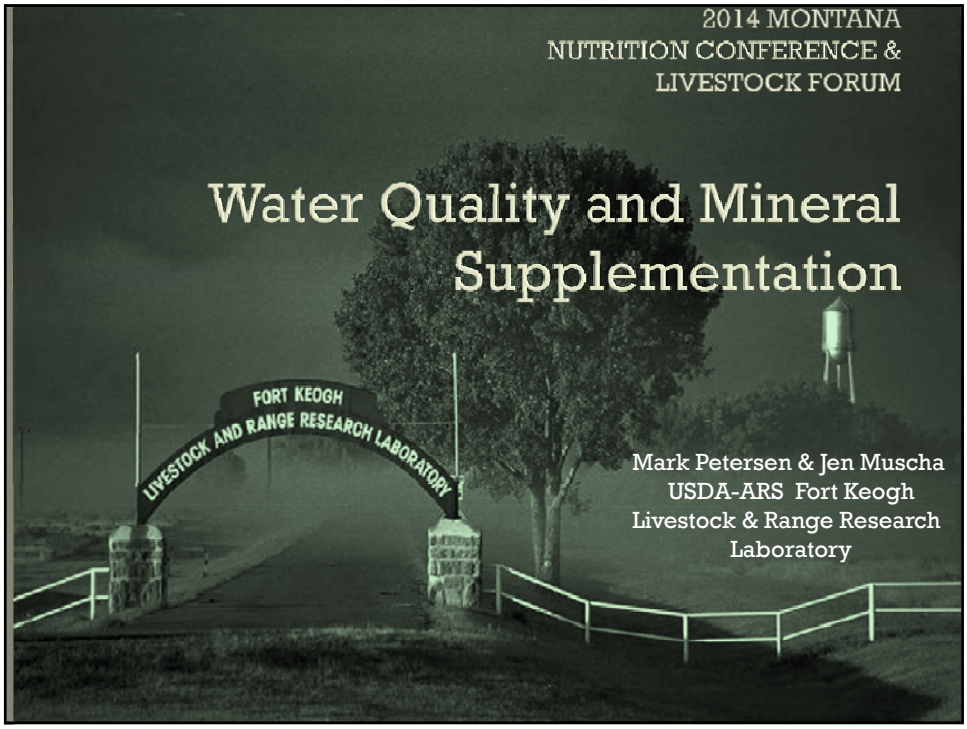


OUTLINE

- Background
  - Water quality
    - Winter water temperature important?
    - How much does water quality change?
  - Forage Mineral
    - Behavioral aspects of self –fed mineral intake
  - Forage+Water+Mineral
- Summary

IS WINTER STOCK WATER TEMPERATURE IMPORTANT?

- Another aspect of quality - Temperature
- Example problem;
  - 8 gallons of water at 35F to 98F
  - Requires 1,830,528 calories
  - Equal to 2.5 lbs corn or 5 lbs of grass hay or 7 lbs native dormant range to heat water

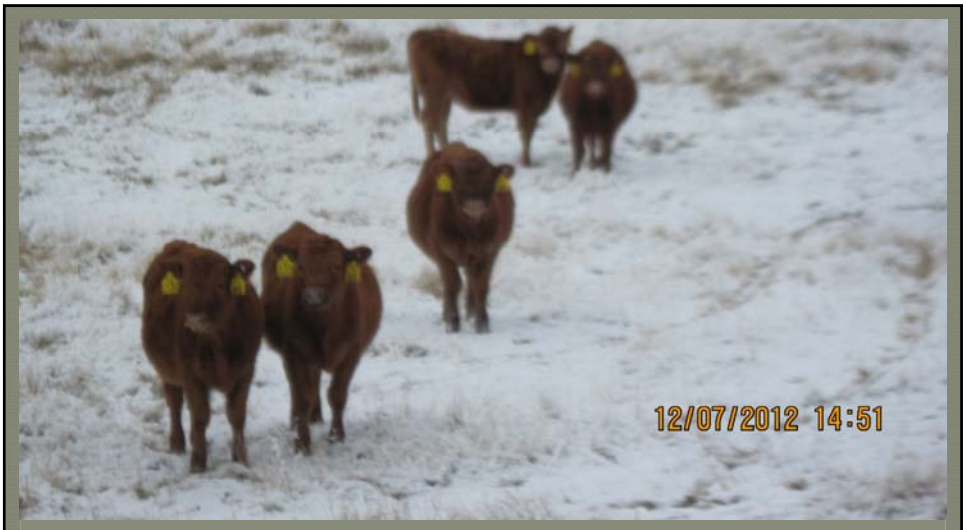
WINTER WARM WATER STUDY

- **Six paddocks**
  - 3 paddocks cold water 45°F
  - 3 paddocks hot water 90°F
    - outdoor tankless water heater
- **Water intake/paddock measured electronic meter**
- **Days were categorized as:**
  - Cold - < 15°F
  - Cool - 15°F to 27°F
  - Warm - > 27°F
- **Cameras at water source**
  - Individual drinkers, Time of day consumed water
  - Number of trips/day

