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GIS Data Development: Comparing Code vs. RTK GPS

Including Discussions on the Importance of Professional GIS Certification and/or Survey Licensing

By: Howard S. Hodder, Jr., GISP

TUGIS
March 19, 2007

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Agenda

- Welcome and Introduction
- Project Background
  - Why did I choose to research this topic?
- Project Goals and Objectives
- Project Methodology (4 Steps)
- Results
  - Project Description / Development
  - RMSE Calculations
  - Developed Network Comparisons
  - Lessons Learned / Project Pitfalls
- Certification / Licensure Importance?
- Questions / Answers / Comments

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Who am I?

- **Howard S. Hodder, GISP,** earned his bachelor's degree in geography from Bloomsburg University in 1998 and will be completing his Masters in GIS from Penn State University in March 2007. He is the Regional Manager of Geographic Information System services in the Lancaster office of HRG and is a certified GIS professional (GISP). As such, he develops and maintains diverse GIS applications for municipalities, authorities, public agencies, and the private sector. He has extensive knowledge of both GPS surveying and GIS technology in addition to his computer programming and Microsoft Access database development skills. His responsibilities include field data collection, internal data processing and editing, project development, map and exhibit creation, and client support. Mr. Hodder also administers web-based GIS applications for our clients. Over the years, he has created dozens of GIS applications covering such uses as utility management (for water, sewer, and stormwater systems), property management, zoning and tax parcel administration, landscape mapping, watershed mapping, and recreational facilities mapping.

GIS Certification Institute

PENNSTATE
College of Earth and Mineral Sciences

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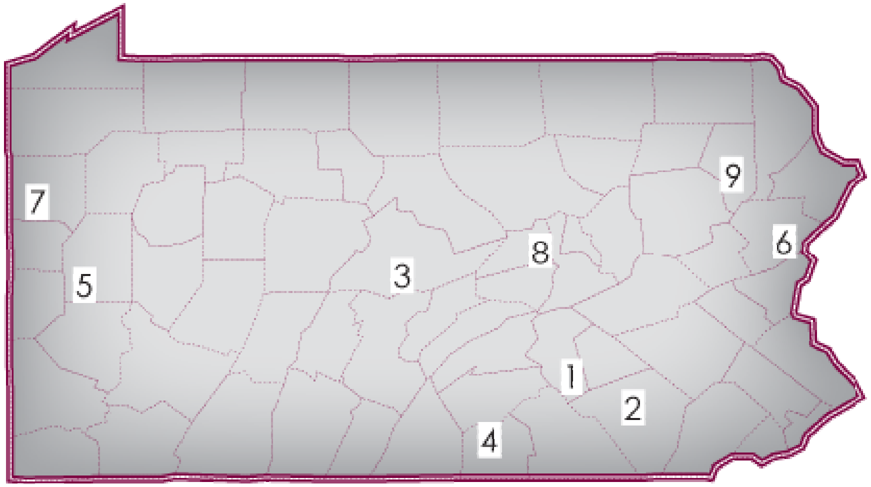
Firm Profile



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Project Background

Many clients do not understand the values of GPS data collection or what is involved with the different GPS data collection techniques.

Many factors need to be addressed and a proper technique chosen before a project begins.

- Data usage – project specific and future use
  – utility network mapping, independent feature locations, etc.
- Data precision – How accurate does the data need to be?
- Collection Techniques – Code vs RTK
- Long Term versus Short Term Benefits / Project Costs

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Project
Goals and Objectives

- Define GPS collection techniques
  - What is Code GPS?
  - What is RTK GPS?
- Present the comparison of Code vs RTK to better define the difference
- Better present the proper GPS data collection technique choice according to specific project types
- Better define the "Who?" of data collection and data development. (Surveyor, GIS Professional, Intern, etc.)

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Code vs RTK

VS

Note: Trimble ProXH and Trimble GPS Total Station 4800 were used for this project.

