South Africa

COTO

Committee of Transport Officials

TECHNICAL METHODS FOR HIGHWAYS

TMH 11

STANDARD SURVEY METHODS

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SYNOPSIS

TECHNICAL METHODS FOR HIGHWAYS 11 (TMH11) is written for the practicing Surveyor and describes current practices for surveys relating to highways, roads and other surveys. The recommendations are based specifically on the South African experience and have the full support and approval of the Committee of Transport Officials (COTO).

Provision is made in this document for Authorities to add specific requirements for projects or applications.

Attention here is drawn to the fact that there are instances where the Client's instructions overrule the TMH11 specifications and the user must be aware hereof.

This document attempts to guide the user with regards to procedural matters and sets minimum specifications that must be met. An assumption is made throughout the document that the user is fully versed in all standard survey practices.

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DEFINITIONS

Term	*Definition*
A-priori	The anticipated errors of survey observations and which are utilised as an input in a least squares adjustment.
A-posteriori	The corrections or residuals to survey observations resulting from the output of the least squares adjustment.
Analogue Aerial Survey Camera	A camera that has all the features of a conventional camera, but it is much larger, is automatic and has been adapted for specific tasks. The camera is mounted in an aircraft. Adjustment of the camera is done mechanically or is electrically assisted.
Annotation	A field process of identifying detail on a photograph and which is not clear or obvious and is then used to enhance the CAD drawing or an Orthophoto.
Basic Survey	The establishment of a survey control network of permanent survey stations on a project.
Benchmark	A survey beacon that has a height which is recorded in reference to the mean sea level.
Borrowpits	An area from which material, usually soil, gravel or sand is removed for a defined use.
Breaklines	Reflect changes in the terrain surface which act as a barrier to the interpolation of a TIN model. Typical breaklines are; top of slopes, bottom of slopes, road edges, shoulder break points, retaining walls, culvert wing walls etc.
Bridge	A structure which spans physical obstacles such as a body of water, valley, road or railway.
Cadastral	As defined in the Land Survey Act, Act 8 of 1997.
CAD	Computer aided drafting.
Calibration Certificate	A certificate issued by survey instrument suppliers once the relevant equipment has been calibrated by an authorised organisation which must have the calibration values stated thereon.
Check Cross-Sections	A physical survey which is of a longitudinal nature and where the direction is at 90° to a given alignment and where its reference point is that alignment and is specifically to provide a quality control measurement in relation to a given survey project.

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Term	*Definition*
Client	Being the organisation or individual who appoints the Surveyor to undertake the survey work.
Conical Beacons	Being an iron peg imbedded in concrete with specifications as defined in **Annexure 10**. Such beacons are used as Permanent Survey Control points and are fixed in Y, X and Z Cartesian coordinates.
Construction Surveyor	A Surveyor employed or appointed by the contractor on construction projects, also referred to as the Contractors' Surveyor
Continuous Model	A continuous drawing to scale which reflects all topographical information and detail where such information and detail is specified in terms of the relevant survey project. 'A0' scale sheets may be extracted from this continuous drawing.
Crabbing	This is where the aircraft containing the Analogue or Digital Survey Camera flies at a skew as a result of cross winds. The angle to the flight line is known as the 'angle of crab'.
Culvert	A structure channelizing water. It is generally used to allow water to pass beneath a road, railway line, or an embankment.
Data Voids During Laser Scanning	Gaps in the scanned data caused by temporary obstructions or inadequate scanning control points.
Datum Level	Is a reference plane used to relate heights to.
Datum Point	A reference point on which a survey is based and can be defined by either horizontal (Y and X coordinates) or vertical (Z height) or both.
Digital Aerial Survey Camera	A large format camera with digital frame sensors based on charge-coupled device (CCD) arrays and has geometric characteristics similar to a film- based camera.
Digital Elevation Model (DEM)	The term DEM is used as a general term for Digital Surface Models (DSM) and Digital Terrain Models (DTM), only representing height information without any further definition about the surface.
Digital Image / Image	A photographic image created either directly with a digital camera or with an analogue metric camera where the negative or diapositive has been scanned to a high degree of accuracy.

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Term	*Definition*
Digital Photogrammetric Workstation (DPW)	Generally referred to as a Software System.
Digital Scanning of Aerial Photographs	A method of converting conventional photographic images to digital images using a high resolution scanner. The scale of the photo and scanning resolution shall determine the Pixel size and the Pixel size shall determine the Ground Sample Data (GSD) on the ground.
Digital Surface Model (DSM)	A surface represented by a Digital Surface Model includes buildings and other objects as where DTMs represent the bare ground.
Digital Terrain Model (DTM)	A mathematical model represented by Y, X and Z Coordinates and which model accurately represents the Earth's surface.
DOP (Dilution of Precision)	Being a mathematical representation for the quality of the GPS position solution. Value 1 indicates a good satellite constellation and high quality data. Value 8 is considered as poor
DTM Filtering	The filtering of a laser Point Cloud by making defined vertical changes so as to significantly reduce the DTM.
Dual Carriage Way	A divided highway comprising of two carriageways and separated by a median.
Ellipsoid	A mathematically-defined surface which approximates the actual Earth's surface. An Ellipsoid therefore enables all geodetic computations to be performed with reference to this Ellipsoid and defines latitude, longitude and elevation.
Epoch 1994.0	The 'Julian epoch' at which the observation was made.
Field Check	Check Surveys undertaken in order to confirm that the survey project adheres to all specifications. Field Checks are carried out by the project Surveyor and the Client.
Flight Lines	The path that the aircraft must fly or has flown in order to photograph the area required to be mapped.
Flight Plan	A plan drawn at a suitable scale showing the actual aerial photography Flight Lines, photo positions and photo numbers.
Gantry	A structure which is located over a road and ordinarily is utilized to hold a sign board.

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Term	*Definition*
GDOP (Geometric Dilution of Precision)	Is a factor in the error calculation made up of PDOP and satellite timing.
Geo TIFF	Being a geo-referenced photo in a specific format (Tagged Image File Format).
Geoid	An equipotential surface and may be described as a mathematical figure of the Earth, a smooth but highly irregular surface that corresponds not to the actual surface of the Earth's crust, but to a surface which can only be known through extensive gravitational measurements and calculations. It can also be described as the true physical figure of the earth in contrast to the idealized geometrical figure of an ellipsoid.
Geodesy	Geodesy, also named Geodetics, a branch of earth sciences, is the scientific discipline that deals with the measurement and representation of the Earth, including its gravitational field, in a three-dimensional time-varying space.
Geodetic	Geodetic datums define the size and shape of the earth and the origin and orientation of the co-ordinates system used to map the earth.
GLONASS	A satellite-based radio navigation system run by the Russian Ministry of Defence. It uses 21 MEO satellites and three spares. Similar to the global positioning system (GPS) in the U.S., GLONASS enables 3D positioning anywhere on earth within 100 – 150 meters for the public and 10 – 20 meters for the military. The first satellite was launched in 1982, and the system became operational in 1993, although the full complement of satellites was not completed until 1995.
GPS	Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed in orbit by the United States Department of Defence, used in the context of this document for surveying purposes.
Ground Sample Distance	Being the distance on the ground represented by one Pixel in a digital image.
GSR	General Safety Regulations in terms of the OH&S Act.
Height Above Mean Sea Level (HMSL)	The elevation on the ground of any object and is defined with reference to the mean sea level.
Illuminated Footprint	The energy in the radar pulse reflected back towards the radar. This is what the radar measures. It is known as radar backscatter.

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Term	*Definition*
Image Resolution	The detail that an image reflects. The term applies to raster digital images, film images and other types of images. Greater Image Resolution then implies greater image detail.
Inertial Measurement Unit (IMU)	A device that senses and quantifies motion by measuring the forces of acceleration and changes in attitude in the pitch, roll, and yaw axes using accelerometers and gyroscopes.
Intermediate Key Points	These are points spaced at every 200m along 'straights' and at every 100m on 'curves' which are staked when setting out a road centre line.
Intermediate Points	Centre line points at 20m intervals and are normally required to define the positions where 'cross-sections' have to be taken.
ITRF91	The International Terrestrial Reference Frame report of 1991.
Key Points	The 'begin curve' (BC), 'begin of transition curve' (BTC), 'begin of circular curve' (BCC), 'end curve' (EC), 'end transition curve' (ETC) and which must be staked when setting out a road centre line.
Kilometer Markers	Reference markers reflecting the distance measured from a specific point and defines the specific kilometer distances on a road route. Kilometer Markers can either be spaced at one kilometer or every 200 meters along the road.
Laser Scanning	Refer to the definition "Lidar Scanning".
Lidar	Light Detection and Ranging also referred to as LIDAR is an optical remote sensing technology that can measure the distance to, or other properties of a target by illuminating the target with light, often using pulses from a laser.
Lidar Scanning	The collection of DTM data using a Lidar scanner and which records thousands of measurements per second thereby creating a very dense Point Cloud dataset.
Lo	The longitude origin of the Cartesian Coordinate system. e.g. Lo 27 uses Longitude 27 as its origin.
Locality Sketch	An inset to a CAD drawing generally at a 1:50 000 scale and which defines the position of the surveyed area, reflected on the CAD drawing, in relation to the greater area surrounding it.
MTLS	Mobile Terrestrial Laser Scanning (MTLS) technology incorporates a vehicle mounted laser scanner, GPS system and an Inertial Measurement System (IMU) which captures high density readings to create a Point Cloud from which a drawing and a DTM model can be created.

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Term	*Definition*
Multiple Returns	The ability of a Lidar System to detect and record Multiple Returns from a single laser pulse, usually first and last return. Multiple Returns typically occur at building edges and in vegetation, e.g. one part of the laser beam may be reflected from the top of the tree and some part within the tree and/or the ground surface.
National Co-ordinate System	Being the official co-ordinate system used in South Africa and which is based on the ITRF91 (Epoch1994.0) coordinates for the Hartebeesthoek Radio Astronomy Observatory (HartRAO) that uses the WGS84 reference system.
National Geodetic Benchmarks (NGBM)	The official Precise Level Bench Marks with elevations based on mean sea level and as published by The Chief Directorate: National Geo-spatial Information (NGI).
National Trigonometric Network	The official Trigonometric Beacons with Y, X and Z coordinates and as published by The Chief Directorate: National Geo-spatial Information (NGI).
Noise during Laser Scanning	Erroneous measurement data resulting from random errors.
North Direction	True North Direction which differs from place to place from magnetic north. The true North Direction on survey drawings in South Africa represents a direction angle of 180° and must be shown on the survey drawings.
Occupational Health and Safety (OH&S) Act, Act 85 of 1993	The act enforcing the safety requirements.
Office Checks	A quality control process undertaken in the office to ensure that the CAD work and deliverables conform to defined specifications and standards. These checks are undertaken by the Surveyor and the Client.
Ortho Rectification	Refer to the definition for Ortho Rectified Photo Image.
Ortho Rectified Photo Image	A digital image where each individual Pixel is rectified in relation to its planemetric position to the same degree of accuracy as the digital elevation model and other vector data.

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Term	*Definition*
Orthophoto	An ortho rectified photographic image superimposed onto a CAD drawing reflecting grid lines, annotated features, contours, Cadastral information and is generally represented on an A0 sheet. This term must be read in the strictest sense i.e. where each individual Pixel is rectified to its planemetric position to the same degree of accuracy as the Digital Elevation Model (DEM) and any vector data. Accordingly, an image that has been stretched or warped to 'fit' Photo Ground Control Points (points identified as common on image and on the ground, is not an Orthophoto).
Overlap (photos)	This is normally expressed as a percentage at which adjacent photographs overlap each other. Forward overlaps on successive photos in a Flight Line are generally 60% and with regards to adjacent Flight Lines (side overlap) they are generally 30%.
PDF	Portable Document Format (PDF) is a file format that preserves most attributes (including color, formatting, graphics, and more) of a source document no matter which application, platform, and hardware type was originally used to create it.
PDOP (Position Dilution of Precision)	An error indicator in reference to the mathematical constellations of the satellites used to trilaterate the position being determined by GPS observations.
Permanent Survey Control	A numbered survey beacon consisting of an iron peg imbedded in concrete which is surveyed and assigned a co-ordinate comprising of Y, X and Z values, also known as Permanent Reference Marks (PRM).
Photo Ground Control Points	A field identification of points on the aerial photograph and which are surveyed and assigned coordinates comprising of Y, X and Z values.
Pillar Beacon	A concrete pillar beacon built to specifications as per **Annexure 11** used as permanent survey control.
Pixel	The smallest element of a digital image.
Planar Target	Is a target normally used for laser scanning that allows for intelligent, automatic identification and extraction of values by using certain software packages.
Point Cloud	The 3D point data collected by a laser scanner. A Point Cloud may be merged with other Point Clouds to form a larger composite Point Cloud. Data from within a Point Cloud may be used to represent traditional survey outputs and Point Clouds may be specified as a deliverable of a survey project.

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Term	*Definition*
Point Density for Laser Scanning	The average distance between Y, X and Z coordinates in a Point Cloud, typically at a specified distance from the scanner. The Point Density specified by the Client or selected by the contractor should be taken as the maximum value for the subject in question and should be dense enough to achieve extraction of detail at the scales specified for the survey project.
Premark	Being a Photo Ground Control Point that is marked prior to undertaking the aerial photography or lidar scanning and as described further in **Annexure 9**.
Professional and Technical Surveyor 's Act, Act 40 of 1984	The Act controlling the registration of Professional and Technical Surveyors.
Pushbroom	The push broom scanner, also known as the linear array sensor, is a scanner without a mechanical scanning mirror or moving parts. Instead, it has a linear array of sensors with one sensor for each area sampled on the ground. Charge coupled devices (CCD) are usually used for the sensors.
Quarry	A type of open-pit mine from which rock or minerals are extracted. Quarries are generally used for extracting building materials, such as crushed stone and construction aggregate.
Rectification	Refer to definition for Ortho Rectified Photo Image.
Registered Professional Surveyor	A person registered as such in terms of Act 40 of 1984.
Registered Surveyor	A person registered as such in terms of Act 40 of 1984.
Registered Survey Technician	A person registered as such in terms of Act 40 of 1984.
Registration during Laser Scanning	The process of combining Point Clouds or transforming them onto a common coordinate system.
Road Prism	Comprises the entire constructed road and is defined from the 'foot to foot of the road filling' or 'top to top of the road cutting' and includes the tarred Road Surface.

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Term	*Definition*
Road Reserve	The official declared/proclaimed boundary of a road. NB: Although fence lines are often referred to as the Road Reserve these do not always coincide with the actual Road Reserve boundary.
Road Reserve Beacons	A beacon demarcating the official position of the Road Reserve.
Road Shoulder	A reserved area adjacent to the verge of a road, motorway or highway.
Road Surface	A durable surface material covering the area intended to sustain vehicular traffic and is generally comprised of asphalt or concrete.
SASRIA	The South African Special Risk Insurance Association who acts as supplementary cover to normal insurance cover.
Sexadecimal	A positional numerical system with a base of 16. It uses sixteen distinct symbols, most often the symbols 0–9 to represent values zero to nine, and A, B, C, D, E, F (or alternatively a–f) to represent values ten to fifteen. For example, the hexadecimal number 2AF3 is equal, in decimal, to (2 × 163) + (10 × 162) + (15 × 161) + (3 × 160), or 10,995.
Shoulder Break Point	The position where a 'change of slope' occurs on the verge of the road that defines the top of the 'road fill'.
Single Carriageway	An undivided road with carriage ways in opposite directions and no median to separate opposing flows of traffic.
Site Plan	A combination of the Locality Sketch and the detail contour survey plan for site surveys.
Solar Altitude	This is the angle of the sun relative to a horizontal line on the surface of the earth. A Solar Altitude of greater than 30° is permissible for aerial photography in South Africa.
South African Geoid 2010	The computation of a hybrid geoid model for South Africa from a combination of gravity data, harmonic coefficients and GPS/levelling data.
South African Road Traffic Signs Manual (SARTSM)	A manual that includes all road traffic signs and other devices which are used to regulate, warn, guide or inform road users. These devices are thus used to achieve an acceptable level of road and traffic safety by ensuring the orderly and predictable movement of all traffic, both vehicular and pedestrian.
Splicing	The process to replace photogrammetric surveyed detail and the TIN (Triangulated Irregular Network) data with ground surveyed data within the Photogrammetric Continuous Model and individual sheets.

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Term	*Definition*
Staking	The setting out of positions on the ground for which the coordinates have been derived from the design by calculation.
STLS	Stationary Terrestrial Laser Scanning (STLS) technology incorporates a tripod mounted laser scanner which captures high density readings to create a Point Cloud from which a drawing and a DTM model can be generated.
Supervising Surveyor	A Surveyor who normally forms part of the Clients' supervisory team (Resident Engineer's team) on construction projects.
Survey Datum	A reference point on the Earth's surface against which position measurements are made and is based on a model of the shape of the earth (reference ellipsoid). In South Africa we use the ITRF91 (Epoch1994.0) coordinates for the Hartebeesthoek Radio Astronomy Observatory (HartRAO) as survey datum.
Survey System	A presentation of coordinates which may either be Geographical (latitude and longitude) or Gauss Conform (Y and X). In South Africa the system is based on the ITRF91 (Epoch1994.0) coordinates for the Hartebeesthoek Radio Astronomy Observatory (HartRAO) that uses the WGS84 reference system.
Surveyor	The organisation or individual appointed by the Client to undertake the survey work in terms of this document.
TIFF	Tagged Image File Format is a file format for storing digital images.
Tilt	The number of degrees which an Aerial Survey Camera Lens axis departs from the vertical.
TIN	Triangulated Irregular Network. This is a triangle format in which DTM data is supplied and then generally used together with CAD and design software packages.
Time-of-Flight Measurement	Distance measurements which are based on the time between emitting a pulse of light and the detection of the reflection of that pulse.
TMH	A specification numbering convention adopted by the Department of Transport for the numbering of different technical manuals and standards, "Technical Methods for Highways".
Traffic Accommodation	Specific requirements to protect the Surveyors and the road users during survey operations. These requirements must be read with the OH&S requirements.
Traffic Volumes	The average number of vehicles per hour traveling on a road.

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Term	*Definition*
Trignet Network	A network of continuously operating Global Navigation Satellite Systems (GNSS) base stations covering South Africa. These stations are managed and controlled by a single control centre situated in the offices of National Geospatial Information (NGI).
Trajectory Report	Mobile Terrestrial Laser Scanner (MTLS) system and positional performance data from each scanning pass produced by post-processing software. Reported parameters may include satellites in view, Position Dilution of Precision (PDOP), Geometric Dilution of Precision (GDOP), uncorrected Initial Measurement Unit (IMU) distance, uncorrected IMU duration, difference in positional solutions between forward and backward processing, and estimated positional accuracy.
WGS84	World Geodetic System 1984 where this is a standard for use in the disciplines of cartography, geodesy and navigation. It comprises a standard co-ordinate frame for the Earth represented by a standard spheroidal reference surface (the datum or reference ellipsoid) for raw altitude data and a gravitational equipotential surface (geoid) that defines the nominal sea level.
Work Zone	The area where traffic accommodation in terms of Chapter 2 is employed and safe for the Surveyor to work in.

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1. INTRODUCTION

This chapter covers general issues as they relate to all types of survey work and which Surveyors must pay particular attention to. A brief description of how to read, interpret and use this document is also included. It be noted further that items covered in this chapter will in some cases be covered in more detail in the chapters that follow.

1.1. How to read and use this document

a) This document is written for the practicing Surveyor and describes current and recommended survey practices.

b) The recommendations are based on the South African experience.

c) Provision is made in this document to augment or add specific requirements for particular projects or applications.

d) The document is divided into chapters, each of which covers a specific aspect, phase or activity.

e) All survey activities of a similar nature are covered in the relevant chapter and are not repeated in other chapters. Whilst some specifications are repeated throughout the document, this is kept to an absolute minimum.

f) General applications applicable to a survey activity are discussed in each chapter. Specific requirements in addition to the general requirements are then also dealt with in the same chapter under relevant sections.

g) The reader's attention is drawn to the convention used throughout this document which is where words that have been defined in the chapter on 'Definitions' will have a leading capital letter so as to differentiate such words from their ordinary dictionary meaning.

1.2. Entry into a region

Before commencing fieldwork in any district or region the Surveyor shall notify the Client under whose jurisdiction the survey falls, give an indication of the nature of the work to be carried out and the area to be surveyed.

The procedure as laid down by the Client must then be followed.

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1.3. Entry onto private property

Before commencing field work on any property, the procedure as prescribed by the Client must be followed when gaining access to a property. The Surveyor shall personally call upon the owner, occupier, or person in charge of the property and request permission to proceed with the survey. Surveyors must inform themselves as to local customs and regulations.

Special approval must be obtained from the relevant rail authorities when working within any railway line reserve.

Where survey work is required within areas under the jurisdiction of the South African Defence Force then special permission must be obtained from the relevant commander managing the area concerned.

Standard forms of notice to owners or occupiers of the land must be obtained from the Client.

Where the owner is not available at the time of calling on the property then the procedure as laid down by the Client must be followed.

In the event of the right of entry being refused, the Surveyor shall inform the Client as soon as possible and await further specific instructions from the Client.

1.4. Ownership of documents and copyright

All documents and data produced as a result of any survey project for which a Surveyor is appointed shall remain the property of the Client and shall not be traded or made available to any third party without the prior written consent of the Client.

1.5. Insurance

The Surveyor shall maintain and be in possession of valid insurance policies as defined below. The cost of these policies will be at the Surveyor's own expense unless otherwise provided for in terms of a written agreement with the Client.

1.5.1 The following risk must be insured:

a) Professional Indemnity Insurance where such insurance shall cover each appointment/project undertaken by the Surveyor and where any exclusions must be approved in writing by the Client;

b) General Public Liability where the extent of such cover must be approved in writing by the Client; and

c) South African Special Risk Insurance Association (SASRIA) – non-political riot and strike.

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1.6. Indemnity

In the context of a survey project the Surveyor shall indemnify the Client against each and every liability which the Client may incur to any other person and against the adverse effects of any claims, including claims by third parties.

1.7. Destruction of property

Where destruction of any kind of vegetation and/or improvement to/or on a property is necessary in order for the Surveyor to perform his activities, then the Surveyor shall maintain an accurate record of such destruction including who the owner is, the title deed description and address of such property. These records must be submitted to the Client.

It be noted further that the Surveyor must obtain and have approval from the owner prior to any destruction taking place and in all respects be subject to all statutory requirements as they would apply to such destruction.

1.7.1 The following records where relevant shall always be provided:

a)	Sugar Cane	:	Area, ration, age and type.
b)	Grain Crops	:	Area, age and type.
c)	Other Crops	:	Area, age and type.
d)	Timber	:	Area, age and type.
e)	Large trees	:	Number, mean circumference and height.
f)	Ornamental shrubs & trees	:	Type & height.

1.7.2 Destruction of other vegetation and/or improvements shall be carried out in terms of statutory, customary or any other well-known provisions.

1.8. Units of measurement

The units of measurement for all dimensional values such as co-ordinates, distances, heights etc. shall be metric and all 'direction' and angles or measurements shall be in Sexadecimal measure.

1.9. Survey System and Datum

1.9.1 Co-ordinates

All survey work shall be based on the ITRF91 (Epoch1994.0) co-ordinates for the Hartebeesthoek Radio Astronomy Observatory (HartRAO) that uses the World Geodetic System (WGS84) reference system known as Hartebeesthoek 94 Datum.

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1.9.2 Height Datum

Elevations shall be based on the National Geodetic Benchmarks (N.G.B.M.).

Where no N.G.B.M. can be located within a 5km radius of the survey then specific written instructions must be obtained from the Client. Unless otherwise instructed by the Client, all heights shall be based on heights above Mean Sea Level (MSL). Also refer to paragraph 5.1.1(g) "Vertical Fixing of Permanent Survey Control beacons"

A Datum Point or Benchmark must be verified from at least one or preferably two other such points before its height may be adopted.

1.9.3 Origin of elevation

The origin of the elevation and the Datum Level point must be recorded in the final co-ordinate list, calculation file and noted on the plan (e.g. Height Datum: N.G.B.M. 34A26=1216.453m or NRB20 = 1314.120m).

If a local height Datum is used then local height selected must differ materially from the MSL for the area and shall be clearly depicted as a "local datum" on all the survey records.

1.9.4 Permanent Survey Control

Permanent Survey Control must be established for all survey projects and must be based on existing and/or the National Trigonometric/Trignet Network.

Permanent Survey Control must be established at 'safe' positions. Each such Permanent Survey Control beacon for road surveys must be marked in the field by painting the closest fence standard or fence post white. An arrow (approximately 400mm x 200mm) must also be painted on a paved surfaced road using white road marking paint and where the arrow points in the direction of where the beacon is located. Also refer to chapter 5 paragraph 5.1.1 (b) (i).

Where there are no fences then the Permanent Survey Control beacon must be marked by a cairn of white washed stones, 0.5m in diameter and height or by a 1.8m iron standard or as otherwise specified by the Client.

1.9.5 Protection of Permanent Survey Control and other survey beacons

To prevent damage to vehicle tyres and/or injury to persons and/or livestock, the following procedures must be followed:

a) Steel pegs embedded in concrete must not protrude more than 5mm above the surface of the concrete;

b) Steel pegs not embedded in concrete must be driven down to within 5mm of the surface of the ground;

c) Roofing screws or steel pegs must be 'flush' with the Road Surface; and

d) Steel pegs used on a gravel road must be sunk to a depth of 70mm below the Road Surface and backfilled with lime.

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1.10. Traffic Accommodation and associated safety regulations

Traffic Accommodation must be carried out on all road surveys as defined in Chapter 2 “SAFETY ADMINISTRATION” of this document.

1.11. Progress reports

Survey reports for all surveys must be submitted on a weekly basis or as otherwise required by the Client. Such reports shall note the progress with respect to the main functions of the survey project (Basic Survey, DTM and detail survey, calculations, cross-sectioning, CAD work, Cadastral compilation, etc.).

1.12. Technical reports

A report dealing with all the technical aspects of the survey, e.g. methodology employed, instruments used, closures, results, name and height of level Datum Point, results of accuracy checks and any other significant details regarding the survey project, must be submitted on completion of the survey project. Refer to **Annexure 1**.

1.13. Certification of survey and signing of technical reports and co-ordinate lists

Only Survey Technicians, Surveyors or Professional Surveyors registered in terms of Act 40 of 1984 may take responsibility for survey projects. The Registered Surveyor must certify that the survey undertaken complies in all respects with the specifications as laid down by the Client. Refer to **Annexure 23**.

The technical report referred to above and the final co-ordinate list shall be signed by a Registered Surveyor.

In addition to the hard copy data sets that must be supplied, the following must also be submitted as part and parcel of the ‘certification’ requirements and must be in digital format:

a) PDF of technical report;

b) PDF of the final co-ordinate list;

c) Certification by the registered Surveyor; and

d) Digital file of the final co-ordinate list.

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1.14. Checks to be undertaken prior to submission

A single check Cross Section must be surveyed every 300m for road surveys. Cross-sections for ground surveys shall cover the entire width of the area to be surveyed and for photogrammetric and lidar surveys up to 75m outside the road reserve. Test cross-sections observations shall be taken at all elements of the road profile. This will then be used as test points to determine the height accuracy of the DTM. These cross-section points shall not form part of the DTM. The differences between the cross-section point heights and the heights of the interpolated points from the final DTM must be submitted with the final survey data.

The test cross-section must be surveyed using a total station survey instrument. Feature codes of where the cross section was taken shall be recorded.

With respect to other ground surveys a minimum number of 'checkpoints' must be surveyed where the minimum is equal to 10% of the total number of 'spotshots' for the entire project. These 'check points' must be well distributed over the entire survey area.

The number and positions of test cross-sections for photogrammetric and lidar surveys for surveys other than road surveys shall be advised by the client.

The differences between the check survey heights and the interpolated point heights, at the same position, shall be submitted with the final data.

The check survey must be done completely independently from the main survey and shall not be done from the same 'setup' station from which the survey was performed.

A complete Field Check and check on all office work undertaken shall be carried out in order to confirm compliance to the relevant survey and Computer Aided Drafting (CAD) specifications. Evidence of such checks must be submitted with the final survey data.

1.15. Delivery notes

A detailed list of all items delivered to the Client must be provided. Where the progressive submission of items is envisaged then such list must be provided with each submission.

All items shall be submitted in good order.

Where progressive submissions have been made, then on completion of the survey project the entire data set must be submitted such that the Client is able to disregard previous submissions. The final submission shall then comprise of the entire survey project data sets.

CDs/DVDs containing the project survey data must be clearly labelled with the project number, project description, date of submission and the data set version number. Data versions shall be numbered in accordance with the example below:

First submission	Version 1.0 (5 March 2011)
Second submission	Version 1.1 (10 March 2011)
Third submission	Version 1.2 (25 March 2011)
Final Submission	Final Version (1 April 2011)

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1.16. Direction of surveys to be reflected on the drawings

Unless otherwise specified all road surveys shall be reckoned from left to right and in the direction of increasing route section numbers or stake values.

Unless otherwise specified, all other surveys shall be presented with the North Direction towards the top of the drawing sheet.

1.17. Change in Lo

Save for the 15 minute exclusion zone, whenever a change in Lo system occurs then the co-ordinate axes and values of both Lo systems shall be shown on the sheet straddling the Lo meridian. It is not permissible to have two survey systems on one electronic CAD sheet. The common sheet which is located on both systems must be duplicated where each is in reference to the relevant Lo system.

Continuous Models must be submitted in two separate files where both reflect the overlapping section.

If a survey does not extend beyond 15 minutes of the Lo system of origin then the system of origin must be used and displayed.

Further, a minimum of three adjoining Permanent survey points on the affected sheet must be depicted in both Lo systems. Both sets of co-ordinates must be recorded in the co-ordinate list and on the relevant plan.

The remainder of the survey must then be completed on the 'new' or adjoining Lo system.

1.18. Registration in terms of the Professional and Technical Surveyors' Act, Act 40 of 1984

Surveys shall be undertaken under the direct supervision of a Registered Surveyor as required and prescribed in the Professional and Technical Surveyors Act, Act 40 of 1984.

All survey reports and co-ordinate lists must be certified in writing by a registered Surveyor.

In this regard the following registration categories are acceptable for the certification of survey work:

a) Surveyors (Engineering and photogrammetric)
b) Professional Surveyors (Land, engineering and photogrammetric)

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2. SAFETY ADMINISTRATION

This chapter informs the Surveyor of his legal responsibilities with regards to safety on site, specific guidance on Traffic Accommodation for different types of roads and varying traffic volumes.

2.1. Safety and environment

2.1.1 Occupational Health and Safety (OHS) Act, Act No. 85 of 1993

In addition to the Surveyor having to fully comply with this document in all respects, the Surveyor shall at all times comply with the Occupational Health and Safety Act, Act No. 85 of 1993 (as amended). The Surveyor remains fully responsible for the health and safety of his employees and road users.

In the context of a survey project the Surveyor shall indemnify the Client against each and every liability which the Client may incur to any other person and against the adverse effects of any claims, including claims by third parties, where such claim is restricted to that claim that would arise from a breach by the Surveyor of the OHS regulations.

Section 37(1) and (2) of the Occupational Health and Safety Act states as follows:

"37. Acts or omissions by employees or mandatories –

(1) Whenever an employee does or omits to do any act which it would be an offence in terms of this Act for the employer of such employee or a user to do or omit to do, then, unless it is proved that-

i) in doing or omitting to do that act the employee was acting without the connivance or permission of the employer or any such user;

ii) it was not under any condition or in any circumstance within the scope of the authority of the employee to do or omit to do an act, whether lawful or unlawful, of the character of the act or omission charged; and

iii) all reasonable steps were taken by the employer or any such user to prevent any act or omission of the kind in question, the employer or any such user himself shall be presumed to have done or omitted to do that act, and shall be liable to be convicted and sentenced in respect, hereof; and the fact that he issued instructions forbidding any act or omission of the kind in question shall not, in itself, be accepted as sufficient proof that he took all reasonable steps to prevent the act or omission.

(2) The provisions of subsection (1) shall mutatis mutandis apply in the case of a mandatory of any employer or user, except if the parties have agreed in writing to the arrangements and procedures between them to ensure compliance by the mandatory with the provisions of this Act".

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Klass Looch Associates, Occupational Health and Safety legislation consultants, have published an article in April 2009 on the internet which stated:

"A typical section 37(2) agreement can contain anything as long as the Surveyor (contractor) is able to perform and it's not against the good morals of society (contro bonos mores).

Compliance with the provisions of the OHS Act must always be a requirement. The Client can add its own in-house procedures.

Once the Surveyor (contractor) signs a written agreement it becomes a lawful enforceable OHS contract and breach will have the same consequences as breach of any other lawful contract".

Refer to **Annexure 26** for a typical example of an agreement between the Surveyor (contractor) and the Client in terms of section 37(2) of the OHS Act.

This example may be altered to suit the Clients' specific requirements.

The Surveyor shall also comply with the following:

a) Under no circumstances may a vehicle cross the median of a dual carriageway road; and

b) The Surveyor must ensure that his personnel are equipped with reflective safety jackets and that these are worn at all times whilst working on or near the road. Any person found not wearing a reflective jacket may be removed from the site until such time as he is in possession of and wearing such a reflective jacket. Reflective safety jackets must be kept in good and clean condition and jackets that are, in the opinion of the Client, ineffective must be immediately replaced with a new jacket by the Surveyor.

2.1.2 General requirements for the Traffic Accommodation on roads and streets

The Surveyor shall be guided by the latest edition of the South African Road Traffic Signs Manual (SARTSM).

At the time of publishing this version of TMH11, the Surveyor must refer to the June 1999 edition of SARTSM and in particular Volume 2 and Chapter 13. This can be obtained from the Government Printing Works.

The Surveyor must also comply with the following:

a) The Surveyor shall at all times have the following available on site:

   i) Site safety officer;

   ii) A suitably stocked first aid box according to General Safety Regulations (GSR 3(2)) where more than five (5) employees are employed on a road survey or other dangerous survey sites;

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iii) A suitably trained and appointed first aid person according to General Safety Regulations (GSR 3(4)) where more than ten (10) employees are employed;

iv) Completed risk assessment schedule for all activities on site;

v) Safe work procedures for all activities on site;

vi) Proof that relevant training has been provided to all staff including OHS Act specified induction training, training in the risk assessments and safe work procedures; and

vii) Proof that the necessary personal protective equipment has been issued.

b) The following requirements shall apply to the field operations:

i) Work to be scheduled so as to avoid traffic congestion; and

ii) In exceptional cases survey work to be undertaken on Saturdays and Sundays or at night so as to avoid traffic congestion. This is especially relevant in major cities.

2.1.3 The survey work

The Surveyor shall be responsible for accommodating traffic whenever surveys are undertaken within a Road Reserve. Traffic shall be accommodated in accordance with the specifications of the South African Road Traffic Signs Manual (SARTSM), Volume 2, Chapter 13, and any applicable Occupational Health and Safety (OHS) Act requirements where the objective of causing the least delay to and disruption of traffic is achieved.

The Surveyor shall always bear in mind the public's right to enjoy the use of the road conveniently and safely and shall be courteous and sympathetic in any discussions or interaction with road users or other contractors working on the roads.

The Surveyor shall submit and have the Client's approval of a programme for the accommodation of traffic in each instance where traffic is encountered and may not commence with surveying activities until full compliance with all requirements has been achieved.

The Surveyor may subcontract the Traffic Accommodation procedures and work provided that such subcontractor is approved by the Client. The subcontractor shall fully comply with all the requirements as specified in this document.

It is again recorded that the Surveyor and/or his subcontractor must have all the necessary equipment available on site as stated in the paragraph headed "General Requirements for Traffic Accommodation on roads and streets". It be noted that this list should not be regarded as exhaustive.

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2.1.4 General restrictions

The following general restrictions shall apply:

a) Under normal conditions this work shall only be carried out between 07h00 and 18h00, Mondays to Fridays, unless otherwise arranged. These conditions may be subject to further restrictions imposed by the Client due to peak traffic hours on public and school holidays or due to reduced visibility, etc.

b) Traffic Accommodation shall be limited to a 1 kilometer stretch of road only.

c) Traffic may only be diverted from the right hand side yellow or white lane and only to such an extent that the traffic can remain contained within the traffic lane affected. Only with the prior written approval of the Client may a lane be closed off completely.

2.1.5 Programme

In the case of National Roads, the Surveyor must inform the Routine Road Maintenance Manager of this programme, provided that the Client has first approved the Surveyor's Traffic Accommodation Programme.

It is again emphasized that no survey work may commence until all requirements as specified in this document, the OHS Act and the SARTSM have been fully complied with.

2.1.6 Safety and the suspension of work

Failure by the Surveyor to provide and maintain Traffic Accommodation as defined in this document shall be sufficient cause for the work to be immediately suspended. Only on full compliance by the Surveyor with the above named requirement may work be re-started provided further that the Client's approval to do so has been confirmed. Penalties, if applicable, may be imposed.