ARTIFICIAL RUMEN & TEMPERATURE

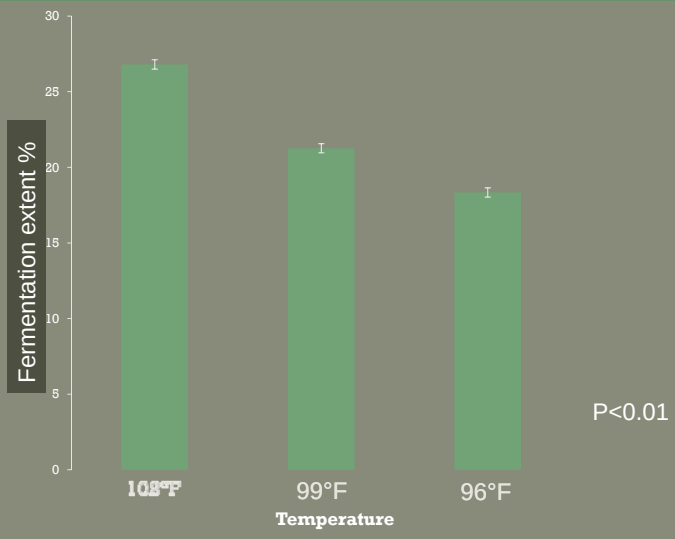
- Use cannulated cows
- Incubate winter diet samples
- 5 different temperatures
  - Body temperature 102°F
  - 99°F
  - 96°F
  - 93°F
  - 91°F

- Can rumen temperature impact digestibility?

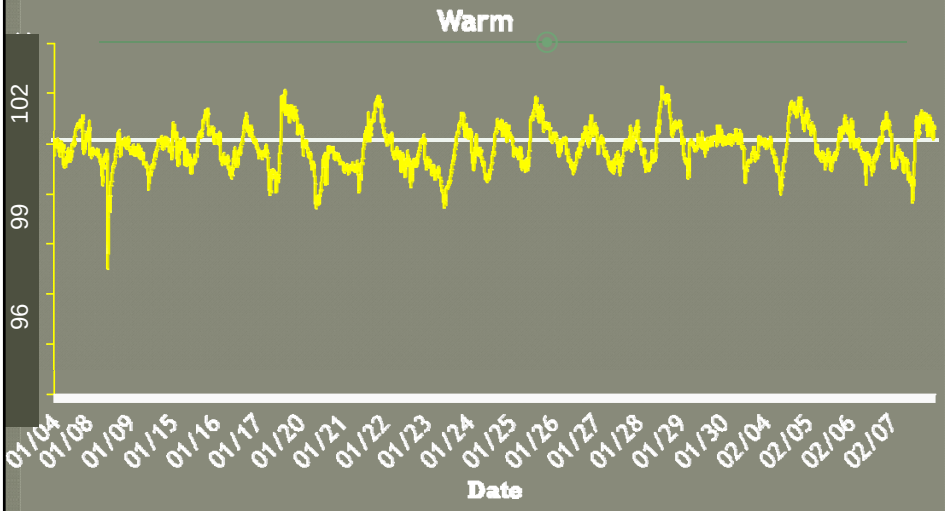


- How does rumen temperature change in Winter?

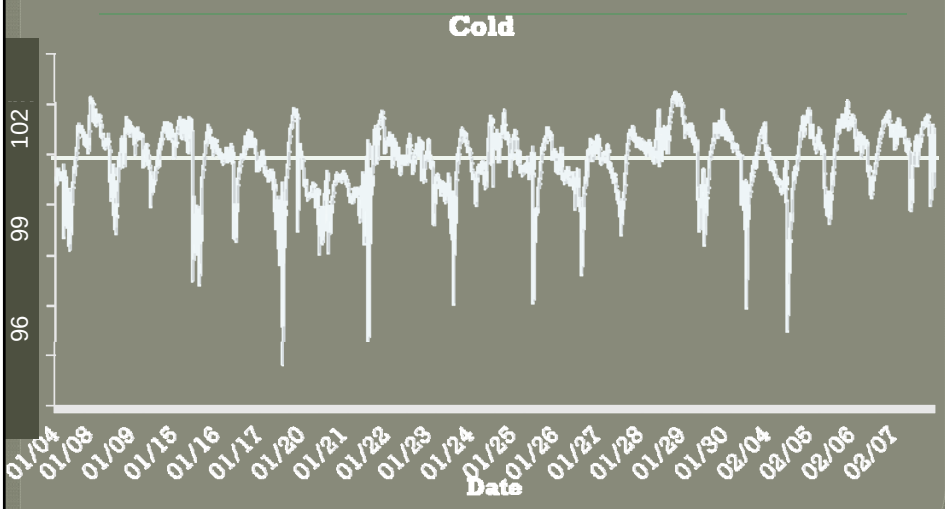
Extent of digestibility Artificial Rumen below body temperature



