THE SURVEY CONTROL SYSTEM FOR METROPOLITAN TORONTO

by R.A. Smith*

Introduction

The Municipality of Metropolitan Toronto was created to undertake major public works projects and to provide Municipal services which are the concern of all area Municipalities. Metropolitan Toronto is composed of thirteen Municipalities, the largest of these, in terms of population being the City of Toronto having a population of approximately 644,000 and the smallest being the Village of Swansea with a population of just under 10,000.

The establishment and maintenance of a major road system, the wholesale supply of water, the probision of major storm and sanitary sewers, regional planning, public housing, homes for the aged, regional parks, basic education costs, and the operation of the police force, are all responsibilities of the Metropolitan Corporation.

A control survey to which the various public and private surveying and engineering projects can be related would appear to fit into the definition of the responsibilities of the Metropolitan Corporation.

Purpose of Control Survey

By a control survey, I mean a survey undertaken to establish a large number of survey monuments, each having known geographic and plane coordinate values. The elevation of the monuments and a series of bench marks is a required part of the control survey. To be effective, the system should be an integral part of a Provincial or Federal control system.

Responsibility for Survey

Is a control survey really a Municipal responsibility?

I have only to quote part of the text of the Order-in-Council dated the 20th of April, 1909 which formally established the Geodetic Survey of Canada to answer this question.

> *"During the last four years, a triangulation has been in progress in the better settled parts of the Provinces of Ontario and Quebec, under the Astronomical Branch of the Department of the Interior, the object of which is to determine with the highest attainable accuracy, the positions of points throughout the country and the lengths and directions of lines which may form the basis of surveys of all purposes, topographic, engineering or cadastral and thereby assist in the survey work carried on by other Departments of the Dominion Government by the Provincial Governments and by Municipalities, private persons or corporations. The operations have also included a considerable length of lines precise levelling."*

Thus 55 years ago the basic principle was laid down that all important surveys should be related to control surveys thus ensuring the coordination of all the different phases of a project and of various projects and providing each survey point with a positive position in relationship to all others.

The responsibility for the establishment of the system can be shared by the three levels of government of by Dominon Government and any other level. The system is most effective if all three levels of government are involved.

Historical Reasons for Control Surveys in Metro

One of the most important trends of our time has been the shift of population from the rural to the urban communities. It has been forecast that by 1980 about 75% of the population of this country will be urban. This trend to urban areas has created a new challenge for the land surveyor with all the complexity of land division required to satisfy the needs of a metropolitan city. Yet all legal surveys in Metro, hand from the thin fabric of the Township surveys performed in 1793.

To illustrate this point further, I would like to make reference to a paper presented by R.M. Anderson, O.L.S., at the last annual meeting of the Ontario Land Surveyors. In it he states, "During the summer of 1793, Governor Simcoe sailed from his headquarters at Niagara-on-the-Lake and set up his famous tent home on

the shore of Toronto Bay. He brought with him soldiers to create a defensive position and civilian artisans, who in the next few years built houses, mills, wharves, warehouses, even a jail. He also brought with him Alexander Aiken, land surveyor. Simcoe instructed Aiken to lay out a small townsite on the north shore of the bay at what is now the foot of Sherbourne Street. This was done and we have the beginning of the Town Plan of York.

"Simcoe's fort, all those first houses, mills, wharves, warehouses have long since disappeared but the posts planted and the lines run through the forest by Alexander Aiken are still the foundation of land ownship in the ancient townsite. This is no isolated instance. The posts planted and the landmarks established in the original surveys of all the townships of the province as well as in the original surveys for all our registered plans mark the true and unalterable corners of the lots involved.

He goes on to state, "I am not criticizing theprinciple. No alternative would escape other difficulties even more formidable. The surveyor, even with the best will in the world, can only establish a limited number of points on the ground. These landmarks are exposed and vulnerable. It seems inevitable that a large portion of them will shortly disappear. A comprehensive program of continued maintenance and repair, while relatively not expensive, seems to have been beyond the vision of public authorities and only limited and spasmodic efforts to save survey fabric have ever been made, by province or municipalities.

