# The evolution of Nova Scotia's coordinate referencing systems

Jason Bond, Coordinate Control Officer, Department of Internal Services, Province of Nova Scotia
William Robertson, Manager of the Control Surveys Division (Retired), Land Registration and Information Service, Council of Maritime Premiers

*Despite its rich history, the evolution of the coordinate referencing system in Nova Scotia has not been well documented. As the foundation for the property boundary fabric and land registration system for the province, it is critical that this knowledge is maintained. It is the key to being able to link surveys of the past with the present. This research strives to capture important coordinate referencing knowledge from those that have worked with the system and have since retired from the Nova Scotia provincial government or former Land Registration and Information Service.*

*A detailed review of documentation discussing various historical aspects of coordinate referencing in Nova Scotia was conducted. Personnel involved with the implementation of the systems were interviewed to provide first-hand accounts of operational details. This information is captured and is presented chronologically. An outlook on the future of the coordinate referencing program is also discussed.*

*Malgré sa riche histoire, l'évolution du système de référencement de coordonnées en Nouvelle-Écosse n'a pas été bien documentée. À titre de fondement du système d'enregistrement foncier et du canevas cadastral de la province, il est essentiel que ces connaissances soient conservées. C'est l'élément clé qui permet de relier les levés du passé à aujourd'hui. La présente recherche vise à saisir des connaissances importantes sur le référencement des coordonnées auprès des personnes qui ont travaillé avec le système et qui ont pris leur retraite du gouvernement provincial de la Nouvelle-Écosse ou de l'ancien Service du cadastre et de l'information foncière.*

*Un examen détaillé de la documentation traitant des divers aspects historiques du référencement des coordonnées en Nouvelle-Écosse a été effectué. Les employés impliqués dans la mise en œuvre des systèmes ont été interrogés pour obtenir des témoignages de première main au sujet des détails opérationnels. Cette information est saisie et présentée de manière chronologique. Un aperçu de l'avenir du programme de référencement des coordonnées fait également l'objet d'une discussion.*

## Introduction

Coordinate referencing systems help to address fundamental societal needs by providing infrastructure to answer the questions "Where am I?" and "Where should I be?" Land administration, property management, engineering, construction and mapping are examples of activities that depend on an underlying coordinate referencing system that is reliable and accurate. Well-established coordinate referencing systems enable asset management and development, which are critical components for sound governance.

Nova Scotia has a rich history in its coordinate referencing program that it has implemented and maintained since the late 1960s. There are at least three distinct coordinate referencing systems that have been implemented in the province. For over three decades, Nova Scotia Land Surveyors (NSLSs) have been regulated to connect their surveys to one of the province's coordinate referencing systems. The practice of relating surveys to a coordinate referencing system allows for meaningful spatial relationships to be defined between parcels of property.

New coordinate referencing systems are developed as technology and knowledge advances and the needs of users become more demanding. As thousands of survey plans are created over time in a particular coordinate referencing system, it is critical that knowledge about each system be well documented and understood. Presently, several provinces in Canada have a single person managing the operations of their respective coordinate referencing system. Many of these people have accumulated decades of knowledge about the inner workings of their respective systems. This knowledge base is typically not found outside the organization. As generations

dx.doi.org/10.5623/cig2015-403 

change, the threat of losing a critical knowledge base that serves as the foundation for geographic information is very real. Some provinces have lost their geodetic capacity altogether.

This paper strives to document information about the historic and current coordinate referencing systems in Nova Scotia. A summary of key terminology is presented, followed by a chronological review of the coordinate referencing systems that have been implemented. An outlook on the future of the coordinate referencing program is also discussed.

## *Coordinate Referencing Concepts and Terminology*

A review of common coordinate referencing concepts and technology is presented before reviewing the evolution of the province's coordinate referencing systems. For a more detailed discussion on these topics, see *Junkins and Garrard* [1998].

Coordinate systems provide a framework to spatially relate features and objects. In their simplest form, one can relate to a two-dimensional planar coordinate system with $X$ and $Y$ axis. Mathematical models are used to project the spherical earth onto a sheet of paper to allow a planar coordinate system to be used. Various projection methodologies exist, each having different distortion characteristics. The Universal Transverse Mercator (UTM) projection is an example of a projection commonly used.

Coordinate systems need to be positioned and oriented to serve as a coordinate referencing system. This is achieved by defining the location of the origin of the coordinate system and by defining the orientation of its axis. Since the earth is three-dimensional, a three-dimensional coordinate system is used for geodetic referencing, with the following typical parameters:

- The origin is defined as the best approximation of the earth's centre of mass (i.e., geocentric).
- The $Z$-axis is parallel to the earth's axis of rotation.
- The positive $X$-axis intersects the Greenwich meridian.

This type of three-dimensional coordinate systems is known as a Conventional Terrestrial Reference System (CTRS). For completeness, a coordinate referencing system must also include any physical constants, parameters and specifications that are required to calculate position using that system.

By adding a reference shape to the coordinate referencing system to represent the earth (generally an ellipsoid), a geodetic datum is defined. Examples of reference shapes include Clarke's Ellipsoid of 1866 (used for the North American Datum of 1927) and the GRS 80 Ellipsoid (used for the North American Datum of 1983).

A coordinate referencing system may allow for various coordinate types to be computed. Examples of different types include:

- Spherical coordinates (geographic latitude and longitude)
- Cartesian coordinates (XYZ)
- Planar coordinates (based on a mapping projection such at 6 degree Universal Transverse Mercator or 3 degree Modified Transverse Mercator)

A physical representation of a coordinate system through a series of survey or control monuments with assigned coordinate values, known as a reference frame, allows users to spatially relate natural features and structures to the coordinate referencing system. Global Navigation Satellite Systems (GNSS) have extended this traditional concept. Conceptually, the satellites from GNSS serve as monuments with assigned coordinates and can serve as a gateway to a specific coordinate referencing system. The reference frame makes the coordinate referencing system tangible and accessible.