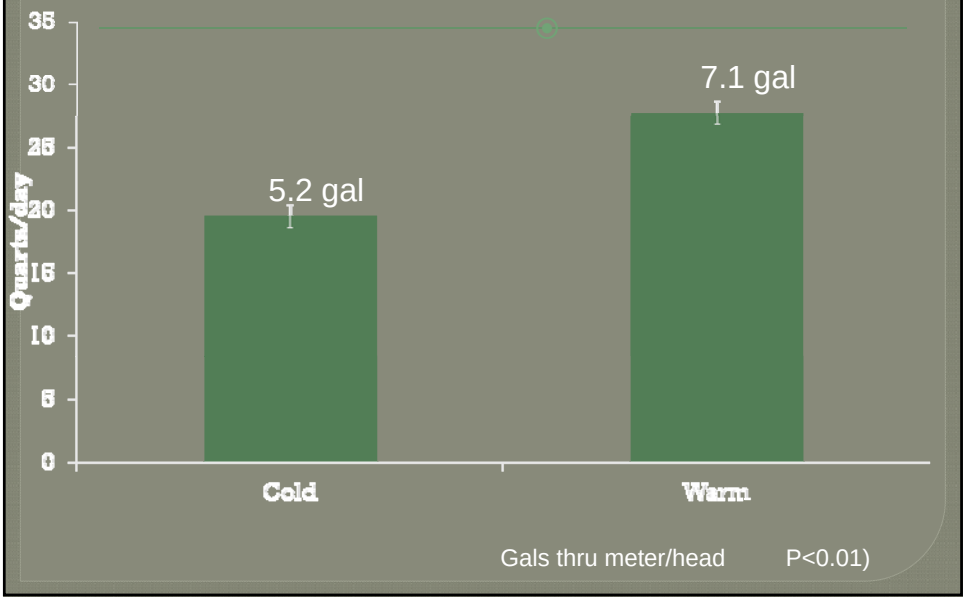
Range cow rumen temperature in winter



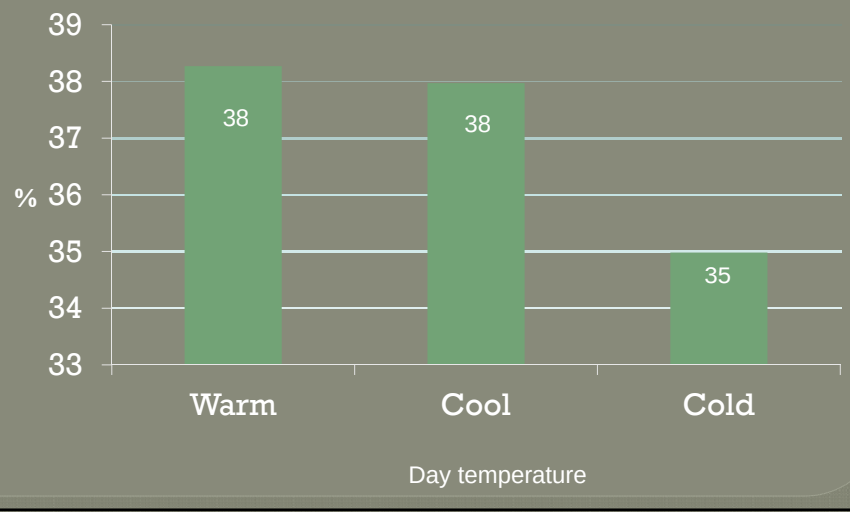
Range cow rumen temperature in winter



Cows drink 25% more warm water



35 % of cows do not drink each day



Water temperature & body weight change

- **Cold** or **warm** water cows lost less than 10 lbs

WINTER WATER TEMPERATURE SUMMARY

- Warm water in winter will promote greater water consumption
- Decrease in rumen temperature will reduce digestion rate
- Water is not consumed daily in winter
- Range cow winter weight loss was not affected by water temperature

Stock Water Quality; Does it change?

- Observations from Customer Focus Group
- May refuse or reduce intake of salt mineral mixes
- High salt content in different pastures?
- Reduce water consumption (TDS>3000ppm)
  - In turn reduces feed intake?
- Effects are magnified with higher temperatures?

Range Cattle Winter Water Consumption

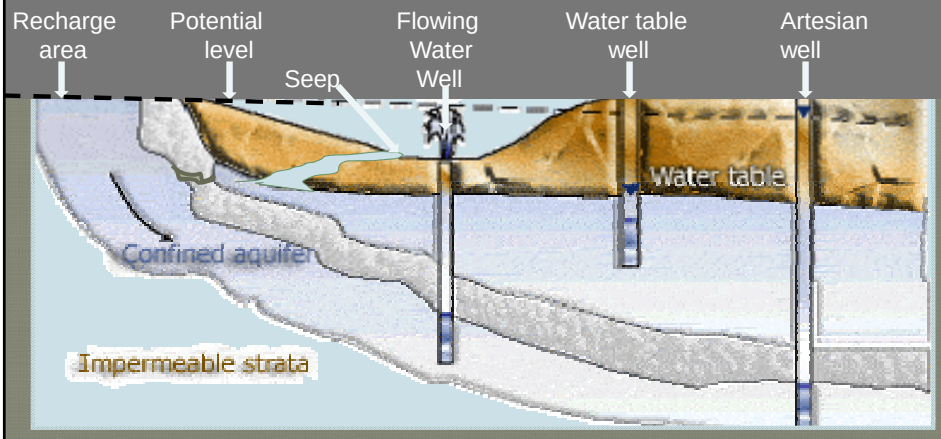
- Salinity
- Total dissolved solids (salts)
- Sum of sodium, chloride, carbonates, nitrates, sulfates, calcium, magnesium and potassium
- Primary analysis and easily commercially available
- High salt content – reduce performance

OUTLINE

- Results Fort Keogh 5 years evaluating;
  - Variability in water quality

BACKGROUND

- Water sources on Ft Keogh
  - Springs
  - Live water
  - Reservoirs
  - Ground
- Does quality differ source?
- Does quality change?



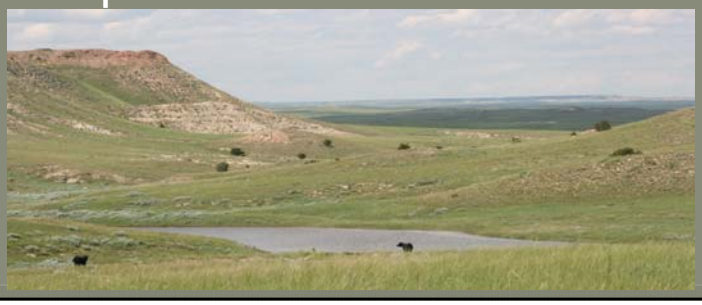
Ground water strata

WATER QUALITY

- Quality important variable
- Six characteristics
  - Odor & taste
  - Chemical properties
  - Toxic compounds
  - Excess minerals
  - Living organisms
  - Temperature

WATER QUALITY

- Concentrations of 300 parts per million (ppm) sodium upper safe limit
- At 800 ppm sodium may cause diarrhea & reduce performance



