WORKSHOP ON THE APPLICATION OF GLOBAL NAVIGATION SATELITE SYSTEMS

Suva, Fij
August 24-28, 2019

UNITED NATIONS
Office for Outer Space Affairs

Linking the Different Coordinate Systems in the Philippines using GNSS

L.P. Balicanta Y.F. Pagdonsolan & J.L.D. Fabila

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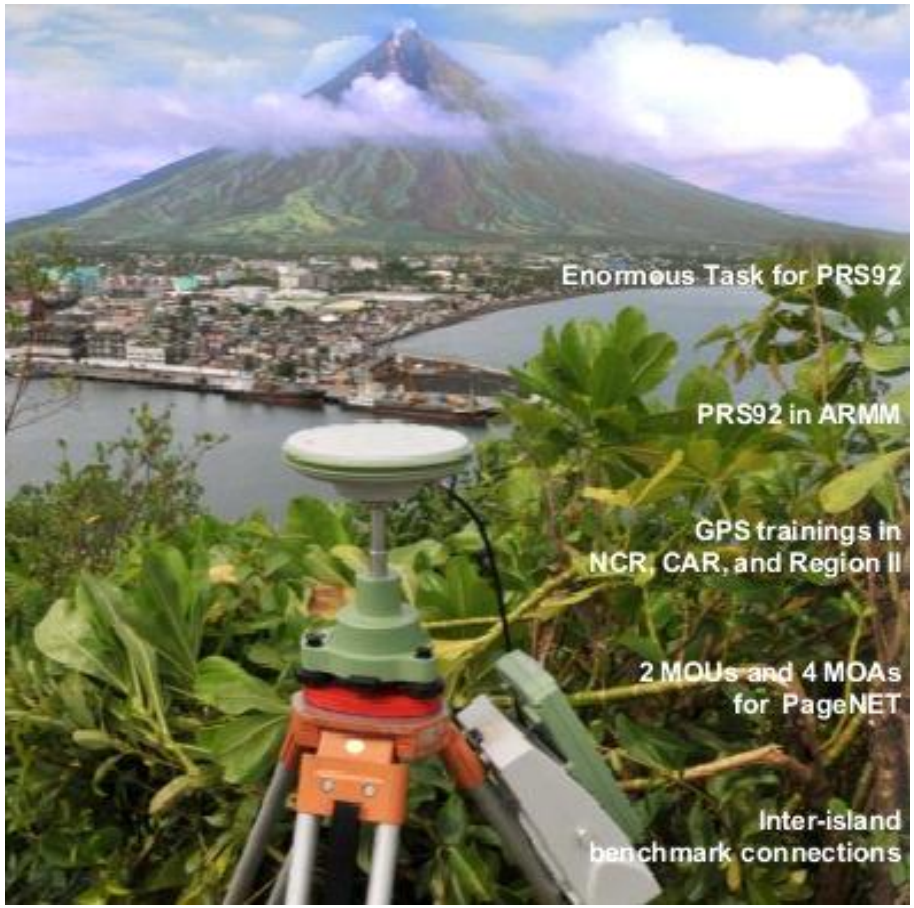
LAND MEASUREMENT

- Essential to Urbanization

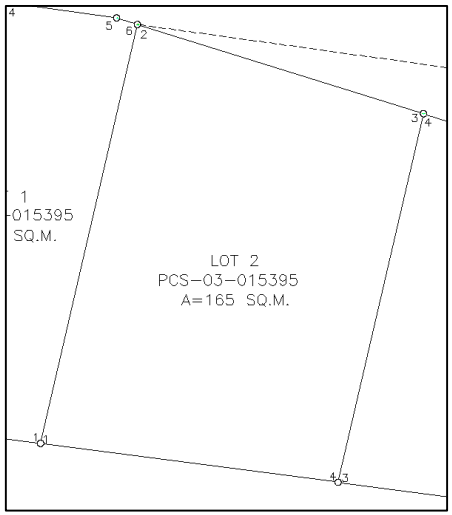


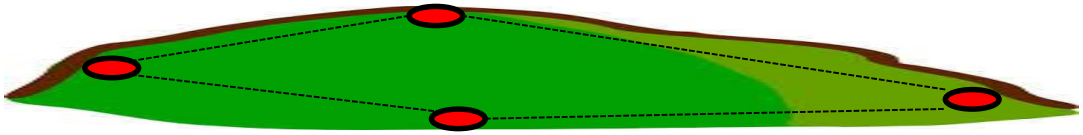
https://www.yumpu.com/en/document/read/48819103/namria-commences-inter-island-benchmark-connections

Frederick Seitz

PROPERTY SURVEYING

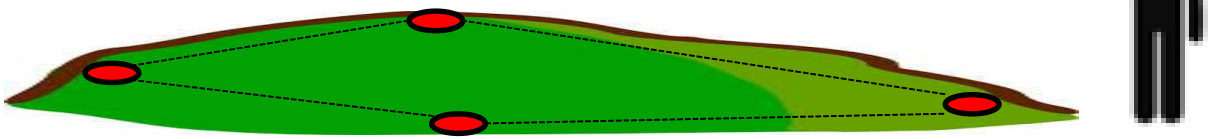
TECHNICAL DESCRIPTION		
LINES	BEARINGS	DISTANCES (m.)
LOT 2 PCS-03-015395		
1-2	N. 13° 00' E.	15.91
2-3	S. 72° 40' E.	11.07
3-4	S. 13° 03' W.	14.00
4-1	N. 82° 32' W.	11.08
Tie-line from BLLM No. 1 CAD 334, Guiguinto Cadastre to corner 1: N. 44° 21' E. 1,847.06 m.		





COORDINATE REFERENCE SYSTEMS

- **Local Plane Coordinate System? Pre 1960s**
- **PPCS-TM/ Luzon 1911? 1960s to 1980s**
- **PPCS-TM/PRS92? 1990s onwards**