Over time, new observation data may be acquired for the reference frame. The new data allows for the mitigation of existing errors and distortions and improvements in accuracies. The updated coordinates represent new realizations of the coordinate referencing system [*Craymer* 2006]. There are various ways in which a coordinate referencing system may be improved, including: 1) better estimation of the earth's centre of mass; 2) better representation of the shape of the earth; 3) better technology to make reference frame observations; and 4) higher density of reference frame monuments.

As technology has evolved, the accuracy of coordinate referencing systems has also generally improved. The adoption of a new coordinate referencing system poses numerous challenges for a jurisdiction in terms of the education of users, updating coordinate values for the reference frame and creating tools to facilitate the transformation of existing data sets to the new system. Because of the costs associated with addressing these challenges, there must typically be significant benefit to moving forward before a jurisdiction would consider adopting a new system.

The term "spatial referencing system" is used both by the Canadian Geodetic Survey (CGS) and the United States' National Geodetic Survey (NGS) to describe federal reference systems. They are referred to as the Canadian Spatial Referencing System (CSRS) and National Spatial Reference System (NSRS), respectively. The scope of their work is generally broader than that of the provinces' efforts since it includes such activities as measuring geopotential, acceleration of gravity, deflections of the vertical, GNSS orbits, tectonic velocity models and orientation, scale and offset information relating federal reference systems to international reference systems. In this paper, the term "spatial referencing system" is reserved for these types of programs that are generally federal in nature. In Nova Scotia, the focus is on the geometric, coordinate relationships and, accordingly, the program is termed the Nova Scotia Coordinate Referencing System (NSCRS). The NSCRS utilizes the provincetools, models and applications to calculate and maintain high accuracy coordinates.

## *The Federal Foundation*

As in most provinces in Canada, the foundation for Nova Scotia's coordinate systems referencing originates with initiatives led by the federal government. For a comprehensive review of these initiatives, see *McGrath and Sebert* [1999]. Being a coastal province with strategic location, Nova Scotia benefitted from the charting work of the Hydrographic Service of the Royal Navy conducted during the latter half of the nineteenth century. The navy's work served as control for the early medium-scale mapping for the province [*Sebert* 1999].

The Geological Survey of Canada was also involved in surveying and mapping activities in Nova Scotia from 1880 onward. By 1910, it had completed a 91-sheet series of 1-inch maps (1 inch to 1 mile scale) covering all of the province except the southwest tip. These maps served as a base for the 20-chain and 40-chain (1:15 480 and 1:31 680) provincial resource development maps. In 1922, the British Geographic Section of the General Staff (GSGS) and the Topographical Survey, Department of the Interior, began topographic mapping at the 1-inch to 1-mile scale. This work was completed in 1956 and eliminated the need for provincial topographic work until the demand for larger scale resource mapping arose in the 1960s [*Sebert* 1999].

In 1913, the North American Datum (NAD) was defined and officially adopted for use by Canada, the United States and Mexico. It was renamed NAD27 following a major readjustment of much of the North American Network. NAD27 was a non-geocentric reference system which used the Clarke Ellipsoid of 1866. The primary reference point of the coordinate system was defined as Meade's Ranch in the state of Kansas. The coordinates of this site were used in the calculation of triangulation networks throughout North America [*Gillis et al.* 2000].

In 1935, the Canadian Geodetic Vertical Datum of 1928 (CGVD28) was officially adopted by an Order in Council. CGVD28 is a tidal datum based on the mean water level at five tide gauges: Yarmouth and Halifax on the Atlantic Ocean; Pointe-au-Père on the St. Lawrence River; and Vancouver and Prince Rupert on the Pacific Ocean. Additionally, a benchmark in Rouses Point, New York, is used as a fixed vertical constraint. The CGVD28 framework currently consists of 94 000 benchmarks across the country that have been measured using precise levelling measurements [*NRCan* 2015A].

Most geodetic work performed prior to the Second World War was done by two federal organizations [*Sebert* 1999]: the Geodetic Survey of Canada (now referred to as Canadian Geodetic Survey), which was formed in 1908 and is responsible for maintaining the CSRS; and the Gravity Section of the Geological Survey of Canada, which is responsible for gravity data. It was founded in 1842 and is Canada's oldest scientific agency [*NRCan* 2015B].

In 1946, the Canadian spatial referencing system was based upon a horizontal triangulation network of about 19 400 km and a vertical control network of approximately 63 000 km of precise levelling. Over the next decade, about 7300 km was added to the conventional triangulation network and 13 000 km was added to the precise levelling network. The introduction of precise Electromagnetic Distance Measurement (EDM) technology in the mid-1950s greatly accelerated Geodetic Survey's work and, by 1959, Canada had a continuous coast-to-coast triangulation network [*Babbage and Roberts* 1999]. The use of EDM technology also had another significant impact—it began to reveal distortions in NAD27. The distortions were caused by non-rigorous adjustment procedures, poor network geometry and the lack of an accurate geoid model to make geodetic corrections to the observations [*Gillis et al.* 2000].

## *Technical Impact of Early Federal Geodetic Work*

The federal adjustment of its triangulation networks brought NAD27 to the Maritimes. The initial NAD27 adjustments used United States Coast and Geodetic Surveys stations at Chamcook and Trescott Rock at the western end of the Bay of Fundy as constraints [*Gillis et al.* 2000]. Despite the aforementioned weaknesses in NAD27, it served as the primary coordinate referencing system for Nova Scotia for several decades.

The federal adjustment of its precise levelling networks brought CGVD28 to the Maritimes. CGVD28 has been the primary source of orthometric heights in Nova Scotia for almost 100 years. It was not until 2015 that CGVD28 heights on some Nova Scotia Control Monuments (NSCMs) were updated with new Canadian Vertical Datum of 2013 (CGVD2013) geoid-based, heights.