2.1.7 General requirements for all work undertaken within the Road Reserve

a) All field staff shall at all times wear reflective jackets.

b) All field survey vehicles shall display roof mounted rotating or flashing amber lights at all times

c) All survey vehicles shall be equipped with a sign on the back of the vehicle displaying "survey vehicle".

d) Except for the high visibility vehicle, no survey vehicle shall be parked on the Road Surface or on the Road Shoulder

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e) Headlights must be on when a survey vehicle is in motion.

Note: A law enforcement officer or any other person authorized by the Client may instruct the Surveyor to immediately suspend all survey work in the event that the above requirements have not been fully met.

2.2. Traffic Accommodation requirements for road surveys

2.2.1 General

a) Chapter 13 of Volume 2 of SARTSM shall be the reference manual for accommodating traffic. In addition specific requirements for certain surveys may be imposed.

b) Four different work patterns are defined as follows:

i) Survey work which extends across the entire Road Prism on a continuous basis including the space 5m beyond the Road Prism;

ii) Survey work restricted to the “Road Shoulder” including the space 5m beyond the Road Prism ;

iii) Survey work restricted to the space 5m beyond the Road Prism ; and

iv) Survey work which extends across the entire Road Prism including the space 5m beyond the Road Prism and where such work is for short durations.

c) The 300m Work Zone in the context of this Chapter is defined as follows:

In order to meet the DTM height accuracy requirements, ’spot shots’ shall be restricted to a maximum distance of 150m from the instrument station i.e. survey control work stations shall not be more than 300m apart.

2.2.2 Low volume traffic on Single Carriageway roads i.e. roads with less than 100 vehicles per hour

a) Definition and requirement

i) Low volume traffic roads are defined as roads with less than a total of 100 vehicles per hour counted in both directions.

ii) A minimum of four flagmen and two sign boards displaying “workmen next 500m” shall be provided.

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b) Protecting the Work Zone on the Road Surface and Road Shoulder and the area up to 5m from the road prism edge (Refer to **Annexure 2**)

i) Phase 1 – Prior to Commencement of Survey Work:

The sign board displaying "Workmen next 500m" must be placed on the paved Road Shoulder or just off the road edge on both sides of the road and 300m on either side of the survey instrument position.

ii) Phase 2 – During Survey Work:

- Position flagman No. 1: 20m behind the survey assistant and facing in the direction of the traffic;
- Position flagman No. 2: at 50m beyond flagman No. 1 and facing the oncoming traffic;
- Position flagman No. 3: on the opposite side of the road 20m in front of the survey assistants and facing the oncoming traffic;
- Position flagman No. 4: at 50m in front of flagman No. 3 and facing the oncoming traffic;
- Flagmen 1, 2, 3 and 4 must at all times maintain these distances and must move with the survey assistants as the survey progresses; and
- More flagmen should be employed in dangerous areas such as sharp curves, steep inclines (road passes) etc.

iii) Further Phases

When moving to the next Work Zone phases 1 and 2 above must be reinstated and carried out as described above.

c) Short periods of static work

This applies to static work on the Road Prism and also to within 5m outside of the Road Prism (Refer to **Annexure 3**).

i) Position flagman No. 1: approximately 20m from the working area. Position flagman No. 2 at 30m behind flagman No. 1. Both must face oncoming traffic;

ii) Position flagman No. 3: at 75m behind flagman No. 2 where he faces the oncoming traffic;

iii) Position flagman No. 4: at 30m in front of the working area in the Road Shoulder opposite to where the work is being carried out and facing the oncoming traffic; and

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iv) Position three (3) cones, 10m apart, so as to demarcate the working area. The middle cone must be opposite the middle of the working area. The cones shall be located in a safe position and must not obstruct the traffic.

d) Surveying on the Road Shoulder (Refer to **Annexure 4**)

i) Position flagman No. 1: approximately 20m behind the survey assistant located closest to the oncoming traffic;

ii) Position flagman No. 2: at 50m behind flagman No. 1;

iii) Position flagman No. 3: on the opposite side of the road 30m in front of the furthermost located survey assistant; and

iv) All flagmen to face the oncoming traffic.

When moving to the next Work Zone phases 1 and 2 above must be reinstated and carried out as described above.

e) Surveying whilst driving with a GPS mounted on a vehicle

i) With the vehicle moving during these surveys, limited Traffic Accommodation, as described below is required.

ii) These surveys must be undertaken at predetermined offsets as instructed by the Client. Driving on the centre line is prohibited.

iii) The vehicle used to undertake this survey must display a high visibility sign (which must first be approved by the Client), have a roof-mounted rotating amber light and the vehicle's headlights must be on.

2.2.3 Medium and high volume traffic on Single Carriageway roads i.e. roads with more than 100 vehicles per hour

a) Definitional requirements

i) Refer to the paragraph above where the four work patterns are defined.

ii) Medium and high volume traffic roads are defined as roads with more than a total of 100 vehicles per hour counted in both directions.

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b) Specific applications

i) Establishment of Permanent Survey Control:

- Beacon building, co-ordinated outside of the Road Prism – requirements in terms of paragraph 2.1.7 "General requirements for all work undertaken within the Road Reserve" shall be applicable.
- Horizontal fixing carried out outside of the Road Prism – requirements in terms of paragraph 2.1.7 "General requirements for all work undertaken within the Road Reserve" shall be applicable.
- Levelling in the area 5m from the Road Prism – **Annexure 7** in terms of paragraph 2.2.3(e) "Surveying on the Road Shoulder" shall be applicable.
- Levelling in the area beyond 5m from the Road Prism – requirements in terms of paragraph 2.1.7 "General requirements for all work undertaken within the Road Reserve" shall be applicable.
- Marking of painted arrows on the road edge of Road Prisms (short duration presence) – **Annexure 6** shall be applicable.

ii) Staking of Kilometer Markers

- Within the Road Prism and for a short duration – **Annexure 6** in terms of paragraph 2.2.2(c) "Short periods of static work" shall be applicable.

iii) Topographical and any other surveys

- Within the Road Prism and Road Shoulder– **Annexure 5** and paragraph 2.2.3(c) "Working on the Road Prism and in the area up to 5m from the Road Prism edge" shall be applicable.

- Within the Road Reserve but in the area beyond 5m from the Road Prism – paragraph 2.1.7 "General requirements for all work undertaken within the Road Reserve" shall be applicable.

iv) Driving on the Road

- Driving on the road with a mounted GPS – requirements in terms of paragraph 2.2.3(f) "Surveying whilst driving with a GPS mounted on the vehicle" shall be applicable.

c) Working on the Road Prism and in the area up to 5m from the Road Prism edge

i) Phase 1 – Protection of the Work Zone when working 150m behind the survey instrument (dual direction traffic) (Refer to **Annexure 5**):

- The survey instrument shall be positioned at point B.
- A high visibility vehicle, or high visibility trailer as indicated in SARTSM Volume 2, Chapter 13, Figure 13.31 and/or **Annexure 5**, must be parked on the road verge 150m behind the survey instrument position (i.e. off the Road Surface).

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- A signboard indicating “Workmen, next 500m” must be placed on the Road Shoulder (or just off the Road Surface edge in the case of an unpaved Road Shoulder) both sides of the road, 300m on either side of the instrument position and in line with survey instrument positions A or C.
- Position the first flagman 50m behind the high visibility vehicle and facing the oncoming traffic.
- A further signboard indicating “Workmen, next 1km” must be placed on the paved Road Shoulder (or just off the road edge in the case of an unpaved Road Shoulder) on both sides of the road, 500m on either side of the instrument position.
- The Work Zone is then protected and the 150m section behind the survey instrument may then be surveyed.
- Flagmen must be employed to protect the Surveyors.

ii) Phase 2: - Protection of the Work Zone when working 150m in front of the survey instrument position (traffic in both directions):

- Move the high visibility vehicle or trailer to a position 30m behind the survey instrument.
- Move the ‘300m sign board’ used in Phase 1 to a position 150m before the instrument (where the high visibility vehicle is parked).
- Position the first flagman 50m behind the high visibility vehicle facing the oncoming traffic.
- Proceed to survey the 150m beyond the survey instrument.
- Flagmen must be employed to protect the Surveyor’s assistants.

iii) Further Phases:

iv) When moving to the next Work Zone, Phases 1 and 2 above must be reinstated and carried out as described above.

v) Flagmen protecting the Surveyors and their assistants in Phases 1 and 2:

- Position flagman No. 3: at 20m behind the survey assistants in the direction of the traffic approaching from behind.
- Position flagman No. 2: at 30m behind flagman No 3.
- Position flagman No. 4: on the opposite side of the road 20m in front of the Surveyor’s assistants in the direction of the oncoming traffic.
- Position flagman No. 5: at 30m in front of flagman No. 4 in the direction of the oncoming traffic.
- Flagmen 2, 3, 4 and 5 must at all times keep their distance from each other and must move with the Surveyor’s assistants as the survey progresses.

d) Short periods of static work (Refer to **Annexure 6**)

i) This applies to work on the Road Prism and also to within 5m outside of the Road Prism.

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- Park the high visibility vehicle or trailer on the Road Shoulder approximately 20m from the working area.
- Position flagman No. 1: at 30m behind the high visibility vehicle.
- Position flagman No. 2: at 75m behind the first flagman.
- Position flagman No. 3: at 30m in front of the working area in the Road Shoulder of the road opposite to where the work is being carried out facing in the direction of the oncoming traffic.
- Position a minimum of 5 cones, 10m apart, to demarcate the working area. The middle or third cone must be opposite the middle of the working area. These cones shall be placed in safe positions and which do not block the traffic lane.

e) Surveying on the Road Shoulder (Refer to **Annexure 7**)

i) This section relates to Traffic Accommodation for Surveyors moving on the Road Shoulder and anywhere up to 5m outside of the Road Prism, for the purposes of levelling etc.

- Park the high visibility vehicle or trailer on the Road Shoulder of the road approximately 20m behind the survey assistant closest to the oncoming traffic.
- Position flagman No. 1: at 30m behind the high visibility vehicle or trailer.
- Position flagman No. 2: at 75m behind flagman 2.
- Position flagman No.3 on the opposite side of the road 30m in front of the front survey assistant.

ii) This configuration must move with the survey team maintaining the specified distances apart.

f) Surveying whilst driving with a GPS mounted on the vehicle

Refer to paragraph 2.2.2(e) “Surveying whilst driving with a GPS mounted on a vehicle”.

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3. SURVEY REGULATIONS AND STANDARDS OF ACCURACY

This chapter specifies all accuracies for different types of large scale surveys. It also makes provision for general comments regarding a specific type of survey activity. Detail specifications on the different activities will be dealt with under the relevant chapters.

3.1. Survey control beacon accuracies

3.1.1 Fixing of Permanent Survey Control Beacons for monitoring surveys

a) General

It is not imperative for survey control for monitoring surveys to be connected to a Survey System and Datum and may be undertaken on a local system. The National Co-ordinate System can be used if so instructed.

The reasons for the preferred use of a local system are as follows:

i) The output data sets reflect displacements and not co-ordinates;

ii) The system can be orientated to suit a particular reference line (for instance if monitoring points are on a straight line and the expected displacements are perpendicular to that line then the y- axis can be placed on that line. The “dx” perpendicular displacements between 2 measurements will then be the same as the difference of the X co-ordinate values between the 2 measurements. The same applies to the “dy” displacements); and

iii) The control co-ordinates must reflect dimensions which are ‘true’ at the site level i.e. the local context.

b) Vertical accuracy

The vertical accuracy to be achieved is as follows:

i) For precise levelling: Not to exceed 3mm per square root of a kilometer for double run levelling; and

ii) For Total Station observations: Total Station observations will not achieve required accuracy specifications as a result of refraction. Accordingly, observations must be undertaken such that the mean vertical angle between 2 observed arcs of circle left and right do not differ by more than 2.5 arc seconds.

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c) Horizontal accuracy

Horizontal accuracy is dependent on the accuracy of distance measurements, horizontal observations, the control network configuration and redundancy of observations and as follows:

i) The use of an instrument with a specification of +/- 2mm +2 ppm for distance measurements. An accuracy of less than 3mm over 500m can be achieved provided accurate pressure and temperature observations are taken and utilised in the reduction of the distances;

ii) The use of an instrument with a 1 second angular measurement capability where a mean error of less than 2 seconds can then be achieved. At a distance of 100m the accuracy is 1mm and becomes progressively larger by 1mm for every increased distance of 100m; and

iii) Accordingly the horizontal accuracy must be less than 2.5mm with a confidence level of 95%.

3.1.2 Fixing of Permanent Survey Control for topographical surveys

a) Horizontal accuracy

i) Triangulation Method

Triangulated survey stations shall be surveyed in accordance with the Land Survey Act 1997, (Act 8 of 1997) and the Survey Regulations promulgated in terms of Section 10 of this Act i.e. to class “A” Accuracy.

Where A is equal to 0.04 + S/30 000 and S is the distance in meters between the known and unknown survey station. The comparison is made between any observed ray or measured distance from the final co-ordinate of the survey station fixed and a known survey station.

ii) Traverse and Polar Method

Traversed survey stations shall be surveyed in accordance with the Land Survey Act 1997, (Act 8 of 1997) and the Survey Regulations promulgated in terms of Section 10 of this Act i.e.to class A Accuracy.

Where A = 0.04 + S/30 000 and the comparison is made to the linear misclosure of the traverse, where S is the total length of the traverse in metres.

iii) Global Positioning (GPS) Survey Method

Global Positioning (GPS) survey stations shall be surveyed in accordance with the Land Survey Act 1997, (Act 8 of 1997) and the Survey Regulations promulgated in terms of Section 10 of this Act i.e. to class A Accuracy.

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Where A = 0.04+ S/30000 and the comparison is made between the vector derived from the final co-ordinate and the measured vector after the datum transformation has been applied. S is the distance in meters between the known and the unknown survey station.

Note: Use of the latest geoidal model by NGI is regionalised for all GPS measurements. These heights shall not be used as final heights for Permanent Survey Control.

iv) The final co-ordinates shall be recorded to two (2) decimals of a meter.

b) Vertical standard of accuracy for Permanent Survey Control

i) Circuit Levelling

The closing error (in metres) of a levelled circuit shall not exceed: 0,003 √setups, in height difference between the forward and reverse levelling of successive Permanent Survey stations e.g. for 1km (10 setups) levelling and 10 setups check levelling = 20 setups. For 1km = 0,003 √20 setups = 0,013m (13mm).

ii) Closing on terminal points

The mean closing error of a levelled circuit between terminal points shall not exceed: 0.013 √K metre, where K is the single length of the circuit in kilometres between the terminal points. For example, for 16km the closing error shall not exceed 0.052m (52mm).

iii) Forward and check spirit levelling shall not be done simultaneously.

iv) The level and check level height differences between successive points shall not exceed 5mm per 300m.

v) The final elevations of spirit levelled beacons shall be recorded to three (3) decimals of a metre.

c) Fixing of working stations for topographical surveys

The accuracy for all working stations shall adhere to the accuracy determined for Permanent Survey Control.

d) Fixing of Photo Ground Control for photogrammetric surveys

Horizontal and vertical Photo Control Points shall be sufficiently accurate so as to meet the requirements as set out in paragraph 3.2.4 “Photogrammetric and Orthophoto detail contour and DTM surveys”.

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3.2 Topographical surveys

3.2.1 Ground detail, contour and DTM surveys

Feature	Resultant Horizontal Accuracy	Vertical Fixing Accuracy
Kerbing and edge of asphalt	50 mm	10 mm
Road Surface (Seal/Asphalt/Concrete)	50 mm	10 mm
Storm water pipes	50 mm	15 mm
Lined Drains	50 mm	15 mm
Gravel Road Surface	100 mm	30 mm
General Topographic Detail of the Road Prism	100 mm	10 mm
Spot shots not on the Road Prism (DTMs)	100 mm	50 mm
All other detail	100mm	50mm

These tolerances apply to the actual spots surveyed.

All features surveyed and which do not form part of the DTM shall be excluded from the DTM.

The accuracy of these types of surveys shall comply with the following:

a) 80% of the 'check points surveyed' must yield a dz or dy & dx value which does not exceed 3 x (three times) the stipulated vertical accuracies and the resultant horizontal linear accuracies must not exceed 1.5 x (one and a half times) the stipulated horizontal accuracies; and

b) Where dz and dy & dx respectively is the difference in the Y, X & Z co-ordinates between the DTM and detail and the 'check points surveyed'.

3.2.2 Ground railway line surveys

Feature	Resultant Horizontal Accuracy	Vertical Fixing Accuracy
Kerbing and edge of asphalt	50 mm	10 mm
Rail levels	20 mm	5 mm
Road Surface (Seal/Asphalt/Concrete)	50 mm	10 mm
Storm water pipes	50 mm	15 mm
Lined Drains	50 mm	15 mm
Gravel Road Surface	100 mm	30 mm
General Topographic Detail of the road and rail prisms	100 mm	10 mm
Spotshots not on the road and rail prisms	150 mm	50 mm
All other detail	100mm	50mm

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These tolerances apply to the actual spots surveyed.

All features surveyed not forming part of the triangulation shall be excluded from the DEM.

The accuracy of these types of surveys shall comply with the following:

a) 80% of the 'check points surveyed' must yield a dz or dy & dx value which does not exceed 3 x (three times) the stipulated vertical accuracies and the resultant horizontal accuracies must not exceed 1.5 x (one and a half times) the stipulated horizontal linear accuracies ; and

b) Where dz and dy & dx respectively is the difference in the Y, X & Z co-ordinates between the DTM and detail and the 'check points surveyed'.

3.2.3 Borrowpit ground surveys

Feature	Resultant Horizontal Accuracy	Vertical Fixing Accuracy
General Topographic Detail and DTM observations	100 mm	50 mm

These tolerances apply to the actual spots surveyed.

All features surveyed and which do not form part of the DTM shall be excluded from the DTM.

The accuracy of these types of surveys shall comply with the following:

a) 80% of the 'check points surveyed' must yield a dz or dy & dx value which does not exceed 3 x (three times) the stipulated vertical accuracies and the resultant horizontal linear accuracies must not exceed 1.5 x (one and a half times) the stipulated horizontal accuracies; and

b) Where dz and dy & dx respectively is the difference in the Y, X & Z co-ordinates between the DTM and detail and the 'check points surveyed'.

3.2.4 Photogrammetric and Orthophoto detail contour and DTM surveys

Feature	Resultant Horizontal Accuracy	Vertical Fixing Accuracy
Kerbing and edge of asphalt	150 mm	100 mm
Storm water pipes	200 mm	100 mm
Lined Drains	200 mm	100 mm
Gravel Roads	200 mm	100 mm
Greenfields	300 mm	150 mm
General Topographic detail	300 mm	150 mm

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These tolerances apply to the actual spots surveyed.

All features surveyed and which do not form part of the DTM shall be excluded from the DTM.

The accuracy of these types of surveys shall comply with the following:

a) 80% of the 'check points surveyed' must yield a dz or dy & dx value which does not exceed 2 x (twice) the stipulated vertical accuracies and the resultant horizontal linear accuracies must not exceed 1.5 x (one and a half times) the stipulated horizontal accuracies; and

b) Where dz and dy & dx respectively is the difference in the Y, X & Z co-ordinates between the DTM and detail and the 'check points surveyed'.

c) The accuracy of the contours shall comply with the following:

   i) 80% of the check points surveyed must yield a dz value which does not exceed 0.2 x (zero point two times) the contour interval and where the contour interval is normally 0.5m, 1.0m, 2.0m etc. and where dz is the difference between the "check point surveyed" elevation and those elevations interpolated from the contours of each "check point surveyed".

3.3 Staking

3.3.1 Staking of road centre line

a) Accuracy of Key points

Key Points shall be staked and fixed in Y, X and Z to the same accuracy as specified above for the fixing of Permanent Survey Control. See Paragraph 3.1.2(a) "Horizontal accuracy" and 3.1.2(b) "Vertical standard of accuracy for Permanent Survey Control". The staked positions may not differ by more than 20mm from their theoretical position.

b) Intermediate points accuracy

Unless otherwise specified, the position of staked points at 20m intervals shall not differ from their required theoretical position by more than 20mm.

The distance between any two consecutive staked points when compared to the theoretical distance shall comply with a 1:1000 accuracy limit and where over a 500m distance the comparison shall comply with a 1:5000 accuracy limit.

Intermediate points need not be spirit levelled. Their heights may be determined using GPS or Tachometric survey methods. Use of the latest South African geoidal model is compulsory when undertaking GPS measurements. The height accuracies shall conform to the requirements stipulated above for the survey of ground detail, contours and DTM survey.

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c) Accuracy for Curves

In the case of curves, the closing error (cord) shall not exceed 1:5000. Any error less than 1:5000 may be adjusted once only and on a pro-rata basis over the entire length of the curve. Where the error exceeds 1:5000 then the curve must be re-staked so that the resultant error is less than 1:5000 and that error is then adjusted on a pro-rata basis over the entire curve length.

The height accuracy must accord with those specified for key and intermediate points staked.

3.3.2 Accuracy of Cross sections

a) Vertical accuracy

Vertical accuracy for measurements on surfaced road shall be 10mm.

Distances measured to any point on the cross section from a 'control point' shall not exceed 150m. This limit is so as to mitigate the refraction effect on the measurement taken.

The Horizontal and vertical accuracy of measurements taken off the Road Surface shall comply with the above accuracies stipulated for ground detail, contour and DTM surveys.

3.3.3 Kilometer Markers and Staked Positions

a) General

Kilometer Marker staked positions must be positioned at a standard offset from the edge of the road. The Kilometer Marker Board must then be placed next to the Road Reserve fence and perpendicular to the road, opposite the Kilometer Marker staked position.

b) Accuracy of Staked Position

The staked position shall be within 100mm of its theoretical position.

c) Height accuracy

Not applicable.

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3.3.4 Road Reserve Beacons

a) Position and accuracy

The position of the staked Road Reserve shall correlate with its theoretical position and where the resultant horizontal displacement does not exceed 50mm.

b) Height accuracy

Not applicable.

3.3.5 'Setting out' for construction works

a) Profiles

- Height accuracy 5mm
- Position and accuracy 20mm

b) Batter boards

- Height accuracy 5mm
- Position and accuracy 100mm

c) Structural Foundation

- Height accuracy 10mm
- Position and accuracy 20mm

3.4 Structural Surveys

- Height accuracy 5mm
- Position and accuracy 5mm

3.5 Accuracy of Monitoring survey

3.5.1 Total Station observations

a) Height accuracy

Total Station observations used to determine heights are affected materially due to the refraction of light and accordingly angular differences between arcs shall not exceed 2.5 arc seconds.

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b) Position and accuracy

The positional accuracy of the target is dependent on several factors such as discussed in paragraph 3.1.1 “Fixing of Permanent Survey Control Beacons for monitoring surveys”. The positional accuracy achieved should be less than 3.0mm with a confidence factor of 95% for such measurements to be useable.

Total Station observations shall be undertaken with a Total Station which guarantees a minimum of 1 arc second in the horizontal and vertical standard deviation which is based on Deutsches Institut für Normung (DIN) 18723 standards. DIN standards are also known as the German Institute for Standards.
Distances: +/- (2 mm +2 ppm) or better

c) Accuracy of precise levelling

Precise levelling accuracy shall not exceed 3mm per km for a ‘double run’ levelling and consecutive monitoring points which are less than 40m apart shall not exceed 0.2mm.

Precise levelling shall be done with a high order precise level instrument and ‘invar’ staves. The level instrument’s specification shall enable a standard deviation per kilometer ‘double run’ levelling of less than 1mm to be achieved.

3.6 Construction supervision surveys

Standards of Accuracy: The standards of accuracy for such surveys shall comply with the relevant Standard Specifications for Road and Bridge Works and the relevant Project Specifications.

3.7 Lidar Scanning

Accuracy of detail with reference to the imagery:

- Height: 100mm
- Position: 100mm

Accuracy of DTM and determined with reference to the laser data:

- Height: 100mm
- Position: 100mm

3.8 Survey instrument accuracies

The Surveyor shall ensure that all instruments and equipment used in a survey are in good order and within proper adjustment. Calibration Certificates issued by the relevant supplier shall not be older than twelve months and shall be submitted on instruction from the Client. The

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Client may demand updated Calibration Certificates should there be any suspicion by the Client as to the accuracy of the instrument.

Accordingly all instruments used on survey projects must be suitable in order to achieve the required accuracies as specified.

3.9 Drafting and Orthophoto image accuracies

The position of all well-defined detail must be plotted in relation to a co-ordinate grid so as to achieve a positional accuracy which does not exceed 0.5mm on the hard copy plan.

The co-ordinates and heights of any feature or spot shot in a digital CAD drawing or Orthophoto shall correlate absolutely with co-ordinates and heights as surveyed when 'snapping' onto such a point in the CAD or Orthophoto.

The accuracy for position and height shall be relative to those prescribed accuracies as stated in the paragraph headed "Photogrammetric and Orthophoto detail contour and DTM surveys". Paragraph 3.2. "Topographical Surveys"

3.10 Accuracy of Cadastral data on topographical plans

Errors in the calculation and plotting of Cadastral boundaries shall not exceed 1mm in reference to the co-ordinate grid.

The co-ordinates when 'snapped' onto for Cadastral beacons in a digital CAD drawing shall correlate exactly with the co-ordinates originally imported into the drawing.

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4. AERIAL PHOTOGRAPHY

This chapter covers all requirements regarding aerial photography for the different applications such as photogrammetric mapping, Orthophotos, GPS supported aerial photography and aerial photography for Lidar surveys.

4.1. Large Format Aerial photography for photogrammetric mapping and the production of Orthophotos (Not applicable to Aerial Photography for Lidar Surveys)

This Chapter deals with the production of vertical aerial photography for the photogrammetric compilation of topographical maps and for the compilation of Orthophotos.

Aerial photography shall adhere to the following specifications:
NB: In case of digital photography the terms 'aerial film', 'canisters' and 'diapositives' may be ignored.

4.1.1 Project definition

a) The scale of conventional Aerial Photography must be defined by the Client and/or must be chosen so as to achieve the required accuracy for the survey project;

b) The Ground Sample Distance (GSD) for digital cameras must be defined by the Client;

c) Panchromatic, colour or infrared Aerial Photography must be defined by the Client; and

d) The aerial photography coverage must be sufficient to produce Orthophotos or photogrammetric mapping of the area required by the Client.

4.1.2 Camera

a) Conventional Analogue Aerial Survey Camera

i) The aerial photography shall be done with an approved, nominally distortion free, standard wide-angle (152mm) photogrammetric camera of 230x230 mm format.

ii) A full calibration report shall be submitted which confirms that the radial distortion of image points with reference to the principal point of auto-collimation does not exceed 0,02mm measured in the focal plane and confirms the lens type, make and manufacturer's number and date when the calibration was done. The validity of this certificate may not exceed 3 years. Should any part of the camera that is affected by the calibration be dismantled, then a new calibration must be carried out after the reassembly of the camera and the relevant certificate issued.

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iii) Any filters used shall be 'plane parallel' to within 10 seconds and be coated to compensate for loss of illumination towards the outer field.

b) Digital aerial survey cameras

i) The aerial photography shall be done using a large format digital frame camera.

ii) The camera shall have digital frame sensors based on Charge-Coupled Device (CCD) arrays using square or rectangular CCD arrays and shall have geometric characteristics similar to a film based camera.

iii) The camera shall be able to use Time Delayed Integration (TDI) methodology to control image movement. The Surveyor shall ensure that no image smear is caused during this process.

iv) The camera shall have the ability to photograph four colour channels.

v) The camera shall be equipped with a sensor of at least 12 000 Pixels at 12 micron CCD. The focal length shall be 120mm.

vi) Within Flight Lines the largest Ground Sample Distance (GSD) should not exceed two times the size of the smallest GSD. This is of particular importance in mountainous areas.

4.1.3 Operational requirements for large format aerial photography – digital and conventional

a) Flight lines

i) Each flight line shall be continuous for its entire length over the area being photographed. 'Breaks' in strip continuity may be allowed if necessitated by unfavourable weather conditions or when a change in altitude is required to comply with side Overlap or scale requirements. When a 'break' in strip continuity occurs, the separate sections of the strip shall Overlap by at least five exposures.

ii) Coverage beyond the limits of the area to be mapped and parallel to the Flight Lines shall not be less than 20% of the width of the photographic strip. The first two and the last two exposures of each strip, including the required Overlap, shall be completely outside of the area being mapped.

iii) Photographs reflecting more than 25% non-stereoscopic area will not be acceptable.

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b) Overlap

i) The ‘fore and aft’ Overlap shall generally average 60% and where any Overlap less than 55% or greater than 65% will be sufficient grounds for a rejection of the entire strip. In the event of extreme variations in elevation in an area, deviations from the above requirement may be permitted. Deviations shall be limited to the area where such conditions prevail provided that complete stereoscopic coverage is maintained at all times.

ii) Unless otherwise specified, the side Overlap (Overlap between parallel strips) must average 30% and any side Overlap less than 20% or greater than 40% will be sufficient grounds for a rejection of the entire strip.

c) Flight Altitude

The actual flying height must correlate with the specified flying height in such a manner that a lower actual flying height is within a 2% tolerance or a higher actual flying height is within a 5% tolerance.

i) Photographic Conditions

Photography must be undertaken only when conditions are such that acceptable images can be produced. Photography must not be attempted when the ground is obscured by haze, smoke, dust or when clouds or cloud shadows could appear on any photograph.

d) Solar Altitude

Unless otherwise specified, photography must be undertaken with a Solar Altitude of not less than 30 degrees. (The Client may place an upper limit on the Solar Altitude in which case this will be defined in the project requirements).

e) Crabbing

During flight, the camera must be compensated for the Crabbing effect of the aircraft in order to ensure that the edges of the photographs in the strip are parallel to within 5 degrees to the line of flight.

f) Tilt

Departure of the camera lens axis from the vertical must normally not exceed 2 degrees. Isolated exposures up to 4 degrees may be allowed in turbulent conditions. Relative Tilt shall not exceed 6 degrees.

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g) Course Corrections

Corrections to the aircraft's course between successive photographs shall not exceed 3°.

4.1.4 Photographic Quality

a) The photography shall be clear and sharp in detail, be of uniform density and have the proper degree of contrast for all detail in order to clearly define detail in both shadow and bright areas. Photography reflecting excessive contrast or are low in contrast may be rejected. The photography shall be free of clouds and cloud or ground shadows, smoke, haze, excessive snow, marks due to processing and handling and any other blemishes.

b) Standard recorded data for Analogue Aerial Photography

The film, contact prints and diapositives/photo scans (whichever is applicable) shall clearly reflect the following data in respect of each exposure:

i) The allocated Photographic Job Number on the right of the photo frame as supplied by the Client;

ii) A standard four digit photo number on the left of the photo frame which must correlate with that of the feeder counter and where the number must comprise of at least four digits with zeroes being used ahead of the digits of a number below 1000;

iii) The strip number;

iv) The calibrated principal distance corresponding with the latest Calibration Certificate;

v) The camera altimeter reading, which must be synchronized with the aircraft's altimeter;

vi) The chronometer which must record South African Standard Time;

vii) The approximate contact scale of the photography;

viii) The date(s) of the photography;

ix) The number of the lens cone;

x) Any other useful data such as a reflection of the face of the circular bubble; and

xi) The job description.

c) Any of the above items not photographically recorded must then be added afterwards and where no such data shall encroach onto the image area or obscure any fiducial marks.

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d) Film Index/Digital Image Index

i) A digital and hard copy index, as per **Annexure 8**, where applicable, must be submitted with every project and must contain the following information: job number, strip number, photo numbers and the date(s) of the photography. This information shall also appear on the film canister if conventional photography has been used and on the DVD and the Flight Plan.

e) Contact Prints and Diapositives/Scans

i) The Surveyor shall submit the following to the Client:

- Two (2) sets of Contact prints (whether conventional or digital photography);
- One (1) set of Diapositives (where analogue mapping is undertaken);
- One (1) set of digital scans or images (where digital mapping is undertaken);
- Aerial film (if applicable); and
- Where contact paper prints must be on double weight, semi matt, waterproof paper or printed on high quality matt photographic paper.

ii) If digital mapping is undertaken no Diapositives need to be submitted. The contact prints must be clean and free from all blemishes and must be thoroughly washed in the case where a chemical process for the development thereof was used.

iii) The contact prints shall be uniform in tone and density and the degree of contrast shall be such that all detail in both dark and bright areas will still be clear.

iv) Unless otherwise specified Diapositives, if required, shall be of a film material which is stable and not subject to any variations in dimension arising from external factors ordinarily affecting film and where differences between the calibrated distance when measured across the fiducial marks must be within 20 microns. Diapositives may be produced by an electronic printer with an automatic balancing of contrast facility. Each diapositive shall reflect all the information as specified for the negative film.

4.1.5 Flight Plan

a) A Flight Plan, drawn on durable paper and supplied in digital PDF and digital CAD formats as specified and with a 1:50 000 Topo Cadastral Map included as a 'backdrop', must reflect the following:

The Flight Plan must show the following information:

i) The approximate contact scale of the photography;

ii) The date(s) of photography;

iii) The make of camera, number of the lens cone, its focal length and type of film used;

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iv) Route number, title and Job Number;

v) The scale of the Flight Plan, coordinate grid system and North sign;

vi) The strip positions and extent of coverage;

vii) Photo centres shall be plotted as accurately as possible. Every fifth or more photo centre must be shown on each strip. The photo centres shall be marked with a cross and labelled with their full exposure number;

viii) The acceptable number of photographs beyond the specified requirement shall be numbered and indicated on the Flight Plan by a broken line;

ix) The numbers of the first and last exposure of each strip shall be reflected and noted in tabular form on the film index; and

x) The contractor's identification mark.

4.1.6 Photography for aerial triangulation

a) When planning the photographic coverage of an area to be mapped and where aerial triangulation is to be used to obtain planemetric and height control, the following shall be borne in mind:

i) In the aerial triangulation block adjustment the largest errors occur along the edges of the block. It is therefore imperative that the photo coverage be extended beyond the borders of the area to be mapped by at least one model at the start and one model at the end of each strip and at least half a strip width along the borders. The perimeter Photo Control Points will, as a result of the above planned photo coverage, fall outside the borders of the area to be mapped, thus maintaining a rigid control network over the photographic block, with the largest errors occurring outside the area being mapped.

4.1.7 GPS supported aerial triangulation

a) The camera’s principal point (at the time of exposure) may be determined by GPS. This then results in the reduction of Photo Control Points required for the aerial triangulation. The Client’s prior approval must be obtained before using this method. The Client may impose additional specifications to be adhered to when employing such method.

b) This method may however not be used for large scale surveys, as defined in paragraphs 6.6 ”Requirements for photogrammetric topographical surveys: 1:500 to 1:2000 scale” and 6.7 “Orthophoto production and DTM surveys”.

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4.2 Digital Scanning of Analogue Aerial Photographs

4.2.1 The scanning of Analogue Aerial Photographs for use in digital photogrammetry must be undertaken with a high-resolution aerial photography scanner where the output is 8-bits for black and white or 24-bits for colour photography and must be in TIFF or JPEG format or as otherwise specified.

4.2.2 The works then comprises of the following:

a) The digital scanning of all Analogue Aerial Photographs to a specified resolution; and

b) Subject to the rough accuracy guideline tabled below the scanning must be done to a resolution of 21 Micron unless otherwise specified.

ACCURACY GUIDELINE			
PHOTO SCALE	**PIXEL SIZE (MICRON)**	**REQUIRED DISK SPACE (MEGABYTES) FOR GREY SCALE TIFF IMAGE**	**PIXEL SIZE ON GROUND (METRES)**
1:2500	12.5	320	0.03
1:2500	25	80	0.06
1:2500	32	49	0.08
1:5000	12.5	320	0.06
1:5000	25	80	0.13
1:5000	32	49	0.16
1:7500	12.5	320	0.09
1:7500	25	80	0.19
1:7500	32	49	0.24
1:10000	12.5	320	0.125
1:10000	25	80	0.25
1:10000	32	49	0.32
1:15000	12.5	320	0.19
1:15000	25	80	0.38
1:15000	32	49	0.48
1:20000	12.5	320	0.25
1:20000	25	80	0.5
1:20000	32	49	0.64

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c) Digital data shall be supplied on clearly labelled DVDs, CDs or removable hard drives which medium will be determined by the data magnitude of the scanned images.

d) All scanned images must be checked prior to submitting same to the Client and where the checking must relate to the actual data transmission medium chosen and submitted.

4.3 Aerial photography for large scale Lidar surveys

4.3.1 Imagery specifications:

a) Cloud free, 24 bit colour digital imagery:

i) If cloud shadows are evident, then these must be ‘smoothed out’ by radiometric techniques;

b) Image Resolution: 10cm Pixel Ground Sample Distance (GSD) or smaller at the time of exposure:

i) 10cm Pixel GSD offers double the resolution of the 15cm Pixel GSD common to standard aerial photography. This is made possible by modern, higher resolution digital cameras;

c) Forward motion compensation must be used or the forward motion should be kept to below 50% of a Pixel;

d) Images shall be 100% suitable to produce high quality orthophotos.

