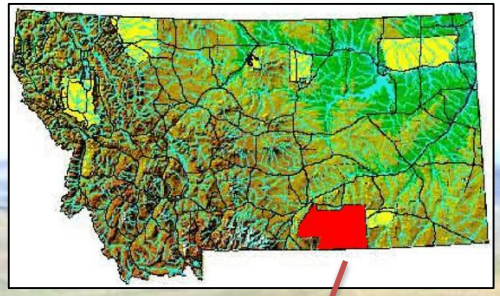
Water, Our Voice to the Future: Climate change adaptation and waterborne disease prevention on the Crow Reservation

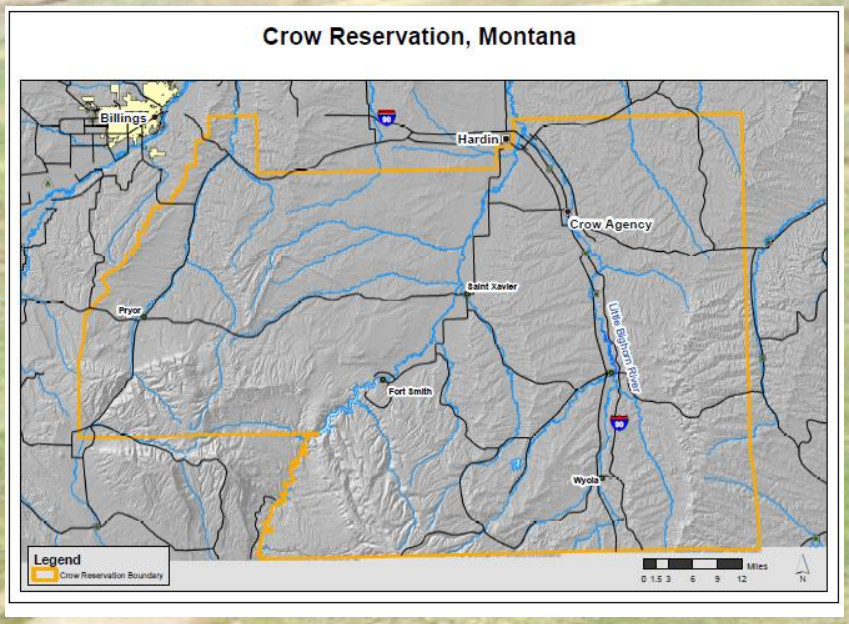
John T. Doyle, Margaret J. Eggers, Anne K. Camper & the Crow Environmental Health Steering Committee

2016 EPA Tribal Progress Review Meeting

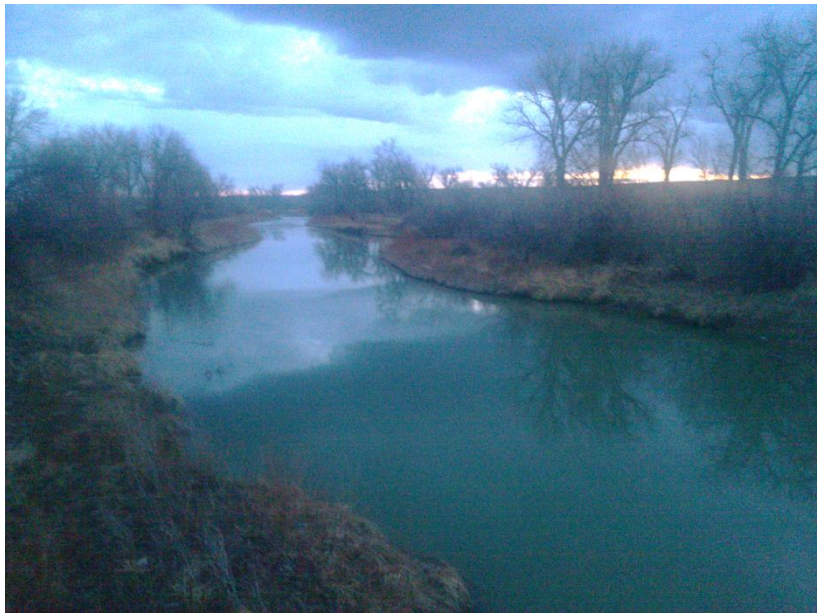
What are the current and projected impacts of climate change on Tribal waters and health?

- Crow Tribal knowledge of climate and ecological changes
- Western science data on past and projected climate changes
- Impacts on groundwater and home well water quality
- Impacts on microbial contamination of surface water



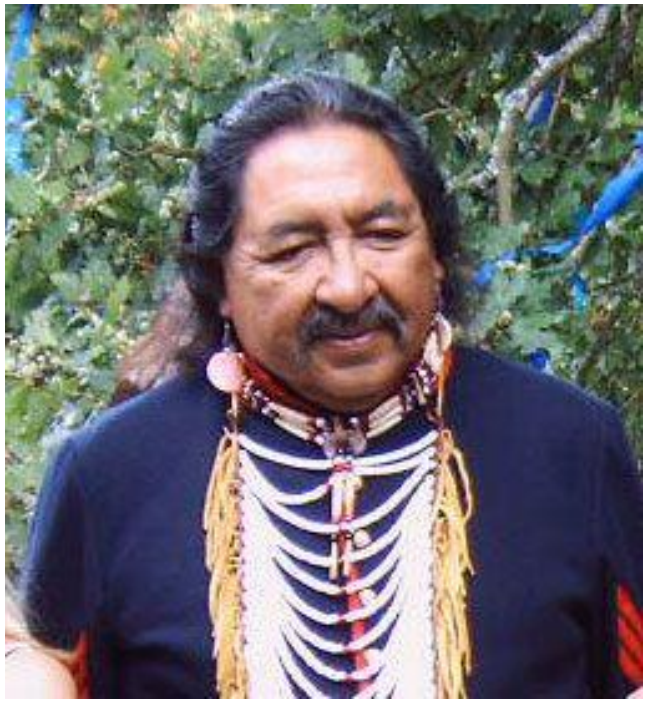


As Elders, we are seeing changes in our local climate and water resources



In winter, the ground used to be consistently snow covered and the temperature stayed below freezing. Now the ground is usually brown in winter and thaws are common.

Interviews with Crow Elders on climate and ecological changes

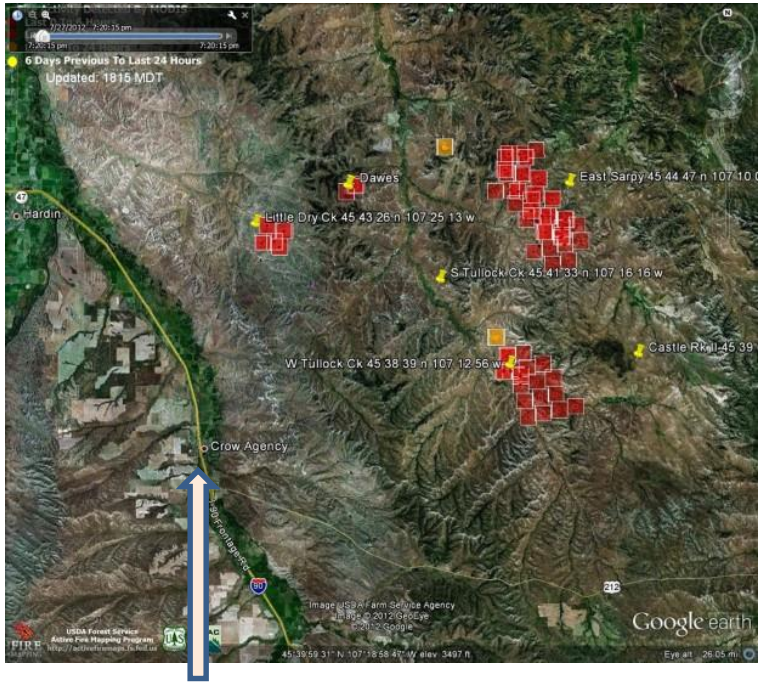


Larson Medicine Horse, Tribal Elder and Sun Dance Chief

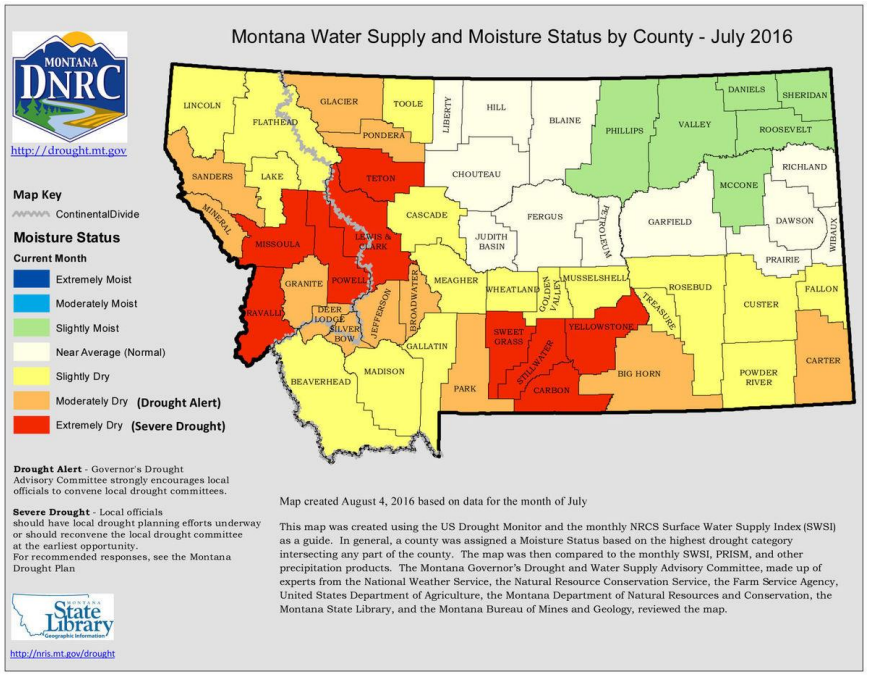
15 Elders interviewed to date; work is ongoing.

Bill Lincoln, Tribal Elder harvesting a medicinal plant with ancient spiritual importance to the Tribe.

2012 Crow Agency fires



Crow Agency



Current drought status

The 2012 summer fires were the worst in living memory for the Crow Reservation. On the adjoining Northern Cheyenne Reservation, 60% of their land burned. Across Montana, > 1.2 million acres burned, the second worst season on record. Subsistence hunting of deer and elk is vital on the Crow Reservation; community members are concerned about loss of forage where the fires blistered the ground.

Tribal Elders' observations

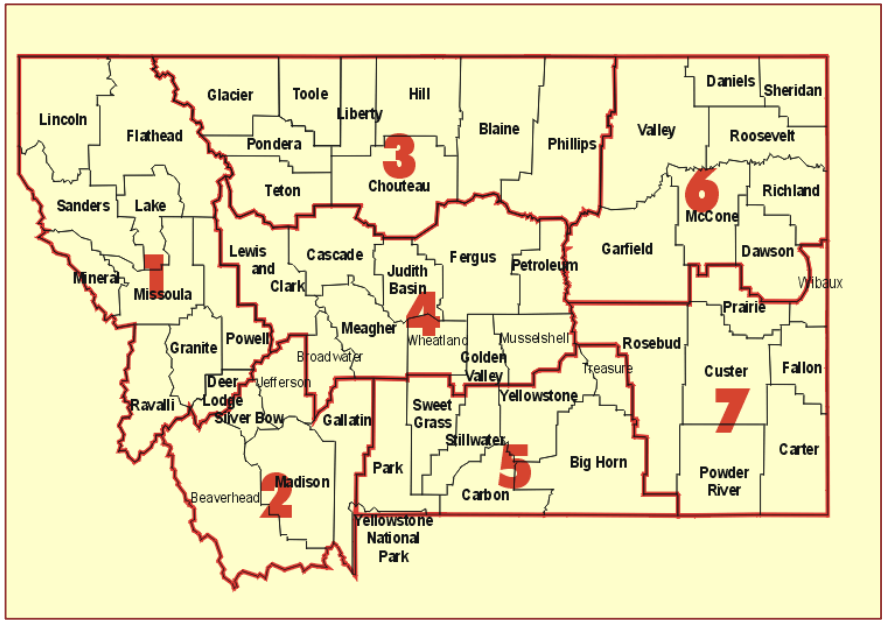
- In every District of the Reservation, there isn't nearly as much snow as 50 years ago. The ground used to be snow-covered winter long.
- Winters used to be far more severe and last longer – it stayed really cold from November through February.
- Now, trees are getting killed by mid-winter thaw–freeze cycles that never used to happen.
- Spring ice break-up on the rivers used to be a dramatic event, and now the winter river ice is thinner and just melts quietly away.
- Summer heat has changed, become much more intense.
- Various fish species have moved upriver, suspect climate change is causing or contributing to this. We see fish and turtles under stress in ways we never used to see; the freshwater mussels are disappearing.
- Many berry species are fruiting earlier than they used to – if they fruit at all. Some berry trees and shrubs are flowering too early, and a later frost then kills the flowers.
- The 2012 fire season was the worst in living memory.
- The nearly back to back 2007 & 2011 spring floods were unprecedented.

How does the measured climate data compare to local knowledge and memory?

Publically available weather station data: Hardin, MT is the only reasonably complete and ongoing source of weather data within 75 kilometers of Crow Agency, MT.

