Data Quality Review and Water Quality Trend Analysis

San Juan Basin Water Quality Analysis

Colorado Oil and Gas Conservation Commission

August 8, 2011

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Introduction

COGCC Orders 112-156 and 112-157 and numerous subsequent COGCC orders require <u>routine water well sampling</u> by operators for new CBM wells since 2000.

- Baseline sampling (pre-drilling)
- Post completion: 1, 3, and 6 years
- Major cations and anions, TDS, iron, manganese, nutrients (nitrates, nitrites, selenium), dissolved methane, pH, presence of bacteria, specific conductance, and field hydrogen sulfide.

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Background

- Analytical data from USGS, BLM, COGCC, and industry studies and other sources.

- Over 15 years of data; over 2,000 wells sampled.

- COGCC contracted a 3rd party consultant (AMEC Geomatrix) to evaluate data to identify areas of concern for further investigation.

  - Implemented study in late 2009.

  - Issued study results June 2010.

  - Updated study results June 2011.

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Scope of Work

- Data quality review

- Trend and data analysis (spatial and temporal)

  - 12 target parameters

  - 2 methane isotopes

  - 2,038 wells

- Data flag development

  - Methane and isotope triggers

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Assumptions

- Target parameter selection

- Methane triggers

- Time-concentration plots (visual trends)

  ▸ Minimum four results

  ▸ Non-detects at detection limit

- Mann-Kendall trend analysis (statistical trends)

  ▸ Minimum four results

  ▸ Uniform value for non-detects

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Target Parameters (No. wells*)

		cations		anions		

- Methane   (547)
- TDS   (399)
- Ca^{++} (373)
- Mg^{++} (373)
- K^{+} (376)
- Na^{+} (375)

- Alkalinity   (95)
- pH   (373)
- CO$_3^{--}$ (123)
- HCO$_3^{-}$ (146)
- Cl^{-} (312)
- SO$_4^{--}$ (380)

cations { }

anions { }

(*560 wells have four or more results for at least one target parameter)
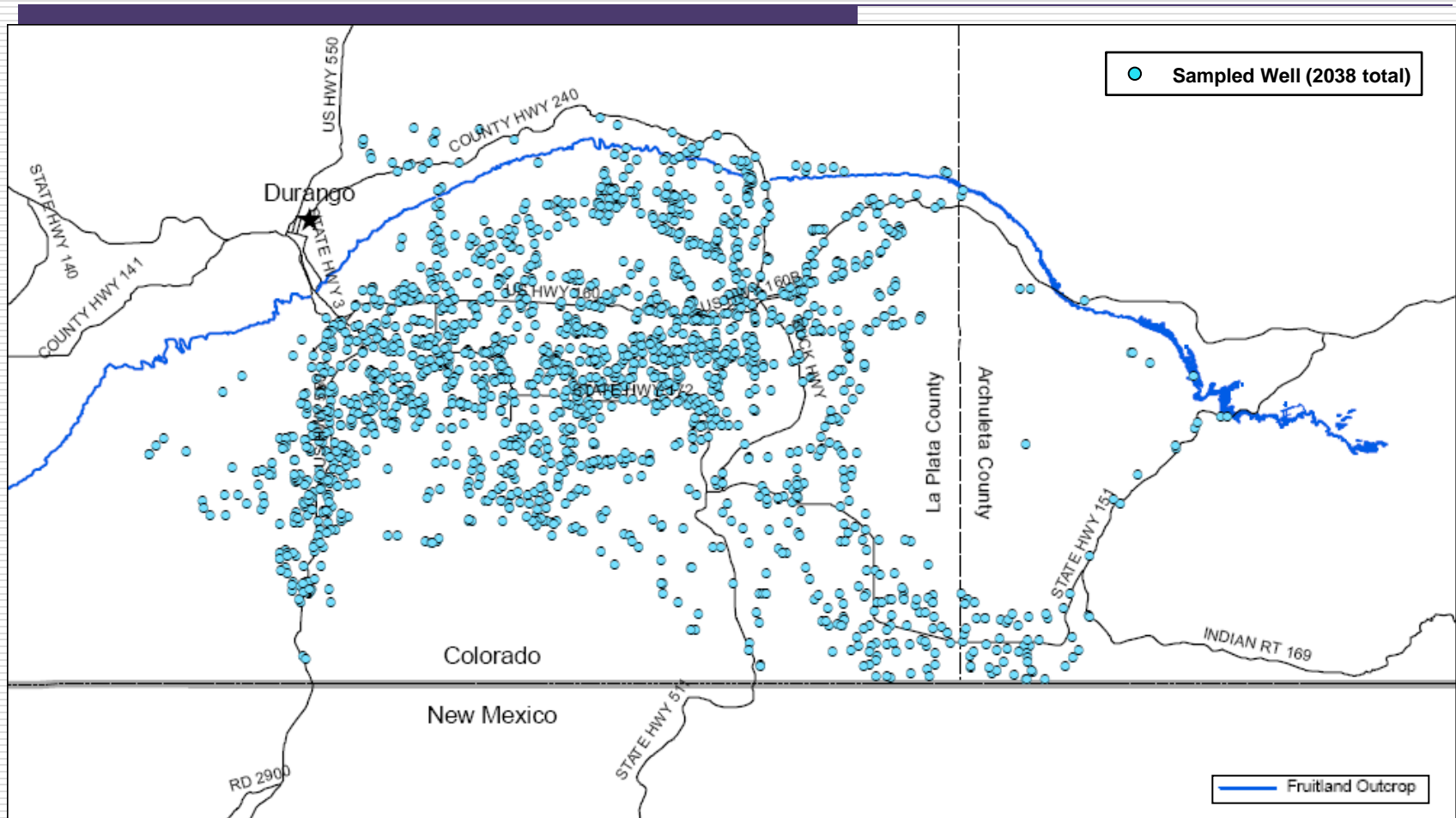
- δD (methane)
- δ^{13}C (methane)

