

The Uganda Geodetic Reference Frame

Implementation strategy

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1. Introduction

1.1 Background

Establishment of a unified geodetic reference network is a priority of the Ministry of Lands, Housing and Urban Development (MLHUD) through the Department of Surveys and Mapping. Uganda Geodetic Reference Frame (UGRF) is main realisation of the Geodetic Reference System for Uganda based on Global Navigation Satellite System (GNSS). The UGRF establishment is a long term and phased program. At the onset I am pleased to report that UGRN established in 2019 is functional including 12 Continuous Operating Reference Stations (CORS) and Network Control Centre (NCC).

2. The main goal

The main goal of the updating and implementing the horizontal geodetic reference framework can be summarised as “*contribution to the enhancement of land administration services in the country, improvement of their reliability and increasing a public confidence in the land administration sector*”

The Uganda Geodetic Reference Frame (UGRF) is the foundation for evidence –based policies, decisions and program delivery. The UGRF underpins the collection and management of nationally integrated geospatial information is used to monitor our dynamic Earth. It is relied upon for social, environmental and economic initiatives, Earth Science, the measuring and monitoring of progress of the 2030 Agenda for sustainable development and other global, regional and national development agenda and initiatives.

3. The main objective

The main objective of Uganda Geodetic Reference Frame (UGRF) initiated by the Government of Uganda is to “*establish a modern reliable and accurate geodetic reference frame for the entire country to support the land administration, physical planning, land development and*

construction industry, environment protection and other spatial data deliveries in different sectors of economy.

The Uganda Geodetic Reference Frame (UGRF) underpins all aspects related to location. In additional survey, mapping and navigation fields, location based positioning applications are increasingly critical for civil engineering, industrial automation, agriculture, construction, mining, recreation, financial transactions, intelligent transport systems, disaster response and emergency management, environmental studies and scientific research. The UGRF enables accurate and robust alignment of spatial datasets – a key requirement for sustainable development in fields such as land use planning and administration, construction and hazard assessment.

4. Uganda Geodetic Reference Frame (UGRF)

Sustaining the Uganda Geodetic Reference Frame (UGRF) will require effort across all five focus areas: Governance, Geodetic Infrastructure, Policies, Standards and conventions; Education, Training and capacity Building; Communication and outreach

4.1 Main stakeholders

There are many players involved in sustaining the Uganda Geodetic Reference Frame (UGRF) including the Ministry of Lands, Housing and Urban Development (MLHUD) and its appropriate structures, including Directorate of Land Management, Directorate of Housing, Directorate of Physical Planning and Urban Development, National Land Information Centre (NLIC), Ministry of Defence (MoD&VA), Ministry of Works (MoW), Ministry of Energy, Ministry of Water and Environment, Ministry of Agriculture Animal Industry and Fisheries (MAIF), Uganda Bureau of Statistics (UBOS), National Environment Management Authority (NEMA), National Forestry Authority (NFA), Uganda National Roads Authority (UNRA), Uganda Wildlife Authority (UWA), Educational Institutions with Speciality with in Geomatics, Private Sector the International Association of Geodesy (IAG) and the International Federation of Surveyors (FIG) and many more.

