GEODETIC ENGINEERS OF THE PHILIPPINES
46TH GEP ANNUAL REGIONAL CONVENTION
(REGIONAL DIVISION III)
Subic Bay Peninsular Hotel, Subic Bay Freeport Zone
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Implementation of RTK for Property Surveys

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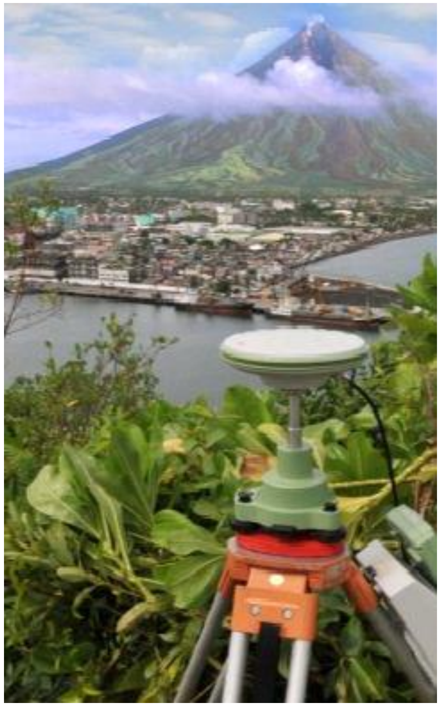
All civilizations that rose to an urban culture need two science-related technology:

- **mathematics for land measurements**

- commerce and astronomy for time-keeping in agriculture and aspects of religious rituals

- Frederick Seitz



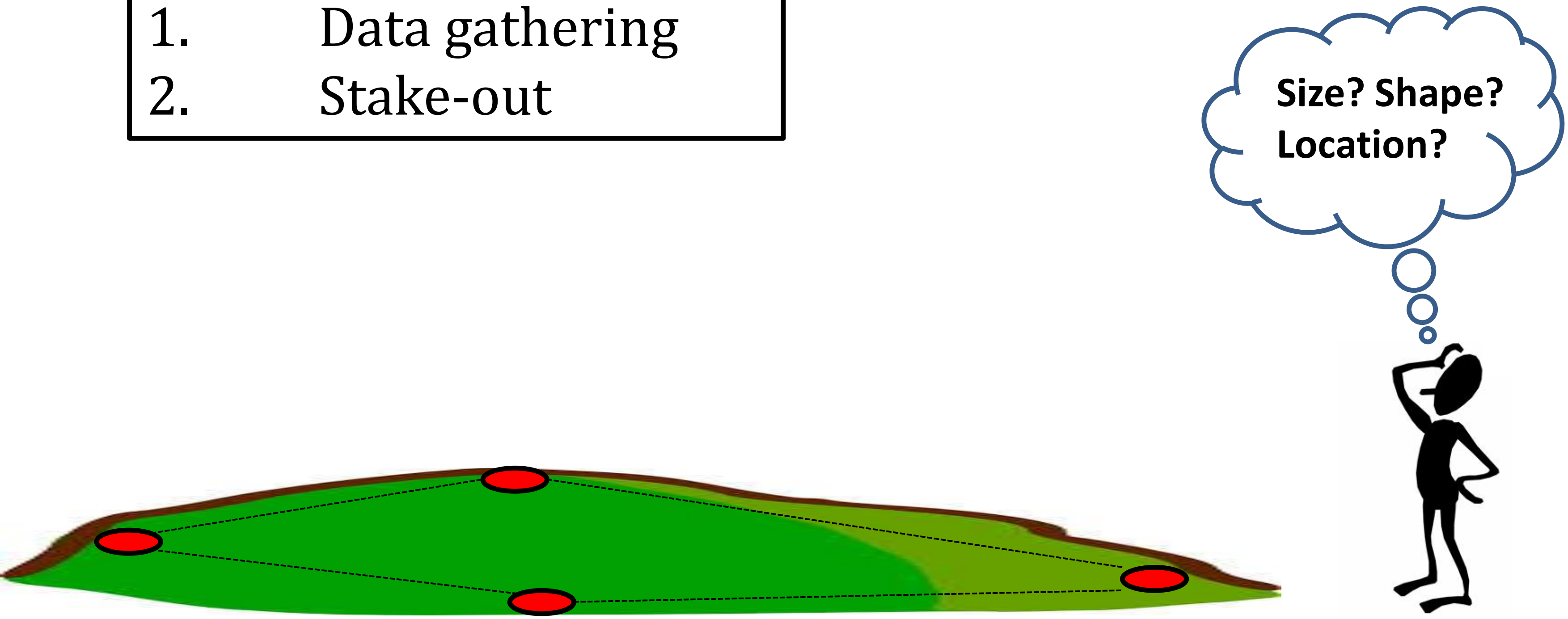
https://www.yumpu.com/en/document/read/48819103/namria-commences-inter-island-benchmark-connections

BACKGROUND

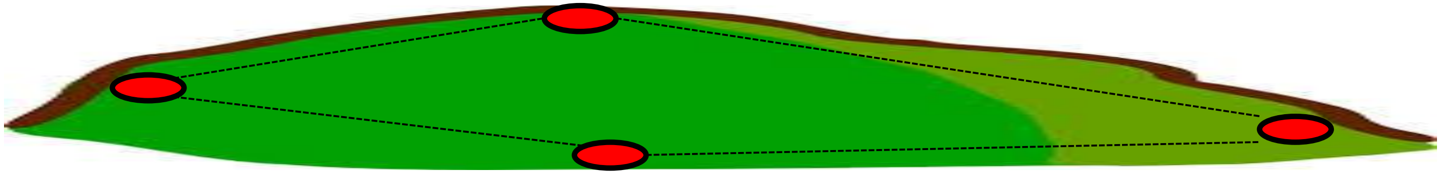
PROPERTY SURVEY

2 major field activities

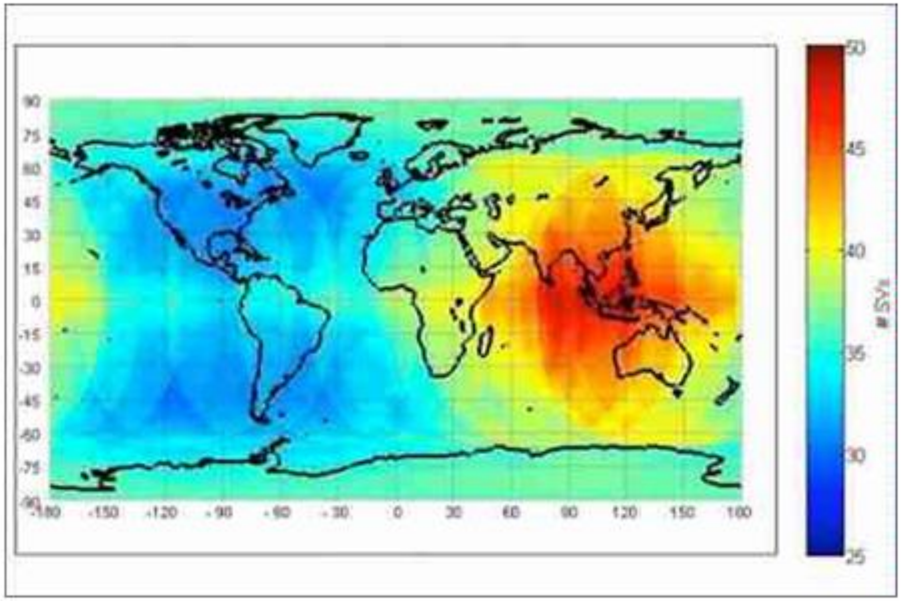
1. Data gathering
2. Stake-out



BACKGROUND



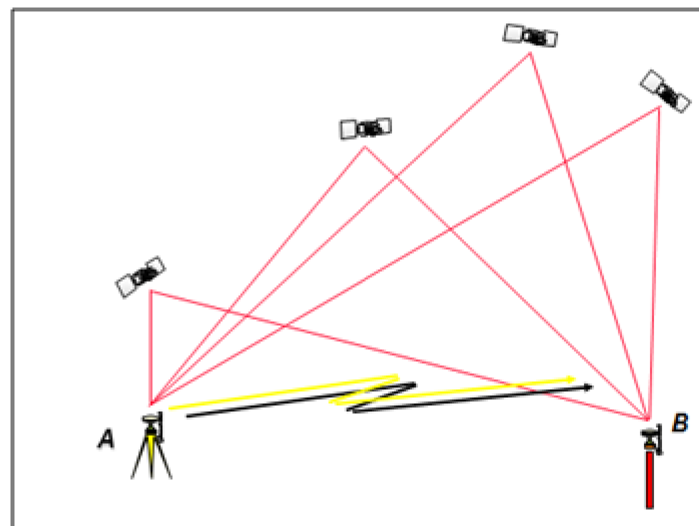
BACKGROUND GNSS



Satellite Positioning Hotspot
http://intranet.eng.unsw.edu.au/system/files/satellitehotspot.jpg

