Environmental Quality Council
Proposed Chapter 1, Appendix H Rule

Kevin Harvey Testimony to the EQC on October 28, 2008

KC HARVEY
Soil & Water Resource Consulting

AN ENERCREST COMPANY

Overview

- My Background
- Soil and Water Chemistry Overview
- Comments on Appendix H

Who am I?

- President of KC Harvey, Inc.
- EVP/Chief Scientist of EnerCrest, Inc.
- M.S. Land Rehabilitation, B.S. Resource Conservation
- National Board Certification in Soil Science
- 28 years worldwide experience
- 10 years CBM experience – CO, MT, WY
- 100s of CBM water management projects
- Performed multiple Section 20 analyses
- Invited by DEQ to participate on Section 20 committee

Who am I?

- I am an Applied Scientist
- What is an applied scientist and what do they do?



Zimmatic


SOIL AND WATER CHEMISTRY REVIEW

Irrigation Water Suitability

- **Excessive salinity (EC) in irrigation water can impact crop growth.**
  - ✓ Excessive salt in soil make it harder for plants to pull water out of soil
- **Excessive sodicity (SAR) in irrigation water can impact soil structure and infiltration / permeability.**
  - ✓ The higher the salt content of the irrigation water or soil, the less impact from SAR

Salinity and Sodicity

- **Effects seen long term (chronic exposure)**
- **Occasional contact:**
  - ✓ No measurable change to soil infiltration
  - ✓ No measurable change to plant production

COMMENTS ON APPENDIX H

General Comments

- Relationships among salinity, sodicity, water, soil, and plants are dynamic
- Comments focused on CBNG development in the PRB
- Flexibility is important
  - ✓ Use for increasing production
  - ✓ Evolving opportunities for use of water
- Proposed rule is conservative and protective

Tier 1 EC Limits Are Conservative

- **100% California yield assumption**
- **Wyoming conditions overshadow effects of water salinity:**
  - ✓ Cold climate and short growing season,
  - ✓ Low precipitation,
  - ✓ Low soil fertility,
  - ✓ Thinly developed soils with low moisture holding capacity,
  - ✓ Different agricultural practices than California.
- **Applying pure irrigation water will not overcome Wyoming limitations & achieve California yield**

Tier 1 EC Limits Are Conservative

- **USDA Salt Tolerance Database (CA)**
  - ✓ Ideal CA growing conditions - different soil chemistry than WY
  - ✓ CA-based 100% yield threshold for alfalfa of 2 dS/m in soil equates to a 1.3 dS/m (1,333 umhos/cm) in water
- **USDA Plant Materials Center at Bridger, Montana**
  - ✓ Yield thresholds based on research and experience in MT, WY, and Western Canada
  - ✓ Saskatchewan field studies indicated no significant difference in yields in soils with EC of 4 dS/m or 8 dS/m (4000 umhos/cm or 8000 umhos/cm)
  - ✓ The USDA Bridger Plant Materials Center selected a soil EC 100% yield tolerance level of 4 dS/m for alfalfa. This equates to a 2.7 dS/m effluent limit for EC

Tier 1 SAR Cap is Conservative

- **SAR in water used to predict SAR of soil in equilibrium with water**
  - ✓ SAR measurement meant to estimate exchangeable sodium percentage (ESP) measurement of the soil
  - ✓ Swelling type clay minerals will begin to swell at ESP of 15
- **Handbook 60 (1954) says SAR of 12 approximates a soil ESP of 15**
  - ✓ Based on analysis of 59 soil samples throughout western U.S.
- **PRB data indicate SAR cap of 16 would be safe**
  - ✓ Based on analysis of 382 soil samples from PRB indicate SAR over predicts ESP

2006 Suarez SAR Infiltration Study

- **Results not applicable to Wyoming**
- **Soil used not representative of Tongue River soil clay content**
- **Soil structure destroyed during sample collection/preparation**
  - ✓ Loss of soil structure and porosity will certainly lead to decreased infiltration rates
- **Amount & rate of water applied not reflective of conditions**
  - ✓ Intensity of test was1000 times greater than average thunderstorm event in Montana and Wyoming
  - ✓ Raindrop impact at this intensity and frequency will seal soil
- **No statistically significant difference in alfalfa yield regardless of SAR**

Tier 2 – Scenarios

- There is no Tier 2 comparison between managed irrigation with CBNG water and WYPDES discharge scenarios
- The managed irrigation scenarios described by Vance do not fall under Tier 2 process or a WYPDES permit.
- Tier 2 process is meant to derive conservative limits for unmanaged irrigation after discharge to channel
- Unmanaged application of CBNG water may occur during large storm events when water is diluted by natural runoff

