Tongue River Modeling Approach and Results

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U.S. Environmental Protection Agency
Region 8
Montana Operations Office

April 6, 2007

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Discussion Topics

- Existing Condition
- Natural Condition
- Hypothetical CBM Discharge Scenarios for Hanging Woman and Badger Creeks

Simulating the Existing Condition

- The existing condition scenario is the baseline from which all other scenarios will be compared.
- Model simulations of the existing condition attempt to replicate the actual hydrologic influences and pollutant generation, fate, and transport from the environment as it existed in September 2006.
- The existing condition scenario has been run for a period of ***10 years*** including 2 wet years, 3 dry years, and 5 average years.
- All of the following scenarios have been modeled for the same set of wet, dry, and average years.
- Factors such as permitted CBM discharge, WWTP discharge, landuse, irrigation, etc. have been simulated for the entire 10 year period as they existed in September 2006.

This existing condition scenario is not intended to replicate the past. Rather, this is a simulation of the conditions that exist “today” over a period of hypothetical wet, dry and average years.

Simulating the Natural Condition

"Natural" levels of EC and SAR

- What is the "natural" condition?
- Is it the pre-settlement, pristine condition without any anthropogenic influence?
- Or is it the "*condition…over which man has no control or…where all reasonable land, soil, and water conservation practices have been applied*" as defined by the Montana Code Annotated (MCA 75-5-306)?
- Or, relative to dams, is it the "*condition resulting from the reasonable operation of dams*" constructed prior to July 1, 1971 (MCA 75-5-306)?

Anthropogenic Factors Potentially Influencing EC and SAR

- Stock ponds
- Irrigation
  - High altitude reservoirs
  - High altitude diversions
  - Interbasin transfers
  - Irrigation withdrawal
  - Irrigation return
- Agriculture
  - Irrigated
  - Non-irrigated
- CBM
  - Direct discharge
  - Discharge to pond
    - On-channel
    - Off-channel
- Coal mining
- Municipal WWTP
- Tongue River Reservoir and Dam operations

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Modeling the condition under which "all reasonable land, soil, and water conservation practices" have been applied

- This model scenario has not been developed.
- To develop such a scenario it would be necessary to define "*all reasonable land, soil, and water conservation practices*" and apply them to each of the factors listed on the previous slide.

Model Treatment of the Anthropogenic Factors Potentially Influencing EC and SAR for the "Natural Scenario"

- ~~Stock ponds~~
- ~~Irrigation~~
  - High altitude reservoirs
  - ~~High altitude diversions~~
  - ~~Interbasin transfers~~
  - ~~Irrigation withdrawal~~
  - ~~Irrigation return~~
- ~~Agriculture~~
  - ~~Irrigated~~
  - ~~Non-irrigated~~

Convert agr. land uses to grassland

- ~~CBM~~
  - ~~Direct discharge~~
  - ~~Discharge to pond~~
    - ~~On-channel~~
    - ~~Off-channel~~
- ~~Coal mining~~
- ~~Municipal WWTP~~
- Tongue River Reservoir Dam operations

Reservoirs remain, but assume run-of-river mode of operation

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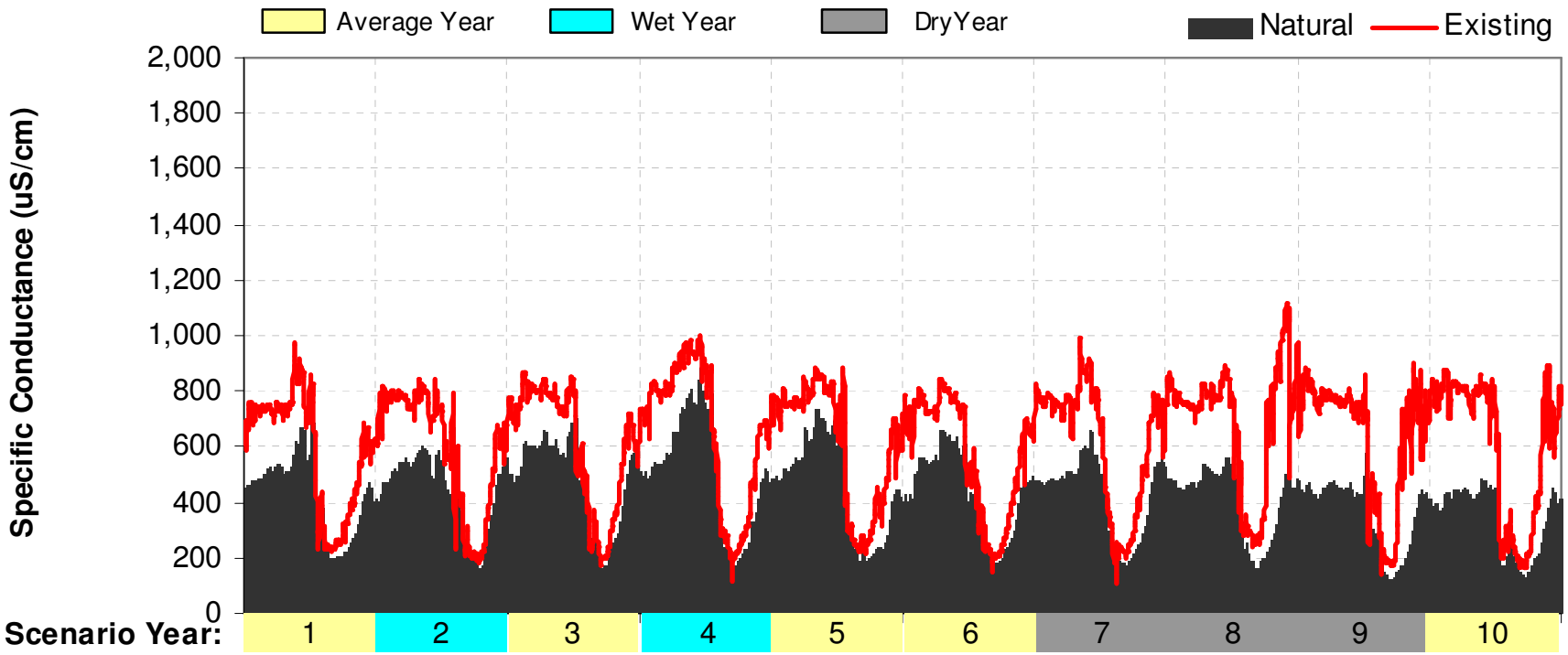
Modeled "Natural" Scenario (continued)

- It is acknowledged that this condition is unattainable and may not meet everyone's definition of "natural".
- However, the model results will place upper bounds on the potential range of affect associated with human influence.
- Additional scenarios have been, or can be, run where one source (e.g., CBM, irrigation, etc.) is removed, individually, from the model to examine the potential magnitude of influence of that source.

Tongue River EC - Where there are exceedences, are they natural or anthropogenic?

- Modeled mean EC under the "existing" condition and "natural" condition are significantly different in the Tongue River from the Stateline downstream to the mouth.