Typical Session Lengths for Static and Rapid Static (Ghilani and Wolf 2008)

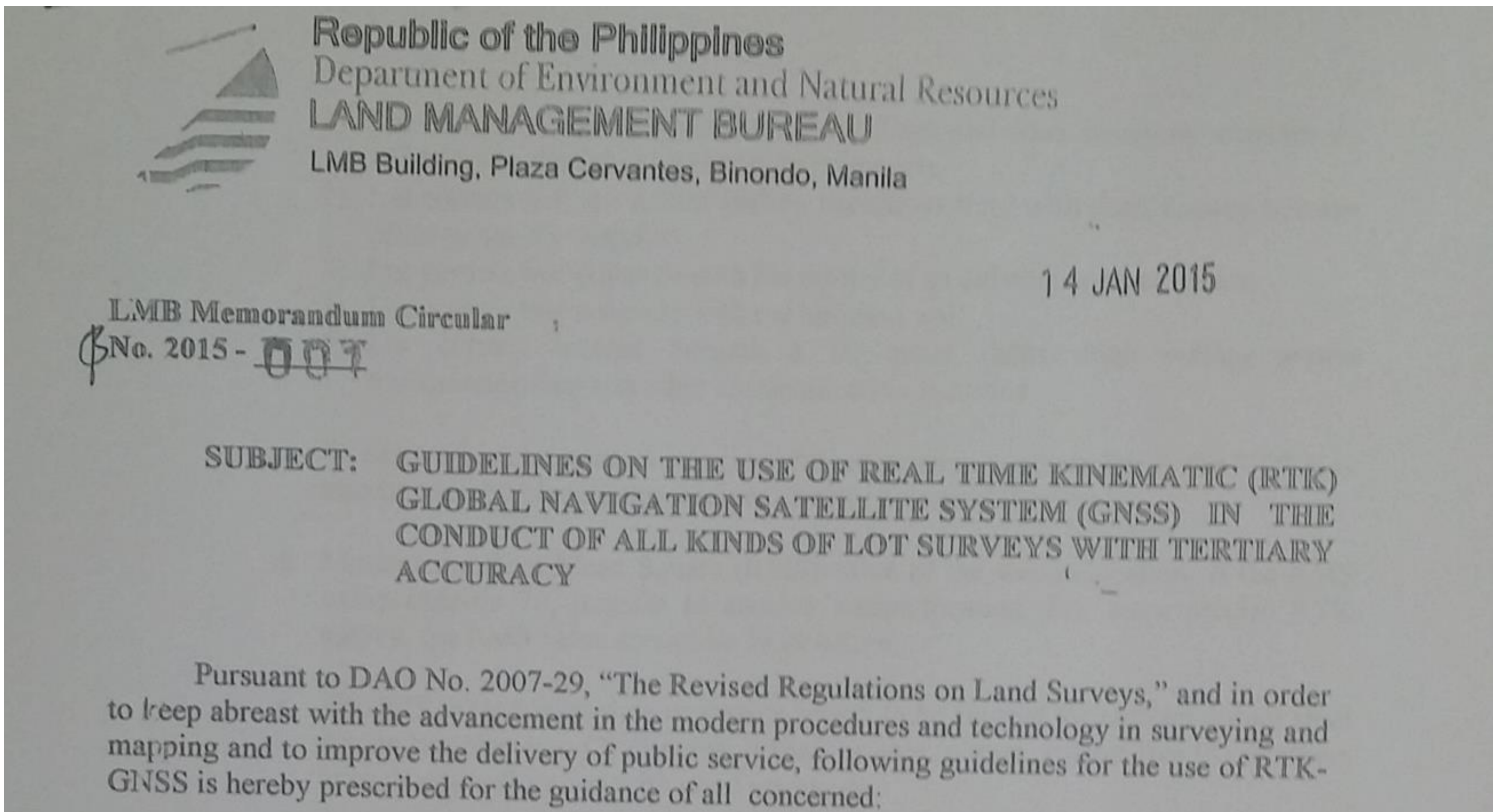
Method of Survey	Single Frequency	Dual Frequency
Static	30 min + 3min/km	20 min + 2min/km
Rapid Static	20 min + 2min/km	10 min + 1min/km



Typical RTK-GNSS Set-up

BACKGROUND
LMB issued MC No. 2015-001

DENR Land Management Bureau (LMB) issued Memorandum Circular No. 2015-001, "*Guidelines on the Use of Real Time Kinematic (RTK) Global Navigation Satellite System (GNSS) in the Conduct of All Kinds of Lot Surveys with Tertiary Accuracy*".



Republic of the Philippines
Department of Environment and Natural Resources
LAND MANAGEMENT BUREAU
LMB Building, Plaza Cervantes, Binondo, Manila

14 JAN 2015

LMB Memorandum Circular
No. 2015 - 001

SUBJECT: GUIDELINES ON THE USE OF REAL TIME KINEMATIC (RTK) GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) IN THE CONDUCT OF ALL KINDS OF LOT SURVEYS WITH TERTIARY ACCURACY

Pursuant to DAO No. 2007-29, "The Revised Regulations on Land Surveys," and in order to keep abreast with the advancement in the modern procedures and technology in surveying and mapping and to improve the delivery of public service, following guidelines for the use of RTK-GNSS is hereby prescribed for the guidance of all concerned:

