Lands Department
Survey and Mapping Office
Geodetic Survey Section

Suggested Procedure of Using Leica LGO Software for Transforming GPS Surveyed Height (Ellipsoidal Height) to Local Height (Height above HKPD) within a Small Local Area

Introduction

In GPS surveys, the surveyed coordinates are in the World Geodetic System 1984 (WGS84) which is a geocentric and earth-fixed coordinates system, and are expressed in terms of geodetic coordinates (i.e. latitude, longitude and ellipsoidal height) or Cartesian coordinates (i.e. geocentric X, Y and Z). In other words, the height value obtained by using GPS is ellipsoidal height which is the height above the WGS84 reference ellipsoid rather than the orthometric height (or height above the geoid surface).

However, the levelling data we used in daily surveying and engineering works is in orthometric height which is the height value referenced to an equi-potential surface called geoid surface. It is therefore one of the main issues to handle in GPS heighting is to transform the GPS surveyed ellipsoidal height to orthometric height (i.e. height above HKPD) in an effective manner.

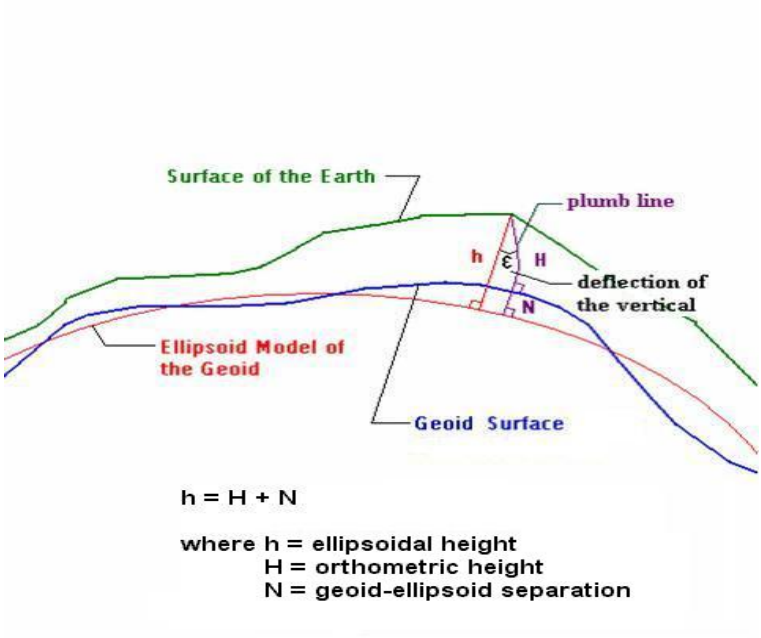


Figure 1 : Relationship between ellipsoidal height and orthometric height

This document outlines the procedures of creating a localized height transformation parameter file for establishing height transformation relationship to transform the GPS surveyed ellipsoidal height to HKPD height within in a small local area (say 15km x 15km or the less) by the use of Leica LGO Version 3.0 software.

Data of Height Model of Hong Kong

In order to create the localized height transformation parameter file for transforming the GPS surveyed ellipsoidal height to HKPD height, a set of control points comprising the WGS84 geodetic coordinates and the HKPD height values is surveyed and maintained by the Geodetic Survey Section of SMO, Lands Department. Users can use this set of height model control point data to establish the height transformation relationship of their project within a local small area.

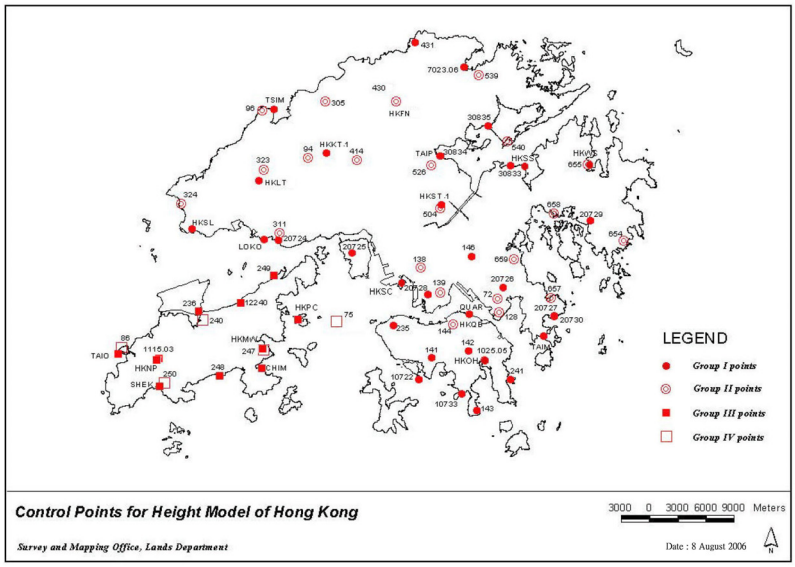


Figure 2 : The distribution plan of the control points for height model of Hong Kong (as at 8 August 2006)

The coordinates list and the control point distribution plan can be obtained from the Geodetic Survey Section of SMO, Lands Department and/or downloaded from the Internet at www.geodetic.gov.hk.

General Procedures

1) Identify at least 4 height model control points surrounding/ within the project area.

2) The selected control points must have the following coordinate information:
   - ITRF96 Geodetic Coordinates (i.e. Latitude, Longitude & Ellipsoidal Height)
   - Height above Hong Kong Principal Datum (i.e. Orthometric Height)

3) The HK1980 Grid Coordinates (i.e. Northing and Easting) of the control points **must** be transformed from the ITRF96 Geodetic Coordinates listed on the coordinate list of the height model of Hong Kong by the use of the 7-P parameters published by the Geodetic Survey Section of SMO.

4) Prepare one ITRF96 Geodetic Coordinates data file for the selected control points in LGO.

5) Prepare another LGO data file for the data of Height above Hong Kong Principal Datum and HK1980 Grid Coordinates of the selected control points.

6) Use the **"Two Step"** transformation model of the **[Datum and Map]** module of Leica LGO Version 3.0 to fit the localized height transformation parameters for height transformation between GPS Height and Local Height.

7) Save the height transformation relationship in a localized height transformation parameter file of LGO.

8) The localized height transformation parameter file can be imported into any Computer with Leica LGO Version 3.0 software and any Leica GPS System 500/1200 Rover for carrying out height transformation for post-processing or real-time positioning.

