COORDINATE TRANSFORMATION FROM KARBALA 1979 AND WORLD GEODETIC SYSTEM 1984 TO IRAQI GEOSPATIAL REFERENCE SYSTEM

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Submitted 30/9/2021 Accepted in revised form 9/1/2022 Published 1/5/2022

Abstract: Nowadays, the transformation between coordinate systems is the major interested problems especially in Iraq. There are many coordinate systems used to produce maps and documentations due to different datums and spheroids. These coordinate systems are preferable to be unified in local countries. Thus, this paper deals with the transformation of coordinate systems of Karbala 1979 Polservice and World Geodetic System (WGS) 1984 to Iraqi Geospatial Reference System (IGRS). Accurate and well distributed control points are selected to cover the study area in Baghdad city, Iraq. Coordinate transformations are implemented using ArcGIS application mainly. Also, MATLAB software is used to convert geographic to map coordinates and vice versa by designing two MATLAB programs. The differences between the coordinate systems have been calculated. The results found that the discrepancies between Karbala 1979 Polservice and IGRS are about 278.6 m, -287.6 m, 0.01 second, and -11.2 second in northing, easting, latitude, and longitude, respectively. The WGS 1984 is superposed to IGRS and the distinction between them is negligible. The map coordinate differences between ArcGIS and MATLAB results are about -16 to 14 mm in northing and about -13 to 12 mm in easting, while the latitude and longitude differences are zero.

Keywords: Coordinate Transformation, Datum, IGRS, Karbala 1979 Polservice, Spheroid, WGS 1984.

1. Introduction
The geodetic networks in Iraq have been passed through different stages. The progression of these networks includes Nahrwan 1934, Nahrwan 1967, Karbala 1979 Polservice, and the modern geodetic network of Iraqi Geospatial Reference System (IGRS). Geodetic networks consist of many control points defined by a datum and a spheroid. Table 1 illustrates the geodetic datums and spheroids used in Iraq. A datum provides a frame of reference for measuring locations on the surface of the earth [1]. The geodetic networks of Nahrwan 1934 and Nahrwan 1967 which have been established by British are called the English networks. These networks are based on Clarke 1880 Royal Geographical Society (RGS) spheroid. All English networks as well as the gravity points are almost completely extinct [2]. The geodetic network of Karbala 1979 Polservice was established by Polish State Enterprise for geodesy and cartography based on Karbala 1979 Polservice datum and Clarke 1880 RGS spheroid. The Iraqi geodetic control networks established by British and Polish are
limited, destroyed, and their data documentations are difficult to obtain.

The American Institution of National Geodetic Survey (NGS) developed the geodetic network in Iraq called the IGRS during the period between (2004) to (2005). The control surveys of IGRS are based on Global Positioning System (GPS). The default GPS observations are based on World Geodetic System 1984 (WGS 1984) datum and ellipsoid. Also, the WGS 1984 with Earth Gravitational Model (EGM 1996 or EGM 2008) is the vertical datum used in GPS receivers [3].

IGRS is a series of six GPS Continuously Operating Reference Stations (CORS) which are spread geographically throughout the Iraq country [4]. The origin of IGRS is the International Terrestrial Reference Frame (ITRF2000) at epoch (1997.0). The original IGRS established in 2005 comprised six CORS and sixty-four High Accuracy Reference Network (HARN) points levelled in six southern provinces in Iraq [5]. Iraqi Ministry of Water Resource, State Commission on Survey installed seven CORS stations and continued establishing the HARN points for whole Iraq provinces [6]. HARN points have been established relative to the CORS network forming the IGRS control network [6]. HARN is like a first order survey control network, while IGRS is a three dimensional coordinate system.

Nevertheless, up to the current IGRS, which was established with the help of the US and British Armies, the geographic coordinate reference systems were two dimensional, i.e. they excluded height information [7]. In most works, the geographic coordinates are measured and then transformed to map coordinates [8]. Universal Transverse Mercator (UTM) map projection is used for obtaining map coordinates. Each UTM zone has a false northing in the northern hemisphere: (0 m) and a false easting for every zone: (500000 m) [9]. A translational shift must be applied to convert coordinates from one datum to another. This situation is further complicated because the horizontal shifts are different for graticule and grid coordinates [10].

