OPERATORS WELLBORE
SURVEY GROUP
SUB-COMMITTEE

SPE International

Wellbore Positioning Technical Section

ISCWSA

The Industry Steering Committee on
Wellbore Survey Accuracy (ISCWSA)

OWSG ISCWSA General Meeting #58 Committee Report

October 19, 2023

Jonathan Lightfoot

Sub-Committee Chair

Our Mission

To promote practices that provide confidence that reported wellbore positions are within their stated uncertainty.

Re-Brand

OWSG: Operational Wellbore Survey Group

Operators, OEMs, Service Partners & Interested Parties

Focus: Case Studies and Operational Practices - Implementation

Meetings every other month

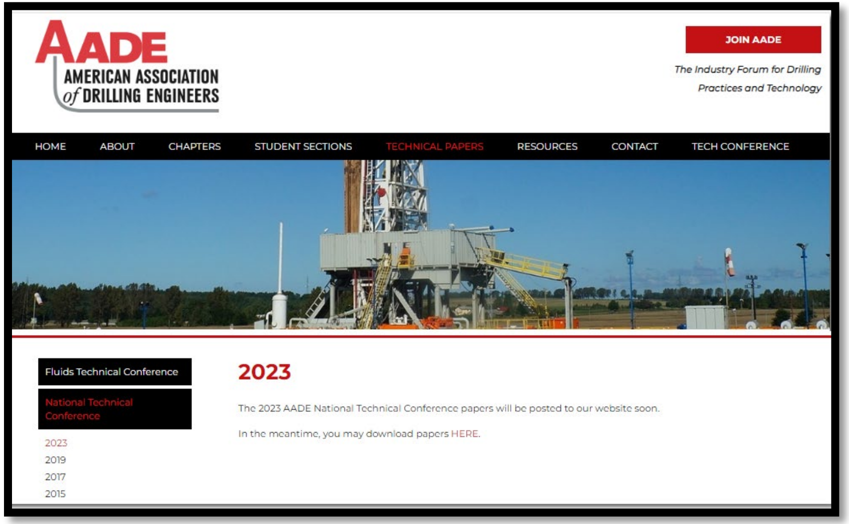
OWSG Chair – Jonathan Lightfoot (Position Open)

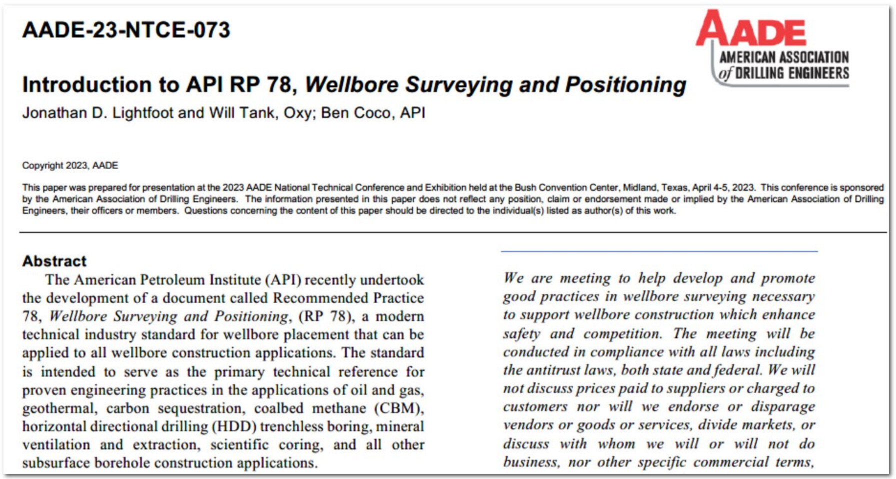
2022-2023 Meetings

1. December 1, 2022: (11/6) – RP 78 Update & IADC Tech Publications
2. Feb 7, 2023: (10/5) – Maximum Survey Intervals
3. May 23, 2023: (6/2) – SPE Connect, SPE DL Program & RP78
4. July 25, 2023: (6/2) – Combined Surveys & Related Quality Control
5. October 3, 2023: (14/9) – Combined Survey Case Study – Mike Calkins
6. October 18, 2023: (19) – OWSG, an Operational Rebranding
   - Future Focus Area on Operational Implementations and Case Studies

AADE NTCE Paper about API RP78 Plus WPTS Work

- 2023: National Technical Conference and Exhibition – Technical Papers





AADE-23-NTCE-073

AMERICAN ASSOCIATION of DRILLING ENGINEERS

Introduction to API RP 78, *Wellbore Surveying and Positioning*

Jonathan D. Lightfoot and Will Tank, Oxy; Ben Coco, API

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This paper was prepared for presentation at the 2023 AADE National Technical Conference and Exhibition held at the Bush Convention Center, Midland, Texas, April 4-5, 2023. This conference is sponsored by the American Association of Drilling Engineers. The information presented in this paper does not reflect any position, claim or endorsement made or implied by the American Association of Drilling Engineers, their officers or members. Questions concerning the content of this paper should be directed to the individual(s) listed as author(s) of this work.