9) In order to ensure the effectiveness of the localized height transformation parameter file, testing points with HKPD height data within the project area should be surveyed by GPS method. Then the transformed orthometric height values of the testing points should be compared with the known HKPD height data to confirm the workability and accuracy of the localized height transformation relationship before formally use of the localized height transformation parameter file for the project area.

"Two Step" Transformation Approach

This transformation approach is developed by Leica Geosystem Ltd. and is bundled in the Leica LGO software. It works by treating the position and height transformation separately. Knowledge of the local map projection and the local ellipsoid is required for the part of position transformation. The height transformation is a single dimension height approximation.

For position transformation, the WGS84 Coordinates are first transformed to Preliminary Local Cartesian Coordinates using a Classical 3D Pre-transformation. These Preliminary Local Cartesian Coordinates are then projected onto a preliminary plane grid using the specified ellipsoid and the known map projection method. With the use of the preliminary plane grid coordinates and the "Real" local grid coordinates, parameters of the Classical 2D Transformation (i.e. 2 shifts, 1 rotation and 1 scale factor) can be calculated by the least square adjustment. Hence, the transformation relationship between the preliminary plane grid coordinates and the "Real" local grid coordinates can be established for use.

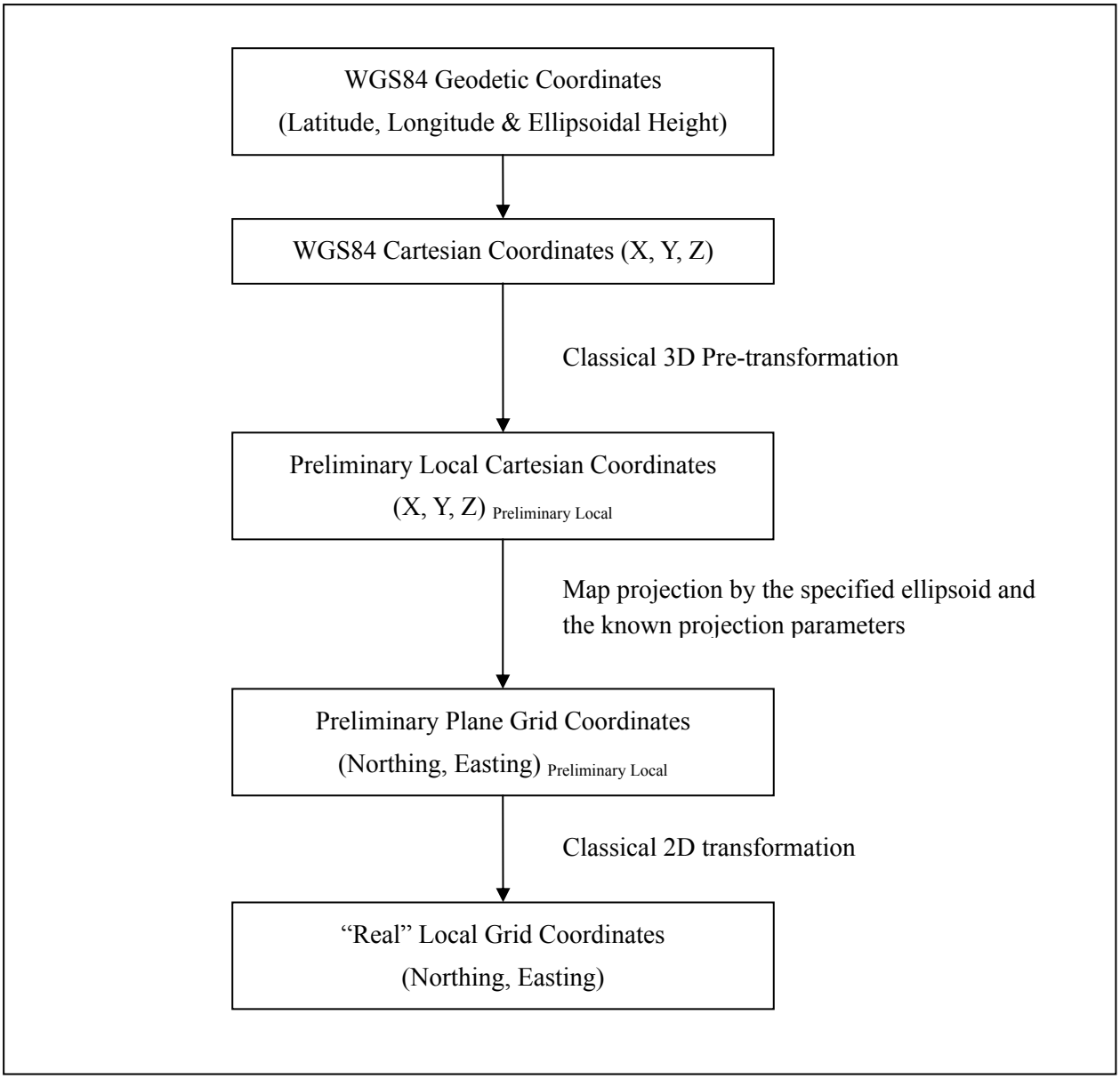


Figure 3 : Workflow of Position Transformation in Two Step Approach

For the height transformation, it is a single dimension height approximation. All the height common points have ellipsoidal heights and orthometric heights. The geoid-ellipsoid separation at each common point position can be easily obtained by the formula shown in Figure 1. Figure 4 illustrates an example of the distribution of geoid-ellipsoid separations in a small local area. Based on the distribution of geoid-ellipsoid separations, a flat plane can be fitted for the approximation of the geoid-ellipsoid separation within the small local area (see Figure 5).

With the approximated value of geoid-ellipsoid separation, ellipsoidal height of a point within the local area can be transformed to orthometric height via the formula shown in Figure 1.