NRMDP 89

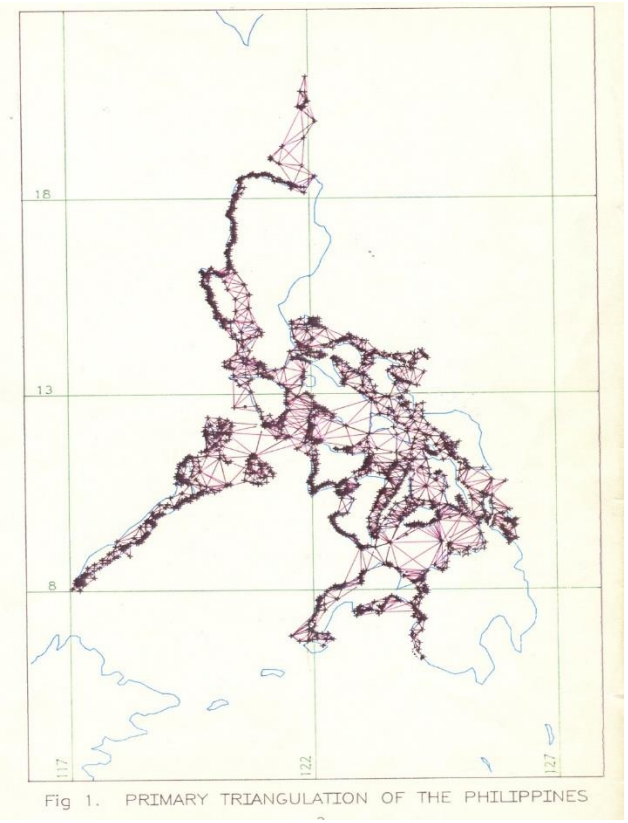


Fig 1. PRIMARY TRIANGULATION OF THE PHILIPPINES

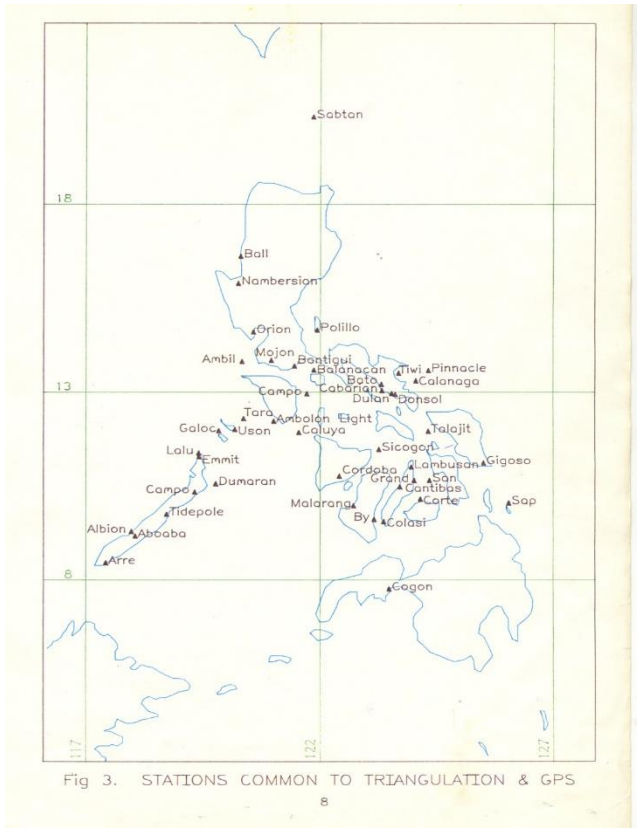


Fig 3. STATIONS COMMON TO TRIANGULATION & GPS

8

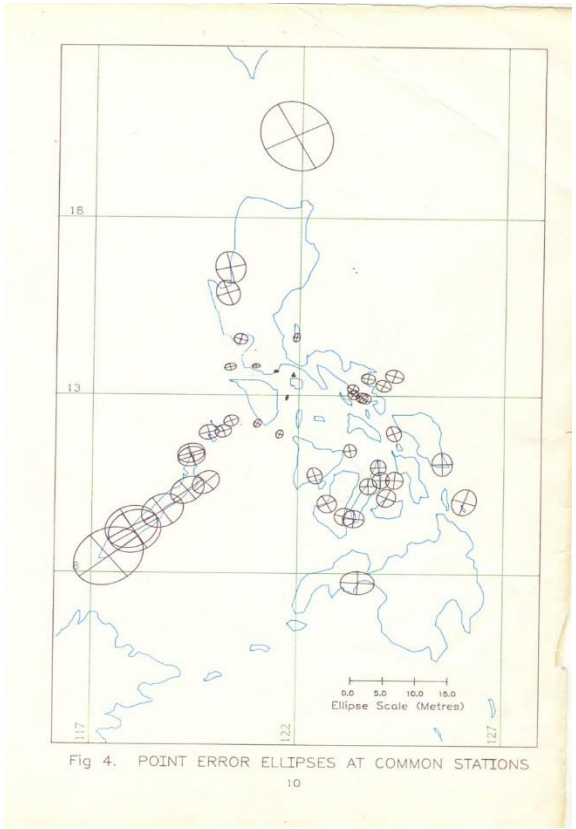
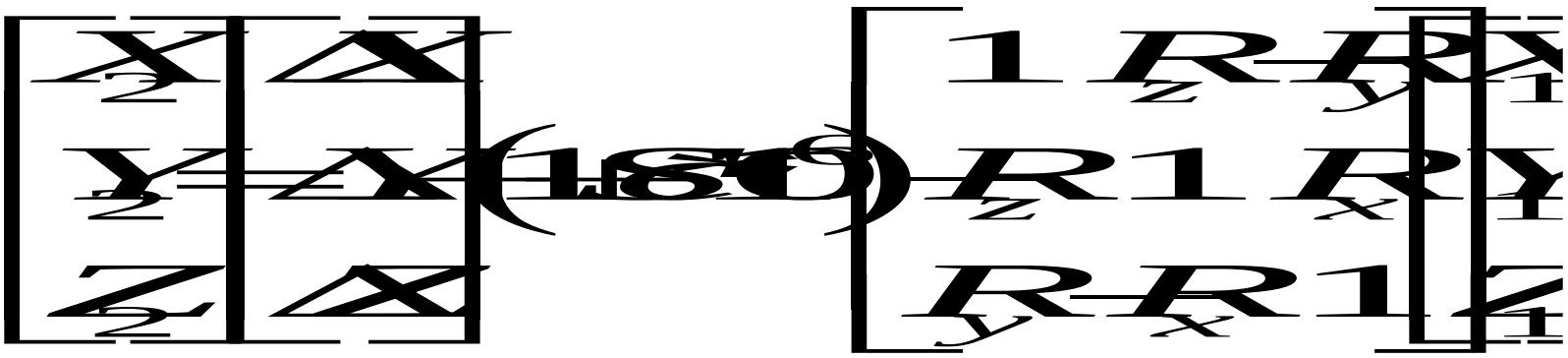


Fig 4. POINT ERROR ELLIPSES AT COMMON STATIONS

10

NRMDP 89

Relationship of WGS84 and PRS92



Transformation from PRS92 to WGS84

$\Delta X = -127.62195$ m

$\Delta Y = -67.24478$ m

$\Delta Z = -47.04305$ m

In arc seconds

$R_x = 3.06762$

$R_y = -4.90291$

$R_z = -1.57790$

Sc = -1.060020000000

PGRS MODERNIZATION

2/23/2016

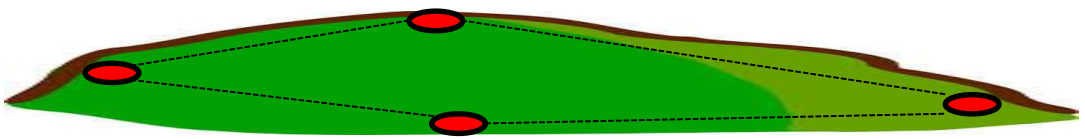
Modernization of the
PHILIPPINE GEODETIC REFERENCE SYSTEM

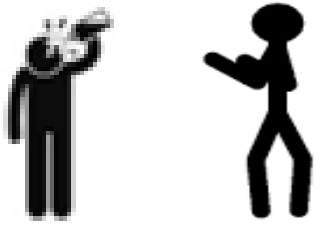
STRATEGIC PLAN 2016-2020

COORDINATE REFERENCE SYSTEMS

- **Local Plane Coordinate System? Pre 1960s**
- **PPCS-TM/ Luzon 1911? 1960s to 1980s**
- **PPCS-TM/PRS92? 1990s onwards**

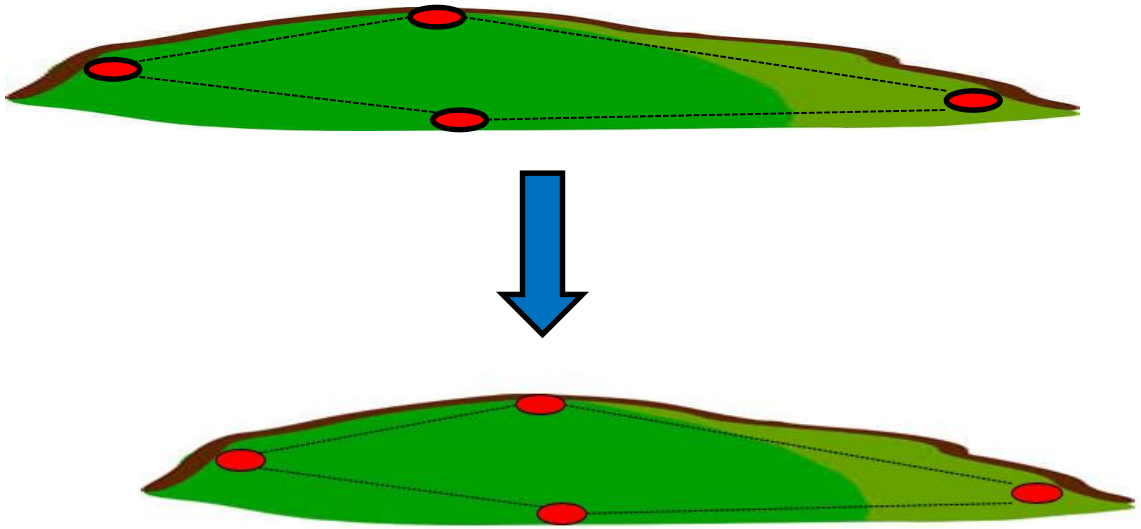
PGD 2016 based on ITRF





EFFECT OF ITRF TO CADASTRE?

- **Local Plane Coordinate System**
- **PPCS-TM/ Luzon 1911**
- **PPCS-TM/PRS92**

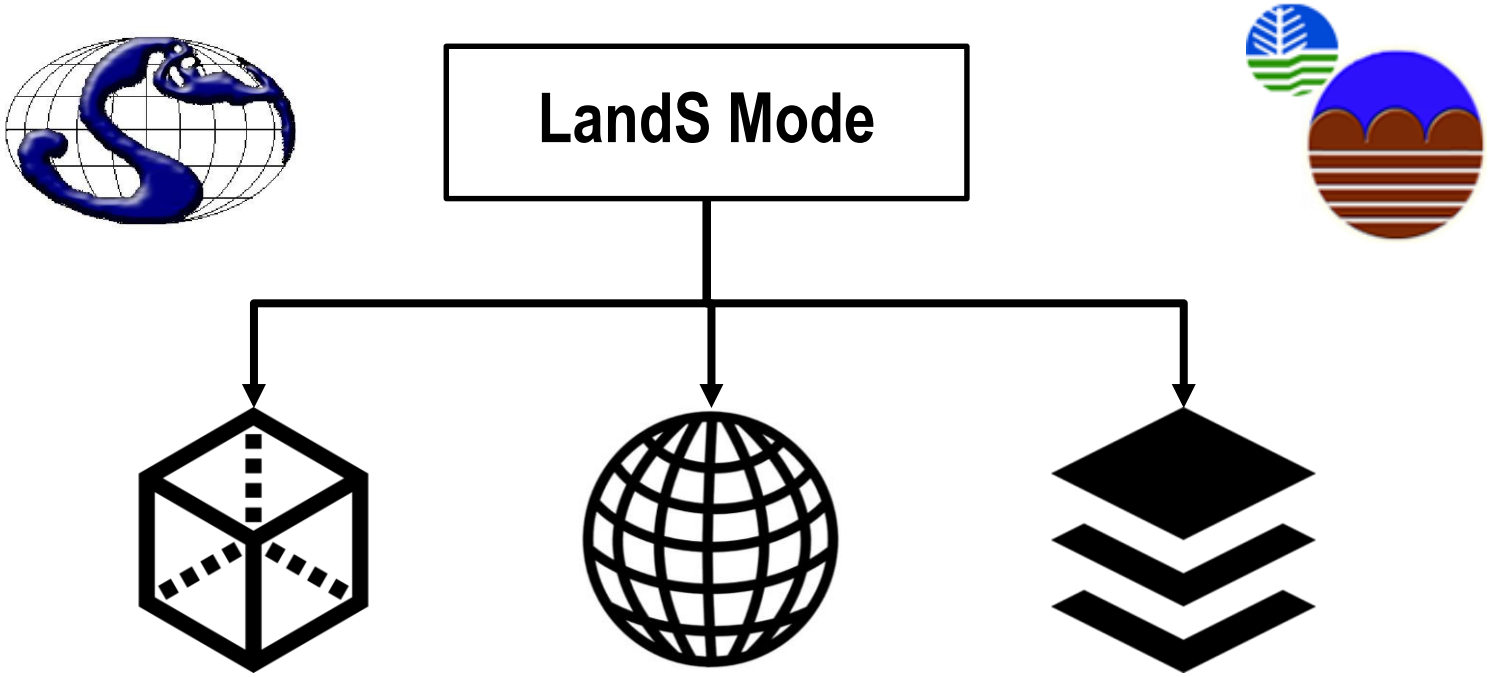


ITRF:
PPCS-TM/ PGD2020

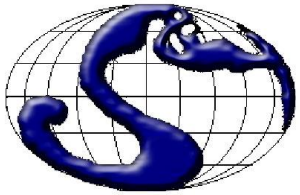
Changes in the land title including the technical description requires a petition for correction or rectification in court in accordance with Section 108 of PD 1529 (Peña, Peña Jr., & Peña Jr., 1994).

Changes in the TD due to cadastral transformation may require changes in the land title, which in turn can be costly for both the government and private owners.