Abstract

The American Petroleum Institute (API) recently undertook the development of a document called Recommended Practice 78, *Wellbore Surveying and Positioning*, (RP 78), a modern technical industry standard for wellbore placement that can be applied to all wellbore construction applications. The standard is intended to serve as the primary technical reference for proven engineering practices in the applications of oil and gas, geothermal, carbon sequestration, coalbed methane (CBM), horizontal directional drilling (HDD) trenchless boring, mineral ventilation and extraction, scientific coring, and all other subsurface borehole construction applications.

We are meeting to help develop and promote good practices in wellbore surveying necessary to support wellbore construction which enhance safety and competition. The meeting will be conducted in compliance with all laws including the antitrust laws, both state and federal. We will not discuss prices paid to suppliers or charged to customers nor will we endorse or disparage vendors or goods or services, divide markets, or discuss with whom we will or will not do business, nor other specific commercial terms,

API RP 78 Wellbore Positioning and Surveying

- 5th Technical Draft Completed (RP78 TG SharePoint)
- Balloting Roster Prepared / Confirmed
- API RP78 Task Group Program Manager (Assigned)

- **Katie M. Burkle, AStd**
- **Senior Program Manager**
- Standards Department
- **o:** 202.682.8507
- **e:** burklek@api.org
- 200 Massachusetts Ave NW
- Washington, DC 20001

American Petroleum Institute

RP 78 Task Group Ballot Roster

- 17 Operators
- 14 Manufacturer or Service Partner
- 11 General Interest

- **42 Total Voting Members Confirmed**

- **API Preparing Ballot & Image Permissions**

Member	Company	Interest Category
Stuart Sargeant	Agilis Software Solutions, Inc.	General Interest
Steve Grindrod	Copsegrove Developments Ltd.	General Interest
Ed Dew	EG Dew Consulting, LLC	General Interest
John Connor	ensoco, Inc.	General Interest
David Gibson	Gibson Reports	General Interest
Harald Bolt	ICT Europe, Ltd.	General Interest
Neil Bergstrom	Independent Consultant	General Interest
Zim Okafor	Independent Consultant	General Interest
Shaun St. Louis	IPM Magnetics	General Interest
Angela Mathis	ThinkTank Maths Limited	General Interest
Mike Calkins	Three Sigma Well Design, LLC	General Interest
Nasikul Islam	AI Driller	Manufacturer-Service Supplier
Ron Deady	APS Technology, Inc.	Manufacturer-Service Supplier
Jamie Stewart	Baker Hughes	Manufacturer-Service Supplier
Aubrey Holt	Bench Tree Group	Manufacturer-Service Supplier
Michael Kuhlman	Cougar Drilling Solutions	Manufacturer-Service Supplier
Maria French	Halliburton	Manufacturer-Service Supplier
Andy McGregor	Helmerich & Payne, Inc.	Manufacturer-Service Supplier
Mariya Kucherenko	MWDPlanet and Lumen Corp.	Manufacturer-Service Supplier
Mike Attrell	Pacesetter	Manufacturer-Service Supplier
Mike Long	roundLAB Inc.	Manufacturer-Service Supplier
Julie Cruse	Scientific Drilling	Manufacturer-Service Supplier
Ross Lowdon	SLB	Manufacturer-Service Supplier
Chad Hanak	Superior QC, LLC	Manufacturer-Service Supplier
Ross Bremner	THREE60 ENERGY	Manufacturer-Service Supplier
Petter Kvandal	akerbp	Operator-User
William T. Allen	BP	Operator-User
Sareddy Escobar Gonzalez	Cenovus	Operator-User
Kevin Sutherland	Chevron	Operator-User
Dalis Deliu	ConocoPhillips	Operator-User
Mark Matalik	Devon Energy Corporation	Operator-User
Heather Vannoy	EOG Resources	Operator-User
Marianne Houbiers	Equinor ASA	Operator-User
Ayush Raj Srivastava	ExxonMobil	Operator-User
Matt Isbell	Hess Corporation	Operator-User
Todd Benson	Hunt Energy	Operator-User
Bruce Gatherer	Iceland Drilling	Operator-User
Ryan Braxton	Pioneer Natural Resources	Operator-User
Will Tank	Oxy	Operator-User
Abdullah M. Al Dossary	Saudi Aramco	Operator-User
Matthew Weber	Shell	Operator-User
Hans Dreisig	Total Energies	Operator-User

Thank you

Next OWSG Meeting: December 5, 2023

Pot-Luck Lunch Mtg in Houston (After)

Survey Uncertainty Quantification with R: Need for an Explicit Definition of the Chi-Square Tests

