuration. The app will indicate incorrect configurations and prevent further readings. If the integrity checks are correct and the reel or probe are successfully connected through Bluetooth, you may continue taking the displacement readings.

7.1 CREATE NEW SITE AND BOREHOLE

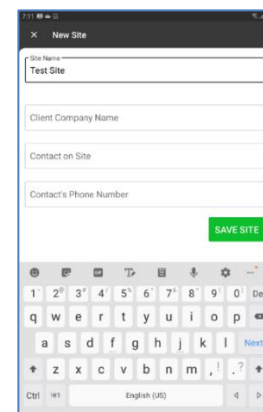
To create a new site and borehole, complete the following steps:

1. Tap **+ NEW SITE**.

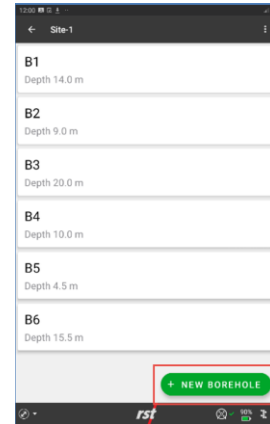


2. Complete the following fields:

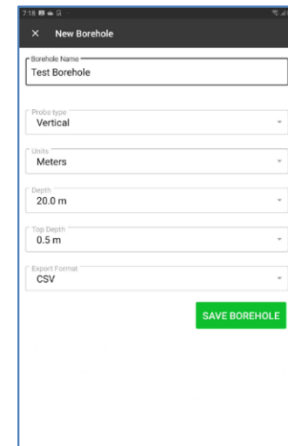
- Site Name (required) – name of the site
- Client Company Name – name of the client's company
- Contact on Site – name of the contact person
- Contact's Phone Number – phone number



3. Tap **Save Site**.
4. Tap **+ NEW BOREHOLE**.



5. Complete the following fields:
 - Borehole Name (required) – name of the borehole
 - Probe Type – select **Vertical** or **Spiral**
 - Depth – depth of the borehole's lowest reading. The depth will always be in increments of 0.5 meters or 2.0 feet
 - Top Depth – depth of the borehole's top reading. This is normally set to 0.5 meters or 2.0 feet
 - Unit – measurement in meters or feet
 - Export Format – select **CSV** or **RPP**



The collected reading file may be in **CSV** (.csv) format which can be imported into Inclinalysis™ and Microsoft Excel or **RPP** (.rpp) which can be imported into Inclinalysis™, DigiPro and Slope Indicator's software. GTilt and GTilt Plus software can also import *.rpp file formats.

6. Tap **SAVE BOREHOLE**.

7.2 ADD VERTICAL READINGS

The reading involves taking the Axis A+/B+ measurements followed by the Axis A-/B- measurements after the probe is rotated 180 degrees.

7.2.1 Take Axis A+ Readings – First Pass

To take an Axis A+ reading, complete the following steps:

1. Lower the probe to the lowest depth of the borehole. Once the probe is at the correct depth and is stationary, the real-time reading stabilizes.



NOTE: Allow 10 minutes for the probe temperature to stabilize before taking readings. See **Care and Maintenance** section for more information.

The new readings screen shows the status of the probe readings refreshed approximately every second. Figure 21 shows a sample Axis A+ reading at bottom depth (10 m) and top depth (0.5 m)

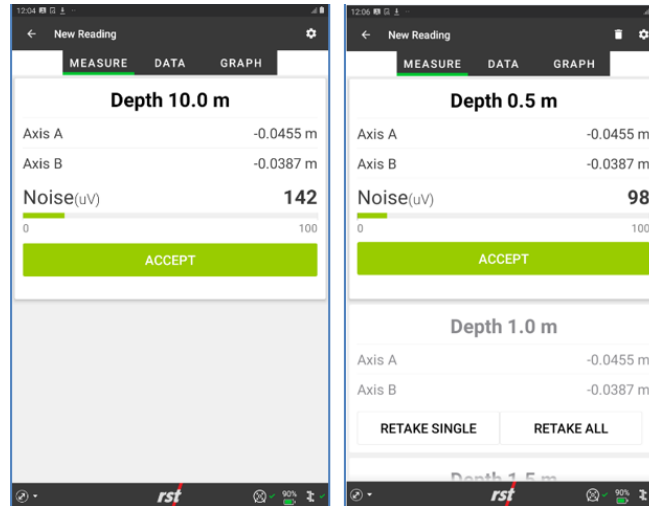


Figure 21: Sample Axis A+ bottom and top depth readings

Axis A and Axis B shows the instantaneous lateral displacement in meters or feet. The Noise (uV) is the difference between the current reading and the previous reading measured in microvolts. A small difference or noise level indicates a stable and accurate reading. The noise level is color-coded and shows as:

- optimal low noise level in green
- marginal noise level in orange
- high noise level in red

The noise level varies based on each borehole location. In noisy environments such as locations with heavy equipment in the vicinity, the acceptance criteria for a reading may be different based on environmental conditions.

2. Tap **ACCEPT** if the probe reading is acceptable. The app then repeats the process for the next depth.

7.2.2 Retake a reading on the Axis A+

To retake a previously accepted reading on the Axis A+, complete the following steps:

1. Lower the probe to the depth where you want to retake the reading.
2. On the app, scroll to the depth and tap **RETAKES ALL** (to retake all readings from the retake depth to the top of the borehole) or **RETAKES SINGLE** (to retake just the reading of the selected depth and for the app to resume from the current depth).

7.2.3 Take Axis A- Readings – Second Pass

The depth reading continues until the probe reading reaches the top depth. Once the top of the hole is reached, the app prompts to turn the probe 180 degrees and lower it back to the bottom of the hole. This is the Axis A- reading.

The app starts the Axis A- depth at the lowest borehole depth. The Axis A- depth reading is similar to the Axis A+ depth reading, but a new checksum data field appears.

The checksum data appears to the right most column preceded by a delta symbol. The real-time checksum value allows monitoring of the second set of readings. If the checksum is large or inconsistent, either the probe has recorded an abnormal reading or the probe is not at the correct measurement depth. Like the Axis A+ procedure, you may continue to take readings until the top of the borehole is reached. If the probe is accidentally raised above the measurement point, lower the probe back below the proper depth and then raise slowly to the correct depth. This ensures consistent and accurate readings.

Figure 22 shows a sample Axis A- reading at the bottom depth (10m) and top depth (0.5m)

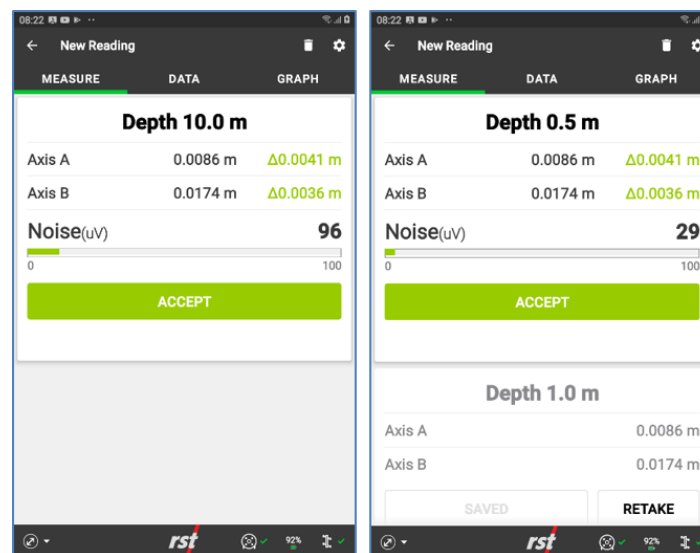


Figure 22: Sample Axis A- bottom and top depth readings

To retake a previously accepted reading on the Axis A-, complete the following steps:

1. Lower the probe to the re-take depth.
2. On the app, scroll to the depth and tap **RETAKES ALL** or **RETAKES SINGLE**.

