Grids & Datums

REPUBLIC OF CROATIA

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"Excavations in Krapina have revealed that the area has been inhabited since the Palaeolithic Age. The initial Roman province of Illyricum was gradually enlarged during a series of wars that brought much of the Dalmatian coast within their control. By 11 *BC*, Rome conquered much of the interior, which was inhabited by the Pannonian tribe, extending the empire's reach to the middle and lower Danube. The realm was reorganized into Dalmatia (the former Illyricum), and Upper and Lower Pannonia, which covered much of the interior of modern Croatia" (*Lonely Planet, 2012*).

"The Croats are believed to be a Slavic people who migrated from Ukraine and settled in present-day Croatia during the 6th century. After a period of self-rule and the establishment of an independent kingdom, Croatians agreed to the *Pacta Conventa* in 1091, submitting themselves to Hungarian authority. By the mid-1400s, concerns over Ottoman expansion led the Croatian Assembly to invite the Habsburgs, under Archduke Ferdinand, to assume control over Croatia. Habsburg rule proved successful in thwarting the Ottomans, and by the 18th century, much of Croatia was free of Turkish control. The Austrian monarchy also acquired control over Dalmatia at the close of the Napoleonic wars following centuries of rule by the Venetian Republic. In 1868, Croatia gained domestic autonomy under Hungarian authority. Following World War I and the demise of the Austro-Hungarian Empire, Croatia joined the Kingdom of Serbs, Croats, and Slovenes (the Kingdom of Serbs, Croats, and Slovenes became Yugoslavia [*PE&RS,* September 1997] in 1929). During World War II, German and Italian troops invaded and occupied Yugoslavia and set up a puppet, Fascist regime to rule a nominally-independent Croatian state. This regime, under the hardline nationalist Croatian Ustasha party, was responsible for the deaths of large numbers of ethnic Serbs, Jews, Roma, and other civilians in a network of concentration camps. It was eventually defeated by the Partisans, led by Josip Broz Tito, in what was essentially a civil war as well as a struggle against the Axis occupiers. The pro-Yugoslav Partisans included many ethnic groups, including a large number of Croatians, and were supplied in large part by the United States and the United Kingdom. Yugoslavia changed its name once again after World War II. The new state became the Federal Socialist Republic of Yugoslavia and united Croatia and several other republics together under the communist leadership of Marshal Tito. After the death of Tito and with the fall of communism throughout Eastern Europe, the Yugoslav federation began to unravel. Croatia held its first multi-party elections since World War II in 1990. Long-time Croatian national-ist Franjo Tudjman was elected President, and 1 year later, Croatia declared independence from Yugoslavia. Conflict between Serbs and Croats in Croatia escalated, and 1 month after Croatia declared independence, the Yugoslav Army intervened and war erupted. The United Nations mediated a cease-fire in January 1992, but hostilities resumed the next year when Croatia fought to regain one-third of the territory lost the previous year. A second cease-fire was enacted in May 1993, followed by a joint declaration the next January between Croatia and Yugoslavia. However, in September 1993, the Croatian Army led an offensive against the Serb-held self-styled 'Republic of Krajina.' A third cease-fire was called in March 1994, but it, too, was broken in May and August 1995, after which Croatian forces regained large portions of the Krajina, prompting an exodus of Serbs from this area. In November 1995, Croatia agreed to peacefully reintegrate Eastern Slavonia, Baranja, and Western Sirmium under terms of the Erdut Agreement, and the Croatian government re-established political and legal authority over those territories in January 1998. In December 1995, Croatia signed the Dayton peace agreement, committing itself to a permanent cease-fire and the return of all refugees" (*U.S. Dept. of State Background Notes, 2012*).

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Slightly smaller than West Virginia, Croatia is bordered by Bosnia and Herzegovina (932 km), Hungary (329 km) (*PE&RS*, April 1999), Serbia (241 km), Montenegro (25 km), and Slovenia (455 km) (*PE&RS*, October 2011). The lowest point is the Adriatic Sea (0 m), the highest point is Dinara (1,831 m), the terrain is geographically diverse with flat plains along the Hungarian border, and low mountains and highlands near the Adriatic coastline and islands (*World Factbook*, 2012).

The coordinate systems that have been used for Yugoslavian lands have been quite diverse through history. Geographic coordinates have been based on the Prime Meridians of Paris, France; Ferro, Canary Islands; Greenwich, England; and also some temporary usage of the Vienna University Observatory where: $\Lambda = 16° \ 22' \ 49.98"$ East of Greenwich (later offset to Paris).

The names of the classical horizontal datums found in Croatia include Hermannskogel 1871, K.u.K. VGI Vienna University System 1892, System 42, and European 1950. The Hermannskogel 1871 datum used the Bessel 1841 ellipsoid where $a = 6,377,397.155$ m, $^1/_f = 299.1528128$, the Vienna University System 1892 used the now obsolete Zach 1812 ellipsoid where $a = 6,376,385$ m, and $^1/_f = 310$, the System 42 used the Krassovsky 1940 ellipsoid where $a = 6,378,245$ m, and $^1/_f = 298.3$, and the European 1950 Datum used the International

ellipsoid where $a = 6,378,388$ m, and $^1/_f = 297$. The "Parisian" system of mapping (based on the Prime Meridian of Paris, where the offset from Greenwich is accepted as $\lambda = 2° 20' 13.95" E$) was cast on the polyhedric projection from 1878 to 1959. The mapping equations for the ellipsoidal polyhedric projection are given in Chapter 3 of the *Manual of Photogrammetry, 5th edition* and soon to be published 6th edition, in which it is identical to the Local Space Rectangular (LSR) when $\alpha = h = 0$.