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5. THE ESTABLISHMENT OF PERMANENT AND OTHER SURVEY CONTROL POINTS

This chapter provides specific guidelines on the establishment of different types of survey control. It prescribes survey procedures, beacon building techniques and the physical distribution of the different types of control beacons. It standardizes the quality and the format of the data and also makes provision for the verification procedures of existing Permanent Survey Control.

5.1. General requirements for Permanent Survey Control and Photo Control Points

5.1.1 General

a) Survey system

i) A back bone of Permanent Survey Control shall be established for all surveys along the survey strip or in an area as defined and shall be on the WGS84 Co-ordinate System. (As per the Hartebeeshoek Radio Astronomy Telescope as the origin of the system).

ii) The Permanent Survey Control shall be based on any existing control system and/or the National Trigonometric Network as specified. Residuals with reference to the adopted control must be submitted with the final survey records.

b) Spacing of the Permanent Survey Control

i) Permanent Survey Control for road surveys must be established in safe positions and not more than 300m apart along the alignment of the road and not more than 1m from the Road Reserve in order to allow the survey instrument to set up with ease. This spacing may be varied with prior approval of the Client. In order to minimise the risk of such survey control being damaged and destroyed it is strongly recommended that such survey control be placed in a staggered fashion on either side of the road provided that no more than three control beacons are placed consecutively on one side of the road.

ii) Permanent Survey Control shall be established in a 300m grid for all others surveys undertaken and where alignments are not involved. This Control shall be established at safe and suitable locations for use during construction activities.

iii) A minimum of three (3) Permanent Survey Control beacons must always be established, irrespective of the size of the survey area.

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c) Marking of Permanent Survey Control beacons

i) For road surveys each Permanent Survey Control beacon must be clearly marked by painting the closest Road Reserve fence standard or post white. An arrow of approximately 400mm x 200mm shall be painted, using white road marking paint, on the hard Road Surface and pointing in the direction of the beacon. Where no fences exist, the beacon must be marked with a cairn of white washed stones 0.5m in diameter and 0.5m in height or to such other specific requirements as dictated to by the Client.

ii) For all other surveys, each Permanent Survey Control beacon must be marked by means of a cairn of white washed stones 0.5m in diameter and 0.5m in height or by a 1.8m iron standard, driven ±0.8m into the ground. The iron standard must be painted with white enamel paint and be placed in such a position so as to protect the beacon. The Surveyor must mark the beacon's position so as to prevent any damage or injury to a person or thing. The marking of beacons in open fields with iron standards is not recommended. These requirements may vary with prior approval from the Client.

d) Numbering of beacons – refer to **Annexure 10**

i) Unless otherwise specified, all Permanent Survey Control for road surveys shall be numbered in sequence and in the direction of increasing route and/or road section numbers. The number must be stamped onto a strip of aluminium 0.7mm to 1.5mm in thickness and firmly set in the concrete surrounding the beacon.

ii) The numbering of beacons for all other surveys shall conform to the Clients' specific requirements and may reflect the year in which it was constructed. After the number a '/' must separate the number and the year, e.g. AB24/10.

iii) Unless otherwise specified, the following information must be stamped with text that does not exceed 7mm;

- Station number/year, e.g. NRB 2/10 or PRD 99/10 for beacons built in 2010.
- Route & section number, e.g. N17/1 for Route N17 Section 1.

The number must be readable when facing in the direction of the next survey station.

e) Establishment of terminal Permanent Survey Control where no existing height control is available

If no level Datum Point is available within 5 kilometers of the survey, the Client may approve the use of the Trignet Base Stations in order to determine orthometric elevations for such control.

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The control points at the start and end of the survey project and those intermediate control points determined by a maximum spacing of 20km must, where GPS is used, be observed in static GPS mode for a minimum period of 2 hours and at 5 second recording intervals. Such control must be processed in reference to a minimum of 2 of the nearest Trignet Base Stations in order to derive orthometric elevations between sequential control observed in static GPS mode. In addition an overlap of static GPS data of at least 5 minutes plus 1 minute per kilometer of the distance between such sequential control, must be observed.

Processing of the GPS observations must be carried out using recognised and acceptable post-processing software which utilises an up to date geoidal model e.g. South African Geoid 2010. The ellipsoidal elevations of the Trignet Base Stations are to be adopted for the purpose of processing the base line vectors. Utilising the geoidal model, orthometric elevations may then be derived. The differences between the adopted and processed elevations must be supplied together with the survey report

Raw survey data, in Receiver Independent Exchange (RINEX) format, calculations and final data must be submitted to the Client for approval prior to finalising the Permanent Survey Control heights.

f) Construction of the Permanent Survey Control beacons

i) Conical Beacons

Unless otherwise specified, every Permanent Survey Control beacon must be constructed using a 16mm diameter steel peg which must be driven into the ground in such a way that the top of the peg is not damaged or burred. The steel peg must be 450mm long, where 30mm of the steel peg must protrude above ground level. A hole, 275mm deep and 300mm in diameter, must be dug around the peg and filled with concrete which is comprised of a mixture of one part fresh cement, three parts clean sharp sand and five parts crushed stone (minimum crushing strength of concrete is to be 15 MPa) and placed so as to leave approximately 5mm of the steel peg protruding above the concrete. Refer to **Annexure 10**.

A mould 250mm in diameter and which does not exceed 100mm in height, must be used to shape and finish off the top of the concrete beacon. The final height of the concrete shall not be more than 25mm above ground level. Refer to **Annexure 10**.

ii) Pillar beacons (Refer to paragraph 5.2.4 “Construction” for additional requirements on Pillar beacons for monitoring surveys)

Pillar Beacons shall only be placed on request from and in consultation with the Client.

Unless otherwise specified, every Pillar Beacon shall be constructed as follows:

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- The base of the beacon must be a solid block of concrete 500mm square and 500mm high and which is comprised of a mixture of one part cement, three parts of sharp sand and four parts of crushed stone. The size of the base may be increased depending on the soil conditions. The Surveyor must advise the Client on any ground conditions where he is of the view that the prescribed dimensions will not result in a stable beacon;

- 8mm reinforced steel bars, 1600mm in length, with wire binders separating the bars in a 150mm square, 200mm apart from top to bottom, must be cast into the concrete block. The reinforced steel must be cast 450mm into the base and must protrude 1150mm above the base;

- A 250mm diameter PVC or pitch fibre casing must be located over the steel bars reinforcing and up to a depth of 150mm into the concrete base and must protrude 1300mm above the concrete base. The casing must be filled with the same concrete mixture as specified for the base;

- The Surveyor must ensure that the casing is 100% vertical and that it is screeded to smooth level surface;

- A 200mm long sleeve, sufficiently large enough to hold a 20mm Ø galvanised pipe, must be cast into the top of the beacon. A removable target, painted red, white and black as indicated in **Annexure 11**, must be placed into the sleeve;

- A brass or stainless steel stud which complies with the specification for "studs in pavements and structures" must be affixed to the base and which will serve as the level (height) for the Pillar Beacon; and

- For detail specifications refer to **Annexure 11**.

iii) Studs in pavements and on structures

Where it is not possible to construct normal beacons, then studs placed into pavements, on structures and rocks must be used. Such studs must comply with the following specifications:

- A hole with a minimum diameter of 10mm must be drilled into the paving/structure/rock. A brass or stainless steel stud with an approximate diameter of 10mm, together with a washer of minimum 20mm Ø must then be inserted into such hole using a suitable epoxy approved by the Client; and

- A circle, 200mm Ø, must be painted around the stud using white road marking paint.

- The beacon number must be punched on the washer.

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g) Vertical fixing of Permanent Survey Control beacons

i) Levelling

- Unless otherwise specified, accuracies to be achieved are set out in paragraph 3.1.1(b) “Vertical accuracy” above. The elevations of Permanent Survey Control and survey ‘working’ control must be determined from spirit levelling.

- Level instrument adjustment checks must be performed daily and prior to the commencement of the survey work and must be recorded in the survey records.

- All Permanent Survey Control elevations and temporary working control must be determined ensuring a double run spirit levelling technique in opposite directions.

- Observation distances shall not exceed 40m.

- Levelling shall not take place within 48 hours after the beacons have been built.

- The final level, recorded to 3 decimals of a metre, must be with reference to the top of the steel peg marking the Permanent Survey Control. Where a steel peg protrudes more than 40mm above the ground then the height difference to the top of the peg above normal ground level must be recorded to two decimals of a metre in addition to its final level.

- Where the control network for the levelling is such that two or more lines of levels run parallel to each other, they shall be connected by cross levelling at intervals not exceeding 1 kilometer. The adjustment of the spirit levelling network must be done in successive circuits commencing from a terminal Bench mark (Datum Point) along the left hand level line, crossing over at a 1 kilometer distance point to the right hand level line and then back to another terminal Bench mark. For successive circuits the survey beacons established at the cross over positions from the left hand to the right hand lines shall be used as terminal Bench Marks.

- All spirit levelling of Permanent Survey Control must, in addition to the reverse levelling, be independently checked by GPS levels or via trigonometrically observed heights and where these are determined during the survey of such Permanent Survey Control.

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- The ‘check’ results shall be recorded as follows and in Excel format:

FINAL LEVELLED HEIGHT	CHECKED LEVEL HEIGHT	DIFFERENCE

Note: Simultaneous levelling using a common staff is not permitted.

ii) Trigonometrical height traversing

Subject to the written approval of the Client, the use of simultaneous reciprocal trigonometric levelling for the determination of elevations in steep terrain and where normal spirit levelling is not possible or practical, may be permitted. If this method of height determination is used, then distances between consecutive survey stations must be within 500m and the vertical angle must be determined from at least two arcs of observations. Signal and instrument heights must be measured and recorded before and after the completion of the observations.

iii) GPS heighting

GPS survey methods shall not be used to determine the elevations of Permanent Survey Control except in the establishment of terminal survey stations as specified in paragraph 5.1.1(e) “Establishment of terminal Permanent Survey Control where no existing height control is available”.

iv) Elevations: reduction and calculation

- The reduction of spirit levelling observations must be done either by the "rise and fall" or "collimation" methods. All adjustments shall be shown and form part of the final data records.
- For simultaneous reciprocal trigonometrical levelling no corrections must be applied for curvature and refraction.
- A comparison of the height differences between successive control beacons determined by the levels and check levels must be submitted in Excel format.
- Reduced levels shall be recorded in full and as follows:
  - Spirit levelling to 3 decimals of a metre.
  - Trigonometrical height traversing to 2 decimals of a metre (3 decimals for simultaneous reciprocal observations).
  - Trigonometrical levelling to 1 decimal of a metre.

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h) Horizontal fixing of Permanent Survey Control

i) General

GPS and Total Station observations are acceptable for the horizontal fixing of Permanent Survey Control and temporary survey control. Single GPS vectors and single Total Station polars are not acceptable. The necessary checks must be carried out in both cases.

Total Station observations undertaken at any control point must consist of at least one arc.

ii) Traversing by Total Station Method

- Unless otherwise specified, the maximum number of traverse legs between traverse terminal points shall be 20 (twenty). Outside orientation observations must be observed wherever possible.

- When traversing between two fixed points, observations must be taken at both fixed points in order for the traverse to be correctly adjusted.

- For accuracy limits and allowable errors see paragraph 3.1.2(a) “Horizontal accuracy”

iii) Global Positioning System Method (GPS)

- In a Global Positioning (GPS) survey the position of a Permanent Survey Control beacon shall be determined from at least two different known points. Sufficient GPS vectors must be measured to determine the local relationship between the GPS datum i.e. World Geodetic System of 1984 (WGS 84) and the National Coordinate System by connecting to at least three trigonometrical stations or other Permanent Survey Control beacons notwithstanding the fact that the Surveyor may have been instructed to base his survey on existing control on site. The Surveyor will generally be instructed to verify existing control.

- For control establishment within a network adjustment, the survey project must be contained within the perimeter as defined by trigonometrical stations or the Permanent Survey Control beacons, thereby ensuring no extrapolation of the survey. All GPS observation adjustments for the determination of the final co-ordinates of the Primary Survey Control beacons must be achieved by post processing. RINEX files of all measurements shall be submitted.

- Surveys undertaken on local coordinate systems must be within the perimeter as defined by the Permanent Survey Control.

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- Traversing between fixed stations using observed GPS vectors is permissible. Traverse closures must adhere to paragraph 3.1.2(a) “Horizontal Accuracy”. Traverse calculations must be submitted.

- If real-time GPS vectors are used for GPS traversing, traverse legs must be measured in both directions.

- Local co-ordinate system parameters must be submitted with the survey data.

iv) Calculations and Co-ordinate List

- A co-ordinate list as per **Annexure 12** must be compiled which must reflect all final co-ordinates and heights of the new Permanent Survey Control and any working control. The co-ordinate list must also contain all points used to base the survey on. The elevation and description of the Datum Point of the survey must be highlighted on this list. The co-ordinate list must be in alphanumeric order.

- The final co-ordinate list must be checked and certified by a Registered Surveyor.

- Whenever control has been measured or observed on more than one occasion, then the comparison between the various measurements and the finally adopted values shall be clearly recorded and must be submitted with the survey data.

Note: Final co-ordinates of all surveyed beacons must be displayed to two decimal places. Final heights must be displayed as specified in Paragraph 5.1(g)(iv) “Vertical fixing of Permanent Survey Control Beacons”.

5.2 Specific requirements for the establishment of monitoring survey control beacons

5.2.1 General

Survey Datum height and position:

Refer to paragraph 3.1.1 “Fixing of Permanent survey control for monitoring surveys”.

5.2.2 Co-ordinates and decimal for fixes

The co-ordinate list must include the co-ordinates of all the control and monitoring points. The Y, X and Z values must be displayed to 4 decimals and rounded off to the nearest 0.1mm.

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5.2.3 Distribution/Geometry

The distribution and geometry of the Control is dependent on several factors and must be considered on a case by case basis and where the Client's approval must be obtained.

5.2.4 Construction

a) The construction of a Pillar Beacon must be comprised of a mild steel or PVC pipe with a minimum diameter of 200mm filled with concrete and steel reinforcement. The column length shall be 1300mm and fixed to a concrete base of 1m² and 500mm in height. Refer to **Annexure 11** for other general requirements related to the construction of Pillar Beacons. The foundations may vary and must be adapted to suit the specific ground conditions or as specified by the Client.

b) Level Bench Marks must consist of either a brass or stainless steel stud affixed to the base of the Pillar Beacon or drilled and affixed into solid rock. The type of studs used may vary in accordance to the specific requirements. Also refer to paragraph 5.1.1(f) "Construction of Permanent Survey Control beacons" for specific requirements on studs in pavement and structures.

5.2.5 Fixing in the vertical and horizontal plane

Refer to paragraphs 3.1.1(b) "Vertical accuracy" and 3.1.1(c) "Horizontal accuracy".

5.3 Specific requirements for the establishment of Bridge structure survey ground control

In addition to the general requirements for the establishment of Permanent Survey Control, the following shall also be applicable:

5.3.1 Establishment of the Permanent Survey Control

a) A minimum of four Permanent Survey Control beacons of a conical or pillar nature as instructed by the Client must be positioned in selected positions within every Bridge structure survey area. This is to ensure proper control of the setting out work and the construction work. It must be specifically noted that these co-ordinates are with reference to the Geodetic co-ordinate system.

b) The Permanent Survey Control beacons must be intervisible and shall be established on the WGS84 Co-ordinate System. (As per the Hartebeeshoek Radio Astronomy Telescope as origin of this system). Further, these beacons must be connected to the network of Permanent Survey Control beacon network alongside the road and directly adjacent to the proposed Bridge structure.

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c) In the absence of existing Permanent Survey Control elevations shall be based on National Geodetic Benchmarks. In the event that there are no such Datum Points within 5km of the Bridge structure, then specific instructions must be obtained from the Client.

d) The construction of these Permanent Survey Control beacons shall be undertaken in accordance with paragraph 5.1.1(f) “Construction of the Permanent Survey Control beacons”.

e) The Construction Surveyor must adjust the published co-ordinates so as to reflect a scale factor of 1 (one) for setting out purposes if necessary.

5.3.2 Spacing of the Permanent Survey Control

a) Care should be taken to ensure that the Permanent Survey Control beacons are placed away from the Road Shoulder and from drains and as far as possible outside areas of agricultural activity. These Permanent Survey Control beacons must not be placed closer than 30m from the centre line of the proposed road and preferably no further than 50m from the proposed location of the Bridge/structure.

b) These beacons must remain in place and functional after completion of the construction work and serve as control for subsequent deflection surveys which may be required as part of the Bridge maintenance program. Due care must be exercised at all times when selecting their positions so as to ensure their stability and safety from possible disturbance during, and after construction.

c) The Surveyor must liaise with and agree with the Client on the proposed positions and type of beacon prior to construction of such beacons.

5.3.3 Fixing of the Permanent Survey Control

a) Horizontal fixing of Permanent Survey Control shall be undertaken in terms of paragraph 5.1.1(h) “Horizontal fixing of Permanent Survey Control”.

b) Vertical fixing of Permanent Survey Control shall be undertaken in accordance with paragraph 5.1.1(g) “Vertical fixing of Permanent Survey Control beacons” and to the level of accuracy as per paragraph 3.1.2(b) “Vertical standard of accuracy for Permanent Survey Control”.

5.4 Specific requirements for the establishment of Permanent Survey Control for Borrowpit surveys

5.4.1 General

In addition to the general requirements for the establishment of Permanent Survey Control, the following shall also be applicable:

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a) A minimum of three (3) inter-visible Permanent Survey Control beacons are required. At least one of the beacons must be located directly adjacent to the Borrowpit boundary to be used for future quantity measurements during the construction phase;

b) Horizontal fixing of this Permanent Survey Control must be undertaken in terms of Paragraph 5.1.1(h) “Horizontal fixing of Permanent Survey Control”. The accuracy levels shall be in accordance with Paragraph 3.1.2(a) "Horizontal accuracy”; and

c) Where the Borrowpit is less than 2km from such Datum Point, the Datum Level must be established by levelling from a known Datum Point.

In the event that the Borrowpit is greater than 2km from a Datum Point then the Datum Level may be established by GPS heighting. This must be achieved by the measurement of two independent GPS vectors to one Borrowpit control point. A geoidal adjustment shall be applied to this final datum height using the latest geoidal model. Refer to paragraph 5.1.1(e) “Establishment of terminal Permanent Survey Control where no existing height control is available” Levelling in terms of Paragraph 5.1.1(g) “Vertical fixing of Permanent Survey Control beacons” to the remaining Borrowpit control points must be undertaken from this Datum Point.

5.5 Photo Ground Control (Applicable to Conventional and Lidar surveys as indicated)

5.5.1 Identification, premarking and fixing of Photo Ground Control for photogrammetric mapping and the production of Orthophotos

a) General requirements for the establishment of Photo Ground Control (PC) points

A Photo Ground Control point (PC) is a premarked point or a point of natural detail which is easily and positively identifiable on an aerial photograph. Further, such points must be chosen so as to ensure that, when viewed stereoscopically, the position and height achieves a high degree of confidence.

i) These points may also be the Permanent Survey Control points which are augmented by Photo Ground Control points which are selected in appropriate areas so as to meet the requirements for Photo Control Points with reference to the aerial triangulation.

ii) All Permanent Survey Control points established on a survey project must also be used as Photo Ground Control and must be marked by means of a white cross (Premark). Where unusual conditions (e.g. on white sand) are encountered then a black cross may be used. These control points must be visible on the photograph. The points shall be physically observed during stereo plotter operations (orientation and/or aerial triangulation) and must be driven according to the survey co-ordinates and shall be observed without positive identification of the exact position;

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iii) The distribution of Photo Ground Control points for photogrammetric mapping (non-Lidar surveys) and the production of Orthophotos must adhere to the following requirements:

- Each fully controlled model must have one control point in each corner of the model which is located well outside of the area to be mapped and is not less than 15mm from the edge of the photograph and one control point in the centre of the stereoscopic model.

- Where aerial triangulation in a block is used then the maximum distance between Photo Ground Control points at the top, the bottom and the centre of the photo shall be determined by the formula 0.27 S where S is the contact scale of the photography. This then represents approximately 3 x the distance between the photo centres of 60% Overlapping photography.

- Where Aerial triangulation is used for a single strip, the photo control distribution at the top, the bottom and the centre of the photo shall be such that at a photo contact scale of 1:6000 the control points must be ± 170mm apart, reckoned in the direction of the flight line and as measured on the photograph compared to ± 1000m as measured on the ground. This distance then represents every second model's base which must apply to any scale photography. No extrapolation shall be permitted. In adverse and extreme terrain conditions these requirements may, in consultation with the Client, be relaxed. These points may be premarked where aerial triangulation is used.

- GPS survey methods shall not be used to determine the elevation of Photo Control Points unless evidence can be submitted that a sufficient number of known height points, spread over the entire survey project, have been included in the observations to model the exact geoid of the area, for interpolation to the geoid on the new points.

- Aerial Triangulation may be used in order to reduce the number of Photo Ground Control Points.

iv) Selection of Photo Ground Control points on existing photography

- A photo control point shall be selected on a photograph using a stereoscope so as to obtain what is known as an "operator's view".

- The emphasis here must be on the quality of the selected point determined by its clear definition and it being on level ground as opposed to the ease with which it can be fixed.

- In extreme terrain conditions such additional points should be identified and fixed.

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v) Marking of identified ground control: Photo Control Points (PC's)

- The point must be marked on the photograph on which it appears nearest to the photo centre, by an ink circle ± 5mm diameter and on the front of the photo and must be numbered as specified.

- Where the point is not premarked then its position must be 'pricked' on the photograph using a very fine needle (a 'pricker'). The number must be printed above the circle on the front of the photograph and then also above the sketch on the back of the photograph.

vi) Field sketch

- Non premarked points must have sketches prepared where these are prepared in the field using a suitable pen in accordance with the following:

  – The photograph must be turned over in the direction of the strip;

  – The sketch must then be drawn on the reverse side of the photograph in relation to the area of the point;

  – The sketch must be drawn as viewed with a stereoscope and not as seen on the ground;

  – The sketch must be annotated by a description of the point so as to assist with its identification in the stereoplotter;

  – Where the selection of a point, which is located on a raised position in relation to the ground level cannot be avoided, the Surveyor shall state clearly as to whether the height refers to the raised position or to ground level and where the height difference must also be recorded; and

  – Sketches for Lidar Photo Ground Control points may be made on a separate sheet of paper. These sketches must be submitted with the final data.

vii) Premarking

- General requirements

  – Each Permanent Survey Control station on a survey project must be premarked;

  – Photo Ground Control points must be premarked such that they from a contrast to the surrounding background and must be positioned where the probability of them being destroyed or covered by dust is minimized;

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- Care must be taken to ensure that the Photo Ground Control point will not be covered by ‘shadow’ during the time that the photographic flights are undertaken; and

- The Surveyor must satisfy himself that the Photo Ground Control point will not be obscured by any feature of a tall nature (i.e. not less than 45° from the horizontal).

- Specific requirements for Photo Ground Control survey Premarks

  - In order for the premark to be clearly seen on the photograph its overall length must be at least 0.5mm measured at the scale of the negative (e.g. for 1:6000 photography the overall length of the premark will be 3.0m – The length of each leg of the premark will thus be 1.5m). Also refer to **Annexure 9.1**.

  - Where a ‘black’ cross is utilised then the width must be at least 0.35m in order to offset the effect of ‘halation’ (flare) and must not display any shiny or reflective material therein.

  - Premarks must not be placed on steep slopes as this then makes it very difficult for the stereoplotter operator to accurately height the point in the photo model. Also refer to **Annexure 9.1**.

- Specific requirements for lidar survey Photo Ground Control Premarks

  In order for the Premark to be clearly seen on the photograph and to be able to adhere to all the specific observational requirements for lidar surveys, the Premark must adhere to the following requirements:

  - The Premark must be in the form of a circle, 600mm in diameter. Also refer to **Annexure 9.2**;

  - The Premark must be on a flat surface and where the surveyed peg is placed in the centre;

  - The ground surface must be smooth and preferably constructed with a concrete surround to the peg;

  - Stones or gravel shall not be used to build a Premark;

  - A Premark must be painted with durable white paint; and

  - Permanent Survey Control can be premarked as per **Annexure 9.1** as if for 1:6000 scale photography.

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viii) Levels of Accuracy

Horizontal and vertical Photo Control Points shall be sufficiently accurate so as to produce data that meets the requirements as set out in paragraph 3.2.4 “Photogrammetric and Orthophoto detail contour and DTM surveys”.

ix) Flight Plan and Photo Control Positions

The Surveyor must submit a copy of the Flight Plan in hard and digital format and on which the Photo Ground Control Points used are clearly shown i.e. reflecting its number and position.

5.6 Verification of existing Permanent Survey Control

The purpose of this survey is to verify the accuracy and quality status of existing Permanent Survey Control prior to be used for any other survey or to base another survey on.

5.6.1 General

a) Obtain a co-ordinate list of the existing Permanent Survey Control to be verified from the Client.

b) Locate the beacons in the field and compile a status report on the quality and functionality of the beacon and submit same to the Client (refer to **Annexure 14** for the format of a status report.)

c) Such a verification survey must be carried out on all beacons located within the limits of a new survey or as otherwise instructed by the Client.

5.6.2 Survey observations

This survey may be undertaken by making use of GPS observations in order to verify the inter-relational co-ordinate accuracy and their relation to the Trigonometric beacons in the area. A single vector onto each point will be permissible.

The heights must be verified by ‘one way spirit-levelling’ in order to be able to compare the height differences and final heights in relation to the given heights and the check levelled heights.

If discrepancies are discovered in position and/or height then a second vector measured from an independent point must be observed for the co-ordinate verification and a second level run must be undertaken with reference to the control points in doubt.

The Surveyor must also record the GPS determined heights. The latest geoidal model must be used to derive orthometric elevations. These corrected heights must then also be compared with the heights as provided by the Client.

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5.6.3 Reporting

a) A comparison/verification and status report must be timeously submitted to the Client for further instructions. The Surveyor must make recommendations to the Client as to the necessary remedial actions that must be taken.

b) Thereafter the Client will issue instruction as to the final acceptance of the co-ordinates for the new survey work.

c) All reports must be submitted with the final data submission on completion of the survey; and

d) Refer to **Annexure 14** for the format of a comparison and verification reports.

5.6.4 Further actions to be taken

In the event that control beacons require either the Y, X and Z values to be re-determined and/or where the existing Y, X and Z values may be adopted then such action and instruction must be confirmed in writing by the Client.

5.7 Ground control for Lidar surveys

5.7.1 The dependency on ground control is far less for photogrammetric surveys and accordingly the requirements are significantly less and as follows:

a) In a typical corridor (e.g. road, pipe route, etc.) a minimum of one ground control point per kilometer must be established;

b) In a typical area of interest (e.g. Greenfields) one ground control point per square kilometer will be sufficient; and

c) There must be a minimum of five ground control points established per project and where such points are well spaced, e.g. survey area corners, the start and end of a corridor, etc.

5.7.2 Ground control may be established by pre- or post-marking as specified in paragraph 5.5.1(a) “General requirements for the establishment of Photo Ground Control (PC) points”.

5.7.3 Different types of ground control required for Lidar surveys:

a) Horizontal ground control which is in reference only to Y and X co-ordinates and vertical ground control which is in reference only to height (Z) control.

5.7.4 The identification and placement of vertical ground control point must comply with the following requirements:

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a) Where a theoretical circle of radius 300mm in diameter around the identified ground control point where such point (peg) is at even level with the surrounding ground, then the relative height difference between any two lidar points within the circle shall not exceed 10mm;

b) The surface area must be free of any vegetation and must be situated on a hard surface such as concrete or a road surface;

c) The surface area within the above named theoretical circle must be of a homogeneous colour and must display good reflective capabilities; and

d) In fact such a point could be chosen in the centre of a road marking line or the like.

5.7.5 It be noted that, where the height of such a point, which is determined by laser methods, exceeds the height of the control point by more than 30mm, then such point may not be adopted as ground control.

5.7.6 The identification and placement of horizontal ground control must comply with the following requirements:

a) The exact position, where a point is to be established in Y and X, must be clearly identifiable;

b) The position must be in contrast to its surroundings so as to ensure that the variations in the reflection can be identified by the laser;

c) An ideal point would be the corner of a painted line (white) on a (black) road surface or the like; and

d) Where the co-ordinate of the ground control point, measured using the laser method, differs by more than half of a pixel in size from that of the surveyed value, then such point may not be used on a ground control point.

5.7.7 It be noted that ground control points, which comply with both of the above named criteria, may then be utilized as individual ground control points provided that the co-ordinates (Y, X and Z) have been determined in accordance with the required specifications.

5.7.8 The establishment of permanent survey control as per paragraph 5.1 “General requirements for Permanent Survey Control and Photo Control Points” and all related paragraphs shall also be applicable to all lidar type surveys.

5.7.9 The existing or newly established permanent survey control shall be used as follows:

a) As the basic network from which all photo ground control is fixed from;

b) For the determination of the local geoid for the project and its subsequent use in all measurement taken on the project; and

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c) As a test point so as to determine the lidar survey accuracy after all surveys have been completed.

5.7.10 Where the permanent survey control is located such that it does not adequately serve as a suitable “test point”, as described above, then an additional point must be established in the immediate vicinity of the relevant permanent survey control point such that such additional point fully satisfies the criteria of a suitable test point,

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6. TOPOGRAPHICAL SURVEYS

This chapter describes the different types of topographical surveys and defines specific obligations that the Surveyor must meet when undertaking such surveys.

- It prescribes what needs to be surveyed for the different scales of surveys and what information is to be provided when submitting the final survey drawing/datasets.
- It also prescribes specific survey observations that must be observed when fixing certain features such as Culverts, drains, manholes etc.
- Borrowpit and railway survey specifications must adhere to the requirements laid down by the relevant authorities.
- Provision for the Client to prescribe certain special requirements is also dealt with in this chapter.

6.1. General requirements for all topographical ground surveys

6.1.1 The Purpose of these surveys

The purpose of these surveys is to represent the original ground line as accurately as possible and to produce a comprehensive topographical survey for the design of relevant engineering facilities, infrastructure etc. In this case this will obviate the necessity for staking, referencing and cross-sectioning with reference to road alignments. This type of survey must be sufficiently accurate so that the setting out of the works can take place immediately prior to construction. The Digital Terrain Model (DTM) which is a product of this type of survey will also be utilised to accurately quantify all earthwork volumes during the construction stage(s).

6.1.2 Phases of the survey

The survey must include the following stages:

a) **Basic Survey:** This being the establishment and survey of a network of Permanent Survey Control located in pre-selected positions and within the survey area as described in terms of paragraph 5.1.1(b) “Spacing of the Permanent Survey Control”.

b) The Detailed and Digital Terrain Model (DTM) Survey

The detail survey: This being the survey of all natural and man-made features which may have an impact on the design or the development itself.

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The Digital Terrain Model (DTM): This being the establishment of a mathematical model of the ground surface where points are surveyed so as to accurately define terrain features that are material to the DTM.

c) **The Mapping:** This being the compilation of drawings from the data recorded during the survey process.

d) **The Cadastral Compilation:** This being the sourcing and compilation of datasets which define the Cadastral boundaries and the property designations and which are then superimposed onto survey drawing(s).

e) **Check Cross-Sections, Office and Field Checks:** This being the quality control survey undertaken prior to the submission of the final output of the survey.

f) **Submitting of Records:** This being the datasets, documents, plans etc. submitted to the Client on completion of the survey project.

6.1.3 Establishment of Permanent Survey Control

A network of Permanent Survey Control beacons must be established for all such survey projects to be utilised for the setting out of the construction works. Refer to Chapter 5 "THE ESTABLISHMENT OF PERMANENT AND OTHER SURVEY CONTROL POINTS".

6.1.4 Detail To Be Surveyed:

As a general requirement, all detail which may have a bearing on the design of the Client's projects must be surveyed.

The standard feature codes as per **Annexure 15** must be used. Where no specific codes have been provided, then new codes may be created taking into account the principals used for the creation of codes for **Annexure 15**. The following is therefore relevant and must be defined by survey:

a) The edges of all existing gravel roads, including the convex or concave shape of the Road Surface and any super-elevation;

b) The edges of asphalt and/or kerb (top and bottom) with respect to all surfaced roads, including the convex or concave shape of the Road Surface and any super-elevation;

c) The positions and invert levels of all side drains (whether lined or not);

d) The size, position and invert levels of all drainage and storm water pipe inlets and outlets, notwithstanding their location being beyond the defined survey area. The inlet must be linked to the correct outlet when shown on the final survey drawings;

e) All drainage structure detail including 'wing walls'. It is noted that the position, height of the 'head wall', invert levels and dimensions must be surveyed and recorded. Sufficient observation must be taken so as to enable the extraction of a section along the drainage

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furrow and the extraction of a cross section across the drainage structure. The generation of accurate contours of the area where the drainage structure is located must be possible from the observations taken (Refer to **Annexure 17**);

f) All power and telephone lines showing individual poles, pylons or structures etc. It be noted that overhead clearances relative to the edge of the Road Surface must be surveyed and recorded. The temperature at the time of measurement must be recorded;

g) Fences;

h) Bridge column/pillar, expansion joints, deck width and length and the horizontal and vertical clearances with respect to overpass Bridges. Such clearances must be measured in relation to both edges of the road. The exact position where the clearances have been measured must then be shown on the CAD drawing;

i) All visible municipal services such as sewerage, water, electricity, lamp posts, traffic lights, etc. Only visible services including markers of underground services must be surveyed;

j) Cover, invert and ground levels of all manholes where the type of service must be recorded as well as the pipe diameter and direction of flow;

k) Valve chambers of existing water mains;

l) 'Top' and 'toe' of cut and fill batters and all changes in terrain slope that may have an impact on the generation of the digital terrain model (DTM) and the contours (These will serve as break lines in the final DTM);

m) Existing accesses to adjoining properties;

n) Cross- and intersecting roads (excluding minor access roads) must be surveyed (the entire Road Reserve) up to a distance of 200m along the intersecting/cross road where distance is measured from the primary road centre line. The road sign destinations of all roads must be shown on the final drawings. Minor cross and intersecting roads and streets must be surveyed (the entire street reserve) up to a distance of 50m along the intersecting/cross streets;

o) Any encroachment onto the Road Reserve;

p) Soil erosion within the survey area;

q) Generally all 'road furniture';

r) All road signs must be surveyed and a photograph taken thereof where their positions and photograph number must be shown on the drawings. The photographs must be supplied in digital format and printed hard copies. The position of all 'gantry footings' and to what extent the gantry extends over the road and further the height clearance between the Road Surface and the bottom of the gantry must be surveyed and shown on the drawings;

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s) All road markings such as yellow lines, lane divider lines, etc., must be surveyed and be shown on the drawings and where the line type (solid, broken, solid and broken, etc.) is clearly indicated;

t) All break lines that might have an impact on the creation of the digital terrain model (DTM);

u) All Permanent Survey Control to be shown on the drawings;

v) Rivers, streams, springs, canals, dams, pans, marshes and areas subject to tidal flooding including their names and annotated where relevant the direction of flow;

w) Highest known flood levels of all major streams/rivers determined from local evidence or information gathered. (The source of such information and the date must be indicated on the drawings);

x) High Water Mark of the sea, tidal rivers etc. and flood levels of streams and dams;

y) A description of the river bed e.g. sandy, boulders, solid rock, silted etc.;

z) Forests, plantations, bushes, shrubs, orchards, hedges and noteworthy trees which may be landmarks or when the preservation of which may be desirable for scenic purposes etc.;

aa) Cultivated lands (where a differentiation is to be made and recorded between dry and irrigated), rock outcrops and continuous rock, cliffs, sand dunes etc.;

bb) Natural drainage lines and drainage structures;

cc) Where applicable, position of foundation 'test holes' where the actual ground level is recorded;

dd) Generally any topographical features;

ee) Road numbers together with the road destination, where this destination is determined by the point and direction where the relevant road exits from the survey area. This must be applied to each drawing submitted;

ff) All buildings where a differentiation is made between the types of construction and whether of a permanent nature or of a temporary nature and where the general use of the buildings or groups of buildings, save for habitable dwellings (e.g. school, store, office etc.) are recorded and shown;

gg) National monuments and buildings/structures of known historical interest. These must be briefly described;

hh) Gates and fences where a differentiation is to be made between ordinary, stock-proof; jackal-proof security fences etc.;

ii) Stone, brick or any other type of walls;

jj) Wells, boreholes, windmills;

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kk) Kilometer markers and the kilometer values shown on the marker board;

ll) Quarries, tunnels, mines and their related work, etc.;

mm) Graves and cemeteries and specifically individual graves; and

nn) Generally all features that are not noted above but could have an impact on the design for which such topographical survey is required.

Every point of detail must be fixed in Y, X and Z and must be presented on the drawings by standard feature descriptions. The density of the survey must be adhered to so as to enable cross-sections to be extracted from the DTM at 10m intervals. (For standard feature description codes refer to **Annexure 15**).