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GPS Data Collection – Differential Surveying (Code)

- Mapping Accuracy:
  - Horizontal = +/- 1 meter. (ProXH =+/- 1ft)
  - Vertical = ~3x's Horizontal
- 1 – 2 minute occupation times.
- Uses the code portion of the GPS signal.
- Requires post-processing for most accurate results.
- Real-time corrections are available.
  (e.g. WAAS)

GPS Data Collection – RTK Surveying

- Survey Accuracy:
  - Horizontal = ± 1cm + 1ppm
  - Vertical = ± 2cm + 1ppm
- 5 second occupation times.
- Relative Positioning uses carrier phase portion of the GPS signal.
- **No post-processing required.**

GPS Data Collection – RTK Surveying

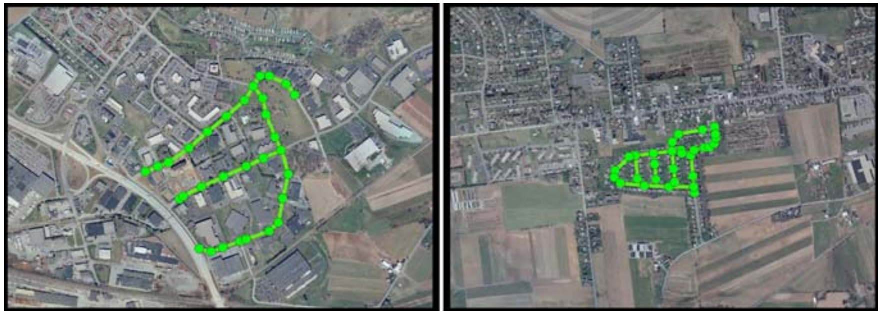
- RTK requires a minimum of two GPS receivers (base station and rover).
- Base broadcasts data to the rover via radio or cellular modem.

"As a rule of thumb, every 10 m of [absolute] error in the base station coordinates can introduce approximately 1 mm/km uncertainty in GPS baseline vectors." (Featherstone and Stewart, p. 44, 2001).

Project Methodology
(Based on Public Sanitary Sewer Network Example)

- **Step One – Data Collection**
  - Survey ~12 Known/Predetermined Benchmarks using both RTK and Code GPS
  - Survey Two Separate Project Areas (~25 features per area) using both RTK and Code GPS in each area and at the same time to control satellite constellation, time of day and weather factors
  - Record time/effort spent for collection and post processing of data and any project pitfalls

Project Methodology
(Based on Public Sanitary Sewer Network Example)



- **Step Two – Utility Network Development**
  - Create utility network systems by connecting the collected features in the predetermined areas
    - Calculate the network length for each project area
    - Calculate the difference between the Code and RTK based network lengths
    - Spatially portray feature locations over predefined base map to show discrepancies

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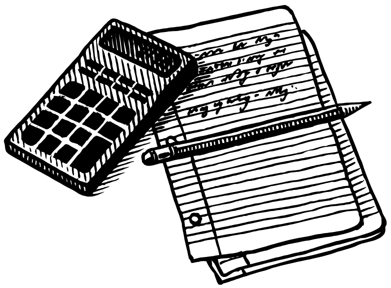
Project Methodology

(Based on Public Sanitary Sewer Network Example)



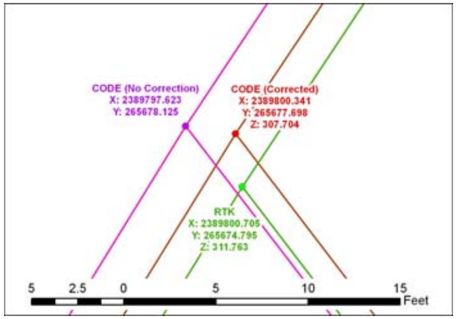
- **Step Three – Error Calculations**
  - Determine final data error calculations for each GPS collection method
    - Calculate Root Mean Square Errors (RMSE) for each GPS collection method by comparing the collected benchmark coordinates to the known/predetermined benchmark coordinates
    - Calculate location discrepancies between the Code and RTK collected features in each area
    - Spatially portray feature locations by overlaying their determined coordinated on a predefined projected base map