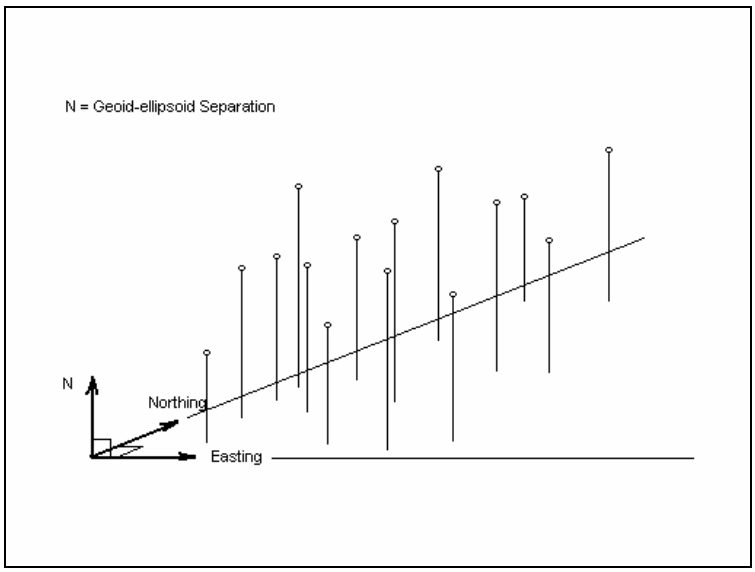


Figure 4 : Distribution of geoid-ellipsoid separation within a small local area

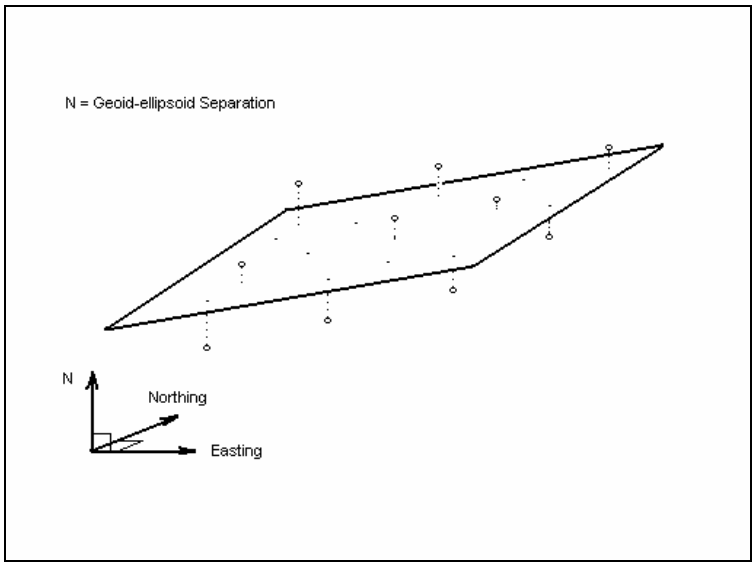


Figure 5 : A flat plane is fitted to represent the geoid-ellipsoid separation of the small local area

Advantages of “Two Step” Transformation

- Errors in local heights (i.e. orthometric height) do not affect the accuracy of position transformation.

- The points used for determining the position and height transformation do not necessarily have to be the same points.

- The distortion effects of the map projection are taken into account in the position transformation which enables us to use this transformation approach for position transformation for larger areas.

- “7-P parameters” published by the Geodetic Survey Section of SMO can be directly used for the classical 3D pre-transformation of the GPS surveyed coordinates in the “Two Step” approach. Hence, the position transformation results (i.e. Northing and Easting) of the “Two Step” transformation can be obtained exactly the same as that of the normal 7-P 3D transformation which we normally use.

Disadvantages of “Two Step” Transformation

- Knowledge of the local projection and local ellipsoid are required. (However, it is not a disadvantage in Hong Kong because the local projection and local ellipsoid of Hong Kong are known.)

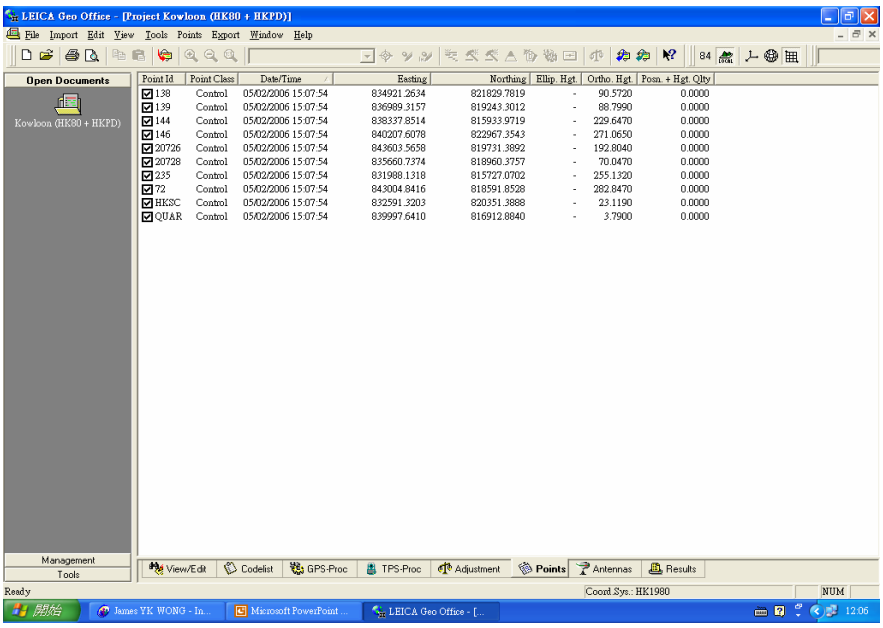
Technical Steps

1) Identify at least 4 height model control points surrounding/ within the project area.

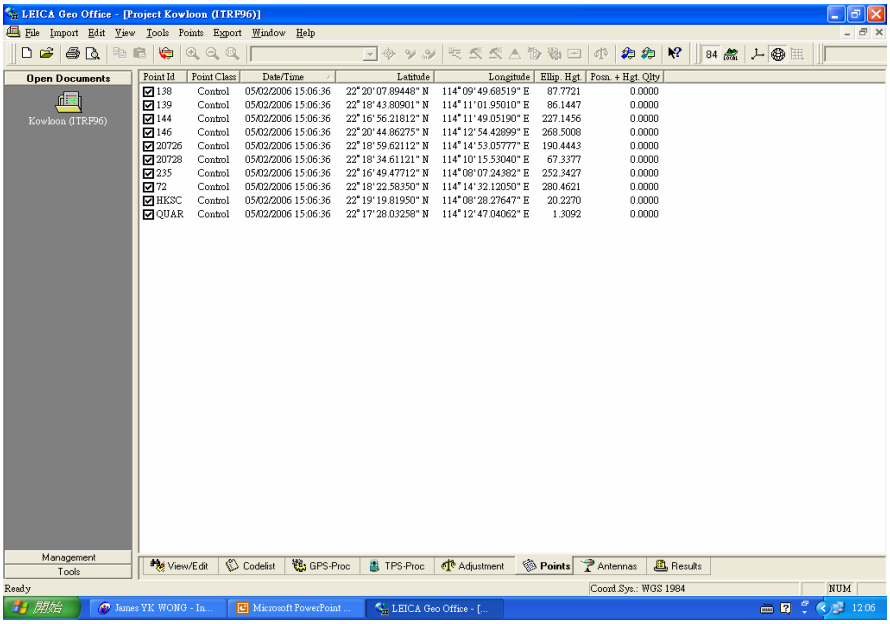
2) The selected control points must have the following coordinate information:
   - ITRF96 Geodetic Coordinates (i.e. Latitude, Longitude & Ellipsoidal Height)
   - Height above Hong Kong Principal Datum (i.e. Orthometric Height)

3) Transform the ITRF96 Geodetic Coordinates of the selected control points into HK1980 Grid Coordinates (i.e. Northing and Easting) by the use of the 7-P parameters published by the Geodetic Survey Section of SMO, which can be downloaded from the Internet at www.geodetic.gov.hk.