Spatial and Temporal Trend Analysis

- Map geographic distribution of methane

- Plot depth distribution of methane

- Time-concentration plots

- Mann-Kendall trend analysis

- Map geographic distribution of target parameters with statistically significant trends
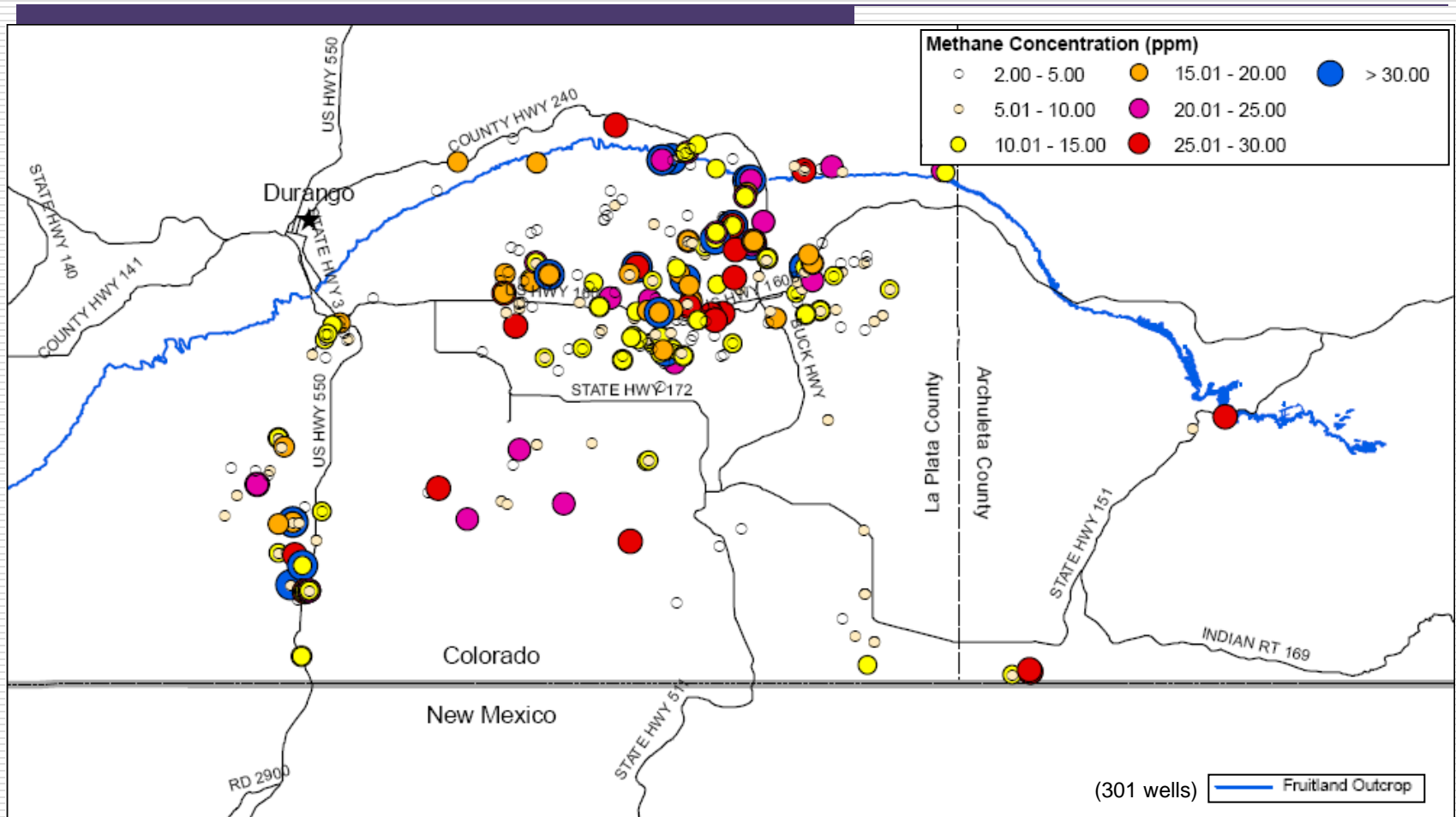
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Distribution of Water Wells with Methane Data