### Table 1. Geodetic datums and spheroids in Iraq

| Datum                | Spheroid            |
|----------------------|---------------------|
| Nahrwan 1934         | Clarke 1880 RGS     |
| Nahrwan 1967         | Clarke 1880 RGS     |
| European 1950        | International 1924  |
| Karbala 1979 Polservice | Clarke 1880 RGS |
| WGS 1984             | WGS 1984            |
| IGRS                 | GRS 1980            |

2. Study Objective and Software Used

The main objective of this study is to convert the commonly used coordinate systems in Iraq (karbala 1979 Polservice and WGS 1984) to IGRS using ArcGIS Desktop 10.8, and then develop equations that can be used to convert the karbala 1979 Polservice geographic and map coordinate systems to IGRS and vice versa within the study area. The coordinate transformations are done with the Project tool in ArcGIS software. In addition, two MATLAB programs are built using MATLAB software version 7.8.0.347 (R2009a) to convert the geographic coordinates to map coordinates and vice versa. The satellite image and control points are obtained from google earth pro 7.1.8.3036 build date 2017.

3. Study Area and Data Collection

The study area is placed in Baghdad city along the river of Tigris in Iraq. It is expanded from (33° 10’ 50” N) to (33° 26’ 40” N) latitude and from (44° 08’ 00” E) to (44° 36’ 50” E) longitude. The study area has been chosen because Baghdad city is the capital of Iraq and it meets the requirement of the research that represented by...
the possibility of reconnaissance the locations of points in the field. Fig.1 shows the location of Baghdad city on the map of Iraq and exhibits Baghdad map as well as the chosen control points (CPs). The map scale on the computer display is (1:250000) as shown in Fig.1. Twenty control points are scattered and distributed covering the whole region. The original data of satellite image and control points have been obtained from the google earth pro. The coordinate system of these data is according to WGS 1984 datum and spheroid. This coordinate system has been modified to IGRS datum and GRS 1980 spheroid using ArcGIS application.

Figure 1. Study area and selected control points
4. Design of MATLAB Programs for Coordinate Transformations

Coordinate transformations are implemented by designing two MATLAB programs. The first program is used for the transformation of geographic coordinates [Latitude (Phi) and Longitude (Lambda)] to map coordinates [Northing (N) and Easting (E)] as shown in Fig. 2, while the second program is used for the inverse transformation of map coordinates to geographic coordinates as shown in Fig. 3. The adopted transformation equations are found in Snyder [11]. The designed programs are listed in Appendix-A.

5. Implementation and Results

The commonly available three coordinate systems in Iraq are Karbala 1979 Polservice, WGS 1984, and IGRS. The spheroidal parameters differences between Karbala 1979 Polservice and IGRS datum and between WGS 1984 and IGRS datum are calculated in Table 2 and Table 3, respectively. The source data include satellite image and twenty control points obtained from google earth pro. These data are based on the geographic coordinate system of WGS 1984.

Table 2. Spheroidal differences between Karbala 1979 Polservice and IGRS datum

| Datum                  | Karbala 1979 Polservice | IGRS        | Differences |
|------------------------|-------------------------|-------------|-------------|
| Spheroid               | Clarke                  | GRS         |             |
|                        | 1880                    | 1980        |             |
| Semi-major Axis (m)    | 6378249.1               | 6378137.0   | −112.145    |
|                        | 45                      | 14140356    |             |
| Semi-minor Axis (m)    | 6356514.8               | 6356752.3   | 237.4445905 |
|                        | 69549776                | 14140356    |             |
| Inverse Flattening (m) | 293.465                 | 298.25722   | 4.792222101 |
|                        | 2101                    | 8002        |             |
| Eccentricity Square (e²)| 0.0068035               | 0.0066943   | −0.00010913 |
|                        | 1128                    | 8002        |             |