WATER QUALITY

- If 3000 or more ppm total dissolved solids
  - A sulfate analysis should probably be conducted
- Sulfates can be high in ground water
- Mature cattle are less susceptible to the effects of sulfates
  - Cause secondary deficiencies (copper, zinc, iron, manganese)

Web site- Water Quality interpetation

http://watercenter.montana.edu/

PROVISIONING STOCK WATER - Alberta

- Study design;
  - Pumped out of reservoir into tank
  - Or drank directly out of reservoir
- Results;
  - Gained better from water in tanks
  - 2 vs. 50 ppm suspended solids
  - Drank more

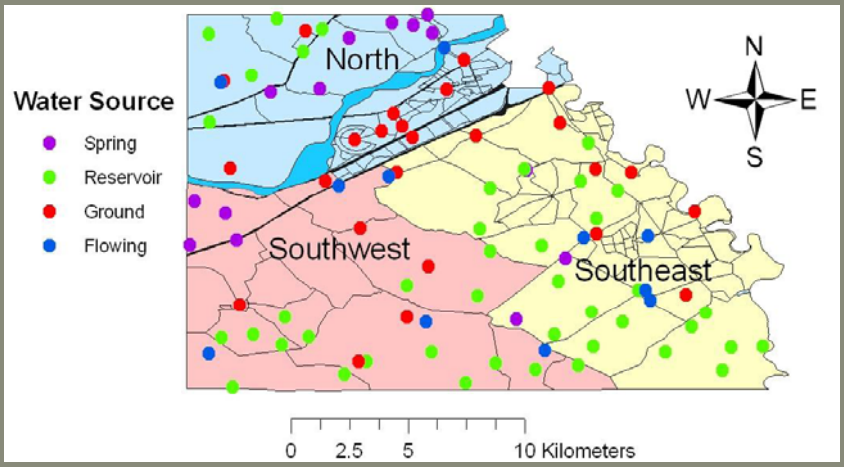
PROVISIONING STOCK WATER Alberta

- Conclusions
  - Cattle preferred 80% of the time water out of a trough (calves even higher %) compared to reservoir or stream

CURRENT WATER QUALITY RESEARCH–Ft Keogh LARRL

- Analysis includes;
  - Sodium, chloride, calcium, magnesium
  - Manganese, iron, fluoride
  - pH/ alkalinity
  - Nitrates, sulfates
  - Conductivity, total dissolved solids
  - Temperature

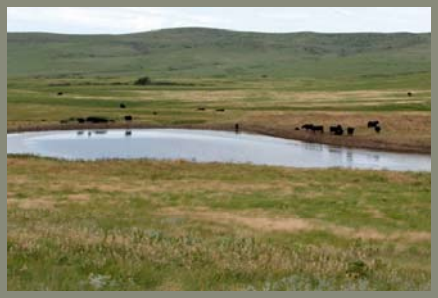
CURRENT WATER QUALITY RESEARCH–Ft Keogh LARRL



2009, 2010, 2011, 2012 and 2013

SAMPLE COLLECTIONS

- 450 possible samples could be collected
- Only 393 were collected
  - All May samples were collected with exception of 1
  - In September, 56 samples could not be collected (25% of sites dried up)



What are sources of variation?

How much does water quality change?

Summary Results for all Minerals

2009 to 2013

	Item	Number of samples Analyzed	Average Concentration ppm	Range of Concentration	% of Samples Exceeding Max Upper Level for Livestock	Maxiumum upper limit
	Calcium	393	47.5	0.51-912	2.5	200 ppm,
	Chloride	393	14.9	0-255	0	300
	Fluoride	393	1.1	0-8	18	*2
	Iron	393	15.9	0-1192	66	*0.4
	Magnesium	393	25.5	0.14-529	3	*100
	Manganese	393	0.3	0-19.8	11	*0.5
	Nitrate	393	0.29	0-26.7	0	*100
	pH	393	8.3	6.95-10.6	36	*8.5
	Sodium	393	281	5.72-3757	42	*300
	Sulfate	393	366	0-9591	37	*300
	TDS	393	939	83-9490	1.5	*3000
	Temperature	393	60° F	42-81° F		

What factors are associated with the lowest quality water?

Fluoride
Iron
Manganese
Sodium
Sulfate

Sodium

Item	Flowing	Ground	Reservoir	Spring		SE ±	mean	upper limit
N	257	444	125	26		50	213	*300
SE	239	443	181	438		63	325	
SW	586	410	220	118		49	333	
$\bar{X}$	360	432	175	194				
	2009	2010	2011	2012	2013			
wet	211	257	244	295	223	38	246	
dry	224	230	453	393	286	48	318	
N	178	252	222	205	168	47	205	
SE	233	262	341	438	322	53	319	
SW	241	216	482	389	273	46	320	
$\bar{X}$	217	243	348	344	254			
Flowing	161	255	593	405	205	66	332	
Ground	471	432	404	423	523	49	450	
Reservoir	97	112	201	282	101	55	158	
Spring	142	174	196	262	188	56	193	

Sodium

Item	Flowing	Ground	Reservoir	Spring		SE +	mean	upper limit
N	257	444	125	26		50	213	*300
SE	239	443	181	438		63	325	
SW	586	410	220	118		49	333	
$\overline{X}$	360	432	175	194				
	2009	2010	2011	2012	2013			
wet	211	257	244	295	223	38	246	
dry	224	230	453	393	286	48	318	
N	178	252	222	205	168	47	205	
SE	233	262	341	438	322	53	319	
SW	241	216	482	389	273	46	320	
$\overline{X}$	217	243	348	344	254			
Flowing	161	255	593	405	205	66	332	
Ground	471	432	404	423	523	49	450	
Reservoir	97	112	201	282	101	55	158	
Spring	142	174	196	262	188	56	193	