Once the top depth is reached on the second pass, the app displays a prompt indicating the reading process is complete and saves the readings automatically in the device's memory.

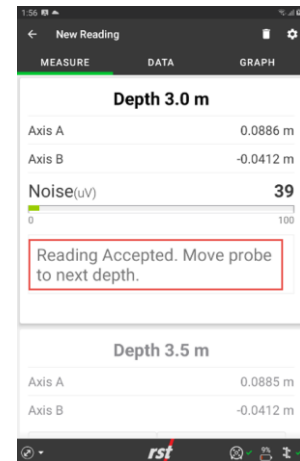
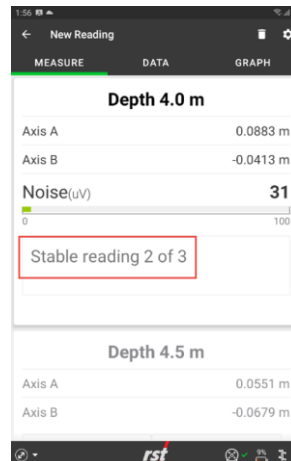
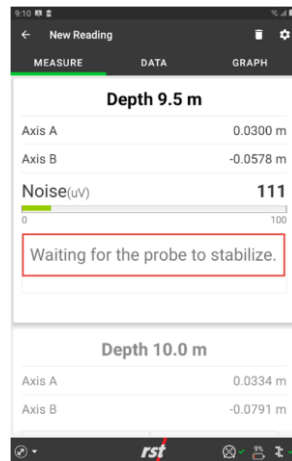
7.2.4 Add Vertical Readings Using Auto Accept

The **Auto Accept** feature detects probe movements and automatically accept readings when the reading has stabilized. The feature display prompts to guide you through the data collection process, such as:

Waiting for the probe to stabilize –app is waiting for probe to stabilize where nose is below threshold

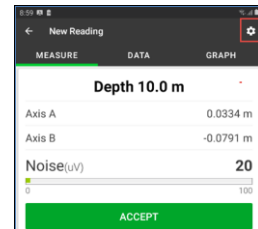
Stable reading x of y – app has x out of y stable readings

Reading Accepted.
Move probe to the next depth –app has accepted reading and you can proceed to next depth



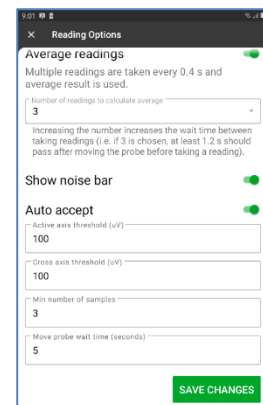
To take a reading with the Auto Accept feature, complete the following steps:

1. Tap **Configuration**.

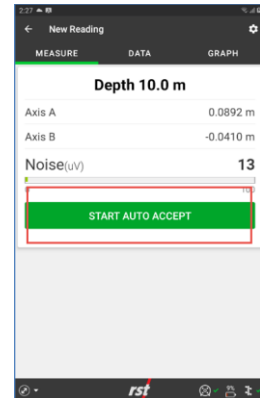


2. Configure reading options in the following fields:

- **Active axis threshold (uV)** – noise threshold for active axis
- **Cross axis threshold (uV)** – noise threshold for cross axis threshold
- **Min number of samples** – minimum number of successive samples where both active axis and cross axis must be less than threshold before probe position is considered stable to automatically accept reading
- **Move probe wait time (seconds)** – amount of time to move probe to next depth before app starts verifying if probe is stable
- **Auto Accept** – activate



3. Tap **SAVE CHANGES**.
4. Tap **ADD READING** to begin the survey and then lower the probe to the bottom depth.
5. Tap **START AUTO ACCEPT**. The first position is measured. The app makes a sound when the probe is stable, and the reading is taken.

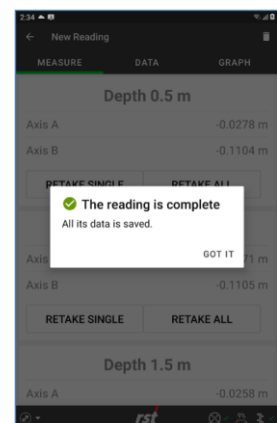


6. Pull the probe up to the next depth. Follow prompts and wait for readings to stabilize and for the app to take the readings. Once the probe reaches the borehole collar, the app will ask for the probe to be removed and rotated.
7. Rotate the probe 180 degrees, insert into the borehole, and then lower to the bottom depth.



8. Tap **OK** on the app to start the second survey pass.

Once the top depth is reached on the second pass, a prompt appears on the app indicating the reading process is complete and the readings are automatically saved in the device's memory.



→ **NOTE:** You may need to adjust the Auto Accept settings in circumstances resulting in ground vibration such as heavy vehicles operating close to the borehole or other construction activity.

RST recommends taking a minimum of three surveys for the baseline set of readings to ensure a good set is acquired. This is the most important set of readings, and you only have one chance to get them right before monitoring can start.

7.2.5 Add Vertical Readings – Data and Graph

The **Add Readings** feature allows you to view the data while taking readings and helps with data validation.

7.2.5.1 Data View

Data View tabulates the recorded readings during the reading process. As readings are collected, new readings are added to the Axis A+/A- and Axis B+/B- table. You can view the data collected for Axis A or Axis B and display the data in Decimal or Scientific notation. Below is a sample data visualization.

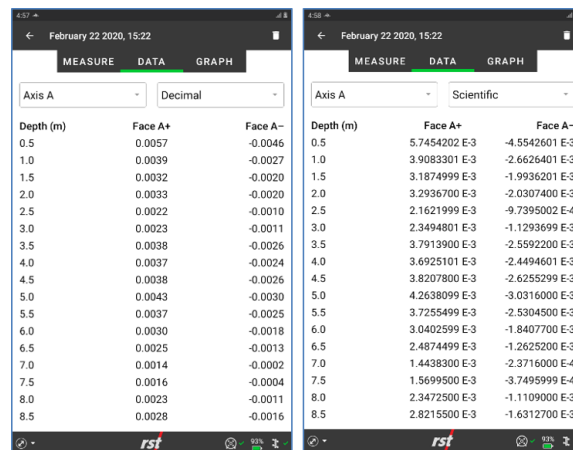


Figure 23: Sample Axis A+ and Axis A- readings

7.2.5.2 Graph View

The Readings Graph feature plots the accumulated data from either Axis A or Axis B in three plotting options:

- Checksum
- Mean Deviation
- Absolute Position

The app generates graphs based on the available data collected during the reading. For borehole depths that have not yet collected readings, the lines are interpolated with dotted lines instead of solid lines. Below is a sample graph with data collected up to a depth of 6 meters.

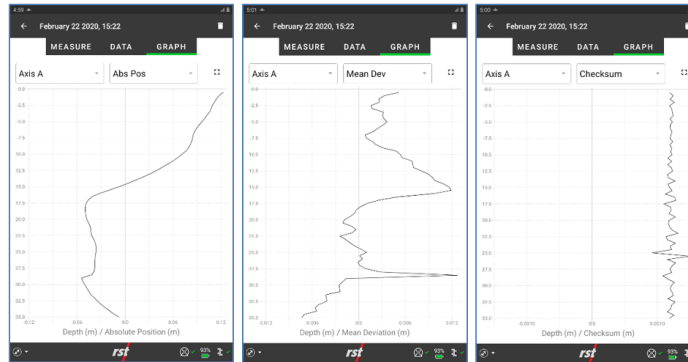


Figure 24: Sample Absolute, Mean Deviation and Checksum plots

Checksum

- Checksum in A+/A- plane = A+ plus A-
- Checksum in B+/B- plane = B+ plus B-

Checksum should be constant and of small magnitude. Large and inconsistent checksums may indicate that a problem exists. However, the consistency of checksums from survey to survey is more important than the actual value of the checksums. Checksum data should be monitored during the survey as a check on data integrity. High checksums can be expected if a settlement coupling has been encountered, a checksum of the order of (+0.0045m and -0.0035m) or (+0.0147ft and -0.0114ft) would be reasonable at consecutive depths/couplings.