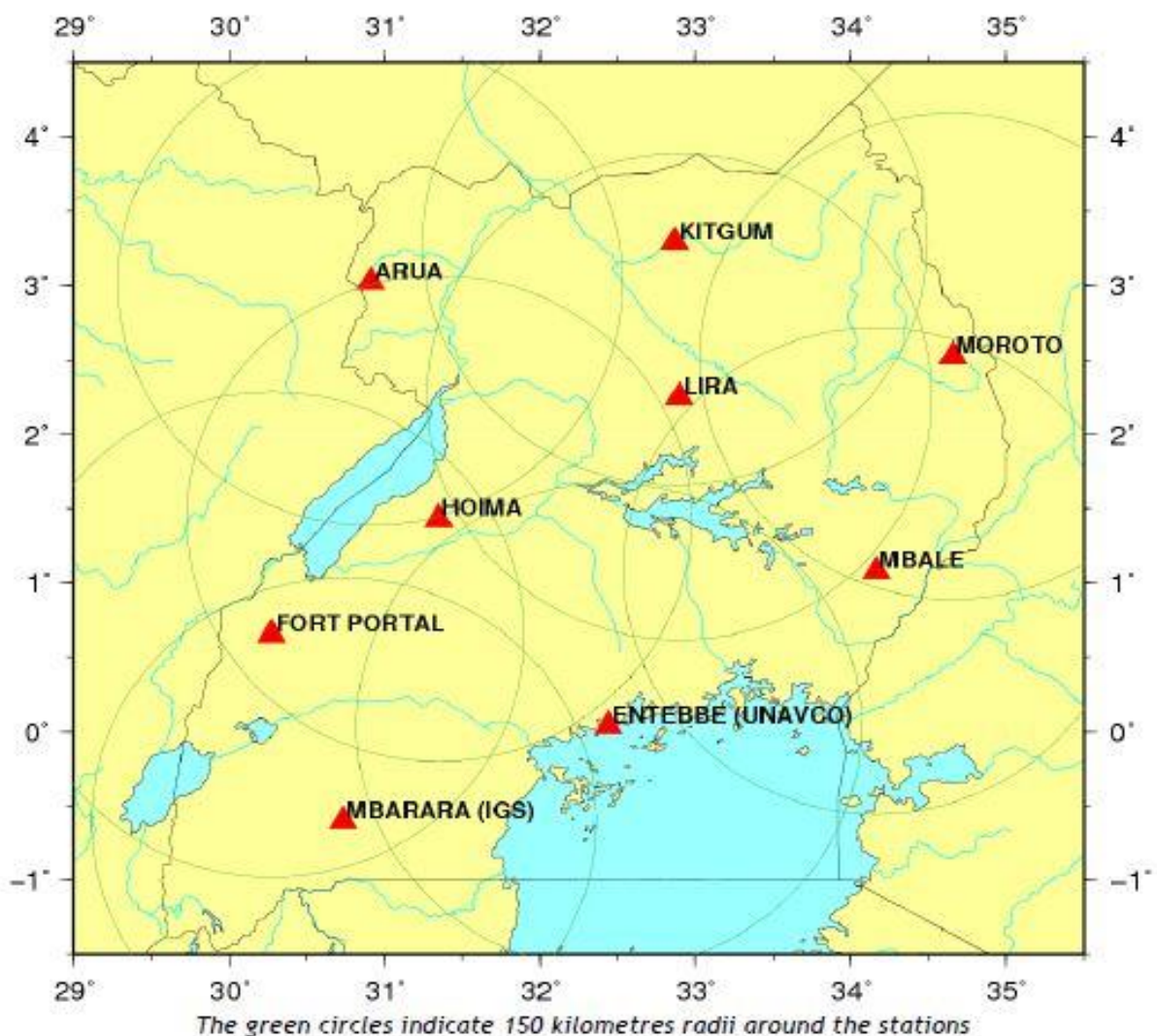
5. Geodetic Infrastructure

Uganda Geodetic Reference Network is composed of two types of controls: Active Control Network - Continuously Operating Reference Stations (CORS) and Passive Control Network Terrestrial Reference Stations. Uganda Geodetic Reference Network has also generated better transformation Parameters between the old datum Arc 1960 and ITRF 2005. Some parameters

had been obtained in 2011 using UGRN. The term Geodetic Infrastructure refers to the instruments, technology, data, data repositories, analysis, human resources, products and services required to observe and model the dynamic Earth.

In 2010 the first task involved establishment of a modern reliable network of 9 major zero Order points and 5 auxiliary points. Which is consistent with the precise world –wide geodetic reference system. ITRF 2005 at epoch 2010.0 were established. The Zero Order points, properly monumental with permanent markers marked the Uganda Geodetic Reference Network (UGRN), firmly fixed and precisely computed.

Realization of the 9 Zero Order Points



6. National Datum Coordinate System and Projection

The New Horizontal Datum of Uganda is: ITRF 2005 and realisation of the reference frame is Zero Order GPS network (Uganda Geodetic Network – UGN). The cartographic projection is

Universal Transverse Mercator UTM zone 35 with standard central meridian 27 and UTM Zone 36 with standard central meridian 33. The principle is that everything new must be done in the new datum. Software must be used to facilitate this process.



7. Uganda Geodetic Reference Network

The 1st and 2nd Order Geodetic Network was carried out between mid-July 2018 and end of January, 2019. The densification of the UGRN was born immediately and has resulted into the birth of 426 passive network points of which 129 First Order spacing between points 30- 40 km with accuracy of 20 mm.

The 297 Second Order Network is based on the CORS and First Order Network. The average distance between the points of the network (including all CORS) and First Order Network is not more than 30 km with accuracy 30 mm and 12 CORS – to achieve regular and homogeneous coverage of the country.

