Semi-quantitative evaluation of fecal contamination by human, ruminant, and alternate sources in Upper Fountain Creek, Colorado

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at the

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Presentation outline

- Introduction to the project
- Process validation
- How was microbial source tracking applied to Fountain Creek?

Colorado Department of Public Health and the Environment

Colorado Springs, Manitou Springs, Green Mountain Falls, Woodland Park

El Paso County

Pikes Peak Area Council of Governments

UNDERSTANDING QUANTITATIVE MICROBIAL SOURCE TRACKING

Why microbial source tracking?

- There are acceptability limits for fecal contamination of resource waters
- Most standards are based on the fecal-indicator bacteria *E. coli* (inland) and enterococci (inland or marine)
- If the standard is violated, what do you do?
  - *E. coli* and enterococci are found in a lot of hosts
  - The CWA says the concentration must be brought down or the waterway must be reclassified
    - Regardless of source or health risk
    - Regardless of cost

Analytical sensitivity
Low level fecal contamination is permitted by U.S. criteria

Table 7.1–1. Recreational water criteria under the Beaches Environmental Assessment and Coastal Health Act of 2000 (U.S. Environmental Protection Agency, 2004).

[mL, milliliters]

Indicator	Geometric mean: 5 samples (density per 100 mL)	Single-sample maximum: criterion may be exceeded in no more than 10 percent of samples (density per 100 mL)			
		Designated beach area[1]	Moderate use, full-body contact[2]	Light use, full-body contact[2]	Infrequent use, full-body contact[2]
	Fresh water				
Escherichia coli	126	235	298	410	576
Enterococci	33	62	78	107	151
	Marine water				
Enterococci	35	104	158	276	501

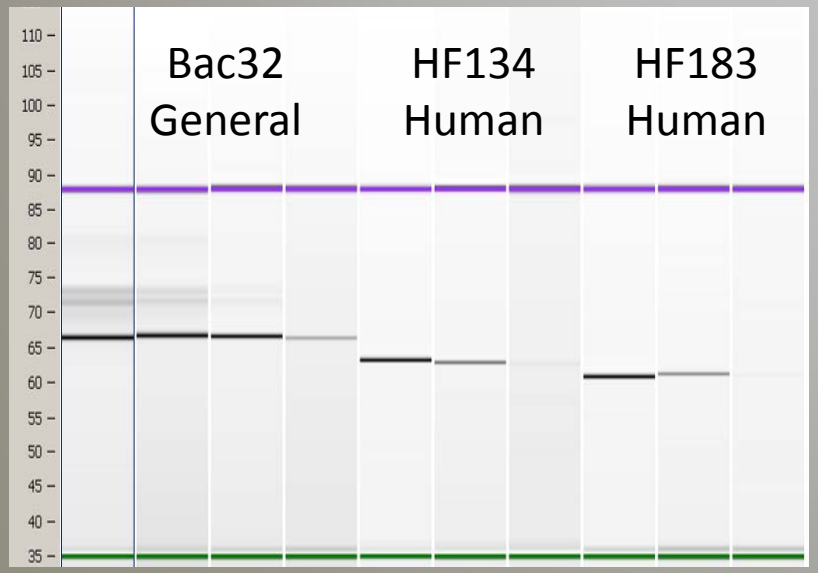
[1]Designated beach areas are frequently lifeguard protected, provide parking and other public access, and are heavily used by the public (U.S. Environmental Protection Agency, 1986, p. 7).
[2]Other recreational uses, which involve various levels of full-body contact, are designated by individual State water-quality standards (U.S. Environmental Protection Agency, 1986, p. 7).

