REPUBLIC OF KENYA
MINISTRY OF ROADS AND TRANSPORT

RDM 1.1

Road Design Manual

Volume 1: Geometric Design

Part 1: Topographic Survey

2025

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Foreword

This manual was developed by the Ministry pursuant to The Fourth Schedule of the Constitution which assigns to the National Government the functions and powers of setting standards for the construction and maintenance of all public roads including those under the County Governments.

It is part of a series of manuals that replace the first generation of road manuals developed in the first and second decades after independence. This second generation of the road manuals were developed to cover the entire road project cycle covering planning, appraisal, design, contracts, construction, maintenance, operations and monitoring. The series incorporates best practices, climate change considerations, and recent technologies to enable the provision of road infrastructure that is safe, secure, and efficient.

Under the Kenya Vision 2030 long term plan, infrastructure expansion and modernisation are some of the foundations for the realisation of economic, social and political transformation of Kenya into a rapidly industrialising middle-income country. The plan envisages an integrated, safe and efficient transport and communication infrastructure network consisting of roads, railways, ports, airports, waterways, and telecommunications infrastructure.

The strategies to be pursued under the Vision 2030 plan to improve infrastructure services and to maximise the economic and social impacts of infrastructure development and management include: Strengthening of the institutional framework for infrastructure development and maintenance; Raising efficiency and quality of infrastructure projects; Enhancing local content of identified infrastructure projects to minimise import content; Benchmarking infrastructure facilities and services provision with globally acceptable performance standards; and, Implementing infrastructure projects that will stimulate demand in hitherto marginalised areas.

The first three 5-year Medium Term Plans (MTP) under the Vision 2030 from 2008 to 2022 targeted construction of 1,950 km, 5,500 km and 10,000 km of new paved roads under MTP I, II and III, respectively, totalling 17,450 km. This was a massive infrastructure development program intended to double the paved road network in 10 years compared to 8,600 km developed from independence in 1963 to 2008.

Implementation of MTP I to III resulted in the construction of 14,000 km of paved roads, which extended the paved road coverage to Arid and Semi-Arid regions, that had been previously neglected. However, some key milestones of the Vision 2030 goals have not been realised. This has been due to internal and external challenges. External challenges included: climate change – prolonged droughts; the emergence of COVID-19 pandemic; global supply chain disruptions; exchange rate volatility; and rising interest rates in the leading economies.

The internal challenges included: inadequate road maintenance equipment; pavement overloading by heavy goods vehicles; huge maintenance backlog of the road network; low contracting and supervision capacity particularly in the Counties; poor quality control and assurance of works; congestion in urban areas; encroachment on road reserves; high costs and delays in payments of land acquisition; lack of harmonisation of cross-border transport regulation and operational procedures; rapid urbanisation; increased traffic volume with exponential growth of motorcycle traffic; high cost/delays in relocation of utilities and services along and across road reserves; inadequate funding of projects and programs; and, delay or default in payments for goods, services and works.

The implementation of MTP III came to an end on 30th June 2023, ushering in the implementation of the Fourth Medium Term Plan (MTP IV), which has been aligned to the aspirations of the Kenya Vision 2030 and the Kenya Kwanza Government's Bottom-Up Economic Transformation Agenda (BETA) planning approach and its key priorities.

BETA is the Government's transformation agenda geared towards economic turnaround through a value chain approach. BETA has targeted sectors with the highest impact to drive economic recovery and growth. This will be achieved through bringing down the cost of living; eradicating hunger; creating jobs; expanding the tax base; improving foreign exchange balances; and inclusive growth. BETA ensures rational resource allocation by eliminating wastage of resources occasioned by duplication, overlaps, fragmentation and ineffective coordination in the implementation of programmes and projects.

The Fourth Medium Term Plan key priorities are clustered under five key sectors, namely: Finance and Production; Infrastructure; Social; Environment and Natural Resources; and Governance and Public Administration. The infrastructure sector seeks to: enhance transport connectivity by constructing 6,000 km of new roads, maintaining rural and urban roads, rail, air and seaport facilities and services; expand communication and broadcasting systems; and promote the development of energy generation and distribution by increasing investments in green energy (geothermal, wind, solar and hydro). The infrastructure gap is expected to be bridged by promoting economic participation of the private sector through public private partnerships in the financing, construction, development, operation, and maintenance of infrastructure.

The plan entails a shift of focus to fundamentals in project planning and implementation which include: respect for technical input, regulations and standard practices; adherence to project life cycle i.e., planning, feasibility studies and design before procurement of works; public and stakeholder consultation; procurement within budgetary ceilings; shifting focus during project implementation from the finished product 'black top' to the construction of the foundation; building local capacity particularly MSMEs by ensuring prompt payments; and capacity building at all levels to enable internalisation of policies and processes.

The first generation of the road manuals were used for 35 to 45 years. It is my sincere hope that the second generation of the road standards which have been developed in alignment with the Government's strategy will provide guidance in solving most of the above challenges and those expected to emerge in the next 50 years. Implementation of the manuals will enable achievement of the Government aspirations which include inclusive growth; creation of sustainable employment; building of MSMEs; climate change adaptation and realisation of the UN SDGs; enhanced efficiency in management of infrastructure and transport system; and, laying the foundation for the next national long-term plan at the end of the Vision 2030.

On behalf of the Government of Kenya, I would wish to thank the European Union for financing the development of the first drafts of the manuals in 2009 and the African Development Bank for the financial support in the review and updating of the manuals. I would also like to thank the members of the National Steering Committee and the Technical Task Force for their input. The Technical Administrators, and the Kenya National Highways Authority (KeNHA) for the procurement and able administration of the consultancy Contract. I also thank the Consultant, TRL Limited for their role in providing technical expertise that was essential for the success of the manuals updating exercise. I also wish to express my deepest appreciation to our stakeholders and all those who have contributed to this process and the staff of the Ministry for their continued input.

Hon. Davis K. Chirchir, E.G.H
Cabinet Secretary, Ministry of Roads and Transport

Preface

This Manual is the first Part of the **Road Design Manual Volume 1: Geometric Design Manual**. This Part sets out standardised methodologies for site investigations, information gathering, undertaking topographic surveys, and reporting the data for sustainable management of the road network in Kenya.

The context of the road design process, its philosophy and principles are discussed in the complete set of the road design manuals developed under this series. The use of each Part of the RDM and the relationship between the Volumes and Parts and the design process are covered. **Volume 1: Part 1 of the RDM** is particularly useful for establishing procedural guidance, specifications, and quality control criteria for performing field topographic surveying in support of planning, engineering and design, construction, as-built documentation and environmental restoration activities.

As much as possible, the traffic engineer should attempt to meet all criteria presented in the Manual. However, the Manual should not be considered a standard which must be met regardless of scope and resource implications. **Volume 1: Part 1** of the **RDM Manual** presents most of the information normally required when in the carrying out topographic surveys for road design purposes; however, it is impossible to address every data requirement which may be encountered. Therefore, the surveyor must exercise good judgment on the scope of individual projects and, frequently, they must be innovative in their approach. This may require, for example, additional research on newer and innovative technologies when undertaking ground field surveys, and in the analysis of data.

Eng. Joseph M. Mbugua, CBS
Principal Secretary, State Department for Roads

Document Management

Document Status

This document has the status of a Manual. Users shall apply the contents there-in to fully satisfy the requirements set out. The content of the manual is based on current practice in Kenya and latest practices in the road sector, both regionally and internationally.

Sources of the Document

Copies of the document can be obtained from:
The Principal Secretary, State Department for Roads, Ministry of Roads and Transport, Works Building, Ngong Road, P.O. Box 30260 - 00100, NAIROBI Email: ps@road.go.ke

A secured PDF copy maybe downloaded from: www.roads.go.ke/downloads

Notification of Errors and Requests for Amendments

While all care and consideration has been applied in the compilation of this document, the Ministry accepts no responsibility for failure in any way related to the application of this manual or any reference documents cited in it.

Requests for edits and corrections can be freely sent to the following address:
The Principal Secretary, State Department for Roads, Ministry of Roads and Transport, Works Building, Ngong Road, P.O. Box 30260 - 00100, NAIROBI Email: ps@road.go.ke

Amendments Request Form:

Request No.	Name	Organisation	Chapter	Page	Section/ Clause	Ref. to: Figure/ Table/	Type of Request	Request

Type of request: General – G; Editorial – E; Technical - T

Amendments to Date:

Amendment No.	Description	Amendment Effective Date	Amendment Approved by

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A National Steering Committee was set up and chaired by the Permanent Secretary, Ministry of Roads and Transport, with the following membership: Principal Secretary for Devolution, Office of the Deputy President; Chief Executive Officer, Inter-Governmental Relations Technical Committee; Chief Executive Officer, Council of Governors; Managing Director and Council Secretary, Kenya Bureau of Standards; Director, National Transport and Safety Authority; Director General, Kenya Roads Board; Director General, Kenya Wildlife Services; Chief Executive Officer, Engineers Board of Kenya; Director General, Kenya Rural Roads Authority; Director General, Kenya Urban Roads Authority; President, Institution of Engineers Kenya; Director Policy, Strategy and Compliance; Kenya National Highways Authority; Chief Engineer, Roads Division, State Department for Roads; Chief Engineer, Materials Testing and Research Division, State Department for Roads.

The technical work was undertaken under the guidance of a Technical Task Force, chaired by Eng. David Maganda, with the following gazetted members: Francis Gichaga (Prof.) (Eng.), Andrew Gitonga (Eng.), Timothy Nyomboi (Dr.) (Eng.), Rosemary Kungu (Eng.), Charles Obuon (Eng.), Sylvester Abuodha (Prof.) (Eng.), Samuel Kathindai (Eng.), Nicholas Musuni (Eng.), Charles Muriuki (Eng.), Tom Opiyo (Eng.), John Maina (Eng.), Fidelis Sakwa (Eng.), Daniel Cherono (Eng.), Maurice Ndeda (Eng.), Theo Uwamba (Eng.).

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Abbreviations

BM	Benchmark
CADD	Computer-Aided Design and Drafting
CSIR	Council for Scientific and Industrial Research
DFL	Design Flood Level
DTM	Digital Terrain Model
EDM	Electronic Distance Measurement
EOD	Environmental Optimised Design
FH	Free Haul
GLONASS	Global'naya Navigatsionnaya Sputnikovaya Sistema
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HFL	High Flood Level
KNSDI	Kenya National Spatial Data Infrastructure
LiDAR	Light Detection And Ranging
LVR	Low Volume Roads
NTN	National Triangulation Network
NGBM	National Geodetic Benchmarks
OGL	Original Ground Level
PAP	Project Affected Persons
PC	Point of Curvature. Point on the Tangent where the Circular Curve begins. Also designated BC or TC
PNT	Positioning, navigation, and timing
PT	Point of Tangency. Where a Circular Curve ends. Also designated EC
RAP	Resettlement Action Plan
ROW	Right of Way
RP	Reference Point
RTK	Real Time Kinematic
TC	Telecommunications Corporations
TRL	Transport Research Laboratory
UAV	Unmanned Aerial Vehicle
UTM	Universal Transverse Mercator

Glossary of Terms

As-built Environment	This refers to the drawings, reports, underground services, etc. that have been recently built by the contractor as part of the completed project deliverables. The final copy of as-built drawings are prepared once the project is fully completed to ensure that the information is accurate and represent ground information.
Authority	A government organisation in Kenya that is responsible for a specific area or function and with vested power or right to make decisions or enforce regulation. These include Ministries, Departments and Agencies (MDA) at national and county levels.
Benchmark	A relatively permanent object, natural or artificial, having a marked point whose elevation above or below a reference datum is known or assumed. Common examples are metal brass set in concrete, reference marks chiselled on large rocks, etc.
Datum	A set of reference points on the earth's surface against which position measurements are made. Horizontal datums are used for describing a point on the earth's surface, in a defined coordinate system. Vertical datums measure elevations or depths.
Digital Terrain Model	This is a topographic model of the bare Earth that can be manipulated by computer programs. The data files contain the elevation data of the terrain in a digital format which relates to a rectangular grid.
Global Navigation Satellite System (GNSS)	Multi-Constellation Satellite System encompassing different types of satellite-based positioning, navigation, and timing (PNT) systems used globally. GPS is one of such systems.
Light Detection And Ranging (LiDAR)	A remote sensing technique that uses laser emitters to map spatial positions and record the reflected wavelengths and intensity of light from objects in the scene.
Photogrammetry	The art, science, and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiant imagery and other phenomena.
Post Processing	This is a method of processing survey data that involves downloading of raw (field) survey data and processing in office. This is different from real time processing of data say when the survey is going on.
Remote Sensing	The science of acquiring information about the Earth's surface without being in contact with it, through sensing and recording reflected or emitted energy and processing, analysing, and applying that information;
Stationing	Stationing is used to establish a reference in highway and building construction. This base line or reference can then be used to locate features along and adjacent to the base line.
Switchback Curves	Tight curves of radii of 20m or less necessary in traversing mountainous and escarpment terrain.

