& GRIDS & DATUMS

REPUBLIC OF KENYA

BY Clifford J. Mugnier, CP, CMS, FASPRS

The Grids & Datums column has completed an exploration of every country on the Earth. For those who did not get to enjoy this world tour the first time, *PE&RS* is reprinting prior articles from the column. This month's article on the Republic of Kenya was originally printed in 2003 but contains updates to their coordinate system since then.

The coast of Kenya was long dominated by Arabs and was seized in the 16th century by the Portuguese. The Europeans were expelled by the Omanis; the coast then came under the rule of the Sultan of Zanzibar, and later leased in 1867 to the British East Africa Association. The British extended their holdings into the interior and fixed an initial southern boundary with the German East Africa Company in 1886. Kenya is bordered on the north by Ethiopia (*PE&RS*, March 2003) (861 km), on the east by Somalia (682 km), on the southeast by the Indian Ocean (536 km), on the south by Tanzania (769 km), on the west by Uganda (933 km), and on the northwest by Sudan (232 km). The lowest point in Kenya is the Indian Ocean, and the highest point is Mount Kenya at 5,199 m. Comprised of the Nairobi Area and seven provinces — Central, Coast, Eastern, North Eastern, Nyanza, Rift Valley, and Western —Kenya is slightly larger than twice the size of Nevada. The former Colony of British East Africa gained independence on 12 December 1963.

Thanks to Morgan W. Davis, "The history of surveying in East Africa begins with the domination of those lands by European powers in the late 1800s. The British entered into a number of agreements defining spheres of influence in 1886, 1890, 1891, and 1894. The present day boundaries between Kenya and its neighbors are a result of legal descriptions hashed out in negotiations and subsequent triangulation and boundary surveys. Negotiations between the United Kingdom and Germany in 1886 and 1890 established spheres of influence north and south respectively, of a line beginning at the Indian Ocean near Vanga and extending to the eastern shore of Lake Victoria: 'The line of demarcation starts from the mouth of the River Wanga or Umbe (Umba), runs direct to Lake Jipe, passes thence along the eastern side and round the northern side of the lake and crosses the Lumi River …

> *"After which it passes midway between the territories of Taveita and Chaga, skirts the northern base of the Kilimanjaro range, and thence is drawn direct to the point on the eastern side of Lake Victoria Nyaza (Lake Victoria) which is intersected by the 1st degree of south latitude."*

The line between the Indian Ocean and Lake Jipe was surveyed by plane table. Most of the mapping in East Africa between 1890 and 1910 was a result of the boundary commissions. Basic topographic mapping of varying quality was accomplished along the narrow zones of the surveyed boundaries. There was little opportunity to extend mapping to the

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interiors of the colonies. An important outcome of this early phase was the consolidation of the War Office as the authority on boundary surveys and maps in Africa. Both the Foreign Office and the Colonial Office relied heavily on the expertise of the War Office on technical matters related to surveying and mapping, as well as for help in wording legal descriptions in negotiations. The Topographic Section of the General Staff of the War Office played a crucial role, as well in the policies and activities of survey departments in the colonies.

The colonial Survey Committee was created in an attempt to organize the mapping effort in the British East African colonies. The first meeting was held on 14 August 1905. They recommended that there be two survey departments, standardized topographic map scales at 1:62,500, 1:125,000, 1:250,000, and 1:1,000,000. In a 1907 meeting, they adopted the Clarke 1858 ellipsoid for Africa. They decided on the spelling of place names on maps. The Committee continued to be an important governing body up to the World War II years. Major E. H. Ellis was appointed Inspecting Officer to the departments in the Uganda and East Africa Protectorates (Kenya) in order to help expedite work. He submitted a comprehensive report in February 1907 in which he noted that a topographic section had not been constituted. He insisted that a full section of 2 officers and 6-8 surveyors be formed. He recommended map sheets covering 45′ longitude and 30′ latitude or 30′ x 30′, at 1:125,000 scale for developed areas, and 1½° longitude by 1° latitude in undeveloped areas, utilizing the rectangular polyconic projection. (*This was the same specification utilized during the same era by the British Survey of India. – CJM*)