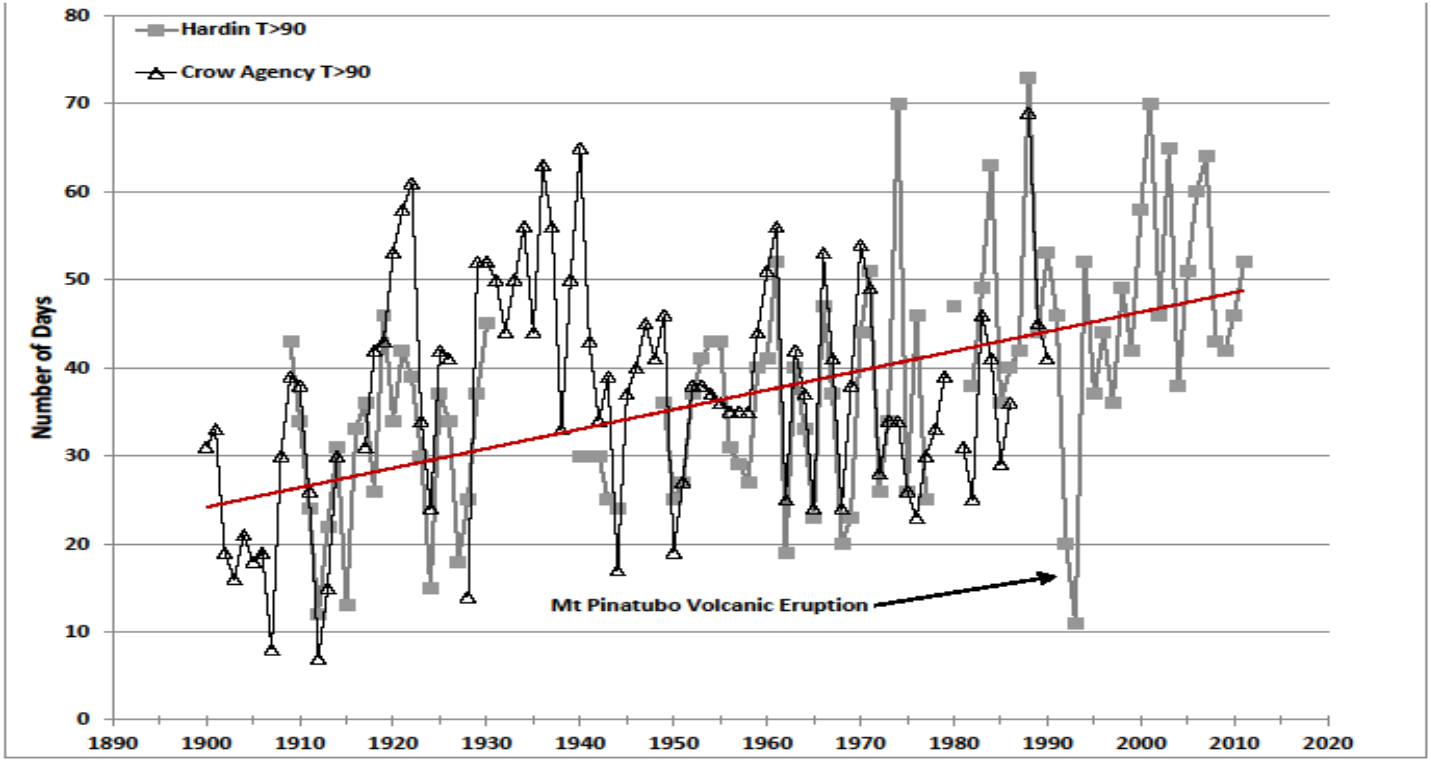
Regional data:
Montana Climate Division 5.

Climate Division data is available on-line from the National Climate Data Center.



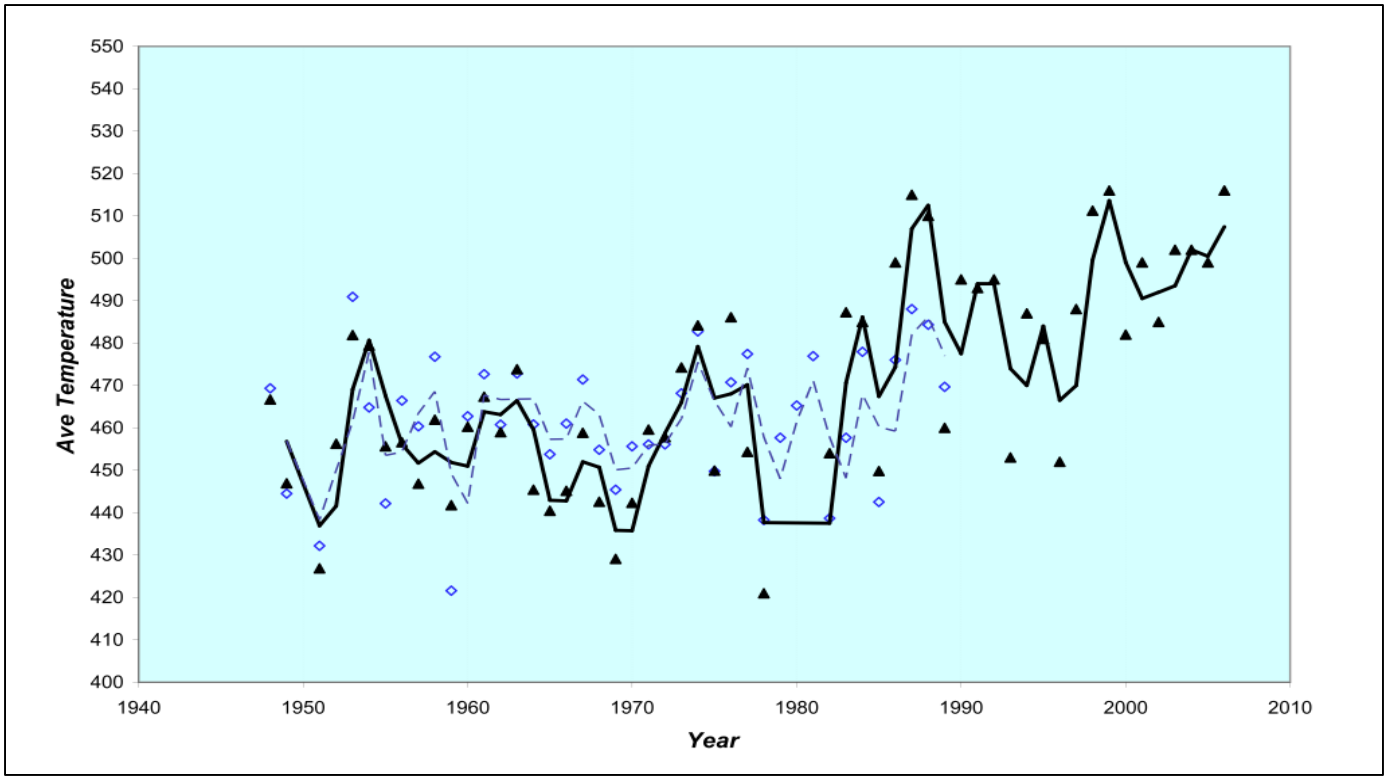
Doyle, J.T., Redsteer, M.H., Eggers, M.J. 2013. Exploring effects of climate change on Northern Plains American Indian health. *Climatic Change.* 120:643–655. doi:10.1007/s10584-013-0799-z. On-line: http://bit.ly/tribal-climate

Summers *are* getting hotter



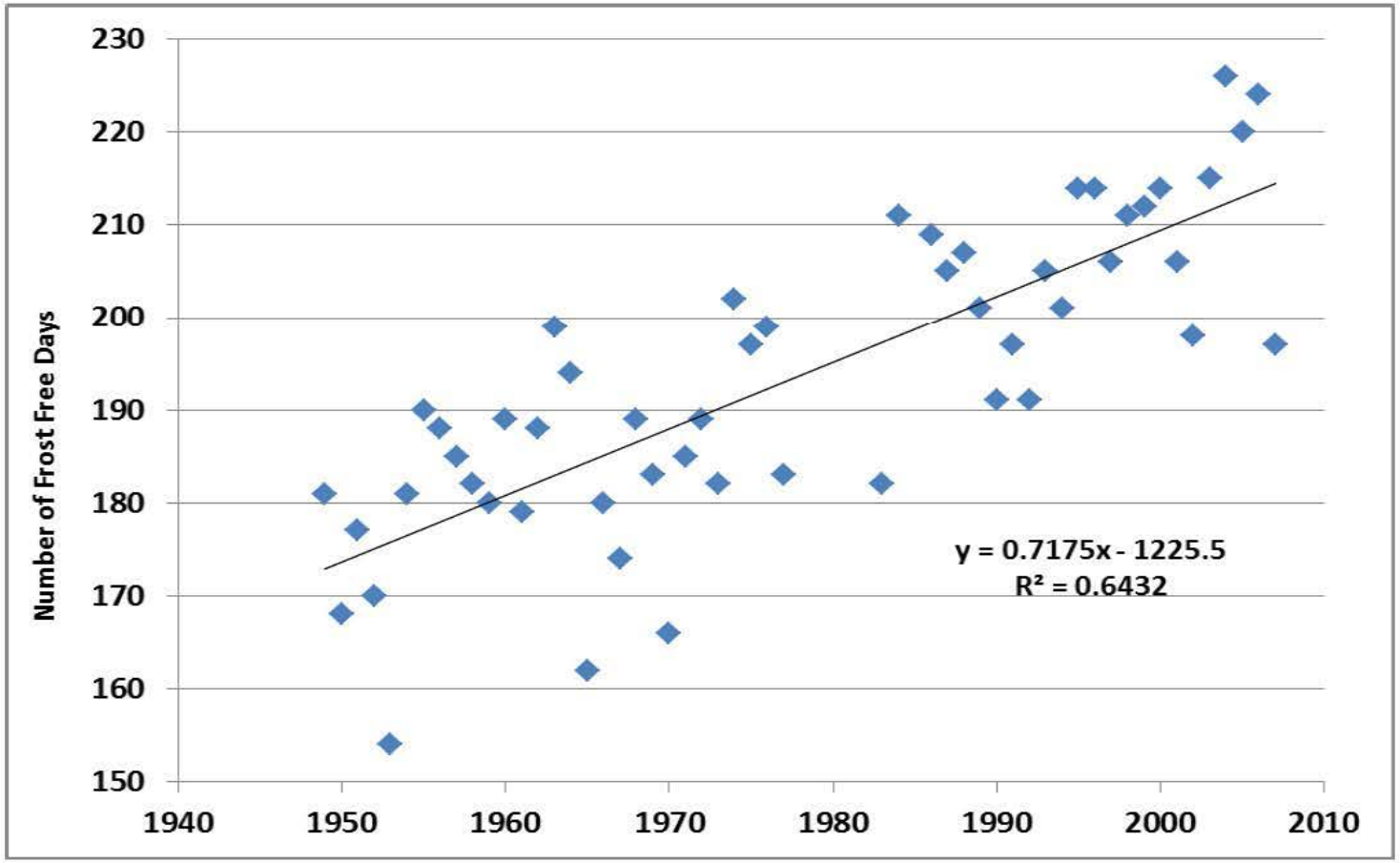
Number of days with temperatures exceeding 90°F (32°C) in Hardin and Crow Agency MT, plotted from National Weather Service daily records (National Climate Data Center). The red line indicates a linear trend of increasing high temperatures based on the data. (A dip in temperature in the early 1990s corresponds to a cold period produced by the volcanic ash from eruption of Mt Pinatubo.)

Increasing average annual temperature



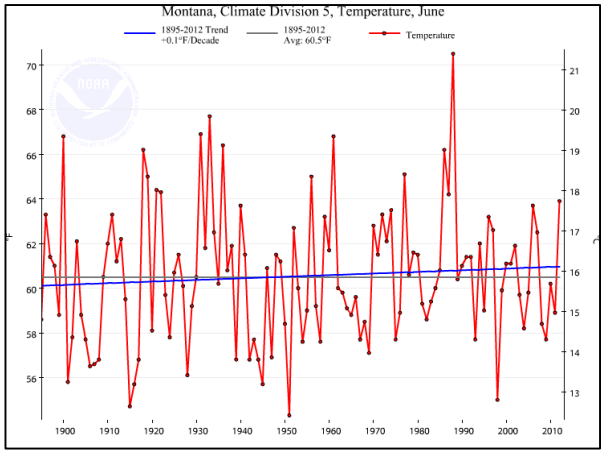
Plot of average temperature for Hardin, MT 1948-2007 (solid triangles) and Crow Agency, MT 1948-1991 (hollow diamonds) showing increase in average temperatures from a mean of 45.6°F in the 1950s to 50.1°F since 2000. Solid black line is 4-year moving average for Hardin data, dashed blue line is 4-year moving average for Crow Agency data. (Data source: National Climate Data Center.)