Glossary of Terms *(continued)*

Survey Accuracy	Tight curves of radii of 20m or less necessary in traversing mountainous and escarpment terrain.
Survey Area	Survey accuracy is the degree of conformity of a particular survey with a given or set survey standard. Accuracy relates to the quality of the result obtained when compared to the set standard.
Survey Datum	The area of interest for which the topographical survey data is required.
Survey of Kenya	This is the official agency of the government of Kenya on all matters affecting land surveys and mapping. The department is responsible for national surveying and mapping and the national focal point of GIS and Remote Sensing
Topographical Survey	Refers to the process carried out to depict natural and man-made features in 3 dimensions (3D) using aerial, remote sensing or ground-based land surveying techniques; A type of survey concerned with capturing an accurate representation of the land, and natural or man-made features.

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1 Introduction

1.1 General

This manual was prepared by the Ministry of Roads and Transport as part of a series of manuals that cover the entire project cycle. The series incorporate best practices, climate change considerations, and recent technologies thereby enabling the provision of road infrastructure that is safe, secure, and resilient.

The Kenya road manual series is as follows:

Project Cycle Stage	Manual: Volume or Part/Chapter	Code
A. General	**Procedures and Standards Manual**	**PSM**
	1. General	
	2. Policies	
	3. Procedures Guidance	
	4. Codes of Practice	
	5. Guidelines	
	6. Product/Testing Standards	
B. Planning	**Network and Project Planning Manual**	**NPM**
	1. Road Classification	
	2. Route/Corridor Planning	
	3. Route/Corridor Planning	
	4. Highway Capacity	
	5. Project Planning	
C. Appraisal	**Project Appraisal Manual**	**PAM**
	1. Environmental Impact Assessment and Audit	
	2. Social Impact Assessment	
	3. Traffic Impact Assessment	
	4. Road Safety Audits	
	5. Project Appraisal	
	6. Feasibility Studies	
D. Design	**Road Design Manual**	**RDM**
	1. Geometric Design	
	2. Hydrology and Drainage Design	
	3. Materials and Pavement Design for New Roads	
	4. Bridges and Retaining Structures Design	
	5. Pavement Maintenance, Rehabilitation and Overlay Design	
	6. Traffic Control Facilities and Communication Systems Design	
	7. Road Lighting Design	
E. Contracts	**Works and Services Contracts Manual**	**WSCM**
	1. Forms of contracts	
	2. Standard Specification for Road and Bridge Construction	
	3. Bills of Quantities	
	4. Standard/Typical Drawings	
F. Construction	**Road Construction Manual**	**RCM**
	1. Construction Management	
	2. Project Management	
	3. Site Supervision	
	4. Quality Assurance	
	5. Quality Control	

This table continues onto the next page...

Project Cycle Stage	Manual: Volume or Part/Chapter	Code
G. Maintenance	**Road Asset Management Manual**	**RAAM**
	1. Maintenance Management	
	2. General Maintenance	
	3. Pavement Maintenance	
	4. Bridges and Structures Maintenance	
H. Operations	**Road Operation Manual**	**ROM**
	1. Traffic Management	
	2. Vehicle Load Control	
	3. Emergency Services	
	4. Tolling	
I. Monitoring & Evaluation	**Road Design Manual**	**MEM**
	1. Performance Monitoring Manual	
	2. Technical Audits	
	3. Poverty, Gender Equality and Social Inclusion Monitoring	

Table 1.1 shows how this part (1 – Topographic Surveys) fits within Volume 1 – Geometric Design, and the wider Road Design Manual structure.

Table 1.1 Road Design Manual (RDM) Coding Structure

Vol.	Manual Title	Part Name	Code
1	**Road Design Manual: Vol. 1** Geometric Design	**Part 1** - Topographic Survey	RDM 1.1
		Part 2 – Traffic Surveys	RDM 1.2
		Part 3 – Geometric Design of Highways, Rural and Urban Roads	RDM 1.3
2	**Road Design Manual: Vol. 2** Hydrology & Drainage Design	**Part 1** – Hydrological Surveys	RDM 2.1
		Part 2 – Drainage Design	RDM 2.2
3	**Road Design Manual: Vol. 3** Materials & Pavement Design for New Roads	**Part 1** – Ground Investigations and Material Prospecting	RDM 3.1
		Part 2 – Materials Field and Laboratory Testing	RDM 3.2
		Part 3 – Pavement Foundation and Materials Design	RDM 3.3
		Part 4 – Flexible Pavement Design	RDM 3.4
		Part 5 – Rigid Pavement Design	RDM 3.5
4	**Road Design Manual: Vol. 4** Bridges & Retaining Structures Design	**Part 1** – Geotechnical Investigation and Design	RDM 4.1
		Part 2 – Bridge and Culvert Design	RDM 4.2
		Part 3 – Retaining Structures Design	RDM 4.3
		Part 4 – Reinforced Fill Structures Design	RDM 4.4
		Part 5 – Bridges and Structures Condition Survey	RDM 4.5
		Part 6 – Bridge Maintenance Design	RDM 4.6
5	**Road Design Manual: Vol. 5** Pavement Maintenance, Rehabilitation & Overlay Design	**Part 1** – Pavement Condition Survey	RDM 5.1
		Part 2 – Pavement Maintenance, Rehabilitation and Overlay Design	RDM 5.2
6	**Road Design Manual: Vol. 6** Traffic Control Facilities & Communication Systems Design	**Part 1** – Road Marking	RDM 6.1
		Part 2 – Traffic Signs	RDM 6.2
		Part 3 – Traffic Signals and Communication System	RDM 6.3
		Part 4 – Other Traffic Control Devices	RDM 6.4
7	**Road Design Manual: Vol. 7** Road Lighting Design	**Part 1** – Grid-connected Road Lighting	RDM 7.1
		Part 2 – Solar Road Lighting	RDM 7.2

This manual must be applied sensibly and flexibly in conjunction with the skill and judgement of the designer. Compliance with the guidance given in the manual does not relieve designers of the responsibility for establishing that their design is suitable, appropriate, safe, and adequate for the purpose stated in the project requirements.

1.2 Objectives of this Part

This manual establishes procedural guidance, specifications, and quality control criteria for performing field topographic surveying in support of planning, engineering and design, construction, and environmental restoration activities.

All Survey work shall be performed and presented in accordance with the requirements of this manual to ensure that uniformity and consistency of detail, format, quality, accuracy, and procedure is achieved.

1.3 Scope of this Part

The Topographic Survey Manual is one of site investigation manuals. Site investigation is a vital and integral part of the location, design, and construction of a road. It provides essential information on the characteristics of the soils along the possible alignments, availability of construction materials, topography, land use, road reserve adequacy, environmental issues, and socio-political considerations among others.

Site investigation techniques encompass a large range of methods and the amount and type of exploration that is needed for a specific road will depend on the nature of the proposed project and the environment in which it is to be built. It is not the purpose of this manual to explain all site investigation techniques. To obtain information on site investigation techniques other than topographic surveys, the reader is referred to the appropriate manuals in Table 1.2.

Table 1.2 References to Relevant Manuals for Different Site Investigation Aspects

Site Aspect	Description	Related Manuals
Hydrological Surveys	This includes surveys to obtain information for assessing the size and design of culverts and other water crossings based on estimates of the water flows obtained from survey information about rainfall, catchment areas and catchment characteristics.	**Road Design Manual:** **Vol. 2:** Hydrology & Drainage Design **Part 1:** Hydrological Surveys
Traffic Surveys	Surveys required to estimate the numbers of vehicles, both motorised and non-motorised, that will use the road.	**Road Design Manual:** **Vol. 1:** Geometric Design **Part 2:** Traffic Surveys
Environmental and Social Impact Assessments	Surveys required to evaluate environmental impacts (including climate change) and how to control them; in which the local communities are consulted about the road project.	**Project Appraisal Manuals:** Environmental Impact Assessment and Audit & Social Impact Assessment.
Road Reserve Survey	Surveys required to inform early on the adequacy of the road reserve to accommodate the minimum geometric design standards.	**Road Design Manual:** **Vol. 1:** Geometric Design **Part 2:** Traffic Surveys
Geotechnical Investigations	Site investigation procedures for materials and for geotechnical issues. It therefore covers subgrade soils, including problem soils, materials for the construction of the pavement layers, foundation investigations for structures, slope stability and landslide issues.	**Road Design Manual:** **Vol. 3:** Materials and Pavement Design for New Roads **Part 1:** Ground Investigation and Material Prospecting

The focus of this manual is therefore to present many of the established surveying and mapping methods along with some of the modern techniques which have changed conventional equipment and procedures in topographic surveying.

It is not the purpose of this chapter to be all inclusive. Specific information concerning techniques, theory, and methodology on topographic survey can be obtained from several supporting manuals, books, and other materials. Two of the Kenya guidelines are:

1. Practicing Guidelines for Non-Title Surveys by the Institution of Surveyors of Kenya (ISK)
2. Survey of Kenya Practice Manual (Survey Manual Published by Survey of Kenya in 1971 and later revisions)
3. Survey Act, Cap 299 and regulations (and later revisions)
4. Land Act, 2012 (and later revisions)

This Manual does not replace the relevant textbooks, nor is it a substitute for sound engineering knowledge, experience, and judgment. Standards are indicated which should be adhered to under normal conditions, while abnormal conditions should be given special consideration in consultation with the **Chief Engineer, Roads**.

1.4 Organisation of the Manual

This manual is organised into five chapters:

Chapter 1: Introduction: This chapter gives a broad background on the concept of ground surveys and site investigations. It also discusses the purpose and scope of this Manual.

Chapter 2: Fundamental Considerations: This chapter details the general survey considerations and aspects.

Chapter 3: Site Investigation: This chapter details the relevant information that should be collected through desk studies or obtained from various agencies prior to ground surveys. It also provides guidance on the level of detail generally required for the site surveys and other investigations at each stage of the road design process.

Chapter 4: Route Corridor Selection: This chapter addresses the process of identification of potential corridors, the method of undertaking a reconnaissance survey and the considerations in route selection.

Chapter 5: Surveys: Stages of surveys, methods of survey, survey applications and specific survey procedures are discussed under this chapter. The last section of the chapter is dedicated to the process of undertaking topographic surveys, key considerations, as well as survey data analysis and reporting.

2 Fundamental Considerations

2.1.1 Units of Measurement

Data for survey work shall be measured and recorded in metric units. The use of metric system of measurement in this Manual is predicated on the common use in surveying and mapping in Kenya.

2.1.2 Surveyor Qualifications

Topographic surveys for the purpose of road design, construction or maintenance in Kenya shall be conducted by qualified and registered surveyor with the Institution of Surveyors of Kenya (ISK) or any other recognised establishment at the time.

2.1.3 Mapping Guidelines

Table 2.1 gives guidance and indicates the recommended scales of mapping required to perform various desk study and design tasks.

Table 2.1 Mapping Scales and Contour Intervals

Purpose of Maps	Map Scales	Contour Interval (m)
Reconnaissance studies for mountainous, rolling, and flat terrain	1:20,000	10
	1:10,000 – 1:15,000	5
Location studies for mountainous, rolling, and flat terrain	1:5,000 Max	5
	1:5,000	2
Rural road design for mountainous, rolling, and flat terrain	1:500, 1:1,000 or 1:2,000	2
	1:1,000 or 1:2,000	1
Urban road design	1:500	0.5
Selected site design	1:100 – 1:200	0.2
Selected site design *(for structures less than 40 metres long)*	1:100	0.2

2.1.4 Aerial Photography Mapping Scales

Table 2.2 gives guidance and indicates the optimum scales of photography required to perform various desk study and design tasks.

Table 2.2 Aerial Photography Mapping Scales

Task Activity	Optimum Air Photo Scale
Feasibility Study	
Route corridor identification	1: 20,000 to 1: 30,000
Terrain classification	1: 15,000 to 1: 25,000
Drainage/Drainage Area mapping	1: 20,000 to 1: 30,000
Landslide hazard mapping	1: 10,000 to 1: 20,000
Contour Mapping for preliminary estimation of quantities	1: 15,000 to 1: 25,000
Preliminary Design	
Detailed interpretation of chosen corridor(s) for geotechnical purposes	1: 10,000 to 1: 15,000
Ground (contour) model for preliminary alignment design	1: 10,000 to 1: 15,000
Detailed Design	
Ground (contour) model for detailed alignment design and quantities	1: 5,000 to 1: 10,000

2.1.5 Right of Way (RoW) Limits

Setting of the road reserve is the sole discretion of the Government of Kenya. The following road reserves widths as stipulated in the **Geometric Design Manual: Part 3** (see section 2.5 and 4.1) are applicable to various road classifications.