Comparison of Modeled Existing Condition and Natural Condition EC in the Tongue River at Stateline



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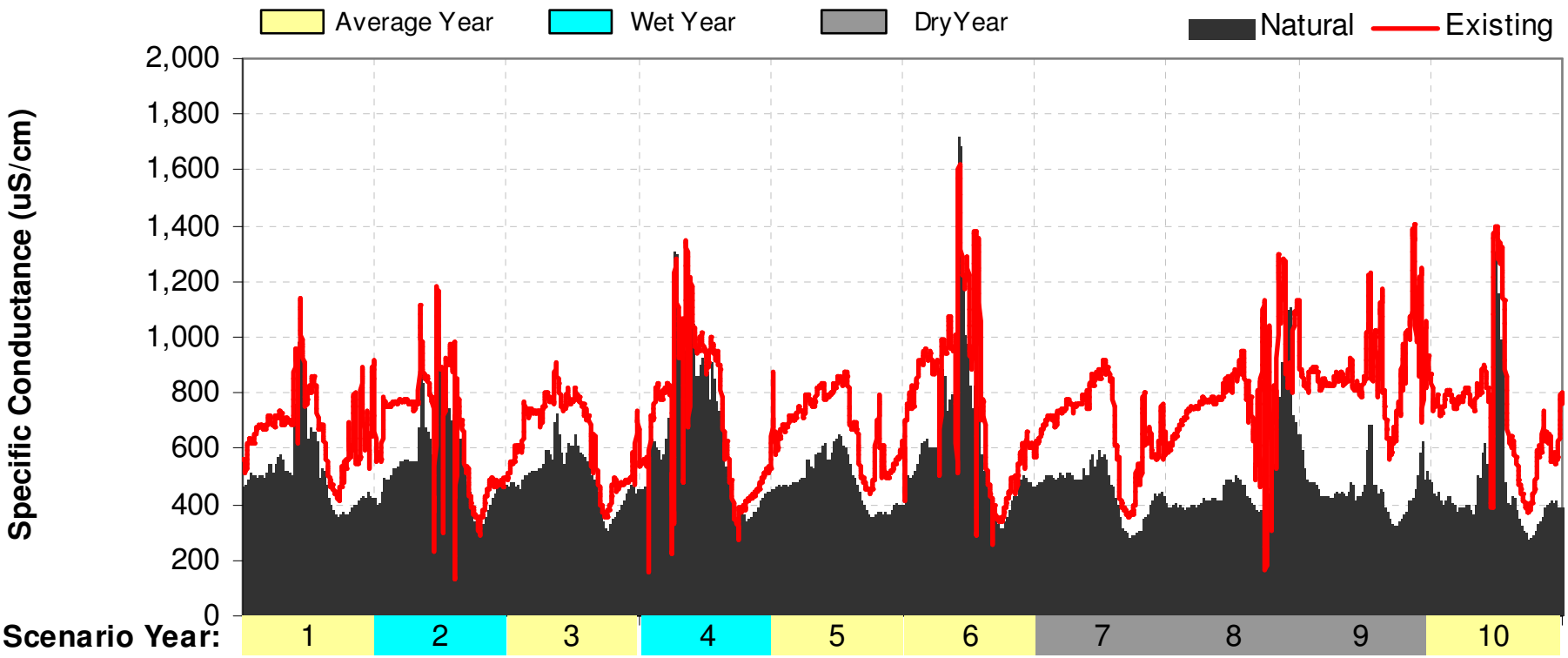
Comparison of Modeled Existing Condition and Natural Condition EC in the Tongue River at Miles City



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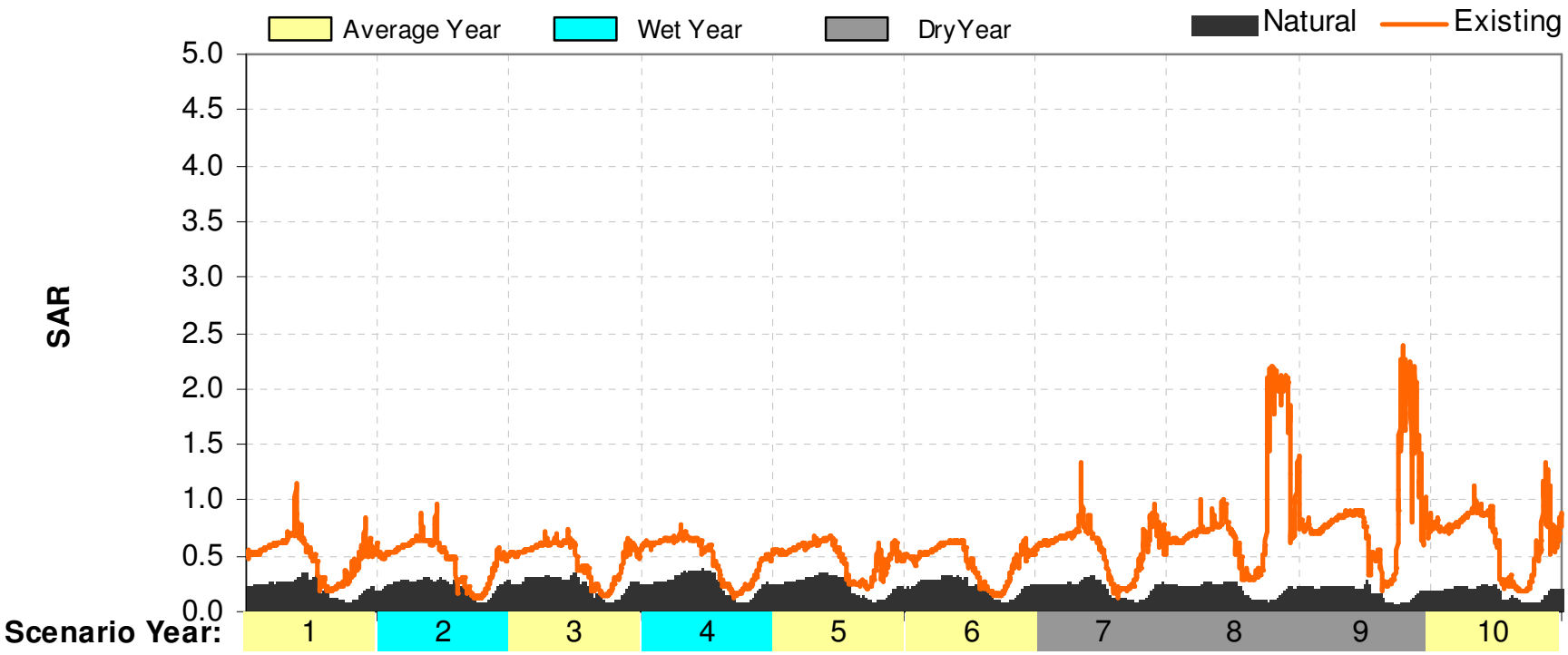
Hanging Woman Creek EC - Where there are exceedences, are they natural or anthropogenic?

- Based on model results, the "natural" and "existing" condition are not significantly different.
- Therefore, it appears that the exceedences that have been observed are largely a result of "natural" conditions.

Tongue River SAR - Where there are exceedences, are they natural or anthropogenic?

- Modeled mean SAR under the "existing" condition and "natural" condition are significantly different in the Tongue River from the Stateline downstream to the mouth.

Comparison of Modeled Existing Condition and Natural Condition SAR in the Tongue River at Stateline