## Atlantic Provinces Surveying and Mapping Program

In the 1960s, it had become apparent that economic development in the Atlantic provinces was being hindered by an outdated land registration system and by a poor mapping compilation from which to plan resource development. The funding required to update provincial mapping resources greatly exceeded the capacity of the Atlantic provinces. In 1966, a proposal was submitted to the Atlantic Development Board by Willis Roberts, Director of Surveys of New Brunswick at that time. The visionary proposed the four-phase plan summarized in Table 1 that would modernize surveying and mapping in the Atlantic region. It was estimated that it would take 35 years to complete the plan with federal assistance, or twice as long without support [*Sebert* 1999].

As a result of Robert's proposal, Nova Scotia's first coordinate referencing initiative was born on March 22, 1968, when the Atlantic Development Board approved the concept of establishing the Atlantic Provinces Surveying and Mapping Program (APSAMP). Funding of the program was stalled by the formation of the newly-created federal Department of Regional Economic Expansion (DREE). DREE supported 90% of the cost of the program ($12 million) from 1969 to 1972 [*Sebert* 1999].

## Technical Impact of the APSAMP Effort

In 1968, coordinates for the first-order network monuments in the province were calculated by Geodetic Survey Division (GSD) using the NAD27 datum. These values were distributed in imperial units. Rigorous geodetic techniques were not utilized for this adjustment (observations were not fully reduced), which resulted in network distortions.

In order to support the development of the second-order survey network as set out in Phase 1 of the APSAMP, the first-order federal network required significant expansion in Nova Scotia. GSD established first-order survey monuments in the Annapolis Valley region in 1969. A military survey crew also established first-order survey monuments in Hants, Kings, Halifax and Lunenburg counties that year. In 1970, further expansion occurred in Halifax and Guysborough counties. Network expansion would continue throughout Nova Scotia over the next two years until a satisfactory density was achieved. In 1972, another federal adjustment was performed using more rigorous geodetic data-handling techniques and a network of approximately 100 first-order federal survey monuments. A stronger geometric network resulted in a more consistent network adjustment across the province [*Flemming* 2014].

Although the APSAMP led to common strategies for managing and funding surveying and mapping initiatives in the Atlantic provinces, each province still set its own operational standards [*LRIS* 1977]. In Nova Scotia, APSAMP was implemented through the Control Surveys, Surveys and Mapping Division of the Department of Lands and Forests.

**Table 1: Four-phase plan for modernizing surveying and mapping in the Atlantic region [*Sebert* 1999; *LRIS* 1977].**

| Phase | Description |
|---|---|
| 1. Surveying | Placing of survey monuments throughout the Atlantic Provinces at a density consistent with the population |
| 2. Mapping | Provincial 1:5000, 1:10 000<br>Municipal mapping at 1:1200, 1:2400, 1:4800 (imperial) and 1:1000, 1:2000, 1:2500 and 1:5000 (metric) |
| 3. Land Titles | Design and implementation of an improved land titles registration system |
| 4. Land Data Bank | Compilation of all land information into a database including the ownership, market value and geographical characteristics of all registered land parcels and Crown lands |

The Division placed a total of 8000 second-order NSCMs during the first five years of operation. Most of these monuments were located throughout the developed areas of the province [*NSLUC* 1995].

## Land Registration and Information Service

During the mid-1960s, New Brunswick, Nova Scotia and Prince Edward Island were investigating ways of conducting interprovincial cooperation. In 1965, the Maritime governments proposed the Maritime Union Study to formally explore opportunities for integrating government services and to address the question of whether or not the Maritime provinces should unite into a single province. Although a plan for political union was rejected, the three provincial governments agreed to establish the Council of Maritime Premiers (CMP) to provide a framework for implementing joint initiatives. One key interest for such initiatives were opportunities for collaboration in delivering land use and tenure programs [*LRIS* 1977].

In April of 1972, APSAMP was extended for an additional year with each province managing its affairs independently. At this time, Newfoundland decided to withdraw from the arrangement and negotiated a separate agreement with DREE. Roberts proposed that the CMP assume the administration of a new program called the Land Registration and Information Service (LRIS) [*Sebert* 1999]. The proposal was approved and in April of 1973, the staff previously employed on APSAMP work by the provinces formed the core of the new organization [*LRIS* 1977].

LRIS was designed to have the same four phases as APSAMP and was also funded through DREE. Experience had shown that the two-year funding periods applied for APSAMP were too short for the magnitude of the project. Roberts was able to negotiate a five-year plan for LRIS, which was the limit for the program at that time. It was assumed that additional five-year plans would follow until the program was fully executed in 30 years. At the end of the first five-year period in 1977, DREE informed the CMP that only one additional year's funding would be provided, and funding would not be available for another five years. From 1968 until 1978, DREE had contributed approximately $34 million to the APSAMP and LRIS programs [*Sebert* 1999].

The coordinate referencing system put in place through Phase 1 of LRIS was state-of-the-art. The system was commonly referred to as the Nova Scotia Coordinate Control System (NSCCS) and its reference frame is illustrated in Figure 1.