BACKGROUND

LandS Mode 2

Proper RTK

Property Survey
using RTK-GNSS

CaliBER

Calibration Baseline
Establishment
Research

LandS Mode 2 Research Team

University of the Philippines, Diliman

Training Center for Applied Geodesy And Photogrammetry

Surveying, Land Administration and Valuation Research Laboratory

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Research Coordinators

Engr. Jesse Jungco
LMB-ProperRTK Coordinator

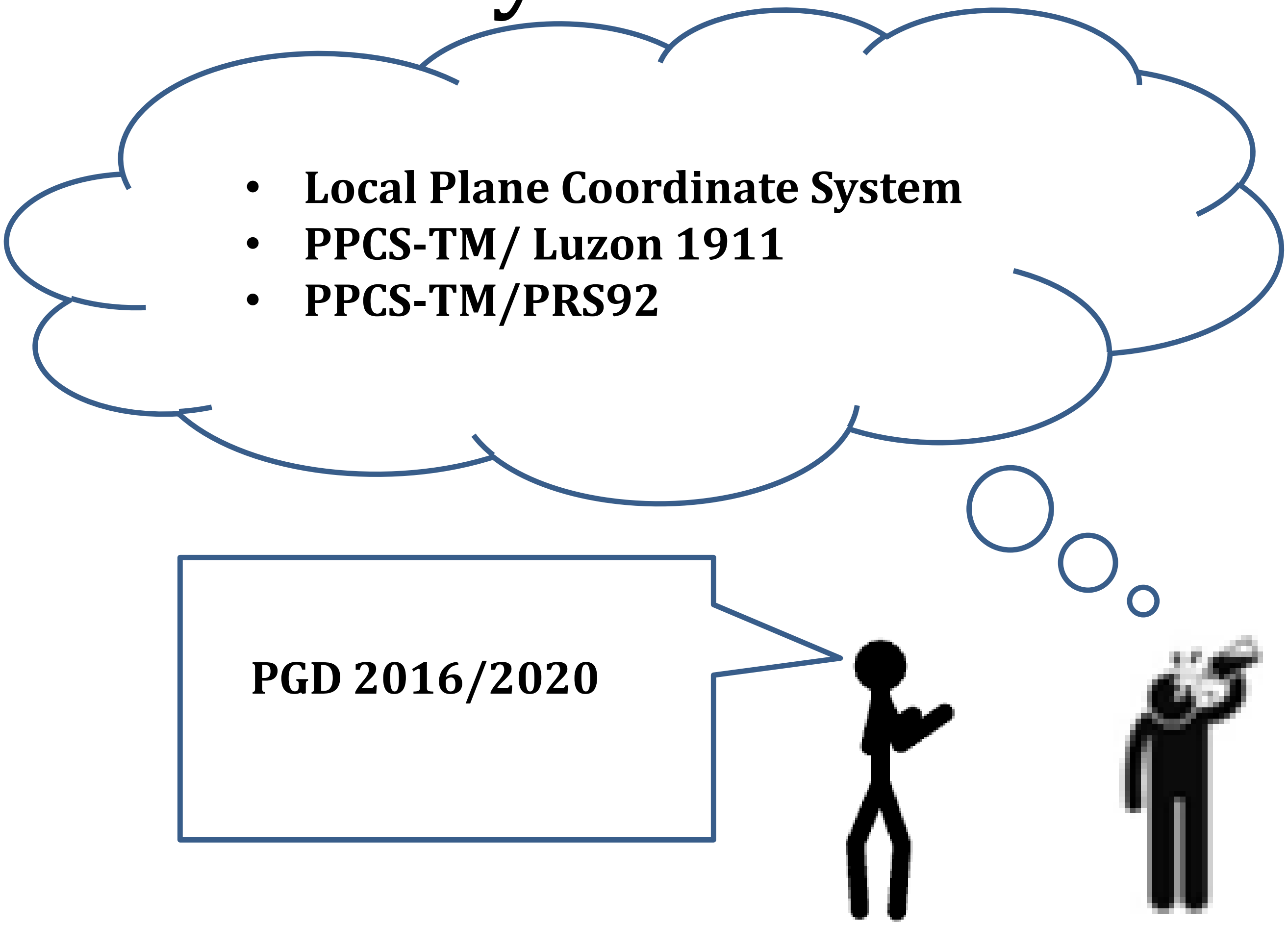
Engr. Jewel Templonuevo
LMB-CaliBER Coordinator

Department of Environment and Natural Resources

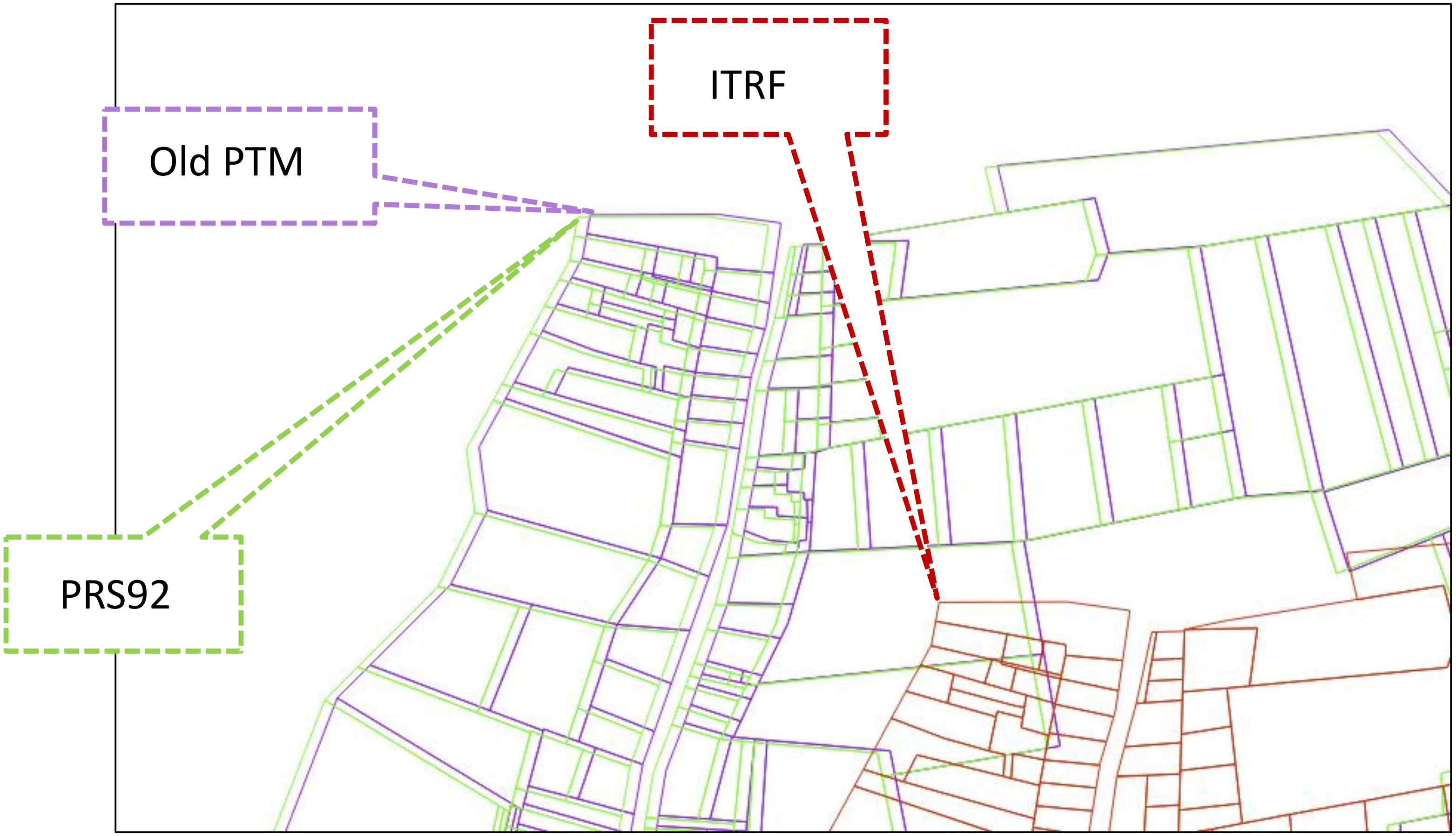
Land Management Bureau

RELATED CONCEPTS AND STUDIES

Coordinate System



Results: from LandS Mode 1

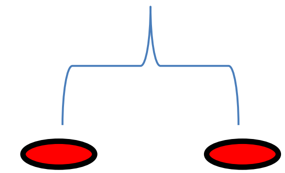


Snapshot of the Cadastral Maps of Guiguinto overlaying the old PTM, Luzon 1911 and ITRF versions.