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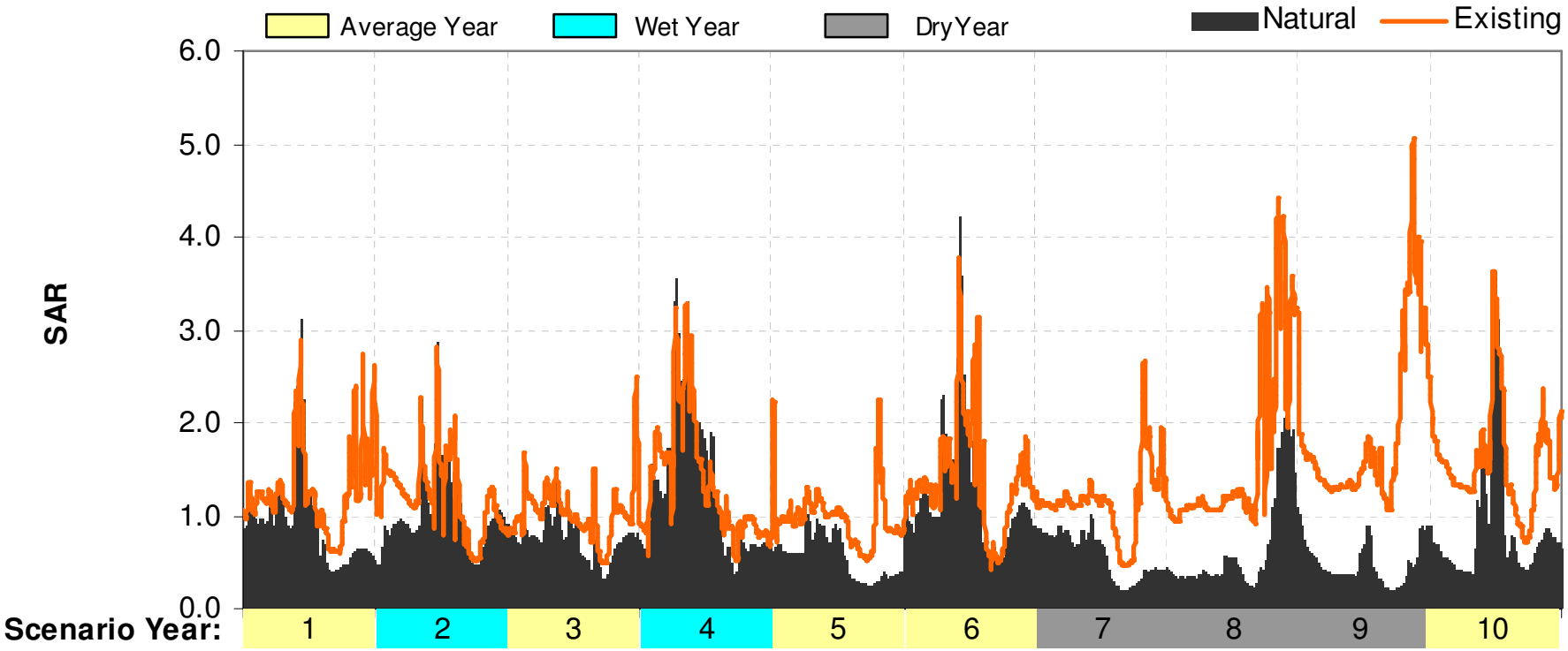
Comparison of Modeled Existing Condition and Natural Condition SAR in the Tongue River at Miles City



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Relative Importance of the Anthropogenic Factors Influencing EC in the Tongue River

- Stock Ponds – insignificant (< 1%)
- Irrigation – substantial (≈ 85%)
- CBM – minor (≈ 14%)

Rough Relative Comparison!!!!!

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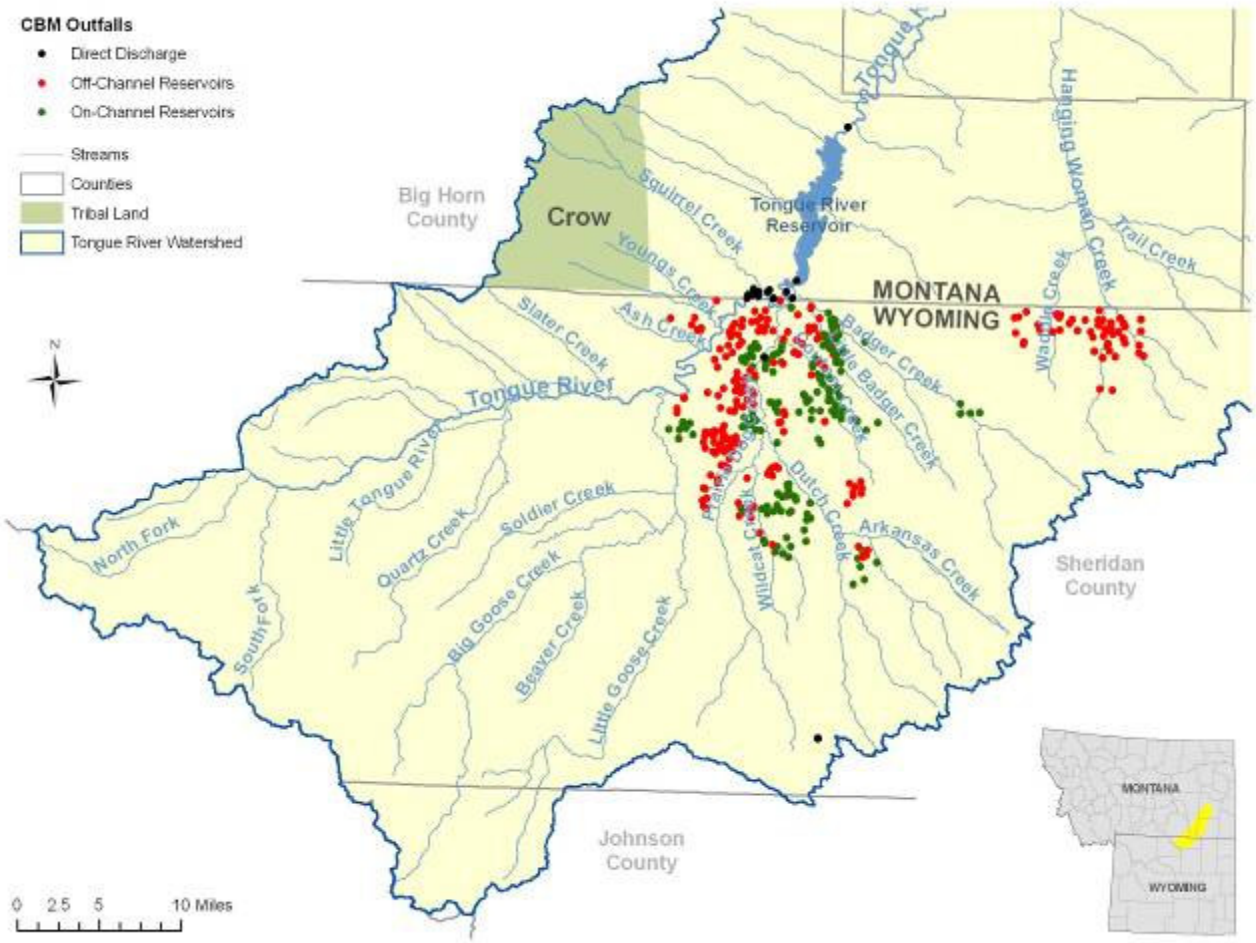
Hanging Woman Creek SAR - Where there are exceedences, are they natural or anthropogenic?

- Based on model results, the "natural" and "existing" condition are not significantly different.
- Therefore, it appears that the exceedences that have been observed are largely a result of "natural" conditions.

Hypothetical CBM Discharge Scenarios for Hanging Woman and Badger Creeks

- The existing condition scenario is the baseline from which these scenarios will be compared.
- For Hanging Woman Creek it is assumed that are 3 permitted outfalls discharging to off-channel reservoirs with an average total discharge flow rate of 0.26 cfs and an average EC and SAR of 1,833 µS/cm and 32.0, respectively.
- For Badger Creek it is assumed that there are 12 permitted outfalls discharging to 3 off-channel and 9 on-channel reservoirs with an average total discharge flow rate of 1.33 cfs and an average EC and SAR of 1,833 µS/cm and 32.0, respectively.