Table 2.3 Road Reserve Widths

Road classification	Desirable (m)	Reduced (m)
Interurban		
A	60 – 120	40 – 60
B	60 – 80	40 – 60
C	40 – 60	≥40
Rural		
D	30 – 40	25 – 30
E	25 – 30	20 – 25
Urban		
UA	60 – 80	40 – 60
UC	40 – 60	30 – 40
UL	30 – 40	20 – 30

Determining the right of way limit involves integrating alignment design with existing commercial and residential development and the surrounding community taking into account the future growth. Setting the right of way limit for a specific project corridor should therefore be based on its gazetted or cadastral surveyed road reserve width as well as adjacent land use.

Reduced widths should be adopted only when this is found necessary for economic, financial, or environmental reasons in order to preserve valuable land, resources, or existing development or when the desirable right of way would incur unreasonably high costs.

For dual or elevated carriageways, it may be necessary to increase the right of way beyond the road reserve widths.

The right of way limits can be set to exclude the acquisition of a particular property because of its historic importance or because it renders a necessary social, educational, governmental, or environmental service to the community. In some cases, this can also be because its acquisition will have severe impact on the economic viability of the property or result in disproportionate acquisition costs. It is recommended the surveyor consults with the designer to afford the project the ability to limit the range of property acquisitions required.

The intent is not to necessarily reduce the size of acquisitions for cost benefit of the project, but also:

a. To reduce the overall number of takings; and

b. To reduce the size of acquisitions to such a degree that the scope of damages to the remaining property is minimised to the greatest extent practical.

2.1.6 Instrument Care and Calibration

As surveying equipment becomes increasingly complex and expensive, care and maintenance is imperative. GPS, Total stations, theodolites, levels, data collectors, Electronic Distance Measurements (EDMs), and all other equipment should be placed in their protective cases when not in use. Similarly, tripods, rods, and range poles should be kept clean and stored in either carrying cases or bins built into the survey vehicles. All the electronic surveying equipment will require periodic servicing and calibration at least once a year to ensure their accuracy and they should be checked regularly.

2.1.7 Classification and Accuracy

Surveys are ranked into order and class based on the accuracy and precision used in the survey. Required accuracy depends on the objectives of the survey. It also depends on the quality of the instruments and equipment employed, the methods and procedures used, the repeatability of measurements, and the ability and experience of the personnel.

To ensure accuracy of surveys, the following general principles must be followed:

- ✓ Select a scale in advance, this determines the plottable error;
- ✓ Work from the most accurate to the least accurate methods;
- ✓ Orient each survey, preferably with respect to true north;
- ✓ Establish horizontal and vertical control: the distance, direction, and difference in elevation between key fixed points. The fixed points are known survey control points or datums;
- ✓ To ensure harmony in the survey works for adjoining road projects/contracts, the survey controls established shall be tied to the National Survey Grid and shall be submitted to the Director of Surveys for approval; and
- ✓ Establish a survey plan that includes checks on accuracy indicators such as redundant points, pacing of measured distances and surveying between fixed positions among others.

The following equation gives the recently applicable accuracy required for the closure of road projects:

$$C = \pm\sqrt{K}$$ Equation 2.1

Where,
C = Maximum permissible error of closure in centimetres.
K = Distance between benchmarks in kilometres.
Alternatively,

$$C = m\sqrt{K}$$ Equation 2.2

Where,
C = Allowable loop/section mis-closure in mm.
m = A constant.
K = Total length levelled between benchmark in kilometres. For loop, K is the total perimeter distance.

Table 2.4 Allowable Loop/section Mis-closure Using Values for Constant m

First Order		Second Order		Third Order
Class I	±0.5 mm $\sqrt{K}$	Class I	±1.0 mm $\sqrt{K}$	±2.0 mm $\sqrt{K}$
Class II	±0.7 mm $\sqrt{K}$	Class II	±1.3 mm $\sqrt{K}$	

2.1.8 Level of Accuracy

Surveying involves determining the relative locations of points on the earth's surface by measuring horizontal distances, angles, differences in elevation and directions. Distances and angles can never be determined exactly since all measurements are subject to error. To control errors, surveys must be conducted according to standard levels of accuracy.

For topographic mapping, the desired level of accuracy is the plottable error, which is the shortest distance that can be depicted on a map at a given scale.

2.1.9 Records and Reports

2.1.9.1 Field Records

As with any engineering activity, the process of recording activities and preparing reports is essential for an efficient and timely operation. The most important information that is recorded during a survey is that of actual field measurements. This information may be recorded in a variety of formats and media. Typically, these measurements are recorded in electronic notebooks and laptops/tablets although field notebooks are still in use.

Besides the daily note keeping required during the performance of normal surveying activities, the surveyor is required to prepare various other reports. Three such reports are the weekly progress reports, the project cost report and finally the survey report.

Unless data collectors or electronic notebooks are used on the project, several notebooks shall be maintained. Each book shall begin with an introductory identification page and include the date, names of crewmembers and their assignments, instrument make/model, serial numbers when applicable, and the weather. Depending on the size and complexity of the survey, these notebooks may be combined. The exact format and type of record to be maintained will be as approved by the surveyor.

A list of the various types of notes are as below:

- ✓ Index.
- ✓ Traverse notes.
- ✓ Global Navigation Satellite System (GNSS) network diagrams.
- ✓ Cross section notes.
- ✓ Project notes.
- ✓ Level notes.
- ✓ Drainage notes.
- ✓ Land use classification notes.
- ✓ Cultural notes.
- ✓ Section corner/property tie notes.

When keeping records for automated surveys, at least one field book shall be used for each project. An index shall be provided to show major headings. Any rolls, maps or other books that cannot practically be included directly in the field book are to be cross-referenced. There are different formats for preliminary and location surveys. Control surveys shall be considered preliminary surveys.

2.1.9.2 Survey reports

Refer to section 5.6.6.

2.1.10 Survey Database

Data storing and archiving is a critical activity in topographic database systems. Firstly, this is due to the relevance of the survey data to other aspects such as quantity estimates in contract management. Secondly, a surveyor may need the Finished Road Levels (FRL) for one project corridor to tie with design of the subsequent sections.

A topographic database is a database which can store and update topographic (spatial) information and relevant attributable information. The Director of Survey, Kenya should be the overarching host of topographic survey database. However, as a supplement, it is important that the various road agencies keep survey data of their respective corridors in an accessible and retrievable GIS database. This can periodically be amalgamated into a central database.

It should be a requirement when submitting survey report that the surveyor also submits and uploads survey data of the OGL (original topographical data) and FRL data (as-built data and 3D data) to the database.

The design of a topographic database should be in a GIS environment, and its design should at minimum include:

- ✓ Identification and analysis of user requirements: To ensure that the database has neither insufficient information nor redundant information.
- ✓ Design of the data collection model: Specifications to reflect system context and user requirements. This should involve the establishment of standards for implementation such as methods of data collection, methods of quality control and design of a 'quality model', and specification for hardware/software support.
- ✓ Selection of the physical model: This is the database management system for processes of data structure and data retrieving.
- ✓ Design of the functional model: This is the tailored data model which supports the user's view on the stored data sets and their application.

3 Site Investigations

3.1 General

In general, there are four stages leading up to and including Final Engineering Design. These are:

1. Identification and general planning.
2. Pre-feasibility study.
3. Feasibility study or preliminary engineering design.
4. Final Engineering Design.

These stages are described in the following sections. The final or detailed engineering design is dealt with in Section 5.6. Not all stages will be required for all projects, particularly for projects for upgrading a road from one class to a higher class.

3.2 Desk Studies and Existing Information

Before any ground survey is carried out and, indeed, before such a survey can be planned and executed, it is important to study all the relevant information that is available about the project area. This is done through systematic desk studies which entail the collection of existing information for review and analysis. Sources of information include the following:

Table 3.1 Sources of Information for Site Investigations

No.		Sources of Information for Site Investigations
1	Existing survey datum (both aerial and terrestrial)	
2	As-built plans	
3	Existing photography (both aerial and ground)	
4	Cadastral/property boundaries	
5	Local land and property ownership	
6	Government agency contacts	
7	Existing maps and charts - these include but are not limited to:	
	a	Topographic maps, registry index maps, natural and political/administrative boundaries, natural vegetation and trees, buildings
	b	Triangulations stations and benchmark locations, level data and tables of elevations
	c	Physical Planning Development Plans
	d	Utility maps (electricity, water, sewerage, and fibre optic cables)
	e	Stream flow maps and data
	f	Water resource maps
	g	Geological maps
	h	Coastline charts
	i	Hydrographic surveys of inland lakes, oceans, and reservoirs
	j	Geodetic Conversion Tables
	k	Seismological studies
	l	Charts of the lakes and connecting waters
	m	Township plots, showing land sub-divisions
	n	Soil charts, maps, and indexes
	o	Forest resource maps including topography, culture, and vegetation classification

In general, some form of desk study is required at most stages in the development of a road project. The scope and level of detail of such desk studies depends on the stage of the project's development, the type of information under consideration (e.g. geotechnical, hydrological, traffic, environmental, social), and the amount of information that is available.

Desk studies are less expensive than site investigations. Therefore, by making use of existing information, the project can (at the very least) be improved, the cost of new site investigations can be reduced, and the effectiveness and efficiency of carrying out the required new site investigations can be considerably enhanced. However, care is required to ensure that any existing data is reliable. In particular, old data might be out of date (e.g. traffic data), or incomplete (e.g. hydrological data).

Desk studies help to check the suitability of all environmental and engineering conditions along different route options. Studying existing documents, including site investigations from earlier projects, and examining maps and aerial photographs/satellite imagery often eliminates an unfavourable route from further consideration, thus saving a considerable amount of time and money. Topographic maps give essential information about the relief of an area, and whether there are any existing routes or not. Aerial photographs/satellite imagery provide a quick means for preparing valuable sketches and overlays for reconnaissance/field surveys.

There are several very helpful sources of information in Kenya that should be used for this purpose. The list of references includes Survey of Kenya; Kenya National Spatial Data Infrastructure (KNSDI) when/if available; and other relevant Government agencies where data relevant for site investigation can be obtained.

3.3 Identification and General Planning

This is the stage at which the need for the project is identified and projects that do not meet selection criteria defined by the appropriate authorities are rejected. For low volume roads this will usually be done at a relatively local level and will be the output of a relatively simple planning process. It is likely that only a desk study and possibly a simple reconnaissance or pre-feasibility survey will be carried out and the project may be rejected on cost grounds if difficult engineering problems are encountered. In contrast, for a major road project the 'project cycle' will include all the stages described below with key decisions made at Agency/Ministry level.

3.3.1 Pre-feasibility Study

This is the stage where an economic and engineering assessment is made to obtain a broad appreciation of the viability of the competing alignment options, and the main engineering problems and any other issues affecting the route are identified (for example, environmental and cultural issues) and likely corridors for the proposed road selected.

One of the most important aspects of the pre-feasibility study is early communication with the people who will be affected by the road and local administrations. Their views are vital for the completion of a successful project and interacting with them throughout the project is essential from the outset.

Site investigations comprise desk study followed by a reconnaissance survey plus some additional testing to confirm the scale of any significant engineering problems within the potential corridors.

A reconnaissance survey provides data that enables specialists to study the advantages and disadvantages of several possible alignments and then to determine which should be considered for further investigation. It is an opportunity for checking the actual conditions on the ground and for noting any discrepancies in the maps or aerial photographs. During this survey, it is necessary to make notes of soil conditions, especially potentially problematic soils; availability of construction materials; unusual grade or alignment problems, water crossings and potential drainage problems; and requirements for clearing and grubbing. It is also very useful to take photographs or make sketches of reference points, structure sites, landslides, washouts, or any other unusual circumstances.

The output of the pre-feasibility study for low volume gravel roads should be a single selected alignment for possible further investigation at the feasibility stage if required. For all paved roads and higher volume gravel roads, more than one viable alignment option should be available.