6.1.5 Digital Terrain Model (DTM)

a) DTM observations shall be taken generally at maximum of 20m spacing (excluding the Road Prism where 10m spacing is required). Depressions evident on the Road Surface will dictate the additional DTM observations that must be taken.

b) In addition to the survey of all normal detail and the DTM survey that covers the entire area of the survey the following must be surveyed using a Total Station or Laser Scanning equipment as detailed. Points surveyed must adhere to a maximum spacing of 10m where a Total Station is used and a spacing of 2m where a Laser Scanning instrument is used. (Reference here is specifically for a Road Prism and shall be used as break lines).

i)	LHS Toe Line	Total Station
ii)	LHS Shoulder Breakpoint	Laser Scanning or Total Station
iii)	LHS Edge Tar/Road Surface	Laser Scanning or Total Station
iv)	LHS Yellow Line	Laser Scanning or Total Station
v)	Centre Line	Laser Scanning or Total Station
vi)	RHS Yellow Line	Laser Scanning or Total Station
vii)	RHS Edge Tar/Road Surface	Laser Scanning or Total Station
viii)	RHS Shoulder Breakpoint	Laser Scanning or Total Station
ix)	RHS Toe Line	Total Station

Also refer to **Annexures 16.1** and **16.2** for typical road profile surveys.

c) Where super-elevation of the road is evident then additional measurements must be observed in order to determine the precise start, rate and length of the super-elevation. This information is specifically important where any change in the super-elevation may be seen with the naked eye.

d) All changes in slope must serve as break-lines in the DTM.

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e) A careful and rigorous quality check must be carried out on the mathematical DTM triangulation in particular where the DTM was computer generated and where there is a general spread of features that will have an impact on the accuracy of the DTM.

f) The decimal point in the height value must denote the actual position of the spot shot observed.

6.1.6 Moving of survey instruments and GPS base stations

Three points on the tar surface of the last row of survey observations from a station shall be marked. Sufficient markings for non-road type surveys shall be made to be identified.

The same positions shall be surveyed from the next instrument station position.

The spot shots for both observations shall be shown on the CAD drawings.

6.1.7 Observation limitations

Survey observations taken on the Road Prism shall be limited to a maximum distance of 150m from the instrument station.

GPS survey observations from a GPS base shall be limited to a maximum distance of 1000m on either side of the base station.

6.1.8 Check surveys

Refer to Chapter 13 “QUALITY CONTROL”.

6.1.9 Data to be supplied

Refer to Chapter 12 “DELIVERABLES”.

6.2 Specific requirements for road detail and a DTM strip survey (including the Road Prism)

In addition to the general requirements stated above, the survey must include the following where applicable:

6.2.1 Phases of the survey

Refer to paragraph 6.1.2 “Phases of the survey”.

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6.2.2 Area to be surveyed

The area to be surveyed is to be indicated by the Client and may comprise of a description, key plan or dimensions. The Client may issue special instructions with respect to the survey of under/overpasses.

6.2.3 Survey equipment

Conventional survey, Global Positioning System (GPS) or Terrestrial and Mobile Laser Scanning equipment may be employed for these surveys, provided that:

a) No elevation observations using GPS equipment are permitted on the Road Prism (toe line to toe line) or for drainage structures;

b) Laser Scanning may only be permitted for the survey up to the Shoulder Break Point of the Road Surface provided that the Shoulder Break Point is clear of vegetation i.e. only the surfaced road area shall be scanned;

c) The methodology used must meet the level of accuracy as specified in Chapter 3 “SURVEY REGULATIONS AND STANDARDS OF ACCURACY” above;

d) For laser type surveys refer to Chapter 14 “LASER SCANNING FOR STRUCTURES, THE COLLECTION OF DIGITAL TERRAIN DATA AND ROAD SURFACE MARKINGS”; and

e) The most recent South African geoid determination must be applied to all GPS measurements if a local geoid was not determined or specified.

6.3 Specific requirements for rail reserve detail & DTM surveys

Specific permission must be obtained from the rail authorities prior to entering into their rail reserve.

In addition to the general requirements stated above, the survey must include the following information where applicable:

6.3.1 Phases of the survey

Refer to paragraph 6.1.2 “Phases of the survey”.

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6.3.2 Area to be surveyed

The area to be surveyed will be determined by the Client.

6.3.3 Survey equipment

Conventional survey and Global Positioning System (GPS) equipment may be used for these surveys provided that:

a) GPS equipment is not permitted for the determination of elevation of railway lines (toe line to toe line) or drainage structures.

b) The methodology used must meet the level of accuracy as specified in Chapter 3 “SURVEY REGULATIONS AND STANDARDS OF ACCURACY” above;

c) For terrestrial laser type surveys refer to Chapter 14 “TERRESTRIAL AND MOBILE LASER SCANNING FOR STRUCTURES AND THE COLLECTION OF DIGITAL TERRAIN DATA AND ROAD SURFACE MARKINGS”

6.3.4 Digital Terrain Model (DTM)

DTM observations on the existing railway prism shall be spaced at a maximum of 10m intervals together with all elements of the railway prism and any change of slopes that will impact on the DTM. The top of the railway line must not be utilised in generating the final DTM but be recorded separately in an Excel file clearly labelled as “top of rail”.

6.3.5 Longitudinal section

a) Longitudinal sectional observations are required to be taken along the top of **each railway line.** The length of such longitudinal section must be confirmed by the Client.

b) The scale of 1:100 in a vertical plane and 1:1000 in a horizontal plane is preferable and where the levels taken on top of the railway lines must be spaced at 10m intervals. The kilometer distances must be recorded and shall always be shown as increasing from left to right relative to the road direction (increasing kilometer distances).

c) The start and end positions of the longitudinal section must be shown on the CAD drawing.

d) The Y, X and Z co-ordinates for the longitudinal section must be supplied in Excel format.

e) No longitudinal section drawings are required.

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6.3.6 Additional detail to be surveyed

In addition to the general requirements these surveys must include the following where applicable:

a) Railway line levels (Both rails) – Not to be used for the DTM;

b) Sufficient information so as to determine radii of railway curves;

c) Railway line kilometer marker positions and their values, including grade posts;

d) Turnouts;

e) Signals;

f) Signal Wire runs;

g) Electrification masts;

h) Telephone and telegraph routes;

i) Power line routes;

j) Cables (signal, power and communication)

k) Railway reserves indicating their ownership and the destinations thereof;

l) Road and Railway layout with leading dimensions in respect of formation width, and distance between carriageways and between railway lines;

m) Position of overhead electrical gantries and masts situated on the railway lines including the exact position of the concrete footings; and

n) Position of cross-over and crossings on railway lines.

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6.4 Site surveys (ground method)

6.4.1 General

Note:

- **Instructions for bridge site surveys will specifically be given by the Client. Instructions to undertake site surveys do not automatically include structural surveys and *visa versa*.**

- **Instructions to undertake site surveys at culverts must be specifically given by the Client. The locations thereof will be listed in the relevant tables as specified.**

This paragraph specifically describes the requirements for all types of site surveys and is to be read with the general requirements as set out in Paragraph 6.1 “General requirements for all topographical ground surveys”.

a) Purpose of Site Surveys

The purpose of this type of survey is to be able to generate an accurate DTM and to provide plans with contours and all topographical features including relevant longitudinal and cross-sections with reference to roads or waterways etc. so as to enable the design and accurate placing of the proposed structures and to establish fixed Permanent Survey Control to be used for future setting out of such structures and the control and monitoring thereof.

b) Phases of the survey

The survey shall include the following phases:

i) **Basic Survey:** This being the establishment and survey of a network of Permanent Survey Control and placed in selected positions within the site area and as defined in terms of paragraph 5.1.1(b) “Spacing of the Permanent Survey Control”.

ii) The Detailed and Digital Terrain Model (DTM) Survey

- **The detailed survey:** This being the survey of all natural and man-made features which may have an impact on the design or development.

- **The Digital Terrain Model (DTM):** This being the observations taken in both position and height and at regular ‘grid’ spacings including all changes of slope and break lines so as to depict the existing terrain to the required accuracy.

iii) **The Mapping:** This being the compilation of drawings from the data recorded during the survey process.

iv) **The Cadastral Compilation:** This being the sourcing and compilation of datasets which define the Cadastral boundaries and property designations and which are then superimposed onto the survey drawing(s).

v) **Check Cross-Sections and Field Checks:** This being the quality control survey undertaken prior to the submission of the final output of the survey.

vi) **Submitting of Records:** This being the datasets, documents, plans etc. submitted to the Client on completion of the survey project.

vii) **Sectioning:** This being the presentation of the ground survey in the form of a cross-section(s) and long-section(s) and in a format or medium as defined by the Client (Sectioning will only be done when specifically instructed by the Client).

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c) Plan requirements

i) Site Plan

Unless otherwise specified, the Site Plan shall comprise of a combination of the Locality Sketch and the detail contour survey plan.

ii) Locality Sketch

Unless otherwise specified, the Locality Sketch shall be shown as an inset on the Site Plan. Relevant detail such as longitude, latitude and a reference to the 1:50 000 maps so as to be able to locate the site from any given direction must be reflected therein.

iii) Survey Plan

The survey plan must be rotated so that the stake value or kilometer distance of the structure increases from left to right. For all other structures the survey plan shall be compiled with the North Direction pointing to the top of the plan.

6.4.2 Specific requirements for Bridge site detail and DTM survey: road crossing (including pedestrian Bridges)

In addition to the general requirements stated in Paragraph 6.1 "General requirements for all topographical ground surveys" and 6.4 "Site surveys (ground method)" this survey must include the following where applicable:

a) Area to be surveyed

Unless otherwise instructed the area to be surveyed must comprise of a circular area defined by a radius of 150 metres as measured from the actual Bridge site centre point. The Client will describe each Bridge site in accordance with the table below:

Bridge Site Description	**Km Ref.**	**Bridge Site Centre Point Coordinates**		**Description of Bridge Site Centre Point**
		WGS 84 Rectangular		
		Y (meters)	**X (meters)**	

The directional convention of a Bridge which will cross over or under a road is determined from facing in the direction of increasing kilometer distance of that road.

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b) Survey equipment

Conventional survey, laser and Global Positioning System (GPS) equipment may be used for this survey provided that the Road Prism (toe line to toe line) is surveyed using Total Stations or Laser Scanners up to the Shoulder Break Point of the Road Prism and subject further to the following:

i) The methodology used must at all times adhere to the levels of accuracy as specified in Chapter 3 "SURVEY REGULATIONS AND STANDARDS OF ACCURACY" above; and

ii) The survey must be based on the Permanent Survey Control beacons within the Road Reserve and on the Permanent Survey Control beacons established specifically for the Bridge site survey.

6.4.3 Specific Requirements for Bridge Site Detail and DTM Survey: River Crossings

In addition to the general requirements stated include the following where applicable:

a) Area to be surveyed

Unless otherwise instructed, the area to be surveyed must comprise of a circular area defined by a radius of 250 metres as measured from the actual Bridge site centre point and always include the area 250 metres upstream and downstream. The Client will describe each Bridge site in accordance with the table below.

The underwater observations must form part of the final DTM.

Special instructions for the surveying of cross-sections through the river and outside of the 250m radius area may be issued by the Client.

Bridge Site Description	Km Ref.	Bridge Site Centre Point Coordinates		Description of Bridge Site Centre Point
		WGS 84 Rectangular		
		Y (meters)	X (meters)	

b) Locality sketch

The Locality Sketch must be shown as an inset on the Site Plan. The position and size of existing structures within 3km upstream or downstream from the proposed Bridge must be shown including a description thereof. It is common that more than two structures on either side are shown.

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c) Survey equipment

Conventional survey, laser and Global Positioning System (GPS) equipment may be used for this survey provided that the Road Prism (toe line to toe line) is surveyed using Total Stations or Laser Scanning up to the Shoulder Break Point and is further subject to the following:

i) The methodology used must at all times adhere to the levels of accuracy as specified in Chapter 3 “SURVEY REGULATIONS AND STANDARDS OF ACCURACY” above; and

ii) This survey must be based on the Permanent Survey Control beacons within the Road Reserve or the Permanent Survey Control beacons established for the Bridge site survey.

d) Sectioning

i) Provided that a DTM is surveyed, no long or cross sections of the river within the 250m radius are required.

ii) The Client must issue a special instruction should cross sections through the river be required outside the 250m radius.

iii) No drawings of any long and cross sections taken are required.

e) Survey plan

Should the Client instruct that the cross-sections taken must be represented on the survey plan and should there not be enough space available, then a separate plan(s) must be prepared.

6.4.4 Specific requirements for Bridge site detail and DTM surveys: railway crossings

In addition to the general requirements stated in paragraphs 6.1 “General requirements for all topographical ground surveys”, 6.3 “Specific requirements for rail reserve detail & DTM surveys” and 6.4 “Site surveys (ground method)” above this survey must include the following where applicable:

a) Area to be surveyed

Unless otherwise instructed, the area to be surveyed must comprise of a circular area defined by a radius of 300 metres as measured from the actual Bridge site centre point. The survey must also include a strip 50m either side of the road centre line and which extends from the 300m radius limit up to 600m or along a railway line up to 400m.

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The Client will describe each Bridge site in accordance with the table below:

Bridge Site Description	Km Ref.	Bridge Site Centre Point Coordinates		Description of Bridge Site Centre Point
		WGS 84 Rectangular		
		Y (meters)	X (meters)	

b) Survey equipment

Conventional survey, laser and Global Positioning System (GPS) equipment may be used for this survey provided that the Road and Railway Prisms (toe line to toe line) are surveyed using Total Stations or Laser Scanning up to the Shoulder Break Points and subject further to the following:

i) The methodology used must at all times adhere to the levels of accuracy as specified in Chapter 3 “SURVEY REGULATIONS AND STANDARDS OF ACCURACY” above.

c) Additional detail to be surveyed in the rail reserve:

i) Railway line levels (both rails). These levels are not be used in the creation of the final DTM;

ii) Sufficient information to determine radii of road and railway line curves;

iii) Railway line kilometer marker board positions and values and grade posts;

iv) Turnouts;

v) Signals;

vi) Signal Wire runs;

vii) Electrification masts;

viii) Telephone and telegraph routes;

ix) Power line routes;

x) Cables (signal, power and communication);

xi) Railway reserves indicating its ownership and the destination;

xii) Road and Railway layout with leading dimensions in respect of formation width, and distance between carriageways and between railway lines;

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xiii) Position of overhead electrical gantries and masts situated over railway lines and including the position of the concrete bases;

xiv) Position of cross-over and crossings on railway lines; and

xv) Where the area is located in a highly urbanised area then detail considered irrelevant may be omitted provided such approval has first been obtained from the Client.

Every point of detail must be fixed in Y, X and Z and must be displayed by a standard feature description. The density of survey must be sufficient to enable cross-section to be extracted from the DTM at 10m intervals.

d) Sectioning

i) Longitudinal sections along railway lines:

- A longitudinal section is required for each track of the railway line affected by the Bridge crossing. These sections must cover a distance of at least 300m on either side of the proposed Bridge(s). The exact length of the survey must be confirmed by the Client.
- Scale of 1:100 in the vertical plane and 1:1000 in the horizontal plane are preferred.
- Kilometer distances must always increase from left to right in relation to the direction of the road. The output provided shall be computer plots and in an appropriate digital format. Each section must be shown as a separate profile. The position of where the sections were taken must be clearly indicated on the survey drawing(s).
- Sections and profiles must be clearly numbered on the CAD drawing.

ii) The longitudinal sections must show the following:

- Levels on top of both tracks of the railway line at 10m intervals together with rail kilometer distances.
- Sufficient survey information must be surveyed so that the designer is able to determine the geometric data with respect to the vertical and horizontal alignments of the tracks of the railway line.
- The crossing point of the rail and road centre lines.
- Railway line destinations.
- The position of existing structures including railway line drainage pipes and services.

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In general all requirements as stipulated by the relevant railway authority must also be considered and met with, if applicable.

e) Road forming part of the railway crossing

All requirements as stipulated in paragraphs 6.1 “General requirements for all topographical ground surveys”, 6.2 “Specific requirements for road detail and a DTM strip survey (including the Road Prism)” and 6.3 “Specific requirements for rail reserve detail & DTM surveys” shall be applicable to this part of the site survey.

6.4.5 Specific requirements for Culvert site surveys

a) Area to be surveyed

The extent and scope of the survey must be supplied by the Client. The Client will describe each culvert site in accordance with the table below:

Culvert Site Description	Km Ref.	Culvert Site Centre Point Coordinates		Description of Culvert Site Centre Point
		WGS 84 Rectangular		
		Y (meters)	X (meters)	

b) Site survey requirements

The survey and drawing requirements for these surveys shall be as per those specified for river crossings in Paragraph 6.4.3 “Specific Requirements for Bridge Site Detail and DTM Survey: River Crossings” above provided that the exact extent and scope of the survey must be supplied by the Client. For further survey requirements on the culvert structure itself refer to **Annexure 17**.

6.5 Borrowpit and Quarry site detail contour survey

6.5.1 General

This paragraph specifically describes the requirements of these surveys and must be read with the general requirements specified in paragraph 6.1 “General requirements for all topographical ground surveys” above.

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a) Purpose of the survey

The purpose of this survey is to produce plans for Quarry sites and Borrowpits as determined and required by the Inspector of mines and for planning and construction purposes.

b) Phases of the survey

Refer to paragraph 6.1.2 “Phases of the survey” above.

c) Survey instruments

Conventional survey, Laser and Global Positioning System (GPS) equipment may be used for this survey, provided that:

i) The methodology used must at all times adhere to the levels of accuracy as specified in Chapter 3 “SURVEY REGULATIONS AND STANDARDS OF ACCURACY” above.

d) Survey control

The survey must be based on a network of Permanent Survey Control beacons. A minimum of three Permanent Survey Control beacons must be established around each Borrowpit for future surveys during the construction phase of a project for which the Borrowpit is to be utilised (Refer to paragraph 5.4 “Specific requirements for the establishment of Permanent Survey Control for Borrowpit surveys”);

e) Digital Terrain Model (DTM)

DTM observations must be taken at maximum spacing of 20m and all changes in slope surveyed. The area is demarcated by the Client and the survey must extend 20m beyond the perimeter of the demarcated area;

6.5.2 Specific requirements for Borrowpit detail and DTM survey

In addition to the general requirements specified in Paragraph 6.1 “General requirements for all topographical ground surveys” the following shall also be applicable:

a) Area to be surveyed

If the Quarry/Borrowpit is unfenced then the Client will indicate where the approximate positions of the proposed corner posts of a fence are which demarcates the area to be surveyed.

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b) The staking of the designed Borrowpit boundary points

i) Where the Quarry/Borrowpit is fenced prior to survey, then the positions of corner posts and gates must be adopted, surveyed and recorded.

ii) The Client must provide the coordinates so as to set out the boundaries of the Borrowpit/Quarry.

iii) Steel pegs 16mm diameter and 450mm in length must be used to demarcate all the corner positions. A substantial cairn of stones shall be placed over each peg and duly painted with a durable white paint.

c) Borrowpit access road survey

d) Area to be surveyed

i) The most logical, practical and the shortest access route to the Borrowpit must be determined and where the Borrowpit is not located directly adjacent to a public Road Reserve and where no alignment is provided;

ii) Unless otherwise specified, in the case of a new access road only the centreline of the proposed access route is to be surveyed at 10m spacings. Where the access road is adjacent to a fence line or a Cadastral boundary, then the fence line must also be surveyed. The survey must take the design of the access road into account where this is obtainable from the Client;

iii) In the case of an existing fenced access road the LHS and RHS road bending points thereof must be surveyed, at an effective minimum spacing of 50m. Where the access road is not fenced the position of the existing road with all its features and beyond 10m from both edges of the road must be surveyed;

iv) Such access roads must be shown on the survey drawings and reflected in a separate CAD layer; and

v) It must be noted that an existing access road which is also a right of way to neighbouring properties shall not traverse through any part of the Borrowpit area as demarcated by the Client.

6.5.3 Specific requirements for Quarry site surveys

In addition to the general requirements specified in paragraph 6.1 “General requirements for all topographical ground surveys” the survey must also include the following:

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a) Quarry surveys where blasting is to take place

i) An area extending 500m from the perimeter of the Quarry is to be surveyed. This must be contoured at 5m intervals and plotted at a scale of 1:2 000.

ii) The area extending 20m from the perimeter of the Quarry must be surveyed to the same specifications as that for Borrowpit surveys specified in Paragraph 6.5.2 "Specific requirements for Borrowpit detail and DTM survey". This shall be contoured at 1m intervals and plotted at a scale of between 1:200 and 1:500 so as to fit onto an A0 sheet.

b) Quarry surveys where no blasting is to take place

i) An area extending 20m from the perimeter of the Quarry is to be surveyed to the same specifications as that for Borrowpit surveys specified in Paragraph 6.5.2. "Specific requirements for Borrowpit detail and DTM survey". Where topographic features such as buildings and power or pipeline servitudes are within 100m of the perimeter of the quarry, then the area must be extended so as to include these features. This area must be contoured at 1m intervals and plotted at a scale of between 1:200 or 1:500 so as to fit on an A0 sheet.

6.6 Requirements for photogrammetric topographical surveys: 1:500 to 1:2000 scale

6.6.1 General requirements

a) Purpose of the survey

The general purpose of this type of survey is to enable the preparation of detailed topographical plans and to provide for the establishment of Permanent Survey Control beacons to be used in future surveys. These surveys are utilised inter alia for the selection/design of a future road centre line but is also used with reference to revision type surveys, the study of the engineering requirements for the future road construction and/or rehabilitation of roads and for the acquisition of land for such road.

b) Phases of the survey

The following are generally recognised as distinct phases of this type of survey and the necessity to carry each phase out will be determined by the Client and recorded in the project instructions.

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i) **The Photography:** This being the aerial photography, the processing of the film, the supply of negatives, contact prints, diapositives, digital images and Flight Plans and as specified in Chapter 4 “AERIAL PHOTOGRAPHY” .

ii) **The Basic Survey:** This being the establishment of a horizontal and vertical survey network of Permanent Survey Control on which the survey must be based.

iii) **The Photo Ground Control:** This being all field survey work required for the establishment of Photo Control Points which must be based on the Permanent Survey Control established for the project, the Annotation of detail on the photographs, the aerial triangulation and additional ground surveys such as the recording of dimensions, height clearances, invert levels etc.

iv) **Photo Annotation:** This being the annotation of features listed under Paragraph 6.6.1(d) “Detail to be surveyed” that is not clearly visible from the aerial photography.

v) **The Mapping:** This being the photogrammetric or other plotting and recording of digital data of all topographical detail and includes the drawing of plans, and the transfer of annotated and field surveyed information onto the drawings.

vi) **The Digital Terrain Model Observations (DTM):** This being the observations in both position and height in a regular grid fashion and recording of all changes in slope and ‘break lines’ so as to represent the existing terrain topography and to the required accuracy.

vii) **The Cadastral Compilation:** This being the collection and compilation of all data which defines the Cadastral boundaries as per the designations determined by the office of the Surveyor–General.

viii) **Quality Control:** This being quality control surveys and office checks undertaken prior to the submission of the final output of the survey.

ix) **Submission of final data:** This being the data that must be submitted to the Client on completion of the survey project.

c) Area to be surveyed

i) The width of the ‘strip’ to be surveyed for a road survey is normally 750m for surveys of 1:2 000 scale, 450m for surveys of 1:1 000 scale and 250m for surveys of 1:500 scale provided the extent has not been delineated on the photographs or otherwise indicated or laid down by the survey requirements of the specific project.

ii) All other areas to be surveyed shall be shown on any plan/photo at a convenient scale to clearly identify the boundaries of the survey area.

iii) The photogrammetric survey is not required within the Road Reserve where ground survey forms part of the photogrammetric survey project. This must however always be confirmed by the Client in writing.

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d) Detail to be surveyed

i) Rock outcrops, cliffs, sand dunes, eroded areas and gullies;

ii) Railways (differentiating between standard and narrow gauge and between Spoornet and privately owned lines). The destination of all railway lines must be indicated on the plans;

iii) Roads (differentiating between bitumen, concrete paved and gravel surfaces) indicating status, number and destination, footpaths, guardrails, kerbing, manholes and side drainage must be shown;

iv) Road markings (i.e. lines dividing lanes on the Road Surface). The line types shall be shown as on the ground, i.e. solid, broken, broken and solid, etc.;

v) Bridges (stating Bridge numbers) and Culverts. Detail such as the dimensions and types of construction for those structures which are situated on or across roads, or which could have a bearing on the drainage thereof (possible annotation required);

vi) Elevations of the centre of the road at the point of intersection of road and Culvert, and including Culvert sizes, invert levels of Culverts, Bridges and manholes (including cover invert and ground levels, the type of service, pipe diameter and direction of flow) must be obtained by means of ground survey methods;

vii) Drainage and irrigation furrows:

- Wherever a surveyed feature of any kind, is contained within well-defined outlines, these outlines shall be shown in their true shape and by the correct symbol;

- In general, all topographical features and manmade structures, the plotting of which must be consistent with the scale of the plans;

viii) With respect to urbanised areas such as townships, industrial or mining sites, etc., written approval must be obtained from the Client to omit same detail which may be considered to be irrelevant or not applicable;

ix) The edges of all existing gravel roads, including the convex or concave shape of the Road Surface and any super-elevation;

x) The edges of the asphalt, and/or kerb (top and bottom) of all surfaced roads, including the convex or concave shape of the Road Surface and any super-elevation;

xi) The positions and invert levels of all side drains (whether lined or not). Inverts to be surveyed by ground method;

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xii) The size, positions and invert levels of all drainage and storm water pipe inlets and outlets, even if these extend beyond the defined survey width and must be surveyed by ground method;

xiii) All drainage structure detail such as wing walls (including their positions, height of the head walls), invert levels and dimensions. Sufficient observation must be taken in order to be able to extract cross-sections along the drainage furrow and across the Culvert. The survey must be done in such a way to represent accurate contours around the Culvert structure and wing wall area. Invert levels must be surveyed by ground survey methods;

xiv) All power and telephone lines including their individual poles or pylons as per their surveyed position and further the overhead clearances relative to the edges of the Road Surface. Overhead clearances must be surveyed by ground method (possible annotation);

xv) Fences;

xvi) Bridge columns/pillars including the horizontal and vertical clearances of all overpass bridges which must be surveyed by ground method;

xvii) All visible municipal services such as sewerage, water, electricity, lamp posts, traffic lights, etc. It is noted that only visible services and markers of underground services are to be surveyed (to be annotated on the photos);

xviii) Cover, invert and ground levels of all manholes which must be surveyed by ground method;

xix) Valve chambers of all existing water mains;

xx) Top and toe of cut and fill batters and all changes in slope that may have an influence on the creation of the DTM and contours generation;

xxi) Existing accesses to adjoining properties;

xxii) Any encroachment within the Road Reserve ;

xxiii) Any soil erosion within the survey area;

xxiv) All road furniture;

xxv) All road signs must be surveyed and their positions accurately depicted on the plan (possible annotation);

xxvi) All break lines that may have an impact on the creation the DTM;

xxvii) Positions of Permanent Survey Control beacons;

xxviii) Rivers, streams, springs, canals, dams, pans, marshes and areas subject to tidal flooding including their names and the direction of flow where applicable;

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xxix) Highest known flood levels of main streams/rivers or as close as possible and where this is determined from local evidence or information gathered (the sourcing of such information, its location and date must be indicated on the plan) (to be annotated on the photos);

xxx) High tide marks and High Water Marks of rivers, streams and dams (to be annotated on the photos);

xxxi) A description of the bed of the stream or river bed e.g. sandy, boulders, solid rock, silted etc. (possible annotation);

xxxii) Forest, bush, shrub, plantations, orchards, avenues, hedges, individual trees which are landmarks, or where the preservation of which may be desirable for scenic purposes, etc.;

xxxiii) Cultivated lands (differentiating between dry and irrigated), rock outcrops and hard or continuous rock areas, cliffs, sand dunes etc.;

xxxiv) Natural drainage lines and manmade drainage improvements;

xxxv) Position of foundation test holes with their ground levels if applicable (possible annotation);

xxxvi) Any special features that may not be of a topographical nature;

xxxvii) Road numbers and the destination in the direction of the road as it exists leaving the surveyed area;

xxxviii) All freestanding buildings, differentiating between types of construction i.e. permanent or temporary and indicating the general use of the buildings or groups of buildings (e.g. school, store, office etc.), save for habitable dwellings (possible annotation);

xxxix) National monuments and buildings or structures of historical value where a brief description is included (to be annotated on the photos);

xl) Fences and their gates (differentiating between ordinary, stock-proof; jackal-proof; security fences etc.) (possible annotation);

xli) Stone, brick or any other type of walls;

xlii) Wells, boreholes, windmills (to be annotated on the photos);

xliii) Kilometer markers with their kilometer values (to be annotated on the photos);

xliv) Quarries, tunnels, mine workings, etc.;

xlv) Graves and cemeteries and individual graves (to be annotated on the photos);

xlvi) In addition, any feature not listed above, that may be required to accurately model the surface or may affect earthworks and designs within the surveyed area; and

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xlvii) Any structures or development which might have an influence on the design.

The above must be fixed in Y, X and Z. The density of the DTM must be sufficient to enable cross-section to be generated from the data at 10 meter spacing.

Contours must be shown at generally 0.5m or 1m intervals and supplemented by 'spot' heights wherever the contours are insufficient to depict the ground surface accurately. Additional spot heights must be observed at regular intervals and also on such features such as roads, railways and bridges etc. and where elevations may affect the future engineering design to be done. In particular, deck levels of all bridges, railway line tracks and major roads, where the latter two must be observed at a minimum spacing of 10m.

6.6.2 Photogrammetrical Digital Terrain Modelling (DTM)

Note: On instruction from the Client the ground surveyed DTM (triangles and detail) must be spliced/added to the photogrammetric DTM (triangles and detail) and from which contours must then be generated. (Refer to paragraph 6.8 "Manipulation of photogrammetric/Lidar DTM and detail survey data by Splicing the ground survey TIN and detail into photogrammetric/Lidar Model" for Splicing methodology)

a) Photogrammetric DTM observations must be observed at maximum spacing of 20m and also at all changes in slope.

b) In addition the following must be observed at spacing of 10m and with reference to the typical cross section of a Road Prism provided that no ground survey Splicing has been specified:

i) LHS Toe Line;
ii) LHS Shoulder Breakpoint;
iii) LHS Edge Tar/Road Surface
iv) LHS Yellow Line;
v) Centre Line
vi) RHS Yellow Line
vii) RHS Edge Tar/Road Surface
viii) RHS Shoulder Breakpoint
ix) RHS Toe Line

c) All the above features must be used as 'break lines' in the generation of the DTM.

d) The DTM density must be sufficient to enable cross-sections to be generated at 10 meter intervals.

e) The decimal point in the height value must denote the actual position of the spot shot observed.

f) The DTM heights must be recorded in a separate layer within the 3D Continuous Model.

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g) No auto correction techniques shall be allowed to generate a DTM.

Note:

i) Lidar technology as specified in paragraph 6.9 "Lidar surveys for the production of Orthophotos and line mapping" (and all other relevant chapters/paragraphs may be used to generate photogrammetric DTMs and line mapping, provided the final product complies fully with all requirements as specified in paragraph 6.6 "Requirements for photogrammetric topographical surveys: 1:500 to 1:2000 scale" (and other relevant chapters/paragraphs of this document.)

ii) Lidar surveys shall only be used with the written permission of the Client. The final deliverables and output shall comply with all specifications where applicable for the production of line mapping as provided for in this document.

iii) Seamless aerial photography as the "Push Broom" digital imagery systems can be used to produce DTMs and line mapping provided the final product adheres to all requirements as stipulated in paragraph 6.6 "Requirements for photogrammetric topographical surveys: 1:500 to 1:2000 scale" and all other relevant chapters in this document.

If a Surveyor intends employing such methodology which must satisfy the requirements of the specific project it shall first be submitted to the Client for approval.

Again all final deliverables and outputs shall fully comply with all specifications contained in this manual for the production of line mapping.

6.7 Orthophoto production and DTM surveys

6.7.1 Purpose of the survey

The purpose of this survey is to produce small and large scale Orthophoto maps.

6.7.2 Phases of the survey (Conventional and Lidar surveys)

The following are generally recognised phases of this type of survey.

a) **The Photography:** This being the aerial photography, the processing and supply of the negative film, all negatives, contact prints, diapositives digital images and Flight Plans. The photo scale or the Ground sample distance, in the case of digital photography, will be determined by the final scale of the Orthophoto required.

b) **The Basic Survey:** This being the establishment of a horizontal and vertical survey network of Permanent Survey Control on which the survey must be based.

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c) **The Photo Ground Control:** This being all field survey work required for the establishment of Photo Ground Control points which must be based on the Permanent Survey Control established for the project, the aerial triangulation and additional ground surveys such as the recording of dimensions, height clearances, invert levels etc.

d) **Photo Annotation:** This being the annotation of features listed under Paragraph 6.7.10 "Features to be annotated in the field and shown as Orthophoto detail (Conventional and Lidar surveys)" that is not clearly visible from the aerial photography.

e) **The Mapping:** This being the recording of all detail as prescribed for production of Orthophotos, the drawing of the plans and the transfer of annotated and field surveyed information onto the drawings.

f) **The Digital Terrain Model Observations (DTM):** This being the observations in both position and height in regular grid fashion and recording of all changes in slope and 'break lines' so as to represent the existing terrain topography and to the required accuracy which is then used to ortho rectify the photo imagery.

g) **The Orthophoto Process:** This being the digital photogrammetric process to produce Orthophoto maps.

h) **The Cadastral Phase:** This being the collection and compilation of data which defines the Cadastral boundaries as per the designations determined by the office of the Surveyor-General.

i) **Quality Control:** This being quality control surveys and office checks undertaken prior to the submission of the final output of the survey.

j) **Submission of final data:** This being the data that must be submitted to the Client on completion of the survey project.

6.7.3 Area to Be Surveyed (Conventional and Lidar Surveys)

a) The scale for the final Orthophotos will be specified by the Client.

b) The width of the strip to be surveyed for road surveys is generally 750m for surveys of 1:2 000 scale, 450m for surveys of 1:1 000 scale and 250m for surveys of 1:500 scale provided that the area is not specifically shown on the photographs or otherwise specified in the Survey Requirements for a particular project.

All other areas to be surveyed must be shown on a plan/photo and at a convenient scale so as to clearly identify the boundaries of the survey area.

6.7.4 The Orthophoto process (Conventional and Lidar surveys)

Before commencing with the preparation of the Orthophotos the Surveyor must submit and have approved a provisional key plan to a scale of 1:50 000, showing the proposed layout of

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the sheets if line mapping was not specified. The plan must also depict major features such as rivers, towns, roads, railways and interchanges within the area to be mapped. On completion of the work, a final key plan layout depicting the final sheets must be provided in digital format. If the production of Orthophotos forms part of photogrammetric line mapping then the sheet layout for the Orthophoto shall be the same as for the Mapping.

6.7.5 Terminology

a) Digital Photogrammetric Workstation (DPW) – generally referred to as a Software System.

b) Digital Image/Image – a photograph taken either directly with a digital camera or with an analogue metric camera where the negative or diapositive has been scanned to a high degree of accuracy.

c) Pixel – The smallest element of a digital image. It is generally used to indicate the degree of accuracy with which a photograph has been scanned or at which it was directly captured in the case of a digital camera. The unit used is generally the micron (one thousand of a millimetre) so a 12.5 micron image will have twice as many Pixels in each row and column as opposed to a 25 micron image. It will therefore have 4 times the storage requirements of the 25 micron image. Refer to Paragraph 4.2 “Digital Scanning of Analogue Aerial Photographs” for the scanning of photographic images.

d) Orthophoto – The term in the strictest sense i.e. where each individual Pixel is rectified to its planimetric position to the same degree of accuracy as the Digital Elevation Model (DEM) and any vector data. An image that has been stretched or warped to fit Photo Ground Control Points (points identified as common on image and ground co-ordinate system) is therefore not regarded to be an Orthophoto.

e) Exterior Orientation – The 6 parameters defining the exact position and altitude of an image in space i.e. the Y, X, Z Coordinates and the 3 rotational angles in the Perspective (projection) Centre.

f) Model – a stereo pair of digital images with a minimum of 55% Overlap.

6.7.6 Obtaining the digital elevation model (Conventional survey)

a) Most sophisticated DPW systems allow the automatic creation of a DEM using auto correlation techniques. It is imperative that the software used for this purpose allows user control over:

i) Minimum correlation values;

ii) Height tolerances; and

iii) Exclusion areas and points, etc. to minimize the generation of garbage information.

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This method will only be allowed for the production of controlled mosaics or small scale Orthophotos. For the production of normal large scale Orthophotos physical DTM and break-line observations must be observed in accordance with Paragraph 6.6.2 “Photogrammetrical Digital Terrain Modelling (DTM)”.