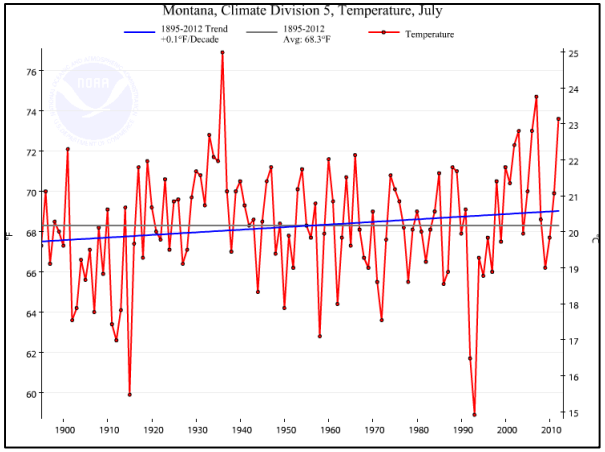
Increase in number of frost free days

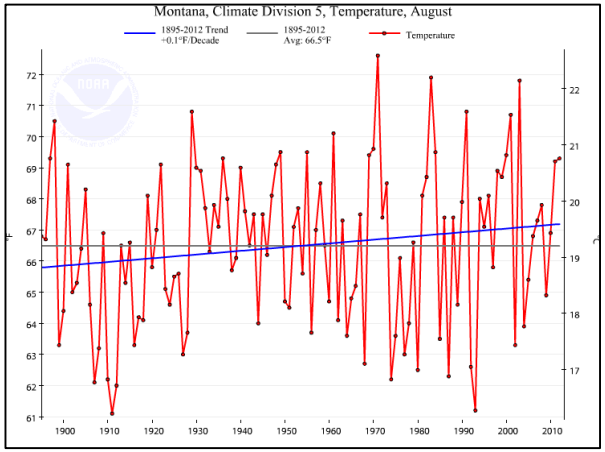


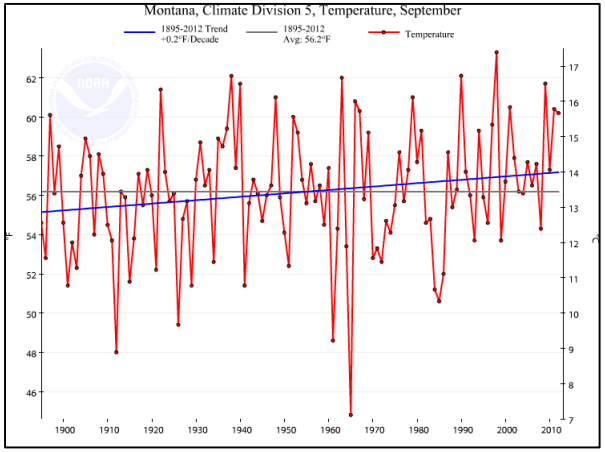
Number of frost free days in Hardin, MT, calculated from historic daily observations. (Data source: National Climate Data Center.)

Montana Climate Division 5: Warmer summers



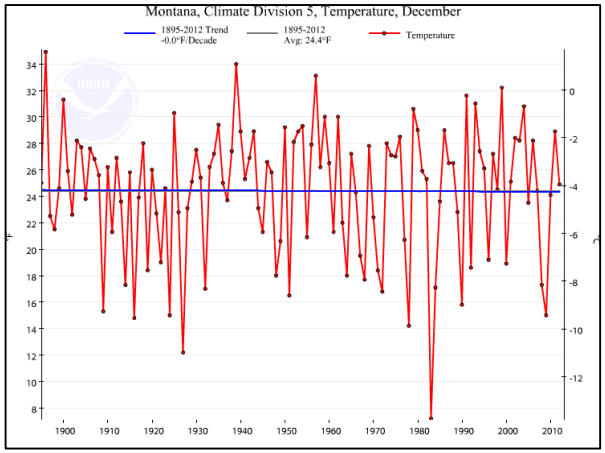


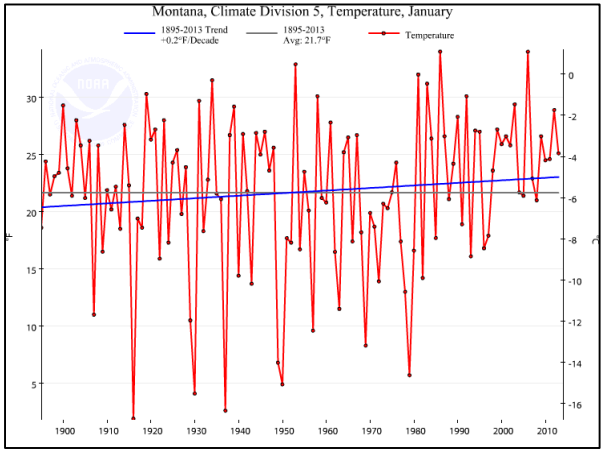


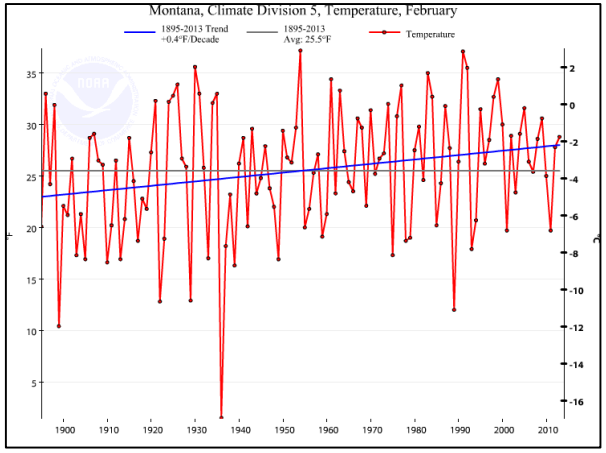


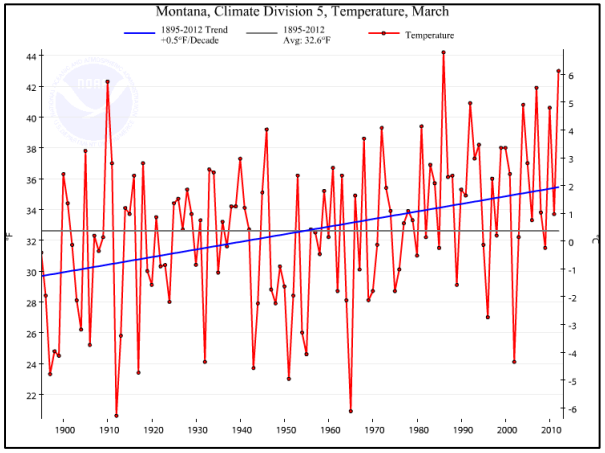
Montana CD5 data shows average monthly temperatures over the past 110+ years have been steadily warming for the summer months of June through September, by 0.1˚ to 0.2˚F per decade.

Montana Climate Division 5: Milder winters



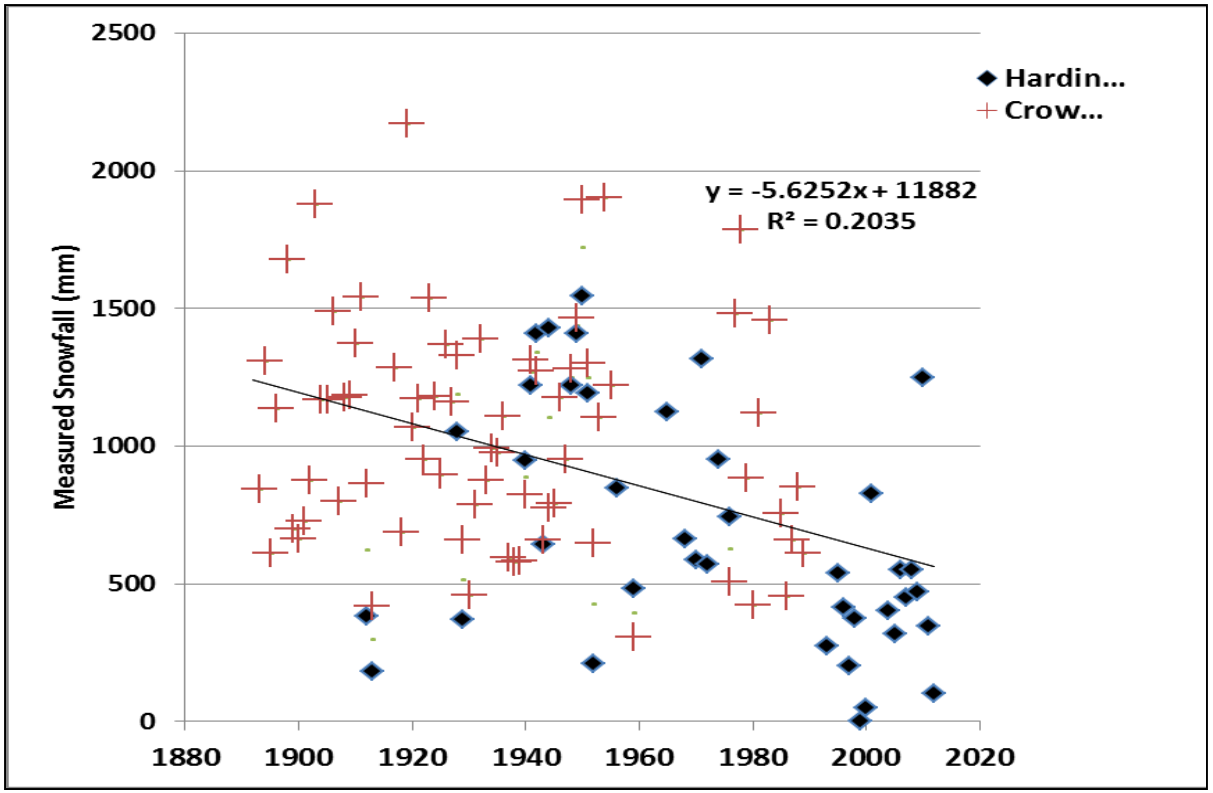






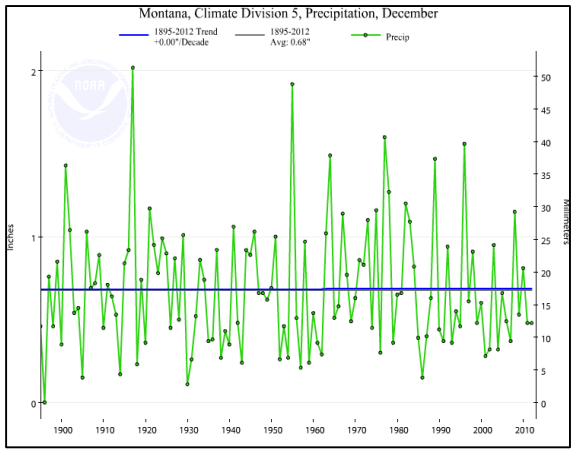
The increase in number of frost-free days is consistent with Montana CD5 data showing that over the past 110+ years, average temperatures for the months of January through March have been steadily increasing (by 0.2˚F, 0.4 ˚ F and 0.5 ˚ F per decade respectively)

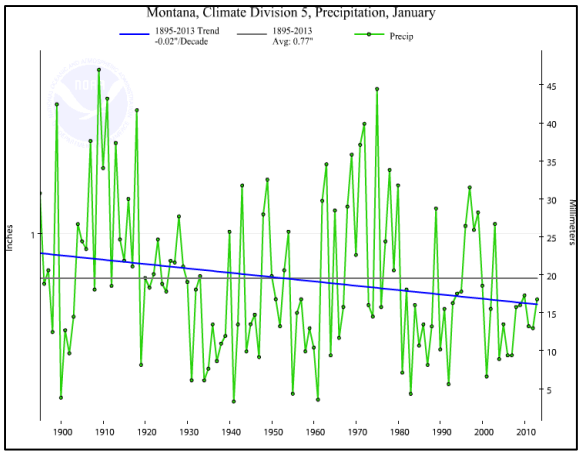
Total annual snowfall

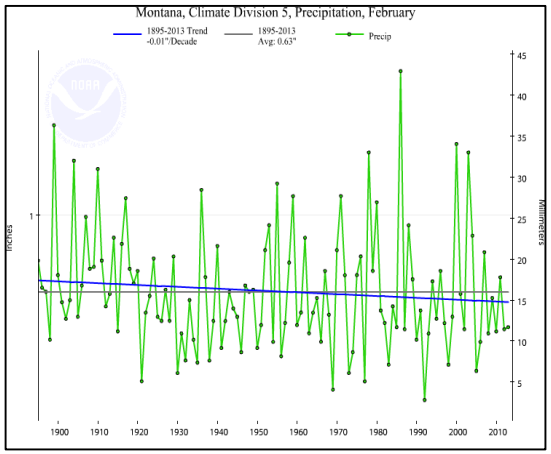


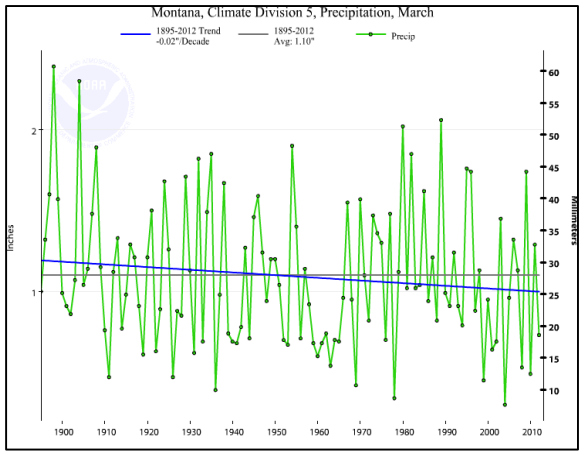
Annual snowfall in millimeters from Hardin MT (1912-2012) and Crow Agency MT (1895-1990) observation sites, calculated in water years. The trendline is calculated from the average of measurements when both locations had measurements, and on the single site's measurements when only one station was operating. Years with more than one month of missing data were deleted from data plot, except for the earliest records. (Data source: National Climate Data Center.)