3.3.2 Feasibility Study or Preliminary Engineering Design

At this stage sufficient data is required to identify the final choice of route and the structural design of the road. The feasibility study survey consists, essentially, of mapping the terrain along the centreline of the viable route or routes identified at the pre-feasibility stage. Sufficient data is required to obtain likely costs to an accuracy of better than about 25%. General costs for similar roads that have been built recently may be used for much of the assessment but the costs for major structures such as bridges and major earthworks need to be estimated sufficiently accurately hence the extent of the site investigation programme is dictated by these requirements.

After the feasibility study there should be sufficient information for the final route alignment to be selected. Minor adjustments to the route alignment may still be necessary during design, but the number of iterations needed to establish the best alignment and confirm the choice of the route should decrease significantly.

In some cases, the choice of final route alignment might depend on factors other than just the engineering factors. Considerations such as environmental issues, numbers of people within a minimum distance from the road, proximity to historic, religious, or other cultural sites and so on might override the basic economic analysis. Decisions based on some form of multi criteria analysis are available and could be used by those responsible if required.

3.4 Scope of Investigations

Table 3.2 summarises the different studies, surveys and investigations required at different stages of the road design process. For low volume roads it will not normally be possible to carry out surveys to the level required for higher classes and the reader should refer to the **RDM 3.4**.

Table 3.2 Summary of Survey Requirements for Route Selection and Design

Stage of Design	Study	Comments
Identification	Engineering Survey	Probably an existing road or track. Very broad-brush approach based on historic records. Major engineering problems identified which may include status of road reserve.
	Social	The need for the road will have been based on the current planning process at regional or local level. Social assessment based on desk study information and concentrated on major issues such as land acquisition and resettlement action plan (RAP).
	Environment	Assessment based on desk study information but concentrated on major issues such as land take and re-instatement. Protected areas including forests should be taken into consideration for site selection.
	Cost estimation	Historic data only. Based principally on terrain and number of structures.
Prefeasibility	Engineering	Each option is broadly specified in terms of alignment, geometric and pavement design, and structures. Limited geotechnical surveys may need to be undertaken together with historic surveys to identify basic designs and availability of materials. Limited evaluation of drainage conditions is also required to identify likely numbers and sizes of drainage structures. The following aspects should be addressed: 1. Drainage areas of main river systems and extent of flooding of low-lying areas. 2. Location of all possible bridge sites and water crossings requiring more than a small culvert. 3. Slope stability and potential landslide problems. 4. Other possible major hazard areas such as poorly drained soils, problem soils, springs, and erosion in river courses. 5. Extent of erosion problems with road drainage requirements. 6. Possible sources of water for construction. 7. Possible sources of construction materials. 8. Assessment of land acquisition/Resettlement Action Plan. 9. Site clearance problems.
	Social	Essential to engage local communities in dialogue concerning the impact of the road. Details now required of land acquisition - and RAP for each option.
	Environment	Many common environmental issues associated with road construction, attention must be paid to borrow and spoil areas and likely changes in drainage patterns plus possible effects of the road on deforestation.
	Cost Estimation	Largely based on historic records but now supplemented with more detail about the scale (and therefore likely cost) of structures.
Feasibility	Engineering	The most favourable bridge sites should be identified. Detailed geotechnical surveys may need to be undertaken in unstable mountainous terrain and for the foundations of major structures. A hydrological study may be needed if substantial rivers are to be crossed. All culverts and water crossings should be identified. The availability of materials should be confirmed. Spoil and borrow areas should be identified. The data should be sufficient for the preferred option to be selected and specified in terms of alignment, geometric and pavement design, and structures.
	Social	The main social issues should have been identified and a preliminary assessment made. Any additional data should be obtained if required.
	Environment	The main environmental issues should have been identified and a preliminary assessment made. Any additional data should be obtained if required.
	Cost Estimation	Data are required that are sufficient to obtain likely costs to an accuracy of better than about 25%. Usually based on historic costs of similar roads supplemented with any additional costs if any expensive structures are required.
Final Engineering Design	The pre-feasibility and feasibility studies will have identified all major issues and should also have provided information on any additional data that might be required for completion of the final design and the required supporting documents outlined in Section 3.1. ***Note:*** *It is important to note that an inadequate design leads to inadequate contract documents which, in turn, leads to contractual disputes and expensive claims by the contractor. It is a false economy to be frugal at this stage of the project cycle.*	

4 Route Corridor Selection

4.1 General

Surveying for road design involves the gathering of field information and measurements for use in locating, designing, and constructing highways and other related features. Field data is collected by terrestrial and aerial methods or by a combination of these two methods. Establishing controls for construction is generally done by ground surveying techniques. (Refer to section 5.6.2.1).

The safety of field crews and the travelling public is a high priority. Surveying activities are not to be attempted on or adjacent to live traffic until appropriate traffic warning and/or control measures have been implemented.

There are two main activities of route selection:

1. Preliminary identification of potential corridors and comparison.
2. Site visit and survey.

4.2 Preliminary Identification of Potential Corridors

The basic requirements of an ideal alignment between two terminal stations are that it should be short, easy to construct and maintain, safe in terms of stability of natural hills and embankment slopes and economical in terms of initial cost, maintenance cost and operating cost.

Using 1:50,000 scale topographical maps and aerial photographs/imagery together with knowledge of the project requirements, it is possible to trace out some possible alternative alignments (satellite imagery and imagery from Unmanned Aerial Vehicles (UAVs) may also be used in determining possible alignments). This is readily accomplished by referring especially to the vertical geometric design criteria for maximum gradient and plotting possibilities through correlation with the contour lines shown on the maps.

For each of the possible alternative alignment corridors, the existing maps should be studied, and aerial imagery examined with appropriate imagery processing software. From this desk study, it will be possible to assess the positive or negative influence of the following local factors:

Table 4.1 Factors Influencing Selection of Potential Corridors

Ref.	Factors
a)	Topographic, geologic, and physical characteristics;
b)	Number, type, and characteristics of watercourses;
c)	Potential risk of landslides, slope instability or floods;
d)	Human settlements affected by the road;
e)	Socio-economic factors impacted by the road; and
f)	Environmental impact of the selected route.

The proposed alternative alignments corridors based on factors in Table 4.1 are next studied, evaluated and compared based on the criteria as per Table 4.2. The best alternatives are then selected for further studies and field assessment.

Table 4.2 Basic Criteria for Route Corridor Selection

Criteria	Route corridor selection
Length of corridor	What are the relative lengths of the alternatives? Normally the shortest distance is preferable. This should however be balanced with grade, as shorter alignments tend to have steeper gradients.
Vertical gradient	What are the typical and maximum gradients of the alternatives? Normally the least severe gradient alternative is preferred. However, the alignment with the lowest gradients may have the longest length.
Existing road	Which alternative more closely follows an existing road or track? This makes survey and construction easier and may indicate the route of least earthworks.
Terrain	Which alternative follows the least severe terrain type? An alignment through, for instance, rolling terrain should be less costly to construct, have lower vehicle operating costs and maintenance costs, and less severe horizontal curves than a route through mountainous terrain. Which route remains for a longer period on a ridgeline? Such an alignment minimises the need for drainage structures.
Land acquisition	Which alignment minimises the need for land acquisition? E.g., consider the amount of farmland to be taken by the road and which alignment minimises the need to demolish buildings and houses, and which alignment requires less resettlement of Project Affected Persons (PAPs)
Large structural features	What is the total number of bridges and their respective estimated spans required for each alternative? What is the total aggregate length of these bridges?
Environmental factors	Which route results in the least environmental disturbance to the surrounding area?
Project cost	Which route has the least overall project cost, including design, construction, maintenance and operation?
Social factors	Which alternative best fits within the social considerations at play? Which one has more positive socio-economic outcomes on the abutting communities and the road users?

4.3 Site Visit and Survey

After the preliminary desk study, a site visit must be made to the area where the road is planned. Where terrain constraints make such a visit problematic, a flight can be made over the terrain and all potential routes can be directly examined from the air.

When potential route corridors have been identified from the desk studies a reconnaissance survey is usually employed to verify, modify, and update the desk study and interpretations, further assess the selected corridors, help determine the preferred corridor, and identify factors that will influence the feasibility of the design concept and relative costs.

The key skills are required as part of the personnel making a site inspection visit include:

1. Highway engineer,
2. Soils & materials engineer,
3. Hydrologist,
4. Surveyor,
5. Bridge/structures engineer,
6. Environmentalist,
7. Sociologist,
8. Local administrative personnel, and,
9. Physical planner

In most cases, the information obtained from the reconnaissance survey will lead to significant modifications of the desk study interpretations. During the reconnaissance survey, additional to the data already collected as per Section 4.2, the following information should be determined:

- ✓ Topographic and geomorphologic characteristics.
- ✓ The location of topographic constrains, such as cliffs, gorges, ravines, rock out crops, and any other features not identified by the desk study.
- ✓ Slope steepness and limiting slope angles identified from natural and artificial slopes (cutting for paths, agricultural terraces, and existing roads in the region).
- ✓ Slope stability and the location of pre-existing landslides.
- ✓ Soils geology, tectonics, rock types, geological structures, rock outcrops, dip orientations, rock strength and rip-ability.
- ✓ Approximate percentage of rock in excavations.
- ✓ Availability of construction materials sources and their distribution.
- ✓ Soil types and depth (a simple classification between residual soil and alluviums/colluviums is useful at this stage).
- ✓ Soil erosion and soil erodibility.
- ✓ Slope drainage and groundwater conditions.
- ✓ Hydrology, drainage stability and the location of shifting channels and bank erosion.
- ✓ Land use, land cover and their likely effect on drainage.
- ✓ Likely foundation conditions for major structures.
- ✓ Approximate bridge spans and the sizing and spacing of culverts.
- ✓ Flood levels and river training/protection requirements.
- ✓ Environmental considerations, including forest resources, land use impacts and socio-economic considerations.
- ✓ Verify the accuracy of the information collected during the desk study.
- ✓ The possibility of using any existing road alignments including local re-alignment improvements.
- ✓ Information on the physical accessibility to bridge sites and the proposed corridors, including the geomorphology of drainage basins, soil characteristics, slopes, vegetation, erosion and scouring.
- ✓ Possible diversion routes during construction.
- ✓ Information on the possible land acquisition.

During the site inspection, the team should examine all alternatives. This information can be combined with the results of the desk study to determine the most appropriate alignment alternative. An appropriate field assessment report of each alternative by each discipline will have to be prepared.

The route selection process will be completed with the selection and recommendation of the best and most viable route for detailed study and design taking due account of construction cost, benefits to the local population, and length of travel for each alternative. The final report will also give details as to why a certain alignment alternative was selected and why others were rejected or not considered.

4.4 Principal considerations for route selection

This section highlights the key issues that require consideration when establishing and finalising the route alignment. For upgrading existing roads many of the points raised will not be relevant. For entirely new roads most of the issues should be considered and can act as a check list for the road designer. A summary of the key issues are highlighted in Table 4.3 and Table 4.4.

Table 4.3 General Considerations for Route Selection

Category	#	Considerations
Engineer-ing	**1.**	The road should be as direct as possible (within the bounds of the geometric standards for the particular class of road) between the cities, towns, or villages to be linked, thereby minimising road user transport costs and probably minimising construction and maintenance costs as well.
	2.	The preferred alignment should be one that permits a balancing of cut and fill to minimise borrow, spoil and haul.
	3.	The road should be close to sources of borrow materials and should minimise haulage of materials over long distances.
	4.	When the road follows a railway line or river, frequent crossings of the railway or river should be avoided.
	5.	The preferred alignment is one that is founded on strong subgrades, thereby minimising pavement layer thicknesses. Therefore, marshy, and low-lying areas and places with poor drainage and weak materials should be avoided.
	6.	‘Problem soils and erosion susceptible soils should be avoided as much as possible.
	7.	An important control point in route selection is the location of river crossings. The direction of the crossings of major rivers should be normal to the river flow.
	8.	When an alignment passes near to a river, flood records for the past 50 years must be reviewed if these are available. Areas liable to flooding and areas likely to be unstable due to toe-erosion by rivers should be avoided. Interviewing local residents is important to provide more information. Where possible, the road should be located such that the road reserve can be wide enough to allow future upgrading to a wider carriageway. Consideration should also be made to have land acquisition for future expansion.
Socio eco-nomic and cultural	**9.**	The road should, as far as possible, be located along edges of properties rather than through them to minimise interference to agriculture and other activities and to avoid the need for frequent crossing of the road by the local people.
	10.	The road should not be so close to public facilities that it causes unnecessary disturbance. Cultural sites such as cemeteries, places of worship, archaeological and historical monuments should be specifically protected. Although a road is designed to facilitate access to hospitals, schools and so on, it should be located at a reasonable distance away for safety and to reduce noise.
Cost	**11.**	Where the proposed location interferes with utility lines (e.g., over-head transmission cables and water supply lines), the decision between changing the road alignment and shifting the utility line should be based on a study of the feasibility and the relative costs.
Environ-mental	**12.**	The location should be such as to avoid unnecessary and expensive destruction of trees and forests. Where intrusion into such areas is unavoidable, the road should be aligned on a curve to preserve the background.
	13.	The road should be ‘integrated’ with the surrounding landscape as far as possible. Normally, it is necessary to study the environmental impact of the road and ensure that its adverse effects are kept to the minimum.
	14.	Areas of valuable natural resources and wildlife sanctuaries should be avoided.