Sodium

Item	Flowing	Ground	Reservoir	Spring		SE +	mean	upper limit
N	257	444	125	26		50	213	*300
SE	239	443	181	438		63	325	
SW	586	410	220	118		49	333	
$\overline{X}$	360	432	175	194				
	2009	2010	2011	2012	2013			
wet	211	257	244	295	223	38	246	
dry	224	230	453	393	286	48	318	
N	178	252	222	205	168	47	205	
SE	233	262	341	438	322	53	319	
SW	241	216	482	389	273	46	320	
$\overline{X}$	217	243	348	344	254			
Flowing	161	255	593	405	205	66	332	
Ground	471	432	404	423	523	49	450	
Reservoir	97	112	201	282	101	55	158	
Spring	142	174	196	262	188	56	193	

Sodium

Item	Flowing	Ground	Reservoir	Spring		SE ±	mean	upper limit
N	257	444	125	26		50	213	*300
SE	239	443	181	438		63	325	
SW	586	410	220	118		49	333	
$\bar{X}$	360	432	175	194				
	2009	2010	2011	2012	2013			
wet	211	257	244	295	223	38	246	
dry	224	230	453	393	286	48	318	
N	178	252	222	205	168	47	205	
SE	233	262	341	438	322	53	319	
SW	241	216	482	389	273	46	320	
$\bar{X}$	217	243	348	344	254			
Flowing	161	255	593	405	205	66	332	
Ground	471	432	404	423	523	49	450	
Reservoir	97	112	201	282	101	55	158	
Spring	142	174	196	262	188	56	193	

Sodium

Item	Flowing	Ground	Reservoir	Spring		SE ±	mean	upper limit
N	257	444	125	26		50	213	*300
SE	239	443	181	438		63	325	
SW	586	410	220	118		49	333	
$\bar{X}$	360	432	175	194				
	2009	2010	2011	2012	2013			
wet	211	257	244	295	223	38	246	
dry	224	230	453	393	286	48	318	
N	178	252	222	205	168	47	205	
SE	233	262	341	438	322	53	319	
SW	241	216	482	389	273	46	320	
$\bar{X}$	217	243	348	344	254			
Flowing	161	255	593	405	205	66	332	
Ground	471	432	404	423	523	49	450	
Reservoir	97	112	201	282	101	55	158	
Spring	142	174	196	262	188	56	193	

Sulfate

Item	Flowing	Ground	Reservoir	Spring		SE +	mean	upper limit
N	407	454	153	45		117	264	*300
SE	179	517	287	701		147	421	
SW	1260	82	398	157		115	474	
$\bar{X}$	582	351	279	301				
	2009	2010	2011	2012	2013			
N	168	303	335	262	203	109	254	
SE	281	273	554	588	497	122	415	
SW	158	162	1005	555	308	107	468	
$\bar{X}$	206	246	631	468	336			
Flowing	144	326	1397	608	337	153	562	
Ground	392	319	322	370	518	113	384	
Reservoir	81	126	431	468	119	128	245	
Spring	192	213	377	427	371	130	316	

Sulfate

Item	Flowing	Ground	Reservoir	Spring		SE +	mean	upper limit
N	407	454	153	45		117	264	*300
SE	179	517	287	701		147	421	
SW	1260	82	398	157		115	474	
$\bar{X}$	582	351	279	301				
	2009	2010	2011	2012	2013			
N	168	303	335	262	203	109	254	
SE	281	273	554	588	497	122	415	
SW	158	162	1005	555	308	107	468	
$\bar{X}$	206	246	631	468	336			
Flowing	144	326	1397	608	337	153	562	
Ground	392	319	322	370	518	113	384	
Reservoir	81	126	431	468	119	128	245	
Spring	192	213	377	427	371	130	316	

Sulfate

Item	Flowing	Ground	Reservoir	Spring		SE +	mean	upper limit
N	407	454	153	45		117	264	*300
SE	179	517	287	701		147	421	
SW	1260	82	398	157		115	474	
$\bar{x}$	582	351	279	301				
	2009	2010	2011	2012	2013			
N	168	303	335	262	203	109	254	
SE	281	273	554	588	497	122	415	
SW	158	162	1005	555	308	107	468	
$\bar{x}$	206	246	631	468	336			
Flowing	144	326	1397	608	337	153	562	
Ground	392	319	322	370	518	113	384	
Reservoir	81	126	431	468	119	128	245	
Spring	192	213	377	427	371	130	316	

Sulfate

Item	Flowing	Ground	Reservoir	Spring		SE +	mean	upper limit
N	407	454	153	45		117	264	*300
SE	179	517	287	701		147	421	
SW	1260	82	398	157		115	474	
$\bar{x}$	582	351	279	301				
	2009	2010	2011	2012	2013			
N	168	303	335	262	203	109	254	
SE	281	273	554	588	497	122	415	
SW	158	162	1005	555	308	107	468	
$\bar{x}$	206	246	631	468	336			
Flowing	144	326	1397	608	337	153	562	
Ground	392	319	322	370	518	113	384	
Reservoir	81	126	431	468	119	128	245	
Spring	192	213	377	427	371	130	316	

Iron

Item	Flowing	Ground	Reservoir	Spring		SE +	mean	upper limit
N	29	3	0	0		19	8	*0.4
SE	45	1	5	17		23	17	
SW	146	3	11	0.2		18	40	
$\bar{X}$	73	2	5	6				
	2009	2010	2011	2012	2013			
Flowing	30	26	15	235	0	23	332	
Ground	0.4	1.0	5.0	3.0	5.0	17	450	
Reservoir	8	13	10	0	28	19	158	
Spring	1	3	12	6	11	20	193	
$\bar{X}$	10	11	10	61	11			