Table 3. Spheroidal differences between WGS 1984 and IGRS datum

| Datum                  | WGS 1984 | IGRS     | Differences  |
|------------------------|----------|----------|-------------|
| Spheroid               | WGS 1984 | GRS 1980 |             |
| Semi-major Axis (m)    | 6378137.0| 6378137.0| 0           |
|                        | 14140356 | 14140356 |             |
| Semi-minor Axis (m)    | 6356752.3| 6356752.3| −0.00010482 |
|                        | 14140356 | 14140356 |             |
| Inverse Flattening (m) | 298.25722| 298.25722| −0.0000014  |
|                        | 2101     | 2101     |             |
| Eccentricity Square (e²)| 0.0066943| 0.0066943| 0.000000000 |
|                        | 8002     | 8002     | 03          |
By using ArcGIS application, the satellite image has been georeferenced to WGS 1984 coordinate system. Then, the WGS 1984 geographic coordinate system has been transformed to the two coordinate systems: Karbala 1979 Polservice and IGRS. Thus, three coordinate systems are available WGS 1984, Karbala 1979 Polservice, and IGRS. The geographic coordinates of Karbala 1979 Polservice and IGRS are listed in Tables 4(a) and 4(b), respectively, while the latitude differences (DLat.) and longitude differences (DLong.) between these two coordinate systems are listed in Table 4(c). The mean of latitude and longitude differences between Karbala 1979 Polservice and IGRS are

| CP   | Latitude Karbala 1979 | Longitude Karbala 1979 |
|------|----------------------|------------------------|
|      | deg  min  sec        | deg  min  sec          |
| CP1  | 33  23  57.486 44   | 10  47.967             |
| CP2  | 33  25  40.614 44   | 15  43.309             |
| CP3  | 33  25  47.921 44   | 22  59.273             |
| CP4  | 33  24  56.024 44   | 29  48.253             |
| CP5  | 33  25  37.625 44   | 35  27.916             |
| CP6  | 33  22  25.944 44   | 26  37.533             |
| CP7  | 33  22  8.054 44    | 19  46.525             |
| CP8  | 33  21  40.642 44   | 14  14.616             |
| CP9  | 33  18  4.414 44    | 9   55.758             |
| CP10 | 33  18  9.510 44    | 15  26.752             |
| CP11 | 33  18  47.440 44   | 23  28.833             |
| CP12 | 33  19  10.082 44   | 29  11.123             |
| CP13 | 33  18  42.133 44   | 33  51.503             |
| CP14 | 33  16  17.452 44   | 30  45.802             |
| CP15 | 33  15  11.714 44   | 19  51.249             |
| CP16 | 33  13  7.095 44    | 11  18.642             |
| CP17 | 33  12  36.548 44   | 16  23.574             |
| CP18 | 33  11  48.908 44   | 22  56.794             |
| CP19 | 33  12  53.024 44   | 29  1.067              |
| CP20 | 33  12  38.554 44   | 34  11.240             |

| CP    | D Lat. | D Long. | CP    | D Lat. | D Long. |
|-------|--------|---------|-------|--------|---------|
| CP1   | −0.018 | −0   | CP11  | 0.013  | −0   |
|       | 11.237 | 11.200 |       | 11.189 | 11.189 |
| CP2   | −0.016 | −0   | CP12  | 0.022  | −0   |
|       | 11.231 | 11.189 |       | 11.178 | 11.178 |
| CP3   | −0.004 | −0   | CP13  | 0.030  | −0   |
|       | 11.216 | 11.180 |       | 11.180 | 11.180 |
| CP4   | 0.008  | 11   | CP14  | 0.031  | −0   |
|       | 11.200 | 11.199 |       | 11.199 | 11.199 |
| CP5   | 0.015  | 11   | CP15  | 0.017  | −0   |
|       | 11.189 | 11.186 |       | 11.186 | 11.186 |
| CP6   | 0.009  | 11   | CP16  | 0.010  | −0   |
|       | 11.201 | 11.212 |       | 11.212 | 11.212 |
| CP7   | 0.000  | 11   | CP17  | 0.019  | −0   |
|       | 11.214 | 11.201 |       | 11.201 | 11.201 |
| CP8   | −0.008 | −0   | CP18  | 0.031  | −0   |
|       | 11.225 | 11.186 |       | 11.186 | 11.186 |
| CP9   | −0.005 | −0   | CP19  | 0.037  | −0   |
|       | 11.226 | 11.175 |       | 11.175 | 11.175 |
| CP10  | 0.003  | −0   | CP20  | 0.046  | −0   |
|       | 11.215 | 11.164 |       | 11.164 | 11.164 |

Mean DLat. 0.012  Mean DLong. −11.202
0.01 second and −11.2 second, respectively, in the study area.

