Grids & Datums

REPUBLIC OF CHINA (TAIWAN)

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"There is evidence of human settlement in Taiwan dating as far back as 30,000 – 40,000 years ago; current prevalent thinking dates the arrival of the Austronesian peoples, ancestors of many of the tribal people who still inhabit Taiwan, between 4,000–5,000 years ago. For most of her long history, China seemed fairly indifferent to Taiwan. Early Chinese texts from as far back as *AD* 206 contain references to the island, but for the most part it was seen as a savage island, best left alone. Contact between China and Taiwan was erratic until the early 1400s, when boatloads of immigrants from China's Fujian province, disillusioned with the political instability in their homeland, began arriving on Taiwan's shores. When the new immigrants arrived, they encountered two groups of aboriginals: one, who made their homes on the fertile plains of central and southwestern Taiwan and the other, seminomadic, lived along the Central Mountain Range. Over the next century, immigration from Fujian increased, these settlers being joined by the Hakka, another ethnic group leaving the mainland in great numbers. By the

"Early records of survey work in Formosa date back to a Japanese Hydrographic Department survey of the west coast in 1897. Between 1900 and 1904 the Government General of Formosa under the supervision of the Japanese Government established approximately 2,000 stations. Japanese Imperial Land Survey initiated their work on a first-order net in Formosa in 1909. The datum for this and succeeding lower-order triangulation is Koshizan 1906 and is defined at: Φ_o = 23° 58' 32.340" North, Λ_o = 120° 58' 25.975" East of Greenwich, initial azimuth: α_o = 63° 46' 57.18" (south end of Horisha base to Koshizan), back azimuth: α = 243° 47' 21.611" (Koshizan to south end of Horisha base). Elevation = 555.34 meters. (*The reference ellipsoid was the Bessel 1841 where: a = 6,377,397 155 meters and the reciprocal of flattening $^1/_f$ = 299.1528128 – Ed.*). Including the 2,000 stations established by the Government General of Formosa, the number of stations established and coordinated into Japanese Imperial Land Survey (*JILS – Ed.*) trig lists is 4,851. Japanese Hydro-

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early 1500s there were three categories of people on the island: Hakka, Fujianese and the aboriginal tribes. Today, Taiwan's population is mainly descended from these early Chinese immigrants, though centuries of intermarriage makes it likely a fair number of Taiwanese have some aboriginal blood as well" (*Lonely Planet, 2010*).

"During the 18th and 19th centuries, migration from Fujian and Guangdong provinces steadily increased, and Chinese supplanted indigenous peoples as the dominant population group. In 1895, a weakened Imperial China ceded Taiwan to Japan in the Treaty of Shimonoseki following the first Sino-Japanese war. During its 50 years (1895-1945) of rule, Japan expended considerable effort in developing Taiwan's economy. At the same time, Japanese rule led to the "Japanization" of the island, including compulsory Japanese education and pressuring residents of Taiwan to adopt Japanese names. At the end of World War II in 1945, Taiwan reverted to Chinese rule. In October 1949 the People's Republic of China (P.R.C.) was founded on the mainland by the victorious communists. Chiang Kai-shek established a 'provisional' Republic of China (R.O.C.) capital in Taipei in December 1949" (*U.S. Dept. of State Background Notes, 2010*).

Taiwan is comprised of the main island, (formerly known as Formosa), the Pescadores, Matsu, and Quemoy islands. Slightly smaller than Maryland and Delaware combined, the terrain is mostly rugged mountains for the eastern two-thirds, flat to gently rolling plains in the west. The lowest point is the South China Sea (0 m); the highest point is Yu Shan (3,952 m) (*World Factbook, 2010*).