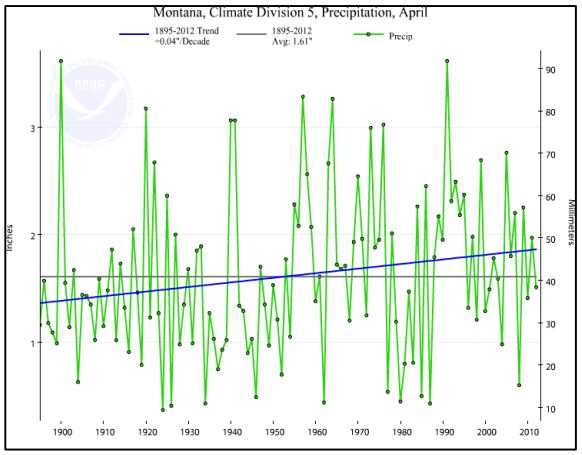
Declining annual precipitation





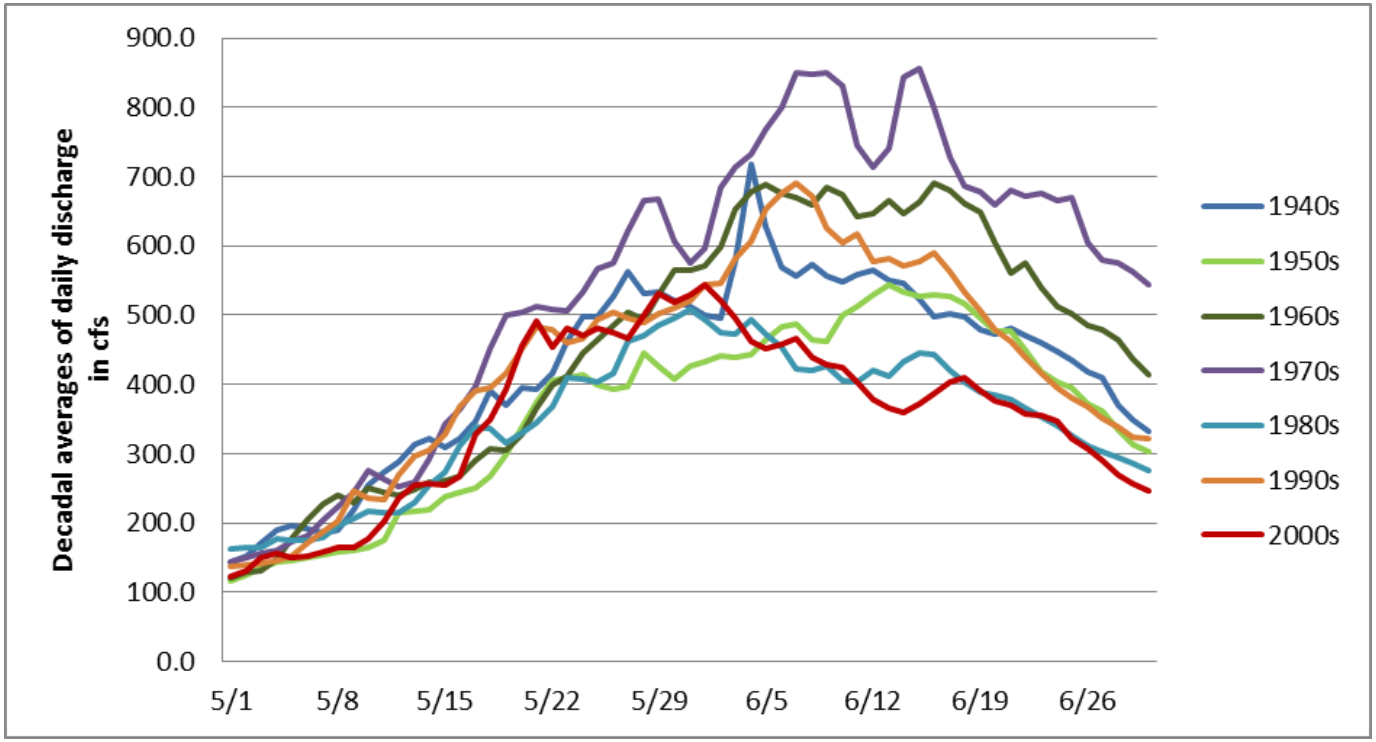






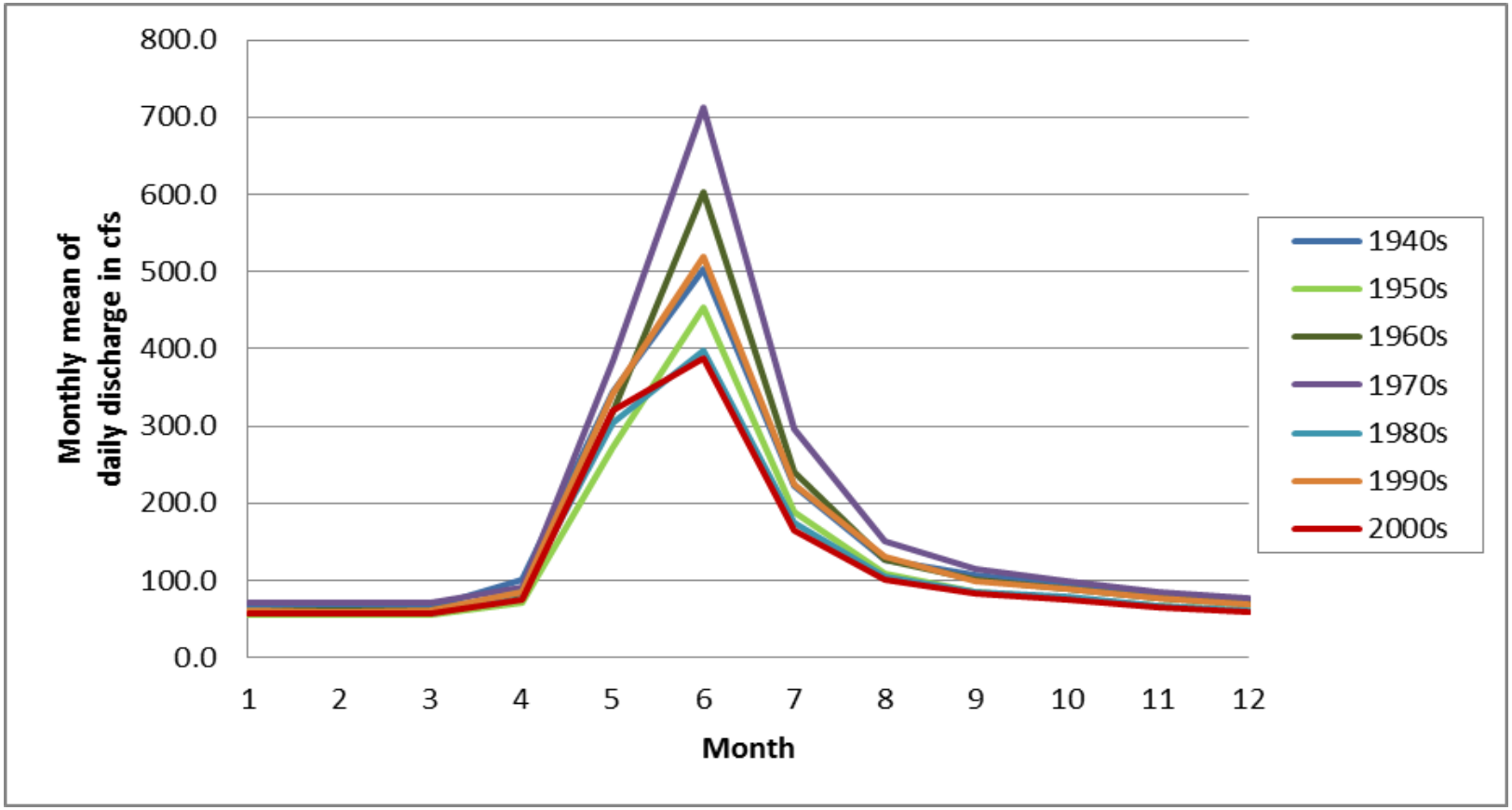
The decline in winter snow pack is not being made up during other seasons; average annual precipitation in MT CD5 has been declining by 0.11” per decade. April’s increase might contribute to flooding?

Is spring runoff occurring earlier?



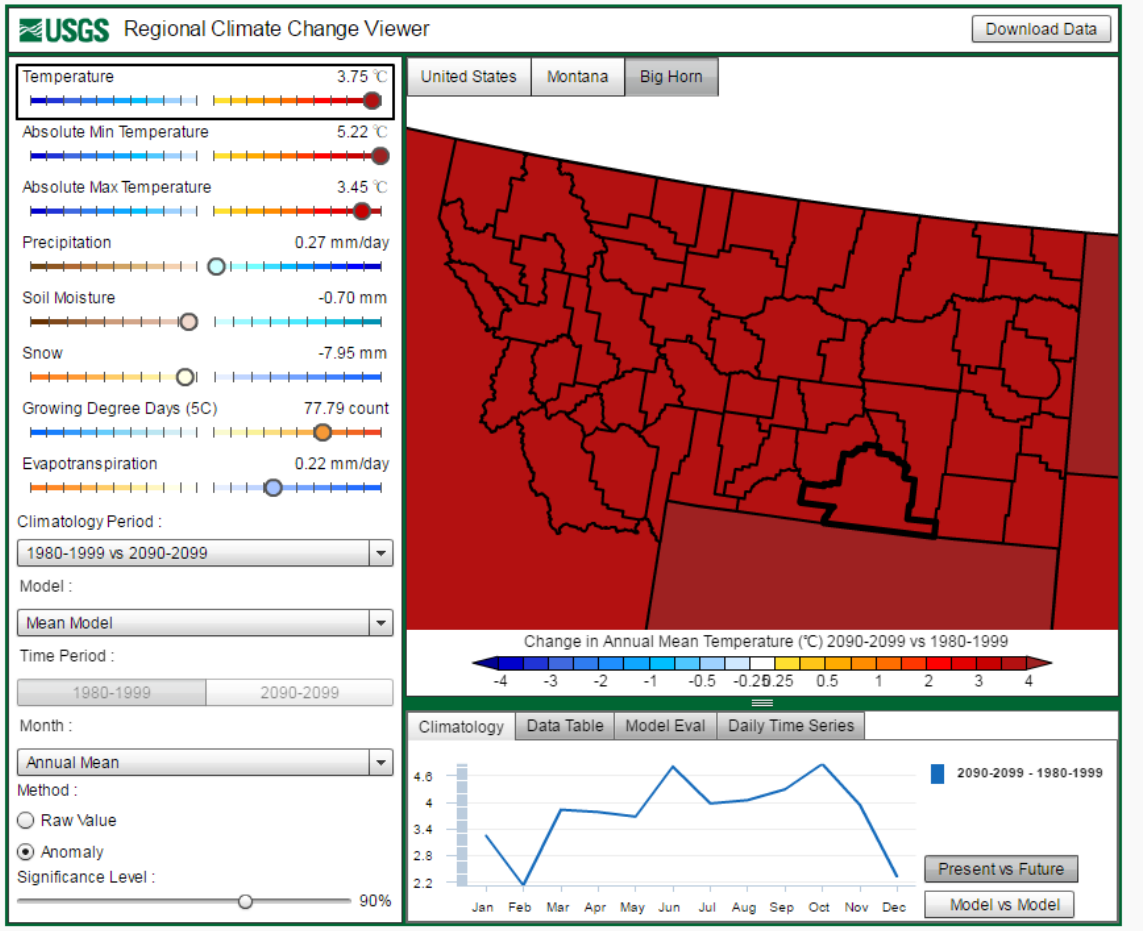
Decadal averages of daily spring runoff for May and June, Little Bighorn River above Wyola, Montana. Earliest spring runoffs on record occurred in the 1980s and 2000s. (Data source: USGS 2012)

Is stream discharge declining?



Little Bighorn River at Montana/Wyoming state line. Monthly averages of daily mean discharge by decade. Lowest discharge decades were the 1980s and 2000s. (Data source: USGS 2012)

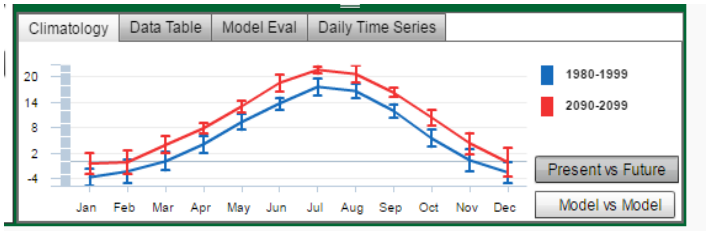
Tribal knowledge & historic climate data concur; What is projected for future climate change?



USGS projected climate change anomalies 1980-1989 vs. 2090-2099 for Big Horn County, MT

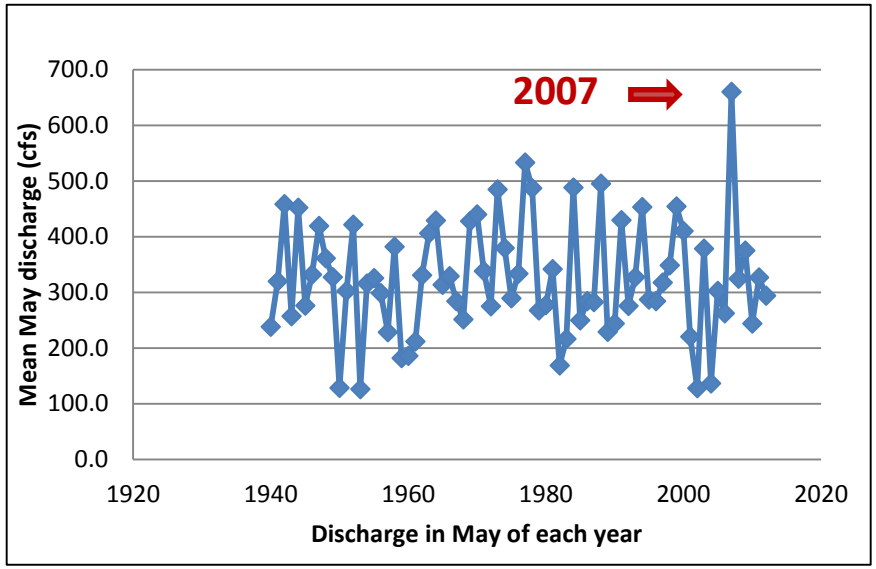
Temperature change is projected to accelerate.