Tier 2 – The Process

1. Determine that artificially or natural irrigation occurs downstream of proposed discharge
2. Sample soils from irrigated fields to determine average root zone EC
3. DEQ applies additional margin of safety to the average root zone EC of field(s)
4. Divide adjusted average root zone EC by the 1.5 concentration factor to estimate long-term water EC applied to field and establish EOP limit for EC
5. Apply Hanson equation at IMP to monitor SAR

Tier 2 – Composite Sampling

- Composite soil sampling is an accepted strategy by the WDEQ, U.S. EPA and scientists worldwide
- Describing and sampling soil profiles in pits is subject to extreme variation between field scientists
- Systematic compositing increases sample precision and allows for comparison between fields
- Landowners do not want soil pits! Less impact with Giddings soil coring
- This sampling approach was agreed to by all parties during initial drafting of Policy and has not been an issue during three years of public comment

Tier 2 – Root Zone or Surface?

- Plants that receive infrequent irrigation or rainfall depend on the entire root zone (Ayers and Westcot, 1985)
- Roots in the PRB typically exhibit depths greater than five feet
- Plants that receive frequent irrigation depend more on the surface soil (Ayers and Westcot, 1985)
- Surface soil EC fluctuates and is not a reliable long-term measurement of soil EC
- We must consider the entire root zone


Top half of soil profile
Bottom half of soil profile

Tier 2 – Real Data

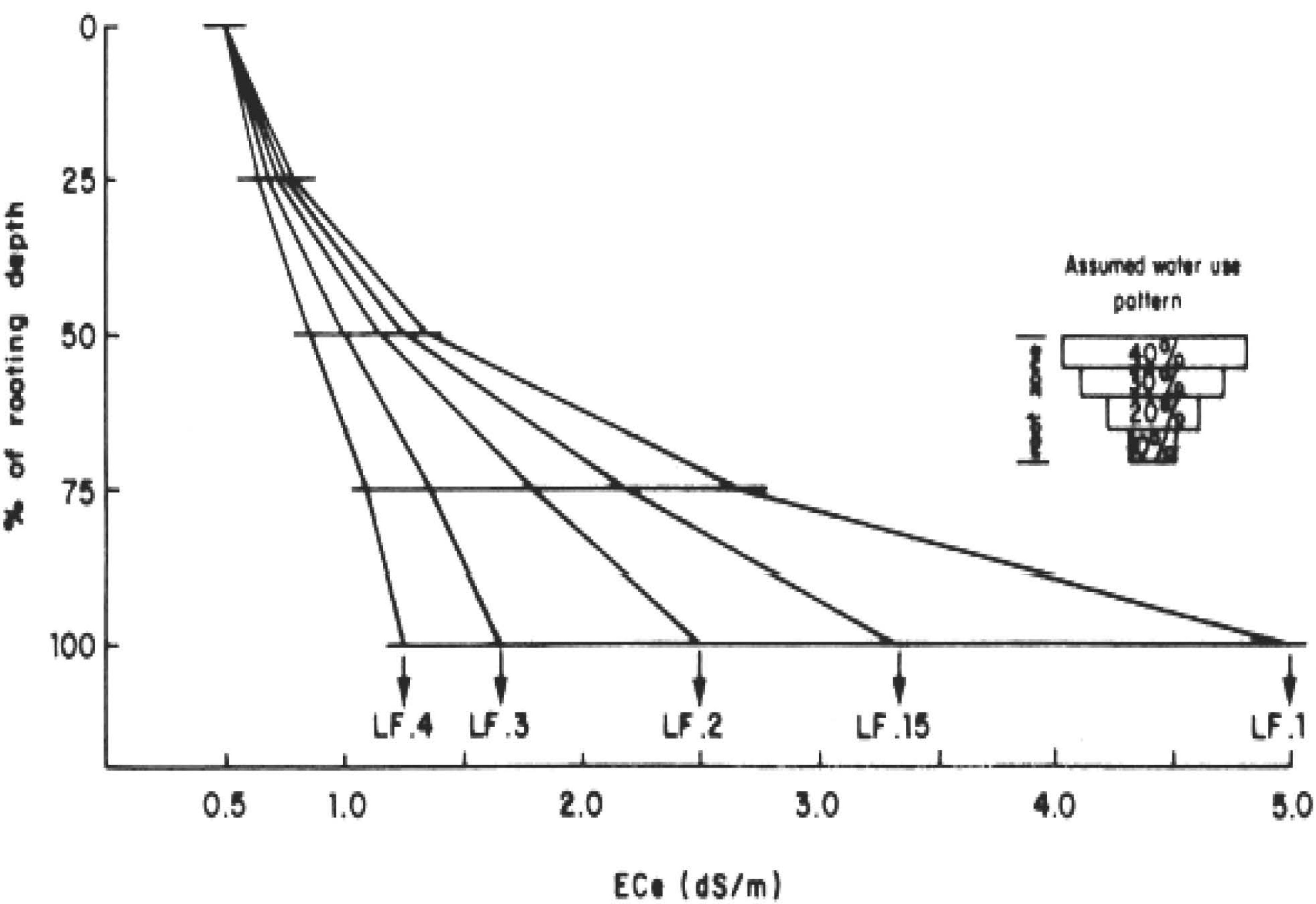
- **Based on 43 Tier 2 fields sampled to-date in the PRB:**
- **The average root zone (0-48”) EC is 6.3 dS/m (6300 umhos/cm)**
  - ✓ This is already higher than the agreed upon 100% yield thresholds for alfalfa (2 dS/m) and western wheatgrass (4.5 dS/m)
  - ✓ A soil exhibiting >4 dS/m is defined as saline
- **Average root zone SAR ranges from 1.1 to 23 with an average of 9.2**