The transformations between the coordinate systems have been implemented using the Project tool in ArcGIS. Also, the Project tool has been used to convert between geographic and map coordinate systems. The geographic coordinates of Karbala 1979 Polservice datum with Clarke 1880 RGS spheroid, WGS 1984 datum with WGS 1984 spheroid, and IGRS datum with GRS 1980 spheroid are projected to UTM zone 38 north. The map coordinates of Karbala 1979 Polservice and IGRS are listed in Tables 5(a) and 5(b), respectively, while the northing differences (DN) and easting differences (DE) between these two coordinate systems are listed in Table 5(c).

### Table 5(a). Karbala 1979 Polservice map coordinates using ArcGIS

| CP  | Northing (m)  | Easting (m) |
|-----|---------------|-------------|
| CP1 | 3695578.491   | 423741.423  |
| CP2 | 3698697.321   | 431393.572  |
| CP3 | 3698849.034   | 442653.430  |
| CP4 | 3697193.956   | 453207.048  |
| CP5 | 3698436.614   | 461984.808  |
| CP6 | 3692597.211   | 448256.467  |
| CP7 | 3692108.820   | 437632.357  |
| CP8 | 3691323.622   | 429048.958  |
| CP9 | 3684715.915   | 422305.624  |
| CP10| 3684808.182   | 430866.977  |
| CP11| 3685895.511   | 443341.117  |
| CP12| 3686545.185   | 452195.542  |
| CP13| 3685651.505   | 459441.496  |
| CP14| 3681217.294   | 454618.749  |
| CP15| 3679286.609   | 437672.193  |
| CP16| 3675542.895   | 424378.084  |
| CP17| 3674544.122   | 432265.157  |
| CP18| 3673011.656   | 442436.457  |
| CP19| 3674934.971   | 451878.131  |
| CP20| 3674453.047   | 459905.755  |

### Table 5(b). IGRS map coordinates using ArcGIS

| CP  | Northing (m)  | Easting (m) |
|-----|---------------|-------------|
| CP1 | 3695857.112   | 423453.746  |
| CP2 | 3698975.944   | 431105.901  |
| CP3 | 3699127.657   | 442365.769  |
| CP4 | 3697472.578   | 452919.396  |
| CP5 | 3698715.237   | 461697.162  |
| CP6 | 3692875.829   | 447968.810  |
| CP7 | 3692387.438   | 437344.692  |
| CP8 | 3691602.239   | 428761.285  |
| CP9 | 3684994.526   | 422017.946  |
| CP10| 3685086.794   | 430579.306  |
| CP11| 3686174.124   | 443053.456  |
| CP12| 3686823.798   | 451907.889  |
| CP13| 3685930.117   | 459153.849  |
| CP14| 3681495.903   | 454331.097  |
| CP15| 3679565.216   | 437384.528  |
| CP16| 3675821.499   | 424090.408  |
| CP17| 3674822.725   | 431977.487  |
| CP18| 3673290.258   | 442148.796  |
| CP19| 3675213.575   | 451590.477  |
| CP20| 3674731.650   | 459618.108  |

### Table 5(c). Map coordinate differences between Karbala 1979 and IGRS using ArcGIS in meters

| CP  | DN  | DE  | CP  | DN  | DE  |
|-----|-----|-----|-----|-----|-----|
| CP1 | 278. | −287. | CP11| 278. | −287. |
|     | 621  | 677  |     | 613  | 661  |
| CP2 | 278. | −287. | CP12| 278. | −287. |
|     | 623  | 671  |     | 613  | 653  |
| CP3 | 278. | −287. | CP13| 278. | −287. |
|     | 623  | 661  |     | 612  | 647  |
| CP4 | 278. | −287. | CP14| 278. | −287. |
|     | 622  | 652  |     | 609  | 652  |
| CP5 | 278. | −287. | CP15| 278. | −287. |
|     | 623  | 646  |     | 607  | 665  |
| CP6 | 278. | −287. | CP16| 278. | −287. |
|     | 618  | 657  |     | 604  | 676  |
| CP7 | 278. | −287. | CP17| 278. | −287. |
|     | 618  | 665  |     | 603  | 670  |
| CP8 | 278. | −287. | CP18| 278. | −287. |
|     | 617  | 673  |     | 602  | 661  |
| CP9 | 278. | −287. | CP19| 278. | −287. |
|     | 611  | 678  |     | 604  | 654  |
| CP10| 278. | −287. | CP20| 278. | −287. |
|     | 612  | 671  |     | 603  | 647  |