Land Sector Modernization



R&D for PGRS



R&D for PGRS

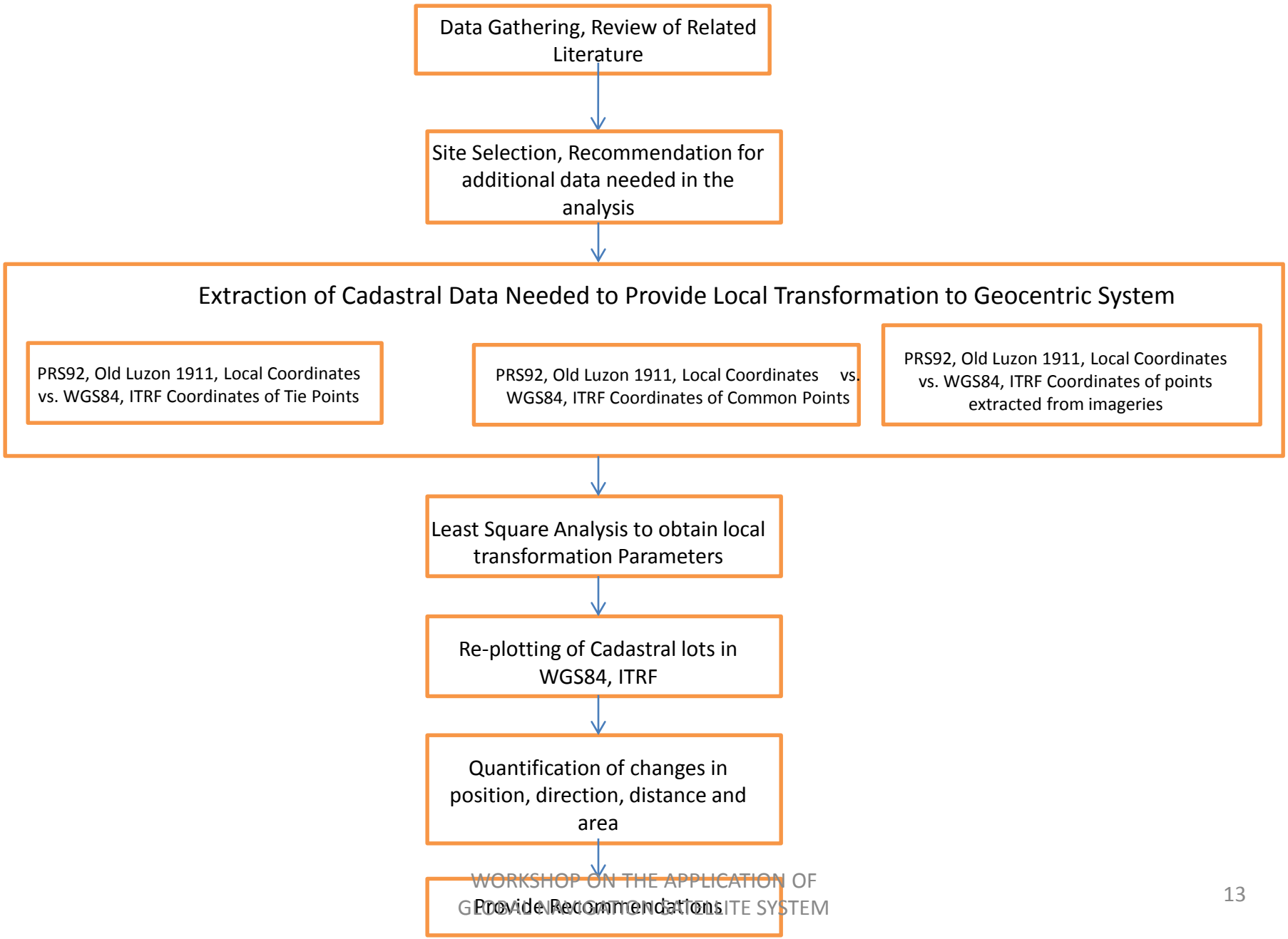
- Component 1: Selection of Most Applicable Datum Transformation Scheme from Local (PRS92) to Geocentric (ITRF2014) Datum
- Component 2: Evaluation and Assessment on the Effects of Shifting the Existing Cadastre to ITRF2014

OBJECTIVES:

The UPSCad's objectives were to provide a methodology, test and implement, and provide analysis in linking the different coordinate reference systems used in the country.

R&D with NAMRIA's objective is to provide a methodology of regenerating cadastral data into the geocentric system.

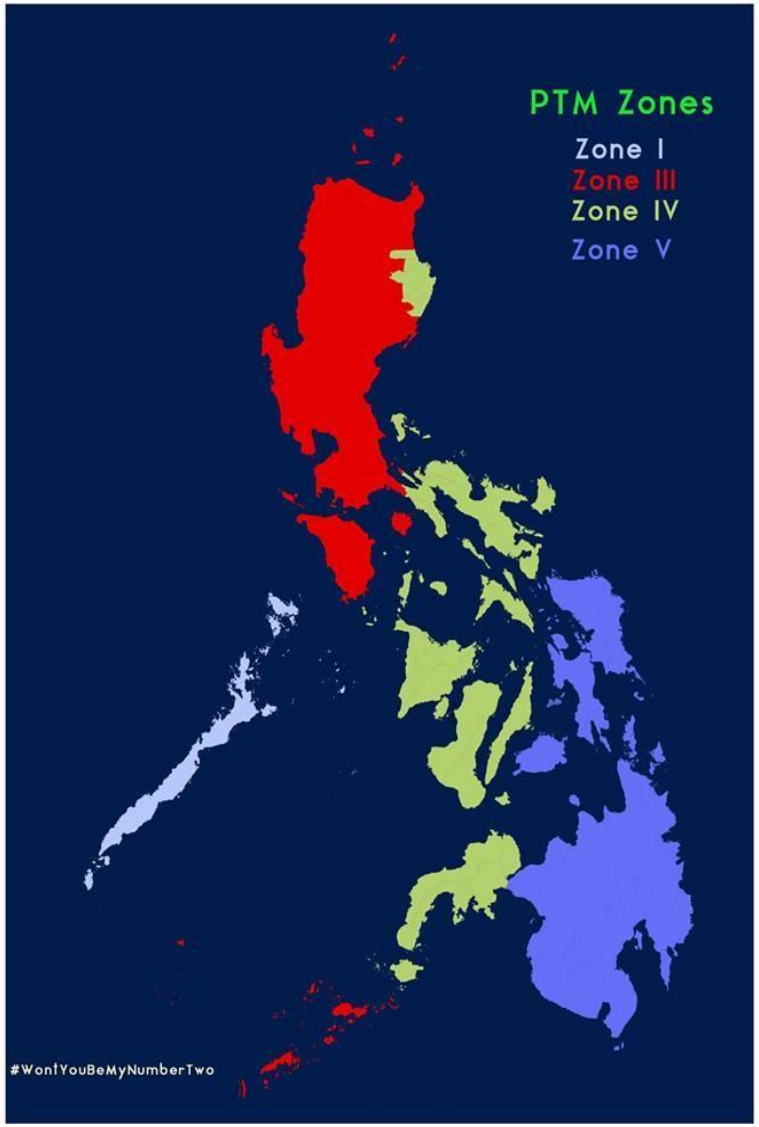
INITIAL METHODOLOGY



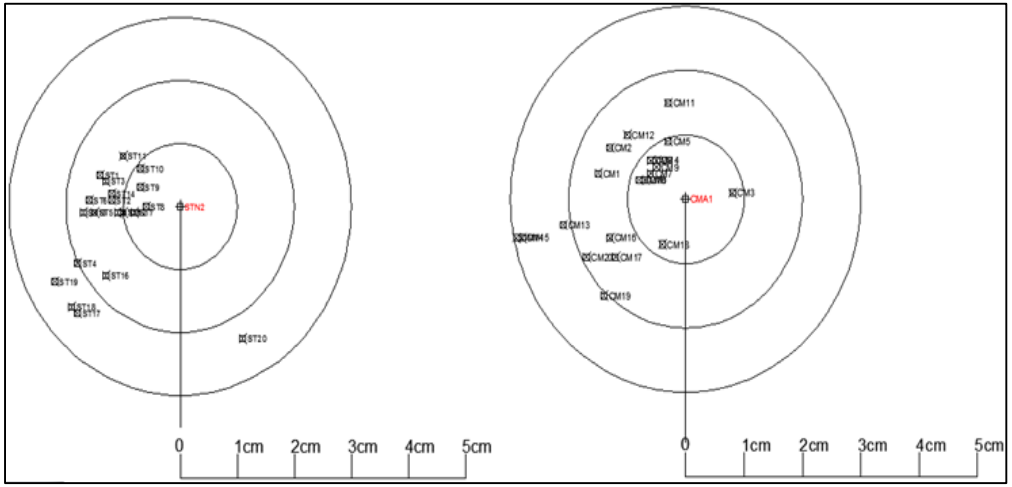
Dataset from LMB and NAMRIA (2017)

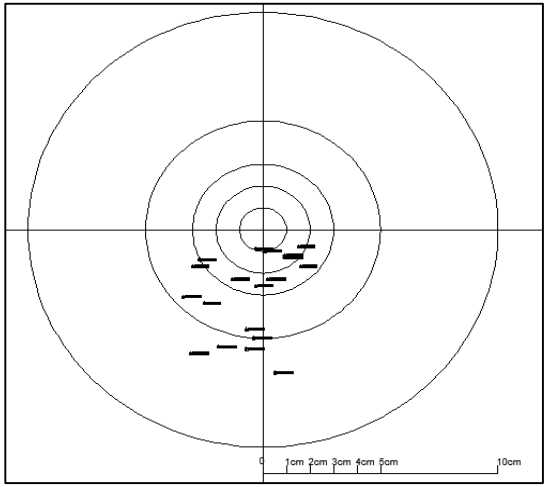
Dataset per Region	LMB	NAMRIA
CAR	*	
NCR		
1		
2	*	
3		
4A		
4B	*	
5	*	
6		
7	*	
8		
9	*	
10		
11		
12	*	
13	**	
ARMM		

Available Data per Region
Unavailable Data
* RTK GNSS observations only
** Data obtained using Transit or TS