Distribution of Water Wells with Methane > 2 ppm

(301 wells)

Mann-Kendall Trend Analysis

Nonparametric* statistical technique to determine the presence or absence of a **statistically significant** trend in concentration over time.

A **test for zero slope** of time-ordered data that is based on nonparametric analog of linear regression.

(*Non-parametric statistics do not assume any underlying distribution in the data whereas parametric statistics assume some underlying distribution, such as normal or log-normal.)

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Mann-Kendall Trend Analysis

Statistical significance determined by comparing the S-statistic and the sample population (**n**) to the table of probabilities at the specified significance level (1-**α**).

For 95% significance, $(1 - α) < 0.05$ True
      α=0.95: $(1 - α) > 0.05$ False

Slope (direction of trend) $S > 0$ Increasing
                                       $S = 0$ No trend
                                       $S < 0$ Decreasing

Mann-Kendall Trend Analysis

- Particularly **well-suited for small data sets** that do not have enough data to establish the underlying distribution as required for most parametric statistical techniques.

- **Insensitive to missing data** (missing values are ignored and do not influence the result).

- **Able to handle non-detects** (non-detect values are replaced with a common value less than the smallest detected concentration).

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Mann-Kendall Example

Parameter	S	n	Probability $(1 - \alpha)$	Direction of Trend	Statistical Significance
Alkalinity	-10	6	0.048	Decreasing	TRUE
Ca	-1	9	0.5	Decreasing	FALSE
Cl	-10	9	0.179	Decreasing	FALSE
CO3	3	4	0.271	Increasing	FALSE
HCO3	-7	5	0.08	Decreasing	FALSE
K	-18	8	0.016	Decreasing	TRUE
Methane	7	7	0.191	Increasing	FALSE
Mg	-11	8	0.114	Decreasing	FALSE
Na	-3	9	0.421	Decreasing	FALSE
pH	0	9	0.54	No Trend	FALSE
SO_4	-9	9	0.209	Decreasing	FALSE
TDS	-9	8	0.169	Decreasing	FALSE

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Summary of Mann-Kendall Results

Parameter	Increasing Trend		Decreasing Trend		No Trend	No. Wells / Analyses
	Statistically Significant	Not Statistically Significant	Statistically Significant	Not Statistically Significant		
Alkalinity	5	34	12	31	13	95
Ca	27	137	24	132	53	373
Cl	20	122	18	117	35	312
CO3	0	19	1	39	64	123
HCO3	14	50	17	50	15	146
K	11	138	13	158	56	376
Methane	10	163	34	200	140	547
Mg	17	125	18	120	93	373
Na	23	119	22	161	50	375
pH	9	96	31	177	60	373
SO_4	14	103	40	170	53	380
TDS	16	108	35	178	62	399
No. Analyses	166	1214	265	1,533	694	3,872
No. Wells	111	435	182	438	354	