Iron

Item	Flowing	Ground	Reservoir	Spring		SE +	mean	upper limit
N	29	3	0	0		19	8	*0.4
SE	45	1	5	17		23	17	
SW	146	3	11	0.2		18	40	
$\bar{X}$	73	2	5	6				
	2009	2010	2011	2012	2013			
Flowing	30	26	15	235	0	23	332	
Ground	0.4	1.0	5.0	3.0	5.0	17	450	
Reservoir	8	13	10	0	28	19	158	
Spring	1	3	12	6	11	20	193	
$\bar{X}$	10	11	10	61	11			

Iron

Item	Flowing	Ground	Reservoir	Spring		SE +	mean	upper limit
N	29	3	0	0		19	8	*0.4
SE	45	1	5	17		23	17	
SW	146	3	11	0.2		18	40	
$\bar{X}$	73	2	5	6				
	2009	2010	2011	2012	2013			
Flowing	30	26	15	235	0	23	332	
Ground	0.4	1.0	5.0	3.0	5.0	17	450	
Reservoir	8	13	10	0	28	19	158	
Spring	1	3	12	6	11	20	193	
$\bar{X}$	10	11	10	61	11			

Iron

Item	Flowing	Ground	Reservoir	Spring		SE +	mean	upper limit
N	29	3	0	0		19	8	*0.4
SE	45	1	5	17		23	17	
SW	146	3	11	0.2		18	40	
$\bar{X}$	73	2	5	6				
	2009	2010	2011	2012	2013			
Flowing	30	26	15	235	0	23	332	
Ground	0.4	1.0	5.0	3.0	5.0	17	450	
Reservoir	8	13	10	0	28	19	158	
Spring	1	3	12	6	11	20	193	
$\bar{X}$	10	11	10	61	11			

Iron

Item	Flowing	Ground	Reservoir	Spring		SE +	mean	upper limit
N	29	3	0	0		19	8	*0.4
SE	45	1	5	17		23	17	
SW	146	3	11	0.2		18	40	
$\overline{X}$	73	2	5	6				
	2009	2010	2011	2012	2013			
Flowing	30	26	15	235	0	23	332	
Ground	0.4	1.0	5.0	3.0	5.0	17	450	
Reservoir	8	13	10	0	28	19	158	
Spring	1	3	12	6	11	20	193	
$\overline{X}$	10	11	10	61	11			

Iron

Item	Flowing	Ground	Reservoir	Spring		SE +	mean	upper limit
N	29	3	0	0		19	8	*0.4
SE	45	1	5	17		23	17	
SW	146	3	11	0.2		18	40	
$\overline{X}$	73	2	5	6				
	2009	2010	2011	2012	2013			
Flowing	30	26	15	235	0	23	332	
Ground	0.4	1.0	5.0	3.0	5.0	17	450	
Reservoir	8	13	10	0	28	19	158	
Spring	1	3	12	6	11	20	193	
$\overline{X}$	10	11	10	61	11			

Iron

Item	Flowing	Ground	Reservoir	Spring		SE +	mean	upper limit
N	29	3	0	0		19	8	*0.4
SE	45	1	5	17		23	17	
SW	146	3	11	0.2		18	40	
$\overline{X}$	73	2	5	6				
	2009	2010	2011	2012	2013			
Flowing	30	26	15	235	0	23	332	
Ground	0.4	1.0	5.0	3.0	5.0	17	450	
Reservoir	8	13	10	0	28	19	158	
Spring	1	3	12	6	11	20	193	
$\overline{X}$	10	11	10	61	11			

Iron

Item	Flowing	Ground	Reservoir	Spring		SE +	mean	upper limit
N	29	3	0	0		19	8	*0.4
SE	45	1	5	17		23	17	
SW	146	3	11	0.2		18	40	
$\overline{X}$	73	2	5	6				
	2009	2010	2011	2012	2013			
Flowing	30	26	15	235	0	23	55	
Ground	0.4	1.0	5.0	3.0	5.0	17	3	
Reservoir	8	13	10	0	28	19	11	
Spring	1	3	12	6	11	20	6	
$\overline{X}$	10	11	10	61	11			

TDS

Item	Flowing	Ground	Reservoir	Spring		SE ±	mean	upper limit
N	879	1362	450	331		129	756	*3000
SE	800	1385	662	1449		162	1074	
SW	1766	1126	759	654		127	1076	
$\bar{X}$	1148	1291	623	811				
	2009	2010	2011	2012	2013			
wet	696	809	884	1003	795	102	837	
dry	774	753	1478	1304	995	124	1060	
N	635	811	815	776	669	124	741	
SE	811	844	1125	1440	1084	139	1060	
SW	758	689	1603	1245	932	121	1045	
$\bar{X}$	734	781	1181	1153	895			
Flowing	579	780	1867	1286	789	174	1061	
Ground	1370	1236	1256	1301	1555	129	1346	
Reservoir	344	392	746	998	357	145	567	
Spring	647	717	854	1030	879	148	825	

TDS

Item	Flowing	Ground	Reservoir	Spring		SE ±	mean	upper limit
N	879	1362	450	331		129	756	*3000
SE	800	1385	662	1449		162	1074	
SW	1766	1126	759	654		127	1076	
$\bar{X}$	1148	1291	623	811				
	2009	2010	2011	2012	2013			
wet	696	809	884	1003	795	102	837	
dry	774	753	1478	1304	995	124	1060	
N	635	811	815	776	669	124	741	
SE	811	844	1125	1440	1084	139	1060	
SW	758	689	1603	1245	932	121	1045	
$\bar{X}$	734	781	1181	1153	895			
Flowing	579	780	1867	1286	789	174	1061	
Ground	1370	1236	1256	1301	1555	129	1346	
Reservoir	344	392	746	998	357	145	567	
Spring	647	717	854	1030	879	148	825	