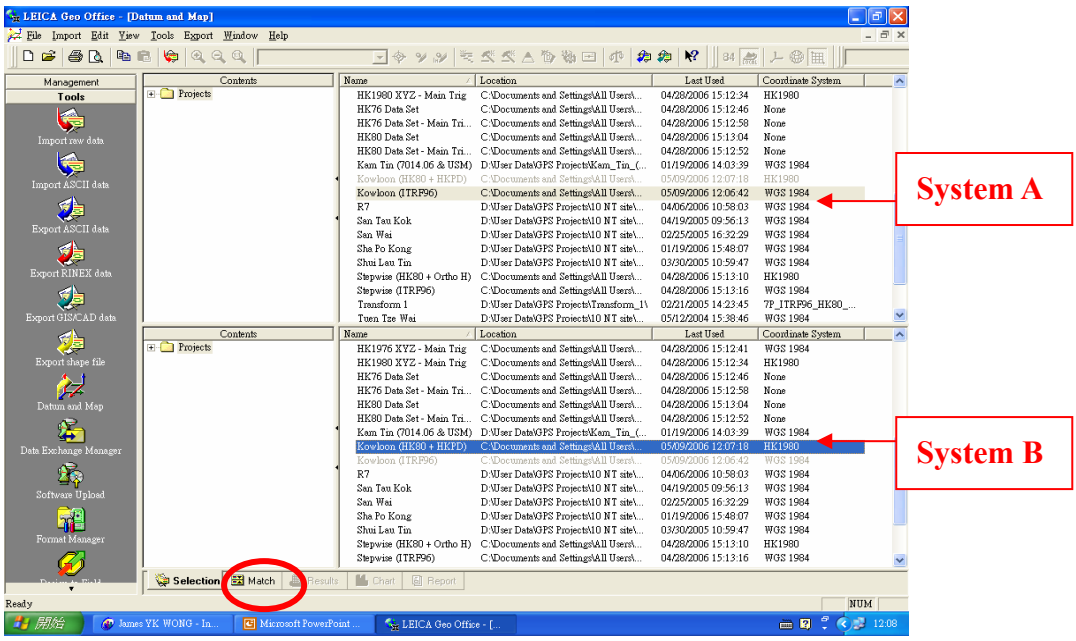
4) Open one LGO project for storing the data of HK1980 Grid Coordinates (Northing, Easting) and height above HKPD (HKPD Height) of the selected control points.



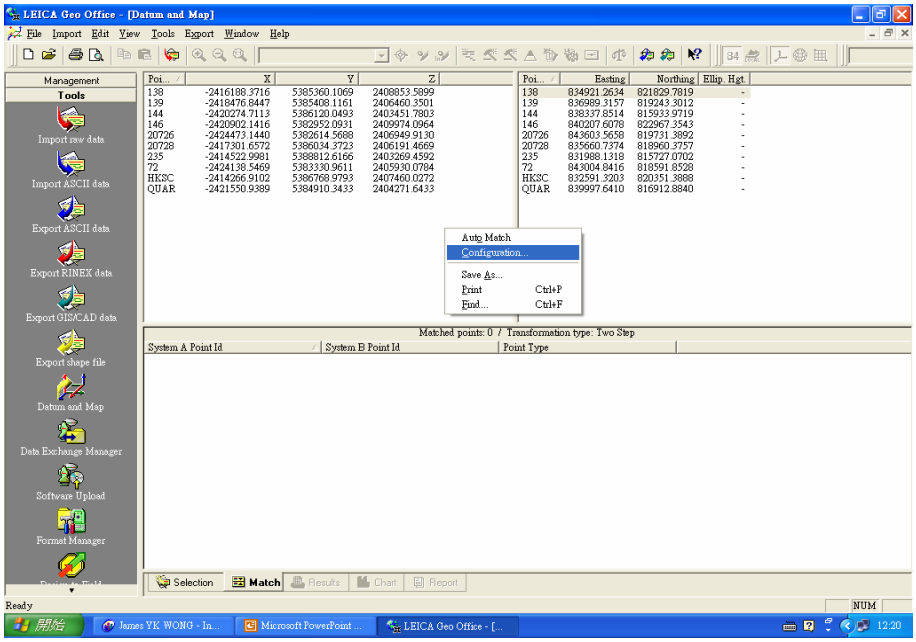
5) Open another LGO project for storing the data of ITRF96 Geodetic Coordinates (Latitude, Longitude & Ellipsoidal Height) of the selected control points.



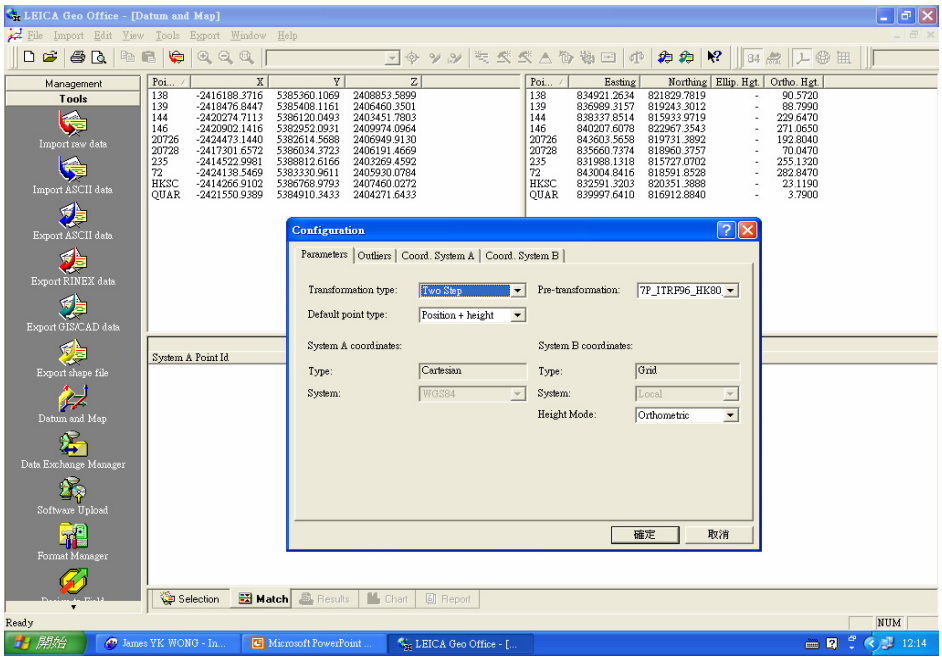
6) Run LGO, click **"Tools"** and **"Datum/Map"** function. Then select the LGO project with ITRF96 Geodetic Coordinates as System A and the LGO project with HK1980 Grid Coordinates & Height above HKPD as System B respectively.