RELATED CONCEPTS AND STUDIES

Common Point

Δd<=10cm



DAO 2007-29

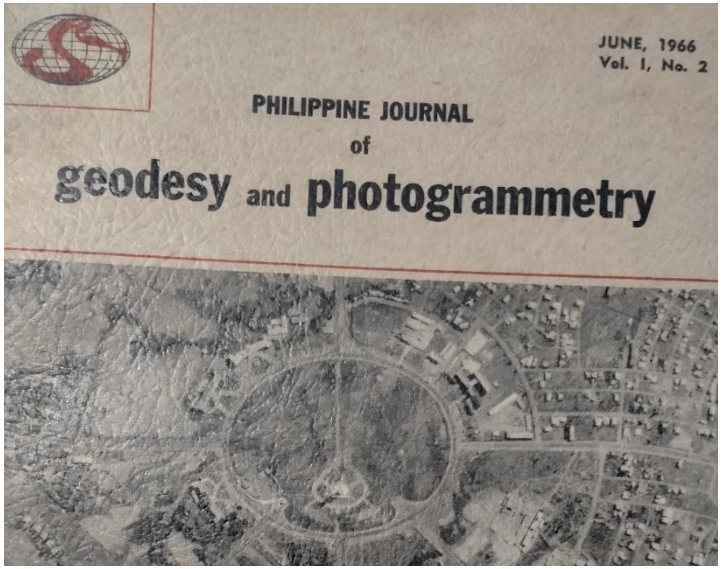
Section 30. Isolated Surveys - In conducting isolated land surveys, the GE shall be guided by the following:

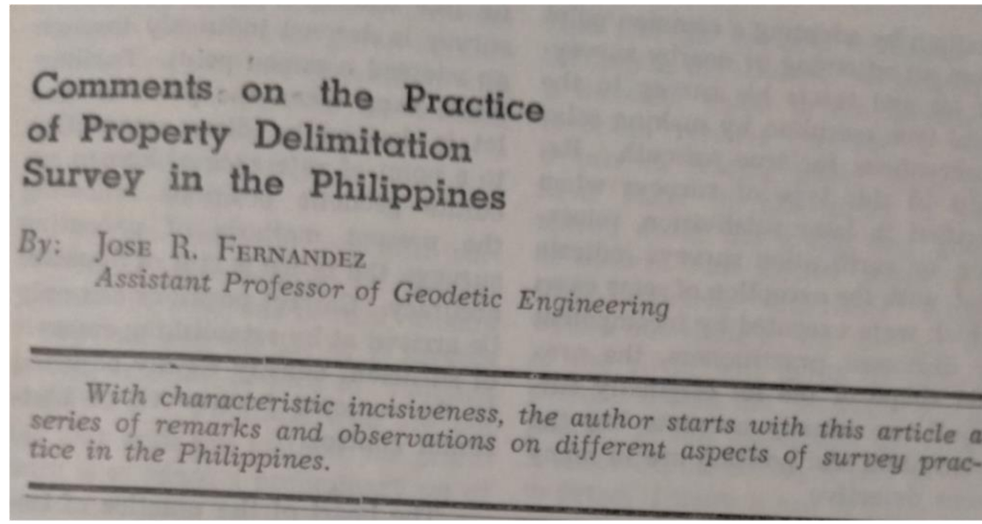
a. Original, subdivision, consolidation or consolidation-subdivision isolated survey, shall be conducted using equipment and methods that will meet the tertiary control accuracy.

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

RELATED CONCEPTS AND STUDIES

Common Point





Comments on the Practice of Property Delimitation Survey in the Philippines

By: Jose R. Fernandez
Assistant Professor of Geodetic Engineering

With characteristic incisiveness, the author starts with this article a series of remarks and observations on different aspects of survey practice in the Philippines.

The **problem with the use of common point** is that **small amount of translation** in the common point will **result to an equivalent shift in the positions of the subsequent surveys** and the **errors become cumulative** when using different common points from different surveys (**Fernandez, 1966**)

RELATED CONCEPTS & STUDIES

Comparison between GPS derived and Astronomic Azimuths

- For rapid static survey, geodetic azimuths computed from logged coordinates and published coordinates of NAMRIA reference points are comparable at least within secondary accuracy (UPTCAGP, 2009)

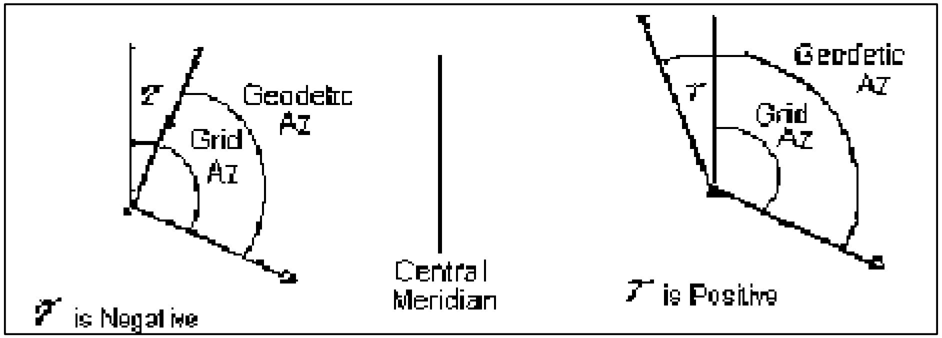
- For project control, geodetic azimuth and astronomic azimuth can be used interchangeably within secondary accuracy (UPTCAGP, 2009)

RELATED CONCEPTS

Azimuth

- Astronomic Azimuth vs. Geodetic Azimuth vs. Grid Azimuth

$$\alpha_G = \alpha_{grid} + \Delta\lambda'' \sin\varphi_1 \text{ (convergence correction)}$$



http://onlinemanuals.txdot.gov/txdotmanuals/ess/images/ess_fig3-7_geodetic_to_grid_azimuth.jpg

$$A = \alpha_G + (\Lambda - \lambda)\sin\varphi + (\xi \sin\alpha_G - \eta\cos\alpha_G)\cot\upsilon$$

where:

A = astronomic azimuth

α_G = geodetic azimuth

Λ = astronomic longitude

ϕ = geodetic latitude

λ = geodetic longitude

ε, η = components of the deflection of the vertical

υ = ellipsoidal zenith angle

A = astronomic azimuth

α_G = geodetic azimuth

RELATED CONCEPTS

Distance

- Ground Distance vs. Geodetic Distance vs. Grid Distance

$D_{geo} = D_{ground}\,(R/\,(R+N+H))$ (Cole 2009)

$D_{grid} = S\ D_{geo}$ (Cole 2009)

where:

D_{geo} = geodetic distance

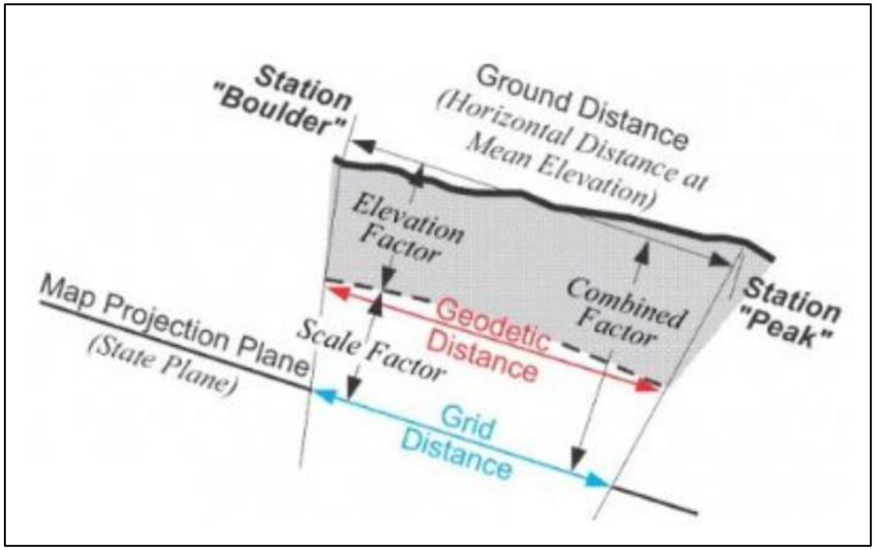
D_{ground} = ground distance

R = mean radius of the reference ellipsoid

N = geoidal separation

H = elevation above the sea level

S = scale factor



https://www.spar3d.com/blogs/from-scratch/vol13no16-state-plane-coordinates/

RELATED CONCEPTS AND STUDIES

RTK-GNSS Performance Under Tree Canopy

- The experiment conducted by Lucas in 2007 showed that the best accuracy achieved by survey grade GPS receiver is 1.46 meters using post processed kinematic technique (Lucas, GPS under the Forest Canopy, 2007).