Tier 2 – 1.5 Concentration Factor

- This refers to the equation: $EC_{soil} = EC_{water} \times 1.5$
- So, for Tier 2, $EC_{soil} / 1.5 = EC_{water}$
- The 1.5 concentration factor from water to soil EC is appropriate and conservative
- 1.5 concentration factor is part of the California 100% yield thresholds
- The 1.5 concentration factor was agreed to by all parties:
  - ✓ Including UW during initial development and during Section 20 AUP public comment
  - ✓ Used in numerous Tier 2 and WYPDES analyses to date

Tier 2 – 1.5 Concentration Factor

- Soil EC profile can be used to estimate the long-term leaching fraction (Figure 2, Ayers and Westcot 1985)
- Leaching fraction can then be used to estimate the water to soil EC concentration factor (Table 3, Ayers and Westcot 1985)



Salinity profile expected to develop after long-term use of water of EC_w = 1.0 dS/m at various leaching fractions (LF) (Ayers and Westcot, 1985).

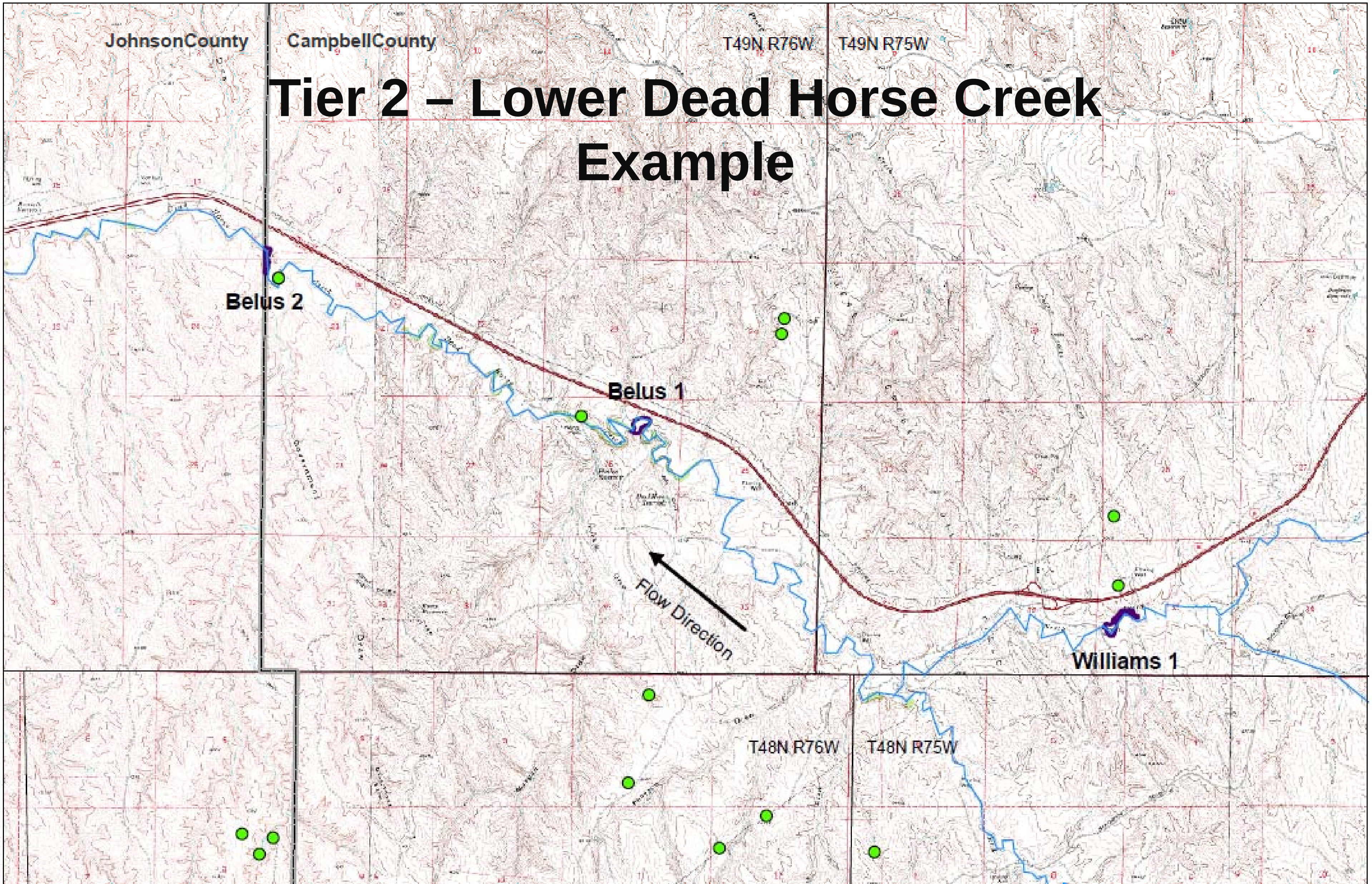
TABLE 3. CONCENTRATION FACTORS (X) FOR PREDICTING SOIL SALINITY (ECe)[1] FROM IRRIGATION WATER SALINITY (ECw) AND THE LEACHING FRACTION (LF)

Leaching Fraction (LF)	Applied Water Needed (Percent of ET)	Concentration Factor[2]
0.05	105.3	3.2
0.10	111.1	2.1
0.15	117.6	1.6
0.20	125.0	1.3
0.25	133.3	1.2
0.30	142.9	1.0
0.40	166.7	0.9
0.50	200.0	0.8
0.60	250.0	0.7
0.70	333.3	0.6
0.80	500.0	0.6

[1] The equation for predicting the soil salinity expected after several years of irrigation with water of salinity ECw is:
EC_e (dS/m) = EC_w (dS/m) x Concentration Factor

[2] The concentration factor is found by using a crop water use pattern of 40-30-20-10. (Ayers and Westcot, 1985).