TDS

Item	Flowing	Ground	Reservoir	Spring		SE ±	mean	upper limit
N	879	1362	450	331		129	756	*3000
SE	800	1385	662	1449		162	1074	
SW	1766	1126	759	654		127	1076	
$\overline{X}$	1148	1291	623	811				
	2009	2010	2011	2012	2013			
wet	696	809	884	1003	795	102	837	
dry	774	753	1478	1304	995	124	1060	
N	635	811	815	776	669	124	741	
SE	811	844	1125	1440	1084	139	1060	
SW	758	689	1603	1245	932	121	1045	
$\overline{X}$	734	781	1181	1153	895			
Flowing	579	780	1867	1286	789	174	1061	
Ground	1370	1236	1256	1301	1555	129	1346	
Reservoir	344	392	746	998	357	145	567	
Spring	647	717	854	1030	879	148	825	

TDS

Item	Flowing	Ground	Reservoir	Spring		SE ±	mean	upper limit
N	879	1362	450	331		129	756	*3000
SE	800	1385	662	1449		162	1074	
SW	1766	1126	759	654		127	1076	
$\overline{X}$	1148	1291	623	811				
	2009	2010	2011	2012	2013			
wet	696	809	884	1003	795	102	837	
dry	774	753	1478	1304	995	124	1060	
N	635	811	815	776	669	124	741	
SE	811	844	1125	1440	1084	139	1060	
SW	758	689	1603	1245	932	121	1045	
$\overline{X}$	734	781	1181	1153	895			
Flowing	579	780	1867	1286	789	174	1061	
Ground	1370	1236	1256	1301	1555	129	1346	
Reservoir	344	392	746	998	357	145	567	
Spring	647	717	854	1030	879	148	825	

Portable TDS Meter

$285

20,000 ppm TDS

Does drier warmer years change water quality?

Drier warmer years reduce quality

Especially surface flowing water and in the south

PREDICTING MINERAL INTAKE FROM WATER

PREDICTING MINERAL INTAKE FROM WATER

Item	Water analysis	Amt supplied in water
Calcium	1.04 ppm	0.045 g/d
Chloride	14 ppm	0.604 g/d
Fluoride	3.3 ppm	142.4 mg/d
Iron	0.04 ppm	1.726 mg/d
Magnesium	0.29 ppm	0.013 g/d
Sodium	365.0 ppm	15.75 g/d
Sulfur	45.29 ppm	1.95 g/d

28 g = 1 oz

PREDICTING MINERAL INTAKE FROM WATER & DIET

Item	Minerals Diet	water & diet	Required intake
calcium	0.48 %	0.484 %	0.36 %
Chloride	14 ppm	0.06 %	?
Fluoride		142 ppm	? **(hi)**
Iron	1,378 ppm	**1,379 ppm**	**50 ppm (hi)**
Magnesium	0.17 %	0.171 %	0.20 % (lo)
Sodium	0.032 %	**1.61 %**	**0.1 % (hi)**
Sulfur	0.17 %	**0.365 %**	**0.15 % (hi)**
Copper	3.0 ppm	3.0 ppm	10 ppm (lo)
Manganese	83.0 ppm	83.0 ppm	40 ppm
Phosphorus	0.18%	0.18%	0.23 % (lo)
Potassium	1.30 %	1.31 %	0.70 %
Selenium	0.13 ppm	0.13 ppm	0.1 ppm
Zinc	21.O ppm	21.0 ppm	30 ppm (lo)

PREDICTING MINERAL INTAKE FROM WATER & DIET

Item	Minerals Diet	water & diet	Required
calcium	0.48 %	0.484 %	0.36 %
Chloride	14 ppm	0.06 %	?
Fluoride		142 ppm	?
Iron	1,378 ppm	1,379 ppm	50 ppm (hi)
Magnesium	0.17 %	**0.171 %**	**0.20 % (lo)**
Sodium	0.032 %	1.61 %	0.1 % (hi)
Sulfur	0.17 %	0.365 %	0.15 % (hi)
Copper	3.0 ppm	**3.0 ppm**	**10 ppm (lo)**
Manganese	83.0 ppm	83.0 ppm	40 ppm
Phosphorus	0.18%	**0.18%**	**0.23 % (lo)**
Potassium	1.30 %	1.31 %	0.70 %
Selenium	0.13 ppm	0.13 ppm	0.1 ppm
Zinc	21.O ppm	**21.0 ppm**	**30 ppm (lo)**

Mineral intake evaluation

- Excess
  - Sodium
  - Sulfate
  - Iron
  - Fluoride
- Deficient
  - Magnesium
  - Phosphorus
  - Copper
  - Zinc

Implications

- Need to know water quality
- Multiple water sites pasture
- During drought forced to drink poorer water
  - At Ft Keogh use North in summer drought
- Use known poor water pasture in winter
  - Use southeast in winter
- Early spring may dilute poor water

Implication

- May result in reduced mineral intake
- Water quality is highly variable
  - Source
  - Location
  - Season
  - Year
- Especially in a dry year check TDS before cattle are moved to a fresh pasture.