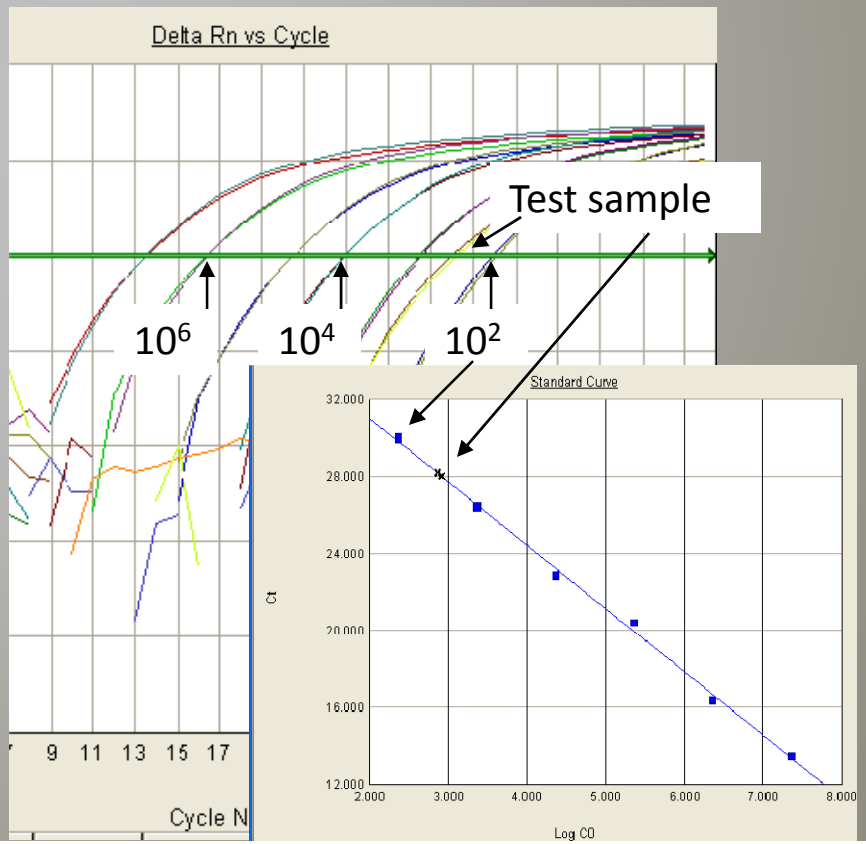
qPCR begins process of quantification

End-point PCR, such as

- *Bacteroidales* markers
- *Enterococcus faecium* human-associated *esp*

Quantitative PCR (qPCR) provides both presence and abundance data for markers





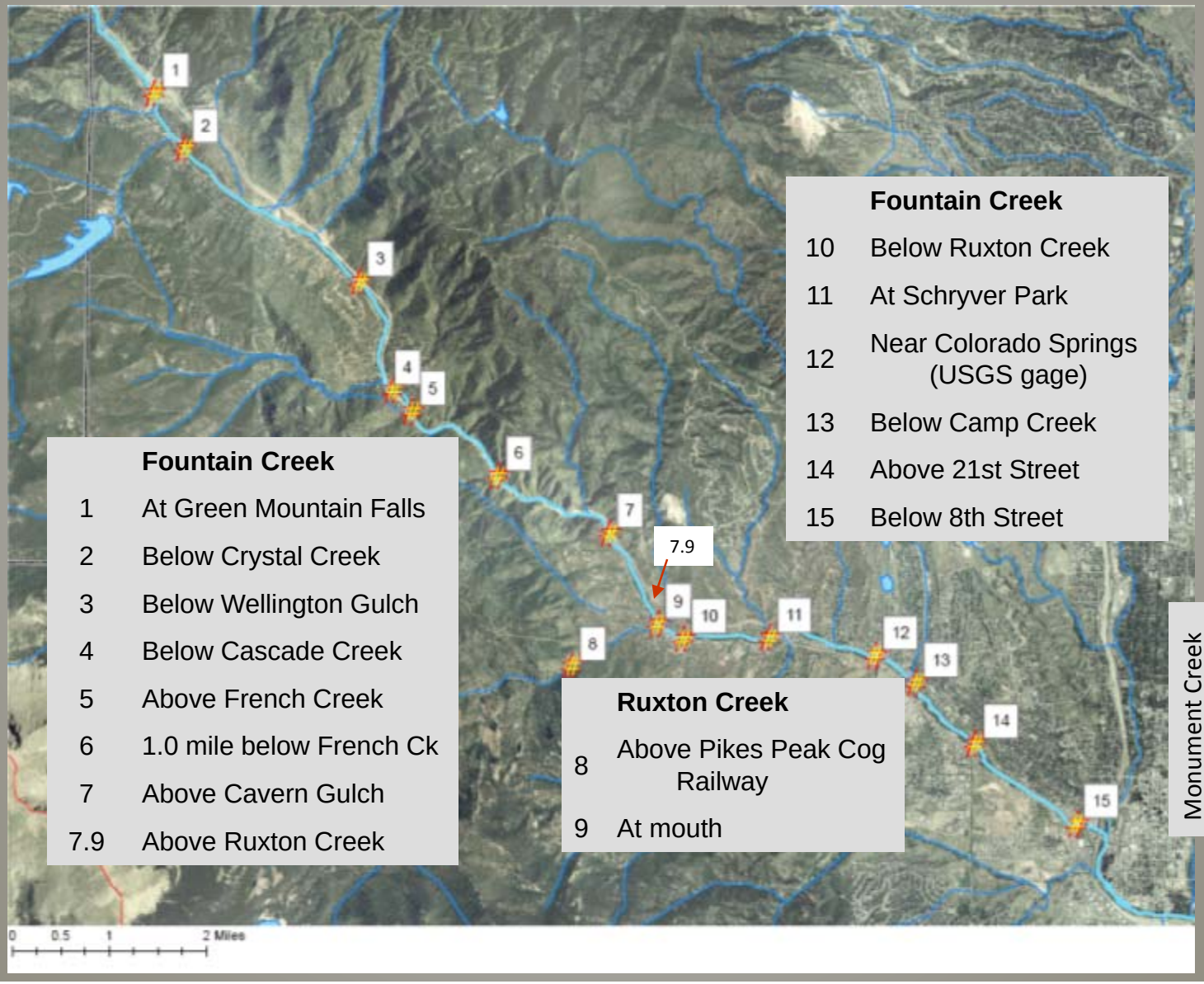
Approach for quantitative evaluation

- Under current US regulations, contamination is measured using fecal-indicator bacteria
- For effective use of MST data for management, host-associated marker data must be interpreted in the same terms
- Governing concept:

$$\frac{E.coli_{feces}}{\text{Marker}_{feces}} \approx \frac{E.coli_{water}}{\text{Marker}_{water}}$$