Tier 2 – Lower Dead Horse Creek Example



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0 0.25 0.5 1 1.5 Miles

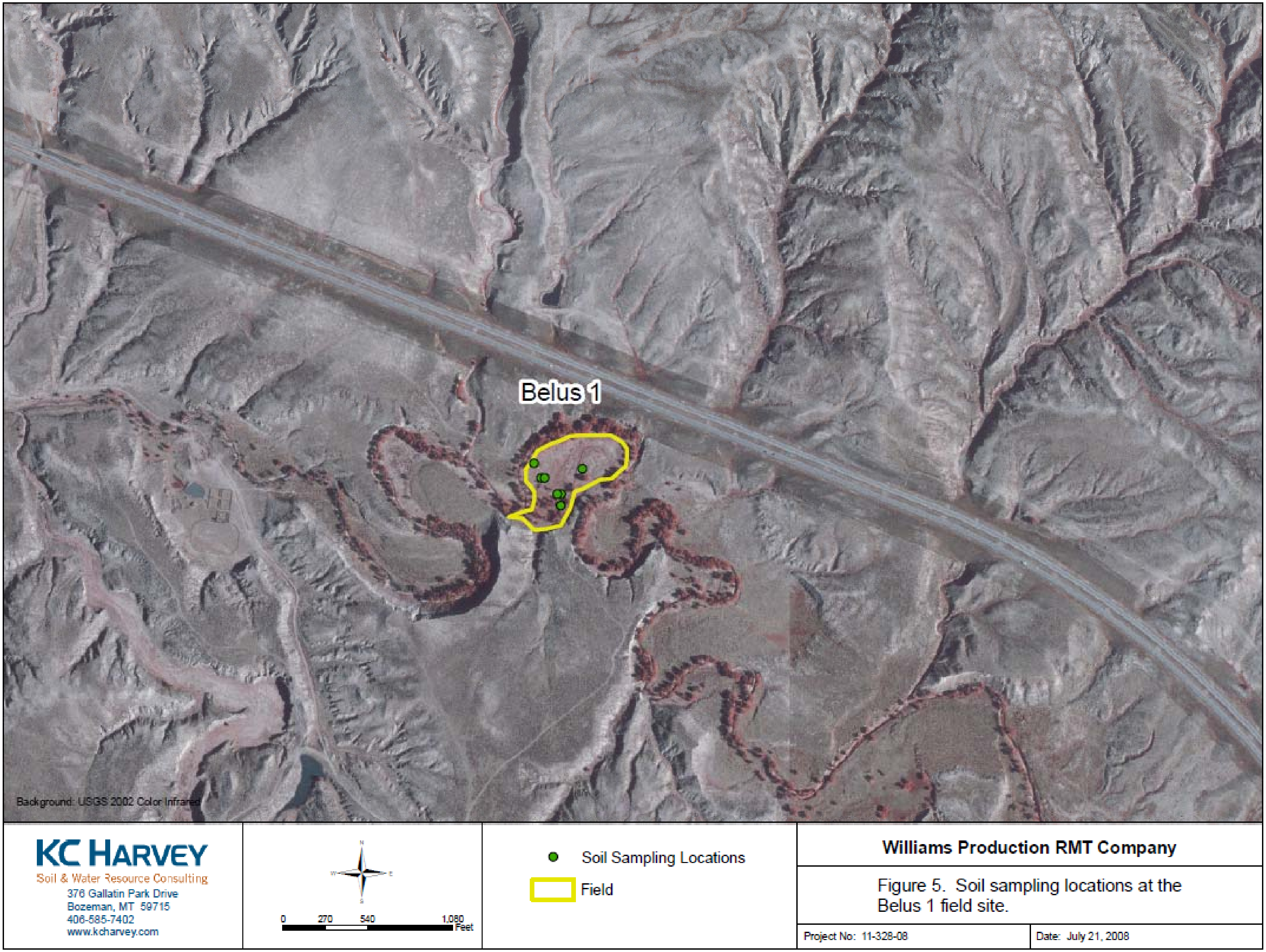
Outfalls

Field

Williams Production RMT Company & Yates Petroleum Company

Figure 1. Agriculturally significant fields identified on Dead Horse Creek.

Project No: 11-328-08 & 11-329-08 | Date: May 9, 2008



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Williams Production RMT Company