Table 4.4 Special Considerations for Route Selection in Mountainous Areas

<table>
<tr><th>Criteria</th><th>#</th><th colspan="2">Special Considerations</th></tr>
<tr><td rowspan="14">General Principles</td><td>1.</td><td colspan="2">Ridge top alignments are often the most stable and least costly. They are also favoured on socio-economic and environmental grounds because they usually follow established lines of communication and habitation. However, steep slopes and changes in ridge-top elevation dictate that alignments are frequently required to traverse a side slope beneath ridge tops.</td></tr>
<tr><td>2.</td><td colspan="2">Climbing sections of mountain roads can be designed as gradual traverses of side slopes at a limiting gradient, as switchbacks, or as a combination of the two.</td></tr>
<tr><td>3.</td><td colspan="2">The alignment should minimise the number of hairpin bends. Where unavoidable, the bends and switchbacks should be located on stable ground.</td></tr>
<tr><td rowspan="3">4.</td><td colspan="2">When choosing between these possibilities, it should be noted that the switchback has the following advantages and disadvantages:</td></tr>
<tr><td>Advantages</td><td>Disadvantages</td></tr>
<tr><td>✓ A greater flexibility in route corridor location can normally be achieved.
✓ The crossing of steep and unstable lower valley side slopes can be minimised or avoided.
✓ The use of switchbacks to connect lengths of relatively easy ground, such as valley floors and ridge tops, can in some cases lead to a more direct alignment with a saving in overall route length.</td><td>✓ On side slopes steeper than 30º, limited space to construct cut and fill slopes necessitates either a relaxation in geometric standards or more expensive retaining structures.
✓ Lack of spoil sites and access difficulties create problems during construction.
✓ Instability and erosion can easily extend from one loop of the road to another, both up slope and down slope.
✓ Storm runoff tends to become concentrated requiring large-capacity drainage structures and erosion protection works, and the cost associated with failure of any part of the drainage system is usually high.
✓ Switchbacks may result in a Departure from Design Standards.</td></tr>
<tr><td>5.</td><td colspan="2">If the topography allows, creating offset switchbacks, in which the curves are not immediately above one another but are staggered across the slope, can reduce the problems associated with switchbacks. This will minimise drainage problems and limit the danger of instability to fewer loops.</td></tr>
<tr><td>6.</td><td colspan="2">High fills should be avoided, and special attention should be paid to the compaction of all fills.</td></tr>
<tr><td>7.</td><td colspan="2">In relatively stable slopes, half cut, and half fill cross-sections should be adopted to minimise the disturbance to the natural ground.</td></tr>
<tr><td>8.</td><td colspan="2">Natural terrain features such as stable benches, ridge-tops, and low gradient slopes should be utilised. If a ridge-top is considered, roads should be located far enough above convergent gully headwalls or confluences to provide a buffer, otherwise, a structure is needed to intercept moving sediment below the road.</td></tr>
<tr><td>9.</td><td colspan="2">In crossing mountain ridges, the road should preferably cross the ridge at the lowest elevation.</td></tr>
<tr><td>10.</td><td colspan="2">Needless rise and fall should be avoided, especially where the general purpose of the route is to gain elevation from a lower to a higher point.</td></tr>
<tr><td>11.</td><td colspan="2">To minimise the adverse effect of moisture on the road environment, an alignment that is predominantly in sunlight should receive priority compared with one that is entirely or partially in the shade throughout the day.</td></tr>
</table>

This table continues onto the next page...

Criteria	#	Special Considerations
General Principles	12.	Locations along river valleys have the inherent advantage of comparatively gentle gradients, proximity to inhabited villages, and an easy supply of water for construction purposes. The advantages of a valley floor alignment are:
	13.	However, despite the attractiveness of a more direct route and low gradients, the construction costs of a valley floor alignment may be significantly higher than a ridge top alternative because of the high costs of bridging and cross-drainage and protective works against erosion.
	14.	On socio-economic grounds, valley routes may be less favoured if most villages are located on ridge tops.
Unstable Terrain	15.	Unstable slopes, areas having frequent landslide problems and benched agricultural fields should be avoided.
	16.	Mid-slope locations on long, steep, or unstable slopes should be avoided. If an unstable area must be crossed, end-hauling excavated material rather than using side-cast methods should be considered.
Erosion Potential	17.	If possible, it is best to avoid areas of high erosion potential. If not, considerable attention is required to dissipate flow in road drainage ditches and culverts and reduce surface erosion (RDM: Vol. 2 - Hydrology and Drainage Design). It is also advisable to consult local hydrological and environmental experts as well as obtain local knowledge and history during the process of route selection to ensure that the selected alignment has a minimum potential for soil erosion and that the project design provides sufficient erosion control measures.
	18.	In selecting the best location for the road, the engineering measures designed to minimise erosion will add to the construction costs but on-going maintenance to deal with debris, blockage and siltation will be required and no erosion protection system is guaranteed to prevent erosion.

5 Surveys

5.1 General

This chapter provides guidance to engineers, surveyors and technicians who are responsible for surveying and/or mapping. Description of data required, and the sources of such data is provided in this chapter as well as guidance for gathering, processing, and documenting the data.

5.2 Stages of Survey

Engineering Surveys generally comprise of five stages of activities from design to completion of construction. These are:

- ✓ Reconnaissance survey.
- ✓ Preliminary survey.
- ✓ Location survey.
- ✓ Detailed (construction) survey.
- ✓ As-built survey.

The surveys should be based on UTM coordinates system based ARC1960 Datum.

5.2.1 Reconnaissance Surveys

The reconnaissance survey is normally performed in connection with early scoping activities on a project. A reconnaissance survey of an area is the examination of a large area to determine feasible highway corridors or alternate locations within a corridor between designated stations. The evaluation of feasible alternatives is a comparison of these corridors or alternative locations in sufficient detail to select the corridor or alternative locations deserving further study. Some of the details collected from reconnaissance surveys include;

- ✓ Valleys, ponds, lakes, marshy land, hills, permanent structures, and other obstructions.
- ✓ Value of gradient, length of gradient and radius of curve.
- ✓ Number and type of drainage structures.
- ✓ High flood level (HFL).
- ✓ Soil characteristics.
- ✓ Geological features.
- ✓ Source of construction materials – stone quarries, water sources.

Aerial photography/imagery, satellite imagery, geological survey maps, survey of Kenya toposheets and forest service maps are often useful for reconnaissance purposes.

Despite the variable sources of information for an Engineering Survey, it essentially consists of four components:

i. Location: positional information to represent detail in its correct relative position.

ii. Definition: accepted descriptive representation of the detail and its component attributes.

iii. Presentation: present the collected detail in a format that is usable, understandable, and unambiguous.

iv. Quality: systematic methodology and auditing procedures to assure the integrity of the information.

5.2.2 Preliminary Surveys

Preliminary surveys are normally performed during the environmental planning and concept study phases of project development. The following are considered preliminary surveys:

- ✓ Aerial surveys.
- ✓ Satellite imagery and remote sensing.
- ✓ Ground control surveys.
- ✓ Topographic surveys.
- ✓ Bridge site surveys.
- ✓ Cadastral surveys.
- ✓ Preliminary alignment surveys.
- ✓ Special surveys (for retaining walls, drainage structures, borrow pits, quarry sites, etc.).
- ✓ Use of drones /UAVs.
- ✓ Land acquisition surveys.

Preliminary surveys provide the necessary data to be used in environmental planning, conceptual studies, bridge design, and highway design. Typically, the direct derivatives of preliminary surveys are topographic and planimetric maps (digital and hard copy), digital terrain data, and approved survey controls including their monumentation.

Aerial surveying is the process of obtaining topographic data from images taken from aeroplanes / UAVs rather than from ground field techniques. Where visibility permits, this method of surveying provides substantial savings in labour for information gathering, and ability to map large areas with ease. However, they have limitations in terms of cost and accuracy. In areas with dense non-arboreal vegetation or arable crop growing in fields, aerial surveying may not offer required accuracy.

Satellite imagery is the method of taking photographs of the earth by means of artificial satellites.

5.2.3 Setting Out Surveys

Setting out surveys are used for setting out the designed highway elements on the ground for execution of the project. In many ways, location surveys are the inverse of preliminary surveys. Preliminary surveys are used to extract and collect field data. Location surveys normally disseminate data back to the field. Location surveys always include the establishment of the highway components such as centreline, edges of the road, road reserves among others and existing features such as, property lines, buildings, and other reference points.

5.2.4 Detailed (Construction) Surveys

Construction surveys include establishing points in addition to those placed during the location survey. These include slope stakes, grade stakes, and culvert and bridge control stakes.

5.2.5 As-built Surveys

The purpose of as-built survey is to show the physical development “as it is built” at completion and depicts the geospatial extent or layout of the physical development in three dimensions. The as-built survey is necessary after construction is completed so as to check on the work of the contractor, verify contractual compliance, and for record purposes to update maps for future reference.

5.3 Information Gathering

Information gathering, as it relates to surveying, consists of two parts:

a. An examination of existing information about the project.

b. The physical gathering of the ground information.

Both parts are of equal importance and careful attention to detail during the first process (a) can lead to substantial savings in time and effort in the next process (b). The surveyor should use as much of the existing information as practical to reduce the time spent gathering actual field data.

5.3.1 Existing Sources

Before any type of survey occurs, a comprehensive search for existing information should be performed. For the most part, the information described below can be obtained from other government agencies. However, the search should not be limited to these agencies. Valuable information may be available from private firms that have worked on/near the project road or within the study area. If this information is available, it should be obtained through the support of the responsible road agency/authority (this support is important for verification of the survey data). Sources of information that are helpful during the course of surveys include the following:

a. **Survey Control Data** Horizontal and vertical control is crucial to performing an accurate and correct survey. Unless it is impracticable, all survey shall be tied to the National Survey Grid and the National Geodetic Benchmarks (NGBM).

   The horizontal and the vertical datum controls information can be obtained from the government-authorised body for National Geodetic Survey of Kenya, i.e. Survey of Kenya.

b. **Horizontal (triangulation stations) and vertical control (benchmarks).** The Survey of Kenya publishes a map showing the status of the horizontal controls that exist in Kenya. Triangulation maps may also be available. These triangulation maps show the triangulation stations monumented points and their general location throughout Kenya. Where available, the surveyor should request the following information for each monument:

   i. BM or triangulation station type and Identification Code. (The ID code is generally stamped on the monument cap).
   ii. Location (province, town, etc.).
   iii. Year the monument was established.
   iv. Geodetic latitude and longitude.
   v. Order of accuracy.
   vi. Elevation in metres.
   vii. UTM coordinates in metres based ARC1960 Datum
   viii. Monument description and historic data.
   ix. Azimuths and distances to neighbouring monuments.
   x. Station recovery/condition notes.

c. **As-built Plans.** Since most of highway construction activity concerns the rehabilitation and/or reconstruction of existing highway facilities, as-built plans can be an excellent source of preliminary information. Depending on the composition of the construction plans, a surveyor may obtain the position and condition of existing control points, right-of-way monuments, BMs, and construction BMs.

It is also recommended that the as-built plans from adjoining projects be used to achieve consistency between projects. Use of adjacent plans allows for the continuity of stationing and control throughout an entire route.

As-built plans and original survey notes can be obtained from the Ministry of Roads and Transport, or the relevant road agency.

d. **Aerial Imagery.** The use of aerial imagery as a source of preliminary surveying information is somewhat limited. General project layouts can usually be obtained from readily available maps rather than from aerial imagery. Alternatively, existing aerial imagery for a current project can often be used by the photogrammetrist. If the physical topography of the route has not been altered, the aerial imagery may be usable.