SUMMARY OF RESEARCH

Study area and sites

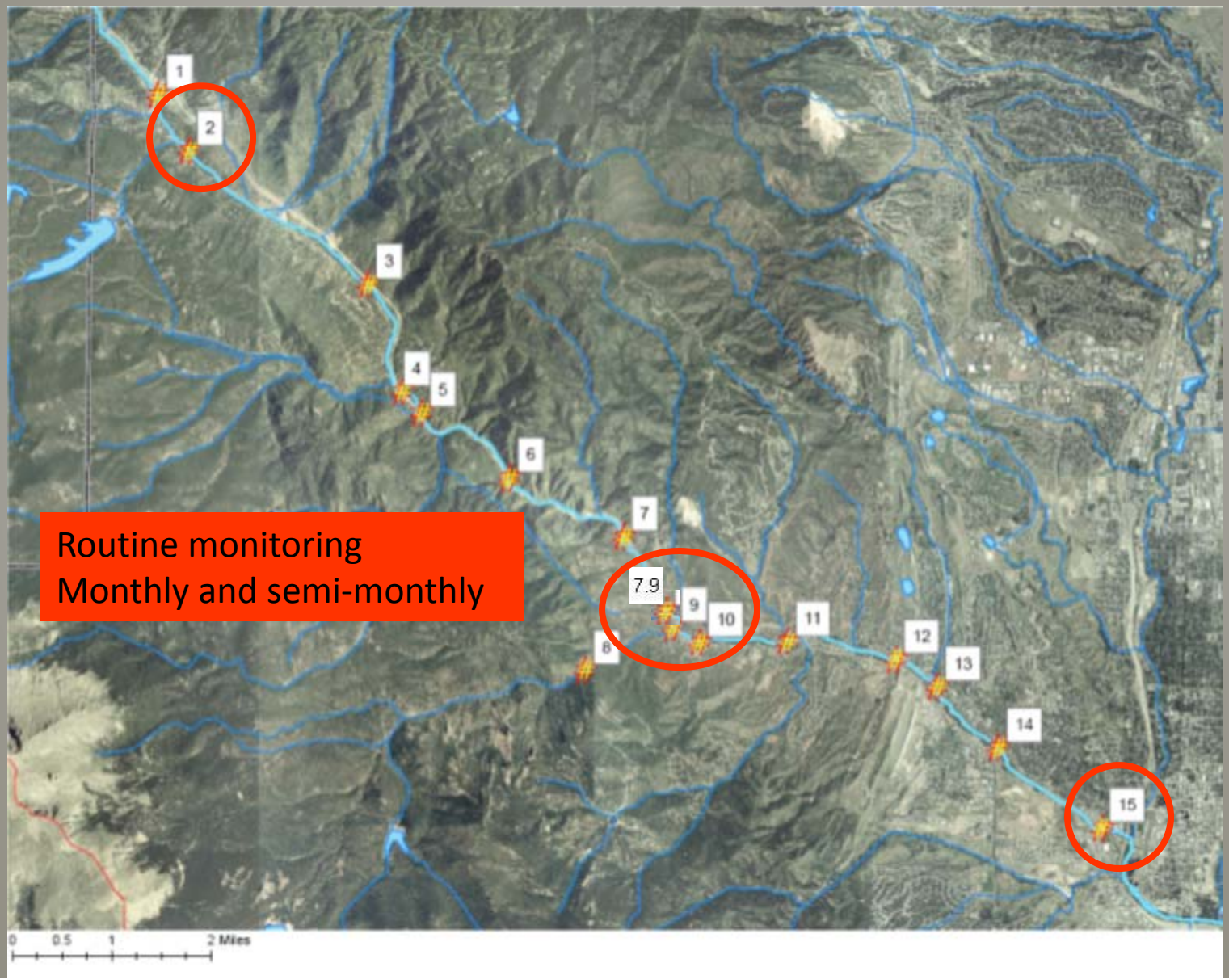


	Fountain Creek
1	At Green Mountain Falls
2	Below Crystal Creek
3	Below Wellington Gulch
4	Below Cascade Creek