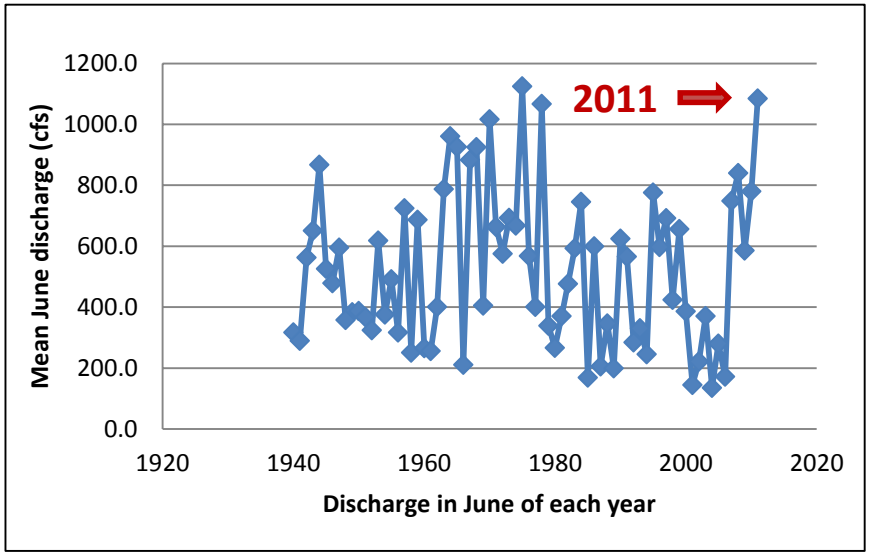
	Past 80 yrs MCD5	Next 80 yrs MCD5 avg	Next 80 yrs Big Horn
March	+ 2.22°C	+ 3.89°C	+ 3.84°C
Sept	+ 0.89°C	+ 4.33°C	+ 4.30°C



http://regclim.coas.oregonstate.edu/

Little Bighorn River flood history





Little Bighorn River, Crow Reservation, Montana. Major floods in 1976, 2007 and *again* in 2011 were unprecedented in living memory and have us concerned about future flooding. (Data source: USGS 2012)

How does flooding affect our health?

- Declining winter snowpack, earlier spring runoff and increasing demand for water for irrigation is resulting in very low late summer river flows. Crow Agency could run out of water altogether in late summer.

- Fecal contamination of home wells
- Property loss & destruction
- Water damaged homes subsequently develop mold
- During the 2011 flood, *Cryptosporidium* levels in the river increased. The local water treatment plant's technology was not adequate to remove all of the parasite's oocysts.

Flooding impacts on home well water?

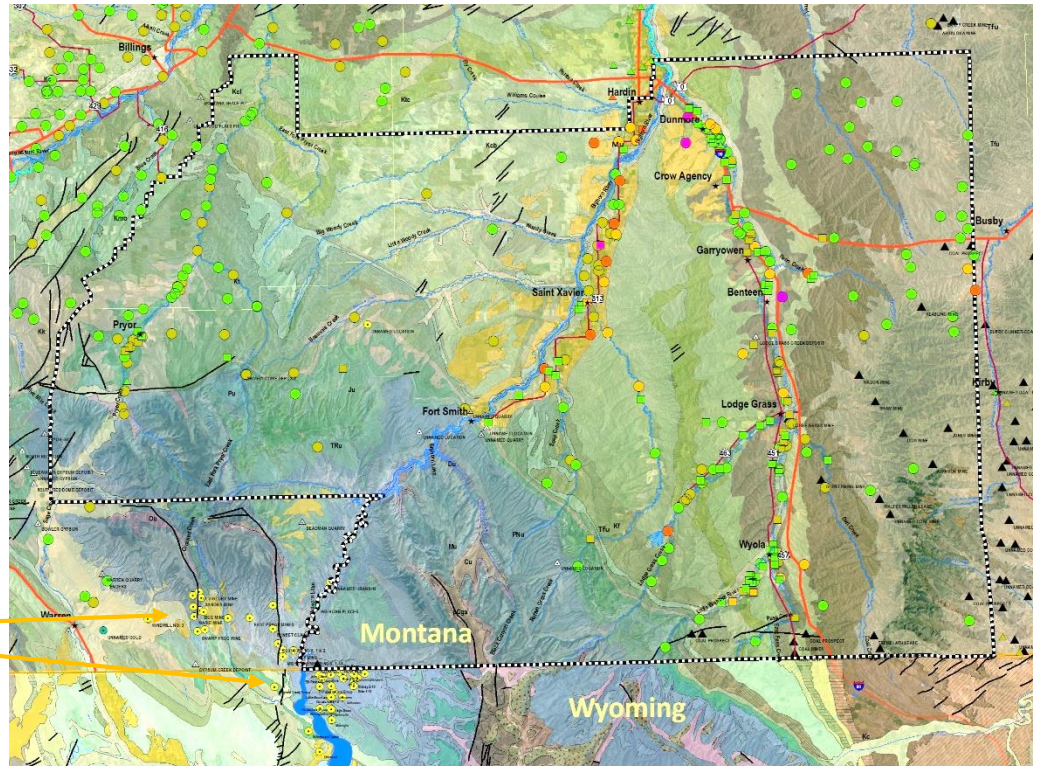
The 2007 and 2011 floods inundated many homes and home wells along the Little Big Horn River on the Crow Reservation, MT. Some springs traditionally used for drinking water were also affected.

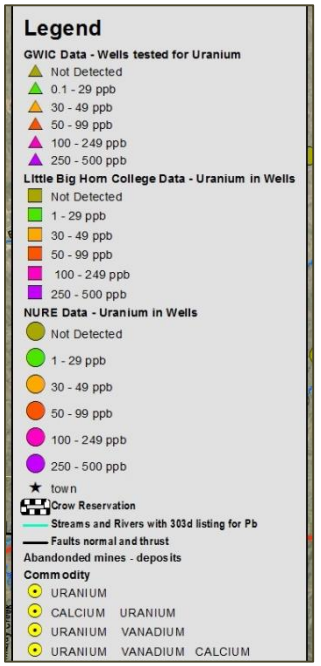
We are testing home wells and important springs for fecal contamination, and are explaining health risks and well head protection.

~ 200 wells tested to date in this project.

55% of home wells tested are unsafe to drink or cook with, as they exceeded an EPA health standard for inorganic, nitrate and/or coliform contamination

Abandoned uranium/ vanadium mines





Uranium in well water on the Crow Reservation

We are testing to see how spring run off will affect manganese, nitrate, arsenic and uranium levels as well as coliform bacteria counts.

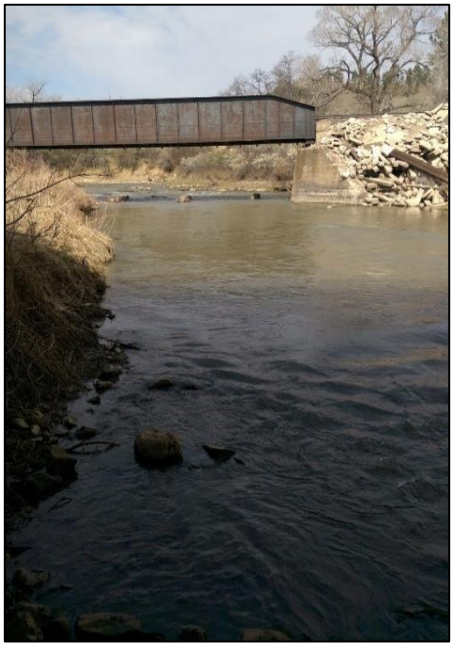
Combining historical information with current river sampling and laboratory tests: Predicting microbe responses to climate change

Microbial water quality: Impacts from climate change on the Little Bighorn River

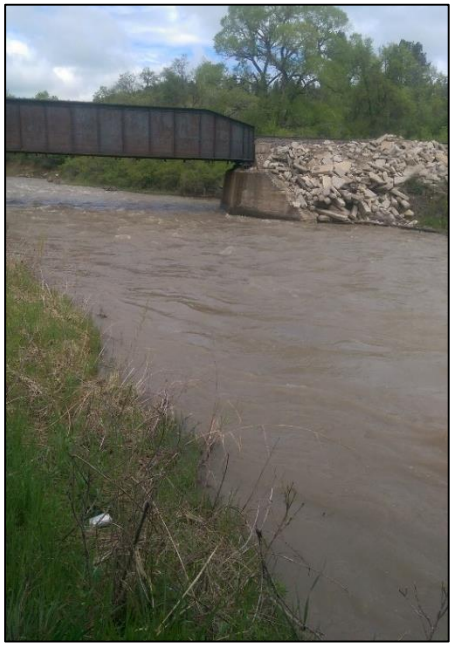
Graduate student: Keenan Brame

- Environmental Indicator Organism Analysis
  - Temporal and Spatial Analysis
  - Planktonic vs Total Coliform and *Escherichia coli* Counts
- Freshwater Microcosm Experiments
  - Planktonic vs Sediment-Associated Pathogens
  - Manipulate Environmental Variables

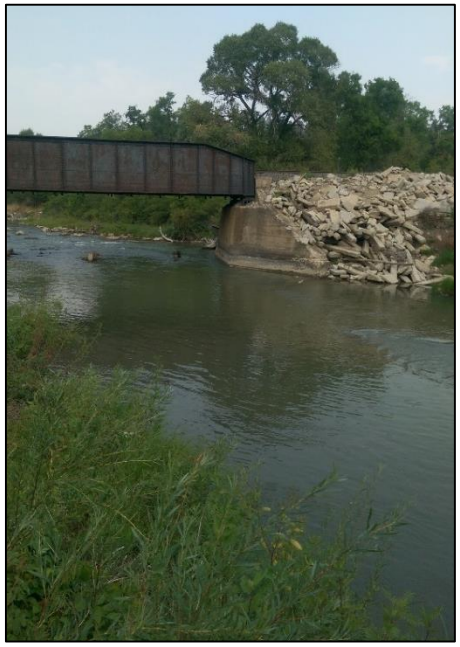
November 2nd , 2015



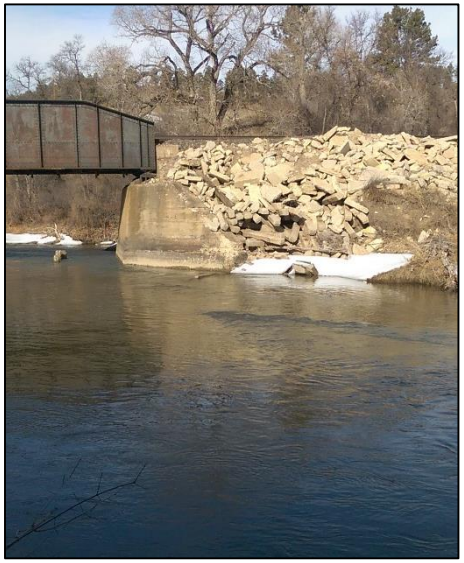
April 21st, 2015



May 27th, 2015



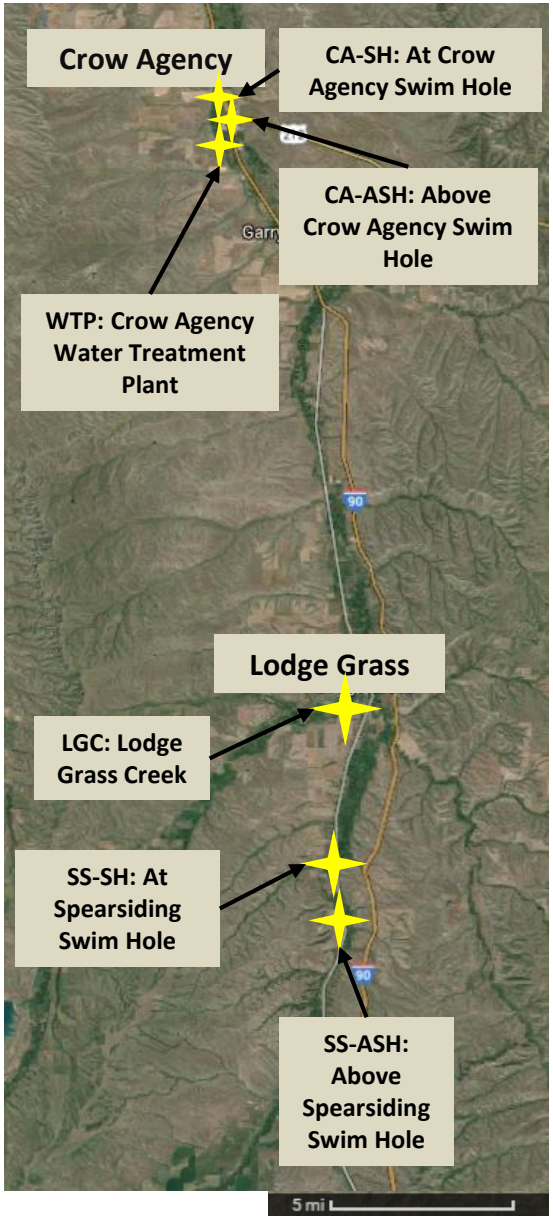
August 21st , 2015



February 10th, 2016

Background: Microbial Pollution on Little Bighorn

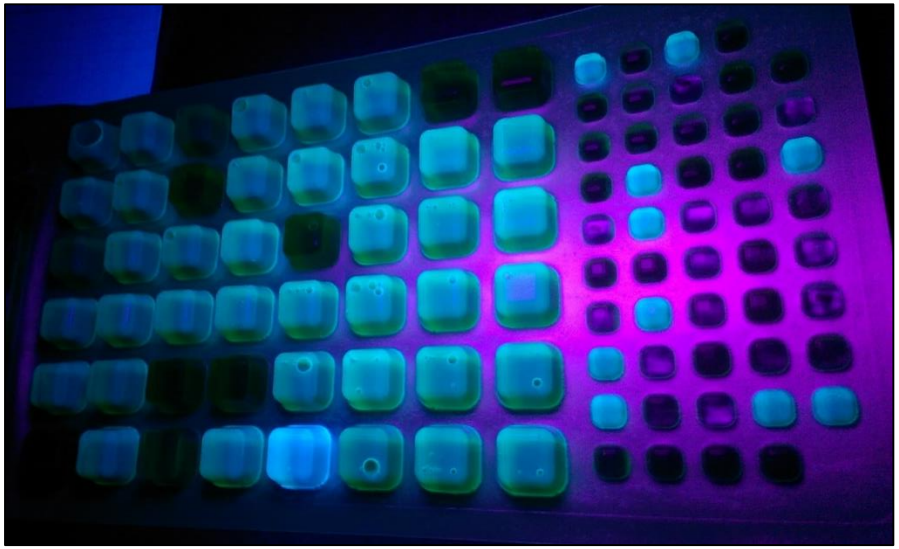
- Spring 2007: *Escherichia coli* exceed 1200 colony forming units (CFU) per 100mL
- Spring runoff 2009: *E. coli* exceed 7100 CFU per 100mL
  - "Bin 4" – Highest risk category for *Cryptosporidium*
- Summer 2011: *Cryptosporidium* oocysts found in every water sample
- 2008, 2009, and 2012: 10 serotypes of *E. coli* harboring both intimin and Shiga toxin genes isolated from swim hole
  - Intimin: Virulence factor of enteropathogenic and enterohemorrhagic *E. coli* strains
  - Shiga toxin: Produced by specific *E. coli* strains with disease-causing potential



