NATIONAL WATER QUALITY MONITORING COUNCIL

Working Together for Clean Water

Sensor Signal Integrity and Data Quality Management: Who is Doing What?

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The four levels of signal-integrity assurance

- Technology
- Model
- Instrument
- Measurement (a.k.a “Activity”, STORET)

Level 1: the Technology (Researchers)

- Discovery of principle, ground-truthing of concept, experiments with prototypes
- Tests to correlate signal with concentration or magnitude
- Characterization of capability in terms of linearity, range, interferences
- Comparisons with other methods that measure the same characteristic
- Technology demonstrations (e.g., by ACT)

Product: Advanced prototypes, verified operating principles

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Example: **Technologies** for measurement of dissolved oxygen

- Winkler titration: 1888, Budapest University, doctoral dissertation.
- Clark-type electrode: early 1950s, Yellow Springs, OH.
- Quenching of luminescence by dissolved oxygen was noted in 1939, first sensors ("optodes") developed in the 1990s

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Level 2: the **Model** (Manufacturers)

- Experiments with materials and parts
- Selection of shape, probe design, weight, power supply, etc.
- Characterization of accuracy, precision, resolution, detection limit, and response time, as well as linearity, range, and interferences

Product: Manufactured instruments with defined specifications

Next: Thorough testing of Model by others (e.g., ACT)

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Example: **Model** Evaluation by ACT

(Alliance for Coastal Technologies)

- Thorough review of protocols and standard operating procedures
- Multiple field deployments
- Determination of accuracy, precision, instrument drift, reliability, and durability, as well as effects and prevention of fouling and other interferences

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Level 3: the Instrument (Buyer)

- Inspection, assembly, deciphering of the manual, and initial operation of the new Instrument
- Verification of accuracy, precision, resolution, detection limit, and response time at various temperatures and ionic strengths, as well as linearity over specified range.
- Testing performance in local waterbodies in attended and unattended modes
- Deciphering the data management software that comes with the Instrument

Product: functional Instrument

"If you think like the developer you can make almost any Instrument work for you"

RK

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About the Instrument…

Assumption: “This is an elaborate and expensive ($10,000!!) sonde

[and automatic] [and it has its own brain!]] [and smart!! – see how it identified the Standard Buffer automatically??];

it must always be very accurate, right?”

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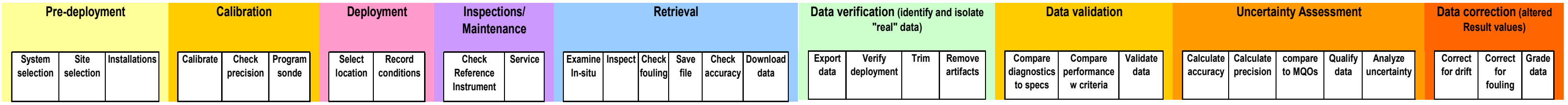
Level 4: the **Measurement** (Field Operator)

- Reading the User's Manual and SOP!
- Deployment, retrieval, cleaning, inspection and maintenance
- Actions to Affect, Check, Record, and Report the quality of each data batch
- Data quality management



Product: Monitoring data of known and documented quality

Calibration: "Comparison of a measurement standard, instrument, or item with a standard or instrument of higher accuracy to detect and quantify inaccuracies and to report or eliminate those inaccuracies by adjustments" [USEPA].

May [should] be SEPARATED into…

Accuracy check: Comparison of the Instrument's reading with a value believed to be the "true" value, without adjustments of the reading. [report]

Calibration adjustment: The action of adjusting the reading of an instrument to have it match a "true" value. (Naturally, you do this after you run the accuracy check…). [eliminate]

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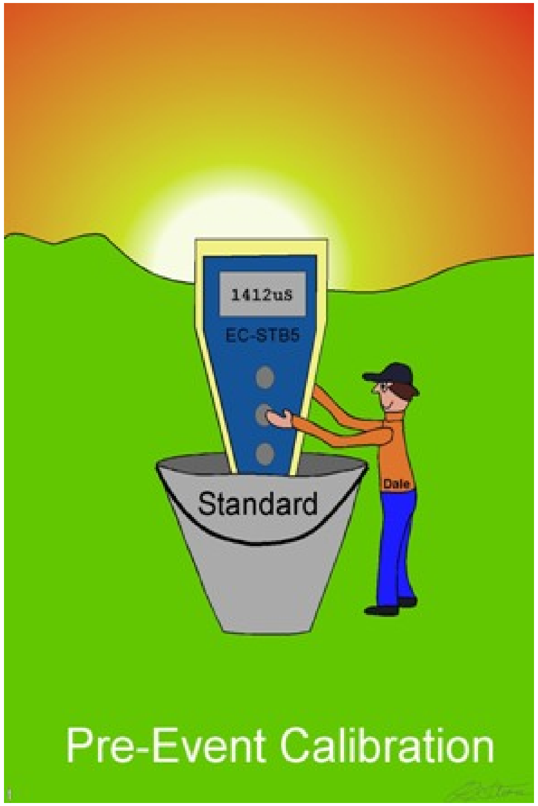
In other words, actions to Affect are inherently different from actions to Check!