5	Above French Creek
6	1.0 mile below French Ck
7	Above Cavern Gulch
7.9	Above Ruxton Creek

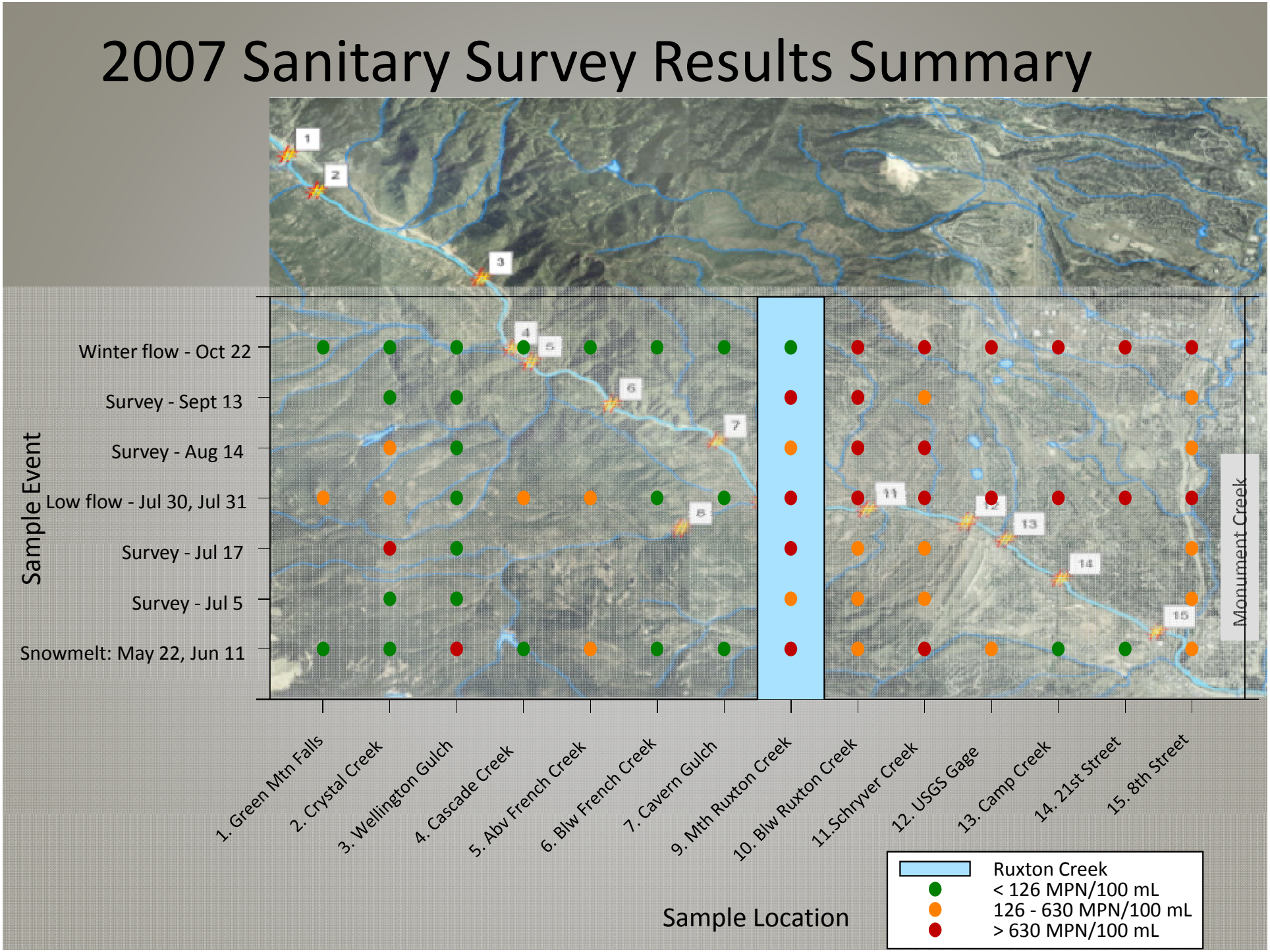
	Ruxton Creek
8	Above Pikes Peak Cog Railway
9	At mouth