- Positional accuracy is degraded as the density of the canopy increases and that positional update is delayed (Zheng, Wang, & Nihan, n.d.)

RELATED CONCEPTS AND STUDIES

- *A Research on the Effect of Different Measuring Configurations in Network RTK Applications (Kutalmis Gumus, 2015)*

  - Determines whether there is a statistically significant difference between coordinates obtained under different elevation angles and measuring epochs through different correction methods in Network Real Time Kinematic Applications.

Study Area

P1(Open Area)

P2(Semi-Open)

P3(Wooded)

P4(Urban)

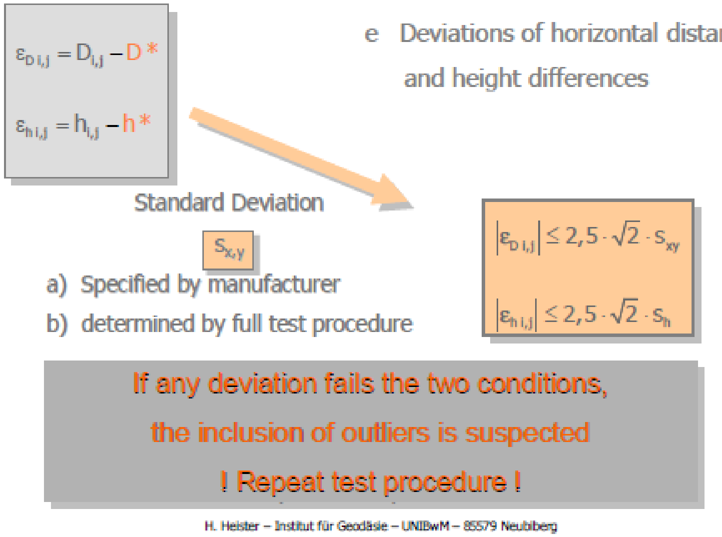
RELATED CONCEPTS AND STUDIES LMB issued MC No. 2015-001

Salient conditions for RTK-GNSS use for isolated surveys

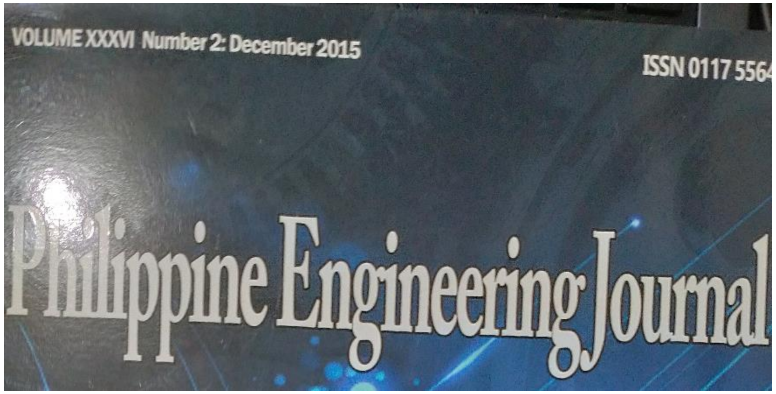
(a) use of calibrated and tested dual frequency GNSS receivers
(b) receiver clearance of 15^o from the horizon
(c) bipod support of poles with receivers during survey
(d) use of electronic total station to augment RTK-GNSS
(e) root mean square (RMS) value must be 35 or below
(f) RTK observation length not less than two (2) minutes
(g) minimum of five (5) satellites must be tracked
(h) baseline length of 200 meters to 1 kilometer shall be established using RTK instrument preferably not more than 1 kilometer from the lot
(i) list of required contents of observation field notes

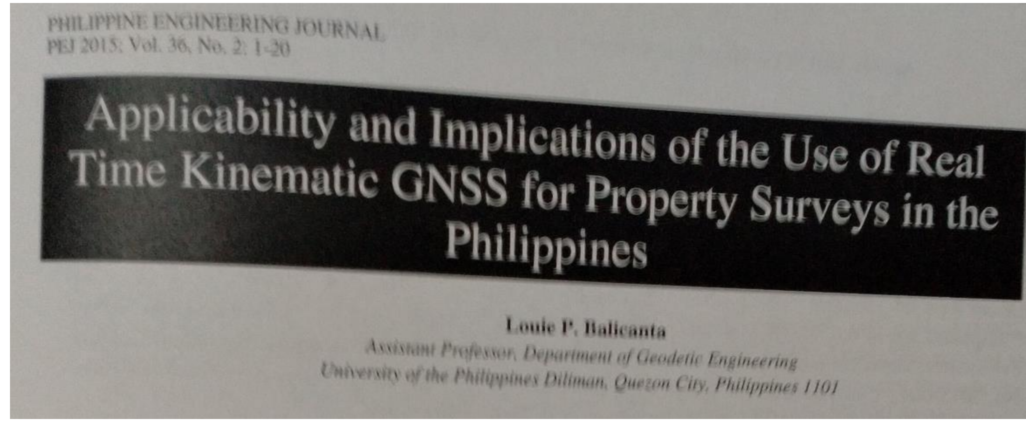
RELATED CONCEPTS AND STUDIES

- *ISO-17123-8: International Standards for Checking GNSS Field Measuring Systems (Heister, 2008)*
  - standardized test for checking if declared precision of receiver is achievable in field
  - requires numerous observations of distances to be compared to actual/known values (Di,j - D*)
  - standard deviation from measurements is then compared to declared standard deviation