All Known Permitted CBM Outfalls in the Tongue River Watershed



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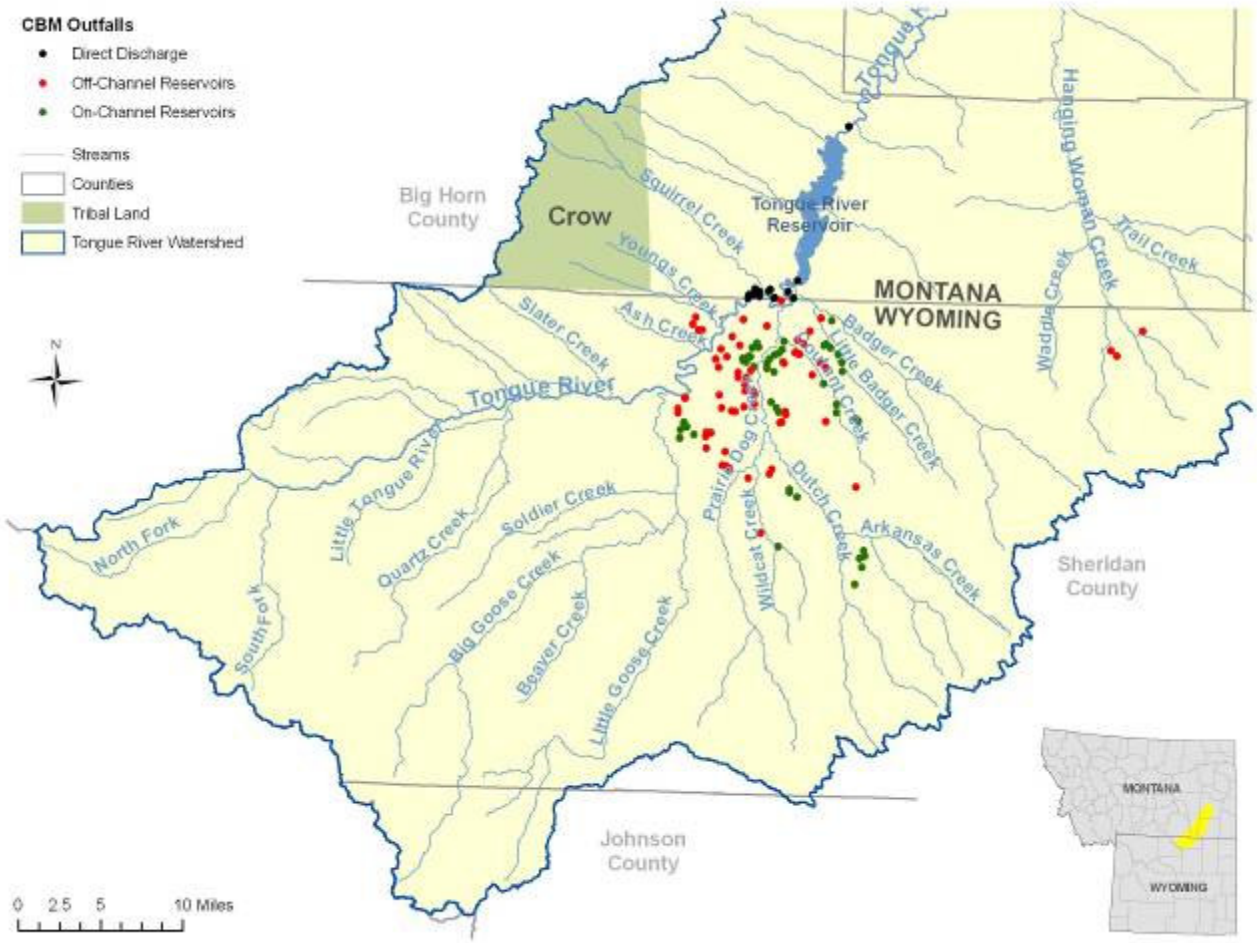
Active CBM Outfalls in the Tongue River Watershed as of September 2006

Modeled for Existing Condition Scenario



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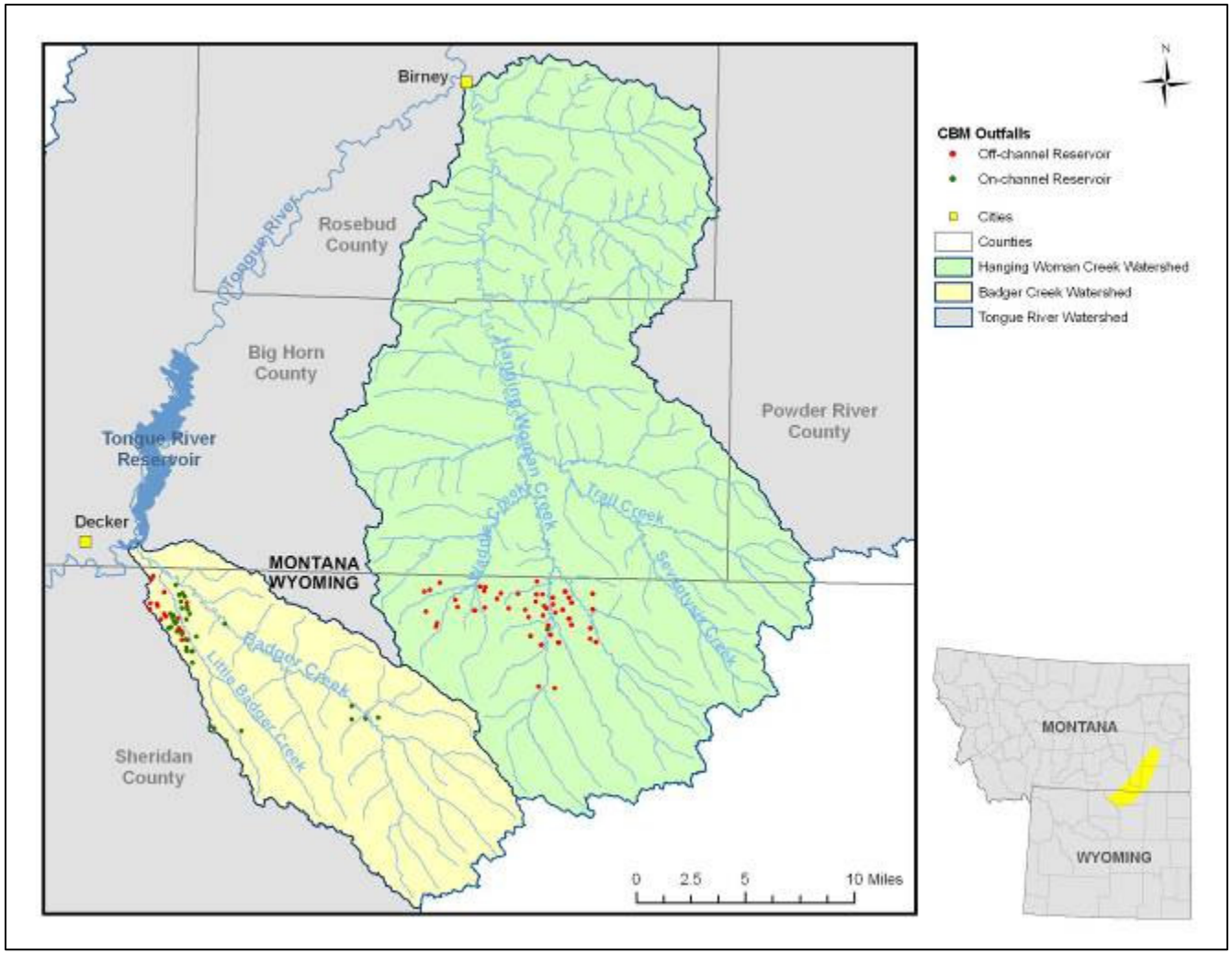
All Known Permitted CBM Outfalls in Hanging Woman and Badger Creeks