Mean DN 278.613 m  Mean DE −287.662 m
On the other hand, the first program designed by MATLAB is used to transform the geographic coordinates obtained by ArcGIS to map coordinates. The resulted Karbala 1979 Polservice and IGRS map coordinates are listed in Tables 6(a) and 6(b), respectively, while the differences between these two coordinate systems are listed in Table 6(c). The results of using ArcGIS and MATLAB show that the mean of northing and easting differences between Karbala 1979 Polservice and IGRS coordinate systems are about 278.6 m and −287.6 m, respectively, in the study area. Also, the second program designed by MATLAB is used to convert the map coordinates to geographic coordinates. The resulted geographic coordinates coincide with ArcGIS results.

### Table 6(a). Karbala 1979 Polservice map coordinates using MATLAB

| CP  | Northing (m) | Easting (m) |
|-----|--------------|-------------|
| CP1 | 3695578.482  | 423741.430  |
| CP2 | 3698697.330  | 431393.575  |
| CP3 | 3698849.023  | 442653.439  |
| CP4 | 3697193.940  | 453207.051  |
| CP5 | 3698436.608  | 461984.809  |
| CP6 | 3692597.205  | 448256.469  |
| CP7 | 3692108.810  | 437632.344  |
| CP8 | 3691323.628  | 429048.970  |
| CP9 | 3684715.928  | 422305.630  |
| CP10| 3684808.176  | 430866.970  |
| CP11| 3685895.523  | 443341.119  |
| CP12| 3686545.180  | 452195.541  |
| CP13| 3685651.499  | 459441.496  |
| CP14| 3681217.283  | 454618.760  |
| CP15| 3679286.613  | 437672.189  |
| CP16| 3675542.882  | 424378.072  |
| CP17| 3674544.127  | 432265.149  |
| CP18| 3673011.645  | 442436.464  |
| CP19| 3674934.973  | 451878.126  |
| CP20| 3674453.042  | 459905.755  |

### Table 6(b). IGRS map coordinates using MATLAB

| CP  | Northing (m) | Easting (m) |
|-----|--------------|-------------|
| CP1 | 3695857.117  | 423453.752  |
| CP2 | 3698975.934  | 431105.890  |
| CP3 | 3699127.669  | 442365.769  |
| CP4 | 3697472.571  | 452919.389  |
| CP5 | 3698715.247  | 461697.172  |
| CP6 | 3692875.815  | 447968.810  |
| CP7 | 3692387.437  | 437344.691  |
| CP8 | 3691602.229  | 428761.296  |
| CP9 | 3684994.534  | 422017.956  |
| CP10| 3685086.779  | 430579.298  |
| CP11| 3686174.112  | 443053.450  |
| CP12| 3686823.812  | 451907.878  |
| CP13| 3685930.125  | 459153.847  |
| CP14| 3681495.891  | 454331.089  |
| CP15| 3679565.205  | 437384.537  |
| CP16| 3675821.487  | 424090.414  |
| CP17| 3674822.733  | 431977.484  |
| CP18| 3673290.254  | 442148.802  |
| CP19| 3675213.572  | 451590.489  |
| CP20| 3674731.661  | 459618.117  |

In Baghdad city, the relationships between Karbala 1979 Polservice and IGRS for both geographic and map coordinate systems have been concluded from the differences in latitudes, longitudes, northings and eastings, as illustrated in Equation 1, Equation 2, Equation 3, and Equation 4. These equations can be used to convert the coordinate systems of Karbala 1979 Polservice to IGRS and vice versa within the study area in Baghdad, Iraq. Figure 4, Figure 5, Figure 6 and Figure 7 show latitude, longitude, northing and easing differences between Karbala 1979 Polservice and IGRS coordinate systems, respectively.