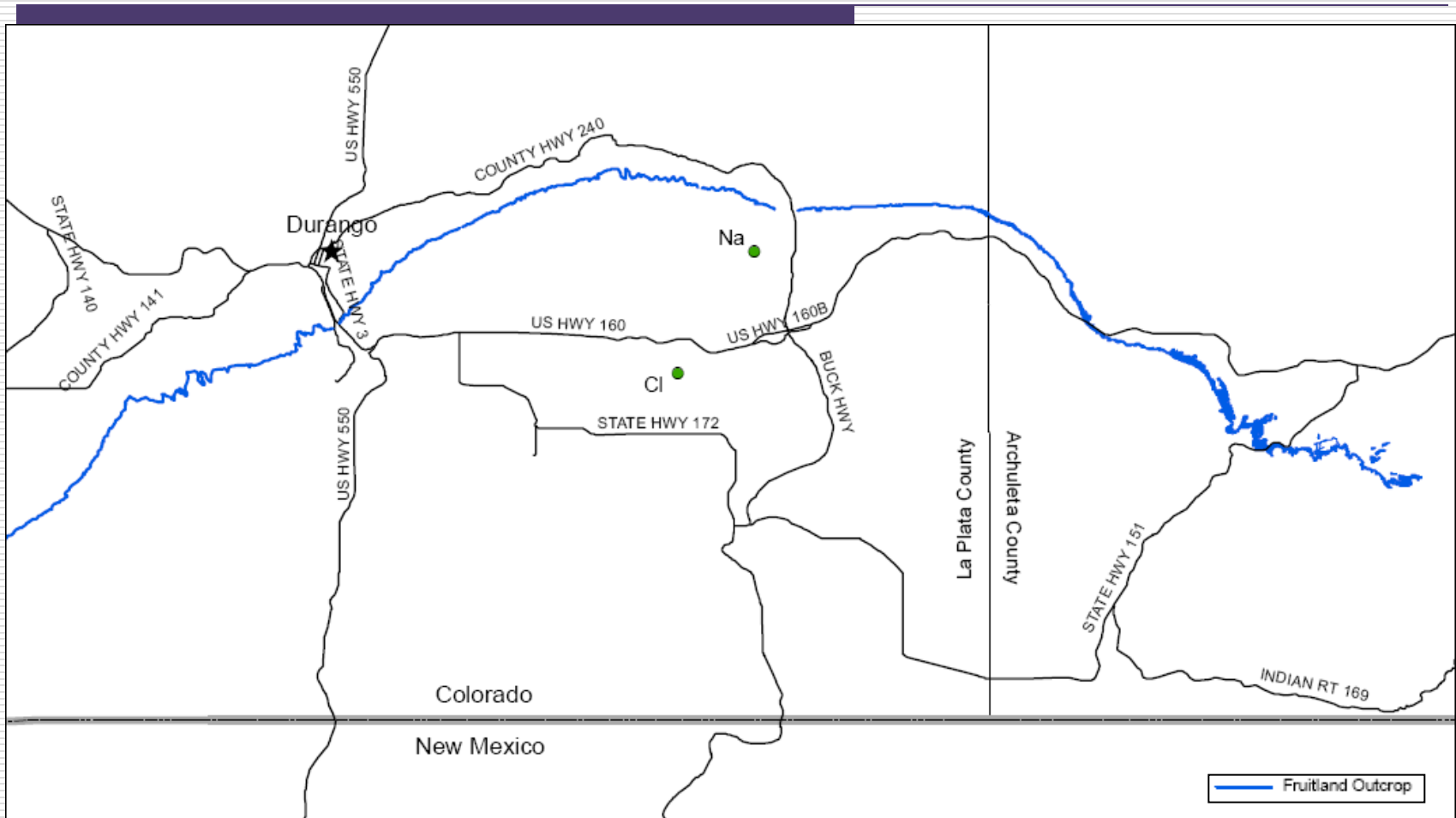**AMEC Geomatrix**

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Visual Trend Analysis + MK