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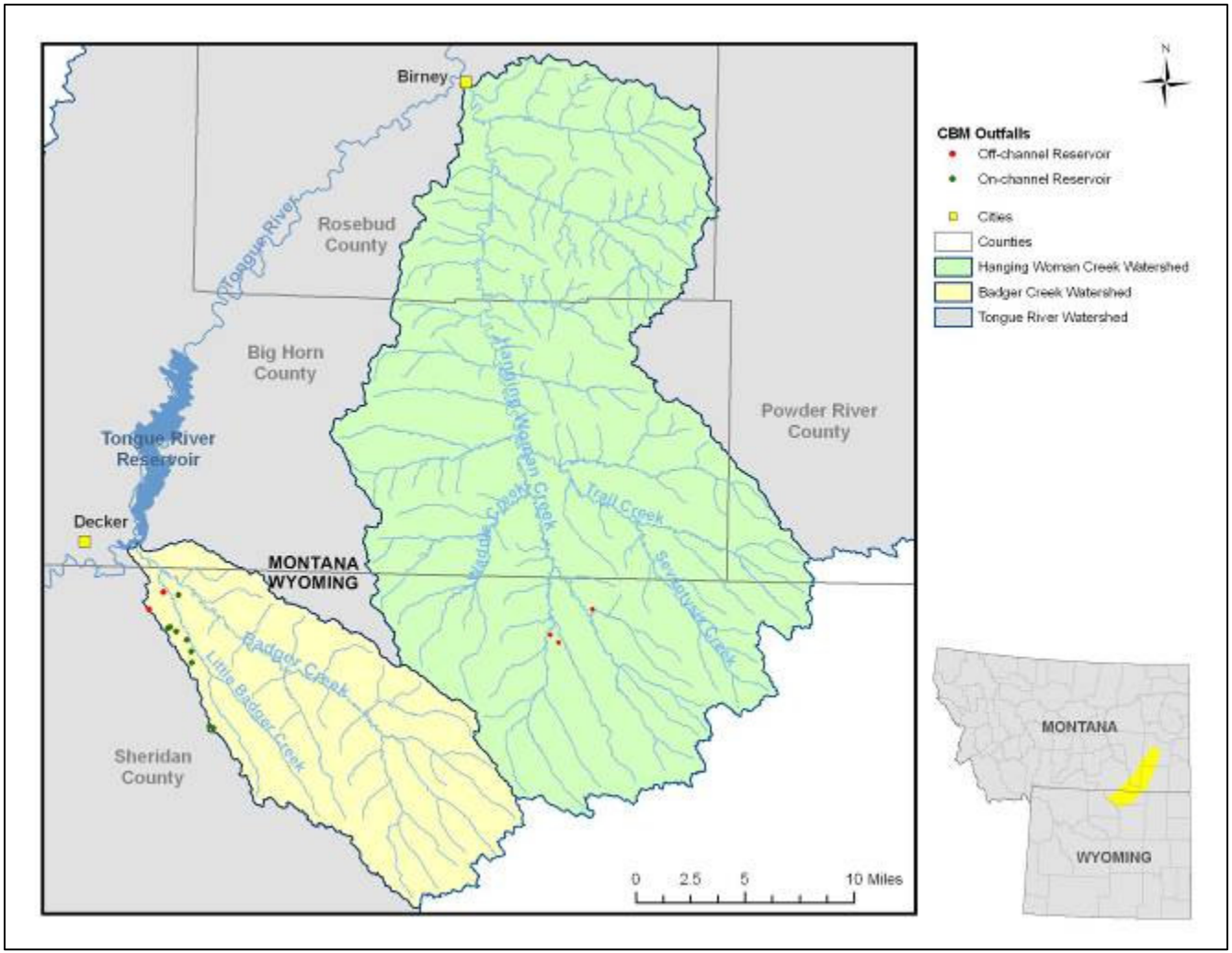
Active CBM Outfalls in Hanging Woman and Badger Creeks as of September 2006

Modeled for Existing Condition Scenario



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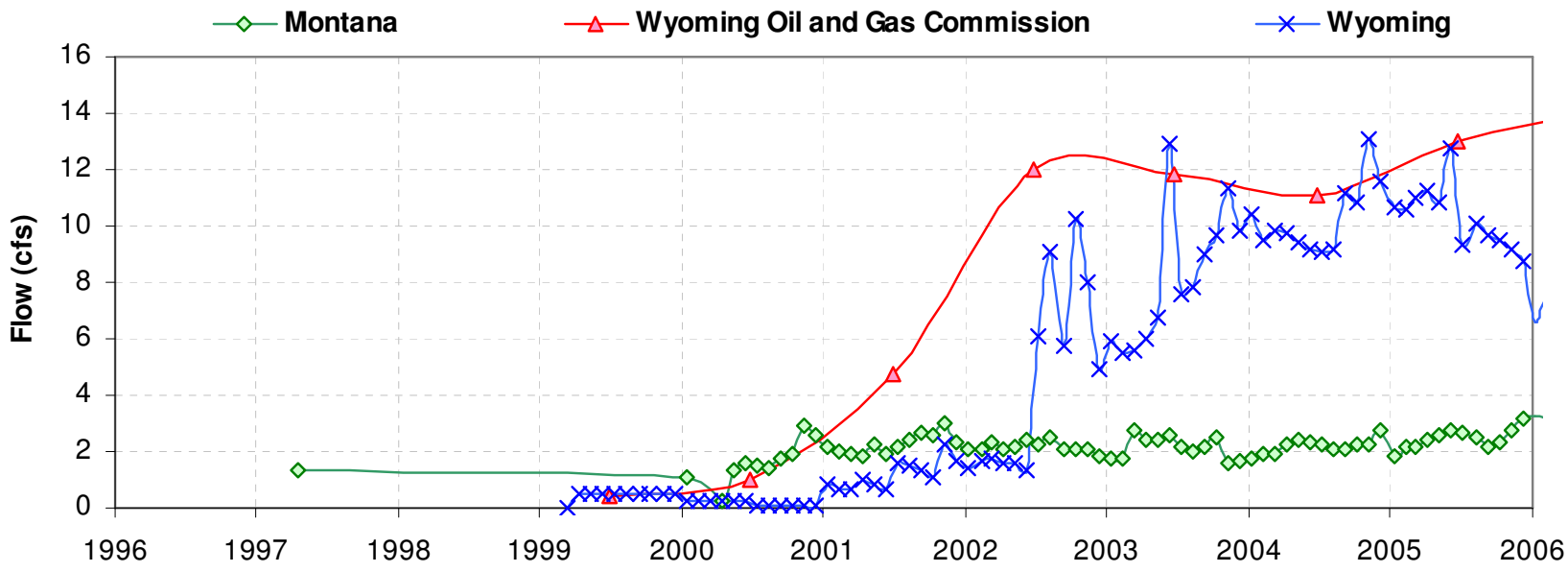
Summary of total monthly CBM discharge from Montana and Wyoming facilities (all available data from 1997-2006)



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The Following Scenarios have been Evaluated…

1. Proposed Draft Permit Limits (EC = 2440, SAR = 8.0)

a. Direct discharge of 5 cfs*
b. Direct discharge of 2.5 cfs
c. Direct discharge of 1.25 cfs

2. Measured Outfall Concentrations (EC = 1996, SAR = 33.8)

a. Direct discharge of 5 cfs
b. Direct discharge of 2.5 cfs
c. Direct discharge of 1.25 cfs

3. Montana Standard (EC = 500, SAR = 3.0)

a. Direct discharge of 5 cfs
b. Direct discharge of 2.5 cfs
c. Direct discharge of 1.25 cfs

*Direct discharge of the reported amount into both Badger and Hanging Woman Creeks

EC, SAR, Sodium, Calcium, and Magnesium Scenario Values

Parameter	Scenario 1 (Draft Permit Limits)	Scenario 2 (Avg Observed)[4]	Scenario 3 (MT Standards)
Calcium (mg/L)	79[1]	9	11.5[5]
Magnesium (mg/L)	79[1]	5	11.5[5]
Sodium (mg/L)	420[2]	493	60[5]
EC	2440[2]	1924	500[6]
SAR	8.0[1]	33.8	3.0[7]

[1]Calculated assuming NA = 420 and EC = 2440
[2]Reported limits in draft permit
[4]Average for the entire period of record from WY DMR data for CBM outfalls in the Hanging Woman and Badger Creek Watersheds
[5]Calculated based on EC = 500 and SAR = 3.0
[6]Montana average monthly and instantaneous maximum standard
[7]Montana growing season monthly average standard