"Equally grave is the problem of obsolescence. I have no reason to suppose that Aiken used anything less effective than the normal equipment and skills of his day. At the best, his equipment and methods gave results appropriate to the standards of the places and times. To have looked for quarter inches or even inches would have been economically out of reach, even if it had been feasible otherwise. How could Aiken have justified to the governor and council money spent for that purpose?

"Yet today, in these same blocks, owners do expect to be told their property boundaries to the quarter inch. The most expensive real estate in the City of Toronto is in the plan in the Town of York. The plan shows not a single measurement."

Mr. Anderson and many others have over the years been highly critical of both the province and the municipalities for the lack of survey maintenance. The Registry Office system was set up to perpetuate Chain of Title, but no system was established to protect the survey posts governing the extent of title.

A control system is the most efficient method of surveying maintenance.

Metro Toronto

It may be in order to inject here a few basic comments concerning the Metropolitan Corporation. It is anticipated that by 1980 the population of Metropolitan Toronto will be 2,300,000 people. Metropolitan Toronto covers an area of about 240 square miles while the City of Toronto property has an area of approximately 34 square miles. Metro is situated on the north side of Lake Ontario and extends along the lake front for approximately 20 miles and north from the lake for about ten miles. The level of Lake Ontario is 245 feet while the heights of land along the northern limits of Metropolitan Toronto have elevations of 625 feet. The area is traversed by four major valleys containing the Rouge River, Highland Creek, the Don River and the Humber River. Approximately 9 per cent of the population of Canada lives in the Metro area and about 11 per cent of the employment for the country is here. The present developed area covers 92 square miles.

The ten year capital works program adopted by Metro in 1963 totals more than one billion dollars, exclusive of area Municipality expenditures, of this about 36% is allocated for roads, sewers, and water, 30% for public transportation, 28% for education and 6% for other Municipal services.

Roads Department

The Metropolitan Government is responsible for the major regional services

while the other Municipalities retain their own local autonomy. One of the major services is the establishment and maintenance of the network or arterial roads and expressways. At the present time, the Roads Department is responsible for about 347 miles of major roads. These roads are, or are to be widened to four or six lanes. From the figures above it can be seen that many more millions of dollars will be spent in the next ten years, on the widening of existing and construction of new roads and expressways. Currently, the Roads Department is acquiring about seven million dollars worth of property a year for roads purchases.

The survey section of the Roads Department provides both engineering and legal survey services for the Department. On large projects, such as the Don Valley Parkway and Gardiner Expressway, consulting engineering firms provide the engineering surveying services and the Roads Department, either with its own staff or by engaging consulting Ontario Land Surveyors carries out all legal surveys.

There is no central surveying or mapping division in Metropolitan Toronto and the Metropolitan Toronto control survey was carried out by the Roads Department staff in cooperation with the Department of Mines and Technical Surveys, Ottawa.

Metro Control Survey

The control survey for Metropolitan Toronto consists of three different surveys. First, a vertical control survey, next, a first order triangulation survey and thirdly, a horizontal control traverse survey.

The vertical control survey was undertaken because the various municipal engineers and surveyors wanted all bench marks in the area related to the same datum. The horizontal coordinate surveys were not undertaken for the basic reasons mentioned but because it was felt that a basic network was required to relate all the various construction projects being undertaken by the Roads Department. In the next few years we anticipate a large increase in the number of bench marks and horizontal control monuments relating to these basic networks.

It would obviously be unwise to establish a system satisfactorily for the needs of one department unless it was ideally suited for the general needs of the community as a whole. Therefore to obtain optimum value from the survey it was decided to perform it at standards acceptable for a city control survey.

Values of Horizontal Control

It is a relatively easy matter to explain to the layman or politician the need for vertical control and the desirability of setting bench marks. It is more difficult, especially considering the costs involved, for the layman to comprehend and appreciate the value of a horizontal control system. Before proceeding further, I would like to state some of the values of such a system.

By a coordination system it is possible to express the position of any point in a simple direct manner. Once the position of a point is known, it can be located on the ground or on any map or plan and its location can be incorporated in any design. In cities where we are forever building up, tearing down, and bulldozing out, and changing property and street lines, it is desirable to establish a framework to which the position of any point can be positively related, thereby enabling all the old, all the new and all the contemplated projects to dovetail together.