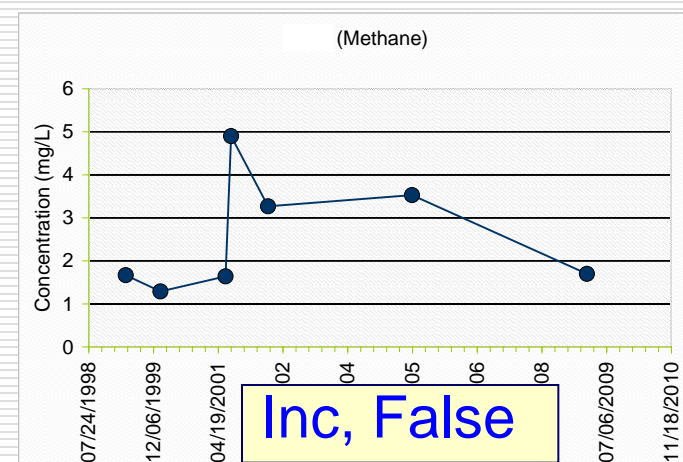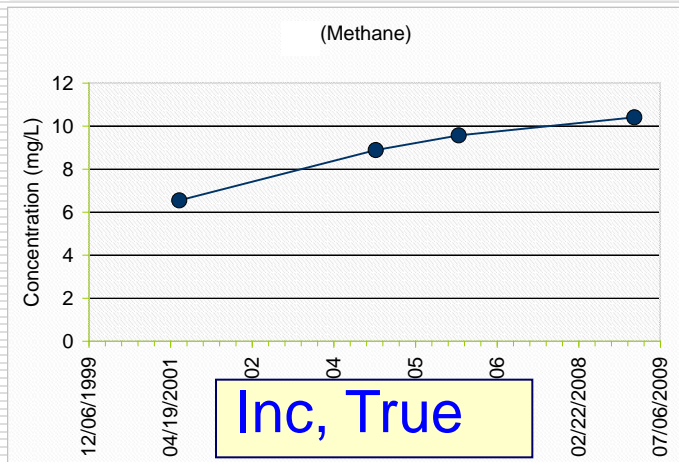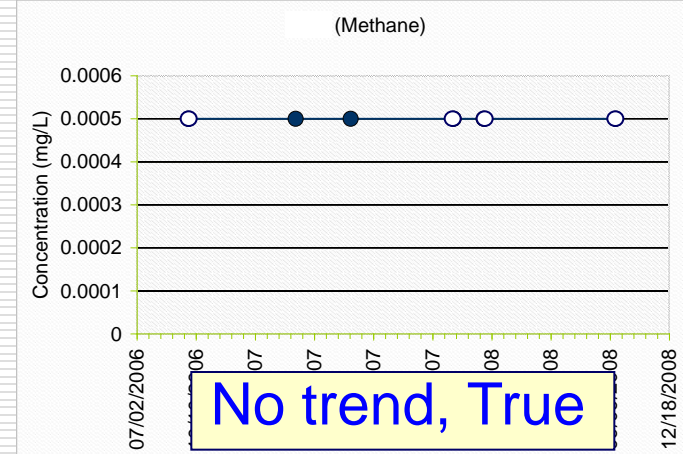