Ontario Specifications for Horizontal Control Surveys (OS 79)

and

Ontario Guidelines for Horizontal Control Surveys (OG 79)

Surveyor General
Ministry of Natural Resources
Ontario

1979 04 28
(Content of Original Cover Page)

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Additional Information

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These specifications (OS 79) and guidelines (OG 79) have been prepared to ensure that as control surveys are performed, a network of coordinated control monuments will be provided in Ontario with a standardized accuracy that will satisfy both private sector and government needs for geographical referencing, mapping, cadastral and engineering purposes.

The Office of the Surveyor General wishes to acknowledge the assistance of the Geodetic Committee of the Association of Ontario Land Surveyors as well as the surveying and mapping communities in both government and private sectors. Their valuable contributions to the development of these specifications and guidelines are appreciated.

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Ontario Specifications for Horizontal Control Surveys, 1979 (OS 79)

Surveyor General

Ministry of Natural Resources
Ontario

1979 04 28

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1. Introduction

Horizontal control surveys have traditionally been classified as first, second, third or fourth order according to standards of accuracy. This traditional method of classification is retained in OS 79.

In addition, OS 79 is designed for the densification and breakdown of geodetic control networks. The classification standards are expressed in terms of statistical 95% confidence regions. An explanation of statistical concepts is contained in Appendix A.

While the quality of the design and fieldwork of a network is best determined by a free or unconstrained adjustment, the classification of each station must be determined by a constrained adjustment. For example, a free adjustment may indicate a point is second order whereas a constrained adjustment might indicate its position relative to neighbouring points does not meet the second order standard, in such a case the station would be classified as lower order.

In many instances traverses will be required for integrated control surveys in urban and rural areas. Triangulation, trilateration, intersection, resection, photogrammetry, Doppler satellite observations, inertial survey systems and other more recently developed techniques and technology may be used to establish control provided the required standard in terms of 95% confidence regions is met.

OS 79 does not provide detailed specifications for first order surveys. Reference should be made to the latest specifications issued by the *Department of Energy, Mines and Resources, Ottawa* for first order work.

2. Classification of Control Survey Networks

Horizontal control shall be classified as first, second, third or fourth order without regard to the method of survey, according to the length of the semi-major axis of the 95% confidence region of a station relative to any other station in the network. The length of the semi-major axis after adjustment must be less than or equal to the value for **r** where **r = Cd** and **r** is expressed in centimetres, **d** the distance between neighbouring points is expressed in kilometres and **C** is a constant with a value of 2 for first order, 5 for second order, 12 for third order and 30 for fourth order control surveys. Notwithstanding, where the length of the semi-major axis after adjustment exceeds the value for **r** where **r = Cd**, the station shall be classified as third order providing **r** is less than or equal to 1 cm. Thus, in order for a station to be classified as third order, the semi-major axis of the 95% confidence region must, after adjustment, be less than or equal to (**12d**) cm or 1 cm whichever is greater, for each neighbouring station.

3. Use of SI (Metric) Units

Units of linear measurement, adjustment data and information shown on plans and monument record forms for surveys performed under OS 79 shall be in SI (metric) units.

4. Control Survey Stations

(a) Location of Station Sites

In choosing a control survey station site, consideration must be given to the permanence and stability of the monument. When it is necessary to place a control survey monument on private lands, the owner's consent shall be obtained. Care and respect of public and privately owned property shall be observed throughout the survey. The site around the monument on private property shall be restored in a manner satisfactory to the owner.

(b) Monuments

Monuments shall incorporate bronze identification caps, which may be:

(i) affixed by a screw connector to a drilled and tapped standard iron bar or rock bar; or

(ii) set in concrete or rock as a rock post.

(Detailed specifications for the design and type of monuments to be used in horizontal control surveys are not included in OS 79. The monument requirements of different organizations requiring or responsible for control surveys vary considerably and are better left in the specifications of such organizations).

(c) Referencing

Control stations are referenced for a variety of reasons, including one or more of the following:

(i) maintain the accepted position of the station;

(ii) assist in locating the station at some future date;

(iii) provide for a check on monument movement; and

(iv) provide convenient references with exact ties from which lost monuments can be replaced.

