1

PRECISION SURVEY PROPERTIES AND TECHNIQUES

OBJECTIVES

After studying this chapter, you should be able to

1. Explain the main properties of precision survey procedure with respect to basic survey procedure
2. Discuss the properties of the main classes of precision surveys
3. Explain different traditional measurement techniques used in precision surveys
4. Discuss the uses of different coordinate systems for precision surveys
5. Discuss the geodetic challenges of some precision survey projects
6. Evaluate some safety issues relating to precision survey projects

1.1 INTRODUCTION

Precision surveying is not a specific area of discipline like geodesy, photogrammetry and remote sensing. It is about applying appropriate field(s) of surveying to projects in order to achieve a desired accuracy (or precision). Ordinary measurements to a few millimetres are sufficiently precise in some projects such as construction of buildings

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and bridges; but greater precision may be required for alignment of prefabricated steel structure or members, and for deformation monitoring. For example, an alignment of magnets of accelerator facilities may be required to a tolerance of up to 0.1 mm or better; in monitoring and deformation surveys, strict requirements on observations and data handling methods are imposed in order to achieve desired accuracy; and in long tunnel surveys, the critical factor is usually to minimize lateral breakthrough error which requires special methods of network design that are different from those applied to ordinary geodetic networks. Precision surveys are done by educated specialists who are able to determine the appropriate instrumentation, evaluate sources of error and prescribe suitable error-mitigating procedures, for a given project.

The most significant properties distinguishing precision surveys from ordinary surveys can be summarized as follows:

1. Precision surveys require the use of precise and expensive instrumentations.
2. Precision surveys require stricter observations and data handling methods, which require directly proportionate increase in time and effort of the surveyor and also increase in cost of the surveys.
3. Precision surveys involve collecting a larger number of observations. In order to obtain accuracies in the millimetre range, a high degree of redundancy is required in the survey network which, in practice, translates into a large number of observations. Redundant observations are needed in order to be able to assess the accuracy and reliability of the results.
4. Precision surveys require more rigorous mathematical treatment for error evaluation. Errors in data handling, from observation stage to final processing can often contribute significant errors in final results. Reducing the magnitudes of these errors in data handling as well as in processing the data can significantly improve the accuracy of the survey.

It is the duty of the surveyor to maintain a degree of precision as high as can be justified by the purpose of the survey, but not higher. For the surveyor to achieve an appropriate degree of precision for a survey, the surveyor must have possessed a thorough understanding of the following:

(a) The intended use of the survey measurements.
(b) Sources of errors and types of errors in survey measurements.
(c) Design of appropriate survey scheme to aid in choosing appropriate survey instruments.
(d) Field survey procedures (including the amount, type, and survey data acquisition techniques) for keeping the magnitude of errors within allowable limits. The procedures should also include performing instrument setup or calibration or both.

(e) Methods of adjustment and analysis of the acquired measurements which will include providing an indication of the quality and reliability of the results.

1.2 BASIC CLASSIFICATION OF PRECISION SURVEYS

It should be mentioned that the classification being attempted in this section is subjective and may not be generally accepted; it is made to facilitate the understanding of various aspects of precision surveys. For the purpose of this book, the high precision survey will be classified to include the following:

1. Geodetic control network surveys
2. Monitoring and deformation surveys
3. Geodetic engineering surveys
4. Industrial metrology
5. Surveys for research and education

1.2.1 Geodetic Control Network Surveys

Geodetic control network survey is a survey process which takes into account the true shape and size of the earth; it employs the principles of geodesy and is generally conducted over large areas with precise instruments and precise surveying methods. The survey is conducted in order to establish horizontal and vertical positions of points as well as three-dimensional positions of points. A geodetic control network is a series of widely-spaced, permanent and interconnected monuments whose positions (or coordinates) and elevations are accurately known. The agencies of governments, such as the Geodetic Survey Division (GSD) of Canada, are primarily responsible for conducting geodetic surveys. Relatively few engineers and surveyors are involved in geodetic control surveys but the resulting data are usually of great importance since they provide precise points of reference to which a multitude of surveys of lower precision may be tied.