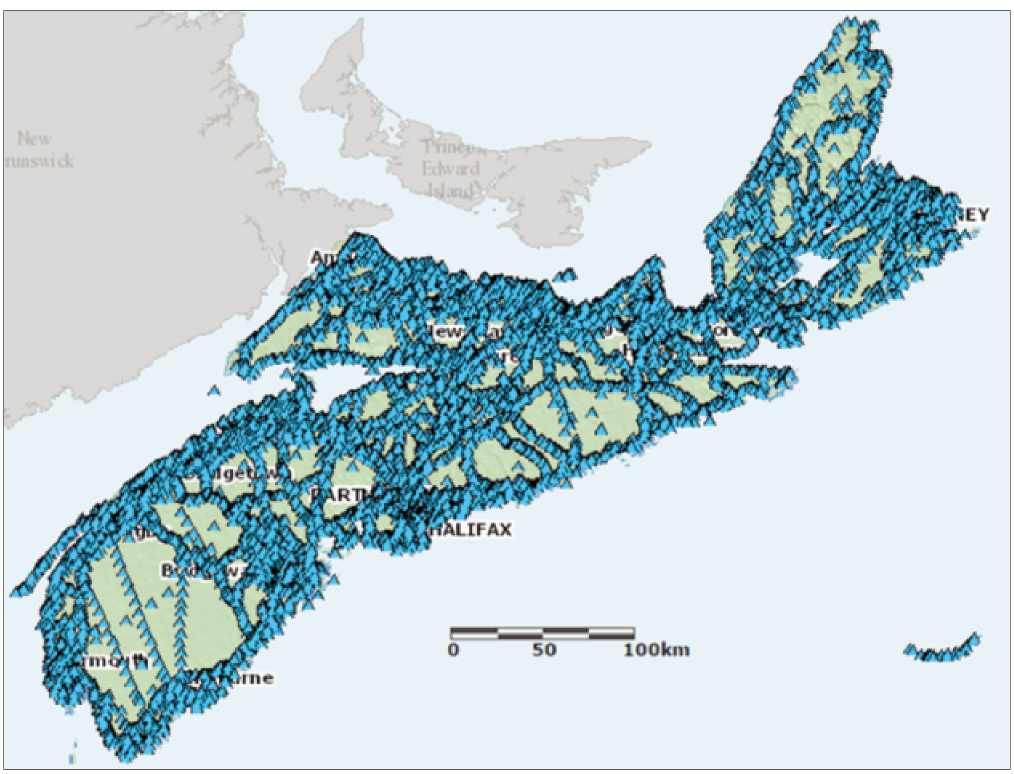


**Figure 1: NSCCS reference frame.**

Practically every inhabited road in Nova Scotia had survey monuments with 1-km spacing or less. The infrastructure was also extended to Sable Island in the early 1980s. For a more detailed discussion on coordinate referencing on Sable Island, see *Bond* [2015].

EDM technologies were becoming more commonplace during the 1970s and were being used on many surveying projects, including the establishment of the NSCCS reference frame. For optimal performance, a calibration procedure was used to account for the non-coincidence of the electrical centre of the EDM with its centring mark. For that purpose, GSD and LRIS cooperated to establish three calibration baselines in Nova Scotia near Lawrencetown, Halifax and Port Hawkesbury.

In southwest Nova Scotia, inertial survey systems were used to densify the survey monument infrastructure. This was a collaborative effort between LRIS, the Nova Scotia Department of Lands and Forests and the federal Department of Energy Mines and Resources. These monuments appear as distinct lines across southwest Nova Scotia and were referred to as ISS points.

Elevations for the second-order survey network were derived from first-order federal benchmarks. Levelling was typically only performed between first-order benchmarks and the nearest second-order survey monument. Elevations were determined for the rest of the network by measuring the slope distance and near simultaneous zenith distances between monuments.

With over 20 000 NSCMs put in place to realize the NSCCS reference frame, it was not long before challenges associated with maintaining and managing this infrastructure became apparent. As new developments took place, it became necessary to densify and measure to new NSCMs to expand the network. It was estimated in the early 1980s that 2% of NSCMs were being destroyed each year and that an additional 1% were required for densification. Consequently, a five-year work program was implemented in 1981 to address these needs [*Dept. of Lands and Forests* 1983].

It was recognized early on that road construction was one of the largest offenders for destroying survey monument infrastructure. To help address the cost of replacing destroyed monuments, a Monument Trust Fund was established in 1982 to allow the Department of Transportation and Communications to transfer funds to cover the cost of replacing monuments. More than 425 monuments were replaced using this fund [*NSLUC* 1995].

By 1983, 23 000 NSCMs had been installed in Nova Scotia. Unfortunately, the 1983–1984 budget cut maintenance of the NSCCS network. Despite cutbacks, the overall quality of the coordinate referencing system remained high for several years, largely because of the abundance of NSCMs. By the end of the 1980s, however, it was apparent that the lack of funding to maintain the infrastructure was taking its toll. In 1989, a proposal was put forward to do a single cycle of maintenance on the reference frame. This involved inspecting and densifying the existing network over a five-year period, at a total cost of $2.25 million. The proposal was rejected due to the high cost [*NSLUC* 1995].

As LRIS was struggling to maintain the NSCCS, the Global Positioning System (GPS) was emerging as a new technology to perform geodetic surveys. GPS offered higher accuracy measurements over longer distances than conventional theodolite and EDM technologies. Additionally, GPS did not require line-of-sight between adjoining monuments. In 1986, LRIS commissioned a study for control surveys for LRIS. The main recommendation of that study was that the LRIS should develop expertise in GPS so that it would be immediately able to take advantage of the technology [*Hamilton and Doig* 1993]. As GPS became more commonplace through the 1990s, it began to reveal distortions in the NSCCS, which was observed using conventional survey instrumentation. As was the case 20 years prior, technology dictated that a higher accuracy coordinate referencing system would be required to support it.

Perhaps the biggest challenge with the LRIS Surveys and Mapping program was that it lacked a sustainable model to maintain the infrastructure. In 1992, a contract was awarded to Angus Hamilton and James Doig to make recommendations regarding the coordinate referencing program for each Maritime province [*NSLUC* 1995]. In March of 1993 they delivered the *Report of the Task Force on Control Surveys in the Maritime Provinces* (see *Hamilton and Doig* [1999]).

LRIS continued to operate using provincial funding until it was closed on March 31, 1994 [*Sebert* 1999]. LRIS left a legacy in terms of the coordinate referencing system it produced. In the most remote regions of the province, one can still locate NSCMs which have existed for over 40 years. The NSCCS effort was so well executed that it would delay the province's effort to migrate to NAD83 for over a decade.