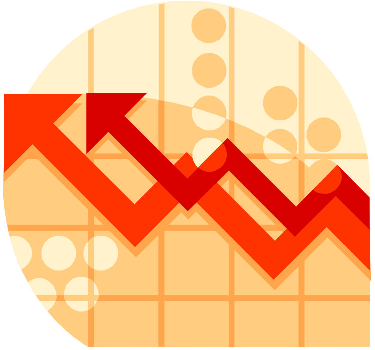
$$\text{RMS Error} = \sqrt{\frac{\sum d^2}{n}}$$

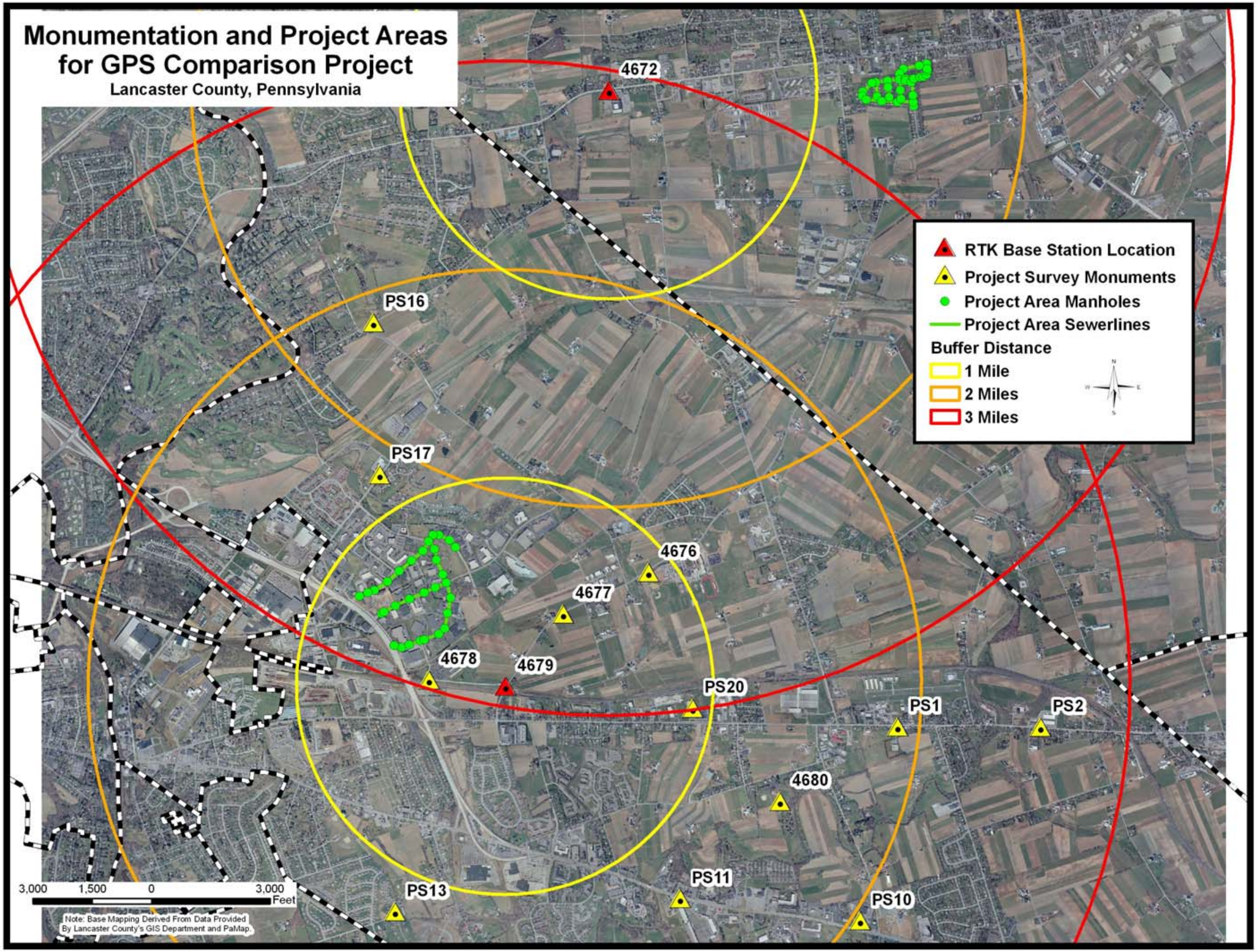
[http://www.geo.ed.ac.uk/agidexe/term?982]