The Hermannskogel 1871 Datum origin is at: $\Phi_o = 48° 16' 15.29"$ N, $\Lambda_o = 33° 57' 41.06"$ East of Ferro, where Ferro = $17° 39' 46.02"$ East of Greenwich and azimuth to Hundsheimer is $a_o = 107° 31' 41.7"$. The most common grid found on that datum is the Yugoslavia Reduced Gauss-Krüger Transverse Mercator. The scale factor at origin ($m_o = 0.9999$), the central meridian of the belt that covers Croatia is $\lambda_o = 18°$ East of Greenwich, and the False Easting = 500 km. The Ministry of Finance used the non-reduced version only between 1938-40 where $m_o = 1.0$.

The K.u.K. VGI Vienna University System 1892 origin is at: $\Phi_o = 48° 12' 35.50"$ N, $\Lambda_o = 16° 22' 49.98"$ East of Greenwich. The K.u.K. VGI Vienna University System 1892 Datum established two baselines in Croatia at Sinj and at Dubica (*Andrew M. Glusic, Mapping of the Countries in Danubian and Adriatic Basins, Army Map Service Technical Report No. 25, June 1959*).

The System 42 Datum origin is at Pulkovo Observatory where: $\Phi_o = 59° 46' 18.55"$ N, $\Lambda_o = 30° 19' 42.09"$ East of Greenwich. The defining azimuth at the point of origin to Signal A is: $\alpha_o = 317° 02' 50.62"$.

The European 1950 Datum origin is at Helmertturm, Pottsdam (Germany) where $\Phi_o = 52° 22' 53.9540"$ N, $\Lambda_o = 13° 04' 01.1527"$ East of Greenwich. The defining azimuth to station Golmberg is: $\alpha_o = 154° 47' 32.19"$,

About 60 years ago, the Army Map Service transformed Hermannskogel 1871 Datum to the European Datum 1950. However, large data sets (including cadastral) still survive on that old datum. The author examined the relation between the two datums and computed new transformations. Twenty two points were used that are common to both datums throughout the former Yugoslavia and a simple three-parameter shift analysis yielded the following: $\Delta X = +770.417$ m, $\Delta Y = −108.432$ m, $\Delta Z = +600.450$ meters. The accuracy of this transformation when expressed in terms of actual geodetic coordinates is: latitude change ($\Delta\phi$) = ± 3.74 meters, longitude change ($\Delta\lambda$) = ± 4.54 meters, and ellipsoid height change (Δh) = ± 12.70 meters. On the other hand, a seven-parameter shift analysis yielded the following: $\Delta X = +758.53$ meters, $\Delta Y = +259.52$ meters, $\Delta Z = +542.18$ meters, Scale = $−6.0 \times 10^{-6}$, Z-rotation (ω) = $+11.29"$, Y-rotation (ψ) = $+2.06"$, and X-rotation (ξ) = $−5.66"$. The accuracy of this transformation when expressed in terms of actual geodetic coordinates is: Latitude change ($\Delta\phi$) = ± 1.07 meters, Longitude change ($\Delta\lambda$) = ± 1.44 meters, and Ellipsoid Height change (Δh) = ± 0.64 meters. For example, station

Vel Gradiste has the following EU50 coordinates: 45° 09' 17.3501" N, 18° 42' 44.9479" E, 0.0 m. and the following Hermannskogel 1871 coordinates: 45° 09' 14.4675" N, 18° 43' 00.7696" E, 0.0 m. The Yugoslavian Reduced Grid coordinates are: Northing (X) = 5,001,303.81 m., Easting (Y) = 556,359.65 m.

The current geodetic situation in Croatia has significantly changed. The Republic of Croatia adopted the Decree on establishing a new official geodetic datum and map projection in the Official Gazettes 110/04 and 117/04. The decree defined the horizontal datum of the Republic of Croatia for the European Terrestrial Reference System for the epoch 1989.0 (ETRS89). The materialization of this reference system is represented by 78 geodetic points defined in the ETRS89 system and is named the Croatian Terrestrial Reference System for epoch 1996.55 or abbreviated HTRS96. The vertical datum is determined by the geoid surface being mean sea level for epoch 1971.5 at five tide gauges along the Adriatic coast at Dubrovnik, Split, Bakar, Rovinj, and Kopar. This system is known as HVRS71. The Croatian gravimetric system is defined at six absolute gravimetric points and 36 points of a 1st order relative gravity network and is known as HGRS03. The map projections used in Croatia include the Gauss-Krüger Transverse Mercator projection with a central meridian at $\lambda_o = 16° 30'$ E, and a scale factor at origin of $m_o = 0.9999$ for cadastral and detailed topographic applications. For general state cartographic purposes, the Lambert Conformal Conic projection is defined with standard parallels of 43° 05' N and 45° 55' N. Since Croatia will be joining NATO in 2013, for military applications the UTM grid has been adopted. All projections are referenced to the HTRS96, and by definition of the ETRS89 System, the ellipsoid of reference is the GRS80 where: a = 6,378,137 m and $^1/_f$ = 298.257223563 (*M. Bosiljevac and Ž. Bačič, The Implementation of New Official Geodetic Datum and Map Projections in the Republic of Croatia, FIG Congress 2010, Sydney, Australia 11-16 April 2010*).

A unique transformation model has been established by the University of Zagreb based on more than 1800 points between Hermannskogel 1871 and HTRS96. While I used 22 points in and around Croatia to achieve a fit of slightly over ±1 meter, their 7-parameter transformation achieved a fit of ±76.5 cm and their (complex) HTRS96/HDKS transformation achieved a fit of ±8.5 cm! This sort of phenomenal transformation accuracy will likely dispel any doubt in recovering cadastral property boundaries from long ago. The software appears available for public use within the Republic.

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