7) Click the Tab **"Match"** to go to next page and then right click the mouse to select **"Configurations"**.

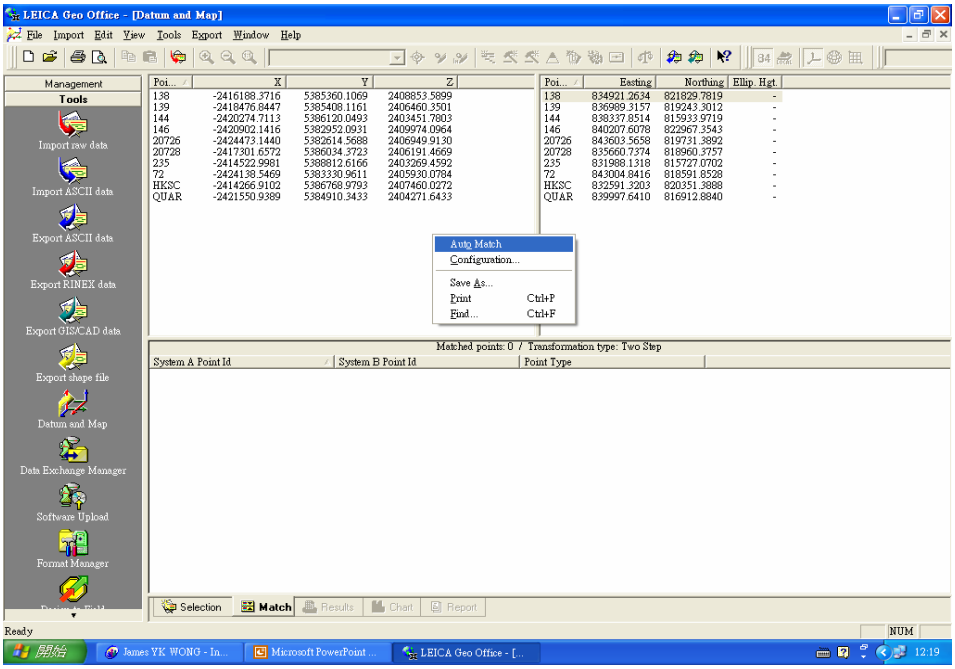


8) Select **"Two Step"** as transformation type and input the ***"7-P parameters published by the Geodetic Survey Section of SMO"*** as the Pre-transformation Parameter set.