Mean Deviation

- A+/A- mean deviation in the A+/A- plane = (A+ minus A-)/2
- B+/B- mean deviation in the B+/B- plane = (B+ minus B-)/2

This represents the mean deviation at each depth.

Absolute Position

An Absolute Position value at a particular depth is the sum of mean deviations starting from the bottom up to that depth. Absolute Position is the profile of the access tube with respect to the vertical axis in a given plane. Absolute Position can also be calculated from the top down, if required, using Inclinalysis™ software.

7.2.6 View Completed Readings (Vertical Probe)

The View Reading List shows a list of readings taken from the borehole sorted by reading timestamp. Items in the list show the reading completion date and time. Tap a borehole from the View Borehole List screen to see the View Readings List.

Tap an item in the list to see the borehole's readings or resume taking the reading from a previously incomplete session. If a reading is incomplete, the status appears as "Incomplete".

Tap **Edit** to edit the borehole information.

Tap **+ ADD READINGS** to take a new reading. See Section 7.2 for the complete steps. Figure 25 shows a sample reading list.

Tap the **Graphs** tab to view the combined graphs of readings from the borehole. See Section 7.2.7 for more information on combined graphs.

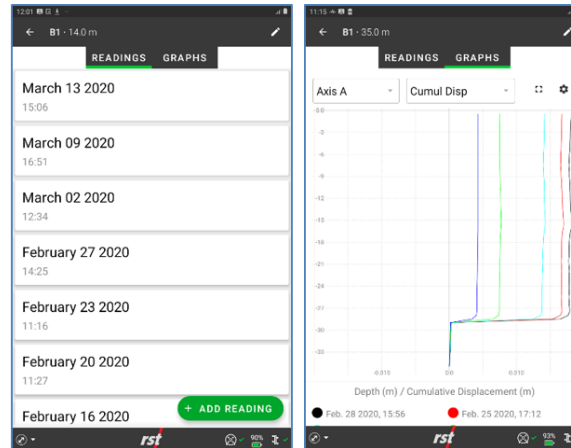


Figure 25: Sample reading list and comparison graph

7.2.7 View Completed Readings – Comparison Graph (Vertical Probe)

The Digital Inclinometer system accurately measures the lateral movement of earthworks and structures. The probe is passed through the inclinometer casing and a reading is taken every 0.5 meter or 2 feet. When the probe is at rest, servo-accelerometers sense the inclination of the access tube in two planes. This inclination is displayed in terms of angular DEVIATION, which is recorded at that particular depth.

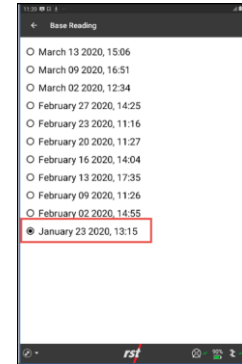
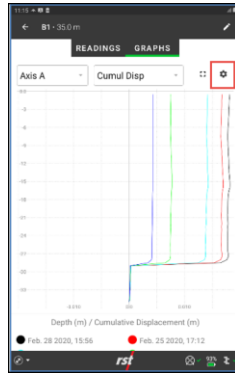
- A+= Face A+ deviation
- A- = Face A- deviation
- B+ = Face B+ deviation
- B- = Face B- deviation

The View Readings Comparison graph combines the multiple readings from one borehole and compares the result against a specific base reading. Typically, a base file (in the form of an initial reading) is chosen and kept the same throughout the life of the inclinometer hole to quantify any lateral displacement that occurred. The comparison graph allows you to analyze results at the borehole and take appropriate actions based on the collected results.

To use the comparison graph, you must configure the desired data set to review and then select the base reading and the comparison reading data sets.

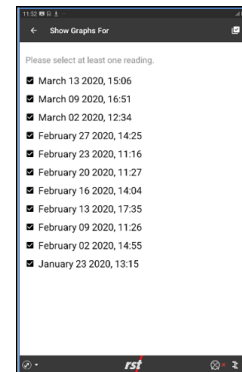
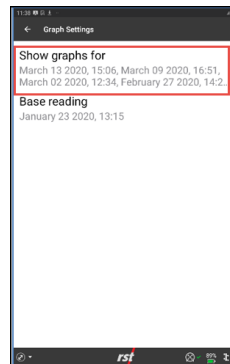
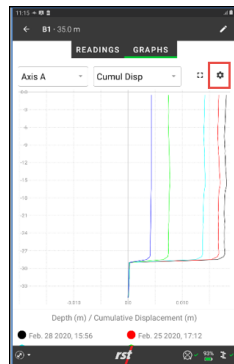
1. Select the base reading.

- Tap **Configuration**.
- Tap **Base reading**.
- Select the base reading date as the reference reading.



2. Select the comparison reading or readings.

- Tap **Configuration**.
- Tap **Show graphs for**.
- Select or deselect readings to compare against the base reading.



3. Select the desired graphs.

The app may plot the following five types of comparison graphs for either Axis A or Axis B:

- Checksum
- Mean Deviation
- Absolute Position
- Incremental Displacement
- Cumulative Displacement

Checksum

- Checksum in A+/A- plane = A+ plus A-
- Checksum in B+/B- plane = B+ plus B-

Checksum should be reasonably constant and of small magnitude; large and inconsistent Checksums may indicate that a problem exists. However, the consistency of checksums from survey to survey is more important than the actual value of the checksums. Checksum data should be monitored during the survey as a check on data integrity. Note that high checksums can be expected if a settlement coupling has been encountered, a checksum of the order of (+0.0045m and -0.0035m) or (+0.0147ft and -0.0114ft) would be reasonable at consecutive depths/couplings.

Mean Deviation

A+/A- mean deviation in the A+/A- plane = (A+ minus A-)/2

B+/B- mean deviation in the B+/B- plane = (B+ minus B-)/2

This represents the mean deviation at each depth.

Absolute Position

An absolute position value at a particular depth is the summation of mean deviations, starting from the bottom up to that particular depth. The Absolute Position is the profile of the access tube with respect to the vertical axis in a given plane. The Absolute Position can also be calculated from the top down, if required, using Inclinalysis™ software.

Incremental Displacement

The Incremental Displacement is the difference in values of mean deviation between the base file (the first set of readings taken) and a selected file or files (usually the latest set of readings) at each depth. You can generate this plot using Inclinalysis™ software.

Cumulative Displacement

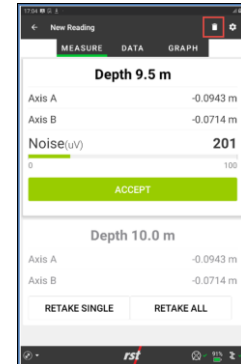
The Cumulative Displacement value at a particular depth is the sum of incremental displacements starting from the bottom up to that particular depth. The profile represents the actual movement (or displacement) which has occurred at all depths between the times that the two sets of readings were obtained.