In urban areas all control survey monuments shall be referenced by horizontal ties (both angular and linear) to at least the nearest four objects of a permanent and stable nature, such as buildings, or concrete structures. Where suitable reference objects are not available, cut crosses, rocks posts, or bronze identification caps affixed to standard iron bars, round iron bars 25 mm in diameter and at least 1.2 m in length or rock bars may be used. The reference points shall be chosen where possible to form a square around the monument. Trees, utility poles, fire hydrants, catch basins, manholes, or fences should not be used.

Distances from the control monument to reference points and check measurements between adjacent intervisible reference points shall be measured to the nearest millimetre. All such distances shall be verified by two independent measurements with the maximum acceptable difference being 0.004 m. Where possible, reference ties should not exceed 50 m. Horizontal directions shall be measured at the control monument to all reference points and to at least one neighbouring control monument. The horizontal directions measured at the control monument to all reference points shall be measured consecutively to the nearest 10 seconds of arc.

In non-urban areas where referencing are primarily to preserve a key point by providing ties of sufficient accuracy and nature to permit the replacement of the monument in its original position, if lost, or to set a new station in the vicinity of the original position, then the rules for referencing control monuments in urban areas shall apply.

In non-urban areas where referencing is primarily to find and check the relative stability of a station at some future date and there is little likelihood that the station will be replaced if lost, the station shall be referenced by horizontal linear measurement to at least three readily identifiable objects within 50 m. Distances from the control monument to reference points shall be measured to the nearest centimetre. In addition, a linear tie or ties shall be made to a prominent topographical feature, such as a road intersection, to enable the location of the monument to be determined from a key plan. Generally, ties to prominent topographic features need only be recorded to the nearest tenth of a kilometre.

If a control monument record form for an occupied control station does not exist, one shall be prepared.

(d) Existing Stations

The position of each existing monument occupied must be checked to ensure that the monument has not been disturbed. Where existing reference ties are considered insufficient, additional ties shall be made and existing ties verified. A new control monument record form shall be prepared and a copy sent to the agency that installed the monument.

(e) Station Identification

A nine digit numbering system has been devised for unique identification of control survey stations in Ontario (see Appendix C). All control monuments shall be numbered in the manner outlined in Appendix C. All nine digits shall appear on the monument. The first three being the agency identifier, the next two indicating the year of installation, the remaining four the sequential number of the monument planted that year by the agency involved. The digits shall be stamped on the bronze identification cap with 5 mm or larger dies prior to the cap being affixed or set.

5. Adjustment

It is recommended that the Multi-purpose Analyses of Network Observations and Reductions computer program (MANOR) is used to co-ordinate, audit, adjust and analyze horizontal control surveys. In any event, the electronic computer program used for the processing of the data must be fully documented and capable of:

(i) Checking and testing all input data for gross errors (punched or observed) before the actual adjustment starts.

(ii) Listing the input data together with the observed distances, directions, and azimuths and the weights and standard deviations of all the observations.

(iii) Performing a least squares adjustment based on weighted observations.

(iv) Providing a listing of the residuals (V's) for all the observations as a result of the adjustment. These residuals should be expressed in either seconds of arc or millimetres and in ppm (parts per million).

(v) Computing co-ordinate values for points and displaying them in both Latitude and Longitude and plane co-ordinate Eastings and Northings.

(vi) Computing co-ordinate values to a precision of at least 0.00001 of a second of arc for Latitude and Longitude and 1 mm for plane co-ordinates.

(vii) Listing the following statistical data as output:

- The variance factor as computed from the adjustment results;
- The relative error ellipses (95% confidence regions) between free stations.

While not mandatory, it is advisable, particularly for larger traverses or densification networks, that prior to the final adjustment, a free adjustment is run in which two stations or one tie point and an azimuth are held fixed. All angles and distances measured shall be properly weighted and used in this adjustment.

Appendix A – Statistical Concepts

Confidence Region

A confidence region is defined as a region within which we have a specified degree of confidence (expressed as a percentage) that the true value lies. For normally distributed observations in two dimensions, a confidence region is bound by an ellipse.

The standard ellipse is based on the standard deviation of unit weight and the network configuration. It bounds a confidence region of from 30% to 39% depending on the number of redundant observations or degrees of freedom in the adjustment.

To classify control surveys, these specifications use the 95% confidence region as a standard. The 95% confidence region about an adjusted point represents the region within which the probability is 0.95 that the true position of the point lies relative to any other point in the network. The 95% confidence region is an enlargement of the standard ellipse obtained by multiplying the axes of the standard ellipse by a factor computed from the number of degrees of freedom.