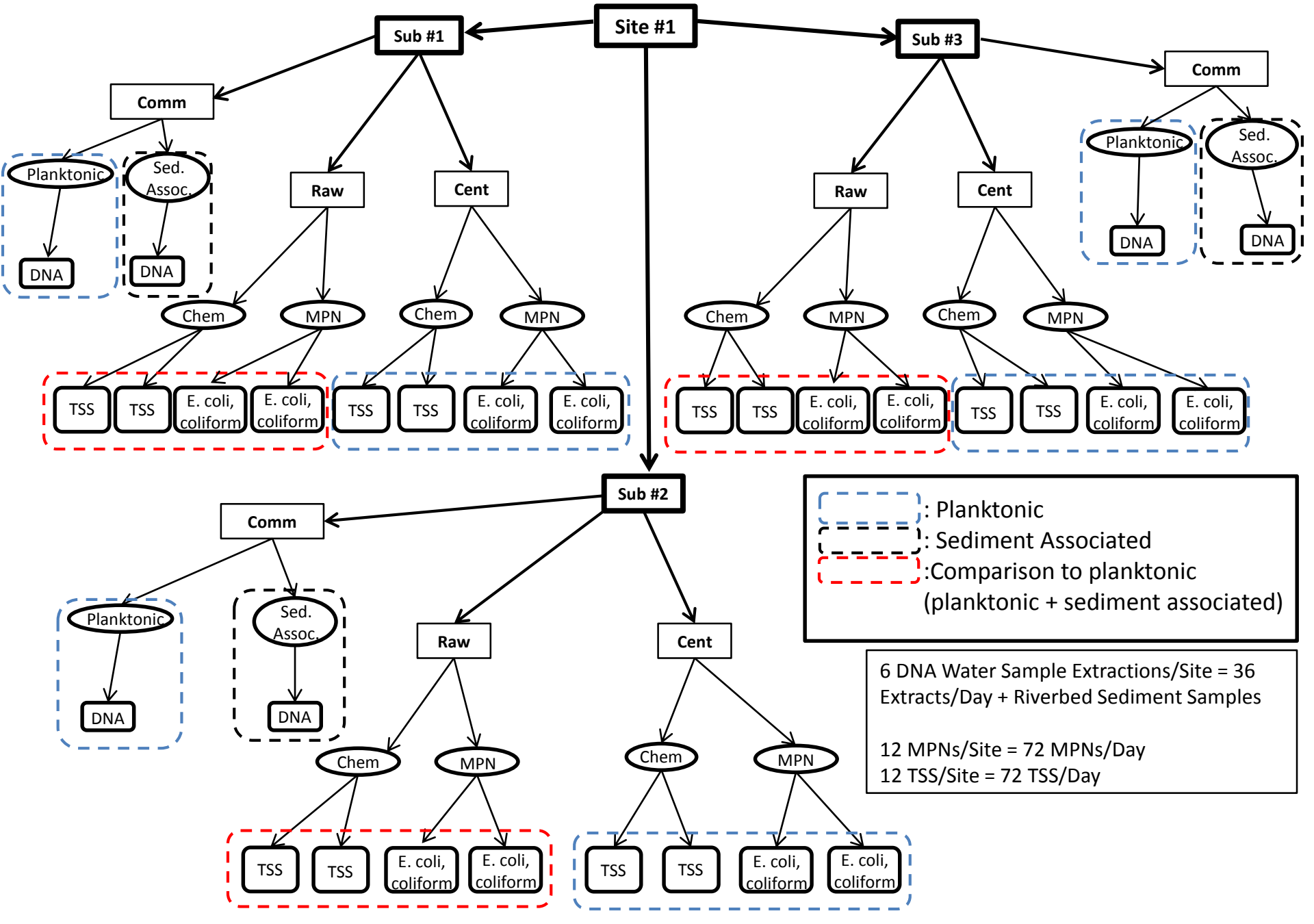
Fecal Indicator Organism Analysis

- 6 sampling sites, minimum 5 times per year (3 years)
  - Sites selected for increased human contact (swim holes, water treatment plant intake), difference between potential increases due to recreation (above each swim hole), and control (tributary)
  - Sampling times selected for various river stages: Pre-runoff, peak-runoff, low flow and high recreation, low flow and declining temperatures, low flow and minimum river temperatures
- IDEXX Colilert® and Quanti-Tray®/2000 Substrate Enzyme Test
  - Most Probable Number for Coliform and *E. coli*
  - Total and planktonic indicator counts

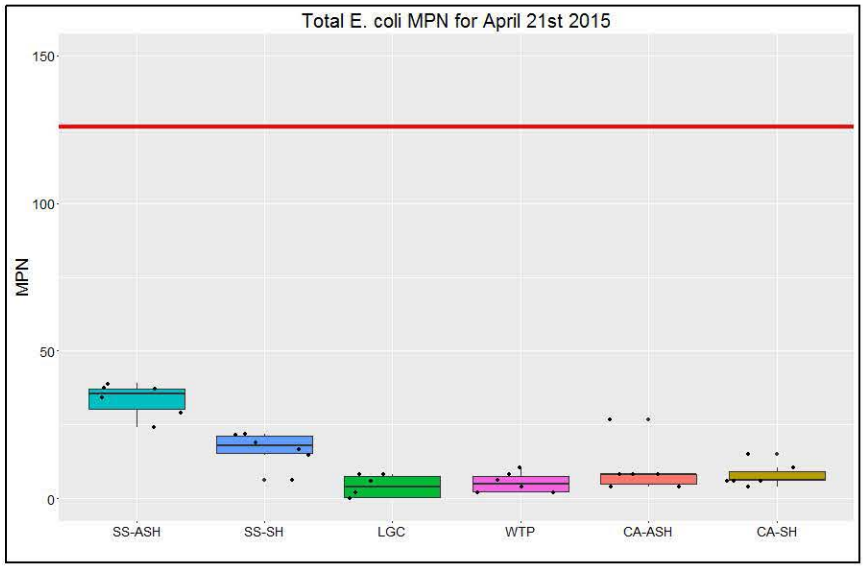
https://www.idexx.com/water/products/quanti-tray.html

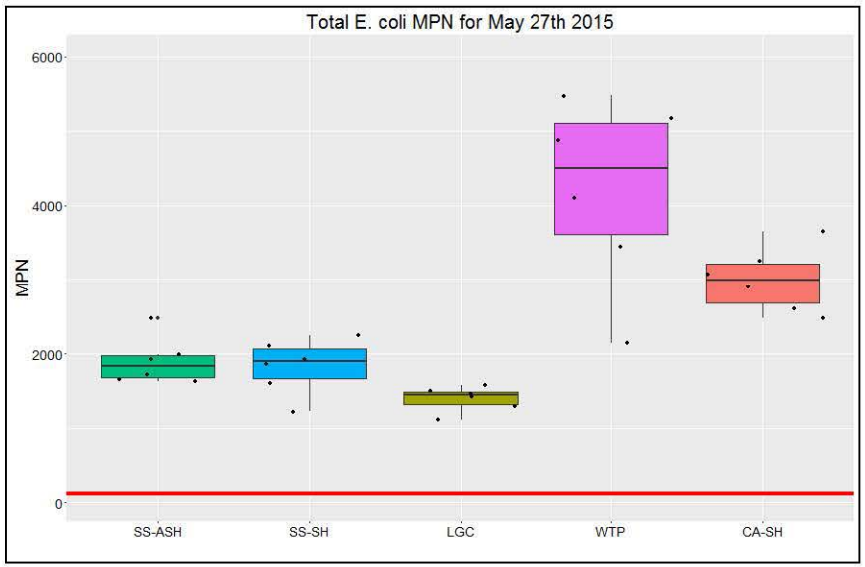


Water Sampling Distribution Chart

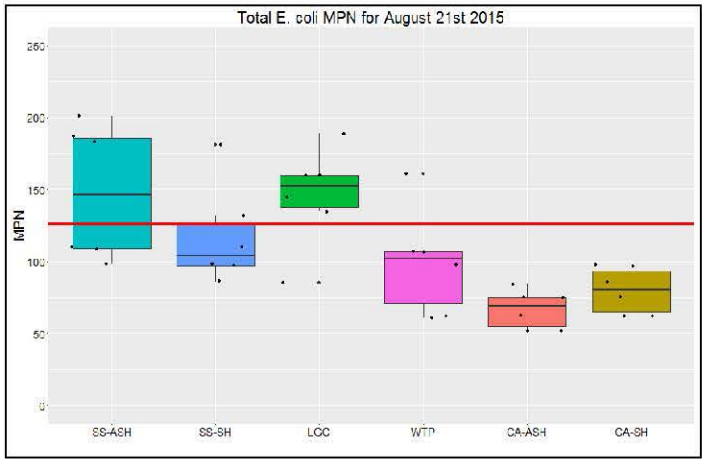


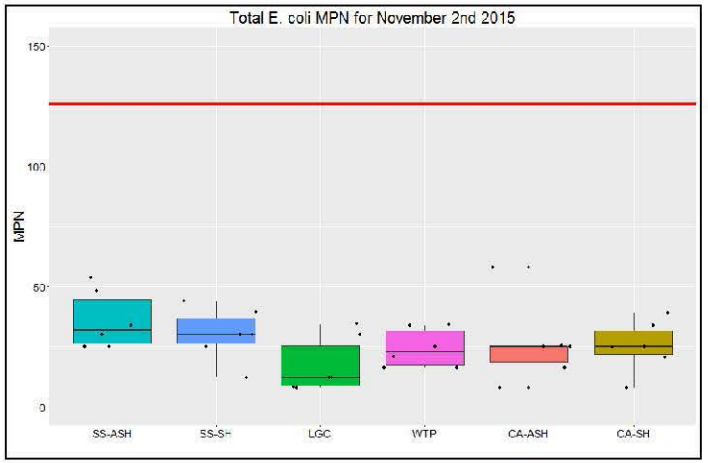
Year 1 *Escherichia coli* MPNs: Total

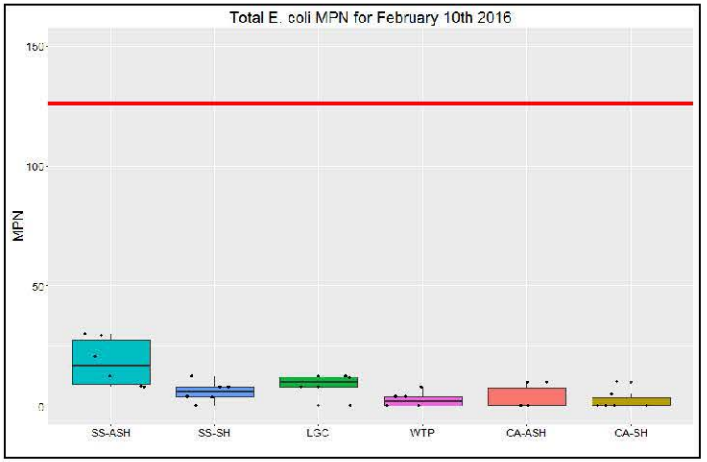




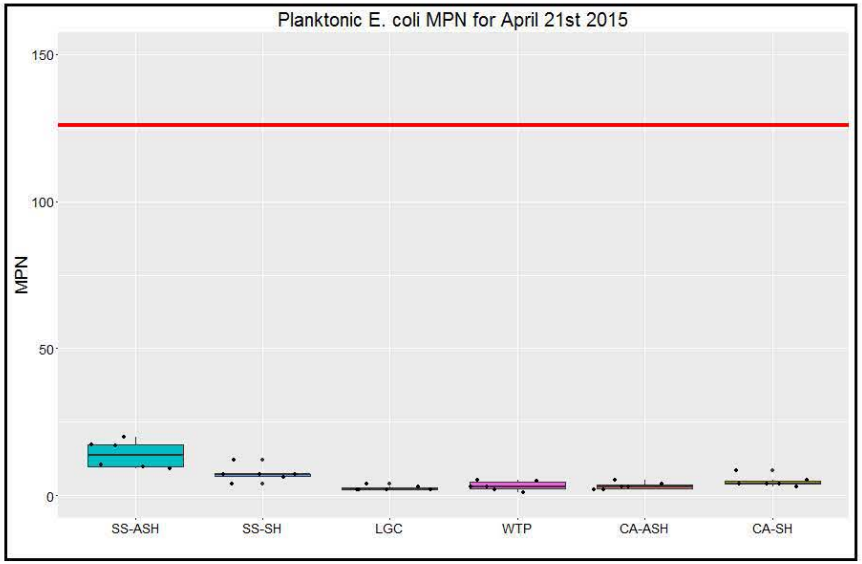
Red line represents EPA recommended limit for recreational use