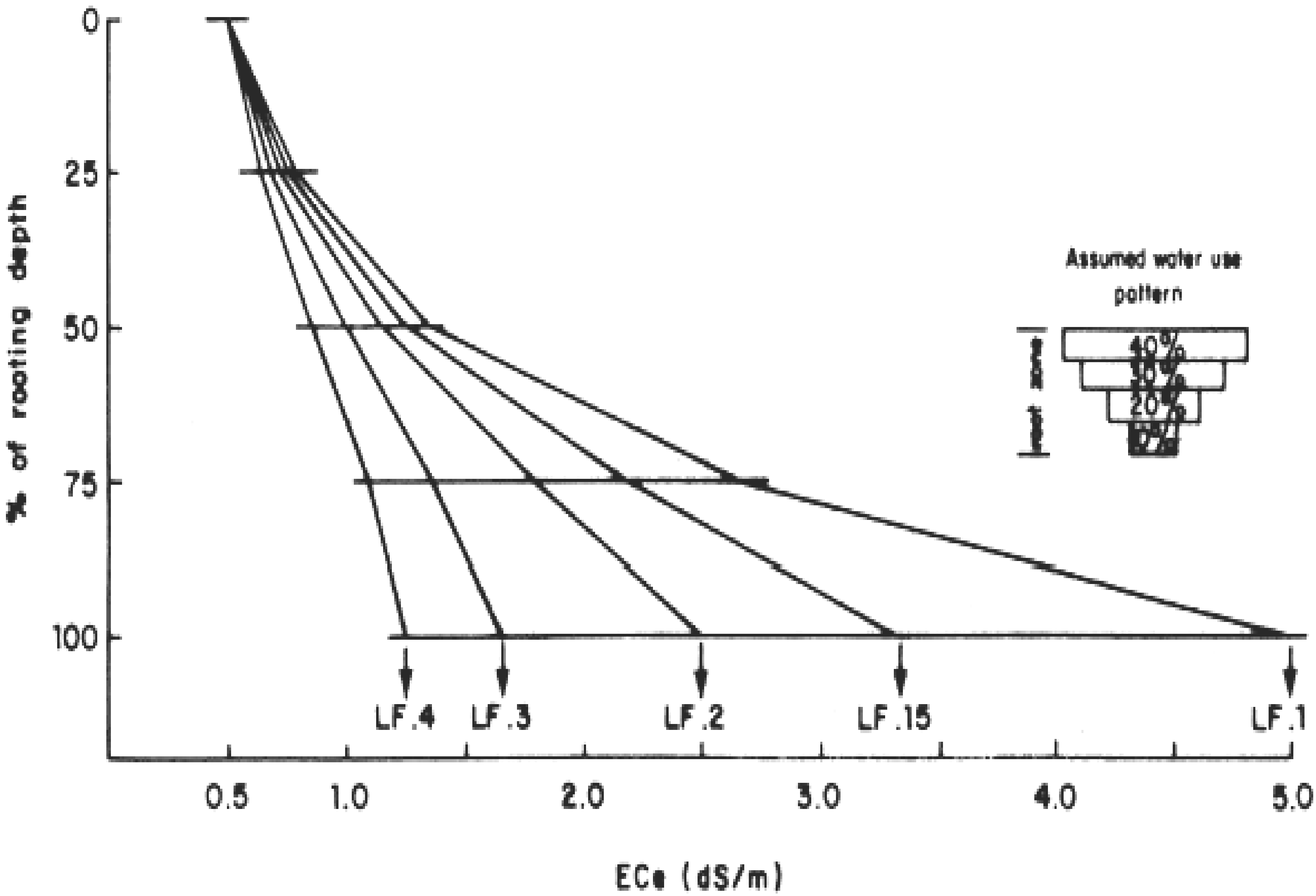
Figure 5. Soil sampling locations at the Belus 1 field site.

Project No: 11-328-08

Date: July 21, 2008

Soil chemical analysis results for the Lower Dead Horse Creek Section 20 site investigation (KC Harvey, June 2008).

Field	Depth	pH	Electrical Conductivity at 25°C (Ec_e)	Ave. Ec_e to a depth of 48 inches.	Sodium Adsorption Ratio (SAR)	Exch. Sodium Percentage (ESP)	Ave. ESP to a Depth of 48 inches	Lime as $CaCO_3$
Belus 1	0 to 12	7.1	1.29	4.5	0.63	1.5	5.4	4.5
	12 to 24	7.3	3.62		1.4	2.2		4.3
	24 to 36	7.4	5.45		5.2	5.0		4.2
	36 to 48	7.6	7.8		14	13		4.3
	48 to 60	7.8	9.25		19	15		4.2