Mike Calkins – Three Sigma Well Design, LLC

Overview

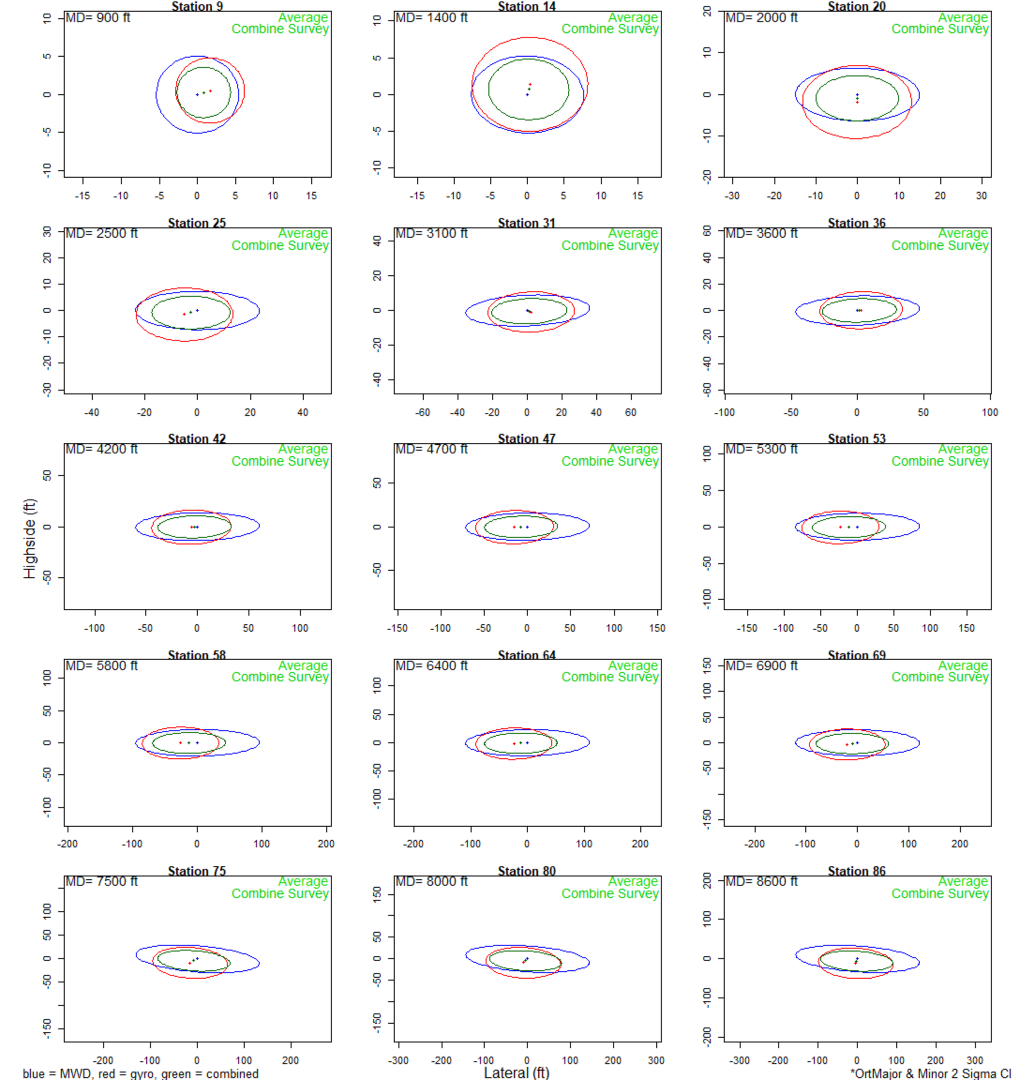
1. *Why?*
2. Combined Survey Project
3. Common Survey QC Tests
   a. Qualitative Ellipse Visual Tests
   b. RIP Test
   c. Chi-Squared Tests
      1. One Sided for Individual Wells
      2. Two Sided for EM Validation & Refinement
4. Current Chi-Square Test Implementation per Ekseth *et al.*, 2007 (SPE-105558)
   a) Limitations, Assumptions, & Concerns
   b) Need to explicitly define all QC Tests so they can be run correctly and consistently
5. Overview of R and preview of current QC Report code(slides to be posted)

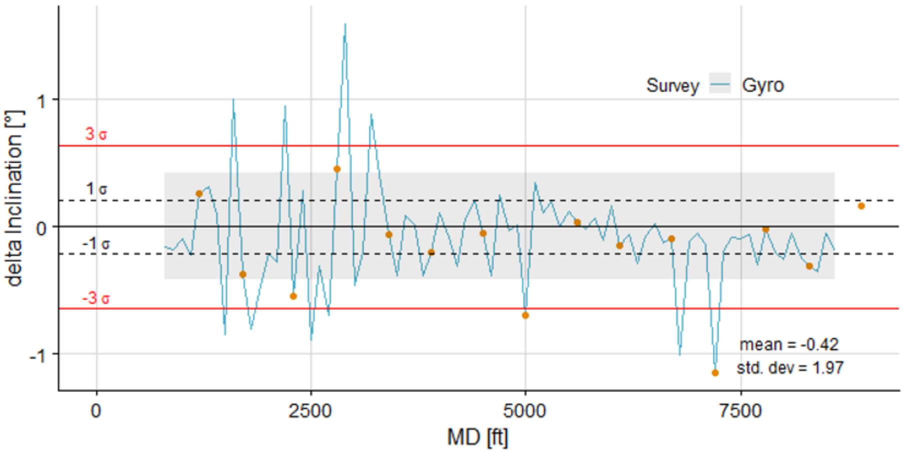
Why?

