

THE REPUBLIC OF FIJI ISLANDS

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Fiji consists of over 300 islands and islets in the South Pacific Ocean of which approximately 110 islands are inhabited. Chief islands include: Viti Levu, Vanua Levu, Taveuni, Kandavu, Koro, Ngau, and Ovalau; with the first three being the largest. The capital is Suva (on Viti Levu) in the Central District. With a population of almost 813,000 people, the republic gained independence from the United Kingdom on October 10, 1970. Fiji has a total coastline of over 1,100 miles; its lowest elevation point is the Pacific Ocean and its highest point is Tomanivi at 1,324m (4344 ft). Endowed with forest, mineral (gold and silver), and fish resources; Fiji is one of the most developed of the Pacific Island economies. The main sources of income are derived from sugar processing and the tourist industry. Fiji was discovered by Tasman in 1643, visited by Captain Cook in 1774, used by escaped convicts from Australia from 1804, surveyed by Commander Charles Wilkes of the U.S. in 1840, offered to Great Britain in 1858, and annexed by the UK in 1874.

European, American, and Australian settlers introduced the concept of land boundaries with monuments, and surveys of properties derived from native people started as early as the 1840s. Angular measurements were recorded in degrees and minutes, while linear measurements were recorded in fathoms or chains & links. The recognized Fijian unit of "fathom" was the distance between the tips of the fingers of a man's outstretched arms! By 1873, surveys were recognized only if performed by licensed Land Surveyors.

The Deed of Cession of 1874 began the Fijian status as a British Crown Colony. Four different categories of land were established. First was land that could be proven to have become the bona fide property of Europeans or other foreigners. Second were lands that were in actual use or occupied by some chief or tribe at the date the deed was signed. Third were the lands required for the probable future support and maintenance of some chief or tribe. Fourth, all lands not contained in the three previous categories were therefore the property of the Crown. Implementing proper surveys according to these categories proved difficult. The Chief Secretary of the Commissioner of Lands traveled to Sidney to engage surveyors for this purpose in 1874. He was authorized to offer an annual salary of £200 for an initial probationary period of three months and £300 per annum thereafter. Four surveyors were engaged; one declined before sailing because he was getting married, another took one look at Levuka, got back aboard the ship and returned to Sidney. Government surveyors were discouraged from hiring boats for transportation and were told to walk instead to keep expenditures to a minimum. Penny-pinching for survey operations continued for a quarter century or so until a comprehensive geodetic survey was realized to be the only solution to a critical need for unified positional control.

On October 26th, 1908, Captain Ley, an officer of the Corps of Royal Engineers, arrived in Fiji with Travis Rimmer, his civilian assistant. Shortly afterwards, Ley was succeeded by Captain G. T. McCaw, R.E. (Thanks to Russell Fox of the Ordnance Survey of Great Britain for the following "micro biography" on McCaw.) In 1870 – McCaw born in

Lurgan, County Armagh, Ireland; 1893 – graduated in arts and science from Trinity College, Dublin; 1893-1903 – employed by Irish Land Valuation Dept.; 1903-06 – Geodetic Survey of Rhodesia; 1906-09 – with the 30th Arc Survey in Uganda; 1910-17 – Officer in Charge for Trig Survey of Fiji; 1917-18 – Geodetic advisor at British Army General HQ, France; 1919-1936 – Tech Assistant at Geographical Section, General Staff (GSGS), British War Office, 1931 – first Editor of the *Empire Survey Review*; 1942 – G.T. McCaw OBE, CMG died. In later years, his protégé, Brigadier Martin Hotine was head of the Directorate of Overseas Surveys. Hotine addressed McCaw as "Uncle" in his correspondence!

The technical instructions initially issued for the Survey of Fiji were "to cover Viti Levu with a system of triangles with sides from 10 to 20 miles long; to measure a primary (baseline) and a check base with probable errors not exceeding 1/50,000 . . ." The site of the primary base was approximately 3 miles long and oriented NNE – SSW running along the tongue of land between the Navua River and the coast. McCaw and Rimmer measured the baseline in 1910 with a probable error of ± 0.013 feet, *i.e.* an accuracy of 1/150,000. For the check base at Lautoka, a line 3 miles 5 furlongs in length was selected from a point near the boundary of the Vitogo Estate. The final check was ± 0.067 feet. Fieldwork on Viti Levu was completed and the party returned to England in March 1912. The Viti Levu Datum of 1912 was referenced to the Clarke 1880 ellipsoid where $a = 20,926,202$ feet (317,063.6667 chains), and $1/f = 293.4663077$. I think it is no coincidence that the ellipsoid parameters and units used for Fiji are exactly the same as used in British