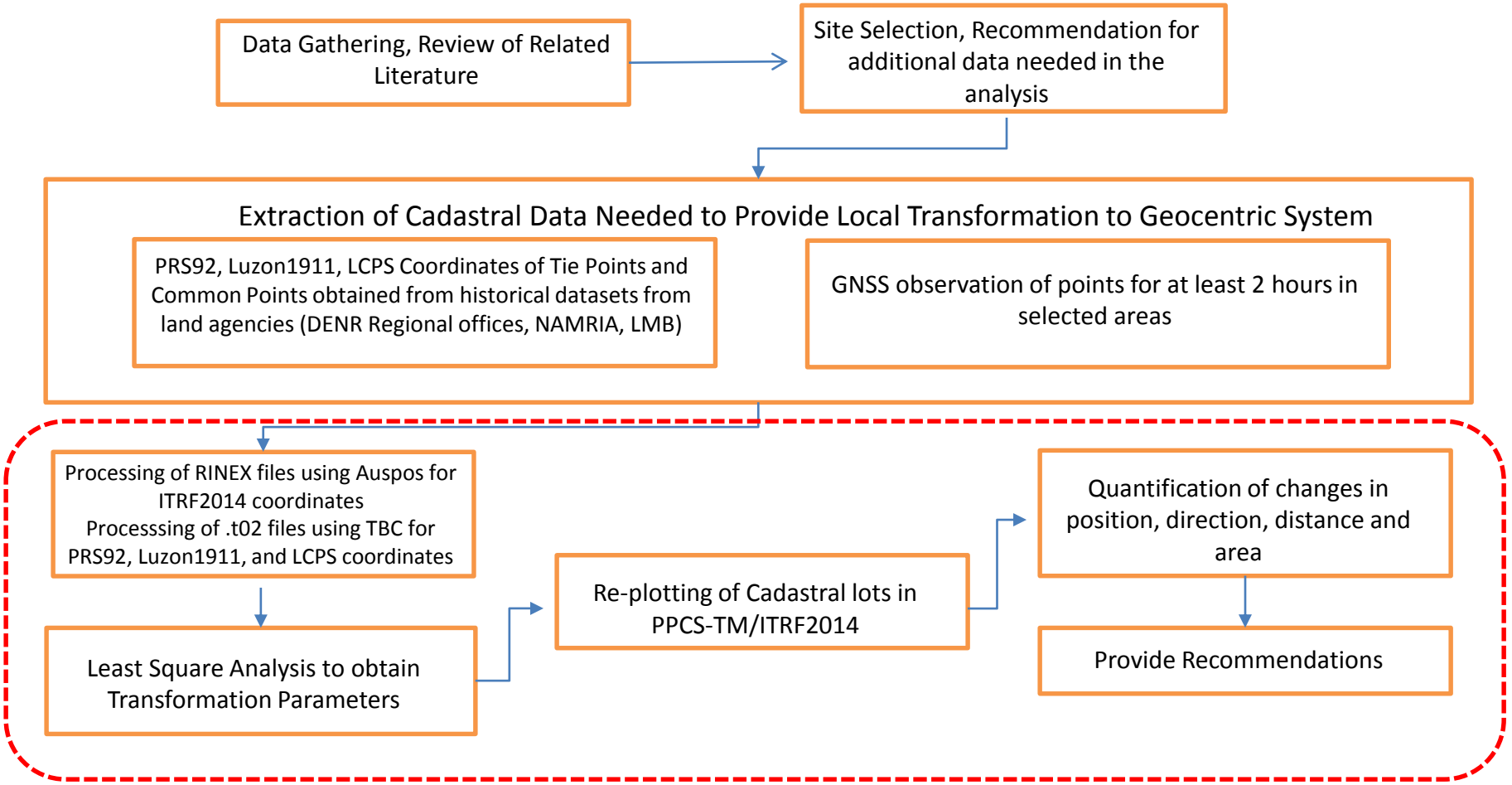
Rapid Static GNSS position vs RTK-GNSS position





Applicability of RTK-GNSS for Property Survey Research (2015)

Methodology

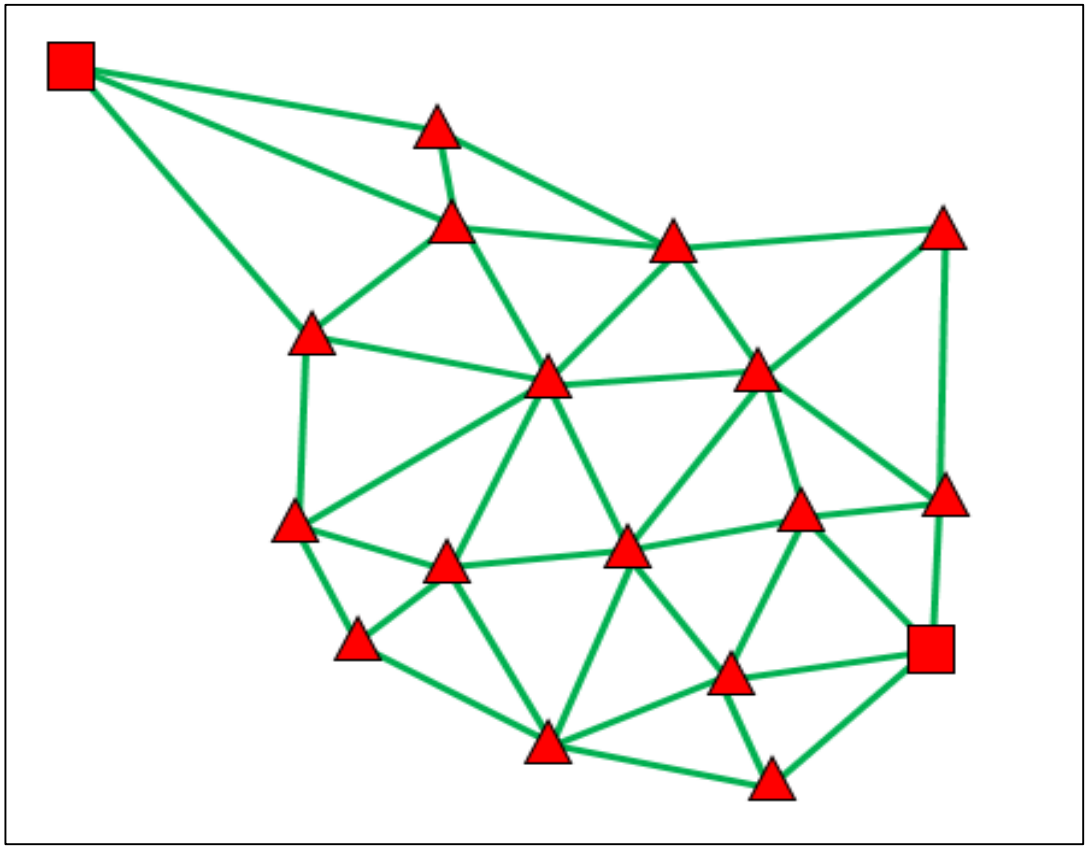


Methodology

Key Ingredients:

1. List of Coordinates of Old Reference Stations
2. List of Coordinates of PRS92 Reference Stations
3. Recovery of Old Reference Stations and PRS92 Reference Stations
4. Cadastral Data
5. GNSS Rapid Static Observations