6.7.7 Photogrammetric DTM (Conventional survey)

Refer to photogrammetric DTM section in Paragraph 6.6.2 “Photogrammetrical Digital Terrain Modelling (DTM)”.

The DTM is observed using photogrammetric methods (spot shots and break lines) or a combination of photogrammetric and ground survey (splicing) from which contours are generated, and are then used to rectify the photographic imagery.

6.7.8 Undertaking the Rectification and production of the Orthophoto (Conventional and Lidar surveys)

a) The Digital Photogrammetric Workstation (DPW) must enable the user to create the Orthophoto automatically once the exterior orientation(s) and DTM have been created.

b) The software used must also enable the Orthophotos to be created as a batch process so that a number of Orthophotos are created, with little or no user intervention, once the parameters have all been set.

c) Each Pixel must be positioned to the same degree of accuracy as the DTM, thus enabling Orthophoto to be used as if all the features were accurately mapped, but with the added advantage of a fully rectified image of the area (Rectification).

d) The mapping scale, contour interval and grid spacing must be proportional to the limits of accuracy for the Orthophoto.

e) The Orthophoto shall be produced as continuous workable size models and also in individual A0 sheets.

6.7.9 Detail to be shown on the Orthophoto sheets (Conventional and Lidar surveys)

a) The following detail shall be shown:

i) A title block in accordance with the Clients’ specifications, where the title of the survey, sheet numbers, scale and a co-ordinate list of the Permanent Survey Control are depicted;

ii) Y & X gridlines every 200mm;

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iii) The compilation of the cadastre in accordance with Chapter 7 “CADASTRAL DATA AND CADASTRAL KEY PLANS FOR TOPOGRAPHICAL AND OTHER SURVEYS”;

iv) Contours at appropriate and agreed intervals. Contour values shall be given at not less than 400mm spacing;

v) All Permanent Survey Control, Benchmarks and Trig Beacons located within the limits of the survey strip;

vi) For road surveys the layout of each strip must be from left to right in the direction of increasing route distance and section numbers, unless this is otherwise specified; and

vii) For non-road surveys the layout must be in accordance with the Client’s requirements. If no requirements are specified then the sheets must be such that the north point is to the top of the sheet.

6.7.10 Features to be annotated in the field and shown as Orthophoto detail (Conventional and Lidar surveys)

a) The features listed below must be annotated in the field and be noted on the final Orthophoto sheet. The description of a feature must be positioned so as clearly to refer to the feature. However, where features are large enough to be clearly visible on the final Orthophoto, such as large rivers, dams, etc., the names of such features need be given:

i) Power lines, telephone lines and fences are to be shown as symbols and not as individual poles, and as close to the correct position of the line as is possible if not clearly visible on the Orthophoto. (The height clearances of all services which cross over a major road must be surveyed by ground survey methods and must then be shown on the Orthophoto).

ii) Underground services (such as pipe lines and cables, the position of which must be ascertained from surface indications).

iii) All fences must be shown, with particular attention given to fences demarcating property boundaries and Road Reserves. In urbanised areas internal fences need not be shown.

iv) Kilometer Markers on roads.

v) River and stream names, springs, canals, boreholes, dams, pans, marshes and areas subject to tidal flooding (with additional spot heights).

vi) The type of crops grown in large cultivated fields.

vii) The origin and the destination of all roads and railway lines.

viii) Description of buildings other than those for residential use.

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ix) Culvert information and invert levels. (Invert levels to be surveyed by ground survey methods).

x) Cemeteries and individual graves.

xi) Any other features that are not clearly visible on the photo.

6.7.11 Rectified ortho images (controlled mosaics)

a) Where ortho rectified images are required for the same area for which photogrammetric line mapping has been done, then the following applies:

i) The rectified image must be generated as per the normal Orthophoto method using the final photogrammetric DTM;

ii) The photo images shall be cut to fit the exact A0 sheet produced for the line mapping; and

iii) No Annotations as stated in paragraph 6.7.10 “Features to be annotated in the field and shown as Orthophoto detail (also applicable to Lidar surveys)” will be required.

Note:

i) Lidar technology as specified in paragraph 6.9 (and all other relevant chapters/paragraphs may be used to generate photogrammetric DTMs and orthophotos, provided the final product complies fully with all requirements as specified in paragraph 6.7 “Orthophoto production and DTM surveys” (and other relevant chapters/paragraphs of this document).

ii) Lidar surveys shall only be used with the written permission of the Client. The final deliverables and output shall comply with all specifications where applicable for the production of line mapping as provided for in this document.

iii) Seamless aerial photography as the “Push Broom” digital imagery systems can be used to produce DTMs and orthophotos provided the final product adheres to all requirements as stipulated in paragraph 6.7 “Orthophoto production and DTM surveys” (and other relevant chapters/paragraphs of this document).

iv) Again all final deliverables and outputs shall fully comply with all specifications contained in this manual for the production of line mapping.

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6.8 Manipulation of photogrammetric/Lidar DTM and detail survey data by Splicing the ground survey TIN and detail into the photogrammetric/Lidar Model

6.8.1 DTM to be spliced

a) This is applicable to all photogrammetric/Lidar surveys where ground surveyed data has been created, as:

i) Line mapping and DTM - Continuous Model.

ii) Bridge site surveys.

iii) All under- and over pass DTMs where the emphasis of the TIN is on the opposite road as indicated on the Continuous Model.

iv) Only the ground surveyed DTM shall be spliced into the Lidar / photogrammetric orthophoto DTM and not the detail.

b) Splicing

i) The surveyed area by ground methods must replace the relevant photogrammetric area data by the removal of the photogrammetric/Lidar triangles and detail and then Splicing the ground survey data into that same area.

ii) The necessary tests must then be undertaken to ensure that all triangles in the newly created TIN are correctly constructed.

iii) Rectification of the photos and production of the final contours can only be undertaken once the 'splicing' has been completed and checked.

iv) The spliced ground survey TIN must be depicted in a different colour in the final TIN and as submitted to the Client.

v) Only the ground surveyed TIN shall be spliced into the orthophoto. No detail shall be spliced.

c) Submission of data

Data submitted must state as to whether the DTM and detail has had Splicing done. It must be clearly recorded on the cover of the CD and also in the final DTM/TIN file name.

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6.9 Lidar surveys for the production of Orthophotos and line mapping

6.9.1 General

Orthophotos and DTMs may be produced from Lidar and digital camera data but must adhere to all the requirements specified for Orthophotos and line mapping with specific respect to the final product and the information to be supplied to the Client.

Refer to paragraphs 6.7. “Orthophoto production and DTM surveys” and 6.8 "Manipulation of photogrammetric DTM/Lidar and detail survey data by the Splicing the ground survey tin and detail into the photogrammetric TIN” under Orthophoto.

6.9.2 Specific Lidar specification

In addition to the general Orthophoto requirements the following shall also apply:

a) Average DTM point density shall not be less than 5 points/m² (equivalent to an average point spacing of 0.45m or less) before filtering.

b) Higher point densities are required such that small features reflecting significant height changes are not missed out.

c) Multiple Returns to be recorded

   i) Laser system should be able to penetrate vegetation where data for both the vegetation and the ground below the vegetation is available. Four (4) returns are preferable.

d) Laser data to be classified

   i) Points should be classified as “ground” and “non-ground” points. Further classification may then be project specific.

   ii) A third class for an elevated Road Surface is also required and is to be named. This is for Road Surfaces that are situated at approximately normal ground level e.g. Bridges. This category is essential in the production of Orthophotos where the combined surface being the ground and elevated Road Surface, is to be used to rectify the imagery.

   iii) Manual checking and editing of the classification shall be undertaken.

e) DTM Filtering – The ground points must be filtered to minimize the number of points that adequately depict the ground surface. The recommended methodology is the use of model key points. The model key points are classified from the ground points so that a required accuracy is obtained. The maximum allowed elevation differences between a ground Lidar point and the triangulated model are set as distances above and below the

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model. The specified range for large scale Orthophotos and DTMs is approximately 50mm.

f) The application must locate a small set of points (model key points) in order to create a triangulated model to the required accuracy.

g) The Client can request that breaklines must be observed and used in the final DTM.

6.9.3 Imagery specifications

a) Cloud free, 24 bit colour digital imagery:

i) Regional weather conditions may prevent the capture of cloud free images. The operator must then contact the Client who will then decide and direct as to the achievement of the best balance between image quality and the meeting of project deadlines.

ii) If cloud shadows are present, these should be smoothed by radiometric techniques.

b) Image Resolution at capture: 10cm Pixel Ground Sample Distance (GSD) or smaller:

i) 10cm Pixel GSD offers double the resolution of the 15cm Pixel GSD commonly encountered in standard aerial photography where this is made possible by modern, higher resolution digital cameras.

c) Forward motion compensation must be used or the forward motion should be kept to below 50% of a Pixel.

6.9.4 Accuracies

a) Accuracies: Y and X – better than 10cm, Z – better than 5cm for flying heights less than 500m (large scale) and 10cm for flying heights of greater than 500m.

i) These 1-sigma accuracies to be relative to the established ground control (40% of all test results to be within the specified accuracy of 5 and 10cm).

ii) 80% of all test results to be within 2.5 times of the 1-sigma accuracy.

iii) Horizontal accuracies determined on imagery (which is based on laser derived DTM for rectification) to also verify laser YX accuracy.

iv) Vertical accuracies determined on laser data.

v) A comprehensive report on the vertical accuracy of the Lidar ground surface must be prepared using both all of the Lidar points and also using the model key points.

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6.9.5 Ground control

a) The Lidar and digital camera survey shall be based on the Permanent Survey Control beacons established for a project. Permanent ground control shall be established to suit the requirements and as specified for all other surveys.

b) If no Permanent Survey Control beacons are to be established then all Photo Ground Control and check point coordinates must be surveyed and calculated in Hartebeesthoek ellipsoidal values. The latest SA Geoid from CDSM in Cape Town must be used to convert ellipsoidal to orthometric values. The Client must approve this methodology as opposed to spirit levelling so as to model the Geoid.

c) Refer to paragraph 5.7 “Ground control for Lidar surveys” for the detail requirement on the establishment of permanent ground control for Lidar surveys.

6.9.6 Formats for final submission to Client

In addition to the requirements specified in paragraphs 12.1 “General – all surveys” and 12.13 “Orthophoto production” the data must also be supplied in the following formats:

a) Imagery formats:

i) GeoTIFF – highest possible resolution to offer detail view of ground features.

ii) Enhanced Compression Wavelet (ECW) – compressed format which offers high resolution, slightly lower than GeoTIFF, but which is more resource effective in CAD environments. A compression ratio of 5 shall be applied.

iii) Sample photo images at the start, middle and end of the project in TIFF format.

b) Laser data formats: (DTMs)

i) Binary formats for further analysis – LAS.

ii) TIN format in MicroStation DGN and AutoCAD DWG formats.

iii) DTM in Model Maker and Civil Designer formats.

c) CAD formats:

i) MicroStation DGN and AutoCAD DWG formats.

d) Line mapping:

If line mapping is required, then the formats and requirements as specified for photogrammetric detail surveys shall apply.

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7. CADASTRAL DATA AND CADASTRAL KEY PLANS FOR TOPOGRAPHICAL AND OTHER SURVEYS

This chapter deals with the sourcing and production of Cadastral Key Plans used for Topographical and other surveys and where the cadastre is of both as yet unregistered as well as registered properties.

7.1 General

The purpose of this phase is to provide current and accurately calculated Cadastral information.

Cadastre **excludes** short term leases, the internal boundaries of separate mining titles which constitute a single mining property, but shall **include** all farms, subdivisions, smallholdings, township erven, servitudes, long term leases, declarations, proclamations, etc., located within the area of interest or surveyed and as at the date of the survey.

Important note: All Cadastral data must be calculated from source i.e. No digital spatial data from the Surveyor-General (S.G.) or any other source may be used as a Cadastral data set in the production of any other type of survey drawing.

7.2 Copies of diagrams

The primary source of Cadastral information must be the relevant office of the Surveyor-General, from whom copies of existing Cadastral compilation sheets and diagrams may be obtained.

7.3 Sorting of diagrams

7.3.1 Diagrams must be grouped in accordance with the 'parent' farms or blocks and in alphabetical order. Within each group the sub-divisional diagrams must be arranged in their S.G. number sequence.

7.3.2 Official S.G. numbers must be used for all diagrams.

7.4 Cadastral calculations

Calculations of Cadastral co-ordinates must be checked using acceptable survey techniques. A complete coordinate list in numerical order must be supplied.

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When using traverses, 'Helmut transformation', polars etc., all calculation must be checked against the residuals given by the relevant software. Closures exceeding Class C accuracy will not be permitted or accepted.

The cadastre at the start, end and on both sides of the survey project area must be calculated in such a manner so as to reflect the entire property(ies) i.e. properties may not be "cut off" and must be shown on the Cadastral Key Plan.

7.5 Cadastral plotting

7.5.1 Entire properties at the edges of a survey shall be reflected on the survey drawing which means they may not be "cut off".

7.5.2 Numbering of Cadastral Beacons

For ease of reference, all beacons used in the Cadastral calculations must be reflected in numerical order. Such numbers shall be noted in red if on Lo and in blue if on any other system, on the compilation plans as well as on the individual diagrams. These numbers shall not be annotated on the final plans.

7.5.3 All boundaries of servitudes and specifically rights of way declarations and proclamations must be depicted by 'dashed' lines except where these lines are also property boundaries.

7.5.4 The entire property affected by the survey must be calculated and plotted.

7.6 Cadastral drafting requirements

7.6.1 All Cadastral farm names must be depicted immediately outside of and at the top or bottom of the surveyed area. This will generally depend on the density, shape and size of the farm boundaries. It may be necessary in some cases to reduce the size of the farm name (not less than 3mm height), to be able to accommodate the name outside of the area surveyed.

7.6.2 Farm names must at all times appear on the edges of the mapping, on every plan and continuous sheet and depicted parallel to the main Cadastral boundaries.

7.6.3 Where properties are small such as in urban areas, careful discretion must be used when annotating the property description and numbers.

7.6.4 The Cadastral description i.e. farm name and S.G. number must be depicted for each farm, subdivision, servitude and especially rights of way.

7.6.5 Care must be taken to ensure that property descriptions correlate with their respective S.G. diagrams.

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7.7 Pen and letter sizes

7.7.1 For pen sizes see the drafting symbol list in **Annexure 21**.

7.7.2 Descriptions of both farms are required to be written along the common boundary line and adjacent to each other.

7.8 Cadastral key plan

7.8.1 Unless otherwise specified, the Surveyor must supply a Cadastral key plan on a standard A0 size sheet(s), in digital format at a scale of between 1/5000, 1/10 000 or 1/25000, which is dependent on the density of the Cadastral information. The key plan must show the following:

a) All survey sheets, accurately plotted on the A0 sheet. A separate CAD layer depicting the survey sheets plotted, must accompany the digital key plan;

b) All farm boundaries, subdivisions and townships. The entire property affected by the survey must be plotted;

c) The extent of the survey area;

d) The edges of roads; and

e) Positions and numbers of all Permanent Survey Control beacons.

7.9 Submission of cadastral data

7.9.1 Cadastral records

All Cadastral data shall be copied to a CD / DVD under separate folders:

7.9.2 Index and S.G. diagram folder:

a) Must be alphabetically sorted with reference to the parent properties.

b) Data shall be supplied in digital format with a folder for each parent property.

c) Sub-folders shall be created for each portion number under the parent property folder.

d) Folder names must refer to the property description.

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7.9.3 Compilations Folder:

Compilation sheets must be saved in sequence, in PDF format.

7.9.4 Co-ordinate Folder:

All co-ordinates to be supplied in Excel format and labelled so as to identify the contents thereof.

7.9.5 Calculations Folder:

All calculations, residuals and co-ordinate lists must form part of the Cadastral records on the CD / DVD.

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8. ENGINEERING AND STRUCTURAL SURVEYS

This chapter covers specific instructions to the Surveyor with respect to engineering and structural type surveys. The intention is also to standardise all outputs and deliverables.

8.1. General

The Surveyor must ensure that at all times the setting out/survey data is compliant with the requirements for setting out of plan data onto the ground or for the collection of ground data and displaying such data on a plan by applying the correct scale and height above sea level corrections.

8.2. Staking (Setting out)

8.2.1 Staking of road alignment

a) Purpose of the survey

The purpose of this survey is for the setting out of survey points, both temporary and permanent and on pre-calculated positions in the field. This may also include the gathering of sufficient field data for the geometric design of a road and before such road is constructed (Sectioning).

b) Phases of the survey

The following are generally recognised as separate phases of this type of survey:

i) **The Basic Survey:** This being the establishment of a horizontal and vertical survey network of Permanent Survey Control beacons (including the supply of all related records) in instances where no Permanent Survey Control beacons were established during previous surveys. See Chapter 5 “THE ESTABLISHMENT OF PERMANENT AND OTHER SURVEY CONTROL POINTS”.

ii) **Staking:** This being the setting out and fixing of the road alignment Key Points and the road alignment intermediate points on the ground whether this is undertaken by centreline or offset staking (with or without referencing).

iii) **Sectioning:** This being the field survey work required to determine the ground profile for the production of long- and cross sections. Note: This phase does not always form part of the staking work unless specified by the Client.

iv) **The Plotting:** This being the extraction and drawing of long- and cross-sections where sectioning forms part of the instruction.

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v) **Checking:** This being the final checking of all information and the supply of all check related records.

vi) **Submission of records:** This being the provision of data that is to be submitted to the Client on completion of the survey project.

c) General

Provision is made for four methods of staking:

i) Normal centre line staking without referencing;

ii) Normal centre line staking with referencing;

iii) Offset Staking without referencing; and

iv) Offset Staking with referencing.

Prior to commencing with such survey, the Surveyor must confirm which method of staking is required and further whether cross-sections are required.

For the production of cross-sections without staking reference must be made to the Chapter on Digital Terrain Models (DTMs).

i) The staking interval

Unless otherwise specified by the Client, the standard staking interval is 20m and 10m in the case of curves with radii of less than 200m.

ii) Stake value

The stake value of any point shall be recorded in metres and to three decimals of a metre, e.g. 1276.320.

iii) Horizontal alignment

- Pre-calculation

The approved horizontal alignment must be supplied by the Client.

iv) Checking

A final co-ordinate list of all points and reference points must be submitted reflecting the differences between the staked coordinate and the co-ordinate supplied for staking.

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d) Basic survey

The provisions of Chapter 5 “THE ESTABLISHMENT OF PERMANENT AND OTHER SURVEY CONTROL POINTS” are applicable.

e) Staking

i) Setting Out of Road Alignment Key Points and Road Alignment Intermediate Points.

The Key Points, e.g. beginning of curve (BC), end of curve (EC), beginning of transition curve (BTC), beginning of circular curve (BCC), etc. and Intermediate Key Points at every even 200m along straights, e.g. 12 200 and 12 400, etc. and on curves every 100m, e.g. 14 100 and 14 200, etc., must be set out from existing Permanent Survey Control beacons. Intermediate Key Points less than 5m from a key point need not be placed or referenced. In the case of curves of less than 200m radius, the position nearest to the centre of the curve must be an intermediate key point.

The centre line intermediate points (20m interval points) required for cross- and longitudinal sections shall be set out from Key Points, Intermediate Key Points or Permanent Survey Control beacons.

All staked key- and Intermediate Key Points shall be recorded for positional checks after the peg has been established in the field. A comparison between the supplied and placed co-ordinate shall be made and submitted with the final data.

- Peg sizes for Key Points

  Steel pegs of a minimum diameter of 10mm and of 300mm in length shall be used for all Key Points.

- Concreting of Key Points

  Pegs for Key Points shall be placed in a concrete casting (minimum depth of 200mm below the ground). The concrete casting must be of a minimum diameter of 200mm and must be moulded so that the peg protrudes not more than 5mm above the surface of the concrete (unless otherwise specified). Refer to Paragraph 5.1.1(f) “Construction of the Permanent Survey Control beaconing” for strength of concrete and Paragraph 5.1.1d) “Numbering of beacons” for numbering and lettering.

  Key Points must not be used until the concrete has set properly.

- Marking of Key Points

  Key Points shall be marked by a cairn of stones of at least 0.3m height and coated with a durable white lime product.

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Intermediate points must be suitably marked to facilitate the measuring and heighting of the cross-sections. Unless specified, pegs are not required to be placed.

ii) Heighting of key and intermediate points

- All staked key and Intermediate Key Points and their reference points (if placed) shall be spirit levelled and their full stake values recorded in metres.
- All Key Points shall be spirit levelled.
- Forward and reverse spirit levelling must not be carried out simultaneously with the same instrument, even if two different staves are used.
- The intermediate points need not be spirit levelled, but may be determined by tachometric or GPS methods, provided that proof that the geoid was properly modelled and that the GPS base length was restricted to 1000m is supplied. The existing Permanent Survey Control levels must be used to model the geoid.
- Height differences of greater than 50mm between the top of the peg and actual ground level must be recorded and noted in the technical report.

f) Offset staking

Offset staking may be permitted only with the approval of the Client.

The offset stake values must be calculated to be perpendicular to the centre line. All Key Points staked at an offset shall indicate the distance and direction from the centre line (e.g. 2200/5m R) on the beacon.

g) Staking with referencing

i) Reference pegs

- As a general rule, reference pegs must be placed at 15m or 20m on either side of the centre line (depending on the width of the Road Reserve) and perpendicular to the centre line (i.e. at 90° to the tangent at the centre line). Reference pegs must be placed where they are least likely to be disturbed.
- The Surveyor must liaise with the Client so as to ensure that reference pegs are placed so as to be clear of any future earthworks.

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ii) Referencing requirements

- Straights- multiples of 200 metres.
- Curves- Begin Curves (BCs), Begin Transitional Curves (BTCs), End Curves (ECs), End Transitional Curves (ETCs) and multiples of 100 metres.
- Short curves under 200m in length- BCs, ECs, etc. as well as the peg nearest to the centre of the curve which shall be an intermediate key point.

iii) Horizontal accuracy

Reference pegs shall be placed within 20mm of their required true position in relation to the centre line peg.

The distance from the centre line of each reference peg must be recorded.

h) Numbering and lettering

i) Pegs indicating the position of the Key Points must be numbered and lettered so as to be read when facing in the direction of increasing stake distance.

ii) The point description (e.g. BC1, EC1, 12 200, etc.) must be punched with lettering of not less than 7mm in size on a strip of non-corrosive metal, 0.7mm to 1.5mm in thickness and firmly set in the concrete or by white road paint where pegs are placed in a tarmac or similar surface.

iii) In the case of reference pegs, the letters R (right reference) or L (left reference) and the offset distance must be displayed.

i) Specific requirements for the staking of the horizontal alignment on an existing surfaced road.

i) All relevant requirements stated above shall apply.

ii) Staked points shall be defined on the existing Road Surface as follows:

- A roofing screw driven flush with the surface of the road;
- A spot with minimum diameter of 10cm painted around the staked point; and
- The staked value painted next to the roofing screw-using road marking paint and recorded to three decimals of a meter for each key point and intermediate key point position. Decimals of a kilometer may be painted on the 20m intermediate staked positions.

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8.3 Long and cross sections

8.3.1 General requirements for cross sections on staked positions

a) This survey must be based on a network of Permanent Survey Control beacons and/or the staked Key Points;

b) No photogrammetric cross sections are permitted;

c) GPS equipment may not be used to determine elevation for points surveyed on the Road Prism (Toe line to toe line) or drainage structures;

d) GPS survey methods may be used for areas which are not on the Road Prism, provided that the Geoid has been correctly modelled using all the existing survey control points in the survey area and the latest South African geoid model. The base lengths are restricted to 1000m; and

e) Cross-sections must be taken at 20m intervals and perpendicular to the staked line and must extend 10m beyond the Road Reserve width, unless otherwise specified.

8.3.2 Long sections

Long sections must be derived from the cross-section measurements as well as from additional measurements taken on the centreline such as at features and changes of slopes.

8.3.3 Measurement requirements for longitudinal and cross-sections

Levels must be taken on the following features and their stake values recorded:

a) All changes in slope.

b) Top and toe of banks, water's edge and bed levels of water courses.

c) Beginning and end of Bridge decks.

d) Invert levels at both ends of Culverts.

e) Railway lines (both rails).

f) Road intersections (both edges).

g) Unless otherwise specified, the following positions shall be surveyed on the typical cross section of the road:

i) All changes of slope
ii) LHS Toe Line
iii) LHS Shoulder Breakpoint

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iv) LHS Edge Tar/Road Surface
v) LHS Yellow Line
vi) Centre Line
vii) RHS Yellow Line
viii) RHS Edge Tar/Road Surface
ix) RHS Shoulder Breakpoint
x) RHS Toe Line
xi) Up to the required width as specified

Refer to **Annexure 15** for expansion of abbreviation.

h) The height of the lowest conductor for power and telephone lines must be determined in relation to the centre line and both Shoulder Break Points of the proposed road.

The heights of power and telephone lines over an existing road must be determined in relation to both edges of the road. The position where the observation is taken must be depicted on the plans.

The height of power lines must not be measured with a staff or tape. The air temperature at time of measuring must be recorded and depicted on the longitudinal section.

i) Where the staked alignment ties into an existing road then levels must be established along the centre line of the existing road at 20m intervals and a distance of at least 200m beyond the staking. Unless otherwise instructed and with reference to minor accesses such levels must be taken up to a distance of 100m beyond the staking.

8.3.4 Omissions from plans

Any topographical feature which has changed or such a feature that does not appear on the survey plan within 50m of the staked line, must be surveyed and updated onto the existing survey plan.

8.3.5 Drawing of sections

a) Drawing of the longitudinal section (if required)

i) Unless otherwise specified, the longitudinal section must be prepared on a standard A0 size sheet and at a scale of 1:100 vertical and 1:1000 Horizontal.

ii) The direction of the profile must correspond to the direction of the increasing stake value on the layout plan.

iii) Each sheet shall begin on an even kilometer distance and there shall be no overlap between adjoining longitudinal sections.

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iv) Where a staked line ties into an existing road alignment the profile shall be extended as per Paragraph 8.3.3 “Measurement requirements for longitudinal and cross-sections”.

v) Additional features

The stake values and height of the following features must be shown on the longitudinal section:

- Beginning and end of Bridge decks;
- Culvert dimensions and invert levels (i.e. inside bottom);
- Railway lines (both rails);
- Intersecting road (both sides);
- Power and telephone lines, as well as height clearances; and
- Underground pipes and cables where their position is marked on the ground surface.

b) Drawing of cross-sections (if required)

i) Unless otherwise specified, the scale shall be 1:100 horizontal and vertical.

ii) Cross-sections shall be plotted parallel to the horizontal edge of the sheet and the stake value must increase from the bottom edge of the sheet towards the top of the sheet, commencing at the bottom left hand corner of the sheet.

iii) Abbreviations: Features must be depicted on the cross-section by using the abbreviations as specified in **Annexure 15**.

8.3.6 Data to be submitted on completion

Refer to paragraphs 12.1 “General – all surveys”, 12.14 “Staking of road alignment” and 12.15 “Cross sections on staked positions for roads”.

8.4 Placing of Road Reserve boundary beacons (non-Cadastral surveys)

8.4.1 Points to be staked

a) The co-ordinates staked are generally those co-ordinates of the Road Declaration and as published in the Provincial or Government Gazette.

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b) In order to clearly demarcate the Road Reserve, a permanent boundary beacons must be placed at the Bending Point of the proposed fence line. The co-ordinates as per the Declaration published are to be used.

8.4.2 Beaconing

a) The boundary beacons shall be a “Y” type iron standard weighing not less than 3kg per metre or an iron peg of not less than 20mm in diameter. The length in each case shall be not less than 600mm and shall be driven into the ground to a depth of at least 550mm. If the boundary beacon is on solid rock, a hole 10mm in diameter must be drilled into the rock and to a depth of 25mm. An identification aluminium tag must be affixed to the iron standard/peg. If deemed necessary, the iron standard or iron peg may be embedded in a symmetrical block of concrete. When the boundary beacon falls in soft sand/ground the length of the iron standard or iron peg must be increased sufficiently to ensure the stability and permanence of the boundary beacon.

b) Where the post(s) of an existing fence coincides with a Bending Point(s), then such fence post(s) may be adopted as the beacon. The top 200mm of the fence post must be painted red with durable oil-based paint.

c) Where the Road Reserve boundary crosses a fenced Cadastral boundary in rural and Urban Areas, Y-type iron standards as specified above must be placed at the intersection of the Cadastral boundary and the Road Reserve boundary so as to demarcate the declared width of the Road Reserve .

d) Where the Road Reserve boundary crosses a Cadastral boundary which is unfenced, then the intersection of those boundaries must be pre-calculated and marked as specified above for a Y-type standard.

e) All placed points shall be recorded for position checks after the peg has been established in the field. A comparison between the supplied and placed co-ordinate shall be made and submitted with the final data on completion.

f) It is to be noted that for some Road Authorities the Road Reserve will, either prior to or after completion of the road construction project, be surveyed by a professional Land Surveyor which will be utilise in the framing and approval of the relevant diagrams used to enable the Road Reserve to be created in Title.

8.4.3 Data to be submitted on completion

Refer to paragraphs 12.1 “General – all surveys” and 12.16 “Staking of Road Reserve boundaries and property beacons”.

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8.5 Placing of property beacons (Cadastral surveys)

8.5.1 Points to be placed

a) This generally entails the re-location of existing Cadastral beacons or the establishment of new Cadastral beacons for a sub-divisional type survey.

8.5.2 Beaconing

a) With respect to the placing of beacons, the Professional Land Surveyor must adhere to the following specifications:

i) 600mm Iron standards as described in Paragraph 8.4.2 “Beaconing” must be used as the beacon and placed in accordance with the Land Survey Act and the Regulation framed thereunder;

ii) Fence posts may be adopted as beacons, provided that they are of a permanent nature, and satisfy the requirements of the Land Survey Act and the Regulation framed thereunder; the top 200mm of all fence posts so adopted as Cadastral beacons must be painted green with durable oil based paint; and

iii) All beacons placed must be marked by a cairn of “white-washed” stones.

b) The placing of beacons is restricted to distances not exceeding 3km from any control point.

c) With respect to the beaconing of the Road Reserve, the Professional Land Surveyor must have regard to the following:

i) Where the Road Reserve has been previously demarcated but is at the time of survey not fenced, then subject to the following provisions, the staked positions may be adopted:

- Where a deviation exceeds a Y, X coordinate misclosure of 0.5m, the Bending Point co-ordinates as supplied must be adopted, provided further that; and

- Where an Acquisition Plan exists with co-ordinates then such co-ordinates shall be adopted.

ii) Where the Road Reserve has not been previously demarcated and is at the time of survey not fenced, then the bending point co-ordinates as supplied must be adopted, unless an Acquisition Plan exists with co-ordinates, then in that event such co-ordinates must be adopted;

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iii) Where the Road Reserve is fenced, it is generally common practice to adopt the fence line as the boundary, provided that no 'small slivers' are created between the fence line at the actual subdivisional boundary and that the adoption of such fence line does not vary the area as quoted on the relevant Acquisition Plan by a percentage factor which exceeds 10% of the area to be acquired. Where this tolerance is exceeded, then the Client must be immediately notified by the Professional Land Surveyor. If a fence post is adopted as a Cadastral beacon, the top 200mm of the fence post must be painted green using durable oil based paint; and

iv) Where a fence post cannot be adopted as a beacon, then the beacon placed must be in such proximity to the fence post so as to minimise this effect on the boundary.

8.5.3 Data to be submitted on completion

i) For beacon relocations, the data shall be submitted in terms of paragraphs 12.1 "General – all surveys" and 12.16 "Placing of road reserve boundaries and property beacons".

ii) For sub-divisional surveys, the data shall be submitted in terms of the Land Survey Act and the regulation framed thereunder.

8.6 The staking of kilometer marker positions on an existing surfaced road

8.6.1 Determination of horizontal road alignment on an existing surfaced road for the staking of route markers

The use of a vehicle mounted GPS to establish the road alignment is permitted for this survey, subject to:

a) The determination of the horizontal alignment co-ordinates where the maximum spacing shall not exceed 20m intervals. Distances between consecutive 20m centre line points must be converted to slope distances. Kilometer marker positions must then be staked at every 200m or 1000m on such slope distances.

b) The survey and recording of the kilometer values of existing provincial kilometer markers positions at approximately 5km intervals.

c) The determination of the horizontal alignment based on a starting point position and kilometer value supplied by the Client.

d) The end point kilometer (km) distance must be established and staked. The Surveyor must determine the distance of this end point in relation to the last whole km distance.

e) The data being supplied in a digital format to the Client shortly after the completion of the horizontal alignment survey and where the following is then relevant:

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i) Prior to commencing with the staking of the marker board positions the following must be undertaken:

- Position of the horizontal alignment i.e. kilometer slope distances, co-ordinates and heights based on a given start point and at 20m intervals in Excel format;
- Provision in the above file of the kilometer slope distance, co-ordinate and height of the end point;
- Provision of the slope kilometer distance, Y and X co-ordinates of the existing kilometer markers positions relative to the above alignment; and
- Provision of the co-ordinate list of all the centre line points at the required stake position (200m or 1000m) intervals in Excel format.

Note: This data must be verified by the Client and be returned to the Surveyor with the necessary comments/approval within 3 working days after such submission.

8.6.2 Staking of Kilometer Marker Positions

a) Determine the position to be staked which must be at an offset (from the edge of the road) from the centre line co-ordinates;

b) Staking the Kilometer Marker positions at a standard interval of an even 200 or 1000 meter slope distance and on an agreed offset to the road centreline which is generally 0.1m from the edge of the road;

c) Staking of terminal points (they are the start and end points of a route section and which may not be at whole kilometer distances) on the Road Surface. This point shall then be marked by a 1.8m y-type-iron standard (protruding 0.8m out of the ground) and painted white and where the top 300mm must be painted red. This iron standard must be perpendicular to the road centre line and placed 3m inside the Road Reserve.

d) The position of the staked points shall not differ from their theoretical position by more than 100mm.

8.6.3 Marking of the Staked Points

a) The staked points shall be reflected on the existing Road Surface as follows:

i) A roofing screw driven flush with the surface of the road;

ii) A spot with minimum diameter of 10cm painted around the staked point using white road marking paint; and

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iii) The staked value painted next to the roofing screw, recorded in kilometers and to one decimal of a kilometer.

8.6.4 Check Survey

a) The staked position must be recorded as WGS84 waypoints in a format that may be imported into a "handheld GPS" and which must be submitted to the Client. This data must also be used to compile a comparison list between the calculated and staked co-ordinate which must also be submitted to the Client on completion of this survey.

b) After completion of the survey the Surveyor must conduct a site visit together with the Client or the Client's representative so as to sign off the works.

8.6.5 Data to be submitted on completion

Refer to paragraphs 12.1 "General – all surveys" and 12.17 "Staking of kilometre marker positions on the existing Road Surface".

8.7 Structural surveys – Bridges, Culverts and Gantries

Note:

Structural surveys do not automatically include the survey of the bridge/culvert sites.

8.7.1 Purpose of the survey

The purpose of this survey is to collect sufficient and accurate As-Built information (dimensions and positions) of an existing structure for use by the design engineers.

Where an existing structure is to be widened then the extent of the survey will largely depend on the nature of such design and accordingly it is therefore very important that the exact scope of the survey and specific requirements for the drawings be first agreed with the Surveyor.

8.7.2 Phases of the survey

The following are generally recognised as separate phases of the survey:

a) **The Basic Survey:** This being the establishment of a horizontal and vertical survey network of Permanent Survey Control beacons (and the supply of all related records) in the event that Permanent Survey Control beacons were not established during previous surveys.

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b) **Structural survey:** This being the field survey work for the purpose of collecting sufficient and accurate As-Built information so as to be able to represent the structure on a drawing and for the production of long- and cross sections. As this phase is not generally included in the standard procedures, specific instructions must be issued by the Client in this regard to ensure that all critical aspects of the structure to be surveyed are captured.

c) **The Plotting:** This being the compilation of drawings which must specifically suit the requirements of a design engineer.

d) **Checking:** This being the final checking of all information and the supply of all relevant check records.

e) **Submission of records:** This being the final data which must be submitted to the Client upon completion of the survey project.

8.7.3 General requirements for the detail survey of existing structures

a) Structures to be surveyed

The Client will issue specific instructions and will describe each structure to be surveyed in accordance with the table below:

Structure Description	Km Ref.	Structure Centre Point Coordinates		Description of Structure Centre Point
		WGS 84 Rectangular		
		Y (meters)	X (meters)	

b) Survey equipment

i) Global Positioning System (GPS) equipment may not be employed for this survey.

ii) Only equipment that will satisfy the accuracy requirements shall be used.

iii) Laser Scanning in terms of Chapter 14 “LASER SCANNING FOR STRUCTURES, THE COLLECTION OF DIGITAL TERRAIN DATA AND ROAD SURFACE MARKINGS” and at paragraph 14.4 “Specific requirements for Stationary Terrestrial Laser Scanning (STLS) of Bridge structures” may be used, provided that requirements as per Chapter 8 “ENGINEERING AND CONSTRUCTION SURVEYS” are fully complied with.

iv) Photogrammetric terrestrial methods may be used provided that all requirements as per Chapter 8 “ENGINEERING AND CONSTRUCTION SURVEYS” are fully complied with.