Aerial imagery can be obtained from road agencies, Survey of Kenya, or private firms.

e. **Existing Maps.** Generally, scales of 1:50,000 and 1:250,000 topographic maps are available covering the desired project area. These maps should be collected from appropriate survey offices. They provide a wide variety of control, land use, and terrain information. Lists of map types containing survey information are as follows:

i. Topographic, and index maps.
ii. Triangulations stations and benchmark locations, level data and tables of elevations.
iii. Stream flow data
iv. Water resources.
v. Geologic maps.
vi. Coastline charts.
vii. Topographic and hydrographic studies of inland lakes and reservoirs.
viii. Plane coordinate tables and UTM projections.
ix. Seismological studies.
x. Charts of the Great Lakes and connecting waters.
xi. Township plots, showing land sub-divisions.
xii. Soil charts, maps, and indexes.
xiii. Forest resource maps including topography, culture, and vegetation classification.

f. **Property Descriptions.** Property descriptions provide information concerning the identity and location of property corners. The surveyor shall make ties to the property corners during the cadastral survey portion of the fieldwork. This data is used by the design engineer when acquiring additional property for road projects.

g. **Government Local Agency Contacts**. Before any surveying activity begins on a project the local representatives of any concerned agency should be contacted to inform the agency that a survey is about to be performed. Special restrictions desired by these agencies, such as fire restrictions, recreational uses, scenic routes, limitations on cutting vegetation, and noise requirements, should be discussed. The agency contact will often provide additional information about availability of existing survey data and the type of ground survey desired. The names of specific agency contacts are usually identified in the reconnaissance report or in the scoping document.

Affected property owners should also be contacted. Where contact cannot be made or permission granted, the surveyor should contact an immediate supervisor rather than trespass.

5.3.2 Physical Ground Information

The type of information gathered during preliminary surveys can be broken down into three different categories: planimetric, topographic, and cadastral.

a. **Planimetric Data** Planimetric data consists of natural and political/administrative boundaries, natural vegetation, and topographic features such as signposts, trees, buildings, etc. Using ground-surveying/aerial techniques these features are located relative to control survey stations monuments.

b. **Topographic Data.** The intent of topographic data gathering is to obtain enough ground points to accurately describe the physical features and general relief of a specific area. Relief may be done using one of the alternative methods described below:

   i. The first method is using a preliminary alignment. Cross sections are measured at regular intervals (usually 20 metres) along this alignment. Additional cross-sections are measured to represent breaks in the topography such as high and low points when located between two consecutive cross sections.

   ii. The second method used to obtain topographic information is the use of radial surveying. In radial surveying, arbitrary points are located and connected to a 'control point'. An instrument is set up on a point with known elevation, and coordinates and readings are taken in a radial pattern around the instrument. Major breaks in the terrain (such as edges of shoulders, catch points, and drainages) are usually strung together in a series of sequential shots. These data points are called discontinuities and are treated differently from other random shots. The intent is to obtain a general description of the terrain, using a digital terrain model (DTM) to build an accurate contour map.

   iii. The third method is the use of aerial photography/imagery to capture topographic data. Aerial photographic/imagery shots are taken along the flight lines (or runs). The overlap between consecutive images is usually 60% while the side lap between flight lines is 30%.

   After collection of ground photo controls (performed using GNSS instruments), the aerial photos/imagery are processed using appropriate software to produce orthorectified images. Based on these orthorectified images, a Digital Terrain Model (DTM) is extracted. The same process is applied in orthorectifying satellite images. Light Detection And Ranging (LiDAR) sensors can also be incorporated with aerial cameras for a more efficient data collection and processing

c. **Cadastral Data.** A cadastral survey is used to locate property boundaries and monuments and is also used to determine their coordinates. Since property and right-of-way documents are often based on the actual location of cadastral monuments, the surveyor should verify these points by running traverses through them or by using the mean of two independent side shots.

5.4 Surveying Applications

Based on the probable flood discharges obtained for a number of rivers / streams, regional flood curves have been derived for major rivers in 5 drainage areas of Kenya.

The derivation of regional flood frequency curves used the following steps:

a. **Measurement of Horizontal Distances** One of the basic operations of surveying is determining the horizontal distance between two points on the surface of the earth. The distance between two points at different elevations is obtained either by computing the horizontal distance from a measured slope distance or by direct horizontal measurement. Distances may be measured by pacing, odometer, stadia, taping, light waves, radio waves, infrared waves, or GNSS.

   The use of stadia has essentially been replaced by Total Stations which employ electronic distance measuring; the stadia method of determining distances will not be discussed in this Manual. Details of this method may be found in any standard surveying textbook.

   Most distances are now measured using Total Stations. These machines use light, radio, micro, or infrared waves to determine the distances between two points. The systems typically consist of a transmitter/receiver unit and a reflector device. The reflector is generally a glass prism. Total Stations are capable of high accuracies over both short and long distances.

   The use of GNSS equipment is also becoming more common as the technology becomes more available.

b. **Levelling Procedures.** Levelling is the surveying operation performed to determine elevations of points, to determine differences in elevations between points, and to control grades and roadway templates in construction surveys. The traditional instrument used is a spirit level. Other instruments used for determining vertical distances are the transit, total station, and digital levels. GNSS can also provide elevations for some purposes but will require specialised methodology to ensure data correction. When differences in elevation are determined either trigonometrically or by using a level machine and a staff, the effects of curvature and refraction must be considered. This is particularly true when the horizontal distances are long and when a high degree of precision is required.

   Levelling with a total station is the fastest and simplest method of determining elevation differences. A total station includes an electronic transit/theodolite combined with an EDM. A BM may be established by the surveyor at predetermined intervals along the survey. The elevations of BMs are determined to varying degrees of accuracy by the field operation.

   Profile levelling is used to determine the elevations of the ground surface along a given line. In highway applications, profile levels are often performed on centreline stations and on cross section reference points.

c. **Measurement of Angles.** A horizontal angle is the angle formed by two intersecting vertical planes. Currently, total stations of high-level accuracy are used to measure angles. The requirements of surveying accuracy for various types of survey projects are listed in Section 2.1.7.

d. **Traverse Surveys and Computations.** A traverse is a series of connected lines of known length and course direction. The lengths of the lines are determined by direct measurement of horizontal distances, by slope measurements, or by other methods as described in Section 5.2.

   Some of the many purposes for which traverse surveys are made are listed below:

   i. To determine the boundaries of individual property.

   ii. To determine the position of arbitrary points from which data may be obtained for preparing various types of maps.

iii. To establish ground control for photogrammetric mapping.

iv. To establish control for gathering data regarding earthwork quantities for highway construction.

v. To establish control for locating highway projects.

In general, traverses may be of two classes. The first class is an open traverse. It starts either at a point of known horizontal position with respect to a horizontal datum or at an assumed horizontal position and ends at an unknown horizontal position. However, with the advancement of survey technology, closed traversing is strongly recommended.

A closed traverse starts at a known point, with defined horizontal position and ends either at the same point, or at another known point. A known horizontal position is defined by one or more of the following:

- ✓ Geographic latitude and longitude.
- ✓ X and Y coordinate on a grid system.
- ✓ Location on, or in relation to, a fixed boundary.

To make an open traverse more reliable, several techniques may be employed:

i. Each distance can be re-measured.

ii. The measurements of the angles at the stations can be repeated.

iii. The directions of the lines can be checked by magnetic bearings or other observations.

A traverse that closes on itself affords a check on the accuracy of the measured angles, as well as an indication of the consistency of measuring distances. A closed traverse that starts at one known position and closes on another is the most reliable, because the position of the final point checks both the linear and angular measurements of the traverse.

e. **Horizontal and Vertical Curves**. The horizontal alignment of a highway consists of a series of curves connected with straight lines. The grade line on a profile is likewise made up of straight lines and curves. These curves may be arcs of circles, parabolas, or spiral curves. The parabola is generally used as a vertical curve on grade lines, while the circle and/or the spiral curves are used as horizontal curves.

f. **Coordinate Sytems.** Computations of traverse point locations are reduced to a series of X and Y coordinate pairs. When practical, the highway survey must be converted to the National plane coordinate system, which is the UTM Zones 36 and 37-grid system. The following are advantages of using the National coordinate system:

- ✓ A traverse of relatively low accuracy run between a pair of control points is raised in accuracy after an adjustment between the control points is made.
- ✓ The use of well-established control points in a traverse eliminates many serious mistakes often made in measuring both distances and angles.
- ✓ A point whose X- and Y- coordinates have been determined can, if lost, always be replaced with the degree of precision with which it was originally established.
- ✓ Maps that have been controlled by coordinated points will always conform when joined, no matter how unrelated the projects, which necessitated the maps.
- ✓ The use of a common reference system for surveys reduces or eliminates costly duplication of control surveys over the same area by various engineers and surveyors.
- ✓ The use of the National coordinate system permits surveys to be carried over nationwide distances by using plane surveying methods with results which approach those obtained by geodetic methods.

Photogrammetric mapping can be conducted at much less expense when all control points in the area to be mapped are on the same system.

Where an assumed datum of coordinate system is used, it should be stated in all field notebooks, maps or plans compiled from the data.

g. **Topographic Surveys.** Topography measurements can be obtained by total station, theodolite and EDM, level and tape, arc and tape, or any other method (such as GNSS equipment and UAV) of measuring angles, elevation, and distance. The choice of equipment is usually based on the degree of accuracy desired and the cost of obtaining the data. In compiling topography, the positions of all planimetric features (such as buildings, fences, and streams) are located with respect to the control line. These items are also plotted on the topographic map (See Section 5.6) which should be tied to the National Survey Grid.

h. **Photogrammetry.** Photogrammetry is the science of making measurements on photographs. Terrestrial photogrammetry applies to the measurement of photographs that are taken from a known ground station, while aerial photogrammetry applies to the measurement of photographs taken from the air. Aerial photogrammetry is most often used in highway design applications.

Usually, a system of control points is located on the ground then targeted so they can be identified in the aerial photographs. Special points called tie points are located on the aerial photographs. The aerial photographs are then scanned with a high-resolution special scanner. These images are then processed using photo imaging software to extract a DTM as discussed in Section 5.6.6.

The main advantages in compiling topographic maps by using aerial photographs over ground methods are as follows:

- ✓ Expandable map widths.
- ✓ Reduced compilation time.
- ✓ Reduced control-surveying time.
- ✓ Highly accurate location of planimetric features.
- ✓ No interference by adverse weather and inaccessible terrain.
- ✓ Uniform accuracy throughout the map.

By the proper selection of flying heights, focal lengths, plotting instruments, and placement of ground controls, photogrammetric mapping can be designed for any map scale ranging from 1:100 to 1:20 000 and smaller.

The following are some of the disadvantages of mapping using aerial photographs:

- ✓ Difficulty plotting areas containing heavy ground cover, such as high grass, timber, and underbrush.
- ✓ High cost per hectare to map areas of 2 hectare or less.
- ✓ Difficulty locating positions of contour lines on flat terrain.
- ✓ Difficulty scheduling photographic flights (most jobs cannot be flown in winter or summer).
- ✓ Supplemental ground survey is required where the ground cannot be seen in the spatial model because of ground cover and where such planimetric features as overhead and underground utility lines must be located on the map. Editing is necessary to include road classification; property boundary lines not shown on the photography; drainage classification; and names of places, roads, and other map features.

The use of UAVs is increasingly becoming popular for undertaking aerial surveys and has been proven to be quite efficient and cost effective. This technology should thus be adopted where possible in undertaking topographical surveys

i. **Global Navigation Satellite Systems (GNSS)** Global Navigation Satellite Systems (GNSS) include constellations of Earth-orbiting satellites that broadcast their locations in space and time, of networks of ground control stations, and of receivers that calculate ground positions by trilateration. GNSS are used in all forms of transportation: space stations, aviation, maritime, rail, road, and mass transit. Positioning, navigation, and timing (PNT) play a critical role in telecommunications, land surveying, law enforcement, emergency response, precision agriculture, mining, finance, scientific research and so on. They are used to control computer networks, air traffic, power grids and more.

At present GNSS includes two fully operational global systems, the United States' Global Positioning System (GPS) and the Russian Federation's GLObal NAvigation Satellite System (GLONASS), as well as the developing global and regional systems, namely Europe's European Satellite Navigation System (GALILEO) and China's COMPASS/Bei-Dou, India's Regional Navigation Satellite System (IRNSS) and Japan's Quasi-Zenith Satellite System (QZSS). Once all these global and regional systems become fully operational, the user will have access to positioning, navigation, and timing signals from more than 100 satellites.

5.5 Specific Survey Procedures

By using the methods discussed in the previous section, the surveyor can perform the more common highway surveying assignments. The survey coordinate system used in Kenya is based on UTM grid and ARC1960 Datum or any other national datum approved by Director of Surveys. Typical highway surveying projects include the following:

- ✓ Control surveys for both ground and aerial projects.
- ✓ General surveys.
- ✓ Location surveys
- ✓ Property surveys.
- ✓ Construction surveys.
- ✓ Bridge surveys.
- ✓ Sundry surveys.
- ✓ Sub-surface utility surveys.
- ✓ As-built surveys.