7.3 DELETE AND CONFIGURE READINGS

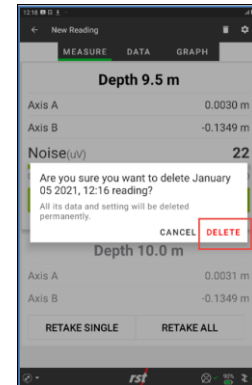
7.3.1 Delete Reading

To delete a reading, complete the following steps:

1. Tap **Delete**. A confirmation prompt appears.



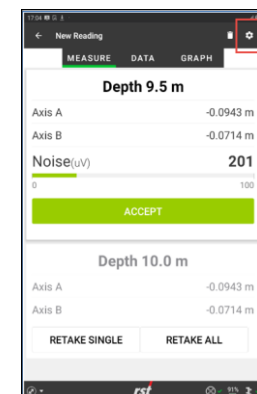
2. Tap **Delete**. The reading is permanently deleted from the list.



7.3.2 Configure Reading Options

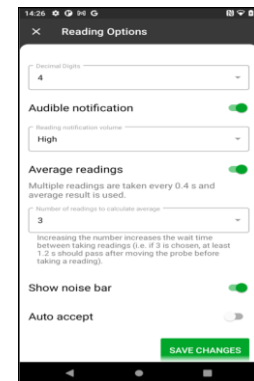
To configure the reading options, complete the following steps:

1. Tap **Configuration**.



2. Configure reading options in the following fields:

- **Decimal Digits** – the number of digits displayed
- **Audible notification** – enable or disable audible notification generated each time the reading is accepted
- **Average readings** – enable or disable averaging the most recent readings to display a more stable reading
- **Number of readings to calculate average** – if Average readings is enabled, this field defines the amount of time between readings
- **Show noise bar** – shows or hides the noise bar
- **Auto Accept** – enable or disable auto accept



3. Tap **SAVE CHANGES**.

8 TAKE READINGS WITH SPIRAL PROBE

The Digital Inclinometer app also supports taking readings from the RST spiral probe which is used to determine down-hole helical deformation of installed inclinometer casing. Operation is similar to the RST vertical inclinometer probe, using the same cable and reel. The procedure to take a reading is similar as the vertical inclinometer survey with one pass.

8.1 CREATE SPIRAL BOREHOLE

Create a borehole specific to the spiral probe, as a borehole may be created either as a vertical or spiral type.

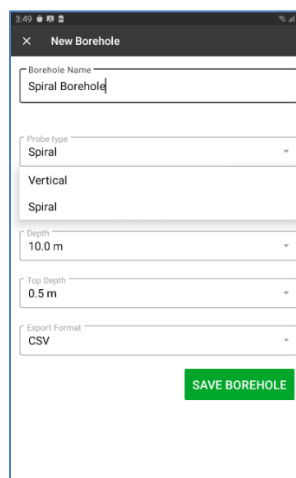


Figure 26: New borehole for spiral probe screen sample

8.2 ADD SPIRAL READINGS – AUTO ACCEPT

The Digital Inclinometer app may be configured for automatic or manual spiral readings. Automatic mode incorporates algorithms to detect if the probe has collected stable readings. Manual mode requires the user to accept readings manually. By default, the Auto Accept reading is enabled at the start of every spiral probe survey.

When the Auto Accept feature is enabled, the Digital Inclinometer app detects probe movements and automatically accept reading when the reading has stabilized. The Auto Accept feature incorporates instruction prompts to guide the user throughout the data collection process. Some of the prompts are shown in figures on the next page. The prompts that are displayed are:

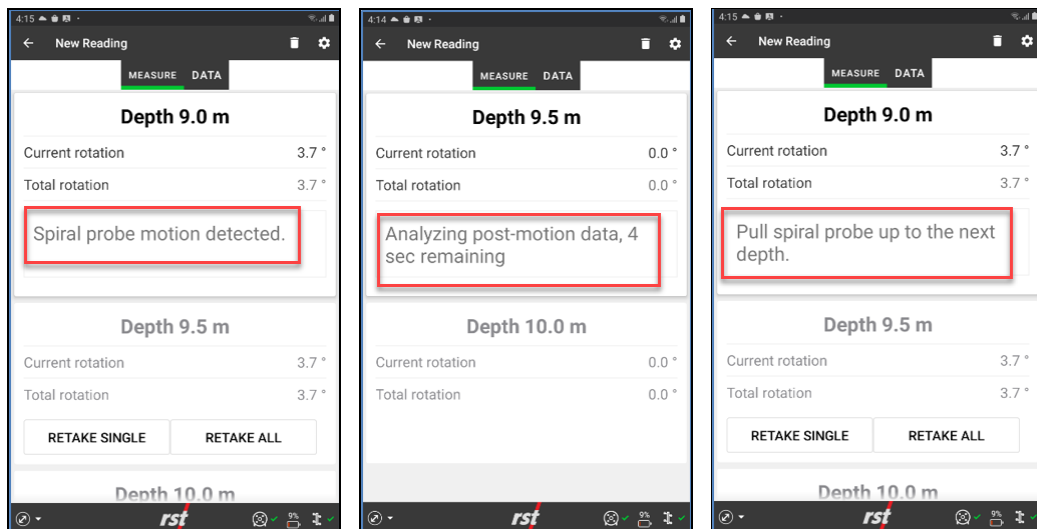
- Waiting for the probe to stabilize – the app is waiting for the probe to stabilize where the nose is below the threshold.
- Stable reading x / y – the app has x out of y stable readings.
- Reading Accepted. Move probe to the next depth – the app has accepted the reading and the user should proceed to the next depth.

The **Auto Accept** feature has prompts to guide you through the data collection process, such as:

Spiral probe motion detected – app detected movement and will commence analyzing post-motion data

Analyzing post-motion data, x sec remaining – analyzing post-motion data procedure is the algorithm to detect when the data readings have stabilized

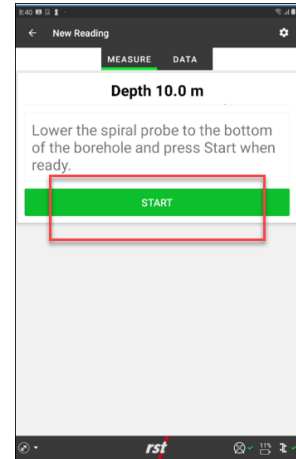
Pull spiral probe up to the next depth – When analyzing post-motion data is complete, the readings are stored, and the app prompts you to pull the probe to the next depth



To take a reading with a spiral probe using Auto Accept, complete the following steps:

1. Tap + **ADD READING**.
2. Lower the probe to the lowest depth of the borehole.
3. Tap **START**.

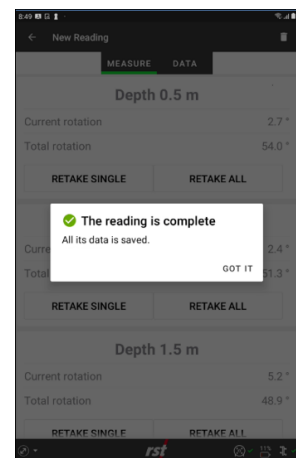
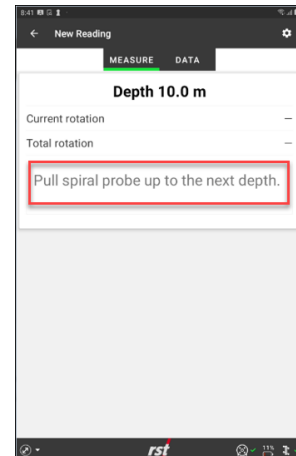
The initial position is measured. The app makes a sound when the probe is stable, and the reading is taken.