Project Methodology
(Based on Public Sanitary Sewer Network Example)

- **Step Four – Results / Conclusions**
  - Present Findings of Real-World Utility Network in a Side-by-Side comparison
    - Include
      - Calculated Errors
      - System Length Calculation Discrepancies
      - Spatial Error using Base Map

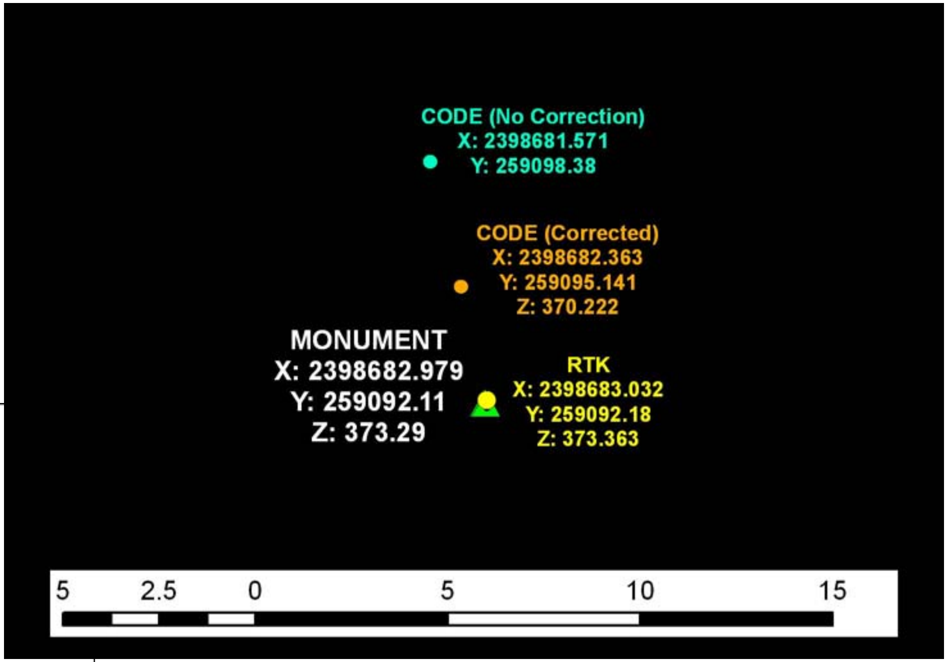




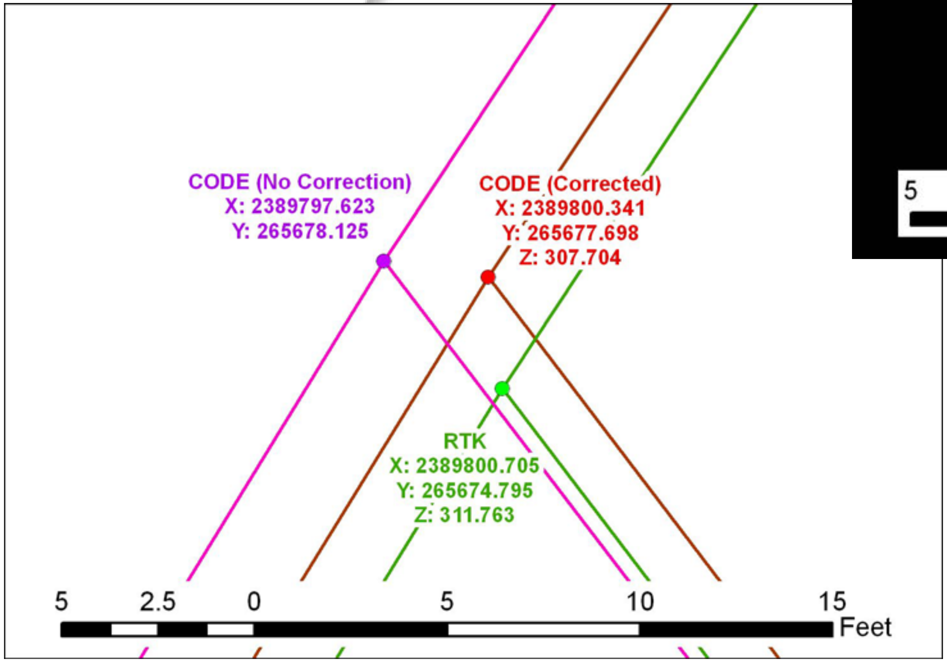


Monumentation and Project Areas for GPS Comparison Project
Lancaster County, Pennsylvania
4672
PS16
PS17
4676
4677
4678
4679
PS20
PS1
PS2
4680
PS11
PS13
PS10
RTK Base Station Location
Project Survey Monuments
Project Area Manholes
Project Area Sewerlines
Buffer Distance
1 Mile
2 Miles
3 Miles
3,000 1,500 0 3,000
Feet
Note: Base Mapping Derived From Data Provided By Lancaster County's GIS Department and PaMap.

Results



Benchmark Comparison



Sanitary Manhole Comparison

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Results

$$\text{RMS Error} = \sqrt{\frac{\sum d^2}{n}}$$

- ***RMS Error –***
  - Root mean square error is a measure of the dispersion of points around a centre. It is mathematically the spatial equivalent to the standard deviation.
  - Often used as a measure of the accuracy of points indicating the discrepancy between known point locations and their calculated locations. i.e The lower the RMS error, the more accurate the point.

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Results
Code , RTK
vs
Benchmarks

(X - Easting) Horizontal Comparison							
ID	Code	RTK	Keyed	E(Code)	E(RTK)	E(Code)^2	E(RTK)^2
4676a	2395345.776	2395347.371	2395347.371	-1.595	0.000	2.544	0.000
4677a	2393193.045	2393193.441	2393193.465	-0.420	-0.024	0.176	0.001