Standard Deviation

Standard deviation is referred to as a standard error or root mean square error. Standard deviation squared σ^2 is referred to as variance.

Standard deviation is a statistical measure of reliability. It is a measure of the dispersion of the observations of a quantity, such as an angle or distance, from the mean of the group of observations. Standard deviation (σ) of an observation can be computed using the following formula:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - m)^2}{n-1}}$$

However, surveyors are generally concerned with the standard deviation of the mean of a set of observations. The standard deviation (σo) of the mean of a set of observations can be computed using the following formula:

$$\sigma_o = \sqrt{\frac{\sum_{i=1}^{n}(x_i - m)^2}{n(n-1)}}$$

Where, in the above two formulae:

$$m = \frac{\sum_{i=1}^{n} x_i}{n} = mean$$

n = number of observations

x_i = ith observation

Appendix B – Glossary of Terms

Adjustment

The process of applying statistical techniques to arrive at an adjusted value of measurement.

Degrees of Freedom

(Redundancy). Corresponds to the number of observed angles and distances in excess of the number required for a unique solution of the unknown parameters.

Least Squares Adjustment

A statistical procedure for estimating the values of parameters in problems in which redundant information in the form of inconsistent observed data exists and in which the sum of the weighted squares of all the residuals derived in fitting the observations to a mathematical model is made a minimum.

Residual (V's)

The difference between a measurement corrected for known systematic errors and the adjusted value of the measurement.

Standard Deviation

See Statistical Concepts.

Standard Deviation of Unit Weight

The standard deviation of an observation with unit weight. It corresponds to the square root of the sum of the squares of the weighted residuals divided by the degrees of freedom.

Variance

The square of the standard deviation.

Weight

The relative value of an observation when compared with other observations to be included in the same adjustment. In general, the greater the precision of an observation, the greater its weight. The weight of an observation is inversely proportional to the observation's variance.

95% Confidence Region

The region bounded by an ellipse having the same orientation as the standard error ellipse but having axes that are a multiple of the axes of the standard error ellipse depending on the degrees of freedom in the network.

Appendix C – Control Survey Station Numbering System for Ontario

A revised eleven (11) digit numbering system has been devised in Ontario for the unique identification of control stations and to accommodate a computerized control survey data bank.

First three digits -- agency number

Next four digits -- year of installation

Last four digits -- annual consecutive number from 0001 to 9999

First three digits -- These three digits are used to uniquely identify the agency whose name appears on the identification cap or tablet. Agency identity numbers have been allocated to most agencies responsible for the installation of control in Ontario. Others will be issued as required by the Surveyor General for Ontario.

Next four digits -- These represent the four numbers of the calendar year in which the monument was installed.

Last four digits -- These are for the consecutive numbering of stations established by an agency in any calendar year. The use of four digits allows each agency to establish up to 9999 monuments in any one year. Where an agency such as the Ministry of Natural Resources establishes monuments in many areas in the same year, blocks of numbers may be assigned for different projects.

Example of numbering -- The number 01019710348 denotes a horizontal control survey monument planted by the agency with the identifying number 010 in the year 1971 and given the sequential number 348. The monument cap itself should be stamped with the number 01019710348.

Appendix D – Control Survey Agency Identifiers

Please contact Parcel Mapping and Georeferencing, Geodetic Services Program via geodesy@ontario.ca for a current agency identifier table.

Ontario Guidelines
for
Horizontal Control Surveys, 1979
(OG 79)

Surveyor General

Ministry of Natural Resources and Forestry
Ontario

1979 04 28

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1. Introduction

These guidelines (OG 79) have been prepared to supplement the Ontario Specifications for Horizontal Control Surveys (OS 79). They presuppose the professional competence of the surveyor to achieve the required accuracies in performing control surveys. Nevertheless, OG 79 provides general guidelines for reconnaissance, network design, procedures and survey returns.

2. Reconnaissance

The procedures followed and methods employed during the design and reconnaissance phase of a control survey can significantly influence the cost and accuracy of the survey as well as the usefulness, permanence and stability of the monuments established.

Since there are a large number of variables in each project, no rigid rules are given for carrying out the reconnaissance. The following procedural guidelines will, however, assist the surveyor in conducting this phase of the work.

(a) It is advisable to start reconnaissance with a study of the most up-to-date maps available. The proposed locations of all new points selected on the maps together with all existing control stations to be used in the survey should be inspected on the ground.