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c) Survey control

i) The survey shall be based on a network of inter-visible Bridge Permanent Survey Control beacons. Refer to paragraph 5.3 “Specific requirements for the establishment of Bridge structure survey ground control”.

ii) Additional control, fixed to the same accuracy as for the Bridge structure control beacons may be required in order to enable all of the required positions on the structure to be observed.

iii) The establishment of Permanent Survey Control beacons around the Gantry is not a requirement. The survey must be based on the existing control along the route.

d) Points to be surveyed

i) Where the structure to be surveyed differs substantially from the standard structures as depicted in **Annexures 17 and 18** to this document, then the Surveyor must obtain clarification from the relevant Structural Engineer on the exact survey requirements and he must do so prior to the commencement of such survey work.

ii) Y, X and Z observation and dimension measurements must generally be in accordance with **Annexures 17 and 18**;

iii) Digital photos must be taken at different views for each structure surveyed and where the view point is described. Such photos and Annotation must be submitted together with the survey records;

iv) Surveyed positions represented by its point number may be shown on such photographs for clarity purposes.

e) Quality control

Office and field quality control must be undertaken on the works. After the drawings have been completed, then at least 10 check observations per structure must be observed in order to check the quality of the work. These check points must not form part of the structural survey data set. Check survey results must indicate the Y, X and Z differences between the data on the drawing and the check data. These check records must be submitted together with the other records of the project;

8.7.4 Specific requirements for a Bridge structure

a) The survey drawing must comprise the following 2-dimensional views (2D):

i) Top view (plan view);

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ii) Cross-section view – the number of sections portrayed must be determined by the type of structure so as to give a clear representation of the structure; and

iii) Both side views.

b) Features to be surveyed

i) The above named views must be surveyed showing the following levels and dimensions which must be measured:

- The total length of each span of each deck;
- The clear span of each span of each deck;
- The width and length of each support at top and bottom;
- The depth of the deck;
- The levels on top of the footings (foundation);
- Position of NJ balustrades, or any other balustrades or handles;
- Levels on the abutment and piers;
- Existing visible services through the deck;
- The soffit levels subject to the following and/or additions:
  - The minimum vertical clearance and all levels and positions on the soffit profile.
  - The level and position at the start and end of each span of each deck.
- The deck levels at regular intervals which shall not exceed 5m and at each end of each span along each edge and centre line of the deck;
- The kerb levels at the supports;
- The asphalt thickness at the kerb at end of the spans on each edge of deck; and
- Intersection angle or angle of skew relative to the river/road/railway line (Refer to **Annexure 27**).

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c) Three dimensional drawing (3D)

A three dimensional (3D) drawing to scale must be compiled showing a combination of the above named views in order to give an accurate representation of the structure.

d) Data to be submitted on completion

Refer to paragraphs 12.1 “General – all surveys” and 12.18 “Structural Surveys – Bridges, Culverts and Gantries”.

8.7.5 Specific requirements for a Culvert structure

a) For Culvert type structures refer to **Annexure 17**. In addition the following additional levels and dimensions must be given:

i) The levels on the top of the headwall, levels of the soffit below the headwall and levels on top of the deck directly behind the headwall at the inlet and outlet. These levels are required for both left and right hand side of the structure.

ii) The invert level at the inlet and outlet.

iii) The dimensions and the relative positions of the wing walls.

iv) The perpendicular width of each ‘opening’ and each support at the inlet and outlet where this is measured at the top and the bottom.

v) The position of headwalls relative to the centre line or staked line of the road.

vi) The angle of skew (Refer to **Annexure 27**).

vii) The extent of the concrete slab at the in- and outlets.

b) Drawings

i) If so instructed, the survey drawing shall be comprised of a 2D front view of the structure depicting all the surveyed dimensions.

ii) Culverts shall always be surveyed in terms of paragraph 8.7.5. ‘‘Specific requirements for a Culvert structure” and be depicted on the survey drawing in plan form. The observed points must form part of the survey data.

iii) In addition to the above the Surveyor may be instructed to prepare specific drawings of the Culvert.

Refer to **Annexure 17**.

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c) Data to be submitted if detail drawings are required.

Refer to paragraphs 12.1 “General – all surveys” and 2.18. ‘‘Structural Surveys – Bridges, Culverts and Gantries”.

8.7.6 Specific requirements for Gantry surveys

a) For gantry surveys and the presentation of the data refer to **Annexures 18.4 and 18.5.** In addition, the following additional levels and co-ordinates must be given:

i) The level on top of the concrete footings.
ii) The level on top of the foot plates.
iii) The level on top of the bolts.
iv) The level on top of the gantry (both sides).
v) The level on top of all sign boards.
vi) The co-ordinates of the setting out points (the centre point between the four outside bolts referred to as POS).

b) Drawings

i) The survey drawing must comprise of a 2D front side view and a top view drawing where all dimensions and levels are indicated as per **Annexures 18.4 and 18.5**.

ii) **Annexures 18.4 and 18.5** only serves as a guideline. The specific survey for different types of gantries must be surveyed by taking the requirements as shown in the annexures into account.

c) Data to be submitted

Refer to paragraph 12.1 “General – All Surveys” and 12.18 “Structural Surveys – Bridges, Culverts and Gantries”.

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9. MONITORING SURVEYS

It is to be noted that this is a highly specialized field and is difficult to cover all specifics for the different types of monitoring projects required by the industry.

This chapter therefore concentrates on general principles which must be complied with and attempts to make provision for anticipated special requirements of a Client.

9.1. General

9.1.1 Project Parameters

a) Subject to the action of forces (both natural and man-made), a deformable body is subject to changes to its shape and position. These changes may occur gradually or suddenly. It is therefore the determination of such movements and shape changes and the interpretation thereof that are the main objection of monitoring surveys.

i) There are both practical and scientific reasons for monitoring being necessary. Practical reasons include the verification of the stability of a structure to be able to assess the impact of any geological hazards, the early detection of the precursors to earthquakes or the determination of early failure signals for structures, embankments or slopes.

ii) Scientific reasons may include the need for the better understanding of the nature of displacements, the testing of new theories which may be applied to the design of structures and to establish prediction methods.

iii) Monitoring by means of survey methods may be defined as the determination of:

- Deflection and/or deformation of a structure. Deflection is a uniform displacement while deformation is random or irregular displacements;
- Subsidence of an embankment which includes subsidence due to underground mining; or
- 'Slip or slide' of a slope.

9.1.2 Project planning

a) With every case being different it must be evaluated according to the ruling circumstances of such case that an appropriate and cost effective monitoring system may be defined/designed after which the monitoring survey may be executed. The manner in which monitoring points are marked, the methodology and instruments used and the arrangement and number of observations taken materially depend on the precision and accuracy demanded by such survey and also the topographical and other

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relevant circumstances. Such geodetic monitoring measurements therefore must be designed for each individual case. There is therefore, by implication, no readily applicable 'survey recipe' that would be capable of meeting all scenarios.

b) The planning of a monitoring system includes but is not limited to the following criteria and which must be considered:

i) Structure/embankment/slope characteristics;

ii) Critical sections to be monitored;

iii) Geology surrounding the monitoring area;

iv) Topography;

v) Survey instruments and accessories;

vi) Economic; and

vii) Accuracy requirements.

9.2 Beaconing and targets

9.2.1 It is of fundamental importance to establish sound and stable reference beacons that are not affected by displacements and which will serve as a base for the monitoring survey. Beacons from which terrestrial observations (horizontal, vertical and distances) are to be observed from must consist of well-constructed Pillar Beacons with a 'forced centering' facility. Permanent Bench Marks for monitoring levelling must be constructed on a sound and stable formation. Refer to paragraph 5.2 "Specific requirements for the establishment of monitoring survey control beacons".

9.2.2 The selection of targets may vary from site to site and be subject to circumstances prevailing at the time of survey. These may generally however consist of a removable target/prism combination which must fit perfectly on a 'pin' embedded in the beacon or on the structure to be monitored or consist of a reflective target which is permanently fixed onto the beacon or the structure to be monitored.

9.3 Observations

The monitoring survey of a monitoring point may be undertaken as follows:

- Three dimensional (dy, dx dz); or
- Vertical only (dz); or
- A combination of the above methods which is determined according to the applicable circumstances and requirements.

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9.3.1 Horizontal and vertical observations

a) A network of beacons are required when three dimensional displacements are to be monitored by means of terrestrial observations and may be any of the following, depending on the specific circumstances:

   i) Intersections to fixed targets by observing horizontal and vertical angles;

   ii) Horizontal, vertical and distance observations to fixed reflective targets using a reflectorless Total Station; or

   iii) Horizontal, vertical and distance observations to fixed points that can accommodate a prism to observe to. This method is more expensive and time consuming than observations taken to reflective targets but these are more accurate and must be considered in certain instances.

b) The necessary accuracy may not always be achievable for vertical monitoring by means of the use of vertical angles due to factors such as the lack of certainty with regards to refraction parameters. Accordingly, precise levelling methods should be used where possible.

c) Specific care must be taken with respect to the following:

   i) Measurement of target and instrument heights where vertical displacements are being determined from vertical angles;

   ii) Temperature and barometer measurements. These are required to adjust distance observations in order to achieve a high order of accuracy. The effect of temperature is 1 ppm error for 1 degree Celsius and 1 ppm error for 5 millibar pressure;

   iii) Calibration of the Total Station. This is with special reference to distance measurements. The fixed network of control on site may also be used to determine the scale factor for the measured distances with the aid of appropriate software; and

   iv) Checking and calibration of prisms. This is to ensure that all prisms used yield correlated distances.

d) Observations must be undertaken with a Total Station which must comply with the following minimum specifications:

   i) Horizontal and vertical accuracy one (1) arc second standard deviation; and

   ii) Distances: +/- (1.5mm + 1.5ppm) or better.

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e) The observations must include two (2) arcs in the horizontal and in the vertical (i.e. 2 x circle left and right) and also the R.O (reference object). The R.O. closures shall not exceed three (3) arc seconds. Distances must be observed for each horizontal direction observed onto a monitoring point.

9.3.2 Precise levelling

a) Vertical displacements generally measured by means of precise spirit levelling. The accuracy and instruments used will be determined in accordance with the specific monitoring circumstances. For example, a concrete structure must be monitored so as to achieve an accuracy of sub millimetres whilst the accuracy required at a slip slope for example may be of a lesser accuracy due to the anticipated larger displacements. Accordingly the monitoring of concrete structures will demand a high order levelling instrument combined with the use of invar staves.

b) In some cases the vertical height measurement method may be used as this is the only method possible. The quality and repetitions with respect to the information gathered as compared with the high cost of carrying out three dimensional observations is relatively low with respect to the precise levelling.

c) Only high order precise level instruments shall be used. The accuracy requirement for such instrument shall be a 1mm standard deviation per km double run levelling.

d) The following procedures must be complied with:

i) A forward and a separate reverse level run must be observed;

ii) The accuracy for the forward and reverse levelling run shall not exceed 0.2mm between two consecutive monitoring points. If the difference between forward and reverse levelling between two consecutive monitoring points is greater than 0.2mm then that setup must be repeated;

iii) The distance between instrument and staff shall not exceed 20m so as to ensure the high accuracy demanded; and

iv) It is noted that in certain circumstances, where large displacements are anticipated, then the above specifications may be reduced.

9.4 Reduction, processing and analysis

a) The ‘raw’ horizontal and vertical data which is downloaded from the Total Station must be reduced so as to be able to compare, the first instance, the observations between circle left and circle right of an arc and, in the second instance, between the arcs to ensure that observations are fully compliant with the specifications and requirements demanded.

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b) The adjustment of the control network and monitoring target observations must be undertaken using a suitable 'least squares' adjustment program where all observed horizontal, vertical and distance observations are utilised. Special care must be taken in awarding realistic a-priori estimates for observations that are in accordance with the accuracy of the instruments as specified. In the adjustment a-priori estimates are to be used that reflect the accuracies of the instrument used. The adjustment of the observations requires a sound knowledge of geodetic survey principles and experience to be able to identify small errors.

c) The precise levelling data must be downloaded and reflected in a spread sheet with the following columns: From, To, Forward, Reverse, Difference in mm, Mean and Final Height.

d) The analysis of the results is a critical and material aspect of the monitoring project and where the results will be heavily scrutinized. The a-priori estimates need to match the a-posteriori estimates to achieve a theoretical ratio of 1. Error ellipses of network and monitoring points are necessary to determine the accuracy of point determination and to derive the possibility of real displacements.

9.5 Presentation of results

A written report which must *inter alia* highlight all the findings must be submitted. The results must be presented in such a manner that is both concise and understandable by the Client. The results must at least include displacement lists, graphs and where applicable subsidence contour plans. Error ellipse values of the control network as well as the monitoring points must also be included so as to indicate the reliability of the observations and fixing of points and to determine with a high degree of certainty the actual existence of a displacement i.e. the possible errors in the observations shall always be less than the minimum displacement values sought. Displacements are to be recorded in mm and contours on any subsidence contour plans are to be recorded in accordance with the magnitude of the displacements and accordingly contour intervals may vary from 1mm upwards.

9.6 Conclusions

9.6.1 The greatest care possible shall guide such monitoring surveys where the results achieved shall meet the objectives of a monitoring project which implies and demands a rigorous approach by the Surveyor at all times. These surveys are vastly different, when reference is made to demanded accuracies from all surveys as described in this manual.

9.6.2 Further, the following is again emphasised and the Surveyor 's attention is specifically drawn thereto:

a) Measurements to be undertaken in the shortest possible time so as to minimise the impact on such observations due to changing environmental/atmospheric circumstances;

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b) Quality control must have been completed and the Surveyor must be fully satisfied that sufficient and accurate observation has been taken so as to yield the required result before the Surveyor leaves the monitoring site. Unlike with other surveys, these types of surveys do not lend themselves to a 'return' visit so as to observe additional observation. This is clearly due to the likelihood of critical and material circumstances changing;

c) GPS equipment may be used for the establishment of a control network and where this is to be established over large distances and where normal terrestrial observations would yield less accurate results, provided that only 'static GPS' observations are carried out and where the results are obtained from post-processing of the GPS observations i.e. no RTK observation shall be permitted;.

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10. SUPERVISION AND CONSTRUCTION SURVEYS FOR THE CONSTRUCTION OF ROADS AND BRIDGES

This chapter outlines the responsibilities of the Supervisory Surveyor who will form part of the Client's supervisory team on construction projects and of the Construction Surveyor who forms part of the construction team.

10.1 Supervision Surveys (RE Team)

This section will focus on the most important functions which must be undertaken so as to carry out the necessary quality control on the construction activities and for the verification of all survey related quantities as then claimed in the contractor's payment certificate.

The Resident Engineer (RE) will generally determine what is expected of the Surveyor and how the Surveyor may assist him and his team of Engineers on site with their obligations and functions and, where using advanced survey techniques, these are then made appreciably more efficient.

Note: Also refer to paragraph 10.2 for the responsibilities of the Construction Surveyor on construction sites.

10.1.1 The purpose of this survey is generally to gather sufficient and specific information by employing various survey techniques so as to assist the RE in ensuring that the Road Project and its entire ancillary works are constructed by a Contractor to within specified tolerances. Accordingly the Survey System established by the Supervisory Surveyor on site must act as an efficient management tool for the RE and his team which he and his team will then utilise in, *inter alia,* the control of all earthwork volumes, the evaluation of any claims from the Contractor, the checking of claims and the final payment certificates issued by the Contractor, the checking of designs from a setting out point of view, the checking of all relevant setting out work carried out by the Contractor's Surveyor , the determination of specific quantities where the material surfaces are rapidly 'covered' and generally to undertake any survey that will assist or enable the RE to make speedy and informed decisions when making an engineering type evaluation of any aspect relating to the Construction Project.

10.1.2 Phases of the survey

a) The following is generally recognised as separate phases of this survey:

i) **The Construction Beacon Survey:** This being the establishment of a network of Permanent Survey Control beacons and the supply of all related records. The Permanent Survey Control beacons may either be pillar type beacons or be normal conical type beacons and where the choice is determined by the type of terrain. (See Chapter 5 "THE ESTABLISHMENT OF PERMANENT AND OTHER SURVEY CONTROL POINTS"). The Supervisory Surveyor shall

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ensure that these beacons are always based on the same Survey Datum as the survey which was undertaken for the design phase of the project;

ii) **The Survey of Ground Lines:** This is to serve as the reference datum for the determination of all quantities;

iii) **The Preparation of a Design Model:** This entails the merging of the design DTM with the origin of ground line DTM and which shall then serves as the 3D survey model against which all construction related surveys and earthwork quantities are correlate to;

iv) **The Checking of the Contractors Staking:** This entails a fully independent survey;

v) **The Measurement:** This being the gathering of sufficient survey records at specific times/periods so as to monitor the Contractor's progress and to determine as to whether the construction works are being constructed to within specified tolerances;

vi) **The Utilization of the Design Model:** This being the management tool utilised for supervision purposes and which includes the following:

- Evaluation of the construction works in relation to the design;
- Calculation and verification of quantities as per the payment items stipulated in the bill of quantities;
- Design alterations and additional designs;
- Evaluation of design alternatives to enable cost comparisons to be made; and
- Generally a management tool for effective site supervision.

vii) **The Collection of As-Built Data:** This includes the noting of all alterations made to the original design of the project.

10.1.3 General

a) It is imperative that, at the start of the project, the Supervising Surveyor has made himself specifically and adequately acquainted with the relevant 'Standard Specifications for Road and Bridge Works' of the Client where particular attention should have been paid to the sections dealing with measurement and payments.

b) The Supervisory Surveyor must also make himself fully acquainted with all contract documents, the bill of quantities, the detail drawings and all surveying information for the project.

c) The Supervisory Surveyor must, in conjunction with the RE then evaluate the contractor's setting out procedures so as to ensure that the complicated elements of

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the road design such as interchanges, structures and any other important aspects can be correctly and accurately placed. Refer to the relevant Standard Specifications.

d) It is extremely important that agreement is reached between the Supervisory Surveyor's measurements and calculations and those of the Construction Surveyor before any material is removed or covered. Where agreement on any differences with respect to the measurements is reached then this must be in writing and submitted to the RE for his approval.

10.1.4 Supervision survey guidelines

The Client will decide which survey methods are to be applicable for supervision purposes where this depends largely on the extent and nature of the project. The survey may be undertaken by conventional or advanced survey methods.

a) Construction survey control beacon survey

i) The Client is obliged to and must ensure that Permanent Survey Control beacons are timeously established such that the construction works may be efficiently set out. The spacing of such control will not exceed 300m. This control can then be used to establish secondary and tertiary control so as to facilitate the efficient and practical setting out of the works.

ii) The Surveyor must therefore ensure that such control is established in accordance with the Client's requirements and must be in accordance with the specifications for the establishment of Permanent Survey Control as described in Chapter 5 "THE ESTABLISHMENT OF PERMANENT AND OTHER SURVEY CONTROL POINTS".

iii) The Permanent Survey Control beacons must be established on the same Survey System as that of the original survey for the design. In the event that there are other control beacons on site then the Supervisory Surveyor must first verify that these beacons are adequate and compliant before handing these over to the Contractor and the Contractor's Surveyor.

iv) Whilst the Supervisory Surveyor may undertake the survey of and establishment of the Permanent Survey Control beacons for the Construction Project, the planning thereof and the coordination of such survey shall be the responsibility of the Client. The RE will issue the final coordinate list and levels of such control to the Contractor prior to the commencement of any construction works. All surveys undertaken during the duration of the Construction Project must be based on this control.

v) It is often the case that adjacent construction projects are let simultaneously and accordingly the above named control must be carefully linked to the control of the adjacent contract. Should there be any discrepancies, these must be referred to the RE and the Client for further specific instructions.

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b) Protection of beacons

i) Where a Permanent Survey Control beacon is damaged during the construction phase then this must be replaced by the contractor at his cost, unless the RE has given written permission to the Contractor to remove/destroy such beacon. The Supervisory Surveyor must then confirm the new values of such a replaced beacon.

ii) Where existing Cadastral beacons may be destroyed as a result of the construction works then these must first be referenced by a Professional Land Surveyor before they are removed/destroyed. This procedure will in no way whatsoever exempt the contractor from the requirements of the Standard Specifications and the Land Survey Act.

c) The ground line survey (reference plane)

The 'ground line' must be surveyed and the DTM created will serve as the reference datum for the determination of all earthwork quantities. The survey may be undertaken at regular cross section or by means of a random Digital Terrain Model (DTM) sufficiently accurate so as to create a true representation of the 'ground line' terrain. Such ground line surveys must be undertaken in all areas affected by the construction works and/or as dictated by the bill of quantities such as Quarries, Borrowpits, spoil areas, road and Bridgework areas etc.

d) The preparation of a design datum model

This entails the merging of the design DTM with the origin of ground line DTM and which shall then serve as the 3D survey model against which all construction related surveys and earthwork quantities are to corelate. All surveys then carried out to determine whether the construction of the works is within specified tolerances and all surveys carried out to determine/verify interim or final quantities (where a material layer to be measured will be covered over) must be entered into this model and is then utilised to determine such interim quantities (final as per the above). In addition this design datum model must be utilised for the check surveys on the Contractor's setting out and to determine as to whether the location of all structures, road works and allied works are in the correct position where related to the actual design.

e) Layer works and the checking thereof

Levels taken on layer works must be undertaken using conventional spirit levelled techniques. Levels are taken on the predetermined cross-sections and on points on each cross-section such that, when compared to the actual design on an absolute level, difference may be deduced.

These differences are presented to the RE or his nominee who will determine as to whether the specific layer passes or fails from a level quality/tolerance perspective. Accordingly, GPS type equipment may not be used for this survey.

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DTM methodology may be employed under certain conditions. These are generally where a large project is underway and such larger works check are frequently required and where the tolerances are such that the interpolated cross-sections derived from the DTM meet the accuracy requirements.

f) Spirit-level Techniques

Where the determination of levels is achieved using standard spirit levelling techniques, then 'closed level runs' must be carried out i.e. circular runs where they 'close' back on the same start point are not permitted.

Levels to determine whether the works has been constructed to within the specified tolerances must be taken at predetermined positions which are derived from the design.

g) Digital Terrain Model (DTM) Technique

i) Where the DTM is created using tachometric measurements, then the surveyed positions may be taken in a regular grid fashion across the area concerned or at predetermined cross-sections at regular intervals. In the latter case it is important that the design levels are then pre-calculated at those same positions so that a direct comparison may be made. DTM observations must be restricted to a sight distance of 100m.

ii) DTM measurements may be undertaken with GPS instrumentation provided that such DTM is utilised only for the determination of progress/interim quantities and provided further that the local geoidal model determined from spirit levelling is utilised to correlate the GPS heights.

h) Measurements and submission thereof

i) Where quality control measurements are taken then such datasets must be submitted in a format where the adherence or non-adherence to specified tolerances is clearly recorded and where the non-adherence to respective tolerances is specifically highlighted. Such datasets must be 'signed off' by the Supervisory Surveyor prior to this being submitted to the RE.

ii) It is imperative and indeed the responsibility of the Supervisory Surveyor to ensure that all datasets relating to quality control and the verification of quantities are properly filed (hard copy and in recognised digital formats). Suitable backups ('father and son') must be made monthly and stored off-site.

iii) All phases of a construction project must be checked. Where 100% of the works cannot be checked as a result of circumstances or as directed by the RE, then a checking regime must be predetermined which is based on acceptable statistical methodologies and must be approved by the RE.

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i) Staking of Road Reserve fence positions

The bend points of the Road Reserve fence which is to be erected by the contractor must be staked at the official Road Reserve coordinates. These co-ordinates are either Cadastral boundary positions, acquisition boundary positions and/or declaration positions.

It is the responsibility of the Supervisory Surveyor to check the setting out of these positions and to ensure that the fence is erected in the correct position. A comparison between the official boundary co-ordinates and the fence position as constructed must be submitted to the RE and Client and marked as As-Built data.

j) As-Built data

The As-Built survey is the responsibility of the Supervisory Surveyor. This process entails the survey of all variations to the original design and the noting of such variations on the hard-copies of the design which are generally held on site. Refer to Paragraph 10.4.9 “Staking of Road Reserve fence positions” for Road Reserve As-Built data.

10.1.5 Standards of accuracy

The accuracy standards for all such surveys shall be as specified in Chapter 3 “SURVEY REGULATIONS AND STANDARDS OF ACCURACY” as well as the Standard Specifications for Road and Bridge Works and the Project Specifications.

10.1.6 Records

a) All relevant survey records compiled during the construction period shall be filed in an orderly manner so as to ensure that the information on all phases of the project may be readily extracted when and if required by the RE and/or Client.

b) All such survey records must be regularly backed up (Dual Backup – backup of the backup system) and safely stored off-site.

c) The final comparisons between the official Road Reserve coordinates and the comparative position of the erected fence must be submitted to the RE on completion of the project. The RE must sign off these records to indicate his acceptance of the results and so certifying that the fence has been erected in the correct position with reference to the published Road Reserve co-ordinates.

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10.2 Construction Survey

The purposed of this chapter is:

a) To give guidance to the Construction Surveyor and with specific regards to his responsibilities on a construction project.

b) To give guidance to both the construction and supervisory engineering teams with regards to their responsibilities towards the Construction Surveyor and design information that will be supplied.

Note: All surveys carried out in terms of the construction project shall *inter alia* conform to the principals, requirements and standards as set out elsewhere in this document

Also refer to paragraph 10.1 for the responsibilities of the Supervisory Surveyor on construction sites.

10.2.1 Setting out principals

It is important that the Construction Surveyor strictly adheres to all principals and requirements as stipulated in this chapter and also in the rest of this document when undertaking the 'setting out' work of a road for construction purposes.

10.2.2 Survey control

a) The Construction Surveyor must undertake all setting out work from the control points as per the original survey undertaken for design purposes unless otherwise instructed in writing by the Client.

b) The Construction Surveyor must establish additional survey control points having regard to requirements for Permanent Survey Control as stipulated in Chapter 5 "THE ESTABLISHMENT OF PERMANENT AND OTHER CONTROL POINTS".

c) The Construction Surveyor may be instructed by the Client to verify the quality and accuracy of the existing Permanent Survey Control as per paragraph 5.6 "Verification of existing Permanent Survey Control". A revised official co-ordinate list may then be issued by the Client in writing which is based on the findings of the verification survey.

10.2.3 Official co-ordinate list

a) A copy of the original co-ordinate list and survey report, signed by the registered Surveyor who established the control for the design survey must be submitted to the Construction Surveyor by the Client.

b) No setting out work may be commenced with until the Construction Surveyor has received the original or official co-ordinate list, unless otherwise specified by the Client in writing.

c) Existing/official survey beacons must be suitably protected by the Construction Surveyor against damage during construction work.

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Damaged/destroyed existing/official beacons shall be replaced by the Construction Surveyor. The final co-ordinate list, which shall be 'signed off' by a Registered Surveyor, must be submitted, within a reasonable time frame, to the Client after all construction activities have been completed

10.2.4 Instruments used for setting out

The Construction Surveyor must use appropriate instruments that are required for the setting out of the works so as to maintain the construction accuracy required. GPS equipment may not be used for setting out final levels for layer works or structures but may be used to set out the position of the profiles.

Where a Total Station is used to set out final levels then the range of all observations and readings must be limited and as defined by the instrument specification and a maximum distance from such Total Station may not exceed 100m.

10.2.5 Setting out data

The following information shall be submitted to the Construction Surveyor before any setting out work may be commenced with:

a) A digital text spread sheet containing the complete horizontal and vertical alignment information. This information shall include, but not be limited to, all curve and super elevation information, the start and end positions and all cross-fall percentages of all super elevation elements.

b) Profile templates for the road cross section (Template)

i) Road profile Template with all the relevant dimensions shall be supplied in digital or hard copy formats.

ii) The Templates shall be referenced to their relevant stake values (changes).

iii) The Templates must clearly define all relevant information of the road profile and must include but not be limited to the following:

- Stake offsets
- Design offsets
- Road profile
- Shoulders
- Kerbs
- Verges
- Drains
- Batters

iv) The stake values defining the transition from one Template to another must be supplied by the Client. This may be in the form of a drawing and/or digital spread sheet.

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c) Co-ordinates, in a digital text document, of all culvert inlet and outlet positions together with invert levels and pipe/box sizes.

d) A plan view digital drawing in DWG or DGN format geo-referenced to suit grids of the project and which can then be used to verify co-ordinates of construction elements shown on any construction drawing.

e) Any relevant information as requested by the Construction Surveyor, in writing to the Resident Engineer (RE), provided that such request is reasonable and will positively contribute to the quality and accuracy of all setting out work for the project and where the RE will be the sole judge of whether such request is reasonable.

10.2.6 Verification of design data prior to the setting out of the works

It is the responsibility of the Construction Surveyor to verify the completeness and functionality of the above information for setting out purposes in relation to the design drawings before commencing with the setting out of the works.

Discrepancies and/or incomplete information must be reported to the Client in writing who must then re-issue the outstanding data and/or corrected design information before the setting out work may be commenced with.

10.2.7 Quality Assurance and Verification of setting out of the construction work

a) The Construction Surveyor must submit all relevant survey checks as required by the Client for quality control of the construction work. The Client may elect to undertake his own checks of the works to verify the Construction Surveyor's checks. (Refer to paragraph 10.1 for guidelines on supervision surveys for construction of roads and bridges).

b) Such quality assurance checks shall include but not be limited to the following:

i) All setting out records (batter boards, profiles, etc.).

ii) Layer work checks with statistic analysis as per the Standard Specifications applicable to the construction project.

iii) Setting out of structures and piling.

iv) Pre and post concrete shutter checks.

v) Any other quality assurance information as required by the Client.

10.2.8 Quantities

a) The Construction Surveyor must maintain and file all records of quantities calculated. The surveyed surfaces used to calculate the quantities and the quantity calculations may be requested by the Client for verification purposes.

b) All relevant surfaces must be surveyed for the calculation of quantities and as defined in the Standard Specifications applicable to the construction project.

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c) The following serves as a guide in the context of payment items for earthworks and which are ordinarily stipulated in the Standard Specifications for construction work. It is to be noted that the Client is within his rights to demand that all quantities measured may require verification and 'signing off' by a Registered Surveyor:

i) Original Ground Lines (OGLS)

Where minimal 'grubbing' is required in bush or plantation areas prior to the 'stripping' of topsoil, the Construction Surveyor must then survey the original ground lines which will then be the 'base' information for the works.

The payment item is normally referred to as "Clear and Grub".

ii) After Topsoil Strip (ATS)

The thickness of topsoil to be stripped must be supplied by the Client. Topsoil is normally moved from the road prism to behind the batter boards for future use on the cut or fill batters, but is subject to the Client's instruction.

The survey data of the ground surface after the topsoil has been 'stripped' will form the base from which all other operations will be measured. This surface is normally known to be the "Payline Surface".

The difference between original ground line and the payline will determine the total quantity of stockpiled topsoil.

This payment item is normally referred to as "Cut to spoil".

iii) Treatment in Place (TIP)

After the pay item "Treatment in Place" is completed on the fill areas, the resulting surface becomes the payline from which the fills and undercuts are measured.

The Surveyor needs to survey this surface prior to any fill or undercut operations are commenced with.

This payment item is normally referred to as "Roadbed Preparation".

iv) Undercuts (UC)

Undercuts are normally done after a written or verbal instruction from the Resident Engineer has been received. The undercut depth in fill areas is quoted as the depth below the after topsoil strip level (Payline) or below finished road level.

The undercut depth in cuttings is quoted as the depth below formation (bottom of lowest layer) or below the finished road level.

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After inspection by the RE, and where possible treatment in place is done, the Surveyor must survey this surface as determined by the RE.

This payment item is normally referred to as “Remove Unsuitables/Undercut”.

v) Backfill of Undercuts

If a specialised type of material is used for backfill, such as rock fill, rock toes, 8 pass material, graded sand or stone the compacted surface must be surveyed.

This payment item is normally referred to as “Cut to fill” and is measured in the fill and not from the source (cut).

vi) In Cuts

In cuts the after topsoil strip surface would become the first surface.

The material in the cut can be classified in various surface groups:

- Fill material

  This may be placed directly into fills where it is paid for in the fill after the surface has been surveyed for final quantities.

  This payment item is normally referred to as “Cut to fill”.

- Cut to spoil

  Material not suitable for fill.

  Subject to instruction from the RE, this top surface must be surveyed before it is moved from the cut.

  Likewise as soon as good material is encountered, the Construction Surveyor must survey this surface, thereby establishing the quantity of “Cut to spoil”.

  This payment item is normally referred to as “Cut to spoil”.

- Intermediate or rock material or boulders

  When harder material is encountered in the cut, this surface should be classified by the RE. These surfaces must be surveyed. Further surveys may be required so as to accurately determine this quantity.

- Material to be placed into a stockpile

  As specified by the RE, there are two scenarios requiring survey:

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The top surface area before any material is moved from the cut, must be surveyed in the cut. The bottom surface area after the stockpiling is complete, must be surveyed in the cut to determine the new reference plane for future measurements.

The cleaned, grubbed surface of the stockpile site is to be surveyed before any material is stockpiled. The stockpile can be surveyed afterward to determine the volume stockpiled. Bulking factors agreed with the RE should be applied to determine the "tight volume" alternately it can be measured at the source (cut).

This payment item is normally referred to as "Stockpiling material".

- Roadbed preparation or treatment in place will be done, if required, when the cut reaches the formation level. No survey of this surface is required. This is quantified by reference to the design.

  This payment item is normally referred to as "Roadbed preparation".

vii) In Fills

- Benching

  The width of benches in the roadbed is to be determined by the Engineer where slopes of greater than 1:10 are found. The method for claiming the bench quantities must be agreed with the RE (paid as "cut to fill" or "cut to spoil") and determined by surveyed measurements. A better option would however be to determine the quantities by reference to the design.

  The material to construct fills may also be classified into different surface groups:

  – 90% fill

    This fill material is soft material from a borrowpit, quarry or cuts.

    Any change of surface (type of fill), must be surveyed for quantity purposes.

    This payment item is normally referred to as "Cut to fill".

  – 8 Pass material

    This is rock with a layer thickness of not more than 500mm.

    The Surveyor needs to survey the bottom surface before 8 pass material is placed and then again after the surface is completed.

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– Rock fill or rock toe

Rock layer thickness of greater than 500mm.

Any change of surface (type of fill), must be surveyed.

viii) Borrow areas

The borrow area must be grubbed where the original ground line remains undisturbed before the Construction Surveyor surveys the original ground line surface.

The borrow area must be surveyed after the topsoil and overburden material has been removed and importantly prior to any useable material is removed from the borrow area.

This payment item is normally referred to as “overburden” or “cut to stockpile” as determined by the RE.

ix) Non pay item operations

Survey records shall be maintained/filed where any earthwork operation carried out is not determined by a payment item or where an operation has to be repeated for any reason.

Where work is to be claimed for under “Dayworks”, the RE must be informed before the operation takes place. The quantities and hours that are claimed under “Dayworks” must be submitted to the Construction Quantity Surveyor immediately so that the quantities and hours may be ‘signed off’ by the RE.

10.2.9 As built information

a) On instruction by the Client, the Construction Surveyor must submit all relevant as built data of the constructed works. The Client may elect to undertake his own as built surveys of the works so as to satisfy himself that the data submitted by the Construction Surveyor is within defined tolerances. All as built information shall be signed off by a registered Surveyor before submission.

b) Such as built checks by the Client may include but not be limited to the following:

i) All underground services laid

ii) All above ground services constructed

iii) Pipe culverts, box culverts and head walls

- All inverts
- Structure type
- Pipe diameter
- All relevant co-ordinates and levels shown on a construction drawing

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vi) Drains and other drainage structures

vii) Pile positions and cut off levels

viii) Final road and earthworks profile

ix) Road reserve boundary fence

x) Any other information requested by the Client

10.2.10 Data to be supplied

The Construction Surveyor shall submit all relevant survey data to the Client. Unless otherwise instructed, all survey and other data sets as specified in this document, shall be submitted to the Client.

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11. SURVEY DRAFTING

This chapter will cover all the requirements with regards to the final presentation of a survey CAD drawing.

These specifications and dimensions refer generally to CAD drawings at a scale of 1:1000. Where other scales are used these must be 'natural' scales and all symbols must be changed in relation to the scale used.