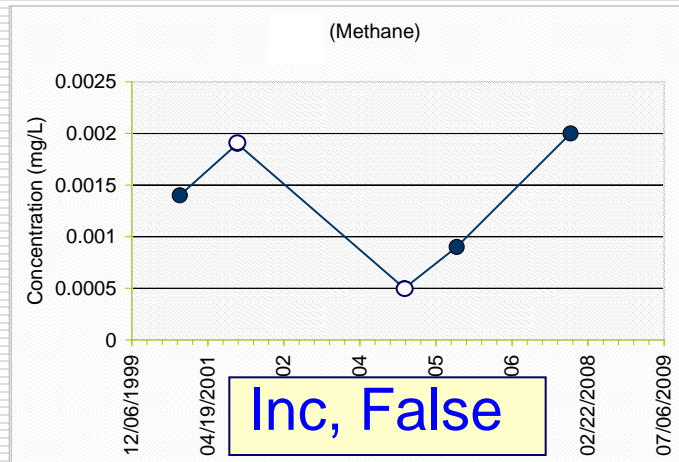
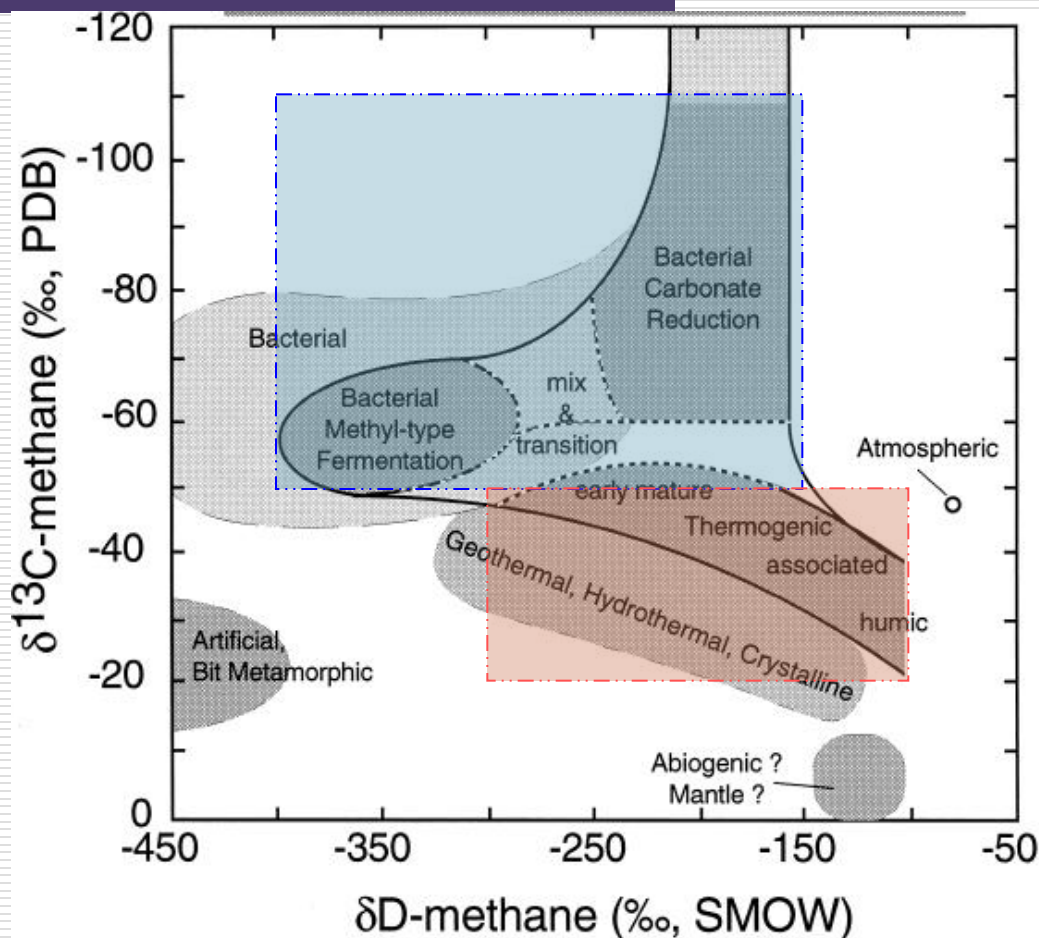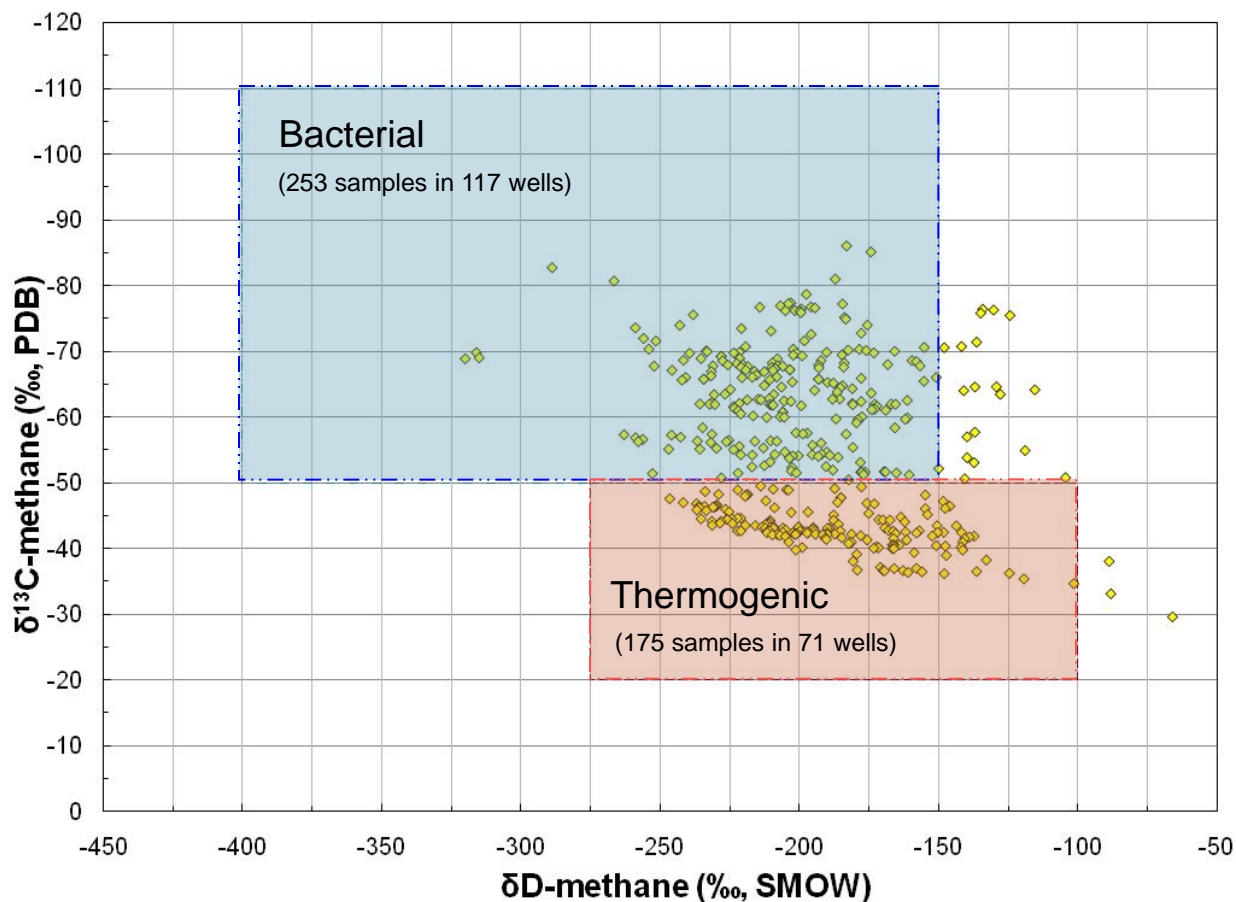# Increasing