The original LRIS vision was to migrate to a land titles system through Phase 3 of the program and to move towards a system with guaranteed boundaries [*LRIS* 1977]. The Land Registration Act was passed by the Nova Scotia legislature in 2001 and came into effect in various counties between March 2003 and March 2005. The Act created a new land titles system with the intent of eventually replacing the existing traditional Registry of Deeds, which has been in existence for over 250 years. Colchester County was the first to implement the system in Nova Scotia, followed by Antigonish, Cumberland and Pictou in December of 2003 [*Hill* 2015].

A property can be registered in the new land titles system on a voluntary basis and must be registered if it is sold or mortgaged. In partnership with the Nova Scotia Barristers' Society, the province provides a limited guarantee of ownership of registered properties. The province guarantees title (ownership) but not boundaries or extent (size). Equivalently, the province affirms that one owns the property rights to a certain parcel of land, but cannot authorize the location, size or location of boundaries. This role is left to a surveyor who can give a professional opinion on these aspects [*Hill* 2015].

## *Technical Impact of the LRIS Effort*

The LRIS changed the way that surveys were conducted in Nova Scotia. LRIS greatly benefitted from being able to draw upon the Department of Surveying Engineering that was formed at the University of New Brunswick (UNB) in 1960. The world-class experts that the department recruited provided the expertise and knowledge necessary to support the creation of a coordinate referencing system for each Maritime province. Custom survey network adjustment software (e.g., LEAP), as well as specialized subroutines for reducing and processing survey observations, were developed either at UNB or internally.

Deficiencies in NAD27 would continue to be exposed with the development of new survey instruments and this resulted in an initiative to define a new datum known as the North American Datum of 1983 (NAD83). The expected unveiling of NAD83 did not coincide with LRIS timelines for producing coordinates for the referencing system for each Maritime province. It was desired to move to a geocentric datum and to migrate to the metric system.

Reluctant to wait for the release of NAD83, the Maritimes leveraged the expertise of the Surveying Engineering Department at UNB, GSD and LRIS to develop a coordinate referencing system based upon the Average Terrestrial System of 1977 (ATS77) datum. This effort led to the publication of coordinates for 40 887 survey monuments in the Maritimes in 1979. The coordinates were calculated in an adjustment that used positions and variance-covariance values from an October 1977 first-order federal network adjustment as constraints [*Gillis et al.* 2000]. Issues with this adjustment would surface over the upcoming years. The problems were later attributed to distance observations not being properly modelled. Maintenance adjustments for localized sections of the network would gradually remove some of these errors [*Flemming* 2014].

In Nova Scotia, two 3°-wide zones were defined to project coordinates using the Modified Transverse Mercator (MTM) Projection. Zone 4 is centred on 61°30' W and uses a false easting of 4 500 000.000 m. Zone 5 is centred on 64°30' W and uses a false easting of 5 500 000.000 m. When developed, it was expected that the parameters used to define the location of the ATS77 ellipsoid relative to the centre of mass of the earth would be close to those defined for NAD83. When NAD83 was finalized, modifications to its reference frame and ellipsoid were introduced, causing a horizontal shift of approximately 4.5 m between ATS77 and NAD83 coordinates [*Gillis et al.* 2000].

The first realization of NAD was performed in 1986 as part of the NAD83 redefinition and adjustment project. This became known as NAD83(1986) or NAD83(Original). In May of 1989, a secondary regional network adjustment for eastern Canada was performed by the federal government. The adjustment used approximately 62 000 stations using the NAD83 datum and conventional observations. The computed coordinates removed most of the distortion in ATS77 but the achievable accuracies were still limited by the accuracies of the original observations [*Gillis et al.* 2000]. The set of coordinates generated, referred to as NAD83(1989), was the first major realization of NAD83 in the Maritimes. A grid shift file named GS7783.gsb was generated to transform between ATS77 and NAD83(1989).

## *Emergence of the Nova Scotia Coordinate Referencing System*

Upon closure of the LRIS, the Nova Scotia Geomatics Centre (NSGC) assumed responsibility of the province's coordinate referencing program under the Land Information Management Services Division of the Department of Municipal Affairs. The program would later move to the Department of Service Nova Scotia and Municipal Relations in 2000. The role of Coordinate Control Officer was established to provide technical expertise for maintaining the

NSCCS. A survey technologist role was also established to support the Coordinate Control Officer. At its peak, the Surveys and Mapping Section of LRIS had over 20 full-time human resources to support it. It was not uncommon to have an additional 20 students employed for summer programs. Maintenance of the NSCCS now resided with two people, while demand for maintaining the system would only continue to rise.

Prior to the LRIS being disbanded, *Hamilton and Doig* [1993] made a number of recommendations for the Maritime provinces to deliver upon their coordinate referencing mandates, including:

1. Adopting a new GPS-based coordinate network, referred to as the Nova Scotia High Precision Network, which would be based upon the Canadian Spatial Referencing System (CSRS)—this realization of NAD83 would be referred to as NAD83(CSRS);
2. Operating the NSCCS and NSHPN in parallel until a formal transition to NAD83(CSRS) was made;
3. Creating cooperation amongst all users of the infrastructure to maintain it;
4. Liaising with the user community on an ongoing basis;
5. Establishing, documenting and maintaining standards and specifications for the NSCRS in conjunction with N.B. and P.E.I.;
6. Developing and maintaining the NSCRS with GPS;
7. Adopting the NSCRS through legislation;
8. Training or recruiting a GPS specialist for the long term;
9. Compiling maps at a scale of 1:10 000 and smaller using the UTM projection; and
10. Compiling maps at a scale of 1:10 000 and larger using the MTM projection.