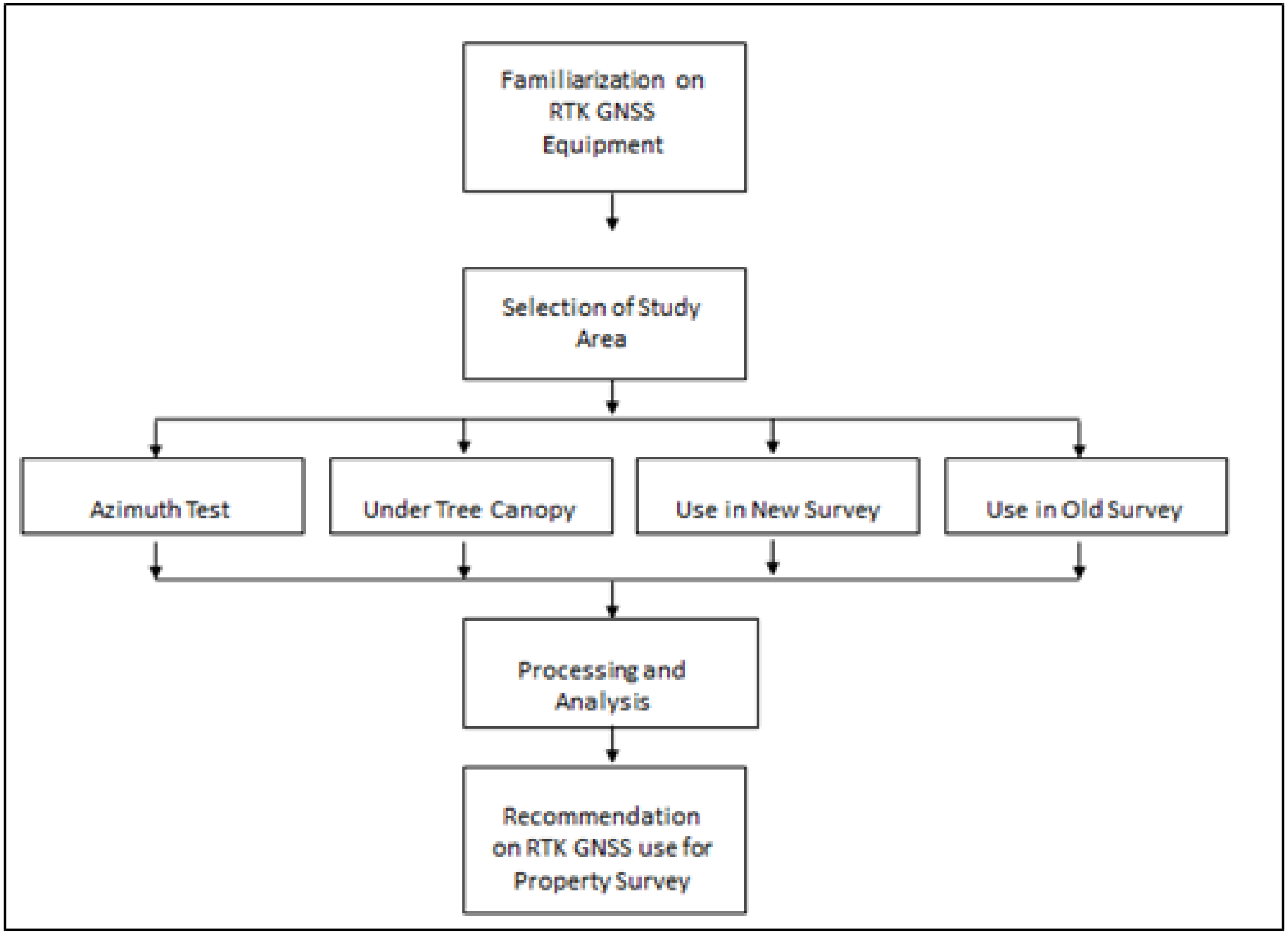
RELATED CONCEPTS AND STUDIES





- "RTK-GNSS is applicable for parcel corner position determination with consideration to limitations such as obstructions, level of accuracy, systematic error from projection, different coordinate systems used in the country, and poor identification of common points."
- Considering the limitations of the study before and the evolving GNSS receiver technology, and update of findings is necessary
- Model for Research Methodology
- GNSS models used were limited

METHODOLOGY



Workflow of the Experiments

RESULTS

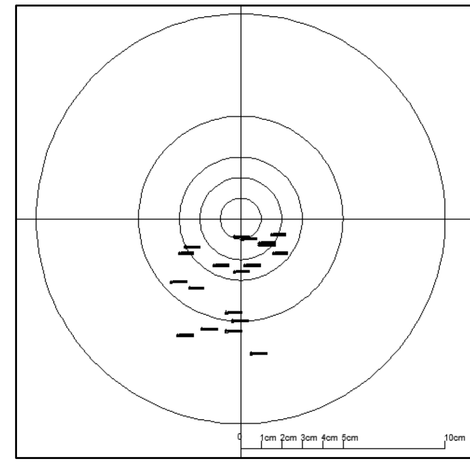
Azimuths for RTK-GNSS

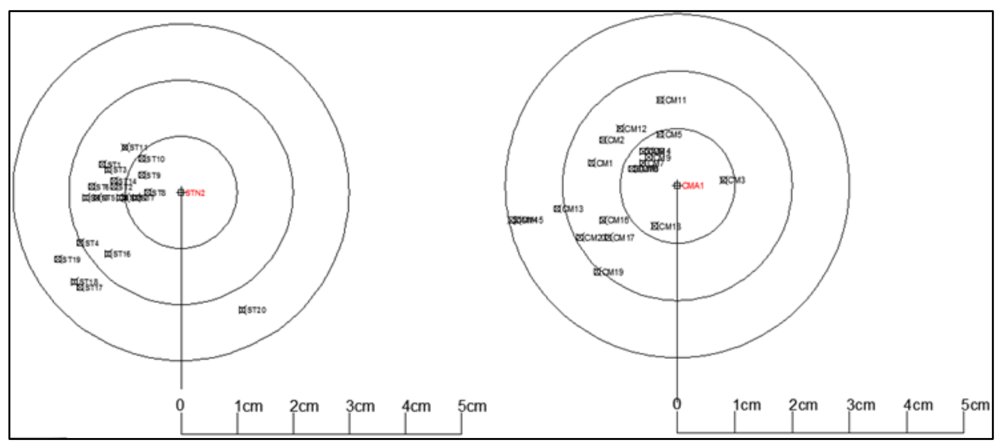
Figure 2. Site 1 used for Azimuth Test

Figure 3. Site 2 used for Azimuth Test

Table 2. Mean horizontal position, minimum no. of satellites and maximum PDOP of the four simulated corners

PT. ID	mean Horizontal Precision (m)	mean minimum no. of satellites	mean Maximum PDOP
STN2	0.017	10	2.795
CMA1	0.011	10	1.815
MMA39B2	0.014	11	2.082





RESULTS
Azimuths for RTK-GNSS

Table 3. Maximum Difference and Standard Deviations between Rapid-Static GNSS positions and RTK GNSS positions

Point ID	Δ Nmax	Δ Emax	σ N	σ E
STN2	-2.5cm	-2.1cm	±1.3cm	±1.1cm
CMA1	1.8cm	-2.9cm	±1.4cm	±0.8cm
MMA39B2	-3.4cm	-6.6cm	±3.6cm	±1.8cm

Table 4. Comparison of Grid Azimuths from Static and RTK Survey

LINE	Grid Azimuth						Difference			PE<15 sec
	From Static			From RTK						Yes/ No
	dd	mm	ss	dd	mm	ss	dd	mm	ss	
STN1-STN2	339	14	30.99	339	18	34	0	-4	-3.01	No
STN1-CMA1	72	20	33.39	72	20	22	0	0	11.39	Yes
MMA39-MMA39B2	89	45	0.69	89	40	28	0	4	32.69	No

Table 5. Comparison of Grid Azimuths using Namria Position and Logged Position of MMA39

LINE	Grid Azimuth						Difference			PE<5 sec
	NAMRIA Position of MMA39			Logged Position of MMA39						Yes/ No
	dd	mm	ss	dd	mm	ss	dd	mm	ss	
MMA39-MMA39B2	89	45	0.69	89	45	0.51	0	0	0.18	Yes

Table 6. Comparison of Geodetic Azimuth and Astronomic Azimuth

LINE	Geodetic Azimuth (Grid Azimuth w convergence correction			Astronomic Azi muth (UPTCAGP 2009)			Difference			PE<10 sec
										Yes/ No
	dd	mm	ss	dd	mm	ss	dd	mm	ss	
MMA39-MMA39B2	89	45	53.84	89	45	45	0	0	8.84	Yes

RESULTS
Under Tree Canopy

Figure 4. Site 3 for RTK-GNSS under Tree Canopy Experimer

Table 7. List of points observed to be fixed and not fixed.