graphic Department stations, which have been adjusted to Japanese Imperial Land Survey work, number 221. The grid system for Formosa is known as the Formosa Grid and is based on the Gauss-Schreiber projection: origin at 23° 40' 00.000" North, 120° 58' 25.975" East. (*The Gauss-Schreiber projection is a Transverse Mercator projected first to an equivalent sphere and then to the ellipsoid; the scale factor at origin is equal to unity, and there was no False Origin per standard Japanese practice of the time. – Ed.*) Control for this grid system is available for first-, second- and third-order Government General of Formosa and Japanese Imperial Land survey stations. However, Station values of 4th order Government General of Formosa and Japanese Hydrographic Department surveys are in terms of geographical coordinates only. Level lines consisting of approximately 700 bench marks were established from 1904 through 1936 by the Japanese Imperial Land survey. The principal level line circles the island, with other lines joining this circuit. Datum point for the levels of Formosa is Kirun tide gauge" (*Army Map Service Geodetic Memorandum File 773.0303, 7 June 1950*). According to John W. Hager, "After 1921, the *JILS* Grid changed the Latitude of Origin for Formosa to φ_o = 24°, and the Central Meridian for Formosa to λ_o = 121°."

When the Republic of China (Taiwan) was established, the China Map Service was moved from the mainland to Taipei. In accordance with standard military practices of the U.S. Army Map Service (AMS), the Japanese Imperial Land Survey triangulation net was recomputed on the International 1924 ellipsoid where a = 6, 378,388 m, and

$^1/_f$ = 297. The datum origin was retained, but was translated to the Chinese Huzi Shan (*Tiger Cub Mountain*). The translation to English was provided by Professor Frank Tsai of Louisiana State University in 2010. Various English spellings of the transliteration can be found in the literature, the one given here is the approved version on the NGA GeoNames server. When the International ellipsoid was adopted with the re-computation of the triangulation in 1950, the UTM Grid was also adopted for Taiwanese Military applications. The civilian cadastral applications continued to use the original Formosa Grid and origin as referenced on the Bessel 1841 ellipsoid for almost two more decades. During the Japanese occupation, a total of 3,873,468 cadastral parcels had been registered to the original grid. Japanese geodetic control combined with cadastral control totaled 7,903 points. Note that the 1950 Taiwan re-computation on the International ellipsoid was accomplished with standard AMS techniques developed for use with mechanical calculators by performing a conformal 2D transformation on the complex plane; the identical way the European Datum of 1950 was computed. According to *TR 8350.2*, the three-parameter shift **from** "Hu-Tzu-Shan" (*sic*) **to** WGS84 is: ΔX = −637 m, ± 15 m, ΔY = −549 m, ± 15 m and ΔZ = −203 m. ± 15 m, based on collocation at 4 points in 1991.

"A new conventional geodetic datum was computed based on geodetic observations carried out in 1978, and the new reference ellipsoid selected was the Geodetic Reference System 1967 (*a = 6,378,160 m*, $^1/_f$ *= 298.25 – Ed.*). The origin point of this datum located at the Hu-Tzu-Shan (*Huzi Shan – Ed.*) astronomic station. The coordinates of this origin and the initial azimuth from this point to the reference point were both based on first-order astronomic observations. Four other basic assumptions for this datum were also made as follows:

(1) The adopted center was the mass center of the earth;

(2) Three axes were aligned parallel to the average terrestrial system;

(3) Astronomic and geodetic coordinates for the origin point were kept the same;

(4) The ellipsoid was assumed to be tangential to the geoid at the origin point.

"Some defects can be clearly seen from the definition of this datum. The assumptions of (3) and (4) might not be valid as the separation between the ellipsoid and the geoid is significant. For the geodetic measurements made for this datum, the fundamental control networks extending from Hu-Tzu-Shan (*sic*) station to some 2,661 points of first-, second-, and third-order control stations were set up using triangulation and trilateration observations.

"The coordinates, including latitude and longitude based on GRS67, grid coordinates based on the 2° – Zone Transverse Mercator (TM) projection, and height above the mean sea level for all geodetic control stations, were released by the Ministry of Interior in 1980. This set of coordinates was called the Hu-Tzu-Shan (*sic*) coordinate system, also named the TWD67 (Taiwan Geodetic Datum based on the GRS67) " (*A Geocentric Reference System in Taiwan, Chang & Tseng,* Survey Review, *vol.35, No. 273, July 1999, pp 195-203*). According to the National Land Surveying and Mapping Center the 2° – Zone Transverse Mercator (TM) projection has a Central Meridian of 121° East for Taiwan Island, Ryukyu, Green Island, and Turtle Island; 119° East for Penghu, Kinmen, and Matsu; 117° East for Tungsha Islands; and 115° East for Nansha Islands. The scale factor at origin is 0.9999, and the False Easting is 250 km for each belt. The specific projection type is defined to be the Gauß-Krüger Transverse Mercator. A shift published in an ESRI thread **from** TWD67 **to** WGS84 is as follows: $\Delta X = -764.558$ m, $\Delta Y = -359.515$ m, $\Delta Z = -180.510$ m, scale = 0.99998180, $R_X = +7.968$", $R_Y = +3.5498$", $R_Z = +0.4063$".