4678a	2389785.967	2389785.769	2389785.767	0.200	0.002	0.040	0.000
4680a	2398682.363	2398683.032	2398682.979	-0.616	0.053	0.379	0.003
PS10a	2400708.423	2400708.965	2400708.952	-0.529	0.013	0.280	0.000
PS11a	2396144.868	2396144.751	2396144.804	0.064	-0.053	0.004	0.003
PS13a	2388927.378	2388927.482	2388927.542	-0.164	-0.060	0.027	0.004
PS16a	2388376.249	2388378.276	2388378.278	-2.029	-0.002	4.117	0.000
PS17a	2388533.099	2388534.260	2388534.314	-1.215	-0.054	1.476	0.003
PS1a	2401662.730	2401663.368	2401663.412	-0.682	-0.044	0.465	0.002
PS20a	2396464.733	2396465.531	2396465.591	-0.858	-0.060	0.736	0.004
PS2a	2405275.125	2405278.178	2405278.198	-3.073	-0.020	9.443	0.000
					Average	**1.641**	**0.002**
					RMSE	**1.281**	**0.040**

Results
Code , RTK
VS
Benchmarks

(Y - Northing) Horizontal Comparison							
ID	Code	RTK	Keyed	E(Code)	E(RTK)	E(Code)^2	E(RTK)^2
4676a	264893.767	264890.935	264890.912	2.855	0.023	8.151	0.001
4677a	263843.920	263841.065	263840.963	2.957	0.102	8.744	0.010
4678a	262173.591	262170.774	262170.784	2.807	-0.010	7.879	0.000
4680a	259095.141	259092.180	259092.110	3.031	0.070	9.187	0.005
PS10a	256068.689	256063.526	256063.395	5.294	0.131	28.026	0.017
PS11a	256631.099	256626.449	256626.265	4.834	0.184	23.368	0.034
PS13a	256300.044	256297.267	256297.181	2.863	0.086	8.197	0.007
PS16a	271223.023	271219.701	271219.697	3.326	0.004	11.062	0.000
PS17a	267371.263	267369.061	267369.049	2.214	0.012	4.902	0.000
PS1a	260985.334	260981.624	260981.588	3.746	0.036	14.033	0.001
PS20a	261451.368	261449.813	261449.756	1.612	0.057	2.599	0.003
PS2a	260974.478	260970.328	260970.292	4.186	0.036	17.523	0.001
					Average	**11.972**	**0.007**
					RMSE	**3.460**	**0.082**