	Fountain Creek
10	Below Ruxton Creek
11	At Schryver Park
12	Near Colorado Springs (USGS gage)
13	Below Camp Creek
14	Above 21st Street
15	Below 8th Street

Sites for 1-year intensive monitoring

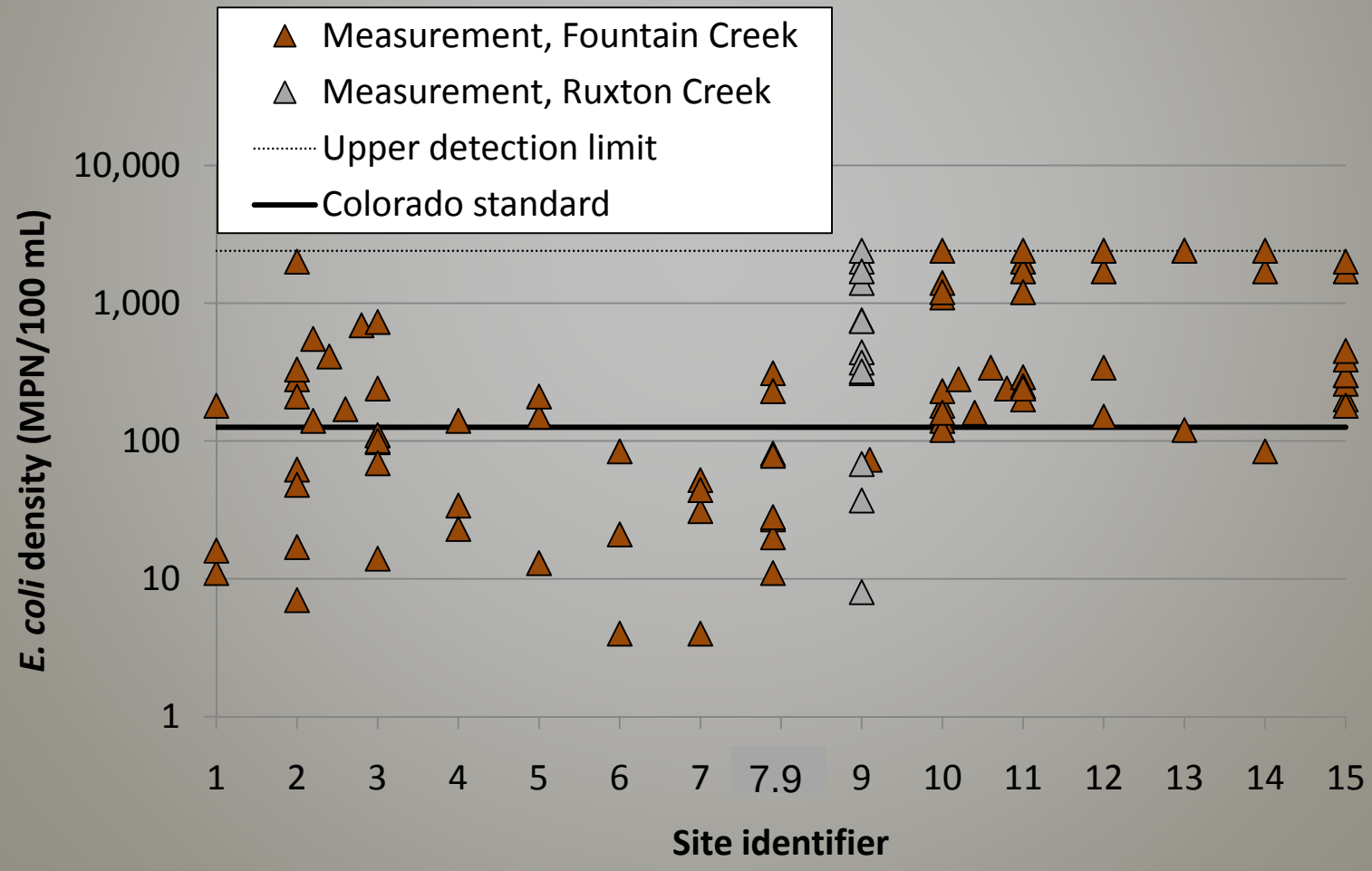


2007 Sanitary Survey Results Summary

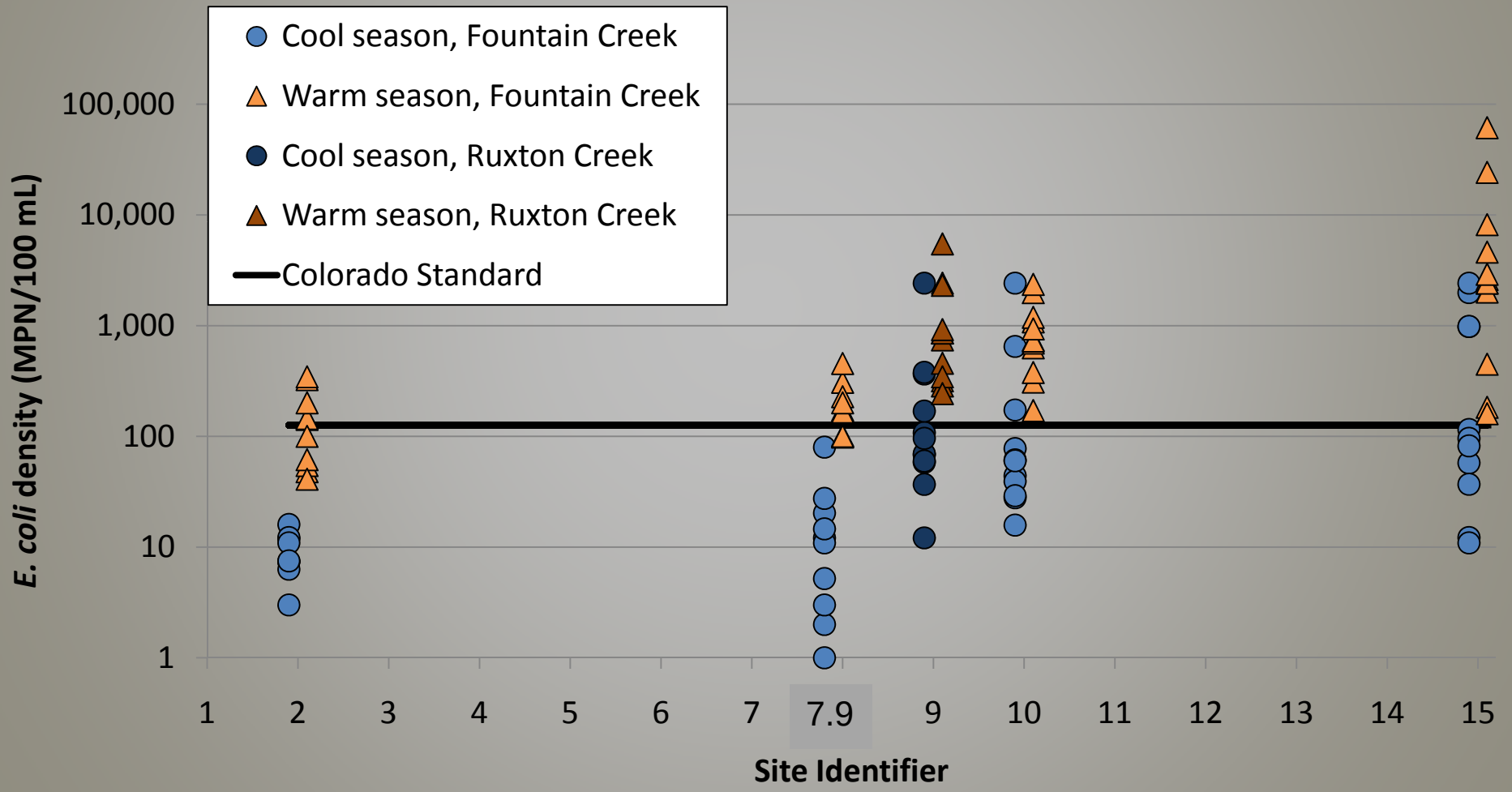


Evaluation of Fecal Contamination

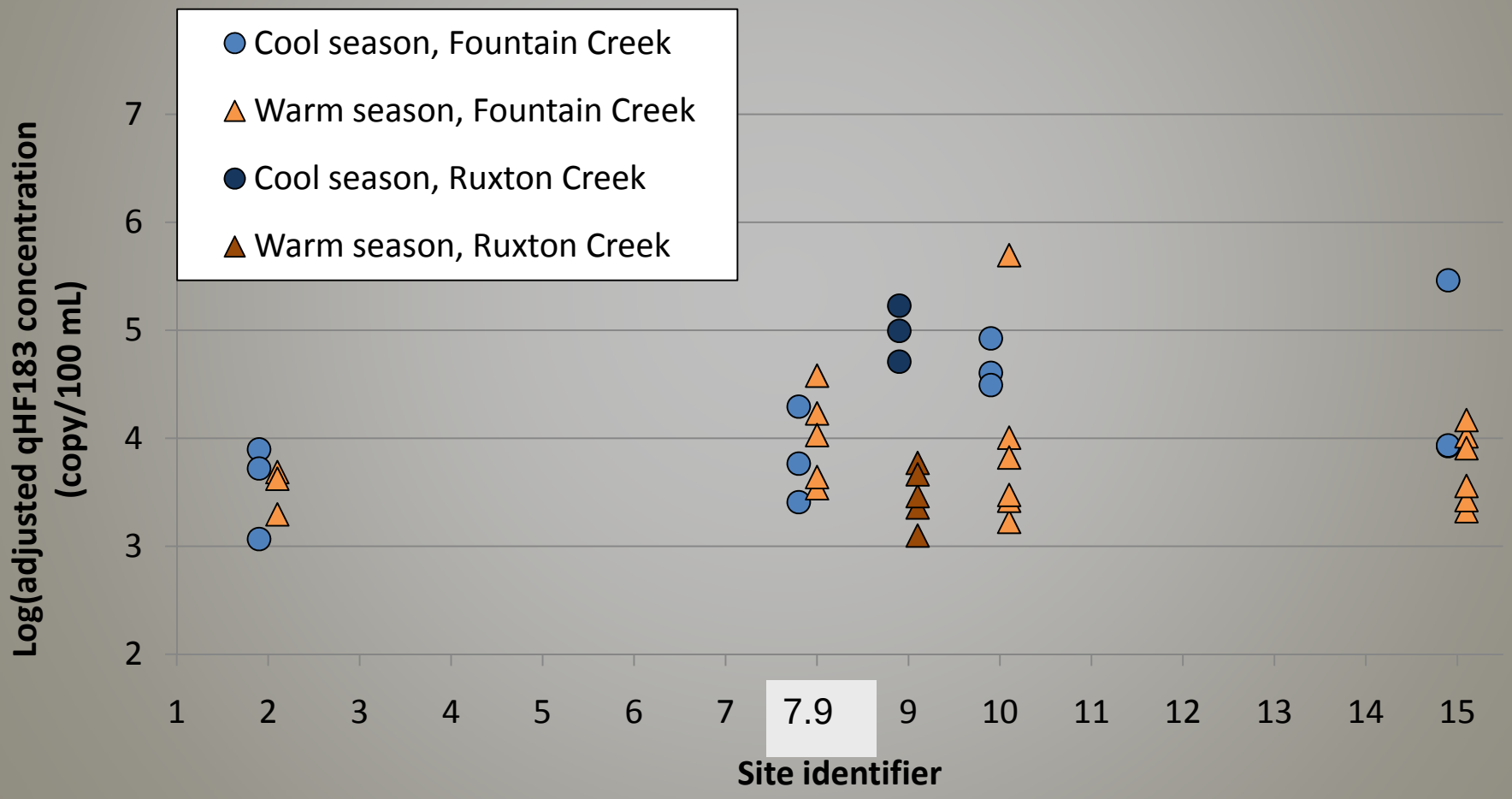
- Sanitary Survey May to September, 2007



Fecal contamination summary 2007-2008



MST results – qHF183
Associated with human contamination



Seasonal synthesis

- *E. coli*
  - Lower in cool than warm weather
  - increase gradually upstream to downstream
- MST markers (general, human- and ruminant associated)
  - about the same in cool as warm weather
  - increase gradually upstream to downstream
- Nutrients
  - About the same in cool as warm weather
- Wastewater organic chemicals
  - Present when both *E. coli* and human-associated MST markers increased

VALIDATION TESTS

MST markers

- AllBac – a marker present in most fecal sources (nonspecific)
- qHF183 – a marker associated with human sources of fecal contamination
- BacHum – a second marker associated with human sources of fecal contamination
- BoBac – a marker associated with ruminant sources of fecal contamination (cattle, deer, elk, etc).