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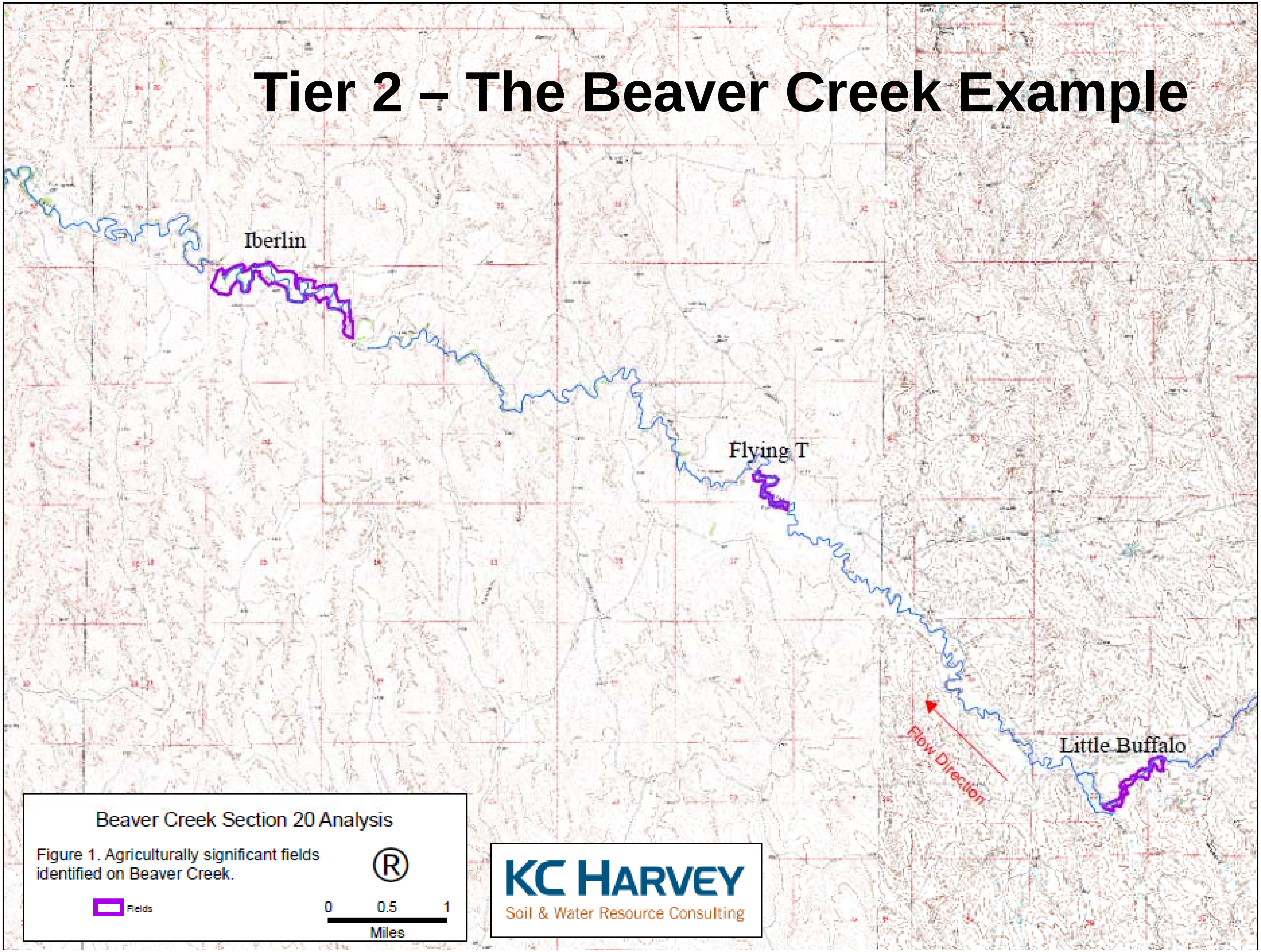
EC_e (dS/m) = EC_w (dS/m) x Concentration Factor

[2] The concentration factor is found by using a crop water use pattern of 40-30-20-10. (Ayers and Westcot, 1985).

Tier 2 – Dead Horse Creek

- Belus 1 field average root zone EC of 4.5 dS/m
- Surface EC = 1.3 dS/m, bottom of root zone EC = 7.8 dS/m; this represents a 6x increase
- A 6x increase in soil EC from top to bottom of root zone equates to a leaching fraction between .15 and .20 (Figure 2, Ayers and Westcot)
- A .15 to .20 leaching fraction equates to a 1.5 concentration factor (Table 3, Ayers and Westcot)
- Avg. root zone EC of 4.5 divided by 1.5 equals 3.0 dS/m EC permit limit (if this were the only field)

Tier 2 – The Beaver Creek Example



Soil chemical analysis results for the Beaver Creek site.[1,2]