4. Pull the probe up to the next depth and repeat the process.

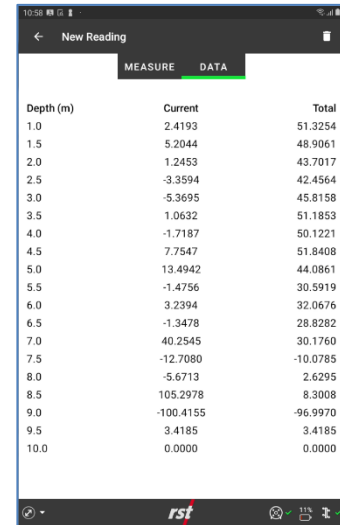
The probe senses movements and takes readings automatically. The app repeats the process for the next depth. Once the top depth is reached, the app indicates the reading process is complete and saves the readings automatically in the device's memory.

To retake a reading, Lower the probe to the depth where you want to retake the reading. On the app, scroll to the depth and tap **RETAKE ALL** (to retake all readings from the retake depth to the top of the borehole) or **RETAKE SINGLE** (to retake just the reading of the selected depth and for the app to resume from the current depth).



8.3 VIEW COMPLETED READINGS

The Add Spiral Readings feature allows you to view data during the reading collection to help with data validation. The Data View tabulates the recorded readings during the reading process. As readings are collected, new reading entries are added to the table. You have the option to view the data collected for spiral and total (cumulative) spiral as shown in the example in Figure 27.



Depth (m)	Current	Total
1.0	2.4193	51.3254
1.5	5.2044	48.9061
2.0	1.2453	43.7017
2.5	-3.3594	42.4564
3.0	-5.3695	45.8158
3.5	1.0632	51.1853
4.0	-1.7187	50.1221
4.5	7.7547	51.8408
5.0	13.4942	44.0861
5.5	-1.4756	30.5919
6.0	3.2394	32.0676
6.5	-1.3478	28.8282
7.0	40.2545	30.1760
7.5	-12.7080	-10.0785
8.0	-5.6713	2.6295
8.5	105.2978	8.3008
9.0	-100.4155	-96.9970
9.5	3.4185	3.4185
10.0	0.0000	0.0000

Figure 27: Sample Data view screen for spiral probe

9 EXPORT AND IMPORT READING FILES

The Digital Inclinometer app data readings may be exported for offline analysis using software such as the RST Inclinalysis™. Export can be done using a USB file transfer cable or by email.

9.1 EXPORT TO DEVICE

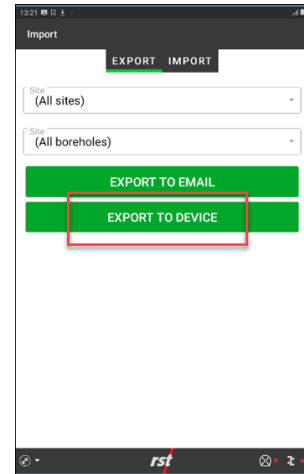
Exporting reading files to the Android device's internal storage stores the selected sites and the boreholes on the device. You can access the files in the device using a USB cable and selecting the Android System USB mode. See Section 16.3 for instructions on setting the Android for file transfer to a PC.

The exported reading files are stored in the phone's storage: *internal shared storage\Android\data\com.rstinstruments\files\export\DigitalInclinometer*.

The folder contains subfolders for the exported site or sites. From each exported site, the borehole reading files can be transferred from the Android device to a computer for analysis.

To export reading files to device, complete the following steps:

1. Tap **MEASURE** on the bottom of screen.
2. Tap **EXPORT TO DEVICE**.



9.2 EXPORT TO EMAIL

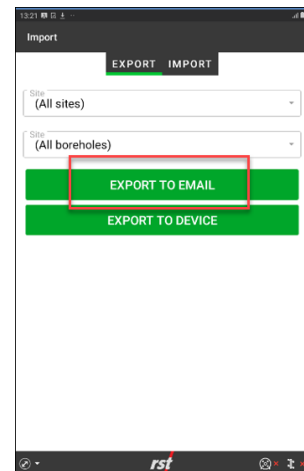
The Android device must have internet access using cellular or Wi-Fi and an email app (such as Gmail) pre-configured with an account.

The Digital Inclinometer app compresses the reading files into a zip file named "DigitalInclinometer.zip". The root folder contains subfolders for each exported site which contains the borehole reading files.

To export reading files by email, complete the following steps:

1. Tap **MEASURE** on the bottom of screen.
2. Tap **EXPORT TO EMAIL**.

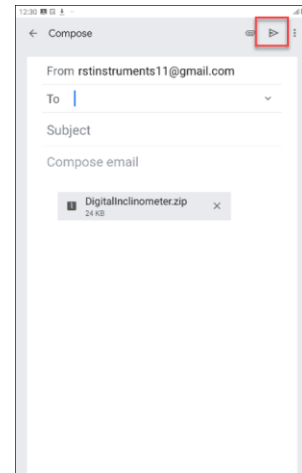
You may have to choose the email app you want to use if the device has more than one.



3. Enter the recipient's email address.

The **Subject** and **Compose email** fields are optional.

4. Tap **SEND**.



9.3 IMPORT READING FILES

The Import Reading Files feature allows data collected from another device from the Digital Inclinometer app to be imported and added to the Android device. This feature allows borehole reading data to be shared amongst the different app platforms (Android, Field PC and Inclinalysis).

The Digital Inclinometer app supports two mechanisms to import reading files:

- Import Files from Android Internal Storage
- Import Zip file

9.4 IMPORT FILES FROM ANDROID INTERNAL STORAGE

Importing reading files from Android storage retrieves the reading files from a specific folder in the Android device. This folder can be accessed on a PC by using a USB file transfer cable and selecting the Android System USB mode to be used for File Transfer. See Section 16.3 for detailed instructions on setting the Android for file transfer to a PC.

The reading files for import are always stored in the folder:

Internal shared

storage\Android\data\com.rstinstruments\files\import\DigitalInclinometer

The DigitalInclinometer folder contains subfolders for the imported site(s). The data from the import folder are imported to the Digital Inclinometer app when the app is launched. The Digital Inclinometer app deletes content of the import folder after importing the content.

9.5 IMPORT ZIP FILE FROM STORAGE

The import zip file allows you to import a zip file that was exported or emailed by another Android device. The zip file is an archive that contains the DigitalInclinometer folder structure.

The zip file may be stored on an external thumb drive or in the Android internal storage area. The Import Zip File opens up the Android file manager that allows you to select the location of the zip file. Select the desired zip file to import into the Digital Inclinometer app.

10 WHAT DOES THE DATA MEAN?

10.1 VERTICAL PROBE DATA

The system has been developed to accurately measure the lateral movement of earthworks and structures. The probe is passed through the inclinometer casing and takes a reading every 0.5m (or 2ft). When the probe is at rest, MEMS accelerometers sense the inclination of the access tube in two planes. This inclination is displayed in terms of angular DEVIATION, which is recorded at that particular depth.

A+ = Face A+ deviation

A- = Face A- deviation

B+ = Face B+ deviation

B- = Face B- deviation



NOTE: The *.csv files can also be opened directly in Excel, however, do not save the files in *.csv format from Excel. This will change the format of the file and you will no longer be able to import the file into GTilt. Always backup your data.

The inclinometer program also allows the option to save the files in *.rpp format. GTilt also recognizes this format, and the files are imported in a similar fashion as described above.

Checksums

Checksums serve two purposes. The first is to allow the user to visualize the magnitude of the systematic bias that may exist in the probe, just in an informative way, as the checksums are not used in any further calculation. That systematic bias is then cancelled by using the Mean deviation defined below in further calculations such as the Cumulative displacement, the Incremental displacement, and the Absolute profile.

The other purpose of the checksums is to act as a diagnosis of the quality of a given survey in the sense that if an individual reading shows a high checksum that was not present at the same elevation in an earlier survey conducted at a previous date, it may mean that one of the two readings in the + or - direction was not done properly, and the user will then be able to repeat that same reading in order to restore the checksum to a similar lower value as in previous surveys.