1. To **explicitly define uncertainty expectations** for survey data and the **means to determine** when a tool is not performing as assumed by the EMs
   - **ISCWSA OWSG Mission Statement**: To promote practices that provide confidence that reported positions are within their stated uncertainty

2. "To **obtain the maximum amount of useful information from the data on hand** without being able to repeat the experiment with better equipment or reduce statistical uncertainty by making more measurements"

   - Bevington, Data Reduction and Error Analysis for the Physical Sciences





Shaded area = Tolerance, orange dots = 15 stations used for the Chi-Square Test

Table 2: Result of all Chi Square (X^2) tests

	X^2 Test Value	Test Limit	Test Conclusion
IDT	60.19	34.4	Fail
ADT	27.88	34.4	Pass
CODT (HLA)	-	-	Pass
X_L	1.01	34.4	Pass
X_H	0.97	34.4	Pass
X_W	0.29	34.4	Pass

QC Test Overview – SPE-212492

- Ellipse Test
- RIP Test
- **Chi-Square Tests (IDT, ADT, CODT)**

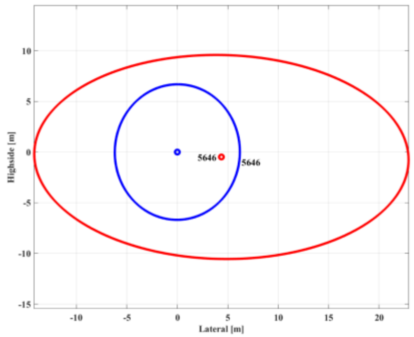


Figure 3—Comparison of GWD OMM (blue) and MWD (red) uncertainty ellipses at 5646m.

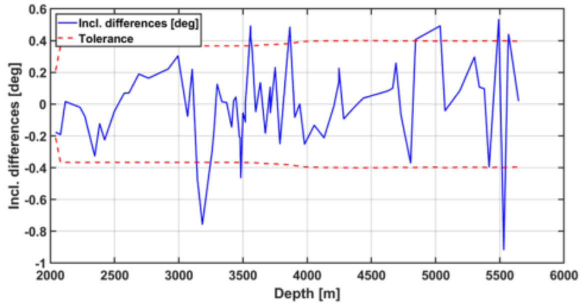


Figure 1—Inclination RIP test between GWD OMM × MWD

$$\chi = \sum_{i=1}^{n} \frac{\Delta x_i^{\,2}}{(\sigma_{1,i}^{\,2} + \sigma_{2,i}^{\,2})} \leq Z_{\gamma,n}$$

x: inclination, azimuth, or CODT (highside/ lateral/ or along-hole)

What is an Explicit Definition? – STDEV.P

Excel Definition and Function:

- Calculates standard deviation based on the entire population given as arguments (ignores logical values and text)
- The standard deviation is a measure of how widely values are dispersed from the average value (the mean).
- Assumptions: Arguments are the entire population (n).
    - If data is for a sample use (STDEV.S)
- For larger sample sizes, STDEV.P and STDEV.S can return ~ equal values
- Calculated using "n" method

$$\sqrt{\frac{\sum(x-\bar{x})^2}{n}}$$

Excel STDEV.P function

Formula	Description	Result
=STDEV.P(A3:A12)	Standard deviation of breaking strength, assuming only 10 tools are produced.	26.05455814

1345	1301	1368	1322	1310
1370	1318	1350	1303	1299

Using the above data results in a standard deviation (p) of 26.05

https://support.microsoft.com/en-us/office/stdev-p-function-6e917c05-31a0-496f-ade7-4f4e7462f285#:~:text=P%20function,-

Chi-Square Test

- A Statistical Measure of ***Goodness-of-Fit***
- **Hypothesis Testing** – Does the survey disagreement exceed our EM expectation
- A normally distributed **measurement and uncertainty** is transformed into a **Chi-Square distributed measurement**
- **5 Tests Total**
  - Inclination – IDT
  - Azimuth - ADT
  - 3 CODTs in HLA reference frame
    - NEV can be tested too, but HLA is preferred
- Results are **compared with a test limit (Z)**
  - Z value = number of stations (n) [15 stations is recommended] and significance level (γ)

$$X = \sum_{i=1}^{n} \frac{x_i^2}{\sigma_i^2} \le Z_{\gamma,n}$$

where $Z_{\gamma,n}$ is the Chi-square test limit for n degrees of freedom, at a significance level of γ. The significance level is, with one exception, fixed at 0.3% throughout this paper, in

SPE-105558 Eqn referenced above

1.0 Sigma Uncertainty/Scaled Variance Expectation Interpretation

Table 2: Result of all Chi Square (X^2) tests

	X^2 Test Value	Test Limit	Test Conclusion
IDT	27.98	34.4	Pass
ADT	18.39	34.4	Pass
CODT (HLA)	-	-	Pass
X_L	1.23	34.4	Pass
X_H	0.87	34.4	Pass
X_W	0.25	34.4	Pass