In late 1908 one officer, three NCOs and a civilian were assembled to begin fieldwork on 1:125,000 sheets for Kijabe and Nairobi, and a special 1:62,500 sheet for Nairobi. Mapping continued until the outbreak of WWI. The Africa Series GSGS 1764 in 33 sheets at 1:250,000 scale covered both Uganda and the East Africa Protectorates. The maps were published in monochrome, principally between 1905 and 1907. These were provisional sheets with a paucity of detail. The maps were later also published in color. Each sheet covered 1½° longitude and 1° latitude with a graticule spacing of 30′. They were reprinted in 1939-1941 during the East African Campaign. It was not until 1953 and thereafter that Series GSGS 1764 was replaced at the same scale by Series GSGS 4801 and subsequently Series Y503.

After WWI, the War Office was no longer available to do work in the African colonies. German East Africa had been assigned to Great Britain as a mandate from the League of Nations in 1919 and was renamed Tanganyika. The Arc of the 30th meridian was proposed as the foundation of triangulation in the East African colonies. Observations on a portion of the arc in western Uganda had been taken prior to 1914, and the triangulation net in Uganda was tied to it. Surveying on the arc had been done in northern Rhodesia, and it was felt that it was important to close the gap in the arc in Tanganyika.

Martin Hotine surveyed the arc of the 30th meridian in Tanganyika between 4½° and 9° South during the years 1931-1933. Depletion of funds in late 1933 left a gap in the arc between 1½° and 4½° South. From July 1936 to August 1937, a survey was conducted wholly within Tanganyika to fill the gap, consisting of observation angles and some azimuths. Uganda had withdrawn from the project due to fears that if their portion of the arc was connected to South Africa, they would be forced to recompute their already completed surveys on a new projection and grid system.

This leads to a major theme of discussion during the years between the two great wars – that of a common datum and projection for all of British Africa. Debate raged over this topic until the exigencies of war during the Second World War permitted the British military to force a solution. In a memorandum circulated in 1926, it was assumed that a common datum could be chosen, utilizing a meridional orthomorphic projection from Khartoum to Cape Town. The Clarke 1880 ellipsoid was suggested. During the second Conference of Empire Survey Officers (1931), it was assumed that all colonial governments would adopt the Transverse Mercator projection because it was already accepted by Egypt, South Africa and two of the West African territories. The width of the zones could not be agreed upon. Kenya saw little prospect in adopting the proposal because its cadastral work was computed on Clarke 1858 and the Cassini projection. Extension and re-computation of its triangulation was more urgent than conversion of its completed surveys to a new datum. In January 1934, GSGS proposed a coordinated projection and grid zone embracing South Africa, South Rhodesia, Sudan, Egypt, and the Central and East African territories. They recommended the Clarke 1880 ellipsoid and the Transverse Mercator projection on a 6-degree grid. The same parameters were recommended in a meeting of a sub-committee of the Colonial Survey Committee on 3 October 1935. Brigadier M. N. MacLeod insisted on the adoption of the meter as the map unit. Each time a new recommendation would be put forward for a common set of map parameters, one or more colonial governing bodies would shoot it down for various reasons.

Lord Hailey wrote *An African Survey* (1938) after his tour of Africa in 1935. His views were taken up by the Colonial Survey Committee in 1939, at which time they once again recommended a 6-degree grid and the adoption of the meter. Whittingdale replied that a 2-degree system was more appropriate for topographic mapping and military surveys. Huntley showed the military advantages of the 2-degree grid (artillery), and that it was inconvenient for cadastral surveyors to apply the corrections that a 6-degree grid would necessitate. (*The same reason for practicality continues to this day for NOT using the UTM grid for civil GIS and surveying applications. – CJM*) South Africa totally opposed the change from 2-degree to 6-degree zones. There was general agreement on the adoption of the meter on map grids.