Checksum in A+/A- plane = A+ plus A-

Checksum in B+/B- plane = B+ plus B-

The checksum should be reasonably constant and of small magnitude, typically less than ± 2 mm (0.08 in) and preferably less than ± 1 mm (0.04 in). Large and inconsistent checksums may indicate that a problem exists. However, the consistency of checksums from survey to survey is more important than the actual value of the checksums. Checksum data should be monitored during the survey as a check on data integrity. Note that high checksums can be expected if a settlement coupling has been encountered, a checksum of the order of ± 4 mm or (± 0.16 in) would be reasonable at consecutive depths/couplings.

Mean Deviation

A+/A- mean deviation in the A+/A- plane = (A+ minus A-)/2.

B+/B- mean deviation in the B+/B- plane = (B+ minus B-)/2.

This represents the mean deviation at each depth, corrected for any systematic bias that can be present in the inclinometer probe as the average of the two measurements opposed at 180 degrees cancel that bias.

Absolute Position

An absolute position value at a particular depth is the summation of mean deviations starting from the bottom up to that particular depth. Absolute position is the profile of the access tube with respect to the vertical axis in a given plane. Absolute position can also be calculated from the top down if required using Inclinalysis™ software.

Incremental Displacement

The incremental displacement is the difference in values of mean deviation between the base file (first set of readings taken) and a compatible file (usually the latest set of readings) at each depth. This plot can be generated using Inclinalysis™ software.

Cumulative Displacement

The cumulative displacement is the result of comparing two sets of mean deviations, usually the base file and the latest or comparison file. The profile represents the actual movement (or displacement) which has occurred at all depths between the times that the two sets of readings were obtained.

Spiral Probe Data

The spiral data file consists of number of records for each depth. Each record comprises of probe depth, spin increment and cumulative probe spin.

Once the data is collected, it can be imported into RST Inclinalysis Software. A spiral correction can then be applied to the Digital Inclinometer data and plots of the corrected borehole data can be created. For further information on Inclinalysis software, please contact RST Instruments Ltd. or visit our website at: <http://www.rstinstruments.com>.

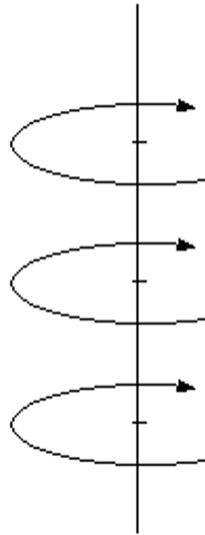


Figure 28: Spiral Data Collection Method

11 SYSTEM COMPATIBILITY

Regardless of the inclinometer system being used, the probe wheels must be placed in the same locations during each profiling of the borehole. This does not necessarily have to be the same depth marked on the inclinometer cable. Always use a consistent top reference, such as the aluminum cable grip provided with all RST Inclinometer systems.

The zero-depth reference on the new MEMS Digital Inclinometer System refers to the midpoint (between the wheel assemblies) of the probe, which is the industry standard. The old RST analog system is referenced to the uppermost set of wheels. You must consider this if you want to directly compare the two sets of readings. It is very important that the data be within 4 mm (0.25"). Otherwise, the data will not match, and the comparison will not be valid.



NOTE: If you are comparing surveys between RST's old analog system and the new MEMS Digital Inclinometer System, ensure that the readings of both systems are taken at the same depths with the proper depth reference. If you are switching between systems, it is good practice to survey the borehole with both systems. If you are satisfied with the data from the new MEMS Digital Inclinometer System, you can then complete the switch.

Some competitor's inclinometers have different cable gripping and locating systems resulting in different depth locations. You must be aware of these differences when trying to compare data between systems.

12 CARE AND MAINTENANCE

12.1 PROBE AND REEL CONNECTORS

Proper care and maintenance of the digital probe and reel connectors will help ensure trouble-free operation of the Digital MEMS Inclinometer System. Failure to follow these guidelines can result in damage or premature wear.

- Ensure the keyway is aligned before threading the connector together.
- Never over-tighten the bulkhead connectors when mounting. Snug (hand-tight) is enough.
- Only twist the brass coupling on the connector. Do not twist the signal cable itself.
- Avoid sharp bends at the cable entry to the connector to prevent irreparable damage to the internal cable wires.
- Clean the plugs and receptacles with a mild soap and fresh water on a regular basis. Do not allow the connectors to become excessively dirty. Never thread the connector when there is debris inside.
- Rinse the connector with alcohol and allow to air dry. Replace the dust caps once the connector is dry.
- Lubricate the mating surfaces with the **supplied silicone spray** on a regular basis. **DO NOT GREASE and avoid using solvent-based lubricants such as WD-40.**
- The amount of silicone spray used should be based on the frequency of use of the probe. One light spray to cover all contacts is enough after cleaning the connector. Ensure the connector is clean and dry before applying the silicone spray.



NOTE: Contact RST Instruments to purchase a replacement bottle of silicone spray.

- Elastomers contained in the connector can be seriously degraded if exposed to solvents, direct sunlight, or high ozone levels for extended periods of time. Always replace the dust caps once the connector is clean and dry.
- Always keep the dust caps clean and free of any foreign materials. Do not place the dust caps where they may become contaminated.
- Always use the dust caps and keep the connectors clean to prevent damage in storage and when in use.



WARNING: Solvent-based lubricants (such as WD-40) should NEVER be used as a lubricant on the connectors. These products will damage the elastomers in the connectors resulting in loss of communication with the digital probe. ONLY use the supplied silicon lubricant or an RST-approved equivalent.

RST recommends 3M Silicone Lubricant (Part # 62467849303), or Haynes Silicone Oil. Contact RST Instruments for questions or additional information.

12.2 INCLINOMETER PROBE

The digital inclinometer probe has high-grade stainless-steel components and is completely sealed. Minimal maintenance is required. Maintenance of the digital inclinometer probe includes the following:

- After the borehole survey is complete, wipe moisture off the probe and place the protective caps over the connectors. If required, rinse the probe in clean water and dry. If the probe is exceptionally dirty, use a mild soap and fresh water to clean.
- Never use solvents to clean the probe, wheels, or connectors.
- Always store the probe in its original case whenever not in use to protect the high precision accelerometers in the probe against excessive shock or vibration.
- Keep both the probe and case clean and dry. If they were not cleaned and dried in the field, be sure to clean and dry them upon return to the office. Do not leave corrosive solutions such as saltwater on the probe, connectors, and cable.

The probe wheels are made with high-grade hardened and heat-treated stainless steel. These are the most robust on the market and are extremely durable. The wheels contain sealed bearings which require no maintenance, except keeping them clean and dry. Avoid exposing the bearings to any particulates that could cause contamination.

- The bearings do not require lubrication. Never use a solvent-based lubricant such as WD-40 on the wheel bearings as this may accelerate bearing degradation.
- DO NOT replace a damaged shear pin in the wheel assembly without consulting RST. Failure to do so may irreparably damage the probe and/or wheel assembly.

12.3 REEL AND CABLE

Maintenance of the reel and cable includes the following:

- The cable has a durable polyethylene jacket. Wipe the cable with a clean rag to dry it off after use. If required, use water and a mild soap to clean it.
- Periodically measure the space between the aluminum cable crimps and the total length of the cable. This will verify the accuracy of downhole depth measurements and ensure maximum repeatability of the inclinometer system readings. Measure the ferrule spacings between the downhole edge of each ferrule (the edges closest to the cable connector) which should be 0.5 meters for metric cables and 2 feet for imperial cables. Ensure to tension the cable to remove any slack while making these measurements.



WARNING: If the surveyed borehole has alkaline groundwater, flush the borehole with fresh water before taking readings. Rinse the cable thoroughly with fresh water after the survey to help minimize potential corrosion of the aluminum cable crimps.