Trend in TDS, Methane
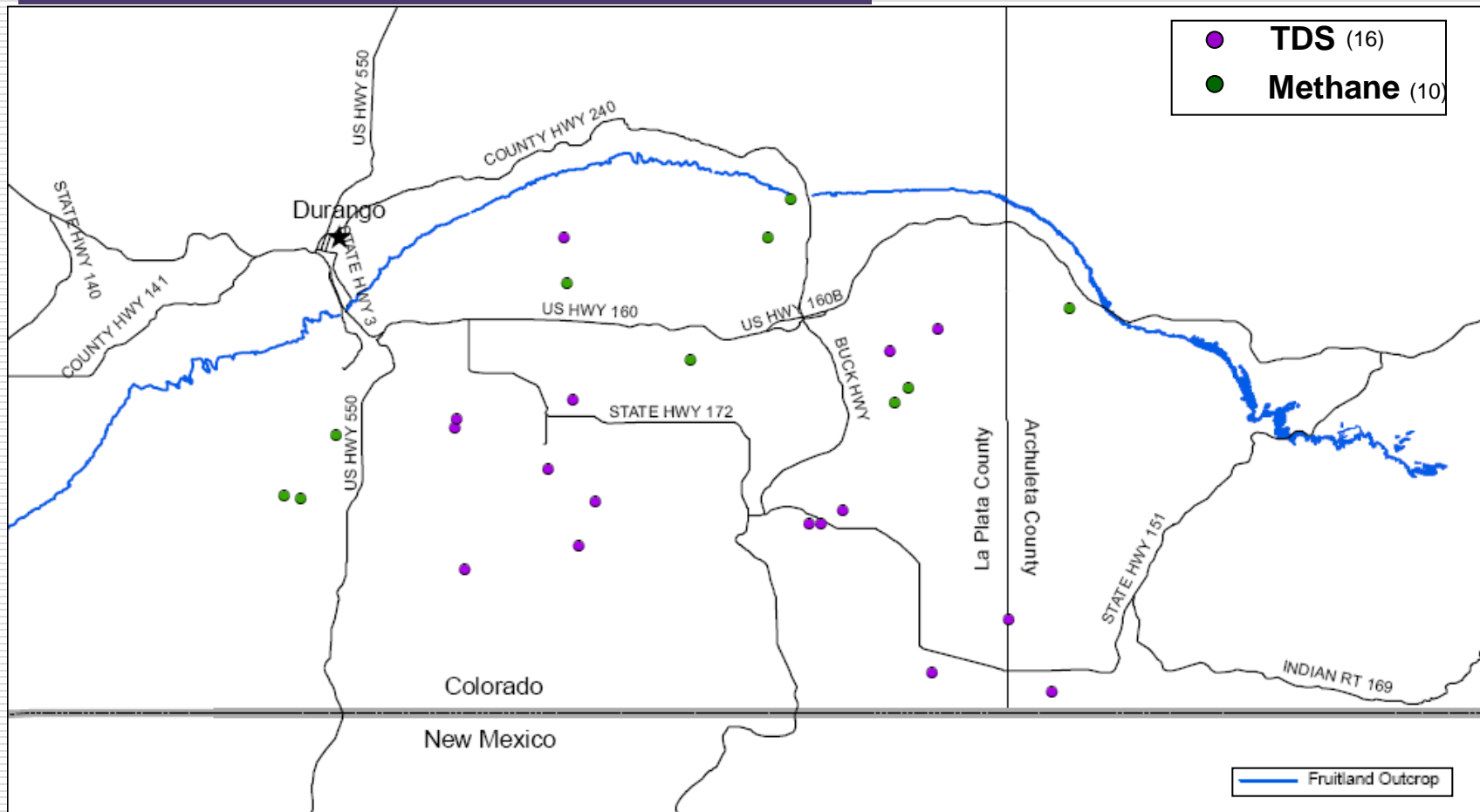
Increasing Trends in Methane _and_ Another Target Parameter