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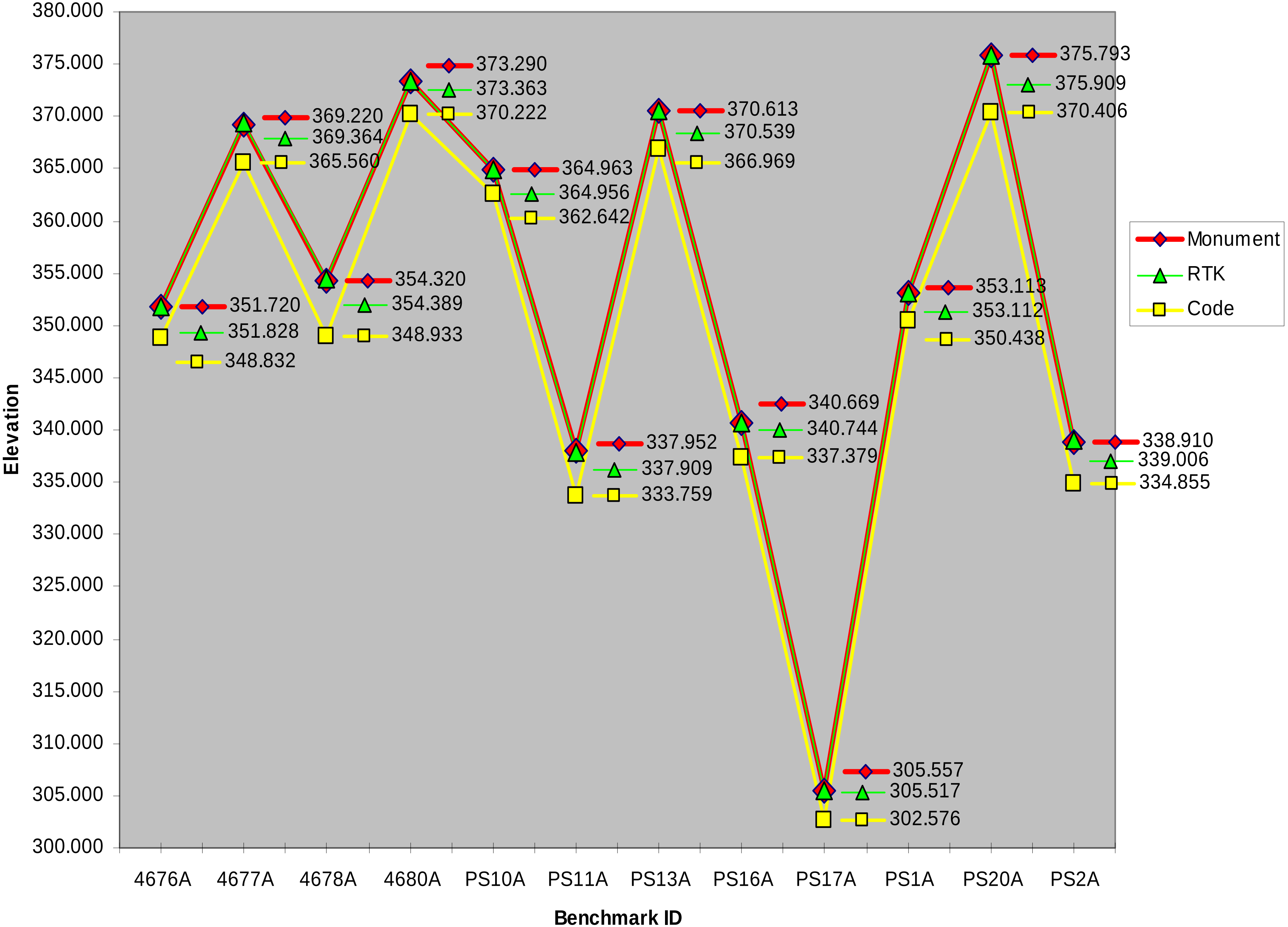
Results
Code , RTK
vs
Benchmarks