12.4 ANDROID DEVICE

To keep the Android device in good condition and working properly, follow these care guidelines:

- Keep the device away from excessive moisture and extreme temperatures. Do not expose it to liquids or precipitation.
- Do not place anything on top of the device to prevent damage to the screen.
- Clean the unit by wiping the screen and the exterior with a soft, damp cloth moistened only with water.
- Avoid exposing the device to direct sunlight or strong ultraviolet light for extended periods of time.
- Also avoid scratching the surface of the screen and banging it against hard objects.

Refer to the manufacturer's manuals for additional care and maintenance instructions.

12.5 CALIBRATION

RST strongly recommends sending the probe back for calibration annually. Due to the high precision nature of the sensors and the sensitivity of the probe, calibration must be done to ensure quality results and continued performance of the probe. Heavy use in adverse conditions may require calibrations to be done more often.

Perform calibration if the probe has been dropped or is damaged. If checksums become significant and they are not due to errors in probe positioning or noise, the probe likely needs to be re-calibrated. Calibration should also be performed after any wheel assembly replacement.

13 SYSTEM SPECIFICATIONS

Inclinometer	
Wheelbase	0.5 m (24 inches)
Probe Length Including Connector	710 mm (28 inches)
Probe Diameter	25.4 mm (1.00 inch)
Probe Weight	1.4 kg (3.0 lbs.)
Probe Material	Stainless Steel
Memory	> 1 000 000 readings
Displacement Error	±2 mm per 25m (±0.1 in. per 100 ft.)
Temperature Rating	-40 to +70oC (-40 to +158oF)
Data Resolution	0.005 mm per 500 mm (0.00002 ft. per 2 ft.)
Full Scale Range	±30 o
Repeatability	±0.002o
Axis Alignment	Digitally Nulled
Cable	
Cable Diameter	6.4 mm (0.25 inches)
Cable Weight	2.3 kg/50 m (3.1 lbs./100 ft.)
Cable Tensile Strength	5.9 kN (1325 lbs.)
Cable Jacket	Polyurethane
Cable stretch suspended in 30m dry borehole	4 mm (0.16 inches)
Cable Reel	
Up to 75 m cable reel diameter	310 mm (12.2 inches)
100 to 200m cable reel diameter	380 mm (15 inches)
+225m cable reel diameter	460 mm (18 inches)
Reel weight with 75m (246') cable	5 kg (11 lbs.)

14 TROUBLESHOOTING

This section includes common issues with the Digital MEMS Inclinometer System, the app and the Android device, and possible solutions.

14.1 DIGITAL INCLINOMETER APP CANNOT CONNECT TO THE REEL

- Make sure the correct reel has been selected. Tap **MEASURE** and then check the Devices screen. The selected reel Bluetooth ID's last four digits should match the serial number of the last four digits of the reel. If the reel is not visible on the list after 20 seconds, go to the next item.
- Press the **RESET** button to ensure that the reel hub power is on. Make sure the status indicator light on the reel hub is either solid or flashing.

Pressing RESET, terminates the reel hub's existing connection and starts the Bluetooth discovery and pairing process. Under normal operating conditions, the Digital Inclinometer app and reel should connect within 30 seconds after pressing RESET.

- Check if the reel is already connected to another Digital Inclinometer app that may be within Bluetooth coverage. If the reel is connected to another app, the reel ID will not appear in the devices list. You must disconnect the reel in the other app.
- If resetting the reel hub once or twice does not solve the issue, close and re-open the Digital Inclinometer app.
- If the reel hub is not on the Devices list, check if Bluetooth in the Android device is turned on. Go to **Settings, Connections** and then go to **Bluetooth**. Perform a Bluetooth device scan and see if the reel hub can be found.
- If the reel hub does not appear in the scan, turn Bluetooth off, wait 2 seconds, and then turn Bluetooth on. Press **RESET** on the reel hub. Perform another Bluetooth device scan and see if the reel hub can be found.
- If you have another Bluetooth device (such as a phone, laptop, or tablet), use that device to verify the reel hub is operational. From the device, use the Bluetooth service to scan for available Bluetooth devices. If the reel hub is on and working, the reel hub device ID should appear on the second Bluetooth device scan.
- If the reel hub is working and broadcasting its device ID, but the reel is not visible, power the Android device off and on again.

14.2 REEL CANNOT CONNECT TO THE PROBE

- Check the threaded electrical connection between the probe and the reel. Ensure that the connector is clean. Check the connector for any damage.

14.3 ANDROID DEVICE DOES NOT HAVE INTERNET OVER WI-FI

- Wi-Fi coverage may be affected by distance from the access point and physical obstructions. Try moving to a different location to see if Wi-Fi coverage improves.
- Check if Wi-Fi settings in the Android device is turned on. Go to **Settings, Connections** and then go to **Wi-Fi**. Check if Wi-Fi is turned on, and if you see the Wi-Fi network, re-enter the network password. If device still won't connect to Wi-Fi, turn off Wi-Fi setting, wait 2 seconds and then turn it back on.
- If you have another Wi-Fi device (such as a phone, laptop, or tablet), use that device to verify the Wi-Fi network is operational. From the device, use the same Wi-Fi credentials to connect to the hot spot. If the device connects to the Wi-Fi, turn the Android device off and on, and then try reconnecting to the Wi-Fi.

14.4 ANDROID DEVICE DOES NOT HAVE INTERNET OVER CELLULAR

- Cellular coverage may be intermittent due to distance to the cell tower and physical obstructions. Consider moving to a different location to see if cellular coverage improves.
- Make sure the SIM card is securely installed in the card slot.
- Check if the network Access Point Name (APN) is correctly configured for the data carrier. Go to **Settings, Network & Internet** and then **APNs**. Verify that the selected APN matches with the APN for the SIM card.

14.5 DIGITAL INCLINOMETER APP CRASHES AT LAUNCH

14.5.1 Clear device storage memory

The Digital Inclinometer app data is corrupted. If the exported file is available, retrieve the data for recovery and re-import. If the app crashes when launched, you may have to clear the Android app's storage memory. Clearing the storage memory permanently deletes all the site and borehole information from the app. See Section 16.5 for instructions on how to delete the application data.

14.5.2 Delete and reinstall app

The Digital Inclinometer app is corrupted and must be deleted and re-installed. Removing the app also permanently deletes all the site and borehole information from the app. If the app's exported file is archived, retrieve the data using the USB file transfer option. See Section 16.5 for instructions on how to delete the app. After deleting the app, install the latest version of the app from the Google Play Store. See Section 16.1 or 16.2 for steps reinstalling the app.

14.6 DIGITAL INCLINOMETER APP CANNOT BE INSTALLED

The app may have a conflict with a previously installed version.

Export the site and borehole data to a backup device or by email. Delete the app and its data from the device. See Section 16.5 for instructions on how to delete the app. Download a new version of the app from the Google Play Store and install. See Section 16.1 or 16.2 for steps reinstalling the app. Import the site and borehole data files to the app.

15 CHARGE THE BATTERY FOR REEL WITH SERIAL NUMBER UNDER 2500

Reels with serial numbers under 2500 have 7.4V lithium-ion batteries that can be removed for recharging. The reel comes with an adapter to charge batteries in a vehicle (12V DC) or power outlet (110-240V AC).

A reel battery can last up to 1 week on standby mode or when not connected to a device. Turn off the reel power when the survey is complete to conserve power. At room temperature (25 degrees, outside during summer), while taking readings, a battery will last approximately 30 hours. Extreme cold or hot temperatures can affect battery performance. Expect shorter battery operation in extreme cold or hot temperatures. RST recommends fully charging batteries before going out to the field and taking extra batteries to allow charging in between readings.