(b) Intervisibility between stations, where a clear line of sight is required, should be verified on the ground where possible. Lines of sight should clear all obstructions by at least one metre horizontally and by at least one metre vertically. The use of towers should be kept to a minimum. Where use of towers cannot be avoided, favourable locations for their erection should be selected during the reconnaissance. Lines of sight should not pass through wire fences, nor heated air from chimneys, air conditioners, etc.

(c) It is advisable to plot the control network on NTS 1:50 000 or 1:25 000 scale maps and to indicate all measurements proposed to be made as well as the approximate elevation of each station.

(d) Control survey stations should be located on prominent sites where visibility is unimpeded in all directions. Sites should be chosen which are not likely to be disturbed by future development. Monuments should be placed on other than privately owned lands where it is possible to do so without significantly weakening the strength of the network design or incurring unreasonable hardship and cost.

(e) Tact and good manners are essential when dealing with the public. Where it is necessary to place a monument on private land no effort should be spared in informing the landowners involved of the purpose and usefulness of the work being done and of the importance of the stability and security of control monuments.

3. Network Design

The importance of an effective network design cannot be too strongly emphasized. The size and shape of the 95% confidence region is dependent not only on the accuracy of the field measurements, but also on the configuration of the control network. In order to ensure that a particular order of accuracy will be obtained before commencing the fieldwork, it is advisable to test the proposed network design and measuring techniques in a suitable computer program using *a priori* estimates for the proposed measurements. A 20% contingency factor should be added to the equipment specifications to ensure the proposed measuring techniques are suitable for obtaining the required accuracy.

The following basic principles should be adhered to in the design of control networks and traverses.

(a) Scale and orientation control for horizontal control surveys should be derived from ties to higher order surveys.

(b) Long and narrow patterns should be avoided in the network design.

(c) A traverse should be as straight as possible. All-stations should be within ¼ D of the line joining the end stations, where D is the distance between end stations.

(d) Stations should be as evenly spaced as possible. No traverse course should differ in length by more than 50% from the average length of all the courses. The ratio of the longest length to the shortest should not be greater than 3 to 1.

(e) All neighbouring points in a survey net should be connected by direct measurement. In built-up urban areas where this is impractical and a traverse must be employed, every effort should be made to ensure that intersecting traverses are established to connect every third or fourth point in the traverse.

(f) No point on a traverse should be closer to an existing control station not forming part of the traverse, than the average distance between the points in the traverse.

(g) A traverse should be oriented at each terminal point by sighting on at least one other existing control station of the same or higher order that is part of the same network as the terminal point.

(h) The analysis of the survey design and the desired accuracy of posi¬tions should dictate the minimum distance between stations, however, as a general rule, the length of a course in a traverse should not be less than two hundred metres.

(i) To facilitate future use of traverse stations, each station should be intervisible at ground level with at least one other station in the traverse network.

4. Procedures

Computations for Statistical tests and rejection criteria for field measurements should, where possible, be made during the progress of the field work, this includes reduction of data collected from tests and calibration of equipment.

(a) Instrumentation

The least count of theodolites used, should not be greater than:

- one second of arc for second and third order surveys, and
- ten seconds of arc for fourth order surveys.

Appropriate electronic distance measuring instruments should be used to measure the distances between control monuments.

Electronic distance measuring instruments should be tested on a precise base line at least once every month when in use. In addition, during the progress of the survey check measurements should be made in the field weekly, between a pair of stable monuments to ensure consistency of measurements.

Tribrachs with built-in optical plummets should be tested for vertical alignment at least once every two weeks.

Stride levels should be used during observations to determine azimuth in second order work.

(b) Observations

Final observations should not be made until station monuments are properly installed and completed.

(i) **Directions** – At each station occupied, horizontal directions should be read consecutively throughout the circle to each station sighted.

The minimum number of sets of readings to be taken together with the maximum allowable standard deviation of the mean of all sets and the maximum allowable deviation of any single observation from the mean for the different orders of surveys are as follows:

Classification	Minimum No. of Sets	σo	Max. Deviation of any single observ. from the mean
Second Order	6	2.0”	5”
Third Order	4	2.8”	5”
Fourth Order	2	8.0”	8”

A set consists of a consecutive series of pointings of the theodolite on one face followed by corresponding consecutive pointings on the opposite face in a reverse order with the setting of the horizontal circle remaining constant throughout.