In-house tests at USGS

- Prepared samples were analyzed “blind”
- High degree of accuracy in presence/absence
  - BoBac was detected in sample 1 because it is carried at low concentration in cat fecal material

		QC Blind 1	**QC Blind 2**	**QC Blind 3**	**QC Blind 4**
Source		Cat and human	Cattle	Horse	Human
Observed	***E. coli***	***>24,000***	***24,000***	***830***	***930***
Marker detected	qHF183	**Detected**	Not detected	Not detected	**Detected**
	BacHum	**Detected**	Not detected	Not detected	**Detected**
	BoBac	**Detected**	**Detected**	Not detected	Not detected

In-house test, quantification

		QC Blind 1	QC Blind 2	QC Blind 3	QC Blind 4
Observed	***E. coli***	***>24,000***	***24,000***	***830***	***930***
Estimated added to test mixture	Human	810	0	0	500
	Ruminants	0	42,000	0	0
	Pets	620,000	0	0	0
	Other	0	0	710	0
Calculated upper limit	Human	**62,000**	ND	ND	7,900
	Ruminant	**67,000**	**350,000**	ND	ND

Preliminary data from Stoeckel, Stelzer, Mau, and Stogner *in review*
ND, marker not detected

$$E.coli_{water,source} \leq \text{Marker}_{water,adj} * E.coli_{feces,0.9} \Big/ \text{Marker}_{feces,adj,0.1}$$

SOURCES TO FOUNTAIN CREEK

The human element

- Though **human-source fecal contamination was not commonly detected**, there were specific instances when human contamination was evident.
- Level of human-source contamination was evaluated by
  - MST marker concentration
  - Pattern of nutrients concentration
  - Wastewater organic chemical detections

Example -- May 01, 2008
Fountain Creek below 8th St (site 15)

- *E. coli* density
  - Above Ruxton Creek (site 7.9) – 80 MPN/100 mL
  - Below Ruxton Creek (site 10) – 61 MPN/100 mL
  - Below 8th Street (site 15) – 2,400 MPN/100 mL
- Elevated MST markers for human fecal contamination at site 15
- Elevated ammonium at site 15
- Wastewater chemicals detected at site 15 (8 of the 10 chemicals detected across 64 samples in this study)

What does this mean?

- Existing management of human, pet, and ruminant fecal material in the study area is mostly effective
  - These sources tended to be detected only when *E. coli* was within standards
  - More resources allocated to managing these "controllable" sources would not have led to Upper Fountain Creek meeting standards
- Under current conditions, Upper Fountain Creek is not expected to meet regulatory limits during warm weather months
- Birds are the only tested source that carries *E. coli* but not MST markers
  - Bird markers are not yet available to confirm birds as causes of *E. coli* exceedances

Pigeons

Manitou

Springs

Rough calculations

- Based on the concentration of *E. coli* in Fountain Creek, the flow, and the concentration of *E. coli* in pigeon feces
  - The combined defecation of 16 to 420 birds directly to Fountain Creek is sufficient to increase *E. coli* by 1,000 MPN/100 mL
  - Numerous birds were seen in the area
  - Power washing bird droppings from concrete to storm drains was observed

Conclusions

- Fountain Creek continued to exceed *E. coli* standards in the summer of 2008
- Controllable sources (human, pets, cattle) generally were not indicated as major sources of fecal contamination
- Bird sources, particularly pigeons, may be a source of the detected fecal contamination

Summary

- This type of research can dramatically enhance effectiveness of TMDL and other water management plans
  - 2007 land use survey overwhelmingly pointed to human or other controllable sources of fecal contamination
  - Exceedances during recreational season supported this concept
  - Only through use of quantitative MST and other host-targeting analysis were humans, pets, cattle and ruminant wildlife excluded as likely sources of fecal contamination in this study


Questions?
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