The sites are located in each settlement with MZO, other significant development areas, along main roads, and very close to all sites of the second phase of the CORS network deployment. Virtually all district main towns have been fitted with first Order geodetic point. Precise location of all First Order points allows carrying out both GNSS and conventional surveying techniques.

Realization of the 426 Passive Network Points

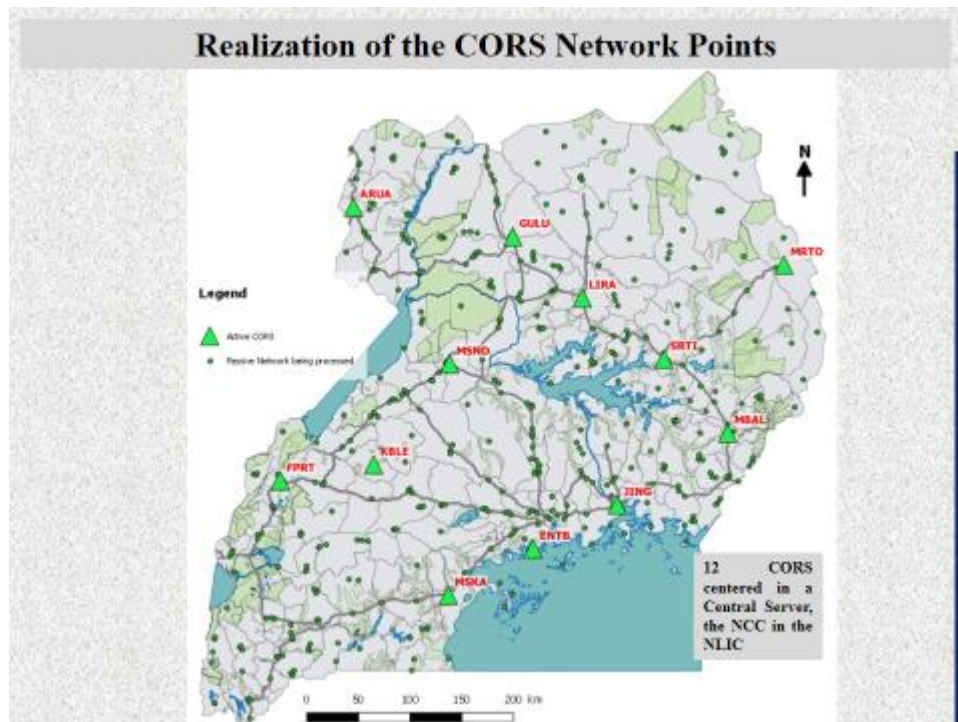
The coordinates of these First Order points were determined by precise Double Differencing Static GNSS positioning from Zero Order Network stations. The final sites were chosen after the field reconnaissance, which led to confirm or adjust but also shift some of the Desktop Design locations.

8. GNSS data Processing

The observation and computation of the CORS Network was based on the International GNSS Service (IGS) reference stations and complied with the IGS/UNAVCO requirements and recommendations. The main GNSS data processing was performed using Bernese (V5.2) software and Trimble Business Centre (v3.9) software depending on baseline length. First Order GNSS network was formed selecting the most suitable baselines according to independent constraints (no trivial baseline kept) statistical quality criteria and loop closure calculation results.

9. CORS Network

The CORS are located in administrative centres at the Ministry Zonal Offices (MZOs) and other government buildings in the administrative centres. Installation has been done on 12 sites in the 1st Phase taking into account MBAR existing CORS. The CORS (Zero Order) network realised a modern geodetic datum and is accessible across the country through the CORS infrastructure. It was tied to the national geodetic reference system to ITRS and serves as the main reference for the other levels of UGRF.