Site	Depth	pH	Electrical Conductivity at 25° C (EC)	Average EC to a Depth of 48 inches	Ca	Mg	Na	Sodium Adsorption Ratio (SAR)	Cation Exch. Capacity (CEC)	Exch. Na	Exch. Sodium Percent (ESP)	Average ESP to a Depth of 48 inches	Lime as $CaCO_3$
	in	s.u.	dS/m		meq/L				meq/100g		%		
Little Buffalo	0-6	7.2	3.69	9.4	20.2	6.86	14.4	3.9	30	1.4	4.5	18.8	2.9
	6-12	7.7	5.62		19.7	9.84	40.9	11	25	2.6	10		3.7
	12-24	8.1	12.1		18.8	29.8	109	22	23	6.9	29		3.4
	24-36	8	12.5		20.7	36.5	96.4	18	21	4.6	22		3.1
	36-48	7.9	8.41		19.6	31.6	66.1	13	20	3.4	17		3.6
	48-72	7.8	7.69		22.0	24.2	58.9	12	19	2.4	13		3.6
Flying T	0-6	7.3	4.78	10.8	21.7	10.2	26.3	6.6	26	1.4	5.4	16.0	3.3
	6-12	7.9	9.16		21.1	18.0	72.6	16	22	3.2	15		3.4
	12-24	8.2	13.2		19.9	33.7	126	24	22	4.3	19		4.2
	24-36	8.2	12.3		24.1	32.6	123	23	22	3.7	17		4.7
	36-48	8	10.9		22.9	31.6	91.9	18	20	3.6	18		4.6
	48-72	7.9	10.9		23.5	31.2	92.5	18	19	3.1	16		4.0
Iberlin	0-6	7.4	2.01	7.2	14.9	4.87	4.35	1.4	32	0.8	2.7	16.0	4.9
	6-12	7.7	4.61		21.1	9.76	27.8	7.1	27	2.0	7.4		4.0
	12-24	7.9	7.35		21.0	18.1	77.2	17	27	4.6	17		4.7
	24-36	8	10.1		19.3	21.7	95.6	21	23	5.6	24		4.6
	36-48	7.9	7.93		19.4	17.3	67.5	16	22	3.9	18		4.3
	48-72	7.9	7.07		18.2	16.2	54.0	13	21	3.2	15		4.0
			Average EC:	9.1							Average ESP:	17.0	

Notes:

[1] Samples were collected on April 18, 2007 at the Iberlin site and on May 17, 2007 at the Flying T and Little Buffalo sites by KC Harvey, Inc. using a Giddings Probe. Samples were analyzed by Energy Laboratories, Inc., Helena, Montana.

[2] pH, EC, calcium, magnesium, and sodium analysis were conducted using a saturated paste extract. Abbreviations used are as follows: s.u.= standard units; dS/m= deciSiemens per meter, meq/L= milliequivalents per liter, meq/100g= milliequivalents per 100 grams of soil, and %= percent

[3] Average EC and ESP to a depth of 48 inches was calculated by averaging the 0 to 6 and 6 to 12 inch depths to derive a 0 to 12 inch value, then averaging together each 12 inch depth increment to a depth of 48 inches.

Site	Depth	Electrical Conductivity at 25° C (EC)	Average EC to a Depth of 48 inches
Little Buffalo	0-6	3.69	9.4
	6-12	5.62	
	12-24	12.1	
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	48-72	7.69	
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	6-12	9.16	
	12-24	13.2	
	24-36	12.3	
	36-48	10.9	
	48-72	10.9	
Iberlin	0-6	2.01	7.2
	6-12	4.61	
	12-24	7.35	
	24-36	10.1	
	36-48	7.93	
	48-72	7.07	
		Average EC:	9.1

Tier 2 – Another View

- Assume in this example that alfalfa growing in Iberlin field in Beaver Creek
- 100% yield thresholds for alfalfa is soil EC of 2.0 dS/m
- Average root zone EC of Iberlin field is 7.2 dS/m
- Avg. root zone EC must exceed 7.2 dS/m to cause a measurable decrease in baseline alfalfa production
- Assume CBNG discharge EC of 2.2 dS/m
- 2.2 dS/m x 1.5 concentration factor = 3.3 dS/m (will not change average root zone EC of 7.2 dS/m)

Tier 2 – SAR

- The chemistry of discharged CBNG water (including EC and SAR) changes as it moves down the channel
- Establish end of pipe EC limit based on Tier 2 analysis
- Monitor SAR above irrigated fields (IMP) by applying "no reduction in infiltration" equation to EC and SAR measured in stream samples
- DEQ has implemented this strategy for several permits in recent months
- In my opinion, this is the only way to apply Hanson (Ayers and Westcot)

Hillel, 2000

Conclusions

- **Tier 1 is very conservative**
  - ✓ EC limits based on California data
  - ✓ Wyoming data demonstrate SAR 16 safe
  - ✓ Suarez Study not right for Wyoming
- **Tier 2 preserves flexibility and ability to use water**
  - ✓ Composite soil sampling is scientifically valid
  - ✓ 1.5 concentration factor is useable for Wyoming soils
  - ✓ Accurate salinity measure requires use of entire root zone
  - ✓ We can predict changes to soil EC from water EC
  - ✓ Best application of Hanson equation is for monitoring SAR at point of use, not the outfall

Closing Comments

- After 10 years experience in CBNG, not aware of any measureable decrease in crop or livestock production
- Proposed rule has protected the irrigation use while in effect as policy
- Continued flexibility necessary to develop the CBNG resource and protect agricultural uses of the water

Thank You!