Geodetic control survey is typically carried out in order to provide:

1. Basic framework (e.g., the Canadian reference framework and the Canadian Spatial Reference Systems (CSRS), the American National Spatial Reference System (NSRS), the European Spatial Reference System (ESRS)) for detailed site plan topographic mapping, boundary demarcation (international, and inter-state or inter-provincial), mapping natural resources, and so on. Generally, it provides control for large geopolitical areas where there is a need to accurately connect with adjacent political areas, and also for the purpose of controlling inter-state transportation corridors, such as highways, pipelines, railroads, and so on.

2. Primary reference for subsequent engineering and construction projects (e.g., building of bridges, dams, tunnels, highways, pipelines, etc.).
3. Reference for positioning marine construction vessels (continuous positioning of dredges and survey boats).
4. Reference for effectively and efficiently monitoring and evaluating deformations of large extent, which may include tectonic plate, land slide, dams, and so on.

1.2.2 Monitoring and Deformation Surveys

Monitoring and deformation surveys are essentially for the purpose of modeling and analysing natural phenomena (earthquakes, landslides, crustal movement) and man-made structures (bridges, buildings, tunnels, dams, and mines). The accuracy requirements of the surveys can differ significantly from those of control or legal surveys. In monitoring and deformation surveys, stricter requirements on observation and data handling methods are usually imposed in determining the relative positions of the monitored or observed stations.

Geodetic control surveys are different from geodetic deformation surveys. In *geodetic control surveys*, the determination of absolute positions (coordinates) of points is of interest while in the *geodetic deformation surveys*, one is interested only in the determination of changes of positions (displacements). Some specific monitoring and deformation surveys projects are as follows:

- Deformation measurements of Flaming Gorge concrete dam on the Green River in Utah (Roehm, L.H., 1968).
- Monitoring Earth filled dams in Southern California (Duffy et al., 2001).
- Monitoring exposed pit walls at the Highland Valley Copper mine in British Columbia, Canada (Wilkins et al., 2003).

Other projects requiring deformation monitoring surveys are as follows:

- Measurement of deformation on buildings exposed to some particular mechanical or thermal strain. Accuracy requirements may be in the order of millimetres for object dimensions of more than 100 m (e.g. cooling towers, chimneys, dams, sluices, cranes, historical buildings, etc.).
- Deformation of concrete tanks used for galvanizing and electroplating may need to be measured under working conditions. The tanks are constructed from special concrete and in operation, are slowly filled with liquid of several tons. The tank walls are subject to critical deformations which may need to be observed at regular intervals.
- Deformation analysis of rotary cement kiln. A rotary kiln is a cylindrical vessel made of steel plate and lined with firebrick. The vessel slowly rotates about its axis between 0.5 and 5 revolutions per minute and continues to run 24 hours a day and only stop a few days once or twice a year for essential maintenance.

The kiln must be monitored for safety reason. By measuring the surface of the vessel, critical areas of the kiln can be detected and deformation monitored.

- Tunnel profile measurement requires measuring tunnel interiors for shape and deformation analysis.

1.2.3 Geodetic Engineering Surveys

Geodetic (or precision) engineering surveys apply rigorous geodetic methods to control and support construction and building projects which include construction and maintenance of tunnels, bridges, hydroelectric power stations, railways, and so on. Unlike in geodetic positioning, geodetic engineering surveys are based on local coordinate systems and relative positioning of objects are of more importance than absolute positioning. Many of today's engineering surveys require relative positional accuracies in the order of 1:100,000 or better. Most first order national geodetic networks, however, may not be suitable for controlling engineering projects where high precision is required because of possible distortions in the national geodetic networks. What is usually appropriate is to adopt appropriate geodetic model and local coordinate system.

Engineering Surveys deals with special survey techniques and precision measurement techniques developed for three purposes:

1. Positioning the construction elements of large engineering works such as dams, tunnels, pipelines, deep mine shafts, high-rise office buildings, and bridges;
2. Deformation monitoring of these works and their surrounding (ground subsidence and slope stability) and their analysis;
3. Positioning and alignment of machinery and scientific apparatus.

"*Mining surveying* is an important branch of engineering surveying dealing with rock stability control and protection of underground and surface structures that may be influenced by ground subsidence" (Chrzanowski, 1999). Actual mining surveying consists of undermining and controlling caving of the ore; it is also necessary that the position of the workings at one level be known precisely at the next level above. Mine surveying are done in cramped areas, with irregular routes, no reference objects such as sun or star to provide azimuth.