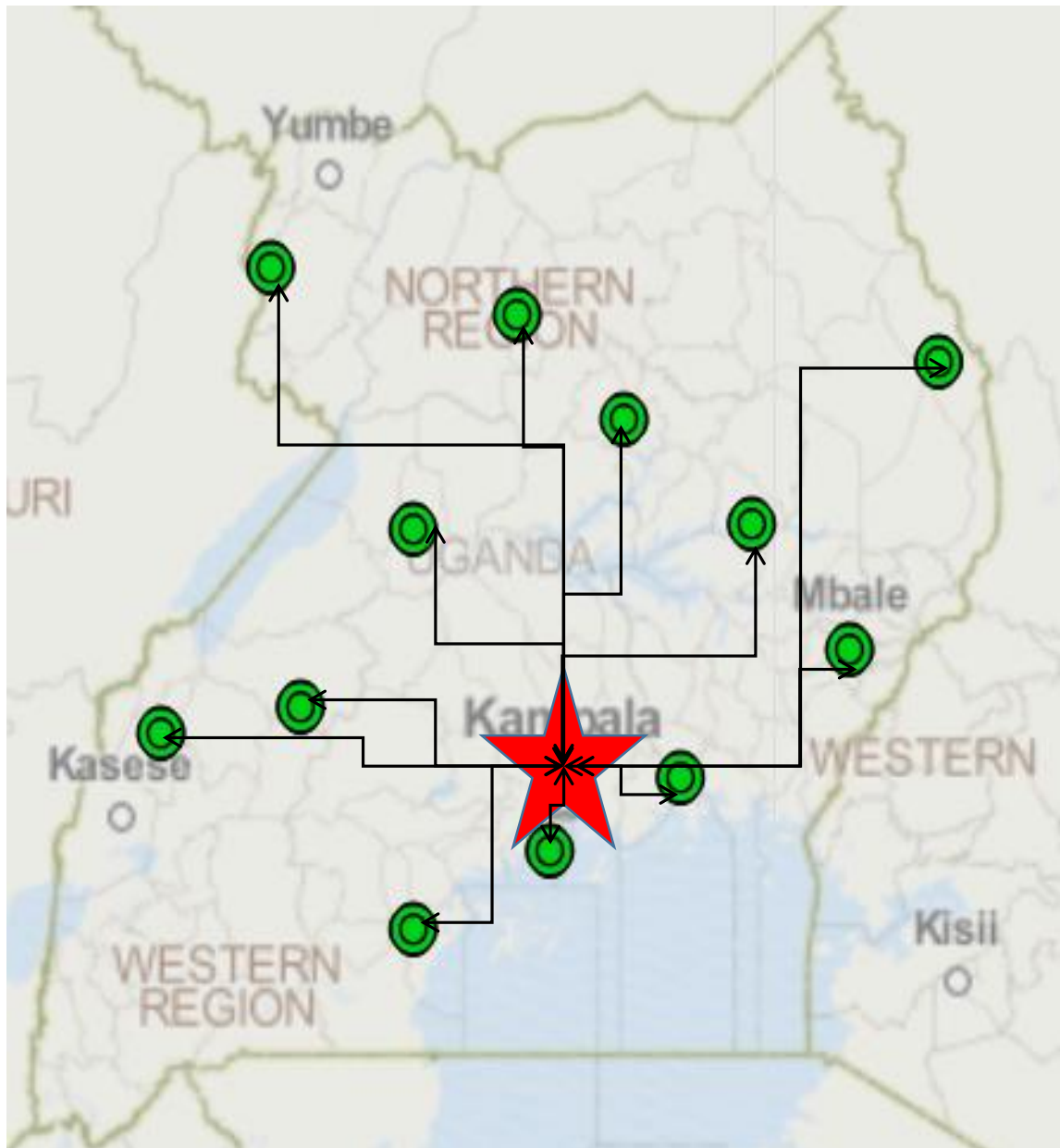
The CORs Network is being installed in two phases depending on the demand and availability of resources and necessary infrastructure. In the first phase the network cover the most economically active areas including the northern corridor, Albertine Grabben Area, power plant construction, natural resources prospection and exploration areas.

10. Network Control Centre

The CORS transmit data to the Network Control Centre (NCC) in the NLIC in Kampala. The NCC is equipped with all the necessary hardware, equipment and software for the efficient control and management of the CORS Network, GNSS observation data storage, maintenance and computation. Installed in the NCC is a large size and high resolution monitor /screen connected to the NMS and demonstrating the system status on-going activities, issues, connected receivers and other characteristics necessary for the system monitoring and monitoring.

The location of the NCC has physical security system, power supply, , dedicated internet communication line for the CORS, power stabilisers for the serves, hardware and equipment installed to protect it from electrical power fluequections and automatically maintain a constant voltage level as well as necessary Uninterrupted Power Supply.

Realization of the CORS Network Control Centre (NCC)



All these components are owned, operated and funded by the Government of Uganda through Ministry of Lands, Housing and Urban Development. To improve the accuracy of and access to the UGRF there is need for higher quality instruments, more instruments to improve access and sustainable funding for analysis and product generation.