AFFECT **CHECK**

ACRR for accuracy (generic)

- AFFECT – Calibrate
- CHECK – Conduct accuracy check (compare to Standard)
- RECORD – Instrument reading +“true” value of Standard
- REPORT – The difference from “true” value, or % accuracy

AFFECT **[Control]** ***(act to influence the outcome)***	**CHECK** ***(test to evaluate or verify)***	**RECORD** ***(keep everything documented)***	**REPORT** ***(communicate the data quality indicator)***
Quality Assurance Actions		**Documentation Actions**	
calibrate (adjustable-reading instruments)	**conduct accuracy check (all instruments)**	**instrument reading and "true" value of Standard**	**Accuracy (bias): Instrument's difference from "true" value, in measurement units or as a percentage of Standard's value**

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ACRR for precision (generic)

- AFFECT – Use consistent procedures
- CHECK – Conduct repeated, independent measurements
- RECORD – Results of repeated measurements
- REPORT – Relative % difference (RPD, or SD, or CV

AFFECT **[Control]** ***(act to influence the outcome)***	**CHECK** ***(test to evaluate or verify)***	**RECORD** ***(keep everything documented)***	**REPORT** ***(communicate the data quality indicator)***
Quality Assurance Actions		**Documentation Actions**	
use consistent procedures under same conditions	**conduct precision checks (repeat measurements of same)**	**results of repeated measurements**	**Relative Percent Difference, Standard Deviation, or Coefficient of Variation**

(Matrix screenshot)

Technology	data quality aspect	Mode	AFFECT [Control] *(act to influence the outcome)*	Check *(test to evaluate or verify)*	Record *(keep everything documented)*	Report *(communicate the data quality indicator)*
			Quality Assurance Actions		Documentation Actions	
conductivity cell	**Accuracy /Bias**	Attended	Conduct one-point calibration in the lab, at a value in the middle of anticipated environmental range, at room temperature **[sp1-3]**, before each Trip. Conduct two point calibration in the field, at values that bracket expected range, at stream temperature, before first use of the day. Make sure the probe is properly hydrated before calibration and before each use; assure sufficient voltage	**C**onduct a one-point accuracy check in the lab, at a mid-range value, at room temperature **[sp2]**, within 24 hrs of Trip's end	**T**emperature of Standard, Instrument conductivity reading, temperature compensation factor (if needed), and "true" value of Standard	Report bias: Instrument drift, i.e., difference from known ("true") value of Standard, expressed either in measurement units or as percent of Standard's "true" value, whichever is higher.
	Accuracy/Bias	**Unattended**	Conduct two-point calibration in the lab, at zero and at value higher than expected range, at room temperature, before deployment and at every maintenance event (if needed)	Conduct three-point accuracy check, w Standards at min/mid/max values of expected range, plus a zero check in air, at room or field temperature, within 24 hrs of retrieval and at every maintenance event, before and after cleaning.	**T**emperature of Standard, Instrument conductivity reading, temperature compensation factor (if needed), and "true" value of Standard	Report bias: Instrument drift, i.e., difference from known ("true") value of Standard, expressed either in measurement units or as percent of Standard's "true" value, whichever is higher.
	Precision	Attended	use consistent procedures under same conditions	Repeat measurements 3-5 times after the reading has stabilized, under controlled (non-changing) environment in the lab, during every calibration or accuracy check event.	Results of the 3-5 measurements after stabilization;	Compute the Standard Deviation of the 3-5 values and report in measurement units **[a4]**
	Precision	**Unattended**	Use consistent procedures under same conditions	Repeat measurements 3-5 times after the reading has stabilized, under controlled (non-changing) environment in the lab, during every calibration or accuracy check event.	Results of the 3-5 measurements after stabilization;	Compute the Standard Deviation of the 3-5 values and report in measurement units **[a4]**
	Lack of interference or contamination	Attended	clean probes			
	Lack/Extent of interference or contamination	**Unattended**	clean probes, treat with anti-fouling agents, adjust deployment duration or maintenance intervals to local conditions	Run fouling comparison test: Measure stream water (in situ or in bucket) before and after cleaning the probe.	Pre-cleaning inspection and photographic records of fouling, Instrument readings before and after probe fouling removal	