A policy for military mapping was defined in July 1940, which utilized the Clarke 1880 ellipsoid and the Transverse Mercator projection with 5-degree zones. The central meridians were placed at 32° 30′ E, 37° 30′ E, and 42° 30′ E. A scale

factor reduction of 0.05% was introduced to provide correct scale on two parallel meridians approximately 1° 49′ on either side of the central meridian. The scale error at the central meridian was about 1:2,000, and it was about 1:2,200 at the edges of the grid zones. The grid was originally in yards, but was later changed to meters. This became known as the East African War System, and it was eventually applied to an area bounded by 19° N, 15° E, 12° S and the Indian Ocean. The Directorate of Colonial Surveys was born on 1 March 1946, with Brigadier Martine Hotine as it first (and only) Director. An allowance of £2 million was approved for this centralized organization of geodetic and topographic surveys. For the first time in the eastern African colonies, two problems, which had plagued the survey effort from the earliest days, were addressed: lack of funds and the lack of a centralized organizing body. In 1947, fieldwork for basic topographic mapping was commenced. The first 1:50,000 scale sheets of Series Y731 were produced for the Kenya Ethiopia Boundary Commission. At least 470 sheets were produced, virtually all of which were contoured, and 64 sheets along the Ethiopian border.

The 1:100,000 scale sheets of Series Y633 were produced between 1958 and 1968, mainly by the Survey of Kenya and the Directorate of Military Survey. A general map series at 1:250,000 (Y503) has been derived from the 1:50,000 and 1:100,000 scale sheets. The Survey of Kenya produced 42 of the 50 sheets needed to cover the country. Kenya is covered by 7 sheets of the 1:1,000.000 International Map of the World. The most commonly used geodetic parameters for maps produced by the Kenyan authorities are: Arc Datum 1960 referenced to the Clarke 1880 (modified) ellipsoid, Transverse Mercator projection with coordinates on the UTM grid.

In the 1970s, first-order EDM traverses were run between stations adjusted on the Arc 1960 Datum and Clifford triangulation. In 1972-1973 the Survey of Kenya, in conjunction with the U.S. Defense Mapping Agency and the Directorate of Military Survey of the U.K. made the first experimental Doppler satellite survey in Kenya. Recently the Kenya Institute of Surveying and Mapping (KISM) took GPS observations on existing control points. A. S. Lwangasi of the University of Nairobi reported the results of a datum transformation carried out on 25 control points from Arc 1960 Datum to WGS 84 Datum: $\Delta X = -179.1$ m ± 0.7 m, $\Delta Y = -44.7$ m ± 0.7 m, $\Delta Z = -302.6$ m ± 2.2 m."

In a letter dated 20th July 1989, J. R. R. Aganyo wrote for the Director of Surveys of the Survey of Kenya that the old Cassini-Soldner used in Kenya has the following parameters: grid name: Cassini-Soldner; years used: since introduction of cadastral surveys; central meridians: 33°, 35°, 37°, 39° East; unit: English Foot where 1 foot = 0.30480 International metres, exactly; ellipsoid: Clarke 1858 where a = 20,926,348 English feet and $^1/_f = 294.26$.

In January 2000, Russell Fox of the U.K. Ordnance Survey sent a memo to me that was written by the famous H. F. Rainsford on 28 September 1961 with the (then) Directorate of Overseas Surveys:

"Since there appears to be some confusion of thought about the 'origin' of the trigonometric data lists produced by this Directorate, the purpose of this paper is to clarify the position so far as possible.

Up to the present date, all trig. Lists have included in the preamble the words – 'New 1950 Arc Datum.' This denotes that the results in the list are based on the Arc of the 30th meridian, which was computed by the D.O.S., from South Rhodesia to Uganda, in the 1950 (circa). The values of the stations accepted as a starting point in South Rhodesia had been computed continuously from South Africa. These Arc results have been held fixed since 1950, and it is hoped that they will remain so for as long as possible in the future, since they are used not only by the D.O.S., but also by the Congo and Portuguese Africa, and they provide a uniform system from the Cape to the Equator.

The South African datum is an arbitrary one, as at no station were the Astronomic and Geodetic latitude, longitude and Azimuth made coincident. On the Arc itself the (A-G) values vary (sometimes quite abruptly) between:

latitude	*+20″ and –30″*
longitude	*+12″ and –10″*
azimuth	*+15″ and –08″*

The only astronomic elements that have been held fixed on the Arc adjustment are – in South Africa one latitude, longitude and azimuth (but each at a different station) and an astronomic azimuth at Kicharere in Uganda, just south of the Equator.

