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Characterisation, modelling and mapping of inland landslides using Laser Scanning and GPS.

Urban Geoscience and Geological Hazards Programme

Internal Report IR/04/081

BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/04/081

Characterisation, modelling and mapping of inland landslides using Laser Scanning and GPS

K. A. Freeborough

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Laser scanner set up, Broadway, Worcestershire

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Foreword

This report is the published product of a study by the British Geological Survey (BGS). It refers to the work carried out on behalf of a Science Budget research project, under the Coastal Geoscience and Global Change (CGGC) and the Urban Geoscience and Geological Hazards (UGGH) Programmes of the BGS.

Acknowledgements

A number of individuals in the BGS have contributed to the project. This assistance has been received at all stages of the study. In addition to the collection of data, many individuals have freely given their advice, and provided the local knowledge so important to the project. Key staff have helped to review draft chapters of this report. Of the many individuals who have contributed to the project I would particularly like to thank the following:

Mr A. Forster

Mr. A. D. Gibson

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1 Introduction

BGS capabilities in geomorphological mapping and slope monitoring have been significantly improved by the acquisition of a high-accuracy global positioning system (GPS) and terrestrially based LIght Distance And Ranging system (LIDAR). This equipment was originally purchased and developed by the BGS CliffScan project, (Project leader Peter Hobbs), part of the Coastal Geoscience and Global Change Programme. The aim of this project is to carry out sequential surveying and modelling of the changing profiles of various sites around the coast of England. Cliff sections provided a good basis for the scanning process, providing the user with good vertical and horizontal sections, constantly changing profiles and stable targets for back-sites (at most locations). The cliff sections also provided definitive breaks of slope i.e. the cliff junction with beach deposits and the top cliff line, which could also be recorded with the GPS. The development programme, undertaken as part of CliffScan has enabled BGS to gain experience in mapping and scanning coastal features. (Hobbs et al 2002, Gibson et al 2003 and Jones 2003). This experience has been applied and further developed by the Landslides Project for the application of these techniques to inland landsides.

Inland landslides occur in a wide variety of geological and geomorphological situations and the method of mapping them depends on factors such as geological setting, topography, time, money and the reason for doing the work. It would be of significant benefit to the Geohazard and Risk Landslides project of the British Geological Survey if the experiences from the coastal use of the Riegl LPM-2K long-range scanner and the GS50 could be applied to inland landslides. This would provide a rapid technique for the characterisation, modelling and mapping of landslides, and also a valuable tool for monitoring ground movement if repeated over a period of time.

The overall objective of the survey at Broadway was to assess the use of and derive a methodology for using the scanner and the GPS for different types of inland landslides as opposed to the established coastal studies. Potentially, inland landslides can be less pronounced than their coastal counterparts, have less definitive boundaries and may cover much larger areas with more obstructions located on and around the slide (i.e. trees). Therefore, revised techniques and more detailed planning may necessary than for the coastal work.

The methodologies described in this report were derived from a series of field tests carried out on the slopes of the Cotswolds Escarpment above the village of Broadway, Worcestershire, United Kingdom on the 24-25 July 2002 (Rowlands et al 2003 and Gibson et al 2003), by a project team from the British Geological Survey and in collaboration with a similar project team from Portsmouth University. (The revised methods have been subsequently applied during commissioned research projects Gibson and Hobbs 2003)

The aim of this report is to provide a general discussion regarding the technical operation, and potential difficulties of using the GS50 GPS and the Riegl LPM 2K laser scanner in the field, to describe a methodology for their use and indicate points for consideration for improving accuracy and efficiency in the future. The methodology described should be used in conjunction with the BGS operating manual for the equipment (Jones 2003) and the manufacturers operating instructions (Leica 2001).

2 The GS50 GPS

Figure 1: The Leica GS50 GPS

2.1 INTRODUCTION

The Leica GS50 GPS consists of an antenna, receiver and battery unit that is carried in a backpack; they are controlled using a hand-held terminal (Figure 1). The manufacturer claims that measurements made using the system have a positional accuracy of 0.5 m in its x, y positions and 1 m in its orthometric heights.

The GS50 can be used to accurately position points and features on the ground, noted on aerial photographs, or to record ground control points as part of a larger survey or ground investigation. The GS50 can also be used as a geomorphological mapping tool, enabling rapid and accurate recording of the positions, boundaries or areas of geomorphological features or other features of interest in the field. Data recorded during the survey, can easily be imported into a standard GIS package after simple processing.

Positional measurements by the GS50 are approximations because, as with all GPS systems, the equipment records position as a point (in longitude and latitude) on a geoid (known as the World Geodetic System 1984 - WGS84) that approximates to the actual earths surface. These measurements can be further processed to give location in any conventional coordinate system including Ordnance Survey National Grid. It is also possible to pre-programme the GPS for small areas so that this processing is carried out as measurements are taken.

2.2 PREPARATION

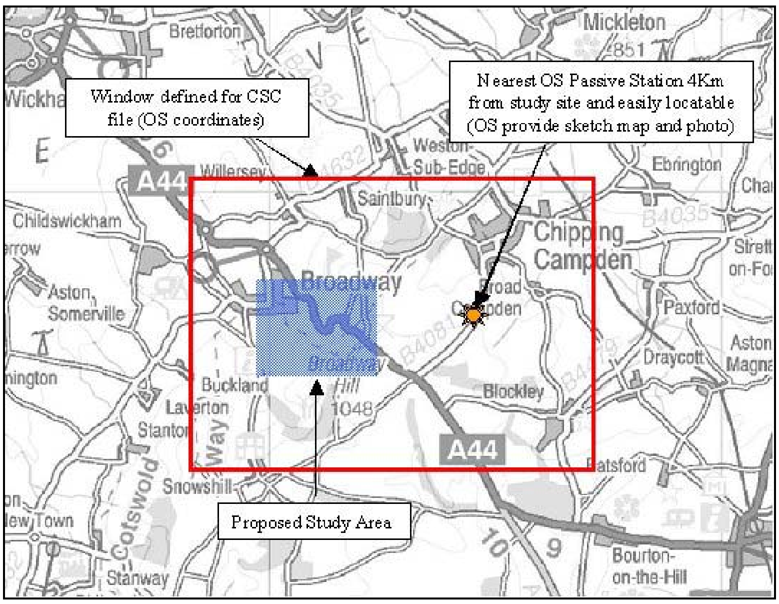
Coordinate Systems

Due to topography and the overall shape of the Earth, the mathematical ellipsoid does not fit exactly the natural geoid. Therefore individual countries have developed their own local geoids and coordinate systems, which can be referred to the geoid using conversion factors.

Taking the distortions of the GPS mapping system into account, several countries have produced tables of conversion factors to directly convert between GPS measured coordinates given in WGS84 and the corresponding local mapping coordinates. Using these tables it is possible to directly transfer into the local grid system without having to calculate individual transformation parameters. Country Specific Coordinate Systems Models (CSC models) are an addition to an already defined coordinate system, which interpolates and applies corrections in a grid file. In order to view the OS coordinates in the field study area a section of the UK CSC can be uploaded on the receiver using the Leica GIS DataPRO software, via the PC card. It is worth noting that the CSC is only valid for projects where the reference station has been established using the OS active network, from the OS web site (www.gps.gov.uk).