Tree no.	GPS+GLONASS Receiver (Date: 10/22/2013, Time: 16:03-17:44)		GPS+GLONASS+BDS Receiver (Date: 10/22/2013, Time: 11:29-12:49)	
	No. of Sat	Fixed/ Not Fixed	No. of Sat	Fixed/ Not Fixed
1	9	Not Fixed	10	Fixed
2	7	Fixed	22	Fixed
3	8	Fixed	14	Fixed
4	11	Fixed	15	Fixed
5	11	Not Fixed	17	Fixed
6	10	Not Fixed	21	Fixed
7	12	Fixed	21	Fixed
8	10	Fixed	15	Fixed
9	12	Fixed	15	Fixed
10	11	Fixed	15	Fixed
11	11	Not Fixed	14	Fixed
12	9	Not Fixed	16	Fixed
13	5	Not Fixed	14	Fixed
14	10	Not Fixed	16	Fixed
15	8	Not Fixed	18	Fixed
16	8	Not Fixed	16	Fixed
17	8	Fixed	20	Fixed
18	9	Fixed	16	Fixed
19	9	Not Fixed	19	Fixed
20	8	Fixed	13	Fixed
21	9	Not Fixed	14	Fixed
22	10	Not Fixed	10	Fixed
23	10	Not Fixed	15	Fixed
24	10	Not Fixed	13	Fixed
25	13	Fixed	16	Fixed
26	8	Fixed	15	Fixed
27	8	Not Fixed	13	Fixed
28	10	Not Fixed	18	Fixed
29	7	Fixed	13	Fixed
30	9	Fixed	13	Fixed

RESULTS
New Survey

Figure 5. Site 4 for RTK-GNSS for New Survey Experiment

Table 9. Mean horizontal position, minimum no. of satellites and maximum PDOP of the four simulated corners

PT. ID	mean Horizontal Precision (m)	mean minimum no. of satellites	mean Maximum PDOP
1	0.015	11	1.993
2	0.011	11	1.696
3	0.016	13	1.696
4	0.008	13	1.702

RESULTS
New Survey

Table 10. Mean positions (in meters) of the four (4) corners of the lot

Corners	Mean N	Mean E	σ N	σ E
1	1620860.305	506293.775	±0.2cm	±0.5cm
2	1620795.197	506298.7978	±0.3cm	±0.3cm
3	1620794.047	506238.6972	±0.2cm	±0.3cm
4	1620861.588	506236.8578	±0.2cm	±0.4cm

Table 11. Grid azimuths and grid distances versus geodetic azimuths and geodetic distances

LINE	Grid Azimuth derived from RTK GNSS			Grid Distance from RTK GNSS (m)	Geodetic Azimuth derived from RTK GNSS			Geodetic Distance from RTK GNSS (m)
	dd	mm	ss		dd	mm	ss	
MMA39-MMA39B2	89	45	0.69	49.991	89	45	53.42	50.003
MMA39-1	195	23	49.78	32.760	195	24	43	32.761
MMA39-2	337	44	30.03	36.223	337	45	22.86	36.225
MMA39-3	53	13	4.81	57.908	53	13	57	57.911
MMA39-4	124	16	43.18	58.355	124	17	37.09	58.358

RESULTS

New Survey

Table 13. Output technical descriptions from RTK-GNSS and Total Station Surveys

TECHNICAL DESCRIPTION		
FROM GRID		
LINE	BEARING	DISTANCE (m)
1-2	S 04-24-40.932 E	65.302
2-3	S 88-54-15.063 W	60.112
3-4	N 1-33-36.042 W	67.565
4-1	S 88-42-32.715 E	56.932
AREA	3880.3337	sqm
FROM GEODETIC		
1-2	S 4-23-48.209 E	65.304
2-3	S 88-55-06.989 W	60.114
3-4	N 1-32-43.424 W	67.569
4-1	S 88-41-37.191 E	56.934
AREA	3880.702	sqm
FROM TOTAL STATION		
LINE	BEARING	DISTANCE (m)
1-2	S 4-23-11.433 E	65.301
2-3	S 88-56-05.346 W	60.105
3-4	N 1-32-04.349 W	67.550
4-1	S 88-41-33.285 E	56.924
AREA	3879.373	sqm

TECHNICAL DESCRIPTION		
FROM GRID		
LINE	BEARING	DISTANCE (m)
1-2	S 04-25 E	65.30
2-3	S 88-54 W	60.11
3-4	N 1-34 W	67.57
4-1	S 88-43 E	56.93
AREA	3880	sqm
FROM GEODETIC		
1-2	S 4-24 E	65.30
2-3	S 88-55 W	60.11
3-4	N 1-33 W	67.57
4-1	S 88-42 E	56.93
AREA	3881	sqm
FROM TOTAL STATION		
LINE	BEARING	DISTANCE (m)
1-2	S 4-23 E	65.30
2-3	S 88-56 W	60.11
3-4	N 1-32 W	67.55
4-1	S 88-42 E	56.92
AREA	3879	sqm

RESULTS

Old Survey

TECHNICAL DESCRIPTION		
LINES	BEARINGS	DISTANCES
LOT 1 PCS-03-015395		
1-2	N.82°34'W.	6.33M.
2-3	N.13°02'E.	14.80M
3-4	N.55°49'E.	2.22M.
4-5	S.82°06'E.	4.00M.
5-6	S.72°41'E.	0.81M
6-1	S.13°00'W.	15.91M
LOT 2 PCS-03-015395		
1-2	N.13°00'E.	15.91M.
2-3	S.72°40'E.	11.07M.
3-4	S.13°03'W.	14.00M
4-1	N.82°32'W.	11.08M

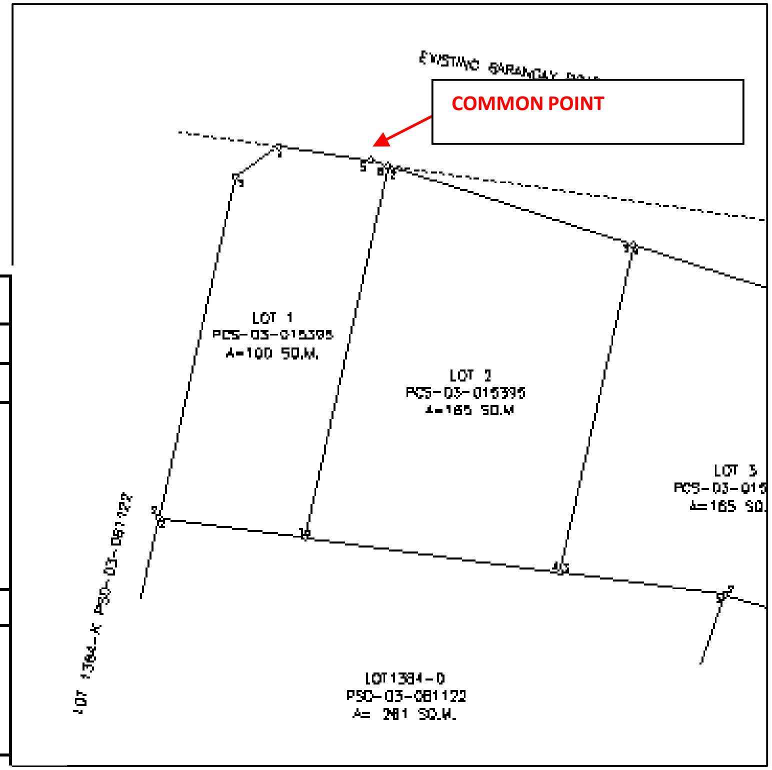


Figure 6. Survey plan with technical description of Site 5 used for RTK-GNSS for Old Survey Experiment

RESULTS
Old Survey

Table 14: Comparison between Theoretical Coordinates and RTK-GNSS Results (in meters)

Lot no./ Corner no.	THEORETICAL COORDINATES		RTK-GNSS RECOMPUTED COORDINATES		Δ N	Δ E	Displacement
LOT 1	NORTHINGS	EASTINGS	NORTHINGS	EASTINGS			
1	1641268.701	487923.976	1641268.729	487924.053	-0.028	-0.077	0.08
2	1641269.521	487917.696	1641269.540	487917.764	-0.019	-0.068	0.07
3	1641283.741	487920.986	1641283.664	487920.972	0.077	0.013	0.08
4	1641284.991	487922.826	1641284.899	487922.785	0.092	0.041	0.10
5	1641284.441	487926.786	1641284.441	487926.786	0.000	0.000	0.00
6	1641284.201	487927.556	1641284.190	487927.517	0.011	0.038	0.04
LOT 2							
1	1641268.701	487923.976	1641268.729	487924.053	-0.028	-0.077	0.08
2	1641284.201	487927.556	1641284.190	487927.517	0.011	0.038	0.04
3	1641280.901	487938.126	1641280.907	487938.078	-0.006	0.048	0.05
4	1641267.261	487934.966	1641267.281	487934.988	-0.020	-0.022	0.03