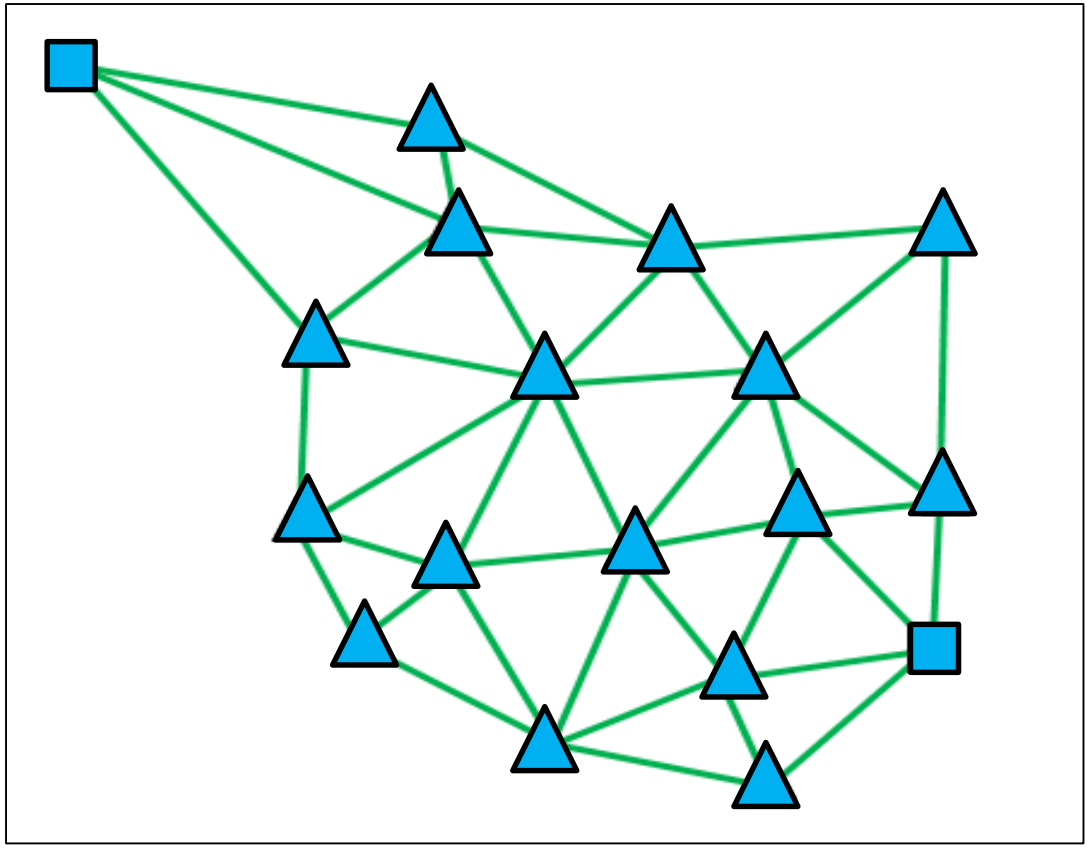
Methodology



PRS92 Station

Old Reference Station

Methodology



PRS92 Station with ITRF2014 Based Coordinates

Old Reference Station with ITRF2014 Based Coordinates

Methodology

Four (4) versions of coordinates used in the analysis

1. Luzon 1911 Theoretical
   - coordinates based from records

2. Luzon 1911 Observed
   -recomputed coordinates based from the adopted fixed points from Cadastral reference points

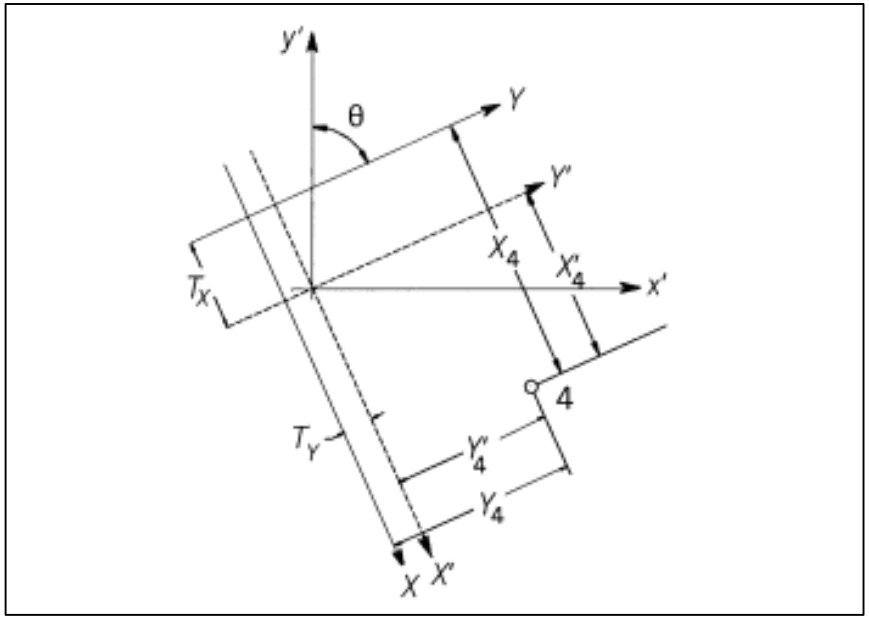
3. PRS92
   -recomputed coordinates of old points referred from a NAMRIA PRS92 control point

4. PGD2016/2020 (PROPOSED)
   -recomputed coordinates using ITRF points obtained using AUSPOS

Methodology

1. Among of the available methods for plane coordinate system transformation, the Least Squares 3-parameter and 4-parameter (Similarity) transformations are the only methods suitable for cadastral survey and data transformation.

- **Data Build-up and Transformation of Cadastral Data from Different Local Plane Coordinate System to PPCS-TM/PRS92**
  R&D in Support of the Implementation of PRS 92, Project Component 4 FINAL REPORT
  UP TCAGP-NAMRIA 2009



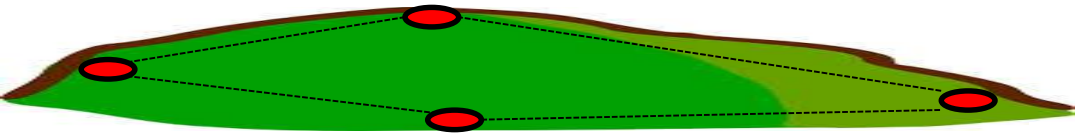
Two-dimensional conformal method (Ghilani & Wolf, 2006)

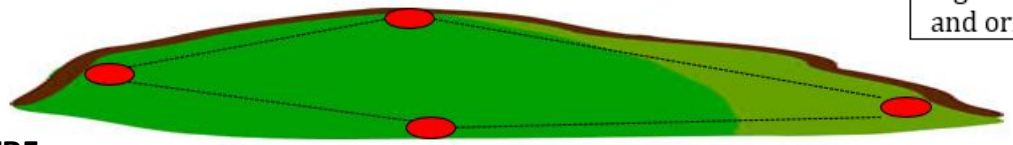
Methodology

Transformation Strategies	
Original Coordinate System	**Transformed Coordinate System**
PPCS-TM/ Luzon 1911 theoretical	PPCS-TM/ PRS92
	PPCS-TM/ PGD 2016
PPCS-TM/ Luzon 1911 observed	PPCS-TM/ PRS92
	PPCS-TM/ PGD 2016
PPCS-TM/ PRS92	PPCS-TM/ PGD 2016

Methodology

- **Local Plane Coordinate System**
- **PPCS-TM/ Luzon 1911**
- **PPCS-TM/PRS92**





ITRF:
PPCS-TM/ PGD2020

PARCEL ANALYSIS

TECHNICAL DESCRIPTION		
LINES	BEARINGS	DISTANCES (m.)
LOT 2 PCS-03-015395		
1-2	N. 13° 00' E.	15.91
2-3	S. 72° 40' E.	11.07
3-4	S. 13° 03' W.	14.00
4-1	N. 82° 32' W.	11.08
Tie-line from BLLM No. 1 CAD 334, Guiguinto Cadastre to corner 1: N. 44° 21' E. 1,847.06 m.		

Criteria
Change in Positions/ Coordinates
Significant change in direction if difference between transformed and original is >= to 1 angular minute
Significant Change in distance if difference between transformed and original is >= 1 centimeter
Significant Change in land area if difference between transformed and original is >= 1 square meter

DAO 2007-29

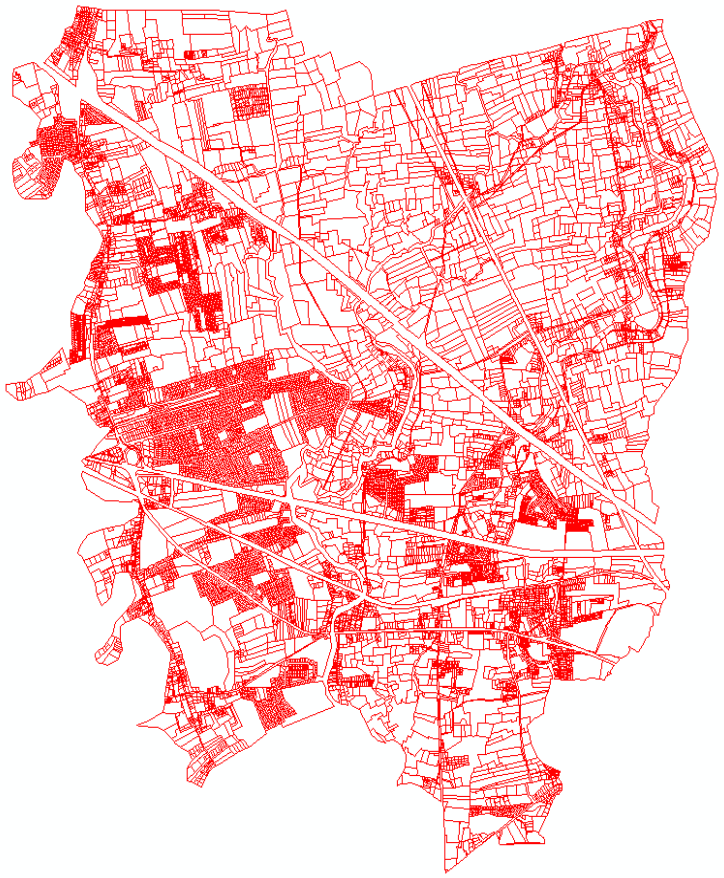
Section 30. Isolated Surveys - In conducting isolated land surveys, the GE shall be guided by the following:

a. Original, subdivision, consolidation or consolidation-subdivision isolated survey, shall be conducted using equipment and methods that will meet the tertiary control accuracy.

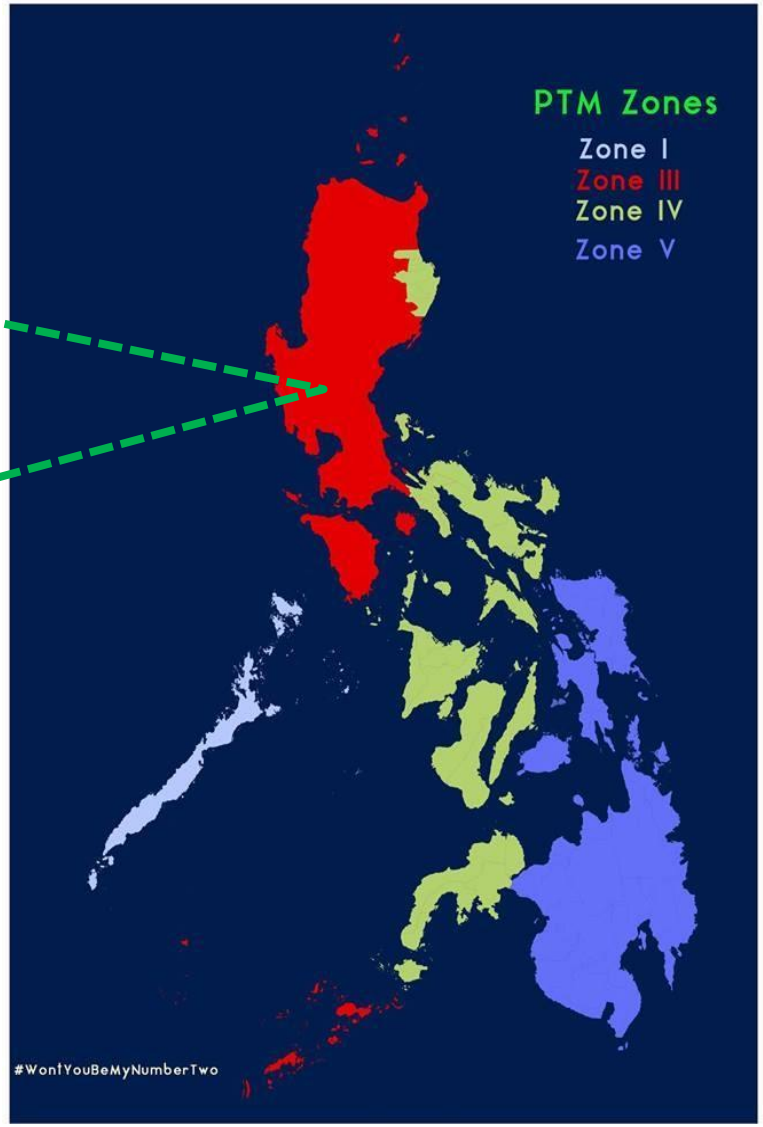
b. When conducting Relocation/Verification Survey, the Allowable Position of Error shall not exceed ± 10 centimeters. However, the allowable difference in the area shall not exceed ±1 square meters for every 1 hectare.