To act upon the first recommendation, the Maritime provinces began discussions with GSD. They agreed to cooperatively establish 12 Canadian Base Network (CBN) reference frame points in the Maritimes. Additionally, the provinces decided to integrate an additional 32 points throughout the Maritimes, forming the Maritime High Precision Network. Observations on this network took place in October 1994, with observation schedules carefully planned. CBN points were observed for a minimum of three 24-hour sessions. Provincial stations were observed for a minimum of three eight-hour sessions. Consequently, the additional Maritime High Precision Network Points became tightly integrated with the CSRS. This first realization of the NAD83(CSRS) framework had an average monument spacing of 60 to 70 km [*Gillis et al.* 2000].

Between 1995 and 1999, each of the Maritime provinces densified the Maritime High Precision Network within their own jurisdictions. In Nova Scotia, a collaborative effort amongst survey resources in the departments of Service Nova Scotia and Municipal Relations, Transportation and Natural Resources would help execute the densification effort. By 2000, 153 Nova Scotia High Precision Network (NSHPN) points were established, with an average spacing of about 20 km (see Figure 2). This system became known as the Nova Scotia Coordinate Referencing System (NSCRS). The cost of this effort was approximately $750,000 [*NSLUC* 1995]. In 2001, an active GPS station (HLFX) was installed at the Bedford Institute of Oceanography to assist in realizing more accurate versions of NAD83(CSRS) through the Canadian Active Control System (CACS).

Similar to the EDM Calibration Baseline initiative, a cooperative program between GSD and the province established a GPS Validation Network for testing the reliability and accuracy of GPS equipment and software. The GPS Validation Network consists of seven NSCMs located in Folly Mountain, Enfield, Musquodoboit Harbour, Montague Road, Mount Uniacke, McGrath and Halifax (on the EDM Calibration Baseline).

Almost all of the NSHPN points were also points in the NSCCS reference frame. This would allow for the generation of a set of transformation parameters to be defined in a grid shift file between ATS77 and NAD83(CSRS) that was named NS778301.gsb. It also reduced costs by recycling existing NSCMs into the new reference frame. The accuracy of this transformation is as good as a few centimetres, but discrepancies as high as 1 to 2 m exist for portions of the network with remaining blunders and/or distortions.

The adoption and migration to NAD83(CSRS) would prove to be a major challenge for the next 15 years in Nova Scotia. This was partially attributed to the NSCCS reference frame creating an unrealistic expectation that survey monuments could be installed and maintained with 1-km spacing across the province. The 20-km spacing of the NSHPN was not practical for survey purposes. Connecting a survey to the NSCRS often meant long drives to occupy a NSHPN monument. Surveyors were forced to decide between leaving expensive GPS equipment unattended in remote locations while conducting a survey and paying someone to guard it.

Between 1995 and 2012, several reviews of the NSCRS would be conducted in an effort to define a strategy to move forward:

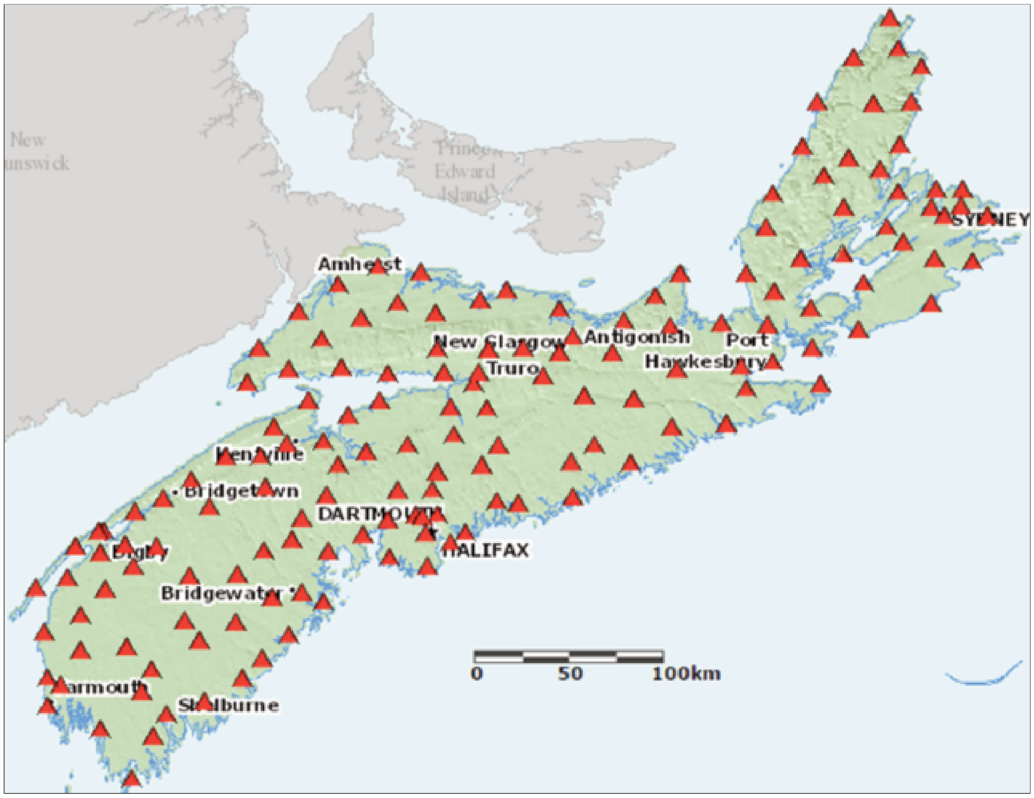


**Figure 2: NSHPN reference framework.**

- A Coordinate Referencing Policy for the Province of Nova Scotia [*NSLUC* 1995]
- Final Report for the Study of the Official Adoption of the NSCRS [*Jaques Whitford* 2002]
- A Spatial Referencing Policy for the Province of Nova Scotia [*GeoNova* 2006]
- Final Report: Nova Scotia Coordinate Referencing System (NSCRS) Future Policy Strategy [*Seely* 2011]

In each report, many of the key recommendations made by *Hamilton and Doig* [1993] resurface. Because of the complexity of the subject matter, the ability to inspire change, particularly when significant funding is required, would be an ongoing challenge. From 2000 onward, NSLSs would continue to express discontent with their inability to access the new NSHPN and the decaying NSCCS network. It was hoped to have NAD83(CSRS) realized through the NSCCS framework. Such a task would involve re-adjusting over 100 000 conventional observations used to estimate the ATS77 coordinates of the NSCCS framework. It was estimated that this would take years to execute. Just like the NAD83(1986) and NAD(1989) realizations, there was no guarantee that the accuracy of the results would be suitable for GPS.