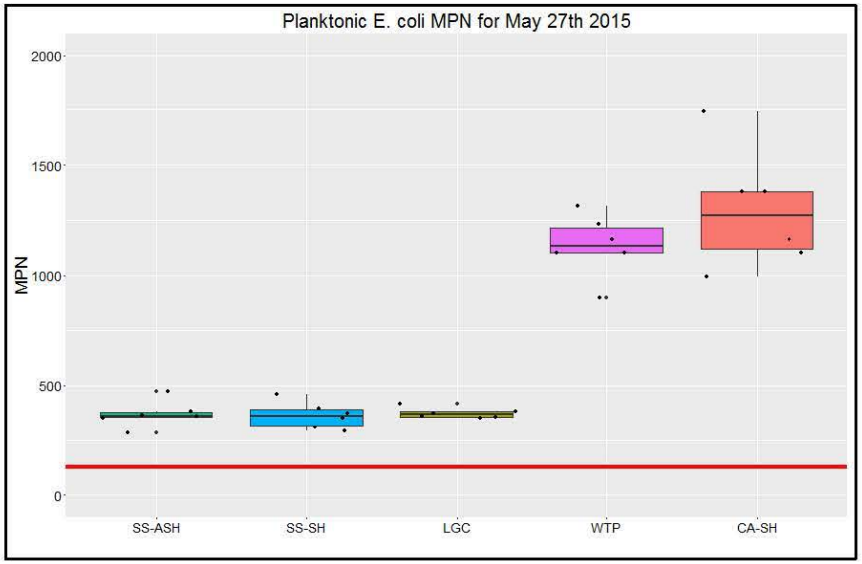




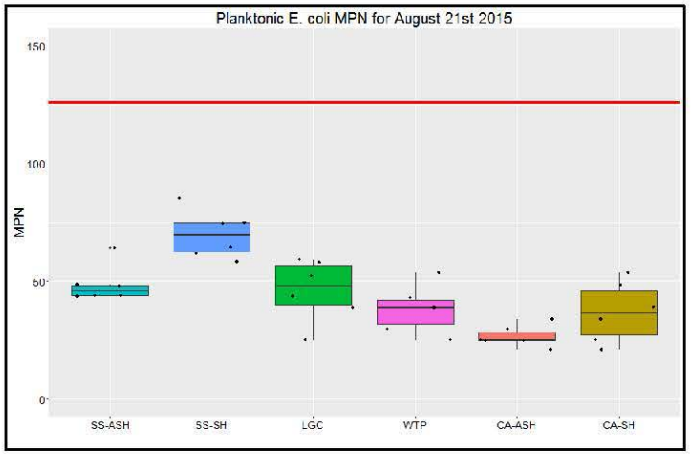


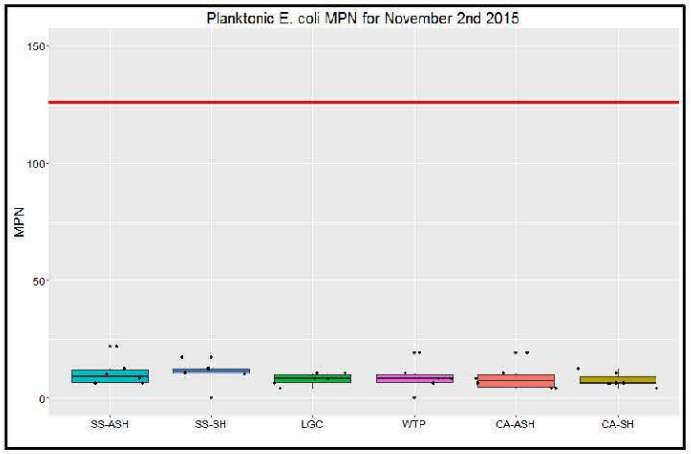
Year 1 *Escherichia coli* MPNs: Planktonic

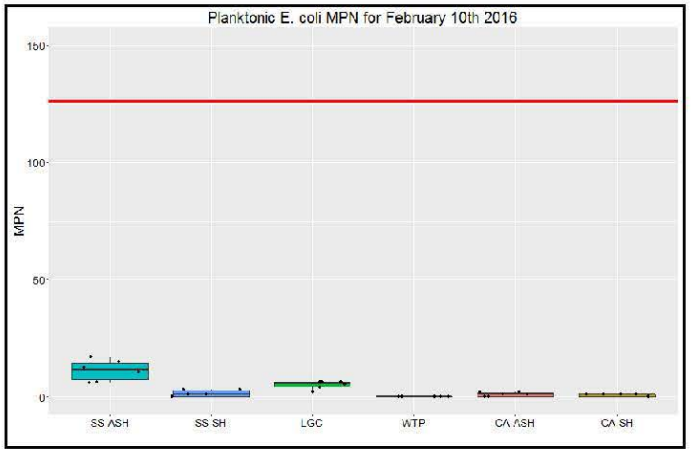




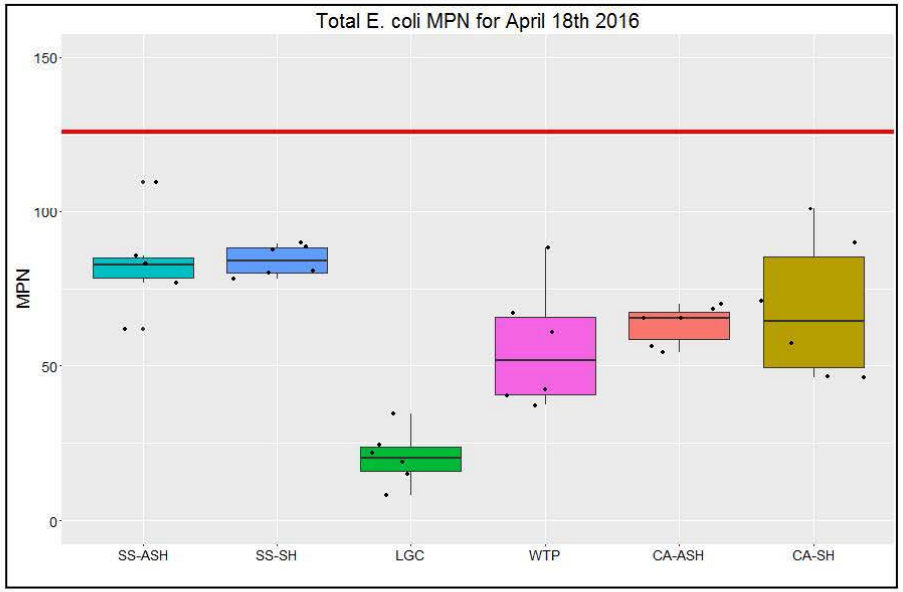
Red line represents EPA recommended limit for recreational use