The centre point of the potential study area is first located using OS maps. This point is then used to locate potential passive stations on the OS web site. From the presented list there are two options; the station nearest to the centre point can be chosen for ease of use and greater (assumed) accuracy, or the nearest station that has the most defining location features can be used. This is chosen if the user wishes, or there is a project requirement, to carry out a check or reference a control point at the specific GPS point when in the field. After the passive station is chosen, a radius or window for the area the requiring OS coordinates is calculated (Figure 2).

Figure 2: Choosing the area for the CSC from a passive OS GPS station

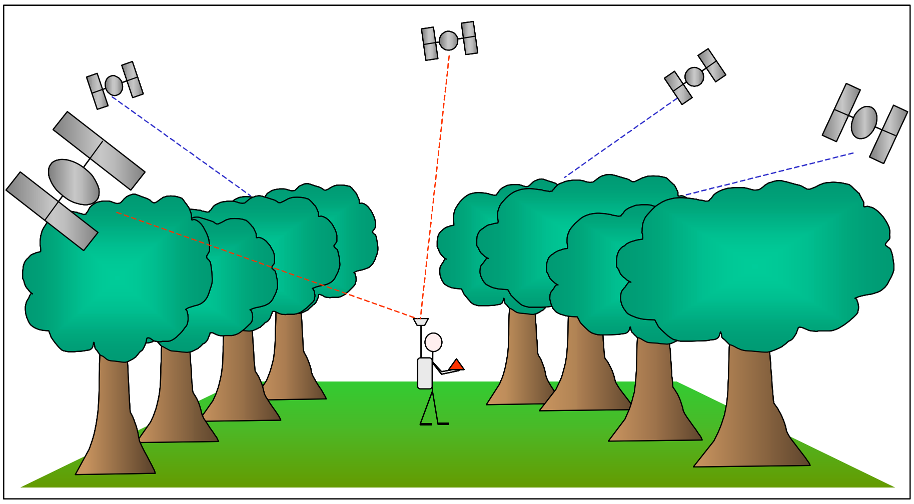


However, if several small areas are to be studied over an extensive region then its is more efficient to load two smaller CSC files onto the receiver rather than one large CSC file thus cutting down the size of the final file. The relevant CSC can then be selected for use when in the field.

Satellite Visibility

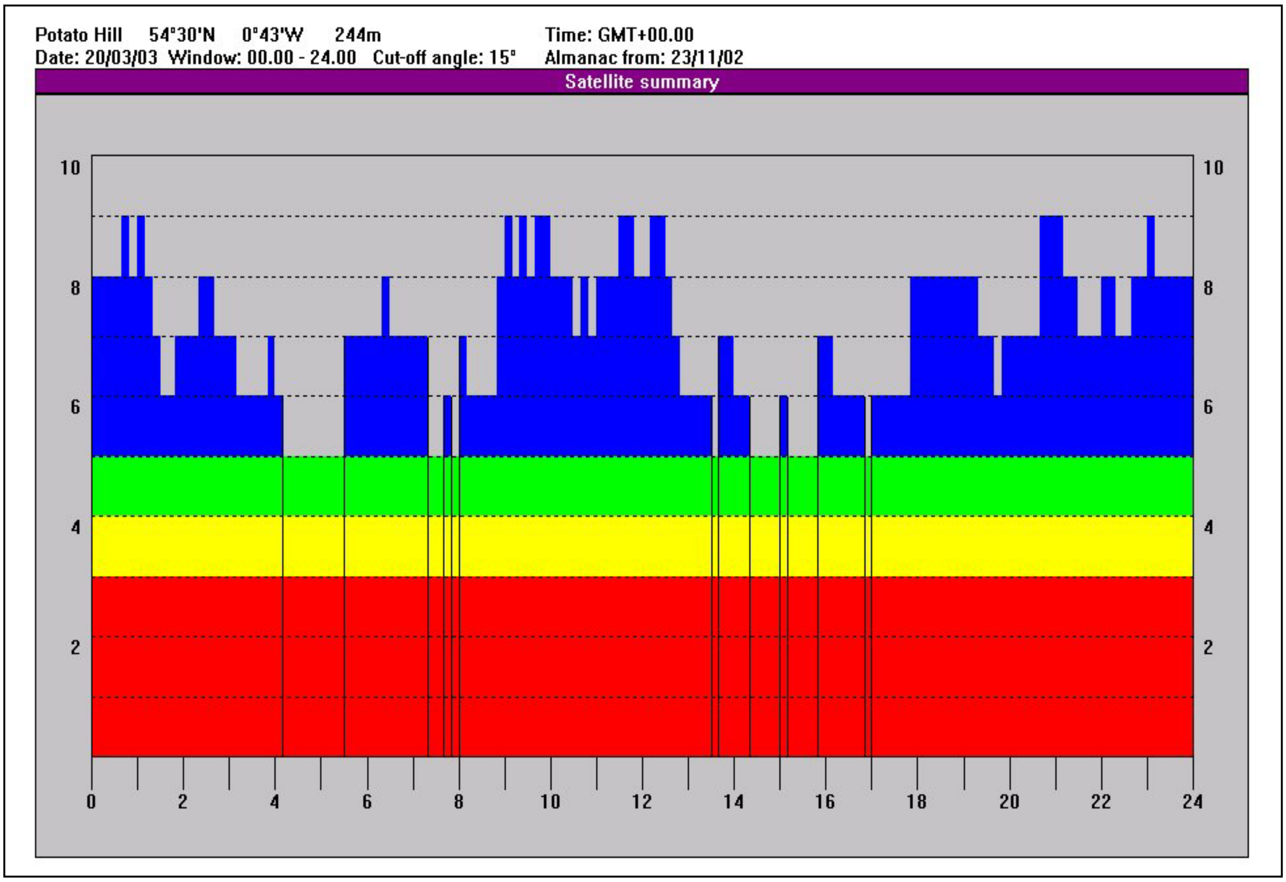
To enable the GPS to locate itself accurately in three dimensions the system requires that at least four satellites are visible to it at all times, however the more satellites that are tracked the more accurate the position will be. In areas where obstructions to reception from the satellites may occur such as dense woodland, urban environments or high cliff faces (e.g. coast, river, scarp or quarry), it is unlikely that the receiver will be able to track enough satellites (Figure 3). This may result in either the inability to collect the required data or extremely poor accuracy of the measurements that are successful.

Figure 3 Using the GPS in dense woodland or obstructive areas results in a significant limitation on the numbers of satellites being tracked



In areas where there may be large obstructions, (cliffs, scarps, cuttings etc) it is useful to check when there are likely to be a sufficient number of satellites visible to the instrument, this can be done using the GPS constellation almanac. The almanac information can be accessed online during an initial desk study and indicates the position and number of the satellites near to a selected site at set times through the day, over a requested period of time (Figure 4). The almanac is accessed through the Leica GPSPro software satellite availability option, and can be studied after the latitude and longitude of the study area are entered in to the site list. It is advisable that this is checked before the field study is carried out if working in areas of woodland or other areas where satellite visibility may be highly restricted, so that work can be planned around the times of potential optimum satellite occurrence.

