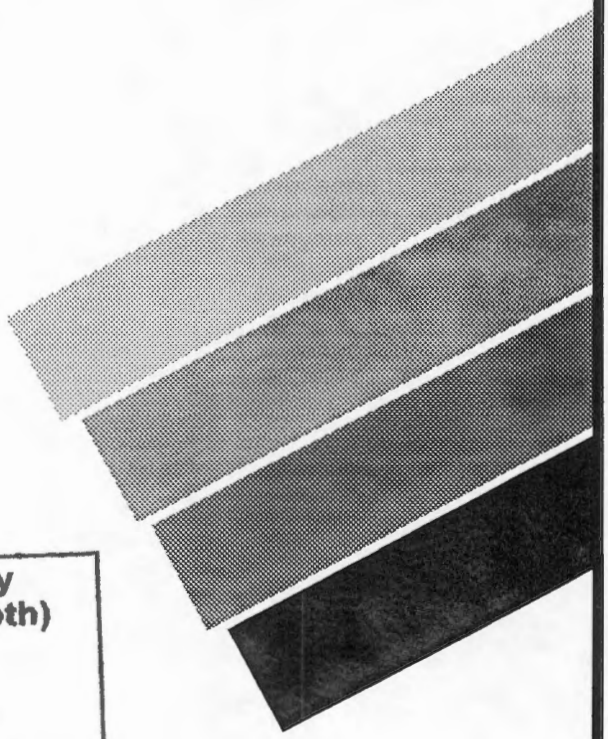
GEODETIC SURVEY DIVISION
CANADA CENTRE FOR SURVEYING
SURVEYS, MAPPING & REMOTE SENSING SECTOR

USER'S GUIDE

# SOFTWARE QUAD







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# 1.0 INTRODUCTION

The Geodetic Survey Division has produced three tables representing geoid-ellipsoid separation (N) values, which can also be referred to as geoidal heights or geoid undulations, and the deflection of the vertical for the north-south ($\xi$) and east-west ($\eta$) components for Canada. These tables are derived from the Canadian geoid model GSD91 (Véronneau, 1992). The national geoid model GSD91 is an improvement on the UNB86 and UNB90 geoid models (Vanicek, 1986 and 1990) by virtue of an updated model of the local gravity field in its computation. A terrain correction that was not present in previous gravity grids was added to the new grid. Also, new gravity observations were added to the database since the last computation, most of which were made in northern British Columbia. The fast Fourier transform technique (FFT) was used instead of the numerical integration technique, although, with regards to accuracy, one technique is not superior to the other. FFT permits a fast computation and eliminates possible skips of a few centimetres that can occur between two adjacent zones of numerical integration. One advantage to the numerical integration technique is that precise geoidal heights can be computed from the local gravity field at any specific coordinates. FFT necessitates a grid computation and an interpolation technique to estimate the geoid height at specific coordinates.

The tables contain geoidal heights and deflections of the vertical with respect to the internationally accepted Geodetic Reference System 1980 (GRS80) of the International Association of Geodesy (Bulletin Géodésique, Paris). This system has been used in the redefinition of the North American Datum 1983 (NAD83) and in the definition of the U.S. military World Geodetic System 1984 (WGS84). The four constants that determine the equipotential ellipsoid of revolution of GRS80 are practically equivalent to those of WGS84. The semi-major axis of the GRS80 ellipsoid is 6378137 metres and the flattening is 1/298.25722101. The WGS84 is used for computing the broadcast orbits of the U.S. Navy Navigation Satellites and for the U.S. Department of Defense Global Positioning System (GPS) satellites. The geoidal height table is thus recommended for use with satellite-derived coordinate values and is also recommended for use with NAD83 coordinate values.

The three tables (N, $\xi$ and $\eta$) cover most of the Canadian territory. It extends to the offshore areas between 46° and 142° west longitude (or E218° to E314°) and from 41° to 72° north latitude. Other tables covering regions outside these limits for the rest of the globe are also available.

Tabular values are given at intervals of 5 arcmins in latitude and longitude. A quadratic interpolation method should be used to interpolate the table. The files of geoidal heights (N) and deflections of the vertical ($\xi$, $\eta$), and the quadratic interpolating software are available on IBM compatible, Macintosh, VAX and SUN computers. These products are distributed by the Geodetic Survey Division.

For further details concerning the accuracy of the geoid models, or to obtain geoid values outside Canada or for any additional information, please contact Marc Véronneau at (613) 995-4345 or André Mainville at (613) 995-4504. We are also available to discuss the need for a more accurate geoid, or to receive any comments you may have.

## 2.0 SOFTWARE QUAD

The Geodetic Survey Division has developed a software package for personal computers to compute geoidal heights and deflections of the vertical in Canada. The computation of a point is done by a quadratic interpolation technique using the nine closest points in a geographical grid. The smoothness of the geoid makes the interpolation an accurate technique. The accuracy in most regions of Canada is ±10 cm over baselines of 100 km. The software can compute three gravimetric quantities at specific stations or along a set of geographic grid points. Some programming techniques to permit fast computation times for the geoidal heights and deflections were used. For example, the model grids are stored as binary integer values (in cm) in a direct access file, accompanied by a slave file which contains a description of the grid, the delimitation of the grid, and its spacing. This technique of storage minimizes the space taken on disk, while allowing the program to get the nine closest points of a station without having to read the full set of grid points at any time.