RESULTS

Combined RTK-GNSS & Total Station Methodology

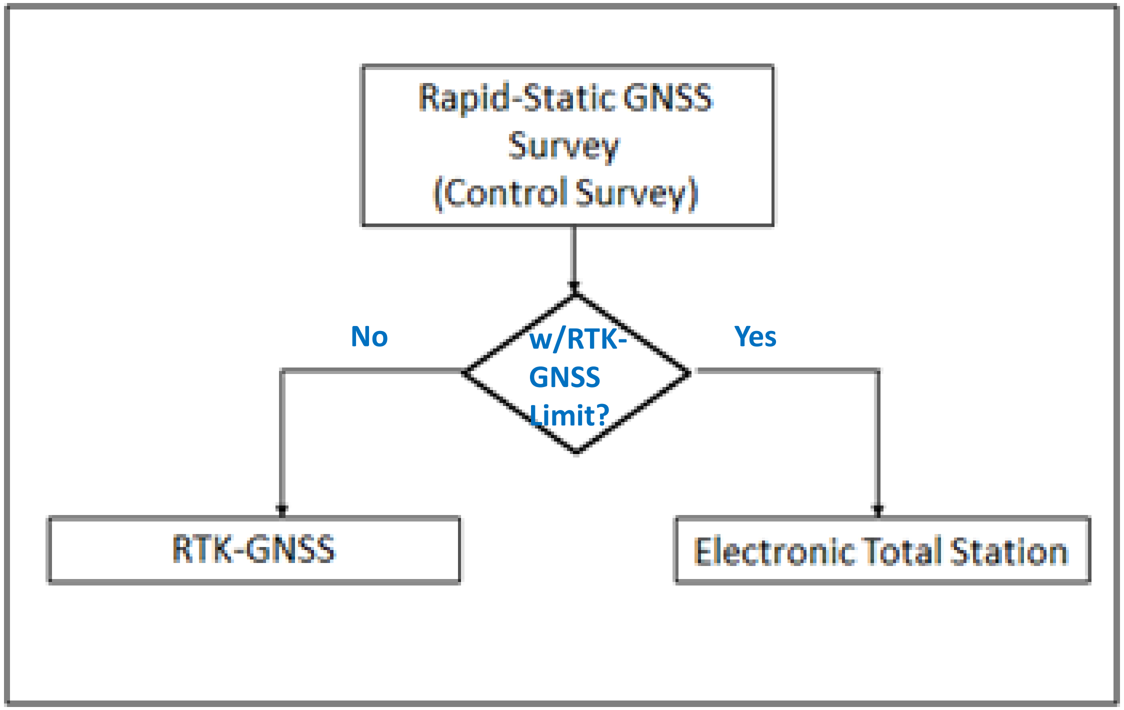


Figure 7. Combined RTK-GNSS-Total Station Methodology

RESULTS

Combined RTK-GNSS & Total Station Methodology

Control Survey

1. Rapid-Static GNSS Survey can be used in establishing controls for the survey.

- connect to old Bureau of Lands, NAMRIA or new DENR-LMS depending on the situation
- Established a pair for electronic total station use.
- Baseline length can be short but at least 50 meters is suggested.

RESULTS

Combined RTK-GNSS & Total Station Methodology

Isolated Survey Implementation

1. RTK-GNSS Survey can be used based on the conditions set by DENR-LMB Memorandum Circular No. 2015-001.

2. In addition surveyor can also consider the following conditions:

(a) receiver clearance of 15º from the horizon can be waived if GNSS receiver can provide positional error not more than five (5) centimeters under satellite-signal obstructions such as tree canopies

(b) rover receivers held is applicable if the circular bubble is balanced by the instrument man

(c) positional precision better than five (5) centimeters can be used as guide to a good observation if RMS is not provided

RESULTS
Combined RTK-GNSS & Total Station Methodology
Isolated Survey Implementation

(d) observation time can be lessened to five (5) 1-second observations depending on the precision shown on the GNSS controller

(e) minimum of 10 satellites are needed to have a good RTK-GNSS Survey results,

(f) PDOP should be better than 2.

3. If these conditions are met, RTK-GNSS can be used for a specific property survey task. If not, the traditional method of using an electronic station should be used.

Grid azimuths and grid distances must be converted to geodetic azimuths and geodetic distances for total station use (especially for long sights)

CONCLUSION & RECOMMENDATION

- RTK-GNSS was shown to be applicable in determining the positions of parcel corners without significant difference compared to traditional method (use of optical instrument)

- Suggested methodologies provided may be used by survey practitioners in conducting property surveys using RTK-GNSS stand-alone or RTK-GNSS combined with an electronic total station.

- However, limitations exist such as obstruction, accuracy within centimeter level and systematic error from projection

- RTK-GNSS like the traditional method is also affected by land survey conditions such as varying coordinate system and poor or wrong identification of common point.

CONCLUSION & RECOMMENDATION

- Due to obstructions which cannot be avoided especially in urban areas, a combined RTK-GNSS-total station survey is the preferred technique.

- Since the main output of RTK-GNSS survey is in terms of grid position there maybe a need to change the requirements for survey plan approval since traverse and lot data computations using side-shot data are not applicable.

CONCLUSION & RECOMMENDATION

- It is recommended that part of the submittal information include base-point used, horizontal precision obtained during the survey and PDOP.

- Solutions on getting the geodetic azimuth and distance may also be included since survey plans are currently in terms of directions and distances.

- Requirement to provide only grid positions can also be recommended.

CONCLUSION & RECOMMENDATION

- Problems pertaining to the three (3) existing coordinate reference systems in the current cadastral database and the possible difference between the technical description of an old survey and the result of RTK-GNSS on lot parcels were not covered by the experiments.

- Surveyors must be aware of these issues when doing surveys to be able to adjust to the situation and provide a sensible solution to a particular property survey problem.

Surveying, Land Administration and Valuation Research Laboratory

Component 1
Property Survey using RTK-GNSS
ProperRTK

Proper RTK
Rationale and Objectives

- **Rationale**
  - As more survey practitioners are aware on the advantages of using RTK-GNSS, an implementing rules and regulations (IRR) is needed to provide a proper way to use of the technology and verify of the results.
  - The IRR should contain not just the standard processes and methodologies in using RTK-GNSS, but also a way to verify the survey outputs.
  - The processes and standards described in the IRR should have a proper basis and tested if applicable.

- **Objectives**
  - To come-up with various methodologies and techniques in evaluating the performance of each GNSS-RTK model that can be used by surveyors for property survey;
  - To implement the tests and experiments;
  - To provide an IVAS process from survey outputs obtained from RTK-GNSS; and
  - To come-up with an IRR on the use of RTK for property survey using research method.

ProperRTK Expected Outputs

- Documentation of the different RTK-GNSS brands and models available in the current market;
- Documentation on the specifications of the different RTK-GNSS brands and models;
- Technical Report describing the implemented test methodologies, statistical analysis and proposals for IVAS; and
- Draft Implementing Rules and Regulations (IRR).

Equipment Testing

- MJAS Zenith Trading
Model: CHCNAV i90
Date / Time: December 18, 2019 / 9:30 am – 5:50 pm



- QuantumLab Geosolutions Inc. (RASA Surveying & Realty)
Model: TITAN TR7
Date / Time: November 22, 2019 / 9:40 am – 4:50 pm




TR7

- CERTEZA Infosys Corporation
Model: Leica GS18T
Date / Time: December 9, 2019 / 9:50 am – 6:15 pm



- GEOLINK Positioning Instruments
Model: SOKKIA GRX3
Date / Time: November 27, 2019 / 9:35 am – 5:10 pm



GRX3

- BRIANNA Innvations & Solutions Corporation
Model: Horizon Kronos C3
Date / Time: December 6, 2019 / 9:55 am – 5:30 pm

Thank you for your attention!!!

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