3.0 Sigma Uncertainty/Scaled Variance Expectation Interpretation

Table 2: Result of all Chi Square (X^2) tests

	X^2 Test Value	Test Limit	Test Conclusion
IDT	3.11	34.39	Pass
ADT	2.04	34.39	Pass
CODT (HLA)	-	-	Pass
X_L	0.14	34.39	Pass
X_H	0.1	34.39	Pass
X_W	0.03	34.39	Pass

Excel Test Limit Equation: CHISQ.INV.RT(0.003,15) = 34.4

Uncertainty Expectation – Test Decision

- How should our expected Variance or Uncertainty(std dev=sqrt(Variance)) sigma be calculated?
- **Not Explicitly Defined!**
  - **1 sigma seems too pessimistic(Prone to Type One Error – False Negative) for reasonable discrepancies**
  - 3 sigma may be too optimistic(Prone to Type Two Errors – False Positive)
- **Column 3 in Table 2** appears to show the average discrepancy/uncertainty ratio required to equal the Selected Test Limit
- Does an Ellipse Test scaled at 1.5 sigma make sense with Poor/Bad actions??

SPE/IADC 105558

High-Integrity Wellbore Surveys: Methods for Eliminating Gross Errors

Roger Ekseth, SPE, Gyrodata; Torgeir Torkildsen, SPE, Statoil ASA; Andrew Brooks, SPE, Baker Hughes Inteq; John Weston, SPE, Gyrodata; Erik Nyrnes, SPE, Statoil ASA; Harry Wilson, SPE, Baker Hughes Inteq; and Kazimir Kovalenko, SPE, Gyrodata

The Chi-square distribution statistical test. A Normally distributed measurement (x) with zero expectation and variance, σ^2, is transformed into an apparent one degree of freedom Chi-square distributed measurement by squaring the measurement and dividing by the variance. A given number (n) of one degree of freedom Chi-square distributed measurements, originating from n independent (uncorrelated) measurements, can be added together into a common Chi-square distributed test variable (X) with n degrees of freedom. The measurements can then be controlled against gross errors at a given confidence (γ) by testing if the following condition is fulfilled:

$$X = \sum_{i=1}^{n} \frac{x_i^2}{\sigma_i^2} \leq Z_{\gamma,n}$$

where $Z_{\gamma,n}$ is the Chi-square test limit for n degrees of freedom, at a significance level of γ. The significance level is, with one exception, fixed at 0.3% throughout this paper, in order to harmonise with the significance level used for the Normal distribution tests.

The Chi-square distribution test may be presented in an alternative form, when all n summed measurements have the same variance, σ^2.

Table 2: Chi-square distribution test limits and standard deviation scaling factors at a 0.3% significance level

n	$Z_{0.003,n}$	$\sqrt{Z_{0.003,n}/n}$
1	8.8	3.0
3	13.9	2.2
5	18.0	1.9
15	34.4	1.5
100	143	1.2
1000	1127	1.1

Summary: Chi-Square Test Items to Address

- **Explicitly *define* sigma/scaled variance**
  - ~~What is our expected uncertainty?~~ **Confirmed at 1.0 sigma**
- **Is *n* selection appropriate at 15 stations for CODT?**
  - **Prone to Type 1 error** relative to RIP Mean and Ellipse Test Limits?
  - Would n=5 make more sense for CODT?
- 0.003 significance *or* 3 sigma?
- Should we *switch* to the term *"Discrepancy" to* refer to "*measurement differences*"?
- How to run the CODT on a lower Survey Leg?
  - Zero Error Tie in and start ~500' out f/ TIP to avoid small error sensitivity
- 0.1 **or** 0.05 **or** 2 sigma for 2 sided test?
  - Mistake made in paper or appendix?
  - Same Test Values referenced as created in single sided test?

Table 2: Chi-square distribution test limits and standard deviation scaling factors at a 0.3% significance level

n	$Z_{0.003,n}$	$\sqrt{Z_{0.003,n}/n}$
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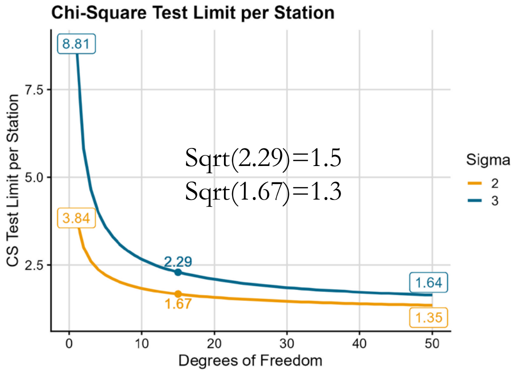


Table 6.2 Confidence limits associated with various $\Delta\chi^2$ contours for one degree of freedom.