For both Karbala 1979 Polservice and IGRS, the map coordinate differences between ArcGIS and
MATLAB results are about (−16 mm to 14 mm) in northing and about (−13 mm to 12 mm) in easting as represented in Figure 8, Figure 9, Figure 10, and Figure 11. The latitude differences and longitude differences between ArcGIS and MATLAB results are equal to zero. In addition, the WGS 1984 is approximately superposed to IGRS and the distinctions between them are negligible within the accuracy limits of coordinate conversion.

\[
\text{Latitude}_{\text{IGRS}} = \text{Latitude}_{\text{Karbala 1979}} + 0.01_{\text{sec}} \quad (1)
\]

\[
\text{Longitude}_{\text{IGRS}} = \text{Longitude}_{\text{Karbala 1979}} - 11.2_{\text{sec}} \quad (2)
\]

\[
\text{North}_{\text{IGRS}} = \text{North}_{\text{Karbala 1979}} + 278.6_{\text{m}} \quad (3)
\]

\[
\text{East}_{\text{IGRS}} = \text{East}_{\text{Karbala 1979}} - 287.6_{\text{m}} \quad (4)
\]
Conclusions

The following findings can be concluded:

1. ArcGIS application is capable of implementing different coordinate transformations. The accuracy of these transformations is adequate for most map production and updating in addition to the facility and rapidity in execution. ArcGIS can provide and save all types of geodatabases flexible for updating and printing in different scales, projections, and coordinate systems.

2. The coordinate discrepancies between Karbala 1979 Polservice and IGRS are about 278.6 m, −287.6 m, 0.01 second, and −11.2 second in northing, easting, latitude, and longitude, respectively. The distinction between WGS 1984 and IGRS coordinates are negligible. The WGS 1984 is equivalent to IGRS within the accuracy limits of coordinate conversion.

3. For both Karbala 1979 Polservice and IGRS, the differences in map coordinates between ArcGIS and MATLAB results are about (−16 mm to 14 mm) in northing and about (−13 mm to 12 mm) in easting. Also, the latitude differences and longitude
differences between ArcGIS and MATLAB results are equal to zero.

7. Recommendation

There are different coordinate systems used in Iraq resulted from different geodetic networks. Some of these geodetic networks such as Nahrwan 1934 and Nahrwan 1967 are completely cancelled in Iraq. Others like Karbala 1979 Polservice network is still used in some projects. The user should take into account coordinate discrepancies before the work. Up to date, some of available maps and documents in Iraq offices and departments have been printed in Karbala 1979 Polservice with Clarke 1880 RGS coordinate system. These maps must be updated and adopted a uniform coordinate system such as IGRS.

Acknowledgements

The author would like to thank Mustansiriyah University (www.uomustansiriyah.edu.iq) Baghdad–Iraq for its support in the present work.

Conflict of interest

The author confirms that the publication of this article causes no conflict of interest.

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Appendix – A

The first program and the second program designed by MATLAB are illustrated in Fig. A-1 and Fig. A-2, respectively.

```matlab
%This Program transforms Phi,Lambda %into N,E using UTM Projection clear;clc;
LD=input('lambda in degree=');
LM=input('lambda in minute=');
LS=input('lambda in second=');
LAM=LD+LM/60+LS/3600;
LAM=LAM*pi/180;
LDo= input ('lambdao in degree=');
LMo= input ('lambdao in minute=');
LSo= input ('lambdao in second=');
LAMo=LAMo*pi/180;
PDo= input('Phio in degree=');
PMo= input('Phio in minute=');
PSo= input('Phio in second=');
Phio=Phio*pi/180;
a1=1
a2=3*e2/8+3*e4/32+45*e6/1024;
a3=151*e1/96;
a4=35*e6/3072;
a5=a*(a1*Phi)- (a2*sin(2*Phi))+ ... 
(a3*sin(4*Phi))- (a4*sin(6*Phi]));
if (Phi == -pi/2) (Phi == pi/2)
x=0; y=0; M=Mo; N=No; K=Ko;
else
XX=Ko*N*(A^3) + (5-18*T^2+72*C-58*ep2)*A^5)/120;
X=XX+500000
Y=Ko*(M-Mo+N*tan(Phi))*(A^2)/2 + ... 
(5+4*T^2+4*C^2)*(A^4)/24 + (61+58*T^2+ ... 
T^2+600*C-330*ep2)*A^6)/720); 
end
```

**Figure A-2.** Program listing for the transformation of northing and easting to latitude and longitude

**Figure A-1.** Program listing for the transformation of latitude and longitude to northing and easting