11.1 Drafting of topographical plans

11.1.1 Drawing requirements

a) The standard sheet size shall be A0 except if otherwise specified.

b) Where the extent of the surveyed area covers an area greater than a single A0 sheet then the final CAD work submitted shall comprise of a 'Continuous Model' drawing and A0 drawing sheets or as otherwise specified by the Client.

c) Continuous Model drawing

i) Continuous Models shall be submitted in 2D and 3D formats. The DTM points feature codes heights and DTM triangles (TIN) must be included in the layer structure of such drawings.

ii) A Continuous Model must comprise a single 'CAD drawing' covering the entire surveyed area i.e. a single digital sheet.

iii) This digital drawing must conform to all the drafting requirements for A0 hard copy sheets and as further specified below.

iv) It is noted that the design engineers generally use this Continuous Model for their design work. Hard copy A0 design sheets are then extracted from this Continuous Model as suited to their requirements.

v) A title block and co-ordinate lists are not required for this type of 'digital drawing'.

d) A0 drawing sheets

i) A0 drawings must be supplied in 2D format.

ii) No (TIN) triangles are required as a layer on the A0 sheets.

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iii) The Continuous Model as specified above must be used to extract the individual A0 survey sheets and in accordance with the approved sheet layout.

iv) Provided that the Continuous Model was compiled in accordance with the drafting specifications then there should be minimal CAD work required to ensure that each A0 sheet is fully compliant with the drawing specifications.

v) A0 hard copy drawings shall only be submitted on completion when instructed to do so.

11.1.2 General requirements for all CAD work

a) Survey drawings must obviously conform to the southern hemisphere conventions i.e. reflecting the correct sign (negative or positive) with respect to the actual grid values.

b) All observed 'spot shot' and feature codes must be incorporated into the Continuous Model in three separate layers i.e. code, height and position. The decimal point of the 'spot shot' must always represent the exact position where the 'spot shot' was surveyed.

c) The DTM 'triangles' for topographical ground surveys must form part of the Continuous Model and be incorporated as a separate layer and named 'DTM triangles'. TIN files for photogrammetric, Lidar and laser scanning surveys can be submitted in a separate folder and not as a folder for the CAD work.

d) Features determined by their grouped nature must be incorporated as separate CAD layers and as specified in **Annexure 20**. The layer structures must be recorded by layer name and not layer number. Careful checks are to be carried out to ensure features of the same or similar nature are not incorporated in different layers.

e) Lettering must be undertaken so that it reads as viewed from the bottom or the bottom right hand corner of a sheet.

f) Unless otherwise specified, only drafting symbols as per **Annexures 19 and 21** may be used.

g) An Overlap between adjacent A0 sheets is not required.

h) The North Direction sign must be reflected on each sheet so that it is in a prominent and easily visible position.

i) A 'schedule block' for the co-ordinate list must be shown on the left hand side of the main title block. The co-ordinates of all Permanent Survey Control which appear on the sheet only must be listed.

j) All datum information as it applies to the coordinates listed must be noted in the 'schedule block' of co-ordinates in the position shown.

k) Plan numbers shall be obtained from the Client.

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11.2 Drafting

11.2.1 The Material

Where the final drawings are required to be on film then such film must comprise of double matt and a stable base transparent film material of high quality.

Film parameters must comply with the following:

- Be between 0,075mm and 0,15mm thick;
- Be 841mm wide; and
- Be 1189mm in length (i.e. A0 Size).

11.2.2 Sheet size

The Continuous Model digital sheet size shall be determined on a case by case basis.

The individual sheet sizes shall be based on the A0 Deutsches Institut für Normung (DIN) size and guided further by specific Survey Requirements or as specified by the Client.

11.2.3 Sheet layout and the sheet layout key plan

a) Individual Sheet Layout

The drafting space must be maximised unless otherwise specified. For all road surveys the sheet layout must be directional from left to right where the direction is determined by the direction of increasing route chainage and section numbers. For non-road/non-linear related surveys, the north orientation must always point towards the sheet top.

b) Sheet Layout key plan

Prior to commencing with the final drafting of a strip or block the Surveyor must submit a sheet layout key plan to the Client for his approval. This must be to a minimum scale of 1:50 000. Plan numbers will be allocated by the Client and must be reflected on the final sheet layout key plan and in the defined spaces therefore. This also then forms a part of the Cadastral Key Plan. Also refer to Paragraph 11.2.3(c) on Key Plans.

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c) Cadastral key plan

The Cadastral key plan must be prepared on a standard A0 sheet and at an appropriate scale, showing the following information:

i) The survey sheets and sheet numbers;

ii) The cadastre within the project area. In urban (towns etc.) areas, block corners and street names are adequate;

iii) All Permanent Survey Control together with its number;

iv) The extent of the survey area. For road surveys the edges of the road must also be shown; and

v) All rivers and primary railway lines.

This sheet will generally be sheet 1 of the A0 sheet range to be submitted.

d) Standardization and uniformity of drafting procedures

In order to standardize drafting procedures, all digital maps must reflect a standardised look with respect to CAD layer names and terms used, colours, line weights and symbols.

Where there is a need for a specific configuration for the CAD work then this must be defined by the Client.

e) Co-ordinate grids and grid values

i) The relevant coordinate grid must appear on each hard copy or digital plan produced. The grid lines shall be 200mm apart and must extend across the plan using a line weight of 0 (zero). (i.e. the use and depiction of single crosses displaying the grid line intersections is not permitted).

ii) The complete coordinate value must be depicted on both ends of the grid lines using a 2.5mm letter size together with a line weight of 0 (zero).

iii) Unless otherwise specified, the table below indicates the grid intervals for various mapping scales that must be utilised:

PLAN SCALE	GRID INTERVAL (METRIC)
1:100	20 metres
1:200	40 metres
1:500	100 metres
1:1000	200 metres
1:2000	400 metres
1:5000	1000 metres

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iv) In addition to the above, grid lines must conform to the following:

- Between any two grid lines the scaled measured distance must be within .3mm of the theoretical distance; and
- The scaled distance for a metre must be within.3mm of its theoretical distance.

11.2.4 Spot heights

a) Where spot heights are annotated so as to emphasise certain topographical features then such Annotation must be aligned parallel with the bottom of the sheet.

b) It is again noted the decimal point of the spot height must serve as the position where the spot shot was surveyed. Spot heights must be depicted with one decimal point of a meter.

c) Spot heights must be of a text height and width of 1.8mm.

11.2.5 Contours

a) Contours must be depicted in two shades of brown.

b) Index contours, which generally occur at an interval 5 x (five times) that of the specified contour interval, must be drawn at a line weight of 1 (one) and must reflect the full contour value above mean sea level (MSL). The intermediate contours must be drawn at a line weight of 0 (zero), with only the last two digits of their value shown.

c) The text of the contour values must be 2.0mm text size and line weight 0 (zero).

d) Contour values must be depicted at both ends of each contour line and at intervals of ± 400mm measured along the contour line.

e) Generally the topography will determine the contour interval. Generally one meter contours are specified for 1:1000 scale drawings in moderate terrain.

11.2.6 Control points

a) Ground control

i) All Control beacons embedded in concrete must be depicted by two concentric circles of 1.5mm and 3.0mm diameter respectively.

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ii) Control beacon's name/number must be contained within a circle of 25mm diameter and placed in an appropriate position 'joined' together with the direction and using a line weight of 1 (one). The name/number indicated at its plotted position must then be removed i.e. not shown.

iii) Control beacon's name/number must correlate to that scribed on the aluminium plate fixed to the concrete and be indicated by a line weight of 1 (one) and 2.5mm text height.

iv) The Permanent Survey Control heights must be depicted to three decimal points of a metre where such heights were determined by the use of spirit levelling.

v) The Photo Control Points (P.C.) must be depicted by a 3mm diameter circle reflecting a horizontal and a vertical diametric line. The text conventions shall be as above for the Permanent Survey Control.

b) Photogrammetric control

i) Aerial triangulated points must be depicted by a circle of 3mm radius and no diametric lines.

ii) The name/number and height must be depicted using a 1.8mm text size. All other conventions are as per paragraph 11.2.6(a) "Ground Control".

iii) 'Tie' points must be depicted as aerial triangulated points provided that the number must prefixed by the letters CP.

iv) Photo centres must be depicted by a 'cross' of 4mm lengths and using a line weight of 1 (one).

All such numbering must be aligned parallel to the direction of the strip using a 1.8 text height and text width. The strip number must be depicted on the LHS of the 'cross'. The exposure number must be depicted in full and to the right of the 'cross'. Both such numbers must be underlined where such underlining is 15mm in length and to which an 'arrowhead' is added and pointing in the direction of the flight line.

11.2.7 Detail

a) Symbols Sizes (refer also to **Annexure 21** for the list of symbols and sizes)

i) Symbols Sizes

Symbols sizes must be depicted at an appropriate scale or as otherwise directed in this document.

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ii) Text sizes

The text sizes are indicated next to each symbol as listed (Refer to **Annexure 21**).

Text sizes must conform to the specifications in this document but shall always be greater than or equal to 1.8mm in height and 1.8mm in width.
General Annotation must be depicted with line weights of 1 (one) and with 2.5mm text sizes.

iii) Line thicknesses

The line thicknesses are indicated next to each symbol as listed (Refer to **Annexure 21**).

NB. All text shall be 'upright' where only capital letters or numerals are permitted.

iv) Colours

The colour intensity for **R**ed, intensity of **G**reen, and intensity of **B**lue (RGB) must comply with colour table.

b) Detail to be shown

Refer to the topographical survey specifications for all detail that must be depicted on the final plans.

11.2.8 Utilities

a) Roads

The status and official road number for all roads must be depicted as follows:

- Names of streets must be depicted as indicated on the relevant General Plan of such township or as determined from field records; and
- Road destinations must be depicted at road ends.

b) Bridges (NB: All dimensions shall be recorded in millimetres)

The name and number of a Bridge (e.g. B12: Glenroy Bridge) must be depicted (where this information may be obtained from the Client if a name and/or number is not displayed on the Bridge structure) must include the number of spans together with their horizontal and vertical dimensions (e.g. 3/1200 X 1600, i.e. number of openings/horizontal dimension X vertical dimension of the openings).

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c) Culverts

Unless otherwise specified, the Culverts size, its dimensions and invert levels must be depicted on the CAD drawing and as specified in **Annexure 17**.

Note: Surveyors may be instructed to compile a Culvert schedule. Refer to Annexure 22.

i) Box Culverts: Indicate the number of openings and horizontal and vertical dimensions (e.g. 2/4000mm x 2500mm BC).

ii) Pipe Culverts: Indicate the number of openings and the diameter (e.g. 600mm Ø PC or 3/600mm Ø PC).

d) Railway Lines

i) The names of all railway stations and railway sidings must be depicted.

ii) The destinations must be depicted at both ends of a railway line as shown on each drawing.

e) Power and Telephone Lines

i) Telephone Lines

Telephone poles shall not be connected with a continuous line but depicted by means of a short line on either side of the symbol circle.

ii) Power Lines

The specified symbol must be used, (i.e. power poles must be connected by a continuous line and the 'zigzag' symbol inserted approximately midway between the power poles or pylons.)

The height clearance (NB: not MSL) between the electrical conductor and the ground surface must be shown on the drawing at the position where it was surveyed. At least two such points must be depicted between poles or pylons. With respect to a road survey, such positions must be relative to a left and right edge of the road.

11.2.9 Topography: cuts and fills

Straight lines (using a hatching symbol) must be used to depicted cuts and fills. The bottom of the cut or fill must be depicted by a broken line unless the cut or fill line is superimposed onto another feature line. The top and bottom of cuts and fills shall always be used as break lines in the DTM.

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11.2.10 Contours, erosion, etc.

a) Contours

Contour values must be readable when viewed from the bottom or right hand side of the plan. These values must be depicted at the start and end of a contour line and also approximately every 400mm along the contour line. The contour value must be aligned with such contour line and where the full contour value for principal (index) contour is depicted and only the last two digits for the intermediate contour. Where the plan distance between principal contours is less than 10mm, then no intermediate contour values need be depicted.

It is imperative that care be taken to ensure that contour values at the start and end points of contours must not be depicted within the survey area. Within the survey area contour values must not cover any detail or a contour line.
Watercourses in such an eroded area must be depicted by the specified symbol with an arrow

b) Erosion

Indicating the direction of flow.

11.2.11 Buildings, trees, etc.

a) Buildings

All buildings must be depicted to reflect their actual shape and size and permanent buildings must be 'hatched'. Buildings such as schools, police stations, shops, factories, flats, offices, garages, hospitals, etc. shall be described according to the function they serve. Buildings for residential use will not have a description depicted.

b) Special features

Names of important features must be depicted.

11.2.12 Roads signs, etc.

a) Road signs must be depicted as per the symbol list in **Annexure 21**. Photographs of all road signs must be supplied in a digital photograph folder. Road sign positions must be numbered on the drawing. This number must correspond to the relevant photograph number as depicted in the digital photograph album provided.

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11.2.13 Vegetation

a) Cultivation

Only perennial crops are required to be described.

b) Orchards, vineyards and hedges

These must be fully described, (e.g. "Vineyard"). In the case of orchards the type of fruit shall also be recorded.

11.2.14 Drafting quality

Drafting shall be of a high quality where its neatness, uniform standard and clarity is of great importance. Generally all conventions described and specified must be fully adhered to so that the final drawing reflects a high quality, professional product.

11.3 Cadastral

11.3.1 The symbolisation of Cadastral boundaries must be strictly in accordance with the line symbols for different features and scales and as specified in the list of symbols in **Annexure 21**. Descriptions must correlate exactly as they appear on the title deed and SG Diagram. Where a re-designation has been effected, this fact must be noted. Text sizes must be as per the list of symbols but may be changed to suit changed circumstances where small properties exist, but shall not be less than 5mm in size.

Cadastral farm boundaries must be specifically highlighted in accordance with the requirements of the Client.

11.3.2 Information relating to all existing proclamations and/or declarations must be depicted on the plans in accordance with the list of symbols. The Road Reserve must be a solid line where these coincide with the boundary line of a registered property. In all other instances, a broken line must be used. The Road Reserve Beacon point numbers must correlate exactly with the proclamation/declaration.

The proclamation/declaration number and Gazette number and date must be depicted on each sheet at an appropriate location on the plan.

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11.4 Title block, North Direction and sheet index

11.4.1 Title block

The title block layout and details must be obtained from the Client.

11.4.2 North Direction

The North Direction symbol must meet the requirements of the Client and shall appear on all sheets.

11.4.3 Sheet layout

Unless otherwise specified, sufficient space must be provided for a sheet layout in the right hand bottom corner of the working area of the sheet unless such provision is not already made for this in the individual title blocks. The sheet layout must depict at least three sheets of which the centre sheet is hatched so as to represent the active sheet. Sheet numbers must be depicted in the sheet layout. Where the sheet layout is complicated then more sheets should be depicted.

11.5 Office check

11.5.1 The Surveyor must submit the first completed sheet together with the relevant CAD data for approval prior to commencing with the remainder of the drafting work.

11.5.2 Field and office check records must be submitted together with the final plans.

11.6 Drafting symbols

11.6.1 For CAD and drafting symbols refer to **Annexure 21**.

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12. DELIVERABLES

This chapter prescribes all matters with respect to the datasets to be submitted to the Client on completion of a Survey Project. The approach is to standardise the datasets as far as digital formats are concerned and goes further to prescribe file and folder conventions that shall be used.
This chapter must be read with the requirements stated in the relevant chapter and the project specifications as all the deliverables are not always listed.

12.1 General – all surveys

12.1.1 All CDs/DVDs/hard drives delivered must be properly labelled and must depict the following information:

a) Complete project description and contract number;

b) Name of the survey organization responsible for the survey;

c) Project number;

d) Submission version number; and

e) Date of submission.

12.1.2 It is important to note that on each occasion that survey data is re-submitted after corrections and/or extensions have been done that the entire dataset be submitted again (i.e. not only the corrected and/or extended datasets). The Client will then delete the previous versions of the CD/DVD submitted in order to avoid confusion.

The CD/DVD labelling for all re-submissions must conform to the requirements in Paragraph 12.1.1 “All CDs/DVDs delivered must be properly labelled and must depict the following information:”.

Where extensions of the survey have been undertaken then this fact must be clearly reflected in such labelling.

Where ground surveyed DTM triangles have been spliced into a photogrammetric DTM the words “spliced DTM” must be stated in the labelling of the CD/DVD and also in the digital file name.

12.1.3 Project files, as per paragraph 12.2.1(d) “Project file in excel and Pdf formats”, must be submitted in hard copy format and in Pdf format and be submitted together with the rest of the datasets and labelled separately as a folder named “Project File”.

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12.1.4 Each and every delivery of data to the Client must be accompanied by a duly completed delivery note (on the Surveyor's letterhead) and which must state the following:

a) Project description, contract number and project number;

b) Every item delivered must be listed separately;

c) The content of the CD/DVD where every file name and the content of such files under the different folders is clearly reflected; and

d) All those outstanding items still to be delivered.

The delivery note must make provision for the Client to acknowledge receipt of such datasets.

12.1.5 A completed survey project must be accompanied by a compliance certificate and which is duly signed by a registered Surveyor. Refer to **Annexure 23**. Only one certificate is necessary for all phases of the survey project**.**

12.2 General requirements for data to be submitted on completion of a topographical survey project

12.2.1 Digital data

The following digital data must be submitted on completion:

a) CAD drawings

i) A0 sheets at the required scale in terms of Chapter 11 "CAD WORK" in 2D, AutoCAD and Micro Station formats;

ii) Continuous Model at the required scale terms of Chapter 11 "CAD WORK" in 2D and 3D, AutoCAD and Micro Station formats;

iii) Cadastral information as super imposed on the final survey drawings in terms of Chapter 7 "CADASTRAL DATA AND CADASTRAL KEY PLANS FOR TOPOGRAPHICAL AND OTHER SURVEYS";

iv) A layout key plan (A0 sheet) at an appropriate scale indicating the cadastre, the survey extent or road alignment, all Permanent Survey Control together with their number and the A0 sheet layout; and

v) The field and office checked drawings, unless specific instructions are issued that this is not necessary. No other hard copy drawings need be supplied.

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b) Digital Terrain Model (DTM)

i) 'Break lines' in 3D (to the same scale as the survey drawing in AutoCAD (.DWG) and MicroStation (.DGN) formats);

ii) DTM Triangle data in AutoCAD (.DWG), Micro Station (.DGN), Model Maker (.TOT) and Civil Designer (.CSD) – 3D format. The CAD format triangles must be submitted as a layer in the 3D continuous survey drawing for all ground survey projects. Triangles are not required on the individual drawing sheets;

iii) DTMs generated from photogrammetric and laser surveys can be submitted as a separate folder and not as a layer in the CAD drawing; and

iv) Spot shots feature codes, positions and heights must be submitted in three separate layers in the 3D continuous survey drawing for ground surveys.

c) Quality control

i) The check cross-section data (in Excel format) depicting the survey code, Y co-ordinate, X co-ordinate, test height, interpolated height and difference in height (ds);

d) Project file in excel and Pdf formats

i) Project files must, in addition to the normal prescribed formats, also comprise the following:

- Survey report in terms of **Annexure 1**;
- Co-ordinate list of Permanent Survey Control used and/or established in terms of **Annexure 12**;
- Level comparisons between the level and its check level together with the errors and the allowable closure errors;
- Calibration results with respect to the existing control and the trigonometric beacon(s);
- Permanent Survey Control verification report;
- Culvert and manhole schedules if relevant;
- Spot shot code descriptions;
- Photos for road signs if relevant;

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- Raw survey data for conventional and GPS surveying labelled in such a way that reductions and calculations by a second party can be undertaken with ease. Static GPS data used for post-processing shall be supplied in Receiver Independent Exchange (RINEX) format;

- Cadastral diagrams, compilations, general plans and co-ordinate lists; and

- Compliance certificate.

Note: The project file must be bound and indexed together with an appropriate front page and must include dividers separating the contents of the file.

e) Cadastral data in excel and Pdf formats

i) All SG diagrams, compilation sheets and general plans in PDF format; and

ii) Cadastral co-ordinate list in Excel format.

12.2.2 Hard copy data

The following hard copy data must be submitted on completion of the project:

a) Project files and the project records in accordance with Paragraph 12.2.1(d) "Project file in excel and Pdf formats". Hard copies of the 'raw survey data' and Cadastral data are not required;

b) Hard copies of the office- and field checked plans. A single plan may be utilised to reflect both these checks; and

c) Delivery note outlining all data submitted to the Client.

12.2.3 General

a) The survey drawings must be presented using the southern hemisphere convention i.e. reflecting the correct sign (positive or negative) as per the grid values;

b) All features must be stored in separate layers together with a description of each layer and must be submitted in 2D and 3D – (Y, X, Z) formats which will be utilised in AutoCAD and Micro Station software packages. The triangles of the DTM model must be provided in 3D and in separate layers in the 3D Continuous Model with the three individual sides of each triangle as two or three separate entities, each with its own (Y, X, Z) dimensions;

c) Spot shot positions, codes and heights must be supplied in three separate layers in the final continuous drawing for all ground surveys;

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d) The position, the number and the elevation of the Permanent Survey Control must be reflected in a separate layer in the CAD drawing. The Y, X, Z values must also be reflected in the co-ordinate table of the A0 sheet;

e) The Excel and the hardcopy co-ordinate list must be compiled in accordance with **Annexure 12.** The final Permanent Survey Control co-ordinates must be certified by a Registered Surveyor by way of a hardcopy certificate in the project file;

f) Plan numbers for the A0 sheets must be confirmed by the Client; and

g) Field and Office Checks must be undertaken on paper plots of the final A0 sheets and must be submitted. Generally no other hard copy plans need to be submitted.

12.3 Detail survey and Digital Terrain Model (DTM) – ground survey

Refer to Paragraph 12.2 “General requirements for data to be submitted on completion of a topographical survey project” for requirements.

12.4 Rail reserve detail and DTM survey

The following digital data must be submitted in addition to the general requirements stated in Paragraph 12.2 “General requirements for data to be submitted on completion of a topographical survey project”:

- Longitudinal sections of the top of the railway line rails per survey drawing; and
- Co-ordinates and heights of all the points contained in the rail long sections.

12.5 Bridge site survey: Road crossing

Refer to Paragraph 12.2 “General requirements for data to be submitted on completion of a topographical survey project” for requirements.

12.6 Bridge site survey: River crossing

The following digital data must be submitted in addition to the general requirements stated in Paragraph 12.2 “General requirements for data to be submitted on completion of a topographical survey project”:

- A separate Locality Sketch for each Bridge site area. The position and size of all existing structures located within three (3) kilometres upstream or downstream of the proposed structure must be shown, together with a description and a digital photograph of each such structure. Generally, only two (2) structures are shown; and
- If so instructed, the long and cross sections where these are depicted within an inset on the survey plans.

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12.7 Bridge site survey: Railway line crossing

The following digital data must be submitted in addition to the general requirements stated in Paragraph 12.2 “General requirements for data to be submitted on completion of a topographical survey project”:

- Locality Sketch depicted within an inset on the survey drawings;
- Longitudinal sections of the railway line rails on the survey drawings; and
- Co-ordinates and heights of each point contained in the railway line rail long section.

12.8 Borrowpit survey

The data must be submitted in terms of the general requirements stated in Paragraph 12.2 “General requirements for data to be submitted on completion of a topographical survey project”.

12.9 Borrowpit access road

The data must be submitted in terms of the general requirements stated in Paragraph 12.2 “General requirements for data to be submitted on completion of a topographical survey project”.

12.10 Staking of Borrowpit boundaries

A complete list of all the staked points for each Borrowpit must be submitted. The list must reflect the design co-ordinates, the staked co-ordinates and the differences between the design and the staked positions of these Y and X co-ordinates.

12.11 Aerial photography

12.11.1 The following records shall be supplied in respect of each project:

a) The entire negative film for each exposure and placed into the standard metal or plastic canister. With respect to digital images these must be in TIFF format;

b) The film index as prescribed in paragraph 4.1.4(d) “Film Index/Digital Image Index”;

c) A sets of contact photographs and/or diapositives depending on the project specification;

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d) A sets of scanned photo images in TIFF format depending on the project specification;

e) The Flight Plan as prescribed in paragraph 4.1.5 “Flight Plan”;

f) A Calibration Certificate for the aerial survey camera as specified in paragraph 4.1.2 “Camera”;

g) The Lidar photography where sample photo images at the beginning, middle and end of the project in TIFF format must be submitted;

h) A covering letter in which all the information being submitted is clearly listed;

i) All other datasets and items as prescribed for a specific project; and

j) The compliance certificate (Refer to **Annexure 23**).

12.12 Photogrammetric detail contour survey

12.12.1 The following data must be submitted in addition to the general requirements stated in paragraph 12.2 “General requirements for data to be submitted on completion of a topographical survey project”:

a) Aerial photographs/rectified photo images on which the Annotation was undertaken from;

b) Photo Ground Control sketches; Final aerial triangulation data;

c) Co-ordinate list of Photo Ground Control ;

d) Scanned photo images/diapositives used for the mapping;

e) Flight Plan showing the number and position of all Photo Ground Control ; and

f) Compliance certificate (Refer to **Annexure 23**).

12.13 Orthophoto production

12.13.1 The Following Data must be submitted in addition to the general requirements stated in paragraph 12.2 “General requirements for data to be submitted on completion of a topographical survey project”:

a) Digital ortho rectified images of the complete Orthophoto at the specified scale must be submitted in Geo TIFF format. (Continuous Orthophoto must be split into reasonably sized digital files);

b) Digital ortho rectified images per A0 sheet and in accordance with the sheet layout.

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c) Plotted A0 Orthophoto sheets (if instructed to do so);

d) Aerial photographs/rectified photo images on which the Annotation was undertaken from;

e) Photo Ground Control sketches;

f) Final aerial triangulation data;

g) Co-ordinate list of Photo Ground Control ;

h) Scanned photo images used for the mapping;

i) Flight Plan showing the number and position of all Photo Ground Control ; and

j) Compliance certificate (Refer to **Annexure 23**).

12.14 Staking of road alignment

12.14.1 The following data must be submitted:

a) Survey report in digital and in a hard copy format;

b) Horizontal alignment, as provided by the Client, in digital and in a hard copy format;

c) Comparison list between the theoretical and actual staked positions;

d) Co-ordinate list of Permanent Survey Control used for the staking;

e) Compliance certificate (Refer to **Annexure 23**).

12.15 Cross sections on staked positions for roads

12.15.1 Data to be supplied:

a) Survey report.

b) Co-ordinate list of Permanent Survey Control used for this survey.

c) Co-ordinate list of the horizontal alignment.

d) Cross-section data in Excel format using the following headings:

STAKED DISTANCE	OFFSET FROM CENTRE LINE	HEIGHT

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e) Co-ordinates, heights and feature codes for all cross section observations in Excel format.

f) Compliance certificate (Refer to **Annexure 23**).

12.16 Placing of Road Reserve boundaries and property beacons

12.16.1 The following information must be submitted:

a) Survey Report;

b) Co-ordinate list of all beacons placed;

c) Co-ordinate comparison i.e. between the co-ordinates provided and those co-ordinates as staked/placed; and

d) Compliance certificate (Refer to **Annexure 23**).

12.17 Staking of kilometer marker positions on the existing Road Surface

12.17.1 The following data must be submitted:

a) Centre line data as surveyed;

b) Slope distances between points and calculated co-ordinates of the stake positions on the edge of the road;

c) Co-ordinates of the actual staked position i.e. where the roofing nail was placed;

d) The differences in Y and X between the theoretical and the actual staked position;

e) Co-ordinates of Permanent Survey Control used for the staking; and

f) Compliance certificate (Refer to **Annexure 23**).

12.18 Structural Surveys – Bridges, Culverts and Gantries

12.18.1 The following data where applicable shall be supplied for structural surveys:

a) Digital data to be supplied:

i) Drawing of the structure in 3D, AutoCAD and MicroStation format showing all the required dimensions and strategic points surveyed at a convenient scale when plotted on an A3 sheet (only bridges unless otherwise specified);

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ii) Drawing(s) of the different views in 2D, AutoCAD and MicroStation format;

iii) Co-ordinates and heights of all observed surveyed positions shall be added to the drawings by way of a table (All structures);

iv) Co-ordinate list of all the strategic points surveyed in an Excel format, together with measured dimensions and invert levels (All structures);

v) Photos of the different views of the structure (All structures);

vi) Raw survey data labelled in such a way so that the reductions and calculations may be readily undertaken by a third party (All structures);

vii) Co-ordinate list of Permanent and other Survey Control used for the survey (All structures);

viii) Results of the 'test' surveys undertaken (All structures);

ix) List of codes/abbreviations (All structures);

x) Culvert schedule (Only culverts unless otherwise specified); and

xi) Survey report (All structures).

b) Data to be supplied in a hard copy format:

i) All information as defined above save for the raw survey data; and

ii) Plans showing the office and field checks (All structures).

c) Compliance certificate (All structures) (Refer to **Annexure 23**)

12.19 Monitoring surveys

12.19.1 A written report in which the key findings are highlighted.

12.19.2 The results must be presented in a meaningful and concise manner so that the Client is able to make an informed decision.

12.19.3 The results must be presented in such a manner so as to clearly reflect the following:

a) Displacements;

b) Graphs;

c) Subsidence contour if relevant; and

d) Error ellipses for the central network and monitoring points where the absolute shifts is clearly evident.

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12.19.4 Displacements must be given in millimetres. The contours reflected on the subsidence contour plans must be determined in accordance with the magnitude of such displacements, and accordingly the contour intervals may vary from 1mm upwards.

12.19.5 Compliance certificate (Refer to **Annexure 23**)

12.20 Permanent Survey Control

12.20.1 Data to be submitted in digital and hard copy formats:

a) Survey report;

b) Co-ordinate list of Permanent Survey Control used and established in terms of **Annexure 12**. The final co-ordinates of the newly established Permanent Survey Control points must be certified by a Registered Surveyor and reflected on the hard copy of the coordinate list in the project file;

c) Level comparisons between the level and the check levels together with the actual and the allowable closure errors in terms of **Annexure 13**;

d) Calibration results with respect to the existing control and trigonometric beacons;

e) Vector data and residuals with respect to new control;

f) Raw survey data for conventional and GPS observations where these are labelled in such a manner that the reductions and calculations may be readily undertaken by a third party. Static GPS data used for post-processing shall be supplied in RINEX format; and

g) Compliance certificate (Refer to **Annexure 23**)

12.21 Verification of existing survey control

12.21.1 Data to be supplied in digital and hard copy format:

a) Survey report which must incorporate a clear recommendation to the Client and which is based on the verification survey;

b) Verification/comparison report;

c) Condition of beacon report;

d) Co-ordinate list of Permanent Survey Control used, established and checked;

e) Level data together with the allowable closure errors and which is used to verify the heights of the existing control;

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f) Calibration results with respect to existing control and trigonometric beacons;

g) Instruction(s) from the Client which are based on the verification report submitted; and

h) Compliance certificate (Refer to **Annexure 23**).

12.22 Supervision surveys for the construction of roads and Bridges

12.22.1 All survey records gathered, compiled and filed during the construction period. These must be submitted in an orderly manner so as to ensure that information on all phases of the construction project may be easily extracted.

12.22.2 Records of the completion survey, the final geometric alignment and all levels on the final layer must be submitted in digital format.

12.22.3 The comparison between the official Road Reserve co-ordinates and those of the erected fence must be submitted to the RE on completion. (The RE must sign this document as acceptance of the results and to certify that the erection of the fence position conforms to the official Road Reserve).

12.22.4 All records (in digital and hard copy format) relating to and which have a direct impact on and which have been used to:

a) Verify quantities for which payment has been made;

b) Undertake quality control surveys relating to the setting out and/or monitoring of the works;

c) Permanent survey control co-ordinates established and fixed;

d) Permanent survey control list submitted to the Contractor; and

e) Records of all disputes.

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12.23 Requirements for the submission of survey data

12.23.1 Data as listed below and relevant for a specific survey must be submitted in a digital and hard copy format as indicated below:

a) Drawings

i) Continuous and individual sheets
ii) Orthophotos

b) DTM data

c) Break line data

d) Co-ordinate lists of Permanent and other Survey Control used and established

e) Level diagram

f) Level reductions

g) Level comparisons

h) Project file (in PDF format)

   i) Index
   ii) Survey report
   iii) Co-ordinate list
   iv) Working plans
   v) Level diagrams

i) Compliance certificate

j) Raw survey data

k) Calculations and residuals

l) Field and office check results

m) Aerial triangulation results and residuals

n) Flight Plans

o) Flight Plan showing Photo Ground Control points

p) Culvert schedules

q) Cadastral data

r) Key plan indicating Cadastral, Permanent Survey Control points and sheet layouts

s) Aerial photos

t) Photographs of all road signs and structures

u) Comparisons relating to staking

v) Any datasets as prescribed per project

w) Quality control check lists

x) Hard copy

   i) Field checked plans
   ii) Aerial photo contact prints
   iii) Aerial films etc.
   iv) Index
   v) Locality plan of the survey

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vi) Survey report
vii) Final co-ordinate list
viii) Field Check results
ix) Quality control check list
x) Level comparisons
xi) Culvert schedule
xii) Manhole schedule
xiii) Photographs of road signs and all other photos
xiv) Compliance certificate (Refer to **Annexure 23**)

12.23.2 Data to be supplied for different types of surveys

a) CAD drawings

FOLDER	SUB-FOLDER	FILE NAME	FORMAT
CAD Drawings	DGN Drawings	Sheet1.DGN	Micro Station
		Sheet2.DGN	Micro Station
		Sheet3.DGN	Micro Station
		Continuous 2D.DGN	Micro Station
		Continuous 3D.DGN	Micro Station
		Keyplan.DGN	Micro Station
		Level diagram.DGN	Micro Station
	DWG Drawings	Sheet1.DWG	AutoCAD
		Sheet2.DWG	AutoCAD
		Sheet3.DWG	AutoCAD
		Continuous 2D.DWG	AutoCAD
		Continuous 3D.DWG	AutoCAD
		Keyplan.DWG	AutoCAD
		Level diagram.DWG	AutoCAD

b) Digital Terrain Model (DTM)

FOLDER	SUB-FOLDER	FILE NAME	FORMAT
DTM	Triangles (Triangular Irregular Network)	TIN.DGN	MicroStation
		TIN.DWG	AutoCAD
	DTM Data	DTM.TOT	Model maker
		DTM.CVD	Civil Designer
		DTM.XLS	Excel
	Break lines	Breaklines.DGN	MicroStation
		Breaklines.DWG	AutoCAD

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Note: Where ground survey DTMs have been spliced into the photogrammetric data, the word "splice" must be added to the file name.

Quality control

FOLDER	SUB-FOLDER	FILE NAME	FORMAT
Quality Control	Test results	Test.xls	Excel
	Test data	Testdata.xls	Excel
	Check list	Checklist.doc	Word

c) Project data

FOLDER	SUB-FOLDER	FILE NAME	FORMAT
Project data	Project File	Report.doc	Word
		Coordinate list.xls	Excel
		Coordinate list.PDF	PDF (signed by Surveyor)
		Levelcheck.xls	Excel
		Level reduction.xls	Excel
		Calibration.xls	Excel
		VerfificationReport.xls	Excel
		CulvertSch.xls	Excel
		ManholeSch.xls	Excel
		Codes.doc	Word or Excel
	Photos	Photo Number.TIFF	TIFF
	Aerial Photos	Photo Number.TIFF	TIFF
General	Raw Data	As descriptive as possible	ASCII or Excel
	Cadastral	Cadastral.DWG	
		Cadastral .PDF	
		Cadastral.DGN	
	Aerial Triangulation	AerialTriang.xls	Excel or any other format
	Flightplan	Flightplan.DGN Flightplan.DWG	MicroStation AutoCAD

Note: The Surveyor must submit all other data not stated above in this folder and using the same file name convention to describe such data in a clear manner.

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d) Sections (i.e. rail, road, river etc.)

FOLDER	SUB-FOLDER	FILE NAME	FORMAT
Sections	Long Section & Description*	LongsectionNo.DGN	MicroStation
		LongsectionNo.DWG	AutoCAD
		LongsectionNo.XLS	Excel
	Cross Section & Description	CrossSectionNo.DGN	MicroStation
		CrossSectionNo.DWG	AutoCAD
		CrossSectionNo.XLS	Excel

Note: *Indicate what type of section is being submitted by adding the following descriptions; rail, road, structure etc.

e) Site surveys (i.e. rail, road, river etc.)

FOLDER	SUB-FOLDER	FILE NAME	FORMAT
Site Survey	Specific Site Description	Refer to paragraph 12.23.2(a) for CAD drawings	
		Refer to 12.23.2(b) for DTMs	
		Locality.PDF for locality plan	PDF

Note: A sub-folder must be created for each site survey so as to indicate which site surveys have been submitted.

f) Borrowpits

FOLDER	SUB-FOLDER	FILE NAME	FORMAT
Borrowpits	Specific Borrowpit Description	Refer to paragraph 12.23.2(a) for drawings	
		Refer to 12.23.2(b) for DTMS	
		Control.xls	Excel (BP Control)
		BdyStake.xls	Excel (boundary staking data)

Note: A sub-folder must be created for each site survey so as to indicate which site surveys have been submitted.