The Year 1950 was used in the title as a convenient epoch mainly to distinguish from previous systems such as the '1935 Arc Datum.' (original emphasis in color)

Tanganyika was the first East African territory in which geodetic trig. control was computed based on the Arc and used for control of topographic surveys. It was known that some of this trig. was not up to primary standards, but it was the only work available and it was hoped that recomputation based on the Arc would produce results of sufficient accuracy for the purpose required.

Since Laplace Azimuths had not been available for the Arc computation nor in Tanganyika, the Tanganyika trig. was computed without holding fixed any azimuths, which were, in any case, of doubtful value. When the trig. computation reached Malindi in Kenya from the Arc it was found that the (A-G) azimuth was approximately 20″.

*It was then decided that a new approach was necessary. Put in new primary circuits based on the Arc, and observe frequent astronomic stations and tellurometer lengths, much closer together than the old measured bases. The trig. circuits (*were*) to be adjusted to the fixed (or nearly fixed) scale and azimuth checks. This policy has been carried out and results have already been circulated for:*

The Lake Circuit
Uganda Primary
Kenya Primary

REPUBLIC OF ICELAND

Dear Mr Mugnier,

I found your name when I came across your 2004 article on Iceland's Grids and Datums.

I've been researching the British invasion and subsequent occupation of Iceland in May 1940, more as a hobby, although with retirement approaching, this might turn into something more substantive.

Having come across your article, and noting that in the case of Iceland there were two datums, I wondered what mapping was available to the British in the lead up to the invasion. My expectation is that the British would have access to the nautical charts required for the maritime aspects of the operation, and probably, street maps for Reykjavík and Akureyri.

Whilst these would have met the needs for planning and meeting immediate objectives, as the troops moved into the hinterland there would have been need for something more detailed. Unfortunately, the plans of the initial operation are only in hard copy and held at the public records office in Kew, London. Unfortunately, due to the COVID lockdowns, this office is closed. Moreover, online research has only shown a 1:500,000 topographical (Landslagsuppdrattur) map produced in 1928 by a Samuel Eggertsson an Icelandic surveyor (1864 - 1949). Eggertsson's work would at least suggest some mapping was available, but once again online searches has produced scant results.

So my question is, through your research are you aware of what mapping coverage was available pre May 1940? Also, if mapping was available are you aware of any German involvement in surveying the country or would this have been solely a a Icelandic/Danish effort?

Thank you in advance for any information or insight you can provide

~ J M Lee BEM, CSMP. CBCI. MSyI
Doran Risk Consulting Ltd

As of 20 December 1946, a cartometric analysis of Islandic source material by William W. Baird of Army Map Service stated:

SUBJECT: Geodetic investigation of source material for AMS 1:50,000 series of Iceland (40045-3, 4, 4)

1. Map series investigated:
   A. S30-DGS-50
   B. S30-GSGS-50 (Grid Shown)
   C. 3-30-37003-100
   D. S30-GI-100
   E. S30-GSGS-100
   F. S30-AMS-100

2. 1:50,000

   The two sets of 1:50,000's have only partial coverage of Iceland. The 50's are quarters of the 100's - detail, features and elevations agree. Both sets of 50's carry a projection based on Copenhagen. To convert to Greenwich a correction of –12″ 34″ 40.35″ must be applied to the meridians.

   A. S30-DGS-50

      The mean differences (control-scaled) were Longitude 1.6″ and Latitude 1.0″. Maximum differences were Longitude from +12.0″ to –2.2″ and Latitude from +2.3″ to –0.7″.

   B. S30-GSGS-50

      The mean differences (control-scaled) were Latitude 1.4″ and Longitude 1.4″. Maximum differences were Latitude from –2.8″ to +0.3″ and Longitude from –3.3″ to +0.3″.

      At the scale of 1:50,000, one second of Latitude equals .024 inches and one second of Longitude equals .010 inches.