STUDY AREA

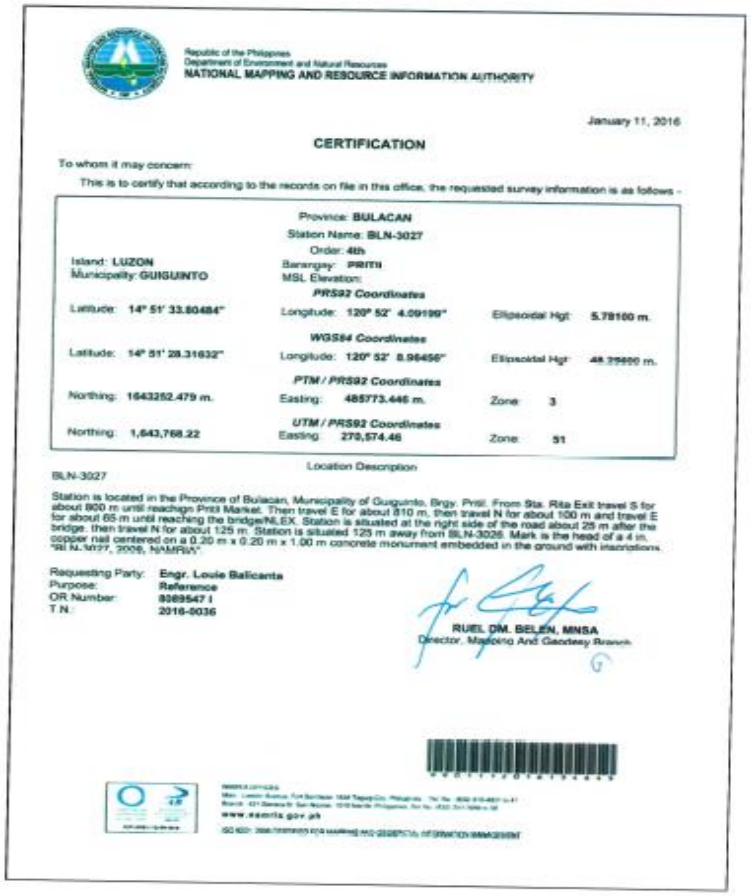
2 STUDY AREAS WERE SELECTED, ONE OF WHICH IS THE MUNICIPALITY OF GUIGUINTO, BULACAN, PHILIPPINES



12,282 PARCELS



DATA ACQUISITION



Republic of the Philippines
Department of Environment and Natural Resources
NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY

January 11, 2016

CERTIFICATION

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows :

Province: **BULACAN**
Station Name: **BLN-3027**
Order: **4th**
Island: **LUZON** Barangay: **PRITI**
Municipality: **GUIGUINTO** MSL Elevation:

PRS92 Coordinates

Latitude: **14° 51' 33.80484"** Longitude: **120° 52' 4.09199"** Ellipsoidal Hgt: **5.78100 m.**

WGS84 Coordinates

Latitude: **14° 51' 28.31632"** Longitude: **120° 52' 8.96456"** Ellipsoidal Hgt: **48.29600 m.**

PTM / PRS92 Coordinates

Northing: **1643252.479 m.** Easting: **485773.446 m.** Zone: **3**

UTM / PRS92 Coordinates

Northing: **1,643,768.22** Easting: **270,574.46** Zone: **51**

Location Description

BLN-3027

Station is located in the Province of Bulacan, Municipality of Guiguinto, Brgy. Priti. From Sta. Rita Exit travel S for about 800 m until reachign Priti Market. Then travel E for about 810 m, then travel N for about 100 m and travel E for about 65 m until reaching the bridge/NLEX. Station is situated at the right side of the road about 25 m after the bridge. then travel N for about 125 m. Station is situated 125 m away from BLN-3026. Mark is the head of a 4 in. copper nail centered on a 0.20 m x 0.20 m x 1.00 m concrete monument embedded in the ground with inscriptions "BLN-3027, 2008, NAMRIA".

Requesting Party: **Engr. Louie Balicanta**
Purpose: **Reference**
OR Number: **8089547 I**
T.N.: **2016-0036**

RUEL DM. BELEN, MNSA
Director, Mapping And Geodesy Branch

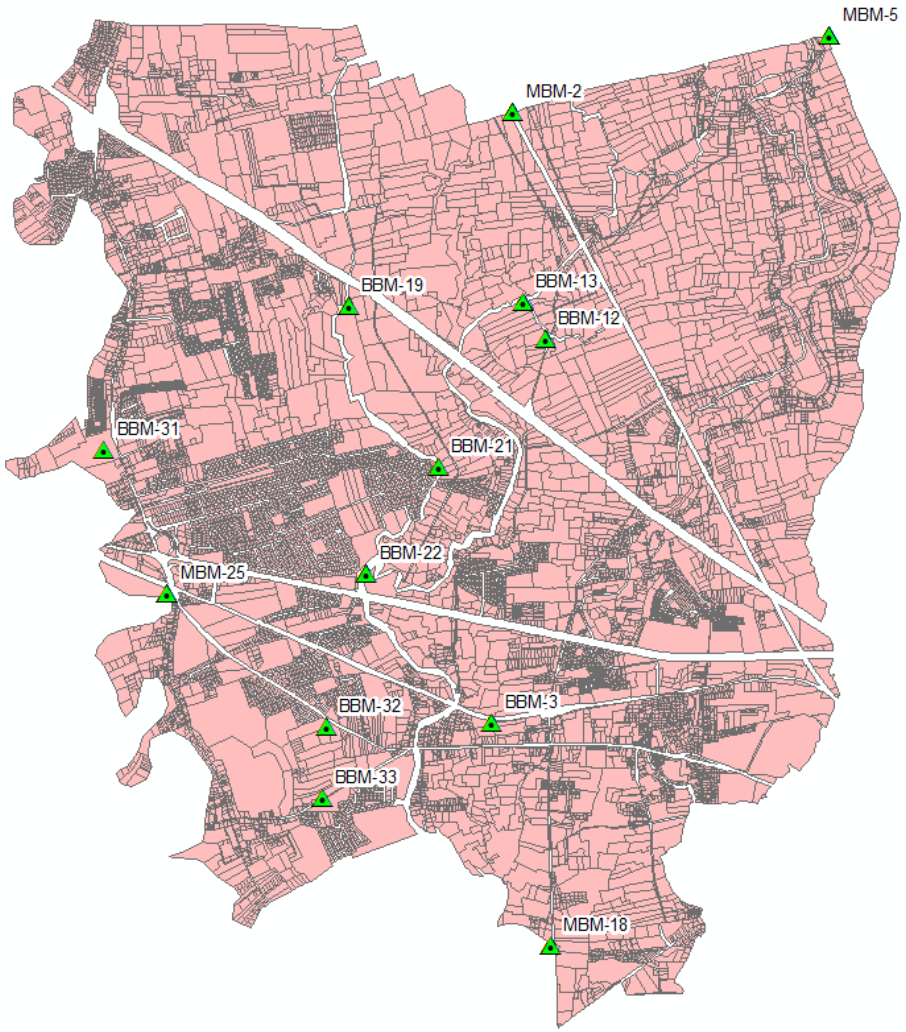
POINT OF REFERENCE	LATITUDE NORTHINGS	LONGITUDE EASTINGS	POINT OF REFERENCE	LATITUDE NORTHINGS	LONGITUDE EASTINGS
BLLM-1	1639977.90	486632.83	BBM-29	1640537.76	486459.55
	14-48-46.292	120-52-32.902	30	1640422.37	486279.47
2	1639875.97	486631.41	31	1641759.03	484717.29
3	1642810.34	485039.94	BBM-32	1640089.48	486057.48
BLLM-4	1643006.02	485092.96			
BBM-1	1639944.59	486617.35	MBM-1	1643714.00	486900.64
2	1640213.52	486836.25	2	1643790.83	487179.68
3	1640118.42	487051.40	3	1643875.58	487511.47
4	1640179.83	487379.21	4	1644201.41	488883.55
5	1639964.73	487394.40	5	1644247.64	489083.24
6	1640264.95	487914.09	6	1643443.82	489380.86
7	1640741.89	488302.87	7	1642606.08	489321.71
8	1641053.84	487957.52	8	1641890.46	489222.76
9	1641877.10	488165.06	9	1640234.74	489165.65
10	1641921.16	487872.30	10	1639702.17	488730.40
11	1641781.28	487480.64	11	1639625.71	488315.55
12	1642427.50	487375.52	12	1639263.54	488062.38
13	1642647.88	487240.59	13	1638876.92	488361.59
14	1642534.14	488105.94	14	1638473.72	488181.37
15	1642531.09	488765.00	15	1638472.44	487851.38
16	1643084.76	487557.21	16	1638546.84	487825.00
17	1643448.80	487768.77	17	1638244.77	487435.74
18	1642998.43	486895.15	18	1638770.14	487405.95
19	1642626.35	486192.17	19	1639374.87	486579.55
20	1642626.24	486192.12	20	1639165.69	485887.62
21	1641651.46	486731.07	21	1639026.21	485674.89
22	1641010.15	486302.07	22	1639131.38	485430.61
23	1640644.22	486093.73	23	1639536.81	485289.41
24	1640434.35	485311.06	24	1639832.77	484718.66
25	1642869.27	485316.28	25	1640893.43	485700.54
26	1642437.71	485413.12	26	1641101.87	484690.05
27	1642029.56	485423.54	27	1641195.86	484716.18
BBM-28	1642178.49	486163.90	MBM-28	1641801.71	484421.63

B.L. NO: Cad-554 LOCATION: Guiguinto, Bulacan

COMPILED BY: E.E. Carasi DATE: 5/16/94 CHECKED BY:

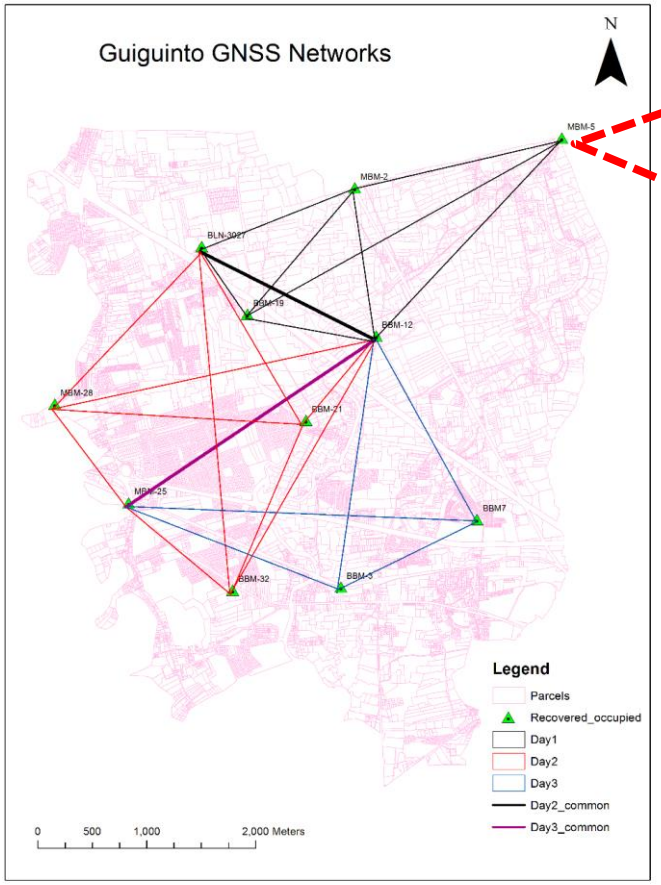
10

DATA ACQUISITION



- 11 boundary/ reference monuments (Luzon 1911) were recovered and 1 NAMRIA GCP (PRS92)

DATA ACQUISITION



2 HOURS OF GNSS OBSERVATION

DATA PROCESSING

Trimble Business Center

Australian Government
Geoscience Australia

3 Computed Coordinates, ITRF2014

All coordinates are based on the IGS realisation of the ITRF2014 reference frame. All the given ITRF2014 coordinates refer to a mean epoch of the site observation data. All coordinates refer to the Ground Mark.