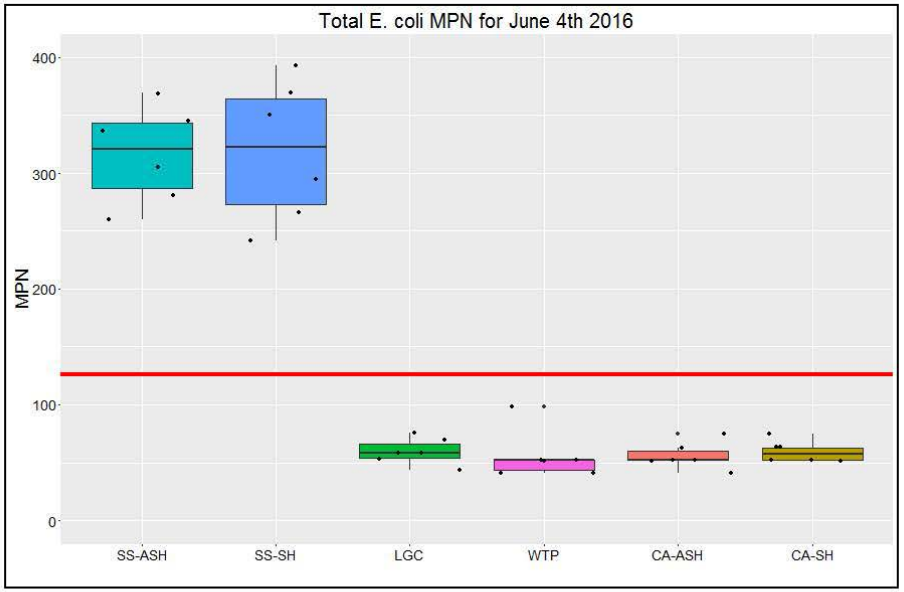


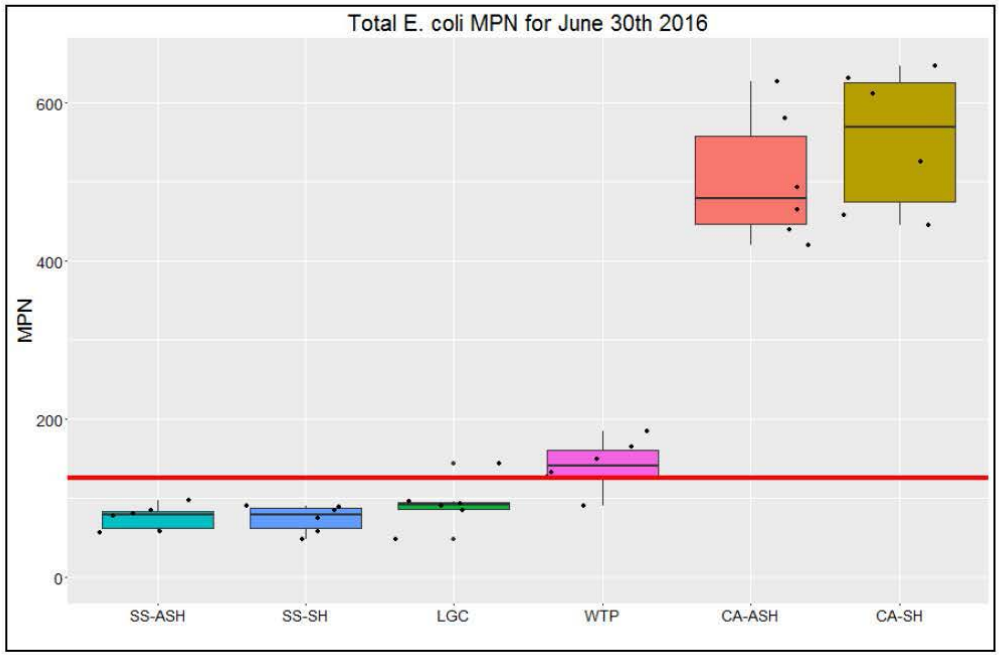




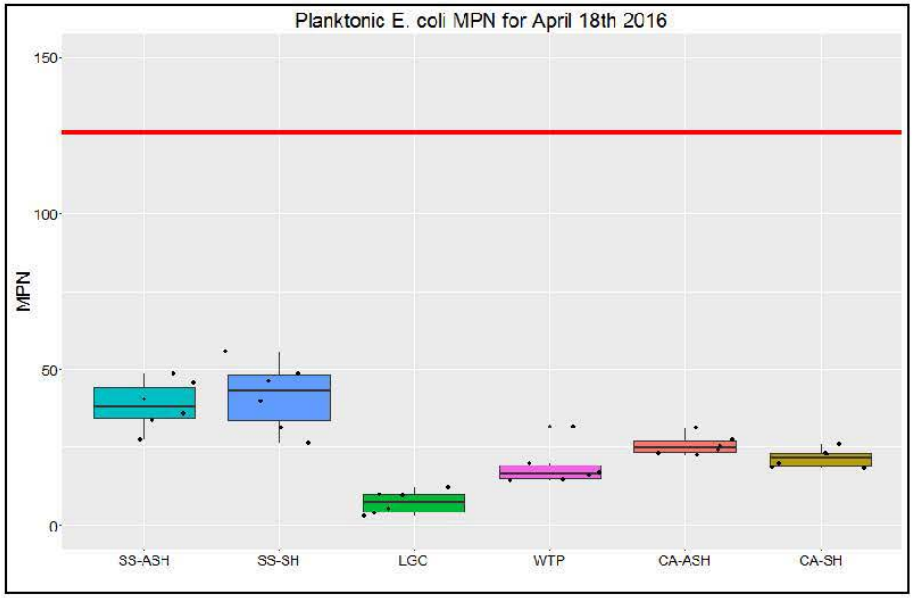
Year 2 *Escherichia coli* MPNs: Total

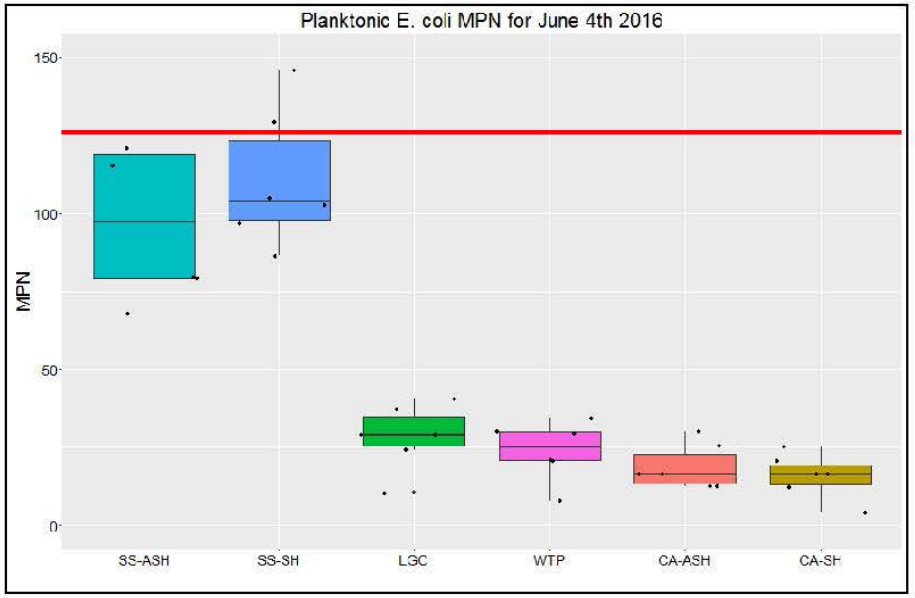


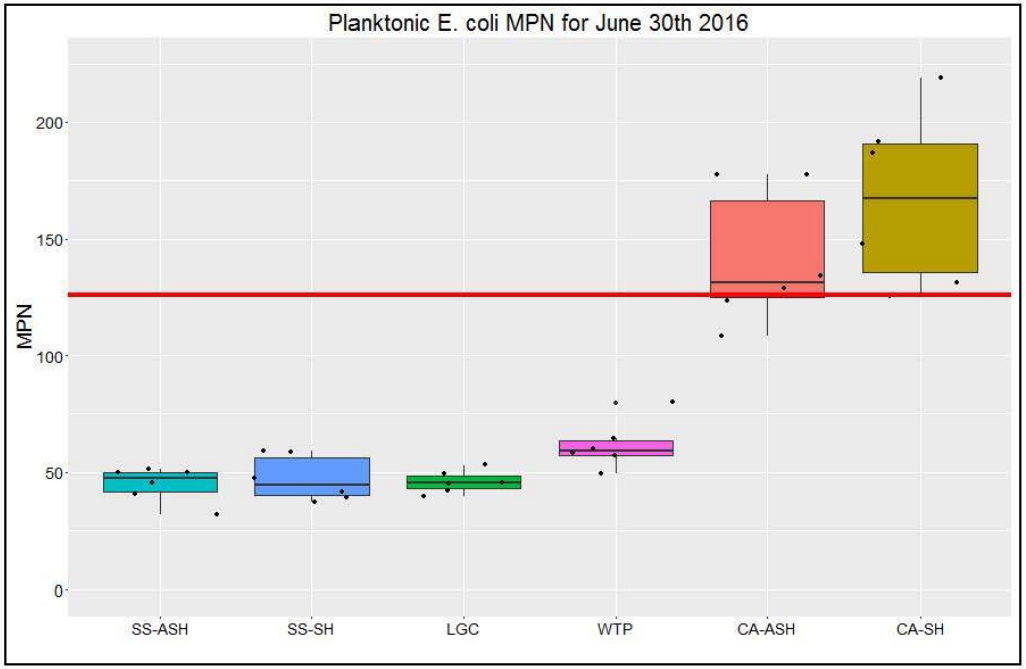




Year 2 *Escherichia coli* MPNs: Planktonic







Indicator Organisms: What's Next?

- Environmental Data: Temperature, nutrient concentrations, pH, TSS
  - TSS: Concentration of indicator organism cells on suspended sediments
- Differences between microbial partitioning over the course of a year
  - Sediment-associated vs planktonic
- Repetition
  - Finish Year 2 (Fall and Winter) + Year 3
- ➢ Relating differences between sampling dates to potential future climate trends

Freshwater Microcosm Experiments

- Sediment-associated microbial number changes
  - Sediments with known microbial loads exposed to river water
  - Suspended microbial populations exposed to river water and sediment
  - ➢ How pathogenic *E. coli* attach/dissociate and survive on sediment
- Microbial response to river quality changes
  - Changes in pathogenic *E. coli*
    - River water temperature
    - Nitrogen and Phosphorus loading
    - Organic Carbon loading
    - Attachment to ranges of sediment size
  - ➢ How pathogenic *E. coli* will respond to projected changes in the climate
- Experiments are in progress

Combining Field and Lab Experiments

- Environmental data
  - Replicate in lab with pathogen manipulation → Understand microbial partitioning
  - ➢ Pathogens planktonic in origin or sediment-associated?
  - ➢ Pathogens attaching to sediment in the water column or dissociating after being introduced from a source?
- Manipulate environmental variables
  - Using collected environmental data, replicate in lab and then change variables to upscale how climate change might affect pathogen survivability and partitioning

How do we engage fellow Tribal members in the research process?









The Crow Tribal community leads this research, education and mitigation project through the **Crow Environmental Health Steering Committee** – a diverse group of Crow Tribal stakeholders who lead this work and meet regularly. Academic partners Drs. Camper and Eggers are non-voting members.

- One on one visits with well owners, recruited by being available whenever and wherever community members approach us, through our personal connections and by knocking on doors around the Reservation
- Regular visits with groups of Elders at their usual meeting places
- Talking with elected representatives of Districts, whenever we can
- Hiring a younger Project Coordinator from the Reservation, who has a Masters degree in community health and social media skills

How do we recruit and engage other collaborators?

We seek colleagues who have complementary expertise and an interest in mentoring Native students, and who are a good fit for our network:

- Drs. Deborah Keil & Jean Pfau, toxicologists, NIH INBRE funding
- Dr. Vanessa Simonds, public health & health literacy, NIH funding
- Drs. Johnnye Lewis, Melissa Gonzales, Joe Hoover & colleagues, U New Mexico, NIEHS – NIH Center grant funding

- Drs. Stephanie Ewing & Jane Klassen – groundwater geochemistry and analytical chemistry; NSF EPSCoR funding
- Dr. Scott Powell and Dr. Joe Hoover – geospatial analysis
- Dr. Ellen Lauchnor, environmental engineer, MSU Extension funding
- Drs. Anne Sylvester (Cornell), Agnes Chan (JCVI), Dave Jackson (JCVI) & Joslynn Lee (CSHL), utilizing genomics to research water quality, NSF

What are the current challenges in your project and what have been successful solutions?

How to reach all of the community on a continual basis? How do we make that sustainable?

- Guardians of the Living Waters collaboration
- Developing BIA Crow climate webpage
- Supporting Crow undergraduate and graduate students
- New Project Coordinator is a younger Tribal member with a Masters in community health

Providing solutions for well owners with unsafe water

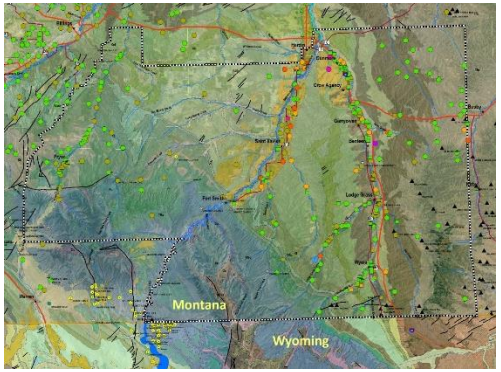
- Water coolers for five gallon jugs
- “Market testing” a low cost, high tech home filtration system

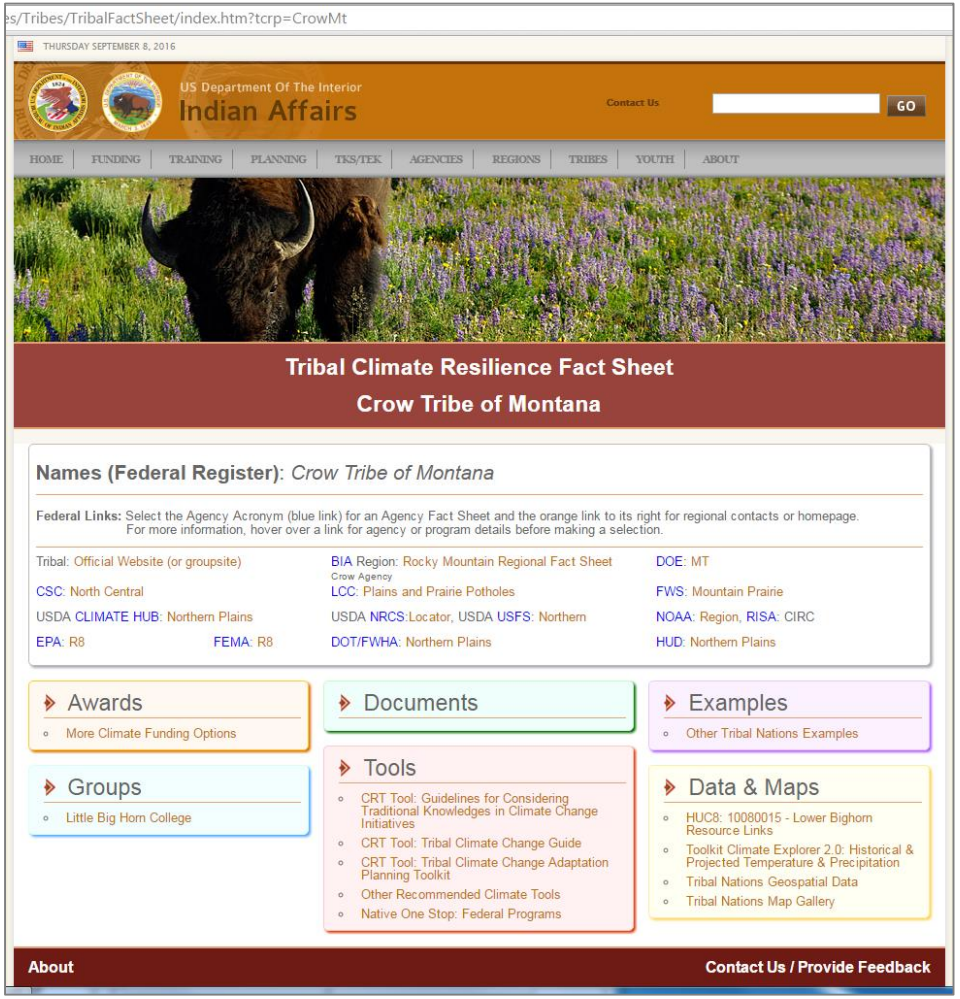
How do we convey the health risks effectively when water contaminants are colorless, odorless and tasteless (or mimic iron)? How do we support change?

- It’s building trust.

What are successful ways we share our work with stakeholders?

- Being a part of the community by listening and understanding what is being shared
- Continued contact, always available for discussion and ideas for solutions, help where we can and refer them for other sources of assistance
- Report back on well test results *in person*, and with written back up.
- Exploring sponsored Facebook page; this BIA website
- GIS maps





http://bia.gov/WhoWeAre/BIA/climatechange/Resources/Tribes/TribalFactSheet/index.htm?tcrp=CrowMt

What are (potential) impacts of your project on tribal health and wellbeing?

- People are now *requesting* that we test their well water through our program, and are making needed changes to ensure safe water for their families.
- Being able to provide water coolers to families with unsafe well water is making a huge difference: "We really like that cooler, we use it all the time."
- Reduced exposures to uranium, manganese, arsenic, nitrate and fecal contamination.
- Increased awareness of water quality and water safety issues – this has really changed. Now people are asking if their well water is affecting their health? Is that spring safe to drink? Will our children get sick from swimming in the rivers?
- Security of knowing that their family's water source for drinking and cooking is safe.

Conclusions

- Lack of or inadequate environmental monitoring in Tribal communities means local knowledge is vital in understanding climate and ecological change.
- We have lived and survived in the same place for many generations – so we see and experience climate change impacts that go beyond what science is currently monitoring.
- Native American and other communities with substantial subsistence activities and traditional uses of river water are at particular risk from climate change, and have greater adaptation challenges.
- We need all sources of knowledge to understand, anticipate and plan how we will cope with climate change and its impacts.
- In Crow, we are now looking for and discussing connections between water and health – this is a new discussion for us.

It takes a whole community

Our thanks and appreciation to the many dedicated community members and student interns who have participated or are participating in this project, and to our colleagues with the Crow Tribe, USGS, EPA, USF&WS, IHS, U of New Mexico, U of Wyoming, J Craig Ventre Institute & Cold Spring Harbor Lab.

It takes all of us to work on change

Crow Environmental Health Steering Committee
John Doyle – Apsaalooke Water & Wastewater Authority (AWWA)
Myra Lefthand – Community Health Educator
Sara Young – MT INBRE Program, MSU
Larry Kindness – AWWA
Eric Bird In Ground – Crow Legislator
Emery Three Irons – Student member
Roberta Other Medicine – Indian Health Service hospital
Dionne Pretty On Top – Indian Health Service hospital
Gail Whiteman – Crow Tribe, Land Management
Connie Howe – Crow EPA
Non-voting academic partners: Drs. Anne Camper & Mari Eggers

Little Big Horn College
Dr. David Yarlott , Dean Lefthand, Dean Small,
and many dedicated business office staff
Past Project Coordinators Ada Bends, Gail Whiteman,
Crescentia Cummins & Tamra Old Coyote
Post-bac Interns Amanda Not Afraid, Emery Three Irons
20+ LBHC Science majors

MSU Bozeman - Current and past student contributors: Keenan Brame, Eric Dietrich, Candy Felicia, Jonah Morsette, Varsha Rao, Chris Allen & ~ 10 Engineers Without Borders volunteers

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& out of state collaborators

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Questions?