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g) GPS data

FOLDER	SUB-FOLDER	FILE NAME	FORMAT
Control	Data	As per GPS	As per GPS
Topographic Survey	Data	As per GPS	As per GPS

- The GPS system and the Geoid used must be submitted.
- File names should reflect the coordinate system and Geoidal model used in each case.
- Separate reference station files should be submitted if necessary.

h) General

- Notwithstanding the above, data submitted must comply with the project specific specifications.
- Data to be submitted but which is not prescribed above must conform to the conventions as above.
- All data submitted must be in an internationally recognizable format.

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13. QUALITY CONTROL

This chapter covers the procedures relating to quality control and which will be undertaken by the Client on the different type of surveys as dealt with in this document.

Further, this chapter also covers the quality control work which must be undertaken by the Surveyor prior to the submission of a completed survey.

The following specifications will enable the systematic evaluation of survey work for acceptance or rejection:

13.1. Topographical surveys and Permanent Survey Control

All quality control work shall be undertaken by a Registered Surveyor.

All survey work undertaken under the above heading must be thoroughly checked and must be certified as having complied with quality standards as more clearly set out below.

Note: The Client will utilise similar quality control standards as those defined in Annexure 24. This may however vary according to project specific requirements.

13.1.1 Quality control office check by the Client

a) Check and certify the completeness of the data submitted where the following is relevant:

   i) That the survey project file is collated in terms of the project specifications;

   ii) That the information and data contained in the survey project file conforms to the project specifications;

   iii) That all work specified in the project specifications have been fully submitted;

   iv) That the digital data is submitted, documented and labelled and is compliant with the terms of the project specifications; and

   v) That the formats of all data submitted (digital and hard copy) fully complies with the project specifications.

b) Check and certify the completeness of the survey work submitted where the following is relevant:

   i) That all work as specified in the project requirements has been undertaken;

   ii) That the required area has been covered by the survey;

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iii) That the Survey System and the datum used conform to both the general standards and also to the special requirements as per the contact document or specifications; and

iv) That all required schedules conform to the prescribed requirements.

c) Check and certify the survey procedures where the functions as listed below conform to the project requirements, specifications and standard survey practices:

i) Horizontal fixing;

ii) Vertical fixing;

iii) Survey control verification;

iv) Tying in and calibration onto and with respect to existing control;

v) DTM and detail observations;

vi) Point numbering;

vii) Structural survey;

viii) Photogrammetric Photo Ground Control configuration;

ix) Photogrammetric Mapping and Orthophotos;

x) Methodology used for aerial triangulation and calculations;

xi) Long- and Cross sections; and

xii) Other work undertaken.

d) Check and certify the calculations and survey reduction procedures where the items listed below conform to standard survey practices and the specific requirements of the project:

i) Horizontal fixing;

ii) Vertical fixing;

iii) Verification of survey control;

iv) DTM and detail positions;

v) Permanent Survey Control values;

vi) Structural dimensions;

vii) Photogrammetric Photo Ground Control;

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viii) Aerial triangulation;

ix) Geo- referencing of the photo images for orthophotos;

x) Scanned images and Pixel size;

xi) Long- and Cross sections; and

xii) Other work undertaken.

e) Check and certify the specified accuracies for the phases of the survey project, as listed below, have been complied with:

i) Horizontal fixing;

ii) Vertical fixing;

iii) Verification of survey control and verification report;

iv) DTM and detail;

v) Permanent Survey Control;

vi) Structural dimensions;

vii) Photogrammetric Photo Ground Control;

viii) Aerial triangulation;

ix) Long- and Cross sections;

x) DTM checks undertaken by the contactor; and

xi) Other work undertaken.

f) Check and certify that the items listed below with reference to the CAD (Continuous Model and individual sheets) drawings conform to the specified requirements:

i) Title block;

ii) Description of the project;

iii) Route and section numbers;

iv) Survey project number;

v) Plan numbers;

vi) Sheet numbers;

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vii) Co-ordinate list;

viii) Survey system;

ix) Grid spacing;

x) Grid values;

xi) Drainage structures and invert levels;

xii) Cad symbols;

xiii) Contours;

xiv) Contour values;

xv) Spot heights;

xvi) Detail and transfer of field checked data onto the final drawings;

xvii) Embankments;

xviii) Destinations;

xix) Vegetation;

xx) Side drains;

xxi) Road numbers;

xxii) Under- and over passes;

xxiii) Cadastre;

xxiv) Ortho-photo image quality and sharpness;

xxv) Cloud cover and cloud shadows;

xxvi) The completion and neatness of all other features;

xxvii) DTM intervals and observation positions;

xxviii) DTM and triangle formation;

xxix) Break lines and the utilization of such break lines;

xxx) DTM digital data;

xxxi) CAD layers; and

xxxii) Check that the CAD data co-insides with the plotted sheets as submitted.

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g) Reporting

i) The Office Checks shall be reported on a check list consisting of all the different elements of the office check (Refer to **Annexure 24**).

ii) After completion of all the final checks, the survey must be certified as complete and compliant with the specified accuracy by a Registered Surveyor or professional Surveyor (Refer to **Annexure 23**).

3.1.2 Quality control Field Check by the Client

a) Permanent Survey Control

i) Check and certification that, with respect to the Permanent Survey Control, their positioning, construction and their stability conforms to the survey specifications and where the procedure is as follows:

- Undertake a check-survey of all the Permanent Survey Control (Normally 300m apart) spread over the entire extent of the project. This survey can be undertaken by using GPS equipment in order to check the relative accuracy of co-ordinate values in relation to the control itself and to the trigonometric beacons in the area. The heights shall be checked by one way spirit levelling in order to compare the height differences between the Surveyors' heights and the check survey heights. Horizontal calibration shall be done by including at least 3 trigometric beacons within the survey area. (No extrapolation shall be done. This calibration may change depending on the Survey Datum prescribed in the project requirements);
- Where horizontal and height errors are evident then these must be further confirmed as such by a further independent survey of that control that appears to be in question;
- A comprehensive report must be submitted where the following aspects are specifically dealt with;
- Quality of the beacon(s);
- The positional integrity and efficiency of its use;
- Distance from the Road Reserve fence or the Declaration boundary (where there is no fence);
- The beacons' stability; and
- The quality checks with reference to the control point's position (XY) and its height (Z) i.e. the actual differences as determined by the check data.

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Reference must also be made to **Annexure 14** in regards to the beacon verification report.

b) Check cross sections

i) Check and certification that the DTM heights conform to the accuracies as per the project specifications.

- Check Cross-Sections must be carried out at 500m intervals which must extend to the full width of the survey area and where all changes of the slope and the features of the Road Prism are surveyed. Such Check Cross-Sections must be observed from the Permanent Survey Control established for the survey project. No GPS observations are permitted and the observations undertaken by a total station survey instrument must be limited in distance to 150 meters Photogrammetric and lidar surveys shall be checked up to 75m outside the road reserve.

c) DTM height comparisons

i) Co-ordinates and the heights of all cross section points surveyed must be calculated; and

ii) The heights for those positions must then be interpolated from the contractor's DTM. A comparison must then be made between the observed 'check' heights and the interpolated heights.

d) Topographical Detail accuracy

i) Detail as specified must be observed and its position calculated. Such positions must then be compared with coordinates as derived from the digital CAD drawing.

ii) Such quality checks must be spread over the entire survey project. The number of check points surveyed is left to the discretion of the Surveyor but must be sufficient to be able to evaluate the accuracy of the detail. The result hereof must be highlighted in the quality control report.

e) Drainage structures

i) Spot checks with respect to the dimensions and invert levels must be undertaken and based on a sample of at least 20% of all structures. The results hereof must be highlighted in the quality control report.

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f) Final quality control report

i) Field Check results must be submitted in separate tables for each of the following:

- Permanent Survey Control;
- Cross Sections (DTM);
- Topographical detail; and
- Drainage structures and, where the contractor's survey, the quality control survey and the residuals (errors) are listed.

ii) Statistical accuracy results must be specifically reported on where a scientific assessment is made on the general accuracy of the entire survey where the Road Prism and the Road Surface are particularly highlighted.

iii) 'Test' results must be expressed as percentages in relation to the total number of test points and where these are grouped in 30mm steps from 0mm to 30mm up to 0mm to 500mm. Errors exceeding 500mm must be highlighted and separately recorded.

iv) With respect to photogrammetric surveys the above may be extended to 1000m where 50mm steps are used.

g) Certification

i) The Registered Surveyor undertaking the quality control survey must certify his findings in writing and must specifically express a view on the completeness, quality and accuracy of the survey checked.

ii) Recommendations in regards to any re-surveys must be made by the registered Surveyor.

iii) Once the registered or professional Surveyor, undertaking the quality control survey, is fully satisfied then he shall certify as such in writing.

13.2 Checking (quality control) by the Surveyor prior to submission of the data

13.2.1 General

The Surveyor must be fully conversant with the checks to be undertaken by the Client. Refer to paragraph 13.1 "Topographical surveys and Permanent Survey Control" above.

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The Surveyor must therefore ensure that the survey that he is required to perform not only conforms to the project specifications but that he pays specific regard to the checks that the Client will perform on his survey. For quality control check lists refer to **Annexure 24**.

13.2.2 The topographical Survey

a) In addition to the checks as specified for laser surveys, a test cross section must be surveyed every 300 meter of the entire extent of the ground survey and must be utilised as test points for the DTM once finalized. These test results must then be submitted with the final survey data. Test cross-sections for photogrammetric and lidar surveys shall extent up to 75m outside the road reserve.

b) The test cross-section must be surveyed using a total station survey instrument. Such observations must be undertaken independently from the original DTM observations and all feature codes of where the spotshot was taken must be recorded. All changes of slope and the features of the road prism shall be surveyed.

c) A field and office check relating to the survey work must be undertaken by the Surveyor. The field and office check plans (prescribed A0 sheets) must be submitted together with the survey data.

d) The Surveyor must complete the quality control check list as per **Annexure 24** and submit same with the final dataset.

13.2.3 Structures

Office and field quality control checks must be carried out on the entire survey. At least 10 check observations per structure must be undertaken in order to check the quality of the survey once the drawings have been completed. These check points must not form part of the structural survey data set. Test results must record the Y, X and Z differences calculated between the data reflected on the drawing and the test data. These results must be submitted together with all other records.

13.2.4 Staking

All positions staked must be checked and compared with the corresponding design coordinates. The differences so determined must be listed in a schedule.

13.2.5 Certification

a) A Registered Surveyor must certify all the check results.

b) A Compliance certificate shall be issued by the Surveyor and which must state that:

i) All work has been thoroughly checked; and
ii) That the work and quality of the work conforms to the project requirements and the relevant specifications. (Refer to **Annexure 23**)

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14. TERRESTRIAL AND MOBILE LASER SCANNING FOR STRUCTURES AND THE COLLECTION OF DIGITAL TERRAIN DATA AND ROAD SURFACE MARKINGS

This chapter deals with the survey of Bridge Structures, the survey to create a Digital Terrain Model (DTM) and the survey of Road Surface Markers. In the case of a Bridge Structure, a Stationary Terrestrial Laser Scanner is used. In the case of a DTM and the survey of the Road Surface Markings both a stationary terrestrial and a mobile scanner can be used. Such survey (3D model) may be utilised by a Consulting Engineer for actual detail design work.

14.1. General terrestrial Laser Scanning requirements

14.1.1 Phases of the survey

a) The following is generally recognised as separate phases with respect to a 'scanned' survey:

i) **Mission planning:** This being the planning of the survey in order to ensure that the required results are obtained;

ii) **Data collection:** This being the actual 'scanning' of the terrain/structure i.e. collection of the raw scanned information; and

iii) **Data processing:** This being the processing of the raw 'scanned' data, the referencing and calibration of such data onto the control points, the line work for structures, Road Surface markings, the determination of break lines and the creation of a Digital Terrain Model (DTM). The DTM must then be matched with the conventional surveyed data outside of the Road Surface in order to generate a combined dataset for the entire project.

14.1.2 Stationary Terrestrial Laser Scanning (STLS)

Stationary Terrestrial Laser Scanning (STLS) technology incorporates a tripod mounted laser scanner which captures high density readings which create a Point Cloud from which a drawing and a DTM model may be created and which accurately represents the area scanned in 3D.

Point Clouds must be absolutely orientated to a specified Survey System using geo-referenced control points.

STLS must comply with the requirements as prescribed in Chapter 6 "TOPOGRAPHICAL SURVEYS".

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14.1.3 Mobile Terrestrial Laser Scanning (MTLS)

Mobile Terrestrial Laser Scanning (MTLS) technology that incorporates a laser scanner(s), a Global Navigation Satellite Systems (GNSS), an Inertial Measurement Unit (IMU) and in some instances a digital imaging mobile platform which produces accurate and precise geospatial data in colour. This data is initially adjusted via post-processing using kinematic Global Navigation Satellite Systems (GNSS) procedures and which are referenced to separate GNSS base stations which are positioned over the entire project area. This GNSS output is then combined with information from the Inertial Measurement Unit (IMU) resulting in geospatial data in the form of a Point Cloud. The Point Cloud is adjusted by a local transformation using control points positioned over the entire project area and which then produces final geospatial data. This data must then be verified by establishing a comparison model from independently surveyed 'check' points.

MTLS must comply with the requirements as prescribed in Chapter 6 "TOPOGRAPHICAL SURVEYS".

Note: Standards of accuracy as prescribed in Chapter 3 "SURVEY REGULATIONS AND STANDARDS OF ACCURACY" must be complied with when employing MTLS and STLS technology.

14.1.4 A Registered Surveyor in terms of paragraph 1.18 "Registration in terms of the Professional and Technical Surveyors' Act, Act 40 of 1984" shall supervise the scanning work.

14.1.5 Project Selection

a) The following factors must be considered when determining whether STLS or MTLS is suitable for a project:

   i) Safety;

   ii) Project time constraints;

   iii) GPS data collection environment; and

   iv) Project size.

b) Typical cases where the use of STLS/MTLS for topographical type surveys may be employed are:

   i) Surveys from which engineering designs will be created;

   ii) As-Built – of a Road Surface;

   iii) As-Built – of a structure (at present the use of STLS is the preferred method);

   iv) Surveys to determine clearances with respect to Bridges;

   v) Surveys for the determination of lines of sight; and

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vi) Surveys to determine earthwork quantities.

14.1.6 Equipment

- The STLS and MTLS equipment must produce data to the specified accuracy for a project.

- MTLS comprises two primary type systems currently supplied by manufactures, namely the survey grade systems and the mapping grade systems. The mapping grade system is mainly used for GIS mapping applications and **may not** be used for topographical survey work. The survey grade system **may be** used for topographical survey work provided the specifications for the registration and geo-referencing of the data are fully complied with.

- All equipment utilised to produce MTLS and STLS data, the control for such data and the undertaking of quality control check readings must comply with the accuracy specifications for a project.

a) Scanners - General

i) Eye Safety

The Surveyor must ensure that written approval from the Department of Health in accordance with their Radiation Control Program is obtained where the use and operating procedures for Laser Scanning are defined. The field Surveyors must successfully conclude a laser safety course as specified by the Department of Health. Proof hereof must be submitted to the Client.

Surveyors must comply with the Occupational Safety and Health Administration (OSHA) – United States Department of Labour Guidelines and Regulation 1926.54 during the period where the written approvals from the Department of Health is awaited. Reference must also be made to OSHA STD 01-05-001 - PUB 8-1.

Generally, the Surveyor must ensure that the 'eye safety' of all concerned, including the general public, is achieved by operating the 'laser' equipment in an appropriate and safe manner.

ii) Scan density (MTLS)

The scan density is determined by the speed at which the MTLS is undertaken. Accordingly this speed must be set so that the required scan density as specified is achieved.

iii) Useful range of scanner

Whilst laser scanners are capable of performing and capturing scanned data over long distances, the scanning work must be planned in such a way as to ensure that the scanned data is always within the working range of the scanner

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i.e. the Point Cloud created must comply with the specified accuracy. It is noted that the working range of a scanner is determined by:

- The range and technical specification of the particular type of scanner to be used; and
- The accuracy specifications for the project.

The above is generally achieved by using techniques such as range and/or intensity filtering during the scanning process and/or by the removal of 'out of working range' data during the post-processing phase.

Unlike with total stations, where the use of specialised targets reduces observation errors over long distances, Laser Scanning targets are designed for a specific distance. Further, most laser scanners do not incorporate a telescope and thus orientation of the equipment must follow a particular procedure. This is achieved by the scanning of targets placed on the control beacons and where sufficient data density must be achieved to model their centre points. Generally, cylindrical, spherical or Planar Targets are used where Planar Targets are preferred as they tend to yield the best results.

The target size, its distance from the scanner and the 'laser spot' size will determine how precise the target centre may be modelled. The distance referred to above is critical in the context of the equipment manufacturers' technical specifications and errors increase, in magnitude, exponentially if this distance is exceeded. In this regard the equipment supplier's targets are recommended as these targets are specifically designed for the scanner frequency.

b) Global Navigation Satellite System (GNSS) for MTLS projects

The GNSS equipment may be used provided the requirements for the fixing of Permanent Survey Control as defined in paragraphs 5.1.1(f) "Construction of the Permanent Survey Control beacons", 5.1.1(g) "Vertical fixing of Permanent Survey Control beacons" and 5.1.1(h) "Horizontal fixing of Permanent Survey Control" are fully complied with).

Additional GNSS equipment requirements are:

i) The use of a dual frequency GNSS receiver which is capable of receiving data at 1 epoch per second or faster.

14.1.7 Local transformation – geo referencing (Applicable to both STLS and MTLS)

a) Description

In order to ensure that accuracy specifications are complied with, the Point Cloud must be processed via a local transformation. Whilst there are well-known transformations, the preferred transformation is one where, using a "least squares

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adjustment" which incorporates the horizontal and vertical residuals where these are determined by the correlation of pre-established local transformation points with their corresponding points in the Point Cloud and which then result in the relevant transformation parameters known as 'translation', 'rotation' and scale applicable to the horizontal values and an 'inclined plane' for the vertical values being determined. The above named transformation parameters are then applied to the Point Cloud to produce an acceptable and accurate final geospatial dataset.

Due to specific technical limitations, GNSS is not sufficiently accurate for the determination of Road Surface levels. Additional control points (known as local transformation points) must be established within the area to be scanned using MTLS, thus enabling the Point Cloud elevation to be further enhanced in level determination. Again, this is achieved using local transformation techniques where this is based on the independently established validation points (control).

b) Placement of local transformation points – control points

i) The placement of control as described below is applicable only when Point Cloud to Point Cloud registration is used. Refer to paragraph 14.2.1 "Field planning procedures" for control configuration for scanners without a compensator.

ii) For the establishment of survey control for structural surveys refer to paragraph 14.4.1 "Stationary Terrestrial Laser Scanning (STLS)".

iii) The Local Transformation Points must be evenly spaced computations throughout the project area so as to avoid extrapolation during the mathematical computations. The maximum spacing between such points shall not exceed 300m for MTLS and 120m for STLS surveys, reckoned in both sides on a road type survey.

iv) With respect to other types of surveys, control must be 300m and 120m square blocks for MTLS and STLS respectively and be over the entire terrain. Control must always be established so as to avoid any extrapolation.

v) The Local Transformation Points must be surveyed to the same standard or better as for Permanent Survey Control prescribed in Chapter 3 "SURVEY REGULATIONS AND STANDARDS OF ACCURACY". Existing Permanent Survey Control must be utilised to determine the values of the transformation points.

vi) Permanent Survey Control must, in addition to the control required for laser surveys, be established so as to fully comply with the specifications relating to topographical survey projects.

c) Quality assessment plan (QAP) (MTLS and STLS)

i) The Surveyor must submit a Quality Assessment Plan (QAP) to the Client, which plan must also comply with all requirements as prescribed in Chapter 13

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"QUALITY CONTROL". This QAP must clearly outline the proposed quality control measures that are to be employed that will achieve the required quality assurance results.

The following check list is a guide for quality assurance:

i) Quality Control (QC) Report

The QC report must have regard to the following:

- Statistical system reports (MTLS and STLS);
- PDOP values during the survey (MTLS);
- Comparison of elevation data from different runs/Overlaps (MTLS);
- Comparison of elevation data from Overlapping (side lap) runs (MTLS);
- Comparison of points at the area of Overlap (end lap) where more than one base is used (MTLS);
- Statistical comparison of Point Cloud data and check points (MTLS and STLS);
- Statistical comparison of adjusted Point Cloud data and redundant check points(MTLS and STLS);
- GNSS Accuracy Report which must include the following (MTLS):
  - Forward/reverse or combined separation plot;
  - Number of satellites bar plot;
  - PDOP, HDOP, VDOP plots;
  - L1 satellite lock/elevation plot; and
  - Estimated position accuracy plot.
- **IMU Accuracy Report which must include the following (MTLS):**
  - IMU position RMS plot; and
  - GNSS/IMU position differences plot.
- **Control Report which must include the following (MTLS):**
  - Table showing the dB between GCPs and known points;
  - Average, minimum and maximum dB; and
  - Average magnitude, RMS and standard deviation
- **Control survey report (MTLS and STLS);**
- Scan seam comparison of elevation data from Overlapping scans **(STLS);**

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- **Statistical comparison of Point Cloud data and control points (MTLS and STLS);**

- **Check cross section data and results (MTLS and STLS).**

- **Point Cloud**

- **The Point Cloud must be filtered to one layer of points which represents the mean value of all scans; and**

- **The "noise" must be removed.**

ii) Check Points Measurements

- The 30m road edge quality control points, if so instructed by the Client, and the 300m cross-sections points in Chapter 13 "QUALITY CONTROL" must also serve as the check points for the laser survey. The results must then be submitted as prescribed in Chapter 13 "QUALITY CONTROL".

- Quality control for structural surveys must be undertaken strictly in terms of Chapter 8 "ENGINEERING AND CONSTRUCTION SURVEYS" paragraph 8.7.3(e) "Quality control".

- Check point elevations must be surveyed using techniques that are capable of achieving a higher accuracy than a MTLS system can achieve. These checks must be undertaken within a maximum spacing of 300m and as prescribed in Chapter 13 "QUALITY CONTROL". The check points must not be used in the transformation.

Note: In addition to the prescribed quality control survey, suitable additional quality checks must be undertaken; and

- Where STLS of structures is undertaken then ten random check points must be surveyed using a total station. The coordinates and heights thereof must then be compared with the final scanned model.

iii) Accuracy Achieved

- The accuracy which is claimed to have been achieved for the final STLS and MTLS geospatial data must comply with those prescribed in Chapter 3 "SURVEY REGULATIONS AND STANDARDS OF ACCURACY"; and

- The Client must conduct check surveys and an Independent Quality Assurance (IQA) review of the QAP.

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14.2 Specific requirements for Stationary Terrestrial Laser Scanning (STLS) on Road Surfaces

14.2.1 Field planning procedures

a) Scanning setups shall not exceed a spacing of 120m;

b) Scanning distances shall not exceed 70m where a 5% to 15% Overlap is maintained;

c) "Grazing ray" observations must be generally avoided where oblique angles must be catered for by overlapping scans;

d) Shadow areas (areas behind obstructions) must be observed by moving the scanner so that these areas are scanned such that the Point Cloud is complete;

e) Where the scanner's instrument height exceeds 1.5m – 1.7m then a heavy duty tripod must be used so as to stabilize the scanner;

f) Scanning shall not be undertaken onto a wet surface;

g) In determining the scanning density, regard must be had to the possible need to extract specific detail, such 'Road Surface markings', directly from the Point Cloud. Where a DTM (grid spacing of 2m x 2m) must be finally produced (refer to paragraph 14.2.3 "Deliverables") then a minimum scan density of 500mm must be used which may require further adjustment for steeper gradients;

h) A suitable number of control points must be observed during the scan so as to achieve the accuracy specified. These must then be used for the geo-referencing of the scanned data. Where the scanner used does not have a compensator then a minimum of 4 (four) points must be observed from each setup. For scanners with a compensator then a Point Cloud to Point Cloud correlation may be used as prescribed in paragraph 14.1.7 "Local transformation – geo referencing (Applicable to both STLS and MTLS)"; and

i) The 'edge of the road' shall be surveyed at 30m spacings and using conventional survey techniques (using a total station) and which points must then be utilised for the quality control on the scanned data if instructed by the Client.

14.2.2 Office procedures and reporting

It is noted that there are two methods for referencing the scans, namely, Point Cloud scan to Point Cloud scan or by way of the utilisation of the Permanent Survey Control.

In both of the above instances a report must be compiled. Where the former method is preferred by the Surveyor then the procedures as defined in paragraphs14.1.7(b) "Placement of local transformation points – control points" and 14.1.7(c) "Quality assessment plan (QAP)" must be used.

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14.2.3 Deliverables

a) Deliverables as defined and described in Chapter 12 read together with Chapter 6 “TOPOGRAPHICAL SURVEYS” must be submitted.

b) In addition to the above, the following must be extracted from the geo-referenced scanned data and submitted:

i) Crown point of the road where applicable;

ii) Coded detail and line data utilising standard codes as per **Annexure 15**;

iii) Surface data for modelling based on a grid spacing of 2m x 2m (DTM);

iv) Surface changes (break lines) and any depressions etc. on the Road Surface;

v) Drainage and other visible structure detail which was possible using the laser scanner;

vi) Where more than one survey technique is utilised (e.g. use of GPS and Total Station) then the data extracted must comply as prescribed in paragraph 14.1.1 “Phases of the Survey”; and

vii) Quality control (QC) report for STLS projects.

14.3 Specific requirements for Mobile Terrestrial Laser Scanning (MTLS) on roads

14.3.1 Establishment of global navigation satellite system (GNSS) Control Stations

a) The ‘dual redundant’ GNSS Control Stations (utilised to control the post-processed kinematic adjustment of the MTLS dataset) must be established at a maximum spacing of 15km so as to ensure that the processed baselines do not exceed 7.5km in length. At least two Control Stations must be established at the start and end of a project respectively. With respect to large projects, additional Control Stations may require to be established so as to comply with the constraints imposed on the baseline distance; and

b) The horizontal and vertical accuracy standards as prescribed for Permanent Survey Control in Chapter 3 “SURVEY REGULATIONS AND STANDARDS OF ACCURACY” will apply to GNSS Control Stations. The Client may however specify more stringent accuracy requirements. It is further noted that the elevations of the GNSS Control Stations must be established only by the use of spirit levelling (double-run).

14.3.2 Field survey planning

a) Prior to the commencement of a MTLS project, an appropriate ‘mission planning’ session must be conducted so as to ensure that, during the scanning operation,

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sufficient and suitably located satellites are continuously available and that the Position Dilution of Precision (PDOP) specifications are adhered to;

b) A minimum of five (5) suitably located satellites must remain in view at any point in the scanning exercise from the GNSS Control Stations and the GNSS unit within the MTLS system. Further, the maximum PDOP must not exceed five (5);

c) A reconnaissance of the project area must be conducted so as to minimise the "noise" created from traffic and other factors during the scanning operation;

d) Scanning shall not be undertaken onto a wet surface;

e) In determining the scanning density, the possible need to extract specific detail, such as 'Road Surface markings', directly from the Point Cloud must be considered. Where a DTM (grid spacing of 2m x 2m) must finally be produced (refer to paragraph 14.2.3 "Deliverables") then a minimum scan density of 500mm must be used which may require further adjustment for steeper gradients;

f) If instructed by the Client, the 'edge of the road' shall be surveyed at 30m spacings and using conventional survey techniques (using a total station) and which points must then be utilised for the quality control on the scanned data;

g) "Grazing ray" observations must be generally avoided where oblique angles must be catered for by Overlapping scans;

h) Shadow areas (areas behind obstructions) must be observed using a Stationary Terrestrial Scanner or Total Station so as to complete the Point Cloud;

i) The careful monitoring of the various aspects of the scanning operation is imperative and will determine the adequacy of the QA process. Accordingly, the Surveyor must take appropriate and timeous actions where the operation incurs adverse conditions which could have a materially negative impact on the final results; and

j) The MTLS equipment must be continuously monitored throughout the data collection operation in order to manage the following aspects:

   i) Degraded or loss of GNSS reception;

   ii) Distance travelled during and the time duration of degraded or loss of GNSS reception (resulting in IMU drift which cannot be corrected for);

   iii) Correct functioning of the laser scanner; and

   iv) Vehicle speed determined by the required point density.

14.3.3 Calibration of equipment

Prior to and after collecting of MTLS data all equipment in the MTLS system must be calibrated in accordance with the manufacturer's specifications. Calibration results must be submitted together with the project survey data.

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14.3.4 Test run

a) In order to ensure the accurate collection of MTLS data, a 'test run' must be conducted. The test run must be of a sufficient length and duration so as to ensure that the system is functioning and collecting data correctly; and

b) Such test data must be submitted on completion of the survey project.

14.3.5 MTLS under structures

Due to the fact that the GPS system will experience loss of satellite coverage when proceeding under structures, the Inertial Measurement Unit (IMU) readings must be closely monitored. Where a separation is evident then STLS data must be observed and later combined with the MTLS dataset so as to enhance the quality of the MTLS data under the structure. Such events may also be experienced in built up and mountainous areas together with high vegetation such as forests which could result in loss of satellite coverage.

14.3.6 Redundancy

a) The collection of MTLS data must be undertaken to achieve a given redundancy with respect to such data collected;

b) The above effectively means that an 'Overlap' of scanned data must be provided for which 'Overlap' may be achieved by:

   a. Two or more passes in the same direction; or

   b. Overlapping passes in opposite directions; or

   c. A combination of the above.

c) With respect to the 'side' Overlap of passes in opposite directions, the redundancy shall be determined by a minimum of 20% of the 'pass width'; and

d) The time period between passes must be determined so as to ensure that the satellite constellation has materially altered (minimum 1 hour).

14.3.7 Check list for documentation to be submitted on completion (where such information must be confirmed prior to the field operations):

a) Who is the project manager;

b) Purpose of project mapping;

c) Map units;

d) Project coordinate system;

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e) Scanner calibration data;

f) Proposed driving plan;

g) GNSS visibility report;

h) Suitable driving speed to obtain required point density;

i) Proposed base station locations;

j) Proposed Ground Control Points (GCPs);

k) Proposed check points; and

l) Driving Plan.

14.3.8 Deliverables

a) Deliverables as defined and described in Chapter 12 “DELIVERABLES” read together with Chapter 6 “TOPOGRAPHICAL SURVEYS” must be submitted.

b) In addition to the above, the following must be extracted from the geo-referenced scanned data and submitted:

i) All data as specified in paragraph 14.3.7 “Check list for documentation to be submitted on completion (where such information must be confirmed prior to the field operations):” ;

ii) Crown point of the road where applicable;

iii) Coded detail and line data utilising standard codes as per **Annexure 15**;

iv) Surface data for modelling based on a grid spacing of 2m x 2m (DTM);

v) Surface changes (break lines) and any depressions etc. on the Road Surface;

vi) Drainage and other visible structure detail which was possible using the laser scanner;

vii) Calibration data; and

viii) Test run data.

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14.4 Specific requirements for Stationary Terrestrial Laser Scanning (STLS) of Bridge structures (Also refer to paragraph 8.7 "Structural Surveys – Bridges and Culverts")

14.4.1 Stationary Terrestrial Laser Scanning (STLS)

a) Field Planning Procedures:

i) All scanned models must be geo-referenced to the Permanent Bridge Control points established at each structure;

ii) Additional control points must be established around the structure where the accuracy of such control must comply with the specified accuracies for Permanent Survey Control;

iii) Scanning observations from control points shall not exceed 70m;

iv) Scanning must be undertaken where the maximum scanned distance shall not exceed 70m from the Bridge structure and where a 30% Overlap is achieved between adjacent scans. In the event that the 70m distance constraint must be exceeded due to circumstances beyond the Surveyor's control, then additional control points must be established on the Bridge structure itself. In such event additional scans shall be observed so as to increase the density of the final geo-referenced Point Cloud. This is generally encountered with extremely high Bridges;

v) In determining the scanning density, regard must be had to the possible need to extract specific detail directly from the Point Cloud. The following minimum scanning densities apply:

- Bridge abutments - 5mm;
- Top of Bridge piers and bearings - 5mm; and
- Remainder of the Bridge – shall not exceed 10mm.

vi) A suitable number of control points must be observed during the scan so as to achieve the accuracy specified. These must be used for the geo-referencing of the scanned data. Where the scanner used does not have a compensator then a minimum of four points must be observed from each setup. For scanner with a compensator a minimum of two control points must be observed together with additional observations taken onto an additional control point (redundancy point to serve as a check point); and

vii) All control points must be positioned so that all surfaces of the Bridge are scanned in such a manner to enable and guarantee the correct modelling of the Bridge from the final Point Cloud.

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14.4.2 Equipment

Phase based laser scanners have specific limitations and are accordingly not suitable for the scanning of Bridges/structures.

14.4.3 Point Cloud

a) The final Point Cloud must be filtered down to a single layer of points which must represent the mean value of all the scans;

b) The Point Cloud database shall be created using only licensed and registered software;

c) The "noise" must be removed as far as is possible; and

d) The Point Cloud database must be supplied in an ASCII format for importing into other software packages.

ASCII format:

SYMBOL	DESCRIPTION
Y	Y-coordinate value of a point
X	X-coordinate value of a point
Z	Z-coordinate value of a point
I	Laser return intensity value of a point (integer, 0 to 255)
R	Digital image Pixel overlay red component value of a point (integer, 0 to 255)
G	Digital image Pixel overlay green component value of a point (integer 0 to 255)
B	Digital image Pixel overlay blue component value of a point (integer 0 to 255)

Note: The R, G and B component above applies only where the scanner has an on-board camera or a mountable camera system and used at the setup position. Having regard to the use of Point Clouds such as an engineering design tool, it is preferable that the archived database is in 'full colour' and where the imagery gathered at each setup is supplied (preferably stitched into a viewable panoramic format of a high resolution for zooming purposes).

14.4.4 'Wire frame model' (Line Mapping)

a) 'Wire frame models' should have sections taken at predetermined intervals provided that abutment faces, centres of piers and joint locations are specifically included;

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b) Where Bridges are located on a curve then the interval between sections will be determined by the radius of the curve i.e. the tighter the curve the shorter the distance between wire frame sections;

c) The long section should follow the Bridge soffit;

d) The wire frame model must accordingly represent the Bridge accurately; and

e) The following features must at the very least be specifically sectioned:

i) Piers – showing the top of the pier;

ii) Abutment – including the bearing seat;

iii) Wing walls;

iv) Bearings;

v) Soffit;

vi) Balustrade detail; and

vii) Deck.

14.4.5 Additional deliverables

All deliverables as prescribed in Chapter 12 “DELIVERABLES” must be supplied and all data must comply with the specification prescribed in paragraph 8.7 “Structural surveys – Bridges and Culverts”.

Acknowledgement: The Majority of these specifications were obtained from the Californian Department of Transportation Survey Manual: Terrestrial Laser Scanning Specifications: CULTRANS

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15. ANNEXURES

This chapter comprises typical examples and must be utilised as a guide in order to ensure compliance with the standards, requirements and quality as specified in this document.

1 Guideline framework for the compilation of survey reports

2 Traffic Accommodation for working on the Road Prism up to 5m from the Road Prism for low volume traffic Roads

3 Traffic Accommodation for static work on the Road Prism and within 5m of the Road Prism for short periods for low volume traffic roads

4 Traffic Accommodation for Surveyors moving only on the shoulder of the road or within 5m outside the Road Prism for low volume traffic roads

5 Traffic Accommodation for working on the Road Prism and up to 5m from the Road Prism for high volume Single Carriageway roads

6 Traffic Accommodation for static work on the Road Prism and within 5m of the Road Prism for short periods for high volume Single Carriageway roads

7 Traffic Accommodation for Surveyors moving only on the shoulder of the road or within 5m outside the Road Prism for high volume Single Carriageway roads

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9 Premarks

- 9.1 Premark for photogrammetric aerial survey
- 9.2 Premark for lidar surveys

10 Conical concrete beacon

11 Pillar Beacon

12 Co-ordinate list

13 Levelling results

14 Reports for the verification of permanent survey control

- 14.1 Beacon construction verification status report
- 14.2 Co-ordinate and height verification survey results
- 14.3 Framework for the compilation of survey reports for verification of survey control

15 Survey feature codes

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16 Typical positions to be surveyed on a Road, Street and Rail Prism

16.1 Typical positions for single carriageway survey points

16.2 Typical positions for dual carriageway and city street survey points

16.3 Typical positions for rail prism and track survey points

17 Survey requirements at drainage structures (culverts)

18 Typical survey points on Bridges

18.1 Position of cross section for top and bottom deck survey points (Bridge Deck)

18.2 positions and dimensions of survey positions on Bridge Piers

18.3 Positions of survey points on Soffit Edges and Abutments

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18.5 Dimensions to be surveyed and shown on the final drawings for gantries (Top view)

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19.1 CAD configurations pages 1 to 10

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21 CAD symbols, sizes and weights

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25 Weekly progress reports

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25.3 Lidar surveys

26 Sample form: Agreement between client and contractor in terms of Section 37(2) of the OHS Act

27 Angle of skew

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