THE REPUBLIC OF ECUADOR

Sir Isaac Newton said that the Earth is flattened at the poles (oblate ellipsoid). But Monsieur Jacques Cassini said that the Earth is prolonged at the poles (prolate ellipsoid). To help settle the argument, the French mission to Quito, which started in 1735, was intended to determine the length of a degree of latitude. The survey was under the direction of Charles-Marie de la Condamine with Louis Godin and Pierre Bouguer of France. The Spanish representatives included Captain Jorge Juan y Santacilla, Captain Antonio de Ulloa (later Governor of Louisiana), and Don Pedro Vicente Maldonado y Sotomayor, a local gentleman of Riobamba, Ecuador. The French mission took ten years to triangulate the 200-kilometer meridional arc from Tarqui (near Cuenca) to Cotchasqui and the French expedition proved, to their chagrin, that the Englishman's theory was correct! The survey is known as the French Mission Datum which found that: a = 6,397,300 meters and $^1/_f$ = 216.8. Another result of the observations was the "toise of Peru," a standard of linear measurement subsequently used in France. Simón Bolívar later liberated South America from the Spanish Crown, and Ecuador was established as a Republic in 1830. No further geodetic surveys were undertaken for almost 200 years after the French Mission Datum was completed, and it was never later used for mapping.

On 30 June 1927, the Technical Commission for the "Survey of the National Topographic Map" was created in Ecuador to coordinate the various existing systems of geographic and plane rectangular coordinates being employed for official engineering applications. There seems to be no surviving record of those earlier systems. On 11 April 1928, the Servicio Geográfico Militar (SGM), "Military Geographic Service," was tasked with the actual job of implementing that survey. The origin of the Ecuador Datum of 1928 was at the Astronomical Observatory of Quito, where: Φ_o = 00° 12' 47.313" South, Λ_o = 78° 30' 10.331" West of Greenwich, and h_o = 2,908 meters. The International ellipsoid (also called the Hayford 1909 and the Madrid 1924), was used where: a = 6,378,388 meters, $^1/_f$ = 297. The defining azimuth from the Datum origin has been lost, but that old observatory is still there in a downtown park. The Ecuadorian Army started their 1:20,000 map series (20-meter contour interval) with the ellipsoidal Flamsteed projection, and the sheets were cast on the graticule without a grid overprint. (The Flamsteed is a sinusoidal projection tangent at the equator.) The sheet line intervals were at integer minutes of longitude (east and west) from the meridian of the Quito Observatory and at integer minutes of latitude (north and south) from the equator. The initial mapping on the Ecuador Datum of 1928 started south of Quito in Riobamba, Maldonado's home town.

In January of 1930, SGM changed the scale of their series to 1:25,000 and the contour interval to 20 meters. This series continued until 1947 when a number of momentous changes occurred in the history of the surveying and mapping activities of all Latin America. According to Ing. Vincente E. Avila, the Ecuadorian SGM substituted their name to Instituto Geográfico Militar (IGM), "Military Geographic Institute," about the same time they attended the Pan American Institute of Geography and History (PAIGH) meeting in Mexico City. At that special meeting, Floyd Hough of the U.S. Army Map Service (AMS), presented a proposal to change the military mapping systems of the western world to the Universal Transverse Mercator (UTM) Grid. Furthermore, in 1947, the Inter American Geodetic Survey (IAGS) was established by AMS, and was headquartered at Corozal, Canal Zone. In the 1950's, several of my classmates at Balboa High had parents that worked for IAGS. Hough later reiterated that proposal in 1952 at the Ciudad Trujillo PAIGH meeting, and IAGS published it in 1956.

The new "standard" topographic mapping format adopted by the Ecuadorian IGM after that 1947 meeting was at a scale of 1:50,000 with 40-meter contours. That new series was still cast on the graticule, but it was based on a sheet interval of 10 minutes of latitude and 15 minutes of longitude. The IAGS assisted IGM in establishing its classical triangulation net, and, by 1951, Ecuador was the first country in South America to have a completely modern geodetic network. A new datum for all of South America was envisaged at the time. The Provisional South American Datum of 1956 was established with an origin at La Canoa, Venezuela as a joint venture among the Republic of Venezuela, IAGS, and other countries. (I once interviewed the Venezuelan "Father" of PSAD 56, Dr. Romero in Caracas. One day I will write a piece on that fascinating talk.) The chains along the Andes Mountains were recomputed on the PSAD 56 where the origin at La Canoa (1951) is: Φ_o = 08° 34' 17.170" North, Λ_o = 63° 51' 34.880" West of Greenwich, and h_o = 178.870 meters. The azimuth to station Pozo Hondo (1951) is: α_o = 40° 22'45.96". The old Datums initially included in the IAGS re-computations were: Old Trinidad 1910, Loma Quintana 1911 (Venezuela), Bogotá 1941 (Colombia), and Quito 1928. The International ellipsoid is the reference surface used for the PSAD 56. The Ecuadorian IGM continued its mapping on the International ellipsoid, it recast existing sheets to the PSAD 56, and it has incorporated the UTM Grid since then for all military mapping. The South American Datum of 1969 has never been used for mapping in Ecuador.