Figure 4: Example of the satellite almanac for a study area in North Yorkshire, using the OS passive GPS station as the centre of the study area



Code List

The GPS can record features as points, lines or areas, these elements can be attributed using a code list. If the data requirements of the study are known (i.e. inland landslide investigation) set code lists can be set up prior to the fieldwork in order to facilitate the collection of the necessary data for positioning and mapping features in the field. These can be created and stored easily and can be any point, line or polygon feature that the user may need to record for their survey. These code lists may be updated when in the field. A full code list for the geomorphological mapping of inland landslides is included in the appendices (Appendix 1). However, features that may be added to the landslide mapping set code list include:

- Landslide deposits (area)
- Back scar (line)
- Landslide crest (line)
- Landslide toe (line)
- Tension cracks (line)
- Targets /backsights (point)
- Station /scanning position (point)
- Fences (line)

- Field boundaries (line / area)
- Break of slope (line)

The use of a set code list also ensures that all members of a project, whether mapping at the same time or not, will record the same data under the same file extensions (point, line or polygon) thus ensuring that the mapping of the landslides is consistent.

Equipment Check

It is very important to ensure that all three batteries for the GS50 are fully charged ready for use and, if carrying out the survey over a number of days, the battery chargers are packed with the rest of the equipment. A check on all equipment (i.e. that all cables are together etc) should also be carried out before departure. For a list of required equipment refer to Appendix 2.

2.3 USING THE GPS IN THE FIELD

2.3.1 Reconnaissance walkover

The initial walkover is an essential precursor to data collection as it provides an occasion for the field group to familiarise themselves with the landslides and geomorphology of the study area. The walkover also provides the opportunity for the selection of possible GPS points required and the selection of control points if using with the laser scanner.

If necessary, it also may be used for the identification of possible permanent project GPS sites (i.e. a particular fence post or a man hole cover), which may not be visible otherwise and may prove useful in repeat or monitoring surveys. These, if recorded in the GS50 can be easily navigated to and revisited during future visits using the equipment.

The walkover also enables the selection of the most appropriate order in which to examine specific sites

2.3.2 Data Collection

Set Up

When using the GS50 in the field it has to be ensured that the antenna pole strap on the top of the mini pack is tightly secured around the telescopic pole. This stops the pole moving too much and keeps it in a near to vertical position thus improving the accuracy of the measurements. The user also has to stand up straight and ensure that the measurement is taken over, or with reference to, the heel of his/her left foot - as the location of the antenna in its correct position is directly above this point (Figure 1)

Antenna Height

The antenna height is measured when the telescopic pole is fully extended and secured, and is measured from the ground to the black line at the base of the white antenna box. The default antenna height is set to 1.9 metres. If the user is taller or shorter than this value or if the GPS measurement is being taken on a tripod or another fixed object the height setting should be changed. If the height is changed through the full configuration menu this will be the new default height. However, if just a couple of readings at a different height are needed the height can be changed through the short cut *Config* button menu (Appendix 3) the height automatically returns to the default height upon switching off the receiver. It is important that the height of the antenna is monitored in case the pole slips, the GPS reading has been taken at a lower or higher point, or if one user changes the default height and another user is not informed.

Getting a Signal

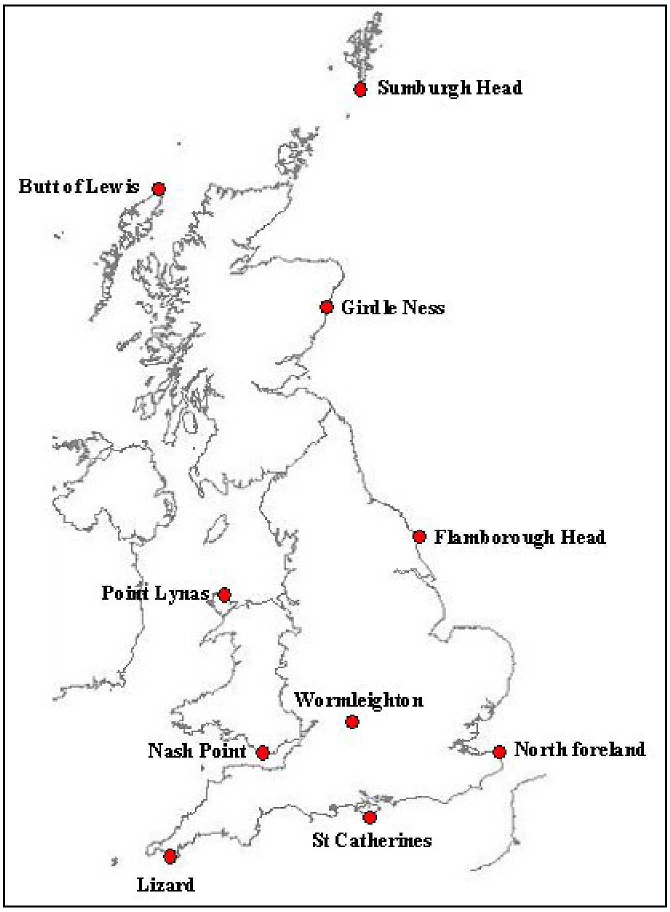
The GS50 works by receiving signals from satellites. When the GPS is in use the number of theoretically visible satellites at a particular location and time, according to the current almanac, is displayed on the hand held terminal (TR500) together with the actual number of satellites visible. In areas where obstructions to the satellites may occur (i.e. dense woodland or urban environments or high cliff faces) it is unlikely that the receiver will be able to track all the available satellites thus leading to a slight degradation in the accuracy of the measurements. Thus if the recent almanac has been checked prior to the survey to calculate the optimum time for working, and any potential obstructions to the signals noted, then receiving signals from surrounding satellites should not cause any problems.

The GS50 triangulates the satellite signals with the signals from a series of inland beacons which, with the exception of Wormleighton, are installed on lighthouses. At the present time there are 10 of these beacons around the UK (Figure 5) ;

- Butt of Lewis, Isle of Lewis
- Flamborough Head, East Yorkshire
- Girdle Ness, Aberdeen
- Lizard, Cornwall
- Mizen Head, Ireland
- Nash Point, South Wales
- North Foreland, Margate, Kent
- Point Lynas, North Wales Coast
- Sumburgh Head, Shetland
- St. Catherine's, Isle of Wight
- Wormleighton, North Oxfordshire

The receiver can be set to automatically gather transmissions from the beacon conveying the strongest signal, which may not necessarily be the one closest to it. If the receiver is struggling to pick up a beacon in automatic mode then by using the 'user defined' option the user can choose which of the 11 beacons they wish the receiver to pick up. This option is extremely useful in areas where transmissions may be slightly obstructed.

<u>Figure 5: Locations of the UK GPS Beacons</u>



The GPS can be set to receive values only of certain accuracy. The GS50 is automatically configured to record points only below 0.6m, however this can be changed and instructions on how to do this and to change the beacon transmission as described above, are recorded in the manual. It is worth noting that the reception and accuracy of measurements can also be affected in areas near overhead power lines.

As previously mentioned, set code lists can be created that ensure all members of a party map and record the points using consistent terms. These code lists can be updated in the field if a feature of interest does not have a code attached to it. A copy of the suggested inland landslide mapping code list is included in Appendix 1 and brief instructions as to the setting up of the lists are included in the basic user instructions in Appendix 3.

Transport and Storage

The GS50 equipment should not be carried loose in a road vehicle as it can be affected by shock and vibration. Care should always be taken to disconnect all cables and pack away the system properly in the backpack and then pack any other equipment tightly around to secure it. However if travelling on a long journey then entire system should be packed away in the red packing case and secured safely to protect it.

Basic instructions for the use of the GS50 in the field are included in the appendices for reference, and full instructions are provided in Jones 2003, Leica 2001.