Land surveying is a highly specialized branch of geodetic engineering surveying that focuses on establishing boundary lines of real property ownerships, which include establishing new boundaries as may be required in re-establishing the original boundaries or in land partitioning; it also deals with the determination of areas of land tracts. With regard to construction projects, the land surveying problem usually arises when costly land acquisition is involved, such as in pipeline surveys.

For convenience and simplicity, engineering and land surveys are usually made as if the surveys are done on a plane earth surface. In this case, plane local coordinate system (requiring map projection process) is commonly used. Since a local coordinate system is an isolated system with respect to other types of coordinate system such as geodetic coordinate (latitude, longitude, ellipsoid height) systems, it is impossible to directly correlate one engineering survey with others when large areas are involved. Moreover, local coordinate systems cannot be extended too much from their origins since the extension may introduce some unacceptable distortions to the surveys.

Some of the geodetic engineering challenges that may be encountered in geodetic engineering surveys include the following:

1. With regard to pipeline projects, for transportation of oil and natural gas, over a long distance, for example, *Trans Mountain Pipeline (TMPL) project* from the oil fields in Alberta to British Columbia (Hamilton, 1951; Chrzanowski, 1999), the following geodetic engineering challenges are encountered:
   - Choosing the best possible route for the pipeline with consideration for the environmental impact of the project as well as the possible presence and impact of subsidence and geological fault lines on the functioning of the pipelines. This will require consulting other geoscientists and using appropriate tools, such as topographic maps, Geographic Information system (GIS), Google Earth tools and LIDAR system, to identify the best route.
   - Acquiring the right-of-way, which may involve relocating and settling the owners of the acquired landed properties; this will require carrying out legal surveys for the route. Today, traditional surveys with theodolite and chains are giving way to the use of modern technology, such as total station equipment and Global Positioning System (GPS).
   - Providing the desired grades of pipelines, since pipelines are sensitive to grades which are very important in the calculation of pumping facilities and attaining appropriate pressures in the pipelines. Today, in establishing grades for pipelines, the use of traditional differential leveling procedure is still common.
   - Ensuring that all necessary safety regulations at all government levels are complied with and that the environmental impact of the pipeline project is minimized.
2. With regard to construction of large dams, such as hydroelectric dams, the following geodetic aspects are usually involved:
   - Preliminary reconnaissance surveys using large-scale (1:50,000 or larger) topographic maps in order to identify and tentatively select the extent of the dam, the reservoir and tail-water areas.
   - Establishing permanent precision survey control stations around the dam site.
   - Mapping the topography beneath the dam with high precision for the purpose of designing the dam and estimating the quantities of materials involved.
   - Mapping the corridors for the layout of power lines; and carrying out other surveys needed for the drawing of general layout plans and the setting out of concrete forms.

- Carrying out precise monitoring surveys to detect and measure any deformation during the dam construction and during the loading and unloading of the dam.
- Carrying out surveys for the positioning of the generating equipment, and the related penstocks and outflow conduits.

Further information on geodetic surveys for large dam construction project can be found in Williams (1958), Moreau and Boyer (1972), and Chrzanowski (1999). Examples of transportation tunneling surveys is the survey for the 14.5 km long railway tunnel at the Rogers Pass in British Columbia, Canada (Lachapelle et al., 1984, 1985, and 1988) and the survey of 50.5 km Channel Tunnel transportation system connecting Britain and France in Europe; and an example of tunneling surveys for scientific research is the tunneling surveys for the Superconducting Super Collider (SSC) project in Texas involving 4.2 m diameter, 87-km-long tunnel (Chrzanowski et al., 1993; Chrzanowski, 1999; Robinson et al., 1995; and Dekrom, 1995).

1.2.4 Industrial Metrology

Metrology, in general, is the science of performing accurate measurement. Industrial metrology is the use of precision measuring techniques for positioning and aligning industrial machinery and scientific apparatus. It deals with aligning components of large antennas (parabolic, flat, etc.), checking aircraft dimensional quality of the various subassemblies which form the structure of the aircraft (aerospace alignment), making geometrical checks on finished components in ship and car buildings, alignment and positioning of magnets of colliders, alignment of accelerator facilities, setting up and aligning machines in the industries, *in-situ* calibration of industrial robots, and so on. These types of project usually require that tight tolerances be satisfied and the work is done in the environment where there are a lot of vibrations and unpleasant conditions. The commonly employed techniques (which are different from those used in conventional geodetic surveys) are based mainly on special mechanical and optical tools such as jig transits, optical squares, aligning telescopes, optical micrometers, laser interferometry.