3.1 Cartesian, ITRF2014

Station	X (m)	Y (m)	Z (m)	ITRF2014 @
4063	-3163791.394	5292776.207	1624920.532	13/03/2018
5876	-3163791.330	5292697.491	1624315.721	13/03/2018
MBM2	-3163791.772	5291935.104	1625442.118	13/03/2018
BJNM	-2148744.724	4373439.991	4098885.607	13/03/2018
CKSV	-2826324.824	5075902.190	2476625.539	13/03/2018
CNMR	-4052052.736	3465029.031	1664653.849	13/03/2018
GUAM	-1639592.669	3568363.626	1488904.400	13/03/2018
HKOH	-2414266.498	5386056.892	2399883.159	13/03/2018
HKSC	-2414266.511	5386768.775	2407459.813	13/03/2018
HKSS	-2414266.387	5377187.968	2418617.527	13/03/2018
JUNA	-3507665.844	4976994.552	2647324.009	13/03/2018
LSBO	-2232166.635	5010439.197	2593842.954	13/03/2018
PIMO	-2913425.695	5286624.412	1601158.381	13/03/2018
PTAG	-2309536.637	5291065.516	1590418.245	13/03/2018
SHAO	-3357171.908	4675665.780	3275369.267	13/03/2018
XMIS	-6116879.385	6039590.007	-1149275.175	13/03/2018

3.2 Ellipsoid, ITRF2014

... in this section, are computed using a spherical harmonic ...008 geoid. More information on the EGM2008 geoid can be ...o.nga.mil/GandG/wgs84/gravitymod/egm2008/.

			psoidal ight(m)	Derived Above Geoid Height(m)
			45.916	3.690
			45.727	3.474
			46.576	4.252
			109.122	118.582
			59.643	40.154
			64.381	9.064
			201.918	146.377
			166.379	168.256
			20.200	22.656
			38.677	40.806
			45.406	26.553
			121.805	102.975
			95.557	51.441
PTAG	14 32 07.59067	121 02 26.75186	86.618	42.897
SHAO	31 05 58.70758	121 12 01.61570	22.030	11.226
XMIS	-10 26 59.85594	105 41 18.61345	261.511	263.028

3.3 Positional Uncertainty (95% C.L.) - Geodetic, ITRF2014

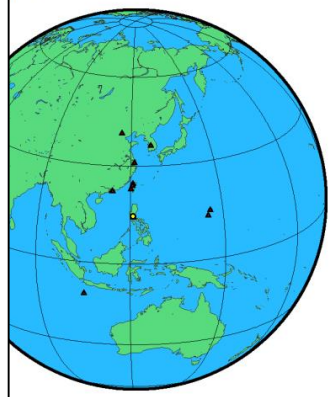
Station	Longitude(East) (m)	Latitude(North) (m)	Ellipsoidal Height(Up) (m)
4063	0.018	0.010	0.040
5876	0.027	0.014	0.059
MBM2	0.023	0.013	0.048
BJNM	0.008	0.006	0.015
CKSV	0.009	0.006	0.018
CNMR	0.009	0.006	0.015
GUAM	0.010	0.006	0.016
HKOH	0.009	0.006	0.016
HKSC	0.009	0.006	0.016
HKSS	0.009	0.006	0.016
JUNA	0.009	0.006	0.016
LSBO	0.009	0.006	0.017

1 User Data

All antenna heights refer to the vertical distance from the Ground Mark to the Antenna Reference Point (ARP).

File	Antenna Type	Antenna Height (m)	Start Time	End Time
...8o	TRMSPS985 NONE	0.882	2018/03/15 02:11:00	2018/03/15 04:47:00
...8o	TRMSPS985 NONE	1.131	2018/03/15 02:18:30	2018/03/15 04:48:00
...8o	TRMSPS985 NONE	1.021	2018/03/15 02:10:30	2018/03/15 04:46:30

g Summary



	User Stations	Reference Stations	Orbit Type
...:30	4060 5876 BBM3	BJNM CKSV CNMR DAEJ GUAM HKOH HKOH HKSC JUNA LSBO PIMO PTAG SHAO XMIS	IGS final

Australian Government
Geoscience Australia

AUSPOS GPS Processing Report

April 26, 2018

This document is a report of the GPS data processing undertaken by the AUSPOS Online GPS Processing Service (version: AUSPOS 2.3) . The AUSPOS Online GPS Processing Service uses International GNSS Service (IGS) products (final, rapid, ultra-rapid depending on availability) to compute precise coordinates in International Terrestrial Reference Frame (ITRF) anywhere on Earth and Geocentric Datum of Australia (GDA) within Australia. The Service is designed to process only dual frequency GPS phase data.

An overview of the GPS processing strategy is included in this report.

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DATA PROCESSING & SCRIPTING

$$E_2 = kE_1\cos\theta - kN_1\sin\theta + Tx \quad \textit{(Equation 1)}$$
$$N_2 = kE_1\sin\theta + kN_1\cos\theta + Ty \quad \textit{(Equation 2)}$$

where:
N_1 and E_1 = *the Northings and Eastings of the point on the source coordinate system;*
N_2 and E_2 = *the Northings and Eastings of the point on the destination coordinate system;*
k = *the scale parameter;*
θ = *the rotation parameter; and*
Tx and Ty = *the translation parameters for Easting and Northing, respectively*

Equation 1 and 2 can be simplified further as shown below:

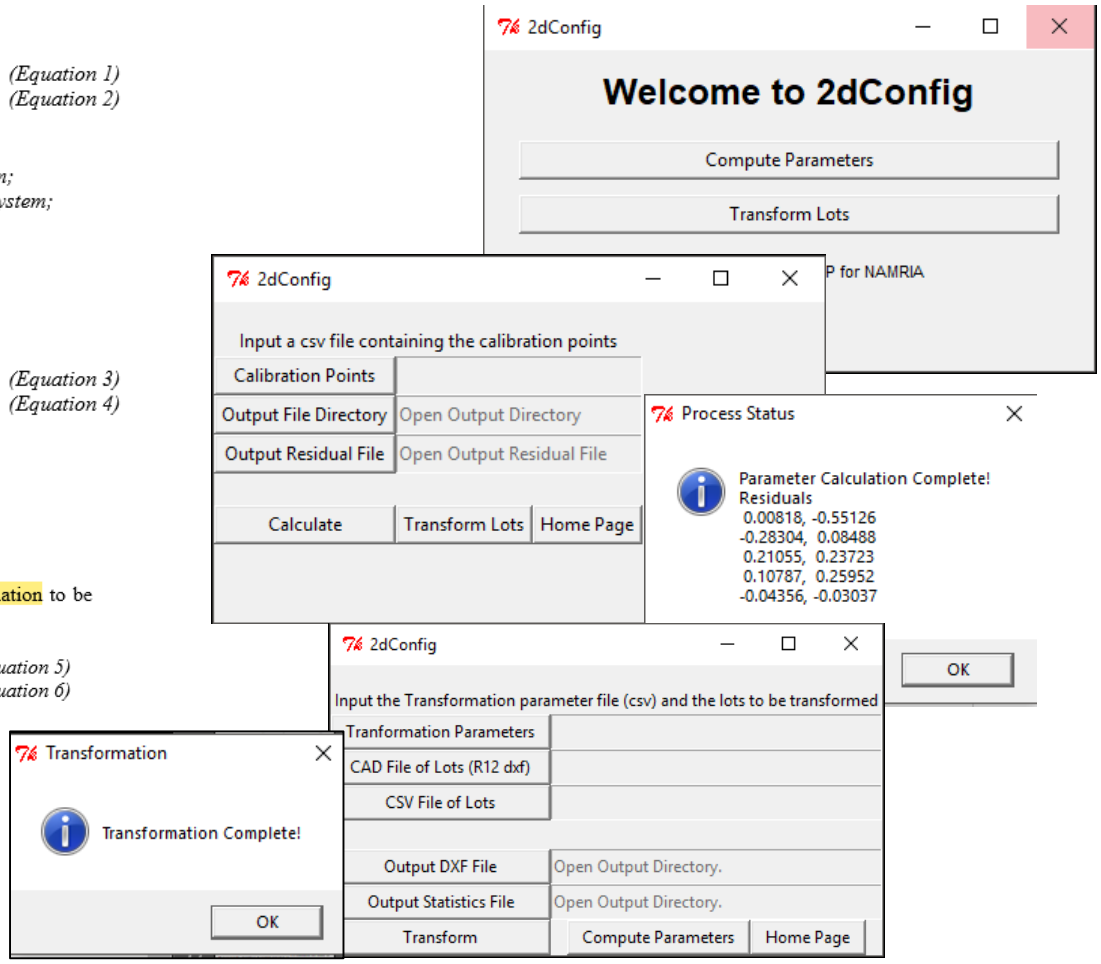
$$E_2 = aE_1 - bN_1 + Tx \quad \textit{(Equation 3)}$$
$$N_2 = aN_1 + bE_1 + Ty \quad \textit{(Equation 4)}$$

where:
a = kcosθ and b = ksinθ (McCoy P.E. & Robert, 2012)