2.3.3 Health and Safety Issues

It is important to remember that the antenna for the GS50 extends from the backpack to a height approximately 0.5m above the users head. Therefore, it is important that care is taken when walking though areas of tree cover and over hanging branches as damage to the antenna, data cables or to the user, or the person following could occur if caught by a branch. Due to this extension, the user also needs to be fully aware of people and objects surrounding them, with regard to the antenna, when bending or crouching to pick things up or to take samples.

If the GPS receiver hardware is used in exposed locations, it is at risk from lightening strikes and the receiver should not be used during a thunderstorm as the user may increase their risk of being struck by lightening. If there is a risk of a thunderstorm whilst in the field, the equipment can be protected further by unplugging all components.

Danger from high voltage flash over also exists near power lines. The antenna should not be used directly under or in close proximity to power lines.

If the GPS user is to be walking away from visual contact with other team members, especially over rough terrain, mobile radios or mobile phones (providing a signal can be obtained) must be used as a means of keeping in contact and as a safety measure.

The user should take extra care travelling over rough ground as a result of the increased risk of tripping while holding the equipment and looking at the handset.

If not set up correctly for the user, carrying the GPS all day may cause backache or muscle strain. It is advisable to take frequent breaks or to take turns if using the equipment over a prolonged period.

Batteries should be properly stored with their contacts covered.

Battery charging must be done in accordance with instructions from Leica

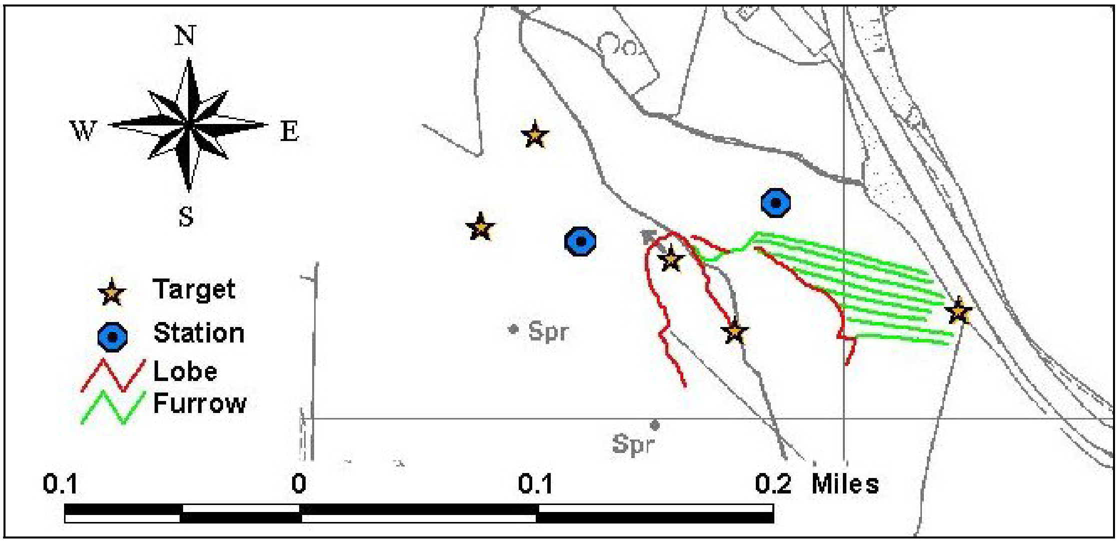
More detailed information on H&S is available from Leica and these should be studied before using the equipment

2.4 DATA PROCESSING AND OUTPUT

During field collection, data are stored on a PC card. Data from the GS50 are down loaded from the PC Card in the GPS receiver, to a compatible computer that has the Leica GIS DataPRO software loaded on it. The Ellipsoid height coordinates are then converted into their orthometric height equivalents (based on the CSC created previously), objects can be added, deleted and arranged as required. Codes, shape files, images and documents can also be utilised.

After the data have been processed in this way and edited to the users requirements it can be exported as an ASCII file, which can then be opened in software, such as Microsoft Excel, where the data can be manipulated or edited into the required format. Alternatively data can be exported as ESRI shape files and these can be opened and manipulated in an ESRI GIS (Geographic Information Systems) package such as ArcView or ArcInfo (see Figure 6).

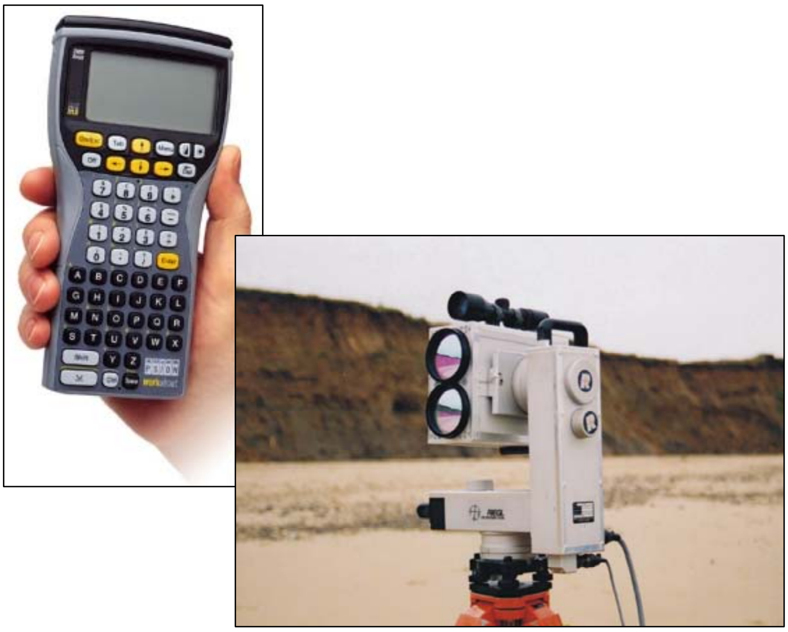
Figure 6: Example of GIS processed basic GPS data with OS Raster map for Broadway, Landslide A.



The data may need the coordinates correcting in Grid InQuest, which provides a means for transforming coordinates between ETRS89 (WGS84) and the National coordinate system for the UK and the Republic of Ireland. More information about the specific packages and the methods of processing the data can be found in the manual by Jones (2003).

3 LPM-2K Scanner

Figure 7: The Riegl LPM-2K Long Range Laser Profile Measuring System



3.1 INTRODUCTION

The Riegl Long Range Laser Profile Measuring system LPM-2K (Figure 7) is a terrestrially based LIDAR system designed for manual or automatic 3D terrain measurement. The laser uses 'last-pulse' time of flight detection to determine the distance of a reflective surface, along with its azimuth and elevation from the instrument position.

The system comprises a laser distance meter, which allows a precise range measurement up to 2km, depending on the reflectivity of the target. With good reflectivity of 80% the measurement range of the LPM-2K is stated as being up to 2km, with badly reflecting targets of around 10% reflectivity, the distance can be as little as 800m. In bright sunlight the operational range is also considerably shorter than under an overcast sky. The accuracy of the LPM-2K is typically ±25mm but in the worst case is stated as being around ±75mm.

(At the time of writing the laser has been used successfully in BGS projects up to a distance of 1.4 km).

3.2 PREPARATION

The use of 1:10k maps, as part of an initial desktop and reconnaissance survey prior to possible scanning work at inland locations is strongly recommended. Most importantly, these maps provide a good indication of the terrain at the study site by indicating potentially steep slopes, roadways and problems due to adverse access to the study area. If the study area is well known and the landslide locations previously noted, it is also useful to sketch potential scanning and GPS positions on to the maps for checking in the field, reducing the walkover time.

