NAD83(CSRS) in Ontario and the Provincial GPS Network

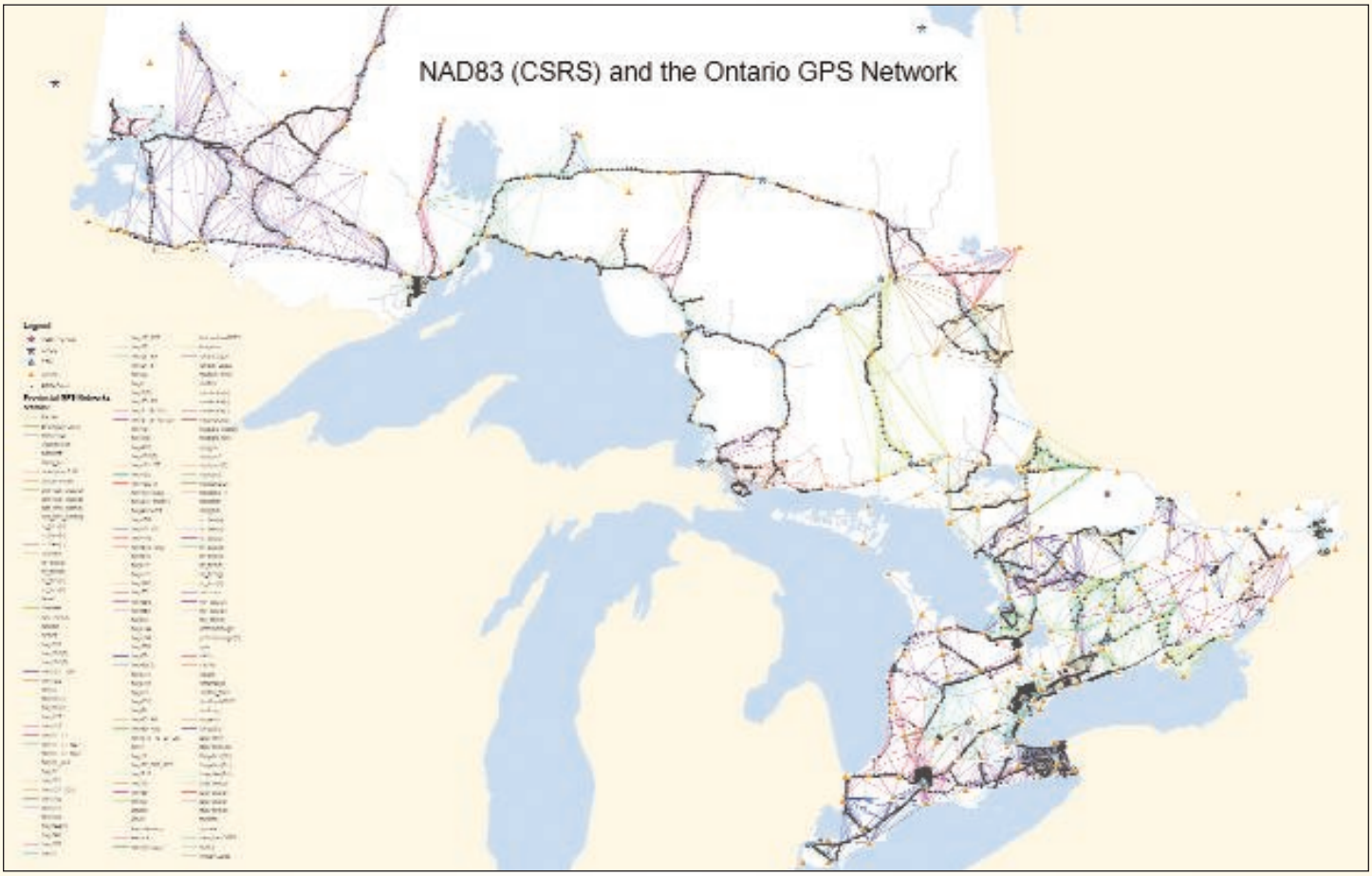
By Robin Poot, O.L.S., O.L.I.P.

I once heard a member from the original NAD83 adjustment team in the US speaking of her experiences of that project. She told the story of spending weeks and years assembling and cleaning survey observations: fastidiously conditioning, adjusting, testing, and readjusting data. With preparations complete, they ran the final adjustment of NAD83 to fanfare and believed they had the "coordinates to end all coordinates." With this they took much deserved leave.

Upon returning, they found disturbing notes to the effect that their coordinates "did not work so well with this new survey technology," i.e. GPS. Coordinate comparisons quickly indicated that GPS was much better than the existing classical network and they proceeded with years of augmenting the classical observation set with GPS. There have been several modifications over the years resulting in many state-level High Accuracy Reference Networks (HARN) and a recent complete readjustment of the national network of GPS data.