5.5.1 Control Surveys

Control surveying is the process of establishing a line or grid of points throughout the project limits. The control points can be established by traversing, triangulation or GNSS in static mode. These points are the traverse points on a traverse line running between two or more points of known geodetic position. These known points form reference points from which all measurements within the project are made. Since the entire project will be relative to these points, extra care should be given to their accuracy and location. Depending on whether the project will be measured by ground methods or by aerial photogrammetry, different requirements exist for the frequency and location of the traverse points.

The established or used survey control points must be referenced to the National Survey Datum. A Survey Datum is the framework upon which all geospatial information is referenced. The Survey Datum not only supports the accuracy of captured survey data, but also provides geospatial correlation with other data sets. It decides the integrity of delivered geospatial products and is the core element for sharing geospatial information within the survey department and other agencies in government, as well as the private sector.

5.5.2 General Surveys

Reconnaissance surveys are divided into two parts, a survey of the area and an evaluation of feasible route alternatives. For scoping purposes, horizontal and vertical information about the area is needed as well as information about cover and culture. This information can be obtained by field surveys; from existing maps or maps compiled specifically for the project; or it can be extracted from aerial photographs, which is probably the most efficient method. Vertical aerial photographs represent the ground surface with sufficient accuracy to determine a feasible corridor.

Topography, geology, land use, ecology, and other features are immediately evident or readily interpreted by stereoscopic examination of the photographs. DTM are easily derived from these surveys.

5.5.3 Location Surveys

A location survey is the placement of the final alignment of the highway as it is to be constructed. Typically, during a location survey, the engineer will establish the following items along the project route. Other actions may be included in the location survey process:

- ✓ Centreline of the roadway alignment.
- ✓ Right-of-way limits (RoW).
- ✓ Reference points (RP).
- ✓ Project control points.

Often, other actions are included in the location survey process. These include the marking of the clearing limits, the movement of temporary benchmarks from inside to outside the construction limits, and the running of profile levels. The centreline is marked with either a small wooden peg or a nail/ steel bar to indicate the point. In addition to the cross-section centreline points, the alignment control points (i.e. PC, PT) may be staked and marked.

If required, the RoW line is designated with a stake placed along the cross section or at intervisible limits. Major breaks in the RoW line are marked with a small wooden peg. Additional control points are placed outside the construction limits provide an extra layer of control coverage.

5.5.4 Property Surveys

A property survey is a means by which the cadastral boundaries along the route can be represented on the various survey maps. If property lines can be determined in the field, they should be tied to the traverse line. The methods used to tie property markers will be of an accuracy that is equal to that of the traverse. A property survey will allow for a careful and precise measurement of land to be acquired for the project road. The following data should be gathered related to properties:

- ✓ Land corners.
- ✓ Lot corners and subdivisions.
- ✓ Right-of-way monuments.
- ✓ Records. The records required include the following:
    - i. Copies of the original government field notes for Township, subdivision, government land survey plans, etc.
    - ii. Prints of any subdivision plans within the area.
    - iii. Prints of master plans covering the general area.

iv. Copies of any records of survey made in the general area and filed in the county.

v. Copies of surveys by various organisations (such as Kenya Railways; county and city authorities; irrigation, water, and drainage agencies; power companies; gas and telephone companies; other government agencies, etc.).

vi. Copies of any title deeds (if required).

vii. Roads authority's documentation or relevant legislation dedicating roads or establishing right-of-way widths.

viii. Political/administrative boundaries. These are required for national forests, parks, and similar boundaries.

5.5.5 Construction Surveys

A construction survey is the process by which construction stakes are placed on the ground that allow the contractor to begin building the roadway template. These points include slope stakes, and minor structure stakes (i.e. culverts and drop inlets). The location and elevation of these grade stakes may be determined from the plans or from computer printout sheets.

5.5.6 Bridge Site Surveys

The fieldwork for a bridge site survey is similar to a normal preliminary survey. The activities of placing project control, running levels, taking cross sections, and making ties to the National Geodetic Coordinate System are still required. However, for bridges and culvert locations, the surveyor should collect the following additional information.

- ✓ Waterway cross sections.
- ✓ Highest watermark (highest flood level).
- ✓ Improved land.
- ✓ Existing bridges.
- ✓ Effect of adjacent structures.
- ✓ Photographs.
- ✓ Extent of flood plain.

5.5.7 Sundry Surveys

Sundry surveys is a term for describing all other miscellaneous types of survey activities. Typical sundry surveys include those of quarry sites, landslide areas, and parking or vista areas. These surveys are to be monumented similarly to preliminary surveys.

5.5.8 Sub-surface Utility Surveys

The survey may require subsurface utility assets to be located. The surveyor shall be responsible for the collection of subsurface utility data for the purposes of planning, detail design, maintenance, and construction. The surveyor when investigating subsurface utilities shall liaise with the appropriate utility owner to determine any conditions that are required by the utility owner are to be met. Location of subsurface utilities shall be undertaken by use of appropriate technologies e.g., Ground Penetrating Radar (GPR).

5.5.9 As-built Surveys

As-built surveys document the precise final locations and layouts of engineering works in three dimensions (3D) and record any design changes that may have been incorporated into the construction. These are particularly important when underground facilities are constructed, so their locations are accurately known for maintenance purposes, and so that unexpected damage to them can be avoided during later installation of other underground utilities.

A complete set of as-built Drawings shall be prepared and submitted as part of the project deliverables. CAD/shapefile and hard copy drawings (with various approvals, endorsements) of the finished project capturing all the as-built features shall be lodged with the relevant Ministry and copies sent to the implementing agency(ies) to determine compliance with plans, note changes, make terminal contract payment, and document the project for future reference.

5.6 Topographic Surveying

Topographic surveys are carried out to determine the planimetric location and/or elevation of surface and subsurface features, facilities, or utilities. These surveys are normally used to prepare highly detailed site maps and 3D digital databases of project sites, facilities and utility infrastructure for future design, ongoing construction, or as-built condition.

5.6.1 Survey Systems

A detailed topographic survey should be carried out along the proposed alignment(s) with the Right of Way (RoW) using the latest surveying techniques, procedures, and equipment.

Some of the surveys systems that may be used in topographic surveys include:

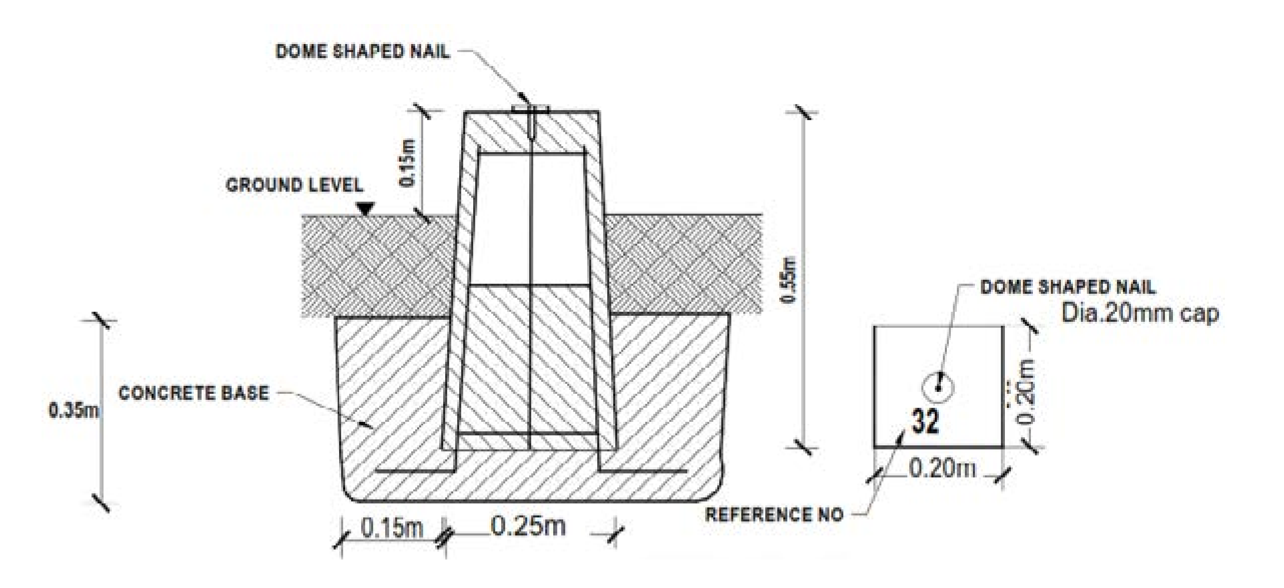
- ✓ Aerial photographic mapping.
- ✓ Terrestrial photogrammetry.
- ✓ Light detection and ranging (LiDAR).
- ✓ Terrestrial survey using conventional survey procedures.
- ✓ GNSS using static and Real Time Kinematic (RTK) procedures.

5.6.2 Establishment of Survey Controls

Primary reference beacons and benchmarks must be established in triplicates at approximately 5-kilometre intervals within the limits of the road reserve. The other controls should be established at between 200 and 300 metre intervals.

The Survey Controls shall be tied to the National Survey grid. Benchmark (BM) heights shall be referenced to the National Datum and shall be submitted to the Director of Surveyors for approval and authentication. Beacons and BMs shall be permanently mounted in the field using a centered Y12 twisted bar (300mm long) in concrete at 200mm diameter and 300mm deep hole.

Figure 5.1a Beaconing of Permanent Controls



Appropriate references and description cards must be provided. A sample of a survey control beacon is presented in Figure 5.1. Figure 5.2 shows an example of location (DTM) of control points during a road construction phase.

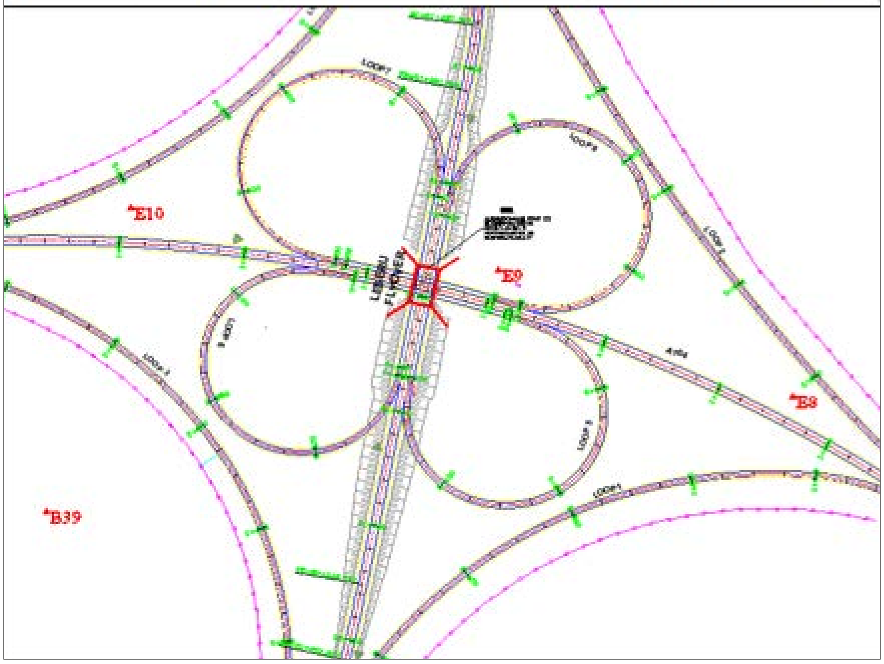
Figure 5.1b Beaconing of Permanent Controls

Coordinate/positional values of survey/beacons points within the final survey data must be true final adjusted positions, which must not be field-captured radiation or RTK GPS positioned. Where GNSS techniques are used to extend survey control, the preferred method is post-processing.

The same survey grid control network shall be used to reference topographic, cadastral and construction surveys. Establishing survey control beacons shall be done in accordance with the relevant laws and regulations and shall be approved by the Director of Surveys. Primary control points shall be obtained from the Survey of Kenya.

Figure 5.2 Control Points on Eldoret Bypass Road

B39	67191.652	744008.011	2006.326	
E10	67452.799	744075.728	2006.982	At along Eldoret – Malaba road
E9	67399.139	744370.141	2010.651	At along Eldoret – Malaba road
E8	67290.562	744606.775	2006.878	At along Eldoret – Malaba road



5.6.2.1 Primary Survey Control (PSC) Points

A primary survey control (PSC) network shall be established as part of the Engineering Survey. The primary survey control network is a key component of the survey datum (horizontal and vertical) and defines the position of a project as evidenced by the coordinates of the survey control network marks.