(Z - Elevation) Vertical Comparison							
ID	Code	RTK	Keyed	E(Code)	E(RTK)	E(Code)^2	E(RTK)^2
4676a	348.832	351.828	351.720	-2.888	0.108	8.341	0.012
4677a	365.560	369.364	369.220	-3.660	0.144	13.396	0.021
4678a	348.933	354.389	354.320	-5.387	0.069	29.020	0.005
4680a	370.222	373.363	373.290	-3.068	0.073	9.413	0.005
PS10a	362.642	364.956	364.963	-2.321	-0.007	5.387	0.000
PS11a	333.759	337.909	337.952	-4.193	-0.043	17.581	0.002
PS13a	366.969	370.539	370.613	-3.644	-0.074	13.279	0.005
PS16a	337.379	340.744	340.669	-3.290	0.075	10.824	0.006
PS17a	302.576	305.517	305.557	-2.981	-0.040	8.886	0.002
PS1a	350.438	353.112	353.113	-2.675	-0.001	7.156	0.000
PS20a	370.406	375.909	375.793	-5.387	0.116	29.020	0.013
PS2a	334.855	339.006	338.910	-4.055	0.096	16.443	0.009
					Average	**14.062**	**0.007**
					RMSE	**3.750**	**0.082**


Elevation
380.000
375.000
370.000
365.000
360.000
355.000
350.000
345.000
340.000
335.000
330.000
325.000
320.000
315.000
310.000
305.000
300.000
4676A
4677A
4678A
4680A
PS10A
PS11A
PS13A
PS16A
PS17A
PS1A
PS20A
PS2A
Benchmark ID
Monument
RTK
Code
351.720
351.828
348.832
369.220
369.364
365.560
354.320
354.389
348.933
373.290
373.363
370.222
364.963
364.956
362.642
337.952
337.909
333.759
370.613
370.539
366.969
340.669
340.744
337.379
305.557
305.517
302.576
353.113
353.112
350.438
375.793
375.909
370.406
338.910
339.006
334.855

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Results
Code vs RTK
Manholes

AREA 1

AREA 2

	RMSE (X)*	RMSE(Y)*	RMSE(Z)*
Code (Uncorrected) - Area1	2.532	3.572	N/A
Code (Corrected) - Area 1	0.288	2.783	3.529
Code (Uncorrected) - Area 2	2.712	3.316	N/A
Code (Corrected) - Area 2	0.509	2.611	3.002

*As compared to the RTK feature location information.

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Results

GPS Technique	Calculated Segment Length (ft) (59 Segments)	Difference (ft) (Compared to RTK Survey)
Code (No Correction)	**14,737.131**	**8.125**
Code (Corrected)	**14,728.458**	**0.548**
RTK	**14,729.006**	**0.000**

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Results - Review

- GPS Calculations
  - Moderate inequalities between utility networks developed by each GPS collection style (linear)
  - High inequalities between Code and RTK field located features (specifically elevations)
    - RTK – Quicker Collection / No Post -Processing
    - Code – Further Range (this is changing)
- Project "Pitfalls"
  - Weather, Equipment, Scheduling
  - Data Collection and Processing Issues / Errors

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Results – Review GPS Data Collection - Factors / Techniques

Some Questions to Consider:

(Define proper GPS data collection techniques according to specific projects.)

Budget / Schedule?

(New RTK Technology – Better Accuracy, Further Distance, Quicker / Cheaper)

Is Elevation Important? How accurate must the data be?

What will be the future use / analysis of the data?

Who will conduct field data collection / process the data?