Nowadays, geodetic measuring techniques are increasingly used in the industry (because of the advent of electronic theodolites which are easily interfaced with computers), where three-dimensional micro-triangulation surveys can be carried out in real-time positioning of industrial components with accuracies satisfying the requirements of industry. For example, in the Chalk River Nuclear Laboratory of the Atomic Energy of Canada in 1987, the University of New Brunswick (UNB) Canada team used 3D coordinating system to align over 40 magnets in a cramped laboratory space over a distance of about 40 m with accuracies better than 0.1 mm in the transverse and vertical directions and better than 0.2 mm in the longitudinal direction (Chrzanowski, 1999).

Industrial metrology or industrial surveying has another specialized component known as *optical tooling* (or *optical alignment*). It is a method of making extremely accurate measurements for manufacturing processes where small tolerances are required. Measurements are usually made by a person interpreting a scale or optical micrometer by looking through an alignment telescope, or the lines and planes are created by a laser with digital measurements.

1.2.5 Surveys for Research and Education

Surveys for research and education deal with scientific experimentation of ideals. They provide theoretical and practical testing procedures for different measurement systems. Some of the examples of such research projects are as follows:

- Photogrammetric and terrestrial deformation surveys for Turtle Mountain (Fraser and Gruendig, 1985; Chapman, 1985).
- Integrated analysis of ground subsidence in a coal mining area: a case study (Chrzanowski and Szostak-Chrzanowski, 1986).
- Implementation of the UNB generalized method for the integrated analysis of deformations at the Mactaquac generating station in Canada (Ogundare, 1990).
- Use of GPS in integrated deformation surveys (Chrzanowski, et al, 1990).

1.3 PRECISION GEODETIC SURVEY TECHNIQUES

Generally, specifications for precision geodetic survey techniques include the least angular count of instruments to be used, number of observations, rejection criteria of observations, spacing of major stations, and the expected angular and positional tolerances. To obtain precise measurements, the surveyor must use precision equipment and precision techniques. Many of the techniques used in precise surveys are adapted from the conventional geodetic positioning methods and instrumentation, but with some differences in the field survey procedures and with the stretching of instrument performance to the limit of accuracy. Conventional (non-Global Navigation Satellite System, non-GNSS) horizontal and vertical survey techniques using traditional ground survey instruments (theodolites, electromagnetic distance measurement (EDM), total stations, levels) and the GPS survey techniques are used.

1.3.1 Positioning using Global Navigation Satellite System

Global Navigation Satellite System (GNSS) currently refers to the United States' *GPS*, the Russian Federation's *GLobal Orbiting NAvigation Satellite Systsem (GLONASS)*, the European Union's *Galileo system* and China's *Compass system*. GPS, however, is currently the predominant satellite surveying system in use; GLONASS is operational, but the full constellation of the satellites is yet to be launched; Galileo and Compass are still under development. All these satellite positioning systems are known collectively as GNSS. The GNSS positioning techniques are now generally used for most horizontal control surveys performed for mapping frameworks. The current trend is to use GNSS in precision surveys, but conventional terrestrial techniques are still required in local and isolated monitoring schemes, especially for economy and relative accuracy. The surface control for large tunnels, such as the 87 km long main Collider tunnel for the SSC in Texas was established by means of GPS surveys using dual frequency equipment (Chrzanowski, et al., 1993). Control stations established using GPS techniques will inherently have the potential for higher orders of accuracy in control surveys.

Selection of the right GNSS receiver for a particular project is critical to the success of the project. Receiver selection must be based on a number of criteria, which include the applications for which the receiver is to be used, accuracy requirements and signal processing requirements. GNSS receivers range from high-end, high-cost, high-accuracy *geodetic quality* through moderate cost, meter-level accuracy *mapping grade*, to low-end, low-cost, low-accuracy *resource grade* or *recreational models*. Geodetic quality type is used mainly in high precision surveys.