When establishing and observing a PSC network, there are a variety of measurement and processing methods available. Equipment and techniques which best suit the requirements of the project shall be selected, keeping in mind the limitations of each technique. Further, when determining the origin for datum establishment and the method adopted for connection, consideration must be given to the identity, reliability and quality of the datum control and undertaken in accordance with established survey best practices.

A PSC point should preferably be located so that it will survive indefinitely i.e., the life of the entire project. However, it is recognised that often during the initial Engineering Survey the extent of the final construction earthworks is unclear, and no guarantee can be made of PSC longevity. If this is the case, the PSC must be positioned on the basis that it would survive intact indefinitely if no construction were to take place, with the condition that PSC should never be placed between the road centreline and an open roadside drain on a formation without kerb and guttering.

The establishment of the PSC points shall be in accordance with the Survey Manual (1971), or any other Manual approved by the Director of Survey at the time of the establishment.

In addition, a PSC point should be:

a. Made of good quality, durable, corrosion resistant materials. It should employ robust construction techniques and where possible be installed in stable ground or in solid rock, such that it is least likely to be subject to local displacement or other seasonal or periodic movements. If a survey control mark is to be installed in an unstable area, permanent marking may require placing deep-seated survey control marks that penetrate the surface soil to the depth of refusal, thus bypassing the zone of seasonal or periodic influence.

b. Permanently and clearly marked with a unique identifier to ensure unambiguous identification. This unique identification shall be through stamping/engraving the identity onto the point as in Figure 5.3.

c. Accessible to allow for its proper use.

d. Located in a position that maximises the use of various measurement techniques and connection to existing and future marks.

e. Located away from underground services in the area.

f. For each PSC point used or established, a control point summary document is required to be completed and supplied as part of the project deliverables. The control point summary document is to include at a minimum:

    i. Project name / description (include project reference, where applicable).

    ii. Mark description & location.

    iii. Photo of mark placed/adopted.

    iv. PSC coordinate information.

    v. Witness marks.

Observation records, data and subsequent adjustments of all PSC points so established to last indefinitely shall be lodged with the Director of Surveys for checking, approval, and authentication in accordance with the Survey Act Cap 299 or any other relevant legislation applicable at the time, governing establishment of Geodetic Survey Controls and provision of their records to the relevant Authority for updating National Geodetic Network database.

Figure 5.3 PSC Point Identification

5.6.2.2 Secondary Survey Control (SSC) Points

Secondary Survey Control (SSC) marks may be placed as required but it is accepted that they may be destroyed during the construction process, and therefore are considered temporary marks only. Where Minor Survey Control marks are placed and coordinated for the purposes of the engineering survey, a list of marks placed, coordinates and heights calculated shall be provided as part of the Engineering Survey Report. SSC points, if placed, must conform to the same level of accuracy as PSC points in accordance with Survey Act Cap 299 and should have a unique identifying label to distinguish them from PSC marks. The SSC points may also be submitted to the Director of Survey for approval and authentication.

5.6.2.3 Benchmarks (BMs)

The levels of all survey control points shall be established by:

i. Differential levelling or GNSS observations separately or in combination.

ii. Two-way differential levelling from a known Benchmark (BM) in accordance with the survey best practices on differential levelling.

iii. One-way differential levelling between at least two known BMs in accordance with the survey best practices on differential levelling.

iv. Static GNSS methods between at least two (preferably three) known BMs in accordance with survey best practices for control surveys by GNSS.

All large structures constructed in a project, which are likely to undergo any form of settlement must have at least one permanent BM, expected to last the lifetime of the structure, be placed at a suitable, stable, and accessible location on the structure and accurately levelled to enable monitoring the vertical motion/stability of the structure. The second BM shall be placed in a nearby, stable and accessible location. The BMs values shall be submitted to the Director of Surveys for approval and authentication.

Table 5.1 details the accuracy requirements for survey controls. Densification is required if the PSC points are not sufficient for setting out. SSC points should similarly be established along the alignment at frequencies necessary to ensure survey tolerances are achieved and to provide intervisibility.

Beacons should be constructed outside the construction zone. Secondary beacons may be placed between 200 − 300 m. Traverse surveys to establish the secondary control stations should be recorded along with accuracies as specified in Section 2.1.8. Elevations should be extended across the control network using differential levelling methods.

Table 5.1 Accuracy Requirement for Survey Control

Levelling	**Accuracy**
Checks between fixed elevations of a loop misclosure shall not exceed	$10\sqrt{k}$ (in mm)
Traverse	**Accuracy**
Maximum number of courses between checks for azimuth	15
Azimuth misclosure shall not exceed	3.0” per station
Position misclosure (after azimuth adjustments) shall not exceed. Whichever gives the smallest permissible error	$1.67\sqrt{1.609K}$ or 1/10,000
Distance measurement shall be accurate to within	1/10,000

K = distance in kilometres

5.6.3 Survey Control Marks and Register

An up to date survey control marks/benchmarks register is required as part of the quality control plan. The information in the register includes but is not limited to the following:

a. A unique number/identifier for each survey control mark/ beacon.

b. Any other identifier such as primary or secondary.

c. Easting, northing and height/elevation of each survey mark, except marks used on reference sightings only.

d. Change and offset of each survey control mark in relation to the road centreline.

e. The side of the road on which the survey control mark is located.

f. Description of the physical nature of each survey control mark, such as pin drilled in tarmac, concrete, etc.

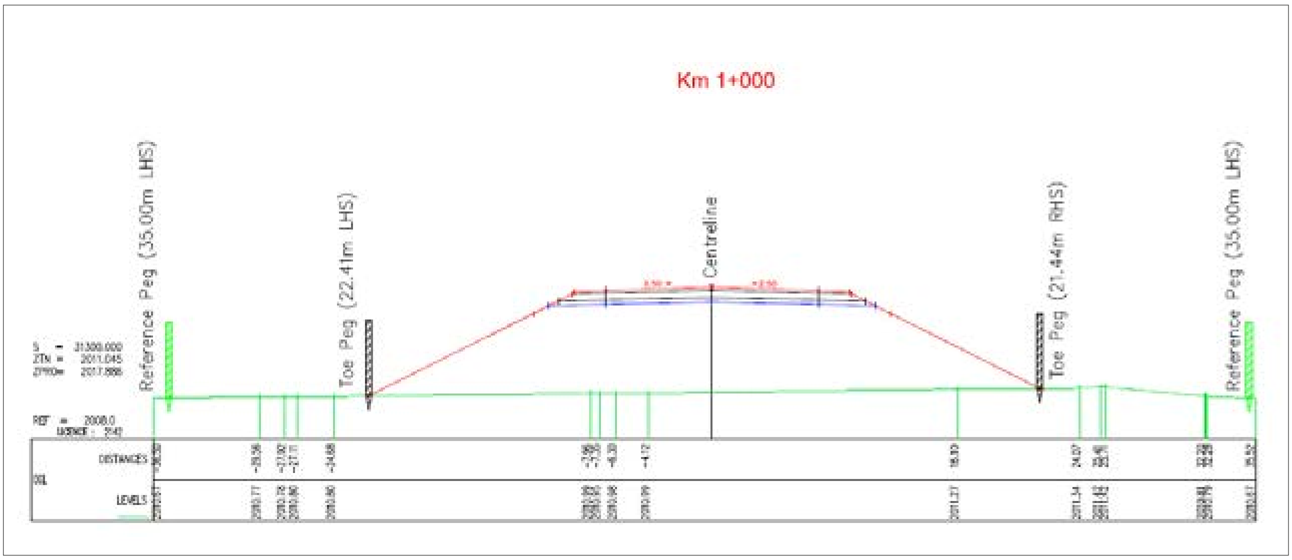
g. Picture and sketch map showing the location of the beacon shall be drawn.

5.6.4 Survey Details

The start and end of all linear features such as centreline, edge of road, drainage etc. must be recorded as well as their cross-sectional shape. All single point features such as signs shall also be recorded and georeferenced.

The toe pegs shall be used to mark the construction width extents while reference pegs shall be set at appropriate offsets beyond the toe peg distances required in every chainage. Reference pegs are for ease in re-establishment of the centreline during construction.

Figure 5.4 Reference Pegs Illustration



Elevation data shall be recorded at a maximum of 20 metre intervals along the proposed road centreline. Both the proposed alignment and existing route shall be surveyed and mapped.

Spot levels along the cross section shall be taken at every change of gradient and at a maximum 20 metre intervals picking up all manmade and natural topographic features and changes along the cross section. However, the interval for spot levels shall be varied based on the condition/topology on site and as per scale of data collection. Close spacing shall be surveyed where terrain is not uniform such as gullies, beginning and end of cuts and embankments, water courses, and on curves. The width of the survey corridor shall extend beyond the Right of Way (RoW) and consider the layout of the existing alignment including the extent of the embankment, cut slopes and general ground profile.

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Surveys

All access and public roads, rail lines and river crossings along the proposed alignment shall be geo-referenced. The topographic survey shall extend a minimum of 30 metres either side of the proposed road centreline. At crossings, survey shall be of sufficient width and detail to allow improvements including grade intersections to be designed.

Underground services and conduits shall be mapped. At rivers, the river crossing sections shall be surveyed at 10 metre intervals along the centreline or at a lesser distance to establish the alignment of the river for the full width of the river's channel and 50 metres beyond.

Details of all features such as structures (bridges, culverts, drainage channels etc.), utilities, existing roads electric and telephone installations, buildings, fencing and trees (with girth greater than 0.3 metres) etc. falling within the extent of the survey shall be recorded.

All natural and artificial features (including underground) occurring within the survey project area shall be captured and represented as points or strings /polygons in the DTM. Features shall be captured at ground level unless specified.

5.6.5 Surface Accuracy and Point Density

Sufficient strings are to be captured across road surfaces to ensure the shape is accurately defined to specified accuracies and tolerances. For sealed road surfaces, sufficient points shall be captured such that accuracy of any point on the surface defined is within the nominated accuracy for the relevant classification plus an error margin of 10mm. For all other surfaces, sufficient points shall be captured such that the accuracy of any point on the surface defined is within one and half the nominated accuracy for the relevant classification. Strings defining the road and formation shall be captured such that their respective points align perpendicular to the direction of the road. The tolerances for detail survey points shall comply with values shown in the Table 5 2.

Table 5.2 Tolerances for Detailed Survey

Feature	Tolerance (m)		Tolerance of any point to straight line fit between
	X and Y	Z	Points X, Y and Z (m)
Structures, buildings, and paved roads etc.	±0.025	±0.015	±0.025
Gravel pavements	±0.050	±0.025	±0.05
All other areas	±0.100	±0.050	±0.100

5.6.5.1 Digital Terrain Model (DTM) Triangulation Dimensions

In addition to satisfying all other accuracy requirements, side lengths of triangles forming the Digital Terrain Model (DTM) to be generated from the survey data must not exceed 20 metres on pavement areas and 25 metres in all other areas. Survey capture density and spacing must ensure that this condition is met. A closer interval shall be adopted for hilly, horizontal, and vertical curved, and mountainous areas.

5.6.6 Survey Reporting

Two reports will be required from the survey process. These include a mobilisation report and field survey report.

Table 5.3 Report Content – Mobilisation Report

Mobilisation report	
1	Introduction
2	Health and safety considerations
3	Personnel mobilised
4	Survey equipment mobilised
5	Calibration
6	Field forms
7	Miscellaneous information

Table 5.4 Report Content – Topographic Field Survey Report

Topographic field survey report		
1	Executive summary	
2	Introduction	
3	Survey location	
4	Scope of work	
5	Survey controls	
6	Personnel	
7	Survey equipment details	
8	Survey details • Establishment of benchmarks • Datum points located and used • Controls established • Measurements – ground/aerial • Traversing/GNSS surveys • Levelling • Detailed surveys • Computations and drawings	
9	Data processing and interpretation	
10	Discussion of survey results	
11	Observations	
12	Field photographs	
13	Conclusions/recommendations	
14	Appendices:	Appendix 1 – Mobilisation report
		Appendix 2 – Survey data and drawings

Notes:

1. There are various design software that can be used for data analysis and reporting including Civil3D, Revit, MicroStation, Inroads , ArcGIS, etc. The selection of the software to use should be based on project requirements, road agency policy, and consideration if the designer can use and access the data and transferability.

2. The surveyor must ensure the DTM model accurately represents the existing road and natural ground features when cross sections are generated from the survey data.

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