By 2011, Nova Scotia's first Coordinate Control Officer and NSCRS Geomatics Technologist had retired. These were the only resources in the provincial government with an intimate knowledge of the coordinate referencing observation and coordinate databases. Over 30 years of knowledge pertaining to a critical piece of the province's infrastructure was gone, leaving an irreplaceable void. Similar situations had arisen in New Brunswick, Prince Edward Island and other provinces across Canada.

In 2012, the province filled the Coordinate Control Officer position. Stakeholder engagement sessions and technological reviews were conducted to examine ways to respond to user needs. A major finding from that process was that several technologies could be embraced to modernize the NSCRS and to help address identified needs. Specifically, these technologies included:

a) Active Control Stations (ACSs)—by permanently installing GPS equipment on NSCMs, users could access the data and not have to physically occupy a traditional NSCM to connect to the NSCRS;

b) Network real-time kinematic (NRTK) surveys—by permanently installing a network of ACSs, users could benefit from reduced distance dependent, GNSS, error sources, resulting in higher accuracy over longer distances;

c) Cellular communications networks—by utilizing the extensive cellular networks in the province, users could benefit from accessing real-time, GNSS positioning services;

d) Crowd sourcing applications—by developing an application to accept observation data from NSCM occupations, NSLSs could contribute to the ongoing maintenance of the NSCRS.

At present, NSLSs are still predominantly conducting surveys in ATS77. A modernization effort was started in 2012 to embrace the above technologies with an emphasis on developing a sustainable maintenance program. It is hoped that the modernized system will address accuracy and accessibility needs of the surveying community and that this will facilitate the migration to NAD83(CSRS). The new CGVD2013 will also be embraced as part of this initiative. Many of the recommendations made by *Hamilton and Doig* [1993] 20 years earlier are being acted upon. It is anticipated that by the end of 2015, 40 ACSs will be installed in Nova Scotia. This infrastructure will not only create more efficient survey methods, but will also provide an opportunity to implement a sustainable maintenance model. A detailed discussion of the NSCRS modernization effort is the topic of a subsequent paper.

## Outlook

The core competency for a coordinate referencing advisor is expertise in geodetic engineering. In Canada, this specialization is now acquired at the post-graduate level at only a handful of universities. At the University of New Brunswick, it is estimated that one student graduates with a specialization in Geodetic Engineering (Master's degree) every two years. With a limited resource pool, strategic planning is required to ensure the successful and sustainable delivery of geodetic referencing initiatives not only in Nova Scotia, but across Canada.

Embracing technology and new strategies to more effectively deliver upon coordinate referencing mandates is critical to ensuring program success. Fortunately, the increasing use of ACSs for machine automation in industries outside of surveying has heightened the awareness of spatial referencing technologies and their value to society in general. The growing demand for spatial data also provides some assurance that coordinate referencing programs will be adequately supported in the future. Regardless of how easy GNSS makes positioning in the future, there will always be a need to be able to return to historic data sets that used different coordinate referencing systems and to have a clear understanding of how the past relates to the present.

## Summary

This document attempts to capture the evolution of coordinate referencing in Nova Scotia for knowledge continuity. Like most provinces in Canada, the foundation of Nova Scotia's coordinate referencing system originates with initiatives led by the federal government. The coordinate referencing system of each Maritime province was impacted by the tremendous vision of Willis Roberts, first by the Atlantic Provinces Surveying and Mapping Program and then by the Land Registration and Information Service.

With the dissolution of LRIS in 1994, each Maritime province assumed responsibility for provisioning a coordinate referencing program. Since that time, Nova Scotia has been attempting to fully migrate its survey work to the GPS-compatible NAD83 datum. Despite the NSHPN having higher accuracy coordinates than the NSCCS network, the greater accessibility of the NSCCS has perpetuated its use. In order to facilitate the migration to NAD83(CSRS), improved accessibility to the NSCRS reference frame would need to be addressed.

In 2012 an effort to modernize the NSCRS through ACSs was begun. The ACSs have provided a new gateway to the NSCRS and have helped to address the accessibility challenge that the NSHPN did not address. Over time, it is hoped that the technology will be embraced and the migration to NAD83(CSRS) will occur. Figure 3 summarizes the main coordinate referencing systems that have been implemented in Nova Scotia. Figure 4 symbolizes the changes that have occurred as represented by the change in NSCM signs over the past several decades.

## Acknowledgements

This work could not have been completed without the input and cooperation of: Bert Seely, Manager of Geographic Information Services Operations (Retired), Department of Housing and Municipal Affairs, Province of Nova Scotia; Norman Hill, Registrar General, Service Nova Scotia, Province of Nova Scotia; Allen Flemming, Coordinate Control Officer (Retired), Department of Housing and Municipal Affairs, Province of Nova Scotia; Pierre Heroux, Head, Analysis and Development Section, Canadian Geodetic Survey, Survey General Branch, Natural Resources Canada; Colin MacDonald, Director, Geographic Information Services, Internal Services, Province of Nova Scotia; Pierre Gareau, Manager of GeoNova Program, Geographic Information Services, Internal Services, Province of Nova Scotia.