(No clue is offered regarding the sense of the rotations, nor is a test point given, nor is accuracy stated.)

The TWD67 was used for almost two decades. "Due to the occurrence of natural disasters, such as earthquakes and typhoons, and the many construction projects undertaken in the island during this period, over 60% of the triangulation points, mostly below 500 meters high, were seriously damaged or even destroyed.

"The final strategy was made by the working committee to establish a fundamental GPS network consisting of 8 permanent tracking stations, 105 first-order, and 621 second-order GPS control stations in the Taiwan area. The schedule was to set up 4 of the GPS control stations in 1993 and 4 others in 1994, to establish 105 first-order GPS control stations in 1995, and to implement 621 second-order GPS stations through 1996 to 1998, all by GPS" (*ibid., Chang & Tseng, 1999*). In 1995-1999, 1,967 third-order control points were established in Taiwan. A follow-up plan for Taiwan Province in 2000-2003 added an additional 2,500 third-order control points, and Taiwan-Fukien added 4,710 control points. The Taiwan Geodetic Datum of 1997 (TWD97) is referenced to the Geodetic Reference System 1980 ellipsoid where: $a = 6,378,137$ m, $1/f = 298.257222101$. TWD97 also uses a variety of Transverse Mercator belts in that the 2° system has Central Meridians at 121°E, 119°E, 117°E, and 115°E; the False Easting for each belt is 250 km, and the scale factor at origin, $m_o = 0.9999$. On the other hand, a 3° system has Central Meridians at 121°E, and 118°E; the False Easting for each belt is 350 km, and the scale factor at origin, $m_o = 1.0$. The standard 6° UTM is also used with Central Meridians at 123°E. amd 117°E . The latitudinal extent of all of the Taiwan TWD97 Grids is from 21° 30' N to 25° 30' N.

Since the adoption of the TWD97, earthquakes have caused major terrestrial movements on the island; "the maximum dislocation of 9.8 meters is among the largest fault movements ever measured for modern earthquakes" (*Establishment and Maintenance of TWD97, Yang, Tseng, and Yu,* ASCE Journal of Surveying Engineering, *November 2001, pp. 119-132*).

Attempts to develop a method for datum transformation between TWD67 and TWD97 have yielded some fascinating results. Using the traditional seven-parameter similarity transformation for Taiwan resulted in a transformation accuracy of ±0.5 m. On the other hand, using a 2D method on a conformal projection (like the U.S. Army Map Service did for Taiwan in 1950), yielded a transformation accuracy of ±0.16 m! (*Coordinate Transformation between Two Geodetic Datums of Taiwan by Least-Squares Collocation, You & Hwang,* ASCE Journal of Surveying Engineering, *May, 2006*). Thanks to John W. Hager, other datums known to exist in Taiwan include for the Pescadores (Penghu Qundao), Kobokutei (Japanese) or Hung-mu-ti (Chinese) where: $\Phi_o = 23° 34' 19.069"$ N, $\Lambda_o = 119° 33' 45.695"$ E, Bessel 1841 ellipsoid until 1950, then International 1924 ellipsoid thereafter; Mazutian at South Point of Base, $\Phi_o = 26° 09' 20.95"$ N, $\Lambda_o = 119° 56' 57.45"$ E, $\alpha_o = 266° 45' 02.24"$ to Fu-wu (from north), International 1924 ellipsoid; Quemoy (Jinmen Dao) 1952 where: $\Phi_o = 24° 25' 52.55" ± 0.56"$ N, $\Lambda_o = 118° 26' 20.69" ± 0.28"$ E, $\alpha_o = 61° 21' 38.89" ± 0.35"$ to East Point of Base (from north).

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