To charge a reel battery, complete the following steps:

1. Turn the cap counterclockwise to unscrew.



2. Remove the battery and place on the Mach 1™ speed charger.



3. After charging is complete, place the battery back into the reel. Make sure the battery contacts align with the contacts in the reel hub for proper operation.

15.1 BATTERY AND CHARGING STATUS

15.1.1 Charging time

The 7.4V 2200mAh lithium-ion batteries supplied with the Digital MEMS Inclinometer System takes approximately 80 minutes to fully charge if completely depleted.



NOTE: Batteries will self discharge when not in use whether they are installed in the inclinometer reel or not. Keep batteries fresh by recharging them on a regular basis.

15.1.2 LED Charge Status Lights

The three LED charge status lights on the front of the Mach 1 charger indicates the status of the battery and the charger.

15.1.2.1 Standby Mode

Without a battery connected, the charger LED on the left marked “MED” will flash indicating that the charger is standing by and waiting for a battery.

STANDBY	FLASHING	OFF	OFF
	MED	HI	MAX

Table 4: Standby Mode

When a battery is connected, the charger will determine battery status and begin charging. The following are the three phases of the charging cycle. The battery may be removed during any of these phases without harm to the battery or charger unit.

Phase I – Initial Charge

All three LEDs flash in sequence from **MED** (left) to **MAX** (right). If the battery is low, this will be the first charge phase. With high-capacity batteries, this phase can sometimes be the longest phase. In some low-capacity batteries and batteries reaching the end of their life, this phase can be very short.

LED Phase I	Sequential Flashing	Sequential Flashing	Sequential Flashing
	MED	HI	MAX

Table 5: Initial charge LED indications



NOTE: When the battery is first connected, the LEDs may instantly indicate MED, HI or MAX charge depending on the charge status of the battery. Charging will continue normally from that point. It is normal for the charger, AC adapter, or the battery to become warm during charging.

Phase II – MED Charge

The **MED** LED is continuously on and the other LEDs flash in sequence. At this point the battery is typically about 50% charged. Some small capacity batteries (650mAh) and worn-out batteries can be as low as 10% charged.

LED Phase II	ON	Sequential Flashing	Sequential Flashing
	MED	HI	MAX

Table 6: MED charge LED indications

Phase III – HI Charge

The **MED** and **HI** LEDs are on, and the **MAX** LED flashes. At this point the battery is typically about 70% charged.

LED Phase II	ON	Sequential Flashing	Sequential Flashing
	MED	HI	MAX

Table 7: HI charge LED indications

Charge Complete – MAX Charge

All three LEDs are on at the same time. Charging is complete and the battery is fully charged. It is recommended to remove the battery at this time.

Charge Complete	ON	ON	ON
	MED	HI	MAX

Table 8: MAX charge LED indications

15.1.2.2 Error Condition – Charge Terminated

If the battery is removed before completely charging, **the charger will show the last complete charging phase for up to 1 minute**. After that, an error appears on the LEDs with the **MED** and **MAX** LEDs coming on at the same time, and the **HI** LED off.

Error Condition	ON	OFF	ON
	MED	HI	MAX

Table 9: Error in charging LED indications

The Error Condition will also be indicated if the charger senses problem with the battery being charged. To reset the error condition, unplug the charger from the power adapter for a few seconds, and then reconnect. If the error occurs again, there may be a defect in the battery that will prevent safe charging. Replace the battery.

16 ANDROID TIPS AND PROCEDURES



NOTE: These tips and procedures work on most Android devices.

16.1 INSTALL THE DIGITAL INCLINOMETER APP FROM THE GOOGLE PLAY STORE

The Digital Inclinometer app is available on the Google Play Store. If the Android device is Google Mobile Services certified, Google Play Store is pre-installed on the device.

To install or update the Digital Inclinometer App from Google Play, complete the following steps:

1. Launch the Play Store app in the Android device.
2. In the top of the Search field, enter “RST Instruments”.
3. Select the **Digital Inclinometer app**.
4. Follow the prompts to install the app.

Once the app is installed, the Digital Inclinometer app appear on the Android device.

16.2 INSTALL THE DIGITAL INCLINOMETER APP APK FROM LOCAL STORAGE

The Digital Inclinometer app may also be distributed as a stand-alone Android application package (APK) file.

To install or update the Digital Inclinometer app from an APK file, complete the following steps:

1. Copy the APK file to the download folder on the internal storage of the Android device.
2. Open the Android file manager app.
3. Go to **Internal Storage** and then **Download folder**.
4. Find the downloaded APK file and tap the file to launch the installer.
5. Follow the prompts to install the app.

Since this method requires the installation from unknown sources, some versions of Android require the device administration option to be set to allow installation from unknown sources. Once the app is installed, the Digital Inclinometer app appear on the Android device.

16.3 CONNECT THE USB FOR FILE TRANSFER

You may connect the Android device internal storage to a computer using a USB cable and selecting the USB operating mode to be in File Transfer Mode. The default operating mode is typically set for No Data Transfer.

To configure the Android device for File Transfer mode, complete the following steps:

1. Go to **Settings**.
2. At the top of the Settings screen, enter “USB” to search. A list of USB options appears.
3. Select **USB Preferences**. The USB Preferences option appears.
4. Select the **File Transfer** option. The connection allows the computer to access the files on the Android internal storage.

16.4 UNINSTALL THE DIGITAL INCLINOMETER APP

You may uninstall the Digital Inclinometer app if the file is corrupted or there's a compatibility issue. Uninstalling the app also permanently removes all the associated data files.

To uninstall the Digital Inclinometer app, complete the following steps:

1. Go to **Settings**.
2. At the top of the Settings screen, enter "APP" to search. A list of apps appears.
3. Select **App Permissions** or **App & notifications**.
4. Tap the **Digital Inclinometer app**.
5. Tap **UNINSTALL** to permanently delete the app and its data from the device.

16.5 DELETE APPLICATION DATA

The Digital Inclinometer app stores data in both cache and storage memory. On rare occasions, you may need to delete the application data to recover from application run-time errors.



NOTE: Deleting storage memory also deletes data and configurations for the Digital Inclinometer app. Make sure to export the Digital Inclinometer data files to a computer or by email.

To delete the Digital Inclinometer App data, complete the following steps:

1. Go to **Settings**.
2. At the top of the Settings screen, enter "APP" to search. A list of apps appears.
3. Select **App Permissions** or **App & notifications**.
4. Tap the **Digital Inclinometer app**.
5. Select the storage option.
6. Select **Clear Storage** to permanently delete the user data and cache.

16.6 CONFIGURE DISPLAY OPTIONS

RST recommends customizing the following display options on your Android device:

- Sleep – specifies the duration of inactivity before the device automatically enters the sleep state. Set the duration to 10 minutes or longer
- Device orientation or auto-rotate screen – set to **Portrait** mode or to **Auto-rotate screen** since the Digital Inclinometer app only operates in Portrait mode
- Font size – set according to personal preference and screen size with maximized font size while minimizing word wrap
- Display size – set according to personal preference and screen size to define the size of the display objects in the app

16.7 CONFIGURE SOUND OPTIONS

The Digital Inclinometer app uses the following sound settings available in Android devices:

- Touch sound – enable or disable the click sound when tapping items on the screen
- Notification sounds – select the sound the device will make when taking a reading

16.8 CONFIGURE TOUCH PANEL CONTROL

The Android device may have customizable touch panel sensitivity options for different input methods or environmental conditions. Using options for specific environmental conditions may improve use of the touch panel. The options may include the following:

- Enable or disable touch sensitivity – some devices may have options to improve the touch panel for different environmental conditions
- Select touch profile – some devices may have different touch control options such as using finger, stylus, or glove