There are two general types of GNSS receivers: *code phase* and *carrier phase*. Geodetic quality receivers process both code and carrier phases. The receivers and their auxiliary equipment can cost several thousands of dollars. A code phase receiver requires access to the satellite navigation message of the P- or C/A-code signal to function, while carrier phase receiver utilizes the actual GNSS signal to calculate position. There are two general types of carrier phase receivers: *single frequency* and *dual frequency*. The single-frequency receivers track the L1 frequency signal and are not very accurate in resolving long baselines where ionospheric effects are very high. Dual frequency receivers track both the L1 and L2 frequency signals and will effectively resolve baselines longer than 20 km where ionospheric effects have a larger impact on calculations. All geodetic quality receivers are multi-channel, in which a separate channel is tracking each satellite in view. Some of the qualities to look for in GNSS geodetic receivers are as follows:

1. In the case of dual frequency receivers, the receivers must provide at least the following time-tagged (based on time of receipt of signal referenced to the receiver clock) observables:
   - Full L1 C/A code, and L1 P-code
   - Continuous full wavelength L1 carrier phase
   - L2 P-code and continuous full wavelength L2 carrier phase
2. In the case of single frequency receivers, the receivers must provide at least the following time-tagged (based on time of receipt of signal referenced to the receiver clock) observables:
   - Full L1 C/A code
   - Continuous full wavelength L1 carrier phase
3. When the GNSS reference receiver is used with a remote one, the reference shall be capable of 10 mm + 2 ppm accuracy or better on baselines of 1–100 km in length when used in the static differential mode. The receivers shall have an accuracy of 5 mm or better on baselines less than 1 km
4. The receiver shall have L1 and L2 full wavelength carrier phase measurement accuracies of 0.75 cm (RMS) or better, exclusive of the receiver clock offset.

5. The receiver shall have an L1 C/A code phase measurement accuracy of 30 cm (RMS) or better, exclusive of receiver clock time and frequency offsets.
6. The processing software must allow baseline computations with the options of using the broadcast and precise ephemerides.

Typical equipment selection for precision GNSS surveys will include the following:

1. A minimum of two receivers (four receivers for economy and efficiency).
2. Ideally, an antenna type with the smallest sensitivity to multipath and the smallest phase center variation should be selected. Same type of antenna for all receivers on the project is recommended to minimize phase centre biases.
3. Dual frequency receivers are recommended where the ionosphere is unpredictable and irregular and also for second order accuracy or better and where the baseline lengths consistently exceed 15 km.

1.3.2 Conventional Horizontal Positioning Techniques

Typical conventional horizontal positioning techniques include triangulation, trilateration, combined triangulation and trilateration, traversing, intersection, and resection. A *triangulation* survey network consists of a series of interconnected triangles in which an occasional line is measured and the remaining sides are calculated from angles measured at the vertices of the triangles. This method of survey was originally favored for extending the first-order control since the measurement of angles (and only a few sides) could be taken more quickly and precisely than the measurement of all the distances as in trilateration. It is now possible to measure precisely the length of a triangle side in about the same length of time as was required for angle measurement. A triangulation net usually offer the most economical and accurate (first-order accuracy) means of developing a horizontal control system when extremely rough terrain is involved.

Trilateration survey network consists of interconnected triangles in which all lengths and only enough angles or directions for azimuth determination are measured. The trilateration techniques have become competitive with the triangulation techniques for establishing horizontal control since the advent of precision EDM. Usually, the triangles of a triangulation or a trilateration network should contain angles that are more than 15–25°. The EDM equipment used should yield the required standard deviations in distances and the distances must be corrected for all systematic instrumental errors and for the effects of atmospheric conditions. Trilateration techniques may be used for extending first-order horizontal control through an entire continent.

Combined triangulation and trilateration network consists of interconnected triangles in which all the angles and all the distances are measured. The combined triangulation and trilateration survey techniques produce the strongest network of horizontal control that can be established by conventional terrestrial methods. Modern terrestrial control survey practice favors the survey techniques since they ensure many redundant measurements. The combined triangulation and trilateration techniques may be used to provide first-order or primary horizontal control for the national control network and the network can be used for earth crustal movement studies, engineering projects of high precision, and so on. The combined techniques have also been used in providing surface geodetic network for tunnel construction, network for preconstruction work for dams.