The horizontal control survey is a yardstick against which all other measurements may be standardized, it is the permanent survey which adds confidence of position and accuracy to the temporary surveys being undertaken day by day. It provides an easy method of calculating, of indexing and of filing and adds permanency to local surveys. It permanently records and relates what you are going to build, what you have built and what you have taken away. It provides an easy method of survey maintenance and makes it possible to retrace accurately old surveys and re-define old survey lines and boundary corners. The system is permanent because it is not dependent upon property lines which are forever changing. It provides a

simple direct way of expressing the position of any point in relationship to X and Y coordinates.

It facilitates the interchangeability of information, making it possible to use other's field notes etc. without rushing to the field to measure ties to common points. It eliminates gross errors whether in measuring or plotting, position is pin pointed, position is positive. It uses the basic principles of proportioning all measurements, this is one of the most important principles in legal surveying. It makes almost any point the starting point for survey and simplifies the transfer of information from the map to the ground or from the ground to the map. It provides the ground control required for proper aerial surveying and mapping.

It permits the laying out of complex engineering projects and allows you to build a small part here and a large section there knowing full well they will fit together. It makes possible the advance planning of projects because you know that they will fit into the overall scheme. It enables the planner to provide information concerning one small part of a project. It enables the expressway planner for example to provide accurate information to adjacent subdividers concerning right-of-way requirements without sending a survey party to the field to run the expressway centre line. Co-ordinate surveys make it possible to effectively precalculate subdivisions and other projects. It relates the underground utilities, presently the location of many of these is buried in the old records. Utility companies are often required to place new services in relationship to street lines, which mean expensive surveys compared with using a coordinate system.

A coordinate survey is therefore the common bond which cements together the various engineering projects and legal surveys being carried out by both the public and private sectors of the community. It is the one thing that adds permanency and confidence in all surveys and projects.

Precise and Secondary Vertical Control

The Roads Department of Metropolitan Toronto first became directly involved in control surveys in 1958 when a meeting was called by the Township Engineer for the Township of Scarborough to discuss the system of bench marks which he wished to establish. This meeting was attended by various members of the engineering and surveying staffs of the area Municipalities and each expressed a firm desire to have all bench marks in the Metropolitan area related to the same datum. It was also the common feeling that the Geodetic datum would be the most desirable to use.

This would involve considerable expense especially for the City of Toronto which had its own system dating back a number of years and all the tablets had elevations stamped on them. These would all have to be removed, new tablets installed. The Roads Department was requested to approach the Department of Mines and Technical Surveys in Ottawa with a view to engaging their services to undertake the survey. Agreement was reached with the Geodetic Survey of Canada and a report was submitted to the Metropolitan Council requesting authority to engage the services of the Geodetic Survey Division of the Surveys and Mapping Branch, Department of Mines and Technical Surveys.

During the summer of 1959 the Roads Department installed approximately 225 new bench mark tablets and pipes. It was estimated that about 4 miles of one-way city levelling could be done in one day and about 400 miles in one season. Considerable time was spent evaluating the merits of various routes. Initially the routes were laid out along existing or future Metro roads. This proved impractical because of heavy traffic, and as many miles of Metro roads are under construction, it would not be possible to cover the area in the time allotted by following these roads. The final routes followed several Railway rights-of-way and a number of the longer less travelled streets.

The standard bronze bench mark tablets of the Geodetic Survey of Canada were

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used. The tablets were set flush in solid concrete walls. Where a suitable location could not be found for a tablet, a brass cap fitted to 5 foot long iron pipe, welded to an iron base, set in concrete was installed in the ground. During the summer of 1960, a five man survey party carried out the levelling. In noisy areas a whistle was used to signal the rodmen when to hold or turn the rod and when to move ahead.

In 1961, a booklet was published listing the location and elevation of the bench marks established. To summarize the work on the vertical control survey, I would like to read to you both the foreword and the report on the Metropolitan Toronto levelling survey from this booklet. The foreword reads as follows:

"This booklet has been prepared for the information and use of surveys and engineers both Municipal and private working in the Municipality of Metropolitan Toronto.

"Bench marks are essential for surveying of the site of any project before and during construction.