$\Delta\chi^2$ contour	1.00	2.71	4.00	6.63	9.00
Measurements within range	68.3% 1σ	90.0%	95.4% 2σ	99.0%	99.7% 3σ

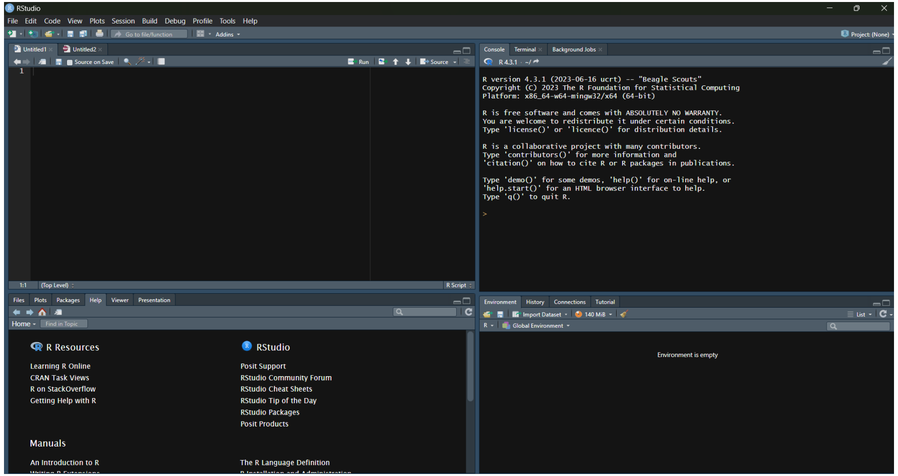
Hughes and Hase, Measurements and their Uncertainties – A Practical Guide to Modern Error Analysis

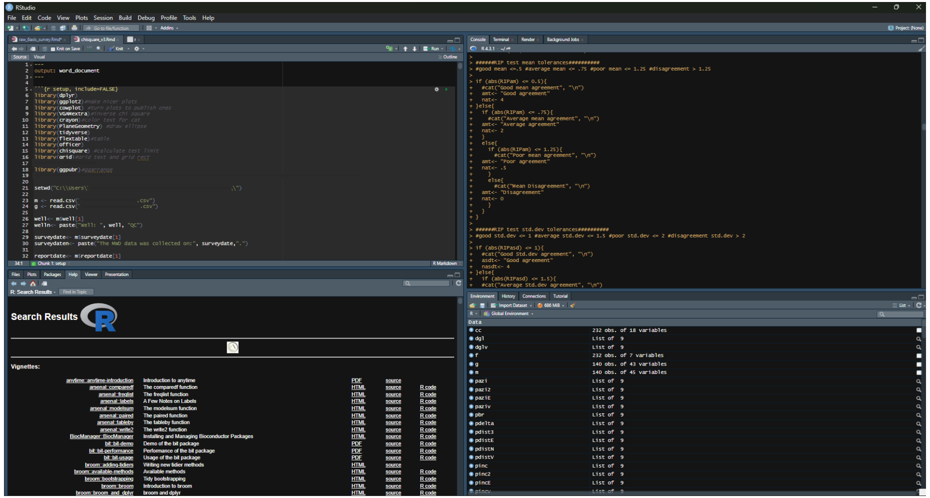
Questions?

tswd@threesigmawelldesign.com

What is R?

- An open-source statistical computing and graphic coding program
- Handles and stores data
- Computes large data and operations
- Functions not available in base package can be easily added by importing other created packages, or you can create your own functions.
- Most users use R studio as it is a more user-friendly interface than R.





Ellipse Test Improvement?

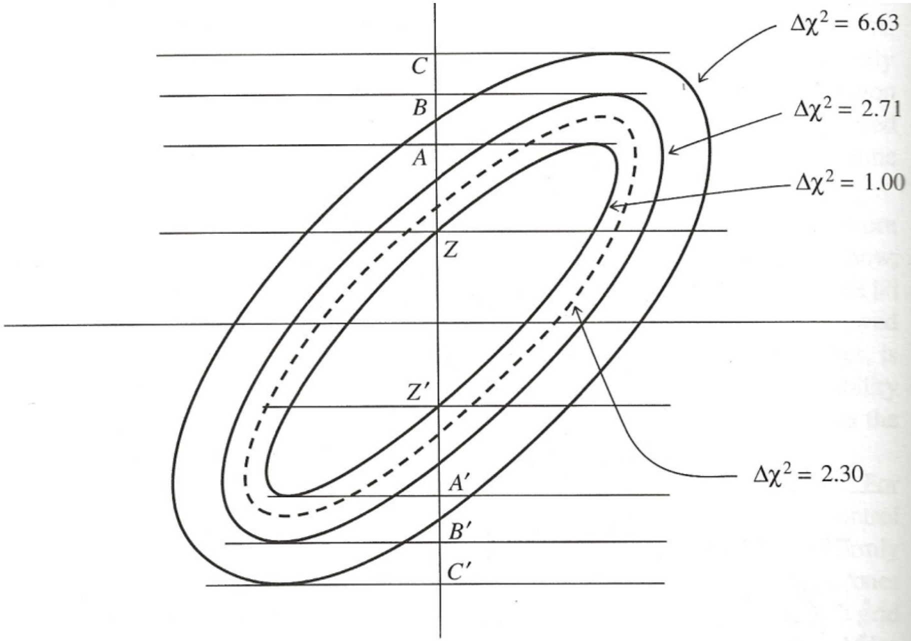
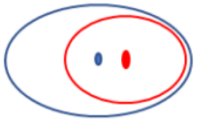
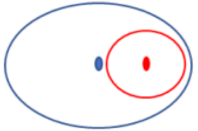
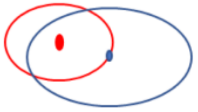
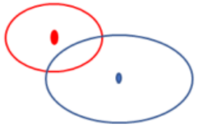
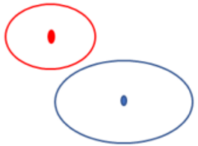