The QA (ACRR) Matrix, ASW 2010

- ASW and Review Panel recommended the minimum actions required for generation of data of known and documented quality
  - Calibration/accuracy check frequency and number of points
  - Repeated measurements
  - Fouling checks
- Various aspects of data quality: accuracy, precision, lack/extent of fouling, etc.
- Attended and unattended modes
- A page for each WQ characteristic, and a general sensors page
- Notes and monitoring tips

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The Sensors Data Quality Management (DQM) Functions Timeline, Part1

Pre-deployment	Calibration	Deployment	Inspections/ Maintenance	Retrieval
System selection; Site selection; Installations	Calibrate; Check precision; Program sonde	Select location; Record conditions	Check Reference Instrument; Service	Examine In-situ; Inspect; Check fouling; Save file; Check accuracy; Download data

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The Sensors Data Quality Management (DQM) Functions Timeline, Part 2

Data verification (identify and isolate "real" data)				**Data validation**			**Uncertainty Assessment**					**Data correction** (altered Result values)		
Export data	Verify deployment	Trim	Remove artifacts	Compare diagnostics to specs	Compare performance w criteria	Validate data	Calculate accuracy	Calculate precision	compare to MQOs	Qualify data	Analyze uncertainty	Correct for drift	Correct for fouling	Grade data

Detail: Calibration and Accuracy Checks

Phase	Calibration			Retrieval					
Task Name	**Calibrate**	**Check precision**	**Program sonde**	**Examine In-situ**	**Inspect**	**Check fouling**	**Save file**	**Check accuracy**	**Download data**
Task content	Calibrate electrode w Standard buffers	Run precision check in situ	Program sonde for deployment	document sonde in situ, pre-retrieval	inspect retrieved sonde	run fouling checks in stream water	save and close sonde file	run accuracy checks w Standard buffers	download sonde file to sonde software on computer
Records	'calibration records' package including diagnostics	repeated measurements	Time, place, initial instrument readings	notes (e.g., buried in sediment), photos	notes (e.g.,covered w biofilm), photos	readings before and after cleaning	file ID etc.	'accuracy check records' package including diagnostics	file ID etc.
Data Elements subject	7.9.3, 7.9.4, 7.9.5	7.10.1, 7.10.2	5.1.1, 6.4.4	6.4.3, 6.4.6, etc.	6.4.3, 6.4.6, etc.	7.10.1, 7.10.2	6.4.4	7.10.1 to 7.10.4	6.4.4

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Sensors data processing, from A to Z

Pre-deployment			Calibration			Deployment		Inspections/ Maintenance		Retrieval					
System selection	Site selection	Installations	Calibrate	Check precision	Program sonde	Select location	Record conditions	Check Reference Instrument	Service	Examine In-situ	Inspect	Check fouling	Save file	Check accuracy	Download data

Data verification (identify and isolate "real" data)				Data validation			Uncertainty Assessment					Data correction (altered Result values)		
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U.S. Geological Survey (USGS) conducted the **Value Engineering Study – Water Quality (2009),** working with the Interstate Council on Water policy (ICWP); study recommendations included (among others):

- Automate/streamline data entry and processing
- Consolidate functionalities of multiple software programs into one solution (identified nine different software programs in use)

Error and Correction

Phase	Uncertainty Assessment					Data correction (altered Result values)		
Task Name	**Calculate accuracy**	**Calculate precision**	**compare to MQOs**	**Qualify data**	**Analyze uncertainty**	**Correct for drift**	**Correct for fouling**	**Grade data**
Task content	calculate measurement accuracy for this episode	calculate measurement precision (for this episode?)	compare quality check outcomes to MQOs	select qualifier for 'met MQOs' (or not) or for error range	run an uncertainty analysis	correct data for instrument drfit	correct data for sensor fouling	assign a quality-grade to the data based on the extent of correction
Records	Quality check outcome: diffrential, percent of Standard	Quality check outcome: Relative Percent Difference	values of MQOs	met/did not meet MQOs	confidence intervals or level	algorithm used, date/time corrected		quality grade
Data Elements subject	7.10.2, 2.3.5	7.10.2, 2.3.5	2.3.6	2.3.6	2.3.5	2.3.3, 8.3.1	2.3.3, 8.3.1	2.3.3

Do we have common rules and criteria for data correction? Do we (should we) use the same correction algorithms and the same grading system?