**Coordinate Referencing Systems in Nova Scotia**

| Horizontal Referencing System: | Unnamed | Nova Scotia Coordinate Control System (NSCCS) | Nova Scotia Coordinate Referencing System (NSCRS) |
|---|---|---|---|
| Datum: | NAD27 | ATS77 | NAD83 |
| Federal Ref. Frame: | 1st Order Network | 1st Order Network | CBN (5), CACS(1) |
| Provincial Ref. Frame: | 8,000 NSCMs | NSCCS - 23,000 NSCMs | NSHPN (153+), NSACS (40) |
| Implemented: | 1968 | 1979 | 2000 NSHPN<br>2015 NSACS |
| Units: | Imperial | Metric | Metric |

| Vertical Referencing System: | Canadian Geodetic Vertical Datum of 1928 | Canadian Geodetic Vertical Datum of 2013 |
|---|---|---|
| Datum: | Mean Sea Level | CGG2013 |
| Ref. Frame: | Almost all NSCMs | CBN, CACS, NSHPN, NSACS |
| Implemented: | 1935 (Federally) | 2013 (Federally) |
| Units: | Imperial / Metric | Metric |

**Figure 3: Main coordinate referencing systems used in Nova Scotia.**

**Figure 4: Evolution of the Nova Scotia Control Monument Sign from 1968 to 2015. Top left—circa 1968; top right—circa 1979; bottom left—circa 1996; bottom right—2015.**

# *References*


Babbage, G., and A.C. Roberts. 1999. Geodesy in Canada, and international and interprovincial boundaries. Chapter Two in *Mapping a Northern Land. The Survey of Canada 1947–1994.* McGill-Queen's University Press, Montreal. 21–75.

Bond, J. 2015. Enabling high precision position monitoring on Sable Island through the Nova Scotia Coordinate Referencing System. Proceedings of the Sable Island Conference 2015, May 2, 2015, Halifax, Nova Scotia.

Craymer, M. 2006. The evolution of NAD83 in Canada. *Geomatica.* 60(2): 151–164

Dept. of Lands and Forests. 1983. Report on status of Nova Scotia coordinate system. Internal Report, Department of Lands and Forests, Province of Nova Scotia.

Flemming, A. 2014. Coordinate Control Officer (Retired), Department of Housing and Municipal Affairs, Province of Nova Scotia. Personal Communication.

GeoNova. 2006. A spatial referencing policy for the Province of Nova Scotia. GeoNova Reference Coordinate System Policy Node, Service Nova Scotia and Municipal Relations.

Gillis, D., A. Hamilton, R.J. Gaudet, J. Ramsay, B. Seely, S. Blackie, A. Flemming, C. Carlin, S. Bernard and L.G. LeBlanc. 2000. The selection and implementation of a new spatial reference system for Canada's Maritime provinces. *Geomatica.* 54(1): 25–41.

Hamilton, A., and J. Doig. 1993. Report of the Task Force on Control Surveys in the Maritime provinces.

Hill, N. 2015. Registrar General, Service Nova Scotia, Province of Nova Scotia. Personal communication.

Jacques Whitford. 2002. A study on official adoption of the Nova Scotia Coordinate Referencing System (NSCRS) by the Province of Nova Scotia. Department of Service Nova Scotia and Municipal Relations.

Junkins, D., and G. Garrard. 1998. Demystifying reference systems: a chronicle of spatial reference systems in Canada. *Geomatica*. 52(4): 468–473.

LRIS. 1977. A new approach to land registration and information. Land Registration and Information Service, The Council of Maritime Premiers.

McEwen, A. 1999. Cadastral surveys in Canada. Chapter Seven in *Mapping a Northern Land. The Survey of Canada 1947–1994.* McGill-Queen's University Press, Montreal. 190–218.

McGrath, G., and L.M. Sebert. 1999. *Mapping a Northern Land. The Survey of Canada 1947–1994.* McGill-Queen's University Press, Montreal.

NRCan. 2015A. Height Reference System Modernization. Natural Resources Canada. *http://webapp.geod.nrcan.gc.ca/geod/hmod/hmod.php*

NRCan. 2015B. Geological Survey of Canada. Natural Resources Canada. *http://www.nrcan.gc.ca/earth-sciences/science/geology/gsc/17100*

NSLUC. 1995. A coordinate referencing policy for the Province of Nova Scotia. Nova Scotia Land Use Committee.

Sebert, L.M. 1999. Provincial topographic mapping. Chapter Four in *Mapping a Northern Land. The Survey of Canada 1947–1994.* McGill-Queen's University Press, Montreal. 116–139.

Seely, B. 2011. Final Report: Nova Scotia Coordinate Referencing System (NSCRS) Future Policy Strategy. Service Nova Scotia and Municipal Relations.

*MS rec'd 15/10/02*
*Revised MS rec'd 15/10/26*

## Authors

*Jason Bond* manages the coordinate referencing system for the Province of Nova Scotia. He has a specialization in geodetic engineering with a focus on GNSS through master's and doctoral degrees at the University of New Brunswick (UNB). Jason also has a Diploma in Cadastral Surveys from UNB and is working towards obtaining a Nova Scotia Land Surveyor designation.

*William Robertson* was the manager of the Control Survey Section of the Land Registration Information Service (LRIS) established through the Council of Maritime Premiers. He has over 20 years experience with the coordinate referencing program for the Maritimes. He has been directly involved with several key projects, including establishing the Primary Control networks for Prince Edward Island and Nova Scotia, the Readjustment of the Maritime Control Network to the ATS77 datum, establishing survey control on Sable Island, early implementation of GPS to establish control on Sable Island and to establish survey control for the construction of the Cobequid Pass Highway. He was a licensed Land Surveyor in New Brunswick and a member of the Association of Professional Engineers in Prince Edward Island and Nova Scotia. ❑