- **RTK GPS**
  - Utility Systems (Networks)
    - » Potable Water
    - » Sanitary Sewer
    - » Storm Water

- **Code GPS**
  - Reference locations
    - » Signs
    - » Crime Locations
    - » Water samples
    - » Wetland Delineation

Defining the "Who?"

GPS Data Collection &

GIS Data Development

– When is a licensed surveyor "needed" for data collection?

(Licensed Surveyor, or supervised by licensed surveyor)

– Who should put the data together in the office?

(GISP – GIS Certification Institute, or supervised by GISP)

Defining the “Who?”

Importance of GIS Certified and Survey Licensed Individuals working on a project

- GPS data collection should be performed by licensed surveyor(?)
  - **SURVEYING** - the practice of measuring angles and distances on the ground so that they can be accurately plotted on a map

    [http://wordnet.princeton.edu/perl/webwn?s=surveying]
  - Importance of data quality and insurance (Surveyor’s Seal)
    - Precise Locations important, Elevations important
  - “True Understanding” of data collection
    - Projection, Datum, Error Calculations
    - Not just know how to use hardware
  - Required by Local / State / Federal Mandates

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Defining the "Who?"

Importance of GIS Certified and Survey Licensed Individuals working on a project

- GIS Certification
  - Still very controversial – Mixed Opinions

    Is there a GIS "profession"?- Multiple uses for GIS

    [Making the case for GIS Professional Certtification, GeoSpatial Matters, Wayne, Lynda, Huxhold, William, and Grams, Scott. www.geoplace.com/hottopics/giscertification/ProCertification.asp]

    [A Critical Perspective on GIS Professional Certification, GeoSpatial Matters, Cordova, Henry. www.geoplace.com/hottopics/giscertification/AntiCertification.asp]

    GIS Art or Science? – Is it certifiable?

    [Stay on Your Own Side, Where is the line between surveying and mapping?. Al Butler, AICP, 2000]
  - Usefulness of Certification
    - Professionalism / Experience
    - QA / QC
    - Standards / Values
    - Code of Ethics

GIS Certification Institute

Defining the “Who?”

Importance of GIS Certified and Survey Licensed Individuals working on a project

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- GIS Certification / Survey License Importance
  - I believe many are unaware of importance of the need for a licensed individual to complete or QA/QC field GPS feature collection and final GIS data development and analysis.
  - Mixed results and opinions for both GIS Certification and GPS Survey by Licensed Surveyor.
  - **DM: Two states (North Carolina and Oregon) have endorsed GISP certification.** **SG:** The North Carolina and Oregon endorsements were unsolicited but not surprising. There are a number of states that have seen tremendous value in the program. Florida, California, Colorado, Michigan, Ohio, Texas, Virginia, Washington, Wisconsin, etc. all have gravitated toward the credential. North Carolina and Oregon have progressive geographic information councils who wanted to back their GIS professionals by removing any doubt or obstacles those professionals had regarding the GISP.

[http://www.directionsmag.com/article.php?article_id=2106&trv=1, Scott Grams, GISCI Update, February 18, 2006.]

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Defining the "Who?"

Importance of GIS Certified and Survey Licensed Individuals working on a project

Final Thought: "It Depends…"

The client must be the final judge as to what type of data collection best suites their circumstances and who will perform the collection, but, in my opinion, it is the consultants' duty to educate the client / prospective client on the different options available so they are able to make that informed decision.

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Questions / Answers / Comments

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Questions / Answers / Comments

- Special Thanks:
  - Scott Faulkner – GPS Field Collection Assistant – Surveyor In Training
  - Chris French – GPS Field Collection Assistant
  - Eric Orndorff – GPS/Survey Manager – MS, PLS
  - Al Kling – Survey Manager – PLS
  - Robert Haag – Survey Manager – PLS
  - Steve Gochenaur – GIS Professional
  - Al Butler – AICP, Certified Mapping Scientist – GIS/LIS
  - Herbert, Rowland & Grubic, Inc. – www.HRG-Inc.com
  - Penn State University – Master of Geographic Information Systems

  http://www.worldcampus.psu.edu/MasterinGIS.shtml