A *traverse* consists of a series of straight lines connecting successive established points along the route of a survey. Distances along the lines are measured using tape or electromagnetic distance measurement (EDM) equipment and the angle at each traverse point is measured using a theodolite or a total station. Traversing is a convenient, fast method for establishing horizontal control in densely built up areas and in heavily forested regions where lengths of sights are too short to allow triangulation or trilateration. The advent of reliable and precise EDM instruments has made traverse method very important in strengthening a triangulation net and in providing control points. In surveying work for tunnels in mountainous areas, a combination of triangulation and traversing is most suitable. The underground survey is based on an open traverse measured with precision theodolite and EDM equipment with precision surveying gyroscope providing orientation. A typical fully automatic precision surveying gyroscope is GYROMAT 2000 with precision of one measurement of astronomic azimuth being ±3-in. This is a gyroscopic traversing for the purpose of guiding the boring machine during tunnel construction. Precision traversing can also be carried out in dam monitoring surveys. In this case, traverses are measured in corridors which have pillars with forced centring tribrachs. Traversing, however, have limited uses in precision surveys since it is incapable of providing sufficient redundancy required in most projects.

Intersection method provides the coordinates of unknown points based on the measurements made from at least two other points. This technique is commonly used in 3D coordinating systems, terrestrial laser scanning systems, automatic monitoring systems, and so on.

Resection method is used in determining the position and height of an instrument setup station by making measurements to at least two points whose coordinates had been previously determined. In this method, the accuracy of resected point increases with strong angular relationship (approaching 90° at the resected point) of the resected point and the observed points, the number of points observed to (creating redundant measurements) and the accuracy of the observed points. Resection has an important advantage of allowing the instrument to be located in any favorable location of choice by the instrument person so that one is not forced to set up on a known point that is in an unsatisfactory location. This procedure allows the effects of instrument centering errors on angular measurements to be minimized since one is not required to center on a particular station.

1.3.3 Geodetic Vertical Positioning Techniques

The geodetic vertical positioning surveys consist of establishing the elevations of points with reference to the geoid. The surveys are used to establish a basic network of vertical control points. From these, the elevations of other positions in surveys are determined by lower-accuracy methods. *Differential leveling* is a precise leveling technique for providing vertical control with high precision (within the limits of first- or special-order accuracy). In dam monitoring, precise leveling is performed along the crest as well as in corridors in the dam. Precision spirit levels with micrometer or digital levels, and invar rods are used in order to obtain a standard deviation of less than *1 mm/km* or better in leveling.

1.4 REVIEW OF SOME SAFETY ISSUES

A safety program should be designed as part of every survey project. In this program, the survey crews are trained or instructed to conform to some designed safety rules that will enable them to perform their duties in a safe manner. Dedicated personnel should be assigned a sole responsibility of managing and promoting the safety of work crews, which includes the following:

- Taking appropriate action in matters relating to safety of the crews
- Creating safety awareness in the crews
- Organizing regular safety meetings as may be needed, usually before starting any hazardous project.

The subjects that are usually considered as part of safety programs may include training of survey crews on the following:

1. How to recognize and avoid or respond to potential hazards, such as poisonous plants, poisonous snakes, insect bites and stings, and so on.
2. How to detect and take precautions with regard to threatening weather conditions, such as tornado, lightening, extreme temperatures, and so on.
3. How to properly use and operate equipment and tools, such as motor vehicle; transportation of tools and equipment, such as cutting tools; proper use of protective equipment and clothing suitable for a work area, which may include use of safety boots, eye protection and gloves; and in the case of working in boats, to use Coast Guard-approved life jackets; and so on.
4. First aid procedures and how to equip themselves with proper first-aid kits with appropriate medication and manuals.
5. Awareness of safety precautions, existing laws and policies with regard to ice crossing, working near traffic, and working underground and under overhead utility lines. For example, when working near traffic, personnel are to be constantly alert, wearing reflective colored vests and hats at all times; when surveying around the Federal highways, the laws concerning security must be strictly obeyed; when working on railway rights-of-way, permission should be secured

from the railway management; and so on. Typically, when working near traffic (within 15 m from the edge of the highway), there should be an appropriate sign boards (about work ahead) 250 m before the survey activity area of 1 km with 100 m buffer ahead displaying another sign board of the ongoing survey activity. There must be a display of sign board also at 100 m before the activity area, showing that “Survey work” is going on ahead. There must also be a first-aid kit in a standby vehicle in case of emergency.