In Section 6.1.2 of DMC 2010-06, it was indicated that the 2D conformal transformation to be implemented between PTM and PRS92 is as follows:

$$E = A * X + B * Y + C_E \quad \textit{(Equation 5)}$$
$$N = -B * X + A * Y + C_N \quad \textit{(Equation 6)}$$

where:
A and B = *scale and rotation constants*
C_E and C_N = *shift constants*
X and Y = *PPCS-TM/Luzon 1911 coordinates*
E and N = *PPCS-TM/PRS92 coordinates*



RESULTS:

COMPUTED COORDINATES FOR GUIGUINTO, BULACAN

	PPCS-TM/LUZON1911 (THEORETICAL		PPCS-TM/LUZON1911 (OBSERVED)		PPCS-TM/PRS92		PPCS-TM/ITRF2014	
POINT NAME	NORTHING	EASTING	NORTHING	EASTING	NORTHING	EASTING	NORTHING	EASTING
BBM3	1640118.420	487051.400	1640118.624	487051.193	1640118.974	487053.740	1640056.143	487198.503
BBM7	1640741.890	488302.870	1640741.982	488302.530	1640742.283	488305.098	-	-
BBM12	1642427.500	487375.520	1642426.674	487375.390	1642427.016	487378.004	1642364.085	487522.632
BBM19	1642626.350	486192.170	1642626.215	486191.852	1642626.595	486194.482	1642563.598	486339.090
BBM21	1641651.460	486731.070	1641651.428	486731.375	1641651.791	486733.967	1641588.834	486878.622
BBM32	1640089.480	486057.480	1640089.657	486057.559	1640090.039	486060.104	1640027.082	486204.813
BLN3027	-	-	1643252.184	485770.745	1643252.479	485773.446	1643189.481	485918.042
MBM2	1643790.830	487179.680	1643790.728	487179.727	1643791.079	487182.385	1643728.127	487326.956
MBM5	1644247.640	489083.240	1644247.590	489082.636	1644247.885	489085.314	-	-
MBM25	1640893.430	485100.540	1640893.430	485100.540	1640893.843	485103.107	1640830.861	485247.795
MBM28	1641801.710	484421.630	1641801.568	484421.610	1641801.995	484424.212	1641738.970	484568.897
	*AS LISTED ON OLD TRAVERSE LIST		*PROCESSED IN TBC WITH MBM25-MBM28-MBM2 AS BASE		*PROCESSED IN TBC WITH BLN3027 AS BASE		*ITRF2014 GRS80 LAT-LONG PROJECTED TO PPCS-TM	

RESULTS

DERIVED PARAMETERS

Cadastre	Parameters	Luzon 1911 theoretical to PRS92	Luzon 1911 observed to PRS92
Guiguinto	Scale	0.99991036	0.99998472
	Rotation (")	4.4	8.2
	Tx (meters)	81.022	55.653
	Ty (meters)	136.972	44.875

Cadastre	Parameters	Luzon 1911 theoretical to PGD 2016	Luzon 1911 observed to PGD 2016	PRS92 to PGD 2016
Guiguinto	Scale	0.99992	0.99996	0.99998
	Rotation (")	7.3	3.2	9.5"
	Tx (meters)	126.232	187.85	230.263
	Ty (meters)	81.988	-20.012	-52.6

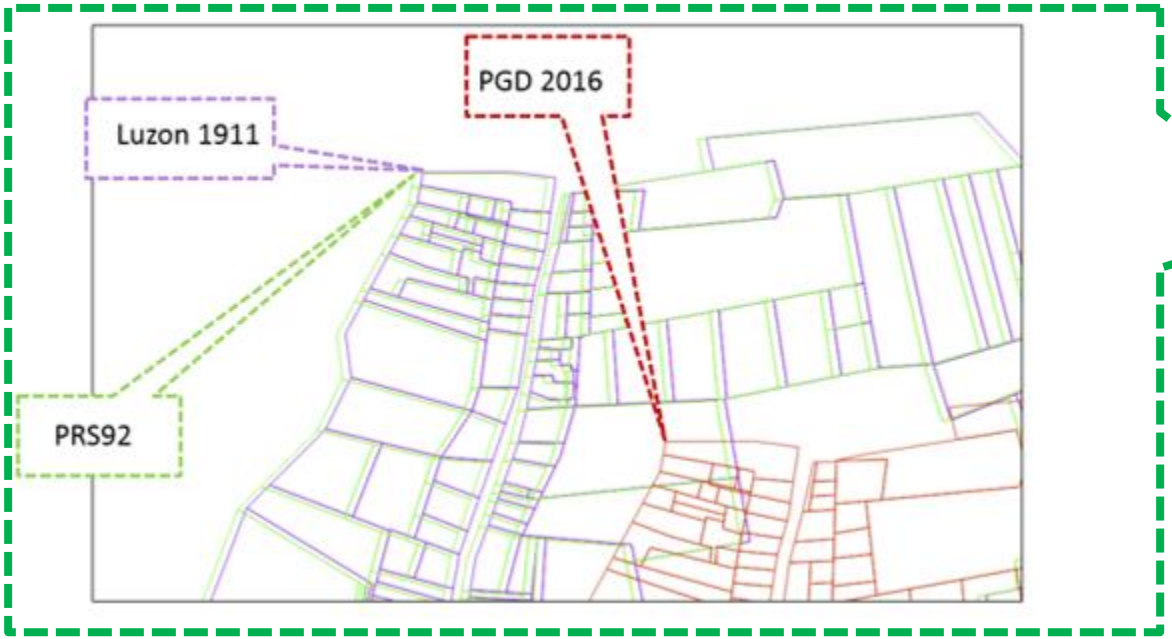
RESULTS

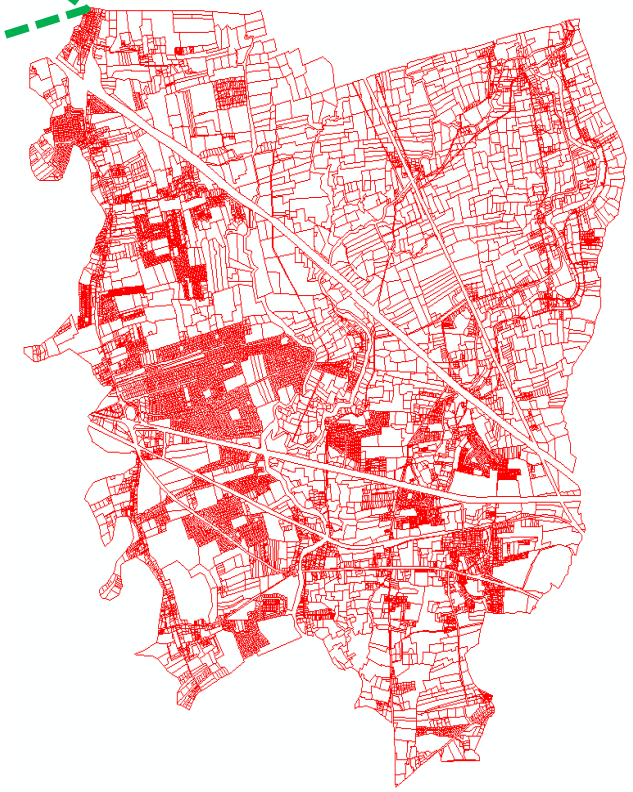
PARCEL ANALYSIS

Cadastre	Parameters	Luzon 1911 theoretical to PRS92	Luzon 1911 observed to PRS92
Guiguinto	Δ Position (m)	Northings: 0.339 Eastings: 2.607	Northings: 0.213 Eastings: 2.460
	Δ direction >= 1'	None	None
	Δ distance >= 1cm	Yes for sides >110 meters	Yes for sides > 750 meters
	Δ area >= 1 sqm.	Yes for areas >6500 sqm	Yes for areas >30000 sqm

Cadastre	Parameters	Luzon 1911 theoretical to PGD 2016	Luzon 1911 observed to PGD 2016	PRS92 to PGD 2016
Guiguinto	Δ Position (m)	Northings: -62.589 Eastings: 152.138	Northings: -62.802 Eastings: 147.182	Northings: -62.939 Eastings: 144.649
	Δ direction >= 1'	None	None	None
	Δ distance >= 1cm	Yes for sides >130 meters	None	None
	Δ area >= 1 sqm.	Yes for areas >6500 sqm	Yes for areas >16000 sqm	Yes for areas >25000 sqm

RESULTS





Snapshot of the cadastral data of Guiguinto in Luzon 1911, PRS92 and PGD2016 plotted in QGIS

SUMMARY & CONCLUSIONS

- The Philippines has several coordinate systems existing and being used by the land surveyors
- Migration to a geocentric system such as ITRF is one of the strategy in the PGRS Modernization by NAMRIA
- NAMRIA, DENR-LMB and the UP TCAGP conducted joint researches to link all the coordinate systems and show the effect of the migration to a coordinate system based on ITRF to the cadastral data (output of property surveys)
- Basic Data needs include cadastral data and reference points related to the cadastral data
- GNSS Rapid Static/ Static Observation is a needed pre-requisite in linking the different coordinate systems and in relating to ITRF2014

SUMMARY & CONCLUSIONS

- The research was successful in relating the different coordinate systems through the 4 parameter similarity transformation

- The land agencies were given several transformation strategies to choose from (e.g. using the recorded old coordinates to the new system or recomputed coordinates to the new system)

- While the rotational parameter does not affect technical descriptions significantly, it was observed that the scale parameter affects side distances and areas of parcels at a certain level

- Regardless of coordinate reference system used, technical descriptions (bearing/ azimuth/ distance and land area) remained the same at least in the majority of the lots in the study area

RECOMMENDATIONS

- DENR Regional Offices may consider adopting the methodology provided, if migration of Cadastral data to ITRF is decided

- Rapid Static/ Static GNSS Survey is recommended in the reoccupation of old reference monuments

- Transformation parameter determination must be obtained out of several iterations that will provide the least effect on scale and rotation

- It is suggested that database for both old and recomputed coordinates of the reference points be kept in the database of the respective land agencies

Results of LandS Mode Research Project submitted to the Director of DENR-LMB together with the researchers and DENR-LMB personnel

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Try not to become a person of success, but rather try to become a person of value ***- Albert Einstein***