Figure 15.6.4. Confidence region ellipses corresponding to values of chi-square larger than the fitted minimum. The solid curves, with $\Delta\chi^2 = 1.00, 2.71, 6.63$ project onto one-dimensional intervals AA', BB', CC'. These intervals — not the ellipses themselves — contain 68.3%, 90%, and 99% of normally distributed data. The ellipse that contains 68.3% of normally distributed data is shown dashed, and has $\Delta\chi^2 = 2.30$. For additional numerical values, see accompanying table.

Press, W. H., B. P. Flannery, S. A. Teukolsky, and W. T. Vetterling, *Numerical Recipes, The Art of Scientific Computing,* Cambridge University Press, New York (1986).

Table 5—Ellipsis of Uncertainty for Survey Quality Analysis

Level Agreement	Description of Agreement level	Action	Pictorial Description of Agreement Level
Very Good	MWD ellipse fully encompasses gyro ellipse, and gyro ellipse encompasses centre of MWD ellipse.	No further investigation needed.	
Good	MWD ellipse fully encompasses gyro ellipse, but gyro ellipse does not encompass centre of MWD ellipse.	No further investigation needed.	
Average	MWD ellipse dows not fully encompass gyro ellipse but overlaps with it. The center of the gyro ellipse lies inside the MWD ellipse.	No further investigation needed.	
Poor	MWD ellipse dows not fully encompass gyro ellipse but overlaps with it. The centre of the gyro ellipse lies outside the MWD ellipse.	Investigate – if unresolved consider re-survey.	
Unacceptable	Ellipses do not overlap.	Probably re-survey immediately and investigate.	

SPE-212492

American Society for Quality(ASQ) – Control Chart

Out-of-control signals

- A single point outside the control limits. In Figure 1, point sixteen is above the UCL (upper control limit).
- 2 out of 3 successive points are on the same side of the centerline and farther than 2 σ from it. In Figure 1, point 4 sends that signal.
- 4 out of the 5 successive points are on the same side of the centerline and farther than 1 σ from it. In Figure 1, point 11 sends that signal.
- A run of 8 in a row are on the same side of the centerline. Or 10 out of 11, 12 out of 14, or 16 out of 20. In Figure 1, point 21 is 8th in a row above the centerline.
- Obvious consistent or persistent patterns that suggest something unusual about your data and your process.

*When you start a new control chart, the process may be out of control. If so, the control limits calculated from the first 20 points are conditional limits. When you have at least 20 sequential points from a period when the process is operating in control, recalculate control limits.

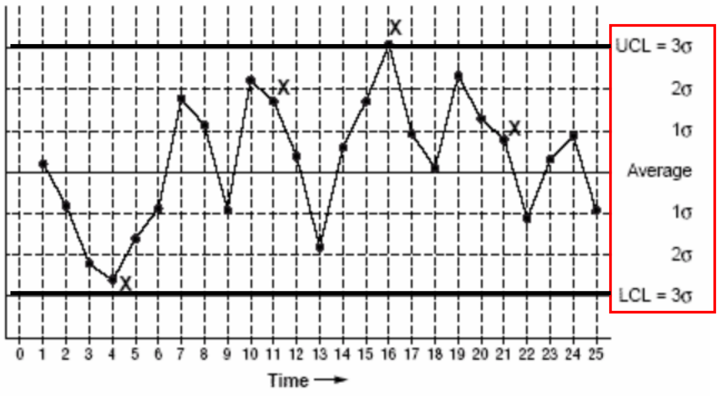
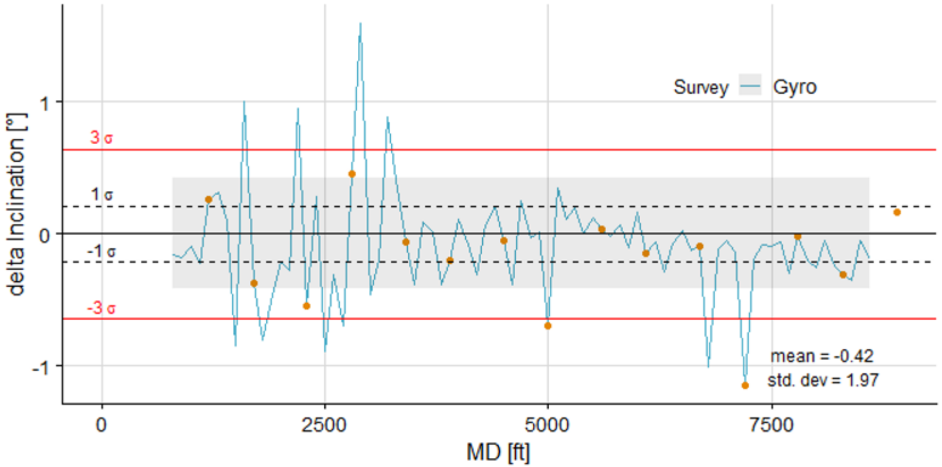