11. Services

The main product is the web site: <http://ugrf.go.ug>. The Uganda Geodetic Reference Frame and 12 CORS stations are established observed and computed. The stations are operational since May 2019. The CORS network provide Real Time Kinematic (RTK) services, Post Processing Positional services (PPS), Online Data Processing services where you upload your Rinex file, we compute and send you back the coordinates in UGRN (ITRF05 epoch 2010.0 and transformation coordinates software, free on line services.

12. Education, Training and Capacity Building

The Ministry of Lands, Housing and Urban Development encourages Ministries, Departments, Agencies and organisations to enhance cooperation in providing capacity building and training to personnel on the establishment, maintenance and use of the CORS network and provision of services to customers. With the aim of ensuring the devolving, sustainability and advancement of the unified national geodetic network

13. Communication and outreach

Geodesy often suffers from being a science which is difficult to describe to decision makers and donors to understand the value of an investment in the UGRF. There is a strong need to raise the general awareness around the value proposition of Geodesy and the Uganda Geodetic Reference Frame.

14. Geoid model

The geoid is defined as the equipotential surface of the earth's gravity field, which best fits, in a least squares sense, mean sea-level and may extend inside the solid body of the earth.

To improve the geoid of Uganda, gravity data is required to fully utilise the potential of GPS-based geodetic surveying. A new geoid model is a basic survey and mapping infrastructure, which will modernise the height system in Uganda, and allow for more economic and efficient height measurement by GPS in support of a large range of applications in a large –scale construction projects, mining, agriculture, food protection and food security.

I am happy to report that Airborne Gravity Survey of Uganda was carried out by the National Space Institute, Technical University of Denmark (DTU) within the International program in January to February, 2020 in cooperation with Ministry of Lands, Housing and Urban Development in connection with the new gravity field model Earth Gravitational Model 2020 (EGM2020).

The results are expected at the end of 2020 and the Model can be used to enhance the vertical Reference Frame for Uganda. This survey could enable a very precise geoid at 5-10 cm accuracy level to be computed across the territory of Uganda, and thus contribute significantly to the ongoing modernisation of the Uganda Geodetic infrastructure.

15. Phase II

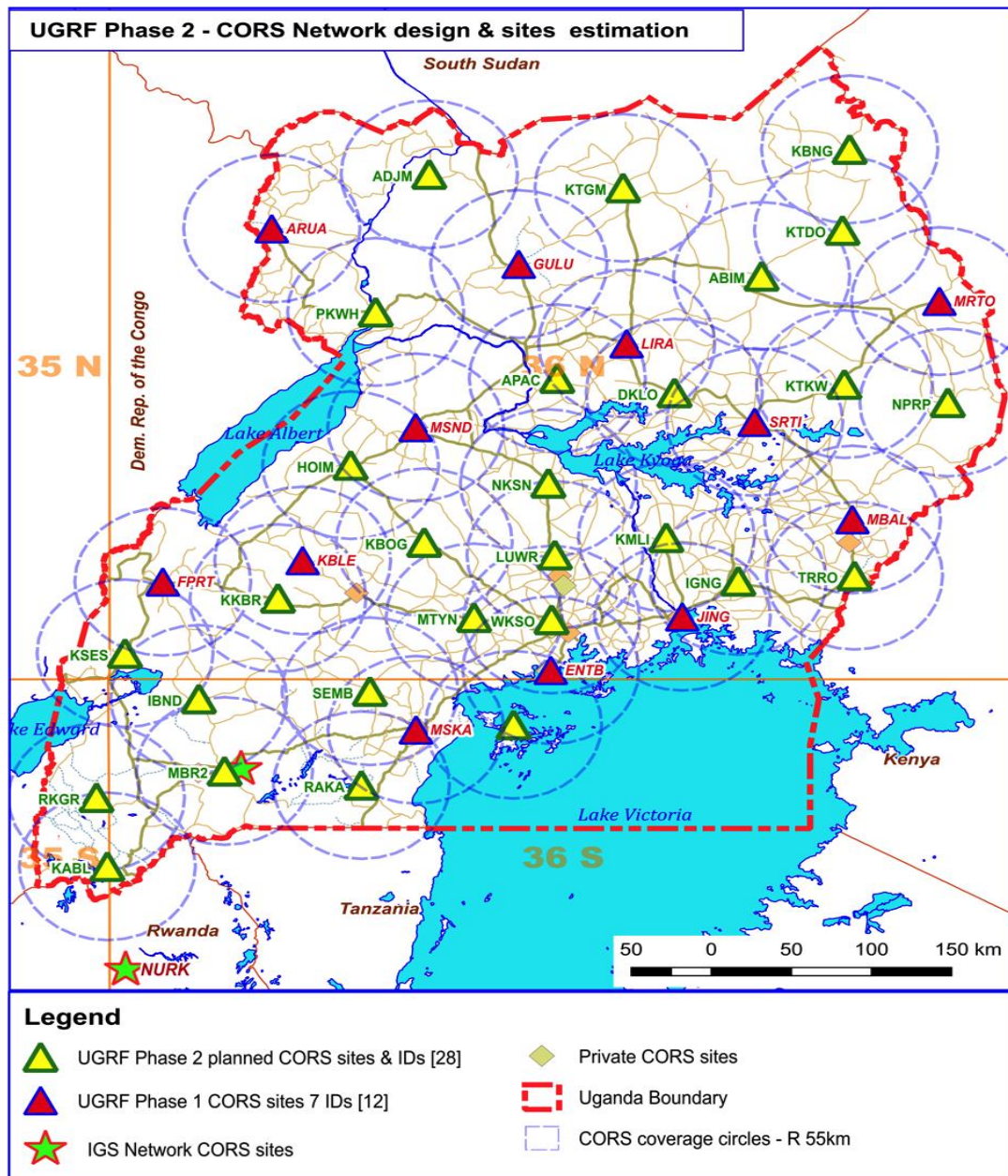
The UGRF Phase 2 is based on the highly technological and fast changing industry. The proposed CORS upgrade establishment and configuration shall be robust , efficient and cost effective including the cost of its maintenance, taking into account consideration scarcity of finance and other resources and shall ensure the sustainability of the CORS network and services.