Variability in range cow mineral consumption

Variability in range cow mineral use

- Factors influencing voluntary loose mineral consumption – speculated
  - season of the year
  - water salinity
  - daily temperature
  - salt bush frequency
  - forage maturity
  - vegetation dry matter content

Variability in range cow mineral use

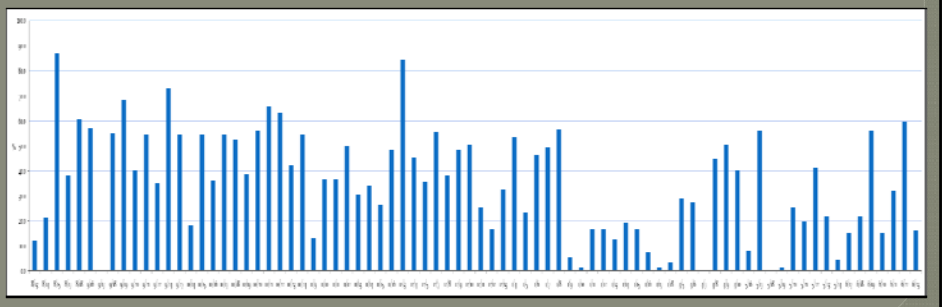
- To evaluate variation in herd mineral intake, individual cow mineral tub use due season and daily high temperature
- 80 mixed-age native English cross-bred cows, access to open range mineral tub (containing 34% salt, 57% minerals and 9% distillers grain)
- Cows rotationally grazed native range. Data not collected in Feb & Mar.
- Bushnell Trophy Cam XLT motion activated trail cameras recorded daily appearance.

Mineral Studies completed or in progress

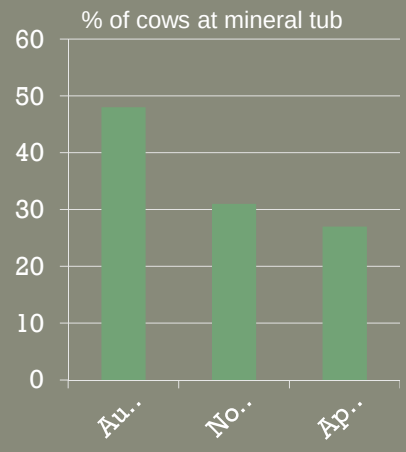
- Magnitude of variability in mineral consumption
- Productivity influences due to mineral consumption

Magnitude of variability in mineral consumption

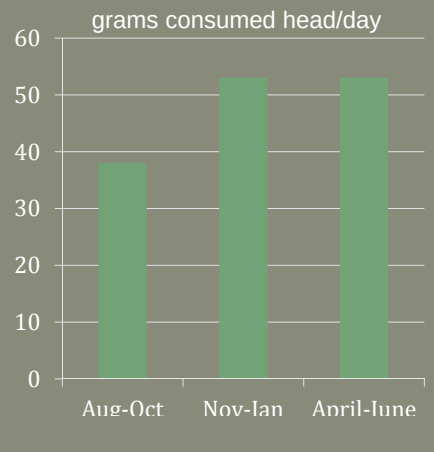
Percent of cows at mineral tub daily throughout study from August 2010-June 2011



Magnitude of variability in mineral consumption



Percent of cows at mineral tub daily by growing season (P<0.01) .



Average mineral daily consumption by growing season (P<0.01).

Variability is large

- Supply mineral to "fix" known deficiencies
- Intake is not predictable
- Our next step add titanium

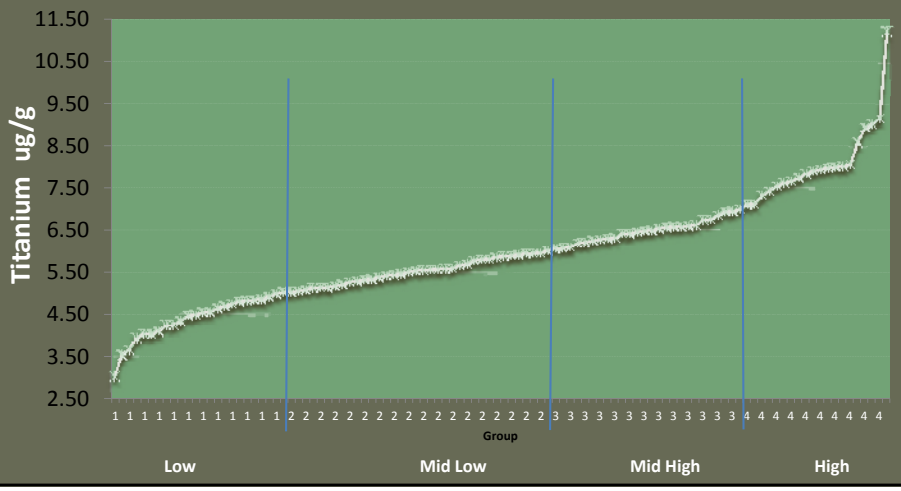
Productivity influences due to mineral consumption

- Why titanium?
- Not in environment
- Marker for intake
- Collected 1,400 fecal samples

Productivity influences due to mineral consumption

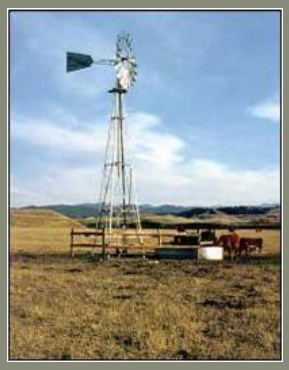
- Rank cows by Ti concentration
- Assumption ;
  - Higher Ti consume more
- Evaluate Ti
  - on calving interval in days
  - Weaning weight
  - Cow wt change weaning to weaning

Distribution of Ti Fecal concentration



Water variability

- Leading conclusion
  - Need to test
  - Portable TDS meter
- Need to develop methods to improve stock water quality



Combined effects; Water, forage & mineral

- Water sample collection
- Plucked forage samples
- Mineral analysis
- Calculated diet composition

Summary

- Mineral research program
  - Water quality
  - Forages
  - Self fed mineral