Figure 1 Control Chart: Out-of-Control Signals

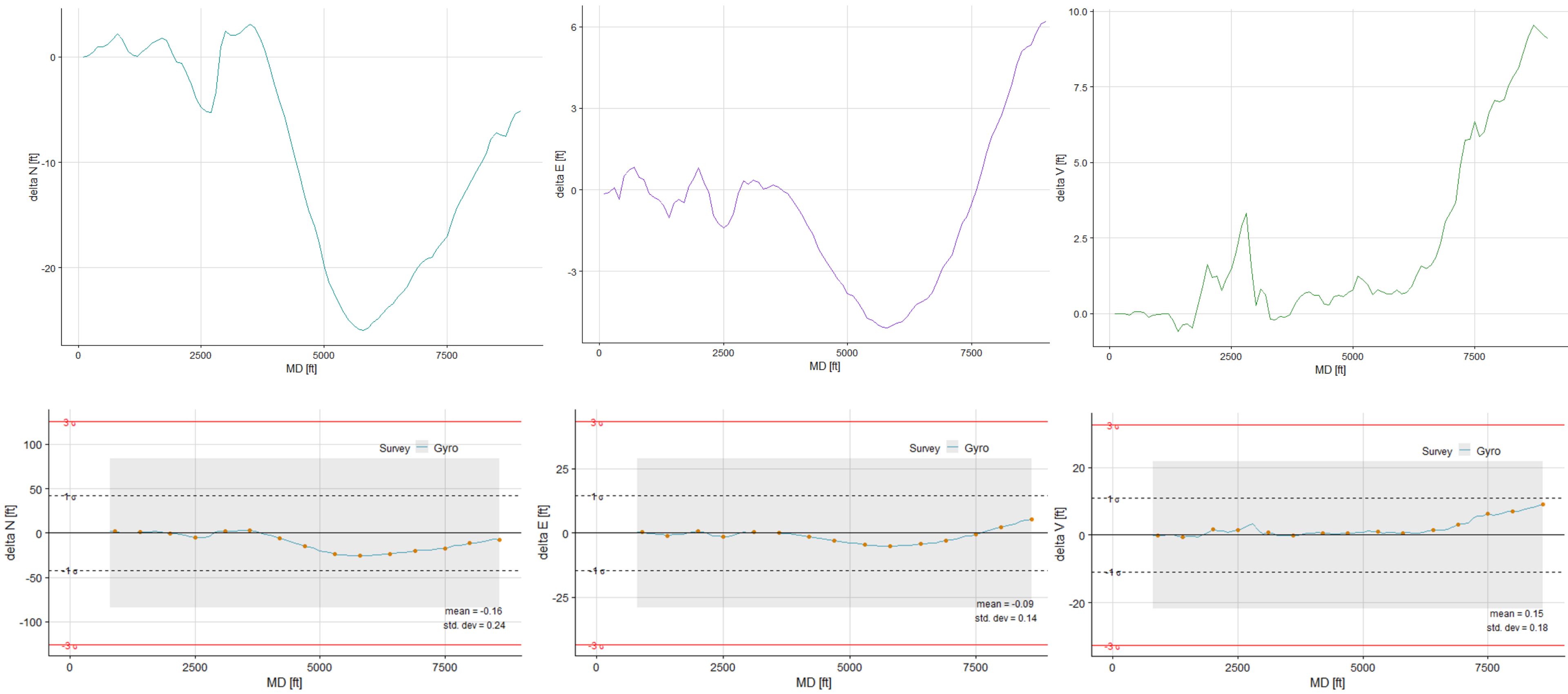
Current RIP/Control Chart Option from R



Shaded area = Tolerance, orange dots = 15 stations used for the Chi-Square Test

https://asq.org/quality-resources/control-chart

Distance RIP Plots – Improvement Idea



Chi Squared References

SPE/IADC 105558

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Published: February 20, 2007 (Peer Reviewed)

IADC/SPE-199554-MS

Validation of Error Models – A Key Component of Risk Mitigation in Wellbore Collision Challenges

Tarig Ali, Adrián Ledroz, and John Weston, Gyrodata; William Allen, BP

Published: February 25, 2020 (Peer Reviewed)