"During recent years the establishment of bench marks in the Metropolitan area has not kept pace with the community's growth. A large number of bench marks in the old area have been destroyed. The levelling datums in the area municipalities were not related one to the other.

"On November 4, 1958 the Roads Department of the Municipality of Metropolitan Toronto was authorized by Council to engage the services of Geodetic Survey of Canada, Department of Mines and Technical Surveys, Ottawa, to assist in establishing a coordinate system of bench marks throughout the Metropolitan Toronto area.

"During the following year route locations were determined and over 250 bench marks, tablets and pipes were installed.

"At this time, I wish to thank all private owners who have cooperated in allowing their property and buildings to be used and to request all those using the tablets to show the proper courtesy and respect to these owners.

"In the Summer of 1960, after the tablets had sat for one winter, Mr. J.E. Lilly, Dominion Geodesist, dispatched a a survey party to carry out the levelling. That fall and winter Mr. Lilly's staff made the least squares adjustments on the network. It is hoped that the major benefit to be accurate relationship between all the utilities, services and other municipal and private construction projects."

The report on the Metroplitan Toronto levelling as written by Mr. J.E. Lilly, Dominion Geodesist reads as follows:

"The levelling program as requested and financed by the Municipality of Metropolitan Toronto was carried out by the Geodetic Survey of Canada during the 1960 field season. The actual levelling operation, under the direction of field supervisor Mr. G. Laflamme and assistant Mr. F. Young was started on May 2 and completed on September 15.

"In general, the actual level routes followed those suggested by the Department of Roads. The outside loop, one east west line and two north south lines were levelled to precise standards. Each of the six loops formed by precise levelling was divided into smaller loops by one-way (secondary) levelling using precise methods. As control on the one-way levelling each small loop was required to close to precise standards of 0.017 VM feet, (M being the distance around the loops in miles). A small percentage of the original one-way levelling had to be levelled in both directions to bring the loop closures within the allowable limits. The complete job required 161 miles of precise levelling and 96 miles of one-way.

"A total of 255 new bench marks were established and some 40 old Geodetic and Public Works bench marks were tied in.

"All new bench marks were numbered consecutively starting with 1 and prefix by the letter "T". The new bench marks were located and installed by the Department of Roads.

"To give the best elevations, precise and secondary levelling were combined in one simultaneous least squares adjustment. Relative weighting of precise to secondary levelling was two to one. To control this adjustment, the elevations of four bench marks as established by the Precise Level Net of Canada were held. The stability of these bench marks numbers 242G, 578F, 181, 272G were proven during the course of levelling."

First Order Triangulation

The Roads Department obtained the approval of the Metropolitan Council to establish a horizontal control system in the Metropolitan area. This project was started before the bench mark project was completed.

Again the Roads Department contacted the Department of Mines and Technical Surveys and asked their assistance and cooperation. Mr. J.E. Lilly, Dominion Geodesist agreed to carry out one season's work and establish as many first order triangulation stations in Metropolitan Toronto as possible.

In the summer of 1960, a two man reconnaissance survey party worked for two months to determine the best locations for the stations. The network was to be related to the existing triangulation stations at King City, Uxbridge and Richmond Hill, all 5 to 10 miles north of Metro.

A survey party of 15 men, including a cook came to Toronto and were billeted

in tents in Sun Valley Park, Pickering Township. Unfortunately it was a rainy year and there was an epidemic of colds and influenza. Later survey parties fared better and stayed at motels.

The entire operation was under the supervision of Mr. C.B. McLellan and his assistant Mr. R. Mayne. The remaining staff were temporary assistants employed for the summer. The Roads Department contributed one man and a station wagon. Geodetic Survey of Canada supplied one tower truck, one pick-up truck and two station wagons.

The operation was divided into several phases, tower erection, tower centering, monument construction, angular measuring, distance measuring, levelling, station descriptions and field calculations. Over a number of the stations, survey towers were constructed. The towers consisted of independent inner and outer steel structures about 100 feet high. The inner tower for the theodolite and tellurometer and the outer tower for the men and lights. The towers were centered over the monuments by optical plumbing. The tower crew was normally composed of four men. A link wire fence was erected around the towers to keep unauthorized individuals from climbing them.