### 2.1 System Requirements

An IBM compatible PC using DOS with a 1.2 mbytes disk drive and a co-processor to run program QUAD is required. A version of the software is also available for Macintosh, VAX, and SUN computers.

### 2.2 Contents of the Diskettes

The software and its data are stored on three diskettes of 1.2 megabytes. The first diskette contains program QUAD, its source code and the geoidal height grid. A sample input file and sample output files are also included on the diskette. The two other diskettes contain grids the deflections of the vertical ($\xi$, $\eta$).

Diskette #1

| | |
|---|---|
| QUAD.EXE | : Executable code file |
| *.FOR | : Source code of QUAD and its subroutines |
| NGSD91.BIN | : Binary file of the geoidal heights grid (N) |
| NGSD91.SLV | : Descriptive slave file of the binary file |
| STATION.DAT | : Example of random stations input file |
| OUTGSD.DAT | : Example of output file for STATION.dat |
| OUTGSD.DET | : Example of detailed output file for STATION.dat |

Diskette #2 North-South components of the deflection of the vertical ($\xi$).

| | |
|---|---|
| XGSD91.BIN | : Binary file of the grid of the deflections of the vertical (x) |
| XGSD91.SLV | : Descriptive slave file of the binary file |

Diskette #3 East-West components of the deflections of the vertical ($\eta$), (defined using positive east longitudes).

| | |
|---|---|
| EGSD91.BIN | : Binary file of the grid of the deflections of the vertical (h) |
| EGSD91.SLV | : Descriptive slave file of the binary file |

## 2.3 Getting Started

Copy the executable code file (QUAD.exe), the binary file(s) (*.bin) and its slave file(s) (*.slv) to one directory on your hard disk. Type **QUAD** to run the program. For the SUN version, QUAD must be typed in small characters.

## 2.4 Software QUAD

QUAD is a user-friendly program written in FORTRAN. This program computes geoid heights and deflections of the vertical across Canada by fitting a quadratic surface to 9 adjacent grid values. The user has the option to compute between 3 gravimetric quantities (N, $\xi$, $\eta$) for specific station coordinates or for a sub-geographical grid. The "Cartesian Grid" option is not operational.

For the "Specific Point Values" option, the user has the option to work in an interactive mode which means that the coordinates of the stations are entered directly from the keyboard or to write a list of the stations' coordinates in a file with a specific format. The format is (6X,A9,24X,A1,I2,I3,F9.6,A1,I3,I3,F9.6) which is the input format of GHOST coordinate files. File STATION.dat on diskette #1 gives you an example of how to set up an input file. The direction of longitude is entered through a prompt or can be indicated directly in the input file. To define east longitude, 'e' or 'E' must be used. Any other symbol or a blank will indicate west longitude. Latitude in the southern hemisphere must be indicated by one of the following symbols:. 'S','s', or '-'. The "File" mode creates two output files. A detailed file with the extension "**.det**" contains the same information and format as the input file plus an extra column for interpolated geoidal heights or components of the deflection of the vertical while the other file with the extension "**.dat**" contains only the results of the quadratic interpolation. The "Interactive" mode does not produce any output files.

For the "Geographical Grid" option, the limits of the grid must be entered in decimal degrees and its spacing in arcmin. The west and east limits of the grid must be positive if using east longitude and negative for west longitude. This option creates two output files. The first file with the extension "**.dat**" contains the selected gravimetric quantity values. They are stored from west to east, starting north, with one value per record. The second file defined by the extension "**.tab**" contains the values in a table format. This file is saved only if 10,000 points or less are computed.

Any extension given to the output filename will be ignored since the software QUAD gives its own extension. If the output file already exists, the software will prompt you to enter a new name.

## 3.0 DATA INFORMATION

The geoidal height is derived from the ellipsoid height (h) and the orthometric height (H) by the following equation:

$$N = h - H$$

The deflection of the vertical has two components, a north-south component $\xi$ and an east-west component $\eta$. These components are represented by the two following equations:

$$\xi = \Phi - \varphi$$
$$\eta = (\Lambda - \lambda)\cos\varphi$$

The astronomic coordinates have been denoted by $\Phi$ and $\Lambda$ while $\varphi$ and $\lambda$ are the geodetic coordinates.

Geoidal heights are expressed in metres and the deflections of the vertical are expressed in arcseconds. It is important to note that the east-west component of the deflection of the vertical ($\eta$) is defined using positive east longitude which is required for GHOST for those who are familiar with the least-squares adjustment program GHOST.

The three sets of gravimetric quantities (N, $\xi$, $\eta$) are stored in binary files. To minimize the space required on disk, geoidal height and deflection of the vertical values were multiplied by 100 and stored as short integer (2 bytes integer). The files being direct-access type allow the program to get the nine closest points of a station without having to read the full set of grid points at any time and avoids using a large amount of memory by storing the values in a vector. Each grid contains 372 rows by 1152 columns for a total of 428,544 grid points. The size of the binary file is 857,088 bytes (428,544 records * 2 bytes/record).

The slave file (extension "slv") describes the binary file by indicating the type of grid, the delimitations of the grid and its spacing, and the factor to transform the integer values to real values.

## *REFERENCES*


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