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Africa, since McCaw had already surveyed in Rhodesia and Uganda. The Latitude of Origin was obtained astronomically from station Monavatu where $\Phi_o = 17^\circ 53' 28.285''$ South $\pm 0.75''$, and the Longitude origin was obtained astronomically at station Suva Longitude pillar (concrete pier in the rear of the offices of the Pacific Cable Board and within a few feet of the high water mark) with telegraphic cable signals from both Vancouver, Canada and from Moreton Bay, Queensland Australia where $\Lambda_o = 178^\circ 25' 35.835''$ East of Greenwich $\pm 0.835''$. The defining azimuth from north was determined at Monavatu to Tikituru to be $\alpha_o = 205^\circ 17' 21.17''$ from observations at Rasusuva and from Nathova. His main instrument was a 6-inch diameter theodolite with an alidade (telescope) level with a par value of $\pi = 5''$. "It was quickly noticed that the bubble used to 'jam' in the vial . . ." He obtained another vial and observed that "a second alidade level was obtained from the makers, and proved not a whit better than the first . . ." He figured a way around it, and all of his work served as a model for decades – his own reports of his work in Fiji were used as textbooks on how to do it throughout the British Empire. McCaw chose the Cassini-Soldner projection for the basis of the Viti Levu Grid where the Latitude of Origin (ϕ_o) = $18^\circ 00'$ South, and the Central Meridian (λ_o) = $178^\circ 00'$ East (per specifications of the Secretary of State). The Scale Factor at Origin (m_o) by definition is unity on the Cassini-chains (88 miles), and the False Easting = 5440 chains (68 miles). Note that one meter = 0.049709782 chains for Fiji. NIMA Technical Report 8350.2, dated January 3, 2000 lists the 3-parameter shift from Viti Levu Datum of 1916 to WGS 84 Datum as: $\Delta X = +51$ meters, $\Delta Y = +391$ meters, $\Delta Z = -36$ meters. These shift parameters were originally pub-

lished in 1987 and have an uncertainty of ± 25 meters in each component. This relation is the result of a single station occupation.

The Trig Survey party returned to Fiji in September 1912 to extend the triangulation of Viti Levu across to Vanua Levu and Taveuni. The baseline for this part of the work was measured from Nasekula towards the sea at Tua Tua and the final measurement over the $3\frac{1}{2}$ miles was accepted at ± 0.015 feet. McCaw reported that the Vanua Levu Datum of 1915 was referenced to the Clarke 1880 ellipsoid also, and the Latitude origin was obtained astronomically from station Numuiloa where $\Phi_o = 16^\circ 23' 38.36''$ South $\pm 0.529''$, and the Longitude origin at station Suva pillar on Viti Levu was adopted. The defining azimuth from north observed at Naseula (East Base) to Vatia is $\alpha_o = 123^\circ 57' 28.75''$. The Grid for the Vanua Levu Datum of 1915 is where the Latitude of Origin (ϕ_o) = $16^\circ 15'$ South, and the Central Meridian (λ_o) = $179^\circ 20'$ East, the Scale Factor at Origin (m_o) = 1.0.

McCaw was concerned about the orientation of these islands with respect to the systematic distortions inherent in the Cassini-Soldner projection. "If an origin be chosen" (as per the Grid Origin above), "and lines be drawn SW and SE from this origin, they will be found to traverse centrally the principal land surfaces. Thus the SW axis, passing near the main stations of Mbulembulewa, Nathau, and Navotuvotu, crosses midway the fine Ndreketi plain and Mbua Province in the extreme west. The SE axis passes up the Mbuthaisau Valley, crosses about midway the Natewa Embayment, passes through the Thakaundrove Peninsula, and leaving the latter near the main station of Navivvia, crosses Taveuni at about one sixth of its length from its centre of figure. The important Lambasa plain lies so close to the origin that the error of projection in this neighbourhood (sic) will be very