3. 1:100,000

   The 1:100,000 series has almost complete coverage of Iceland and on most of the sheets the projection is based on Greenwich, but a few sheets carry meridians based on Copenhagen. To convert to Greenwich, use the same correction as was given for the 50's.

   A. 3-30-37003-100 and S30-GI-100 are original Danish map work. S30-GSGS-100 is a British G.S.G.S. War Office series and S30-AMS-100 is an A.M.S. redraft of the G.S.G.S. series. All four series seem equally reliable for most areas, but the original Danish maps have a few spots which do not agree with the control values by several seconds, mostly in the vicinity of Akureyri.

   B. About fifty points were scaled from the various 1:100,000 series and the mean differences (control-scaled) were Longitude 3.7″ and Latitude 1.5″.

Maximum differences were Longitude –0.5″ to +28.1″ and Latitude from –1.4″ to +3.4″.

4. Horizontal Datum

   The horizontal datum appears to be based on the astronomical station of Reykjavik.

   Latitude
   64° 08′ 31.88″ N.

   Longitude
   34° 30′ 31.5″ W. – Meridian of Observatory at Copenhagen

   Longitude
   21° 55′ 51.15″ W. – Greenwich

5. Vertical Datum – Mean Sea Level

   To determine the altitude of certain convenient points a levelling was carried to them starting from mean sea level and ending on trigonometric stations near the coast and from these points the height of all other points was determined by trigonometric leveling.

6. Recommendations

   A. The 1:50,000 maps appear to be sufficiently accurate to be used for position in the contemplated new 1:50,000 series of Iceland.

   B. The 1:100,000 series is not as accurate as the 50 series. The position of control points is fairly reliable but the detail between control stations is generalized and does not agree exactly with multiplex compilations made in a stereo test for portions of two sheets.

All these results have been headed, as before, 'New 1950 Arc Datum', because the fundamental datum, which is the Arc, has not been changed. Whenever the new coordinates differ from the previous; this is due to a re-computation (including new observations) of part of the trig. system.

To avoid any further misunderstanding in the future it is proposed to change the heading of trig. lists now to 'New 1960 Arc Datum.' Most of the Tanganyika main trig. has still to be recomputed and a letter will be sent to each territory indicating the particular trig. chains which have already been recomputed and circulated under the 1950 heading.

The Figure of the Earth used is the Modified Clarke 1880, for which a = 6378249.145 and r = 293.465 in International Metres. The geodetic tables used are Latitude Functions Clarke 1880 Spheroid, *Army Map Service, but most D.O.S. computations are now done on the Electronic Computer, which computes its own geodetic factors* 'ab initio'. *Coordinates are also produced on the U.T.M. projection."*

Thanks go to Washington Abuto wherein his letter of 24 November 1997 for the Director of Surveys of the Survey of Kenya enclosed a paper detailing much of Kenya's history of Grids and Datums. That paper, authored by Mahinda, served as the basis of much of the specific geodetic history quoted in Davis' graduate-level term paper of 1999.

Kenya Update

AFREF Newsletter No. 5, (*2008*) reports a Molodensky-Badekas 7-parameter transformation solution for Kenya based on twenty common points between WGS84 and Arc 1960 Datum. Although the parameters are listed, no coordinates are listed for the Arc60 Datum origin point necessary for a Molodensky-Badekas model so the model is likely Bursa-Wolfe, instead. Furthermore, no guidance is provided regarding which direction the parameters are intended to be used, nor are any test points provided. https://www.rcmrd.org/newletters

AFREF Newsletter No. 11, (*2010*) reports on the KENREF (Kenya Reference Frame) proposal that will include CORS at 21 primary stations and eventually 71 stations at secondary locations. https://www.rcmrd.org/newletters

Renewing Kenya Vertical Datum by Davin N. Siriba (2020) https://issuu.com/iskkenya/docs/isk_journal_april_2019__9_/s/10844529

Assessment of EGM2008 using GPS/levelling and free-air gravity anomalies over Nairobi County and its environs by Patroba Achola Odera, *South African Journal of Geomatics, Vol. 5, No. 1, February 2016*. http://sajg.org.za/index.php/sajg/article/viewFile/356/218.

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