(ii) **Lengths** – Distances measured by electronic distance measuring systems should be made in accordance with manufacturers' specifications.

When making microwave measurements wet and dry bulb thermometer readings are critical as an error of 1°C can produce a corresponding error of up to 10 ppm.

The maximum allowable standard deviations of the mean of all sets of distance measurements for the different orders of surveys are as follows:

Classification	σo for Traverse	σo for Trilateration
Second Order	10 ppm	5 ppm
Third Order	20 ppm	10 ppm
Fourth Order	40 ppm	20 ppm

(iii) **Azimuths** – Assuming Polaris observations will be used to determine the astronomic azimuth, a set will comprise successive pointings on the reference object and Polaris on one face followed by successive pointings on Polaris and the reference object on the other face.

The minimum number of sets to be taken together with the maximum allowable standard deviation derived from the mean of all sets for the different orders of survey are as follows:

Classification	No. of Sets	σo
Second Order	12	1.5”
Third Order	4	3.0”
Fourth Order	4	6.0”

(iv) **Checks** – For the different orders of survey, the maximum allowable angular misclosure

a) between control azimuths is as follows:

Classification	Maximum Allowable Angular Misclosure
Second Order	5” $\sqrt{n}$
Third Order	10“$\sqrt{n}$
Fourth Order	20” $\sqrt{n}$

b) For self-closing loops is as follows:

Classification	Maximum Allowable Angular Misclosure
Second Order	3” $\sqrt{n}$
Third Order	6” $\sqrt{n}$
Fourth Order	12” $\sqrt{n}$

n = the number of angles involved.

(v) **Elevations** – The elevation of each station should be determined to an accuracy sufficient to ensure that the accuracy of measured distances between stations is not significantly affected by the process of reducing the measured distances to mean sea level.

5. Returns of Survey

The following provides an indication of what should be prepared by the surveyor and submitted as returns of survey to the client agency. Specific instructions by the client agency may require additional items or modifications to those listed in OG 79.

a) A list of items comprising the returns.

b) A report which provides a brief resume of the work performed and outlines the following:

   (i) Reconnaissance and final network design including reconnaissance maps and results of simulation computations.

   (ii) Owner’s name and address, where permission to enter private property was obtained.

   (iii) Any unusual problems or difficulties reencountered such as owner’s refusal or entry, locations where towers were requires, heights of towers used, etc.

(iv) Any significant deviation from the OS 79 specifications together with an explanation. This includes an explanation of any inconsistencies in the final adjustment.

(v) List of equipment used together with results of calibration and testing.

(vi) An explanation of how the weighting of measurements was derived.

(vii) A list of stations held fixed in the final adjustment together with the source of the fixed values.

c) A completed or updated horizontal control monument record form for each monument occupied or inspected. Each horizontal control station should be referenced by a Key Plan and a Reference Sketch. The Key Plan should show sufficient ties and information to facilitate the locating of the station on maps, aerial photographs and on the ground.

The Reference Sketch should show both angular and linear ties to reference objects in the vicinity of the monument as well as any check measurements between intervisible reference objects. Reference objects should be clearly described. A sample horizontal control monument record form is shown in Appendix A. A completed form is shown in Appendix B.

d) A computer listing of input as well as output of all computations together with an explanation of any inconsistencies.

e) A plan on transparent mylar plotted to scale showing the location of control stations, monument names or numbers, observed lines of sight between stations, symbols indicating the angles and lines along which distances or azimuths have been measured, important topographical and cultural features, a legend, a key plan, the scale, the name of the agency for whom the survey was performed, name and signature of the surveyor who performed the work and the date of the completion of the survey and of the plan. Plans should not exceed 107 cm in width and should not be folded.