The upgraded UGRF CORS Network will be to provide the definition of the modern Uganda Datum and national coordinate Reference System using UTM projection for the whole country and also ensure a tie between the national geodetic datum and the global ITRF and the African Reference Frame (AFREF).

The 2nd phase will involve enhancement and upgrade of the continuously operated Reference Stations (CORS) Network and the Network Control Centre (NCC) and NMS including the Department of Surveys and Mapping (DSM) mirror site.

The NCC and the mirror (backup) of the NCC shall be upgraded and updated in the same locations of the NCC selected during the phase 1 at the premises of the NLIC and in the DSM premises in Entebbe.

Phase 2 will also entail capacity building and training of personnel in the establishment, maintenance and use of the network and CORS stations and provision of services to customs;



16. Challenges

- Obsolete Laws. The current Survey Act and regulations have been overtaken by technological advances (GNSS technology, CORS, ITRF) and land administration innovations (Pro Poor, Systematic Demarcation (SD), and Fit For purpose FFP approaches and GIS);
- Lack of an accurate Geoid Model. Uganda needs an accurate Geoid Model to finalise the primary geodetic Infrastructure of the country. Due to Uganda complex topographical and geological background (high plateau, high mountains and volcanoes, rift valley) achieving a reliable and accurate gravimetric geoid model will be a real challenge, requiring careful work and redundant methodology;

- iii. The cost of CORS and NCC system internet connectivity and electricity maintenance is high. Electricity and Internet connectivity should be designed to ensure the permanency of connectivity using the redundancy of the NCC to CORS sites;
- iv. Lack of redundancy. Lack of geodetic infrastructure and poor accessibility in some regions. Uganda should establish at least 35 CORS all over the country such that no one point of the country is further than 60 km from a CORS;
- v. Additional capacity development to make the best use of UGRF and its ongoing sustainability. This is largely due to lack of skilled personnel to maintain the newly established Uganda Geodetic Reference Network. The personnel in the Department of Surveys and Mapping (DSM) and IT personnel in the National Land Information Centre (NLIC) who are currently monitoring and maintaining the network are new and are yet to gain experience on the job;
- vi. Budget. Finally adequate budget to monitor and maintain CORS network is urgently needed.

17. Conclusion

The Ministry of Lands, Housing and Urban Development recognises that the Uganda Geodetic Reference Frame (UGRF) is the foundation for evidence – based policies, decisions and program delivery. The UGRF is no longer reserved for use by earth scientists alone, instead it underpins the collection and management of integrated geospatial information and is relied upon for social, environmental and economic initiatives.