small." He developed a correction factor for this Datum that resulted in the most unique projection for a Grid in the world; the Hyperbolic Cassini-Soldner where the abscissae (Eastings) are reduced by the factor $\frac{1}{3} X^3 \text{Osin}1''$ and where the factor $O = \frac{1}{2} \nu \rho \sin 1''$. In my column on the Czech Republic, the reader may recall that the Radius of the Gaussian Sphere = $[\nu \rho]^{-1/2}$. The False Northing = 16,628.885 chains, and the False Easting = 12,513.318 chains because McCaw took the Hyperbolic Cassini-Soldner coordinates of the "natural" origin in the Viti Levu system of the meridian $179^\circ 20'$ and the parallel $16^\circ 15'$. These manipulations, as I understand them, were to minimize the distortions in the land areas of the main islands while maintaining a consistent-appearing Grid coordinate system for Viti Levu, Vanua Levu, Tanvenui, etc. The field party left Fiji in 1915 and the final report was published in 1917 after meeting the geodetic demands of the First World War. An example point in the McCaw report lists the Vanua Levu Datum of 1915 coordinates of "Ndana" (Station 21) as: $\phi = -16^\circ 50' 29.2435''$ S, $\lambda = 179^\circ 59' 39.6115''$ E. (Thanks to Litea Biukoto of the South Pacific Applied Geoscience Commission (SOPAC) for a copy of that report.) A report printed in 1985 lists the Hyperbolic Cassini-Soldner coordinates of "Dana" as: $X = 1,601,528.90$, $Y = 1,336,966.00$. (Thanks to Mal Jones of Perth, Australia for a copy of that report.)

Russell Fox informs me, "In 1956 the New Zealand Surveyor General's Office readjusted McCaw's work on one datum (Fiji 1956) using the International Spheroid and the UTM Grid. That was used on military mapping from circa 1960 onwards. DOS (Directorate of Overseas Surveys) did Tellurometer (electronic distance meter or EDM) traversing in the 1960's to strengthen and densify the trig network."

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In 1978, two senior personnel from the New Zealand Department of Lands and Survey undertook a review of survey and mapping activities in Fiji. As a result, the Australian Army Survey Corps (RASVY) established a number of Doppler (TRANSIT satellite) stations for mapping control and determination of the exclusive economic zone. In 1984 field work began by the New Zealanders for further Doppler surveys and for the recomputation of McCaw's Datums of Fiji. First order astronomic latitudes, longitudes, and azimuths were observed at a total of eight stations. In general these coincided with either the original McCaw stations or with the Doppler stations. New First order EDM traverses were undertaken around the periphery of Viti Levu, through Vanua Levu and across the 100 km wide strait between the two islands. By late 1985 all the observa-

tions required for the primary network had been completed. According to Hannah and Maseyk (*Survey Review* **30**, 231– January 1989), “In the first instance the complete set of Ley-McCaw triangulation data as given by the historic records was accepted in total. The only exception to this being the deletion of five stations which had been positioned weakly by either resection or intersection.” Note this is the same general philosophy as adopted by the U.S. National Geodetic Survey when they did the North American Datum in the mid 1980s. The result of the New Zealand observations and adjustment was the Fiji Geodetic Datum of 1986. A new unified Cartesian system was also devised; it is called the Fiji Map Grid (FMG) and is based on the Gauss-Krüger Transverse Mercator projection where: Latitude of Origin (ϕ_o) = 17° 00' South, and the Central Meridian (λ_o) = 178° 45' East. The Scale Factor

at Origin (m_o) = 0.99985, the False Northing = 4,000 km, and the False Easting = 2,000 km. The ellipsoid of reference is the WGS 72 where $a = 6,378,135$ m, and $1/f = 298.26$. Franck Martin of SOPAC lists transformation parameters on their Internet site as: “from WGS84 to Fiji Geodetic Datum” as determined by the Forestry Department of Fiji as: $\Delta X = +35.173$ meters, $\Delta Y = -136.571$ meters, $\Delta Z = +36.964$ meters, Scale = $+1.537 \times 10^6$, $R_x = -1.37$ arc seconds, $R_y = +0.842$ arc seconds, and $R_z = +4.718$ arc seconds. I have not verified these transformation parameters with respect to the WGS84 Datum, but in 1985 the Fiji Department of Lands and Survey listed the FMG coordinates of “Dana” as $X = 2,132,200.63$ m, $Y = 4,016,984.99$ m. (Thanks to John Hagar, retired from NIMA, for his generous help and counsel.)

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