Whenever possible, photographs should be viewed stereographically during the desk study, this provides some indication of possible lines of sight between locations, indicating the feasibility of possible scanning locations before a walkover is carried out. However, it is important to remember when, and in what season, the photograph was taken as seasonal leaf cover can be a significant obstacle for scanning locations –the possibility of new buildings should also be considered if the photographs or base-maps are old.

Equipment Check

It is very important to ensure that all three batteries for the Scanner and Psion are fully charged ready for use and, if carrying out the survey over a number of days, the battery chargers are packed with the rest of the equipment. It is also vitally important to check there is enough space for data storage on the Psion, especially if the scans are to cover large areas. It is advisable to carry out a trial scan/ ground control exercise prior to departure. A check on all equipment (i.e. that all cables are together etc) should also be carried out before departure. For a list of required equipment refer to Appendix 4.

3.3 USING THE LASER SCANNER IN THE FIELD

3.3.1 Reconnaissance Walkover

The walkover survey provides the opportunity to assess the field area before scanning takes place. A number of important functions are performed at this stage:

- Appropriate control points can be identified for use either as scanning stations or survey backsights. Ideally these should be outside areas of active landsliding – giving confidence in point position and simplifying procedures for subsequent surveys. The selection of the most appropriate locations and order in which to examine the specified sites is critical to a successful survey. It is at this point that decisions should be made regarding the exact vertical and horizontal extents of the scan coverage, the range between the extremities of the target area and the scanner, lines of sight and the time required to carry out the scan. The appropriate scan window, including all required features and the amount of wasted space in a window.

- The appropriate resolution of the scan –point spacing on the ground needs to be less than half of the ‘wavelength’ of the feature you wish to scan. For instance if your scan is to model terracettes 1 m in height, your scan points need to be a **maximum** of 0.5 m apart, otherwise the feature will not be picked up.

- Safe and easy access to potential sites. Although good access may be indicated on aerial photographs and maps, these cannot always be considered reliable and field access is often hampered by obstructions such as barbed wire fences, ditches, overgrown hedges, livestock and busy roadways. The weight, size and shape of the equipment should not be underestimated.

- It is vitally important at the site selection stage to visualise exactly what data will be obtained from the scan – as a rule of thumb **if you cannot easily imagine what your elevation model will look like your model will not work.**

Some practical aspects of this are demonstrated by a LiDAR survey carried out at Broadway (Figure 8). The main hindrance to the identification of possible scanning locations proved to be the dense woodland coverage and high hedgerows within the study area. As the Broadway field visit occurred in July, the area was covered by large tall trees with fully developed leaf cover. This limited the field of view for sections of, or in some cases, the entire slide.

Scanning of Landslide B, although thought to be viable from the desk-study was found to be impossible in the field. Dense tree cover on the higher sections and in the areas surrounding the slide obstructed the line of sight from the ground sites. Many of the trees had grown in the seven years between the time of the photography and this survey. Access was also limited by the presence of the A44 Broadway road bypass as it ran through the middle of the study area At the time of the attempted survey the field in which the landslide was situated was occupied by a herd of horses which would have precluded access to the field for reasons of health and safety (to the field party, equipment and the horses).

Landslide A offered much better access, very little tree cover was present and entry to the field system was via a partially metalled trackway. The scan stations were clearly visible to each other as were a number of control points used as backsights. Two overlapping scans were carried out which produced a survey sufficiently dense to detect the desired features (16^{th} Century ridge and furrow features, intersected by a more recent landslide).

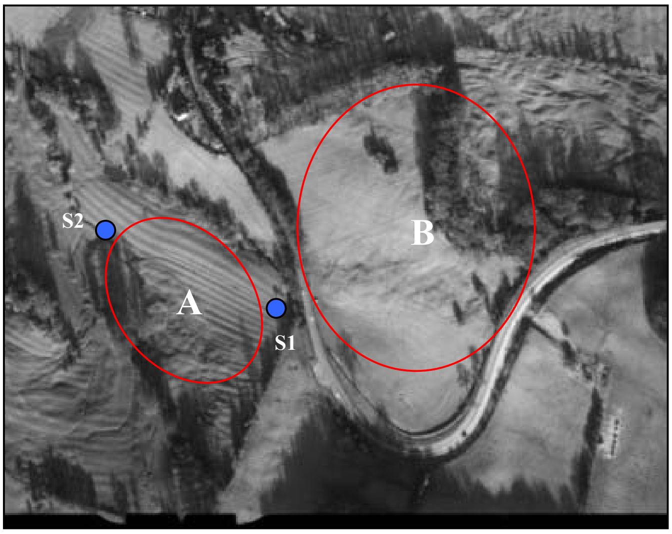
Figure 8: LiDAR scanning sites at Broadway, Cotswolds

Landslide A:

Slightly smaller less defined sliding, ridge and furrows to aid dating but lines of sight for scanning are identified and potential stations locations noted.

Landslide B:

Large slide, well pronounced but potential lines of sight for scanning entire slide are not present due to the presence of trees and bypass



(Rowlands et al 2003)

Good, well defined landslide for potential scanning. However line of sight and therefore majority of landslide from location of photograph obscured by trees and roadway.

3.3.2 Data Collection

Setting Up

Although it is satisfactory to model the ground surface from a single scan, a minimum of two scans provide better results because the ground points are usually closer together, the same section is scanned from different angles to create a fuller image which makes post-processing and merging of scans easier. Errors are also easier to correct when there are two independently sited scans to compare. Overlapping scans are also able to cover a wider area and are more effective at avoiding areas of sky. For the scanning of linear features such as coastal cliffs it is more usual to set scanning stations along a baseline terrain (see Appendix 5).

After ensuring the ground is stable and setting up the tripods in the required positions, it is important that the tripods are <u>not moved</u> during, between or after completion of the scans. This is in order to obtain as accurate a GPS reading as possible for the location of the LPM-2k scanner during the scanning periods.

A hand held Psion Workabout Data Logger loaded with the appropriate software is used to record the data collected during the scans. The Psion is small and can be hand held or fitted to the leg of the tripod whilst the scan is in progress. It is practical for fieldwork as it can be transported within the scanner carrying case, and is resistant to most inclement weather and small enough to be easily protected in heavy rain. The scanner can be used in the field with a laptop computer but this has proved to be impractical, because of difficulty in carrying it with the rest of the LPM-2K and the fragile nature of a laptop in the field with regard to lack of weather proofing.

Do not remove both the AA batteries and the internal (watch type) battery at the same time. This will result in the loss of all data from the Psion, if any batteries do need to be changed, do this one at a time.

Programming the scanner

The project name given at the start of the session is the project name for the field study area and the different station data sets are held within the one file. A straightforward system has been established for the naming of the project files, enabling any person to understand which set of data they are looking at and to provide basic information for easy comparisons of the scans. Within this system the name of the site is abbreviated and the month and year added as the numbers for the project files and the scan location added for the scan file name. As an example using the Broadway, July 2002 scans;

- The project file name was **broad72**
- The file names of the two landslide scans carried out on the first site were **broadS1** and **broadS2**,
- Using the same project name, the second site scans became **broad2S1** and **broad 2S2** etc.