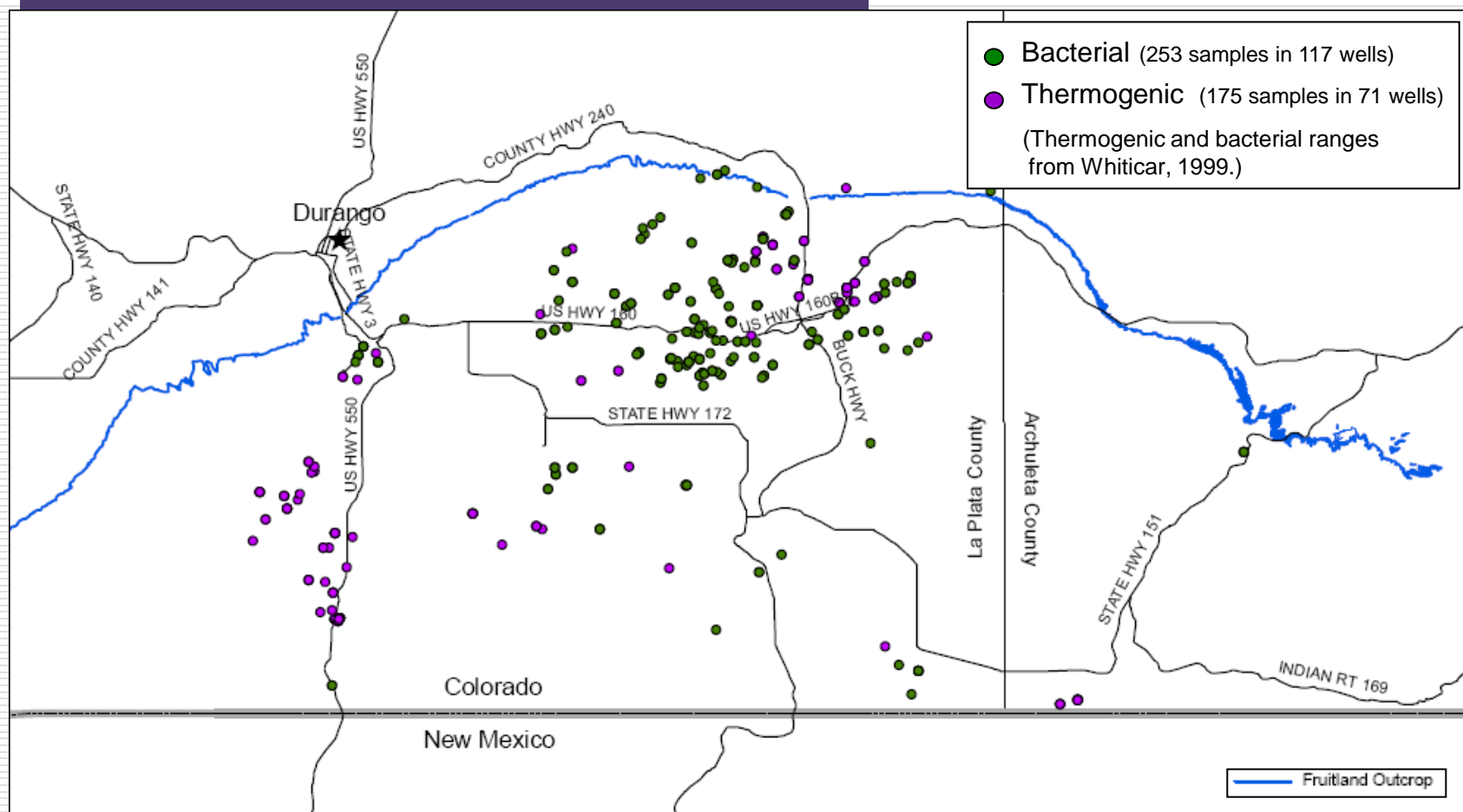# C-, H-isotope Signatures of CH$_4$ Sources (Whiticar, M.J. [1999])

C-, H-isotope Signatures in Wells with CH$_4$ > 2ppm

(Thermogenic and bacterial ranges from Whiticar, 1999.)

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C-, H-isotope Signatures in Wells with CH$_4$ > 2ppm

Legend:
- Bacterial (253 samples in 117 wells)
- Thermogenic (175 samples in 71 wells)

(Thermogenic and bacterial ranges from Whiticar, 1999.)

Fruitland Outcrop

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Updated Report

Trend and Data Analysis
San Juan Basin Water Quality Analysis Project

San Juan Basin, Colorado

June 20, 2011

http://cogcc.state.co.us/

Click on *Library* and then click *San Juan Basin*

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Next Steps

- Detailed review of wells showing trending in constituents.

- Additional investigation and possible corrective action for confirmed areas-of-concern.

- Annual updates to include new data.

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