The concrete monuments were constructed in two sections. The lower section was 2'6" square and 2' deep. The upper section was pyramidal measuring only 1'6" square at the top and it was 4'6" deep set flush with the ground. Brass tablets were set in the top of each section. The Metropolitan Corporation acquired a parcel of land about 25' square at each monument site.

Where stations were on the roofs of high building tablets were placed in the roof. An aluminum tripod on a wooden stand and weighted down with sand bags was placed over these stations. At the Imperial Oil building a safety cable was attached to roof rings and safety belts were attached to the cable.

The angles were measured at night using a Wild T3. Lights were set at the remote stations. Three observing parties and one light crew worked at night, keeping in contact by two-way radios. The light crew attached clocks to stations at St. Clair, Victory and Carlings. The lights at High Park were left on permanently. Some difficulty was experienced at the Imperial station because the lights were shining into nearby apartment buildings.

The distances were measured by tellurometer and only on two occasions did the instruments have to be repaired. When tellurometers were on the towers, the 12 volt battery was connected to the bottom of the tower. The positve to the outside and the negative to the inside structure. The longest distance measured, station to station, in the survey was about 29 miles and the shortest about 4 miles. On the average the triangulation stations are 5 miles apart. Twenty-four first order triangulation stations were established in and around Metropolitan Toronto. The Imperial Oil building near the intersection of Avenue Road and St. Clair Avenue became the main focal point for the network. From here the panorama of the whole city is laid out before you.

Second Order Traversing

To make any use of the network it was necessary to establish a large number of control stations on the ground. The Roads Department wrote to the Dominion Geodesist and asked if his staff could establish these stations. We were advised that the Topographical Survey section of the Department of Mines and Technical Surveys would be able to establish a network at second order control points in the Metropolitan area. Arrangements were completed in March of 1962 for a two year cost sharing project.

The second order stations were established by traversing between the first order stations. Consideration was given to running the traverses along the Metropolitan roads and establishing monuments at the road intersections. When a field

reconnaissance was made, it was found that in most cases it would not be practical to use the routes along Metro roads. It was therefore decided to run the traverses across country along the most convenient routes and establish survey monuments, so at least three fall within any circle having a 1 mile radius.

A field party consisting of two and sometimes three field officers from the Topographical Survey and several part-time assistants was assigned to this project. This staff was supplemented by a number of engineer assistants from the Roads Department.

The survey was conducted along the basic standards set down by the Department of Mines and Technical Surveys . A paper on this survey was presented by Mr. L.E. Pelton, to the last annual meeting of the Ontario Land Surveyors. Mr. Pelton was in charge of the field survey and part of his paper reads as follows:

"A Geodimeter 4B was used for night measurements of traverse distances up to 4 miles. Tellurometers were used for distances over 4 miles and for a few of the shorter distances where intervening lights or other obstacles made light measurements difficult. Two Geodimeter distances were measured for each required length. This was done by using a 2 foot aluminum bar mounted on a tripod at the reflector end. The first position was exactly 25 centimeters in front of the true station and the second 25 centimeters behind the station. These two readings were checked against each other and meaned to give the required distance. This gave the advantage of two separate readings with a minimum of work, as both the instrument and reflector were set up and only the prism housing at the reflector needed to be moved. This also helped to lessen the possibility of ambiguities. An attempt was made to keep Geodimeter distances greater than 1000 feet. For distances less than 1000 feet, double readings were taken in both directions and meaned. For short distances of say 200 feet a calibrated chain was used. All Geodimeter distances to side shots were checked with rough tellurometer distances in order to avoid possible five meter ambiguities that occasionally turn up in the Geodimeter computations. The rate of progress averaged about eight angles per day and several double distances (e.g. fourteen measurements) per night. From preliminary computations about 95% of the Geodimeter lengths appeared to be better than 1 : 40,000. A Wild T2 was used for angle measurements along with tribrachs which allowed the interchange of instrument or target without moving the tripod. Eight sets of horizontal angles were read for each required angle and a deviation of five seconds from the mean accepted. If a reading differed by more than five seconds, extra sets were taken until a suitable mean was obtained. One set of vertical angles was taken at each station in order to calculate differences in elevation. These were necessary for reducing the slope distances to horizontal distances at sea level. Loops were run to check the angulation and for side shots two different angles were read at the instrument station, using two adjacent stations for the initial sightings, in order to provide a check. The unadjusted azimuth closures of 90% of the loops fall within three seconds times $\sqrt{N}$ where N is the number of courses between azimuth control. The remainder of the azimuth closures fall within five seconds times N."