Make sure that different names are used for different sites. **If more than one scan is carried out in the same project file use different names/numbers for each backsight – otherwise previous data will be overwritten.**

The height of the scanner can be measured in two ways either by measuring from the collimation level to ground level every time or by measuring the height of the tripod each time as the collimation to tripod distance is always 0.33m if the scanner has been set up correctly.

The LPM-2K scans a window specified by the user, choosing points at the top right to bottom left of the study area, and using a specified horizontal and vertical step increment defining the aerial extent and point density of scan. The amount of sky within the scan window inhibits the speed of the completion of the scan because the sky provides no reflective signal for the laser. This is a significant issue for coastal landslides (i.e. monitoring irregular cliff shapes from a position constrained by the sea). The ‘problem’ of sky in a scan window is not such an issue for the inland slides, it is easier to pick sites with better viewing angles and there is generally more time available, allowing the generation of several smaller scans which can avoid sky in the field of view.

The scanner can also be used to record individual targets or features in manual mode. In a two scan station set-up, both station tripods are also used as a backsight for the each of the scans, thus adding to the importance of not moving them until the completion of the scanning. The GPS readings aid the transformation of the image into a grid co-ordinate system using PC software.

Although geo-rectification of scan points needs only one backsight to orient the scan and scanning location. It has been found from previous use, and again during this inland study, that at least three targets or backsights are desirable. This allows the data to be processed more than once and for those scans (which theoretically should mesh perfectly) to be compared. It has also been found that one or two of the targets should be located outside the scan window as this improves the potential positional accuracy of the final model further.

The name given for each of the backsights that are added to the projects backsight file must match in name and case to those given to the GPS points. If this system is used then back sight data from the scan and the GPS then can be merged upon processing.

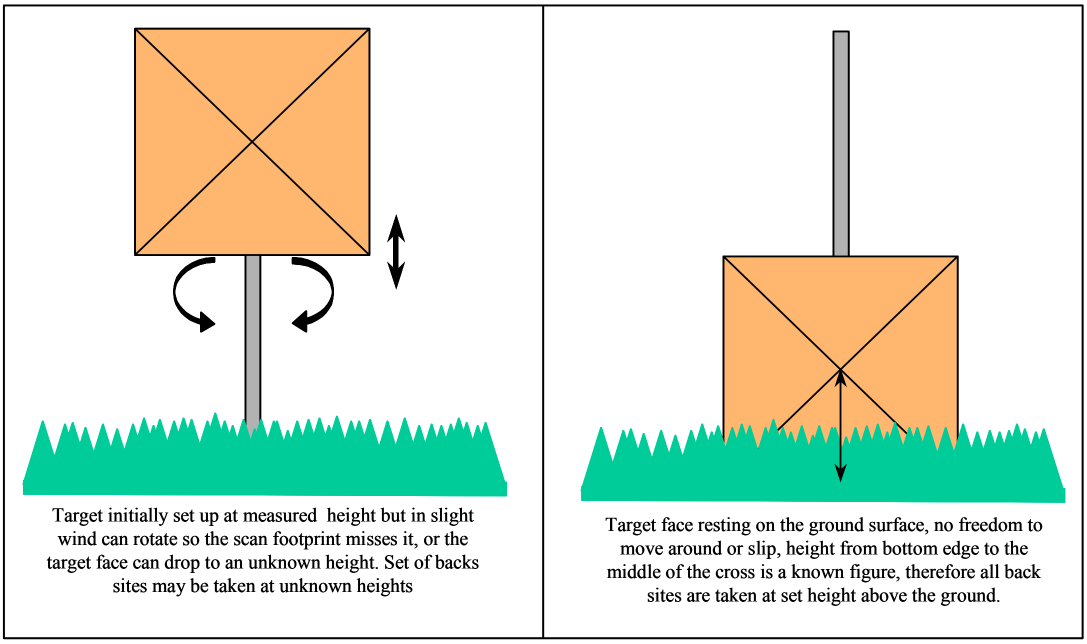
For the backsights to the tripods a small highly reflective 300 x 250mm target, to a distance of 175m, is used. This, although small, is very easily visible through the viewing telescope and improves the accuracy of sighting to the tripods. Use of this backsight is recommended as the target has a significantly higher reflectivity than most other surfaces and obtaining a good signal from it provides a guarantee that the backsight is accurate.

Mounted brightly painted 750 x 750 mm targets were used as target sights for backsights and control points in the field where no or few standard fixed potential control points could be identified in the field. Targets of this size are used for two reasons; to maximise potential for the scan footprint to hit the target and to ensure the targets appear on pixellated photographs when they are also being used for photogrammetric purposes.

Two distance values are recorded for the location of each target by shooting the laser to the centre of the cross at a measured height above ground and, as an extra comparison, to the ground immediately at the base of target. On this trial study it became clear that several problems were being incurred using this method. Some of the looser target faces were slipping after measuring the height to centre and some were rotating if caught by a cross breeze, making sighting difficult and the recorded location of the targets in comparison with the GPS wrong, as the scan footprint missed the target face (Figure 9).

On completion of the scan, and after the laser has been turned off (care being taken to do so in the correct order) it can be packed and moved to the next scanning site. When doing this it is important that the telescope and the cables are removed and the scanner is placed back in its box before being moved, because trying to carry it alone or moving it whilst still attached to the tripod may result in it being damaged.

Figure 9: Setting up of targets for laser scanner backsights



By comparing the distance recorded by the scanner with the results gained from manual laser range finding binoculars, it also became clear that the ground at the base of the target was proving difficult to accurately hit as it was unclear where the base of the target leg actually was in relation to the laser foot print.

The solution reached in this instance involved resting the base of the target face square on the ground, thus the actual height to the centre of the cross could be measured and the height remained constant throughout the scanning process, this also prevented the target rotating in the cross breeze and at same time the point of contact between the base of the target and ground could be recognised and sighted to if necessary.

3.3.3 Health and Safety

In addition to usual BGS Health and Safety considerations, a number of issues specifically concerned the use of the equipment. The laser scanner is extremely heavy (approx 30Kg with case) and access to potential study sites is an important issue. The selection of sites where the laser can be pulled along in a trolley are the easiest solution, however this is not always possible and the laser may need to be carried. Proper gates and crossing paths should be used at all times to avoid injury and strain to the carrier and damage to the equipment.

Although the laser is a Class 3b safety laser, meaning that it is operationally safe to use in public areas, the surroundings must still be considered. Therefore, the laser should not be used in residential or public areas if possible. If this in unavoidable and the laser is to be used in such an area then permission from the relevant parties must be obtained. Obvious signs and restrictive tape must also be used in order to prevent members of the public walking directly in front or looking into the laser whilst in use. It is recommended that scanning is not carried out across any transport corridors.

If the ground underfoot is wet then it is important that the electrical equipment is stored in the carrying case to avoid damage and risk of shock.

3.4 DATA PROCESSING AND OUTPUT

The scan data require several different software packages for retrieval and manipulation. Data from the Psion are transferred to the PC using a serial port and PsiWin Software. The data can be viewed initially in Riegl LPMScan and then processed and tied in with the GPS data in 3DLM Manager.

LPMScan allows the operator of the 3d imaging sensor to perform a large number of tasks and mainly uses a 2D image preview to check that the image is valid, The 3DLM software is designed to take the output from the Psion Workabout and orient the data into real world coordinates.

Once all data have been collected on the same PC, they can be processed and modelled in proprietary packages such as Surfer 8 and viewed in packages such as ArcView.