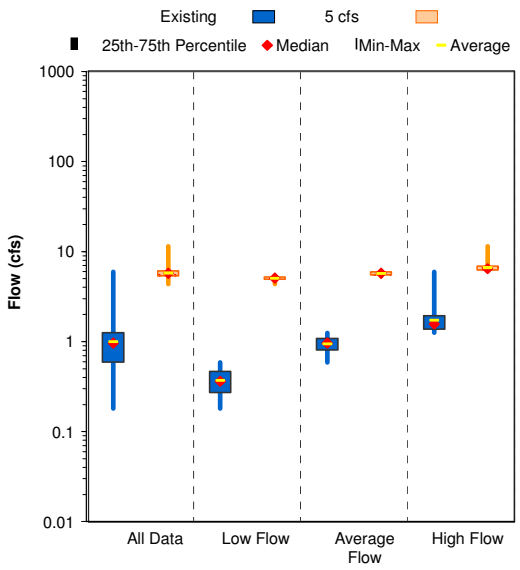
Scenario 1

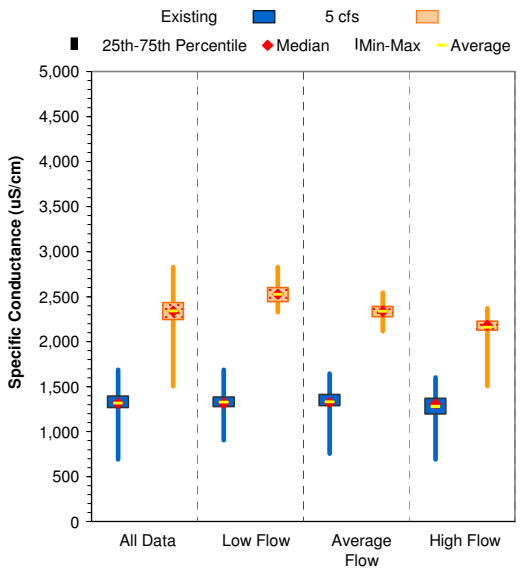
Proposed Draft Permit Limits (EC = 2440, SAR = 8.0)

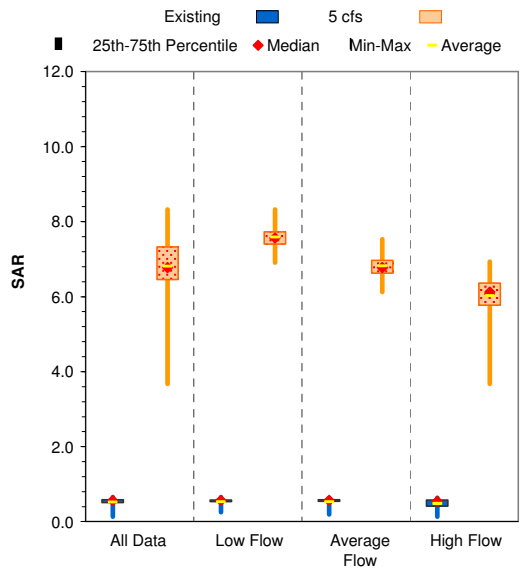
a. EC = 2440 with direct discharge of 5 cfs*
b. EC = 2440 with direct discharge of 2.5 cfs
c. EC = 2440 with direct discharge of 1.25 cfs

*Direct discharge of the reported amount into both Badger and Hanging Woman Creeks

Badger Creek Near Mouth
Scenario 1a
(EC = 2440, SAR = 8.0, 5 cfs)







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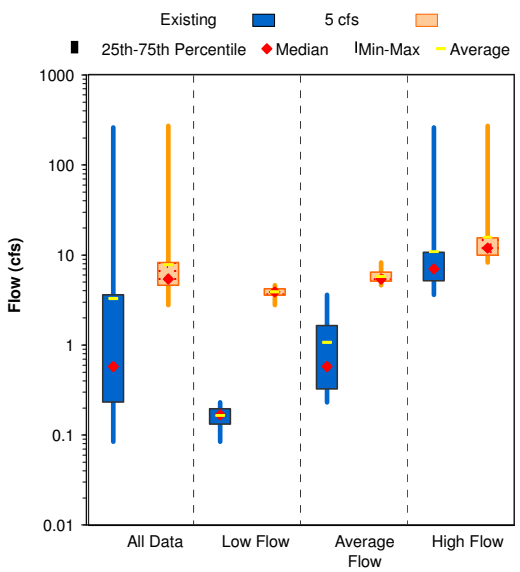
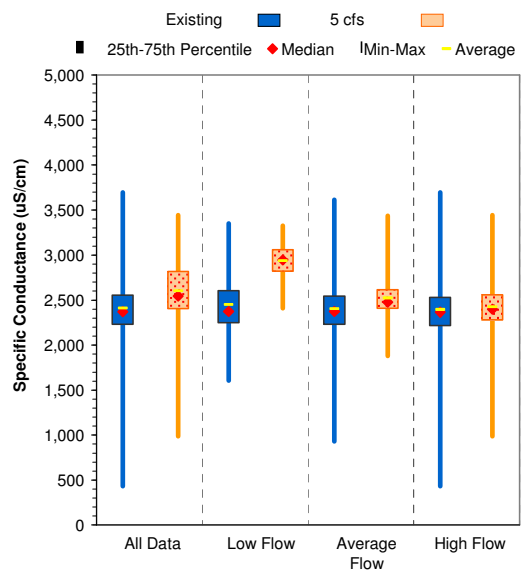
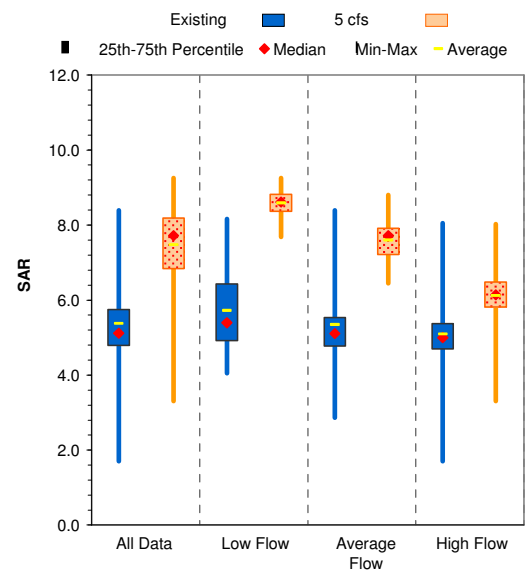
Hanging Woman Creek near Birney
Scenario 1a

(EC = 2440, SAR = 8.0, 5 cfs)







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Comparison of Scenario 1 to the Existing Condition Scenario

EC = 2440, SAR = 8.0	Badger Creek at Mouth	Hanging Woman Creek near Birney		Tongue River above TY Ditch	
Discharge Rate (cfs)	5	5	1.25	5	1.25
Mean EC	▲	▲	▲	▲	▲
Mean SAR	▲	▲	▲	▲	▲
Frequency of Exceedence of the average growing season EC Standard	—	—	—	▲	▲
Frequency of Exceedence of the average growing season SAR Standard	▲	▲	▲	—	—
Mean Flow	▲	▲	▲	—	—

▲ = Simulated relative increase

▼ = Simulated relative decrease

— **= Simulated no change**

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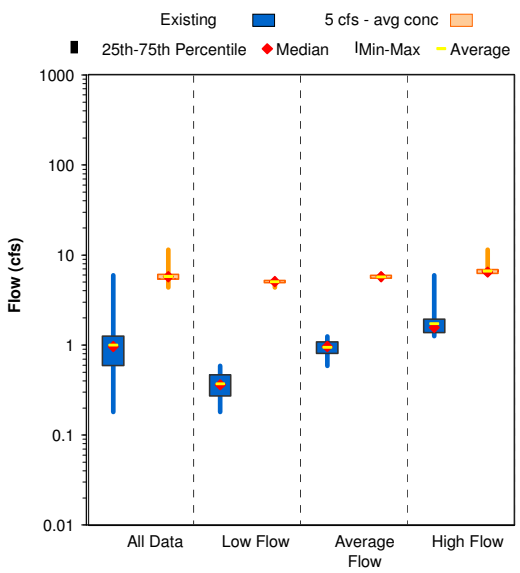
Scenario 2