This project required close cooperation between the reconnaissance crew, the monument crew, the man contacting the property owners and the survey party.

When a private ownere had to be contacted, arrangements were started that day and in most instances immediate approval was obtained verbally for the setting of the monument on private land. The Department did not attempt to obtain agreements from the owners. This would have involved considerably more time and possibly the paying of a sum of money for the privilege of siting the monument. It was felt the owners would, in most cases, be cooperative and advise the Department when and if the monument had to be disturbed. A bi-yearly inspection of the monument locations is to be made and monuments in areas under construction will be referenced.

A total of 382 concrete monuments were established in Metropolitan Toronto and 40 tablets were set in sidewalks or on bridges. In addition, a number of reference monuments were set, where it was anticipated that the true monument might be destroyed in the near future.

As many of the monuments as possible were set on public lands, a number were established on Hydro rights-of-way, some on railway rights-of-way, in park lands, on church properties, at school lands etc. These locations were more desirable as they were less vulnerable to destruction and readily accessible. On the Hydro rights-of-way all monuments were buried 1-1/2 feet below the ground surface as requested by the H.E.P.C. With several of the large public organizations, such as the Hydro it was necessary to enter into formal agreements.

The field work is now completed and the two seasons work is being combined in one simultaneous area type least-square adjustment. When the Province decides on the projection system to be used for Ontario, rectangular coordinates will be calculated for each station. The Metropolitan control survey will then form an integral part of the control system for the Province of Ontario.

It is important to note that an Ontario Land Surveyor was assigned to the project each year. Thus providing the authority to use the results of these surveys for legal purposes.

Ontario Land Surveyors performing surveys in the area for Government Departments, Commissions or Agencies can, by agreeing upon standards of field and office procedure, greatly increase the number of monuments with known coordinate values in the next few years.

Several survey organizations are already relating their major surveys to the network and others have indicated that they will as soon as the information concerning the monument positions and their rectangular coordinate values is made public.

SUMMARY

The following requirements have been satisfied by the Metropolitan Toronto control survey.

(a) A survey network to control and relate all Metro roads projects and provide the ground control for aerial surveys.
(b) A system of monuments established, in most cases, in permanent positions.
(c) A system of monuments of sufficient density to relate major public works projects.
(d) A system satisfactory for legal survey purposes.
(e) A system established by a competent government authority.
(f) A system established at standards of accuracy acceptably for city control survey.
(g) A system that can easily be expanded to satisfy the ultimate needs of the area.
(h) A system which will be used immediately by many Metropolitan Departments to coordinate and corelate their work.

* *Supervisor of Surveys, Roads Department, Metropolitan Toronto. Condensed from Mr. Smith's paper presented to the C.I.S. Convention, Ottawa, February, 1964.*

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COMMITTEE REPORTS

SOME COMMENTS ON COMPLAINTS

It was considered that the best interests of the membership might be served if some of the Complaints Committee's problems were made known. Some may say that "this couldn't happen to me" or "I wouldn't do anything like that", but nevertheless it may be interesting to know how terrible the other fellow is.

A typical complaint is overcharging. The client gets mad and says so to anyone who will listen. In actual fact there is no overcharging; it's a matter that the costs have gone way up and everyone is surprised, including the Surveyor. This situation would be helped if the Surveyor were to keep his client aware of costs, especially when they go over any estimate he may have given. People like to be brought in on things, especially when the bill is high and it's costing them money. An explanation of the price included with the bill may save a complaint. The ole area that has no previous retracement is bound to be costly and the first survey may cost the earth. The first client has to bear the cost of years of boundary line neglect; the second client may apparently get more for his money.

Another common complaint is the same boundary line in two different places. This is particularly hard for either neighbour to understand, and in the case of overlapping deeds can lead to distress and loss of harmony. As long as both surveys