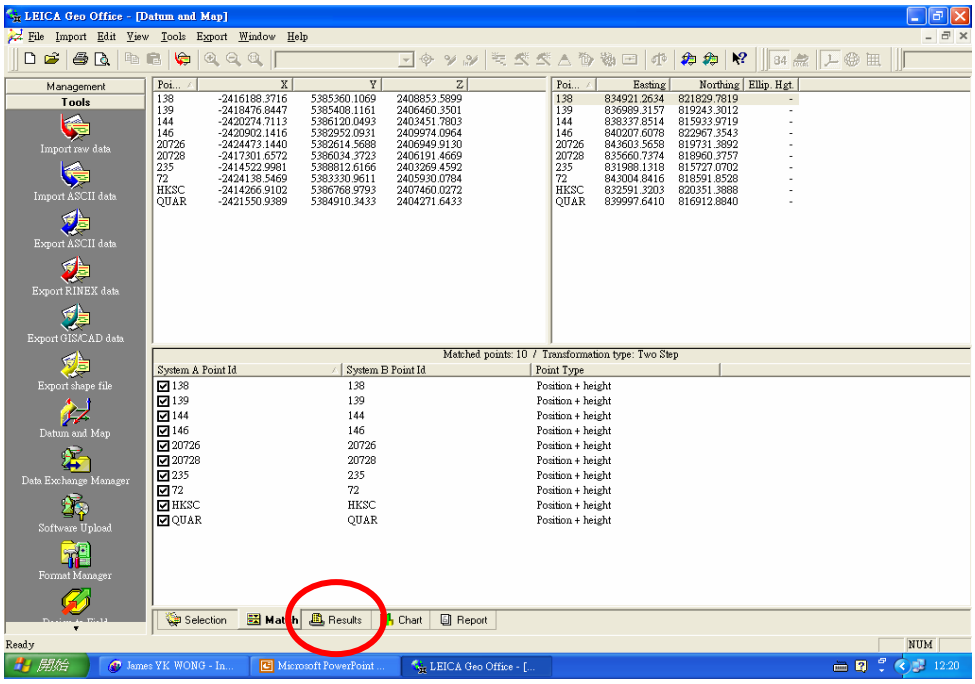


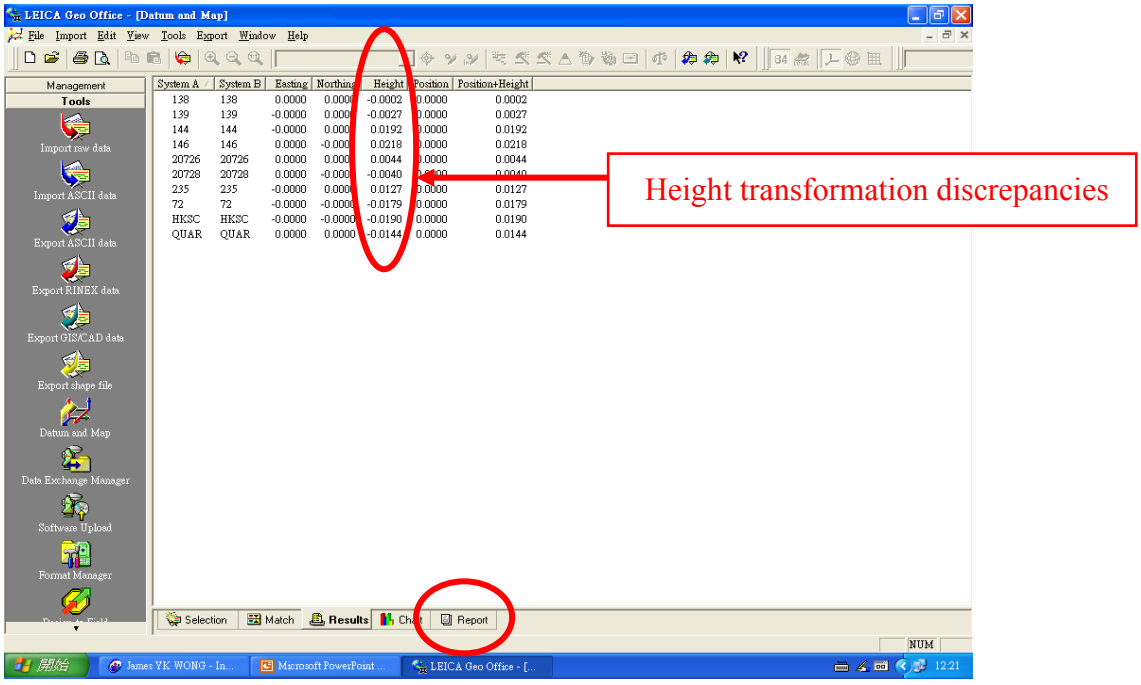
After setting the appropriate options, click **"Confirm"** to quit this dialogue box.

9) Right click the mouse and select **"Auto Match"** to process the data.

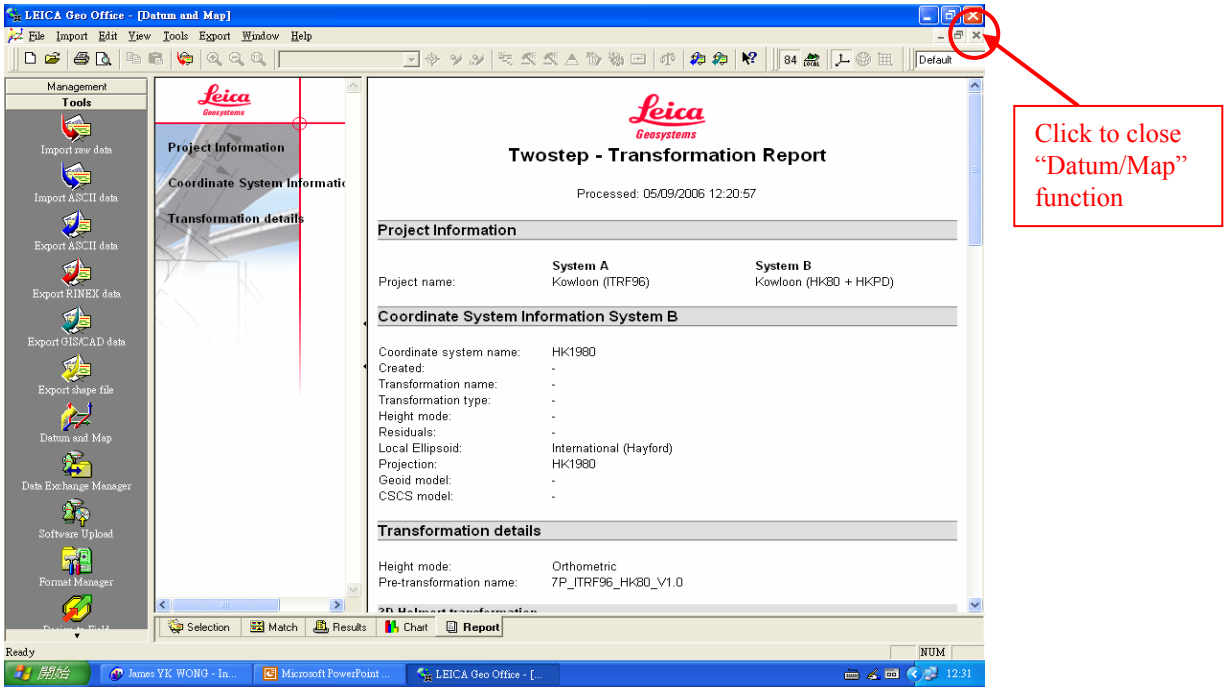


10) Click the Tab **"Results"** to see the resulted height transformation discrepancies for confirming the effectiveness of the height transformation after transformation parameter fitting.