Most mapping of Ecuador has been flown and compiled by IGM because of la Ley de la Cartografia Nacional de 1978, "the 1978 Law of National Mapping." Essentially, this formed a near-perfect monopoly for the benefit of the Army so that most original mapping must be done by IGM. This law has resulted in allowing the establishment of a large well-equipped national agency that is intended to meet the needs of

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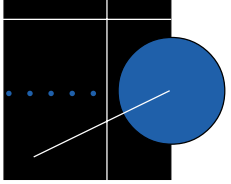

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both the military and local government, while helping to support other activities of the military. This sort of mapping arrangement is the rule, rather than the exception for much of Latin America. Military security for mapping is also a major concern for an army that has spilled blood during this decade.

Back in the early 1980's, the City of Guayaquil contracted with IGM for a cadastral mapping project. The compilation scale was 1:1,000, and 1982 photo control was by aerotriangulation from traverse densification of classical Second Order (IGM/IAGS) triangulation. Like most countries in South America, the Ecuadorian cartographers have agreed with the advice of AMS and have shunned the use of the UTM Grid for civilian cadastral mapping. The initial Grid established by IGM was based on a Gauss-Krüger Transverse Mercator projection. The scale factor at origin, $m_o = 1.0$, the central meridian of the belt (C.M.), λ_o = 79° 53' 05.8232" West of Greenwich, the False Easting at C.M. = 624 kilometers, and the False Northing = 10,000,051.000 meters. However, the population of Guayaquil doubled in the next 10 years, and the city experienced substantial environmental difficulties because of that explosion of people.

In the early 1990's, the Republic of Ecuador contracted with the University of New Orleans (UNO) for an environmental assessment and subsequent remediation design for the sanitary sewer system of Guayaquil. As an Environmental Protection Agency "Center of Excellence," UNO is a source in the U.S. for foreign governments seeking technical help with urban waste management technology. UNO went into a partnership with a local university in the city, the Escuela Superior Politécnica del Litoral (ESPOL). The analysis and design needed a GIS to maximize efficiency and minimize costs, so UNO and ESPOL performed a differential GPS survey of the City of Guayaquil. We occupied a number of existing IGM triangulation stations as well as new photo-identifiable points based on recent IGM aerial photography. Co-located fiducial points were observed according to DMA/NIMA specifications, and NIMA performed the subsequent fiducial point adjustment to the precise ephemeris.

The UNO/IGM solution from PSAD 56 to WGS 84 for a 7–Parameter Molodensky model (using the PSAD 56 origin at La Canoa *with Northern latitude*), yielded: $\Delta X = -263.91$ m, $\Delta Y = -25.05$ m, $\Delta Z = -285.81$ m, scale $= -3.61 \times 10^{-6}$, $R_z = -36.88$", $R_y = -3.42$", $R_x = +3.54$". A computational test point for instance, is station "Panoramico" where the PSAD 56 coordinates are: ϕ = 02° 11' 43.9093" South, λ = 79° 52' 45.4601" West, and h = 68.614 m. The "Panoramico" WGS 84 coordinates are: ϕ = 02° 11' 55.8406" South, λ = 79° 52' 53.4010" West, and h = 68.530 m. I prefer to use the Molodensky model to the Bursa-Wolf model in cases like this when the local area is a great distance from the datum origin. Note that the net computational results (of shift transformations) are identical, but the shift parameters in this case are less correlated and thus they appear more meaningful with the Molodensky model.

A new Grid was devised for the City of Guayaquil based on the Normal Mercator projection, WGS 84 Datum. The origin is at the Rotonda of Simón Bolívar in downtown Guayaquil. The scale factor at origin, $m_o = 0.999272829$, the central meridian (C.M.) λ_o = 79° 52' 45.16" West of Greenwich, the False Easting at C.M. = 500 kilometers, and the False Northing = 2,242,320.510 meters at ϕ = 02° 11' 33.09" South. The ellipsoid of reference is the WGS84 where a = 6,378,137 meters, $^1/_f$ = 298.257223563. Because most of our UNO graduate students on the project were visiting professors from the ESPOL University in Guayaquil, the name was dubbed the "ESPOL La Rotonda Grid." The city has recently contracted with IGM for a new cadastral mapping system and GIS. They are continuing with the new Datum and Grid. IGM is currently participating in the SIRGAS project to establish a single, unified datum for all of South America using GPS techniques with technical assistance from NIMA.