Correction of Sensors' Data

I looked for guidance, tried a number of keyword combinations… Found an internal USGS memo,

"Office of Water Quality Technical Memorandum 2012.04" which talks about

"Auto-correction loader (ACL) Program automates the computation and loading of data corrections directly from SiteVisit into ADAPS"

- Problem: these evolving tools are moving targets; rules and criteria for data correction are not permanently established (?)
- Need to improve public accessibility/ease of finding (i.e., relevant information should not be hidden)
- Not all agencies are looking for common tools; some create their own (incompatible?) systems

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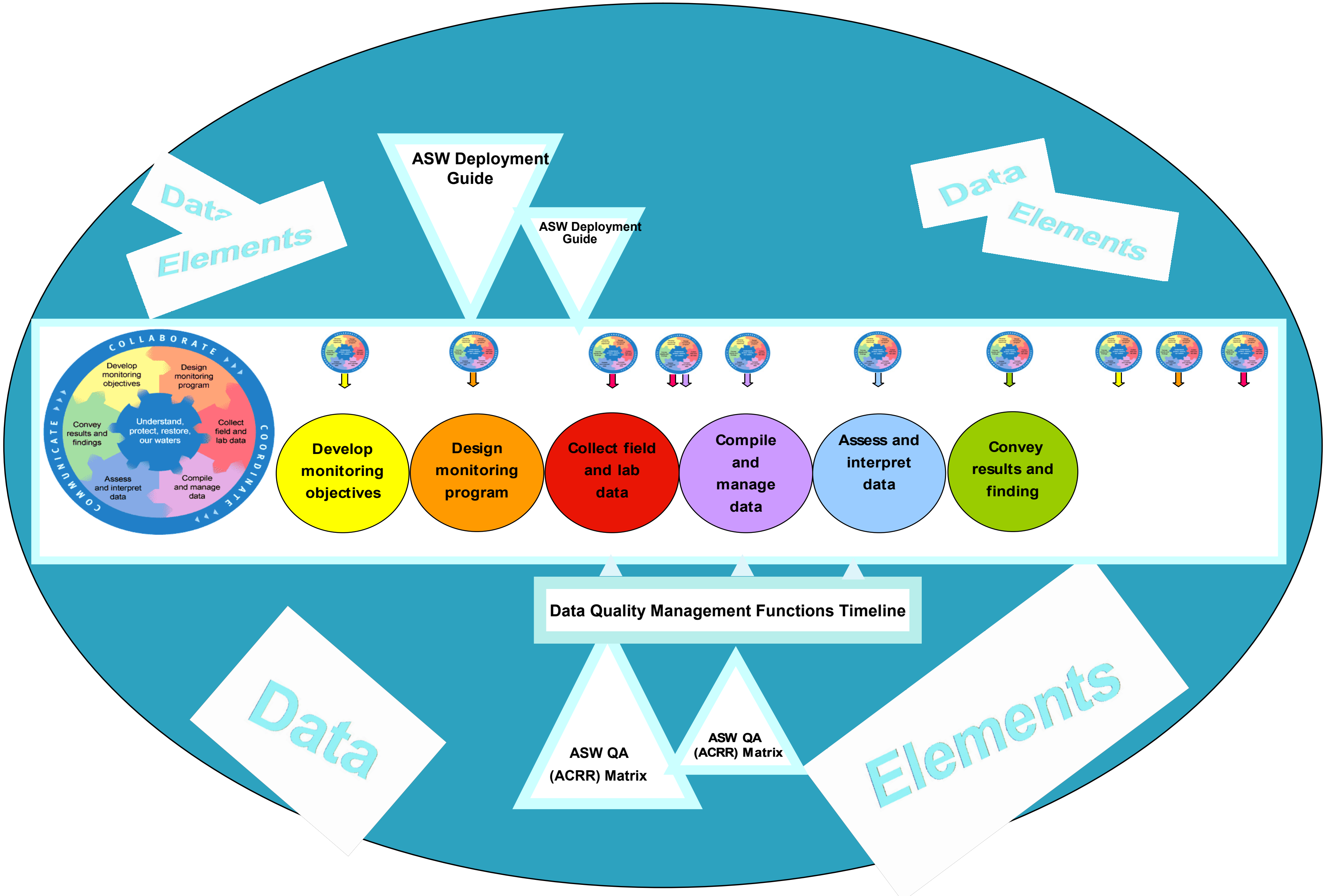

http://www.watersensors.org/

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Thanks For Listening

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