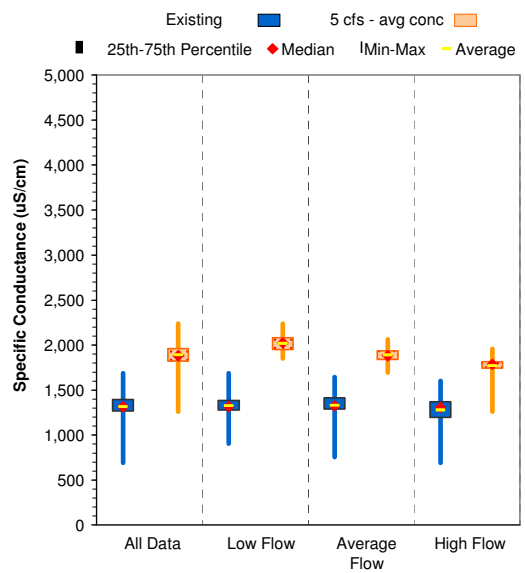
Measured Outfall Concentrations (EC = 1996, SAR = 33.8)

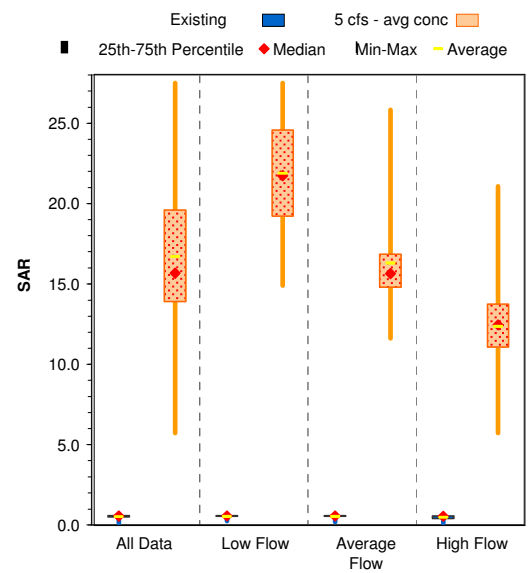
a. Direct discharge of 5 cfs*
b. Direct discharge of 2.5 cfs
c. Direct discharge of 1.25 cfs

*Direct discharge of the reported amount into both Badger and Hanging Woman Creeks

Badger Creek Near Mouth
Scenario 2a
(EC = 1996, SAR = 33.8, 5 cfs)







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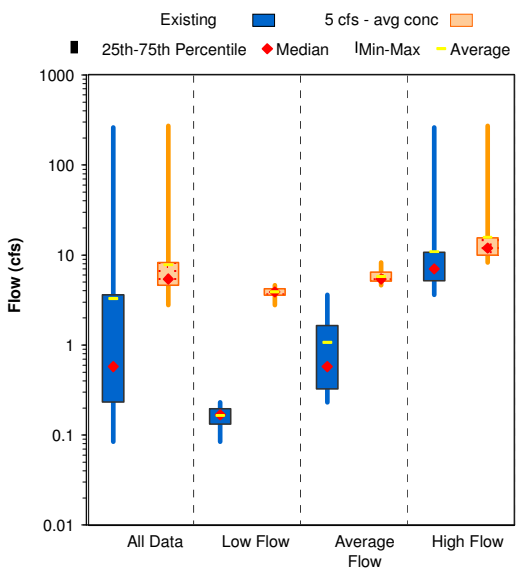
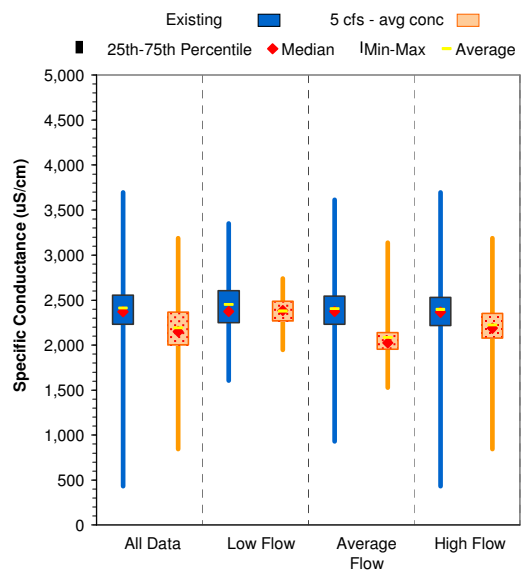
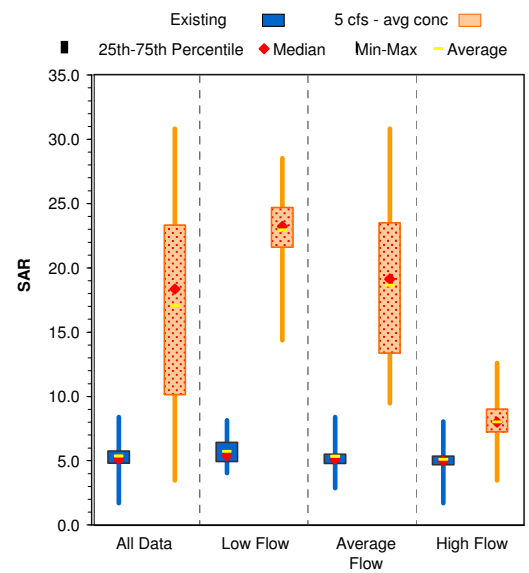
Hanging Woman Creek near Birney
Scenario 2a

(EC = 1996, SAR = 33.8, 5 cfs)







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Comparison of Scenario 2 to the Existing Condition Scenario

EC = 1996, SAR = 33.8	Badger Creek at Mouth	Hanging Woman Creek near Birney		Tongue River above TY Ditch	
Discharge Rate (cfs)	5	5	1.25	5	1.25
Mean EC	▲	▼	▼	▼	▼
Mean SAR	▲	▲	▲	▲	▲
Frequency of Exceedence of the average growing season EC Standard	—	—	—	▲	▲
Frequency of Exceedence of the average growing season SAR Standard	▲	▲	▲	▲	—
Mean Flow	▲	▲	▲	—	—

▲ = Simulated relative increase

▼ = Simulated relative decrease

— **= Simulated no change**

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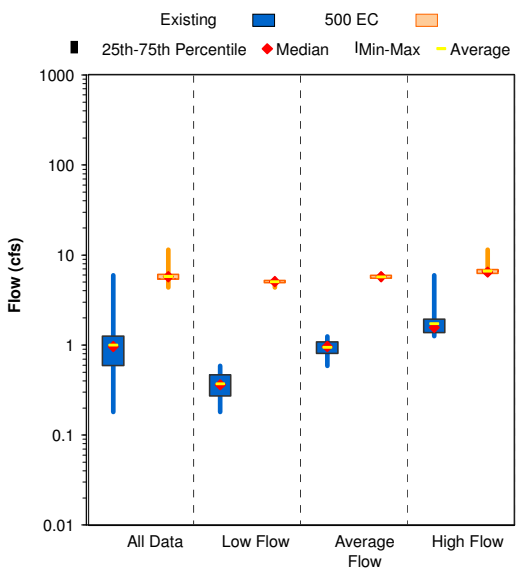
Scenario 3