4 Comments

It has been suggested that for future inland work the use of aerial photography as part of an initial desktop and reconnaissance survey prior to possible scanning work would eliminate some of the difficulties and time wastage that was experienced during this study. Aerial photography would provide some indication of possible lines of sights between locations, thus indicating possibly scanning locations before a walkover is carried out. The use of aerial photographs and maps together could provide information on terrain and access, especially important for the fieldwork involving the Laser scanner.

There are issues regarding health and safety that have been mentioned, and must be adhered to. One of the main issues regarding the laser scanner must be the transportation of the instrument and access to potential sites. This is not something that should be taken lightly as the equipment **is** heavy and suitable methods of transportation and extreme care should be taken when moving it. If the user is unsure about how to move the equipment or struggles transporting the scanner by his/ herself then they should stop immediately and call for assistance to avoid injury. This must be taken into consideration in the project /fieldwork planning and risk assessment.

Study of the GPS online almanac is extremely important if accurate data are required and the areas to be working in or near are likely to be affected by obstructions to the GS50 receiving satellite data.

Overall, the GS50 GPS and LPM-2K laser scanner have proved to be extremely valuable tools for relatively rapid, accurate data collection. The use of both pieces of equipment in the monitoring of coastal cliff retreat within the BGS has been very successful. The procedures developed by that project have been successfully used to observe and measure inland landslides at Broadway. A number of issues have arisen which specifically concern inland areas. Recommendations arising from this work are included in this report.

It is hoped that this report can be used as an aid to planning of future work regarding operational and health and safety issues and the assessment of the suitability of suggested study areas.

Appendix 1

CODE LIST FOR LEICA GS50

An example code list for geomorphological mapping and laser scanning of landslides (inland and coastal). Before recording the data the user can add a comment, name or attribute to the feature for identification purposes. If the data are to be used alongside the scan data then the GPS and backsight data have to match in both name and case.

Code	**Code Note**	**Type**
B_cliff	Base of cliff	Line
B_scar	Back scar	Line
B_slope	Break of slope	Line
C_Cracks	Crown cracks	Line
Crest	Landslide crest / crown	Line
Feature	Feature of interest	Point
Fence	Fence	Line
Field	Field boundary	Line
M_scarp	Minor Scarp	Line
Photo	Photo location	Point
R_ridges	Transverse ridges	Line
Slide	Landslide deposits	Area
Station	Station (scanning position)	Point
Target	Targets (backsights)	Point
Tension	Transverse tension cracks	Line
Toe	Landslide toe	Line

Appendix 2

CHECK LIST FOR LEICA GS50 GPS

Initial set up;

- Up load CSC file onto receiver if requiring OS coordinate whilst in the field
- Ensure ALL batteries are fully charged
- Check online almanac if survey areas may be affected by obstructions

Ensure all GS50 components are present;

- Minipack carrier
- Receiver
- RTB Antenna
- RTB module screwed into Port 1
- Terminal (red keypad)
- PC card
- Black Telescopic rod in back of minipack
- Cables
  - Grey Lemo connection cable
  - 30cm co-axial cable (RTB receiver to Antenna Port)
  - Long co-axial cable (RTB to Antenna)
- 3x fully charged batteries
- Battery charge

Field use;

- Ensure the antenna pole strap on the top of the mini pack is tightly secured around the telescopic pole (this keeps the pole up straight and stops it moving around to much).
- Ensure all cables are correctly and securely plugged in to ports
- Create code list for data recording (if not carried out in office)
- Select nearest inland/lighthouse beacon rather than roaming receiver if the accuracy is poor or if the contact with the chosen beacon is lost.
- Stand up straight when recording data

Appendix 3

LEICA GPS GS50 - BASIC USER INSTRUCTIONS FOR DATA COLLECTION

On

Select Job

Scroll down to 'job', highlight and Enter.

Scroll down and choose required job, Enter

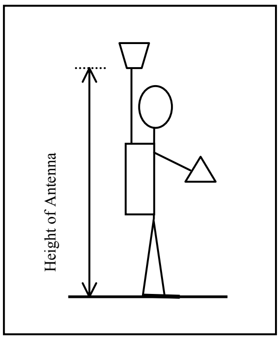
F1

NB: 'Job' is your Working file – Leave the co-ordinate system and Code list as set as should have all relevant landslides mapping needs entered!

Or

To add to codelists, select F2 'New' and add extra codes

Antenna Height:



Press Config button

Select option **2** (*Operation*) by scrolling & highlighting & Enter

Select option **5** (*Antenna*) by scrolling & highlighting & Enter

Scroll down to antenna height and type in required height.

Enter

F1

NB: The Antenna height is measured to the base of the white square receiver.

Data collection:

Example 1: Point data

Select code by highlighting & Enter	*e.g. Photo Point*
F1	Occupies and takes position

Will continue to do this until reaches accuracy set: if only basic reading required just press F1 to stop manually

Example 2: Area data

Select code by highlighting & Enter	*e.g. Landslide*
F1	**Occupies and takes position**

Walk around object to be mapped without pressing anything

Before pressing F1 –can view the plotted area by pressing **Shift F4** then press **F1** to finish

F1 – stops data collection

Example 3: Line data

Select code by highlighting & Enter	*e.g. Base of Cliff*
F1	**Occupies and takes position**

Walk along object

F1 **– stops data collection**

Nested Points: During Line and Area Data collection

If there are feature points along the collection line that you also wish to record:

Eg: recording the position of a path and reach a manhole that needs recording

F2	*Nested*	
Select code by highlighting & Enter	*e.g. Target*	
F1	**Occupies and takes position**	
F4	*resume*	***Resumes collection of line feature and can continue walking***

Quick keys:

F7 - satellite info

F8 - list of points *then F3 edit: gives coordinates of point (Easting and Northing if using a CSC and Lat - Long if WGS84*

F4 attr: Gives attributes of point (added written details!)

See Jones (2003) for full user instructions

Appendix 4

CHECKLIST FOR LPM-2K LONG-RANGE LASER SCANNER

Initial set up;

- Desk study of topographic maps and stereoscopic aerial photographs for potential line of sight and access issues.
- Check data storage capacity on Psion
- Ensure BOTH batteries are fully charged

Ensure all LPM-2K components are present;

- Laser distance meter with pan and tilt mount
- Zoom telescope
- Power supply and interface cable
- Psion
- Joystick
- Adjustable tribrach with bubble level (for mounting the LPM-2K on a tripod)
- Tripod (two are needed to ensure accurate GPS and backsight measurements without moving between scans)
- Two batteries
- Battery Charger
- Psion charger

Field use;

- Do not move tripods until all scans are completed
- Ensure all cables are correctly and securely plugged in to ports
- Follow the correct file naming procedure;

  i.e.: Broadway July 2002

  -The project file name was **broad72**

  -The file names of the two landslide scans carried out on the first site were **broadS1** and **broadS2**,

-Using the same project name, the second site scans became **broad2S1** and **broad 2S2** etc