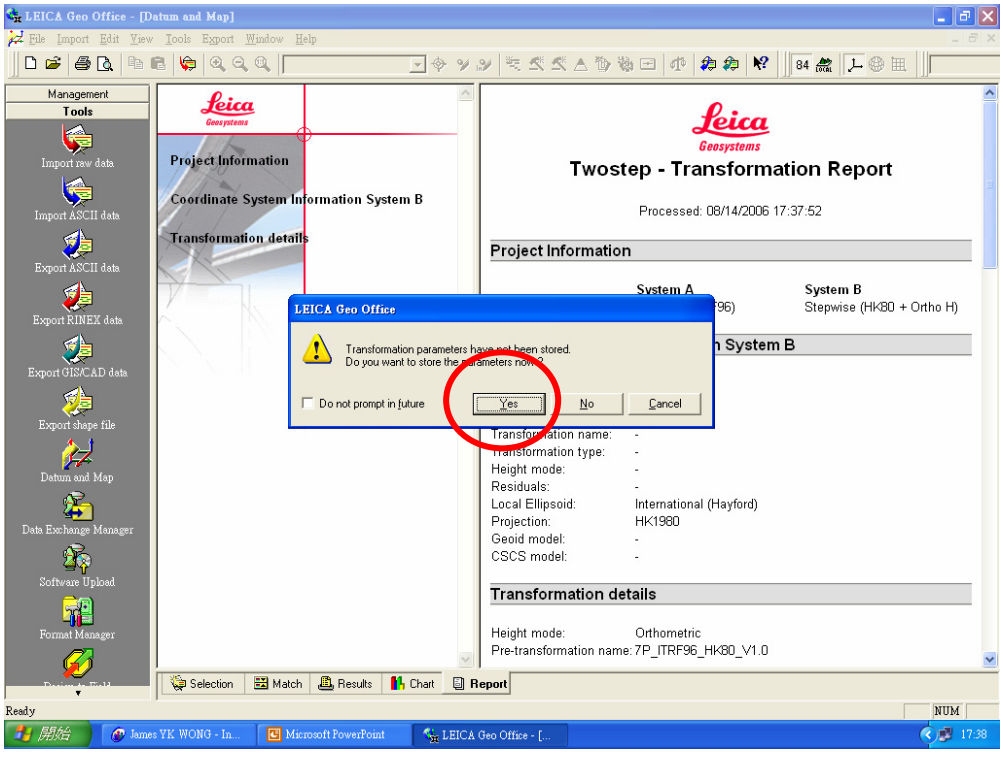


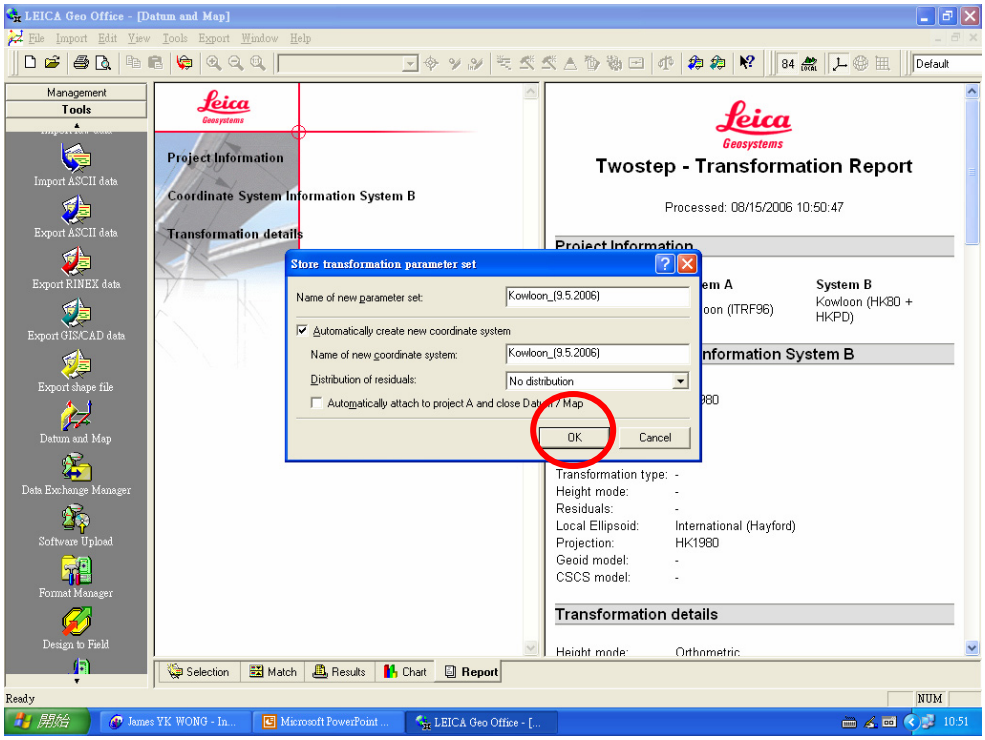


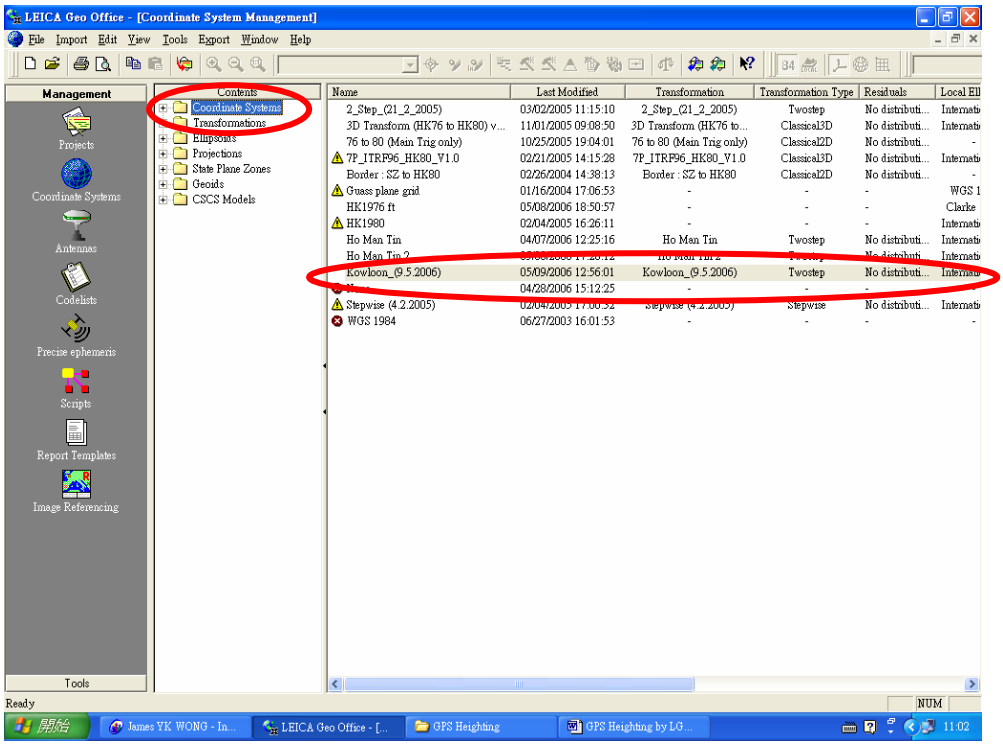
11) Also, you can click the Tab **"Report"** to generate a Transformation Report for detailed result evaluation and record keeping. A sample of the Transformation Report is attached at Appendix I for general reference.



12) If the transformation discrepancies of all control points are acceptable, click the "x" button to close the "Datum/Map" function. Then follow the instructions shown on screen to save the resulted transformation relationship and parameter set into a localized "Coordinate System" of LGO.