Canada took a different approach. Preparations began for a high quality nationwide GPS network of monuments that can be occupied by the public — the Canadian Base Network (CBN). The CBN forms the primary densification of the Canadian Spatial Reference System (CSRS) and consists of about 160 concrete pillars (36 in Ontario) with forced-centering plates. There have been three major occupations of the network over 15 years. The result is a mm-level nationwide network which has, amongst other things, revealed post glacial rebound of up to 1.5 cm/year around Hudson Bay.

The CBN is low density by survey standards with a monument spacing of 100 to 200 kilometres. To densify the network in Ontario for more practical use, the MTO and MNR co-observed about 174 additional stations during the 1997 CBN survey campaign, resulting in 210 stations in Ontario with 50 to 100 kilometre spacing. This level in the hierarchy of the CSRS is known as the Ontario High Precision Network (OHPN) and has an accuracy of about 2 cm.



This figure depicts the configuration of OHPN and higher stations as of CBN 3. The connections between the OHPN and higher stations are not shown to avoid clutter.

From 1989 leading up to this period, the MTO and MNR had been conducting second and third order control surveys with GPS. These surveys have good relative accuracy in the traditional sense, but are compromised by the distortions in the original NAD83 control network. This practice continues to today.

Some of the networks established prior to 1997 may have been connected to the CSRS, but only by coincidence, during the OHPN campaign. Many of the primary GPS control surveys since 1997 have been properly connected to the CSRS; however, some were not. Furthermore, some of the original networks, when combined in a single adjustment, were shown to have deficiencies.

It was obvious that additional observations were required to complete and improve the set of provincial GPS observations before a final adjustment was made.

In 2006 the MTO made preparations to complete the existing GPS networks and make an adjustment of all provincial GPS control survey data collected since 1990. Problematic existing networks and networks lacking proper integration were identified. Reconnaissance was performed and GPS observations were conducted by consultant assignment.

All observations were complete and integrated into the GPS database by the end of 2006; final preparations were made for the provincial adjustment. Networks were re-analyzed for internal and external consistency by readjusting individual networks and then grouping those networks into larger blocks (each consisting of about 10% of the provincial network) for adjustment and analysis. Final analysis, cleaning, error estimate scaling, and quality checks were completed and the observations were ready.

The constraints for the provincial adjustment were extracted as 3D coordinate observations with variance-covariance information from the federal CBN adjustment version 3, whose nominal coordinate epoch is the epoch of co-observation of the OHPN.

Constraints and observations were adjusted in GeoLab. Here are some statistics for the full provincial network adjustment:

- 40 hours of computer time,
- 31,000 GPS baselines: about 20,000 occupations or 5000 sessions,
- 6450 stations,
- 164 individual networks comprising about 125 GPS control survey projects.

Estimated variance factors, residuals, and standard and relative error ellipses indicated a successful adjustment with a significant portion of the network falling in the 2-5 cm absolute accuracy range with most of the network having a relative accuracy of 2 cm (between connected stations). Minimally constrained and weighted constraint adjustments were compared for large-scale adjustment biases.

What does this mean to the user? If you were to make a well-determined GPS observation between any two points in the GPS network, even points on opposite sides of the province that were never connected, the observation should agree with the coordinates by about 5 cm. Comparison of CSRS coordinates to an autonomous solution such as Precise Point Positioning (CSRS-PPP) will yield similar results. Any two near points will agree with a GPS observation by about 2 cm.

When we compare the resulting NAD83(CSRS) values to NAD83 (Original) values we see coordinate differences up to a metre and more for the province of Ontario. Relative coordinate differences within the operational range of kinematic GPS, say within a 15 km radius from a base station, can exceed 30 cm! Relative coordinate differences within a modest area of 10 km can reach or exceed 10 cm. Based on these coordinate differences we see that NAD83(CSRS) is 1 to 2 orders of magnitude more accurate than NAD83(Original) in the context of modern positioning systems.

With the adjustment complete, the geodetic observations and adjustment results were loaded into the MNR provincial control survey database – COSINE.

The MNR has also developed, in conjunction with the Geodetic Survey Division of Natural Resources Canada, a centimetre to decimetre level grid shift transformation between NAD83(Original) and NAD83(CSRS). The transformation was based on a preliminary NAD83(CSRS) adjustment of the Ontario network supplied by the MTO and is available through COSINE.

It is important to note that the GPS network station density is less than the original classical network, with station spacing between 1 and 15 km where GPS projects were conducted. The accuracy of the transformation depends on how close you are to one of the GPS network stations, all of which were adjusted in both NAD83(Original) and NAD83(CSRS).

The completion of these tools and coordinates comes at a good time. With services like CSRS-PPP, OPUS and regional RTK networks providing wide area or autonomous positioning with high accuracy, the adjustment of Ontario's GPS network serves as a basis for high-quality georeferencing, technique verification, and technique interoperability.

After 15 years of integrating classical and space-based techniques within an incompatible datum realization, we now have a publicly available datum realization, NAD83(CSRS), that can support modern georeferencing requirements.

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