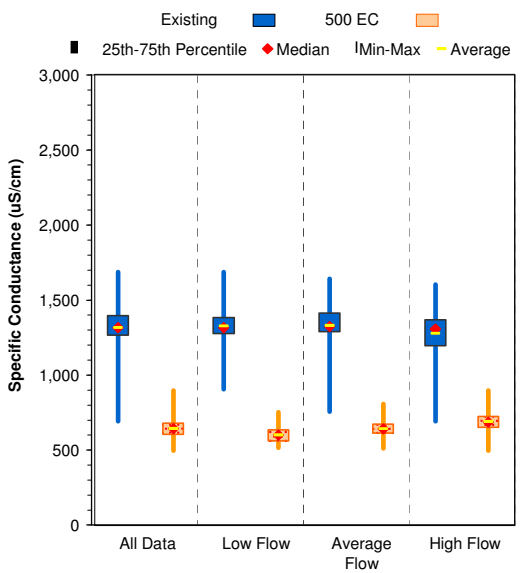
Montana Standard (EC = 500, SAR = 3.0)

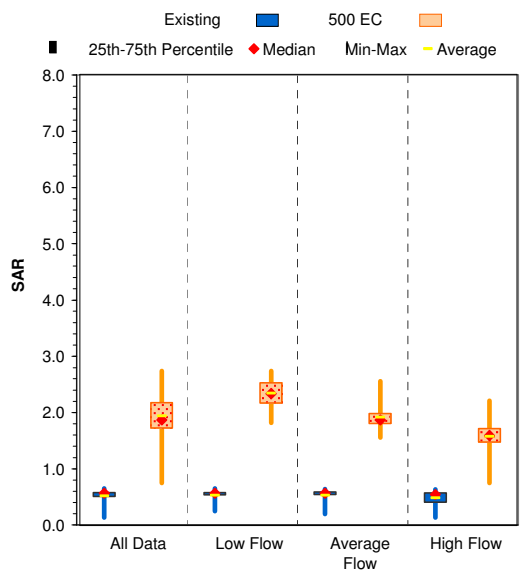
a. Direct discharge of 5 cfs*
b. Direct discharge of 2.5 cfs
c. Direct discharge of 1.25 cfs

*Direct discharge of the reported amount into both Badger and Hanging Woman Creeks

Badger Creek Near Mouth
Scenario 3a
(EC = 500, SAR = 3.0, 5 cfs)







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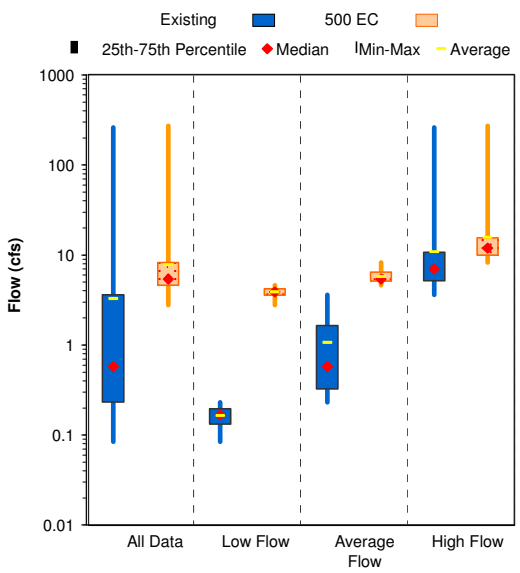
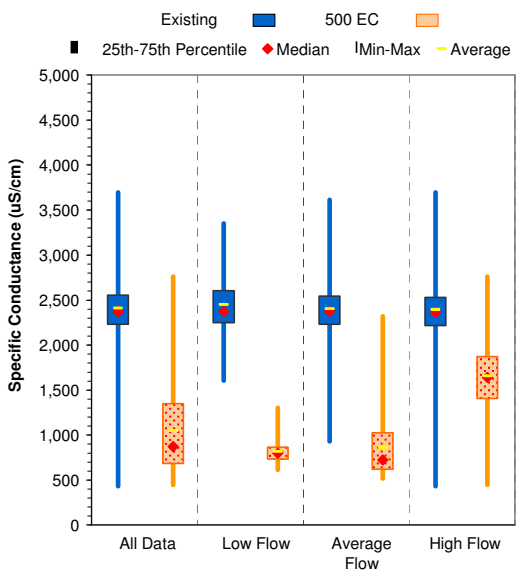
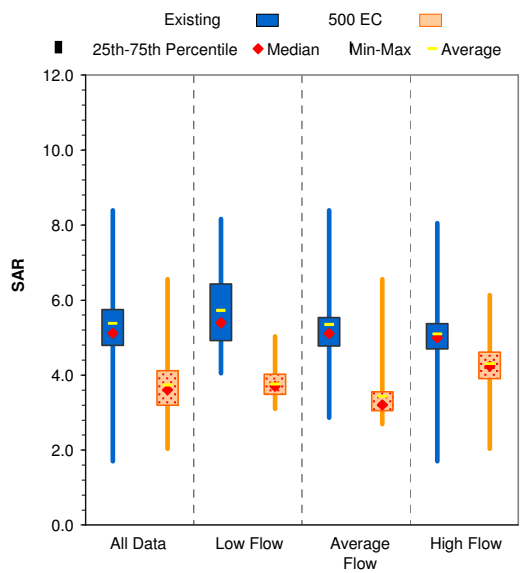
Hanging Woman Creek near Birney
Scenario 3a

(EC = 500, SAR = 3.0, 5 cfs)







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Comparison of Scenario 3 to the Existing Condition Scenario

EC = 500, SAR = 3.0	Badger Creek at Mouth	Hanging Woman Creek near Birney		Tongue River above TY Ditch	
Discharge Rate (cfs)	5	5	1.25	5	1.25
Mean EC	▲	▼	▼	▼	—
Mean SAR	▲	▼	▼	▼	—
Frequency of Exceedence of the average growing season EC Standard	▼	▼	—	—	—
Frequency of Exceedence of the average growing season SAR Standard	—	—	—	—	—
Mean Flow	▲	▲	▲	—	—

▲ = Simulated relative increase

▼ = Simulated relative decrease

— **= Simulated no change**

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What end-of-pipe effluent limits, what volumes, and during what months can discharge to Hanging Woman Creek and Badger Creek occur, and meet Montana's expectations?

Background

- Monthly average EC standards are already exceeded in the Tongue River at Birney and Miles City, and in Hanging Woman Creek.
- The nondegradation EC threshold is already exceeded ≥ 75% of the time in the Tongue River in Montana and most of the time in Hanging Woman Creek.
- During the growing season, the SAR nondegradation threshold is already exceeded between 25 and 50% of the time in the Tongue River in Montana.
- The average SAR standards are already exceeded in Hanging Woman Creek >71% of the time.
- There is insufficient monitoring data to characterize water quality and flow conditions in Badger Creek.

What end-of-pipe effluent limits, what volumes, and during what months can discharge to Hanging Woman Creek and Badger Creek occur, and meet Montana's expectations? (continued)

Questions

- Is the expectation that there are no exceedences of the EC and SAR standards?
- Or is the expectation that there are no further water quality degradation?

What end-of-pipe effluent limits, what volumes, and during what months can discharge to Hanging Woman Creek and Badger Creek occur, and meet Montana's expectations? (continued)

Assumptions

- For the purposes of this analysis, it is assumed that the goal is no further degradation and, based on discussions with Montana, no perennial flow where none exists today.
- The simulated "existing condition" scenario is the baseline used for comparison.

What end-of-pipe effluent limits, what volumes, and during what months can discharge to Hanging Woman Creek and Badger Creek occur, and meet Montana's expectations? (continued)

- Given the range of direct discharge scenarios evaluated
  - EC would need to be between 500 and 1900, and
  - SAR would need to be between 3.0 and 8.0.
  - This assumes direct discharge between 1.25 and 5 cfs to both Hanging Woman and Badger Creeks.
- However, model results suggest that discharge flows of as little as 1.25 cfs propagate flow into the Tongue River.
- It should be noted that there is insufficient data to characterize the relationship between surface and groundwaters in the beds of Hanging Woman and Badger Creeks. Therefore, model-based conclusions regarding perennial flow cannot be verified.