Appendix A

Sample Horizontal Control Monument Record Form

HORIZONTAL CONTROL MONUMENT RECORD

Ontario
MINISTRY OF NATURAL RESOURCES
SURVEYS AND MAPPING BRANCH
QUEEN'S PARK, TORONTO, ONTARIO

MONUMENT Nº ______________________

INSCRIPTION ON MONUMENT FOUND ______________________

N KEY PLAN	N REFERENCES

MONUMENT TYPE ______________________
____

RELATION TO GRADE
cm above ☐
cm below ☐
flush ☐

DESCRIPTION OF LOCATION ______________________
____
____
____

MON.RECORD FORM COMPLETED BY: ______________________ DATE ____________

STATIONS SIGHTED AT GROUND LEVEL ______________________
____

STATIONS SIGHTED AT TOWER LEVEL (HEIGHT ________ m) ______________________
____

PROMINENT POINTS SIGHTED FROM STATION:

______________________ BACKSIGHT ____________ ANGLE ____________
______________________ BACKSIGHT ____________ ANGLE ____________

ELEVATION ______________ metres (precise/approximate)

METHOD USED TO ESTABLISH ELEVATION ______________________

MON. RECORD FORM REVISED BY: ______________________ DATE ____________

Appendix B

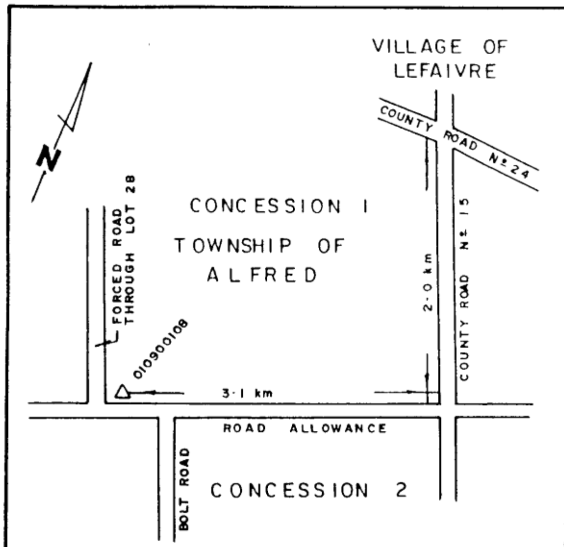
Sample Completed Horizontal Control Monument Record Form

HORIZONTAL CONTROL MONUMENT RECORD

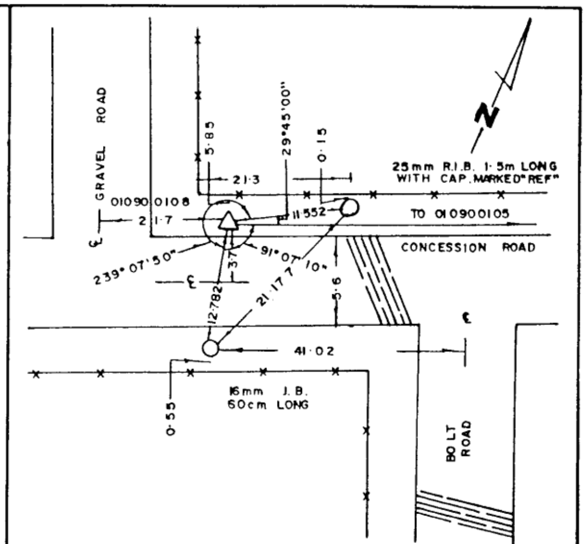
Ontario
MINISTRY OF NATURAL RESOURCES
SURVEYS AND MAPPING BRANCH
QUEEN'S PARK, TORONTO, ONTARIO

MONUMENT Nº 010900108

INSCRIPTION ON MONUMENT FOUND ______



KEY PLAN



REFERENCES

MONUMENT TYPE Bronze Cap on Top of 25 mm Diameter Round Iron Bar 1.5 m long.

RELATION TO GRADE: cm above ☐ / 19 cm below ■ / flush ☐

DESCRIPTION OF LOCATION The monument is located on the northerly shoulder of the road allowance between Concessions 1 and 2, approximately 3.1 km west of County Road No. 15 and 21.7 m east of the centre line of grade of a forced road through Lot 28, Concession 1, in the Township of Alfred.

MON. RECORD FORM COMPLETED BY: David P.J. Schultz, O.L.S. DATE 30/11/1990

STATIONS SIGHTED AT GROUND LEVEL 010900105, 010900109

STATIONS SIGHTED AT TOWER LEVEL (HEIGHT ______ m) ______

PROMINENT POINTS SIGHTED FROM STATION:

______ BACKSIGHT ______ ANGLE ______

______ BACKSIGHT ______ ANGLE ______

ELEVATION 52.17 metres (precise/~~approximate~~)

METHOD USED TO ESTABLISH ELEVATION Third Order Levelling

MON. RECORD FORM REVISED BY: ______ DATE ______