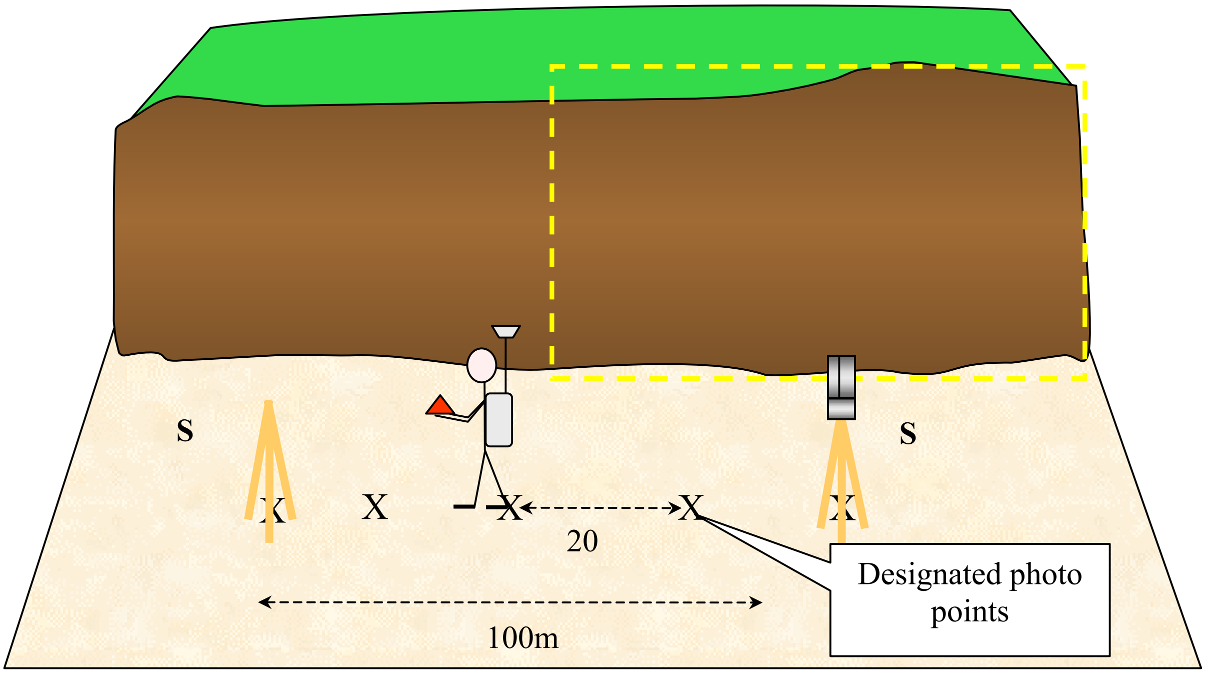
- Check size of scan window and time approximated for scan to complete
- Choose sensible back sights and locations for targets – with at least one or two being located outside the scan window, and ensure they are stable.
- Is there a backsight a long distance from the scanner (>200 m provides greater accuracy)
- If using the laser in a public area ensure permission is obtained and appropriate signs and reflective tape are used.

See Jones (2003) for full user instructions

Appendix 5

CARTOON DIAGRAMS OF COASTAL AND INLAND LANDSLIDE SCANNING.

Figure 1: Cartoon example of field set up for coastal landslide scanning



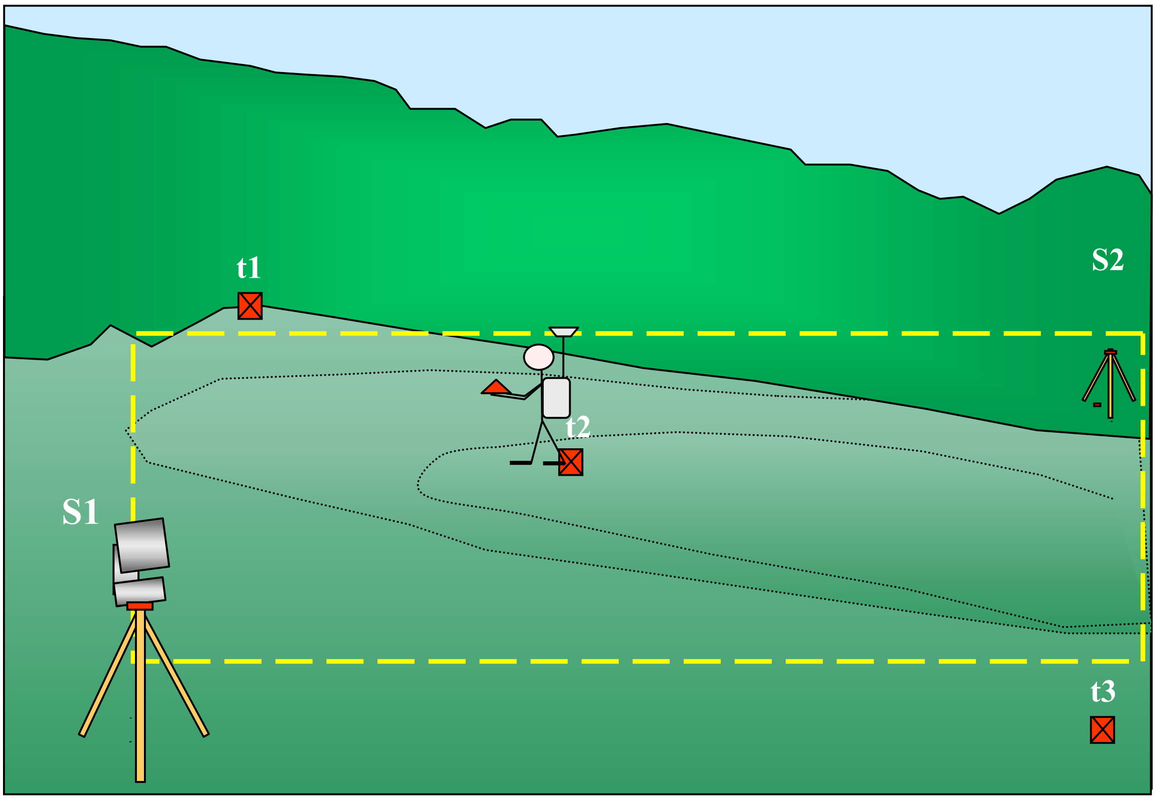
The coastal set up is a very simple set up. The scan locations are set approximately 100m apart at low tide and as far away from the cliff face as are safely possible. The scan windows are set to overlap in the centre section of the scan section thus providing ground points to link the scans together upon processing. These ground truth points may be reflective targets landslide features but must be visible from both locations.

Photo points are situated at 20m intervals between the two sites. A photographic sweep of the cliff section is then taken at each point for photogrammetric processing.

GS50 GPS measurements are recorded at each station and photo point. If it is safe to do so and the proper safety equipment is being worn, break of slope lines can be recorded at beach level and within the slide features. The top of the cliff line can also be mapped by using the offset function on the GPS recording the data points at a safe distance from the cliff edge.

Both sets of data can be imported into a GIS for spatial and geological analysis.

Figure 2: Cartoon example of field set up for inland landslide scanning



The positions of scan stations and backsights are finalised by the initial walkover survey when tree lines and other obstructions can be monitored.

At least two scans are needed, one from either side of the slide. Unlike the coastal sections there is no fixed placing for these stations and the positions are obstacle and slide dependant e.g. in the above diagram the positions are limited by the trees, hedgerows and fences along the edges of a shallow slide. Again the stations are positioned so that there are ground truth points, these are provided by the positioning of reflective targets, within the scans for linking the scans together. The setting of the stations in this way also ensures that the perspective of the slide is recorded.

The GS50 is used to record the station and target locations. It can also be used to map breaks in slope and to draw cross sections of the slide as well as map any other relevant features of the slide. Again both sets of data can be imported into a GIS for spatial and geological analysis.

References

Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

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