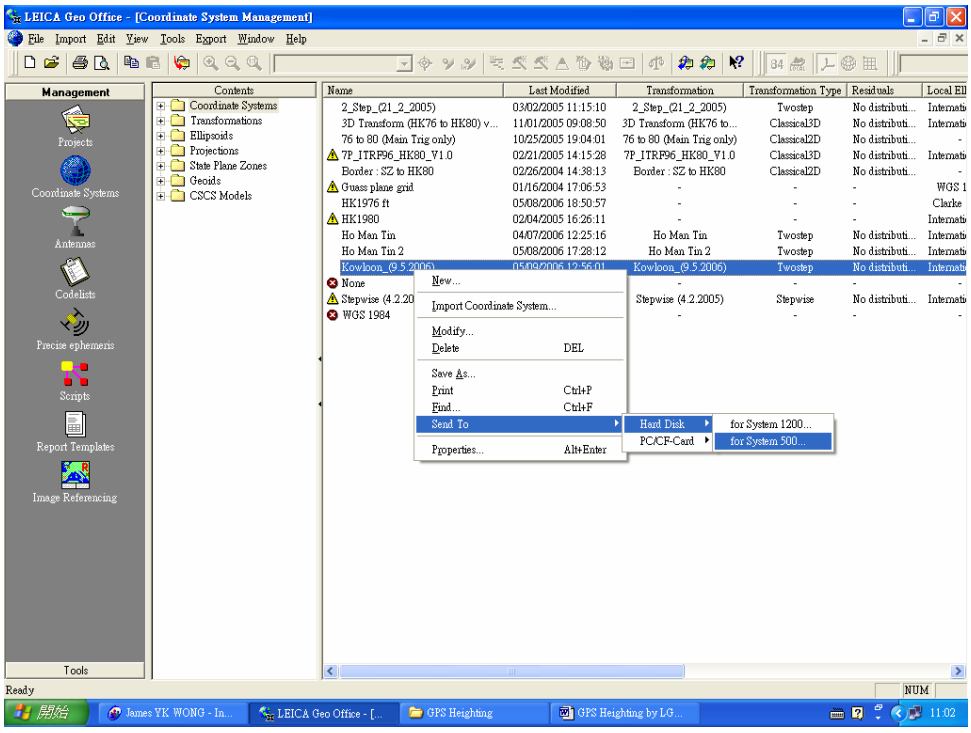






13) Now, the resulted localized “Coordinate System” can be used in this LGO computer for carrying out localized coordinates and height transformation.

14) If you want to export the localized “Coordinate System” to other LGO computer or other Leica GPS rover for coordinate and height transformation, you should move the cursor to point to the required “Coordinate System” shown on the coordinate system list and right click the mouse. Then select **“Send To” → “Hard Disk”** to create a localized coordinate and height transformation parameter file.



15) As a result, a localized coordinate and height transformation parameter file called **“TRFSET.DAT”** or **“GPSTRF.DAT”** is produced for storing the coordinate transformation relationships and their transformation parameters. By the use of this transformation parameter file, the plane grid coordinates and height transformations can be carried out simultaneously by Leica LGO/ SKIPro software or Leica GPS rovers.

16) Users can import this transformation parameter file into any computer with Leica LGO/ SKIPro software for coordinate and height transformations in office.

17) Users can also import this transformation parameter file into Leica GPS System 500/1200 receivers for RTK/ DGPS surveys in real-time basis on site.

18) In order to ensure the effectiveness of the localized coordinate and height transformation parameter file, testing points with HKPD height data within the project area should be

surveyed by GPS method. Then the surveyed ellipsoidal height values of the testing points should be transformed to orthometric height values by the use of the localized coordinate and height transformation parameter file. The transformed orthometric height values should be compared with the known HKPD height data to confirm the workability and accuracy of the localized height transformation relationship before formally use of the localized height transformation parameter file for the project area.

Remarks

1) This procedure is suitable for establishing GPS height transformation relationship within small local area (say 15 km x 15 km area). Please note that a flat plane cannot fully represent the actual geoid-ellipsoid separations in large area. If the geoid undulation is large at the subject area, the area over which the transformation is carried out should be reduced.

2) Checking points should be provided to test the transformation effectiveness and accuracy of the established height transformation relationship and parameters before formally use.

- END -

Prepared by : Geodetic Survey Section, SMO, Lands Department
Date : 1 September 2006

Appendix I

A sample of the Transformation Report

Twostep - Transformation Report

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Project Information

	System A	System B
Project name:	Kowloon (ITRF96)	Kowloon (HK80 + HKPD)

Coordinate System Information System B

Coordinate system name:	HK1980
Created:	-
Transformation name:	-
Transformation type:	-
Height mode:	-
Residuals:	-
Local Ellipsoid:	International (Hayford)
Projection:	HK1980
Geoid model:	-
CSCS model:	-

Transformation details

Height mode:	Orthometric
Pre-transformation name:	7P_ITRF96_HK80_V1.0

3D-Helmert transformation

Number of common points:	10
Transformation model:	Bursa-Wolf

No.	Parameter	Value
1	Shift dX	162.6190 m
2	Shift dY	276.9610 m
3	Shift dZ	161.7630 m
4	Rotation about X	0.06774 "
5	Rotation about Y	-2.24365 "
6	Rotation about Z	-1.15883 "
7	Scale	1.0942 ppm

2D-Helmert transformation

Number of common points:	10	
Sigma a priori:	1.0000	
Sigma a posteriori:	0.0000	
Rotation origin:	X0:	819024.9370 m
	Y0:	837730.2276 m

No.	Parameter	Value	rms
1	dE	0.0000 m	0.0000 m
2	dN	0.0000 m	0.0000 m
3	Rotation	0° 00' 00.00030"	0° 00' 00.00038"
4	Scale	0.0003 ppm	0.0018 ppm

Height transformation

Number of common points:	10		
Mean transformation accuracy:	0.0166 m		
Parameters:	-0.00000129	-0.00000402	-0.0477 m
Inclination of height in X:	-0° 00' 00.26608"		
Inclination of height in Y:	-0° 00' 00.82918"		

Residuals

Grid:

System A	System B	Point type	dE [m]	dN [m]	dHgt [m]
138	138	Position + height	0.0000 m	0.0000 m	-0.0002 m
139	139	Position + height	0.0000 m	0.0000 m	-0.0027 m
144	144	Position + height	0.0000 m	0.0000 m	0.0192 m
146	146	Position + height	0.0000 m	0.0000 m	0.0219 m
20726	20726	Position + height	0.0000 m	0.0000 m	0.0044 m
20728	20728	Position + height	0.0000 m	0.0000 m	-0.0040 m
235	235	Position + height	0.0000 m	0.0000 m	0.0127 m
72	72	Position + height	0.0000 m	0.0000 m	-0.0179 m
HKSC	HKSC	Position + height	0.0000 m	0.0000 m	-0.0190 m
QUAR	QUAR	Position + height	0.0000 m	0.0000 m	-0.0144 m

Graphical overview: