2011 Progress Report
Tongue River Agronomic Monitoring and Protection Program

Tongue River Information Program

Prepared for:

Montana Board of Oil & Gas Conservation

Montana Department of Natural Resources and Conservation

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Foreword

The Tongue River Information Program (TRIP) would not have been possible without the financial support of the Montana Board of Oil and Gas Conservation (MBOGC) who have funded the effort since late 2006. The monitoring program was initiated in 2003 by Fidelity Exploration and Production Company who provided funding to plan and implement the initial Tongue River Agronomic Monitoring and Protection Program (AMPP). Additionally, the authors wish to thank each of the landowners who afforded us access to their fields and agronomic records. Finally, we wish to thank all of the members of the field sampling crew from K. C. Harvey, Fehringer Agricultural Consulting and HydroSolutions Inc. We also appreciate Energy Labs efforts to provide public access to all AMPP data through their web site.

Executive Summary

Irrigators that rely on Tongue River water for crop and forage production have expressed concern about potential adverse impacts that coalbed natural gas (CBNG) development may have on irrigation water quality. Currently, the Tongue River enjoys good quality water that is used to irrigate more than 20,000 acres of land in Montana and over 50,000 acres in Wyoming, while supporting a healthy fishery within and below the Tongue River Reservoir.

The Agronomic Monitoring and Protection Program (AMPP) was commissioned and funded by Fidelity Exploration & Production Company (Fidelity). It was designed by two professional soil scientists and an agronomist, namely William Schafer, Kevin Harvey, and Neal Fehringer. During summer and fall of 2003, landowners who irrigated a minimum of 80 acres with Tongue River water were invited to become cooperators in AMPP. All landowners participate on a voluntary basis and specific location of sampled fields is confidential.

The AMPP soil and crop testing program has provided agronomic assistance to participants, helped irrigators better understand potential effects of CBNG development on their irrigated fields, and has documented regional trends in irrigated soil characteristics. AMPP consists of three tiers of sampling:

- Tier 1, which assesses crop yield factors, soil fertility, electrical conductivity (EC) and sodium adsorption ratio (SAR) in selected fields;

- Tier 2, which includes Tier 1 parameters as well as more detailed sampling, and measurement of exchangeable sodium percentage (ESP), texture, bulk density, water intake rate, clay mineralogy, and soil classification as well as determination of crop yields and forage quality (including sodium content) and soil fertility in 16 fields; and

- Tier 3, which consists of crop and forage test plots employing mixtures of Tongue River water and CBNG production water.

This report contains results of Tier 2 sampling from the program's inception in fall 2003 through fall 2010 sampling. The purpose of the program is three-fold: 1) to measure baseline soil characteristics; 2) to identify changes in soil chemical and physical properties, if any, and to explore the potential relationship to CBNG development; and 3) to annually monitor crop yields and forage quality (including minerals such as sodium). To date, soil samples have been collected from AMPP sites nine times: October 2003, April and October 2004, October 2005, December 2006, September 2007, October 2008, October 2009 and October 2010.

Since 2006, a companion report, The Tongue River Hydrology Report, has been produced and published simultaneously with the AMPP report. It may be accessed at the Montana Board of Oil and Gas Conservation (http://bogc.dnrc.mt.gov/coalbedmeth.asp).

Study Approach

In selected fields spaced at intervals along the Tongue River (and its tributaries of Prairie Dog Creek and Otter Creek), detailed soil sampling was performed to determine seasonal changes in soil chemistry, and to assess soil characteristics at depths up to 8 feet. Tier 2 soil sampling used a representative number of composite sub-samples collected from a portion of each field that consisted of the largest soil mapping unit from the County Cooperative Soil Survey. Composite samples were collected from the following depth intervals: 0 to 2, 0 to 6, 6 to 12, 12 to 24, 24 to 36, 36 to 60, and 60 to 96 inches. Laboratory analyses included soil texture, EC, SAR, ESP, soil texture, clay mineralogy, trace metals, plant available nutrients, and other properties. Neal Fehringer, Certified Professional Agronomist, has formulated ranch-specific recommendations for all Tier 2 fields annually.

Laboratory Analysis and Quality Assurance

The Sampling and Analysis Plan for the AMPP was circulated for review among numerous Federal Agency staff members after its formulation in 2003. Samples were collected, handled and analyzed under a stringent quality assurance program. The objective of the quality assurance plan is to ensure that data collected in Tongue River AMPP are of known and acceptable quality to differentiate spatial and temporal soil chemical trends for Tier 2 samples and to provide agronomic advice.

Each set of Tier 2 soil samples were collected from the same composite sub-sample locations using GPS technology and from the same depth increments. This controlled sampling approach is necessary to minimize effects of natural soil variability on results. Samples were transported to the laboratory under chain-of-custody. The certified laboratory used an internal quality assurance program to maintain analytical precision and accuracy.

All analytical results, including quality assurance samples, were distributed to the public on the Energy Laboratory web site (http://energylab.com/default.aspx). AMPP and MBOGC web sites also contain details of the program (http://www.tongueriverampp.com and http://bogc.dnrc.state.mt.usCoalbedMeth.asp, respectively). The generalized location of AMPP sites is shown in Figure A. Only landowner/cooperators were provided with the alpha code corresponding to their fields.

Results

Sixteen fields, including 14 irrigated fields and two dry land fields, were initially selected for Tier 2 AMPP in 2003. The same 14 irrigated fields remained in the program through 2010. Ten fields are irrigated with Tongue River water and are distributed along the entire length of the River from above the Tongue River Reservoir to the lower T&Y Irrigation District east of Miles City. Two fields are irrigated with water from Tongue River tributaries (Prairie Dog and Otter Creek). Two reference fields outside the Tongue River Drainage are part of AMPP, one irrigated with water from the Yellowstone River and one with water from the Big Horn River. The two dry land fields are located in the Tongue River floodplain in the same soil-mapping unit as the nearby irrigated AMPP fields, but have not been monitored beyond the initial baseline characterization.

Tongue River irrigation water is of high quality, except for occasional exceedances of the Montana monthly average EC standard near the mouth of river during low flows, and meets irrigation water quality standards adopted by the State of Montana (ARM 17.30.670) (Figure B). Irrigation water has year-to-year variations in EC and SAR, which are mostly related to the rate of river flow, with EC and SAR declining in higher flow years such as 2005, 2007, 2008, 2009 and 2010 and increasing in dry years such as 2004 and 2006. EC and SAR increase somewhat in the downstream direction below the Tongue River Dam, mostly due to increased proportions of sodium and sulfate ions. An overview of the hydrology and water quality of the Tongue River watershed is presented in a companion report, The Tongue River Hydrology Report, prepared under this same contract by HydroSolutions Inc.

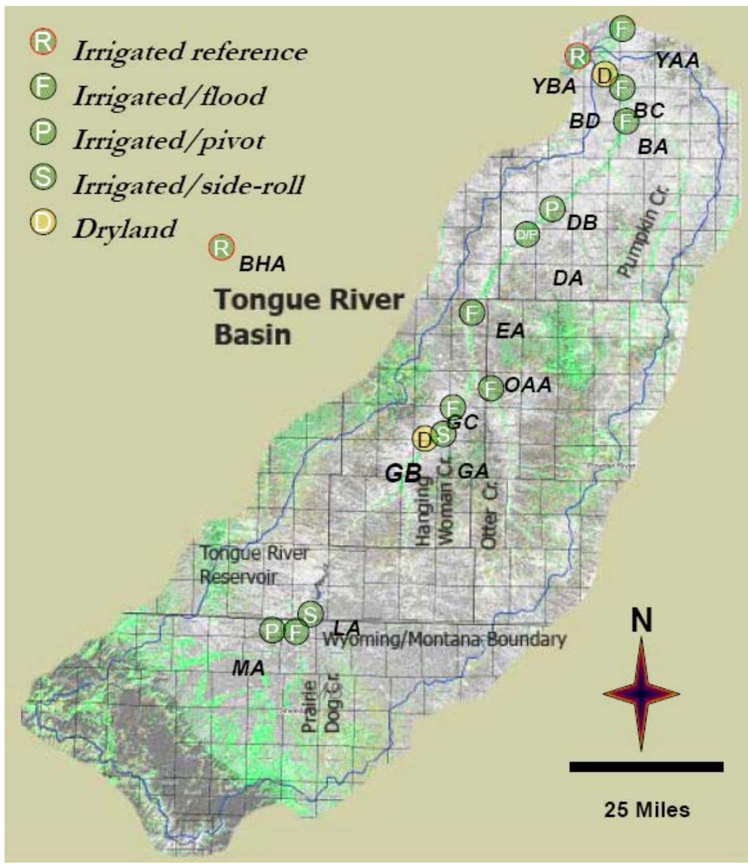

Figure A   Location of Fields Used in the Tongue River AMPP.

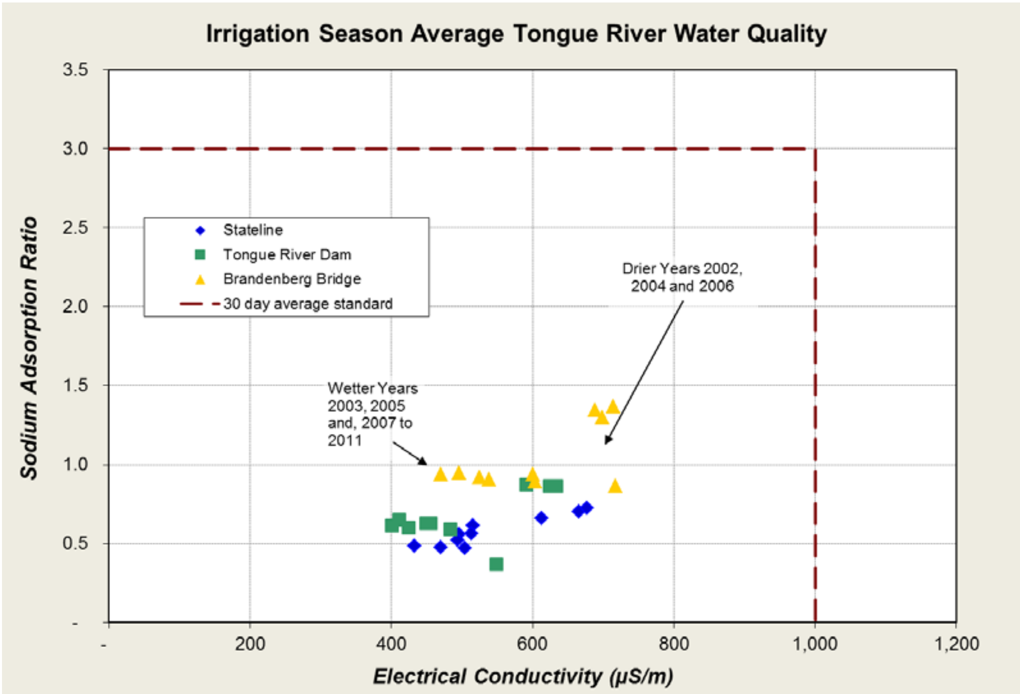

Figure B Estimated Average Tongue River Irrigation Water Quality in 2002 through 2010.

Variation in Crop Production & Mineral Content of Forages

Documented crop yields for 2003 were based on grower records. During the 2004 through 2010 growing seasons, plant collections were taken in Tier 2 fields at every soil sample collection point (GPS waypoint) prior to each cooperator crop harvest. Plant material from each field was weighed, sent to a laboratory for analysis, and yields adjusted to 12% moisture content for forages that were hayed and 70% for corn silage. Sugar beet and small grain yields are listed as harvested and not moisture adjusted. Feed analyses include nutritional parameters and a complete mineral determination (sodium, calcium, sulfur, etc.).

Large differences in forage yield were evident between sites, but yield variations showed no systematic changes through time. A myriad of factors have affected forage crop yields including age of stand, quantity of irrigation water used, fertilizer applied, weed and insect control, climate, and number and timing of cuttings. Although it is difficult using existing data to precisely determine causes of yield variations among AMPP fields, it is clear that:

- Yields are comparable to average irrigated forage production from Big Horn, Custer, and Rosebud Counties in 2004 through 2010.

- Yields do not show a decreasing trend between 2004 and 2010.

- Yield differences are not correlated with average salinity (Figure C) or sodium levels.

- Yields appear to be limited to around 2 tons per acre in fields where less than 8 inches of irrigation was applied in below average precipitation years.

- Yields in 2004 were reduced by a late killing freeze on May 12.

- On certain years at various locations, alfalfa yields have been reduced by severe alfalfa weevil infestations prior to first cutting. Alfalfa yields are also lower on first year stands.

With elevated sodium levels a hallmark of CBNG water, increases in sodium content of forage crops should be among the first effects of CBNG activity because plants take-up what is applied to the soil. Alfalfa at site MA, which is located near most of the CBNG water discharge sites, had a sodium level of 0.07% in both 2004 and 2005. Sodium then declined to 0.04% in 2006 and returned to 0.07% and 0.08% in 2007 and 2008. Sodium at site MA decreased to 0.02% in 2009 and was 0.03% in 2010. LA, which is below all CBNG water discharge points and above the Tongue River Reservoir, has had a steady decline in sodium from 0.06% in 2004, 0.05% in 2005, 0.04% in 2006, 0.03% in 2007, and 0.02% in 2008 through 2010.

No changes in sodium content of forages have been detected for the period of 2004 to 2010 due to CBNG development. As of 2010, fields within the Tongue River Drainage have forage sodium at or below 2004 levels for Sites MA, LA, GC, EA (2005 levels), DA, DB, YAA, and OAA. For site GA, sodium was below 2004 levels as of 2009. This field was planted to hay barley in 2010 and forage sodium content was considerably higher than when it was in grass/alfalfa from 2004 through 2009. For Site BA, the 2010 level is below 2008, the first year it was planted to alfalfa. Site BC sodium content for 2008, the last year it was in grass/alfalfa, was below 2004 levels. YBA, which is irrigated with Yellowstone River water, had similar variations in sodium content as forages from fields in the Tongue River Drainage. The average sodium content of all fields increased slightly from 2009 to 2010 because of the elevated sodium content of the hay barley at Site GA. Sodium levels vary mostly in response to crops being grown (Figure E).

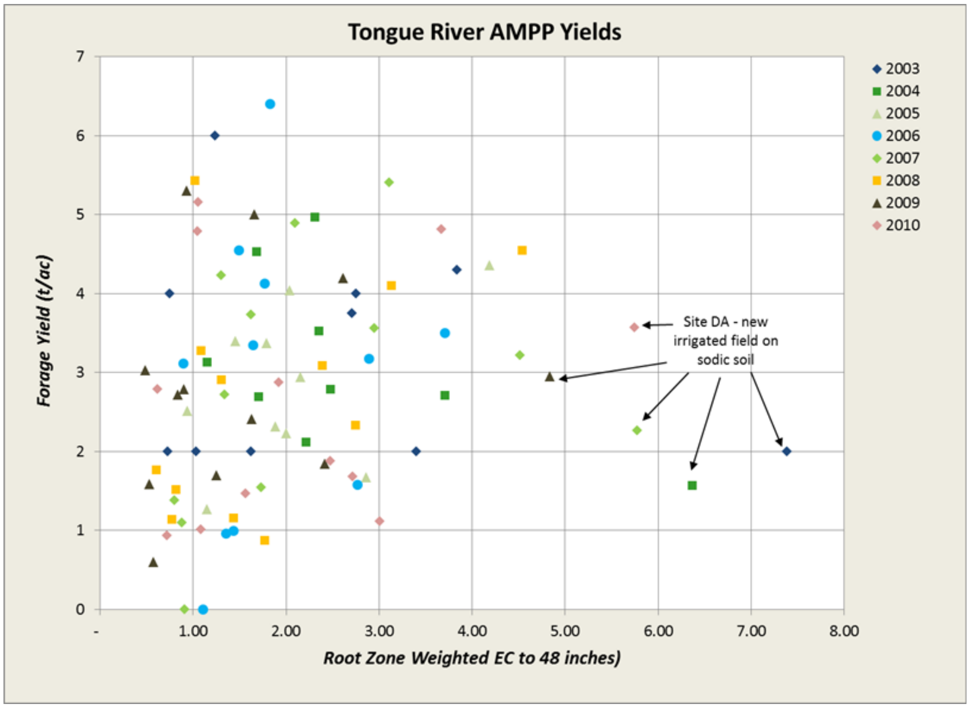

Figure C Comparison of AMPP Forage Yield to Average Root Zone Salinity (EC dS/m) in 2003 through 2010.

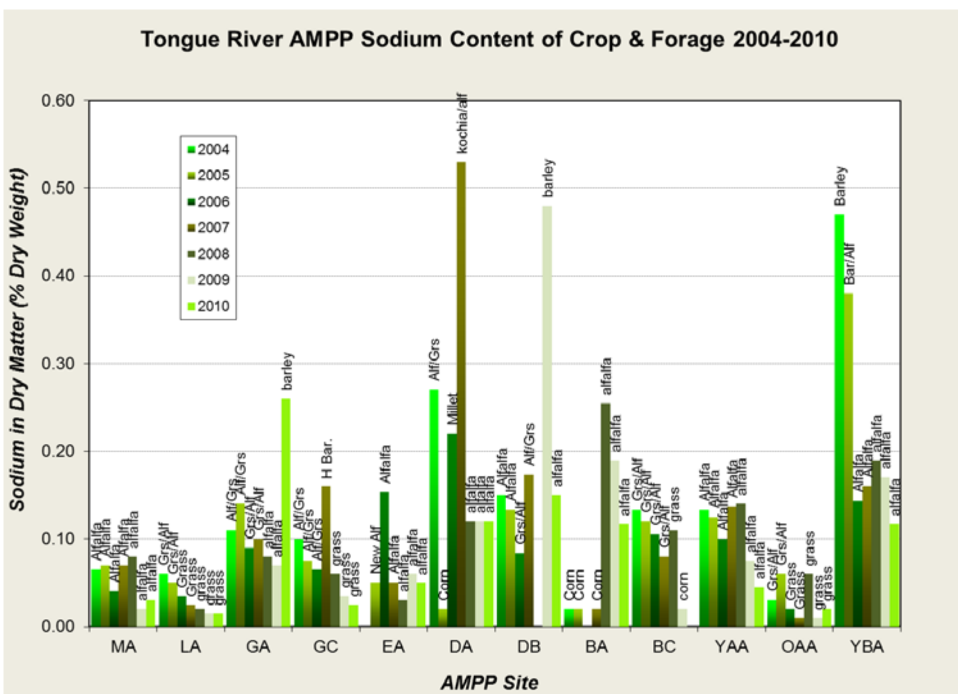

Figure D Comparison of Sodium Content in Forages in Fields that have been Planted to the Same Crop for at Least Three Out of Seven Years, 2004 to 2010.

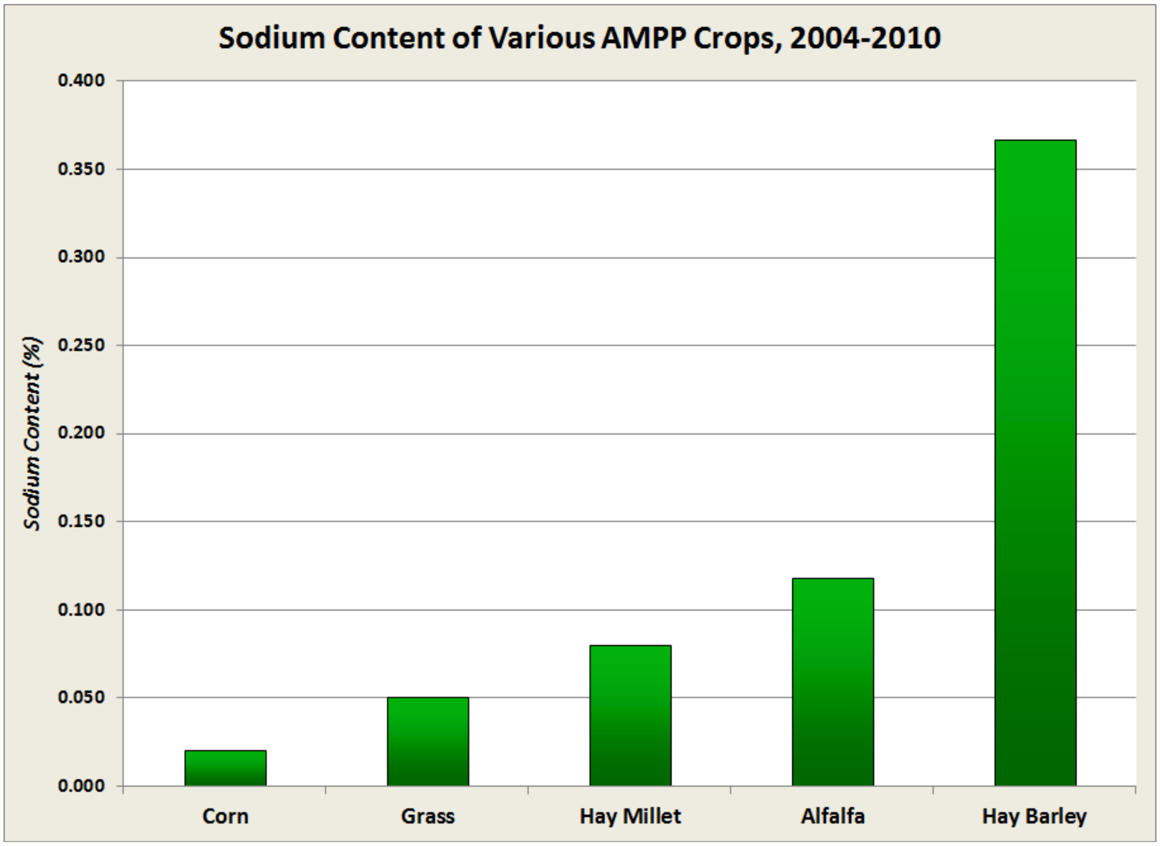

Figure E Average Sodium Content of AMPP Forages Harvested, 2004 to 2010.

Properties of AMPP Soils

Irrigated Tongue River soils exhibited both similarities and differences. All AMPP soils were derived from recent floodplain sediments and showed characteristic horizontal layering with slight differences in clay content and organic matter. All soils had abundant lime at every depth, indicative of their geologic youth. Additionally, all soils were lower in clay content and expansive clays than is conventionally believed to be the case in southeastern Montana.

Overall, irrigated fields in the Tongue River Drainage were medium-textured, meaning they had nearly equal proportions of sand, silt, and clay. Soil texture is important in irrigated soils because soils with too much clay may have low permeability and poor drainage. However, soils with too much sand may drain too rapidly and will have low water and nutrient-holding capacities. Tongue River soil textures were classified as loam, clay loam or silty clay loam (Figure F). All Tongue River soils had water infiltration or intake rates that are considered suitable for sustained irrigation. There was no correlation between intake rate and either clay content or ESP. Intake rates have not varied through time.

Clay mineralogy of irrigated soils affects their susceptibility to excess sodium levels. For example, Bauder (no date) illustrated the dependence of sodium sensitivity to clay mineralogy based on irrigation water quality guidelines developed by the United Nations (Table A).

According to Bauder, SAR levels in irrigation water less than 6 do not create a problem if the dominant clay mineral is smectite. This “safe” level of SAR increases to 8 for illite-dominated soils and to 16 for kaolinitic soils. Irrigated Tongue River soils have a mixed mineralogy (Figure G) in which kaolinite is the most abundant clay mineral followed by illite. Based on UN irrigation water quality guidelines, a SAR level in irrigation water up to 8 would be safe to use on Tongue River soils. The current Montana water quality standard for SAR on the Tongue River is 3.0 (30-day average) or 4.5 (instantaneous) during the irrigation season.

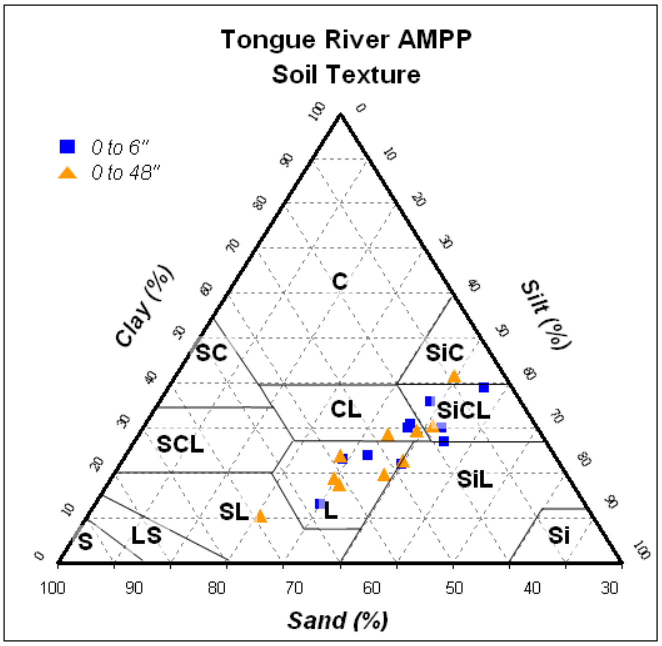

Figure F Texture of Surface Soils and the Average

Root Zone Texture of AMPP Soils.

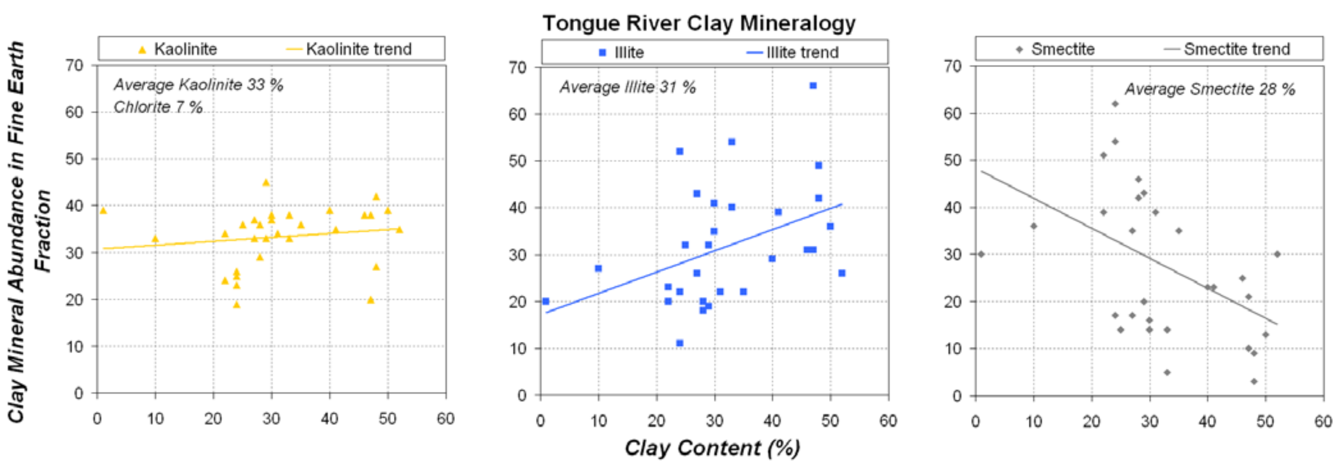

Figure G Clay Mineral Abundance in AMPP Soils.

Table A Guidelines for Irrigation Water Quality Established by the World Food and Agriculture Organization (after Bauder no date)

	Intensity of Problem[1]		
Water Constituent	**No Problem**	**Moderate**	**Severe**
Salinity (decisiemens/meter)	<0.7	0.7-3.0	>3.0
Permeability (rate of infiltration affected) by Salinity (decisiemens/meter)	>0.5	0.5-0.2	<0.2
Adjusted SAR; soils are: Dominantly smectites	<6	6-9	>9
Dominantly illite-vermiculite	<8	8-16	>16
Dominantly kaolinite or sesquioxides	<16	16-24	>24

From Bauder (no date) Source: Modified from R.S. Ayers and D.W. Westcott, "Water Quality for Agriculture," Irrigation and Drainage Paper, 29, FAO, Rome, 1976; rev. 1986.

[1]Based on the assumptions that the soils are sandy loam to clay loams, have good drainage, are in arid to semiarid climates, that irrigation is sprinkler or surface, that root depths are normal for soil, and that the guidelines are only approximate.

Lastly, samples collected from 0 to 6 inches in irrigated Tongue River soils were, with one exception, non-saline and non-sodic (Figure H). This means that Tongue River soils do not exhibit an adverse accumulation of soluble salts or sodium, even though these conditions are common elsewhere in southeastern Montana soils (Bauder, no date). The single exception was site DA, which is located near the mouth of an ephemeral tributary to the Tongue River. This field was brought under irrigation in August 2003. During the first full irrigation season (2004), enough salts were leached from the 0-6 inch depth that the soil was no longer classified as saline.

Statistical Variation in AMPP Samples

Statistical analysis was performed to determine whether there were any significant changes in soil chemical properties during the time spanned by the eight sampling events. Sites were considered random observations so trend analysis was performed on depth and time as factors. Most soil properties exhibited significant statistical variation between depths. Many soil properties including EC, and soluble calcium, magnesium, and sodium also decreased with time. Based on this decreasing trend, CBNG discharges are clearly not impacting irrigated soils. Decreases in EC and soluble ions were most pronounced in 2008 through 2010, which corresponded to the return to more normal rainfall and stream flow after a multi-year drought cycle. Statistical analysis, however, showed no significant correlation to either applied irrigation water or rainfall.

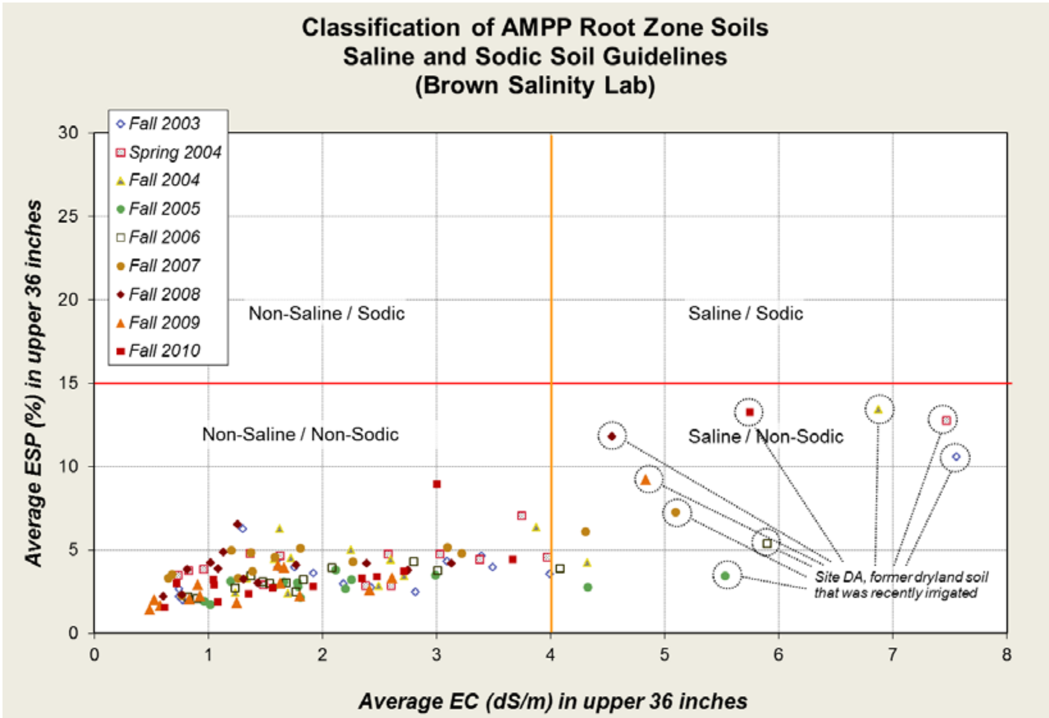

Figure H Salinity and Sodium Levels in Irrigated Tongue River Soils in Fall 2003, Spring 2004, and Fall 2004 through 2010.

Variations in Soil Properties Related to Soil Depth

Statistical analysis showed that all soil properties exhibited significant variation with soil depth and between locations. While changes in soil properties with depth differed greatly from site to site, soil properties averaged across sites portrays generalized depth trends. For example, clay content tended to be higher near surface than at depth, which is typical of floodplain deposits. Conversely, soil pH was slightly lower near-surface than at depth, which is typical of most western soils. At depth, abundant lime tends to control pH around 8.0, while closer to the soil surface; organic matter causes a slightly lower pH.

Average EC increased with depth to about 48 inches, where the maximum average value of 4 dS/m occurred and then decreased to around 2.5 dS/m at 8 feet in depth (Figure I). The EC increase that occurs with depth is typical of both dryland and irrigated soils in semi-arid climates. Infiltration of rainwater and low EC irrigation water tends to maintain low EC levels near the surface. As plant roots extract water from the soil, they absorb water and exclude most soluble ions causing a progressive accumulation of salts. Roots are primarily distributed throughout the upper 3 to 5 feet of soil, causing a build-up in EC near the root zone base. The EC difference between top and base of the root zone provides an indication of the amount of water that percolates through the soil. When this quantity of water is expressed as a percentage of applied water, it is called the “leaching fraction” (LF) in irrigated soils. Estimated average leaching fraction for AMPP soils was 11%.

ESP (Figure J) also increased with increasing depth in a similar manner to EC, except that maximum average ESP occurred at the greatest sampled depth of 5 to 8 feet. Soil water has higher EC and ESP deeper in the soil profile due to the pattern of water removal by plant roots. Changes in sodium status with depth are a bit more complex, because as salts are concentrated by plant water uptake, soil minerals enriched in calcium and magnesium tend to form, causing a shift towards higher proportions of sodium vs. calcium and magnesium, resulting in a higher SAR and ESP.

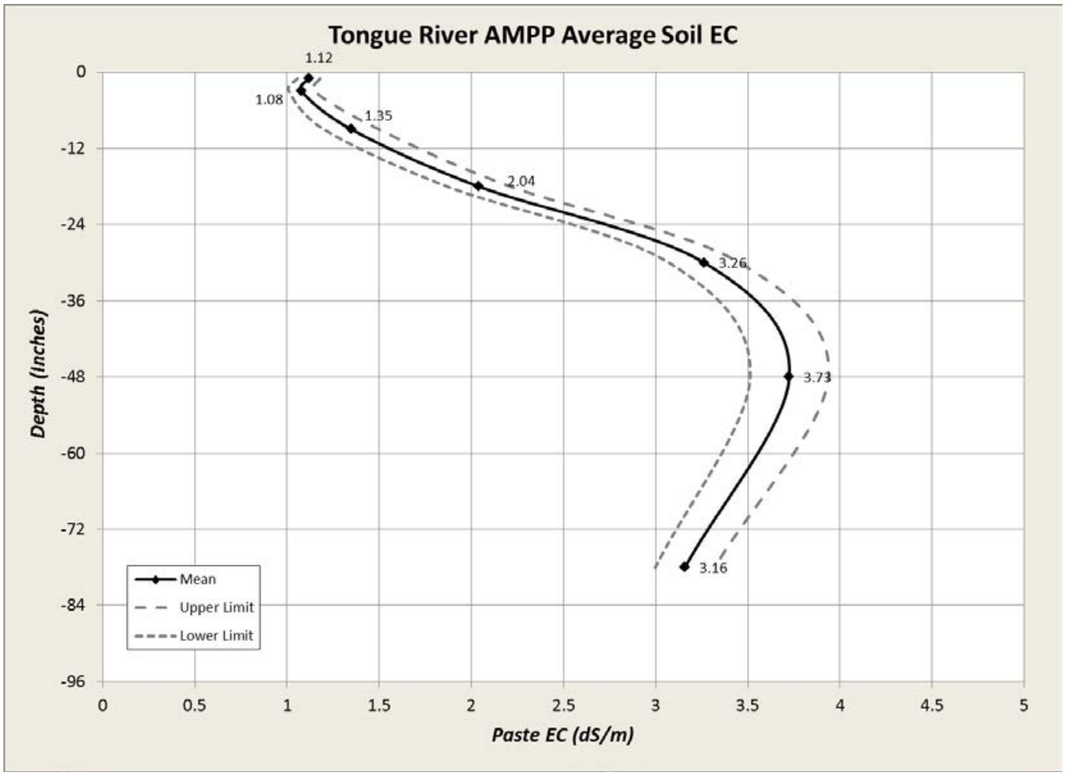

Figure I Trend in Average EC with Depth in Composite Samples from Fields Irrigated with Tongue River Water.

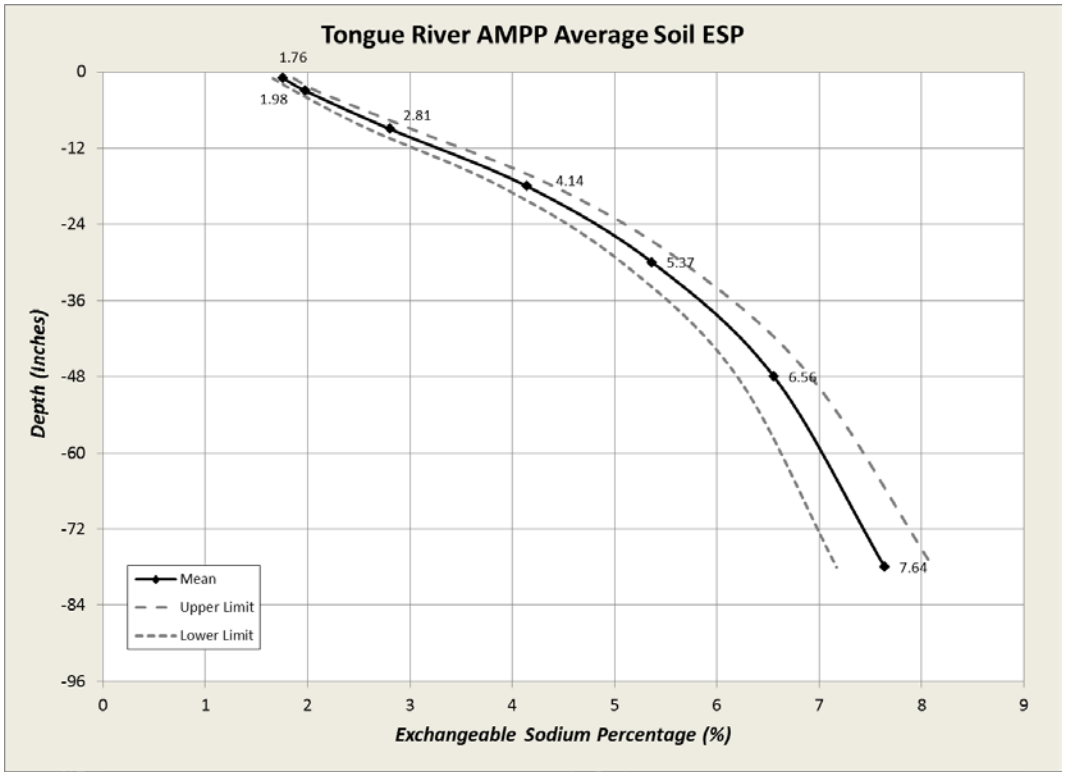

Figure J Trend in Average ESP with Depth in Composite Samples from Fields Irrigated with Tongue River Water.

Comparison of EC and ESP in AMPP Fields

Measured SAR is often used to predict the ESP that would develop in soils with sustained irrigation. In most regions, ESP follows a linear relationship with SAR developed by USDA (1954). The SAR and ESP relationship is weak in the AMPP data, however. SAR tends to under-predict ESP at a SAR of 5 or less, and over predict ESP above SAR 10. ESP measurements are thought to be more subject to error than SAR measurements. Therefore SAR is probably a better indicator of sodium status than ESP in AMPP soils.

Some individual fields exhibited changes in ESP due to site-specific agronomic management even when no basin-wide trends were evident. For example, ESP at 0 to 2 inches decreased from fall 2003 to fall 2004 at the BHA reference site which is irrigated from the Big Horn River. The field was in sugar beets in 2003 and had high soil moisture at harvest. Once beets were defoliated and dug, soil moisture and salts were drawn upward as the soil surface dried. The water evaporated, leaving salts behind, thus accumulating at the soil surface. Fall 2003 ESP was 6.1 in the 0 to 2 inch depth. Then in 2004 and 2005, winter wheat was in the field. The wheat canopy was more open than the beet crops, therefore, the soil surface dried slowly as the crop matured, which reduced surface salt accumulation. Fall 2004 and 2005 ESP values were 2.1 and 3.3, respectively. BHA was in beets again in 2006. In fall 2006, 0 to 2 inch ESP was 8.2 even though over four inches of precipitation was received between the 2006 final irrigation in early September and harvest in late November. ESP was only 3.4 as of fall 2007 following barley. ESP following the 2009 beet crop was 2.8 and was 2.0 after the 2010 winter wheat crop.

After three beet crops with completely different environmental conditions post harvest, this phenomenon is apparently a result of beet leaves accumulating sodium. This ESP increase is unique to the 0 to 2 inch depth following beets. ESP for 0 to 6 inches was 4.2 (beets), 2.0 (wheat), 2.9 (wheat), 2.6 (beets), 3.7 (barley), 3.1 (barley), 2.4 (beets), and 2.3 (wheat) from fall 2003 to fall 2010, respectively.

Plant uptake weighted average EC in the upper 48 inches is shown in (Figure K). Average EC for all soils was around 2.0 dS/m and most individual fields fell close to this value. Sites GC, DB, and BA had lower than average EC, probably owing to application of a greater quantity of irrigation water and/or soil water leaching at these sites. Site DA had higher than average EC, which was probably caused by a high water table and contributions from tributary runoff onto this field that was non-irrigated prior to 2003.

Depth weighted ESP (Figure L) averaged 3% to 4% and all but one field had ESP values close to this value. This exception was site DA, a field recently brought under irrigation that also had high EC values. Greasewood, a common indicator of sodium-enriched soils, is abundant in the vicinity of this field near the mouth of Foster Creek.

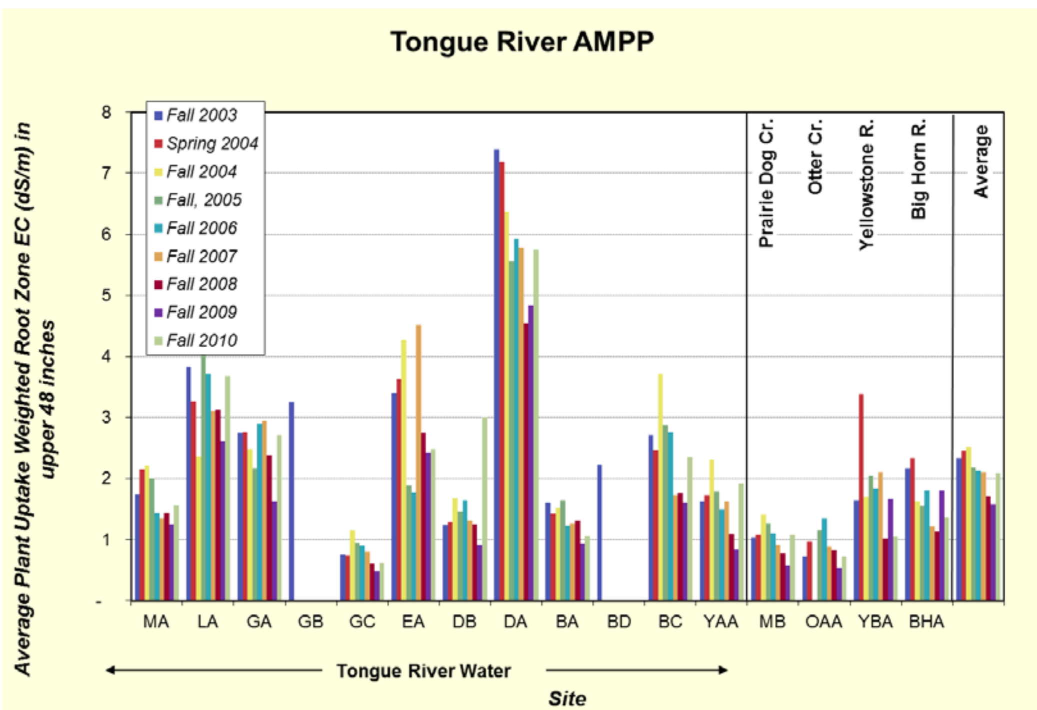

Figure K Plant Uptake-averaged Paste EC (dS/m) to 48 Inches in AMPP Sites for Each Sampling Period.

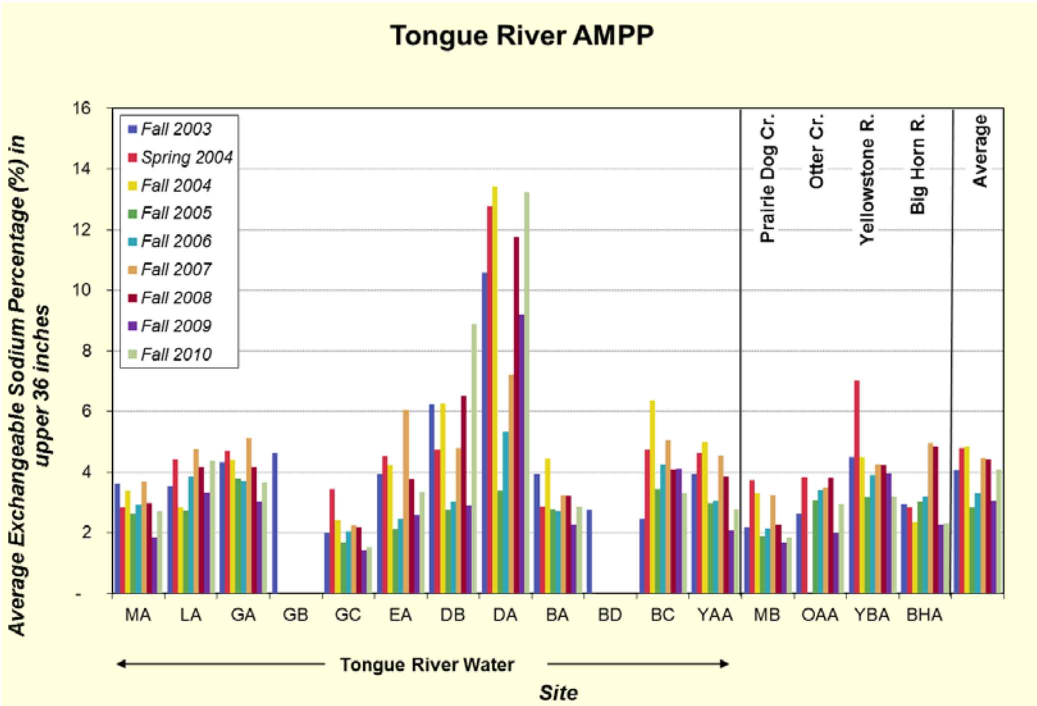

Figure L   Average ESP (%) to 36 Inches in AMPP Sites for each Sampling Period.

Changes in AMPP Soils through Time

Soil EC, soluble calcium, magnesium and sodium exhibited statistically significant decreases through time. Trends were confined to the upper 36 inches of soil while below 36 inches, no significant changes were observed. Average EC in the upper 36 inches of soil showed clear downward trends (Figure M) that were especially evident in 2008 and 2009. Even though all soluble ions decreased in concentration through time the SAR, a ratio of sodium over calcium plus magnesium did not exhibit a trend.

Statistical tests indicate that EC and soluble ions decrease with time but are not correlated to rainfall, applied irrigation water, or differences in irrigation water quality between years. A combination of these factors may have caused the decreased EC or other factors may account for the trends. For example, decreasing EC may be due to overall improvements in management attributable to agronomic advising provided under AMPP.

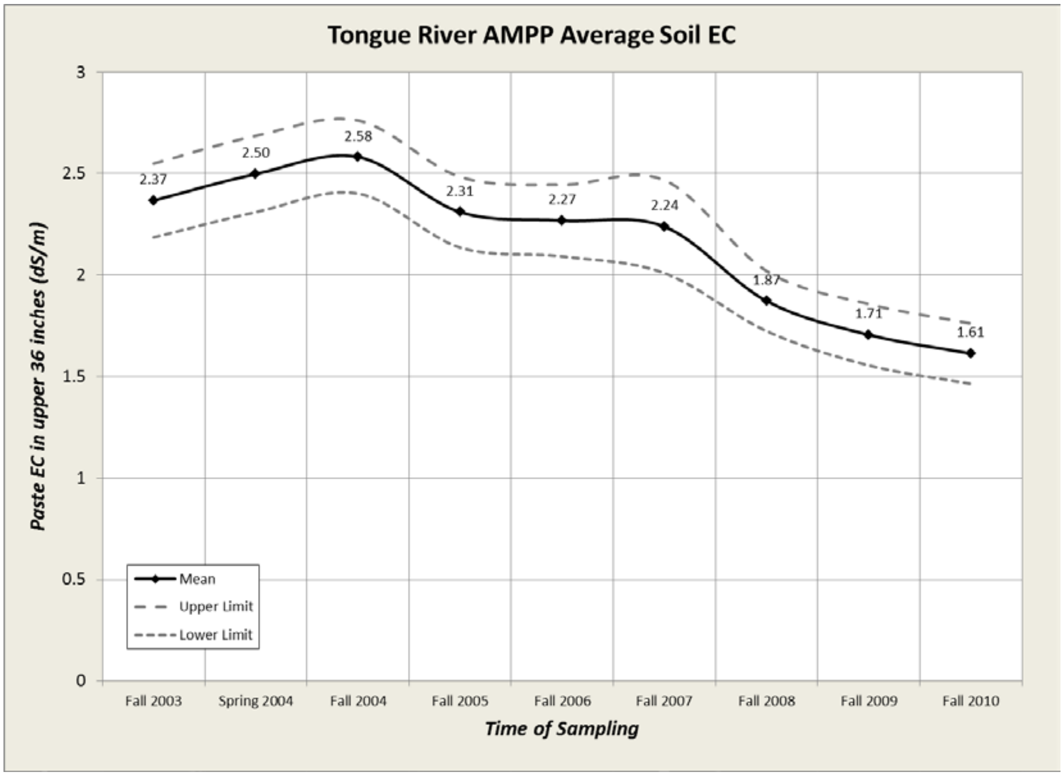

Figure M Trend in Average EC from zero to 36 Inches from Composite Samples Irrigated with Tongue River Water.

1.0 Introduction

The Powder River Basin in Wyoming and southern portions of Montana hosts extensive reserves of natural gas in coal seams within the Fort Union Formation. Coal seams must be de-pressurized by pumping water to facilitate release of coalbed natural gas (CBNG) or methane contained in the coal. This produced water naturally contains moderate levels of dissolved ions in which sodium is the dominant cation (or positively charged ion) and bicarbonate the primary anion (negatively charged ion). Electrical conductivity (EC) and sodium adsorption ratio (SAR) typically range from 1,000 to 2,500 µS/cm (µmhos/cm) and 10 to 60, respectively. Groundwater produced from coal beds has historically been used throughout southeastern Montana for domestic and stock water uses.

1.1 Purpose of AMPP

Irrigators that rely on Tongue River water for crop and forage production have expressed concern about potential adverse impacts that CBNG development may have on irrigation water quality. Currently, the Tongue River enjoys good quality water that is used to irrigate more than 8,100 ha (20,000 acres) of land while supporting a healthy fishery within and just below the Tongue River Reservoir. In recent years, water quality monitoring and regulatory programs have been implemented to protect water quality for irrigation and other uses in southeastern Montana including development of stringent water quality standards for electrical conductivity and sodium adsorption ratio, extensive surface water monitoring, and development of basin wide surface water models and water quality control programs.

Agronomic Monitoring and Protection Program (AMPP) was commissioned by Fidelity Exploration and Production Company in 2003. Since November 2006, AMPP has been supported by the Montana Department of Natural Resources' Board of Oil and Gas Conservation (Tom Richmond, Administrator). AMPP was designed by two professional soil scientists and a certified agronomist, namely William Schafer, Kevin Harvey, and Neal Fehringer, respectively. During summer and fall of 2003, landowners who irrigated a minimum of 32 ha (80 acres) with Tongue River water were invited to become cooperators in AMPP. An information package about AMPP provided to cooperating landowners is attached as (Appendix A). All landowners in AMPP participate on a voluntary basis and specific locations of sampled fields are confidential at the request of landowners.

The purpose of this program is to measure baseline soil characteristics and annually monitor crop yields and forage quality and mineral content (especially sodium). Subsequent annual soil sampling will also help identify and manage any soil chemical trends related to CBNG development that could impair future crop yields.

1.2 AMPP Timeline

- July 2003: Met with State NRCS Personnel in Bozeman, Montana to explain AMPP program.

- August 2003: AMPP announced and cooperating landowners, ranchers and irrigators contacted for participation in the program. Presented AMPP program details to Conservation District Boards in Custer, Big Horn, and Rosebud County. AMPP scientists present at Eastern Montana Fair in Miles City, Montana to sign-up cooperators and answer questions about program.

- September - October 2003: Finished signing-up cooperators. Field sampling completed for initial testing to build baseline data. Twenty-five fields sampled in the Tier 1 program. Sixteen fields sampled in the Tier 2 program including dryland, flood and sprinkler irrigated fields and, for comparison, fields irrigated with other water sources.

- November 2003: Presented details of initial sampling on "Berg in the Morning" radio show and at the Montana Salinity Control Association's "Coalbed Methane Forum" during the Montana Association of Conservation Districts' annual meeting in Billings, Montana.

- December 2003: Results of the initial testing publicly available on Energy Labs, Inc. web site.

- January 2004: Baseline Tier 1 and Tier 2 monitoring results were presented at the annual meeting of the Soil and Water Conservation Society in Billings, Montana.

- March 2004: AMPP web site launched. Delivered soil test results to cooperators, reviewed results, and adjusted cropping and fertilizer recommendations for 2004.

- April 2004: Spring monitoring event completed - 14 fields sampled in Tier 2 program. Tier 3 field plot study initiated and soil sampling performed.

- May 2004: Tier 3 plots established and crops planted.

- June 2004: AMPP program details and results presented at CBM Fair in Gillette, Wyoming.

- August 2004: First complete year of Tier 2 monitoring results were presented at the Coalbed Natural Gas conference in Laramie, Wyoming.

- September 2004: Completed harvest of Tier 3 field test plots for first growing season.

- October 2004: Fourteen fields sampled during ongoing Tier 2 program. Twenty-four fields assessed as part of ongoing Tier 1 agronomic consulting program.

- December 2004: Presented AMPP results to Rosebud Creek Drainage Task Force meeting in Lame Deer, Montana.
- March 2005: Met with cooperators to review soil test results and adjust 2005 cropping recommendations. Presented AMPP results to Custer County and Big Horn County Conservation Districts' monthly meetings.
- April 2005: Crops established in Tier 3 plots for 2005 growing season.
- June 2005: AMPP results presented at CBM Fair in Gillette, Wyoming.
- September 2005: Completed harvest of Tier 3 Field test plots for second growing season. AMPP results presented at Montana Ag Law Conference in Billings, Montana.
- October 2005: Fourteen fields sampled during ongoing Tier 2 program. Twenty-four fields assessed as part of ongoing Tier 1 agronomic consulting program. Tier 3 test plots also soil sampled.
- December 2005: AMPP Executive Summary Report completed and submitted to Montana Board of Environmental Review.
- March 2006: Met with cooperators to review soil test results and adjust 2006 cropping recommendations.
- April 2006: Crops established in Tier 3 plots for 2006 growing season.
- June 2006: AMPP results presented at CBM Fair in Gillette, Wyoming.
- Summer 2006: Harvested forage from each Tier 2 field to determine yield, feed quality, and mineral content.
- September 2006: Completed harvest of Tier 3 Field test plots for third growing season. AMPP results presented at Montana Ag Law Conference in Billings, Montana.
- November 2006: Funding for AMPP provided by the Montana Board of Oil and Gas Conservation.
- December 2006: Fourteen fields sampled during ongoing Tier 2 program. Eighteen fields assessed as part of ongoing Tier 1 agronomic consulting program. Tier 3 test plots also soil sampled.

- February 2007: Met with cooperators to review soil test results and adjust 2007 cropping recommendations. Presented AMPP results to Custer County and Big Horn County Conservation Districts' monthly meetings. Monitoring Program Development and Study Design.

- April 2007: Performed Tier 3 test plot weed control.

- May 2007: Released 2007 AMPP Fact Sheet, Executive Summary and Progress Report. TRIP Hydrology Report released.

- June 2007: Established pinto beans at Tier 3 plots. First cuttings from Tier 2 and 3 locations. TRIP results presented at Montana Ag Law Conference in Billings, Montana.

- July, August, September 2007: Second and third cuttings from Tier 2 and 3 locations. Harvested pinto beans (September).

- September 2007: Fourteen fields soil sampled during ongoing Tier 2 program. Seventeen Tier 1 fields soil sampled.

- October 2007: AMPP results presented at Montana Ag Law Conference in Billings, Montana.

- January 2008: TRIP present at Ag Technology and Construction Expo in Billings, Montana.

- February-May 2008: TRIP results presented to Rosebud Watershed Group, Custer & Big Horn County Conservation Districts; Independent Petroleum Association of Mountain States (IPAMS) in Denver; Colorado Public Health Department (Denver); and Montana Geological Society (Billings). Delivered soil test data and fertilizer recommendations to cooperators.

- April 2008: TRIP information presented via Helena and Sheridan (WY) radio stations. Tier 3 test plot maintenance and planted hay barley.

- May 2008: TRIP Hydrology report released.

- June 2008: Released 2008 AMPP Fact Sheet, Executive Summary, and Progress Report. Tier 2 forage as well as Tier 3 alfalfa harvests.

- July –September 2008: Continued Tier 2 harvests and harvest hay barley at Tier 3 site.

- September 2008: TRIP planning meeting in Bozeman.

- October 2008: Soil sampled Tier 1 & 2 fields and Tier 3 site.
- December 2008: Presented AMPP findings to Billings Area Legislators.
- February-May 2009: Met with cooperators to review soil test data and fertilizer recommendations.
- May 2009: Tier 3 maintenance and planted pinto beans.
- June-August 2009: Tier 2 and 3 forage harvests.
- July 2009: Presented Tongue River Hydrology and AMPP findings to annual meeting of Montana Association of Professional Landmen in Billings.
- October 2009: Soil sampled Tier 1 & 2 fields and Tier 3 site.
- October 2009: Soil sampled Tier 1 & 2 fields and Tier 3 site.
- January 2010: Present at 3-day Ag Technology & Construction Expo. Gave presentation of TRIP findings each day.
- February 2010: Presented TRIP findings at Montana Agri-Trade Exposition.
- February-June 2010: Met with cooperators to review soil test data and fertilizer recommendations.
- April 2010: Interviewed by journalists at Billings Gazette, Miles City Star, and Northern Ag Network. On “Voices of Montana” radio program located in Billings, MT.
- May 2010: Tier 3 maintenance and planted hay barley.
- June-September 2010: Tier 2 and 3 forage harvests.
- October 2010: Soil sampled Tier 1 & 2 fields and Tier 3 site.

1.3 AMPP Program Overview

AMPP was designed by Dr. Bill Schafer, Soil Scientist; Kevin Harvey, Certified Professional Soil Scientist; and Neal Fehringer, Certified Professional Agronomist. Fidelity Exploration & Production Company, a coalbed natural gas producer operating in Montana, sponsored the first three years of the program. MBOGC began funding the program as of November in 2006. The soil and crop testing program will help irrigators better understand potential effects of CBNG development on their irrigated crops. This package of soil sampling and analysis, cropping system evaluation, and interpretation is being provided at no cost to cooperating irrigators who use Tongue River water. The program consists of three tiers of sampling including:

- Tier 1, which assesses crop yield factors, soil fertility, pH, EC and SAR in selected fields;

- Tier 2, which includes Tier 1 parameters as well as more detailed sampling at depth, and measurement of exchangeable sodium percentage (ESP), texture, bulk density, water intake rate, clay mineralogy, selected trace elements, soil classification and determination of crop yields and forage quality; and

- Tier 3, which will consist of crop and forage test plots employing mixtures of river and CBNG produced water.

The purpose of this program is three-fold; to measure baseline soil characteristics; in subsequent annual monitoring events, to identify potential changes in soil chemical and physical properties related to CBNG development that could impair future crop yields; and to monitor crop yields and mineral content of forages produced, including sodium. To date, soil samples have been collected from AMPP sites seven times: October 2003, May 2004, October 2004, October 2005, December 2006, September 2007, October 2008, October 2009 and October 2010. This report provides the program results to date for the Tier 2 sampling program.

1.4 Site Selection

Sixteen fields were selected for study in Tier 2 AMPP (Figure 1-1). Ten fields were irrigated with Tongue River water and were distributed along the entire length of the River from above the Tongue River Reservoir to the lower T&Y Irrigation District east of Miles City. Two additional Tongue River fields were selected that were non-irrigated, but were located in the floodplain and in the same soil map unit as the nearby irrigated fields. Finally, two fields were irrigated with water from Tongue River tributaries (Prairie Dog and Otter Creek), and two reference fields were irrigated with Yellowstone River or Big Horn River water.

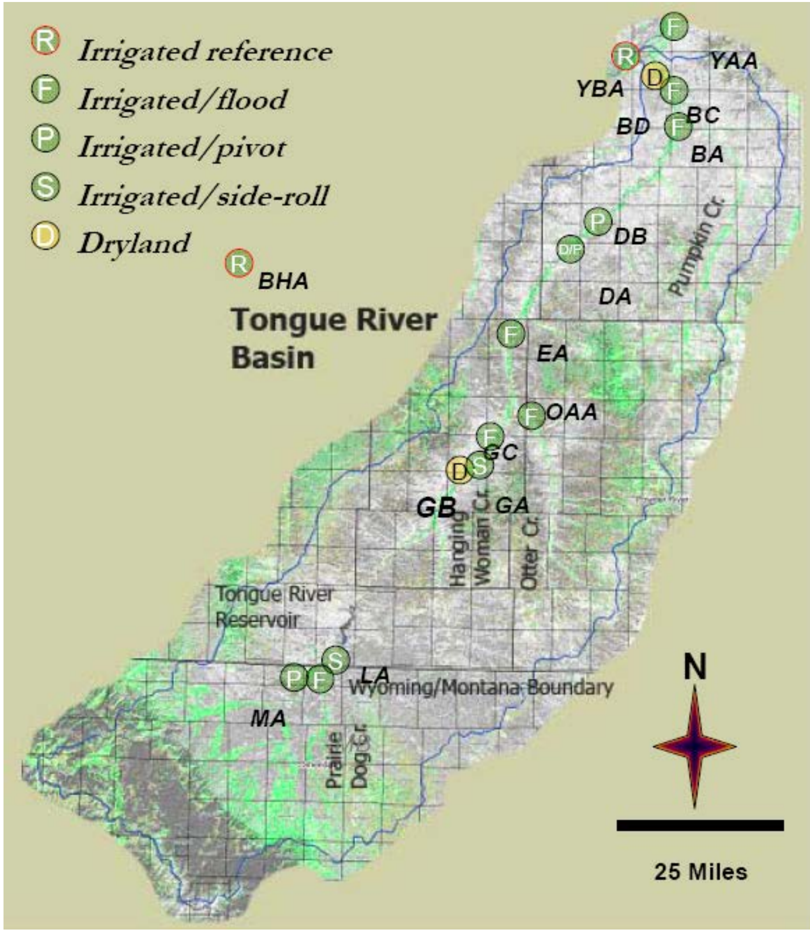

Figure 1-1 Location of Fields Used in the Tongue River AMPP.

1.5 Monitoring Program Design

1.5.1 Tier 1 – Soil Sampling and Crop Recommendations

For all Tier 1 fields, composite soil samples, obtained at depths of 0 to 6; and 6 to 24 inches, were collected during each fall sampling event and analyzed by Energy Labs Inc. (a certified commercial analytical laboratory) for pH, organic matter, soil texture, EC, SAR and plant available nutrients. Seventeen to twenty-five fields have been sampled under the Tier 1 program during eight sampling events (fall 2003 to fall 2010). In addition, a detailed agronomic assessment of each field was made. Ranch-specific recommendations were formulated by Neal Fehringer. These detailed plans provided recommendations regarding fertilizers; weed, disease, and insect control; soil amendments; crop rotations; stand establishment; varieties; seeding rates, dates, and depth; and how to deal with problem soils. These comprehensive recommendations will assist each producer in better understanding soils, soil chemistry, and irrigation management. This agronomic assessment will be repeated in the future, which will reinforce previous management actions.

1.5.2 Tier 2 – Soil Sampling and Crop Recommendations

In selected fields spaced at intervals along the Tongue River and on tributaries Prairie Dog Creek and Otter Creek (Figure A), as well as two reference fields, detailed soil sampling was performed to determine seasonal changes in soil chemistry, and to assess soil characteristics at depths of up to 8 feet. Tier 2 soil sampling used a representative number of composite sub-samples collected from a portion of each field that consisted of a single soil mapping unit from the County Cooperative Soil Survey. Composite samples were collected from the following depth intervals: 0 to 2, 0 to 6, 6 to 12, 12 to 24, 24 to 36, 36 to 60, and 60 to 96 inches. Laboratory analyses included pH, organic matter, soil texture, EC, SAR, ESP, clay mineralogy, trace metals, plant available nutrients, and other properties. Neal Fehringer also made detailed agronomic assessments and formulated ranch-specific recommendations for all Tier 2 fields.

Typical soils targeted for sampling in Sheridan County included the Kishona-Cambria association; in Big Horn and Rosebud County, soils included the Havorson, Havre, and Yamac series. In Custer County (including the T&Y Irrigation District east of Miles City along the Yellowstone River), sampled soils included Yamacall, Harlake, Sonnett and Kobase series.

In the first year of sampling (Fall 2003), an additional set of samples were collected at each Tier 2 location and a third set of samples was collected at two sites. Each set of samples addressed a specific issue as described below.

Reference Pedon Samples: A backhoe pit was excavated in the same Tier 2 field sampled above (Appendix D). A detailed soil profile description was prepared of the soil using methods and nomenclature described in Schoeneberger et al., (2002). Samples were collected from each genetic horizon described, and sampling extended to at least 48 inches in depth. Clay mineralogy was performed on the clay-sized particles of the fine earth fraction from 2 selected horizons from each reference pedon.

Grid Samples: A final set of samples was collected to assess spatial variability of soil properties (Appendix C). In two fields, samples were collected from three depth increments at 10 or more locations within the field. Each individual sample was submitted for analysis without compositing. In this way, spatial variability of each soil property can be quantified.

1.5.3 Tier 3 – Irrigated Crop and Forage Test Plots

Numerous water management strategies have been developed by petroleum companies to store, utilize, or discharge CBNG production water. Some of the water management options may entail discharge of production water into surface waters, so long as the receiving water can comply with irrigation water quality standards. Consequently, irrigators should not expect to apply undiluted CBNG production water except in special circumstances where “managed irrigation” programs are developed near the CBNG fields. Under managed irrigation, texturally suitable soils will be amended with chemicals such as gypsum and sulfur to reduce ESP in irrigated soils.

Irrigators using Tongue River water may experience slight changes in EC and SAR in their water supply if CBNG development expands in the Tongue River Basin. However, EC and

SAR must not exceed prescribed water quality limits adopted by the State of Montana, which were developed to protect irrigation uses of water. In order to evaluate potential effects associated with blending CBNG production water with Tongue River water, a series of irrigated test plot experiments began in the spring of 2004.

Test plots were placed on a medium-textured soil typical of the upper Tongue River. The ongoing test plots evaluate different mixtures of Tongue River water and CBNG water applied to a hay barley-alfalfa rotation and pinto beans, under both sprinkler and flood irrigation.

Experimental design consisted of four mixtures of water ranging from 100%Tongue River water to a 50/50 blend of Tongue River and CBNG-produced water. While water quality criteria will likely limit CBNG discharge to a dilution ratio in the range of 1 to 8 or less, plots are evaluating water mixtures with proportionally greater amounts of CBNG water so that a minimum effects threshold could be determined. Each plot is replicated three times. Additionally, a split plot design was used so that two rotations could be assessed. Soil and crop/forage samples are collected from all plots annually to assess trends in soil chemistry, yield and/or quality. Test plot results are described in the 2009 Irrigated Crop and Forage Test Annual Report, a companion report.

2.0 Quality Assurance Plan

2.1 Quality Assurance Objectives

The objective of the quality assurance plan is to ensure that data collected in Tongue River AMPP are of adequate quality to provide agronomic advice for Tier 1 and 2 fields, to differentiate spatial and temporal soil chemical trends for Tier 2 samples, and to evaluate effects of combining water produced from CBNG operations with Tongue River water on irrigated crop production, forage quality and soil chemistry in Tier 3 samples. The following field and laboratory quality assurance steps were used to ensure that data are useable for the aforementioned objectives, and that data are of measurable and acceptable quality.

2.2 Field Sampling Methodology

Field samples were collected using a combination of grab and composite sampling techniques. Sample collection techniques were noted for each sample on chain-of-custody forms and in a field notebook. Sample~~s~~ tags were designated using a convention that describes the type of sample, its depth of collection, and the general location, while maintaining the specific location confidential. Each landowner field was provided with a unique site designation (e.g. MA in example), which preserved the anonymity of the landowners.

Example Sample Designation **T2/MA-10-(0-6")**

- T2 — Tier 1, 2, or 3 program
- MA — Tongue River stream reach & arbitrary site designation within reach
- 10 — Sample Code: 1 – reference pedon, 10 – field composite, 11-30 discrete sample, 50 field replicate sample, TP1-2-4 (test plot, replicate, and plot number)
- (0-6") — Depth (inches)

Record Cropping System Information – Each landowner is interviewed annually (generally during the fall sampling) to determine field history, planting dates and rates, cropping sequence, yields, herbicide use, soil amendments (fertilizers, etc.), soil testing, grazing history, irrigation dates and rates, and irrigation scheduling methods. This data is recorded on a three-part form titled "Soil Sampling Information" that both the cooperator and Neal Fehringer sign to verify data accuracy. During each soil sampling and crop harvesting event, a "Field Inspection Report" is filled out by Neal Fehringer. This report lists the AMPP site inspected; crop in the field; crop stage and condition; weeds, insects, and diseases as well as recommended controls; soil moisture probes; and recommended irrigation start dates. This form is only signed by the agronomist. Copies of both reports are given to the landowners to be filed in their AMPP notebook.

Identify Soil Sampling Locations – During the initial fall 2003 sampling, sample collection locations were selected based on soil mapping information, landowner input, and location of underground utilities, if any. A representative sampling area was designated within the dominant soil series mapped within each field. Two types of samples were initially collected within the designated sampling area: reference soil horizon samples collected from a backhoe pit, and composite samples collected from selected depth intervals.

Reference Pedon Description and Sampling (Initial sampling event only) – The reference soil horizon sampling was only conducted once, at program inception. A detailed soil description was developed for each field and soil horizon samples were collected in fall 2003. A trench was excavated to a depth of 60 inches. Soil pit location was identified using a GPS unit. The soil profile was described using methods from *Field Book for Describing and Sampling Soils Version 2.0* (Schoeneberger et al. 2002). Soil samples were collected from each horizon. General landform and vegetation features were also noted. The soil profile and associated field were photographed.

Composite Sample Collection and Handling – Composite soil samples are collected from the same locations periodically during the AMPP sampling program. A composite sampling transect was initially laid out within the target soil map unit for each field using an irregular pattern, which depended on field and soil unit size and geometry. All composite locations were marked with survey flags. One sub-sample was used for each 5 acres of field area, with a minimum of 10 sub-samples per field. The first composite sample was co-located with the reference pedon location. Each composite sub-sample site was located using a global positioning system (GPS). For later sampling events, original field composite sites were located using a survey grade field GPS unit.

A truck mounted Giddings hydraulic probe was used to collect subsamples from six of the seven depth increments (0 to 6, 6 to 12, 12 to 24, 24 to 36, 36 to 60, and 60 to 96 inches) at each sub-sample location. The 0 to 2 depth was obtained by using a six inch wide tile spade. Sub-samples were placed into separate clearly marked collection buckets. When all samples were collected from a field, soil material from each depth was thoroughly mixed and a final composited sample was tagged and placed in a plastic bag. If the overall sample volume was too large, the final composite sample was obtained by using a riffle splitter. Due to having problems with wet-compacted soil not being able to be broken up fine enough to get through the riffle splitter, all soil was bagged in larger bags in 2008 and 2009. In 2010, samples were split by using an empty bucket and pouring half into the bucket and half outside the bucket for the 36 to 60 and 60-96 inch depths.

Sample Transport - Samples were transferred under chain-of-custody to Energy Laboratories within the appropriate holding period. Samples were stored in coolers or similar containers and sealed with chain-of-custody seals.

2.3 Chain of Custody and Sample Management

All samples were maintained within a chain of custody to prevent tampering with sample integrity. Custody seals were placed on all shipping containers used for transporting samples from the field, and custody sheets corresponded to each batch of samples. After signature by lab personnel indicating release of the samples, chain-of-custody forms were archived.

2.4 Laboratory Methods of Analysis

Standard analytical methods were used for determination of all soil properties as described in (Table 2-1).

Table 2-1 List of Extractions and Analytical Procedure Used for the Tongue River Samples.

Analytical Suite	Analyte	Extraction	Determination see below	Unit? Comments
Preparation All Soil Samples	Oven dry	Air dry or oven dry to constant weight at not more than 50 Celsius	NA	Report air dry water content on weight basis
	Grind	Grind in flail type laboratory mill	NA	
	Sieve	Sieve through ASTM #10, 2mm sieve	NA-	Report coarse fragment weight percentage
	Subsample split	Use riffle type splitter	NA	
Suite 1	pH	Saturation extract [5]	9040 [4]	Standard units
	EC	Saturation extract [5]	D1125-95A [6]	Deci siemens/m
	Soluble calcium	Saturation extract [5]	200.7 [2]	meq/L
	Soluble magnesium	Saturation extract [5]	200.7 [2]	meq/L
	Soluble sodium	Saturation extract [5]	200.7 [2]	meq/L
	SAR	NA	NA	Calculation - (Na/((Ca+Mg)/2)^.5, ions in meq/L
	Chloride (Spring 2004 samples only)	Saturation extract [5]	300.0 [2]	mg/L
	Saturation percentage	Saturation extract [5]	Oven dry	Weight %, oven dry basis
Suite 2	CEC	8-3: CEC of arid soils [5]	200.7 [2]	meq/100g
	ESP	13-3.3.1: Ammonium acetate extract [5]	200.7 [2]	Calculation – (NH_4OAc Extr Na - soluble Na)/CEC, in meq/100g
	texture	Mechanical analysis by hydrometer [5]	Oven dry	8-hr hydrometer method for clay, Weight percent, oven dry basis
	Alkalinity	Saturation extract [5]	2320B [7]	
	Lime (%)	Lime [5] or suitable		Weight percent, oven dry

Analytical Suite	Analyte	Extraction	Determination see below	Unit? Comments
		alternate method		basis
Suite 3	Nitrate as N	KCl extract	353.2 [3]	mg/kg soil
	Sulfate as S	Saturation extract [5]	200.7 [2]	meq/L
Suite 4	Organic matter	Walkley Black [5]	NA	Weight percent, oven dry basis
	Phosphorus	24-5.4: Olson (sodium bicarbonate) [5]	200.7 [2]	mg/kg soil
	Potassium	13-3.3.1: Ammonium acetate [5]	NA	mg/kg soil
	Zinc	19-3.3: DTPA [5]	200.7 [2]	mg/kg soil
Suite 5	Barium	Hot water extract [5]	200.7 [2]	mg/kg soil
	Boron	Hot water extract [5]	200.7 [2]	mg/kg soil
	Fluoride	Hot water extract [5]	4110 B [7] or 300.0 [3]	mg/kg soil
	Selenium	Hot water extract [5]	200.8 [2]	mg/kg soil
Suite 6	Clay mineralogy	NA	NA	Prepare 25 g split sample for submission to outside laboratory

1 – from Methods for Chemical Analysis of Water and Wastes. 1979. (EPA/600/4-79/020) (not used in 2011 report)
2 - Methods for the Determination of Metals in Environmental Samples Supplement 1. 1994. (EPA/600/R4/111)
3 - Methods for the Determination of Inorganic Substances in Environmental Samples (EPA/600/R-93/100)
4 – Test Methods for Evaluating Solid Wastes – Chemical and Physical Methods. EPA SW-846
5 – Agronomy Monograph Number 9 (1984)
6 - Annual Book of ASTM Standards, Vols. 11.01 and 11.02
7 - Standard Methods for the Examination of Water and Wastewater, 18th, 19th & 20th Editions

2.5 Quality Assurance (QA) Samples

Field and laboratory quality assurance samples were used to control and measure the numerical accuracy and precision of the samples collected in Tongue River AMPP (Table 2-2).

Table 2-2 Quality Assurance Samples, Frequency, and Control Limits for the Tongue River Samples.

QA Test	Field or Lab Method	Description	Frequency	Control Limits	Audit Procedure
Blind Field Preparation Duplicate	Field	Split randomly selected sample in field and submit blind to lab	1:20	Precision less than 30% RPD	Flag results that fail
Lab Control Sample	Lab	Run well-mixed field sample in each batch	Min freq of 1:20 or 1/batch	Accuracy 80 to 120% of mean value	Re-calibrate prior to running batch
Lab duplicate	Lab	Randomly selected split sample	Min freq of 1:20 or 1/batch	Precision less than 20% RPD	Flag samples that fail if average concentration in pair is greater than 2 times MDL

QA Test	Field or Lab Method	Description	Frequency	Control Limits	Audit Procedure
Spike Recovery	Lab	Digestate solution spike (not matrix spike), to determine recovery	Min freq of 1:20 or 1/batch	Accuracy 80 to 120% based on % spike recovery	Flag samples that fail if concentration in spiked sample is greater than 2 times MDL

*Precision - Relative Percent Difference (RPD) = 100*abs (Value$_1$ – Value$_2$)/ (Value $_{mean}$)* [1]
Accuracy - Percent Recovery (PR) = 100(Measured LCS Value– Reference LCS Value)/ (Reference LCS Value)* [2]
Accuracy - Percent Spike Recovery (PR) = 100(Spiked Value– Unspiked Value)/ (Spike Level)* [3]

2.6 Use and Distribution of Analytical Results

All analytical results including quality assurance samples are distributed to the public on Energy Laboratory's web site (http://www.energylab.com). Only landowner/cooperators were provided with the code corresponding to their fields. General information about AMPP is available at MBOGC's web site (http://bogc.dnrc.state.mt.us. CoalBedMeth.asp).

2.7 Field Quality Assurance (QA) Results

Blind field samples were collected during each sampling event at a frequency of 1 in 20 samples. Duplicates were initially selected at random and were collected by splitting a prepared sample in the field using a riffle-type splitter. Paired samples were submitted "blind" to the laboratory meaning that they did not know what natural sample to which a QA sample corresponded. Wet weather in 2006 made sample splitting difficult and apparent differences in field duplicate samples resulted. In 2007 duplicate samples were chosen in the laboratory so that the duplicate sample could be split from a pulverized, dry sample. Starting in 2008, the entire Giddings core sampling process was duplicated for creation of the blind field duplicate sample. The 2008 and later duplicate samples would be expected to have somewhat greater variability than earlier duplicates due to change in sample collection.

Sample results were compared using relative percent difference, which is a measure of the precision of the sample splitting process and the laboratory sample management and analysis (Eqn [1]). The control limit developed for blind field samples was 30%.

Precision - Relative Percent Difference (RPD) = 100*abs (Value$_1$ – Value$_2$)/ (Value $_{mean}$) **[1]**

With the exception of nitrate, sulfate and CEC determinations (Table 2-3), overall average results were within control limits established for blind field duplicates. The cause for the poor reproducibility of nitrate, sulfate and CEC determinations will be investigated and corrected, if possible. A number of analytical measurements had precision between 20% and 30%, which although meeting QA control limits indicates that care must be exercised when assessing small differences in these measurements. Parameters with average relative percent differences of 20% to 30% included soluble calcium, magnesium and sodium; SAR; ESP; phosphorus; and lime.

All blind field duplicates for saturation percentage, pH, lime, organic matter, ammonia acetate extractable potassium, DTPA extractable zinc, and water soluble boron and fluoride were within control limits. A variable number of individual data pairs differed by more than 30% including 19 of 66 determinations for soluble calcium, 20 of 66 for magnesium, 19 of 66 determinations for soluble sodium, and 19 of 63 measurements of exchangeable sodium percentage.

Based on QA measurements (Table 2-4), individual measurements of soil parameters that use standard laboratory techniques may be expected to vary from a duplicate analysis by an average of 19% and can vary by more than 30% (Figure 2-1). The potential magnitude of sampling and laboratory error must be considered when comparing results of samples collected on different dates. Differences of up to 30% may result from variation caused by standard sampling and laboratory practice and may not reflect actual changes in soil properties. For example, fall 2006 samples had much poorer QA results (35.2% average RPD) than other sampling campaigns. Internal laboratory QA results for fall 2007 were consistent with earlier groups of samples, so poor results in 2006 were likely the result of the aforementioned difficulty with splitting wet samples, incorrect sample labeling or sample mismanagement after collection. Results in 2007 improved to an average of 15.2% relative percent difference, although soluble ions had poor reproducibility in 2007. At least one sample pair in 2007 (site DA 24 to 36 inches) had such poor agreement that one sample of the QA pair may have been mislabeled or corrupted in the lab. Overall average RPD increased to 28.8% in 2008 but decreased in 2009 to 18.5% and was 20.3% in 2010 which is similar to the 2005 to 2009 average of 22.6%. A graphical comparison of 2010 RPD's with all data is provided in Figure 2-1.

Collection of a large number of samples using careful collection techniques, such as employed in AMPP, reduces the effects of sampling and analytical variability (which are random and unbiased) so that changes in soil chemistry smaller than 15% to 30% can be detected. Additionally, use of a rigid QA program provides appropriate feedback to maintain careful sampling, sample management, and laboratory technique.

Table 2-3 Summary of Field Quality Assurance Analysis of Blind Field Duplicates Expressed as Relative Percent Difference Among Data Pairs.

Parameter	Overall (Max pairs=67)	
1 : Saturation Percentage	**5.3%**	63
1 : pH (Paste)	**1.4%**	63
1 : Electrical Conductivity (Paste)	**19.8%**	67
1 : Calcium (Paste)	**26.6%**	66
1 : Magnesium (Paste)	**26.9%**	66
1 : Sodium (Paste)	**28.7%**	66
1 : Sodium Adsorption Ratio	**21.0%**	66
1 : Alkalinity (Paste)	**13.5%**	29
1 : Chloride (Paste)	**18.2%**	33
2 : Cation Exchange Capacity	**46.4%**	28
2 : Exchangeable Sodium	**11.3%**	63
2 : Exchangeable Sodium Percentage	**23.1%**	37
2 : Lime as CaCO3	**26.1%**	63
2 : Sand	**5.6%**	62
2 : Silt	**19.3%**	61
2 : Clay	**6.4%**	61
3 : Nitrate as N	**38.1%**	18

Parameter	Overall (Max pairs=67)	
3 : Sulfate (Paste)	**30.5%**	19
4 : Organic Matter	**5.9%**	3
4 : Phosphorus	**22.2%**	3
4 : Potassium	**3.8%**	2
4 : Zinc	**3.8%**	2
6 : Barium	**8.6%**	3
6 : Boron	**16.3%**	4
6 : Fluoride	**4.6%**	6
6 : Selenium	**13.1%**	4
Average Relative Percent Difference	**15.3%**	36

Table 2-4 Detailed Results of Field Quality Assurance Analysis of Blind Field Duplicates Expressed as Relative Percent Difference Among Data Pairs for Last 6 Years.

Parameter	Fall, 2005 (6 pairs)		Fall, 2006 (6 pairs)		Fall, 2007 (10 pairs)		Fall, 2008 (5 pairs)		Fall, 2009 (5 pairs)		Fall, 2010 (5 pairs)	
1 : Saturation Percentage	2.0%	6	10.9%	6	5.0%	6	8.3%	5	7.2%	5	2.8%	5
1 : pH (Paste)	0.4%	6	1.1%	6	1.7%	6	1.8%	5	1.0%	5	2.4%	5
1 : Electrical Conductivity (Paste)	17.7%	6	48.7%	6	31.2%	10	19.2%	5	26.0%	5	27.8%	5
1 : Calcium (Paste)	22.1%	6	55.5%	6	33.1%	9	34.1%	5	29.7%	5	37.7%	5
1 : Magnesium (Paste)	28.2%	6	59.6%	6	43.7%	9	24.9%	5	34.2%	5	28.3%	5
1 : Sodium (Paste)	34.4%	6	62.4%	6	36.5%	9	28.7%	5	29.8%	5	23.0%	5
1 : Sodium Adsorption Ratio	23.0%	6	37.9%	6	25.3%	9	37.0%	5	18.0%	5	12.0%	5
1 : Alkalinity (Paste)	NA		19.5%	6	NA	0	NA	0	NA	0		0
1 : Chloride (Paste)	NA		93.0%	6	18.1%	5	39.7%	5	28.9%	5	40.0%	0
2 : Cation Exchange Capacity	5.5%	6	25.2%	6	11.7%	6	5.6%	5	10.4%	5	6.4%	1
2 : Exchangeable Sodium	16.8%	6	36.4%	6	18.8%	5	13.3%	5	18.4%	4	33.6%	5
2 : Exchangeable Sodium Percentage	28.8%	6	33.3%	6	14.1%	6	20.9%	5	19.6%	5	47.6%	4
2 : Lime as CaCO3	7.2%	6	15.3%	6	7.1%	5	2.7%	5	3.2%	5	2.5%	5
2 : Sand	5.2%	6	25.0%	6	12.4%	5	52.6%	5	35.9%	5	15.7%	5
2 : Silt	5.6%	6	12.4%	6	6.1%	5	12.6%	4	8.3%	5	3.2%	5
2 : Clay	10.1%	6	27.8%	6	10.0%	5	10.3%	5	10.3%	5	7.2%	5
3 : Nitrate as N	NA	-	NA	-	37.2%	3	49.5%	2	11.8%	2	5.5%	1
3 : Sulfate (Paste)	NA	-	NA	-	17.9%	3	95.9%	2	55.9%	2	30.0%	1
4 : Organic Matter	NA	-	NA	-	1.8%	1	NA	0	NA	0		
4 : Phosphorus	NA	-	NA	-	50.0%	1	NA	0	NA	0		
4 : Potassium	NA	-	NA	-	NA	-	NA	0	NA	0		
4 : Zinc	NA	-	NA	-	NA	-	NA	0	NA	0		
6 : Barium	NA	-	NA	-	NA	-	16.7%	1	NA	0		
6 : Boron	NA	-	NA	-	NA	-	NA	0	NA	0		
6 : Fluoride	NA	-	NA	-	NA	-	26.3%	1	NA	0		
6 : Selenium	NA	-	NA	-	NA	-	NA	0	NA	0		
Average Relative Percent Difference	15.2%	6	35.2%	6	15.2%	10	28.8%	5	18.5%	5	20.3%	2

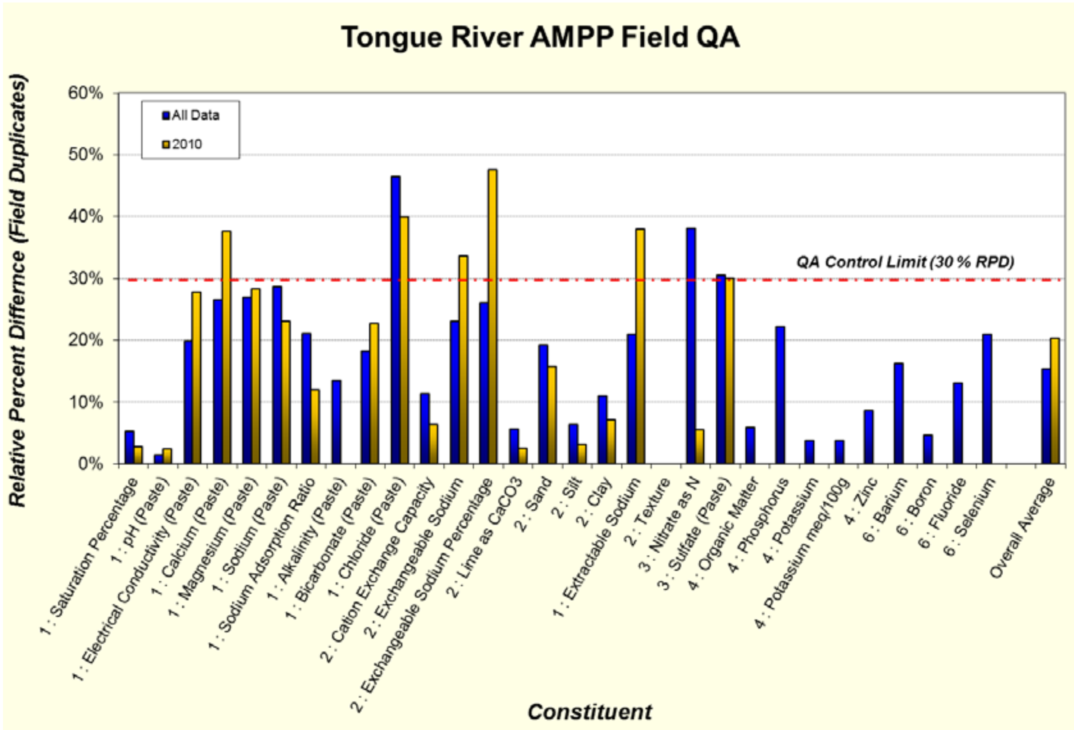

Figure 2-1 Average Relative Percent Difference of Field Quality Assurance Analysis of Blind Field Duplicates.

2.8 Comparison of SAR and ESP

An excess amount of exchangeable sodium can reduce intake rate in soils. Typical threshold of acceptable sodium is 15% of the exchange sites, or an ESP of 15%. Soil ESP can be difficult and expensive to measure in soils and errors have been attributed to ESP measurements in Powder River Basin soils (Ganjegunte and Vance 2006). Measurement of SAR, which is determined from soluble calcium, magnesium and sodium in saturated paste extract, is often used as a surrogate for ESP in assessing sodium hazard.

The theoretical basis for assessing sodium hazard from soluble ions is based on cation exchange processes. Monovalent cations such as sodium can exchange for divalent cations such as calcium or magnesium held on an exchanger such as a clay mineral (Eqn [2]). The proportion of sites occupied on an exchanger (e.g. the mole fraction (X)) can be estimated using the exchange selectivity equilibrium coefficient (K_v) that is specific to the clay mineral and ion pair considered. The Vanselow equation [3] relates mole fraction, equilibrium coefficient, and ion activity. Rearrangement of the Vanselow equation and taking the square root of the expression results in the expression for sodium adsorption ratio in [4]. Therefore, the chemistry of ion exchange indicates that SAR should have a linear correlation with ESP (which is the mole fraction of sodium on the exchange complex).

$Ca^{+2} + 2Na\text{-}X_2 = 2Na^{+} + Ca\text{-}X_2$ [2]
$K_v = ([\alpha_{Na}]^2 / [\alpha_{Ca}])\ ([X_{Ca}] / [X_{Na}]^2)$ [3]
$[Na] / ([Ca]+[Mg])^{0.5}$ [4]

Early work at the US Salinity Lab (1954) established a relationship between SAR and ESP that has been used by most scientists over the last 50 years. In the Salinity Lab equation, a SAR of 12 corresponds to an ESP of 15%. Irrigation water quality guidelines, which are based on SAR, were developed on the basis of this SAR-ESP equation.

Paired SAR and ESP data from AMPP soils do not follow the Salinity Lab SAR-ESP equation, especially at low and high SAR levels (Figure 2-2). In general, the Salinity Lab curve under predicts AMPP ESP for SAR less than 5 and over predicts ESP above a SAR of 5. In general, ESP and SAR correlation is poor indicating that one or both measurements may provide misleading estimates of sodium hazard.

Internal QA results for SAR and ESP measurements were similar with average relative percent difference of 20.7% and 24.4% respectively. Lab procedure for ESP relies on measured CEC as well as "exchangeable" sodium, which are determined by subtracting soluble sodium (from the paste extraction) from extractable sodium. CEC measurements in AMPP are somewhat suspect, especially for low clay soils, because the CEC/clay ratio often exceeded 100 meq/100g, which is considered high for soils with mixed mineralogy. Overestimation of CEC would lead to erroneously low ESP values. For these reasons, AMPP SAR measurements are considered to provide a better indication of sodium hazard than ESP measurements. Ganjegunte and Vance (2006) also concluded that SAR measurements provide more reliable estimates of sodium hazard than ESP in the Powder River Basin. The reason for the unexpected relationship between SAR and ESP in AMPP soils is attributed to abundant calcium and magnesium carbonate minerals that may complicate CEC determination.

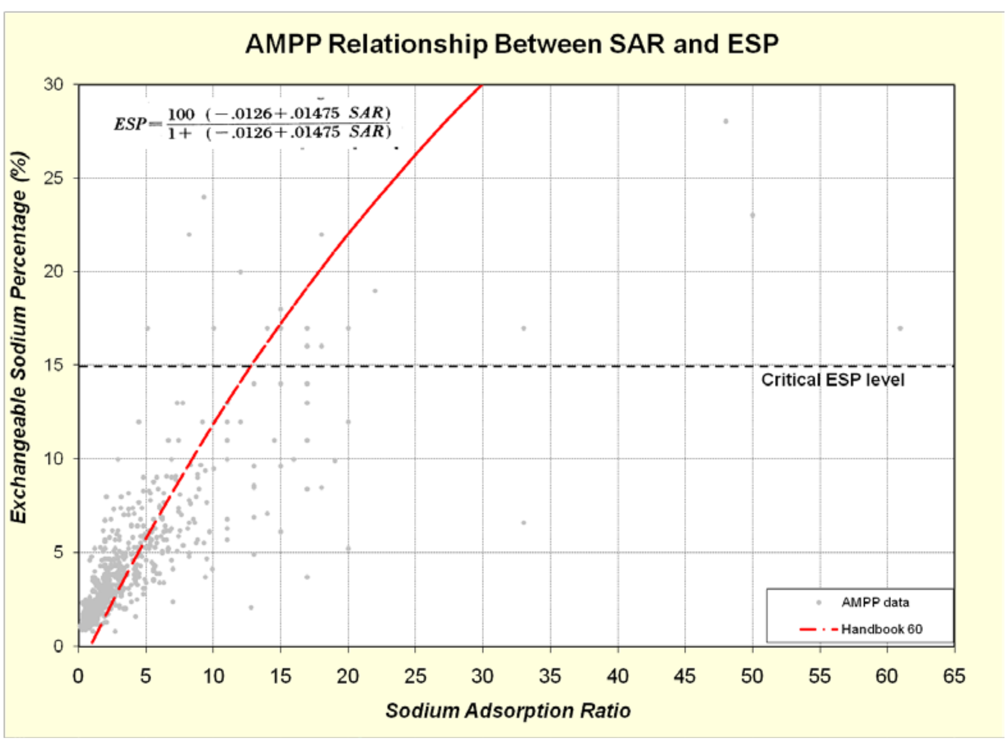

Figure 2-2 Relationship between AMPP SAR and ESP.

2.9 Natural Variability of Soils

Variability of field measurements due to sampling and laboratory techniques was found to account for variations of up to 15% to 30%. Another source of soil variability is natural spatial variation that occurs laterally and with depth. AMPP was designed to minimize effects of spatial variability by using composite soil samples and standardized soil sample depths. However, it is important to understand the magnitude of spatial variability, especially when comparing AMPP data to soils data compiled from other sources.

Soil properties often vary with depth. Natural soil-forming processes and agricultural management tend to amplify differences in soil properties within the soil profile. These changes result principally from the fact that the water content, water movement, temperature, and biological activity in soils all vary with depth.

Surface soil layers typically have more flux of water, have more pronounced seasonal variation in water content and temperature, and have more biological activity (e.g. root mass and microbial activity) than in deeper layers. Through hundreds to thousands of years, these processes tend to increase organic matter levels, decrease pH, and remove soluble salts and lime near the soil surface. Soluble salts, lime, and clay minerals often accumulate within or near the base of the root zone at 24 to 30 inches. Most Tongue River soil properties including physical properties such as texture and chemical properties such as EC and exchangeable sodium percentage (ESP) were found to vary significantly with depth (Appendix C).

Another important factor which influences variability of soil monitoring data is lateral spatial variability. In order to assess spatial variability in AMPP fields, each composite subsample collected in the upper 24 inches from two representative fields were individually analyzed in fall 2003. Field MA, which was 60 acres in size, was sampled using 12 subsamples, while field YAA (19.3 acres) had 10 subsamples. Results of the spatial variability assessment are included in (Appendix C).

2.10 Lab Quality Assurance (QA) Results

The laboratory QA program consists of several steps including instrument calibration and continuing calibration verification, laboratory duplicate determinations, analysis of laboratory control samples, and measurement of the recovery of known amount of constituent added to soil extractions. The laboratory quality control process insures that data are of a known and consistent quality. Inspection of the lab control reports from 2003 to 2010 indicates that analyte spike recoveries, duplicates, lab control samples, and other QA procedures were within established control limits.

3.0 Basin-Wide Trends in Soil Properties

Overall trends in irrigated soil properties are evaluated in this section. AMPP sampling design permitted evaluation of differences in mean soil properties with soil depth (section 3.3.1), differences between AMPP sites (section 3.3.2), and differences in mean soil properties through time (section 3.3). Of these, changes that occur through time are most pertinent to the question of whether CBNG development has affected irrigated soils.

Some soil properties are static by nature and do not change appreciably through time, while others are dynamic and may vary in response to precipitation patterns or agricultural management. Examples of intrinsically static soil properties (unchanged over tens to hundreds of years) are sand, silt, and clay content; lime content; cation exchange capacity; and organic matter content. Organic matter can change if the soil has been recently brought into cultivation or is eroding.

If temporal changes in static properties are detected, then sampling or analytical error are likely causes. Dynamic soil properties are more likely to vary between years because they may be affected by changes in irrigation and/or crop management, climate, or irrigation water quantity or quality (although analytical and sampling errors must also be considered). Examples of dynamic soil properties include EC, soluble cations, SAR, and nutrient content. Detecting time trends in dynamic soil properties is the best way to watch for soil changes that may be associated with CBNG development. In order to attribute soil chemical trends to root causes, however, climate and irrigation water quality for the period of record must be considered.

3.1 Climate and Irrigation Water Quality Data

The Tongue River Basin suffered an extended period of drought that began in the late 1990’s. Drought continued in 2003 and 2004 with precipitation below average for both years in Miles City (Figure 3-1) and Sheridan (Figure 3-2). Rainfall in 2003 was near-normal in the spring but was far below normal in the growing season and through the fall and winter. The pattern was the opposite in 2004 with winter and spring precipitation below normal and growing season rainfall above average. In 2005, and 2007 to 2010 growing season precipitation returned to normal to above normal conditions largely due to high rainfall in May and June. The year 2006 was dry. Rainfall was higher than normal in 2010.

From 2003 through 2007, the annual temperature was also warmer than average at Miles City (Figure 3-3) and Sheridan (Figure 3-4), but only 2003, 2006 and 2007 were warmer than average during the growing season.

The primary concern addressed by AMPP is the potential for irrigation water quality to decrease in quality as a result of CBNG development in the basin. Further, the concern is that change in water quality could cause changes in soil chemistry that reduce or impair crop production and/or increase management costs.

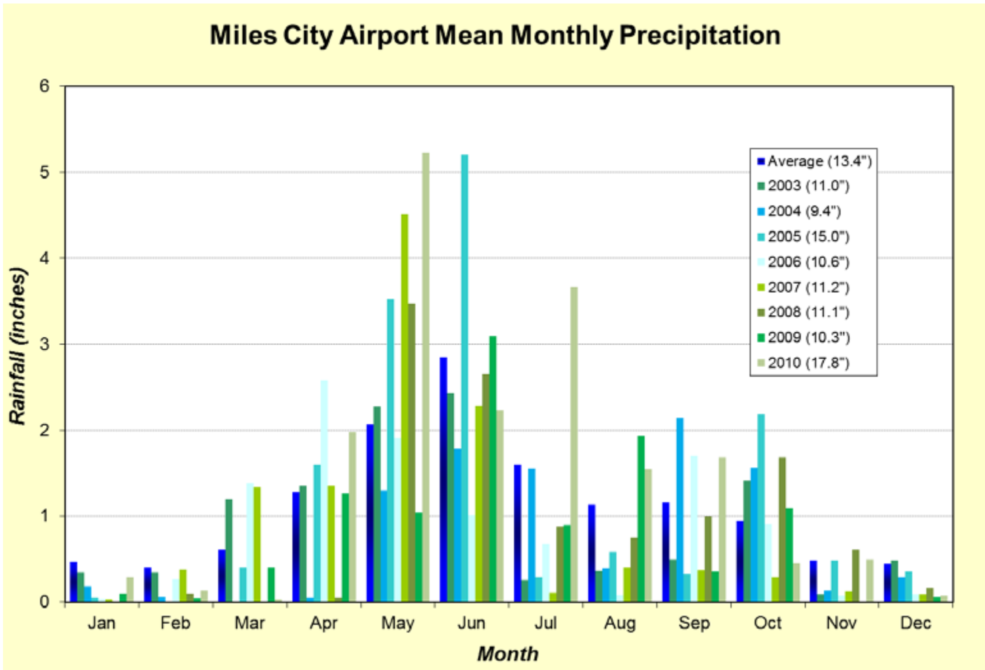

Figure 3-1   Monthly Average Precipitation at the Miles City Airport (NCDC Station 245690) for the 1937 to 2004 Period of Record, 2003 through 2010.

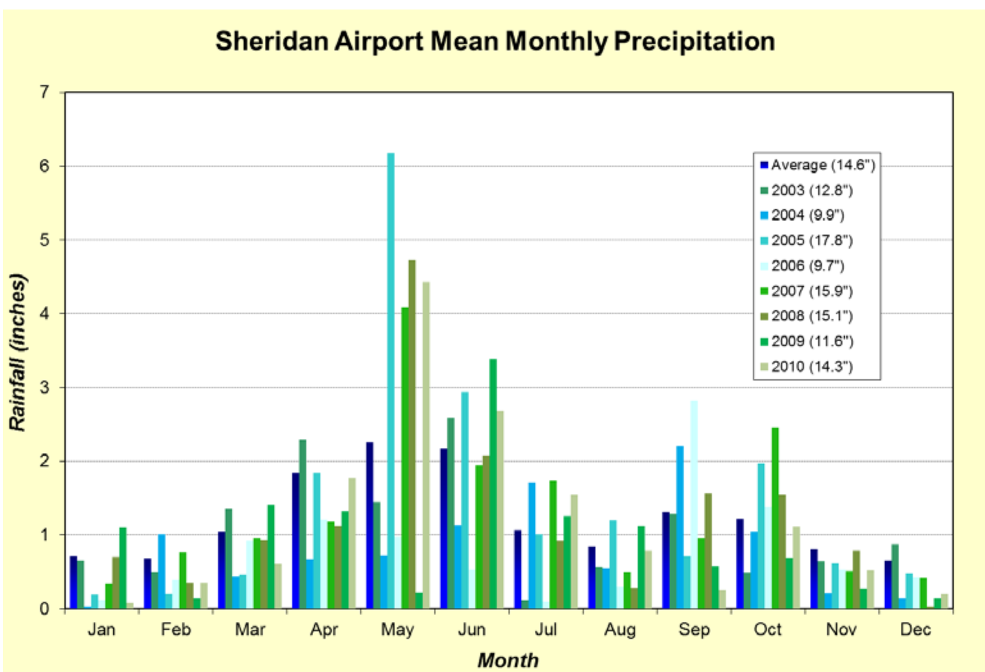

Figure 3-2   Monthly Average Precipitation at the Sheridan Airport (NCDC Station 488155) for the 1948 to 2004 Period of Record, 2003 through 2010.

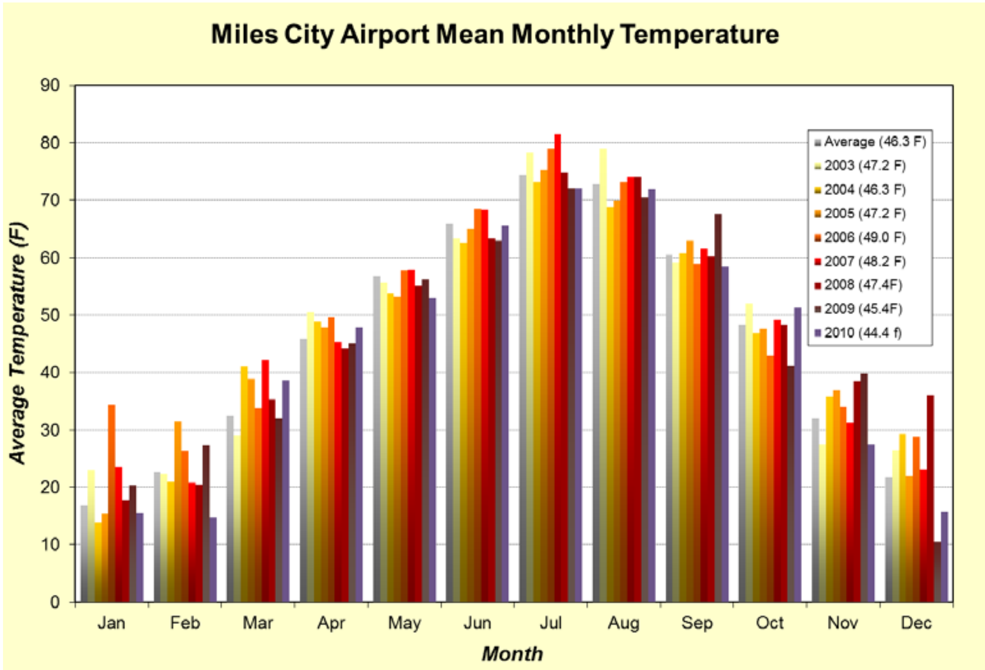

Figure 3-3 Monthly Average Temperature at the Miles City Airport (NCDC Station 245690) for the 1937 to 2004 Period of Record, 2003 through 2010.

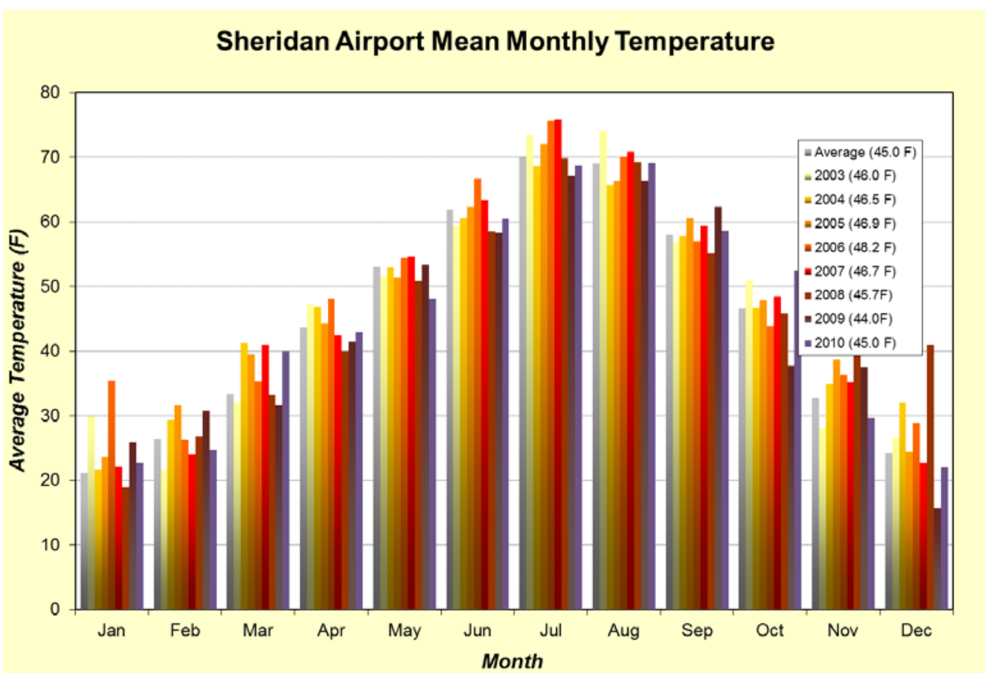

Figure 3-4 Monthly Average Temperature at the Sheridan Airport (NCDC Station 488155) for the 1948 to 2004 Period of Record, 2003 through 2010.

Data collected by the United States Geological Survey were used to estimate the average flow and water quality that occurred in 2003 through 2010, and to compare this data to long term records. Because daily flow and EC data are generally available at a number of stations on the Tongue River, comparison of flow and EC are easily performed. However, SAR comparison is difficult in that calcium, magnesium and sodium ion concentrations were only measured periodically. Therefore, in order to estimate seasonal SAR, the statistical relationship between daily flow and SAR was determined using available data. These flow/water quality expressions were then used to estimate average SAR.

Flow was below average in 2002 through 2006. River flow was well above normal in 2007, 2008 and 2010 and near normal in 2009 (Figure 3-5). Annual flows are based on water quality data collected by USGS (http://tonguerivermonitoring.cr.usgs.gov/). Estimated EC and SAR were both higher from 2002 through 2006 than the long-term average at all stations but were near normal after 2006. This is in keeping with lower than average flow for the 2002 to 2006 period, and the fact EC and SAR tend to increase at lower flows. A gradual decrease in flow and increase in EC and SAR also occurs from the Dam to Brandenburg Bridge. These downstream changes are probably due to the combined effect of natural processes and irrigation withdrawals and return flows. Both tributary waters and irrigation return flows have higher EC and SAR than Tongue River water. Both of these water sources make up a progressively larger fraction of flow when traveling downstream, resulting in downstream EC and SAR increases.

Irrigation water quality varies naturally from year to year even without the influence of CBNG activities. Generally, EC and SAR tend to increase in drier years.

- Changes in water quality that are unrelated to normal annual fluctuations may be caused by other land use activities in the Tongue River Basin. For example, irrigated acreage has increased in recent years, and many fields have been converted from flood to sprinkler irrigation, substantially reducing return flow. Water quality in irrigated basins may be affected by irrigated acreage, irrigation method and quantity of return flow.

- Increases in constituents such as EC and SAR that are critical measures of water quality may not necessarily cause adverse effects on crop production.

It is important to recognize three important aspects of irrigation water quality, namely;

- Comparison of average Tongue River water quality (Figure 3-5) to the irrigation water quality guidelines in Table 3-1 indicates that EC and SAR fall in an acceptable range, with no restrictions on use due to either EC or SAR.

- Tongue River water above the T&Y Diversion generally meets all State of Montana water quality requirements for irrigation water quality.

- Review of the other water quality constituents indicates that there are no potentially toxic ions, trace element, nitrate, bicarbonate or pH problems in Tongue River water.

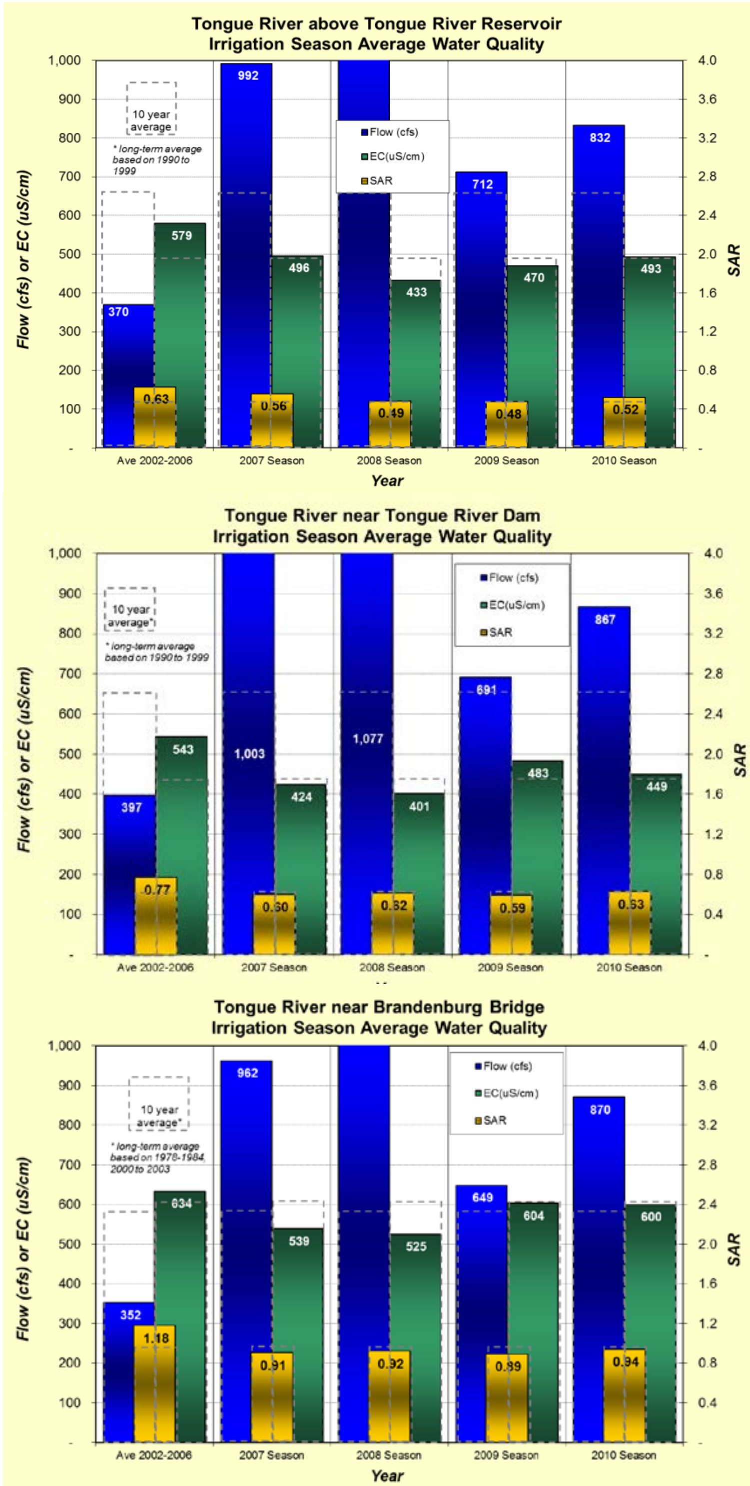

Figure 3-5 Estimated Tongue River Flow, EC and SAR During the May 1 to September 30 Growing Season in 2002 through 2010 (Daily Average Data).

Table 3-1 Interpretation of Irrigation Water Quality (Ayers and Westcot 1994)[1].

					Degree of Restriction on Use		
Potential Irrigation Problem				**Units**	**None**	**Slight to Moderate**	**Severe**
Salinity *(affects crop water availability)*[2]							
	EC_w			dS/m	< 0.7	0.7 – 3.0	> 3.0
	(or)						
	TDS			mg/l	< 450	450 – 2000	> 2000
Infiltration *(affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)*[3]							
SAR	= 0 – 3	**and EC_w**	=		> 0.7	0.7 – 0.2	< 0.2
	= 3 – 6		=		> 1.2	1.2 – 0.3	< 0.3
	= 6 – 12		=		> 1.9	1.9 – 0.5	< 0.5
	= 12 – 20		=		> 2.9	2.9 – 1.3	< 1.3
	= 20 – 40		=		> 5.0	5.0 – 2.9	< 2.9
Specific Ion Toxicity *(affects sensitive crops)*							
	Sodium (Na)[4]						
	surface irrigation			SAR	< 3	3 – 9	> 9
	sprinkler irrigation			me/l	< 3	> 3	
	Chloride (Cl)[4]						
	surface irrigation			me/l	< 4	4 – 10	> 10
	sprinkler irrigation			me/l	< 3	> 3	
	Boron (B)			mg/l	< 0.7	0.7 – 3.0	> 3.0
	Trace Elements (see Table 21)						
Miscellaneous Effects *(affects susceptible crops)*							
	Nitrogen (NO_3 - N)			mg/l	< 5	5 – 30	> 30
	Bicarbonate (HCO_3)						
	(overhead sprinkling only)			me/l	< 1.5	1.5 – 8.5	> 8.5
	pH				**Normal Range 6.5 – 8.4**		

1 - Adapted from University of California Committee of Consultants 1974.

2 - EC_w means electrical conductivity, a measure of the water salinity, reported in deciSiemens per meter at 25°C (dS/m) or in units millimhos per centimeter (mmho/cm). Both are equivalent. TDS means total dissolved solids, reported in milligrams per liter (mg/l).

3 - SAR means sodium adsorption ratio. SAR is sometimes reported by the symbol RNa. See Figure 1 for the SAR calculation procedure. At a given SAR, infiltration rate increases as water salinity increases. Evaluate the potential infiltration problem by SAR as modified by EC_w. Adapted from Rhoades 1977 and Oster and Schroer 1979.

4 - For surface irrigation, most tree crops and woody plants are sensitive to sodium and chloride; use the values shown. Most annual crops are not sensitive; use the salinity tolerance tables (Tables 4 and 5). For chloride tolerance of selected fruit crops, see Table 14. With overhead sprinkler irrigation and low humidity (< 30%), sodium and chloride may be absorbed through the leaves of sensitive crops. For crop sensitivity to absorption, see Tables 18, 19 and 20.

3.2 General Water Quality Characteristics

The proportion of various common ions in water samples is often used to generalize the nature and chemical evolution of water from different sources. Overall similarities and differences in water type provide clues to processes affecting water quality. Four types of water samples from the Tongue River basin were compared using Piper diagrams including Tongue River surface water, shallow groundwater samples from AMPP, AMPP soil extracts, and CBNG produced water (Figure 3-6).

Water from CBNG wells are dominated by sodium and bicarbonate ions while all other waters sampled in the Tongue River basin are calcium-magnesium-bicarbonate trending toward sodium-sulfate type water. Gradual chemical changes that occur in a downstream direction in the Tongue River are reflected on the Piper diagram as an increase in the proportion of sodium and sulfate while calcium and bicarbonate decrease. These changes could not result from introduction of CBNG water, which is bicarbonate dominant.

Introduction of a small amount of shallow groundwater or soil solution (e.g. irrigation return flow) could account for chemical changes observed in the Tongue River as it moves downstream. Both soil solution and groundwater have greater proportions of sulfate and sodium than are found in the Tongue River.

If soil solution or shallow groundwater is derived from Tongue River water applied as irrigation to soils, why do they differ chemically? Evaporation is thought to be the reason for higher proportions of sulfate and bicarbonate in soil water and groundwater. As soil water evaporates, calcium and magnesium carbonate minerals tend to form and calcium and magnesium ions are also removed by ion exchange on clay minerals. Sulfate and sodium tends to remain in solution, accounting for their dominance in soil water and groundwater. Changes in cation and anion composition as a function of increasing salinity is shown in Figure 3-7.

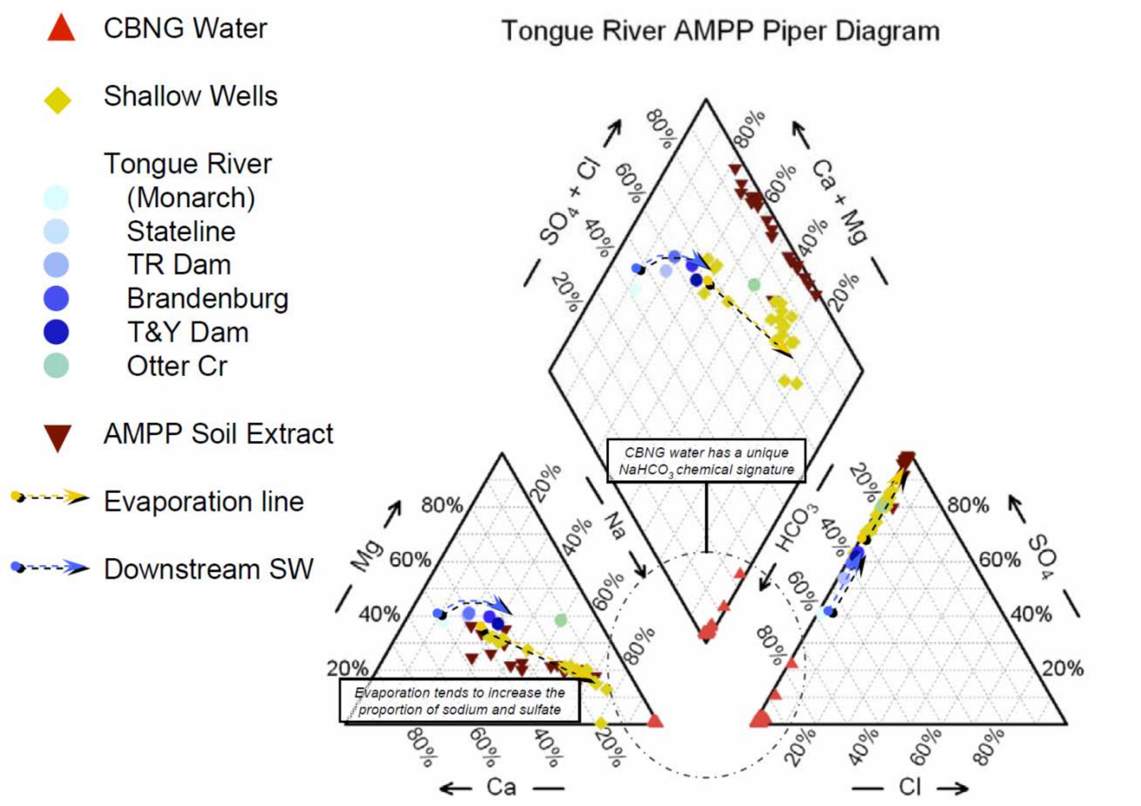

Figure 3-6 Piper Diagram of Various Water Samples from the Tongue River Basin.

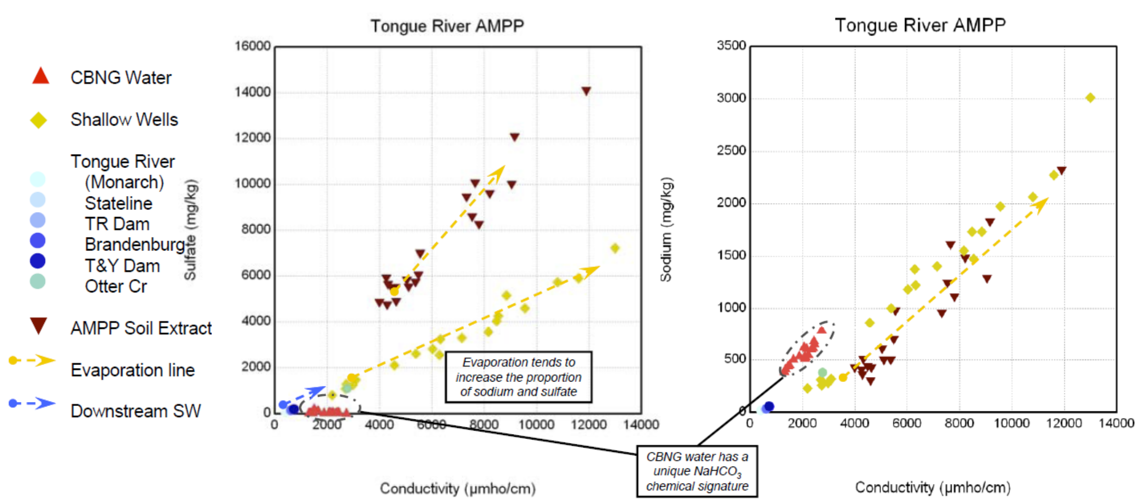

Figure 3-7 Correlation of Sulfate and Sodium with EC in Various Water Samples from the Tongue River Basin.

3.3 Statistical Trend Analysis of Basic Soil Properties

A statistical analysis was performed to determine whether there were any significant changes in soil chemical properties during the project duration from 2003 to 2010. Additionally, the analysis assessed whether soil properties tend to vary in a systematic fashion with depth. The statistical analysis was confined to composite samples from the 10 sites that were irrigated with Tongue River water and only used fall sampling data to avoid potential seasonality effects (Table 3-2 and Appendix E).

The trends through time were analyzed for each soil depth separately using linear mixed effect models (Pinheiro and Bryk 2002). A mixed effect model contains an additional random term in addition to the model error term. In the case of the AMPP data, repeated measures at sites were analyzed as a random term. Model coefficients were estimated using maximum likelihood, optimized iteratively through Expectation-Maximization and Newton-Raphson methods (Lindstrom and Bates 1988). Significance of various linear models formulations was assessed using Akaike's Information Criterion (AIC; Burnham and Anderson 2003), with favor given to the parsimonious model (e.g., less complex – having fewer terms) in situations where AIC scores were within two points of one another. Modeling was carried out using the R statistical environment (R Core Development Team), and specifically the NLME (e.g. non linear mixed effects) package (Pinheiro and Bates 2000). Reports containing all models are included in Appendix E.

Time trends were assessed only for those soil properties most closely linked to potential CBNG impacts; namely pH, EC, soluble calcium, magnesium, sodium, and SAR. These soil properties were modeled singly as unknowns with time of sampling and average clay content included as variables. Time of sampling was coded using values of 1 through 8 for each fall sampling event. Clay content was included as a variate in some model formulations because many landowners maintain that high clay soils are most susceptible to impact from CBNG (Appendix E-1).

In a second step in the time trend analysis, other covariates were included in model formulations to see if their inclusion improved overall model fit. The likelihood ratio test (LRT) was used to determine whether inclusion of other factors caused significant improvement in fit from models developed in the first pass of testing (Appendix E-2). The covariates evaluated in the second pass of modeling included:

1. Fixed effect for average irrigation season streamflow

2. Fixed effect for November-June precipitation in Miles City

3. Fixed effect for season average conductivity, soluble calcium, magnesium or sodium in irrigation water below the Tongue River Dam (as appropriate)

4. Combinations of above.

All measured soil properties exhibited significant statistical variation between soil depths. Only a few soil properties significantly varied with time, however. These included electrical conductivity, soluble calcium, magnesium and sodium.

3.3.1 Depth Variation in AMPP Soil Properties

Statistical analysis showed that soil properties exhibited significant variation with soil depth and between locations (Appendix E). While changes in soil properties with depth differed greatly from site to site, the “average” relationship between various soil properties and depth portrays general depth trends. For example, clay content (Figure 3-8) tended to be higher near surface than at depth, which is typical of fluvial deposits, which “fine upwards”. Conversely, soil pH (Figure 3-9) was slightly lower near-surface than at depth, which is typical of most western soils. At depth, abundant lime tends to control pH around 8.0, while closer to the soil surface; organic matter causes a slightly lower pH.

Average EC increased with depth to about 48 inches, where maximum average value occurred and then decreased slightly from 4 feet to 8 feet (Figure 3-10). EC increasing with depth is typical of both dryland and irrigated soils in semi-arid climates. Infiltration of rainwater or low EC irrigation water tends to maintain low EC levels near the surface. As plant roots extract water from the soil, they absorb mostly pure water and exclude soluble salts. A gradually decreasing proportion of soil water is extracted by plants with an increase in depth of the root zone. Consequently, the greatest accumulation of soluble salts should be expected near the base of the root zone.

The magnitude of increase in salinity that occurs between the top and base of the root zone provides an indication of the proportion of water extracted by plants and the remainder, which percolates through the soil passing the base of the root zone. When the quantity of deep percolation is expressed as a percentage of applied water, it is called the “leaching fraction (LF)” in irrigated soils.

Leaching fraction can be determined from changes in soil EC with depth by applying the simple formula [5] where EC of irrigation water divided by EC of drainage water is the leaching fraction (Ayers and Westcot 1994). The long-term average EC of Tongue River irrigation water is around 650 µS/cm. Drainage water EC can be estimated (Eqn [6]) from measured soil EC by correcting for the difference in water content of a saturation paste extract (water content at which soil EC is measured) and field soil water content in the deep soil horizons (assumed to be at field capacity since deep drainage occurs). The ratio of saturation water content to field capacity (θ_s/θ_{fc}) varies widely but averages around 2.

$$\mathbf{LF = EC_i/EC_d} \quad [5]$$
$$\mathbf{EC_d = EC_e \times \theta_s/\ \theta_{fc}} \quad [6]$$

Average saturated paste extract EC in deep horizons is around 3 dS/m, so average EC of drainage water from irrigated soils is around 6 dS/m. Assuming average irrigation water EC of 0.65 dS/m, the leaching fraction is around 11%. This is the long-term average quantity of leaching compared to the quantity of rainfall plus applied irrigation water. If average rainfall is 14 inches, and applied irrigation is 26 inches, then on average, about 4.4 inches of leaching occurs. Deep water movement will not occur after each irrigation, but is likely to occur during wetter seasons of the year (e.g. March through May), and in wetter years.

The higher EC levels that occur at 3 to 4 feet in depth may result from a temporary accumulation of soluble salts resulting from the recent multi-year drought cycle, because of associated reductions in the amount of applied irrigation water. The accumulation may also be indicative of a shallow water table that impedes removal of salts by deep drainage. The magnitude and timing of leaching may also vary between flood and sprinkler irrigated sites.

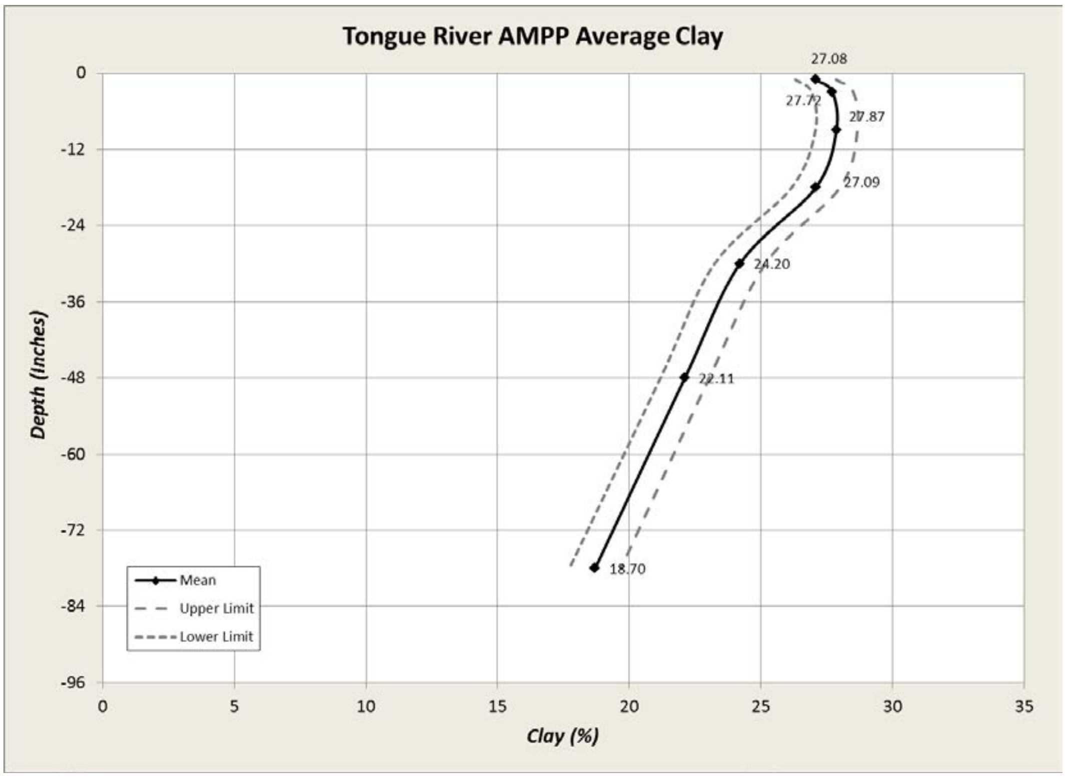

Figure 3-8 Trend in Average Clay Content with Depth in Composite Samples from Fields Irrigated with Tongue River Water.

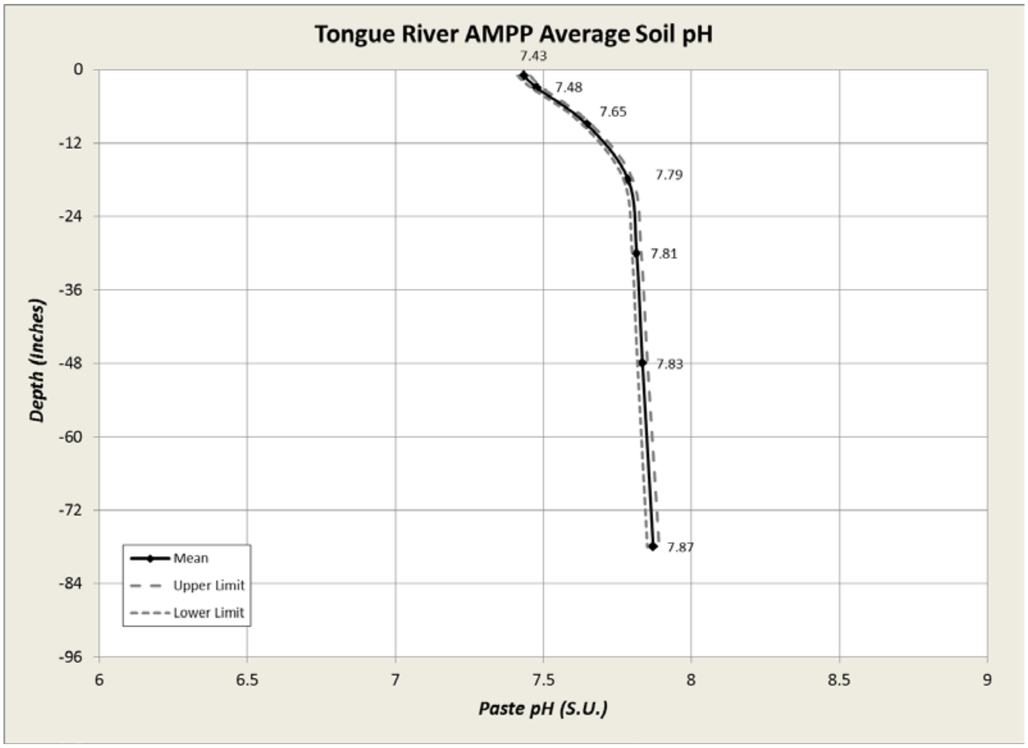

Figure 3-9 Trend in Average pH with Depth in Composite Samples from Fields Irrigated with Tongue River Water.

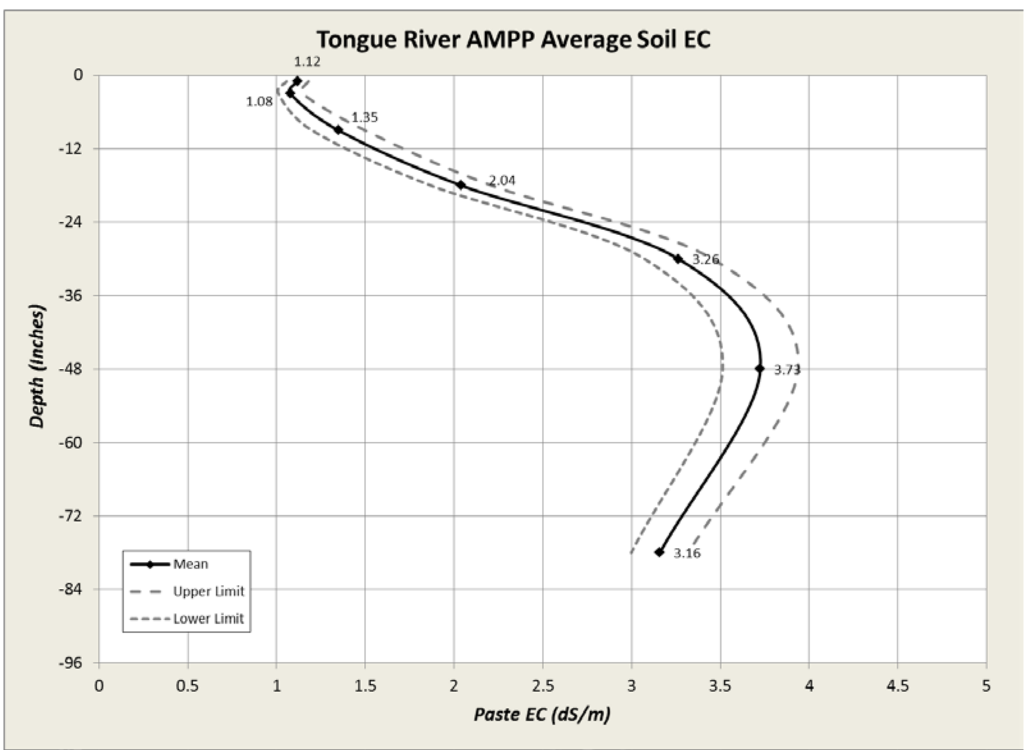

Figure 3-10 Trend in Average EC with Depth in Composite Samples from Fields Irrigated with Tongue River Water.

Average ESP and SAR also increase with depth, but not in the same way as EC. ESP increases more continuously from an average of around 2% near the soil surface to about 8% in the 5 to 8 foot depth (Figure 3-11). ESP increase is in part related to the increased EC at depth. Average soil EC (Figure 3-10) increases from about 1 dS/m to 4 dS/m between the surface and 48 inches in depth. Since average EC increases by a factor of 4, SAR and ESP should increase by a factor of 2 from the surface SAR of 1 or surface ESP of 2%. The actual increase is much larger. The larger increase in ESP is attributed to selective removal of calcium and magnesium from solution due to formation of calcite and magnesium-calcite in deeper soil layers, and to selective removal of ions by clay minerals (e.g. ion exchange).

The more pronounced increase in sodium with depth than calcium and magnesium is illustrated in Figure 3-12. SAR, as expected, also increases with depth and reaches a maximum value in the deepest sampled soil interval (5 to 8 feet) (Figure 3-13).

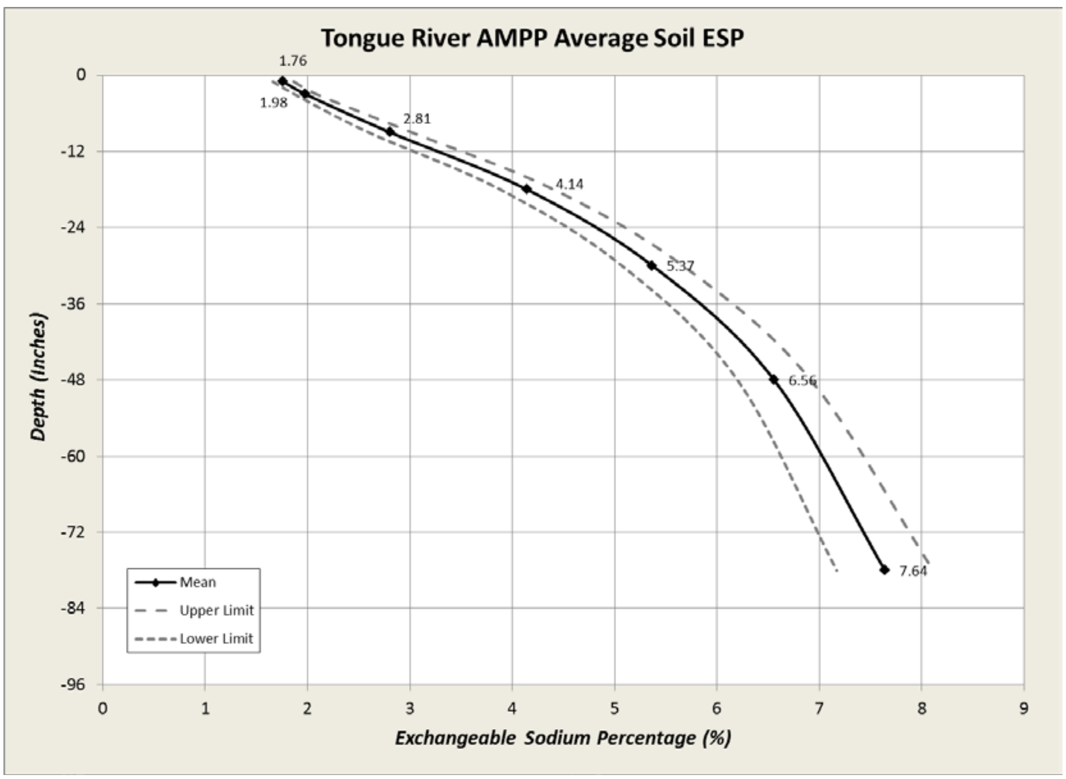

Figure 3-11 Trend in Average ESP with Depth in Composite Samples from Fields Irrigated with Tongue River Water.

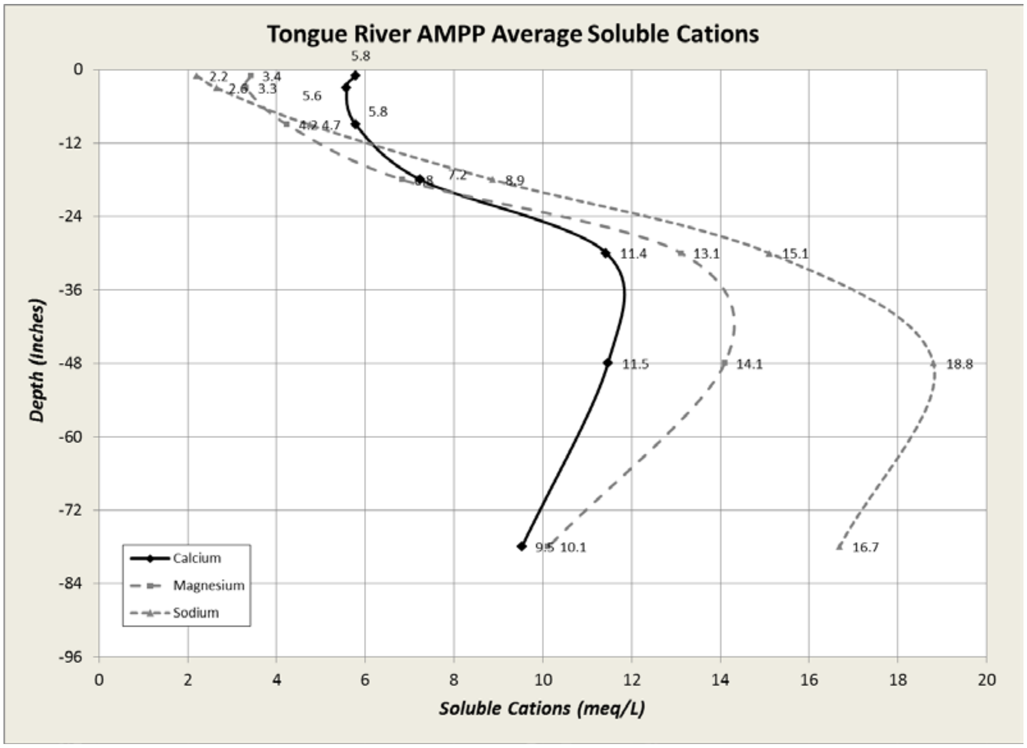

Figure 3-12 Trend in Average Sodium, Calcium, and Magnesium with Depth in Composite Samples from Fields Irrigated with Tongue River Water.

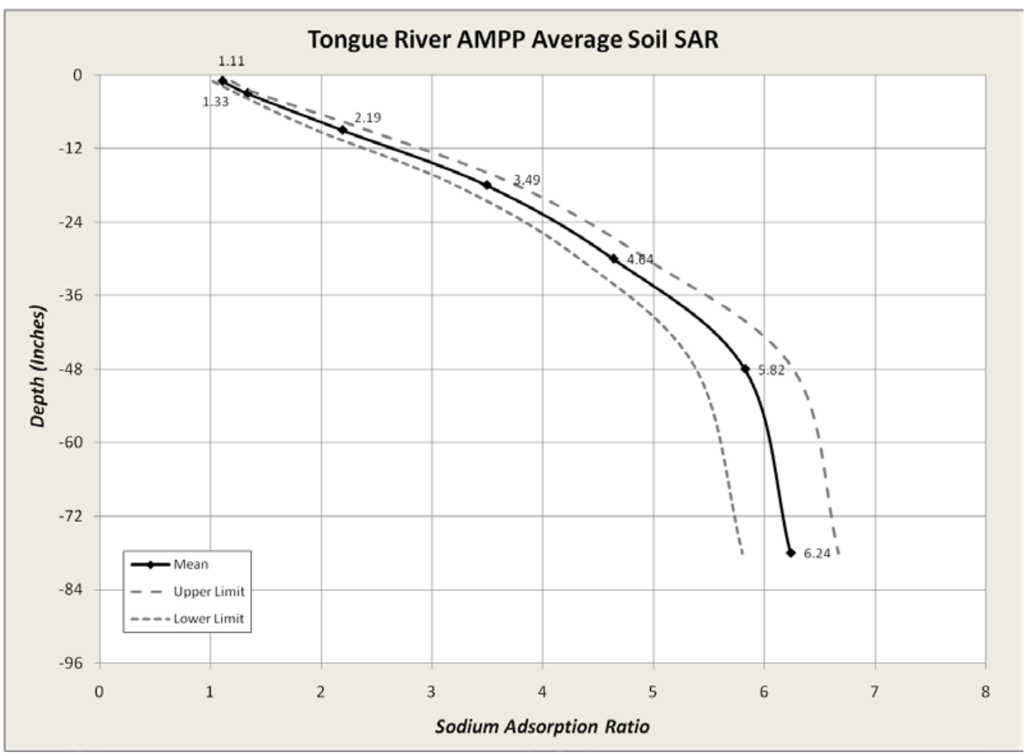

Figure 3-13 Trend in Average SAR with Depth in Composite Samples from Fields Irrigated with Tongue River Water.

Increasing EC with depth is consistent with withdrawal of about 85% to 90% of rainfall and applied irrigation water through crop uptake and evaporation. Additionally, the observed increase in ESP and SAR is attributed to evaporative concentration of salts and due to precipitation of calcite and magnesium-calcite compounds.

A geochemical model was used to determine whether evaporation and formation of soil minerals (e.g. calcite and gypsum) would simulate both the EC and SAR trends observed with depth. The model used, called PHREEQC (Parkhurst and Appelo 1999), is commonly used for geochemical evaluations involving evaporation and chemical precipitation. The composition of typical Tongue River water was input into the model and plant removal of water was then simulated by evaporating the water in steps until only 2% of the original water remained. The model simulations included three differing assumptions about formation of soil minerals. In the first case, no minerals were permitted to form. In the second case, calcite ($CaCO_3$) and gypsum ($CaSO_4 \cdot H_2O$) were allowed to form. In the third case, calcite, gypsum and a calcite phase containing magnesium substituting for the calcium ($Ca_{(1-x)}Mg_{(x)}CO_3$) were allowed to form. All minerals included in the simulations are commonly observed in AMPP soils.

The model results were evaluated in two ways. First, calculated values of EC and SAR derived from the simulated evaporation of Tongue River water were compared to saturated paste extracts obtained from deep horizons of AMPP Tongue River irrigated soils. Additionally, shallow boreholes were installed in selected AMPP fields to observe whether shallow groundwater occurred in AMPP soils, and also to sample the chemistry of shallow groundwater. If deep percolation from irrigated soils reaches the shallow groundwater, the chemistry should be similar to the saturated paste extracts for the deeper soil horizons. The water quality of samples obtained from the boreholes was also compared to model simulations. Water quality data from the shallow boreholes, and depth to groundwater, are presented in Figures 3-14 and 3-15.

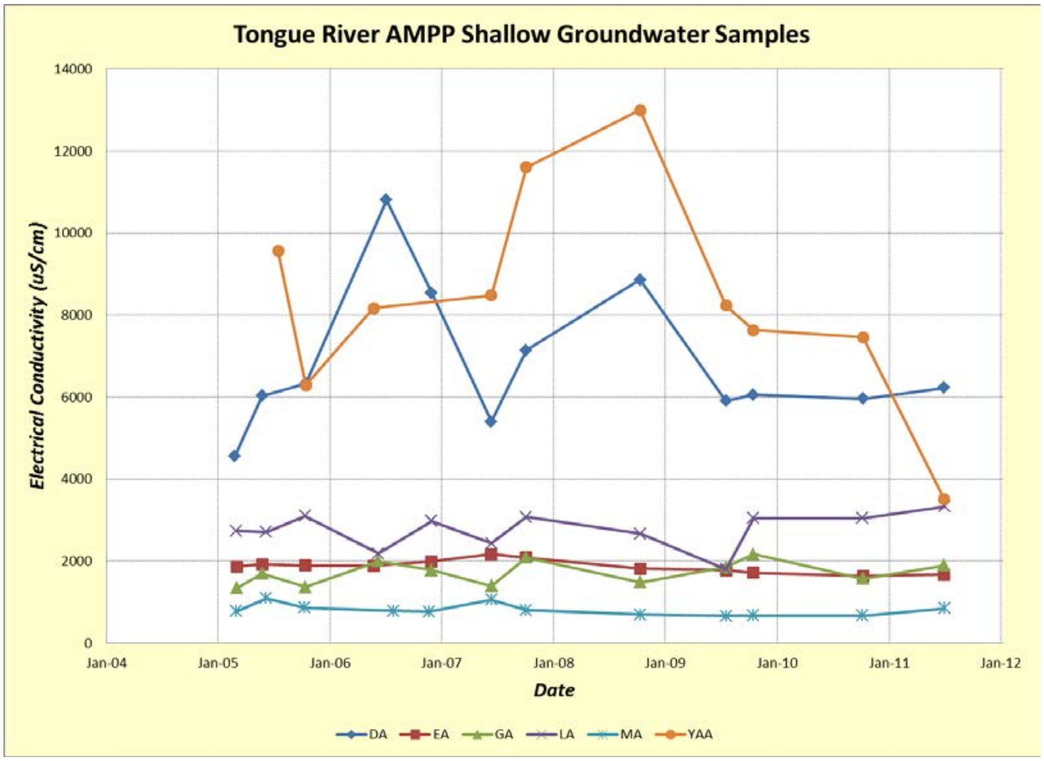

Figure 3-14 Trends in EC in Shallow Borehole Water Samples in Selected AMPP Fields in the Upper Tongue River.

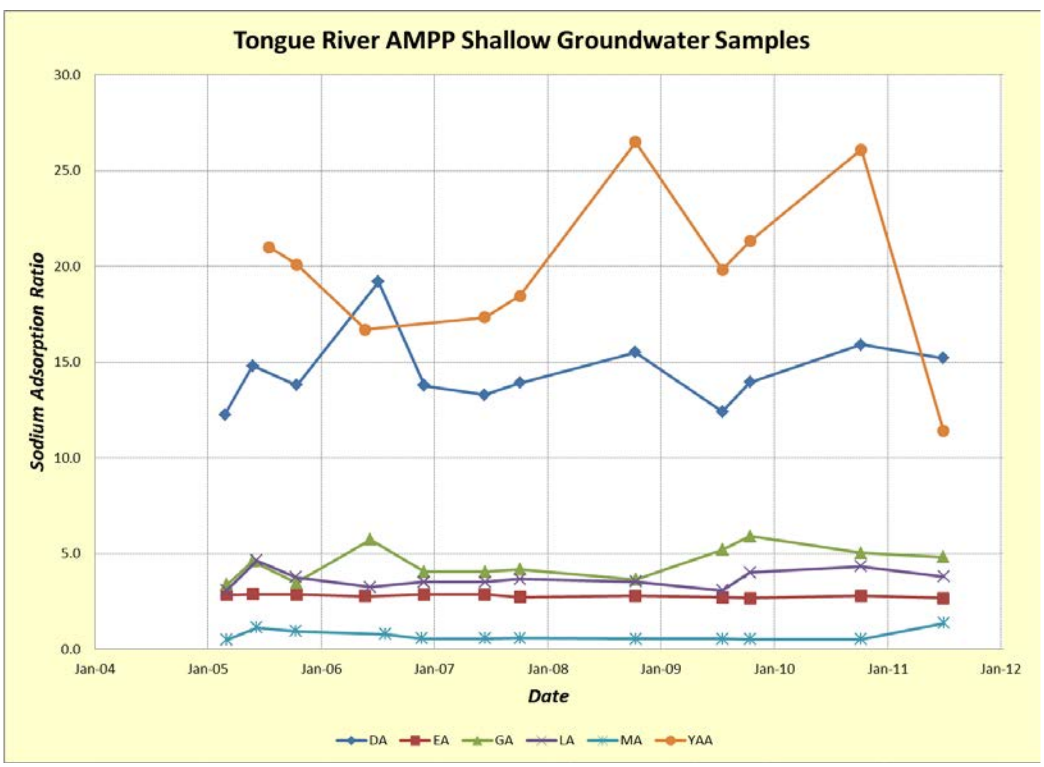

Figure 3-15 Trends in SAR in Shallow Borehole Water Samples in Selected AMPP Fields in the Middle Tongue River.

Results of the geochemical modeling are shown in Figure 3-16, and the ternary diagrams of Figure 3-17. The model shows that if no soil minerals formed, SAR in the deeper soil layers at an EC of 5 to 10 dS/m would only be in the range of 2 to 3. If calcite and gypsum form (which does not remove magnesium from soil water), SAR would range from 3 to 8 in the EC range of 5 to 10. If a magnesium calcite is also allowed to form, then SAR could range from 3 to 17, which is close to the observed range found in soil extracts. The trend in EC versus SAR in soil extracts yielded a slightly higher SAR at a specific EC level than was predicted by the geochemical model. This small difference is attributed to the effects of ion exchange on SAR levels.

The trend in EC and SAR in water samples obtained from shallow boreholes was very similar to observations in soil extracts, which lends support to the hypothesis that shallow groundwater quality is determined by percolation of water from irrigated soils. Additionally, EC and SAR levels observed in deep soil horizons and in boreholes corresponded to a range in simulated leaching fraction from 5% or less to greater than 30%. The most commonly observed EC and SAR values corresponded to a leaching fraction of 10% to 20%.

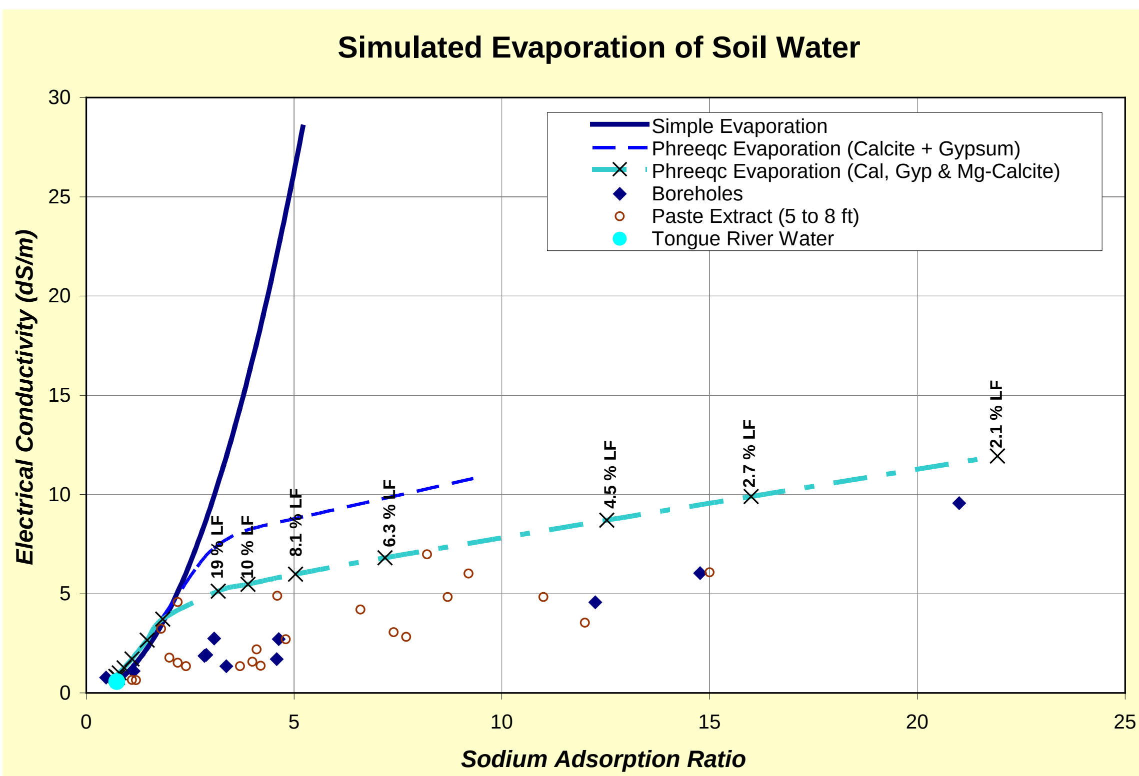

Figure 3-16 Comparison of Simulated Tongue River Water Evaporation to Saturated Paste Extract and Shallow Borehole Water Quality.

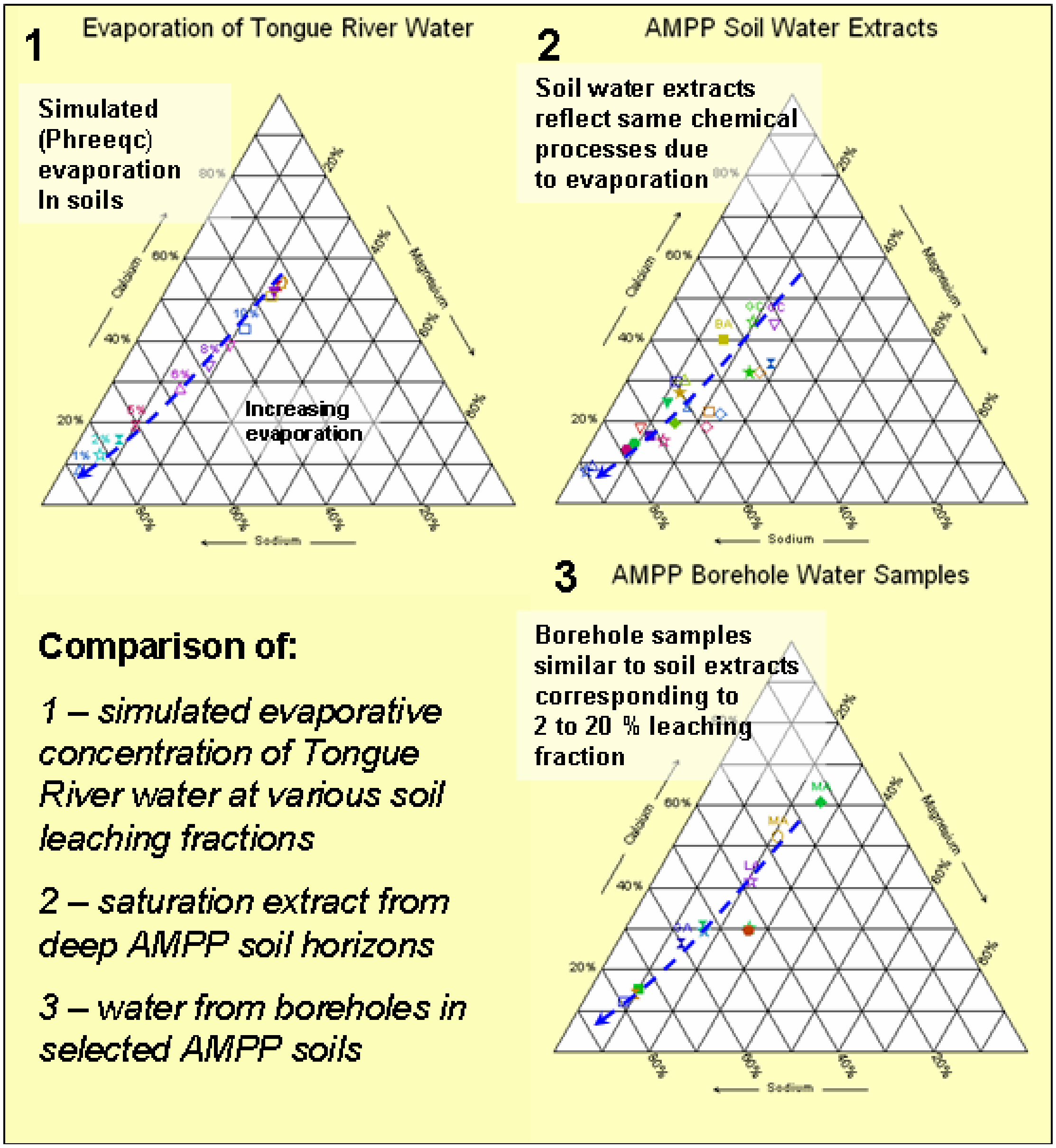

Figure 3-17 Ternary Diagrams of Soluble Calcium, Magnesium and Sodium in Simulated Tongue River Water Evaporation, Saturated Paste Extracts and Shallow Borehole Water Samples.

3.3.2 Differences Between AMPP Sites

Soil properties in fields monitored by the AMPP were highly variable. This is not surprising given the natural variability in soil properties. Differences in physical soil properties such as sand, silt and clay content are likely due to differences in geology and soil development processes. Other soils properties such as electrical conductivity and nutrient status are more unlikely to be affected by differences in agronomic management or CBNG development.

Soil properties that change little through time (sand, silt, clay, saturation water content, organic matter and lime) were averaged for all composite samples to a depth of 36 inches (12 inches for organic matter). Although there are significant differences between sites (Figure 3-18 to 3-23), there is no systematic change with location along the Tongue River. Sand content (Figure 3-18) averaged 25%, but was less than 15% at sites GC, BC, BD, and BHA. Site BD had corresponding higher silt content (Figure 3-19) while remaining sites were higher in clay (Figure 3-20). Average clay content across all sites was only 28%, which dispels conventional wisdom that Tongue River irrigated fields have high clay soils. While a few sites, notable site BC, have relatively high clay content, most soils are medium-textured with loam or silt loams predominant.

Saturation percentage, which is the water content at which soil appears saturated, (Figure 3-21) averages about 40% by weight, and generally parallels clay content. Sandier soils have saturation percentage around 30% while finer textured soils reach as high as 60%. Saturation percentage is important, because it is the water content at which the saturated paste extract solution is prepared. As such, saturation percentage influences measured EC, soluble calcium, magnesium, and sodium levels. As saturation percentage increases, ion concentrations decrease.

Organic matter content (Figure 3-22) varies from 1% to 2% in the upper 12 inches, while lime content (Figure 3-23) ranges from 4% to 10% with a possible decrease in lime content from the upper to lower river.

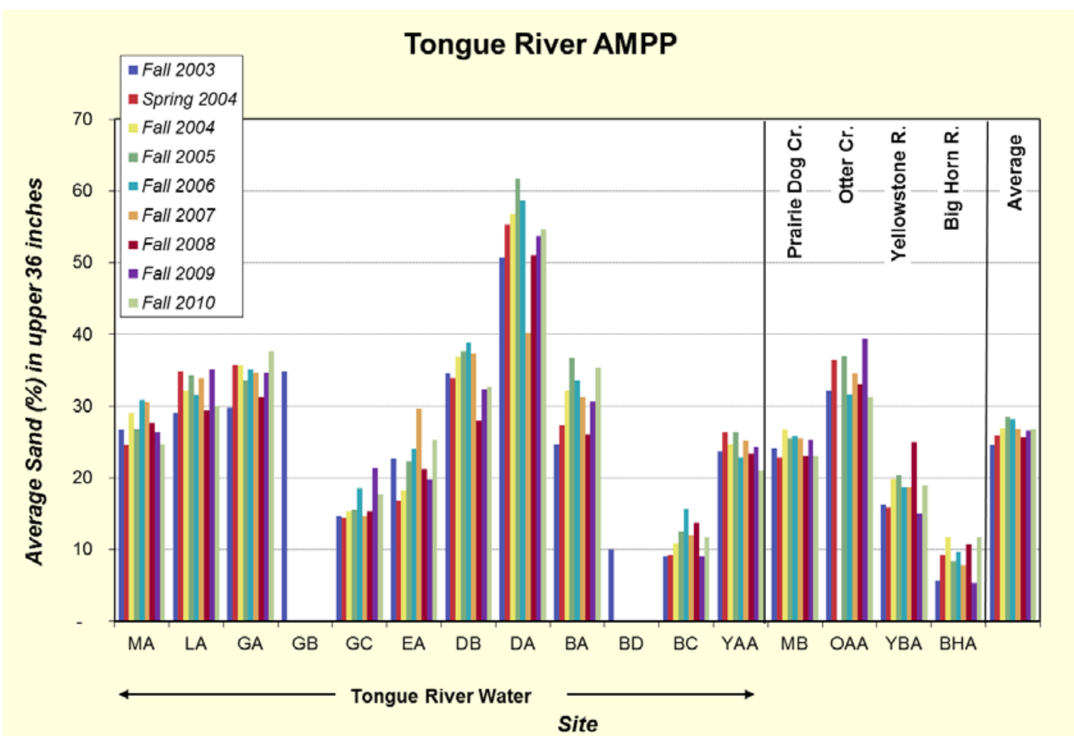

Figure 3-18 Average Sand Content (%) in the <2mm Fraction to 36 Inches in AMPP Sites for each Sampling Period.

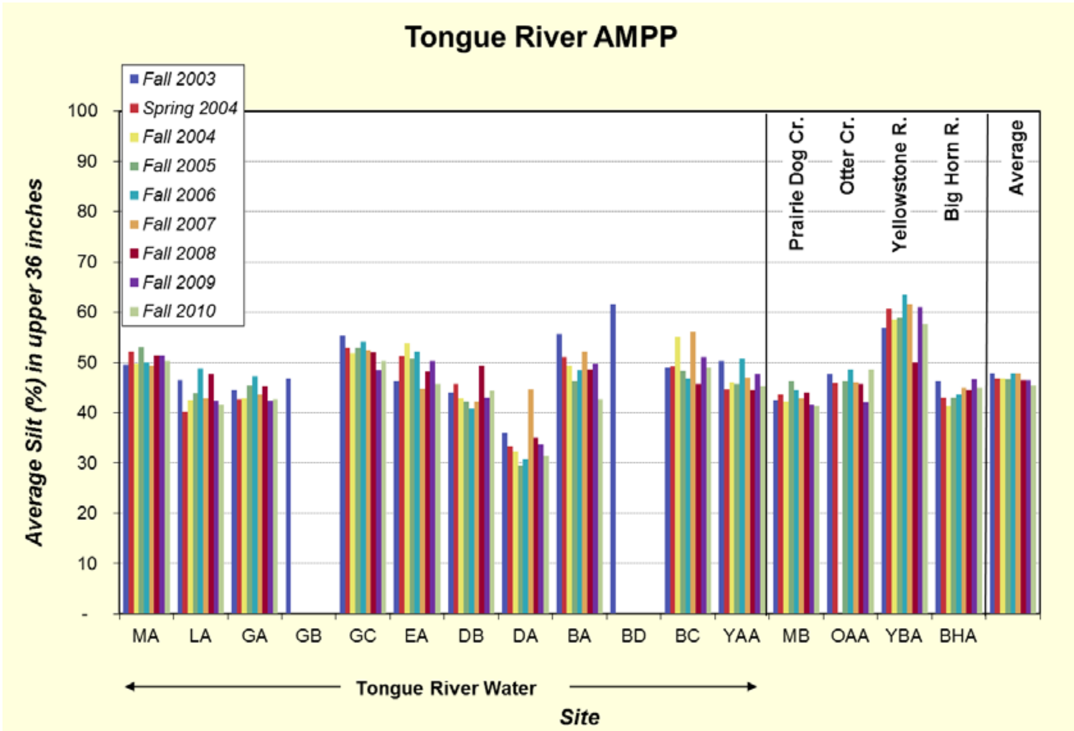

Figure 3-19 Average Silt Content (%) in the <2mm Fraction to 36 Inches in AMPP Sites for each Sampling Period.

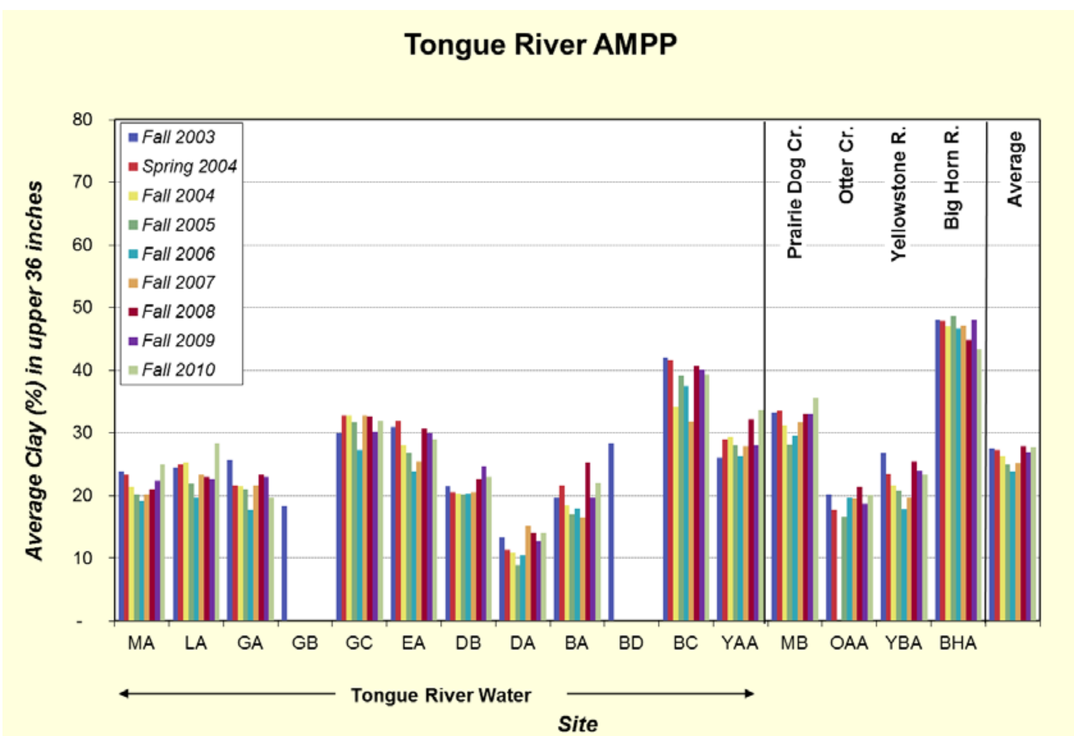

Figure 3-20 Average Clay Content (%) in the <2mm Fraction to 36 Inches in AMPP Sites for each Sampling Period.

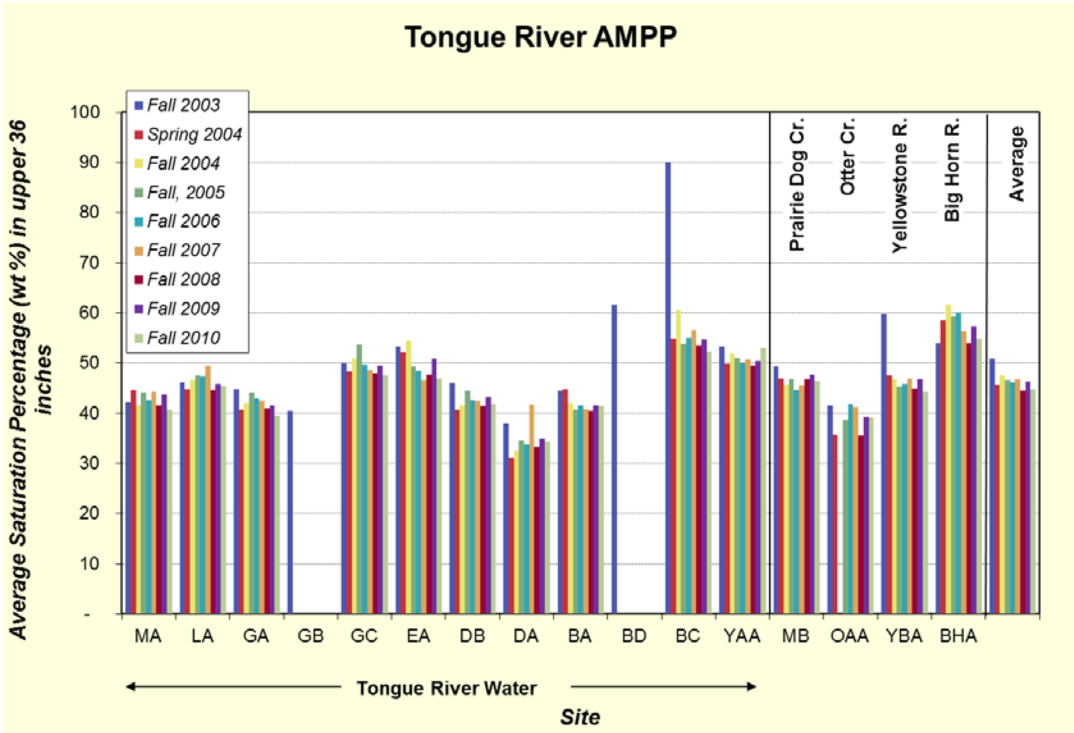

Figure 3-21 Average Saturation Percentage Water Content to 36 Inches in AMPP Sites for each Sampling Period.

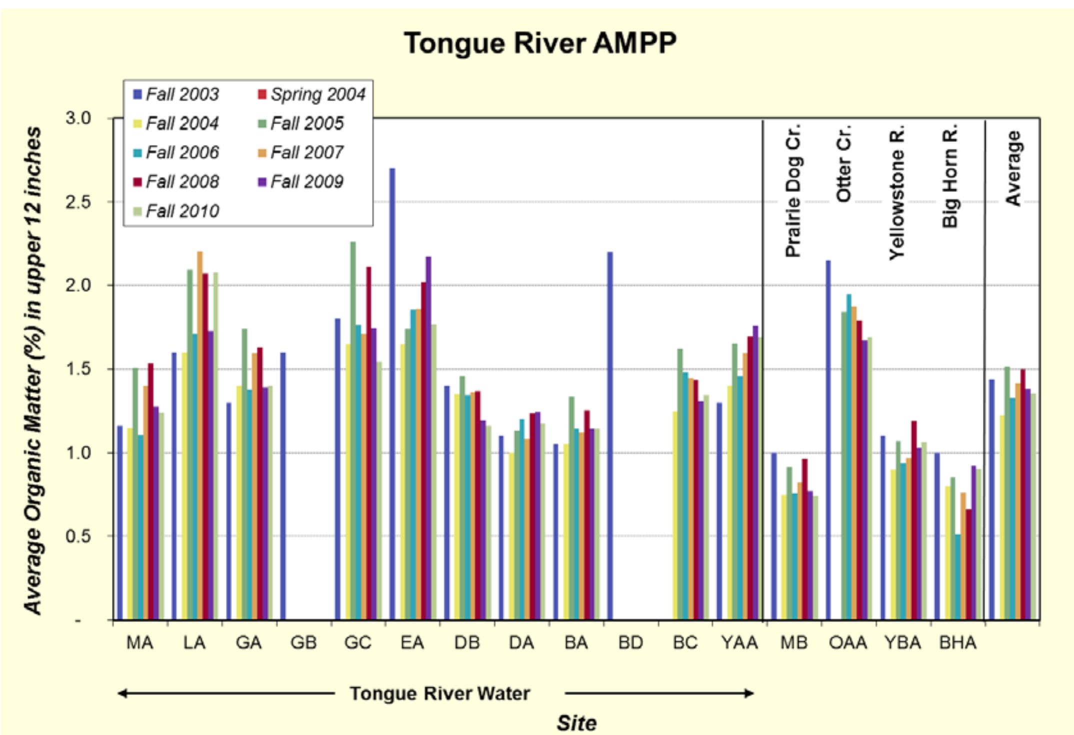

Figure 3-22 Average Organic Matter Content (%) to 36 Inches in AMPP Sites for each Sampling Period.

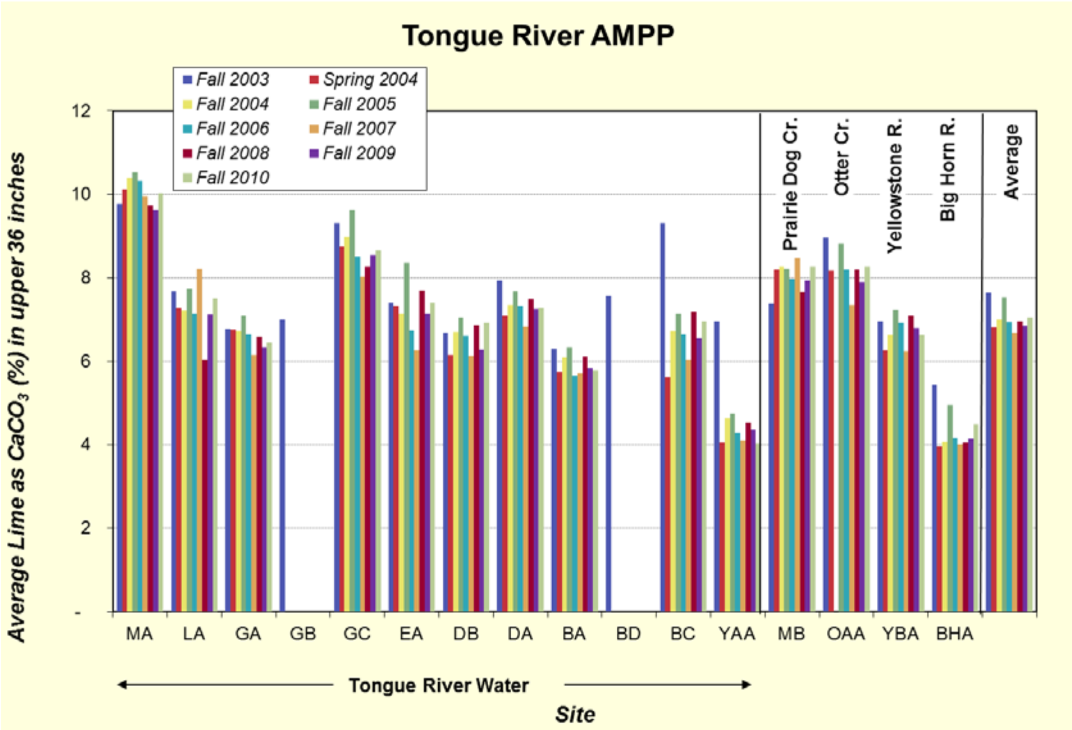

Figure 3-23 Average Lime Content (as CaCO3 %) to 36 Inches in AMPP Sites for each Sampling Period.

Soil pH, EC, ESP and SAR (Figure 3-24 to 3-28) are properties that are more sensitive to short term changes in management, water quality, and climate than the static soil properties discussed above. As such, changes in these properties through time are carefully scrutinized to detect changes due to CBNG development or other factors. The following section discusses time trends in these soil properties. Differences in EC and SAR that exist between sites are described below.

Average pH of all soils (Figure 3-24) fell in a very narrow range of 7.6 to 8.0 that reflects control of soil pH by abundant lime in Tongue River soils. When lime is present, soil pH tends to remain between 7.5 and 8.3 unless very high sodium levels exist. In sodic soils, pH may exceed 9.0.

Depth-weighted average EC in the upper 36 inches is shown in Figure 3-25. The average for all soils was around 2.5 dS/m and most individual fields fell close to this average value. Sites GC, DB, and BA had lower than average EC, probably owing to application of a greater quantity of irrigation water at these sites. Site DA, had higher than average EC, which was probably caused by contributions from tributary runoff onto this field, that prior to 2003 was non-irrigated. In irrigation research, soil EC is often expressed on a “root zone uptake weighted” basis. This approach reflects the fact that most water uptake (about 40%) occurs in the upper 25% of the root zone, and only about 10% of the water is taken up from the deepest part of the root zone (e.g. 36 to 48 inches). Root zone uptake weighted EC (Ayers and Westcot 1991) (Figure 3-26) was similar to depth weighted average EC (in the upper 3 feet of soil).

Depth weighted ESP (Figure 3-27) averaged just over 4% and most soils had field-average ESP values close to this value. The only exception was site DA, which was recently brought under irrigation and which also had high EC values. Greasewood, a common indicator of sodium-enriched soils, is abundant in the vicinity of this field near the mouth of Foster Creek.

Average ESP (Figure 3-27) and SAR values (Figure 3-28) in AMPP soils averaged about 3.5% and 3% respectively. Most soils with the exception of DA, the former dryland site had values that were close to the average values. In general, fields with higher than average EC also had higher than average SAR or ESP.

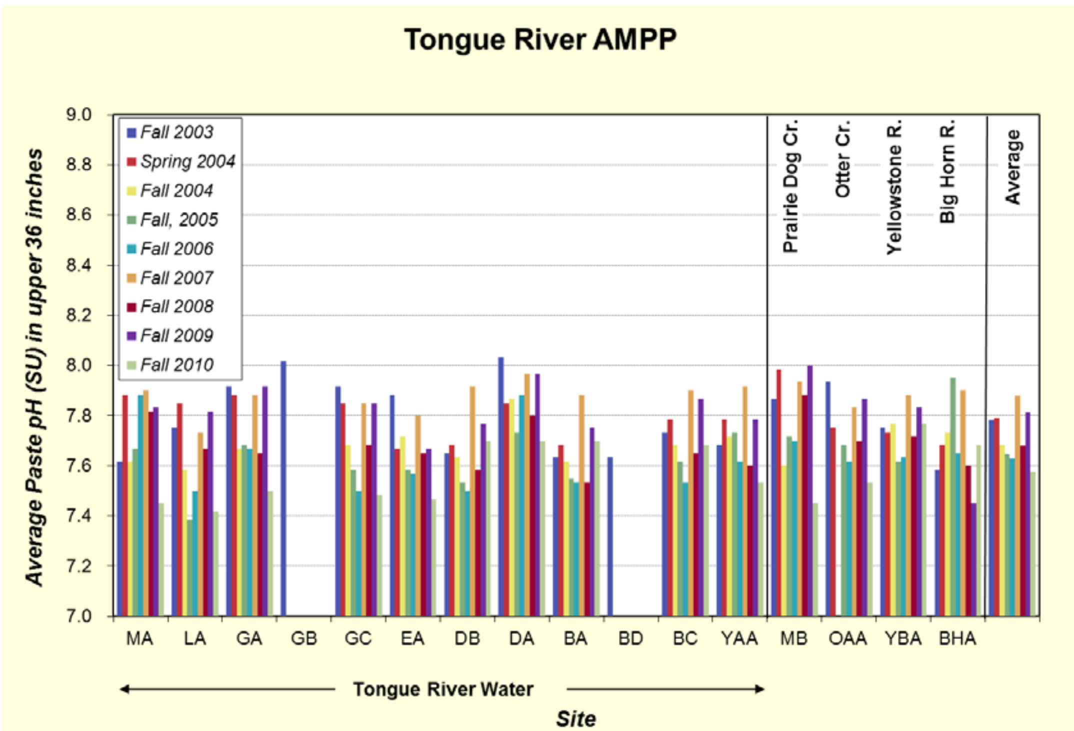

Figure 3-24 Average Paste pH to 36 Inches in AMPP Sites for each Sampling Period.

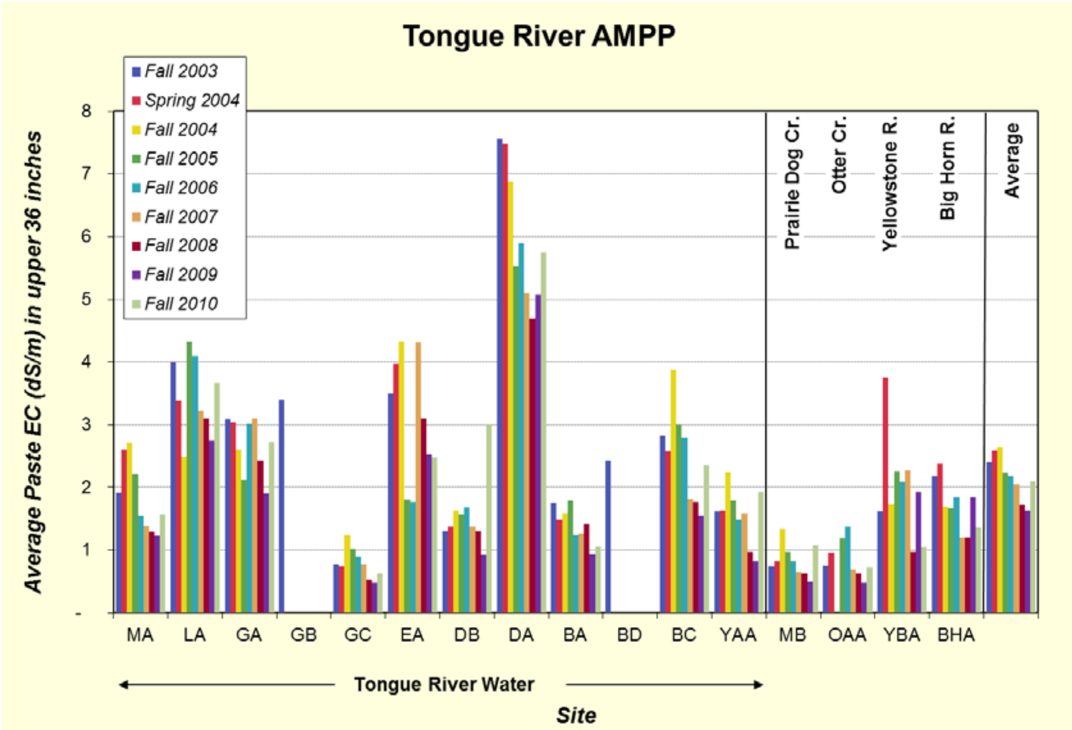

Figure 3-25 Average Paste EC (dS/m) to 36 Inches in AMPP Sites for each Sampling Period.

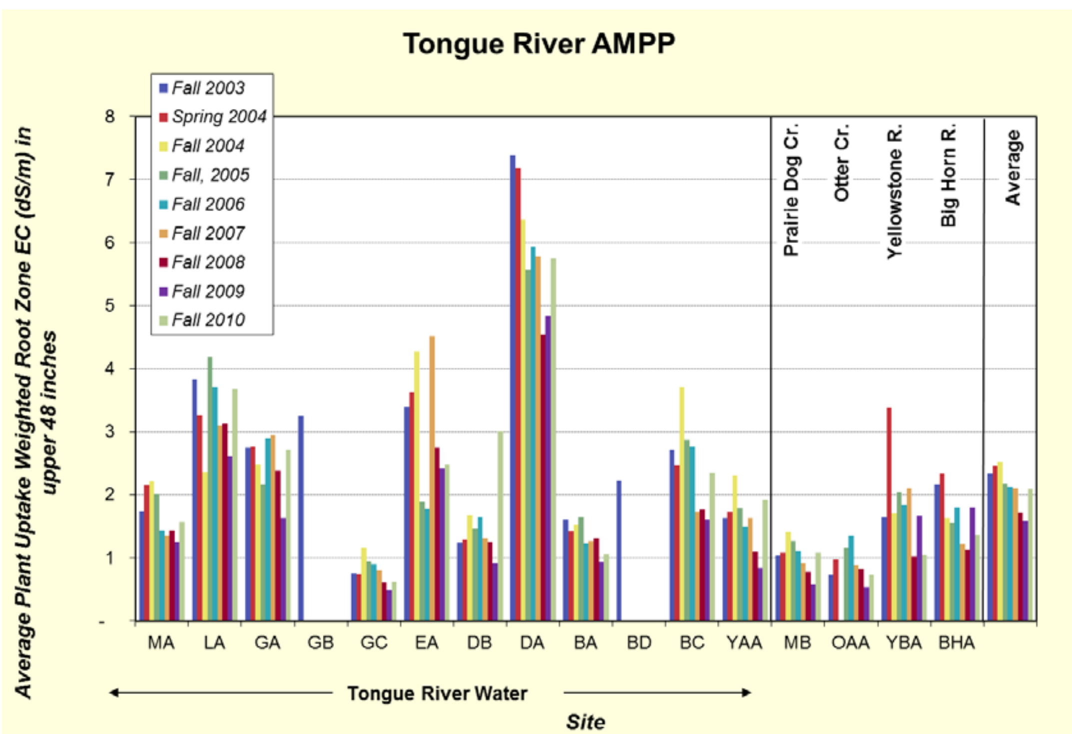

Figure 3-26 Root Zone Water Uptake Averaged Paste EC (dS/m) to 48 Inches in AMPP Sites for each Sampling Period.

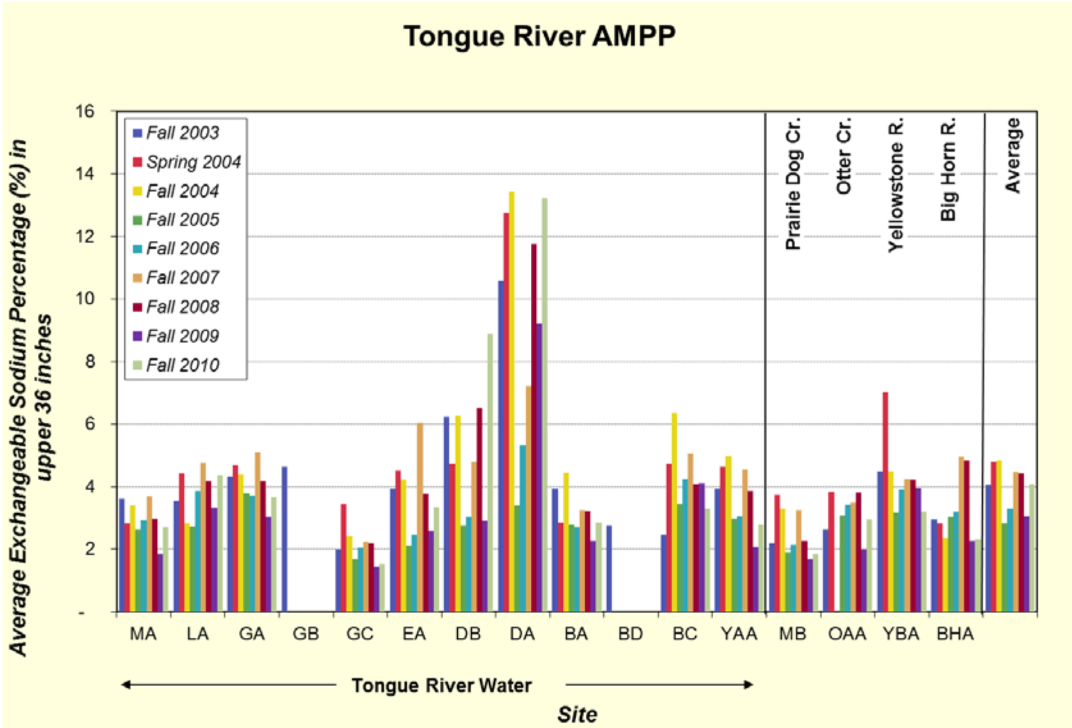

Figure 3-27 Average ESP (%) to 36 Inches in AMPP Sites for each Sampling Period.

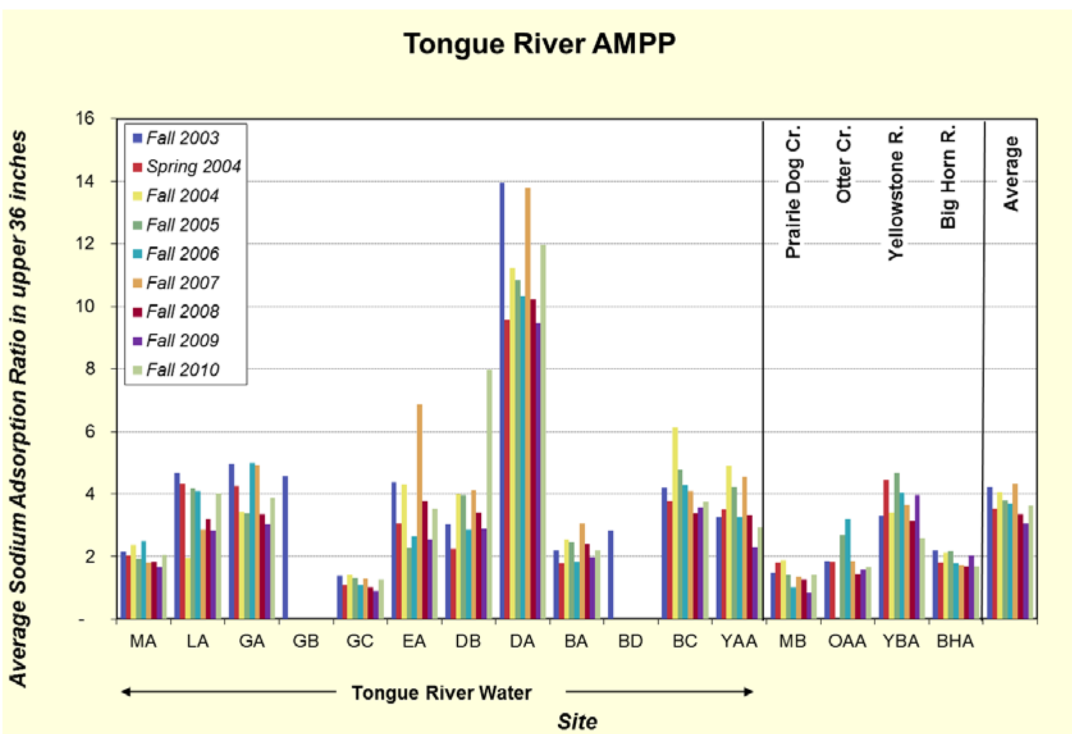

Figure 3-28 Average Paste Extract SAR to 36 Inches in AMPP Sites for each Sampling Period.

3.3.3 Trends in AMPP Soil through Time

Four soil properties exhibited statistically significant changes through time (Appendix E). These were EC, soluble calcium, magnesium and sodium (Table 3-2 and Figures 3-29 to 3-31). In all cases concentrations were found to decrease through time but trends were confined to the upper 36 inches of soil. Below 36 inches, no significant changes were observed. Average EC in the upper 36 inches of soil showed clear downward trends (Figure 3-29) that were especially evident in 2008 and 2009. Even though all soluble ions decreased in concentration through time (Figure 3-30), the SAR, a ratio of sodium over calcium plus magnesium did not exhibit a trend.

A graph of EC by depth at all Tongue River sites (Figure 3-31) showed that EC decreased in most fields in the upper 24 to 36 inches from 2003 to 2010. Below 36 inches in depth no significant overall trends emerged. Some sites increased in deep EC through time (LA and DA), others decreased in deep EC (BC and YBA), and others did not change appreciably. The reference sites (YBA and BHA) showed a weak tendency to decrease in EC from 0 to 12 inches through time.

Table 3-2 Statistical Significance of Linear Mixed Effects Models for 2003 to 2010 AMPP Soils Data[1].

Depth	Electrical Conductivity	Soluble Calcium	Soluble Magnesium	Soluble Sodium
0-2	()	()	()	()
0-6	(–)	NC	(–)	(–)
6-12	NC	(–)	NC	NC
12-24	(–)	(–)	(–)	(–)
24-36	(–)	NC	(–)	(–)
36-60	NC	NC	NC	NC
60-96	NC	NC	NC	NC

NC – no time trend model was statistically significant at p<5%
(–) time trend model was significant at p<5% and there was a decreasing trend with time
1 – One time trend model for soil pH was significant at the 60 to 96 inch depth. It was considered a random occurrence.

Causes for the decrease in EC and soluble ions were further evaluated by considering the effects of Tongue River streamflow and water quality during the irrigation season, and precipitation during the previous November-June period. There were no significant improvements in model fit when these covariates were included in the model. Therefore, decreases in EC, and soluble ions were not significantly correlated with precipitation, applied irrigation water or irrigation water quality. The EC decreases may be caused by a combination of these factors, or due to overall improvements in management attributable to agronomic advising provided under AMPP.

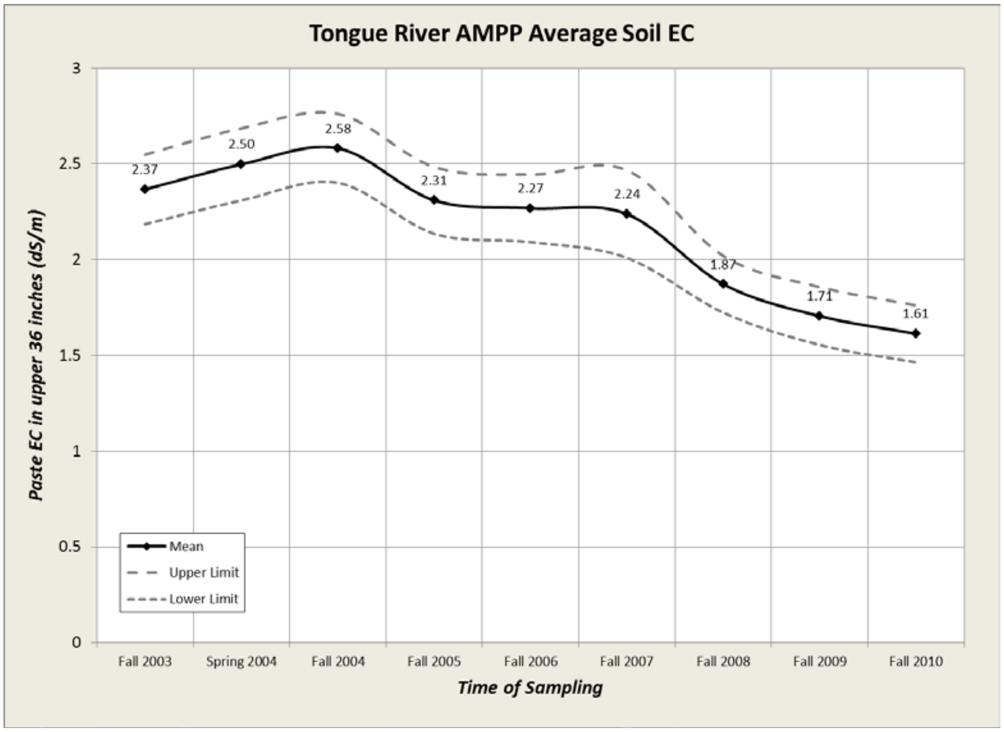

Figure 3-29 Trend in Average EC from Composite Samples Irrigated with Tongue River Water.

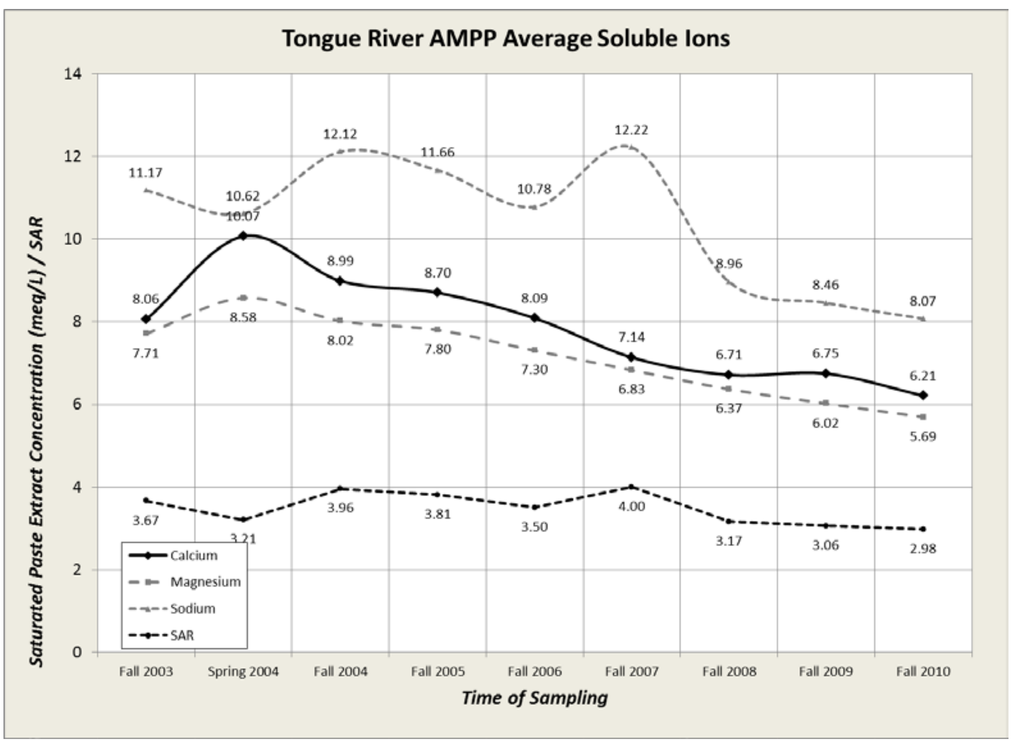

Figure 3-30 Trend in Average Soluble Calcium, Magnesium, and Sodium from Composite Samples Irrigated with Tongue River Water.

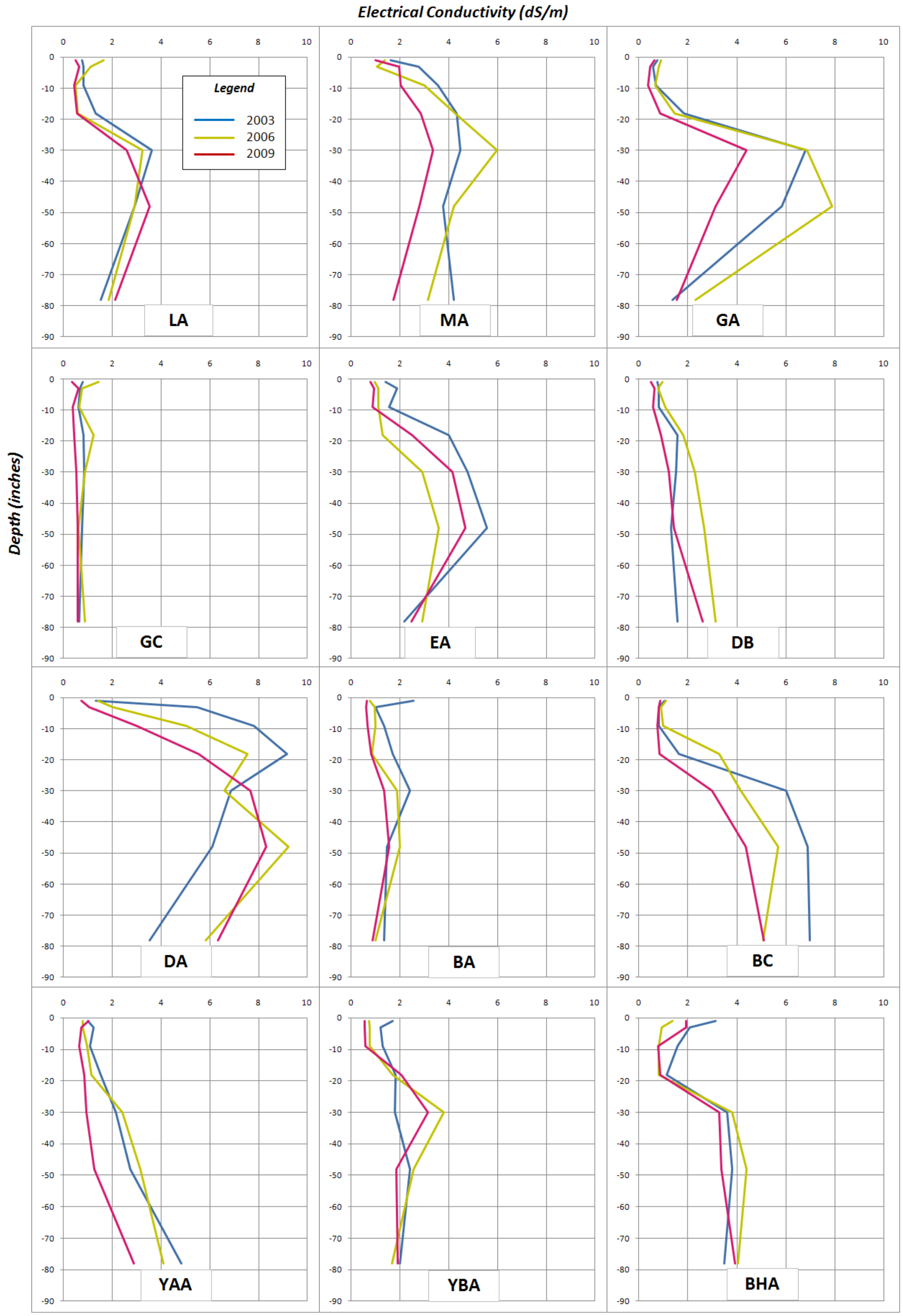

Figure 3-31 Trend in EC by Depth in Irrigated Tongue River and Reference Fields.

3.3.4 Variation in Intake Rate through Time

Soil infiltration or intake rate is an important property for sustained irrigation. Ideal soils should have an intake rate between 0.2 and 2.0 inches per hour (Scherer et al. 1996). Reduced intake rate is symptomatic of sodium induced permeability problems.

Intake rate was measured in selected AMPP soils in fall 2003, spring and fall 2004, fall 2007 and fall 2008. A device called a tension infiltrometer (Figure 3-32) was used to measure intake rate.

Soil hydraulic properties are inherently variable so that even when numerous measurements of a property like intake rate are recorded, estimate of mean hydraulic properties results are still highly variable.

Two to three intake rate readings were collected from all sampled fields on each of the five dates listed above.

Figure 3-32 Device Used to Measure Soil Intake Rate for the AMPP Soils.

In general, there were no statistical differences in intake rate between measurement dates that indicate a consistent trend in intake rate (Figure 3-33). Fall 2004 had a statistically lower intake rate than in previous measurements, but was not significantly different from 2007 or 2008. Some soils had frozen surface layers in fall 2004, which was thought to contribute to the lower intake rate readings. Infiltration measurements in fall 2005 and 2006 were not taken because of frozen soil surfaces and/or zones. Sampling events were in late October 2005 and mid-December 2006.

Additionally, even though average intake rate ranged from 0.4 inches per hour at site BC to 2.0 inches per hour at site DB, there were no statistically significant differences between sites because of large within field variability (Figure 3-34). Nonetheless, all sites had intake rates that were within the range that is suitable for flood or sprinkler irrigation according to Scherer et al. (1996). Intake rates were not measured after 2008 due to the high inherent variability in measurements.

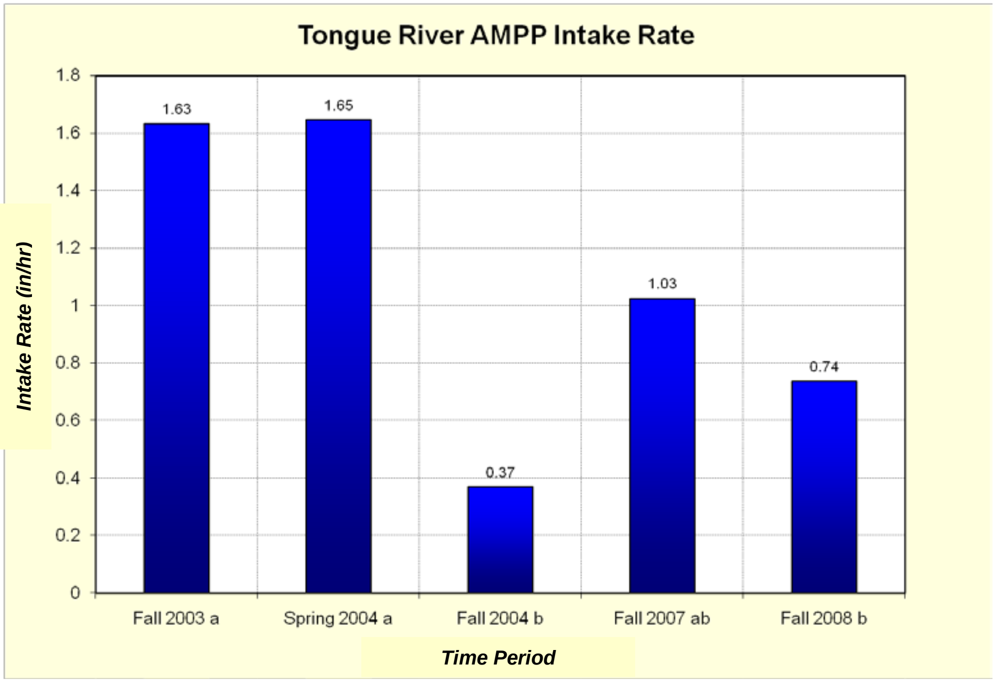

Figure 3-33 Average Soil Intake Rates over Time

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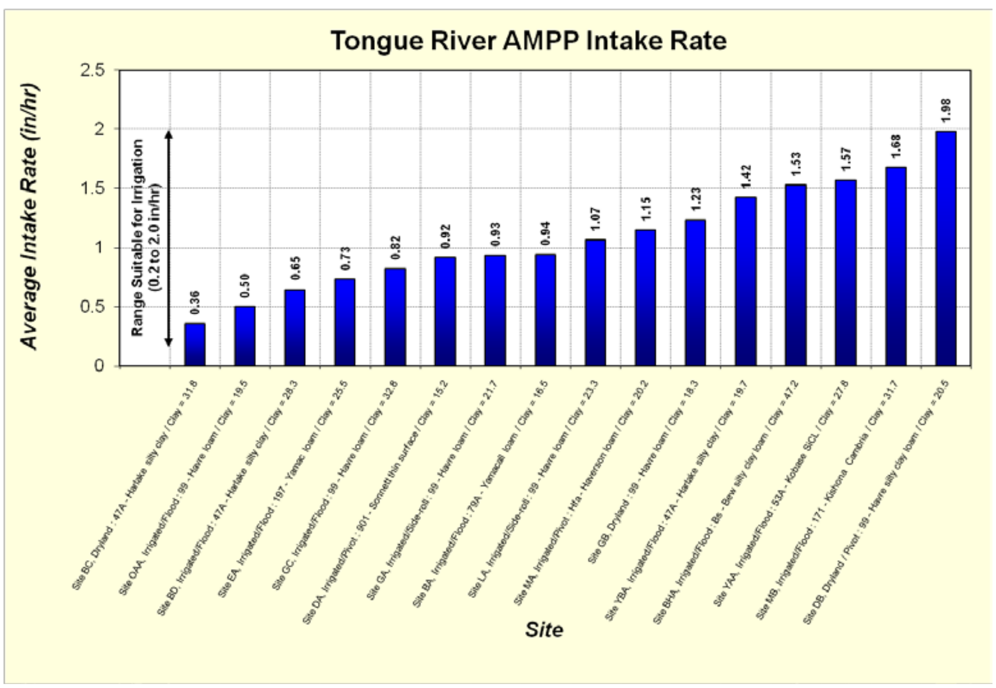

Figure 3-34 Average Soil Intake Rates at AMPP Sites.

3.4 Variation in Crop Yield and Mineral Content

Crop production was estimated based on grower records only in 2003 (Table 3-3). From 2004 through 2010 yields were estimated by the grower and based on weight of forage determined by the AMPP agronomist. During the 2004 through 2010 growing seasons, plant clippings were taken in Tier 2 fields at every soil sample collection point (GPS waypoint) prior to each forage cutting by cooperators. If a crop is normally hayed, collected plant material is air dried then net weight is determined, forage processed through a chipper/shredder, and a representative sample sent to a laboratory for analysis. Crops that are normally ensiled (primarily corn) are processed immediately to replicate this harvest process. Yields are adjusted to 12% moisture content for hayed forages and 70% for ensiled crops. Feed analyses include nutritional parameters as well as a complete mineral determination (sodium, calcium, sulfur, and others). Irrigation water applied and yield information provided by growers is contained in Table 3-3 for 2003 and 2004, Table 3-4 for 2005 and 2006, Table 3-5 for 2007 and 2008, and Table 3-6 for 2009 and 2010. Detailed harvest data and agronomic management utilized for each AMPP field are summarized in Tables 3-7 to 3-13 for the 2004, 2005, 2006, 2007, 2008, 2009 and 2010 growing seasons, respectively. More complete forage analysis data is contained in Appendix F.

Large differences in forage yields were evident between sites, but yield variations showed no systematic changes through time. A myriad of factors have affected forage crop yields including age of stand, quantity of irrigation water used, fertilizer applied, weed and insect control, climate, and number and timing of cuttings. Although it is difficult using existing data to precisely determine causes of yield variations among AMPP fields, it is clear that there is no systematic decline in yields that could be associated with discharge of water from CBNG operations.

Yield results are somewhat difficult to compare due to differences in cropping systems between fields. However, large differences in yield were evident between sites, even when similar crops, such as alfalfa or mixed grass and alfalfa, were compared. Variations in crop yield did not appear to correspond to differences in either EC (Figure 3-35) or ESP (Figure 3-36) of the fields. Only the amount of irrigation water used (Figure 3-37) seemed to influence forage yields.

Overall AMPP crop and forage yields were comparable to the range of yields generally obtained by growers in southeastern Montana. Lack of correlation between crop yields and soil salinity or sodium levels, and generally good crop and forage yields indicates that salinity and sodium in Tongue River water have no adverse effect on irrigated crops.

Vegetation takes up minerals contained in soil and water. If sodium increases in irrigation water, sodium concentration in the plant material will also increase, although other factors may also influence sodium uptake. Tier 2 forage mineral analysis provided a means of detecting changes in the abundance of sodium in water or soils, which could be the result of CBNG development. Forage sodium monitoring provides an indicator of sodium content in irrigation water, but should not be used to infer a deleterious effect on forage quality. If sodium content increases in forages, it does not imply that the forage is toxic or otherwise unsuitable for animal consumption. As sodium content of forage increases, livestock merely decrease their salt intake. Reduced supplemental salt intake has been observed in cattle that drink CBNG water.

No changes in sodium content of forages have been detected for the period of 2004 to 2010 due to CBNG development. In 2004 and 2005, forage sodium contents were relatively constant in fields that were in the same crop both years. However, for 2006, nine of the ten fields that have had the same crop for at least two of the three years had sodium levels at or below the previous two years (Figure 3-38). The exception was alfalfa at the EA site, near Brandenburg Bridge, which increased in sodium substantially in the third cutting. This resulted in the 2006 average sodium content for EA to increase, compared to 2005. EA third cutting alfalfa had 0.36% sodium. The first and second cuttings were 0.06% and 0.04%, respectively. This site was fallowed in 2004 and alfalfa established in 2005. In 2006, first year of full production, first cutting was destroyed by a severe hail storm as it was being swathed. The alfalfa struggled to recover for the second cutting, and was not irrigated for the second or third cuttings. Lack of irrigation may have caused sodium to increase. Third cuttings have tended to have higher sodium levels than first and/or second. For 2007, eight of eleven that have been the same crop for at least three out of four years were at or below the 2004-2006 average sodium levels. As of 2008, six of six fields that have had the same crop since 2004 and are within the Tongue River Drainage, have forage sodium levels that are at or below 2004 figures (MA, LA, GA, EA, BC, and YAA). DB, which has had the same crop from 2004 through 2007, has a slight elevated sodium when compared to 2004 OAA’s sodium content has varied from 0.01% to 0.06% during 2004 to 2010, This site has been in grass/alfalfa since before 2004. It is along Otter Creek, near Ashland. OAA has not been irrigated during the 2004 to 2010 period, so natural precipitation has caused its sodium content variations. YBA, which is irrigated with Yellowstone River water and has been in alfalfa since second cutting in 2005, had a steady increase in sodium content from 2006 (0.14%) to 2008 (0.19%) and then a decline in 2009 and 2010 (0.12%). The Yellowstone River above Miles City, which is where water is taken for YBA, contains no CBNG discharge water. YBA had similar variations in sodium content as forages from fields in the Tongue River Drainage.

With elevated sodium levels in CBNG water, increases in sodium content of forage crops should be among the first effects of CBNG activity because plants take-up what is applied to the soil. Alfalfa at site MA, which located near most of the CBNG water discharge sites, had a sodium level of 0.07 % in both 2004 and 2005. It then declined to 0.04 % in 2006, returned to 0.07 % in 2007, and was 0.08 5 during 2008, 0.02 % in 2009 and 0.03 % in 2010. LA, which is below all CBNG water discharge points and above the Tongue River Reservoir, has had a steady sodium decline from 0.06 % in 2004, 0.05 % in 2005, 0.04 % in 2006, 0.03 % in 2007, and 0.02 % in 2008 through 2010. Sodium decline in 2006 forages could be attributed to the significant ESP decline in fall 2005 soil samples (Figure 3-27).

Sodium levels have varied between AMPP locations due to soil EC and ESP as well as crops being grown (Figure 3-38). In 2004, the highest sodium level (0.47%) was in hay barley at YBA, which is irrigated with Yellowstone River water. In 2005, YBA also had the highest sodium level (0.59%) which was hay barley under seeded to alfalfa for first cutting. However, sodium was only 0.17% in the pure alfalfa hay harvested for second cutting in 2005. Site DA, which has the highest soil EC and ESP, had a sodium level of 0.27% in the 2004 alfalfa/grass, but only 0.02% in the 2005 corn silage. For 2006, this field was in peas the first cutting (no feed analysis) and hay millet for the second crop (0.22%). For 2007, it was seeded to alfalfa/grass. First cutting was predominantly weeds, such as kochia, and had a sodium content of 0.81%. Kochia has a high salt tolerance. Second cutting was alfalfa/grass (0.25% sodium). In 2008, sodium increased in 5 fields and decreased in 4 fields that remained in the same crop. Overall, sodium content decreased in 2008 by 30% compared to 2007 levels, and decreased again in 2009 over 2008. Average sodium increased slightly from 2009 to 2010 because of the elevated sodium content of the hay barley at GA. If this hay barley value (0.26%) is removed from the data set, the 2009 and 2010 average forage sodium content is the same.

Another example of plants absorbing what is applied to the soil was that mineral content changed at individual AMPP locations in response to fertilizer applications. In 2004, phosphorus in alfalfa hay at YAA site increased from 0.20% to 0.29% in the first cutting to second cutting, respectively. The landowner applied 20-100-0 (actual N-P_20_5-K_2O) per acre after first cutting. Normally, phosphorus levels decline from first to third cutting. Other minerals remained unchanged when comparing the same crop from year to year at individual AMPP locations.

Table 3-3 Generalized Cropping System, Irrigation Management, and Crop Yields in 2003 and 2004.

		Year		2003				2004				
		Started	Irrigation	Num	Water		Grower	Num	Water		Yields	
Site	Water Source	Irrigate	Method	Irri.	App (in.)	Crop	Yields	Irri.	App (in.)	Crop	Grower	AMPP
MA	Tongue River	2000	SR-Pvt	8	3	New Alf	*	27	27	Alfalfa	2.5T	2.12T
MB	Prairie Dog Crk	1903	Flood	2	12	Hay Millet	2T	1	2	Barley	*	*
LA	Tongue River	1988	SR	7	21	Grs/Alf	4.3T	5	14	Grs/Alf	3.7T	3.53T
GA	Tongue River	1973	SR	4	12	Alf/Grs	4T	4	21	Alf/Grs	2.75T	2.79T
GB	N/A (dryland)	N/A	N/A	0	0	Range	*	0	0	Range	*	*
GC	Tongue River	1950	Flood	2	9	Alfalfa	4T	3	24	Alf/Grs	3.75T	3.13T
OAA	Otter Creek	1978	Flood	0	0	Grs/Alf	2T	0	0	Grs/Alf	*	1.14T
EA	Tongue River	1950	Flood	2	10	Hay Millet	2T	0	0	Fallowed	*	*
DA	Tongue River	2003	Pivot	1	1	Grs/Alf	2T	8	24	Grs/Alf	2.5T	1.57T
DB	Tongue River	1943	Fld-Pvt	10	15	Alfalfa	6T	6	24	Alfalfa	5.5T	4.53T
BA	T & Y Ditch	1903	Flood	5	25	Corn	26T	4	20	Corn	20T	18.81T
BC	T & Y Ditch	1903	Flood	3	18	Alf/Grs	3.75T	3	15	Grs/Alf	2T	2.71T
BD	N/A (dryland)	N/A	N/A	0	0	Imp Range	*	0	0	Imp Range	*	*
YAA	T & Y Ditch	1913	Flood	2	12	New Alf	2T	3	15	Alfalfa	5T	4.97T
YBA	Yellowstone Rvr	1940	Flood	0	0	Barley	80 bu	2	8	Bar Hayed	2T	2.69T
BHA	Big Horn River	1903	Flood	4	24	Beets	39T	2	12	W. Wht.	126 bu	125 bu

Irrigation Method: If two types are listed, the first one is the original and the second is the current method.

Yields:
Grower: Yields were taken from Soil Sampling Information sheets. They are yield estimates that the cooperating grower figured the field to make. Yields are at varying moistures.

Waypoint: Harvests taken from each soil sampling waypoint. First year this occurred was 2004. Yields for hay and grain are 12% moisture. Corn silage yields are 70% moisture.

* Did not harvest due to being dryland range, newly established alfalfa, crop not being planted, or did yield enough to harvest due to lack of irrigation water.

** Includes fall grazing instead of taking a 3rd cutting.
*** Includes hailed out first cutting that yielded almost nothing.

Table 3-4 Generalized Cropping System, Irrigation Management, and Crop Yields in 2005 and 2006.

		Year		2005					2006				
		Started	Irrigation	Num	Water		Yields		Num	Water		Yields	
Site	Water Source	Irrigate	Method	Irri.	App (in.)	Crop	Grower	AMPP	Irr.	App (in.)	Crop	Grower	AMPP
MA	Tongue River	2000	SR-Pvt	0	0	Alfalfa	2.25T	2.23T	10	10	Alfalfa	0.75T	0.99T
MB	Prairie Dog Crk	1903	Flood	0	0	Fallow	*	*	0	0	New Grs	0T	0T
LA	Tongue River	1988	SR	2	6	Grs/Alf	5T	4.36T	4	12	Grs/Alf	4.25T	3.50T
GA	Tongue River	1973	SR	3	17	Alf/Grs	4.75T	2.94T	3	15	Alf/Grs	3.4T	3.17T
GB	N/A (dryland)	N/A	N/A	0	0	Range	n/a	n/a	0	0	Range	*	*
GC	Tongue River	1950	Flood	2	16	Alf/Grs	3T	2.51T	3	18	Alf/Grs	3.5T	3.11T
OAA	Otter Creek	1978	Flood	0	0	Grs/Alf	1T	1.27T	0	0	Grs/Alf	1T	0.96T
EA	Tongue River	1950	Flood	3	18	New Alf	3T	2.32T	1	6	Alfalfa	4T***	4.13T
DA	Tongue River	2003	Pivot	8	13	Corn	21T	31.52T	12	12	Peas/Millet	9 Bu**	18.2B/.9T
DB	Tongue River	1943	Fld-Pvt	5	18	Alfalfa	4.5T	3.40T	26	26	Alf/Grs	3.8T	3.35T
BA	T & Y Ditch	1903	Flood	4	24	Corn	27T	27.97T	2	12	S. Wht.	62 Bu	55.8 Bu
BC	T & Y Ditch	1903	Flood	2	12	Grs/Alf	2T	1.67T	0	0	Grs/Alf	1.0T	1.58T
BD	N/A (dryland)	N/A	N/A	0	0	Imp Range	*	*	0	0	Imp.Range	*	*
YAA	T & Y Ditch	1913	Flood	2	12	Alfalfa	5T**	3.37T	3	18	Alfalfa	5.5T	4.55T
YBA	Yellowstone Rvr	1940	Flood	1	7	H Bar/Alf	2.7T	4.04T	4	24	Alfalfa	6.3T	6.40T
BHA	Big Horn River	1903	Flood	0	0	W. Wht.	78 bu	76.7 bu	4	24	Beets	36.7T	45.36T

Irrigation Method: If two types are listed, the first one is the original and the second is the current method.

Yields:

Grower: Yields were taken from Soil Sampling Information sheets. They are yield estimates that the cooperating grower figured the field to make. Yields are at varying moistures.

Waypoint: Harvests taken from each soil sampling waypoint. First year this occurred was 2004. Yields for hay and grain are 12% moisture. Corn silage yields are 70% moisture.

* Did not harvest due to being dryland range, newly established alfalfa, crop not being planted, or did yield enough to harvest due to lack of irrigation water.

** Includes fall grazing instead of taking a 3rd cutting.

*** Includes hailed out first cutting that yielded almost nothing.

Table 3-5 Generalized Cropping System, Irrigation Management, and Crop Yields in 2007 and 2008.

		Year		2007					2008				
		Started	Irrigation		Water		Yields			Water		Yields	
Site	Water Source	Irrigate	Method	Irr.	App (in.)	Crop	Grower	Waypnt	Irr.	App (in.)	Crop	Grower	Waypnt
MA	Tongue River	2000	SR-Pvt	0	0	Alfalfa	3.2T	2.72T	8	8	Alfalfa	0.75T	1.16T
MB	Prairie Dog Crk	1903	Flood	0	0	n/a	0.0T	0.00T	4	24	Hay Millet	0.8T****	1.14T
LA	Tongue River	1988	SR	3	9	Grass	6.4T	5.41T	4	12	Grass	5.25T	4.10T
GA	Tongue River	1973	SR	3	18	Alf/Grs	3.0T	3.56T	2	12	Alfala	4T	3.09T
GB	N/A (dryland)	N/A	N/A	0	0	Range	*	*	0	0	Range	*	*
GC	Tongue River	1950	Flood	2	12	H. Barley	2.0T	1.38T	3	18	Grs/Alf	1.5T	1.77T
OAA	Otter Creek	1978	Flood	0	0	Grass	1.0T	1.10T	0	0	Grass	1.25T	1.52T
EA	Tongue River	1950	Flood	0	0	Alfalfa	3.3T	3.22T	0	0	Alfalfa	3T	2.33T
DA	Tongue River	2003	Pivot	7	13	Alfalfa	3.0T	2.26T	6	12	Alfalfa	4.5T	4.55T
DB	Tongue River	1943	Fld-Pvt	6	12	Alf/Grs	3.8T	4.23T	1	2	S. Wht.	53.8 bu	47.5 bu
BA	T & Y Ditch	1903	Flood	4	24	Corn	24T	26.27T	3	18	H. Bar/Alf	3T	2.91T
BC	T & Y Ditch	1903	Flood	1	6	Grs/Alf	Grazed	1.54T	2	12	Grs/Alf	Grazed	0.87T
BD	N/A (dryland)	N/A	N/A	0	0	Imp. Rnge	*	*	0	0	Imp. Rnge	*	*
YAA	T & Y Ditch	1913	Flood	3	18	Alfalfa	6.0T	3.73T	2	12	Alfalfa	5T	3.28T
YBA	Yellowstone Rvr	1940	Flood	2	12	Alfalfa	6.7T	4.89T	3	18	Alfalfa	5.75T	5.43T
BHA	Big Horn River	1903	Flood	1	6	M. Barley	120 bu	n/a	1	6	M. Barley	110 bu	114.8 bu
	AVERAGE WATER APPLIED				**8.1**					**9.6**			

Irrigation Method: If two types are listed, the first one is the original and the second is the current method.

Yields:
Grower: Yields were taken from Soil Sampling Information sheets. They are yield estimates that the cooperating grower figured the field to make. Yields are at varying moistures.

Waypoint: Harvests taken from each soil sampling waypoint. First year this occurred was 2004. Yields for hay and grain are 12% moisture. Corn silage yields are 70% moisture.

* Did not harvest due to being dryland range, newly established alfalfa, crop not being planted, or did yield enough to harvest due to lack of irrigation water.

** Includes fall grazing instead of taking a 3rd cutting.
*** Includes hailed out first cutting that yielded almost nothing.

MA site is at the Wyoming-Montana state line.
GB & BD are dryland sites.
YAA is east of Miles City on the T & Y District.
YBA is watered from the Yellowstone River near Miles City.
BHA is watered from the Big Horn River near Hardin.

Table compiled by Neal E. Fehringer, Certified Professional Agronomist, C.C.A. on 1/20/04, revised 1/30/07.

Table 3-6 Generalized Cropping System, Irrigation Management, and Crop Yields in 2009 and 2010.

		Year		2009					2010				
		Started	Irrigation	Water			Yields		Water			Yields	
Site	Water Source	Irrigate	Method	Irr.	App (in.)	Crop	Grower	Waypnt	Irr.	App (in.)	Crop	Grower	Waypnt
MA	Tongue River	2000	SR-Pvt	0	0	Alfalfa	1.5T	1.70T	0	0	Alfalfa	1.3T	1.47T
MB	Prairie Dog Crk	1903	Flood	2	12	Grain Hay	0.5T	0.60T	0	0	Triticale	1.5T	1.01T
LA	Tongue River	1988	SR	4	12	Grass	4.2T	4.2T	4	12	Grass	5.6T	4.81T
GA	Tongue River	1973	SR	2	12	Alfalfa	3.5T	2.41T	2	9	H. Barley	1.75T	1.68T
GB	N/A (dryland)	N/A	N/A	*	*	Range	*	*	*	*	Range	*	*
GC	Tongue River	1950	Flood	3	18	Grs/Alf	4.0T	3.03T	2	12	Grs/Alf	3.75T	2.79T
OAA	Otter Creek	1978	Flood	0	0	Grs/Alf	1.3T	1.59T	0	0	Grs/Alf	1T	0.93T
EA	Tongue River	1950	Flood	0	0	Alfalfa	1.3T	1.84T	0	0	Alfalfa	2T	1.88T
DA	Tongue River	2003	Pivot	6	12	Alfalfa	4.4T	2.95T	6	12	Alfalfa	4T	3.57T
DB	Tongue River	1943	Fld-Pvt	4	8	H. Barley	3.1T	2.79T	5	8	Alfalfa	1.2T	1.11T
BA	T & Y Ditch	1903	Flood	3	18	Alfalfa	5.5T	5.30T	3	18	Alfalfa	6T	5.16T
BC	T & Y Ditch	1903	Flood	5	30	Corn	29.2T	34.01T	0	0	S. Wht.	70 bu	72.6 bu
BD	N/A (dryland)	N/A	N/A	*	*	Imp. Rnge	*	*	*	*	Imp. Rnge	*	*
YAA	T & Y Ditch	1913	Flood	2	6	Alfalfa	3.0T	3.02T	3	18	Grs/Alf	3.75T	2.87T
YBA	Yellowstone Rvr	1940	Flood	3	18	Alfalfa	5.5T	5.00T	2	12	Alfalfa	5.0T	4.79T
BHA	Big Horn River	1903	Flood	5	25	Beets	36.5	40.11T	1	6	W. Wht.	110 bu	107.6 bu
	AVERAGE WATER APPLIED				**12.2**					**7.6**			

Irrigation Method: If two types are listed, the first one is the original and the second is the current method.

Yields:

Grower: Yields were taken from Soil Sampling Information sheets. They are yield estimates that the cooperating grower figured the field to make. Yields are at varying moistures.

Waypoint: Harvests taken from each soil sampling waypoint. First year this occurred was 2004. Yields for hay and grain are 12% moisture. Corn silage yields are 70% moisture.

* Did not harvest due to being dryland range, newly established alfalfa, crop not being planted, or did yield enough to harvest due to lack of irrigation water.

** Includes fall grazing instead of taking a 3rd cutting.
*** Includes hailed out first cutting that yielded almost nothing.

MA site is at the Wyoming-Montana state line.
GB & BD are dryland sites.
YAA is east of Miles City on the T & Y District.
YBA is watered from the Yellowstone River near Miles City.
BHA is watered from the Big Horn River near Hardin.

Table compiled by Neal E. Fehringer, Certified Professional Agronomist, C.C.A. on 1/20/04, revised 1/30/07.

Table 3-7 Agronomic Management and Crop Yields in 2004.

Site	Year	Crop	Cutting	Date	Harvest Wt,lbs	% Water	Yield @ 12%	Ft² Harvest	Yield T/Ac		Act. Nutrients App./Ac., lbs
MA	2004	Alfalfa	1st	7/1	2.6	10.0	2.7	52.27	1.11		12-70-0-0-4
			2nd	9/30	3.2	33.5	2.4	52.27	1.01		0-0-0-0-0
						TOTALYIELD			2.12	AVE	12-70-0-0-4
LA	2004	Grs/Alf	1st	6/28	5.0	9.6	5.1	52.27	2.14		38-12-0-0-0
			2nd	9/16	3.4	13.7	3.3	52.27	1.39		70-40-30-0-0
						TOTAL YIELD			3.53	AVE	118-82-0-0-0
GA	2004	Alf/Grs	1st	6/28	2.6	9.4	2.7	43.56	1.34		0-0-0-0-0
			2nd	8/20	3.2	20.1	2.9	43.56	1.45		0-0-0-0-0
						TOTAL YIELD			2.79	AVE	0-0-0-0-0
GC	2004	Alf/Grs	1st	6/15	2.1	9.3	2.2	43.56	1.08		15-40-100-0-3
			2nd	7/30	2.1	8.6	2.2	43.56	1.09		0-0-0-0-0
			3rd	9/23	2.0	15.6	1.9	43.56	0.96		0-0-0-0-0
						TOTAL YIELD			3.13	AVE	15-40-100-0-3
DA	2004	Alf/Grs	1st	6/22	1.1	9.7	1.1	47.92	0.51		100-70-40-0-3
			2nd	8/2	2.5	18.0	2.3	47.92	1.06		0-0-0-0-0
						TOTAL YIELD			1.57	AVE	100-70-40-0-3
DB	2004	Alfalfa	1st	6/15	18.3	9.0	18.9	340.00	1.21		20-50-80-0-3
			2nd	7/22	4.5	9.0	4.6	43.56	2.30		0-0-0-0-0
			3rd	9/1	2.6	31.2	2.0	43.56	1.02		0-0-0-0-0
						TOTAL YIELD			4.53	AVE	20-50-80-0-3
BA	2004	Corn	Chop	9/16	279.2	76.8	215.9	250.00	18.81		200-70-0-0-0
						TOTAL YIELD			18.81	AVE	200-70-0-0-0
BC	2004	Grs/Alf	1st	6/22	2.3	9.0	2.4	43.56	1.19		100-40-0-0-0
			2nd	8/2	7.8	9.2	8.0	260.00	0.67		0-0-0-0-0
			3rd	9/16	1.8	17.1	1.7	43.56	0.85		0-0-0-0-0
						TOTAL YIELD			2.71	AVE	100-40-0-0-0
YAA	2004	Alfalfa	1st	6/15	14.8	9.3	15.3	180.00	1.85		0-0-0-0-0
			2nd	7/22	3.4	10.8	3.4	39.20	1.91		22-104-0-0-0
			3rd	10/6	16.6	20.4	15.0	270.00	1.21		0-0-0-0-0
						TOTAL YIELD			4.97	AVE	22-104-0-0-0
OAA	2004	Grs/Alf	1st	6/28	2.2	9.1	2.3	43.56	1.14		0-0-0-0-0
						TOTAL YIELD			1.14	AVE	0-0-0-0-0
YBA	2004	Barley	1st	7/3	5.2	9.1	5.4	43.56	2.69		35-40-20
						TOTAL YIELD			2.69	AVE	35-40-20
BHA	2004	W Wht	Harvest	7/22	7.5	12.0	7.5	43.56	125.0		200-30-20-0-0
						TOTAL YIELD (bu/ac)			125.0		200-30-20-0-0

Table 3-8 Agronomic Management and Crop Yields in 2005.

Site	Year	Crop	Cutting	Date	Harvest Wt,lbs	% Water	Yield @ 12%	Ft^2 Harvest	Yield T/Ac		Act. Nutrients App./Ac., lbs
MA	**2005**	Alfalfa	1st	6/20	5.2	9.3	5.4	52.27	2.23		0-0-0-0-0
			2nd	Did not get a second cutting due to pivot wheel tracks too deep.							0-0-0-0-0
						TOTALYIELD			**2.23**	**AVE**	**0-0-0-0-0**
LA	**2005**	Grs/Alf	1st	6/20	7.4	9.2	7.6	52.27	3.18		95-40-40-0-0
			2nd	8/26	2.8	10.8	2.8	52.27	1.18		45-0-0-0-0
						TOTAL YIELD			**4.36**	**AVE**	**140-40-40-0-0**
GA	**2005**	Alf/Grs	1st	6/7	1.1	8.4	1.1	21.78	1.15		90-60-60-0-0
			2nd	7/29	1.8	12.4	1.8	21.78	1.79		0-0-0-0-0
						TOTAL YIELD			**2.94**	**AVE**	**90-60-60-0-0**
GC	**2005**	Alf/Grs	1st	6/7	2.5	8.8	2.6	43.56	1.30		30-40-50-0-0
			2nd	8/26	2.4	11.1	2.4	43.56	1.21		0-0-0-0-0
			3rd	Did not get a 3rd cutting.					n/a		n/a
						TOTAL YIELD			**2.51**	**AVE**	**30-40-50-0-0**
EA	**2005**	New Alf	1st	7/29	4.6	11.1	4.6	43.56	2.32		11-52-30-0-0
						TOTAL YIELD			**2.32**	**AVE**	**11-52-30-0-0**
DA	**2005**	Corn	Chop	9/13	253.5	58.9	347.3	240.00	31.52		170-80-50-0-2
						TOTAL YIELD			**31.52**	**AVE**	**170-80-50-0-2**
DB	**2005**	Alfalfa	1st	6/7	1.9	8.4	2.0	43.56	0.99		11-52-30-0-0
			2nd	7/29	2.6	11.4	2.6	43.56	1.31		0-0-0-0-0
			3rd	9/13	2.2	11.8	2.2	43.56	1.10		0-0-0-0-0
						TOTAL YIELD			**3.40**	**AVE**	**11-52-30-0-0**
BA	**2005**	Corn	Chop	9/6	331.0	70.9	321.1	250.00	27.97		170-40-60-0-2
						TOTAL YIELD			**27.97**	**AVE**	**170-40-60-0-2**
BC	**2005**	Grs/Alf	1st	6/7	2.0	9.9	2.0	43.56	1.02		35-20-35-0-0
			2nd	7/29	1.3	12.9	1.3	43.56	0.64		0-0-0-0-0
			3rd	Grazed				n/a	n/a		n/a
						TOTAL YIELD			**1.67**	**AVE**	**35-20-35-0-0**
YAA	**2005**	Alfalfa	1st	6/7	2.1	9.1	2.2	39.20	1.21		15-65-75-0-0
			2nd	7/29	3.9	11.9	3.9	39.20	2.17		0-0-0-0-0
			3rd	Did not have 3rd cutting due to lateness of 2nd.					Second was actully		n/a
						TOTAL YIELD			**3.37**	**AVE**	**15-65-75-0-0**
OAA	**2005**	Not cropped in 2005									
YBA	**2005**	Bar/Alf	1st	7/7	7.7	35.2	5.7	43.56	2.84		0-0-0-0-0
		Alfalfa	2nd	9/6	2.4	11.4	2.4	43.56	1.21		0-0-0-0-0
						TOTAL YIELD			**4.04**	**AVE**	**0-0-0-0-0**
BHA	**2005**	W Wht	Harv	7/22	4.6	12.0	4.6	43.56	76.7		200-40-30-0-0
						TOTAL YIELD			**76.7**		**200-40-30-0-0**

Table 3-9 Agronomic Management and Crop Yields in 2006.

Site	Year	Crop	Cutting	Date	Harvest Wt,lbs	% Water	Yield @ 12%	Ft² Harvest	Yield T/Ac		Act. Nutrients App./Ac., lbs
MA	2006	Alfalfa	1st	8/8	2.3	9.0	2.4	52.27	0.99	T/Ac	0-0-0-0-0
LA	2006	Grass	1st	6/21	24.2	6.9	25.6	270.00	2.07		100-35-50-0-0
			2nd	8/16	18.3	14.5	17.8	270.00	1.43		45-0-0-0-0
						TOTAL YIELD			3.50	AVE	145-35-50-0-0
GA	2006	Grs/Alf	1st	6/21	1.5	7.7	1.6	21.8	1.57		15-30-40-0-0
			2nd	8/8	1.7	17.6	1.6	21.8	1.60		0-0-0-0-0
						TOTAL YIELD			3.17	AVE	15-30-40-0-0
GC	2006	Alf/Grs	1st	6/21	2.3	8.4	2.3	43.56	1.17		30-40-60-0-0
			2nd	8/8	3.8	10.2	3.9	43.56	1.94		0-0-0-0-0
						TOTAL YIELD			3.11	AVE	30-40-60-0-0
EA	2006	Alfalfa	1st	6/5	3.25	9.5	3.3	43.56	1.67		0-0-0-0-0
			2nd	7/17	3.25	11.2	3.3	43.56	1.64		0-0-0-0-0
			3rd	10/4	2.55	43.3	1.6	43.56	0.82		0-0-0-0-0
						TOTAL YIELD			4.13	AVE	0-0-0-0-0
DA	2006	Peas	1st	7/17	1.3	12.0	1.3	52.27	18.20	Bu/Ac	0-0-0-0-0
		H. Millet	2nd	10/4	2.3	16.0	2.1	52.27	0.88	T/Ac	0-0-0-0-0
										AVE	0-0-0-0-0
DB	2006	Grs/Alf	1st	6/5	2.4	9.1	2.5	43.56	1.24		0-42-70-0-2
			2nd	7/17	2.0	8.2	2.1	43.56	1.04		0-0-0-0-0
			3rd	8/21	2.3	16.9	2.1	43.56	1.06		0-0-0-0-0
						TOTAL YIELD			3.35	AVE	0-42-70-0-2
BA	2006	S. Wht	Harv	7/17	3.35	12.0	3.35	43.56	55.83	Bu/Ac	80-70-60-0-3
BC	2006	Grs/Alf	1st	6/5	6.0	9.4	6.2	43.56	3.09		0-0-0-0-0
			2nd	7/18	1.5	8.6	1.6	43.56	0.78		0-0-0-0-0
						TOTAL YIELD			3.87	AVE	0-0-0-0-0
YAA	2006	Alfalfa	1st	6/5	3.2	7.9	3.3	39.20	1.86		12-55-55-0-0
			2nd	8/1	2.7	9.1	2.8	39.20	1.55		0-0-0-0-0
			3rd	10/4	9.0	16.1	8.6	164.00	1.14		0-0-0-0-0
						TOTAL YIELD			4.55	AVE	12-55-55-0-0
MB	2006	New Grs	Seeded to grass in June.				n/a	n/a	n/a		0-0-0-0-0
OAA	2006	Grass	1st	6/21	1.8	5.9	1.9	43.56	0.96	T/Ac	0-0-0-0-0
YBA	2006	Alfalfa	1st	7/10	4.0	9.50	4.1	43.56	2.06		0-60-60-0-2-1B
			2nd	8/21	4.7	8.70	4.8	43.56	2.41		0-0-0-0-0
			3rd	10/4	4.0	15.0	3.9	43.56	1.93		0-0-0-0-0
						TOTAL YIELD			6.40	AVE	0-60-60-0-2-1B
BHA	2006	Beets	Dug	10/6	208.3	As Is	n/a	100.00	45.4	T/Ac	200-130-0-0-0

Table 3-10 Agronomic Management and Crop Yields in 2007.

Site	Year	Crop	Cutting	Date	Harvest Wt,lbs	% Water	Yield @ 12%	Ft^2 Harvest	Yield T/Ac		Act. Nutrients App./Ac., lbs
MA	**2007**	Alfalfa	1st	6/16	6.40	10.4	6.5	52.27	**2.72**	**T/Ac**	**0-0-0-0-0**
LA	**2007**	Grass	1st	6/15	6.05	10.1	6.2	32.20	4.18		140-0-50-0-0
			2nd	8/24	2.60	16.9	2.5	43.56	1.23		45-0-0-0-0
					TOTAL YIELD				**5.41**	**AVE**	**165-0-50-0-0**
GA	**2007**	Grs/Alf	1st	6/15	1.85	9.5	1.9	21.78	1.90		15-30-40-0-0
			2nd	7/30	1.65	11.4	1.7	21.78	1.66		0-0-0-0-0
					TOTAL YIELD				**3.56**	**AVE**	**15-30-40-0-0**
GC	**2007**	H Bar.	1st	9/19	2.78	12.5	2.8	43.56	1.38		0-0-0-0-0
					TOTAL YIELD				**1.38**	**AVE**	**0-0-0-0-0**
EA	**2007**	Alfalfa	1st	6/15	3.15	9.7	n/a	n/a	2.22		0-0-0-0-0
			2nd	7/23	Baled	11.2	n/a	n/a	1.00		0-0-0-0-0
					TOTAL YIELD				**3.22**	**AVE**	**0-0-0-0-0**
DA	**2007**	Alf/Grs	1st	7/1	Baled to AMPP harvesting.				1.49	T/Ac	40-40-0-3-0
			2nd	8/20	1.95	12.1	1.9	52.27	0.81	T/Ac	0-0-0-0-0
					TOTAL YIELD				**2.30**	**AVE**	**40-40-0-3-0**
DB	**2007**	Alf/Grs	1st	6/4	3.25	10.5	3.3	43.56	1.65		13-60-27-5-0
			2nd	8/6	4.25	12.5	4.2	43.56	2.11		0-0-0-0-0
			3rd	9/20	1.30	37.5	0.9	43.56	0.46		0-0-0-0-0
					TOTAL YIELD				**4.23**	**AVE**	**13-60-27-5-0**
BA	**2007**	Corn	1st	9/5	215.4	58.0	301.6	250.00	**26.27**	**T/Ac**	**220-80-90-0-3**
BC	**2007**	Grs/Alf	1st	6/12	1.85	10.8	1.9	43.56	0.94		0-0-0-0-0
			2nd	9/5	1.30	15.2	1.3	43.56	0.63		0-0-0-0-0
					TOTAL YIELD				**1.56**	**AVE**	**0-0-0-0-0**
YAA	**2007**	Alfalfa	1st	6/4	2.30	11.4	2.3	39.20	1.29		0-0-75-0-0
			2nd	7/30	3.05	10.2	3.1	39.20	1.73		0-0-0-0-0
			3rd	9/10	1.35	15.8	1.3	39.20	0.72		0-0-0-0-0
					TOTAL YIELD				**3.73**	**AVE**	**0-0-75-0-0**
MB	**2007**	Weeds	Grass did not take.				n/a	n/a	n/a		**0-0-0-0-0**
OAA	**2007**	Grass	1st	6/15	2.15	10.3	2.2	43.56	**1.10**	**T/Ac**	**0-0-0-0-0**
YBA	**2007**	Alfalfa	1st	6/4	2.90	9.70	3.0	43.56	1.49		0-55-20-0-1-1B
			2nd	7/17	3.60	7.80	3.8	43.56	1.89		0-0-0-0-0
			3rd	9/5	3.30	19.4	3.0	43.56	1.51		0-0-0-0-0
					TOTAL YIELD				**4.89**	**AVE**	**0-55-20-0-1-1B**
BHA	**2007**	M. Bar	Did not take a harvest because field combined before arrived.								

Table 3-11 Agronomic Management and Crop Yields in 2008.

Site	Year	Crop	Cutting	Date	Harvest Wt,lbs	% Water	Yield @ 12%	Ft^2 Harvest	Yield T/Ac	Act. Nutrients App./Ac., lbs
					Grams		Grams			
MA	2008	Alfalfa	1st	6/23	2.67	8.3	3	52.27	**1.16 T/Ac**	**0-0-0-0-0**
LA	2008	Grass	1st	6/23	7.27	8.7	8	52.27	**3.14**	140-0-50-0-0
			2nd	8/23	2.35	14.2	2	52.27	**0.95**	45-0-0-0-0
						TOTAL YIELD			**4.10 T/Ac**	**165-0-50-0-0**
GA	2008	Alf/Grs	1st	6/30	12.24	7.8	13	230.00	**1.21**	15-30-40-0-0
			2nd	Yield based on bale count.				n/a	1.88	0-0-0-0-0
						TOTAL YIELD			**3.09 T/Ac**	**15-30-40-0-0**
	2008	Barley	1st	Yield based on bale count.					**3.76 T/Ac**	**15-30-40-0-0**
GC	2008	Grs/Alf	1st	9/2	27.78	14.9	27	330.00	**1.77 T/Ac**	**0-0-0-0-0**
EA	2008	Alfalfa	1st	6/17	3.07	7.1	3	43.56	**1.62**	0-0-0-0-0
			2nd	7/29	1.46	14.3	1	43.56	**0.71**	0-0-0-0-0
						TOTAL YIELD			**2.33 T/Ac**	**0-0-0-0-0**
DA	2008	Alf/Grs	1st	6/17	4.39	7.9	5	52.27	**1.91**	50-26-0-0-0
			2nd	7/29	3.92	12.9	4	52.27	**1.62**	0-0-0-0-0
			3rd	8/25	2.48	12.9	2	52.27	**1.02**	0-0-0-0-0
						TOTAL YIELD			**4.55 T/Ac**	**50-26-0-0-0**
DB	2008	S. Wht.	Harv	7/29	2.85	12.0	3	43.56	**47.54 Bu/Ac**	**140-40-0-0-0**
BA	2008	Bar/Alf	1st	7/25	5.93	13.8	6	43.56	**2.91**	16-78-0-0-0
			2nd	Did not get a harvest for yield.						0-0-0-0-0
						TOTAL YIELD			**2.91 T/Ac**	**16-78-0-0-0**
BC	2008	Grass	1st	6/17	1.67	7.6	2	43.56	**0.87 T/Ac**	**0-0-0-0-0**
YAA	2008	Alf/Grs	1st	6/17	3.42	7.7	4	39.20	**1.99**	11-52-0-0-0
			2nd	8/25	2.35	13.1	2	39.20	**1.29**	0-0-0-0-0
						TOTAL YIELD			**3.28 T/Ac**	**11-52-0-0-0**
MB	2008	H Millet	1st	9/10	2.32	13.3	2	43.56	**1.14 T/Ac**	**0-0-0-0-0**
		Yield compromised by neighbor's cattle repeatedly getting into field and grazing crop.								
OAA	2008	Grass	1st	6/30	2.90	7.8	3	43.56	**1.52 T/Ac**	**0-0-0-0-0**
YBA	2008	Alfalfa	1st	6/17	4.11	8.1	4	43.56	**2.14**	0-55-20-0-1-1B
			2nd	7/28	3.85	14.2	4	43.56	**1.88**	0-0-0-0-0
			3rd	9/16	3.07	19.0	3	43.56	**1.41**	0-0-0-0-0
						TOTAL YIELD			**5.43 T/Ac**	**0-55-20-0-1-1B**
BHA	2008	M. Bar.	Harv	7/16	5.51	12.0	6	43.56	**114.8 Bu/Ac**	**90-30-20-0-0**

Table 3-12 Agronomic Management and Crop Yields in 2009.

Site	Year	Crop	Cutting	Date	Harvest Wt,lbs	% Water	Yield @ 12%	Ft^2 Harvest	Yield T/Ac		Act. Nutrients App./Ac., lbs
					Grams		Grams				
MA	**2009**	Alfalfa	1st	6/23	4.2	14.0	4.1	52.27	**1.70**	**T/Ac**	**0-0-0-0-0**
LA	**2009**	Grs/Alf	1st	6/18	7.1	13.3	7.0	52.27	2.90		140-0-50-0-0
			2nd	*	1.28	11.0	1.3	T/Ac	1.29		45-0-0-0-0
						TOTAL YIELD			**4.20**	**T/Ac**	**165-0-50-0-0**
GA	**2009**	Alfalfa	1st	6/19	3.0	13.8	3.0	43.56	1.48		15-30-40-0-0
			2nd	*	0.9	12.9	0.9	T/Ac	0.93		0-0-0-0-0
						TOTAL YIELD			**2.41**	**T/Ac**	**15-30-40-0-0**
GC	**2009**	Grs/Alf	1st	6/19	5.00	14.5	5	43.56	**2.43**		**80-40-0-0-0**
			2nd	*	0.60	11.3	1	T/Ac	**0.60**		**0-0-0-0-0**
						TOTAL YIELD			**3.04**	**T/Ac**	**80-40-0-0-0**
EA	**2009**	Alfalfa	1st	6/19	3.0	17.0	2.9	43.56	1.43		0-0-0-0-0
			2nd	10/26	0.8	11.0	0.8	43.56	0.41		0-0-0-0-0
						TOTAL YIELD			**1.84**	**T/Ac**	**0-0-0-0-0**
DA	**2009**	Alfalfa	1st		4.1	14.9	4.0	52.27	1.66		17-80-80-0-0
			2nd		24.8	14.1	24.2	408	1.29		0-0-0-0-0
						TOTAL YIELD			**2.95**	**T/Ac**	**17-80-80-0-0**
DB	**2009**	H Bar.	1st	7/6	2,569	13.3	2,531	43.56	**2.79**	**T/Ac**	**55-70-0-0-0**
BA	**2009**	Alfalfa	1st	6/16	5.6	15.3	5.4	43.56	2.70		11-52-30-0-0
			2nd	7/25	3.4	16.0	3.3	43.56	1.64		0-0-0-0-0
			3rd	*	0.98	13.1	0.97	T/Ac	0.97		0-0-0-0-0
						TOTAL YIELD			**5.31**	**T/Ac**	**11-52-30-0-0**
BC	**2009**	Corn	Silage	9/16	295	60.3	390	250	**34.01**	**T/Ac**	**200-100-60-0-0**
YAA	**2009**	Alfalfa	1st	6/10	4.1	15.7	3.9	43.56	1.95		
			2nd	9/16	1.6	15.0	1.5	43.56	0.77		
						TOTAL YIELD			**2.72**	**T/Ac**	
MB	**2009**	Grn Hay	1st	7/14	1.3	17.2	1.2	43.56	**0.60**	**T/Ac**	**0-0-0-0-0**
OAA	**2009**	Grs/Alf	1st	6/19	3.2	12.9	3.2	43.56	**1.59**	**T/Ac**	**0-0-0-0-0**
YBA	**2009**	Alfalfa	1st	6/10	3.6	15.4	3.4	43.56	1.71		0-0-0-0-0
			2nd	7/25	4.0	18.3	3.7	43.56	1.84		0-0-0-0-0
			3rd	9/16	3.0	15.2	2.9	43.56	1.45		0-0-0-0-0
						TOTAL YIELD			**5.00**	**T/Ac**	**0-0-0-0-0**
BHA	**2009**	Beets	Harv	10/17	176.8	As Is	n/a	96	**40.1**	**T/Ac**	

Table 3-13 Agronomic Management and Crop Yields in 2010.

Site	Year	Crop	Cutting	Date	Harvest Wt.lbs	% Water	Wt. @ 12%	Ft^2 Harvest	Yield	% Cr. Protein	Act. Nutrients App./Ac., lbs
MA	**2010**	Alfalfa	1st	6/30	1,793	21.5	1,599	52.27	**1.47 T/Ac**	**11.9**	**0-0-0-0-0**
LA	**2010**	Grs/Alf	1st	6/30	3,986	17.7	3,728	52.27	3.42	8.8	140-0-50-0-0
			2nd	*	1.40	12.6	1.39 T/Ac		1.39	14.9	45-0-0-0-0
							TOTAL YIELD		**4.81 T/Ac**	**11.9**	**165-0-50-0-0**
GA	**2010**	Barley	1st	8/4	2,177	17.7	2,036	58.30	**1.68 T/Ac**	**106.0**	**0-0-0-0-0**
GC	**2010**	Grs/Alf	1st	6/25	2,177	17.7	2,036	43.56	2.24	7.3	100-20-0-0-0
			2nd	*	0.55	12.2	0.55 T/Ac		0.55	13.4	0-0-0-0-0
							TOTAL YIELD		**2.79 T/Ac**	**10.4**	**100-20-0-0-0**
EA	**2010**	Alfalfa	1st	6/25	1,277	19.0	1,175	43.56	1.29	16.1	0-0-0-0-0
			2nd	9/13	566	18.0	527	43.56	0.58	12.5	0-0-0-0-0
							TOTAL YIELD		**1.88 T/Ac**	**14.3**	**0-0-0-0-0**
DA	**2010**	Alfalfa	1st	6/21	2,547	21.1	2,284	52.27	2.10	16.1	17-80-80-0-0
			2nd	8/2	1,723	18.0	1,606	52.27	1.47	16.0	0-0-0-0-0
							TOTAL YIELD		**3.57 T/Ac**	**16.1**	**17-80-80-0-0**
DB	**2010**	Alfalfa	1st	8/2	1,097	18.8	1,012	43.56	**1.11 T/Ac**	**20.1**	**30-150-150-0-0**
BA	**2010**	Alfalfa	1st	6/21	2,427	19.4	2,223	43.56	2.45	14.3	18-46-0-0-0
			2nd	8/2	1,648	17.8	1,539	43.56	1.70	17.4	0-0-0-0-0
			3rd	9/13	1,027	21.2	920	43.56	1.01	18.1	0-0-0-0-0
							TOTAL YIELD		**5.16 T/Ac**	**16.6**	**18-46-0-0-0**
BC	**2010**	S. Wht. Grain		8/4	2,116	12.0	2,116	58.30	**72.6 Bu/Ac**		**60-50-30-0-0**
YAA	**2010**	Alfalfa	1st	6/14	1,542	18.1	1,542	39.20	1.89	11.4	60-0-0-0-0
			2nd	9/13	804	18.8	804	39.20	0.98	15.0	0-0-0-0-0
							TOTAL YIELD		**2.87 T/Ac**	**13.2**	**60-0-0-0-0**
MB	**2010**	Grn Hay	1st	6/30	962	16.1	917	43.56	**1.01 T/Ac**	**6.00**	**0-0-0-0-0**
OAA	**2010**	Grs/Alf	1st	6/25	905	17.5	848	43.56	**0.93 T/Ac**	**10.90**	**0-0-0-0-0**
YBA	**2010**	Alfalfa	1st	6/14	2,394	19.7	2,185	43.56	2.41	14.3	0-75-60-0-0
			2nd	8/2	1,536	17.5	1,440	43.56	1.59	16.6	0-0-0-0-0
			3rd	9/13	783	18.7	723	43.56	0.80	21.1	0-0-0-0-0
							TOTAL YIELD		**4.79 T/Ac**	**17.3**	**0-75-60-0-0**
BHA	**2010**	W. Wht. Grain		7/30	4,207	12.0	4,207	62.50	**107.6 Bu/Ac**		**90-30-20-0-0**

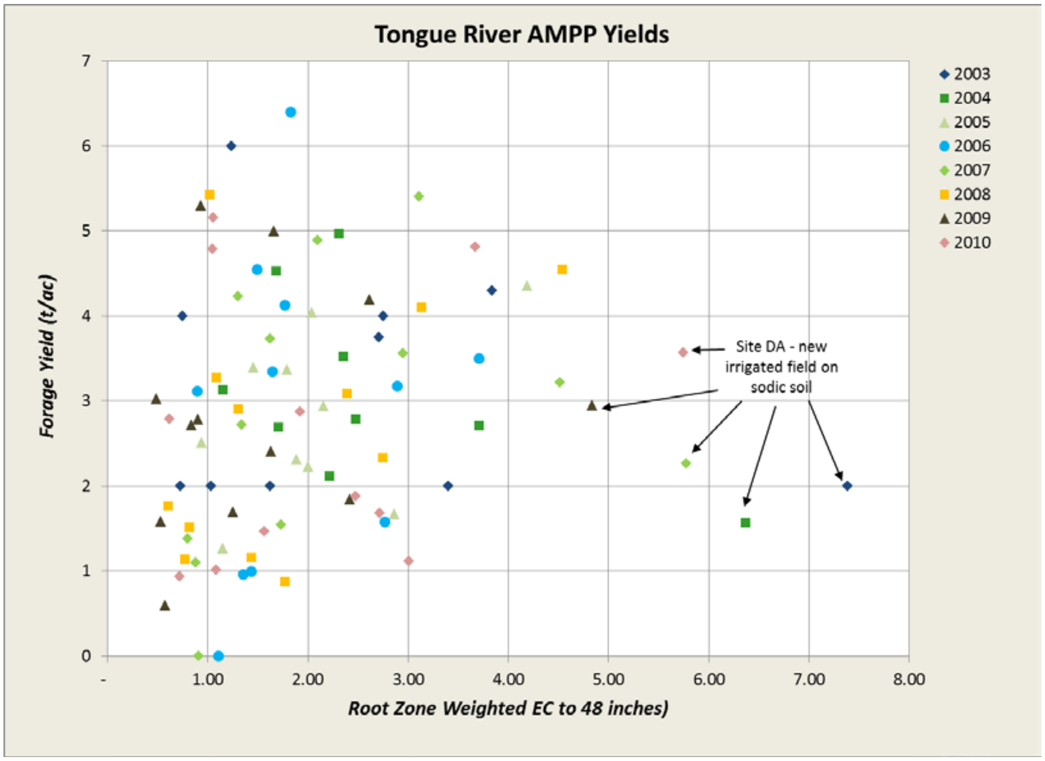

Figure 3-35 Trend in Average Electrical Conductivity Compared to Forage Yields for Fields Irrigated with Tongue River Water in 2003 through 2010.

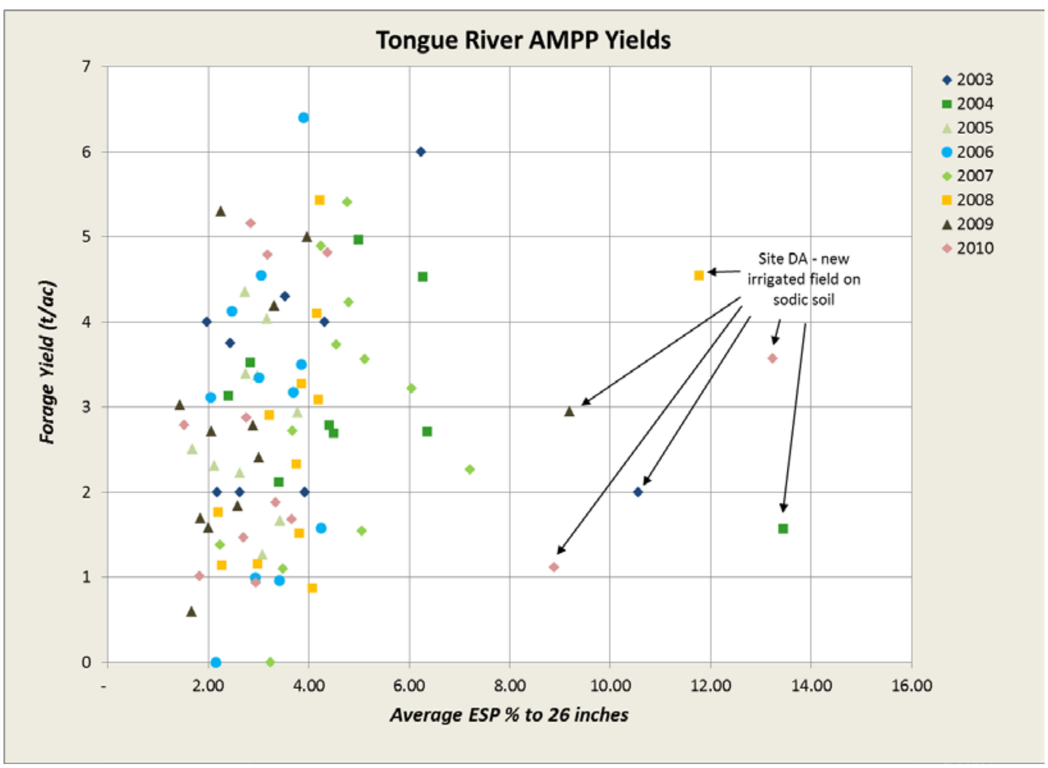

Figure 3-36 Trend in Average Exchangeable Sodium Percentage Compared to Forage Yields for Fields Irrigated with Tongue River Water - 2003 through 2010.

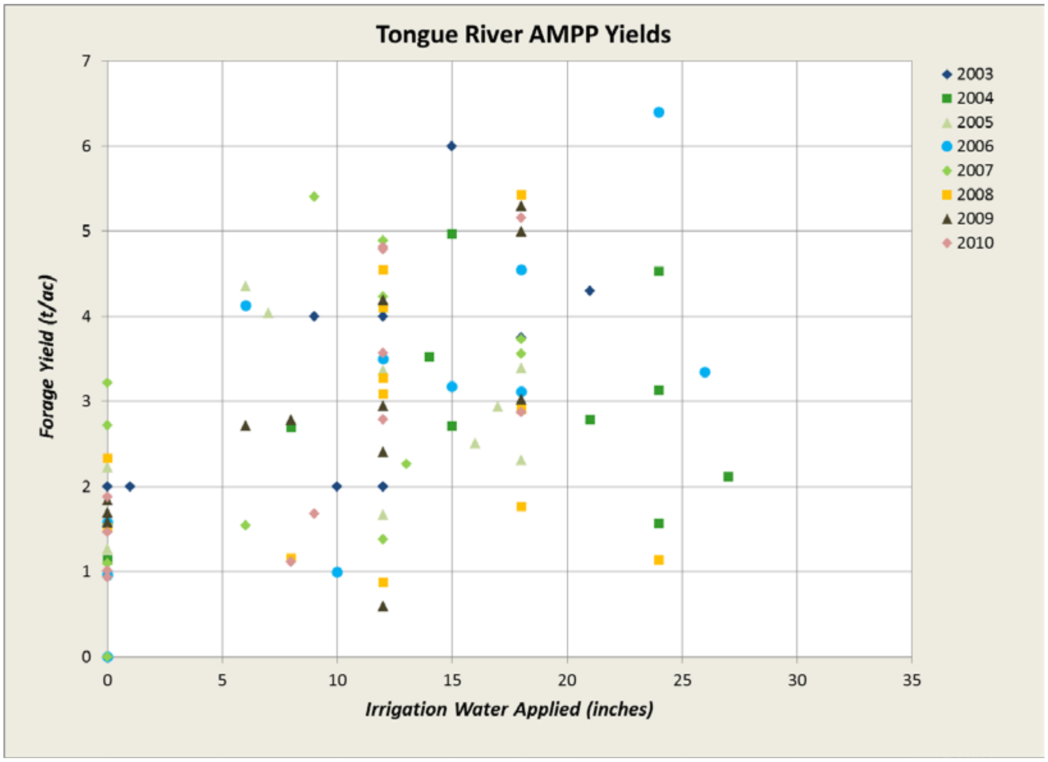

Figure 3-37 Comparison of AMPP Forage Yield to Amount of Irrigation Water Applied in 2003 through 2010.

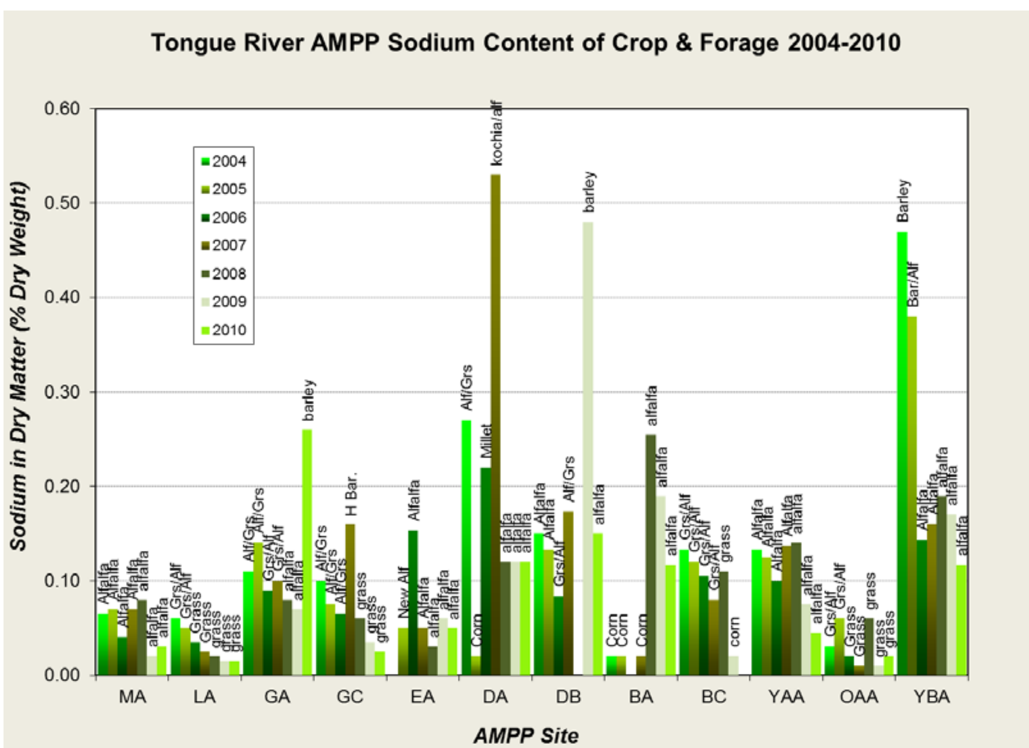

Figure 3-38 Average Sodium Content in Forage Harvested in 2004 through 2010.

3.5 Variation in Trace Metal Abundance

Selected trace metals were analyzed at two depths (0 to 2 and 36 to 60 inches) in AMPP soils (Table 3-14) from 2003 to 2010. All trace elements were within a safe range for crops grown in Montana. Boron and zinc, which are also plant nutrients, were adequate to slightly deficient. Element concentrations showed only minor variation between sites or with depth with the exception of barium which was at times elevated in surface horizons. Higher barium near the soil surface was attributed to lower sulfate levels in shallow soils. Barium solubility is usually controlled by formation of barite ($BaSO_4$), which has a low solubility. At lower sulfate concentrations, the equilibrium concentration of barium tends to increase.

Table 3-14 Average 2003 to 2010 Levels of Trace Elements in AMPP Soils.

Site	Depth (inches)	Barium mg/L Method SW6010B	Boron mg/L Method SW6010B	Fluoride mg/kg Method A4500-F C	Selenium mg/L Method SW6010B	Zinc mg/kg Method SW6010B
MA	0 to 2	3.33	0.70	0.61	0.05	1.17
MA	36 to 60	1.22	0.78	1.28	0.05	
LA	0 to 2	1.91	0.62	0.89	0.04	1.28
LA	36 to 60	0.52	0.54	1.35	0.04	
GA	0 to 2	3.16	0.76	0.92	0.05	0.66
GA	36 to 60	0.79	0.89	1.36	0.06	
GB	0 to 2		0.30			0.39
GB	36 to 60		0.70	1.90	0.04	
GC	0 to 2	2.75	0.55	0.86	0.06	0.69
GC	36 to 60	1.65	0.70	0.97	0.08	
EA	0 to 2	2.53	0.69	0.73	0.07	0.72
EA	36 to 60	1.10	0.93	1.28	0.04	
DB	0 to 2	2.59	0.77	0.99	0.05	1.16
DB	36 to 60	1.11	0.71	1.00	0.04	
DA	0 to 2	1.54	0.75	0.77	0.04	0.69
DA	36 to 60	0.89	0.80	1.47	0.03	
BA	0 to 2	2.63	0.67	0.99	0.04	1.20
BA	36 to 60	1.01	0.81	1.01	0.04	
BD	0 to 2	9.00				1.17
BD	36 to 60					0.50
BC	0 to 2	2.30	0.79	1.06	0.05	0.91
BC	36 to 60	0.47	1.03	1.11	0.08	
YAA	0 to 2	2.86	0.70	0.98	0.05	0.56
YAA	36 to 60	0.62	0.70	1.50	0.03	
MB	0 to 2	2.64	0.62	0.73	0.03	0.28
MB	36 to 60	0.57	0.68	1.16	0.04	
OAA	0 to 2	3.97	0.68	0.33	0.08	0.90
OAA	36 to 60	0.86	0.61	0.92	0.04	
YBA	0 to 2	2.36	0.77	1.17	0.06	0.63
YBA	36 to 60	1.48	0.89	1.50	0.03	
BHA	0 to 2	2.84	0.77	1.08	0.04	0.99
BHA	36 to 60	2.71	0.93	1.44	0.04	

4.0 Tier 2 – Trends for Individual Fields

4.1 Tongue River Irrigated and Dryland Sites

4.1.1 Site MA

A side roll (wheel line) was installed at site MA in 2000. It was replaced with a pivot in 2003. New alfalfa was planted in August 2003. Alfalfa was not harvested in 2003, but yielded 2.1 to 2.2 tons per acre in 2004 and 2005 based on waypoint yields. About 27 inches of irrigation water was applied in 2004, but there was no irrigation in 2005 due to deep wheel tracks. In 2006, 10.9 inches of irrigation water were applied to the alfalfa which yielded 1 ton per acre in a single cutting. Although the alfalfa was not irrigated or fertilized in 2007, it yielded 2.7 tons per acre in one cutting owing to ample spring rains. Alfalfa yield was 1.16 tons per acre in 2008 with 8 inches of applied irrigation water and was 1.7 tons per acre in 2009 without irrigation. In 2010, alfalfa yielded 1.47 tons per acre again without irrigation.

Soil characteristics remained relatively unchanged from 2003 through 2010 at site MA, despite changing irrigation management (Table 4-1 and 4-2). EC was low near soil surface (except in 2010), increased to a maximum at a depth of 24 to 36 inches and again decreased with depth (Figure 4-1). This pattern of EC with depth indicates that a shallow water table exists at least during the irrigation season, causing water (and contained salts) to flow downward from the soil surface and upward from the water table. Salinity in the 0 to 2 inch layer was probably elevated in 2010 due to dry conditions prior to sampling. Salinity at 24 to 36 inches increased from fall 2003 to spring 2004, but has steadily decreased from fall 2004 to 2007. In 2008, salts and sodium increased slightly below 36 inches, probably due to accumulation in the capillary fringe above the water table. EC in shallow groundwater (Figure 3-14 and 3-15) ranged from 800 to1,000 µS/cm and SAR values were less than 1.2, indicating that shallow groundwater at this location was similar to Tongue River water.

As of fall 2010, EC, SAR and ESP in the top 24 inches are at or below fall 2003 levels indicating no sodium accumulation in the primary root zone. Below 36 inches, EC, ESP, and SAR increased slightly (Figures 4-1, 4-2, and 4-3). The pH (Figure 4-4) of the 0 to 2 and 0 to 6 inch depths were nearly identical on all dates and remain near 7.5, further indicating that the sodium status of this soil has not measurably changed through time. If sodium is increasing in either irrigation water or soil, it would accumulate in the top six inches, particularly in the upper two. The pH increases as sodium increases in soil and water. A sodic soil has a pH of greater than 8.5

Table 4-1 Soil pH, EC, Saturation Extractable Ions and SAR for Site MA

Depth (inches)		pH (Paste) s_u_ Method ASAM10-3_2	Electrical Conductivity (Paste) mmhos/cm Method ASAM10-3	Saturation Percentage wt% Method USDA27a	Calcium (Paste) meq/l Method SW6010B	Magnesium (Paste) meq/l Method SW6010B	Sodium (Paste) meq/l Method SW6010B	Sodium Adsorption Ratio unitless Method Calculation	Alkalinity (Paste) meq/L Method ASA10-3	Bicarbonate (Paste) meq/L Method ASA10-3	Carbonate (Paste) meq/L Method ASA10-3	Chloride (Paste) meq/L Method ASA10-3
1-Fall, 2003												
0	2	7.6	0.76	40.7	3.8	1.8	2	1.2	5.4			
0	6	7.4	0.81	41.3	4.4	2.1	2.6	1.5	5.5			
6	12	7.5	0.82	42.2	4.6	2.6	2.3	1.2	4.1			
12	24	7.7	1.33	42.8	4.4	5	4.7	2.2	3.5			
24	36	7.7	3.61	41.9	15.5	28.3	13.3	2.8	2.5			
36	60	7.7	2.9	36.5	9.3	21.5	10	2.6	2.4			
60	96	7.7	1.52	29	4.8	6.8	5.3	2.2	2.4			
2-Spring, 2004												
0	2	7.6	1.4	43.6	8.29	4.35	1.66	0.7	5.6			0.71
0	6	7.7	0.73	43.1	3.51	1.67	1.01	0.6	3.6			0.71
6	12	7.8	0.53	43.4	2.73	1.51	1.36	0.9	3.6			2.12
12	24	8	1.08	44.6	3.62	4.01	3.33	1.7	3.6			1.55
24	36	7.9	6.1	45.8	22.5	48.8	18.2	3	2.6			0.71
36	60	8.1	3.51	40.7	7.13	21.1	11.2	3	2.2			0.56
60	96	8.1	0.82	30.4	2.26	2.96	3.18	2	2.8			0.42
3-Fall, 2004												
0	2	7.3	0.74	40.5	3.78	2.54	1.34	0.76	7.2			
0	6	7.4	0.66	40.6	3.09	1.56	1.83	1.2	4			
6	12	7.5	1.03	41.2	4.16	3.37	3.06	1.6	3.4			
12	24	7.7	1.77	43.6	5.16	7.23	5.41	2.2	3.2			
24	36	7.7	5.53	40	15.3	42.1	17.5	3.3	2.4			
36	60	7.7	2.36	37.4	4.64	10.1	7.06	2.6	2.4			
60	96	7.6	1.77	27.9	5.1	7.1	4.83	2	2			
4-Fall, 2005												
0	2	7.4	1.09	45.8	5.56	3.52	0.56	0.26				
0	6	7.5	0.88	44.4	4.86	2.65	0.97	0.5				
6	12	7.5	0.97	43.9	4.89	3.2	2.49	1.2				
12	24	7.7	1.68	43.6	5.84	7.09	4.54	1.8				
24	36	7.8	4	44.5	9.13	25.7	11.2	2.7				
36	60	7.8	3.27	39.8	6.64	18.7	12.2	3.4				
60	96	7.7	2.23	28.9	7.09	11.7	6.14	2				
5-Fall, 2006												
0	2	7.5	1.64	48.2	7.81	5.34	1.51	0.59				0.54
0	6	7.5	1.11	48	5.88	3.29	2.13	0.99				0.36
6	12	7.8	0.49	42.5	2.58	1.44	1.5	1.1				0.1
12	24	8	0.6	42.1	2.3	2.21	2.3	1.5				0.05
24	36	8	3.23	40.6	11.1	21	16	4				1.16
36	60	7.9	2.9	37.6	8.8	19.1	12.4	3.3				0.39
60	96	7.8	1.84	27	6.35	8.94	5.19	1.9				0.05
6-Fall, 2007												
0	2	7.7	0.92	46.3	4.72	2.98	0.76	0.39				0.7
0	6	7.6	0.86	48	4.84	2.75	1.07	0.55				0.91
6	12	7.8	0.51	44.5	2.42	1.6	1.52	1.1				0.3
12	24	8	0.68	45.1	2.35	2.55	2.29	1.5				0.3
24	36	8	2.81	41.6	8.76	18	9.89	2.7				0.6
36	60	8	3.04	41.2	6.55	19.5	13.3	3.7				1.27
60	96	8	1.45	31.8	4.07	6.6	5.27	2.3				0.56
7-Fall, 2008												
0	2	7.5	0.68	45.7	3.11	1.9	0.74	0.47				0.34
0	6	7.4	0.66	43.4	3.12	1.85	1.01	0.64				0.68
6	12	7.7	0.45	41.4	1.86	1.19	1.3	1				0.39
12	24	8	0.71	41.4	1.77	2.32	2.84	2				0.49
24	36	7.9	2.59	40.7	6.17	15.4	8.22	2.5				0.73
36	60	7.9	4.81	37.3	10.5	31.6	17.8	3.9				1.2
60	96	7.8	2.96	27.8	8.86	16.5	9.16	2.6				0.82
8-Fall, 2009												
0	2	8	0.5	47.6	2.93	1.66	0.26	0.17				0.2
0	6	7.6	0.65	46.8	2.85	1.46	2.23	1.5				0.98
6	12	7.8	0.43	42.5	2.37	1.28	0.91	0.67				0.32
12	24	7.9	0.55	43	2.32	2.2	2.1	1.4				0.27
24	36	7.9	2.58	43.3	8.65	18.2	8.47	2.3				0.57
36	60	7.9	3.54	43.9	9	28.4	13.7	3.2				0.66
60	96	8	2.12	35.1	7.85	13.6	7.33	2.2				0.4
9-Fall, 2010												
0	2	7.5	3.25	40.5	11.1	10.8	13.4	4				
0	6	7.2	0.8	41.6	4.41	2.4	0.93	0.5				
6	12	7.3	0.6	38.3	2.99	1.79	1.71	1.1				
12	24	7.5	1.2	40.9	3.97	4.65	4.49	2.2				
24	36	7.6	2.57	40.9	6.34	15.1	9.27	2.8				
36	60	7.6	4.12	38.1	9.21	24.7	16.5	4				
60	96	7.4	1.99	29.2	6.54	9.53	6.39	2.2				

Table 4-2 Soil Texture, Lime, CEC and ESP for Site MA.

Depth (inches)		Sand % Method ASA15-5	Silt % Method ASA15-5	Clay % Method ASA15-5	Texture unitless Method ASA15-5	Lime as CaCO3 wt% Method USDA23c	Cation Exchange Capacity meq/100g Method SW6010B	Extractable Sodium meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
1-Fall, 2003									
0	2	31	49	20	L	8.4	27.1		2.2
0	6	26	50	24	SiL	8.6	26.3		2
6	12	26	51	23	SiL	9	23.2		2.4
12	24	26	50	24	SiL	10.5	17.7		4.7
24	36	28	48	24	L	10	25.3		3.9
36	60	44	37	19	L	9.2	16.5		4.6
60	96	58	29	13	SL	8.5	15.4		4
2-Spring, 2004									
0	2	30	48	22	L	8.1	24.7	0.53	1.8
0	6	28	50	22	SiL	10.7	24.4	0.49	1.8
6	12	25	51	24	SiL	8.8	21.1	0.57	2.4
12	24	21	55	24	SiL	10.8	23.4	0.83	2.9
24	36	26	51	23	SiL	9.8	21.4	1.58	3.5
36	60	36	43	21	L	10.9	19.2	1.24	4.1
60	96	57	28	15	SL	9.4	14.4	0.74	4.4
3-Fall, 2004									
0	2	38	45	17	L	8.3	27.9		1.9
0	6	35	44	21	L	8.8	29.6		2.4
6	12	29	50	21	SiL	9.2	28.4		2.4
12	24	26	51	23	SiL	11.5	28.7		3
24	36	29	51	20	SiL	10.7	25.5		4.8
36	60	40	45	15	L	11.5	21.3		5.1
60	96	61	29	10	SL	9.4	16.9		4.7
4-Fall, 2005									
0	2	28	50	22	SiL	9.1	27		2.3
0	6	27	52	21	SiL	9.1	27.2		1.4
6	12	28	52	20	SiL	9.3	27.1		1.8
12	24	26	54	20	SiL	11.9	25.3		2.5
24	36	27	53	20	SiL	10.5	23.2		3.8
36	60	36	46	18	L	11.3	19.3		4
60	96	71	19	10	SL	9.6	15.7		1.3
5-Fall, 2006									
0	2	32	47	21	L	8.8	29.2		1.3
0	6	36	45	19	L	8.5	26.6		1.7
6	12	27	53	20	SiL	9.6	25.8		1.7
12	24	27	53	20	SiL	10.5	26.8		2.1
24	36	34	48	18	L	11.4	21		5
36	60	42	40	18	L	9.5	17.7		5
60	96	72	19	9	SL	7.7	12.2		3.8
6-Fall, 2007									
0	2	29	51	20	SiL	8.3	24.3		1.8
0	6	29	50	21	SiL	8.3	24.3		1.8
6	12	28	52	20	SiL	9.4	23.8		2.3
12	24	31	47	22	L	10.5	20.3		3.3
24	36	32	50	18	SiL	10.5	19.4		5.7
36	60	38	46	16	L	10.8	16.9		7
60	96	58	30	12	SL	8.6	13.8		4.7
7-Fall, 2008									
0	2	28	50	22	SiL	8.4	26.4		1.3
0	6	30	50	20	SiL	8.2	26.1		1.5
6	12	28	50	22	SiL	8.8	24.1		2.2
12	24	24	54	22	SiL	11.2	23.2		2.9
24	36	30	50	20	SiL	9.5	20.5		4.2
36	60	42	40	18	L	10.2	17.1		5.6
60	96	62	26	12	SL	8.6	12.1		5.2
8-Fall, 2009									
0	2	28	50	22	SiL	8.4	25.7		0.6
0	6	24	52	24	SiL	8.4	26		0.3
6	12	26	52	22	SiL	9	23.1		1
12	24	28	50	22	SiL	10.6	20.8		2
24	36	26	52	22	SiL	9.6	21.9		2.9
36	60	36	46	18	L	10.1	17.4		4.2
60	96	50	34	16	L	9.9	15.1		3.5
9-Fall, 2010									
0	2	32	44	24	L	7.31	12.8		5.5
0	6	24	50	26	SiL	8.5	15.9		0.6
6	12	28	48	24	L	9.07	13.6		1.4
12	24	20	54	26	SiL	11.1	13.6		3
24	36	28	48	24	L	10.2	12.8		4.1
36	60	38	42	20	L	10.2	10.9		5.6
60	96	60	26	14	SL	8.56	8.43		3.7

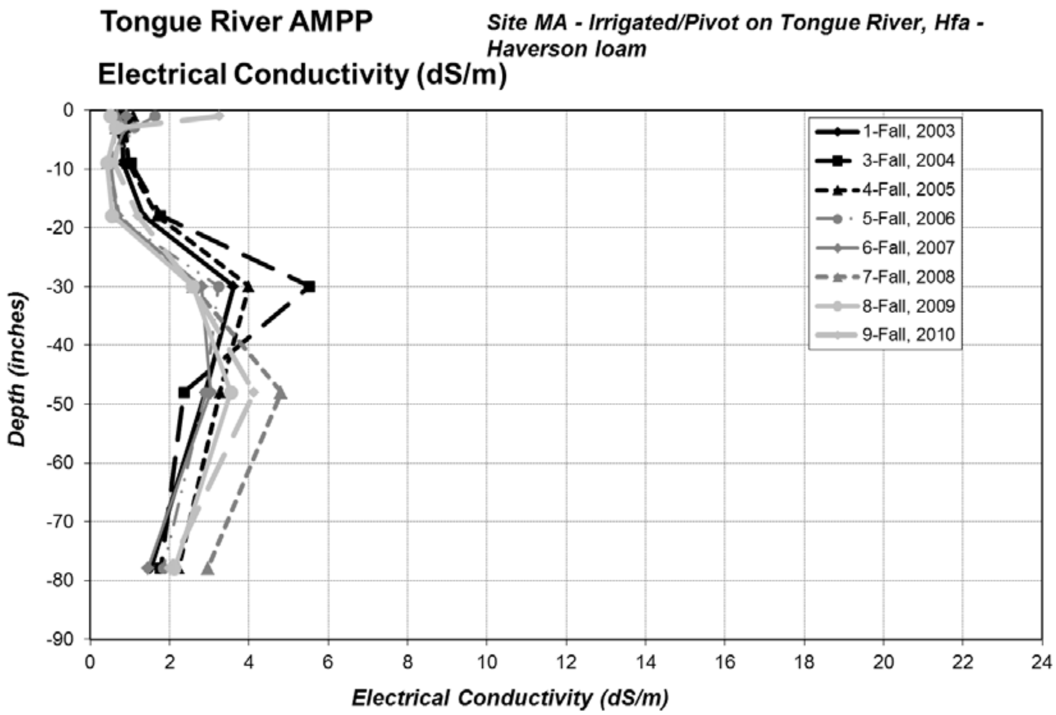

Figure 4-1 Trends in EC with Depth for Site MA.

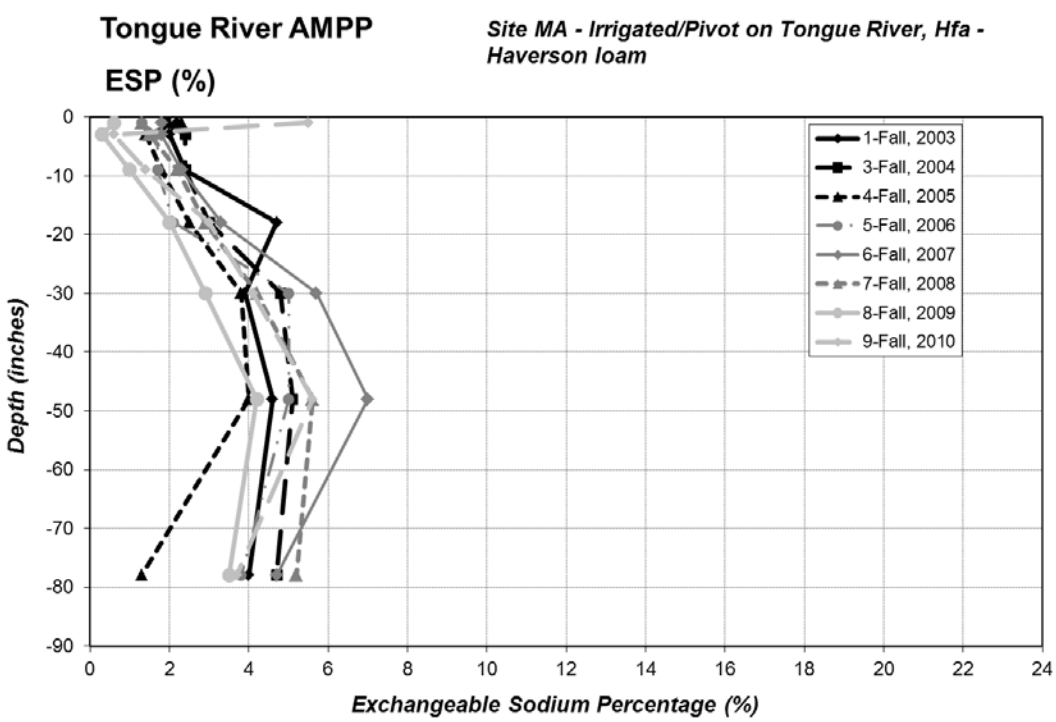

Figure 4-2 Trends in ESP with Depth for Site MA.

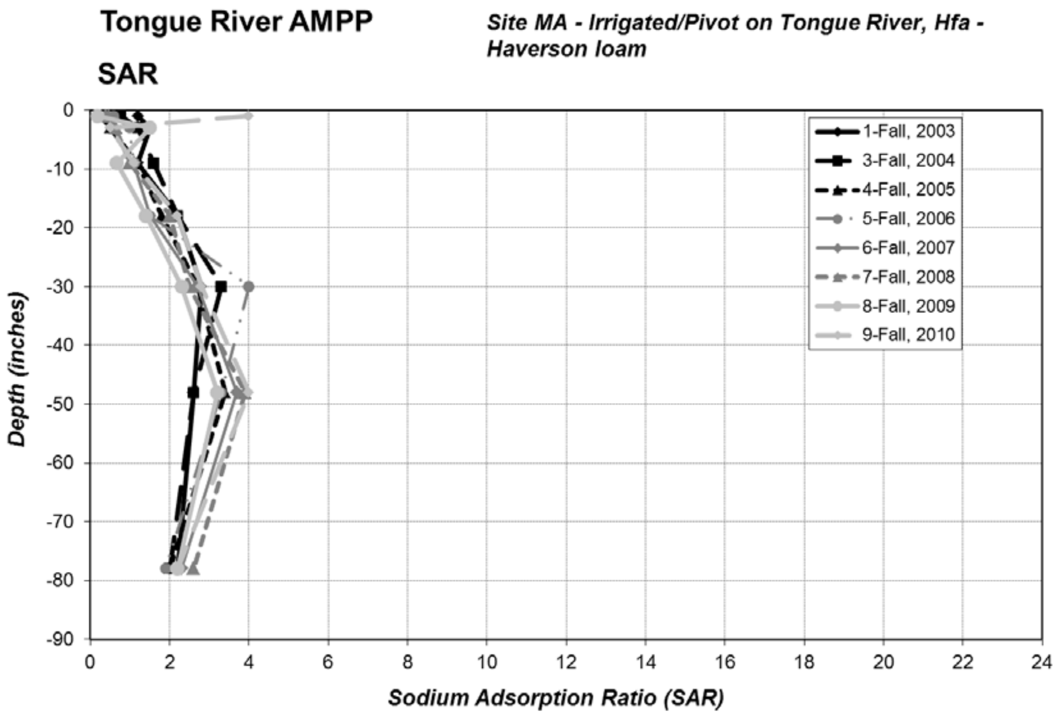

Figure 4-3 Trends in SAR with Depth for Site MA.

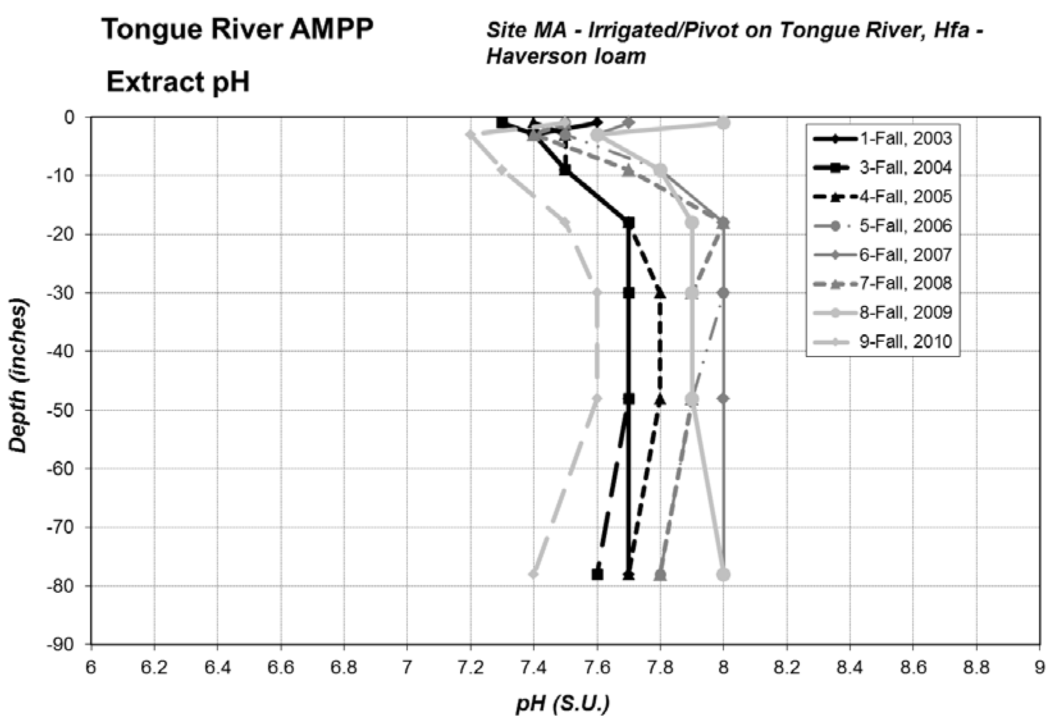

Figure 4-4 Trends in pH with Depth for Site MA.

4.1.2 Site LA

Site LA (Table 4-3 and 4-4) consists of an older stand (planted in 1988) of predominantly grass (95%) and alfalfa (5%) that is irrigated with a side-roll system. Waypoint yields have varied from 3.5 to 5.4 tons per acre with 21 inches of irrigation water applied in 2003, 14 inches in 2004, 6 inches in 2005, 12 inches in 2006, 9 inches in 2007, and 12 inches each in 2008, 2009 and 2010.

Salinity has been variable through time (Figure 4-5), perhaps in response to irrigation quantity and timing. Salinity decreased in the upper 3 feet from 2003 to 2004, with a commensurate increase below 3 feet. Salinity increased from 2004 to 2006, which may have been the result of reduced irrigation. However, EC decreased from 2006 to 2010 even though only 9 to 12 inches of water were applied. Five acres in the northwest field corner were under water for about half of the growing season due to the high level of water in the Tongue River Reservoir in 2007. The water table is locally within 3 feet of the soil surface at site LA and had an EC of 2.7 dS/m and a SAR of 3 to 4.6 (Figures 3-14 and 3-15). The elevated water table probably accounts for the pattern of EC with depth, causing maximum EC levels to form just above the water table.

ESP, SAR and pH levels (Figures 4-6 to 4-8) in site LA were more stable than EC. Sodium was low near the surface and increased moderately with depth indicating that site LA generally maintains adequate leaching.

Table 4-3 Soil pH, EC, Saturation Extractable Ions and SAR for Site LA.

Depth (inches)		pH (Paste) s_u_ Method ASAM10-3_2	Electrical Conductivity (Paste) mmhos/cm Method ASAM10-3	Saturation Percentage wt% Method USDA27a	Calcium (Paste) meq/l Method SW6010B	Magnesium (Paste) meq/l Method SW6010B	Sodium (Paste) meq/l Method SW6010B	Sodium Adsorption Ratio unitless Method Calculation	Alkalinity (Paste) meq/L Method ASA10-3	Bicarbonate (Paste) meq/L Method ASA10-3	Carbonate (Paste) meq/L Method ASA10-3	Chloride (Paste) meq/L Method ASA10-3
1-Fall, 2003												
0	2	7.3	1.62	54.1	8.2	5.4	4	1.5	8.2			
0	6	7.4	2.76	51.5	14.4	8.9	12.5	3.7	5.2			
6	12	7.7	3.56	47.5	15.7	9.8	20.1	5.6	3.6			
12	24	7.8	4.33	47.4	21.7	18.8	22.1	4.9	2.9			
24	36	7.9	4.48	41.6	19.8	22.6	20.8	4.5	2.5			
36	60	8	3.78	36.3	10.2	16.1	23.8	6.6	2.7			
60	96	7.8	4.2	31.4	11.5	18.5	25.4	6.6	2.6			
2-Spring, 2004												
0	2	7.5	2.52	52.7	19.8	9.83	2.4	0.6	5.2			0.71
0	6	7.5	1.72	50.4	14.2	7.5	2.96	0.9	6.2			0.99
6	12	7.8	1.43	42.8	8.43	4.33	5.32	2.1	3.8			0.42
12	24	7.9	3.28	47.4	13.7	11.9	15	4.2	3			0.42
24	36	8	5.28	40.5	22.3	23.7	30.9	6.4	2.6			0.14
36	60	8.1	5.86	38.4	20.7	25.2	29.3	6.1	2.2			0.42
60	96	7.9	3.38	23.8	10.6	14.3	22.2	6.3	3			0.42
3-Fall, 2004												
0	2	7	1.77	58.2	9	5.46	2.57	0.96	9.2			
0	6	7.2	1.65	51.4	7.78	4.01	3.17	1.3	7.4			
6	12	7.5	0.92	45.9	4.58	2.29	2.71	1.5	5			
12	24	7.7	1.48	48.5	6.06	4.41	4.3	1.9	4.1			
24	36	7.7	4.71	42.5	24	21.9	12.1	2.5	2.8			
36	60	7.8	4.54	40.2	12.4	16.8	20	5.2	2.8			
60	90	7.7	4.89	31.1	17.8	23.5	20.9	4.6	2.6			
4-Fall, 2005												
0	2	6.6	2.41	61.4	19.4	7.61	1.81	0.49				
0	6	6.7	2.07	54	15	6.89	2.02	0.61				
6	12	7.2	2.8	47.5	16.2	10.2	8.87	2.4				
12	24	7.5	4.49	46.9	21.1	18.1	19	4.3				
24	36	7.7	6.06	44.9	24	32.1	31.7	6				
36	60	7.7	6.57	37.9	22.5	32.8	36.3	6.9				
60	96	7.7	4.95	32.1	10.1	16.9	34.9	9.5				
5-Fall, 2006												
0	2	7.1	1.38	58.4	8.51	3.16	1.99	0.82				0.48
0	6	7.1	1.07	51.9	6.33	2.72	2.97	1.4				0.46
6	12	7.3	3	49	21	12.6	5.12	1.2				1.34
12	24	7.5	4.26	46.7	25.7	21.5	17.6	3.6				0.86
24	36	7.8	5.97	45	22.7	28.3	33	6.5				1.67
36	60	7.7	4.2	37.4	13.7	19.5	20	4.9				0.36
60	96	7.7	3.14	29.8	7.33	11.4	13.2	4.3				0.17
6-Fall, 2007												
0	2	7.4	1.06	30.2	5.67	2.56	2.37	1.2				0.6
0	6	7.4	1.12	55.8	6.55	3.12	2.43	1.1				0.99
6	12	7.6	3.28	50.8	20.8	13.2	9.72	2.4				0.81
12	24	7.8	3.34	48.9	18.3	13.3	10.5	2.6				0.4
24	36	7.9	4.14	46.4	16.9	18.4	16.5	3.9				0.5
36	60	8	3.98	62.7	6.85	10.9	13.3	4.5				0.3
60	96	8	4.3	46.4	7.16	13.7	28.4	8.8				0.4
7-Fall, 2008												
0	2	7.4	0.57	56.8	2.86	1.37	0.98	0.67				0.34
0	6	7.3	1.46	54.1	8.93	4.24	2.44	0.95				0.32
6	12	7.5	2.39	48.5	13.4	8.67	8.55	2.6				0.57
12	24	7.8	4.64	38.2	17.3	18.9	18.4	4.3				0.98
24	36	7.8	2.74	44.5	11	8.69	9.69	3.1				0.31
36	60	7.8	4.19	37.3	14.6	18.2	14.9	3.7				0.3
60	96	7.9	3	29.9	5.23	9	15	5.6				0.35
8-Fall, 2009												
0	2	7.3	1.01	61.8	6.73	3.03	1.83	0.83				0.58
0	6	7.4	1.98	53.5	14.4	7.06	5.32	1.6				0.6
6	12	7.7	2.03	48.7	12.8	7.9	7.5	2.3				0.32
12	24	7.9	2.85	46.4	18.1	13.7	11	2.8				0.24
24	36	8	3.37	40.2	17.2	18.4	15.3	3.6				0.28
36	60	8.1	2.81	37.5	9.52	12	16.4	5				0.24
60	96	8	1.73	31.6	4.97	6.66	9.64	4				0.22
9-Fall, 2010												
0	2	7	4.04	57.1	24.1	12.3	18	4.2				
0	6	7	2.65	51.3	12.4	7.29	8.13	2.6				
6	12	7.3	3.17	45.1	17.1	9.56	12.4	3.4				
12	24	7.5	4.13	46.8	22.3	15.4	17.5	4				
24	36	7.6	4.65	41.1	21.4	19.6	21.9	4.8				
36	60	7.6	3.38	38.9	12.7	14.3	14.3	3.9				
60	96	7.6	3.68	28.7	8.35	11.1	19	6.1				

Table 4-4 Soil texture, Lime, CEC and ESP for Site LA.

Depth (inches)		Sand % Method ASA15-5	Silt % Method ASA15-5	Clay % Method ASA15-5	Texture unitless Method ASA15-5	Lime as CaCO3 wt% Method USDA23c	Cation Exchange Capacity meq/100g Method SW6010B	Extractable Sodium meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
1-Fall, 2003									
0	2	29	49	22	L	6.7	41.2		1.9
0	6	25	48	27	CL	7.1	39.7		3.1
6	12	27	47	26	L	7.7	39.7		3.5
12	24	23	50	27	CL	8.2	36.2		3.6
24	36	38	42	20	L	7.4	30.5		3.7
36	60	53	33	14	SL	8.7	27.5		5.1
60	96	62	28	10	SL	8.5	23.1		5.2
2-Spring, 2004									
0	2	34	41	25	L	6.7	29.1	0.6	1.6
0	6	33	43	24	L	6.4	26.1	0.71	2.2
6	12	32	44	24	L	7.8	22.6	0.93	3.1
12	24	28	44	28	CL	7.7	25.1	1.76	4.2
24	36	44	33	23	L	7	19	2.48	6.4
36	60	47	32	21	L	7.4	16.6	2.27	6.9
60	96	73	16	11	SL	6.7	10.6	1.34	7.7
3-Fall, 2004									
0	2	32	44	24	L	6.3	33		1.4
0	6	30	46	24	L	6.7	29.4		2
6	12	29	45	26	L	7.8	28.3		2
12	24	26	46	28	CL	7.5	26.9		2.7
24	36	41	36	23	L	6.9	23.5		3.8
36	60	45	33	22	L	7.1	23.8		5.4
60	90	60	26	14	SL	8.1	16.3		6.8
4-Fall, 2005									
0	2	34	45	21	L	7.1	31.9		0.9
0	6	34	45	21	L	7.2	30.6		1.3
6	12	32	46	22	L	8.2	26.9		2.3
12	24	30	46	24	L	7.8	25.9		2.5
24	36	40	40	20	L	7.7	22.3		3.9
36	60	55	29	16	SL	7.3	20.2		4.6
60	96	61	25	14	SL	8.4	16.8		4.7
5-Fall, 2006									
0	2	37	46	17	L	6.3	35.1		1.3
0	6	34	49	17	L	6.3	31.6		2.1
6	12	29	50	21	SiL	7	33		2
12	24	27	52	21	SiL	7.5	29.5		3.8
24	36	36	45	19	L	7.3	26.4		5.7
36	60	49	34	17	L	6.8	22.6		5.3
60	96	70	21	9	SL	7.1	17.2		4.4
6-Fall, 2007									
0	2	34	46	20	L	6.3	30.7		2.4
0	6	34	44	22	L	6.2	29.8		2
6	12	31	45	24	L	8.1	26.1		4.2
12	24	32	44	24	L	9.3	25.7		4.7
24	36	37	40	23	L	8.2	22.7		6.5
36	60	24	56	20	SiL	6.7	18.1		7.7
60	96	61	29	10	SL	8.2	15		9.2
7-Fall, 2008									
0	2	34	42	24	L	4.8	33.4		1.2
0	6	30	46	24	L	9.5	30		1.7
6	12	34	40	26	L	7.5	29.6		3.5
12	24	24	56	20	SiL	3.2	20.4		5.6
24	36	32	44	24	L	6.4	25.2		4.3
36	60	52	30	18	L	6.7	18.5		6
60	96	62	24	14	SL	7.6	15.5		8.4
8-Fall, 2009									
0	2	34	42	24	L	5.9	32.2		1
0	6	32	44	24	L	6.5	29.2		1.7
6	12	30	46	24	L	7.6	28.6		2.6
12	24	30	46	24	L	7.5	23.4		3.3
24	36	44	36	20	L	6.8	18.6		4.5
36	60	54	30	16	SL	6.8	17.6		6
60	96	58	26	16	SL	7	17.5		5
9-Fall, 2010									
0	2	36	38	26	L	6.11	19.3		3.8
0	6	30	42	28	CL	6.48	20		2.5
6	12	30	44	26	L	7.97	16		3.4
12	24	24	44	32	CL	7.84	17.2		4.3
24	36	36	38	26	L	7.45	14.2		5.9
36	60	48	30	22	L	7.63	12.7		4.6
60	96	60	24	16	SL	6.56	9.01		6.4

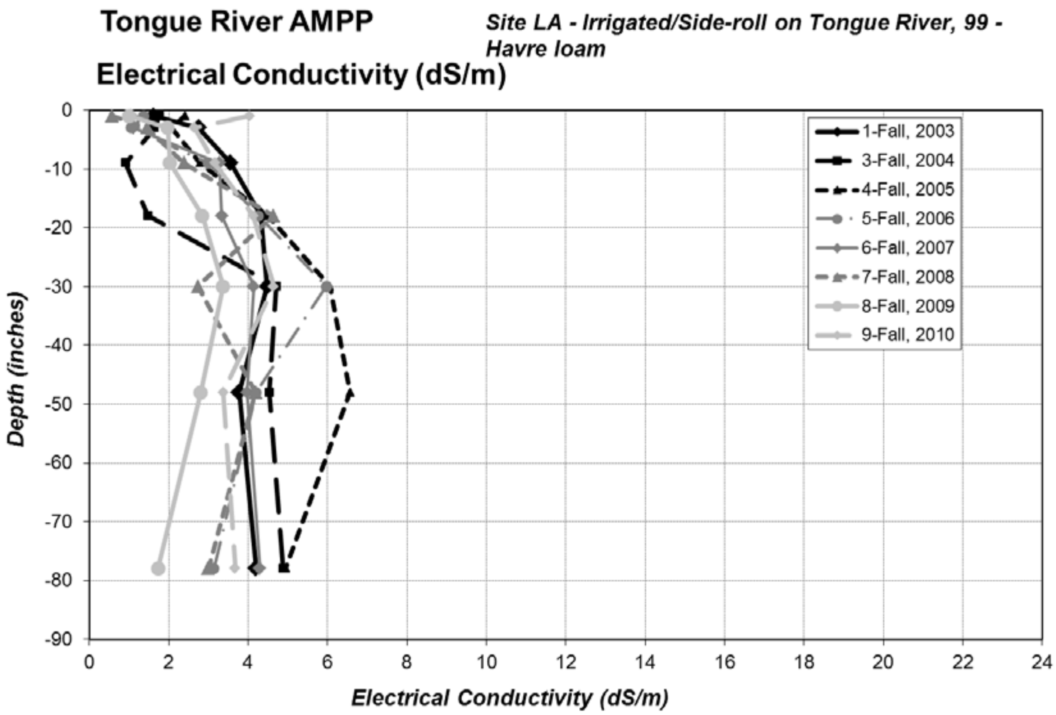

Figure 4-5 Trends in EC with Depth for Site LA

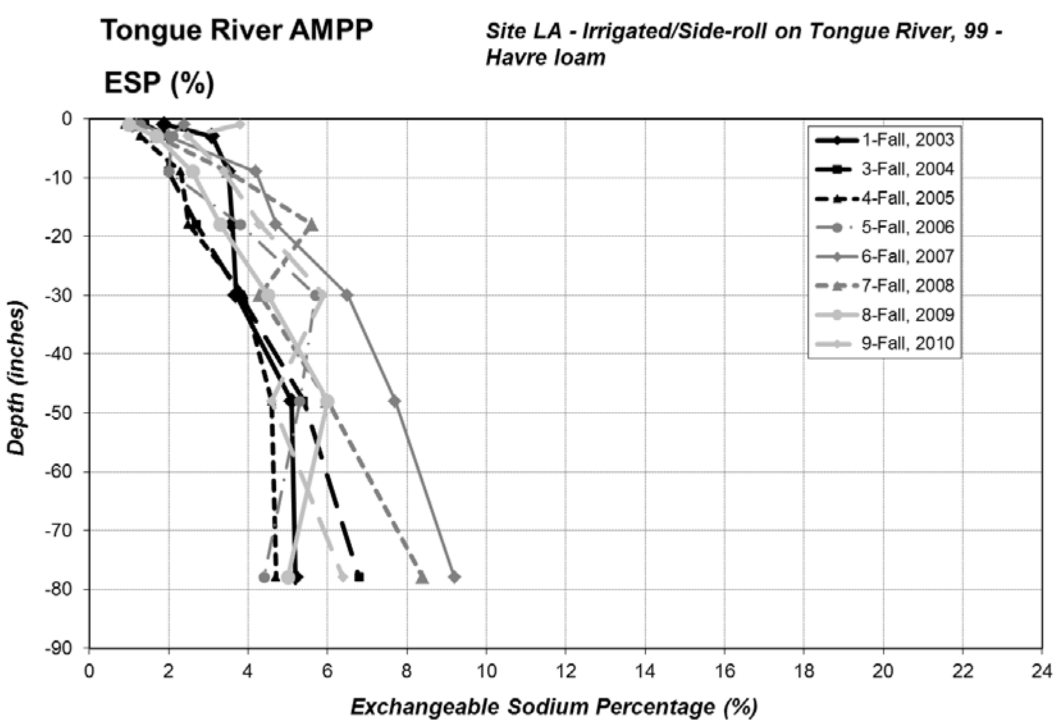

Figure 4-6 Trends in ESP with Depth for Site LA.

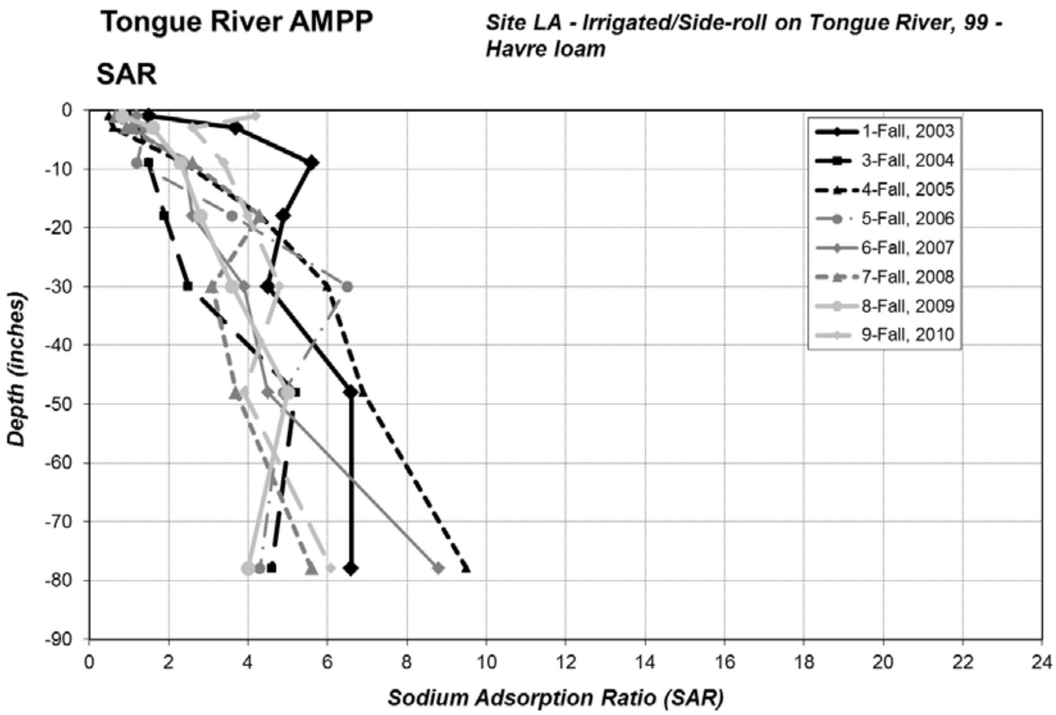

Figure 4-7 Trends in SAR with Depth for Site LA.

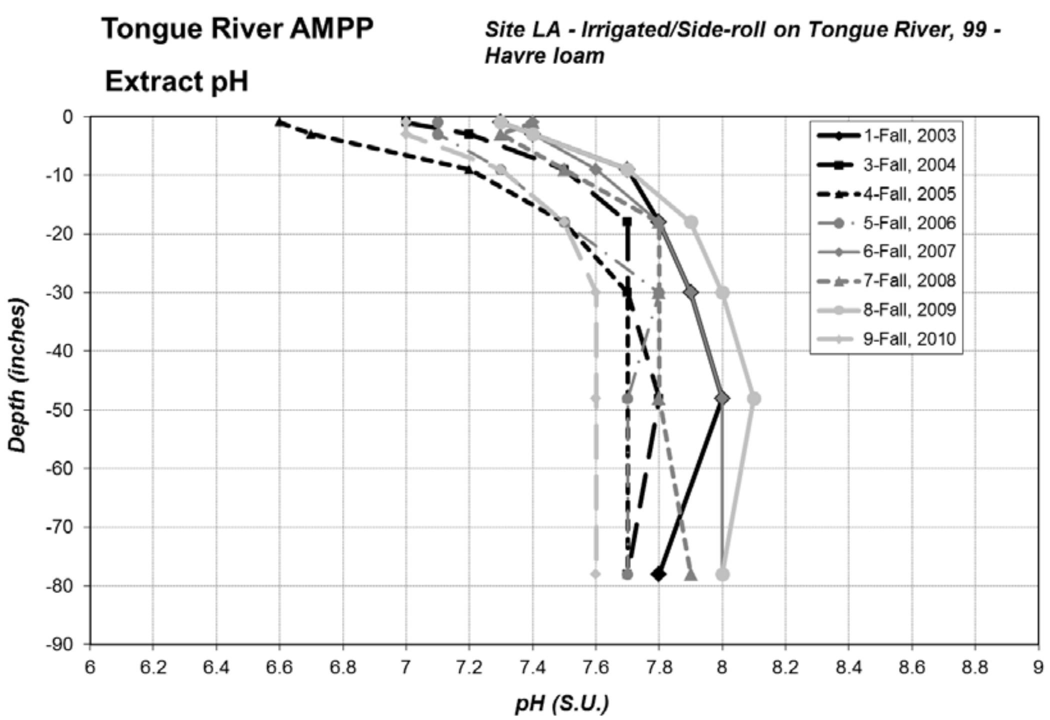

Figure 4-8 Trends in pH with Depth for Site LA

4.1.3 Site GA

Site GA (Table 4-5 and 4-6) is also irrigated with a side-roll sprinkler and contains an alfalfa/grass stand. Hay barley was planted in 2010 that yielded 1.68 tons per acre. This field is located on a bench of the Tongue River. Waypoint based yields from 2004 to 2009 were 2.4 to 3.6 tons per acre for alfalfa/grass within the AMPP monitoring area, but were reported to be higher for the field overall. Portions of the field that were lower in the floodplain (outside of the AMPP monitoring area) most likely had slightly better yields. Applied irrigation water varied from 12 to 20 inches in 2003 through 2009, though only 9 inches was needed for 2010 hay barley.

Soil EC generally increased from less than 1 dS/m in the upper foot to 5 to 7 dS/m at 3 feet in depth, and then decreased at 8 feet. Surface EC levels did not change through time, but tended to decrease at 3 feet in 2004, 2005 and 2009, and increased in 2006 and decreased after 2006 (Figure 4-9). An increase in the duration of irrigation sets from after 2004 (sets changed from 12 to 24 hours) caused the removal of salts. Higher rainfall in 2005, 2007, 2008 and 2010 may also have contributed to salt decreases. Depth to water at site GA was 8 to 9 feet and EC was 1.4 to 1.7 dS/m while SAR ranged from 3.4 to 4.6 (Figure 3-14 and 3-15). Soil ESP, SAR, and pH were generally unchanged through time (Figure 4-10 to 4-12), with the exception of ESP at 8 feet which varied widely. ESP decreased from 2004 to 2005 and from 2008 to 2009 at site GA.

Table 4-5 Soil pH, EC, Saturation Extractable Ions and SAR for Site GA.

Depth (inches)		pH (Paste) s_u_ Method ASAM10-3_2	Electrical Conductivity (Paste) mmhos/cm Method ASAM10-3	Saturation Percentage wt% Method USDA27a	Calcium (Paste) meq/l Method SW6010B	Magnesium (Paste) meq/l Method SW6010B	Sodium (Paste) meq/l Method SW6010B	Sodium Adsorption Ratio unitless Method Calculation	Alkalinity (Paste) meq/L Method ASA10-3	Bicarbonate (Paste) meq/L Method ASA10-3	Carbonate (Paste) meq/L Method ASA10-3	Chloride (Paste) meq/L Method ASA10-3
1-Fall, 2003												
0	2	7.7	0.76	45.1	4.2	2.4	1.4	0.8	5.9			
0	6	7.8	0.59	45.1	3.1	1.6	1.4	0.9	4.3			
6	12	7.7	0.69	43.2	3.5	1.9	2.4	1.4	5.2			
12	24	7.9	1.84	50.2	6.3	6.4	8.9	3.5	3.6			
24	36	8.1	6.8	40.1	21	32.7	40.6	7.8	2.2			
36	60	8	5.82	36.2	16.8	22.9	37.1	8.3	2.4			
60	96	8.1	1.37	30.5	2.4	3.2	7	4.2	3			
2-Spring, 2004												
0	2	7.7	0.67	43.9	4.48	2.51	1.19	0.6	6.2			1.41
0	6	7.7	0.64	42.3	4.4	2.32	1.48	0.8	5.2			3.24
6	12	7.8	0.63	40.3	3.65	1.9	2.19	1.3	4.4			0.71
12	24	7.9	2.13	41.7	8.3	7.94	9.96	3.5	3.6			0.85
24	36	8	6.34	39.1	19.1	28.4	31.7	6.5	3.2			1.55
36	60	8	5.98	31.4	16.8	28.4	30	6.3	2.4			1.83
60	96	8.2	1.91	31.7	3.38	3.81	9.59	5.1	3.4			0.56
3-Fall, 2004												
0	2	7.4	1.05	44.8	5.29	3.46	1.61	0.77	9.3			
0	6	7.4	0.92	45.7	4.64	2.58	2.74	1.4	7.7			
6	12	7.6	0.78	42.8	3.87	2.34	2.66	1.5	5.2			
12	24	7.7	2.24	41.4	8.16	6.88	7.84	2.9	4.5			
24	36	7.8	4.71	40.4	12.9	21.6	20.8	5	3.5			
36	60	7.9	5.23	33	12	21.5	28.3	6.9	2.9			
60	90	8	3.06	30.4	4.48	7.58	18.1	7.4	3.2			
4-Fall, 2005												
0	2	7.3	0.88	46.8	5.48	2.88	0.77	0.38				
0	6	7.3	0.91	47.7	5.23	2.8	1	0.5				
6	12	7.6	0.6	41.8	3.57	1.98	1.66	1				
12	24	7.8	1.44	45.9	4.1	4	5.52	2.7				
24	36	7.8	4.16	41.8	12.3	18.1	20.9	5.4				
36	60	8	5.93	37.9	12.3	28.8	40	8.8				
60	96	7.8	2.46	29.8	3.88	7.11	13.3	5.7				
5-Fall, 2006												
0	2	7.2	0.9	68.7	5.26	3.27	1.08	0.52				0.13
0	6	7.3	0.81	50.5	4.63	2.39	1.39	0.74				0.07
6	12	7.5	0.66	40.5	3.67	2	1.3	0.77				ND
12	24	7.7	1.45	42.5	4.7	4.31	5.14	2.4				0.04
24	36	7.9	6.86	40.9	17.4	30.5	42.2	8.6				1.47
36	60	8	7.89	34.3	14.4	31.6	53.4	11				2.13
60	96	7.9	2.31	29.9	3.23	5.17	12.2	6				0.39
6-Fall, 2007												
0	2	7.6	1.07	48.6	6	3.45	1.77	0.81				0.88
0	6	7.7	0.85	48.3	4.52	2.84	1.23	0.64				0.81
6	12	7.8	0.55	43.4	2.96	1.59	1.66	1.1				0.42
12	24	7.9	3.01	40.9	10.5	11.8	14.7	4.4				1.27
24	36	8	5.59	40.8	16.9	28.8	35.7	7.5				1.55
36	60	8.1	6.47	34.6	16	32.5	35.6	7.2				2.11
60	96	8.1	2.19	34.6	4.48	6.96	11.2	4.7				0.91
7-Fall, 2008												
0	2	7.4	0.88	47.6	5.32	2.61	0.78	0.39				0.25
0	6	7.5	0.71	45.6	4.47	2.2	0.94	0.51				0.28
6	12	7.6	0.87	43.2	4.64	2.4	1.39	0.74				0.3
12	24	7.6	2.42	39.6	10.8	8.63	8.5	2.7				0.69
24	36	7.8	4.08	39	12.6	21.5	22.2	5.4				0.89
36	60	7.9	5.31	34.6	13.1	26.9	31.6	7.1				1.1
60	96	8	2.24	28.8	3.49	6.22	13.8	6.3				0.74
8-Fall, 2009												
0	2	7.6	0.63	48.2	3.86	1.95	0.75	0.44				0.28
0	6	7.7	0.48	44.6	3.22	1.57	0.71	0.46				0.28
6	12	7.8	0.39	41.5	2.27	1.16	0.72	0.55				0.26
12	24	8	0.88	42.6	3.75	2.84	3.3	1.8				0.4
24	36	8	4.4	39.2	16.4	22.4	22	5				0.56
36	60	8	3.13	37.4	10.5	15.5	15.3	4.2				0.44
60	96	8.3	1.55	30.5	3.35	5.72	9.72	4.6				0.25
9-Fall, 2010												
0	2	7.2	1.09	45.4	7.08	3.28	1.23	0.54				
0	6	7.2	0.77	43.7	4.74	2.13	1.25	0.67				
6	12	7.4	0.66	39.3	3.4	1.75	1.54	0.96				
12	24	7.5	2.21	41.6	8.76	7.62	8.71	3				
24	36	7.7	5.56	35.4	18.3	30.5	29.9	6.1				
36	60	7.7	6.56	40	21.4	34	38.8	7.4				
60	96	7.8	3.58	30.7	5.42	10.5	23.6	8.4				

Table 4-6 Soil texture, Lime, CEC and ESP for Site GA.

Depth (inches)		Sand % Method ASA15-5	Silt % Method ASA15-5	Clay % Method ASA15-5	Texture unitless Method ASA15-5	Lime as CaCO3 wt% Method USDA23c	Cation Exchange Capacity meq/100g Method SW6010B	Extractable Sodium meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
1-Fall, 2003									
0	2	35	41	24	L	5.6	33.4		1.1
0	6	29	45	26	L	5.6	29.4		1.6
6	12	28	44	28	CL	6	13.7		3.5
12	24	28	44	28	CL	7.3	20.5		5
24	36	33	45	22	L	7.2	22.7		5.4
36	60	56	28	16	SL	5.5	17.5		7.6
60	96	76	16	8	SL	5.3	17		3.8
2-Spring, 2004									
0	2	30	44	26	L	5.7	23.7	0.56	2.1
0	6	38	39	23	L	5.7	21.2	0.61	2.6
6	12	30	47	23	L	6.4	19.2	0.69	3.2
12	24	29	46	25	L	7.4	20	1.41	5
24	36	44	39	17	L	6.8	14.8	2.16	6.2
36	60	59	30	11	SL	5.9	9.97	1.76	8.2
60	96	82	11	7	LS	4.9	4.54	1.08	17
3-Fall, 2004									
0	2	36	40	24	L	5.7	26.3		1.6
0	6	34	43	23	L	5.8	26.8		2.3
6	12	26	48	26	L	6.7	23.4		2.7
12	24	34	44	22	L	7.2	21.2		4.8
24	36	43	39	18	L	6.7	17.7		5.9
36	60	56	30	14	SL	6.2	13.8		10
60	90	66	22	12	SL	6.1	11.3		11
4-Fall, 2005									
0	2	43	37	20	L	5.7	31.6		1.1
0	6	34	45	21	L	6.1	25.6		2
6	12	31	48	21	L	6.6	24.8		1.9
12	24	30	46	24	L	7.6	22.4		3.7
24	36	38	44	18	L	7.3	20.6		5.7
36	60	43	39	18	L	7.3	16.9		5.7
60	96	69	20	11	SL	6.1	13		6.3
5-Fall, 2006									
0	2	11	55	34	SiCL	7.7	41		1.3
0	6	29	48	23	L	5.6	33.4		1.4
6	12	33	48	19	L	5.9	25.3		1.8
12	24	30	51	19	SiL	7.3	23.4		2.9
24	36	44	43	13	L	6.9	19		6.6
36	60	56	35	9	SL	6.3	13.9		12
60	96	78	19	3	LS	5	11.7		7.5
6-Fall, 2007									
0	2	36	42	22	L	5.4	27.7		1.4
0	6	28	46	26	L	5.3	28.2		1.9
6	12	30	46	24	L	5.8	27.3		2
12	24	34	44	22	L	6.5	21.9		5.3
24	36	41	41	18	L	6.4	20.9		8.1
36	60	50	36	14	L	6	16.3		8.9
60	96	71	23	6	SL	5.1	14		5.9
7-Fall, 2008									
0	2	14	60	26	SiL	5.6	26.9		1.2
0	6	32	42	26	L	5.6	26.3		1.6
6	12	28	46	26	L	5.9	25.9		1.9
12	24	30	46	24	L	7.1	21.4		4.2
24	36	34	46	20	L	6.9	19		6.6
36	60	42	40	18	L	6.6	14.9		8.9
60	96	70	18	12	SL	5.3	11.4		8.6
8-Fall, 2009									
0	2	34	44	22	L	5.2	24.6		0.9
0	6	36	42	22	L	5.4	23.5		1
6	12	36	40	24	L	5.6	22.9		1.1
12	24	30	46	24	L	6.9	22.8		2.4
24	36	38	40	22	L	6.6	17.3		5.6
36	60	46	36	18	L	6.1	15.3		4.6
60	96	72	18	10	SL	5	9.07		5.2
9-Fall, 2010									
0	2	34	44	22	L	5.48	16.1		1.1
0	6	36	42	22	L	5.42	14.2		1.1
6	12	38	42	20	L	5.99	13.8		1.7
12	24	32	46	22	L	7.16	13.5		3.3
24	36	44	40	16	L	6.44	9.92		6.3
36	60	36	44	20	L	6.69	12.7		8.1
60	96	78	16	6	LS	5.18	4.99		9.4

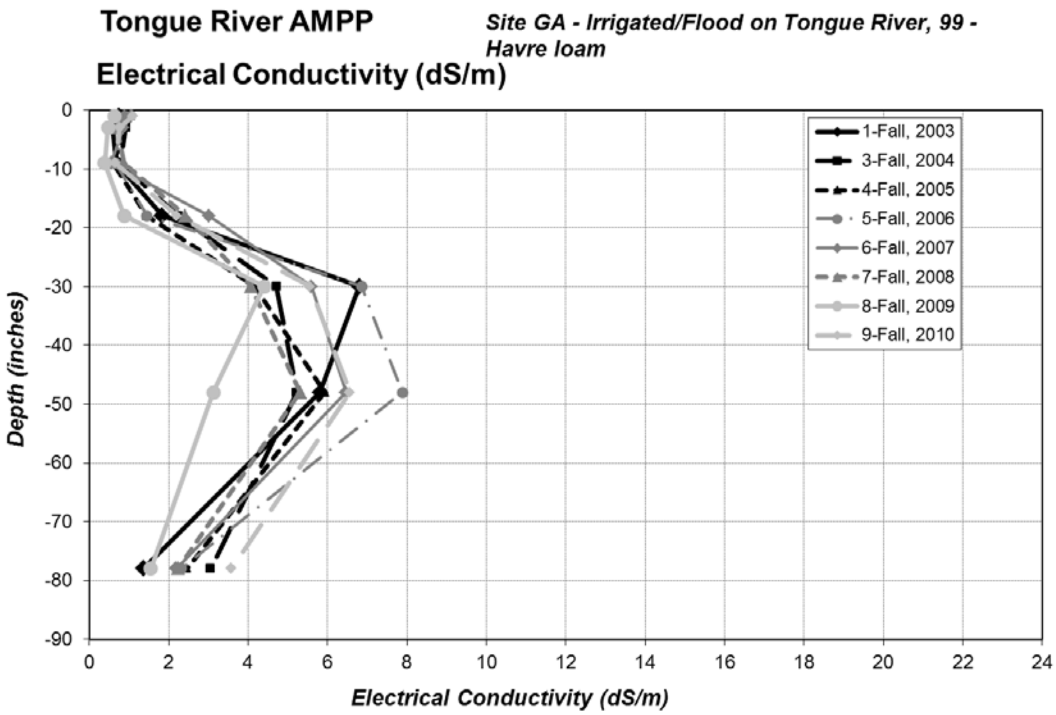

Figure 4-9 Trends in EC with Depth for Site GA.

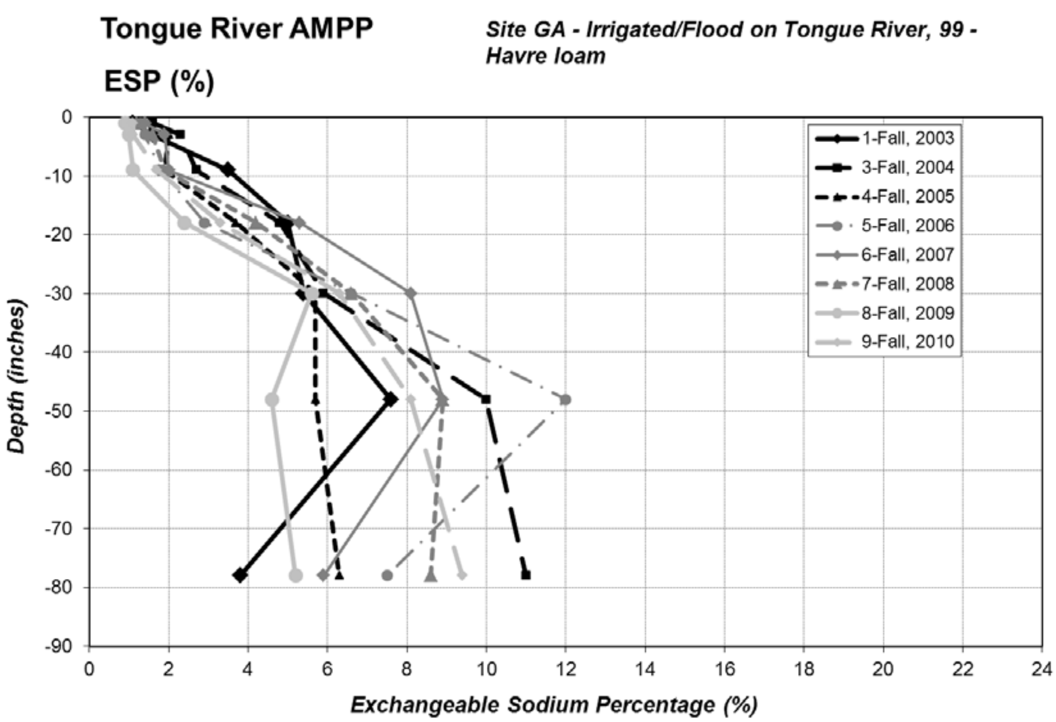

Figure 4-10 Trends in ESP with Depth for Site GA.

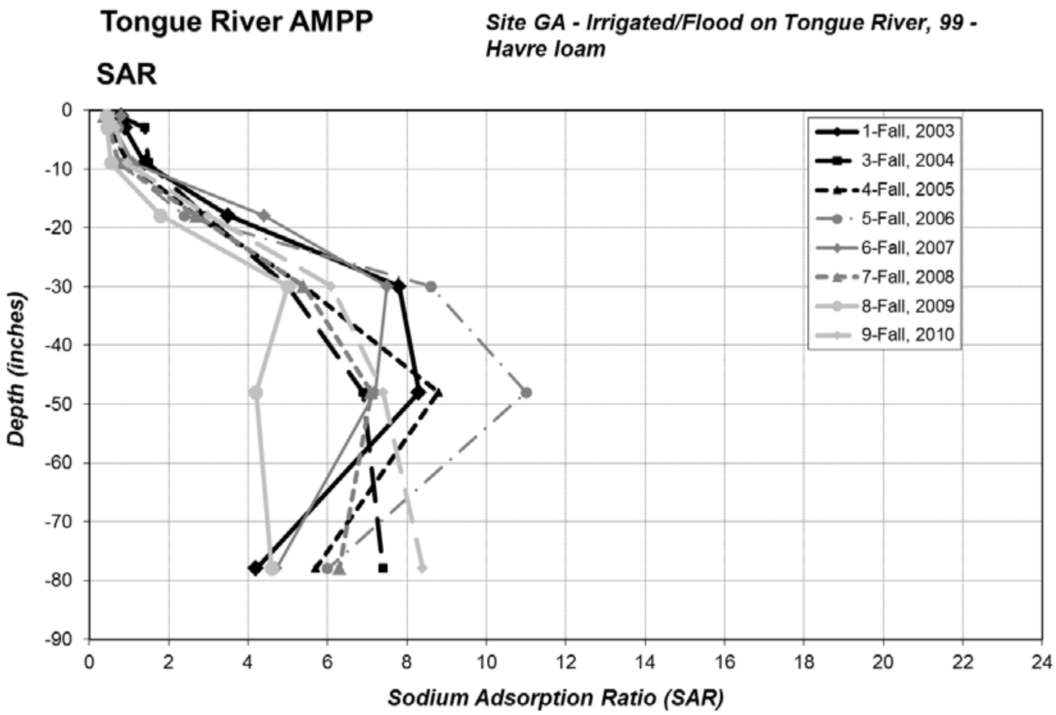

Figure 4-11 Trends in SAR with Depth for Site GA.

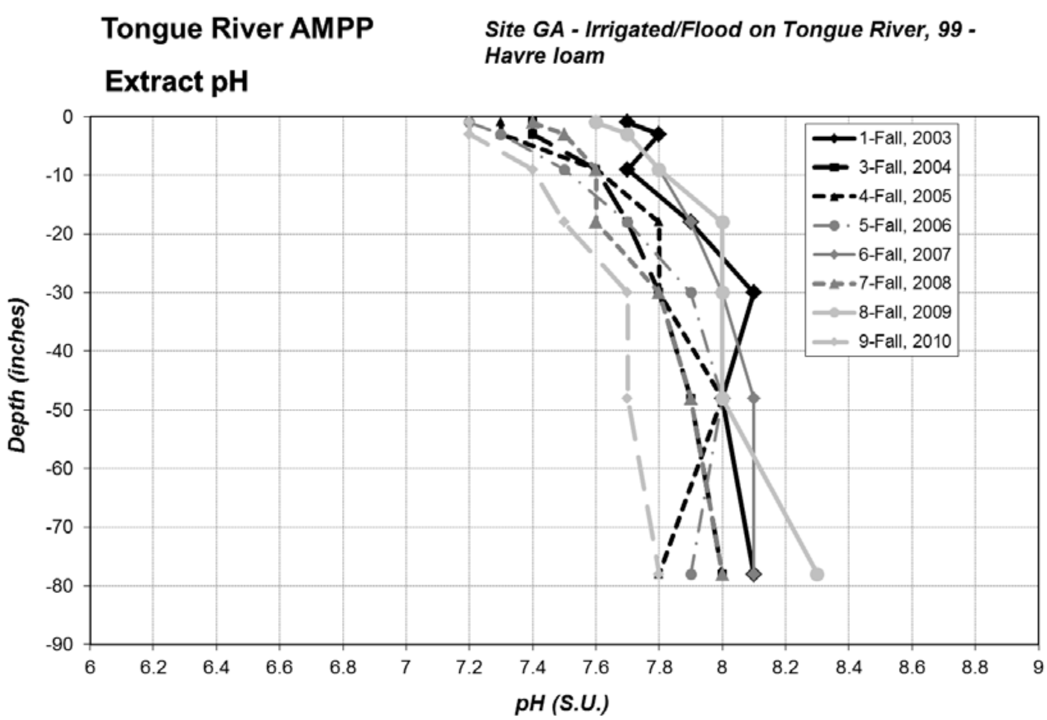

Figure 4-12 Trends in pH with Depth for Site GA.

4.1.4 Site GB

Site GB (Table 4-7 and 4-8) is a dryland native range field that was sampled only in 2003 to provide a comparison between irrigated and dryland fields that had the same soil mapping unit and similar landscapes. Soil EC, ESP, SAR and pH (Figures 4-13 to 4-16) are very similar between sites GA and GB except salts had been leached by the irrigation water from the 12-24 inch depth in GB to 24-36 inch depth in GA.

Table 4-7 Soil pH, EC, Saturation Extractable Ions and SAR for Site GB.

Depth (inches)		pH (Paste) s_u_ Method ASAM10-3_2	Electrical Conductivity (Paste) mmhos/cm Method ASAM10-3	Saturation Percentage wt% Method USDA27a	Calcium (Paste) meq/l Method SW6010B	Magnesium (Paste) meq/l Method SW6010B	Sodium (Paste) meq/l Method SW6010B	Sodium Adsorption Ratio unitless Method Calculation	Alkalinity (Paste) meq/L Method ASA10-3	Bicarbonate (Paste) meq/L Method ASA10-3	Carbonate (Paste) meq/L Method ASA10-3	Chloride (Paste) meq/L Method ASA10-3
1-Fall, 2003												
0	2	7.7	0.73	43.6	5	1.9	0.4	0.2	6.5			
0	6	7.9	0.63	42.1	3.8	1.6	0.6	0.4	5.1			
6	12	8	0.64	38.5	2.6	1.6	1.7	1.2	4.9			
12	24	8.1	4.05	39.2	14	17.4	16.8	4.2	3.7			
24	36	8	5.49	42.1	13.1	26.6	30.8	6.9	2.4			
36	60	8.1	6.85	42.7	17.6	37.7	32.7	6.2	2.4			
60	96	8	2.64	35.4	5.3	10.3	15.6	5.6	2.8			

Table 4-8 Soil Texture, Lime, CEC and ESP for Site GB.

Depth (inches)		Sand % Method ASA15-5	Silt % Method ASA15-5	Clay % Method ASA15-5	Texture unitless Method ASA15-5	Lime as CaCO3 wt% Method USDA23c	Cation Exchange Capacity meq/100g Method SW6010B	Extractable Sodium meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
1-Fall, 2003									
0	2	37	49	14	L	4.3	28.7	0.4	1.2
0	6	33	50	17	SiL	5.9	27.7	0.3	1
6	12	34	47	19	L	6.3	23.2	0.5	1.8
12	24	36	46	18	L	7	22.9	1.5	3.5
24	36	35	46	19	L	7.9	15	2.6	9
36	60	41	41	18	L	7.8	14.1	2.4	6.8
60	96	56	28	16	SL	8.3	21.6	1.3	3.6

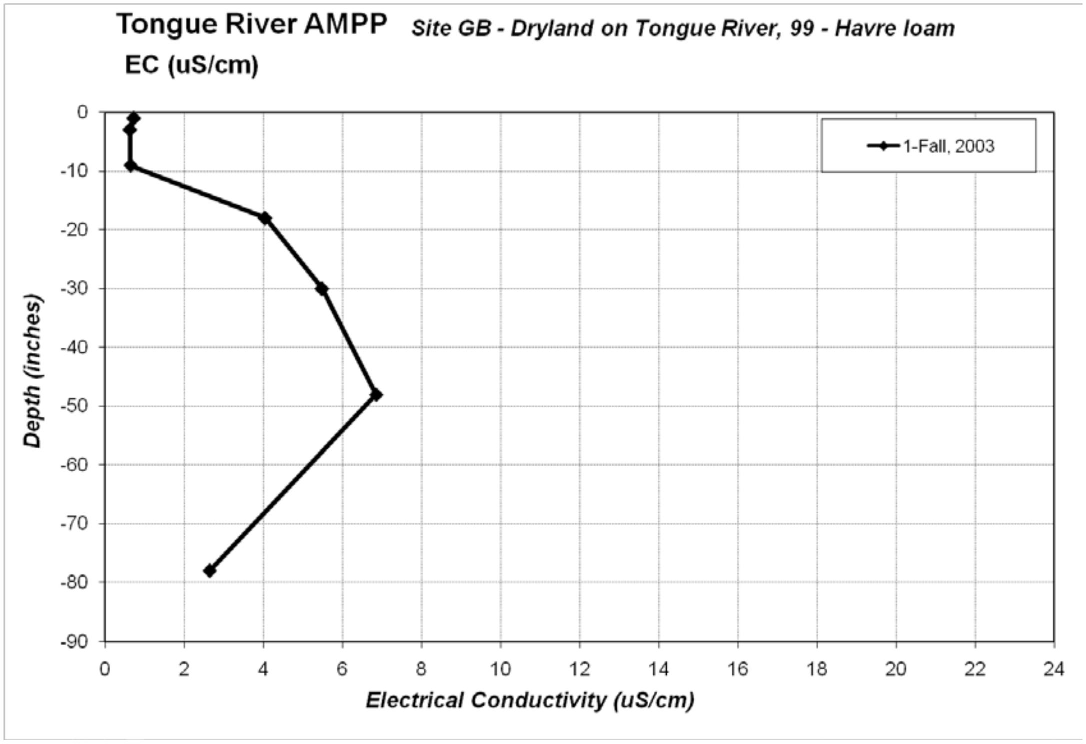

Figure 4-13 Trends in EC with Depth for Site GB.

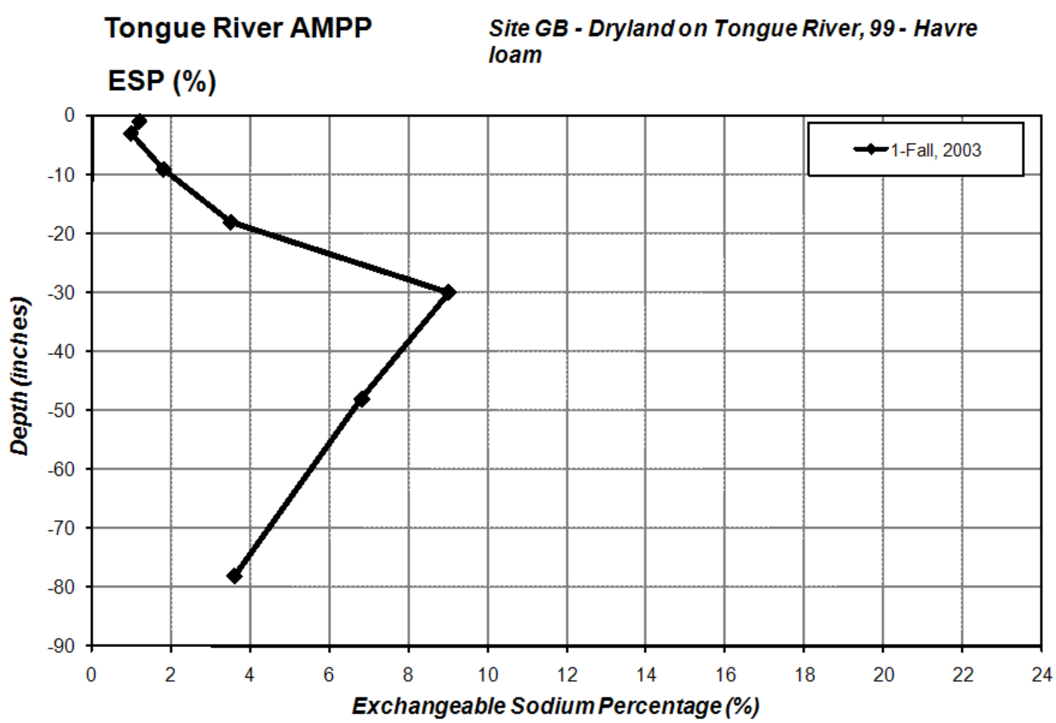

Figure 4-14 Trends in ESP with Depth for Site GB.

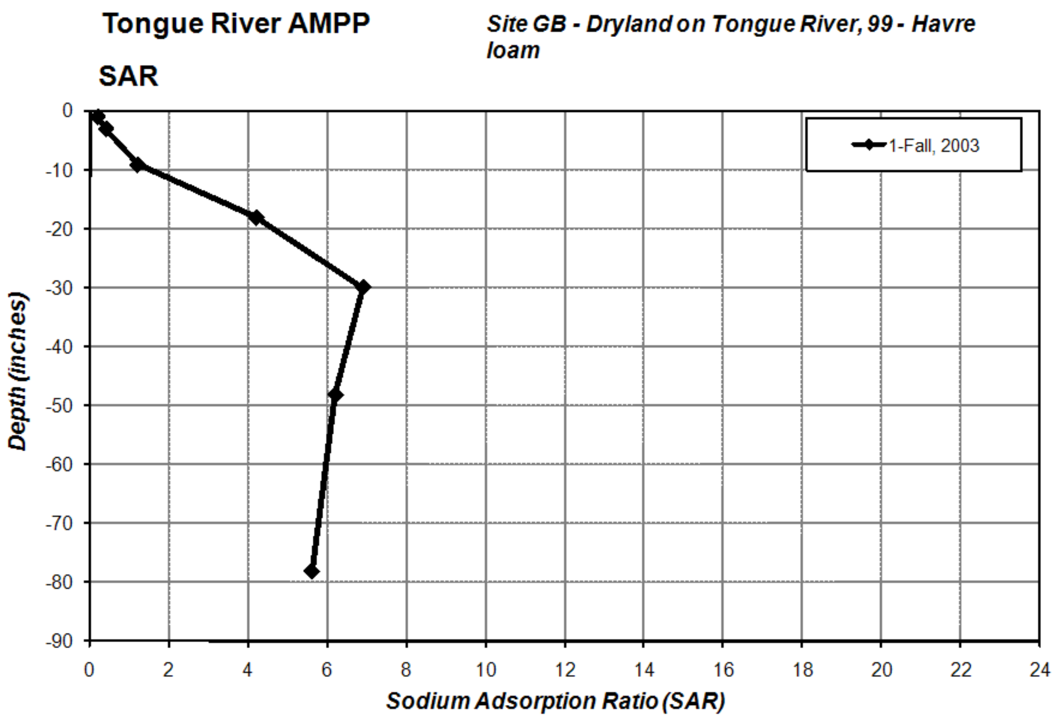

Figure 4-15 Trends in SAR with Depth for Site GB.

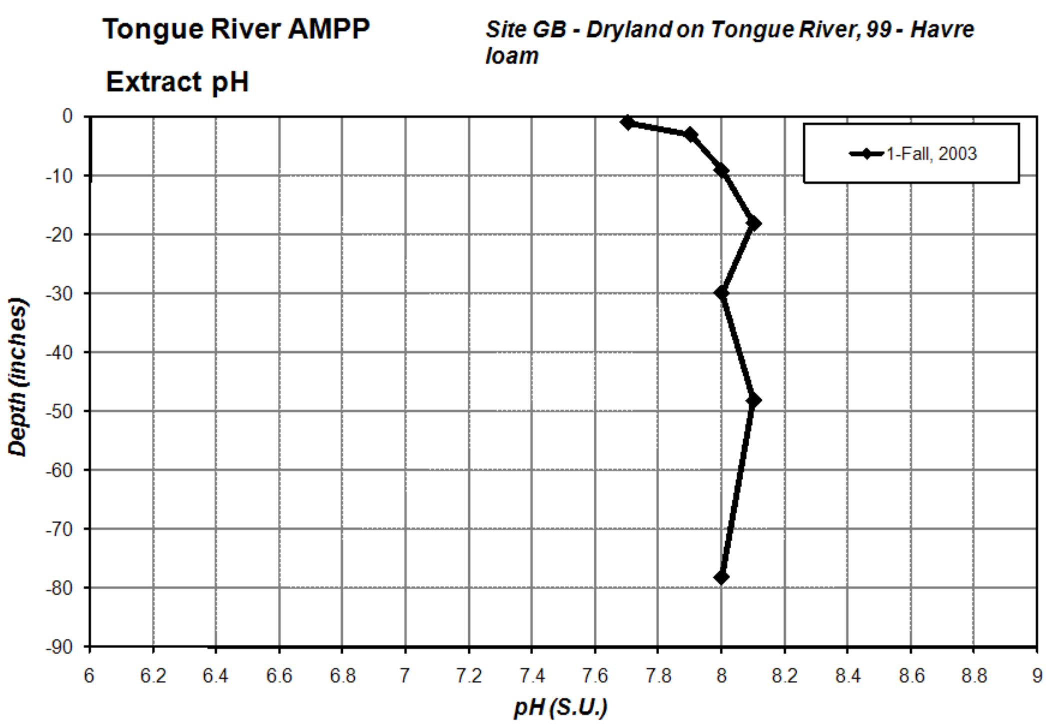

Figure 4-16 Trends in pH with Depth for Site GB.

4.1.5 Site GC

Site GC (Table 4-9 and 4-10) was a flood-irrigated alfalfa field that has been land-leveled. Alfalfa yields varied from 2.5 to 3.2 tons per acre and 16 to 24 inches of applied irrigation water. Due to the alfalfa stand thinning from age, it was torn out and planted to hay barley in 2007. Yield was 1.4 tons per acre because of being planted late spring. Twelve inches of water were applied in 2007. An irrigated grass mixture with 10% alfalfa was planted spring 2008 and yielded 1.8 tons per acre in 2008 with 18 inches of applied water. According to the cooperator, this established stand of grass/alfalfa yielded 4 tons per acre in 2009 with 18 inches of irrigation, while waypoint yield was 3.03 tons per acre. The grower yield was 3.75 tons per acre (2.79 tons per acre waypoint) in 2010 with 12 inches of applied irrigation water.

All soil properties (Figure 4-17 to 4-20) were uniform with depth and through time indicating that this field has a higher leaching fraction than other AMPP fields and was well-drained (e.g. no water table within 8 feet of surface).

Table 4-9 Soil pH, EC, Saturation Extractable Ions and SAR for Site GC.

Depth (inches)		pH (Paste) s_u_ Method ASAM10-3_2	Electrical Conductivity (Paste) mmhos/cm Method ASAM10-3	Saturation Percentage wt% Method USDA27a	Calcium (Paste) meq/l Method SW6010B	Magnesium (Paste) meq/l Method SW6010B	Sodium (Paste) meq/l Method SW6010B	Sodium Adsorption Ratio unitless Method Calculation	Alkalinity (Paste) meq/L Method ASA10-3	Bicarbonate (Paste) meq/L Method ASA10-3	Carbonate (Paste) meq/L Method ASA10-3	Chloride (Paste) meq/L Method ASA10-3
1-Fall, 2003												
0	2	7.7	0.78	64.1	4.6	2.8	1.5	0.8	6.6			
0	6	7.8	0.67	57.9	3.6	2.1	1.7	1	5			
6	12	7.9	0.61	54.1	2.7	1.6	2.3	1.5	3.5			
12	24	7.9	0.83	50.6	3.7	2.4	2.6	1.5	2.2			
24	36	8	0.86	43.4	4	2.6	2.5	1.4	2.7			
36	60	7.9	0.77	38.9	3.3	2.4	2.3	1.3	2.7			
60	96	8	0.64	27.4	2.7	2	1.9	1.2	2.9			
2-Spring, 2004												
0	2	7.5	1.58	58.7	8.07	5.14	1.74	0.7	7			4.94
0	6	7.7	0.72	56.8	3.93	2.27	1.35	0.8	5.6			2.4
6	12	7.8	0.53	50.5	2.57	1.57	1.62	1.1	4			1.27
12	24	7.9	0.78	47.9	3.38	2.12	2	1.2	2.8			1.13
24	36	7.9	0.81	43.3	3.68	2.4	2.01	1.2	3.2			1.41
36	60	7.8	0.99	39.5	5.35	3.74	2.59	1.2	3.6			8.04
60	96	7.9	1.27	24.9	6.8	4.51	5.02	2.1	3.6			1.13
3-Fall, 2004												
0	2	7.3	1.29	69.7	5.69	3.57	2.11	0.98	9.2			
0	6	7.9	1.12	59.8	6.22	3.91	2.5	1.1	8.8			
6	12	7.6	0.94	55.8	4.45	2.83	2.74	1.4	4.8			
12	24	7.6	1.25	51.1	5.32	3.54	3.23	1.5	3.6			
24	36	7.7	1.43	43.9	6.43	4.47	3.33	1.4	3.3			
36	60	7.6	0.76	36.7	3.8	2.54	2.14	1.2	3.6			
60	90	7.5	0.65	30	2.87	2.65	1.8	1.1	3.8			
4-Fall, 2005												
0	2	7.2	1.23	69.7	6.39	4.05	1.19	0.52				
0	6	7.3	0.87	64.1	5.43	3.38	1.35	0.64				
6	12	7.6	0.62	57.8	3.23	2.15	1.96	1.2				
12	24	7.7	0.87	51.5	4.07	2.81	2.96	1.6				
24	36	7.6	1.45	48.3	7.78	5.32	3.69	1.4				
36	60	7.6	0.93	38.5	4.89	3.37	2.49	1.2				
60	96	7.6	0.8	27.3	3.61	2.74	2.25	1.3				
5-Fall, 2006												
0	2	7.4	0.79	51.4	4.18	2.4	0.8	0.44				0.17
0	6	7.1	1.09	59.3	5.99	3.85	1.5	0.68				0.38
6	12	7.5	0.63	53.7	2.88	1.93	1.49	0.96				0.28
12	24	7.6	0.67	48.2	2.98	2.07	1.74	1.1				0.36
24	36	7.6	1.17	44.4	5.53	3.92	2.95	1.4				0.49
36	60	7.6	1.17	38.8	5.15	3.69	2.63	1.2				0.09
60	96	7.5	0.92	26.8	4.05	3.01	2.06	1.1				0.05
6-Fall, 2007												
0	2	7.8	0.7	58.7	3.97	2.36	1.42	0.8				0.53
0	6	7.6	0.84	53.4	4.64	2.77	1.47	0.76				0.7
6	12	7.7	0.66	52.6	3.4	2.15	1.48	0.89				0.35
12	24	7.9	0.72	47.4	3.14	2.24	2.34	1.4				0.4
24	36	8	0.85	45.2	3.49	2.58	2.84	1.6				0.53
36	60	7.9	1.19	31.2	5.5	4.09	3.35	1.5				1.41
60	96	7.8	0.99	24.9	4.42	3.34	2.24	1.1				0.85
7-Fall, 2008												
0	2	7.4	0.8	61	4.59	2.77	0.71	0.37				0.54
0	6	7.4	0.6	58.7	3.2	1.96	1.02	0.64				0.41
6	12	7.5	0.48	56.2	2.21	1.37	1.11	0.83				0.21
12	24	7.8	0.42	43.3	1.57	1.03	1.21	1.1				0.22
24	36	7.8	0.63	43.4	2.49	1.64	1.85	1.3				0.33
36	60	7.7	1.38	36.4	6.41	4.43	2.51	1.1				0.41
60	96	7.7	1.31	29	6.06	4.96	2.47	1				0.38
8-Fall, 2009												
0	2	7.6	0.36	62.6	2.19	1.35	0.78	0.59				0.3
0	6	7.5	0.61	63.5	3.7	2.26	0.89	0.52				0.38
6	12	7.8	0.37	54.4	2.2	1.25	0.94	0.72				0.22
12	24	7.9	0.43	47.7	2.22	1.44	1.3	0.96				0.13
24	36	8	0.53	42	2.59	1.74	1.74	1.2				0.13
36	60	8	0.58	34.2	3.18	2.08	1.82	1.1				0.21
60	96	8	0.58	23.5	2.91	2.14	1.43	0.9				0.25
9-Fall, 2010												
0	2	7.2	0.79	57.7	4.41	2.47	1.37	0.74				
0	6	7.3	0.68	56.6	3.5	2.02	1.44	0.87				
6	12	7.4	0.54	52.3	2.59	1.57	1.59	1.1				
12	24	7.5	0.53	46.6	2.23	1.5	1.72	1.3				
24	36	7.6	0.61	41.6	2.26	1.49	2.18	1.6				
36	60	7.5	0.96	32.2	4.14	2.86	3.02	1.6				
60	96	7.5	1.05	25.2	4.37	3.33	2.73	1.4				

Table 4-10 Soil Texture, Lime, CEC and ESP for Site GC.

Depth (inches)		Sand % Method ASA15-5	Silt % Method ASA15-5	Clay % Method ASA15-5	Texture unitless Method ASA15-5	Lime as CaCO3 wt% Method USDA23c	Cation Exchange Capacity meq/100g Method SW6010B	Extractable Sodium meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
1-Fall, 2003									
0	2	15	52	33	SiCL	10.5	37.5		1.7
0	6	12	53	35	SiCL	9.7	42.2		1.3
6	12	8	57	35	SiCL	8.8	39.1		1.8
12	24	10	59	31	SiCL	9.2	33.3		2.2
24	36	24	52	24	SiL	9.5	28.7		2.2
36	60	31	47	22	L	8.7	24.2		2.4
60	96	52	32	16	L	8.1	17.6		3.4
2-Spring, 2004									
0	2	11	52	37	SiCL	8	36.8	0.71	1.6
0	6	5	56	39	SICL	8.2	29.3	0.81	2.5
6	12	7	53	40	SiC	8.5	30.3	0.99	3
12	24	12	55	33	SiCL	9.2	25.7	1.11	4
24	36	25	49	26	L	8.7	22.1	0.89	3.6
36	60	30	46	24	L	8.1	18.3	1.05	5.2
60	96	40	51	9	SiL	5.9	10.8	0.99	8
3-Fall, 2004									
0	2	12	53	35	SiCL	8	31.5		1.5
0	6	13	51	36	SiCL	8.2	30.9		1.6
6	12	11	52	37	SiCL	8.9	22.6		2.8
12	24	12	54	34	SiCL	9.3	25.2		2.6
24	36	22	50	28	CL	9.1	25		2.4
36	60	40	40	20	L	8.1	20.9		2.9
60	90	63	26	11	SL	6.8	15.1		3
4-Fall, 2005									
0	2	16	49	35	SiCL	8.6	43.1		1
0	6	12	53	35	SiCL	9	35.9		1.3
6	12	7	56	37	SiCL	9.8	30.2		1.8
12	24	15	54	31	SiCL	10.1	32.7		1.7
24	36	22	50	28	CL	9.4	27		1.8
36	60	40	40	20	L	10	21.5		2.5
60	96	61	28	11	SL	8.2	16.8		2
5-Fall, 2006									
0	2	35	46	19	L	5.1	28.4		1.5
0	6	10	55	35	SiCL	8.2	38.3		1.4
6	12	9	58	33	SiCL	8.8	31.8		1.9
12	24	17	57	26	SiL	9.2	29.4		2
24	36	29	49	22	L	7.8	24.5		2.5
36	60	31	50	19	SiL	8.5	22		2.9
60	96	68	24	8	SL	5.9	14.7		2.9
6-Fall, 2007									
0	2	10	53	37	SiCL	7.8	30.4		1.6
0	6	10	54	36	SiCL	7.8	34.1		1.6
6	12	12	53	35	SiCL	7.8	30.2		2
12	24	15	52	33	SiCL	8.3	27.9		2.3
24	36	18	52	30	SiCL	8	26.6		2.6
36	60	50	34	16	L	7.1	17.3		3.4
60	96	73	17	10	SL	6	13.4		3.7
7-Fall, 2008									
0	2	4	58	38	SiCL	8.1	29.7		1.3
0	6	8	52	40	SiC	7.9	29.4		1.5
6	12	8	52	40	SiC	8.3	28.8		1.7
12	24	20	50	30	SiCL	8.7	22.3		2.3
24	36	18	54	28	SiCL	8	22.3		2.7
36	60	20	56	24	SiL	7.6	18.9		3.1
60	96	54	30	16	SL	7.2	14.4		3.4
8-Fall, 2009									
0	2	16	50	34	SiCL	8.3	27.4		0.9
0	6	18	47	35	SiCL	8.2	30.2		0.9
6	12	14	50	36	SiCL	8.6	24.7		1.1
12	24	16	53	31	SiCL	9	24.7		1.4
24	36	32	44	24	L	8.2	21.3		1.9
36	60	42	38	20	L	7.5	16.1		1.8
60	96	70	20	10	SL	6	9.47		2.7
9-Fall, 2010									
0	2	12	52	36	SiCL	8.35	20.4		0.7
0	6	8	54	38	SiCL	8.15	25.6		0.9
6	12	10	52	38	SiCL	8.73	22.4		1.3
12	24	16	52	32	SiCL	9.19	17.7		1.6
24	36	28	46	26	L	8.34	13.3		1.9
36	60	48	36	16	L	7.9	10.5		2.3
60	96	64	26	10	SL	6.79	7.7		2.7

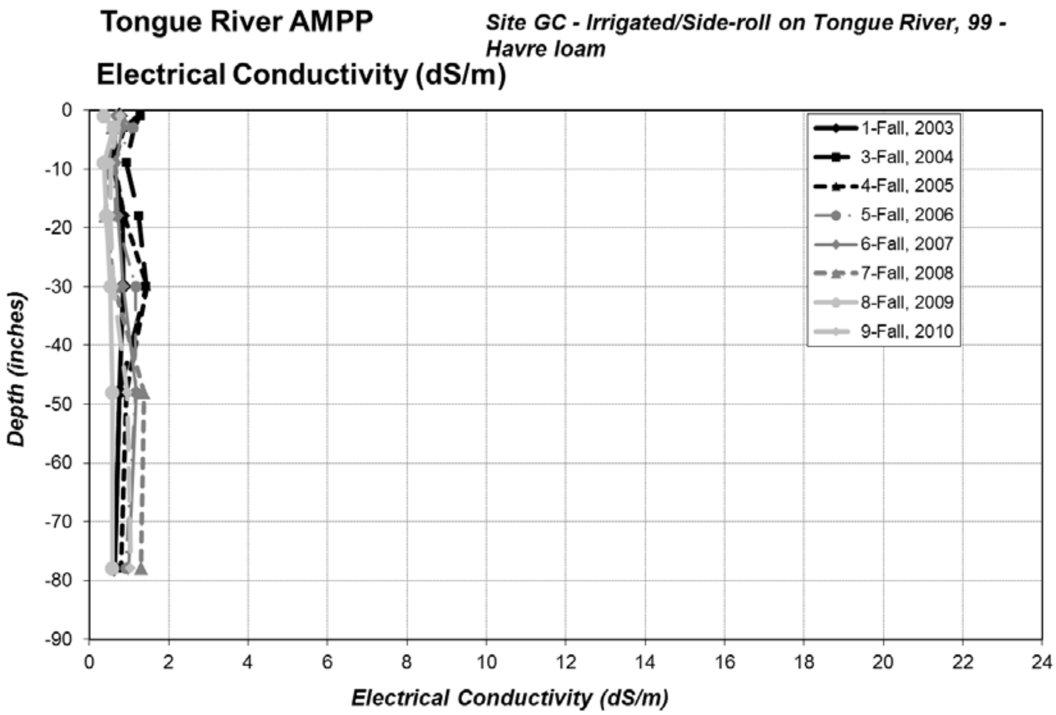

Figure 4-17   Trends in EC with Depth for Site GC.

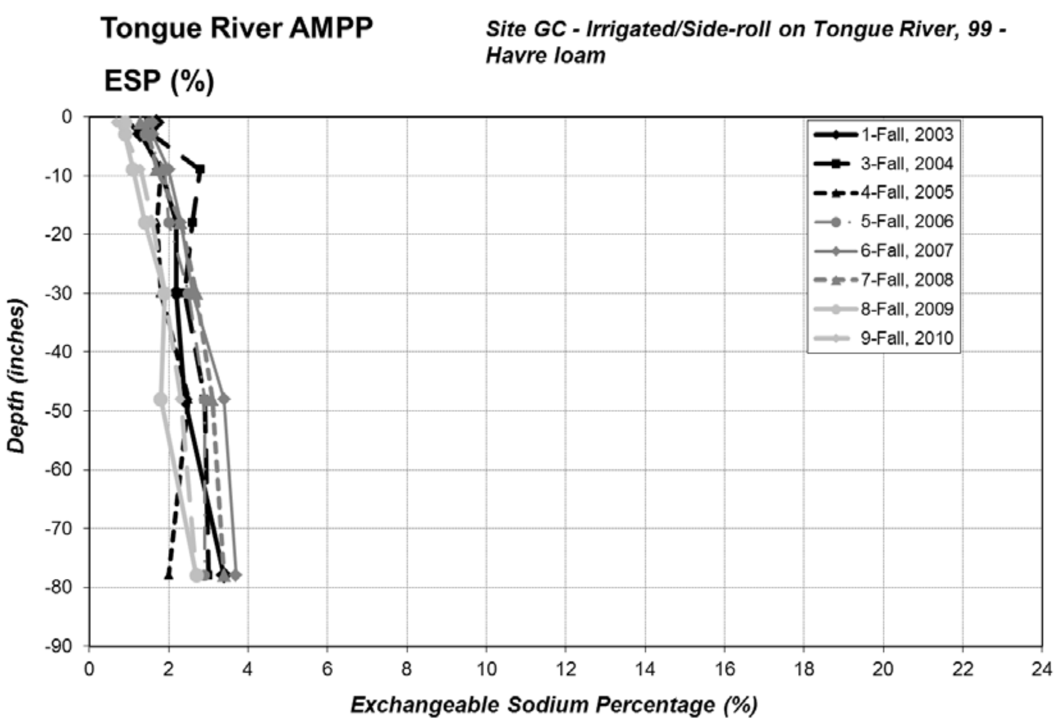

Figure 4-18   Trends in ESP with Depth for Site GC.

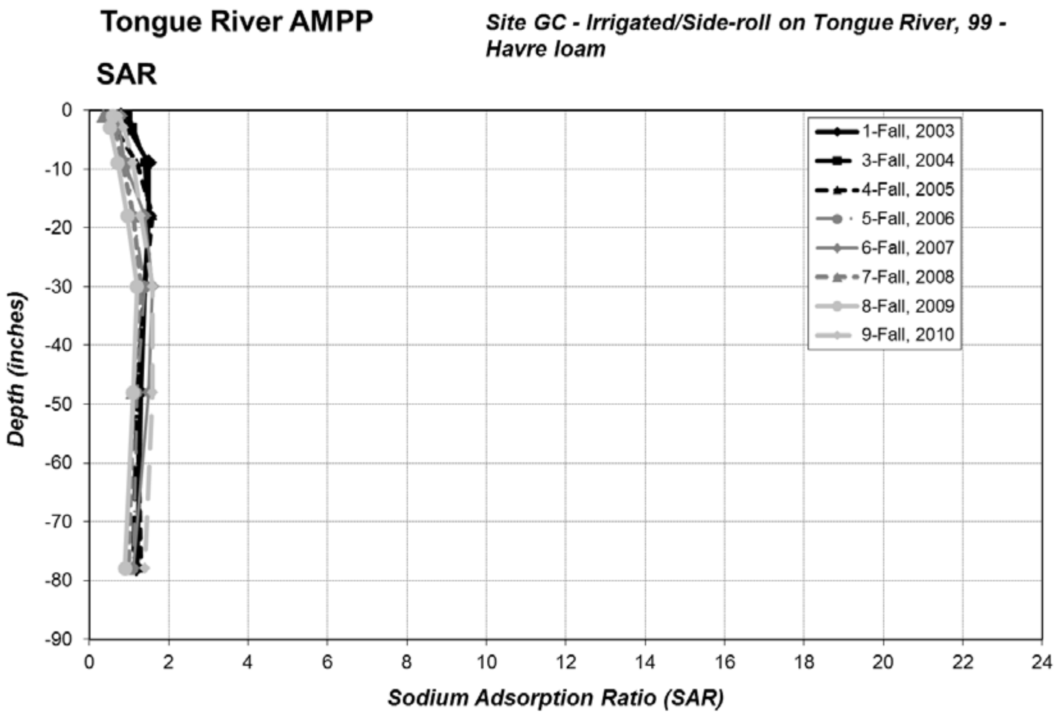

Figure 4-19 Trends in SAR with Depth for Site GC.

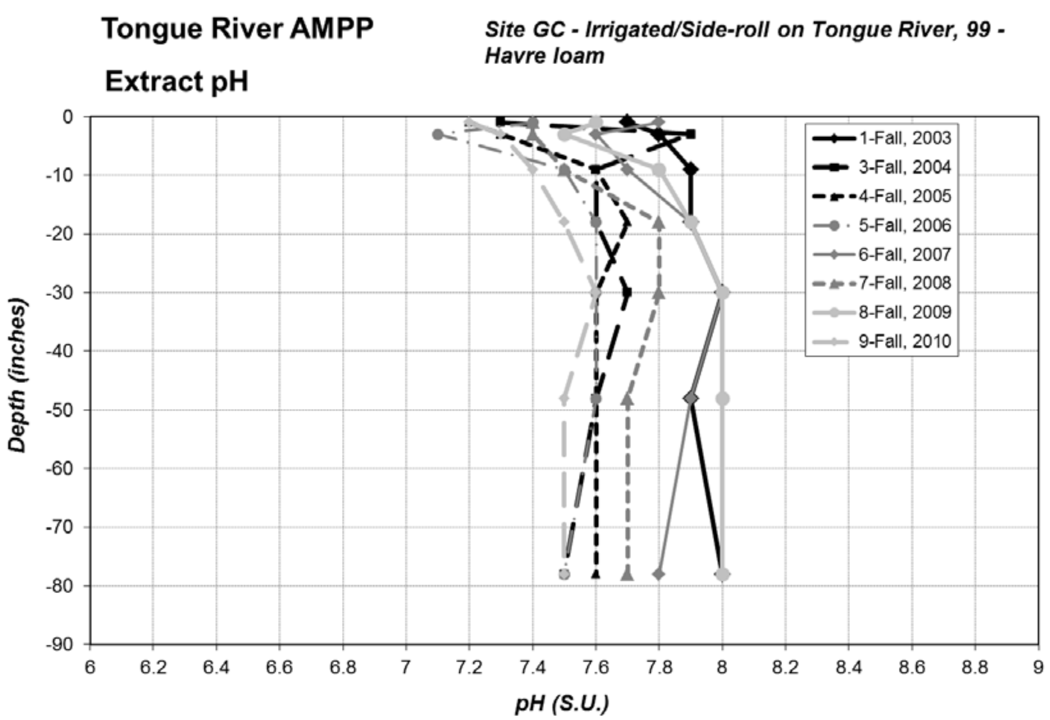

Figure 4-20 Trends in pH with Depth for Site GC.

4.1.6 Site EA

Site EA (Table 4-11 and 4-12) was in a transitional cropping pattern with hay millet in 2003, fallow in 2004, and new alfalfa established in 2005. This field is flood irrigated. About 10 inches of irrigation water was applied in 2003. Irrigation was increased in 2005 to 18 inches to support the new alfalfa stand. Only 6 inches of irrigation water was applied in 2006 and none was applied in 2007 although the field yielded over 4 tons per acre in 2006 and 3.2 tons per acres in 2007 suggesting that the field is sub-irrigated. EA was not irrigated in 2008 or 2009 but yielded 2.3 and 1.8 tons per acre in two cuttings. Site EA yielded 1.88 tons per acre in 2010 and no water was applied.

The third cutting in 2006 had a sodium content of 0.35% while the first two cuttings averaged 0.05%. EA was irrigated only once in 2006 and that was prior to the first cutting. That cutting was destroyed at harvest time (early June) from a hail that killed 90% of a neighboring corn field. The higher sodium levels in the third cutting may have resulted from diminished sub-irrigation water as 2006 Tongue River streamflows were substantially below long-term average, 155 vs. 605 cfs, respectively (Figure 3-5).

EC at site EA (Figure 4-21), like at most AMPP sites, was low (<2 dS/m) near surface and increased to around 5 dS/m at 3 to 5 feet in depth. Salinity decreased significantly in 2005 in the upper 4 feet in response to increased leaching from irrigation and rainfall. EC at depth remained low in 2006, but increased slightly in subsequent years, probably owing to the lack of irrigation to remove salts. The EC pattern with depth was similar in 2007 with one exception - measured EC was 12.1 at the 6 to 12 inch depth while the 0 to 6 and 12 to 24 inch depths remained low. Soil SAR and ESP were also elevated in 2007 at this depth only. This unusual increase in EC was confirmed by a repeated analysis of a subsample split obtained in the lab. Elevated EC, SAR, and ESP were not evident in the 2008 through 2010 samples indicating these 2007 elevated parameters may have been due to a mis-labeled or mis-managed sample.

ESP, SAR and pH (Figure 4-22 to 4-24) exhibited an increase with depth as occurs in most AMPP soils. ESP and SAR decreased from 2004 through 2006 owing to irrigation management, but increased in 2007 and 2008, perhaps due to the lack of irrigation coupled with evaporation from a water table. Sodium levels decreased in 2009 compared to 2008. Site EA had a water table at 7 feet in depth (Figure 3-14 and 3-15) with an EC of 1.9 dS/m and an SAR of 2.9.

Table 4-11 Soil pH, EC, Saturation Extractable ions and SAR for Site EA.

Depth (inches)		pH (Paste) s_u_ Method ASAM10-3_2	Electrical Conductivity (Paste) mmhos/cm Method ASAM10-3	Saturation Percentage wt% Method USDA27a	Calcium (Paste) meq/l Method SW6010B	Magnesium (Paste) meq/l Method SW6010B	Sodium (Paste) meq/l Method SW6010B	Sodium Adsorption Ratio unitless Method Calculation	Alkalinity (Paste) meq/L Method ASA10-3	Bicarbonate (Paste) meq/L Method ASA10-3	Carbonate (Paste) meq/L Method ASA10-3	Chloride (Paste) meq/L Method ASA10-3
1-Fall, 2003												
0	2	7.6	1.4	57.8	7.1	4.4	2.9	1.2	7.6			
0	6	7.8	1.88	60.1	9.3	5.7	5.4	2	6.4			
6	12	7.9	1.55	47.6	5.7	4	6.6	3	4			
12	24	7.8	4	53.7	17.6	14.9	18.5	4.6	3.2			
24	36	8	4.77	52.3	16.1	21.1	24.2	5.6	2.8			
36	60	7.9	5.58	50.1	17.4	28.1	26.7	5.6	2.4			
60	96	8	2.19	45.6	5	9.3	11	4.1	2.8			
2-Spring, 2004												
0	2	7.5	0.99	58.2	6.09	3.46	1.87	0.9	8.4			0.71
0	6	7.6	0.94	56.3	5.42	3.09	2.33	1.1	10			0.71
6	12	7.6	2.66	55.6	13.5	10	7.16	2.1	4.6			0.42
12	24	7.6	4.6	51.8	24.6	21.2	13.1	2.7	4			0.56
24	36	7.8	5.52	48.5	20	24.9	20.7	4.4	3.6			0.28
36	60	8	4.17	42.8	8.41	16.1	19.6	5.6	3			0.56
60	96	7.8	3.16	40.7	11.6	16.3	11.7	3.1	2.6			0.42
3-Fall, 2004												
0	2	7.6	1.09	55.5	5.09	3.29	2.17	1.1	9.5			
0	6	7.5	2.28	54.7	10.7	6.64	5.49	1.9	6.4			
6	12	7.6	3.3	56.1	15.2	11.4	12.5	3.4	3.6			
12	24	7.8	5.37	54.5	22.7	19.6	21.7	4.7	2.9			
24	36	7.8	4.81	53.4	16.7	18.9	22.1	5.2	3.1			
36	60	8	5.88	45.3	14.4	25.4	30	6.7	2.4			
60	90	8	2.7	43.2	4.51	9.14	12.5	4.8	2.8			
4-Fall, 2005												
0	2	7.3	1.26	61.9	7.94	5.39	1	0.39				
0	6	7.3	1.14	57.6	6.4	4.16	1.59	0.69				
6	12	7.6	0.91	46.3	4.54	3.1	2.83	1.4				
12	24	7.6	1.26	44.7	4.43	3.55	4.62	2.3				
24	36	7.7	3.14	51.5	12.3	13.1	11.2	3.2				
36	60	7.8	4.74	43.1	14.7	25.6	28.3	6.3				
60	96	7.9	3.56	45.6	7.86	17.7	21.6	6				
5-Fall, 2006												
0	2	7.4	0.97	58.2	5.84	3.27	0.72	0.34				0.21
0	6	7.3	1.11	54	5.77	3.96	1.21	0.55				0.75
6	12	7.5	1.12	48.7	5.16	3.42	2.51	1.2				0.27
12	24	7.6	1.28	46.3	4.09	3.55	5.28	2.7				0.27
24	36	7.7	2.92	47.5	9.81	11	12.6	3.9				0.38
36	60	7.9	3.59	38.6	7.31	13.9	18.7	5.7				0.21
60	96	7.9	2.92	35.8	5.78	12.8	12.7	4.2				0.59
6-Fall, 2007												
0	2	7.6	1.21	57.4	6.13	3.62	2.5	1.1				0.85
0	6	7.6	0.96	53.1	5.41	3.57	1.51	0.71				0.88
6	12	8.3	11.9	31	16.1	25	101	22				2
12	24	7.7	2.44	47.6	11.4	8.67	7.57	2.4				0.7
24	36	7.8	4.01	50.3	19.2	18.6	16.9	3.9				0.42
36	60	8.2	3.87	49.2	5.37	12.2	24.4	8.2				0.7
60	96	8.1	2.46	50.3	4.01	8.79	13.5	5.3				0.53
7-Fall, 2008												
0	2	7.3	1.2	59.8	7.1	3.75	0.48	0.21				0.35
0	6	7.4	0.79	52.6	4.49	2.58	0.83	0.44				0.3
6	12	7.7	0.79	46	3.49	2.38	2.14	1.2				0.42
12	24	7.6	2.97	45.6	14.5	12.3	12.1	3.3				0.42
24	36	7.8	5.55	48.3	20.2	25.9	27.5	5.7				0.52
36	60	7.8	4.31	42.7	10.6	20.9	21.2	5.3				0.31
60	96	7.9	3.04	36.4	5.87	13.1	15.6	5.1				0.3
8-Fall, 2009												
0	2	7.4	0.8	63.5	4.61	2.68	0.63	0.33				0.37
0	6	7.5	0.93	60	4.85	2.59	0.82	0.43				0.34
6	12	7.7	0.89	50.8	4.5	3.2	2.5	1.3				0.43
12	24	7.6	2.51	47.1	14.5	12.1	7.67	2.1				0.42
24	36	7.8	4.15	50.3	16.9	20.4	17	3.9				0.48
36	60	8	4.69	41.7	13.9	24.9	23.2	5.3				0.47
60	96	8	2.48	41	5.64	13	12.4	4.1				0.37
9-Fall, 2010												
0	2	7.2	1.07	59.2	4.61	3.3	0.52	0.26				
0	6	7.2	0.78	50.4	4.35	2.55	0.76	0.41				
6	12	7.4	0.74	44.8	3.63	2.43	2.21	1.3				
12	24	7.5	1.8	45.8	7.01	5.86	6.19	2.4				
24	36	7.6	6.14	47.2	23.9	27	28.4	5.6				
36	60	7.7	4.07	43.5	10.1	20.5	20.1	5.1				
60	96	7.7	4.06	43.9	9.79	18.9	19.2	5.1				

Table 4-12 Soil Texture, Lime, CEC and ESP for Site EA.

Depth (inches)		Sand % Method ASA15-5	Silt % Method ASA15-5	Clay % Method ASA15-5	Texture unitless Method ASA15-5	Lime as CaCO3 wt% Method USDA23c	Cation Exchange Capacity meq/100g Method SW6010B	Extractable Sodium meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
1-Fall, 2003									
0	2	31	42	27	CL	6	32.5		2.4
0	6	17	54	29	SiCL	6.3	32.5		2.8
6	12	21	52	27	CL	6.5	31.1		4
12	24	20	45	35	SiCL	7.3	30.2		4.3
24	36	29	41	30	CL	8.5	25.1		4.1
36	60	30	42	28	CL	8.1	24.2		4
60	96	19	56	25	SiL	7.6	20.8		5.3
2-Spring, 2004									
0	2	21	50	29	CL	5.8	26.4	0.51	1.5
0	6	17	53	30	SiCL	5.9	28.6	0.7	2
6	12	12	54	34	SiCL	6.1	26.6	1.33	3.5
12	24	13	51	36	SiCL	7.2	26.3	1.83	4.4
24	36	23	49	28	CL	8.8	20.5	2.31	6.4
36	60	36	42	22	L	8.1	19.6	2.17	6.8
60	96	39	37	24	L	8	16.9	1.2	4.3
3-Fall, 2004									
0	2	22	51	27	CL	6.1	26.8		1.6
0	6	18	56	26	SiL	6.3	35.5		1.6
6	12	17	53	30	SiCL	6.5	28		3.8
12	24	17	50	33	SiCL	7.1	26.3		4.8
24	36	20	57	23	SiL	7.9	24		5.2
36	60	34	40	26	L	8.5	22.7		5.2
60	90	33	41	26	L	8.5	18.6		6.4
4-Fall, 2005									
0	2	22	52	26	SiL	6.7	33.8		1.2
0	6	19	56	25	SiL	7	34.7		1.2
6	12	23	53	24	SiL	7.7	30.3		1.7
12	24	26	46	28	CL	7.8	32.5		2.1
24	36	20	52	28	SiCL	9.9	31.2		2.8
36	60	38	40	22	L	9.3	25.1		3.4
60	96	38	34	28	CL	9.4	27.8		3.4
5-Fall, 2006									
0	2	22	57	21	SiL	5.9	35		1.1
0	6	24	51	25	SiL	4.6	39.5		1
6	12	20	58	22	SiL	5.4	32.2		1.6
12	24	28	49	23	L	7.2	31.5		2.8
24	36	22	53	25	SiL	8	34.1		3.3
36	60	48	39	13	L	7.8	26.1		4.3
60	96	48	39	13	L	7	24.1		4.3
6-Fall, 2007									
0	2	21	54	25	SiL	5.4	32.6		0.8
0	6	21	55	24	SiL	5.5	30.9		1.3
6	12	63	28	9	SL	6.1	12.9		21
12	24	26	46	28	CL	6	28.4		3.1
24	36	21	47	32	CL	7	27.3		4.9
36	60	37	44	19	L	7.7	20.9		6.6
60	96	36	36	28	CL	6.9	27.4		5.4
7-Fall, 2008									
0	2	18	54	28	SiCL	5.7	33.2		1
0	6	18	50	32	SiCL	6.1	32		1.2
6	12	25	47	28	CL	6.7	26.4		2.3
12	24	24	46	30	CL	7.4	27.6		3.8
24	36	18	50	32	SiCL	9.3	24.4		5.7
36	60	32	42	26	L	8.7	21.1		6.4
60	96	38	38	24	L	8.1	17.4		6.3
8-Fall, 2009									
0	2	16	54	30	SiCL	5.8	30.4		0.2
0	6	20	54	26	SiL	5.9	27.5		0.4
6	12	18	56	26	SiL	6.8	23.2		1.3
12	24	22	48	30	CL	6.8	25.2		2.3
24	36	18	48	34	SiCL	8.3	24.6		4.6
36	60	36	42	22	L	7.8	18.5		5.4
60	96	36	38	26	L	7.2	19.4		4.8
9-Fall, 2010									
0	2	20	52	28	SiCL	5.75	21.4		0.5
0	6	26	48	26	L	6.31	18		0.8
6	12	22	50	28	CL	7.03	15.1		1.9
12	24	30	40	30	CL	7.28	15.7		3.6
24	36	22	48	30	CL	8.22	14.2		5.1
36	60	32	42	26	L	8.17	12.2		6.1
60	96	34	40	26	L	7.7	12.1		6.8

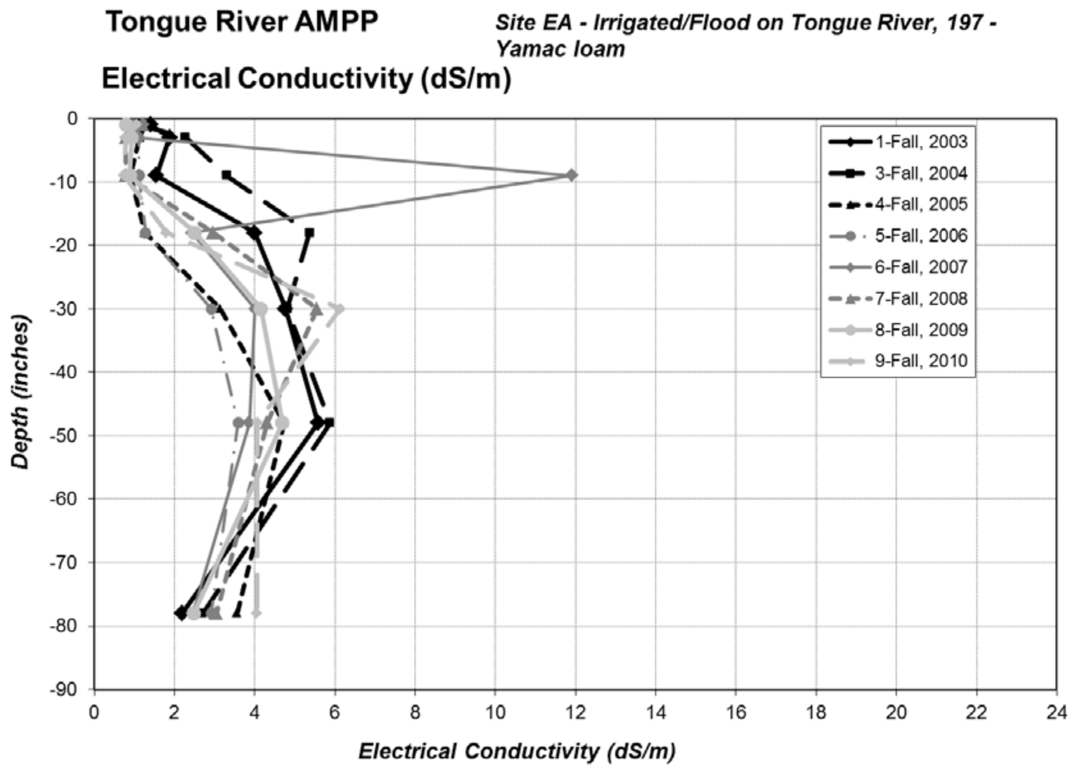

Figure 4-21 Trends in EC with Depth for Site EA.

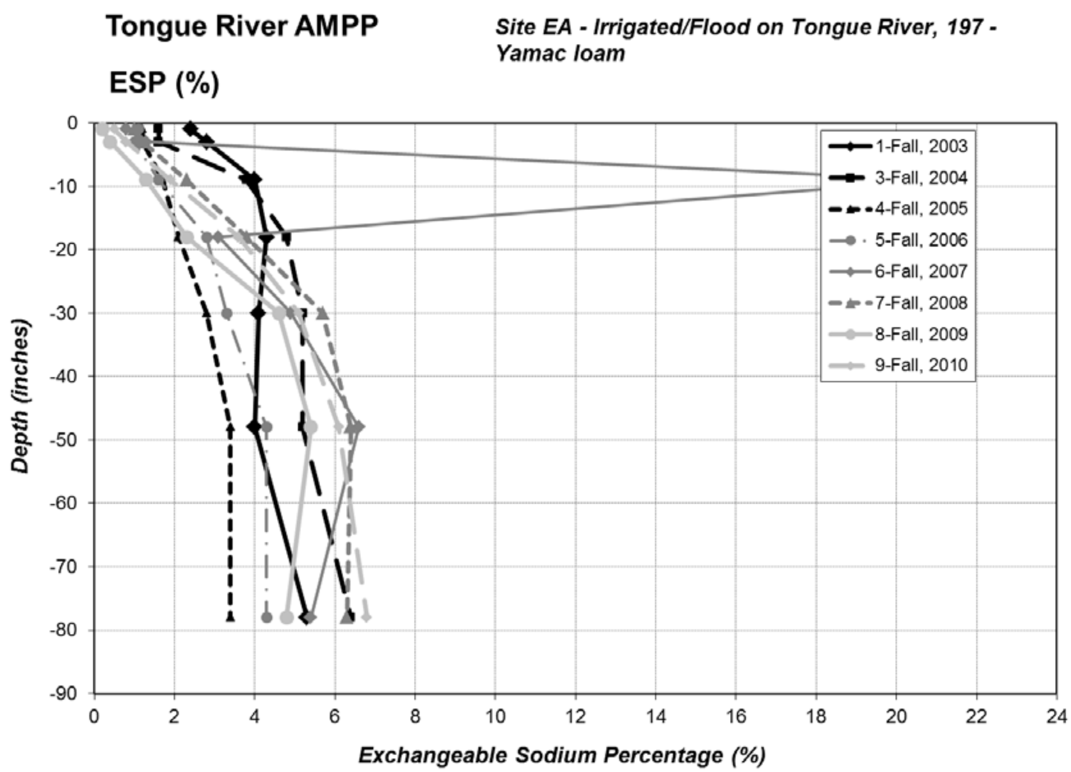

Figure 4-22 Trends in ESP with Depth for Site EA.

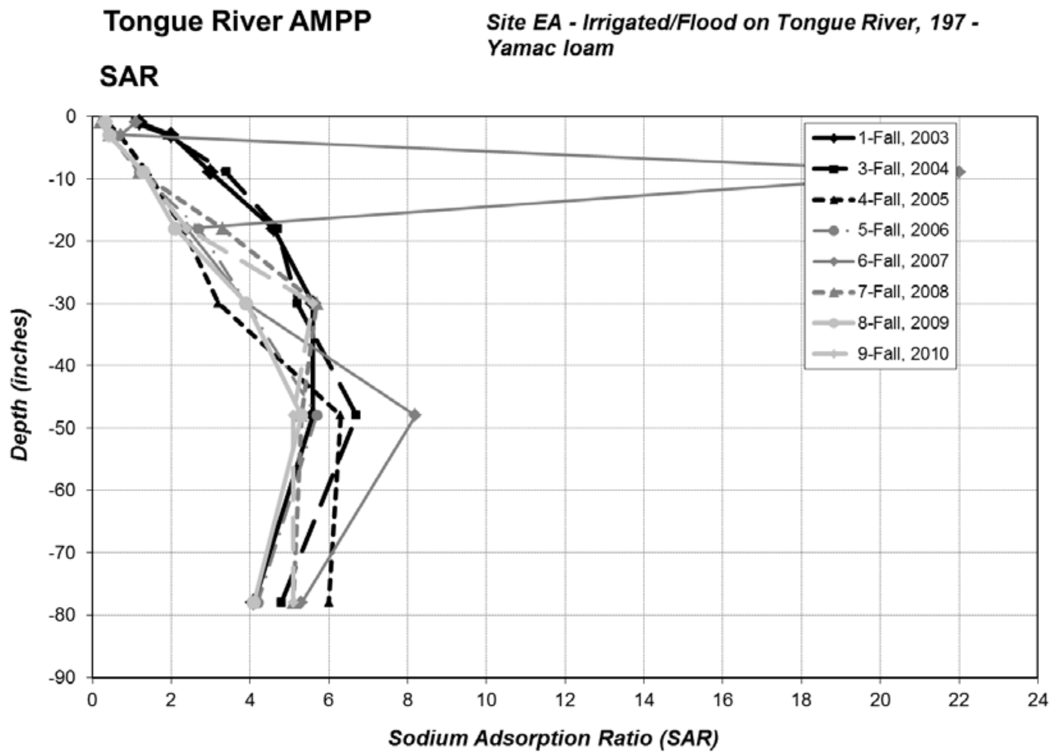

Figure 4-23 Trends in SAR with Depth for Site EA.

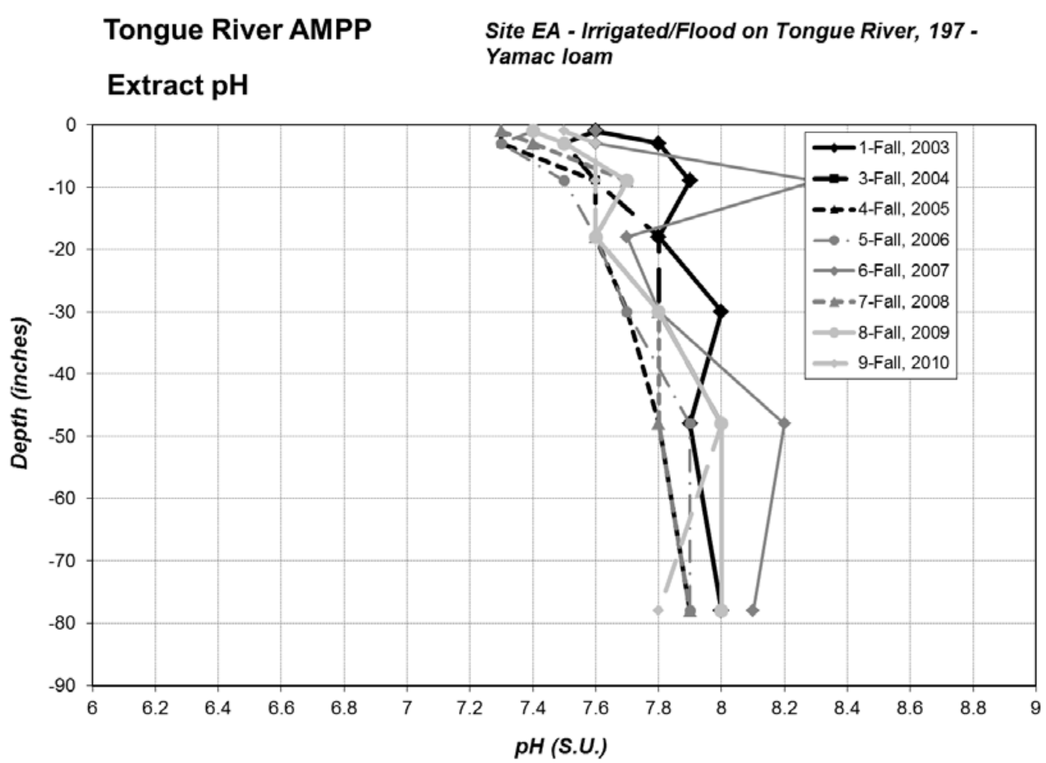

Figure 4-24 Trends in pH with Depth for Site EA.

4.1.7 Site DA

Site DA (Table 4-13 and 4-14) was a dryland field in 2003 in which a center pivot was installed and was first operated in late summer in 2003, applying an inch of water total. Over the years, DA received event water during high flows in Foster Creek. The field was in alfalfa/grass in 2003 and 2004 with 2004 yields of 1.6 tons per acre. Corn yield in 2005 was 31 tons per acre. The field was cropped with peas followed by millet in 2006 with yields of 18 bushels and 0.9 tons/ per acre, respectively. The field was seeded to alfalfa/grass spring 2007. First cutting contained a high percentage of weeds, particularly kochia, resulting in a sodium level of 0.81%. Second cutting was over 95% alfalfa/grass and had a sodium level of 0.25, which is the same as 2004 levels (0.27verage) when the field was last in alfalfa/grass. Alfalfa yielded 2.3, 4.6, 3.0, and 3.6 tons per acre in 2007 through 2010, respectively. Applied irrigation water was 24, 13, 12, 13, 12, 12, and 12 inches in 2004 through 2010, respectively.

EC at site DA (Figure 4-25) reflects historical effects from tributary drainages. The field is located near the mouth of a tributary to the Tongue River, which intermittently conveys water with elevated EC and SAR. As a result, soil EC was the highest of any AMPP field, increasing from 2 to 3 dS/m near surface to 9 dS/m at 3 feet in depth. Surrounding dryland fields have abundant greasewood, which is an indicator of sodium-enriched soils.

EC levels decreased dramatically in the upper 2 feet of soil between 2004 and 2006. This was due to the change in water source, application of 24 inches of irrigation water in 2004, 13 inches in 2005 plus above average 2005 growing season, and 12 to 13 inches of irrigation water in 2006 through 2010. Soluble salts were effectively removed from the upper 2 feet of soil by the end of the second cropping season on this new pivot, but salts were still present in the 3 to 5 foot zone. Similar to site EA, EC increased abruptly at the 36 to 48 inch depth to 8.7 dS/m in 2007. In this case, a split sample obtained in the lab had an EC of 0.91 indicating a QA error. A similar discrepancy was noted in the split sample analysis for SAR (18.4 and 1.7), so the lab data for this sample is assumed to be invalid. The vertical EC and SAR profile in 2008 was less erratic than in 2007, and reflected continued declines in EC and SAR. Site DA has a high water table at 3 feet, which may account for the slow removal of salts below 3 feet. Water in boreholes had an EC of 4.5 to 11 dS/m and an SAR of 12 to 20 (Figure 3-14 and 3-15).

ESP, SAR, and pH (Figure 4-26 to 4-28) at site DA also reflect the influences of the elevated EC and SAR tributary water that historically spread over this field. ESP in the upper 5 feet appeared to decrease from 12% to 15% in 2003 and 2004 to around 4% in 2005 and 2006, indicating a rapid decrease in exchangeable sodium status. However, CEC was also much higher in 2005 and 2006 than in earlier years, which probably results from lab error. Overestimation of CEC would explain the apparent ESP decrease. SAR probably provides a more realistic measure of sodium status at site DA from about SAR 17 in 2003 to 11 in 2008 at 12 to 24 inches. ESP showed a large increase below 24 inches in 2010 that is attributed to groundwater recharge from Foster Creek in the above average 2010 rainfall.

Table 4-13 Soil pH, EC, Saturation Extractable Ions and SAR for Site DA.

Depth (inches)		pH (Paste) s_u_ Method ASAM10-3_2	Electrical Conductivity (Paste) mmhos/cm Method ASAM10-3	Saturation Percentage wt% Method USDA27a	Calcium (Paste) meq/l Method SW6010B	Magnesium (Paste) meq/l Method SW6010B	Sodium (Paste) meq/l Method SW6010B	Sodium Adsorption Ratio unitless Method Calculation	Alkalinity (Paste) meq/L Method ASA10-3	Bicarbonate (Paste) meq/L Method ASA10-3	Carbonate (Paste) meq/L Method ASA10-3	Chloride (Paste) meq/L Method ASA10-3
1-Fall, 2003												
0	2	7.4	1.33	39.6	6.1	3.5	3.8	1.8	9.4			
0	6	7.6	5.49	42.4	21.9	13	30.2	7.2	5.4			
6	12	7.8	7.8	41.9	20.9	18.7	48.5	11	4.8			
12	24	8.1	9.16	36.5	19.3	24.8	79.5	17	3.2			
24	36	8.3	6.86	35.6	7.8	12.8	53.9	17	2.8			
36	60	8.1	6.09	35.1	7.7	11.9	51.1	16	2.8			
60	96	8	3.54	25.6	5.2	5.7	27.3	12	3.2			
2-Spring, 2004												
0	2	7.4	3.55	34.3	21.2	10	8.99	2.3	8.8			2.4
0	6	7.5	4.29	35	26.1	13.5	15.7	3.5	6.6			2.68
6	12	7.8	7.32	34.1	29.7	20.8	41.6	8.3	5.6			0.99
12	24	8	9.05	31.2	19.5	20.4	56	13	4.2			1.27
24	36	7.9	7.56	27.7	17.8	22.6	46.5	10	4			1.55
36	60	7.8	6.31	25.5	17.6	21.5	34.2	7.7	2.8			0.99
60	96	7.9	3.85	21.3	7.77	8.47	23.2	8.2	3.2			0.42
3-Fall, 2004												
0	2	7.5	1.64	38.4	5.92	4.47	4.07	1.8	10.7			
0	6	7.6	1.99	39.1	12.6	7.91	6.59	2	10			
6	12	7.6	5.11	36.7	26.2	16.6	21.7	4.7	5.3			
12	24	8	8.22	30.8	21.7	20.5	64.5	14	3.8			
24	36	8	8.85	29	18.6	20.8	67.9	15	3.3			
36	60	8	7.13	27	12.5	16.4	56.4	15	4			
60	90	7.8	6.08	25	11.4	12.3	51.5	15	4.8			
4-Fall, 2005												
0	2	7.4	0.8	37.9	5	2.53	1.33	0.69				
0	6	7.4	4	37.3	20.4	10.3	19	4.8				
6	12	7.6	4.8	38.1	20.8	12.7	28.4	7				
12	24	7.7	4.65	35.3	12.6	11	32.4	9.4				
24	36	8	7.55	30.7	14.3	18	68.3	17				
36	60	7.9	8.97	27.6	16.1	21.9	85.8	20				
60	96	7.8	4.69	24.8	7.19	7.78	41.4	15				
5-Fall, 2006												
0	2	7.6	1.42	37.6	4.44	3	4	2.1				ND
0	6	7.6	2.04	38.4	7.45	4.15	7.21	3				0.68
6	12	7.7	5.05	36.6	22.8	13.5	26.3	6.2				0.99
12	24	8	7.54	32.5	18.2	18.6	54.2	13				0.86
24	36	8	6.61	31.4	13.8	17.6	50.5	13				1.98
36	60	8.1	9.23	28	16.6	25.4	83.2	18				2.46
60	96	7.9	5.83	24.3	8.79	11.1	47.2	15				1.32
6-Fall, 2007												
0	2	7.7	1.03	38.2	3.87	2.94	3.1	1.7				0.47
0	6	7.7	1.59	37.4	7.83	4.81	4.66	1.8				0.7
6	12	7.9	1.45	37	6.12	3.98	5.92	2.6				0.4
12	24	8.2	7.66	36.2	16.8	17.7	69.9	17				1.64
24	36	7.9	0.91	51.6	3.28	2.22	2.86	1.7				1.23
36	60	8.4	16.5	36.8	18	31.4	162	33				2.56
60	96	8.1	7.59	29.7	9.03	12.4	64.7	20				1.69
7-Fall, 2008												
0	2	7.4	1	36.6	4.19	2.42	3.03	1.7				0.36
0	6	7.5	0.99	40.3	4.79	2.82	2.03	1				0.31
6	12	7.7	3.45	35.3	13.8	9.97	18.8	5.5				0.55
12	24	7.8	5.56	31.3	15.9	16.2	42.5	11				1.1
24	36	8	6.32	30.7	10.8	15.7	54.9	15				1.2
36	60	7.9	7.18	27.2	15.1	21.2	61.2	14				1.3
60	96	7.9	4.22	24.2	6.33	7.44	37.7	14				0.74
8-Fall, 2009												
0	2	7.5	0.73	39.3	4.08	2.15	1.36	0.77				0.15
0	6	7.6	1.07	40	5.33	3.04	3.7	1.8				0.3
6	12	7.8	3	36.7	11	7.08	17.3	5.8				0.41
12	24	8	5.53	35	16.8	16.7	36.6	8.9				0.69
24	36	8.2	7.67	31.5	14.2	20	57.3	14				1.1
36	60	8.2	8.3	30.6	12.2	19.1	70	18				1.4
60	96	8.1	6.34	30.1	8.25	12.7	54.5	17				1
9-Fall, 2010												
0	2	7.2	0.78	37.2	4.58	2.09	1.82	1				
0	6	7.3	1.41	39.2	6.35	3.17	5.59	2.6				
6	12	7.5	5.1	38.2	22.4	14.3	30.9	7.2				
12	24	7.8	6.86	33.3	19.2	19.4	53	12				
24	36	7.9	8.42	31.3	14.8	20.4	73.1	17				
36	60	7.8	7.02	27.6	11.5	14.9	58	16				
60	96	7.7	6.64	25.3	9.5	11.8	55	17				

Table 4-14 Soil Texture, Lime, CEC and ESP for Site DA.

Depth (inches)		Sand % Method ASA15-5	Silt % Method ASA15-5	Clay % Method ASA15-5	Texture unitless Method ASA15-5	Lime as CaCO3 wt% Method USDA23c	Cation Exchange Capacity meq/100g Method SW6010B	Extractable Sodium meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
1-Fall, 2003									
0	2	50	38	12	L	7.5	14.9		5.1
0	6	49	36	15	L	7.5	15.3		9.1
6	12	45	40	15	L	7.9	16.5		6.3
12	24	45	39	16	L	7.9	14.6		11
24	36	60	31	9	SL	8.2	10.4		13
36	60	69	21	10	SL	6.9	13.2		10
60	96	82	14	4	LS	6.3	8.8		20
2-Spring, 2004									
0	2	52	37	11	L	7.1	15.8	0.88	3.6
0	6	47	40	13	L	7.1	16.5	1.34	4.8
6	12	43	42	15	L	7.2	13.7	2.75	9.7
12	24	55	34	11	SL	7.8	13.2	3.58	14
24	36	66	25	9	SL	6.3	7.72	2.61	17
36	60	69	23	8	SL	6.2	7.69	2.04	15
60	96	84	11	5	LS	4.5	5.44	1.67	22
3-Fall, 2004									
0	2	51	37	12	L	7.4	12.8		3.7
0	6	50	37	13	L	7.3	13.1		5.2
6	12	49	39	12	L	7.8	13.1		7.4
12	24	60	30	10	SL	7.1	9.26		17
24	36	61	29	10	SL	7.4	9.83		17
36	60	76	18	6	SL	6.6	9.74		18
60	90	67	25	8	SL	6	9.14		14
4-Fall, 2005									
0	2	51	37	12	L	7.7	20		1.7
0	6	48	39	13	L	7.8	21.2		3.1
6	12	54	34	12	SL	7.7	21.6		2.4
12	24	67	25	8	SL	7.3	16.1		3.7
24	36	67	27	6	SL	8	11.8		3.7
36	60	69	21	10	SL	6.7	12.7		5.2
60	96	85	11	4	LS	5.9	5.18		17
5-Fall, 2006									
0	2	52	34	14	L	6.9	43.2		1.3
0	6	52	35	13	L	7.1	22.8		3.3
6	12	46	40	14	L	9.9	20.9		5.1
12	24	63	27	10	SL	7.1	15.3		6.9
24	36	64	28	8	SL	6.4	15.8		4.9
36	60	70	22	8	SL	6.1	13.2		8.5
60	96	84	11	5	LS	5.6	13.5		9.6
6-Fall, 2007									
0	2	53	37	10	SL	6.5	18.4		2.2
0	6	50	39	11	L	6.6	19.1		2.8
6	12	51	39	10	L	7	17.3		4.3
12	24	50	40	10	L	7.1	16.1		16
24	36	20	55	25	SiL	6.6	28.9		2.1
36	60	52	34	14	L	6.3	17.3		17
60	96	68	24	8	SL	5.5	14.6		17
7-Fall, 2008									
0	2	45	39	16	L	7.1	17.9		3
0	6	47	37	16	L	7.2	17.4		2.8
6	12	47	37	16	L	7.6	15.7		7.8
12	24	55	31	14	SL	7.5	15.1		13
24	36	51	37	12	L	7.6	12.5		17
36	60	65	24	11	SL	6.2	11.2		14
60	96	67	23	10	SL	4.6	11.3		15
8-Fall, 2009									
0	2	50	36	14	L	6.8	15.7		0.6
0	6	48	38	14	L	7	15.6		1.7
6	12	50	36	14	L	7.3	14.5		5.7
12	24	52	36	12	L	7.4	12.8		9.9
24	36	60	28	12	SL	7.2	11.7		14
36	60	66	22	12	SL	6	11.3		17
60	96	64	22	14	SL	6	11.9		16
9-Fall, 2010									
0	2	50	34	16	L	6.97	10.3		1.5
0	6	50	34	16	L	6.82	10.2		1.7
6	12	50	34	16	L	7.49	9.95		7.7
12	24	56	30	14	SL	7.38	7.7		16
24	36	58	30	12	SL	7.27	6.51		19
36	60	76	14	10	SL	5.83	4.92		21
60	96	70	18	12	SL	5.78	6.04		24

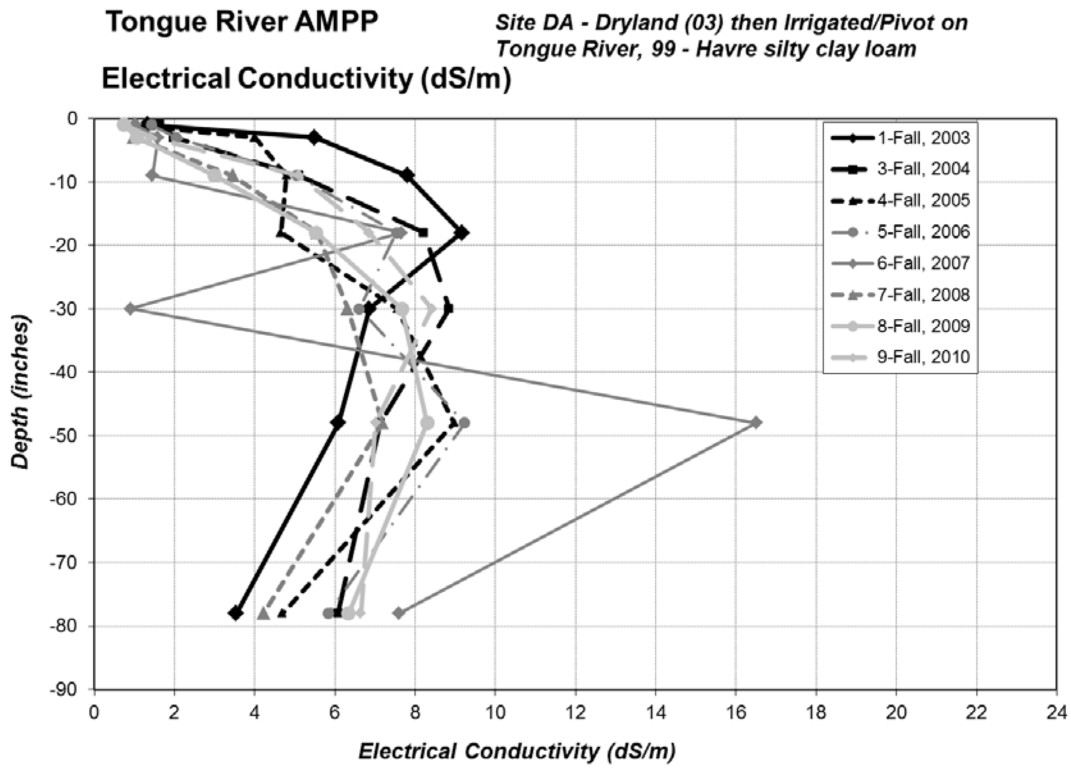

Figure 4-25 Trends in EC with Depth for Site DA.

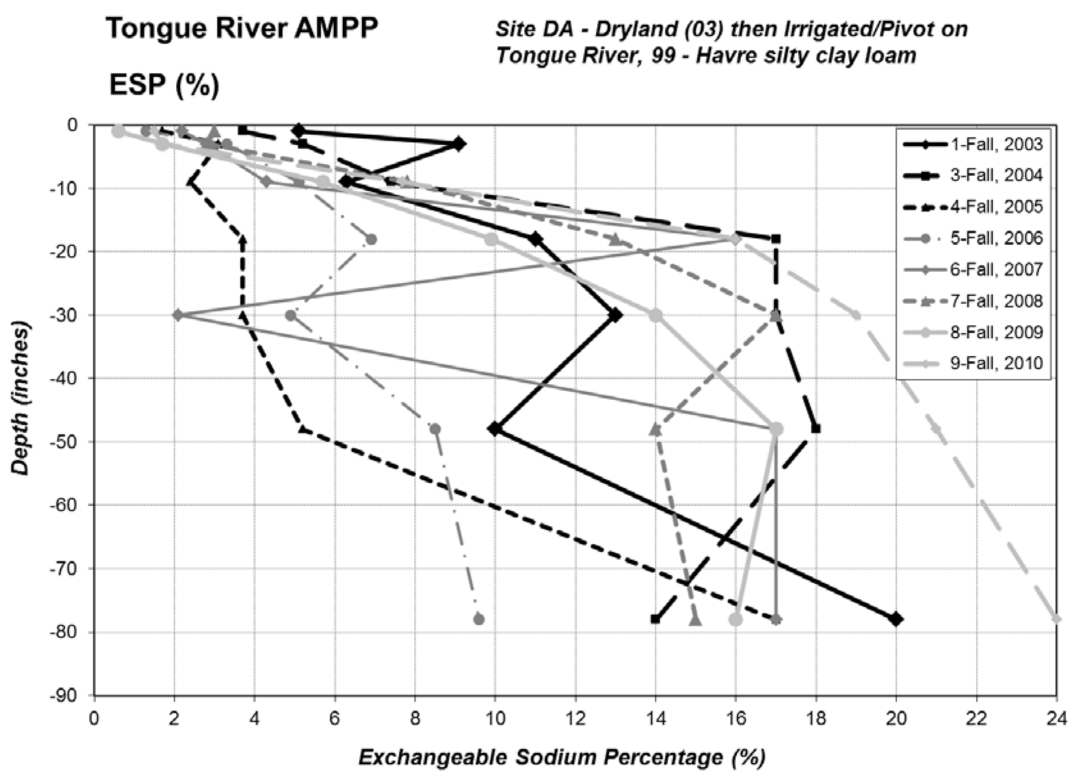

Figure 4-26 Trends in ESP with Depth for Site DA.

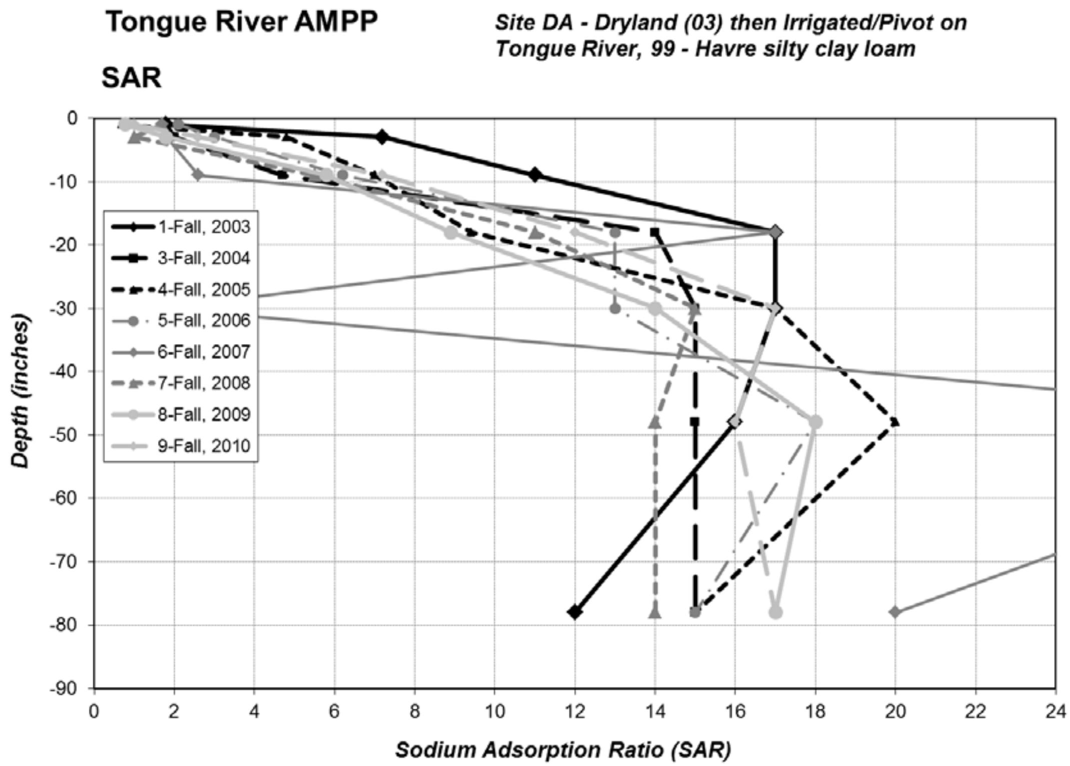

Figure 4-27 Trends in SAR with Depth for Site DA.

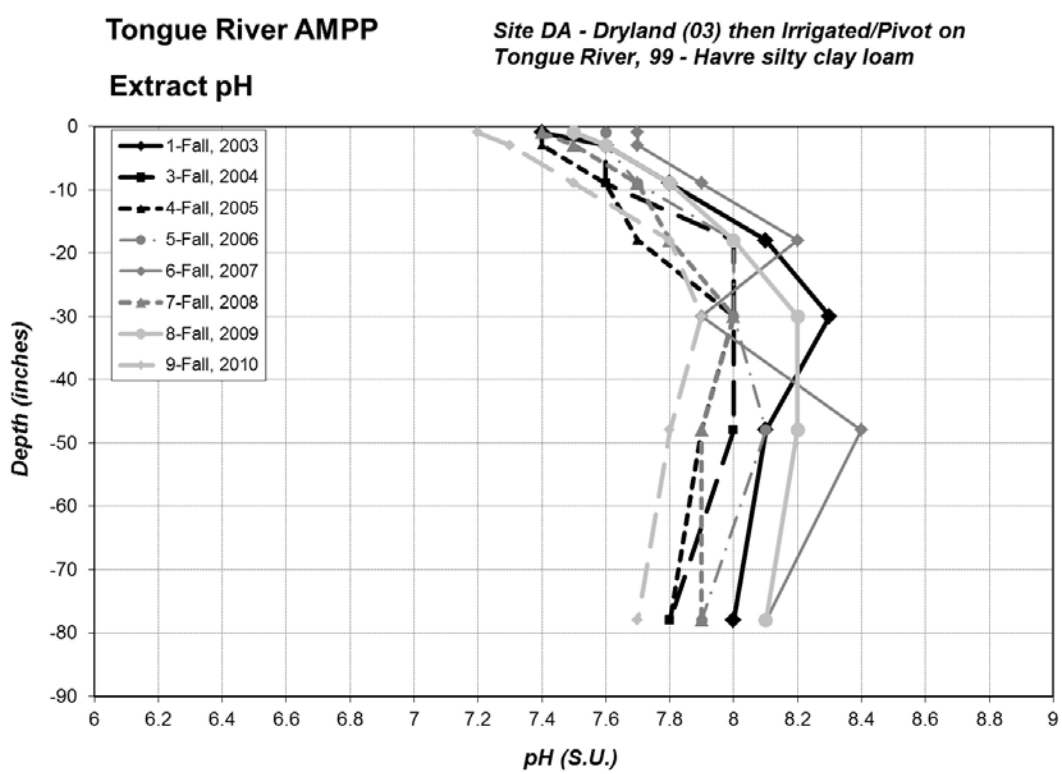

Figure 4-28 Trends in pH with Depth for Site DA.

4.1.8 Site DB

Site DB (Table 4-15 and 4-16) is located just north of site DA on somewhat more clay-rich soils. Site DB was in alfalfa that yielded 3.4 t/ac to 4.5 t/ac until 2007, based on waypoint harvests. The field was planted to spring wheat in 2008 that yielded 48 bu/ac and a 2009 hay barley crop yielded 2.8 tons per acre. One cutting of new alfalfa yielded 1.1 tons per acre in 2010 with 8 inches of applied water. The field is irrigated from a center pivot system applying from 12 (2007) to 26 (2006) inches per year from 2003 to 2007. Only 2 inches were applied in 2008 and 8 inches each in 2009 and 2010.

A spike in 2007 second cutting sodium level (0.24%) resulted in the highest average sodium level of 0.17% during the first four years of this study. The 2004 average was 0.15% with 2005 (0.13%) and 2006 (0.08%). Sodium was lowest in 2006, which was the year that the highest amount of irrigation water was applied (26 inches). Conversely, the highest sodium level resulted in 2007, which had the lowest amount of irrigation water applied (12 inches) to the forage crop present from 2003 to 2007. Sodium content of the new alfalfa stand was 0.15% in 2010 with 8 inches of water applied.

EC at site DB (Figure 4-29), unlike site DA, increases only slightly from 1 dS/m near surface to 2 to 3 dS/m as depth. EC near the surface did not vary appreciably between years except 2010, but varied somewhat more widely in subsoil layers. Soil EC below 24 inches increased significantly in 2010. This increase is attributed to development of a high water table in the wetter than average rainfall and runoff year. The groundwater EC at neighboring site DA is 6,000 uS/cm, which is nearly identical the deep soil EC that developed in 2010.

ESP, SAR and pH pattern with depth was similar to many irrigated AMPP sites (Figure 4-30 to 4-32) showing low levels near surface and moderately higher levels at depth. ESP decreased markedly between 2004 and 2005, increased through 2008 and declined in 2009. SAR and ESP increased at depth in 2010, likely due to a shallow water table. SAR levels at site DB are a better indicator of sodium status, and did not vary widely between years (except 2010).

Table 4-15 Soil pH, EC, Saturation Extractable Ions and SAR for Site DB.

Depth (inches)		pH (Paste) s_u_ Method ASAM10-3_2	Electrical Conductivity (Paste) mmhos/cm Method ASAM10-3	Saturation Percentage wt% Method USDA27a	Calcium (Paste) meq/l Method SW6010B	Magnesium (Paste) meq/l Method SW6010B	Sodium (Paste) meq/l Method SW6010B	Sodium Adsorption Ratio unitless Method Calculation	Alkalinity (Paste) meq/L Method ASA10-3	Bicarbonate (Paste) meq/L Method ASA10-3	Carbonate (Paste) meq/L Method ASA10-3	Chloride (Paste) meq/L Method ASA10-3
1-Fall, 2003												
0	2	7.3	0.77	63.7	3.5	2.4	2.3	1.4	6.8			
0	6	7.3	0.83	66.1	3.6	2.5	3.1	1.8	6			
6	12	7.6	0.83	51.2	2.7	1.7	4.3	2.9	4.2			
12	24	7.7	1.57	42.5	5	3.8	7.2	3.4	3.4			
24	36	7.8	1.51	36.7	4.4	3.9	6.6	3.2	2.8			
36	60	7.8	1.33	31.9	3.3	2.9	6.6	3.7	3.6			
60	96	7.9	1.57	32.6	3.5	4	7.8	4	2			
2-Spring, 2004												
0	2	7.3	1.15	49.7	6.71	4.51	2.18	0.9	4			2.26
0	6	7.4	1.39	49	7.13	4.79	3.24	1.3	8.8			0.99
6	12	7.7	0.9	49.1	3.68	2.38	4.26	2.4	4.6			0.42
12	24	7.8	1.64	39.9	6.09	4.37	6.81	3	3.8			0.42
24	36	7.7	1.33	33	5.95	4.26	4.42	2	2.8			0.56
36	60	7.8	0.78	31.2	2.57	1.98	3.98	2.6	3.2			0.85
60	96	7.9	1.81	29.4	4.08	4.3	9.14	4.5	2.8			0.28
3-Fall, 2004												
0	2	7.2	0.99	63.4	4.5	3.14	3.04	1.6	7.8			
0	6	7.3	1.39	56.4	5.62	3.76	4.47	2.1	8.6			
6	12	7.5	1.41	52.1	5.14	3.25	6.23	3	7.1			
12	24	7.7	1.55	37.1	3.86	2.75	7.44	4.1	3.7			
24	36	7.8	1.93	33.2	4.02	3.16	10.5	5.6	3.5			
36	60	7.7	2.69	31.9	7.33	6.35	12.4	4.8	2.7			
60	90	7.9	2.82	30	4.41	5.24	16.8	7.7	2.6			
4-Fall, 2005												
0	2	7	0.84	62.4	5.14	3.33	1.85	0.9				
0	6	7.2	0.69	59	3.44	2.17	2.38	1.4				
6	12	7.6	0.92	48.6	3.86	2.34	5.36	3				
12	24	7.6	1.86	41	5.87	4.28	11	4.9				
24	36	7.6	2.05	38.4	6.28	5.36	10.7	4.4				
36	60	7.6	1.66	31.9	5	4.91	7.51	3.4				
60	96	7.7	2.63	31.9	6.31	7.12	16	6.2				
5-Fall, 2006												
0	2	6.8	0.97	66.4	4.89	3.17	2.27	1.1				0.04
0	6	7.3	0.8	56.9	3.27	2.09	2.44	1.5				0.13
6	12	7.5	1.09	52.4	3.81	2.4	3.94	2.2				0.21
12	24	7.6	1.82	39.6	5.99	4.38	7.25	3.2				0.07
24	36	7.5	2.28	33.8	8.39	6.43	9.04	3.3				0.54
36	60	7.6	2.66	29.7	7.11	6.96	11.4	4.3				0.46
60	96	7.9	3.14	30.2	5.02	6.48	20.3	8.5				0.31
6-Fall, 2007												
0	2	7.6	0.82	60.6	3.22	2.3	2.24	1.4				1.17
0	6	7.6	0.76	53.6	3.2	2.14	2.14	1.3				0.6
6	12	7.9	0.83	50	2.86	1.98	3.89	2.5				1.06
12	24	8	1.63	39.4	4.07	3.26	9.94	5.2				0.7
24	36	8	1.7	36.2	3.64	3.62	9.35	4.9				0.7
36	60	8.2	1.6	29.3	2.89	3.4	9.32	5.3				1.06
60	96	8.1	2.05	33.9	3.59	4.37	11.7	5.9				0.42
7-Fall, 2008												
0	2	7.1	0.7	52.2	3.76	2.25	1.43	0.82				0.3
0	6	7.2	0.71	57.6	3.04	2	1.79	1.1				0.41
6	12	7.5	0.99	47.5	3.81	2.43	3.3	1.9				0.52
12	24	7.7	1.25	38.4	3.35	2.5	6.86	4				0.38
24	36	7.7	1.81	33.3	5.38	4.39	9.75	4.4				0.45
36	60	7.8	1.78	28.6	3.63	3.52	11.1	5.9				0.42
60	96	7.8	3.32	30.1	7.44	7.23	23.7	8.8				0.37
8-Fall, 2009												
0	2	7.7	0.5	47.6	2.25	1.47	1.93	1.4				0.28
0	6	7.6	0.65	50.1	3.07	1.86	2.16	1.4				0.34
6	12	7.6	0.59	52	2.3	1.41	2.56	1.9				0.39
12	24	7.8	0.91	43.2	3.04	2.13	4.92	3.1				0.2
24	36	7.9	1.22	35.5	3.65	2.91	6.83	3.8				0.29
36	60	8	1.42	34.7	3.62	2.89	9.27	5.1				0.32
60	96	8.1	2.61	27.9	4.15	4.91	19.1	9				0.34
9-Fall, 2010												
0	2	7.4	1.1	52.9	6.06	3.52	4.46	2				0.4
0	6	7.5	1.36	53.5	8.28	3.67	6.96	2.8				0.6
6	12	7.5	1.76	49	6.78	4.34	9.12	3.9				0.3
12	24	7.8	2.17	39.1	5.21	3.92	14.5	6.8				0.5
24	36	7.8	5.52	35	13.4	10.3	42.5	12				0.6
36	60	8	6.26	31	9.76	10.1	57.6	18				1
60	96	8.3	6.23	32.2	4.71	8.01	61	24				0.9

Table 4-16 Soil Texture, Lime, CEC and ESP for Site DB.

Depth (inches)		Sand % Method ASA15-5	Silt % Method ASA15-5	Clay % Method ASA15-5	Texture unitless Method ASA15-5	Lime as CaCO3 wt% Method USDA23c	Cation Exchange Capacity meq/100g Method SW6010B	Extractable Sodium meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
1-Fall, 2003									
0	2	17	43	40	SiC	3.8	38.1		2.4
0	6	21	42	37	CL	4.1	33.6		2.7
6	12	26	46	28	CL	5	25.5		4.7
12	24	36	46	18	L	7.8	17.6		7
24	36	44	42	14	L	7.7	13.7		8
36	60	56	34	10	SL	4.3	10.9		8.2
60	96	60	31	9	SL	6.7	11.6		7.4
2-Spring, 2004									
0	2	24	47	29	CL	5.5	27.6	0.72	2.2
0	6	22	47	31	CL	4.8	30.2	0.78	2
6	12	19	53	28	SiCL	5.7	26.6	1.08	3.3
12	24	31	48	21	L	7.7	18.6	1.36	5.9
24	36	50	39	11	L	5.5	13.1	0.89	5.7
36	60	64	27	9	SL	7.1	7.59	0.68	7.3
60	96	65	28	7	SL	7	6.75	1.11	12
3-Fall, 2004									
0	2	22	40	38	CL	4.8	28.5		2.3
0	6	20	44	36	SiCL	4.3	29.9		2.3
6	12	23	47	30	CL	5.5	26		3.5
12	24	40	44	16	L	7.6	15		7.1
24	36	49	39	12	L	7.6	11.3		8.8
36	60	60	29	11	SL	4.1	10.4		9
60	90	67	24	9	SL	7.1	9.73		13
4-Fall, 2005									
0	2	22	43	35	CL	5.4	44		1.2
0	6	24	43	33	CL	5.1	39.4		1.5
6	12	26	46	28	CL	6	34.5		2.2
12	24	36	46	18	L	7.8	23.2		3.1
24	36	52	36	12	L	7.8	17.1		3.3
36	60	65	26	9	SL	7.5	13		4.2
60	96	67	25	8	SL	7.2	12		5
5-Fall, 2006									
0	2	27	38	35	CL	4	46.7		1.5
0	6	27	42	31	CL	4.6	38.5		1.9
6	12	22	49	29	CL	4.7	27.2		3.6
12	24	41	38	21	L	7.7	23		3.3
24	36	51	39	10	L	7.5	23.7		3
36	60	64	30	6	SL	6.6	18.1		4
60	96	65	30	5	SL	6.2	15.8		6.8
6-Fall, 2007									
0	2	25	47	28	CL	5.1	32.7		1.8
0	6	26	46	28	CL	5	33.8		1.9
6	12	22	49	29	CL	5.4	30.9		3.3
12	24	42	38	20	L	6.1	22.9		5.8
24	36	46	41	13	L	7.1	17.8		6
36	60	61	31	8	SL	6.4	13.3		7.8
60	96	61	31	8	SL	6.5	11.6		8.4
7-Fall, 2008									
0	2	43	21	36	CL	5.1	33.7		1.5
0	6	17	43	40	SiC	4.7	31.9		6.8
6	12	23	47	30	CL	5.9	28.8		10
12	24	29	53	18	SiL	7.9	18.7		4.9
24	36	35	50	15	SiL	7.4	16.1		6.2
36	60	37	53	10	SiL	6.4	11.2		8.9
60	96	45	43	12	L	7	12.8		11
8-Fall, 2009									
0	2	28	42	30	CL	5	27.6		1.2
0	6	26	44	30	CL	5.1	27.9		1.3
6	12	24	42	34	CL	4.4	30		1.9
12	24	28	48	24	L	6.9	22.6		3
24	36	44	38	18	L	7.2	15		4.1
36	60	44	38	18	L	6.7	15		5.9
60	96	66	24	10	SL	6.6	8.65		11
9-Fall, 2010									
0	2	20	46	34	SiCL	5.22	27		2.1
0	6	18	48	34	SiCL	5.38	26		3
6	12	22	46	32	CL	5.69	24.9		3.5
12	24	34	46	20	L	7.51	16.6		6.4
24	36	44	40	16	L	7.72	10.5		17
36	60	54	32	14	SL	7.19	9.14		23
60	96	54	34	12	SL	7.09	7.38		28

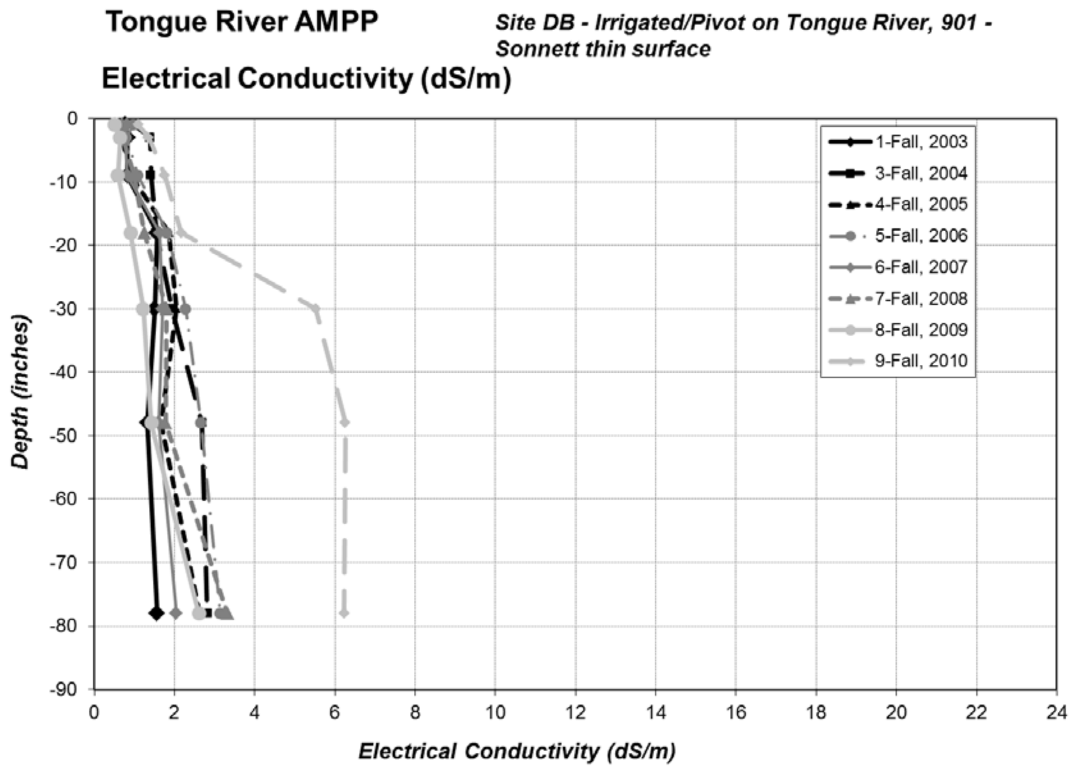

Figure 4-29 Trends in EC with Depth for Site DB.

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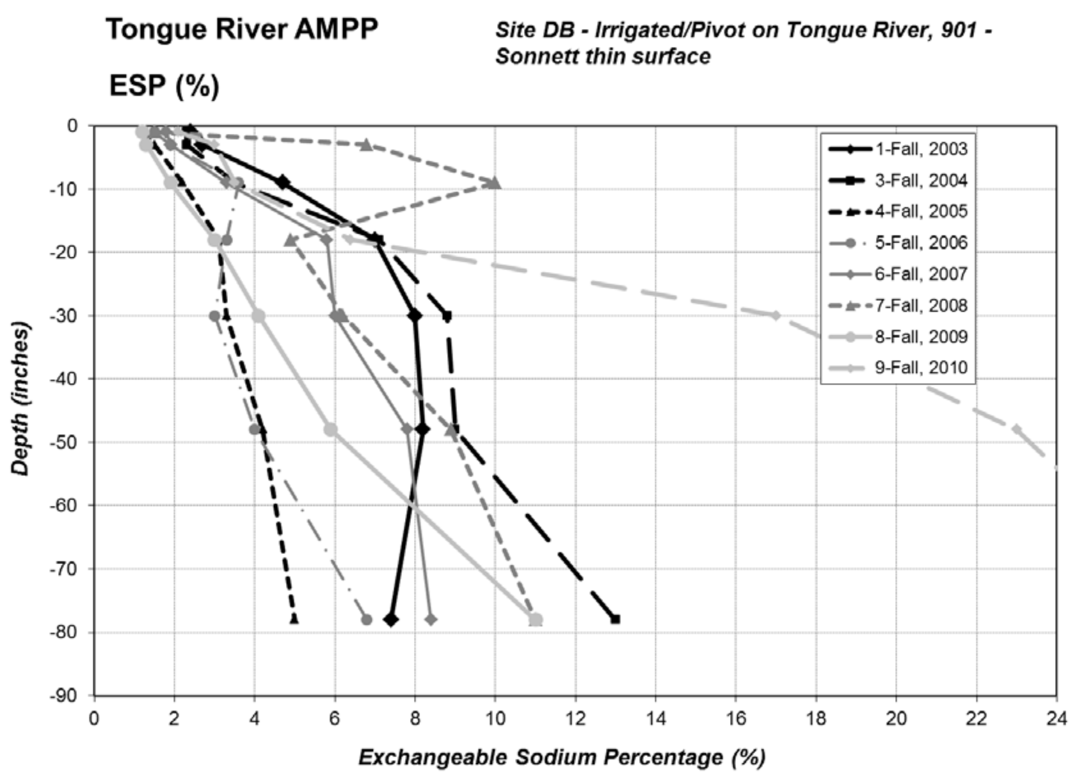

Figure 4-30 Trends in ESP with Depth for Site DB.

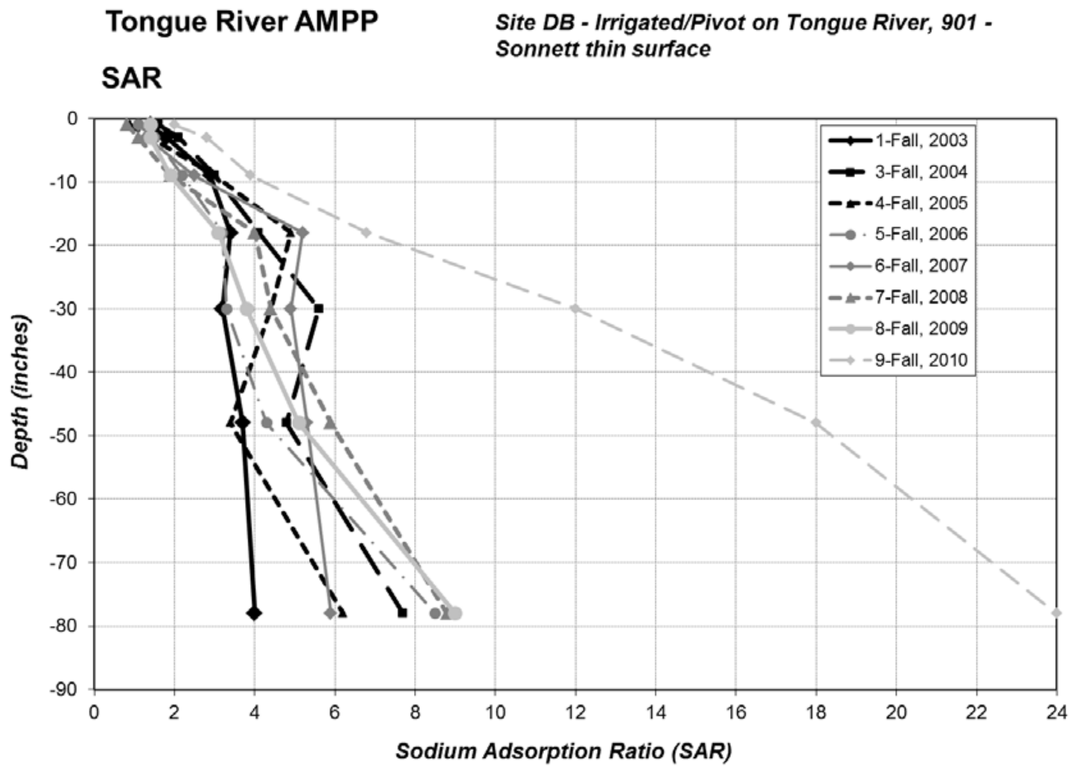

Figure 4-31 Trends in SAR with Depth for Site DB.

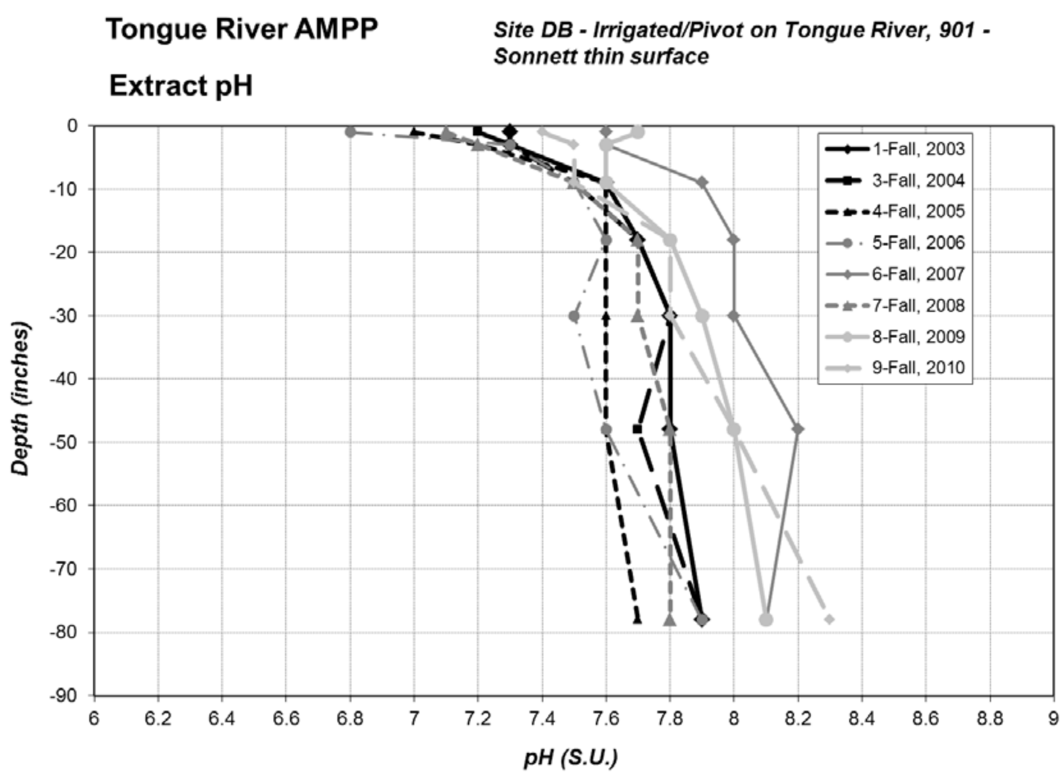

Figure 4-32 Trends in pH with Depth for Site DB.

4.1.9 Site BA

Site BA (Table 4-17 and 4-18) borders the Tongue River and is flood irrigated with water from the T&Y canal just below Pumpkin Creek. The field was in continuous corn from 2003 to 2005 with yields ranging from 19 to 28 tons per acre. Corn yield was 19 tons per acre in 2004 due to the late freeze on May 12 which resulted in only two-thirds of a stand at harvest time. The field was planted to spring wheat in 2006, which yielded 55 bushels per acre Corn was planted again in 2007 and yielded 26.3 tons per acre. The 2007 yield was lower than 2005 because the stand was approximately 90% of 2005. Applied irrigation water varied from 18 to 25 inches in most years, except for the 2006 spring wheat crop when it was reduced to 12 inches. In 2008 alfalfa was established under a hay barley cover crop which yielded 2.9 tons per acre with application of 18 inches of irrigation water. The alfalfa yielded 5.2 tons per acre in 2009 and 5.16 tons per acre in 2010 with 18 inches of water applied each year.

Sodium levels were 0.02% for all three years of corn, regardless of stand and yield. Corn had the same level of sodium when planted at DA site, which had much higher salt and sodium levels indicating that corn has little tendency to take up sodium.

Use of ample irrigation water has maintained relatively low EC levels throughout the soil profile at site BA (Figure 4-33). BA has had the highest average amount of irrigation water applied at 19.9 inches per acre since 2003. The field, which is located on a bench above the Tongue River, appears to be well-drained, accounting for the low EC levels in the 3 to 8 foot zone.

ESP and SAR at site BA are also low, reflecting the irrigation management and good drainage conditions (Figures 4-34 and 4-35). Like many other fields, ESP decreased between 2004 and 2005, remained low in 2006, increased slightly in 2007 through 2008, and then decreased in 2009. Soil EC and SAR increased slightly in 2010. Trends in pH levels are shown in figure 4-36.

Table 4-17 Soil pH, EC, Saturation Extractable Ions and SAR for Site BA.

Depth (inches)		pH (Paste) s_u_ Method ASAM10-3_2	Electrical Conductivity (Paste) mmhos/cm Method ASAM10-3	Saturation Percentage wt% Method USDA27a	Calcium (Paste) meq/l Method SW6010B	Magnesium (Paste) meq/l Method SW6010B	Sodium (Paste) meq/l Method SW6010B	Sodium Adsorption Ratio unitless Method Calculation	Alkalinity (Paste) meq/L Method ASA10-3	Bicarbonate (Paste) meq/L Method ASA10-3	Carbonate (Paste) meq/L Method ASA10-3	Chloride (Paste) meq/L Method ASA10-3
1-Fall, 2003												
0	2	7.5	2.56	48.5	13.8	6.3	3.1	1	5.2			
0	6	7.7	1	48.6	4.2	2.4	2.8	1.5	4			
6	12	7.7	1.34	49.4	5.3	3.7	3.8	1.8	3.2			
12	24	7.6	1.7	45.8	5.6	4.7	5.3	2.4	3.2			
24	36	7.6	2.4	38.7	9.3	7.7	7.4	2.5	2.8			
36	60	7.8	1.46	40.4	4.3	3.6	6.1	3.1	3.2			
60	96	7.9	1.35	28.6	3.3	2.6	6.4	3.7	3.6			
2-Spring, 2004												
0	2	7.6	0.89	53.4	5.77	2.86	1.63	0.8	5.8			0.85
0	6	7.6	0.91	50.6	5.54	2.75	2.07	1	5			0.85
6	12	7.7	1.09	50.4	5.89	3.52	2.99	1.4	4			1.83
12	24	7.7	1.61	43.4	6.82	5.47	4.94	2	4			0.71
24	36	7.7	1.86	40.5	7.32	5.94	5.24	2	2.8			1.27
36	60	7.8	1.61	34.2	5.89	4.67	5.5	2.4	3			0.85
60	96	7.8	1.07	27.3	3.22	2.32	4.87	2.9	6			0.14
3-Fall, 2004												
0	2	7.3	3.13	48.4	15.4	7.97	4.09	1.2	5.2			
0	6	7.5	1.33	47.7	5.55	2.86	3.24	1.6	3.8			
6	12	7.6	1.12	46.8	4.73	2.85	3.7	1.9	3.8			
12	24	7.6	1.75	42	5.97	4.61	6.32	2.8	2.8			
24	36	7.7	1.76	36.8	5.36	4.32	6.72	3	2.6			
36	60	7.7	1.51	36.2	4.71	3.6	5.46	2.7	2.5			
60	90	7.6	1.35	28.4	4.95	3.2	4.79	2.4	2.5			
4-Fall, 2005												
0	2	7.5	0.66	47.6	4.43	2.19	1.31	0.72				
0	6	7.5	0.66	47.9	3.93	1.92	1.87	1.1				
6	12	7.6	0.92	44.1	5.03	2.83	2.94	1.5				
12	24	7.5	2.48	41.7	9.95	8.1	7.67	2.6				
24	36	7.6	2.1	34.3	7.47	5.96	8.6	3.3				
36	60	7.6	1.59	38.6	5.79	4.18	6.5	2.9				
60	96	7.6	0.89	27.7	3.33	2.32	4.76	2.8				
5-Fall, 2006												
0	2	7.4	0.76	48.1	3.6	1.84	1.85	1.1				0.18
0	6	7.5	0.96	48.8	4.41	2.2	2.37	1.3				0.1
6	12	7.5	1	46.1	4.8	2.57	2.71	1.4				0.21
12	24	7.6	0.85	40.7	3.23	2.13	2.98	1.8				0.43
24	36	7.5	1.88	36.4	6.69	5.2	5.44	2.2				0.22
36	60	7.6	1.99	35.8	6.46	5.34	6.33	2.6				0.44
60	96	7.6	0.99	28.3	2.99	2.05	3.84	2.4				0.4
6-Fall, 2007												
0	2	7.6	1.78	45.8	8.09	4.71	6.92	2.7				1.29
0	6	7.7	0.74	45.3	3.75	1.96	2.18	1.3				0.88
6	12	7.8	1.14	42.8	3.41	2.44	5.81	3.4				0.88
12	24	8	1.09	41.1	2.85	2.35	5.56	3.4				0.85
24	36	7.9	1.76	37.1	5.95	5.24	8.13	3.4				1.13
36	60	7.9	2.06	37.7	7.69	5.89	8.43	3.2				0.99
60	96	8	1.14	25.8	3.41	2.38	5.03	3				0.99
7-Fall, 2008												
0	2	7.4	0.63	47.2	3.56	1.8	1.27	0.78				0.58
0	6	7.3	0.74	47.8	3.87	2.04	1.42	0.83				0.53
6	12	7.5	0.58	45.4	2.73	1.52	1.71	1.2				0.31
12	24	7.6	1.12	40.2	4.16	3.11	4.66	2.4				0.38
24	36	7.6	2.46	34.8	9.93	8.43	9.96	3.3				0.75
36	60	7.6	2.15	33.3	8.92	6.82	8.78	3.1				1
60	96	7.8	1.2	28.7	3.85	2.68	5.7	3.2				0.52
8-Fall, 2009												
0	2	7.5	0.65	49.3	4.13	2.21	1.49	0.84				0.22
0	6	7.6	0.62	47.9	3.55	1.85	1.73	1				0.35
6	12	7.7	0.66	46	3.01	1.74	1.96	1.3				0.21
12	24	7.8	0.83	42	3.62	2.64	3.43	1.9				0.2
24	36	7.8	1.34	35.9	5.63	4.71	5.92	2.6				0.24
36	60	7.8	1.57	34	6.19	4.99	6.47	2.7				0.57
60	96	8	0.87	28.1	2.83	2.09	4.31	2.8				0.44
9-Fall, 2010												
0	2	7.4	0.75	48.2	4.41	2.31	1.53	0.83				0.2
0	6	7.4	0.81	48.2	4.4	2.41	1.8	0.98				0.2
6	12	7.6	0.79	44.5	3.99	2.18	2.48	1.4				0.1
12	24	7.8	0.95	41.5	3.51	2.6	3.93	2.2				0.2
24	36	7.8	1.18	36.2	3.63	3.12	5.78	3.2				0.2
36	60	7.8	2.14	35.4	7.83	6.49	9.85	3.7				0.7
60	96	7.9	1.37	29.5	4.16	3.13	6.67	3.5				0.3

Table 4-18 Soil Texture, Lime, CEC and ESP for Site BA.

Depth (inches)		Sand % Method ASA15-5	Silt % Method ASA15-5	Clay % Method ASA15-5	Texture unitless Method ASA15-5	Lime as CaCO3 wt% Method USDA23c	Cation Exchange Capacity meq/100g Method SW6010B	Extractable Sodium meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
1-Fall, 2003									
0	2	18	58	24	SiL	6.1	29.2		1.7
0	6	10	66	24	SiL	6.3	30		2.2
6	12	18	58	24	SiL	6.7	29.4		2.6
12	24	18	61	21	SiL	6.6	25.6		3.2
24	36	42	44	14	L	5.8	12.5		6.2
36	60	36	48	16	L	6.3	14.5		7.4
60	96	69	23	8	SL	5.5	13.3		5.2
2-Spring, 2004									
0	2	19	54	27	SiCL	5.4	23.3	0.45	1.6
0	6	18	55	27	SiCL	5.4	23.1	0.49	1.7
6	12	16	59	25	SiL	5.9	21.5	0.7	2.6
12	24	27	52	21	SiL	6.1	19	0.62	2.1
24	36	38	44	18	L	5.5	16.7	0.93	4.3
36	60	47	39	14	L	5.8	14.1	0.82	4.4
60	96	72	20	8	SL	5.4	9.57	0.72	6.2
3-Fall, 2004									
0	2	24	52	24	SiL	5.6	21.7		2.3
0	6	22	55	23	SiL	5.8	21.4		2.5
6	12	23	55	22	SiL	6.2	20.8		2.9
12	24	29	52	19	SiL	6.5	16.6		4.9
24	36	45	41	14	L	5.8	13.4		5.7
36	60	44	42	14	L	6.3	12.3		5.2
60	90	68	23	9	SL	5.2	8.87		6.8
4-Fall, 2005									
0	2	24	52	24	SiL	6	27.4		1.6
0	6	25	53	22	SiL	6.2	27.9		1.5
6	12	27	53	20	SiL	6.4	23		2.2
12	24	31	51	18	SiL	6.8	21.6		2.8
24	36	53	35	12	SL	5.9	15.9		3.7
36	60	47	41	12	L	6.2	20.5		2.9
60	96	74	20	6	SL	5.8	16.8		3.3
5-Fall, 2006									
0	2	26	52	22	SiL	5.4	27.3		1.8
0	6	23	54	23	SiL	5.3	27.6		1.9
6	12	26	53	21	SiL	6	26.6		2.1
12	24	28	53	19	SiL	5.8	23.8		2.4
24	36	48	39	13	L	5.5	17		3.7
36	60	50	39	11	L	5.2	14.8		4.3
60	96	72	21	7	SL	4.3	9.62		4.6
6-Fall, 2007									
0	2	23	55	22	SiL	5.3	28.7		0.8
0	6	24	55	21	SiL	5.3	28		1.9
6	12	24	56	20	SiL	5.7	25.5		2
12	24	28	56	16	SiL	6.3	22.3		3.1
24	36	42	45	13	L	5.3	19.1		4.7
36	60	44	44	12	L	5.8	19.5		4.1
60	96	80	17	3	LS	5.2	10.6		4.5
7-Fall, 2008									
0	2	17	57	26	SiL	5.7	26.2		1.5
0	6	19	33	48	C	5.7	27.2		1.6
6	12	17	55	28	SiCL	6.2	25.3		2.1
12	24	21	57	22	SiL	6.6	22.6		3.1
24	36	39	45	16	L	5.8	18.3		4.7
36	60	43	43	14	L	5.8	17.3		4.3
60	96	69	21	10	SL	5.2	11.7		5
8-Fall, 2009									
0	2	22	54	24	SiL	5.4	25.2		0.7
0	6	20	56	24	SiL	5.5	26		0.8
6	12	20	54	26	SiL	5.9	23.6		1.3
12	24	28	54	18	SiL	6.1	19.4		2.3
24	36	44	40	16	L	5.7	15.4		3.4
36	60	46	28	26	L	5.5	14.7		3.4
60	96	66	24	10	SL	5.2	7.2		5.3
9-Fall, 2010									
0	2	22	52	26	SiL	5.48	20		1.1
0	6	22	52	26	SiL	5.53	21.6		1.5
6	12	22	52	26	SiL	5.93	21.2		2
12	24	24	54	22	SiL	6.22	17.4		3.1
24	36	60	22	18	SL	5.38	13		3.7
36	60	48	38	14	L	5.63	10.7		4.8
60	96	70	20	10	SL	5.3	6.66		5.4

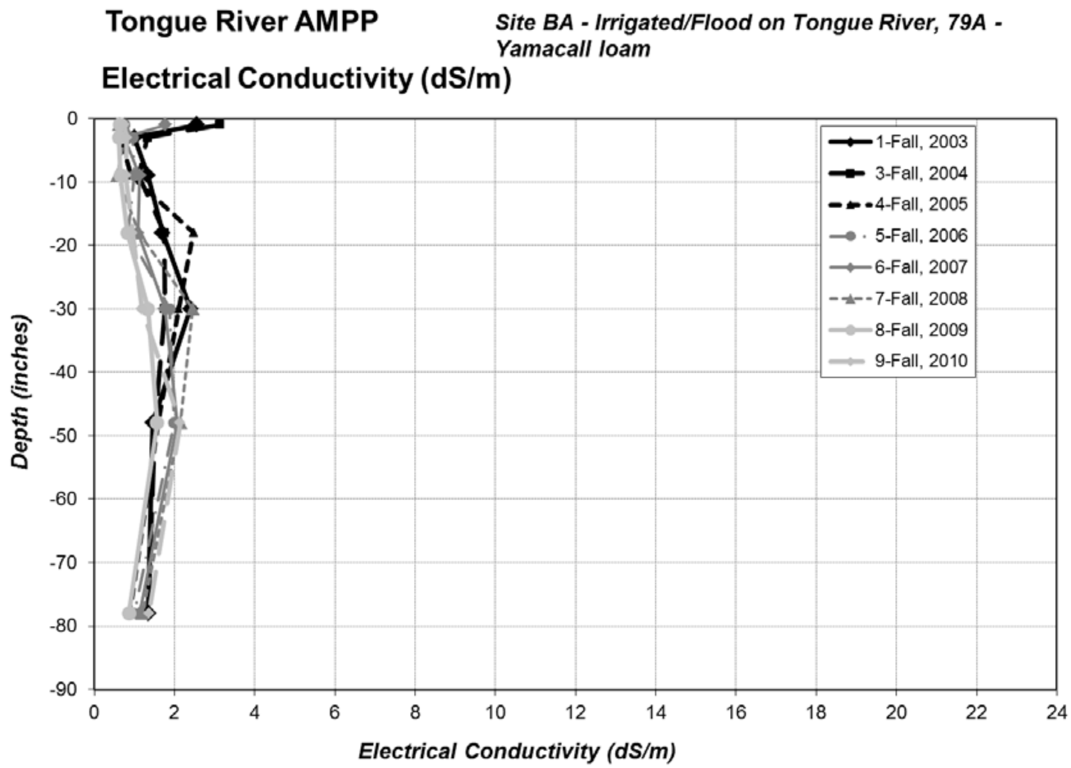

Figure 4-33 Trends in EC with Depth for Site BA.

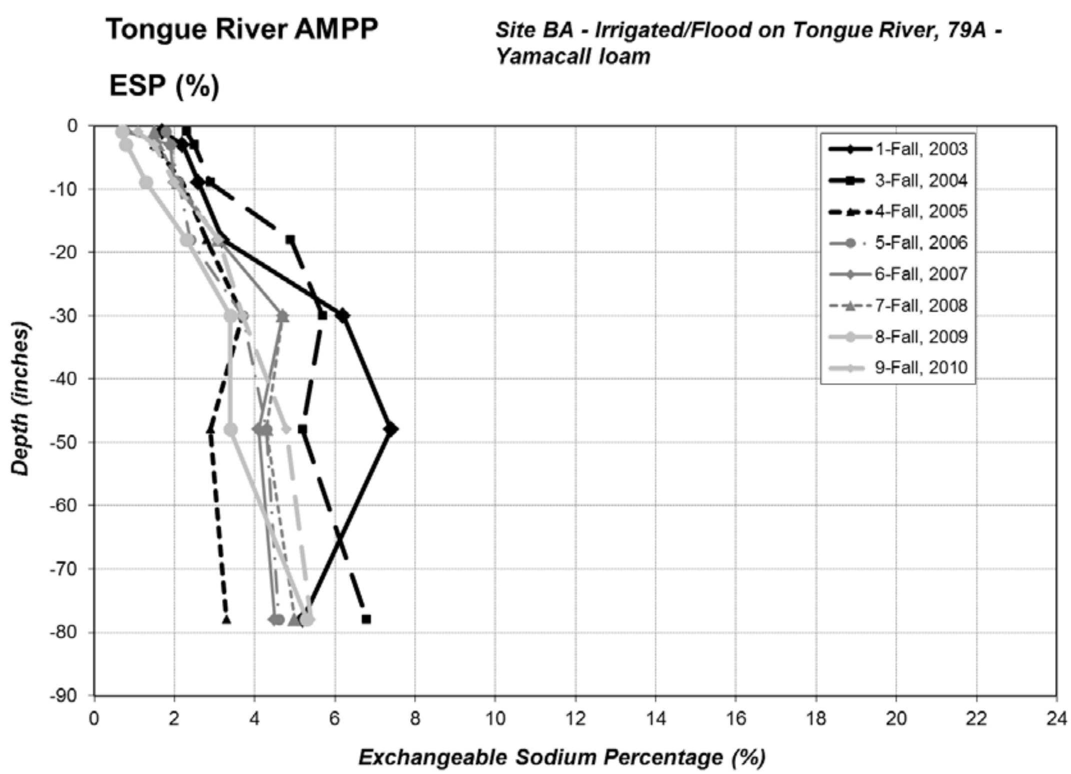

Figure 4-34 Trends in ESP with depth for Site BA.

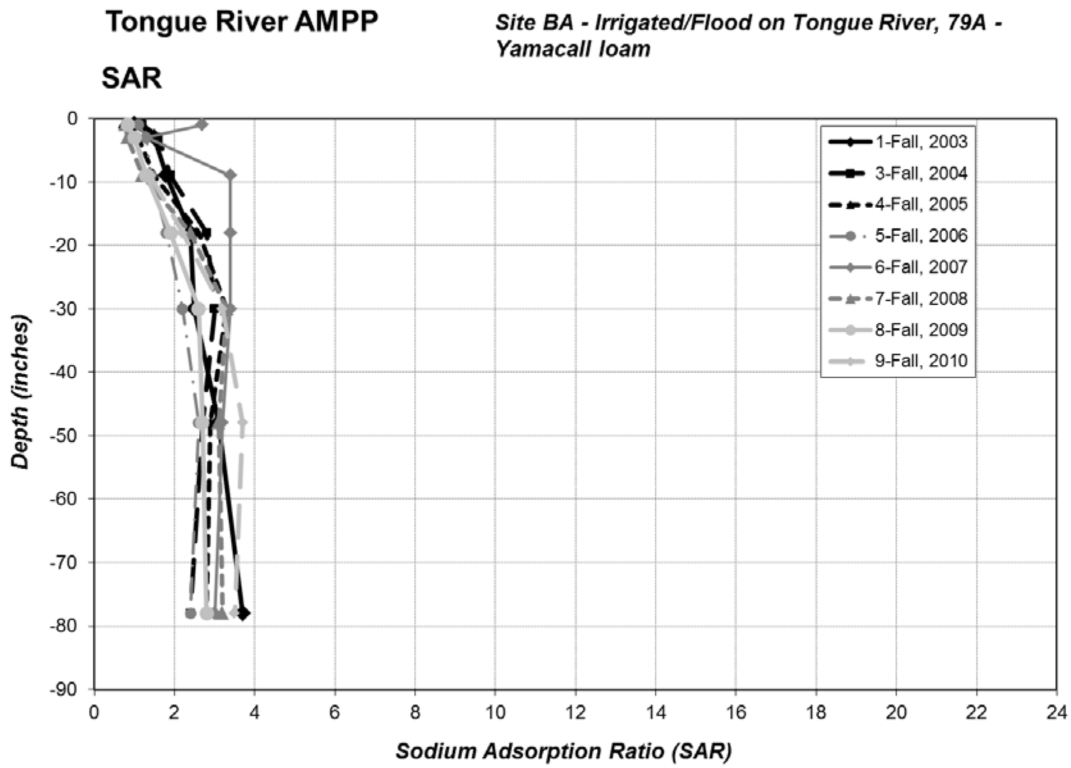

Figure 4-35 Trends in SAR with Depth for Site BA.

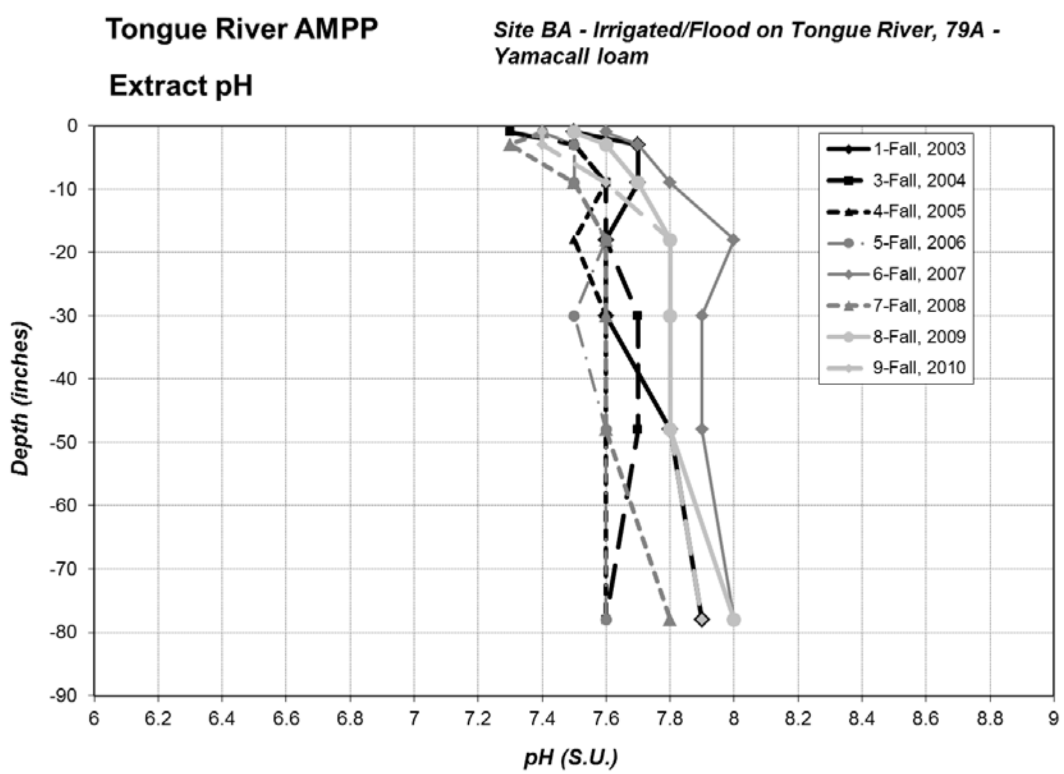

Figure 4-36 Trends in pH with Depth for Site BA.

4.1.10 Site BC

Site BC (Table 4-19 and 4-20) was an older stand of grass/alfalfa that is flood irrigated with Tongue River water obtained from the T&Y Canal. Site BC soils are the highest in clay content of any AMPP fields at about 45%. Yields were 3.7, 2.7, 1.7, 1.6, 1.5, and 0.9 tons per acre in 2003 through 2008. In 2007 and 2008, BC had been grazed prior to each cutting accounting for at least 50% reduction in measured yield. Applied irrigation water was 18, 15, 12, 0, 6 and 12 inches in 2003 through 2008, respectively. The field was planted to corn in 2009, which yielded 34 tons per acre with 30 inches of applied water. Corn sodium level was 0.02%, as with corn grown at any AMPP site, regardless of soil EC and SAR level. Spring wheat was grown at site BC in 2010 and yielded 72.6 bushels grown as a non-irrigated crop.

Forage sodium content has generally been declining since 2004. Test levels have been 0.13%, 0.12%, 0.11%, 0.8%, and 0.11% from 2004 through 2008, respectively.

EC (Figure 4-37) increased from around 1 dS/m in the upper 18 inches to around 7 dS/m below 3 feet in depth. As of fall 2010, EC is at or below fall 2003 levels for all depths. The soil is probably poorly drained judging from the elevated salinity, its location in the lower Tongue River floodplain, and high clay content. ESP (Figure 4-38) appeared to increase from 2003 to 2004, decrease again in 2005 then rebound in later years. The 2010 SAR (Figure 4-39) is below fall 2003 levels in the top 24 inches. Below 36 inches, results have been variable. The pH (Figure 4-40) was typical of AMPP soils showing no change through time.

Table 4-19 Soil pH, EC, Saturation Extractable Ions and SAR for Site BC.

Depth (inches)		pH (Paste) s_u_ Method ASAM10-3_2	Electrical Conductivity (Paste) mmhos/cm Method ASAM10-3	Saturation Percentage wt% Method USDA27a	Calcium (Paste) meq/l Method SW6010B	Magnesium (Paste) meq/l Method SW6010B	Sodium (Paste) meq/l Method SW6010B	Sodium Adsorption Ratio unitless Method Calculation	Alkalinity (Paste) meq/L Method ASA10-3	Bicarbonate (Paste) meq/L Method ASA10-3	Carbonate (Paste) meq/L Method ASA10-3	Chloride (Paste) meq/L Method ASA10-3
1-Fall, 2003												
0	2	7.5	1.05	53	3.4	2.8	2.5	1.4	7.8			
0	6	7.5	0.82	53.3	2.8	2.2	2.6	1.6	6.4			
6	12	7.7	0.82	53.3	2.2	1.9	3.4	2.4	5.6			
12	24	7.8	1.63	155	4.1	3.6	8.1	4.2	4.4			
24	36	7.8	6	61.9	19.4	16.4	24.7	5.8	2.8			
36	60	7.8	6.9	66.1	19.9	15	34.3	8.2	2.8			
60	96	7.8	6.98	49.6	20	13.9	33.8	8.2	3.3			
2-Spring, 2004												
0	2	7.5	0.94	52.8	4.11	2.79	3.19	1.7	7.6			1.55
0	6	7.6	0.93	50.2	5.09	3.61	3.37	1.6	5.6			0.71
6	12	7.7	0.91	51.2	3.53	2.79	4.35	2.4	6			0.42
12	24	7.9	1.4	54.1	3.5	3.17	6.78	3.7	4			0.14
24	36	7.8	5.41	59.8	25.9	20.7	25.3	5.2	2			0.42
36	60	7.9	5.99	59.4	23.7	16.8	32.9	7.3	2.2			0.85
60	96	7.9	6.76	50.1	29	20.6	36.8	7.4	2.6			0.85
3-Fall, 2004												
0	2	7.3	1.6	61.2	6.72	5.4	3.94	1.6	10.8			
0	6	7.4	1.4	54.8	5.62	3.95	4.46	2	5.8			
6	12	7.7	2.34	56.9	6.7	5.4	10.7	4.4	3.9			
12	24	7.7	3.12	59.8	11	9.22	14.7	4.6	1.9			
24	36	7.8	6.64	65.9	23.8	18	41.8	9.1	3.2			
36	60	7.8	6.98	73.7	22.3	15.8	48.5	11	2.3			
60	90	7.8	6.01	65.9	22.2	13.4	38.6	9.2	2.2			
4-Fall, 2005												
0	2	7.2	1.31	58.3	6.78	4.86	2.04	0.85				
0	6	7.3	0.92	55.1	5.38	3.7	2.77	1.3				
6	12	7.6	0.81	51.4	3.31	2.47	4.65	2.7				
12	24	7.8	1.96	53.3	5.7	4.82	11.4	5				
24	36	7.6	6.15	54.9	27	20	32.1	6.6				
36	60	7.8	7.02	64.3	23	17.3	48.6	11				
60	96	7.7	6.53	51.8	24.7	15.6	43.7	9.7				
5-Fall, 2006												
0	2	7.3	1.11	61	5.8	4.16	1.85	0.83				0.05
0	6	7.1	0.91	55	4.2	3	2.22	1.2				0.08
6	12	7.5	0.99	47.4	3.27	2.41	3.95	2.3				0.09
12	24	7.6	3.29	56.8	11.4	9.75	13.2	4				0.16
24	36	7.7	4.16	57	15.1	12	22.5	6.1				0.63
36	60	7.8	5.68	60.1	19.4	14.6	39	9.4				1.02
60	96	7.8	5.08	49.4	19.5	12.1	35.2	8.8				0.9
6-Fall, 2007												
0	2	7.5	0.97	59.5	4.07	2.98	2.07	1.1				1.06
0	6	7.7	0.74	54.8	3.02	2.17	1.84	1.1				0.5
6	12	7.9	0.48	52.4	1.57	1.18	2.05	1.8				1.06
12	24	8	0.9	53.4	2.61	1.97	4.12	2.7				0.5
24	36	7.9	4.03	62.8	14.8	11.9	23.6	6.5				0.94
36	60	7.8	4.43	61.5	20.8	14.3	21.7	5.2				0.47
60	96	8	6.07	59.7	18.5	12.2	46.2	12				0.79
7-Fall, 2008												
0	2	7.5	0.58	48	2.5	1.84	1.91	1.3				0.34
0	6	7.5	0.69	53.8	3	2.13	2.24	1.4				0.46
6	12	7.6	0.75	50.3	2.78	2.09	2.49	1.6				0.54
12	24	7.8	0.95	53.4	2.63	2.17	5.39	3.5				0.42
24	36	7.6	3.64	55	16.7	12	17.9	4.7				0.32
36	60	7.7	4.67	56.9	17.9	12.8	28.7	7.3				0.4
60	96	7.7	4.07	49.1	19.2	11.7	21.4	5.5				0.2
8-Fall, 2009												
0	2	7.7	0.87	49.4	4.07	2.85	2.3	1.2				0.33
0	6	7.7	0.83	52.9	3.7	2.65	2.44	1.4				0.97
6	12	7.7	0.75	53.6	3.32	2.47	3.06	1.8				0.25
12	24	8	0.86	51.2	2.43	2.07	5.24	3.5				0.23
24	36	7.9	2.99	59.6	12.6	9.86	17.1	5.1				0.4
36	60	7.9	4.38	57	17.7	12.8	26.7	6.8				0.49
60	96	8	5.1	52.2	16.3	11.8	34.2	9.1				0.47
9-Fall, 2010												
0	2	7.4	0.99	51.3	6.85	3.68	1.61	0.7				0.7
0	6	7.5	0.98	52.5	5.46	3.67	2.16	1				0.8
6	12	7.6	0.75	50.7	3.17	2.51	3.26	1.9				0.3
12	24	7.8	1.1	50.4	3.31	2.7	6.1	3.5				0.2
24	36	7.7	5.32	54.8	25.4	19.4	26.2	5.5				ND
36	60	7.8	6.09	62.6	23.9	17	39.9	8.8				ND
60	96	7.9	8.62	58.8	23.3	17.3	68.8	15				ND

Table 4-20 Soil Texture, Lime, CEC and ESP for Site BC.

Depth (inches)		Sand % Method ASA15-5	Silt % Method ASA15-5	Clay % Method ASA15-5	Texture unitless Method ASA15-5	Lime as CaCO3 wt% Method USDA23c	Cation Exchange Capacity meq/100g Method SW6010B	Extractable Sodium meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
1-Fall, 2003									
0	2	18	51	31	SiCL	9.7	41.8		1.4
0	6	17	51	32	SiCL	9.6	41.1		1.7
6	12	13	51	36	SiCL	9.7	45		2
12	24	8	48	44	SiC	9.4	50.8		1.6
24	36	4	48	48	SiC	8.9	43.7		3.9
36	60	5	49	46	SiC	9.4	39.1		4.8
60	96	23	45	32	CL	10.2	30.3		5
2-Spring, 2004									
0	2	19	48	33	SiCL	6.6	28.8	0.71	1.9
0	6	16	48	36	SiCL	6.6	27.2	0.86	2.5
6	12	13	51	36	SiCL	6.7	30.9	1.06	2.7
12	24	8	49	43	SiC	4.2	31.1	2.07	5.5
24	36	5	49	46	SiC	6	31.3	3.43	6.1
36	60	8	50	42	SiC	6.8	26.4	5.32	13
60	96	25	44	31	CL	7.3	21.6	3.39	7.2
3-Fall, 2004									
0	2	21	50	29	CL	7	26.6		2.5
0	6	17	68	15	SiL	7.1	27.1		2.9
6	12	16	50	34	SiCL	7.2	26.5		4.8
12	24	9	56	35	SiCL	6.5	28.4		5.5
24	36	7	50	43	SiC	6.5	31.5		9.7
36	60	3	49	48	SiC	6.5	28.7		13
60	90	13	42	45	SiC	7	24.8		12
4-Fall, 2005									
0	2	19	49	32	SiCL	7.1	39.4		1
0	6	18	50	32	SiCL	7.4	37.9		1.4
6	12	17	52	31	SiCL	7.6	35.5		2.2
12	24	13	47	40	SiC	7.4	40.2		3.4
24	36	7	47	46	SiC	6.5	31.2		5.1
36	60	5	52	43	SiC	4.8	36.3		6.8
60	96	19	48	33	SiCL	7.9	28.2		6.1
5-Fall, 2006									
0	2	18	51	31	SiCL	6.5	37.7		1.5
0	6	20	48	32	SiCL	6.6	37.2		1.7
6	12	26	47	27	CL	7.3	32.2		2.8
12	24	12	47	41	SiC	6.5	38.1		4.6
24	36	12	46	42	SiC	6.5	35.9		5.9
36	60	6	51	43	SiC	6.7	33.9		9.4
60	96	28	43	29	CL	7.4	25		9
6-Fall, 2007									
0	2	17	51	32	SiCL	6.4	33.3		1.8
0	6	18	49	33	SiCL	6	34.2		1.8
6	12	16	50	34	SiCL	6.2	28.9		2.6
12	24	10	50	40	SiC	6.3	29.8		3.9
24	36	9	69	22	SiL	5.7	29.9		9.1
36	60	5	52	43	SiC	6.2	25.2		8.3
60	96	13	52	35	SiCL	6.5	23.6		12
7-Fall, 2008									
0	2	14	48	38	SiCL	7	30.3		2.1
0	6	18	47	35	SiCL	7.2	29.6		2.1
6	12	12	51	37	SiCL	7.1	28.4		2.5
12	24	10	48	42	SiC	7	32.3		4.3
24	36	16	40	44	C	7.4	35.4		5.6
36	60	6	52	42	SiC	7.6	26		9.9
60	96	20	44	36	SiCL	7.4	23.1		7.5
8-Fall, 2009									
0	2	14	52	34	SiCL	6.7	32		1.1
0	6	14	52	34	SiCL	6.8	31.8		1.2
6	12	12	54	34	SiCL	6.9	31.9		1.6
12	24	10	50	40	SiC	6.8	27.8		4.4
24	36	4	50	46	SiC	6	27.9		6.5
36	60	10	52	38	SiCL	7.1	25		8.3
60	96	22	46	32	CL	7.7	27.5		8.3
9-Fall, 2010									
0	2	16	50	34	SiCL	7.01	24.5		1
0	6	16	48	36	SiCL	6.86	24.2		1.1
6	12	14	50	36	SiCL	6.98	23.9		1.8
12	24	12	48	40	SiC	6.84	25.3		3.4
24	36	8	50	42	SiC	7.1	24.9		5
36	60	4	48	48	SiC	6.56	29.6		9
60	96	12	46	42	SiC	6.88	26.2		14

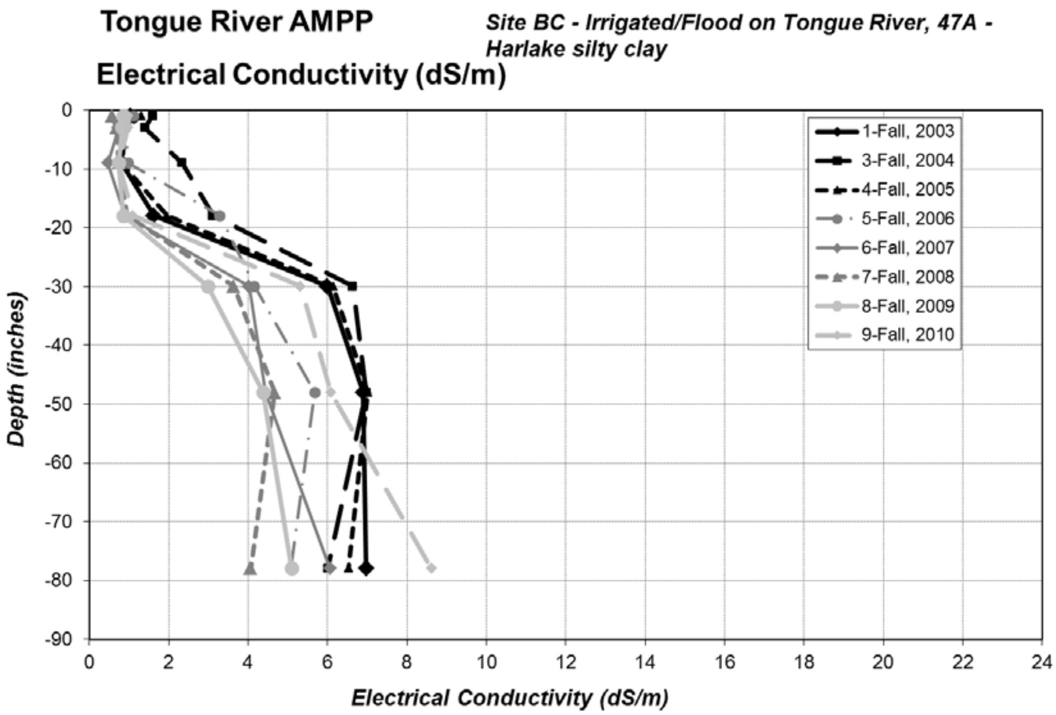

Figure 4-37 Trends in EC with Depth for Site BC.

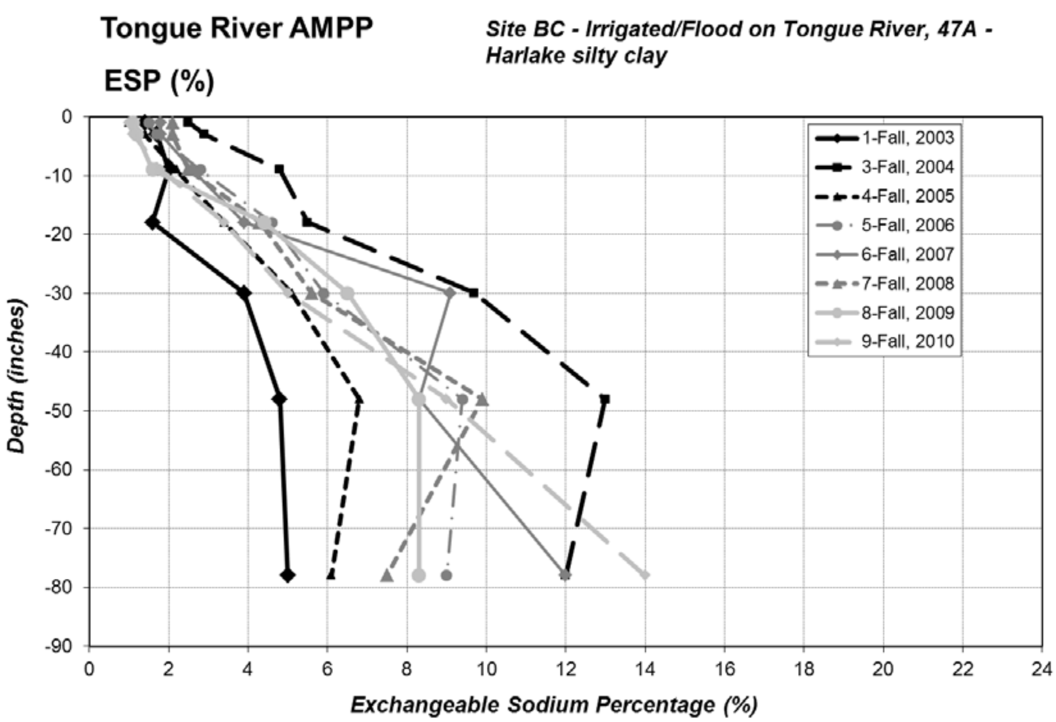

Figure 4-38 Trends in ESP with Depth for Site BC.

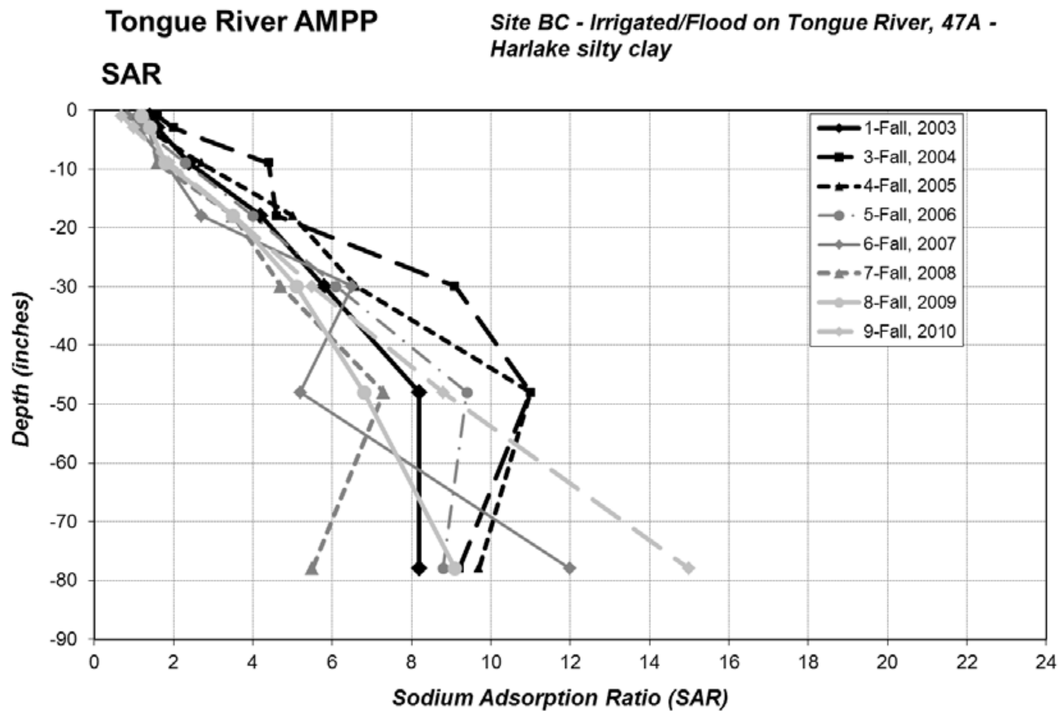

Figure 4-39 Trends in SAR with Depth for Site BC.

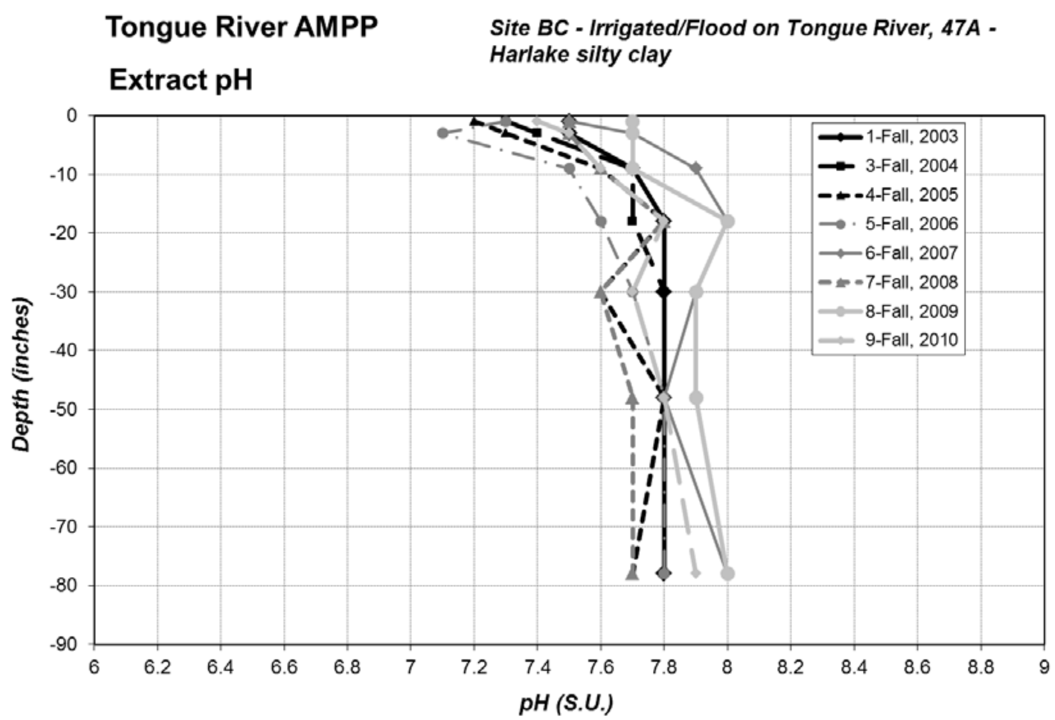

Figure 4-40 Trends in pH with Depth for Site BC.

4.1.11 Site BD

Site BD (Table 4-21 and 4-22) is a dryland field of improved pasture grass located across the Tongue River from site BC that was sampled in 2003 to identify differences in salinity, SAR, ESP, and pH between irrigated and dryland soils. This site had the same soil mapping unit as BC and YBA at Fort Keogh. The area had spreader dikes installed.

Soil EC (Figure 4-41) ranged from 1 to 3 dS/m at 12 and 36 inches, respectively. ESP (Figure 4-42) increased from 1 near-surface to around 6% at depth, while SAR (Figure 4-43) varied from 0.5 to 7 across the same depth intervals. Soil pH (Figure 4-44) ranged from 7.1 to 8.1, similar to most AMPP soils. This dryland soil had slightly lower EC and sodium levels than its irrigated counterparts indicating that the irrigated soil does not have adequate drainage or is not provided with enough irrigation water to induce leaching for salinity control.

Table 4-21 Soil pH, EC, Saturation Extractable Ions and SAR for Site BD.

Depth (inches)		pH (Paste) s_u_ Method ASAM10-3_2	Electrical Conductivity (Paste) mmhos/cm Method ASAM10-3	Saturation Percentage wt% Method USDA27a	Calcium (Paste) meq/l Method SW6010B	Magnesium (Paste) meq/l Method SW6010B	Sodium (Paste) meq/l Method SW6010B	Sodium Adsorption Ratio unitless Method Calculation	Alkalinity (Paste) meq/L Method ASA10-3
1-Fall, 2003									
0	2	7.1	0.88	77.2	3.8	1.8	0.8	0.5	7.2
0	6	7.2	0.83	67.3	4.1	2.1	1.1	0.6	7
6	12	7.6	0.73	60.7	2.8	1.6	1.3	0.8	5.5
12	24	7.7	2.86	60.4	7.5	6.8	7	2.6	4.4
24	36	7.8	3.65	60.3	11.1	11.5	14.3	4.3	3.6
36	60	8	3.24	47	10	10.6	16	5	2.9
60	96	8.1	2.68	41.2	3.1	5.7	14.4	6.9	3.2

Table 4-22 Soil Texture, Lime, CEC and ESP for Site BD.

Depth (inches)		Sand % Method ASA15-5	Silt % Method ASA15-5	Clay % Method ASA15-5	Texture unitless Method ASA15-5	Lime as CaCO3 wt% Method USDA23c	Cation Exchange Capacity meq/100g Method SW6010B	Extractable Sodium meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
1-Fall, 2003									
0	2	18	52	30	SiCL	4.4	54.5		1.1
0	6	17	54	29	SiCL	5.3	40.7		1.2
6	12	5	62	33	SiCL	7.3	35.9		1.5
12	24	7	64	29	SiCL	8	34.6		2.9
24	36	12	63	25	SiL	8.4	31.9		4
36	60	20	58	22	SiL	8.1	27.2		4.6
60	96	51	36	13	L	6.9	18.7		6.3

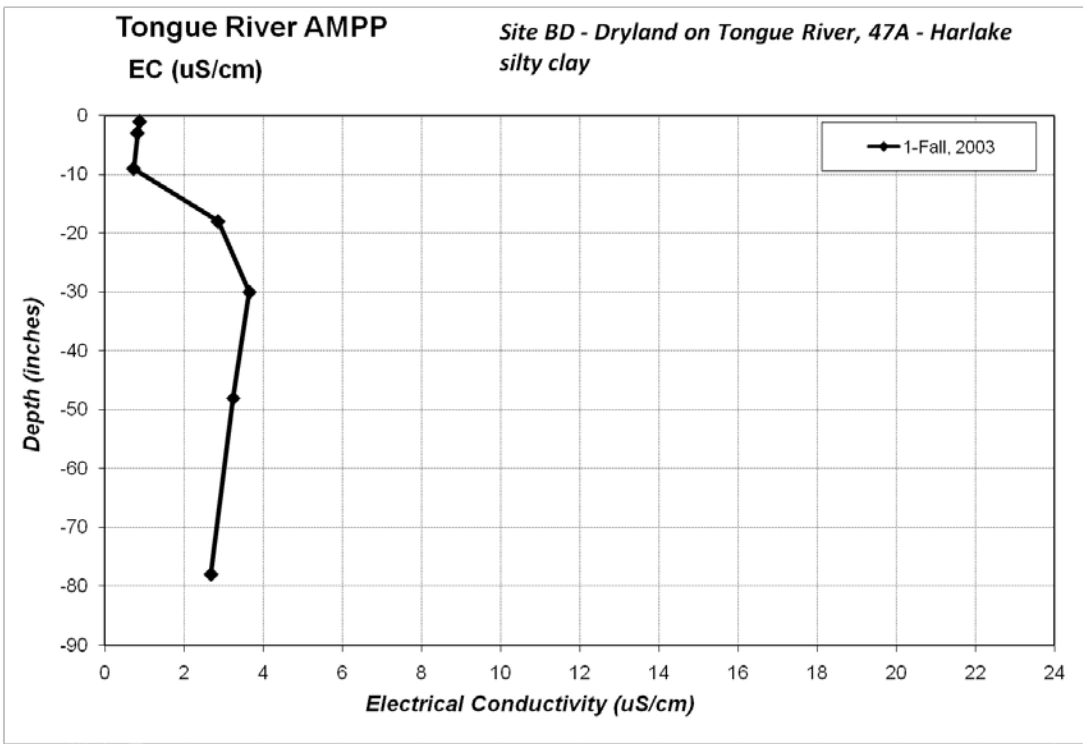

Figure 4-41 Trends in EC with Depth for Site BD.

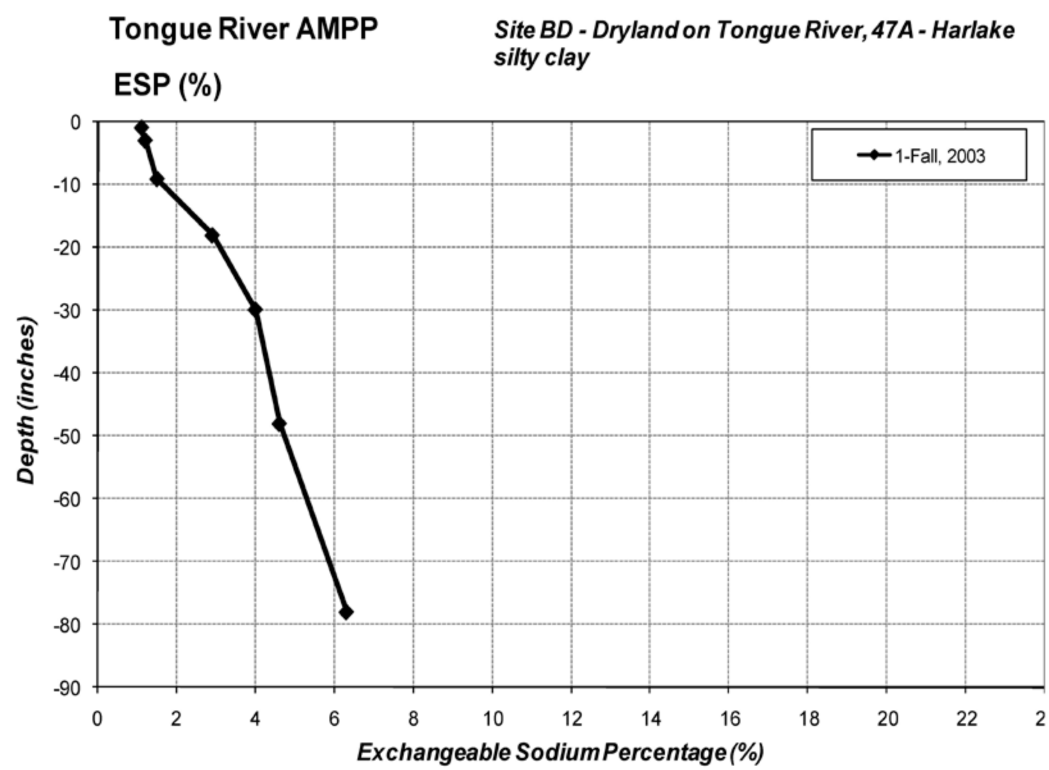

Figure 4-42 Trends in ESP with Depth for Site BD.

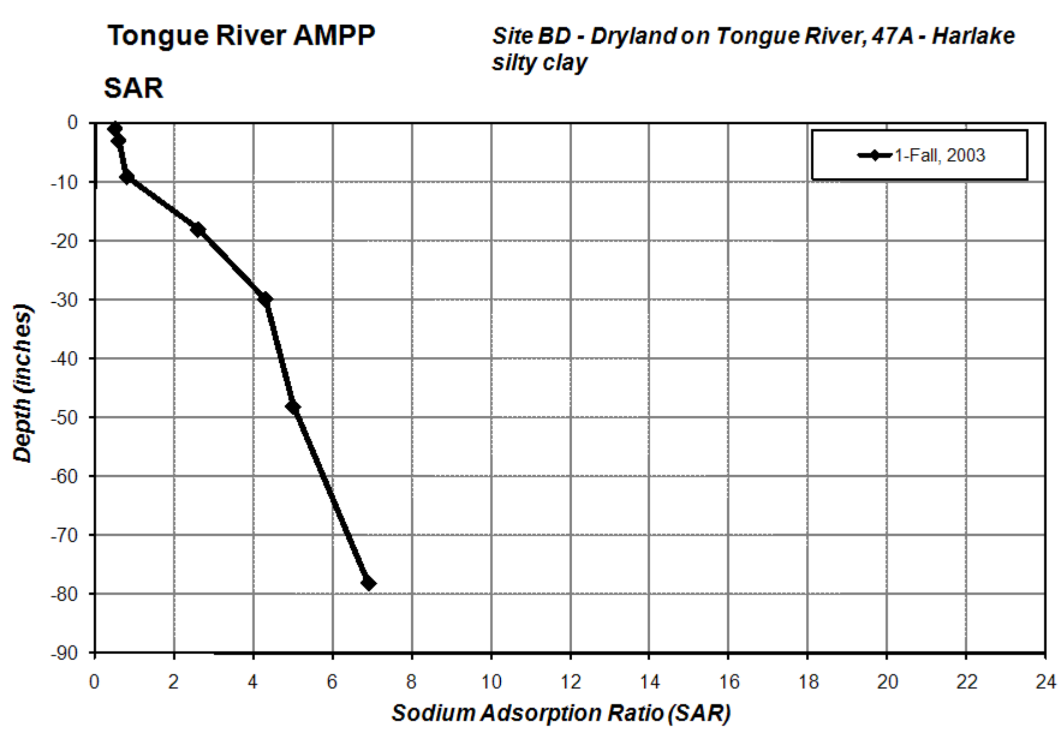

Figure 4-43 Trends in SAR with Depth for Site BD.

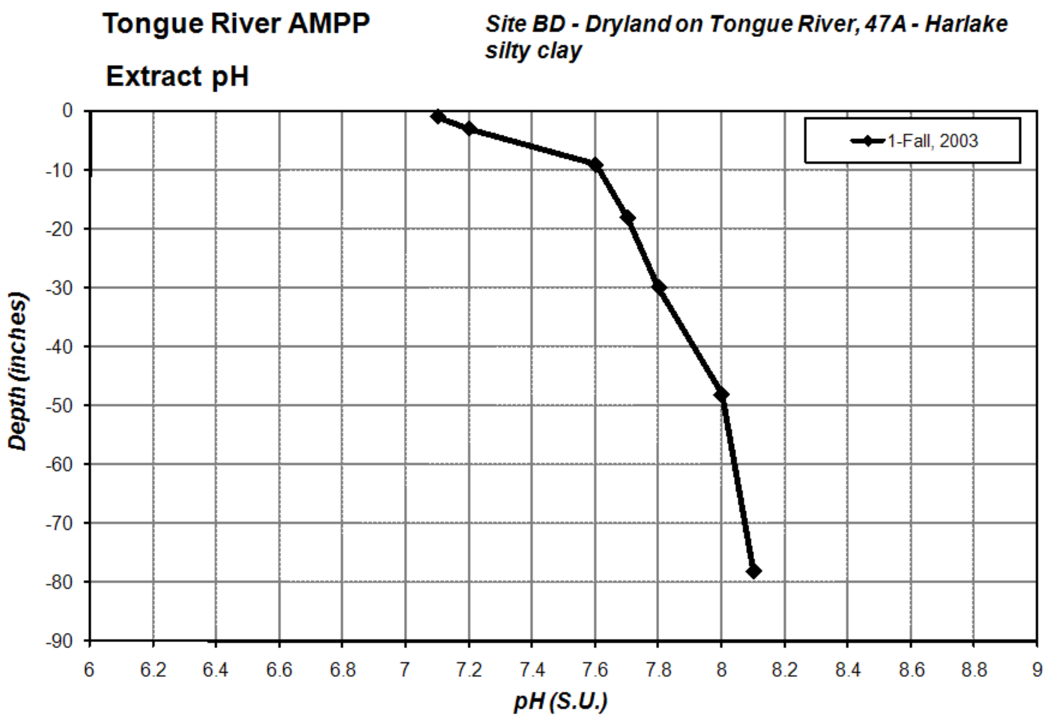

Figure 4-44 Trends in pH with Depth for Site BD.

4.1.12 Site YAA

Site YAA (Table 4-23 and 4-24) is a flood-irrigated alfalfa field located in the T&Y irrigation district on a terrace of the Yellowstone River about 8 miles downstream of the confluence of the Tongue River with the Yellowstone River. Alfalfa yields were 2.0, 5.0, 3.4, 4.6, 3.7, 3.3, 3.0 and 2.9 tons per acre in 2003 through 2010, respectively, while applied irrigation water was 6 to 18 inches per year, mostly 12-18 inches.

Soil EC (Figure 4-45) increased in a linear fashion from 1 dS/m near surface to around 5 to 6 dS/m in the 5 to 8 foot zone. Water obtained at 6 feet below the surface from a shallow borehole had an EC of 4 to 13 dS/m and a SAR of 12 to 27 (Figure 3-14 and 3-15). ESP and SAR appeared to increase during drought years in 2003 and 2004, and then decreased in 2005 and 2006, similar to the pattern for other AMPP sites (Figure 4-46 and Figure 4-47). EC and sodium levels increased from 2006 to 2008, but remained similar to 2004/2005 levels; pH (Figure 4-48) did not change appreciably through time. Soil EC and sodium levels dropped from 2008 through 2010 despite only 6 inches of irrigation water applied in 2009. As of fall 2010, EC, and SAR are at or near fall 2003 levels indicating no sodium or salinity build-up.

Table 4-23 Soil pH, EC, Saturation Extractable Ions and SAR for Site YAA.

Depth (inches)		pH (Paste) s_u_ Method ASAM10-3_2	Electrical Conductivity (Paste) mmhos/cm Method ASAM10-3	Saturation Percentage wt% Method USDA27a	Calcium (Paste) meq/l Method SW6010B	Magnesium (Paste) meq/l Method SW6010B	Sodium (Paste) meq/l Method SW6010B	Sodium Adsorption Ratio unitless Method Calculation	Alkalinity (Paste) meq/L Method ASA10-3	Bicarbonate (Paste) meq/L Method ASA10-3	Carbonate (Paste) meq/L Method ASA10-3	Chloride (Paste) meq/L Method ASA10-3
1-Fall, 2003												
0	2	7.6	1	53.9	4.8	3.2	2.6	1.3	7			
0	6	7.6	1.22	56.2	5.5	3.9	3.7	1.7	5.4			
6	12	7.7	1.1	49.4	4.1	3.3	4	2.1	4.8			
12	24	7.7	1.53	55.4	5.1	4.7	6.4	2.9	4.2			
24	36	7.7	2.15	51.7	5.5	4.7	11	4.9	4.2			
36	60	7.9	2.73	50.7	6	5.1	15.9	6.8	4			
60	96	7.8	4.83	52.5	13	9.9	29.3	8.7	3.6			
2-Spring, 2004												
0	2	7.6	0.92	49	4.14	2.85	2.43	1.3	7.2			0.85
0	6	7.6	0.92	51.6	4.14	2.77	2.72	1.5	8			0.71
6	12	7.7	0.68	51.5	3.01	2.14	2.81	1.8	4.8			0.56
12	24	7.8	1.73	49.1	6.55	6.16	7.06	2.8	1.2			0.28
24	36	7.9	2.37	49	5.12	4.35	13	6	4.6			0.28
36	60	8	4.08	56.2	7.46	5.99	26.4	10	3.4			0.42
60	96	7.8	6.88	51.1	20.9	14.3	47.7	11	3.2			0.71
3-Fall, 2004												
0	2	7.5	1.08	57.3	5.45	4.04	3.88	1.8	8.2			
0	6	7.5	1.35	53.8	5.93	4.11	4.36	2	6.9			
6	12	7.6	1.41	51.6	5.38	4.12	5.03	2.3	5.3			
12	24	7.7	2.45	51.2	7.82	7.09	11.3	4.1	4.9			
24	36	7.9	2.92	52.1	5.17	4.54	19.1	8.7	4.6			
36	60	7.9	4.41	51.9	8.11	6.53	30.9	11	3.2			
60	90	7.9	4.83	48.6	9.64	7.58	32.8	11	3.2			
4-Fall, 2005												
0	2	7	1.35	63.1	2.88	2.09	1.04	0.95				
0	6	7.5	0.78	57.4	4.83	3.4	2.26	1.1				
6	12	7.7	0.95	49.6	4.69	3.69	3.87	1.9				
12	24	7.8	2.24	50	7.48	7.65	10.6	3.9				
24	36	7.8	2.25	49.8	5.19	5.05	16.5	7.3				
36	60	7.8	3.24	48.9	7.8	6.97	25.4	9.3				
60	96	7.8	4.48	46.6	11.4	9.13	33.9	11				
5-Fall, 2006												
0	2	7.4	0.78	53.4	3.77	2.48	1.47	0.83				0.38
0	6	7.4	0.79	51.8	3.79	2.45	1.77	1				0.1
6	12	7.5	0.98	52.6	4.29	3	2.67	1.4				0.19
12	24	7.7	1.14	50	3.15	2.66	3.97	2.3				0.22
24	36	7.7	2.41	47.8	5.85	5.6	13.4	5.6				0.09
36	60	7.5	3.16	53.5	9.42	8.05	24	8.1				1.46
60	96	7.8	4.08	45.4	9.47	8	26.2	8.9				1.21
6-Fall, 2007												
0	2	7.5	1.06	56.3	4.02	2.75	2.53	1.4				0.53
0	6	7.7	0.71	55.6	3.2	2.16	1.9	1.2				0.35
6	12	7.8	0.79	50.5	3.32	2.36	3.03	1.8				1.06
12	24	8.1	1.63	51.1	3.74	3.43	11	5.8				0.35
24	36	7.9	2.37	48.2	6.31	5.28	14	5.8				1.06
36	60	8	3.65	49.7	9.3	7.97	24.3	8.2				0.53
60	96	8.1	7.7	50.7	17.5	14.3	64.2	16				1.59
7-Fall, 2008												
0	2	7.2	0.77	56.9	4.19	2.65	1.4	0.76				0.3
0	6	7.3	0.63	53.5	2.95	1.98	1.67	1.1				0.23
6	12	7.5	0.55	48.9	2.43	1.56	1.88	1.3				0.25
12	24	7.7	0.76	46.9	2.33	1.8	4.9	3.4				0.58
24	36	7.7	1.56	50.3	3.97	3.16	9.42	5				0.29
36	60	7.7	3.12	46.7	9.44	7.35	20.2	7				0.33
60	96	7.7	4.3	43.1	14.1	9.93	29.6	8.6				0.37
8-Fall, 2009												
0	2	7.3	1.04	62.3	5.42	4	2.26	1				0.68
0	6	7.5	0.72	58	3.83	2.77	2.19	1.2				0.34
6	12	7.8	0.64	51.2	2.84	2.04	2.41	1.5				0.18
12	24	7.8	0.84	48.2	3.44	2.98	3.84	2.1				0.22
24	36	7.9	0.94	48.6	2.96	2.49	5.59	3.4				0.22
36	60	7.9	1.25	47.1	3.63	2.67	6.59	3.7				0.2
60	96	8	2.89	46.4	8.13	7.14	20.3	7.4				0.42
9-Fall, 2010												
0	2	6.9	1.71	61.8	6.83	7.17	2.95	0.83				0.8
0	6	7.1	1.56	57.4	11.2	6.71	4.06	1.4				0.5
6	12	7.5	1.08	52.5	4.92	3.6	3.84	1.9				ND
12	24	7.7	2.02	48.4	8.43	7.21	9.21	3.3				0.2
24	36	7.6	2.6	55.6	10.7	9.28	11.9	3.8				ND
36	60	7.7	2.7	50.5	9.27	8.59	18	6				ND
60	96	7.8	3.44	44.2	8.83	7.87	24	8.3				ND

Table 4-24 Soil Texture, Lime, CEC and ESP for Site YAA.

Depth (inches)		Sand % Method ASA15-5	Silt % Method ASA15-5	Clay % Method ASA15-5	Texture unitless Method ASA15-5	Lime as CaCO3 wt% Method USDA23c	Cation Exchange Capacity meq/100g Method SW6010B	Extractable Sodium meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
1-Fall, 2003									
0	2	28	40	32	CL	6.6	35.8		2
0	6	18	52	30	SICL	6.7	39.3		2
6	12	28	50	22	SiL	7	30.9		3
12	24	34	45	21	L	6.7	38.9		3.6
24	36	14	55	31	SiCL	7.3	32.9		5.7
36	60	26	48	26	L	7.5	30.3		6.2
60	96	29	45	26	L	7.5	28.8		5.5
2-Spring, 2004									
0	2	29	43	28	CL	3.7	27.2	0.75	2.3
0	6	23	47	30	CL	3.9	28.6	0.73	2.1
6	12	23	45	32	CL	2.6	28.7	0.8	2.3
12	24	29	43	28	CL	4.4	24.9	1.42	4.3
24	36	27	45	28	CL	4.5	24.9	2.48	7.4
36	60	29	43	28	CL	4.3	24.9	4.42	12
60	96	26	45	29	CL	4.7	25.6	5.01	10
3-Fall, 2004									
0	2	22	48	30	CL	4	28.5		2.3
0	6	23	46	31	CL	4.1	29.4		2.6
6	12	21	48	31	CL	4.5	30.9		3.1
12	24	26	46	28	CL	4.7	27.2		4.1
24	36	26	45	29	CL	4.9	27		8
36	60	28	46	26	L	4.5	25		11
60	90	32	45	23	L	5.1	21.3		11
4-Fall, 2005									
0	2	27	44	29	CL	3.8	39.3		1.1
0	6	24	47	29	CL	4.2	38.8		1.2
6	12	26	45	29	CL	4.7	37.5		1.7
12	24	28	44	28	CL	4.5	37.9		2.4
24	36	26	47	27	CL	5.3	33		5.1
36	60	30	45	25	L	5.4	32.6		5.5
60	96	32	44	24	L	6.1	30.4		5.7
5-Fall, 2006									
0	2	23	48	29	CL	3.5	41.4		1.4
0	6	23	50	27	CL	3.8	37.2		1.4
6	12	20	51	29	SiCL	3.9	38.7		1.9
12	24	20	52	28	SiCL	4.4	36.1		3.1
24	36	27	50	23	SiL	4.6	34.5		4.4
36	60	29	50	21	SiL	4.5	33		6.3
60	96	34	45	21	L	4.8	29.1		8.4
6-Fall, 2007									
0	2	25	46	29	CL	3.5	34.5		2
0	6	23	50	27	CL	3.7	33.8		2
6	12	22	48	30	CL	3.5	31.1		2.7
12	24	27	46	27	CL	4.6	31.1		5.8
24	36	26	46	28	CL	4.1	29.8		5.5
36	60	28	47	25	L	4.3	28.9		7.8
60	96	29	44	27	CL	5.3	30		11
7-Fall, 2008									
0	2	22	44	34	CL	3.9	35.3		1.4
0	6	20	45	35	SiCL	4	34		1.9
6	12	24	42	34	CL	4.4	30		2.4
12	24	24	46	30	CL	4.9	30.6		3.7
24	36	24	44	32	CL	4.5	31.5		5.7
36	60	24	49	27	CL	5	28.2		7
60	96	30	44	26	L	5.7	25.9		8.6
8-Fall, 2009									
0	2	24	46	30	CL	3.9	35.3		0.9
0	6	24	46	30	CL	4	35		0.9
6	12	22	48	30	CL	4.2	32.9		1.3
12	24	24	48	28	CL	4.6	31		2
24	36	26	48	26	L	4.4	32.1		3.1
36	60	34	42	24	L	4.9	30.6		3.3
60	96	30	46	24	L	5.2	28.6		6.3
9-Fall, 2010									
0	2	20	44	36	SiCL	3.37	31.1		1.1
0	6	22	46	32	CL	3.51	26.9		1.7
6	12	20	46	34	SiCL	3.89	27.8		1.9
12	24	24	44	32	CL	4.19	27.5		3.1
24	36	18	46	36	SiCL	4.21	30.7		3.4
36	60	26	42	32	CL	4.63	22.9		6.4
60	96	32	42	26	L	5.27	19.6		8.2

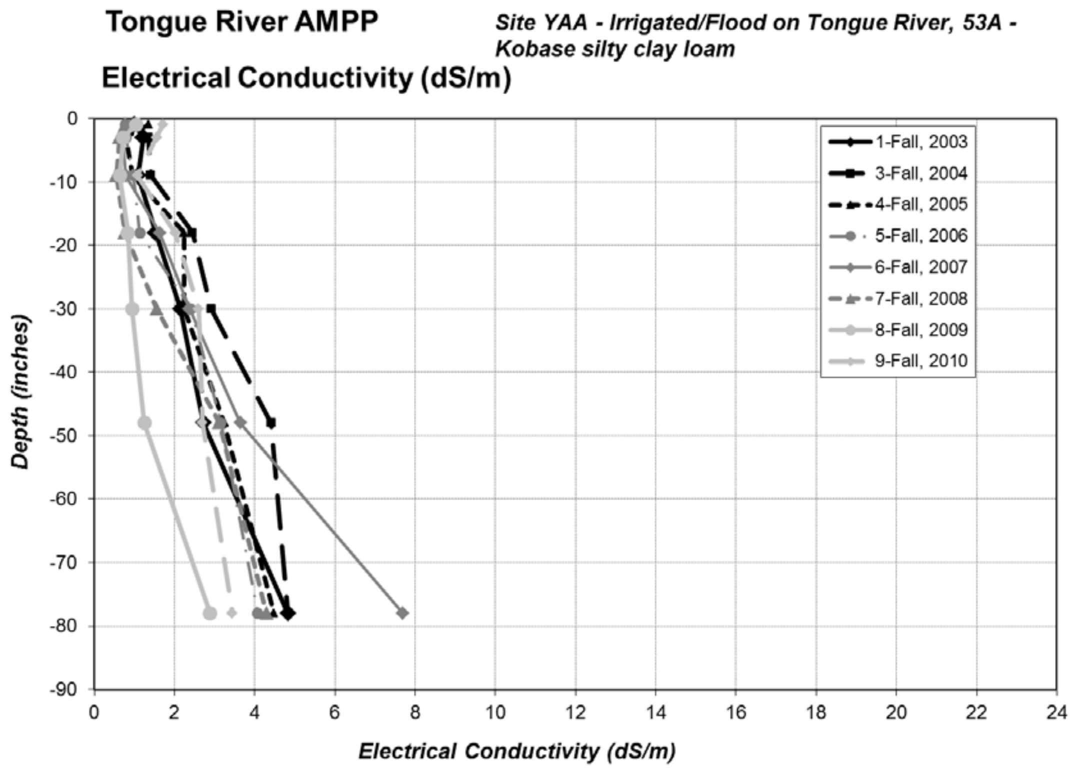

Figure 4-45 Trends in EC with Depth for Site YAA.

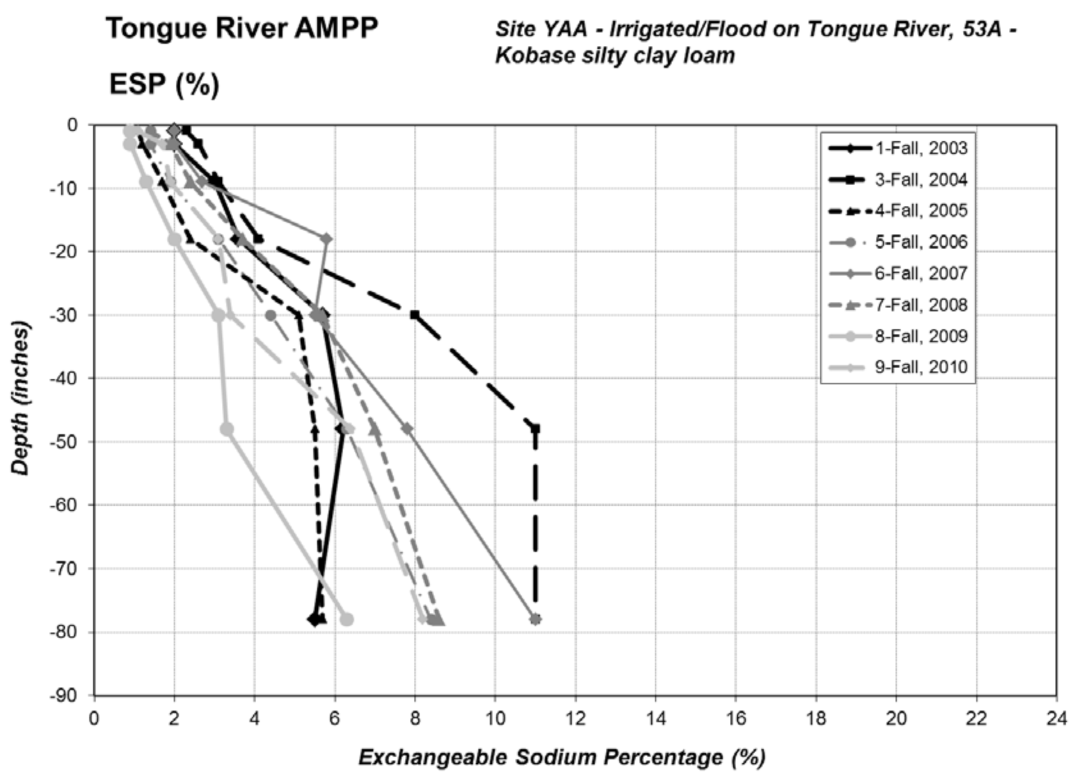

Figure 4-46 Trends in ESP with Depth for Site YAA.

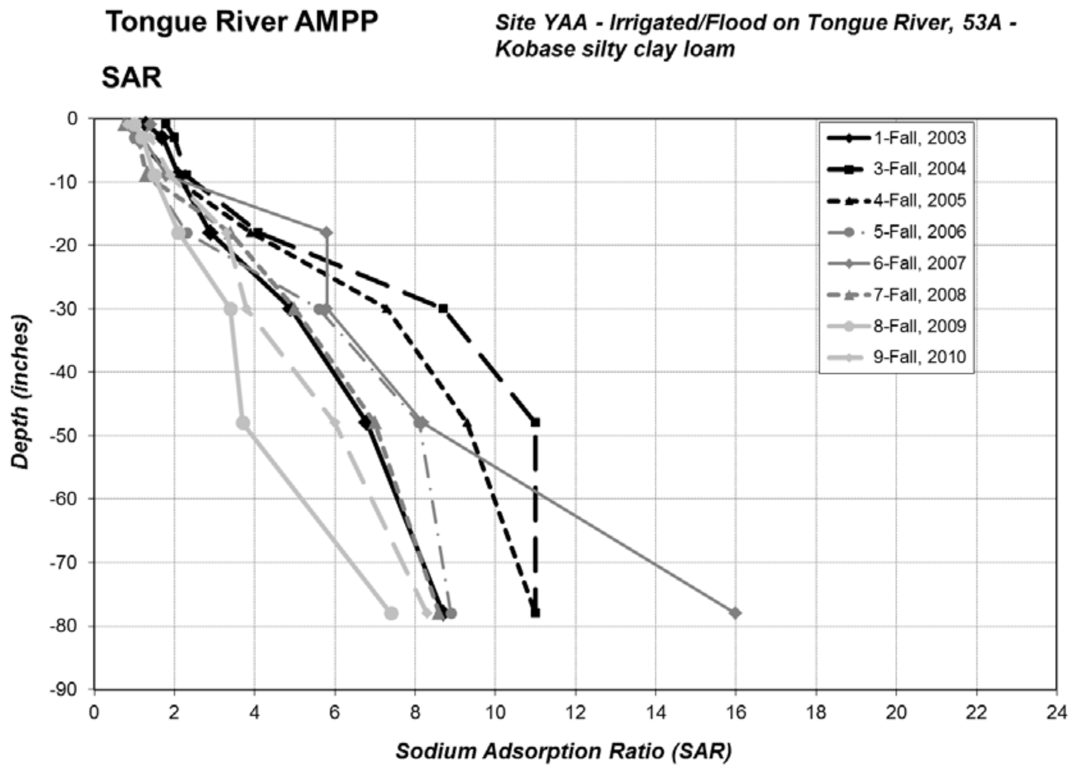

Figure 4-47 Trends in SAR with Depth for Site YAA.

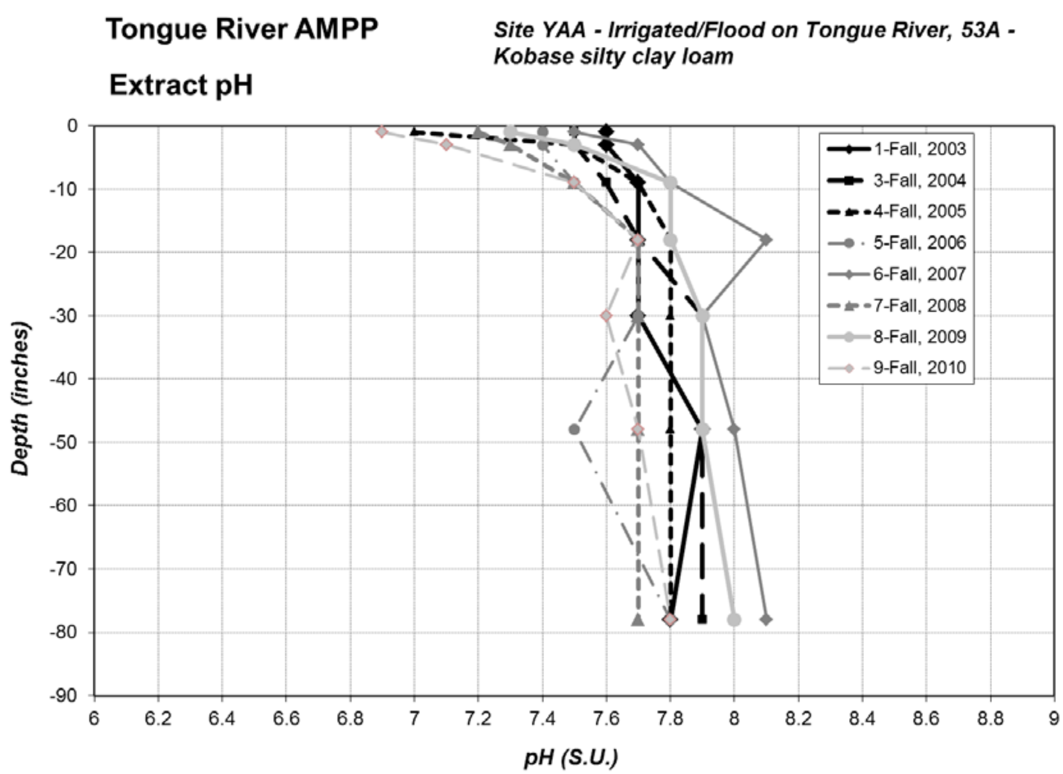

Figure 4-48 Trends in pH with Depth for Site YAA.

4.2 Tongue River Tributary AMPP Sites

4.2.1 Site MB

Site MB (Table 4-25 and 4-26) is irrigated with water from Prairie Dog Creek and is located in Wyoming just above the confluence with the Tongue River. A hay millet crop was harvested from the field in 2003. Hay barley was planted in 2004 but was not harvested due lack of broadleaf weed control. MB was fallowed in 2005. Grass was seeded in 2006, but was not irrigated and failed to establish. MB was mostly weeds in 2007 and 1.1 tons per acre of hay millet was harvested in 2008. The field had a poor crop (0.6 tons per acre) of grain hay in 2009. Yield was poor due to neighbor's cattle grazing prior to harvest. Triticale was planted in 2010 and yielded 1.01 tons per acre non-irrigated. Irrigation was erratic with 12 and 2 inches applied in 2003 and 2004, respectively. No irrigation occurred in 2005, 2006, 2007 and 2010. In 2008, 24 inches of irrigation water was applied. Twelve inches were applied in 2009.

In fall 2003 composite samples, EC (Figure 4-49) was generally below 1 dS/m in the upper 24 inches, but increased to around 4 dS/m at 48 inches and again decreased to less than 3 dS/m from 5 to 8 feet. This pattern of salinity may be due to the water table being within 6 to 8 feet of the surface. SAR and ESP increased only modestly with increasing depth.

Measured EC, ESP, SAR, pH (Figures 4-49 to 4-52) showed few trends through time, except showing a decrease in EC and sodium from 2008 through 2010. Low precipitation amounts and limited irrigation may account for the lack of change in soil chemistry. Application of 12 inches of irrigation in 2009 and high rainfall in 2010 may have promoted salt removal.

Table 4-25 Soil pH, EC, Saturation Extractable Ions and SAR for Site MB.

Depth (inches)		pH (Paste) s_u_ Method ASAM10-3_2	Electrical Conductivity (Paste) mmhos/cm Method ASAM10-3	Saturation Percentage wt% Method USDA27a	Calcium (Paste) meq/l Method SW6010B	Magnesium (Paste) meq/l Method SW6010B	Sodium (Paste) meq/l Method SW6010B	Sodium Adsorption Ratio unitless Method Calculation	Alkalinity (Paste) meq/L Method ASA10-3	Bicarbonate (Paste) meq/L Method ASA10-3	Carbonate (Paste) meq/L Method ASA10-3	Chloride (Paste) meq/L Method ASA10-3
1-Fall, 2003												
0	2	7.5	0.82	40.5	3.7	3	1.6	0.9	4			
0	6	7.5	0.81	40.8	3.7	3	1.5	0.8	5.5			
6	12	7.7	0.6	43.3	2.5	2.3	1.3	0.8	4.3			
12	24	8	0.63	53.5	2.3	2.4	2	1.3	3.2			
24	36	8	0.89	52.4	2.5	3	3.8	2.3	3.1			
36	60	7.8	3.89	44	22.3	24.9	9.1	1.9	1.4			
60	96	7.8	3.23	43.5	20.7	20.4	8.1	1.8	1.2			
2-Spring, 2004												
0	2	7.7	0.62	40.9	2.86	2.4	0.98	0.6	4.4			0.71
0	6	7.6	0.55	43	2.6	2.06	1.15	0.8	3.2			0.56
6	12	7.9	0.74	47.8	2.75	2.33	1.49	0.9	3.6			2.12
12	24	8.1	0.58	48.7	1.86	1.93	2.1	1.5	3			0.28
24	36	8.1	1.26	46.5	4.11	5.5	6.07	2.8	2.4			0.28
36	60	7.9	3.95	47	22.6	23	8.34	1.7	1.6			0.42
60	96	7.8	3.71	42.8	24.6	22.6	8.67	1.8	1.6			0.14
3-Fall, 2004												
0	2	7.4	0.53	38.4	2.32	1.81	0.99	0.69	5			
0	6	7.3	0.76	44.2	3.24	2.79	1.34	0.77	4			
6	12	7.5	0.77	46.3	3.26	3.42	1.73	0.95	3.6			
12	24	7.7	0.73	48.4	2.16	2.78	2.72	1.7	3.2			
24	36	7.7	2.51	43.5	6.37	10.1	7.88	2.8	2.4			
36	60	7.6	3.79	39.6	12.8	19.5	11.9	3	2			
60	96	7.6	4.58	42.5	23.1	24.5	10.9	2.2	1.4			
4-Fall, 2005												
0	2	7.5	0.78	40.8	4.3	3.33	0.79	0.4				
0	6	7.5	0.6	42.3	2.95	2.46	0.97	0.59				
6	12	7.6	0.85	44.9	3.17	3.21	1.87	1				
12	24	7.8	0.85	49.5	2.92	3.6	2.44	1.4				
24	36	7.8	1.32	47	3.54	4.97	4.04	2				
36	60	7.6	4.49	46.8	24.5	25.3	9.03	1.8				
60	96	7.6	4.23	47.2	23.1	22.8	9.41	2				
5-Fall, 2006												
0	2	7.4	0.66	41.1	3.09	2.17	0.23	0.14				0.04
0	6	7.5	0.64	46.9	3.08	2.3	0.4	0.24				ND
6	12	7.5	1.22	46	5.01	4.83	1.83	0.83				0.07
12	24	7.8	0.61	44.4	2.12	2.51	1.28	0.84				0.16
24	36	7.8	0.93	43.2	2.54	3.41	2.88	1.7				0.38
36	60	7.6	3.67	40.5	20.2	20.7	6.83	1.5				1.42
60	96	7.6	4.01	43.1	22.8	21.2	7.29	1.6				1.45
6-Fall, 2007												
0	2	7.7	0.79	42	3.56	2.65	0.74	0.42				1.17
0	6	7.6	0.51	42.9	2.74	2.04	0.64	0.41				0.81
6	12	7.8	0.6	46.1	2.38	2.52	1.71	1.1				0.4
12	24	8	0.5	45.6	1.95	1.97	1.66	1.2				0.3
24	36	8.1	0.91	46.4	2.69	3.38	3.59	2.1				0.42
36	60	7.8	3.57	42.9	19.6	21.6	8.33	1.8				0.47
60	96	7.8	3.87	42.4	23.4	23.1	9.58	2				0.28
7-Fall, 2008												
0	2	7.7	0.54	42.4	1.78	1.7	1.23	0.93				0.31
0	6	7.7	0.46	43.4	1.57	1.31	1.52	1.3				0.39
6	12	7.8	0.63	46.7	2.42	2.19	1.58	1				0.3
12	24	8	0.6	49.1	1.83	2.35	1.76	1.2				0.28
24	36	7.9	0.74	46.3	2.23	2.81	2.21	1.4				0.2
36	60	7.8	2.28	42.9	9.94	11.9	4.31	1.3				0.17
60	96	7.7	3.78	43.5	17.5	20.1	8.41	1.9				0.25
8-Fall, 2009												
0	2	7.8	0.49	43.8	1.99	1.72	1.14	0.84				0.24
0	6	7.8	0.44	44	2.14	1.5	1.11	0.82				0.3
6	12	8	0.41	52.1	3.28	1.81	1.21	0.76				0.19
12	24	8.1	0.53	51	3.24	2.31	1.3	0.78				0.16
24	36	8	0.53	44.1	2.61	2.75	1.53	0.93				0.16
36	60	7.9	1.43	43.4	7.53	8.31	2.76	0.98				0.16
60	96	7.9	2.55	45.7	19.4	16.6	5.32	1.2				0.19
9-Fall, 2010												
0	2	7.3	0.98	40.9	4.42	3.45	1.41	0.71				
0	6	7.3	0.74	41.7	3.13	2.44	1.92	1.2				
6	12	7.4	0.74	47	2.65	2.23	2.45	1.6				
12	24	7.5	0.98	48.1	3.4	4.05	2.84	1.5				
24	36	7.5	0.88	46.9	2.56	3.51	2.42	1.4				
36	60	7.4	3.2	42.5	17.3	18	4.56	1.1				
60	96	7.6	3.98	43.1	24.4	24.2	8	1.6				

Table 4-26 Soil Texture, Lime, CEC and ESP for Site MB.

Depth (inches)		Sand % Method ASA15-5	Silt % Method ASA15-5	Clay % Method ASA15-5	Texture unitless Method ASA15-5	Lime as $CaCO_3$ wt% Method USDA23c	Cation Exchange Capacity meq/100g Method SW6010B	Extractable Sodium meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
1-Fall, 2003									
0	2	23	46	31	CL	1.2	27.4		2
0	6	26	45	29	CL	1.2	35.5		1.5
6	12	25	42	33	CL	2.9	34.6		1.6
12	24	23	41	36	CL	9.3	33.9		1.9
24	36	24	43	33	CL	10.8	29.4		3.1
36	60	30	42	28	CL	7.8	26.7		3.3
60	96	31	41	28	CL	5.9	28.2		3.3
2-Spring, 2004									
0	2	27	45	28	CL	1.1	24.8	0.48	1.8
0	6	24	46	30	CL	1.6	24.2	1.15	4.6
6	12	21	42	37	CL	4.7	28.5	0.76	2.4
12	24	16	47	37	SiCL	10.6	24.7	0.92	3.3
24	36	30	40	30	CL	10.8	22.9	1.29	4.4
36	60	29	43	28	CL	7.1	20.8	1.35	4.6
60	96	38	36	26	L	5.8	20.2	1.24	4.3
3-Fall, 2004									
0	2	28	47	25	L	1.5	29.5		1.8
0	6	28	42	30	CL	1.6	33		1.9
6	12	22	45	33	CL	5.8	31.8		2.4
12	24	22	42	36	CL	10.3	31.9		3
24	36	33	41	26	L	10.8	27.3		4.7
36	60	44	33	23	L	8.3	22.6		5.1
60	96	38	37	25	L	6.9	27.7		4.2
4-Fall, 2005									
0	2	29	45	26	L	1.9	24		1.4
0	6	29	45	26	L	2.5	29.5		1.3
6	12	22	45	33	CL	5.8	29.5		1.6
12	24	21	53	26	SiL	10.3	27.9		1.9
24	36	30	41	29	CL	10.2	25.6		2.3
36	60	35	39	26	L	7.4	24.7		2.6
60	96	36	38	26	L	7	23.6		2.5
5-Fall, 2006									
0	2	30	46	24	L	1.2	27.9		1.1
0	6	28	45	27	CL	1.8	27.6		1.4
6	12	23	46	31	CL	5.2	24.7		1.9
12	24	22	45	33	CL	9.8	25.8		2.1
24	36	30	43	27	CL	10.6	24.4		2.7
36	60	48	33	19	L	6.5	19		3.1
60	96	43	36	21	L	5.3	23.4		3.3
6-Fall, 2007									
0	2	28	46	26	L	1.1	24.4		1.7
0	6	29	43	28	CL	0.4	24.7		1.7
6	12	22	44	34	CL	6.4	25.3		2.2
12	24	19	45	36	SiCL	10.9	24		3.7
24	36	32	40	28	CL	11.1	22.4		4.1
36	60	36	40	24	L	7.7	21.3		3.7
60	96	40	38	22	L	6.3	19.8		4.7
7-Fall, 2008									
0	2	20	52	28	SiCL	0.3	26.1		1.7
0	6	28	42	30	CL	1.9	28.1		1.7
6	12	22	46	32	CL	5	27.5		1.9
12	24	20	44	36	SiCL	8.9	27.6		2.3
24	36	24	44	32	CL	10.6	24.5		2.7
36	60	36	38	26	L	7.6	21.2		3.2
60	96	40	34	26	L	5.2	20.5		4.4
8-Fall, 2009									
0	2	26	46	28	CL	1.4	27.3		1.1
0	6	28	42	30	CL	1.6	24.7		1.2
6	12	20	44	36	SiCL	5.2	30.2		1.6
12	24	22	42	36	CL	10.2	23.9		1.8
24	36	30	40	30	CL	10.2	20.8		1.8
36	60	38	36	26	L	7.3	19.1		2
60	96	34	40	26	L	5.9	20.8		2.5
9-Fall, 2010									
0	2	26	44	30	CL	1.43	10.1		1.4
0	6	26	42	32	CL	1.82	15.8		1.2
6	12	20	42	38	SiCL	5.13	16.7		2
12	24	18	42	40	SiC	10.1	17		1.8
24	36	28	40	32	CL	11.2	14.2		2.1
36	60	32	40	28	CL	7.77	13.5		2.4
60	96	40	34	26	L	5.85	13		3.8

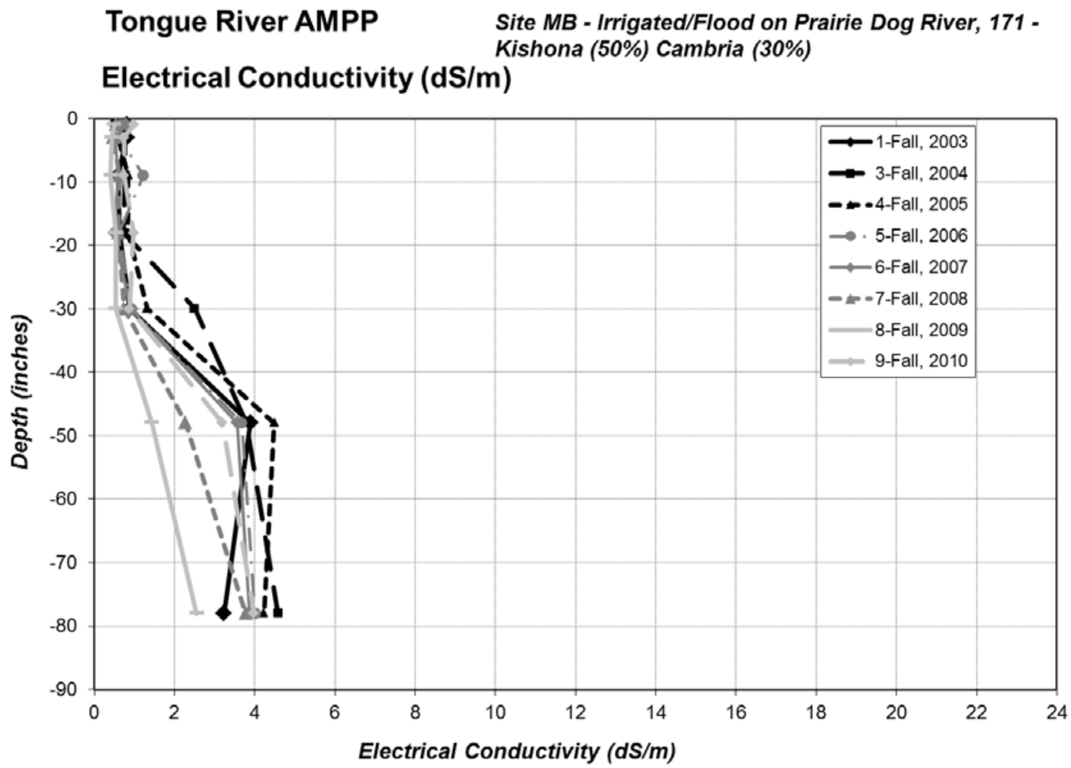

Figure 4-49 Trends in EC with Depth for Site MB.

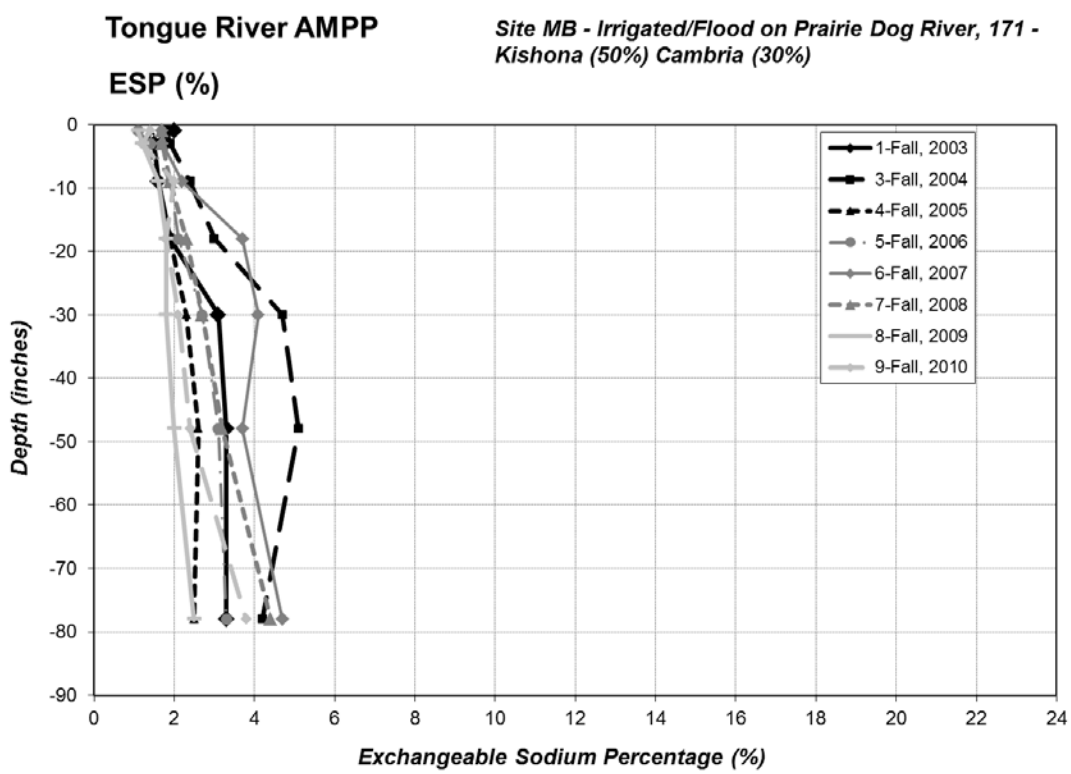

Figure 4-50 Trends in ESP with Depth for Site MB.

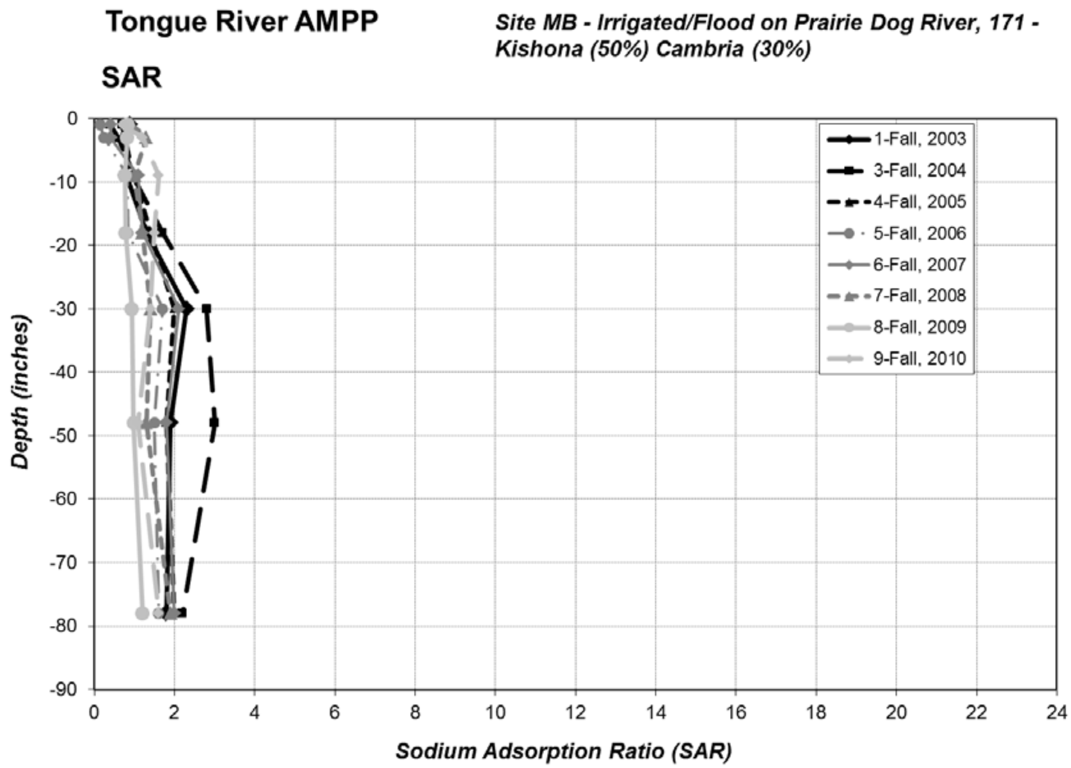

Figure 4-51 Trends in SAR with Depth for Site MB.

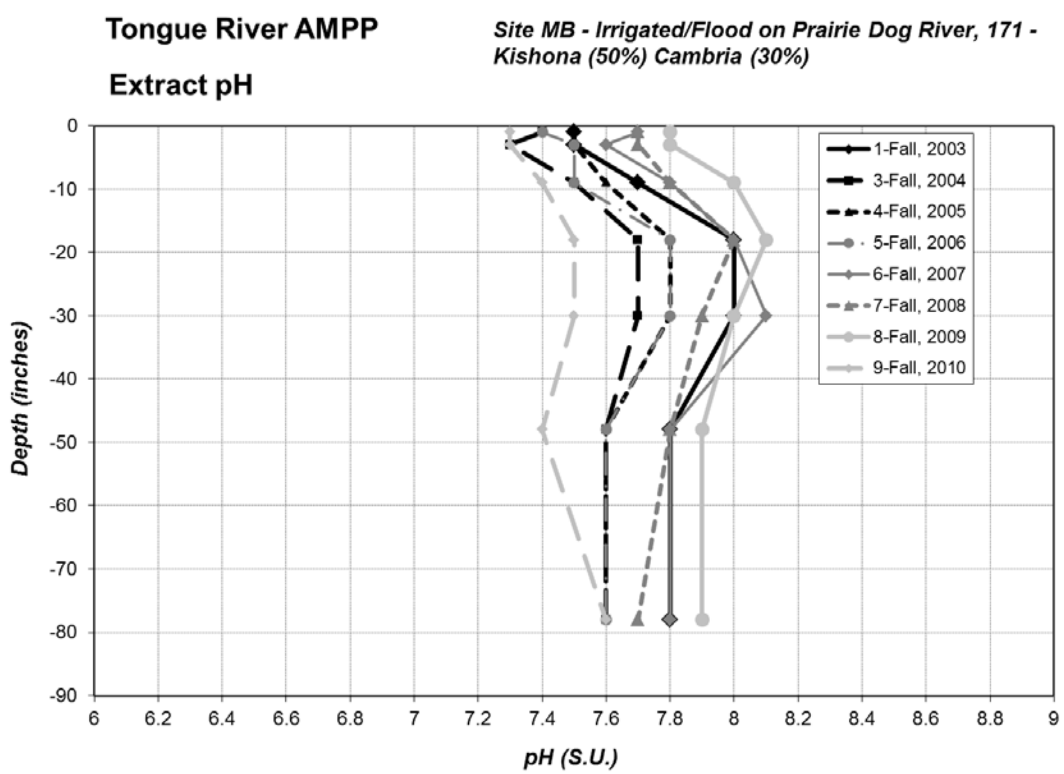

Figure 4-52 Trends in pH with Depth for Site MB.

4.2.2 Site OAA

Site OAA (Table 4-27 and 4-28) was formerly flood irrigated with water from Otter Creek, but has not been non-irrigated from 2003 through 2010. Yields were about 1 to 2 tons of dryland (or subirrigated) grass/alfalfa mix hay during this period.

Despite higher EC and SAR typically found in water from Otter Creek, site OAA had a surprisingly low EC (Figure 4-53), ESP (Figure 4-54), and SAR (Figure 4-55). Trends in pH are shown in (Figure 4-56). The chemistry was similar to Tongue River soils, which may be because the field has been mostly rain fed as opposed to irrigated with more saline Otter Creek water. It is also possible that the field was only irrigated from Otter Creek historically when flows were higher and EC values more comparable to the Tongue River.

Table 4-27 Soil pH, EC, Saturation Extractable Ions and SAR for Site OAA.

Depth (inches)		pH (Paste) s_u_ Method ASAM10-3_2	Electrical Conductivity (Paste) mmhos/cm Method ASAM10-3	Saturation Percentage wt% Method USDA27a	Calcium (Paste) meq/l Method SW6010B	Magnesium (Paste) meq/l Method SW6010B	Sodium (Paste) meq/l Method SW6010B	Sodium Adsorption Ratio unitless Method Calculation	Alkalinity (Paste) meq/L Method ASA10-3	Bicarbonate (Paste) meq/L Method ASA10-3	Carbonate (Paste) meq/L Method ASA10-3	Chloride (Paste) meq/L Method ASA10-3
1-Fall, 2003												
0	2	7.7	0.88	51.3	5.7	2.3	0.6	0.3	8.1			
0	6	7.8	0.64	50.8	3.9	2	0.8	0.4	5.8			
6	12	7.6	0.48	42.7	2	1.4	1.2	0.9	3.8			
12	24	8	0.78	40.5	2.8	2	3	1.9	3.1			
24	36	8.1	0.89	37.3	2.2	1.9	4.3	3	3.2			
36	60	8.1	0.96	44.5	2.8	2.4	4.3	2.6	3			
60	96	8.2	2.57	39.7	5.3	10	15	5.4	2.7			
2-Spring, 2004												
0	2	7.4	0.48	44.6	2.99	1.25	0.54	0.4	7			0.42
0	6	7.4	0.62	42.6	3.66	2.02	0.84	0.5	7.4			0.42
6	12	7.7	0.69	38.6	2.77	2.06	1.26	0.8	4.8			0.71
12	24	7.8	0.63	33.5	2.01	1.58	2.51	1.9	4.6			0.42
24	36	7.9	1.59	33.2	4.53	4.09	5.81	2.8	3.6			0.71
36	60	7.9	2.08	36.4	4.51	6.06	8.92	3.9	4.4			0.56
60	96	8.1	3.87	37	6.16	14.5	23.7	7.4	2.8			1.27
4-Fall, 2005												
0	2	7.1	1.19	55.4	7.61	3.39	1.19	0.51				
0	6	7.3	0.78	47.8	4.73	2.8	0.45	0.23				
6	12	7.6	0.59	40.9	2.96	2.76	0.78	0.46				
12	24	7.8	1.15	37	2.97	2.88	5.01	2.9				
24	36	7.8	1.75	34.6	3.94	3.72	9.08	4.6				
36	60	7.8	1.79	40.4	4.67	4.93	9	4.1				
60	96	8.1	2.64	39	3.93	8.1	16.3	6.6				
5-Fall, 2006												
0	2	7.3	0.95	51.8	5.98	2.28	0.18	0.09				0.1
0	6	7.3	0.79	51.5	4.7	2.52	0.24	0.13				0.05
6	12	7.6	0.54	45	2.61	2.24	0.57	0.37				0.07
12	24	7.7	0.86	40.6	2.28	1.81	4.1	2.9				0.08
24	36	7.7	2.61	36.9	5.52	6.13	13.8	5.7				0.38
36	60	7.7	3.08	40	9.17	11.6	12.9	4				0.45
60	96	7.9	4.01	38.8	9.52	13.4	20.7	6.1				1
6-Fall, 2007												
0	2	7.5	0.78	52.7	4.86	1.83	0.77	0.42				0.56
0	6	7.3	0.95	49.7	5.93	2.95	0.66	0.31				0.53
6	12	7.7	0.57	42	2.94	2.42	0.58	0.35				0.56
12	24	7.9	0.55	43.2	1.7	1.42	2.7	2.2				0.28
24	36	8.1	0.68	34.5	1.11	0.95	4.64	4.6				0.56
36	60	8	2.65	42.2	7.35	7.87	14.6	5.3				1.06
60	96	8.1	3.17	39.2	6.17	9.42	17.4	6.2				0.88
7-Fall, 2008												
0	2	7.2	0.55	50.1	6.89	2.65	1.2	0.68				0.52
0	6	7.4	0.76	44.7	4.42	2.04	0.52	0.29				0.44
6	12	7.6	0.5	36	2.38	1.73	0.54	0.38				0.36
12	24	7.8	0.58	35.4	1.39	1.17	2.14	1.9				0.27
24	36	7.8	0.66	31.2	1.5	1.23	3.02	2.6				0.25
36	60	7.7	2.62	37.4	8.43	8.49	12.6	4.3				0.48
60	96	7.9	3.16	36.7	6.96	13.5	17.8	5.6				0.53
8-Fall, 2009												
0	2	7.5	0.55	53.4	3.47	1.38	0.53	0.34				0.29
0	6	7.5	0.51	47.7	3.25	1.44	0.38	0.25				0.34
6	12	7.9	0.36	42.3	1.87	1.32	0.67	0.53				0.3
12	24	7.8	0.43	39.1	1.72	1.39	1.64	1.3				0.23
24	36	8.1	0.59	33.9	1.37	1.21	3.87	3.4				0.28
36	60	8.1	1.09	38.5	2.58	3.04	6.29	3.8				0.38
60	96	8.2	1.76	41.6	3.65	6.39	10.9	4.9				0.43
9-Fall, 2010												
0	2	7	0.9	53.5	6.09	2.55	0.45	0.22				
0	6	7.2	0.68	47.3	4.54	1.99	0.39	0.22				
6	12	7.4	0.56	42.8	2.67	2.03	0.78	0.51				
12	24	7.6	0.63	37.6	2.1	1.73	2.55	1.8				
24	36	7.7	0.62	34.6	1.22	0.96	3.8	3.6				
36	60	7.6	1.63	41.2	4.18	3.77	8.45	4.2				
60	96	7.7	2.52	36.9	4.78	7.98	12.4	4.9				

Table 4-28 Soil Texture, Lime, CEC and ESP for Site OAA.

Depth (inches)		Sand % Method ASA15-5	Silt % Method ASA15-5	Clay % Method ASA15-5	Texture unitless Method ASA15-5	Lime as CaCO3 wt% Method USDA23c	Cation Exchange Capacity meq/100g Method SW6010B	Extractable Sodium meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
1-Fall, 2003									
0	2	28	47	25	L	8.1	29.6		1.7
0	6	30	49	21	L	9.5	27.9		1.9
6	12	27	51	22	SiL	8.5	25.6		1.5
12	24	27	51	22	SiL	8.9	21.2		2.4
24	36	41	42	17	L	9	18.2		3.8
36	60	21	51	28	CL	9.2	25.3		3.8
60	96	36	42	22	L	6.7	21.7		4.5
2-Spring, 2004									
0	2	39	44	17	L	6.9	19	0.44	2.2
0	6	31	48	21	L	7.5	21.6	0.44	1.9
6	12	30	49	21	L	8.1	19.9	0.43	1.9
12	24	38	45	17	L	8.3	16.5	0.68	3.6
24	36	41	44	15	L	8.4	14.1	1.03	6
36	60	35	46	19	L	8.4	16.3	1.37	6.4
60	96	34	47	19	L	8.3	15.3	2	7.4
4-Fall, 2005									
0	2	32	49	19	L	7.6	30		1.5
0	6	32	50	18	SiL	7.4	27.6		0.9
6	12	30	50	20	SiL	8.9	23.1		1.6
12	24	37	45	18	L	9.3	20.1		3.1
24	36	43	44	13	L	9	15.6		4.9
36	60	35	46	19	L	9.7	20.1		3.8
60	96	37	45	18	L	10.3	17.1		5.2
5-Fall, 2006									
0	2	37	48	15	L	6.7	27.3		1.1
0	6	27	56	17	SiL	7.5	35.7		1
6	12	23	56	21	SiL	8.2	26.5		1.7
12	24	31	50	19	SiL	8.5	21.1		3.6
24	36	39	40	21	L	8.2	16.5		5.3
36	60	31	52	17	SiL	8.5	17.9		5.8
60	96	33	52	15	SiL	9.3	17.2		7.3
6-Fall, 2007									
0	2	34	48	18	L	6.4	24.6		1.5
0	6	32	47	21	L	6.4	24.8		1.5
6	12	27	51	22	SiL	7.3	23.6		1.6
12	24	34	45	21	L	7.4	22.3		3
24	36	40	44	16	L	7.8	16.3		5.9
36	60	28	49	23	L	7.6	22.4		5.6
60	96	32	46	22	L	7.9	19.8		6.9
7-Fall, 2008									
0	2	38	42	20	L	7	23.7		1.1
0	6	30	48	22	L	7.2	23.2		1.5
6	12	32	46	22	L	7.9	18.4		1.8
12	24	28	48	24	L	8.5	18		4.1
24	36	40	42	18	L	8.5	13.3		5.7
36	60	27	59	14	SiL	8.8	17.6		5.1
60	96	36	44	20	L	8.8	15.9		7.9
8-Fall, 2009									
0	2	36	44	20	L	6.4	23.5		0.4
0	6	34	46	20	L	7	22		0.6
6	12	30	48	22	L	7.8	19.5		0.8
12	24	42	38	20	L	8.3	16		1.3
24	36	44	41	15	L	8	13.5		4
36	60	34	44	22	L	8.3	16		5.6
60	96	34	46	20	L	9.1	16		7.3
9-Fall, 2010									
0	2	34	44	22	L	6.82	15.4		0.3
0	6	32	46	22	L	7.26	14.7		0.7
6	12	28	50	22	SiL	8.17	14.9		0.8
12	24	30	50	20	SiL	8.63	10.8		2.6
24	36	34	48	18	L	8.43	8.82		5.5
36	60	28	50	22	SiL	8.57	11.3		3.5
60	96	38	44	18	L	9	9.97		6.3

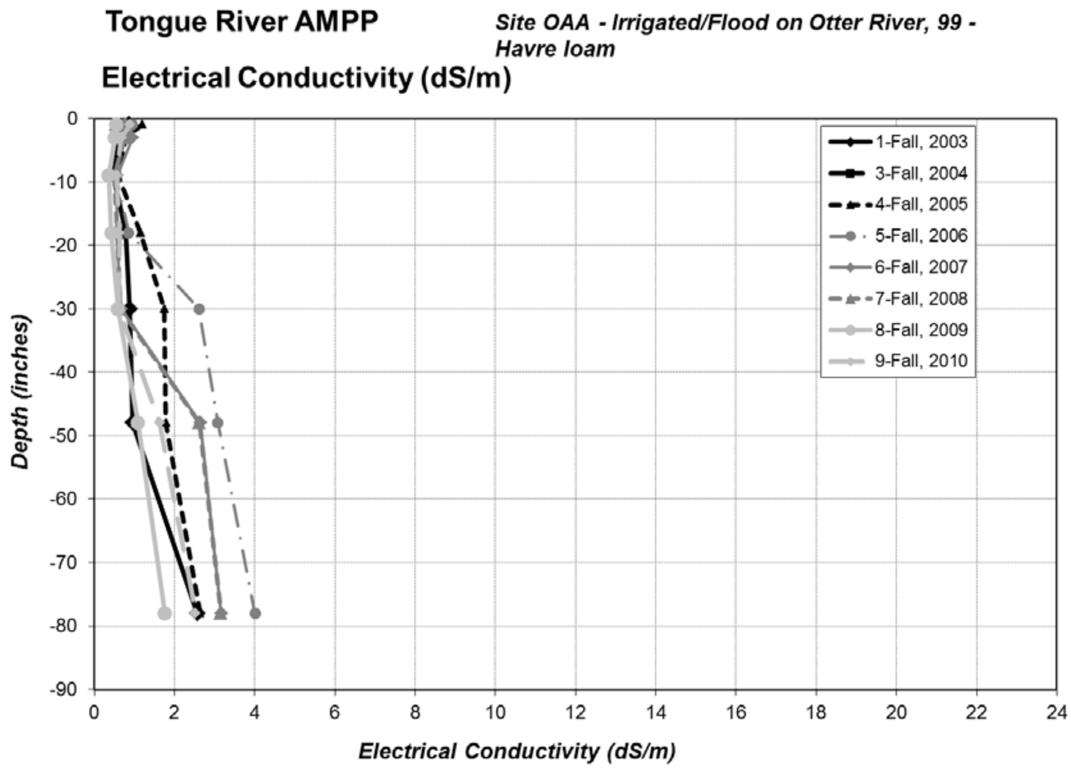

Figure 4-53 Trends in EC with Depth for Site OAA.

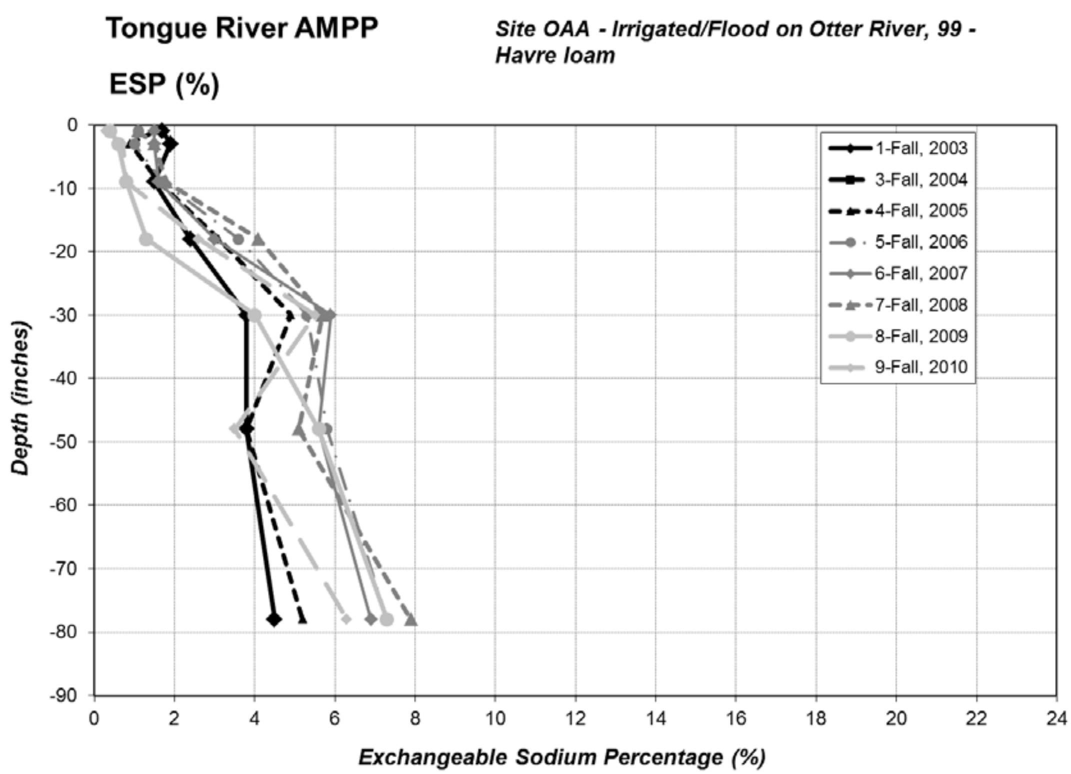

Figure 4-54 Trends in ESP with Depth for Site OAA.

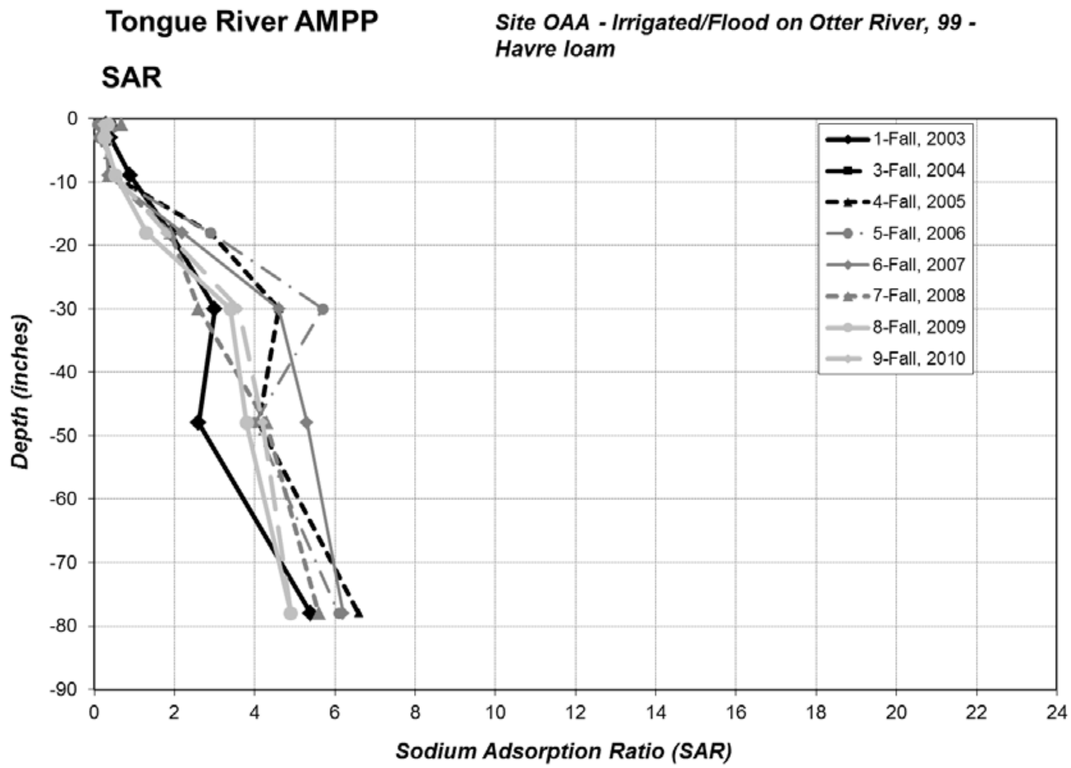

Figure 4-55 Trends in SAR with Depth for Site OAA.

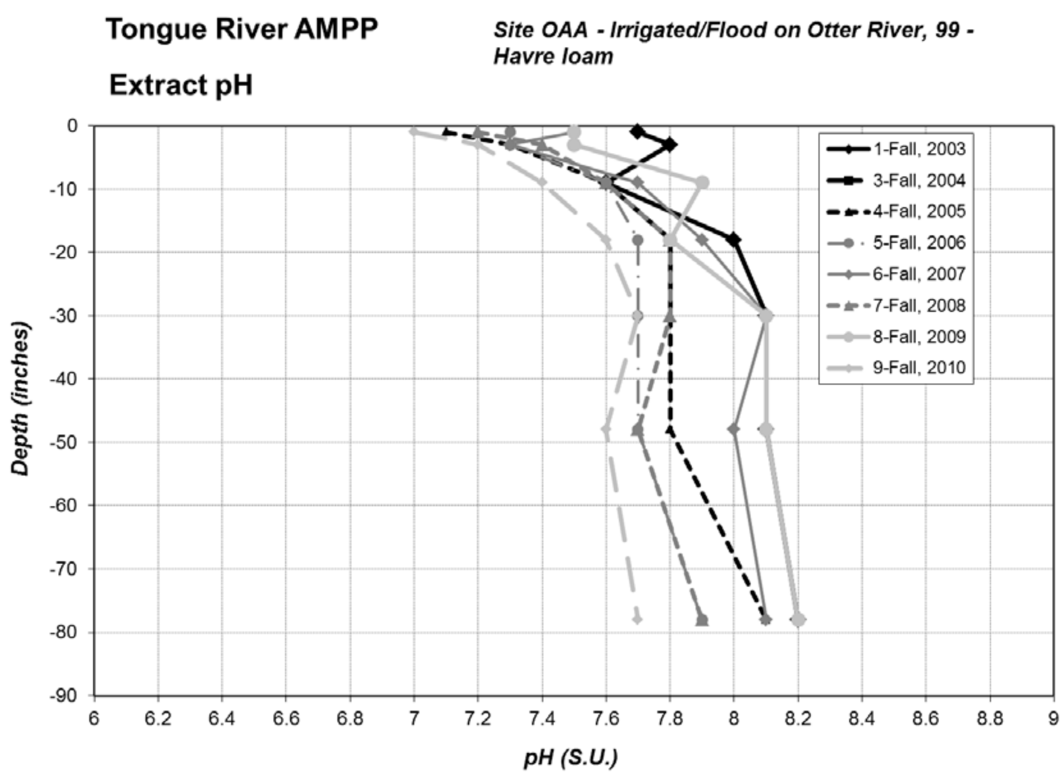

Figure 4-56 Trends in pH with Depth for Site OAA.

4.3 Reference AMPP Sites in Other River Basins

4.3.1 Site YBA

Site YBA (Table 4-29 and 4-30) is located on the Fort Keogh Experiment Station on a bench above the Yellowstone River. The field was in barley for grain in 2003, barley for hay in 2004, hay barley under seeded to alfalfa in 2005, and established alfalfa in 2006 through 2010. Yields were 80 bushels, 2.7 tons, 4.0 tons, 6.4, 4.9, 5.4, 5.0 and 4.8 tons per acre in 2003 through 2010, respectively. It is flood irrigated, receiving 0, 8, 7, 24, 12, 18, 18, and 12 inches of applied irrigation in 2003 through 2010. Yields have been declining since 2006 due to an aging and thinning stand.

Highest forage sodium contents thus far in AMPP have been in the hayed barley in 2004 and first cutting 2005 at 0.47% and 0.59%, respectively. Since the second cutting in 2005, alfalfa has had an average sodium content of 0.16%, ranging from 0.10% to 0.22%. Alfalfa annual average sodium content for 2005 to 2009 has been 0.17%, 0.14%, 0.16%, 0.19%, and 0.17%, respectively.

Soil EC above 36 inches (Figure 4-57) was erratic but the lowest values were recorded in 2008 and again in 2010. Similarly, ESP varied through time but tended to remain low (1% to 3%) in the upper 12 inches and increased with increasing depth (Figure 4-58). SAR (Figure 4-59) showed an increasing trend with depth between 2003 and 2005, but pH did not change (Figure 4-60).

Table 4-29 Soil pH, EC, Saturation Extractable Ions and SAR for Site YBA.

Depth (inches)		pH (Paste) s_u_ Method ASAM10-3_2	Electrical Conductivity (Paste) mmhos/cm Method ASAM10-3	Saturation Percentage wt% Method USDA27a	Calcium (Paste) meq/l Method SW6010B	Magnesium (Paste) meq/l Method SW6010B	Sodium (Paste) meq/l Method SW6010B	Sodium Adsorption Ratio unitless Method Calculation	Alkalinity (Paste) meq/L Method ASA10-3	Bicarbonate (Paste) meq/L Method ASA10-3	Carbonate (Paste) meq/L Method ASA10-3	Chloride (Paste) meq/L Method ASA10-3
1-Fall, 2003												
0	2	7.4	1.71	58.1	9.6	3.3	3.7	1.5	9.6			
0	6	7.6	1.19	58.4	4.8	2.1	3	1.6	5.2			
6	12	7.7	1.3	58.4	5.4	2.9	3.4	1.7	4.4			
12	24	7.8	1.83	55.5	5.9	3.5	8	3.7	4.4			
24	36	7.8	1.78	65.5	4.7	3.1	9	4.5	4			
36	60	7.9	2.42	54.5	5.2	3.5	15.5	7.4	4			
60	96	8.2	2	69.2	1.7	1.2	15.2	13	4.4			
2-Spring, 2004												
0	2	7.7	1.42	50.3	8.19	3.33	3.96	1.6	4.6			0.99
0	6	7.6	2.48	49.9	14.7	5.6	7.31	2.3	3.8			2.54
6	12	7.6	2.83	53	15.6	6.46	9.73	2.9	5.4			5.08
12	24	7.8	3.48	47.4	11.7	7.42	14.7	4.8	3.2			3.81
24	36	7.8	5.12	43.5	18	11.8	22.4	5.8	2.4			3.24
36	60	7.8	2.49	46.1	5.2	3.28	13.7	6.7	3.4			1.27
60	96	8	2.2	46.1	2.78	1.63	15.2	10	5			1.55
3-Fall, 2004												
0	2	7.5	1.89	48.5	10	3.9	4.93	1.9	4.2			
0	6	7.6	1.37	49.3	6.43	2.49	3.74	1.8	3.7			
6	12	7.6	1.07	49.2	5.47	2.19	3.14	1.6	4			
12	24	7.8	1.98	46.2	7.37	4.88	7.22	2.9	2.4			
24	36	7.9	1.98	44.7	5.45	3.8	12.1	5.6	2.6			
36	60	7.9	2.27	51.9	3.07	2.02	16.9	11	3.3			
60	90	8.2	1.98	58.2	2.19	1.32	22.6	17	3.6			
4-Fall, 2005												
0	2	7.4	0.89	46.5	6.14	2.3	1.98	0.96				
0	6	7.5	0.79	46.8	4.76	1.92	2.96	1.6				
6	12	7.6	1.3	47	6.54	2.86	5.39	2.5				
12	24	7.6	2.4	44.8	9.68	6.75	12.1	4.2				
24	36	7.7	3.33	44	10.9	8.2	21.6	7				
36	60	8	2.36	52.6	3.21	2.18	21.3	13				
60	96	8.1	2.1	57.1	1.44	0.87	19.6	18				
5-Fall, 2006												
0	2	7.5	0.74	53.4	4.28	1.48	1.15	0.68				0.61
0	6	7.5	0.75	47.2	4.08	1.55	1.35	0.8				0.17
6	12	7.5	0.75	46.4	3.67	1.66	2.45	1.5				0.21
12	24	7.7	1.72	44.7	5.35	3.67	7.24	3.4				0.56
24	36	7.7	3.79	45.8	11	8.24	19.6	6.3				0.49
36	60	7.8	2.57	50.1	4.38	2.97	18.2	9.5				0.57
60	96	8.3	1.68	59.4	1.5	1.04	19.2	17				0.14
6-Fall, 2007												
0	2	7.6	0.82	46.2	4.39	1.85	2.31	1.3				1.06
0	6	7.7	0.65	46.5	3.73	1.57	1.79	1.1				0.7
6	12	7.8	0.81	45.7	4.16	1.97	2.45	1.4				0.42
12	24	7.9	3.2	48.3	16.1	11.9	13.4	3.6				1.41
24	36	8	2.89	46.3	8.19	6.86	15.7	5.7				1.41
36	60	8	2.7	48.3	6.39	4.17	17.4	7.6				1.41
60	96	8.6	1.95	61	0.99	0.74	16.6	18				1.06
7-Fall, 2008												
0	2	7.4	0.54	48.2	3.38	1.28	1.02	0.67				0.19
0	6	7.5	0.63	48.6	3.82	1.53	1.54	0.94				0.39
6	12	7.6	0.62	46.5	2.67	1.29	2.37	1.7				0.43
12	24	7.8	1	43.3	3.04	2.11	5.75	3.6				0.93
24	36	7.8	1.27	43.7	3.57	2.87	7.69	4.3				1.3
36	60	7.9	2.19	45.7	3.68	2.71	15.1	8.5				1.2
60	96	8.1	1.84	45.6	2.28	1.18	14.9	11				1.1
8-Fall, 2009												
0	2	7.6	0.56	49.4	3.6	1.32	1.42	0.91				0.22
0	6	7.6	0.56	50	3.42	1.38	1.74	1.1				0.34
6	12	7.8	0.58	49	2.96	1.39	2.2	1.5				0.39
12	24	7.9	2.06	44.8	7.83	6.22	9.64	3.6				1.6
24	36	7.9	3.15	45.8	10.1	8.14	17.8	5.9				2.9
36	60	8	1.86	51.2	2.97	2.2	13.5	8.4				0.83
60	96	8.3	1.91	54.8	1.64	1.33	15.4	13				0.53
9-Fall, 2010												
0	2	7.6	0.89	51.4	7.17	2.21	2.09	0.97				0.4
0	6	7.6	0.71	48.8	3.96	1.56	1.91	1.2				0.3
6	12	7.6	0.64	46.5	3.23	1.45	2.12	1.4				0.2
12	24	7.8	0.64	43.7	2.47	1.72	2.99	2.1				0.2
24	36	7.9	1.36	41.8	3.61	2.88	7.54	4.2				0.2
36	60	7.9	3.14	48.5	7.22	5.85	23.5	9.2				0.7
60	96	8	4.42	50.7	5.56	5.09	38.3	17				1.1

Table 4-30 Soil texture, Lime, CEC and ESP for Site YBA.

Depth (inches)		Sand % Method ASA15-5	Silt % Method ASA15-5	Clay % Method ASA15-5	Texture unitless Method ASA15-5	Lime as CaCO3 wt% Method USDA23c	Cation Exchange Capacity meq/100g Method SW6010B	Extractable Sodium meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
1-Fall, 2003									
0	2	13	64	23	SiL	6.9	30.7		2.3
0	6	16	59	25	SiL	6.7	32.9		2.3
6	12	16	60	24	SiL	7	30.6		2.3
12	24	10	56	34	SiCL	6.7	35		7.3
24	36	23	55	22	SiL	7.3	28.5		3.9
36	60	18	56	26	SiL	6.7	30.7		5.9
60	96	14	58	28	SiCL	6.6	32.4		8.6
2-Spring, 2004									
0	2	17	58	25	SiL	6	23.3	0.66	2
0	6	15	59	26	SiL	5.8	22.2	1.15	3.5
6	12	10	63	27	SiCL	6.2	23.8	1.46	4
12	24	14	63	23	SiL	6.8	22.3	2.5	8.3
24	36	21	58	21	SiL	6	21.5	2.9	9
36	60	15	58	27	SiCL	6.1	19.1	2.6	11
60	96	23	51	26	SiL	5.6	23.8	2.9	9.5
3-Fall, 2004									
0	2	20	57	23	SiL	6.6	21.1		2.9
0	6	16	59	25	SiL	6.2	22.8		2.9
6	12	19	58	23	SiL	6.6	22.8		2.7
12	24	18	61	21	SiL	7.2	19.6		4.4
24	36	24	56	20	SiL	6.3	19		6.3
36	60	18	56	26	SiL	6.1	21		13
60	90	20	50	30	SiCL	6.1	24.5		17
4-Fall, 2005									
0	2	19	59	22	SiL	6.7	35.6		1.2
0	6	20	57	23	SiL	6.7	35.3		1.7
6	12	18	58	24	SiL	7.3	30.4		2.3
12	24	21	59	20	SiL	7.7	30.4		3.4
24	36	21	60	19	SiL	7	30.8		4.1
36	60	21	54	25	SiL	6.3	24.8		8.5
60	96	21	48	31	CL	5.5	26.9		16
5-Fall, 2006									
0	2	19	60	21	SiL	6.2	31.1		1.4
0	6	18	62	20	SiL	6.4	30.5		1.6
6	12	16	63	21	SiL	6.9	31.1		2
12	24	18	65	17	SiL	7.5	25.5		4.2
24	36	21	63	16	SiL	6.6	23.4		5.7
36	60	23	56	21	SiL	5.6	28.1		7.7
60	96	19	54	27	SiCL	6	32.8		14
6-Fall, 2007									
0	2	22	58	20	SiL	5.6	27.7		2
0	6	19	61	20	SiL	6	27.2		2.1
6	12	17	63	20	SiL	6	26.9		2.2
12	24	14	65	21	SiL	6.6	27.7		4.3
24	36	24	58	18	SiL	6.1	23.9		6.3
36	60	17	55	28	SiCL	5.3	30.7		7
60	96	24	54	22	SiL	5.6	27.6		22
7-Fall, 2008									
0	2	14	58	28	SiCL	6.2	28.9		1.3
0	6	14	56	30	SiCL	6.6	28.2		1.7
6	12	76	ND	27	SCL	6.7	26.2		2.8
12	24	16	60	24	SiL	7.6	21.2		4.6
24	36	14	62	24	SiL	7	22		5.8
36	60	18	54	28	SiCL	6.3	24.5		11
60	96	24	50	26	SiL	6.7	23		17
8-Fall, 2009									
0	2	18	58	24	SiL	6	28.6		0.6
0	6	14	60	26	SiL	6.4	26.8		0.8
6	12	12	62	26	SiL	6.4	27.2		1.8
12	24	16	60	24	SiL	7.5	22		4.5
24	36	16	62	22	SiL	6.5	23.8		6.1
36	60	14	60	26	SiL	6	27.5		8.8
60	96	20	54	26	SiL	6	27		16
9-Fall, 2010									
0	2	14	58	28	SiCL	5.89	21.8		1.3
0	6	16	58	26	SiL	6.19	23.6		1.4
6	12	18	56	26	SiL	6.24	21.3		1.5
12	24	16	60	24	SiL	7.18	17.7		2.8
24	36	24	56	20	SiL	6.47	16.1		5.3
36	60	16	56	28	SiCL	6.11	20.7		9.4
60	96	24	48	28	CL	5.85	20.3		15

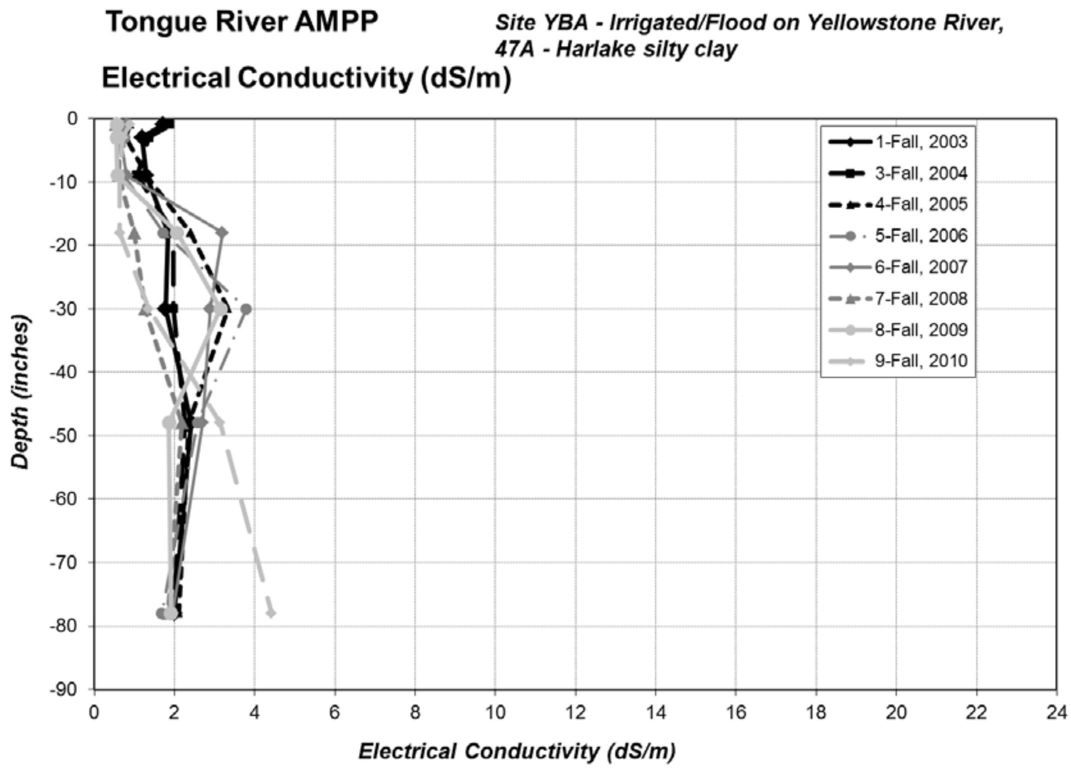

Figure 4-57 Trends in EC with Depth for Site YBA.

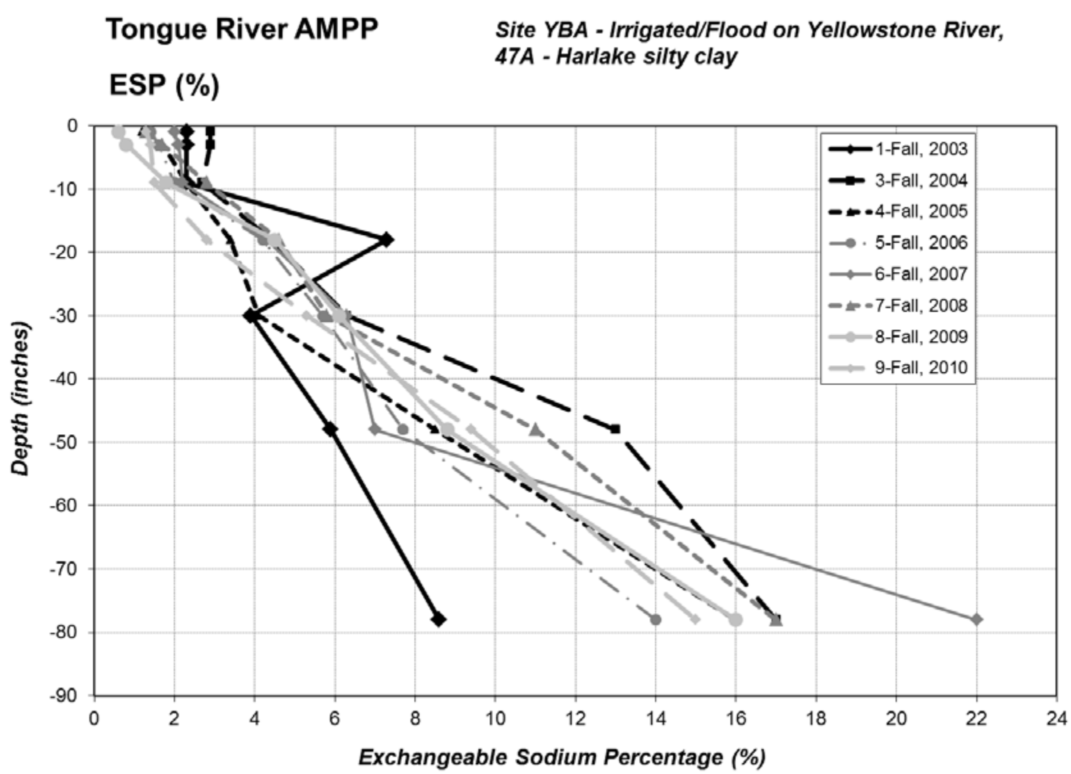

Figure 4-58 Trends in ESP with Depth for Site YBA.

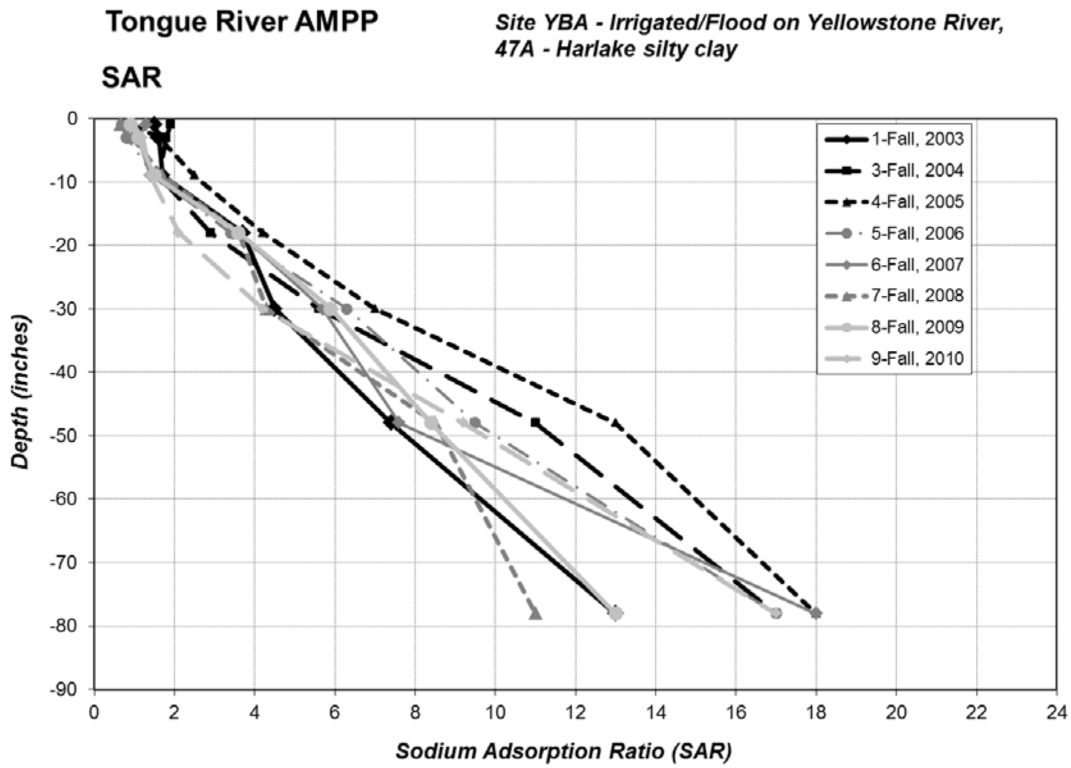

Figure 4-59 Trends in SAR with Depth for Site YBA.

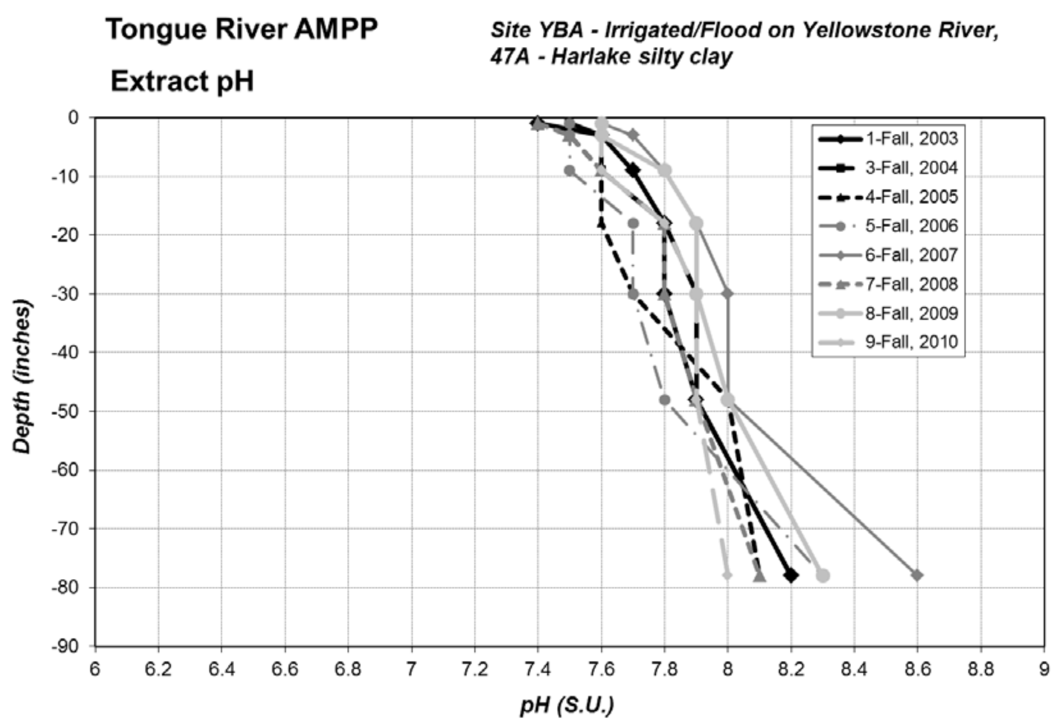

Figure 4-60 Trends in pH with Depth for Site YBA.

4.3.2 Site BHA

Site BHA (Table 4-31 and 4-32) is a reference field flood-irrigated with Big Horn River water. It was planted to beets (39 tons per acre), winter wheat (120 and 77 bushels per acre), sugar beets (45 tons per acre), and 2 years of malt barley (120 and 115 bushels per acre) in 2003 through 2008, respectively. In 2006, cooperator yield was 36.7 tons per acre due to having to top the beets twice. The field was back in beets in 2009 (40.1 tons per acre). The field yielded 107.6 bushels of winter wheat in 2010.

BHA was harvested late November 2006 due to heavy precipitation beginning early October. By late November, beets had frozen and needed topping twice to remove the frozen portion of the beet. Quantity of irrigation water was 24 inches in 2003 to 12 inches in 2004, zero in 2005, 24 inches in 2006, 6 inches in 2007 and 2008, and 25 inches in 2009, and 6 inches in 2010. Amounts varied due to changes in crop requirements and precipitation received.

EC, ESP, and SAR at site BHA were elevated in the 0 to 2 inch depth in 2003 (Figure 4-61 to 4-63), but subsequently decreased. The 0-2 inch ESP, and SAR were elevated again fall 2006, EC was somewhat elevated in that depth fall 2007. This pattern is probably because soil must be moist for digging beets. Once the beets were defoliated, soil moisture (and salts) rapidly moved to the surface and evaporated, leaving the salts behind. In 2004, 2005, 2007, 2008 and 2010, the small grain canopy was more open than with the beet tops, therefore the soil surface dried slowly, reducing the wicking of salts upward. After 2006, it appears that beet leaves also accumulated sodium that is present at the soil surface after mechanical defoliation. EC, ESP and SAR were significantly higher in 2003, 2006 and 2009 when compared to soil samples collected after small grain crops. This occurred even after all the precipitation in 2006, but decreased in 2007 and 2008. Except for the 0 to 2 inch depth, EC, ESP, SAR, and pH (Figure 4-64) values are relatively unchanged with depth or through time except for an overall increase in EC in 2007, indicating that the soil is well-drained and is adequately leached to maintain a salt balance. An apparent increase in ESP in 2007 is attributed to low measured values for CEC.

Table 4-31 Soil pH, EC, Saturation Extractable Ions and SAR for Site BHA.

Depth (inches)		pH (Paste) s_u_ Method ASAM10-3_2	Electrical Conductivity (Paste) mmhos/cm Method ASAM10-3	Saturation Percentage wt% Method USDA27a	Calcium (Paste) meq/l Method SW6010B	Magnesium (Paste) meq/l Method SW6010B	Sodium (Paste) meq/l Method SW6010B	Sodium Adsorption Ratio unitless Method Calculation	Alkalinity (Paste) meq/L Method ASA10-3	Bicarbonate (Paste) meq/L Method ASA10-3	Carbonate (Paste) meq/L Method ASA10-3	Chloride (Paste) meq/L Method ASA10-3
1-Fall, 2003												
0	2	7.3	3.14	43.9	8.2	4.7	13.6	5.4	14.7			
0	6	7.5	2.07	56	7.2	3.5	7.3	3.2	7.2			
6	12	7.6	1.57	54	4.8	4	5.6	2.7	5			
12	24	7.7	1.14	56.1	3	1.8	4.2	2.7	3.3			
24	36	7.5	3.6	50.8	23.1	11.6	8.3	2	3.2			
36	60	7.5	3.8	50.8	25.5	11.7	9.2	2.1	2.8			
60	96	7.5	3.5	44.7	22.3	12.3	8	1.9	2.2			
2-Spring, 2004												
0	2	7.5	3.36	53.3	13.5	5.77	11.8	3.8	4.8			0.99
0	6	7.6	1.95	55.7	8.24	3.38	5.95	2.5	8			1.69
6	12	7.7	1.42	58.2	7.03	2.86	4.55	2	4			3.81
12	24	7.7	2.14	60.7	11.8	6.45	4.97	1.6	4			0.85
24	36	7.7	3.32	58.2	26.3	12.7	8.01	1.8	2			0.42
36	60	7.6	3.51	51.7	27.3	12.1	9.11	2	4			0.42
60	96	7.6	3.17	51	22.6	12.6	7.5	1.8	2			0.42
3-Fall, 2004												
0	2	7.7	1.04	55.9	3.93	1.86	5.18	3	4			2.44
0	6	7.7	0.89	58.9	3.01	1.33	5.15	3.5	4			1.72
6	12	7.7	0.8	65.5	3.31	1.51	4.38	2.8	4			0.77
12	24	7.8	1.11	64.4	4.44	2.42	4.9	2.6	2			1.33
24	36	7.7	3.14	58	22.6	10.6	7.65	1.9	1			0.93
36	60	7.6	3.34	55.1	26.3	11.5	8.33	1.9	1			0.51
60	96	7.7	3.44	52.6	26.3	13.3	7.81	1.8	2			0.47
4-Fall, 2005												
0	2	8.1	0.47	55.8	1.51	0.61	3.07	3				
0	6	7.9	0.8	57.4	3.84	1.52	4.56	2.8				
6	12	8	0.69	58	2.67	1.1	4.36	3.2				
12	24	8.1	0.91	63.6	4.07	2.13	4.93	2.8				
24	36	7.8	3.35	56.5	29.2	12.7	9.8	2.1				
36	60	7.8	3.12	49.8	26.7	9.74	8.33	2				
60	96	7.7	2.83	52.9	21.9	10.1	5.97	1.5				
5-Fall, 2006												
0	2	7.7	1.38	62.1	3.23	1.54	8.19	5.3				4.95
0	6	7.5	0.92	57.6	4.11	1.77	3.72	2.2				0.75
6	12	7.6	0.83	55.9	3.67	1.62	3.47	2.1				0.24
12	24	7.8	0.82	64.1	3.04	1.55	3.52	2.3				0.15
24	36	7.6	3.81	59.4	26.8	11.9	8.17	1.9				0.75
36	60	7.6	4.39	47.6	33	14.8	12.8	2.6				0.82
60	96	7.5	4.05	47.6	26.6	15.2	9.26	2				0.87
6-Fall, 2007												
0	2	7.8	0.92	50.8	3.64	1.67	3.32	2				3.52
0	6	7.8	0.74	56.7	2.31	1	3.47	2.7				1.64
6	12	7.8	0.66	58.3	2.51	1.05	3.07	2.3				0.7
12	24	8	0.6	57.1	1.78	0.93	2.65	2.3				0.7
24	36	7.9	2.31	54.6	15.1	8.61	5.59	1.6				0.5
36	60	7.8	2.94	47.6	16.9	8.41	7.2	2				0.7
60	96	7.8	2.71	47.3	17	10.9	6.66	1.8				0.42
7-Fall, 2008												
0	2	7.5	0.69	49.9	2.91	1.22	3.19	2.2				1.93
0	6	7.4	0.71	54.9	1.79	1.17	2.69	2.2				0.7
6	12	7.6	0.52	52.7	1.73	0.82	2.6	2.3				0.33
12	24	7.7	0.63	53	2.48	1.18	3.23	2.4				0.33
24	36	7.6	2.38	55	19.1	8.21	6.03	1.6				0.34
36	60	7.6	2.22	50.6	19.6	6.81	5.66	1.6				0.51
60	96	7.6	2.48	46.3	20.4	9.42	6.09	1.6				0.57
8-Fall, 2009												
0	2	7.4	1.92	59.4	7.49	3.32	10.2	4.4				6.6
0	6	7.3	1.93	59.1	9.12	4	8.78	3.4				3.7
6	12	7.4	0.79	58.3	3.64	1.59	3.67	2.3				0.48
12	24	7.6	0.89	61.4	3.43	1.85	3.83	2.4				0.22
24	36	7.4	3.27	51.9	27.8	13.2	8.4	1.8				0.23
36	60	7.4	3.38	51.2	26.9	10.4	8.16	1.9				0.46
60	96	7.4	3.94	51.2	31.9	17.4	10.6	2.1				0.44
9-Fall, 2010												
0	2	7.5	0.83	50.2	2.96	1.16	3.59	2.5				2
0	6	7.6	0.68	55.5	2.19	0.88	3.74	3				1
6	12	7.7	0.61	57.4	2.3	0.81	3.14	2.5				0.32
12	24	7.8	0.63	58.2	2.5	1.14	3.17	2.4				0.35
24	36	7.6	3.07	49.9	25.1	10.5	6.69	1.6				0.34
36	60	7.6	2.97	48.4	23.2	10.3	7.65	1.9				0.34
60	96	7.6	2.74	49.8	24.6	10.6	6	1.4				0.43

Table 4-32 Soil texture, Lime, CEC and ESP for Site BHA.

Depth (inches)		Sand % Method ASA15-5	Silt % Method ASA15-5	Clay % Method ASA15-5	Texture unitless Method ASA15-5	Lime as CaCO3 wt% Method USDA23c	Cation Exchange Capacity meq/100g Method SW6010B	Extractable Sodium meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
1-Fall, 2003									
0	2	9	45	46	SiC	4.1	40.4		6.1
0	6	10	44	46	SiC	3.1	31.9		4.2
6	12	4	50	46	SiC	3.1	36.9		2.7
12	24	3	45	52	SiC	7.6	37		2.7
24	36	7	47	46	SiC	5.6	40.4		2.7
36	60	22	48	30	CL	4.8	29.3		3.4
60	96	31	38	31	CL	3.8	29.8		3.8
2-Spring, 2004									
0	2	10	45	45	SiC	2.3	29.8	1.47	2.8
0	6	11	44	45	SiC	2.3	29.5	1.13	2.7
6	12	8	44	48	SiC	2.8	31.6	1.04	2.5
12	24	9	40	51	C	4.9	28.7	1.1	2.8
24	36	9	45	46	SiC	4.4	25.8	1.27	3.1
36	60	15	48	37	SiCL	2.9	22.8	1.21	3.2
60	96	25	38	37	CL	6.5	22.2	1.18	3.6
3-Fall, 2004									
0	2	14	41	45	SiC	2.7	36.3		2.1
0	6	15	40	45	C	2.6	43.4		2
6	12	13	42	45	SiC	3	38.8		2.2
12	24	9	40	51	C	4.9	36.1		2.4
24	36	12	43	45	SiC	4.5	31.6		2.6
36	60	15	46	39	SiCL	3.3	28.3		2.4
60	96	23	37	40	C	5.8	33.4		2.5
4-Fall, 2005									
0	2	8	44	48	SiC	3.4	36.8		3.3
0	6	8	44	48	SiC	3.2	34		2.9
6	12	10	40	50	C	4.1	36.6		2.7
12	24	7	43	50	SiC	6	34.1		3.2
24	36	9	44	47	SiC	5.2	29.4		3.1
36	60	13	46	41	SiC	4.1	26.5		3.1
60	96	22	35	43	C	5.8	29.2		3.3
5-Fall, 2006									
0	2	14	43	43	SiC	2.8	37.4		8.2
0	6	14	41	45	SiC	2.6	38.9		2.6
6	12	12	43	45	SiC	3.6	37.5		3
12	24	9	44	47	SiC	5.2	32.3		3.8
24	36	7	45	48	SiC	4.2	28.7		3
36	60	18	51	31	SiCL	3.7	24.6		2.6
60	96	23	42	35	CL	5.2	28.2		5.6
6-Fall, 2007									
0	2	11	45	44	SiC	2.7	30.9		3.4
0	6	12	43	45	SiC	2.6	32		3.7
6	12	9	45	46	SiC	2.7	27.6		3.8
12	24	7	45	48	SiC	4.9	23.2		5.8
24	36	6	46	48	SiC	4.5	23.4		5.3
36	60	12	51	37	SiCL	3.1	18.6		6.7
60	96	22	41	37	CL	3.6	20.4		6.2
7-Fall, 2008									
0	2	24	34	42	C	2.5	32		3.1
0	6	14	42	44	SiC	2.5	33.3		3.2
6	12	12	43	45	SiC	4	30.2		3.8
12	24	11	45	44	SiC	4.9	19.2		6
24	36	8	46	46	SiC	4	20.7		5
36	60	16	48	36	SiCL	2.5	20.6		5
60	96	28	38	34	CL	6.6	25.6		4
8-Fall, 2009									
0	2	6	44	50	SiC	2.7	36.5		2.8
0	6	6	44	50	SiC	2.5	36.5		2.4
6	12	2	48	50	SiC	3.1	36.9		1.7
12	24	2	44	54	SiC	5	29.4		2.6
24	36	10	50	40	SiC	4.6	24.9		2.1
36	60	8	50	42	SiC	3.8	24		2.5
60	96	18	38	44	C	4.8	28		1.8
9-Fall, 2010									
0	2	14	40	46	C	3	25.5		2
0	6	8	42	50	SiC	3	26.7		2.3
6	12	10	40	50	C	4	23.5		1.8
12	24	10	46	44	SiC	5	21.1		2.4
24	36	16	48	36	SiCL	5	18.4		2.5
36	60	8	40	52	C	4	15.7		2.2
60	96	24	38	38	CL	6	15		2.7

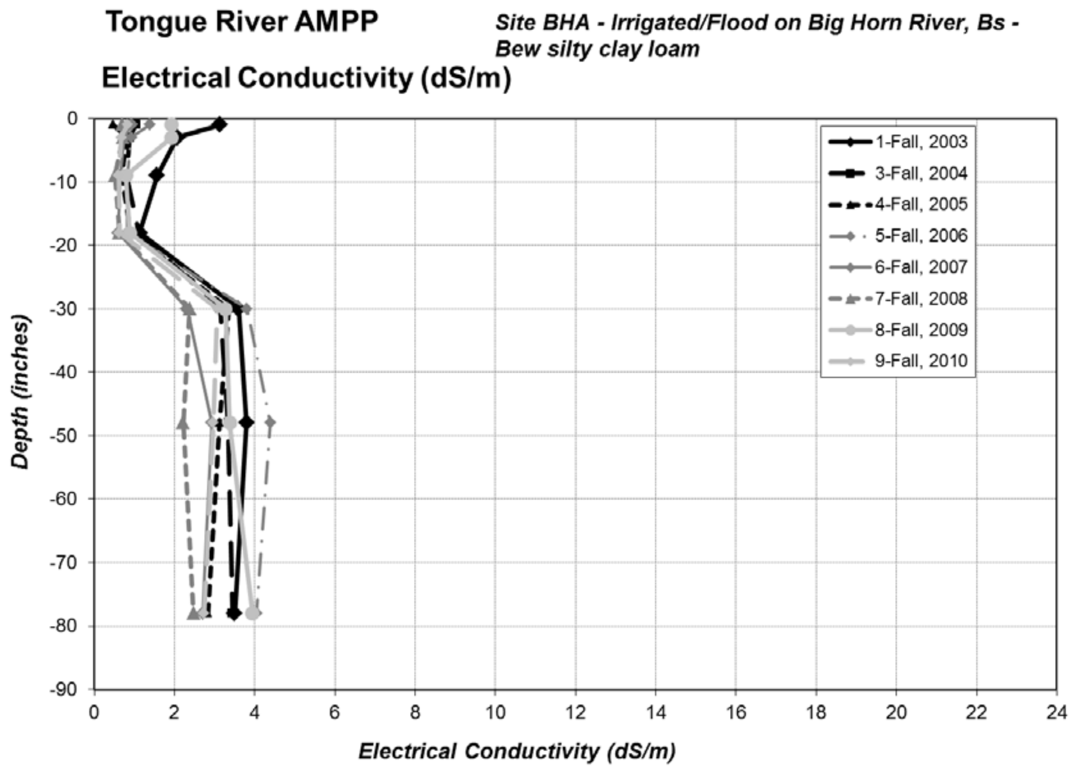

Figure 4-61 Trends in EC with Depth for Site BHA.

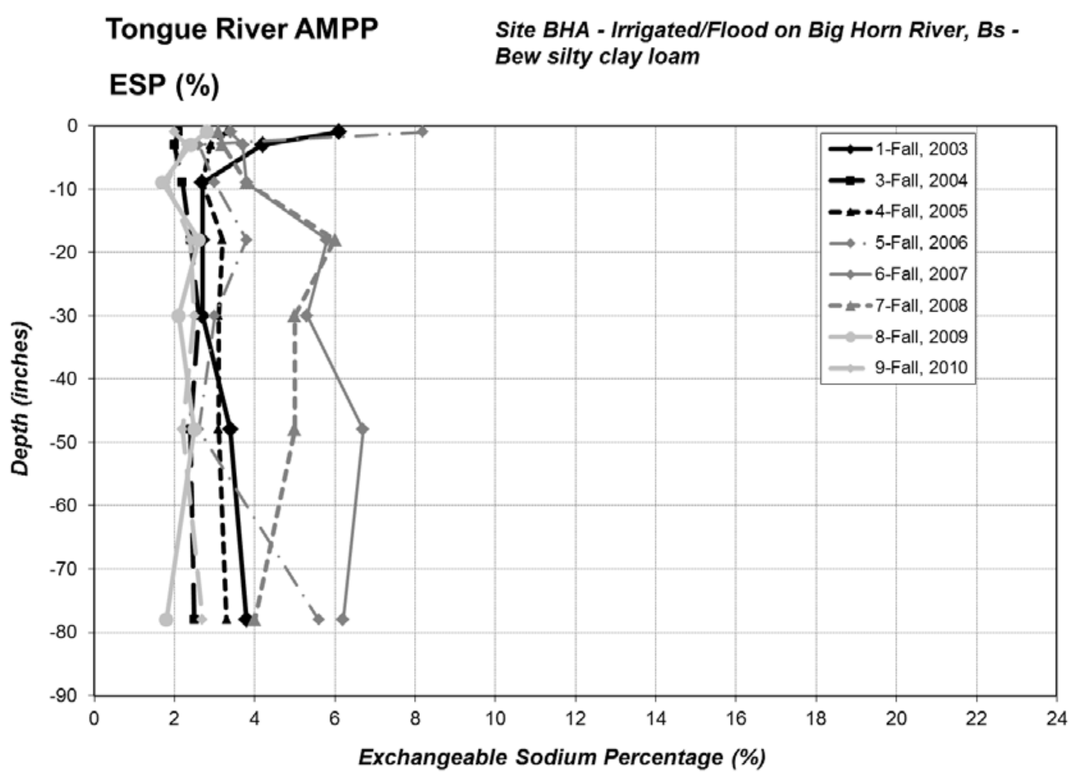

Figure 4-62 Trends in ESP with Depth for Site BHA.

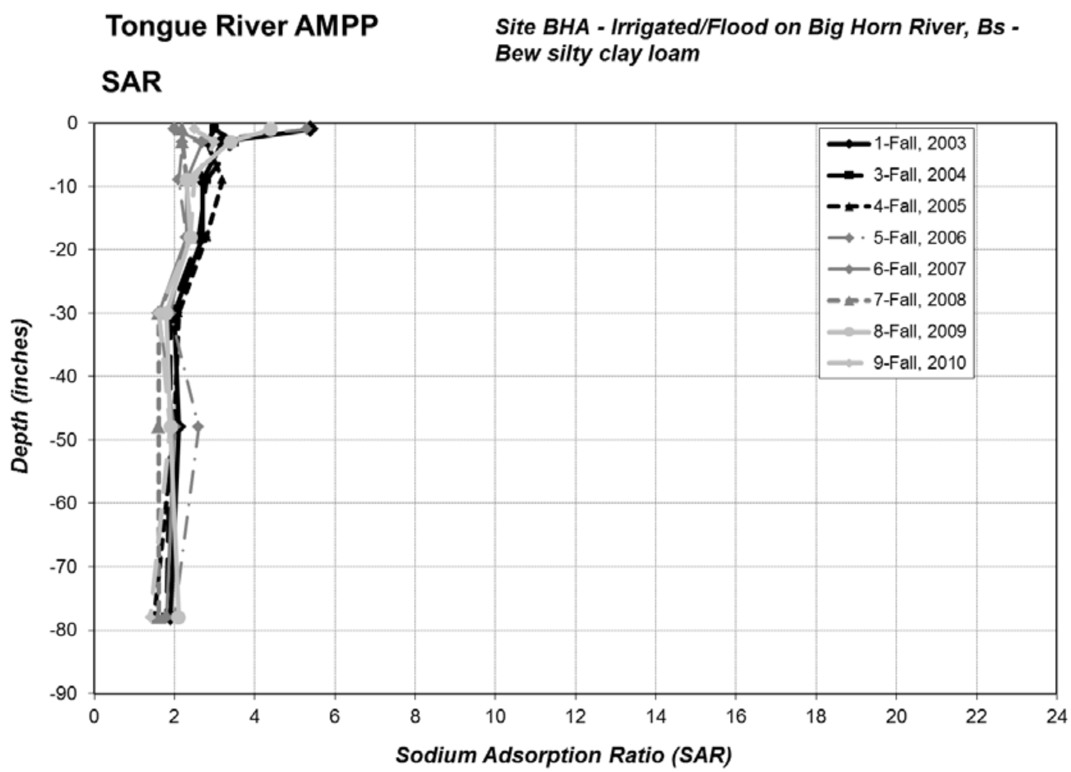

Figure 4-63 Trends in SAR with Depth for Site BHA.

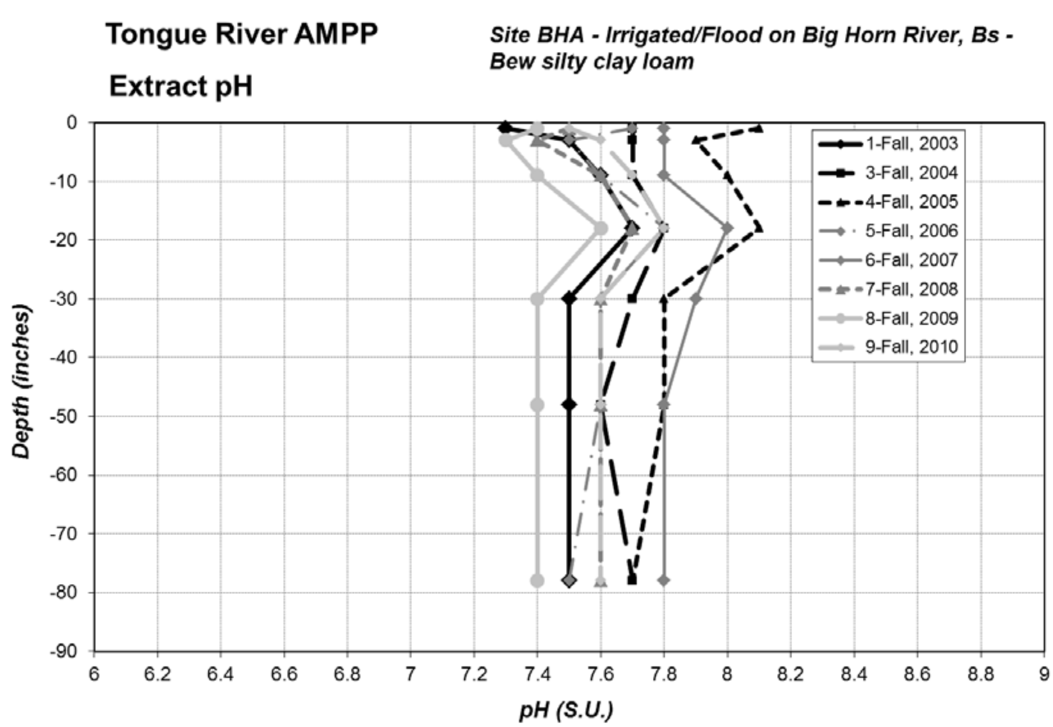

Figure 4-64 Trends in pH with Depth for Site BHA.

5.0 Summary and Recommendations

- Ten Tongue River fields irrigated with water from the Tongue River are being monitored for their baseline soil chemistry and to detect soil chemical changes that may occur through time.

- AMPP consists of three tiers of sampling. Tier 1 soil sampling and crop monitoring is provided to facilitate development of crop systems management plans, provided as a service to participating growers. Tier 2, described in this report, is a systematic basin-wide soil sampling effort repeated each fall since 2003 and spring 2004. Tier 2 also is a systematic crop harvesting program repeated each growing season prior to each harvest from AMPP fields. Tier 3, described in a separate report, consists of test plots to evaluate irrigation with varying mixtures of CBNG produced water and Tongue River water.

- Tier 2 fields represent a wide variety of cropping systems including alfalfa, grass, hay barley, wheat, millet, peas, and corn. Forage yields (grass, alfalfa, and alfalfa/grass) ranged from 1 to 6 tons/ per acre. Yields were comparable to average yields from Big Horn, Custer and Rosebud Counties in 2003 through 2010. Variations in crop yields observed between AMPP fields were not correlated to differences in salinity or sodium levels. Other factors, especially crop and irrigation management as well as environmental conditions, appeared to more strongly affect yields.

- EC and SAR of Tongue River irrigation water varies seasonally in response to the quantity of surface water flow. During high flow periods in May and June when surface water is dominated by snowmelt of mountain snowpack, EC and SAR are lowest. At other times of the year, groundwater baseflow, which is higher in EC and SAR, provide a larger proportion of flow.

- The general chemistries of Tongue River surface water, shallow groundwater, and soil water are a calcium-magnesium-sulfate type water. Produced water from CBNG operations is quite distinct being almost exclusively sodium and bicarbonate. Therefore, modest downstream increases in the proportion of sodium and sulfate in the Tongue River are likely due to input of shallow groundwater and/or irrigation return flows.

- Measured SAR is often used to predict ESP that would develop in soils with sustained irrigation. In most regions, ESP follows a linear relationship with SAR developed by USDA (1954). SAR and ESP relationship is weak in the AMPP data, however. SAR tends to under-predict ESP at a SAR of 5 or less, and over-predict ESP above SAR 10. ESP measurements are thought to be more subject to error than SAR measurements. Therefore SAR is probably a better indicator of sodium status than ESP.

- All Tongue River soils had water infiltration or intake rates that are considered suitable for sustained irrigation. There was no correlation between intake rate and either clay content or ESP. Intake rates did not vary through time.

- EC and SAR of irrigation water vary between years in response to precipitation. Wet years have lower EC and SAR than dry years. There is a tendency for EC and SAR to gradually increase in a downstream direction. Despite these seasonal, annual, and spatial variations in EC and SAR, the Tongue River generally meets Montana irrigation water quality standards, except occasionally below the T&Y Diversion Dam. Hydrology of the Tongue River is described in more detail in the 2010 Tongue River Hydrology Report (HydroSolutions 2011).

- Since water from CBNG operations contains excessive levels of sodium, sodium content of plant tissue may provide an early indication of CBNG effects. Plant tissue samples collected from irrigated crops and forages did not show a trend of increasing sodium levels indicating that CBNG activity is not affecting major ion uptake (including sodium) by crops.

- Irrigated soils with clay texture and a predominance of swelling clays (e.g. smectite) are known to be more susceptible to the adverse effects of sodium. Tongue River AMPP soils are not high-clay, and do not have predominantly smectite clays. Scientific literature indicates that the “safe” level of SAR in irrigation water for these soils would be 8 or higher (Bauder, no date).

- Except for site DA, soils monitored in AMPP were non-saline and non-sodic to a depth of 3 feet according to criteria developed by the Brown Salinity Lab.

- Irrigated Tongue River soils are mostly loam, or silty clay loam in texture, and have an average clay content of about 26% near surface decreasing to about 19% at 48 inches in depth. Clay-textured soils (e.g. with more than 40% clay sized particles in the < 2 mm sized fraction) occur infrequently in the Tongue River floodplain. BC is the only location with more than 40% clay.

- AMPP soils are generally non-saline and non-sodic near surface. Average EC is about 1.2 dS/m in the upper 6 inches and increases to around a maximum EC of 4 dS/m at 36 inches in depth, and gradually decrease to 3 dS/m at 8 feet. Average ESP is less than 2% in the upper 6 inches and increases with depth to 7% at 60 inches.

- Despite these generalizations, soils monitored in Tier 2 varied significantly between sites, and most soil properties exhibited some characteristic pattern with depth. Spatial differences between AMPP soils did not appear to relate to the location of CBNG activities. It appeared to be caused by random variation in soil properties caused by the variable nature of river flood deposits that the soils formed in, and due to differences in agronomic management.

- Soil EC and soluble calcium, magnesium and sodium decreased significantly over the 2003 to 2010 monitoring period. Declines were especially evident after 2006, the last year of a multi-year drought cycle.

6.0 References Cited

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7.0 Appendices

Appendix A

AMPP Flyer sent to Tongue River Irrigators

AMPP
Agronomic Monitoring and Protection Program

To sign up for the program, please return the card included in this mailing in the self-addressed envelope. We will contact you to schedule a sampling and consultation. Please feel free to call with your questions at 1-877-771-1677.

See us at the Eastern Montana Fair!! Neal Fehringer, Kevin Harvey, and Dr. Bill Schafer will be available at the Eastern Montana Fair in Miles City. They will be in the Exhibition Hall at a booth answering questions regarding the Agronomic Monitoring & Protection Program from 1 to 6 pm on Friday, August 22; and, from 10 am to 4 pm on Saturday, August 23. Stop by and have an ice cold water or pop and we'll answer your questions and discuss any concerns you may have. Look for the booth with the big blue AMPP banner.

AMPP
Agronomic Monitoring and Protection Program

From: Neal Fehringer, Certified Professional Agronomist (CPAg)
Kevin Harvey, Certified Professional Soil Scientist (CPSSc)
Dr. Bill Schafer, Soil Scientist

Date: August 15, 2003

Fidelity Exploration & Production Company has engaged our services to collect baseline soil and crop data in your area. This information will help you and Fidelity (along with the State and Federal Agencies who monitor coalbed natural gas development) better understand the potential effects of coalbed natural gas (CBNG) development on your soils and irrigated crops. Additionally, the information gathered through the Tongue River Agronomic Monitoring and Protection Program (AMPP) will give you the opportunity to improve and protect your operations. We are requesting your voluntary participation in this program.

To gather the necessary baseline data, we have designed the AMPP which includes collecting soil and crop samples throughout the Tongue River drainage. In designing this sampling program we have sought advice and review from scientists affiliated with Montana State University and the Natural Resources Conservation Service. We hope that landowners throughout the basin, like yourself, will allow us to gather these samples from their irrigated fields. The sampling and analysis, which is free to you, will not only provide information essential to understanding the potential impacts of development, but it will also provide data and analysis valuable to your crop production. Specifically, this service will provide you factual documentation of your crop yields and soil characteristics such as nutrient availability, electrical conductivity (EC), and sodium adsorption ratio (SAR) prior to the full development of CBNG production. The data and analysis you will receive from this free testing program will also include a detailed agronomic assessment of the field(s) we test.

To complete this assessment, a composite soil sample will be collected from the field and the overall crop or forage conditions will be evaluated. Neal Fehringer, a Certified Professional Agronomist, will then provide ranch-specific recommendations. The detailed plan will discuss:

- Fertilizer
- Soil amendments
- Stand establishment
- Seeding rates, dates and depth
- Weed, disease and insect control
- Cropping rotations
- Varieties
- How to deal with problem soils

This comprehensive agronomic assessment will allow you to better understand your soil chemistry and methods of crop management. With your permission, this agronomic assessment can be repeated in the future thereby enabling Fidelity and yourself to further understand the impacts of water discharges from CBNG production.

If you currently irrigate 80 or more acres using water from the Tongue River, you are eligible for this free service. Additionally, irrigators using water from tributaries to the Tongue River, especially Hanging Woman, Otter Creek and Pumpkin Creek may also be eligible.

To sign up for the program, please return the card included in this mailing in the self-addressed envelope. We will contact you to schedule a sampling and consultation. Please feel free to call with your questions at 1-877-771-1677.

See us at the Eastern Montana Fair!! Neal Fehringer, Kevin Harvey, and Dr. Bill Schafer will be available at the Eastern Montana Fair in Miles City. They will be in the Exhibition Hall at a booth answering questions regarding the Agronomic Monitoring & Protection Program from 1 to 6 pm on Friday, August 22; and, from 10 am to 4 pm on Saturday, August 23. Stop by and have an ice cold water or pop and we'll answer your questions and discuss any concerns you may have. Look for the booth with the big blue AMPP banner.

Q&A

...with Fidelity Exploration & Production Company

Responses by:
Bruce Williams, Vice President of Operations
Fidelity Exploration & Production Company

Does the creation of this program mean that Fidelity believes impacts will occur from its water discharges into the Tongue River?

The best information we have to-date indicates our discharge of unaltered groundwater into the Tongue River has not had and will not have a negative impact on irrigated land downstream from our operations. However, we would like to gather scientifically sound baseline data at the early stages of development to be able to track any significant changes if they occur and to spot them early on. That's the reason for the AMPP. Every human activity, whether it's grazing cattle, irrigating alfalfa or extracting natural gas – has impacts. The issue is whether the impacts are significant enough to create damage or whether they can be managed in a way to minimize or eliminate it.

About the testing itself, how intrusive is it? How long will you need to be on my land doing the actual testing?

Prior to conducting any testing, Neal Fehringer, Kevin Harvey, and Dr. Bill Schafer would like to meet with individual landowners for the purpose of discussing where to conduct the testing, meaning which field or fields, and how that testing will be conducted. For most fields, the soil sampling program would be identical to that used by fertilizer dealers. Kevin and Bill would like to take composite soil samples using a truck-mounted 2" boring tool from three different depths at 5 to10 different locations across a field. In eight to ten instances the sampling would be more detailed and analysis would be done by excavating one to two backhoe pits to a 6 to 8 foot depth in addition to collecting the composite sample. To minimize any impacts, they will use a rubber-tired backhoe, will select the location of the pit under the landowner's direction, and will reclaim the area where the pit is excavated. Depending upon the outcome of their discussions with individual landowners, they estimate that the time they would need to complete this testing would be no more than half a day. During that time period, Neal will further conduct a crop yield analysis through conversations with the landowner and a field investigation.

When will the initial testing be done?

We would like to complete the testing this September.

You mention that follow-up testing will be done to determine if damage has occurred. Will this testing also be free of charge to the participating landowners? And, when do you think this testing will be done?

Neal, Kevin, and Bill believe that conducting additional testing next spring is essential to understanding the dynamics of increased discharge from Fidelity's operations and seasonal variabilities. Additionally, periodic sampling may be continued throughout the period of CBNG development as long as a significant number of landowners want to continue to participate in the program. Again, this testing would be free and would be conducted with the cooperation of the landowner.

Who created this program?

The Tongue River Agronomic Monitoring and Protection Program was designed by Neal Fehringer, Kevin Harvey and Dr. Bill Schafer.

Neal is a Certified Professional Agronomist and has been providing agronomic services in the region for over 20 years. He was accredited as a Certified Crop Advisor in 1995, and a Certified Professional Agronomist in 1998, by the American Society of Agronomy. He also served on the Montana Agricultural Experiment Station State Advisory Commission from 1996 to 1999 and on the Southern Montana Agricultural Experiment Station Advisory Committee from 1990 to 1999.

Kevin Harvey is a board Certified Professional Soil Scientist (also by the American Society of Agronomy) and has 23 years experience providing environmental consulting services to the private and public sector throughout the U.S., Canada, Mexico and Europe. Mr. Harvey's technical strengths are in soil science, land reclamation, surface water chemistry and hydrology, and general environmental problem solving.

Bill Schafer earned a Ph.D. in Soil Science from Montana State University in 1979 and has managed over 300 environmental projects involving mining, irrigated agriculture, hazardous waste remediation and petroleum development. Dr. Schafer's expertise includes mine reclamation, water quality, soil science, irrigated and dryland agricultural systems, and surface water, groundwater, and unsaturated zone hydrology. While on the faculty at Montana State University (1976 to 1985) and the Cooperative Extension Service (1980 to 1985), Dr. Schafer's responsibilities included identification and management of saline and sodic soils, irrigation water quality, and soil fertility.

How did you select the scientists which designed the AMPP?

Your question goes to the heart of a larger question of "whose science do you trust." I understand where some people might be skeptical of scientists hired by industry given the amount of misinformation that has been distributed by those that oppose CBNG development. Be assured that our scientists have the highest integrity and are impartial. We are asking them to use their knowledge and education to determine the actual characteristics of the land, crops, and soils. We are not asking them to provide data that proves our position. We don't operate that way. We are not telling them what to do, or how to do it.

To participating landowners, we will split the samples that are retrieved so – if you choose – you can have your own tests done by whomever you select. This testing, of course, needs to be done at your expense. In order to produce scientifically valid data, certain testing protocols must be followed. If you desire to test the split sample, we will provide the information for this protocol.

Additionally, we have asked scientists from Montana State University and the Natural Resources Conservation Service to become cooperators in the program. Incidentally, we have also invited scientists that have worked with the Northern Plains Resource Council to participate in this program alongside us, but they declined our invitation.

Isn't it true that you want this information in order to defend Fidelity against litigation brought forward by the Northern Plains Resource Council, the Tongue River Water Users' Association, and the Montana Environmental Information Center?

Yes, this is true. In 2001, these organizations sued the Montana Department of Environmental Quality and Fidelity. The organizations alleged that the Department's issuance of Fidelity's permit violated state laws and the constitution and specifically, that the discharge of unaltered groundwater authorized by Fidelity's permit has caused, is causing, and will cause harm to the environment. (Tongue River Water Users' Association, et al. v. Montana Department of Environmental Quality and Fidelity Exploration & Production Company, CDV-2001-258). As part of our legal discovery process Fidelity believes we need to gather scientific data to determine if our discharges have caused harm or will cause harm in the future. However, Fidelity also believes this information is essential as we move forward with production so that all of us can base our decisions on the facts rather than speculation or exaggeration.

We did seek access to gather this scientific data on lands owned by members of these organizations, but their attorneys denied us access stating they did not believe the information we are seeking is relevant to the litigation. Unfortunately, District Court Judge Jeffrey Sherlock agreed that the information was not relevant. While this legal battle continues, we are attempting to gather this baseline data through these voluntary means.

We simply do not understand why these organizations would deny us the right to gather this information. The information will be useful to agricultural producers and to CBNG developers. If these groups are right about CBNG development, this information would prove their claims. Since they want to obstruct us from getting this information, we think they believe, as we do, that it will disprove their claims. In essence, these groups don't want us – or you – to get the information that proves our point that damage has not occurred.

But, aside from these legal issues, it just makes good common sense to gather this information in order to create baseline data for the future. Regardless of litigation implications, Fidelity intends to continue with this program in order to make sure that its discharges will not negatively impact your soils or crop production.

How will Fidelity use the data that is collected from this program? Will the information be made public?

We would also like to publish a summary of the data in an annual publication, which will be distributed to cooperators, local Conservation Districts and NRCS offices for the benefits of all agricultural producers. If you like, the location of your field can be protected by using a code to refer to each sample. In this way only you, and not your neighbor, will know your results or that you have participated in the program. The information gathered through the AMPP could also potentially be used by Fidelity to defend itself in the litigation mentioned in the previous question as well as in possible future actions. Through this litigation, it is possible that the information will be available to the public in court records, which are available to the media.

Appendix B

Quality Assurance Sample Results

Table B-1 AMPP blind field duplicate analyses for suite 1

SampleEvent	Site	AveDep	Sample	QA	CollectionDate	1 : Dry Wt	1 : Saturation Percentage	1 : pH (Paste)	1 : Electrical Conductivity (Paste)	1 : Calcium (Paste)	1 : Magnesium (Paste)	1 : Sodium (Paste)	1 : Sodium Adsorption Ratio	1 : Alkalinity (Paste)	1 : Bicarbonate (Paste)	1 : Carbonate (Paste)	1 : Chloride (Paste)
1	BC	-48	10	BFD	15-Oct-03		66.1	7.8	6.9	19.9	15	34.3	8.2	2.8			
1	BC	-48	50	QA	15-Oct-03		64.5	7.8	6.66	18.9	14	32.2	7.9	3			
1	BD	-48	10	BFD	21-Oct-03		47	8	3.24	10	10.6	16	5	2.9			
1	BD	-48	50	QA	21-Oct-03		44.2	7.9	4.89	18.9	17.6	20.9	4.9	3.5			
1	BHA	-18	10	BFD	22-Oct-03		56.1	7.7	1.14	3	1.8	4.2	2.7	3.3			
1	BHA	-18	50	QA	22-Oct-03		56	7.7	1.08	4	2	4.4	2.5	4			
1	DA	-48	10	BFD	11-Oct-03		35.1	8.1	6.09	7.7	11.9	51.1	16	2.8			
1	DA	-48	50	QA	11-Oct-03		32	8.1	6.03	7.7	12	49.2	16	3.4			
1	DB	-9	1	BFD	11-Oct-03	602	70.8	8.4	18.9	24.6	29.4	169	33	5.2			
1	DB	-9	50	QA	11-Oct-03		81.5	8.9	19.7	11.6	17.9	196	51	8			
1	EA	-48	10	BFD	10-Oct-03		50.1	7.9	5.58	17.4	28.1	26.7	5.6	2.4			
1	EA	-48	50	QA	10-Oct-03		45.1	7.9	4.2	10.2	18.2	18.8	5	2.4			
1	GA	-19	1	BFD	08-Oct-03	592	61.3	7.9	0.63	2.7	1.3	1.8	1.3	2			
1	GA	-19	50	QA	08-Oct-03		61.8	7.9	0.72	3.2	1.5	1.9	1.3	2.3			
1	GA	-78	10	BFD	08-Oct-03		30.5	8.1	1.37	2.4	3.2	7	4.2	3			
1	GA	-78	51	QA	08-Oct-03		31	8.1	1.4	2.6	3.4	7.2	4.1	2.8			
1	GC	-78	10	BFD	09-Oct-03		27.4	8	0.64	2.7	2	1.9	1.2	2.9			
1	GC	-78	50	QA	09-Oct-03		27.4	8.1	0.59	2.5	1.8	1.8	1.2	2.6			
1	LA	-18	10	BFD	02-Oct-03		47.4	7.8	4.33	21.7	18.8	22.1	4.9	2.9			
1	LA	-18	50	QA	02-Oct-03		48.7	7.8	3.57	19.9	15.8	13.9	3.3	2.8			
1	MA	-3	10	BFD	01-Oct-03		41.3	7.4	0.81	4.4	2.1	2.6	1.5	5.5			
1	MA	-3	50	QA	01-Oct-03		41.2	7.8	0.7	3.6	1.8	1.5	0.9	4.6			
1	MA	-8	1	BFD	01-Oct-03	529	40.6	7.6	0.72	4.7	2.3	0.8	0.4	3.2			
1	MA	-8	52	QA	01-Oct-03		42	7.7	0.7	3.7	1.9	0.8	0.4	2.7			
1	MA	-30	10	BFD	01-Oct-03		41.9	7.7	3.61	15.5	28.3	13.3	2.8	2.5			
1	MA	-30	53	QA	01-Oct-03		43.8	7.9	3.3	11.5	24.2	11.4	2.7	2.4			
1	MB	-3	10	BFD	30-Sep-03		40.8	7.5	0.81	3.7	3	1.5	0.8	5.5			
1	MB	-3	50	QA	30-Sep-03		39.6	7.5	0.86	3.5	3	1.7	0.9	5.5			
1	OAA	-1	10	BFD	09-Oct-03		51.3	7.7	0.88	5.7	2.3	0.6	0.3	8.1			
1	OAA	-1	50	QA	09-Oct-03		52.1	7.7	0.83	5.7	2.3	0.6	0.3	8			
1	YAA	-9	10	BFD	14-Oct-03		49.4	7.7	1.1	4.1	3.3	4	2.1	4.8			
1	YAA	-9	51	QA	14-Oct-03		50.7	7.7	1.04	3.6	2.8	3.5	2	4.6			
1	YAA	-40	1	BFD	14-Oct-03	588	32.9	8.1	2.07	2.4	3.9	13.4	7.5	5.8			
1	YAA	-40	50	QA	14-Oct-03		39.5	8.1	2	2.6	4.2	12.9	7	6.4			
1	YBA	-48	10	BFD	20-Oct-03		54.5	7.9	2.42	5.2	3.5	15.5	7.4	4			
1	YBA	-48	50	QA	20-Oct-03		56.7	7.9	2.18	4.6	3.1	12.6	6.4	4			
2	BA	-18	10	BFD	14-Apr-04		43.4	7.7	1.61	6.82	5.47	4.94	2	4			0.71
2	BA	-18	50	QA	14-Apr-04		46.8	7.7	1.86	7.62	6.39	4.48	1.7	3.2			1.27
2	EA	-18	10	BFD	14-Apr-04		51.8	7.6	4.6	24.6	21.2	13.1	2.7	4			0.56
2	EA	-18	50	QA	14-Apr-04		52.7	7.7	3.09	15.9	13.3	10.9	2.8	4			0.28
2	GA	-48	10	BFD	30-Apr-04		31.4	8	5.98	16.8	28.4	30	6.3	2.4			1.83
2	GA	-48	50	QA	30-Apr-04		33.7	8.2	7.4	18.9	38	48.9	9.2	2.2			2.68
2	MB	-48	10	BFD	30-Apr-04		47	7.9	3.95	22.6	23	8.34	1.7	1.6			0.42
2	MB	-48	50	QA	30-Apr-04		45.7	7.9	3.61	16.5	19.5	8.77	2.1	1.6			0.56
2	YAA	-18	10	BFD	14-Apr-04		49.1	7.8	1.73	6.55	6.16	7.06	2.8	1.2			0.28
2	YAA	-18	50	QA	14-Apr-04		48.7	7	1.66	5.36	5.26	6.52	2.8	4			0.42
3	BA	-30	10	BFD	13-Oct-04		36.8	7.7	1.76	5.36	4.32	6.72	3	2.6	ND (1)	ND (1)	
3	BA	-30	50	QA	13-Oct-04		35.4	7.7	1.66	5.23	4.1	6.27	2.9	2.5	ND (1)	ND (1)	
3	BHA	-18	10	BFD	07-Sep-04		64.4	7.8	1.11	4.44	2.42	4.9	2.6	2			1.33
3	BHA	-18	50	QA	07-Sep-04		57	7.9	1.1	4.55	2.33	4.78	2.6	2			1.21
3	DA	-30	10	BFD	13-Oct-04		29	8	8.85	18.6	20.8	67.9	15	3.3	ND (1)	ND (1)	
3	DA	-30	50	QA	13-Oct-04		29.4	8.2	11.4	19.4	28.6	102	21	3.4	ND (1)	ND (1)	
3	GA	-30	10	BFD	13-Oct-04		40.4	7.8	4.71	12.9	21.6	20.8	5	3.5	ND (1)	ND (1)	
3	GA	-30	50	QA	13-Oct-04		39.1	7.8	6.19	17.2	26.9	28.3	6	3	ND (1)	ND (1)	
3	MA	-30	10	BFD	12-Oct-04		40	7.7	5.53	15.3	42.1	17.5	3.3	2.4			
3	MA	-30	50	QA	12-Oct-04		39	7.7	6.38	18.4	48.7	20.2	3.5	2			
3	YAA	-30	10	BFD	13-Oct-04		52.1	7.9	2.92	5.17	4.54	19.1	8.7	4.6	ND (1)	ND (1)	
3	YAA	-30	50	QA	13-Oct-04		50.8	7.9	2.27	4.41	3.65	13.8	6.9	3.5			
4	BHA	-48	10	BFD	08-Aug-05		49.8	7.8	3.12	26.7	9.74	8.33	2		1.27		
4	BHA	-48	50	QA	08-Aug-05		50.8	7.9	2.75	23.8	8.56	7.4	1.8		1.17		
4	DA	-30	10	BFD	27-Oct-05		30.7	8	7.55	14.3	18	68.3	17		3		
4	DA	-30	50	QA	27-Oct-05		30.2	7.9	7.63	16	17.3	57.4	14		2.4		
4	EA	-30	10	BFD	26-Oct-05		51.5	7.7	3.14	12.3	13.1	11.2	3.2		3.06		
4	EA	-30	50	QA	26-Oct-05		51.9	7.7	4.53	19.8	23.7	25.8	5.5		4.62		
4	GA	-30	10	BFD	26-Oct-05		41.8	7.8	4.16	12.3	18.1	20.9	5.4		3.32		
4	GA	-30	50	QA	26-Oct-05		42.4	7.8	6.12	18.5	29	34.5	7.1		3.03		
4	LA	-30	10	BFD	25-Oct-05		44.9	7.7	6.06	24	32.1	31.7	6		2.75		
4	LA	-30	50	QA	25-Oct-05		43.1	7.7	5.76	22.7	28.7	25.9	5.1		3.03		
4	YAA	-30	10	BFD	27-Oct-05		49.8	7.8	2.25	5.19	5.05	16.5	7.3		4.77		
4	YAA	-30	50	QA	26-Oct-05		48.9	7.8	2.17	4.86	3.91	13.2	6.3		3.44		
4	YBA	-30	10	BFD	28-Oct-05		44	7.7	3.33	10.9	8.2	21.6	7		2.26		
4	YBA	-30	50	QA	28-Oct-05		44.9	7.6	2.66	8.7	6.41	17.9	6.5		2.53		
5	BA	-30	10	BFD	12-Dec-06		36.4	7.5	1.88	6.69	5.2	5.44	2.2		2.13		0.22
5	BA	-30	50	QA	13-Dec-06		47.7	7.7	3.49	10.1	7.72	16.8	5.6		2.8		1.68
5	DA	-30	10	BFD	12-Dec-06		31.4	8	6.61	13.8	17.6	50.5	13		2.23		1.98
5	DA	-30	50	QA	12-Dec-06		33	8	8.85	18	24.6	80.1	17		2.8		0.24
5	GA	-30	10	BFD	13-Dec-06		40.9	7.9	6.86	17.4	30.5	42.2	8.6		2.84		1.47
5	GA	-30	50	QA	12-Dec-06		42.1	7.9	6.28	19.7	29.8	41.5	8.4		2.4		1.36
5	LA	-30	10	BFD	13-Dec-06		45	7.8	5.97	22.7	28.3	33	6.5		2.43		1.67
5	LA	-30	50	QA	11-Dec-06		39.6	7.7	1.9	6.61	5.72	6.68	2.7		2.2		0.64
5	OAA	-30	10	BFD	13-Dec-06		36.9	7.7	2.61	5.52	6.13	13.8	5.7		3.38		0.38
5	OAA	-30	50	QA	12-Dec-06		43.2	7.8	5.45	25.3	29.3	27	5.2		4		0.5
5	YAA	-30	10	BFD	13-Dec-06		47.8	7.7	2.41	5.85	5.6	13.4	5.6		4.06		0.09
5	YAA	-30	50	QA	13-Dec-06		48.9	7.8	2.96	6.83	6.8	17.7	6.8		3.2		0.38
6	BA	-3	10	BFD	20-Sep-07		45.3	7.7	0.74	3.75	1.96	2.18	1.3		4.8		0.88
6	BA	-3	50	QA	20-Sep-07		48.6	7.6	0.84	5.02	2.73	2.77	1.4		3.74		0.97

Table B-1 (con't)

SampleEvent	Site	AveDep	Sample	QA	CollectionDate	1 : Dry Wt	1 : Saturation Percentage	1 : pH (Paste)	1 : Electrical Conductivity (Paste)	1 : Calcium (Paste)	1 : Magnesium (Paste)	1 : Sodium (Paste)	1 : Sodium Adsorption Ratio	1 : Alkalinity (Paste)	1 : Bicarbonate (Paste)	1 : Carbonate (Paste)	1 : Chloride (Paste)
6	BC	-18	10	BFD	21-Sep-07		53.4	8	0.9	2.61	1.97	4.12	2.7		3.2		0.5
6	BC	-18	50	QA	20-Sep-07				0.69	1.92	1.37	3.54	2.8				
6	DA	-30	10	BFD	20-Sep-07		51.6	7.9	0.91	3.28	2.22	2.86	1.7		4		1.23
6	DA	-30	50	QA	19-Sep-07				0.92	4.12	2.57	196	35				
6	EA	-9	10	BFD	19-Sep-07		31	8.3	11.9	16.1	25	101	22		3		2
6	EA	-9	50	QA	19-Sep-07		31.3	8.1	12.1	17.3	26.7	105	22				
6	EA	-78	10	BFD	19-Sep-07		50.3	8.1	2.46	4.01	8.79	13.5	5.3		3		0.53
6	EA	-78	50	QA	19-Sep-07		44	8	2.42	4.11	9.89	13.1	5		2.36		0.55
6	GA	-9	10	BFD	19-Sep-07		43.4	7.8	0.55	2.96	1.59	1.66	1.1		4.5		0.42
6	GA	-9	50	QA	19-Sep-07		41.3	7.7	0.69	3.09	2.04	1.96	1.2		3.15		0.73
6	MA	-30	10	BFD	18-Sep-07		41.6	8	2.81	8.76	18	9.89	2.7		3.2		0.6
6	MA	-30	50	QA	18-Sep-07		42.6	7.9	2.83	7.79	15.7	10.6	3.1		3.05		0.73
6	OAA	-30	10	BFD	19-Sep-07		34.5	8.1	0.68	1.11	0.95	4.64	4.6		5.19		0.56
6	OAA	-30	50	QA	19-Sep-07				0.83								
6	YAA	-18	10	BFD	20-Sep-07		51.1	8.1	1.63	3.74	3.43	11	5.8		3.2		0.35
6	YAA	-18	50	QA	20-Sep-07		51.7	7.9	2.1	5.76	5.96	14.3	5.9		3.15		0.49
6	YAA	-78	10	BFD	20-Sep-07		50.7	8.1	7.7	17.5	14.3	64.2	16		2.8		1.59
6	YAA	-78	50	QA	20-Sep-07				5.17	10.8	8.47	41.1	13				
7	BC	-30	10	BFD	24-Oct-08		55	7.6	3.64	16.7	12	17.9	4.7		2.39		0.32
7	BC	-30	50	QA	24-Oct-08		65.4	7.7	3.82	13.1	10.1	21.3	6.2		2.19		0.33
7	EA	-1	10	BFD	23-Oct-08		59.8	7.3	1.2	7.1	3.75	0.48	0.21		11.7		0.35
7	EA	-1	50	QA	22-Oct-08		60	7.5	0.97	5	2.83	0.82	0.41		9.28		0.44
7	GA	-18	10	BFD	22-Oct-08		39.6	7.6	2.42	10.8	8.63	8.5	2.7		3.18		0.69
7	GA	-18	50	QA	22-Oct-08		42.5	7.8	1.73	4.92	4.89	7.87	3.6		3.58		0.16
7	GC	-48	10	BFD	22-Oct-08		36.4	7.7	1.38	6.41	4.43	2.51	1.1		1.99		0.41
7	GC	-48	50	QA	22-Oct-08		41.5	7.8	1.2	5.03	3.95	3.8	1.8		3.38		0.33
7	YBA	-9	10	BFD	24-Oct-08		46.5	7.6	0.62	2.67	1.29	2.37	1.7		4.37		0.43
7	YBA	-9	50	QA	24-Oct-08		48.3	7.7	0.78	3.03	1.46	3.05	2		3.88		0.33
8	BC	-30	10	BFD	29-Oct-09		59.6	7.9	2.99	12.6	9.86	17.1	5.1		2.22		0.4
8	BC	-30	55	QA	29-Oct-09		67.5	7.9	3.84	18	13.8	23	5.8		2.06		0.54
8	EA	-1	10	BFD	28-Oct-09		63.5	7.4	0.8	4.61	2.68	0.63	0.33		8.23		0.37
8	EA	-1	53	QA	28-Oct-09		64.5	7.5	0.79	5.74	2.78	0.63	0.31		8.47		0.31
8	GA	-18	10	BFD	27-Oct-09		42.6	8	0.88	3.75	2.84	3.3	1.8		2.51		0.4
8	GA	-18	51	QA	27-Oct-09		40.8	7.8	1.45	5.58	5.39	6.23	2.7		2.73		0.51
8	GC	-48	10	BFD	27-Oct-09		34.2	8	0.58	3.18	2.08	1.82	1.1		1.52		0.21
8	GC	-48	52	QA	27-Oct-09		40.1	8	0.87	4.46	3.22	2.67	1.4		1.7		0.25
8	YBA	-9	10	BFD	29-Oct-09		49	7.8	0.58	2.96	1.39	2.2	1.5		3.84		0.39
8	YBA	-9	54	QA	29-Oct-09		49.9	7.7	0.5	2.45	1.04	1.8	1.4		3.46		0.22
9	BC	-30	10	BFD	15-Dec-10		54.8	7.7	5.32	25.4	19.4	26.2	5.5		3.04		
9	BC	-30	54	QA	15-Dec-10		52.3	7.7	3.32	12.7	10.6	19.1	5.6		4.46		0.5
9	EA	-1	10	BFD	20-Oct-10		59.2	7.2	1.07	4.61	3.3	0.52	0.26		9.81		
9	EA	-1	53	QA	20-Oct-10		58.6	7.5	1.34	8.26	3.95	0.58	0.23		11.4		0.8
9	GA	-18	10	BFD	20-Oct-10		41.6	7.5	2.21	8.76	7.62	8.71	3		3.1		
9	GA	-18	51	QA	19-Oct-10		40.5	7.5	3.25	11.1	10.8	13.4	4		3.67		
9	GC	-48	10	BFD	20-Oct-10		32.2	7.5	0.96	4.14	2.86	3.02	1.6		2.84		
9	GC	-48	52	QA	20-Oct-10		33.5	8.1	1.21	4.69	3.09	3.67	1.9		1.84		0.2
9	YBA	-9	10	BFD	15-Dec-10		46.5	7.6	0.64	3.23	1.45	2.12	1.4		5.14		0.2
9	YBA	-9	55	QA	15-Dec-10		47.3	7.6	0.7	4.32	1.82	2.37	1.4		5.19		0.3

Table B-2 AMPP blind field duplicate analyses for suite 2

SampleEvent	Site	AveDep	Sample	QA	CollectionDate	2 : Cation Exchange Capacity	2 : Exchangeable Sodium	2 : Exchangeable Sodium Percentage	2 : Lime as CaCO3	2 : Sand	2 : Silt	2 : Clay
1	BC	-48	10	BFD	15-Oct-03	39.1		4.8	9.4	5	49	46
1	BC	-48	50	QA	15-Oct-03	37		5.8	9.6	5	50	45
1	BD	-48	10	BFD	21-Oct-03	27.2		4.6	8.1	20	58	22
1	BD	-48	50	QA	21-Oct-03	28		3.9	8.6	19	58	23
1	BHA	-18	10	BFD	22-Oct-03	37		2.7	7.6	3	45	52
1	BHA	-18	50	QA	22-Oct-03	35		3.8	5.8	10	44	46
1	DA	-48	10	BFD	11-Oct-03	13.2		10	6.9	69	21	10
1	DA	-48	50	QA	11-Oct-03	12.9		15	6.6	64	24	12
1	DB	-9	1	BFD	11-Oct-03	26.7		6.6	7.9	8	62	30
1	DB	-9	50	QA	11-Oct-03	21.8		9.9	7.7	9	64	27
1	EA	-48	10	BFD	10-Oct-03	24.2		4	8.1	30	42	28
1	EA	-48	50	QA	10-Oct-03	26.4		5	8	32	42	26
1	GA	-19	1	BFD	08-Oct-03	40.1		1.5	6.2	ND (1)	54	46
1	GA	-19	50	QA	08-Oct-03	40.4		1.6	6.6	ND (1)	52	48
1	GA	-78	10	BFD	08-Oct-03	17		3.8	5.3	76	16	8
1	GA	-78	51	QA	08-Oct-03	12.6		4.5	5.1	75	17	8
1	GC	-78	10	BFD	09-Oct-03	17.6		3.4	8.1	52	32	16
1	GC	-78	50	QA	09-Oct-03	15.7		3.2	9.6	62	26	12
1	LA	-18	10	BFD	02-Oct-03	36.2		3.6	8.2	23	50	27
1	LA	-18	50	QA	02-Oct-03	40.3		3.1	7.9	26	49	25
1	MA	-3	10	BFD	01-Oct-03	26.3		2	8.6	26	50	24
1	MA	-3	50	QA	01-Oct-03	32.3		1.9	8.4	25	51	24
1	MA	-8	1	BFD	01-Oct-03	22.3		2.3	9.6	24	54	22
1	MA	-8	52	QA	01-Oct-03	33		1.3	9.7	25	53	22
1	MA	-30	10	BFD	01-Oct-03	25.3		3.9	10	28	48	24
1	MA	-30	53	QA	01-Oct-03	29.5		3.3	10.2	30	47	23
1	MB	-3	10	BFD	30-Sep-03	35.5		1.5	1.2	26	45	29
1	MB	-3	50	QA	30-Sep-03	34.8		1.8	1.3	28	43	29
1	OAA	-1	10	BFD	09-Oct-03	29.6		1.7	8.1	28	47	25
1	OAA	-1	50	QA	09-Oct-03	32.8		1.1	10.4	29	47	24
1	YAA	-9	10	BFD	14-Oct-03	30.9		3	7	28	50	22
1	YAA	-9	51	QA	14-Oct-03	34.6		2	7	27	48	25
1	YAA	-40	1	BFD	14-Oct-03	26.2		6.2	7.6	44	38	18
1	YAA	-40	50	QA	14-Oct-03	29.3		5	7.7	45	38	17
1	YBA	-48	10	BFD	20-Oct-03	30.7		5.9	6.7	18	56	26
1	YBA	-48	50	QA	20-Oct-03	34.9		6.1	6.6	16	53	31
2	BA	-18	10	BFD	14-Apr-04	19		2.1	6.1	27	52	21
2	BA	-18	50	QA	14-Apr-04	18.1		4.5	6.4	25	53	22
2	EA	-18	10	BFD	14-Apr-04	26.3		4.4	7.2	13	51	36
2	EA	-18	50	QA	14-Apr-04	22.2		3.2	7.1	19	50	31
2	GA	-48	10	BFD	30-Apr-04	9.97		8.2	5.9	59	30	11
2	GA	-48	50	QA	30-Apr-04	12.5		11	6.5	51	34	15
2	MB	-48	10	BFD	30-Apr-04	20.8		4.6	7.1	29	43	28
2	MB	-48	50	QA	30-Apr-04	22.7		3.8	7.1	31	39	30
2	YAA	-18	10	BFD	14-Apr-04	24.9		4.3	4.4	29	43	28
2	YAA	-18	50	QA	14-Apr-04	27.1		4	4.2	25	47	28
3	BA	-30	10	BFD	13-Oct-04	13.4	0.8	5.7	5.8	45	41	14
3	BA	-30	50	QA	13-Oct-04	12.7	0.8	6.7	5.8	45	40	15
3	BHA	-18	10	BFD	07-Sep-04	36.1		2.4	4.9	9	40	51
3	BHA	-18	50	QA	07-Sep-04	27.8		3.3	5.3	2	45	53
3	DA	-30	10	BFD	13-Oct-04	9.83	1.7	17	7.4	61	29	10
3	DA	-30	50	QA	13-Oct-04	9.67	2	20	7.2	62	29	9
3	GA	-30	10	BFD	13-Oct-04	17.7	1	5.9	6.7	43	39	18
3	GA	-30	50	QA	13-Oct-04	17.9	1.5	8.5	6.7	42	39	19
3	MA	-30	10	BFD	12-Oct-04	25.5	1.2	4.8	10.7	29	51	20
3	MA	-30	50	QA	12-Oct-04	25.6	1.5	5.8	10.6	33	50	17
3	YAA	-30	10	BFD	13-Oct-04	27	2.1	8	4.9	26	45	29
3	YAA	-30	50	QA	13-Oct-04	27.4	2	7.3	4.8	28	46	26
4	BHA	-48	10	BFD	08-Aug-05	26.5	0.8	3.1	4.1	13	46	41
4	BHA	-48	50	QA	08-Aug-05	26.8	1.3	4.8	4	12	49	39
4	DA	-30	10	BFD	27-Oct-05	11.8	0.4	3.7	8	67	27	6
4	DA	-30	50	QA	27-Oct-05	9.95	0.7	2	7.1	68	24	8
4	EA	-30	10	BFD	26-Oct-05	31.2	0.9	2.8	9.9	20	52	28
4	EA	-30	50	QA	26-Oct-05	32.6	0.8	2.4	9.3	21	48	31
4	GA	-30	10	BFD	26-Oct-05	20.6	1.2	5.7	7.3	38	44	18
4	GA	-30	50	QA	26-Oct-05	20.4	1.1	5.4	7.4	42	42	16
4	LA	-30	10	BFD	25-Oct-05	22.3	0.9	3.9	7.7	40	40	20
4	LA	-30	50	QA	25-Oct-05	22.3	1.1	5	7.8	42	37	21
4	YAA	-30	10	BFD	27-Oct-05	33	1.7	5.1	5.3	26	47	27
4	YAA	-30	50	QA	26-Oct-05	31.4	1.6	10	4.3	26	47	27
4	YBA	-30	10	BFD	28-Oct-05	30.8	1.3	4.1	7	21	60	19
4	YBA	-30	50	QA	28-Oct-05	32.5	1.3	4	6.9	19	61	20
5	BA	-30	10	BFD	12-Dec-06	17	0.6	3.7	5.5	48	39	13
5	BA	-30	50	QA	13-Dec-06	24.8	1.4	5.7	6.8	18	61	21
5	DA	-30	10	BFD	12-Dec-06	15.8	0.8	4.9	6.4	64	28	8
5	DA	-30	50	QA	12-Dec-06	12.4	0.9	7.3	7.1	59	31	10
5	GA	-30	10	BFD	13-Dec-06	19	1.2	6.6	6.9	44	43	13
5	GA	-30	50	QA	12-Dec-06	18.5	1.3	7	6.8	36	45	19
5	LA	-30	10	BFD	13-Dec-06	26.4	1.5	5.7	7.3	36	45	19
5	LA	-30	50	QA	11-Dec-06	17.3	0.5	2.9	5.4	44	43	13
5	OAA	-30	10	BFD	13-Dec-06	16.5	0.9	5.3	8.2	39	40	21
5	OAA	-30	50	QA	12-Dec-06	22.7	0.8	3.6	6.4	42	39	19
5	YAA	-30	10	BFD	13-Dec-06	34.5	1.5	4.4	4.6	27	50	23
5	YAA	-30	50	QA	13-Dec-06	30	1.4	4.8	4.8	28	46	26
6	BA	-3	10	BFD	20-Sep-07	28	0.5	1.9	5.3	24	55	21
6	BA	-3	50	QA	20-Sep-07	25.9	0.5	1.8	5.4	20	56	24

Table B-2 (con't)

SampleEvent	Site	AveDep	Sample	QA	CollectionDate	2 : Cation Exchange Capacity	2 : Exchangeable Sodium	2 : Exchangeable Sodium Percentage	2 : Lime as CaCO3	2 : Sand	2 : Silt	2 : Clay
6	BC	-18	10	BFD	21-Sep-07	29.8	1.2	3.9	6.3	10	50	40
6	BC	-18	50	QA	20-Sep-07							
6	DA	-30	10	BFD	20-Sep-07	28.9	0.6	2.1	6.6	20	55	25
6	DA	-30	50	QA	19-Sep-07							
6	EA	-9	10	BFD	19-Sep-07	12.9	2.7	21	6.1	63	28	9
6	EA	-9	50	QA	19-Sep-07	11.1	1.9	17				
6	EA	-78	10	BFD	19-Sep-07	27.4	1.5	5.4	6.9	36	36	28
6	EA	-78	50	QA	19-Sep-07	19.7	1.2	6.1	7.5	33	43	24
6	GA	-9	10	BFD	19-Sep-07	27.3	0.6	2	5.8	30	46	24
6	GA	-9	50	QA	19-Sep-07	23.5	0.4	1.7	5.1	33	43	24
6	MA	-30	10	BFD	18-Sep-07	19.4	1.1	5.7	10.5	32	50	18
6	MA	-30	50	QA	18-Sep-07	19.4	0.9	4.8	9.9	29	51	20
6	OAA	-30	10	BFD	19-Sep-07	16.3	1	5.9	7.8	40	44	16
6	OAA	-30	50	QA	19-Sep-07							
6	YAA	-18	10	BFD	20-Sep-07	31.1	1.8	5.8	4.6	27	46	27
6	YAA	-18	50	QA	20-Sep-07	31.1	1.6	5.1	4.3	23	47	30
6	YAA	-78	10	BFD	20-Sep-07	30	3.3	11	5.3	29	44	27
6	YAA	-78	50	QA	20-Sep-07							
7	BC	-30	10	BFD	24-Oct-08	35.4	2	5.6	7.4	16	40	44
7	BC	-30	50	QA	24-Oct-08	37	2.5	6.8	7.1	10	44	46
7	EA	-1	10	BFD	23-Oct-08	33.2	0.3	1	5.7	18	54	28
7	EA	-1	50	QA	22-Oct-08	35.8	0.3	0.8	5.7	22	51	27
7	GA	-18	10	BFD	22-Oct-08	21.4	0.9	4.2	7.1	30	46	24
7	GA	-18	50	QA	22-Oct-08	20.8	1	5	7.4	36	43	21
7	GC	-48	10	BFD	22-Oct-08	18.9	0.6	3.1	7.6	20	56	24
7	GC	-48	50	QA	22-Oct-08	18.1	0.5	2.5	7.9	38	42	20
7	YBA	-9	10	BFD	24-Oct-08	26.2	0.7	2.8	6.7	76		27
7	YBA	-9	50	QA	24-Oct-08	28.7	0.6	2.2	6.8	20	56	24
8	BC	-30	10	BFD	29-Oct-09	27.9	1.8	6.5	6	4	50	46
8	BC	-30	55	QA	29-Oct-09	28.2	1.9	6.8	5.8	2	48	50
8	EA	-1	10	BFD	28-Oct-09	30.4		0.2	5.8	16	54	30
8	EA	-1	53	QA	28-Oct-09	31.8		0.3	5.6	20	52	28
8	GA	-18	10	BFD	27-Oct-09	22.8	0.6	2.4	6.9	30	46	24
8	GA	-18	51	QA	27-Oct-09	17	0.5	2.8	6.9	38	42	20
8	GC	-48	10	BFD	27-Oct-09	16.1	0.3	1.8	7.5	42	38	20
8	GC	-48	52	QA	27-Oct-09	18.5	0.3	1.7	8.1	32	44	24
8	YBA	-9	10	BFD	29-Oct-09	27.2	0.5	1.8	6.4	12	62	26
8	YBA	-9	54	QA	29-Oct-09	26.3	0.3	1.3	6.3	18	56	26
9	BC	-30	10	BFD	15-Dec-10	24.9	1.2	5	7.1	8	50	42
9	BC	-30	54	QA	15-Dec-10	25.1	1.2	4.8	7	12	50	38
9	EA	-1	10	BFD	20-Oct-10	21.4	0.1	0.5	5.75	20	52	28
9	EA	-1	53	QA	20-Oct-10	24.1		0.1	6.03	21	51	28
9	GA	-18	10	BFD	20-Oct-10	13.5	0.4	3.3	7.16	32	46	22
9	GA	-18	51	QA	19-Oct-10	12.8	0.7	5.5	7.31	32	44	24
9	GC	-48	10	BFD	20-Oct-10	10.5	0.2	2.3	7.9	48	36	16
9	GC	-48	52	QA	20-Oct-10	11.8	0.3	2.8	7.67	44	37	19
9	YBA	-9	10	BFD	15-Dec-10	21.3	0.3	1.5	6.24	18	56	26
9	YBA	-9	55	QA	15-Dec-10	21.8	0.2	1.1	6.32	14	60	26

Table B-3 AMPP blind field duplicate analyses for suite 3 through 5

SampleEvent	Site	AveDep	Sample	QA	CollectionDate	3 : Nitrate as N	3 : Sulfate (Paste)	4 : Organic Matter	4 : Phosphorus	4 : Potassium	4 : Potassium meq/100g	4 : Zinc	5 : Chlorite	5 : Illite	5 : Kaolinite	5 : Smectite	6 : Barium	6 : Boron	6 : Fluoride
1	BC	-48	10	BFD	15-Oct-03												ND (5)	ND (1)	ND (1)
1	BC	-48	50	QA	15-Oct-03												ND (5)	ND (1)	ND (1)
1	BD	-48	10	BFD	21-Oct-03							0.5					ND (5)	ND (1)	ND (1)
1	BD	-48	50	QA	21-Oct-03												ND (5)	ND (1)	ND (1)
1	BHA	-18	10	BFD	22-Oct-03	2.9	6.2												
1	BHA	-18	50	QA	22-Oct-03	5	5.6												
1	DA	-48	10	BFD	11-Oct-03												ND (5)	ND (1)	ND (1)
1	DA	-48	50	QA	11-Oct-03												ND (5)	ND (2)	ND (1)
1	DB	-9	1	BFD	11-Oct-03	1.9	228												
1	DB	-9	50	QA	11-Oct-03														
1	EA	-48	10	BFD	10-Oct-03												ND (5)	ND (1)	ND (1)
1	EA	-48	50	QA	10-Oct-03												ND (5)	ND (1)	ND (1)
1	GA	-19	1	BFD	08-Oct-03	3.3	3.6						7	31	38	25			
1	GA	-19	50	QA	08-Oct-03	7.1	3.6												
1	GA	-78	10	BFD	08-Oct-03														
1	GA	-78	51	QA	08-Oct-03														
1	GC	-78	10	BFD	09-Oct-03														
1	GC	-78	50	QA	09-Oct-03														
1	LA	-18	10	BFD	02-Oct-03	0.3	58.8												
1	LA	-18	50	QA	02-Oct-03	0.7	47.4												
1	MA	-3	10	BFD	01-Oct-03	1.5	2.4	2.32	8.8	521	521	0.6					ND (5)	0.5	ND (1)
1	MA	-3	50	QA	01-Oct-03	1.2	2	2.2	8.7	524	524	0.53					ND (5)	0.5	ND (1)
1	MA	-8	1	BFD	01-Oct-03	34.8	1.8												
1	MA	-8	52	QA	01-Oct-03	22.1	1.7												
1	MA	-30	10	BFD	01-Oct-03														
1	MA	-30	53	QA	01-Oct-03												ND (5)	0.6	1.1
1	MB	-3	10	BFD	30-Sep-03	7.9	1.6	2	14	483	483	0.22					ND (5)	0.5	ND (1)
1	MB	-3	50	QA	30-Sep-03	7.5	1.8	1.8	12	518	518	0.22					ND (5)	0.5	1.1
1	OAA	-1	10	BFD	09-Oct-03														
1	OAA	-1	50	QA	09-Oct-03														
1	YAA	-9	10	BFD	14-Oct-03	1	5.2												
1	YAA	-9	51	QA	14-Oct-03	0.9	4.2												
1	YAA	-40	1	BFD	14-Oct-03														
1	YAA	-40	50	QA	14-Oct-03														
1	YBA	-48	10	BFD	20-Oct-03												ND (5)	ND (1)	ND (1)
1	YBA	-48	50	QA	20-Oct-03												ND (5)	ND (1)	ND (1)
2	BA	-18	10	BFD	14-Apr-04	44.5	9.62												
2	BA	-18	50	QA	14-Apr-04	52.6	11.7												
2	EA	-18	10	BFD	14-Apr-04	< 0.1 (0.1)	57.6												
2	EA	-18	50	QA	14-Apr-04	< 0.6 (0.6)	35.7												
2	GA	-48	10	BFD	30-Apr-04												1	1.6	1.5
2	GA	-48	50	QA	30-Apr-04												0.66	1.5	1.8
2	MB	-48	10	BFD	30-Apr-04												0.6	1.2	1.2
2	MB	-48	50	QA	30-Apr-04												0.58	1.3	1.3
2	YAA	-18	10	BFD	14-Apr-04	10.4	16.6												
2	YAA	-18	50	QA	14-Apr-04	2.7	14.3												
3	BA	-30	10	BFD	13-Oct-04														
3	BA	-30	50	QA	13-Oct-04														
3	BHA	-18	10	BFD	07-Sep-04	3.4	8.08												
3	BHA	-18	50	QA	07-Sep-04	2.3	8.18												
3	DA	-30	10	BFD	13-Oct-04														
3	DA	-30	50	QA	13-Oct-04														
3	GA	-30	10	BFD	13-Oct-04														
3	GA	-30	50	QA	13-Oct-04														
3	MA	-30	10	BFD	12-Oct-04														
3	MA	-30	50	QA	12-Oct-04														
3	YAA	-30	10	BFD	13-Oct-04														
3	YAA	-30	50	QA	13-Oct-04														
4	BHA	-48	10	BFD	08-Aug-05													0.6	1.5
4	BHA	-48	50	QA	08-Aug-05													0.6	1.5
4	DA	-30	10	BFD	27-Oct-05														
4	DA	-30	50	QA	27-Oct-05														
4	EA	-30	10	BFD	26-Oct-05														
4	EA	-30	50	QA	26-Oct-05														
4	GA	-30	10	BFD	26-Oct-05														
4	GA	-30	50	QA	26-Oct-05														
4	LA	-30	10	BFD	25-Oct-05														
4	LA	-30	50	QA	25-Oct-05														
4	YAA	-30	10	BFD	27-Oct-05														
4	YAA	-30	50	QA	26-Oct-05														
4	YBA	-30	10	BFD	28-Oct-05														
4	YBA	-30	50	QA	28-Oct-05														
5	BA	-30	10	BFD	12-Dec-06														
5	BA	-30	50	QA	13-Dec-06														
5	DA	-30	10	BFD	12-Dec-06														
5	DA	-30	50	QA	12-Dec-06														
5	GA	-30	10	BFD	13-Dec-06														
5	GA	-30	50	QA	12-Dec-06														
5	LA	-30	10	BFD	13-Dec-06														
5	LA	-30	50	QA	11-Dec-06														
5	OAA	-30	10	BFD	13-Dec-06														
5	OAA	-30	50	QA	12-Dec-06														
5	YAA	-30	10	BFD	13-Dec-06														
5	YAA	-30	50	QA	13-Dec-06														
6	BA	-3	10	BFD	20-Sep-07	8.5	2.93	2.24	7.8	126	126	0.48					1	0.21	
6	BA	-3	50	QA	20-Sep-07	7.6	3.08	2.2	13			0.42					0.96	0.24	
6	BC	-18	10	BFD	21-Sep-07	3.6	5.66												
6	BC	-18	50	QA	20-Sep-07														
6	DA	-30	10	BFD	20-Sep-07														
6	DA	-30	50	QA	19-Sep-07														
6	EA	-9	10	BFD	19-Sep-07	6.8	147												
6	EA	-9	50	QA	19-Sep-07														
6	EA	-78	10	BFD	19-Sep-07														
6	EA	-78	50	QA	19-Sep-07		23.5												
6	GA	-9	10	BFD	19-Sep-07	5.8	1.69												
6	GA	-9	50	QA	19-Sep-07	9.9	2.01												
6	MA	-30	10	BFD	18-Sep-07														
6	MA	-30	50	QA	18-Sep-07		28.8												
6	OAA	-30	10	BFD	19-Sep-07														
6	OAA	-30	50	QA	19-Sep-07														
6	YAA	-18	10	BFD	20-Sep-07	4.4	15												
6	YAA	-18	50	QA	20-Sep-07	7.2	20.6												
6	YAA	-78	10	BFD	20-Sep-07														
6	YAA	-78	50	QA	20-Sep-07														
7	BC	-30	10	BFD	24-Oct-08														
7	BC	-30	50	QA	24-Oct-08														
7	EA	-1	10	BFD	23-Oct-08														
7	EA	-1	50	QA	22-Oct-08														
7	GA	-18	10	BFD	22-Oct-08	11	26												
7	GA	-18	50	QA	22-Oct-08	6.4	2.8												

Table B-3 (con't)

SampleEvent	Site	AveDep	Sample	QA	CollectionDate	3 : Nitrate as N	3 : Sulfate (Paste)	4 : Organic Matter	4 : Phosphorus	4 : Potassium	4 : Potassium meq/100g	4 : Zinc	5 : Chlorite	5 : Illite	5 : Kaolinite	5 : Smectite	6 : Barium	6 : Boron	6 : Fluoride
7	GC	-48	10	BFD	22-Oct-08												0.33		0.76
7	GC	-48	50	QA	22-Oct-08												0.39		0.99
7	YBA	-9	10	BFD	24-Oct-08	16	2.2												
7	YBA	-9	50	QA	24-Oct-08	10	3												
8	BC	-30	10	BFD	29-Oct-09														
8	BC	-30	55	QA	29-Oct-09														
8	EA	-1	10	BFD	28-Oct-09														
8	EA	-1	53	QA	28-Oct-09														
8	GA	-18	10	BFD	27-Oct-09	5	6.9												
8	GA	-18	51	QA	27-Oct-09	5.4	14	1.34	2.9	75	75	0.47					0.45		0.78
8	GC	-48	10	BFD	27-Oct-09												0.46		0.64
8	GC	-48	52	QA	27-Oct-09	3.8	8.3												
8	YBA	-9	10	BFD	29-Oct-09	6.9	2.5												
8	YBA	-9	54	QA	29-Oct-09	8.1	1.6												
9	BC	-30	10	BFD	15-Dec-10														
9	BC	-30	54	QA	15-Dec-10	6.6	40.1												
9	EA	-1	10	BFD	20-Oct-10														
9	EA	-1	53	QA	20-Oct-10														
9	GA	-18	10	BFD	20-Oct-10	5.8	23												
9	GA	-18	51	QA	19-Oct-10														
9	GC	-48	10	BFD	20-Oct-10												0.4	0.1	1.1
9	GC	-48	52	QA	20-Oct-10														
9	YBA	-9	10	BFD	15-Dec-10	5.3	1.7												
9	YBA	-9	55	QA	15-Dec-10	5.6	2.3												

Table B-4 AMPP blind field duplicate relative percent difference for suite 1 data pairs.

Site	AveDep	Sample	QA	Collection Date	1 : Saturation Percentage	1 : pH (Paste)	1 : Electrical Conductivity (Paste)	1 : Calcium (Paste)	1 : Magnesium (Paste)	1 : Sodium (Paste)	1 : Sodium Adsorption Ratio	1 : Alkalinity (Paste)	1 : Bicarbonate (Paste)	1 : Chloride (Paste)
BC	-48	10	BFD	10/15/03	2%	0%	4%	5%	7%	6%	4%	7%	no data	no data
BD	-48	10	BFD	10/21/03	6%	1%	41%	62%	50%	27%	2%	19%	no data	no data
BHA	-18	10	BFD	10/22/03	0%	0%	5%	29%	11%	5%	8%	19%	no data	no data
DA	-48	10	BFD	10/11/03	9%	0%	1%	0%	1%	4%	0%	19%	no data	no data
DB 1	-9	1	BFD	10/11/03	14%	6%	4%	72%	49%	15%	43%	42%	no data	no data
EA	-48	50	QA	10/10/03	11%	0%	28%	52%	43%	35%	11%	0%	no data	no data
GA	-19	1	BFD	10/08/03	1%	0%	13%	17%	14%	5%	0%	14%	no data	no data
GA	-78	10	BFD	10/08/03	2%	0%	2%	8%	6%	3%	2%	7%	no data	no data
GC 2	-78	10	BFD	10/09/03	0%	1%	8%	8%	11%	5%	0%	11%	no data	no data
LA	-18	10	BFD	10/02/03	3%	0%	19%	9%	17%	46%	39%	4%	no data	no data
MA	-8	1	BFD	10/01/03	3%	1%	3%	24%	19%	0%	0%	17%	no data	no data
MA	-30	10	BFD	10/01/03	4%	3%	9%	30%	16%	15%	4%	4%	no data	no data
MA	-3	10	BFD	10/01/03	0%	5%	15%	20%	15%	54%	50%	18%	no data	no data
MB	-3	10	BFD	09/30/03	3%	0%	6%	6%	0%	13%	12%	0%	no data	no data
OAA	-1	10	BFD	10/09/03	2%	0%	6%	0%	0%	0%	0%	1%	no data	no data
YAA	-40	1	BFD	10/14/03	18%	0%	3%	8%	7%	4%	7%	10%	no data	no data
YAA	-9	10	BFD	10/14/03	3%	0%	6%	13%	16%	13%	5%	4%	no data	no data
YBA	-48	10	BFD	10/20/03	4%	0%	10%	12%	12%	21%	14%	0%	no data	no data
BA	-18	10	BFD	04/14/04	8%	0%	14%	11%	16%	10%	16%	22%	no data	57%
EA	-18	10	BFD	04/14/04	2%	1%	39%	43%	46%	18%	4%	0%	no data	67%
GA	-48	10	BFD	04/30/04	7%	2%	21%	12%	29%	48%	37%	9%	no data	38%
MB	-48	10	BFD	04/30/04	3%	0%	9%	31%	16%	5%	21%	0%	no data	29%
YAA	-18	10	BFD	04/14/04	1%	11%	4%	20%	16%	8%	0%	108%	no data	40%
BA	-30	10	BFD	10/13/04	4%	0%	6%	2%	5%	7%	3%	no data	no data	no data
BHA	-18	10	BFD	09/07/04	12%	1%	1%	2%	4%	2%	0%	0%	no data	9%
DA	-30	10	BFD	10/13/04	1%	2%	25%	4%	32%	40%	33%	no data	no data	no data
GA	-30	10	BFD	10/13/04	3%	0%	27%	29%	22%	31%	18%	no data	no data	no data
MA	-30	10	BFD	10/12/04	3%	0%	14%	18%	15%	14%	6%	18%	no data	no data
YAA	-30	10	BFD	10/13/04	3%	0%	25%	16%	22%	32%	23%	no data	no data	no data
DA	-30	10	BFD	10/27/05	2%	1%	1%	11%	4%	17%	19%	no data	22%	no data
EA	-30	10	BFD	10/26/05	1%	0%	36%	47%	58%	79%	53%	no data	41%	no data
GA	-30	10	BFD	10/26/05	1%	0%	38%	40%	46%	49%	27%	no data	9%	no data
LA	-30	10	BFD	10/25/05	4%	0%	5%	6%	11%	20%	16%	no data	10%	no data
YAA	-30	50	QA	10/26/05	2%	0%	4%	7%	25%	22%	15%	no data	32%	no data
YBA	-30	10	BFD	10/28/05	2%	1%	22%	22%	25%	19%	7%	no data	11%	no data
BA	-30	10	BFD	12/12/06	27%	3%	60%	41%	39%	102%	87%	no data	27%	154%
DA	-30	10	BFD	12/12/06	5%	0%	29%	26%	33%	45%	27%	no data	23%	157%
GA	-30	50	QA	12/12/06	3%	0%	9%	12%	2%	2%	2%	no data	17%	8%
LA	-30	50	QA	12/11/06	13%	1%	103%	110%	133%	133%	83%	no data	10%	89%
OAA	-30	50	QA	12/12/06	16%	1%	70%	128%	131%	65%	9%	no data	17%	27%
YAA	-30	10	BFD	12/13/06	2%	1%	20%	15%	19%	28%	19%	no data	24%	123%
BA	-3	10	BFD	09/18/07	7%	1%	13%	29%	33%	24%	7%	no data	25%	10%
BC	-18	10	BFD	09/18/07	no data	no data	26%	30%	36%	15%	4%	no data	no data	no data
DA	-30	10	BFD	09/18/07	no data	no data	162%	123%	163%	189%	166%	no data	no data	no data
EA	-78	10	BFD	09/18/07	13%	1%	2%	2%	12%	3%	6%	no data	24%	4%
EA	-9	10	BFD	09/18/07	1%	2%	2%	7%	7%	4%	0%	no data	no data	no data
GA	-9	10	BFD	09/18/07	5%	1%	23%	4%	25%	17%	9%	no data	35%	54%
MA	-30	10	BFD	09/18/07	2%	1%	1%	12%	14%	7%	14%	no data	5%	20%
OAA	-30	10	BFD	09/18/07	no data	no data	20%	no data	no data	no data	no data	no data	no data	no data
YAA	-78	10	BFD	09/18/07	no data	no data	39%	47%	51%	44%	21%	no data	no data	no data
YAA	-18	10	BFD	09/18/07	1%	3%	25%	43%	54%	26%	2%	no data	2%	33%
BC	-30	50	QA	10/24/08	17%	1%	5%	24%	17%	17%	28%	no data	9%	3%
EA	-1	50	QA	10/22/08	0%	3%	21%	35%	28%	52%	65%	no data	23%	23%
GA	-18	50	QA	10/22/08	7%	3%	33%	75%	55%	8%	29%	no data	12%	125%
GC	-48	50	QA	10/22/08	13%	1%	14%	24%	11%	41%	48%	no data	52%	22%
YBA	-9	50	QA	10/24/08	4%	1%	23%	13%	12%	25%	16%	no data	12%	26%
BC	-30	10	BFD	10/29/09	12%	0%	25%	35%	33%	29%	13%	no data	7%	30%
EA	-1	10	BFD	10/28/09	2%	1%	1%	22%	4%	0%	6%	no data	3%	18%
GA	-18	10	BFD	10/27/09	4%	3%	49%	39%	62%	61%	40%	no data	8%	24%
GC	-48	10	BFD	10/27/09	16%	0%	40%	34%	43%	38%	24%	no data	11%	17%
YBA	-9	10	BFD	10/29/09	2%	1%	15%	19%	29%	20%	7%	no data	10%	56%
		Average RPD (%)			5.5%	1.2%	21.4%	27.4%	28.8%	28.1%	20.5%	14.1%	17.8%	46.7%
		Completeness (%)			93%	93%	100%	98%	98%	98%	98%	41%	44%	44%

Table B-5 AMPP blind field duplicate relative percent difference for suite 2 data pairs.

Site	AveDep	Sample	QA	Collection Date	2 : Cation Exchange Capacity	2 : Exchangeable Sodium	2 : Exchangeable Sodium Percentage	2 : Lime as CaCO3	2 : Sand	2 : Silt	2 : Clay	2 : Texture
BC	-48	10	BFD	10/15/03	6%	2%	19%	2%	0%	2%	2%	match
BD	-48	10	BFD	10/21/03	3%	9%	16%	6%	5%	0%	4%	match
BHA	-18	10	BFD	10/22/03	6%	29%	34%	27%	108%	2%	12%	match
DA	-48	10	BFD	10/11/03	2%	9%	40%	4%	8%	13%	18%	match
DB 1	-9	1	BFD	10/11/03	20%	28%	40%	3%	12%	3%	11%	match
EA	-48	50	QA	10/10/03	9%	4%	22%	1%	6%	0%	7%	match
GA	-19	1	BFD	10/08/03	1%	13%	6%	6%	no data	4%	4%	match
GA	-78	10	BFD	10/08/03	30%	12%	17%	4%	1%	6%	0%	match
GC 2	-78	10	BFD	10/09/03	11%	0%	6%	17%	18%	21%	29%	match
LA	-18	10	BFD	10/02/03	11%	19%	15%	4%	12%	2%	8%	match
MA	-8	1	BFD	10/01/03	39%	18%	56%	1%	4%	2%	0%	match
MA	-30	10	BFD	10/01/03	15%	0%	17%	2%	7%	2%	4%	match
MA	-3	10	BFD	10/01/03	20%	15%	5%	2%	4%	2%	0%	match
MB	-3	10	BFD	09/30/03	2%	15%	18%	8%	7%	5%	0%	match
OAA	-1	10	BFD	10/09/03	10%	22%	43%	25%	4%	0%	4%	match
YAA	-40	1	BFD	10/14/03	11%	5%	21%	1%	2%	0%	6%	match
YAA	-9	10	BFD	10/14/03	11%	20%	40%	0%	4%	4%	13%	match
YBA	-48	10	BFD	10/20/03	13%	4%	3%	2%	12%	6%	18%	match
BA	-18	10	BFD	04/14/04	5%	49%	73%	5%	8%	2%	5%	match
EA	-18	10	BFD	04/14/04	17%	34%	32%	1%	38%	2%	15%	match
GA	-48	10	BFD	04/30/04	23%	53%	29%	10%	15%	13%	31%	match
MB	-48	10	BFD	04/30/04	9%	7%	19%	0%	7%	10%	7%	match
YAA	-18	10	BFD	04/14/04	8%	1%	7%	5%	15%	9%	0%	match
BA	-30	10	BFD	10/13/04	5%	0%	16%	0%	0%	2%	7%	match
BHA	-18	10	BFD	09/07/04	26%	1%	32%	8%	127%	12%	4%	match
DA	-30	10	BFD	10/13/04	2%	16%	16%	3%	2%	0%	11%	match
GA	-30	10	BFD	10/13/04	1%	40%	36%	0%	2%	0%	5%	match
MA	-30	10	BFD	10/12/04	0%	22%	19%	1%	13%	2%	16%	match
YAA	-30	10	BFD	10/13/04	1%	5%	9%	2%	7%	2%	11%	match
DA	-30	10	BFD	10/27/05	17%	55%	60%	12%	1%	12%	29%	match
EA	-30	10	BFD	10/26/05	4%	12%	15%	6%	5%	8%	10%	match
GA	-30	10	BFD	10/26/05	1%	9%	5%	1%	10%	5%	12%	match
LA	-30	10	BFD	10/25/05	0%	20%	25%	1%	5%	8%	5%	match
YAA	-30	50	QA	10/26/05	5%	6%	65%	21%	0%	0%	0%	match
YBA	-30	10	BFD	10/28/05	5%	0%	2%	1%	10%	2%	5%	match
BA	-30	10	BFD	12/12/06	37%	80%	43%	21%	91%	44%	47%	match
DA	-30	10	BFD	12/12/06	24%	12%	39%	10%	8%	10%	22%	match
GA	-30	50	QA	12/12/06	3%	8%	6%	1%	20%	5%	38%	match
LA	-30	50	QA	12/11/06	42%	100%	65%	30%	20%	5%	38%	match
OAA	-30	50	QA	12/12/06	32%	12%	38%	25%	7%	3%	10%	match
YAA	-30	10	BFD	12/13/06	14%	7%	9%	4%	4%	8%	12%	match
BA	-3	10	BFD	09/18/07	8%	0%	5%	2%	18%	2%	13%	match
BC	-18	10	BFD	09/18/07	no data	no data	no data	no data	no data	no data	no data	match
DA	-30	10	BFD	09/18/07	no data	no data	no data	no data	no data	no data	no data	match
EA	-78	10	BFD	09/18/07	33%	22%	12%	8%	9%	18%	15%	match
EA	-9	10	BFD	09/18/07	15%	no data	21%	no data	no data	no data	no data	match
GA	-9	10	BFD	09/18/07	15%	40%	16%	13%	10%	7%	0%	match
MA	-30	10	BFD	09/18/07	0%	20%	17%	6%	10%	2%	11%	match
OAA	-30	10	BFD	09/18/07	no data	no data	no data	no data	no data	no data	no data	match
YAA	-78	10	BFD	09/18/07	no data	no data	no data	no data	no data	no data	no data	match
YAA	-18	10	BFD	09/18/07	0%	12%	13%	7%	16%	2%	11%	match
BC	-30	50	QA	10/24/08	4%	22%	19%	4%	46%	10%	4%	no match
EA	-1	50	QA	10/22/08	8%	0%	22%	0%	20%	6%	4%	no match
GA	-18	50	QA	10/22/08	3%	11%	17%	4%	18%	7%	13%	match
GC	-48	50	QA	10/22/08	4%	18%	21%	4%	62%	29%	18%	no match
YBA	-9	50	QA	10/24/08	9%	15%	24%	1%	117%	no data	12%	no match
BC	-30	10	BFD	10/29/09	1%	5%	5%	3%	67%	4%	8%	no match
EA	-1	10	BFD	10/28/09	5%	no data	40%	4%	22%	4%	7%	no match
GA	-18	10	BFD	10/27/09	29%	18%	15%	0%	24%	9%	18%	no match
GC	-48	10	BFD	10/27/09	14%	0%	6%	8%	27%	15%	18%	no match
YBA	-9	10	BFD	10/29/09	3%	50%	32%	2%	40%	10%	0%	no match
		Average RPD (%)			11.4%	18.3%	24.0%	6.2%	20.6%	6.5%	11.3%	no data
		Completeness (%)			93%	90%	93%	92%	90%	90%	92%	100%

Table B-6 AMPP blind field duplicate relative percent difference for suite 3 through 5 data pairs.

Site	AveDep	Sample	QA	Collection Date	3 : Nitrate as N	3 : Sulfate (Paste)	4 : Organic Matter	4 : Phosphorus	4 : Potassium	4 : Zinc	6 : Barium	6 : Boron	6 : Fluoride	6 : Selenium	RPD
BC	-48	10	BFD	10/15/03	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	5%
BD	-48	10	BFD	10/21/03	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	17%
BHA	-18	10	BFD	10/22/03	53%	10%	no data	no data	no data	no data	no data	no data	no data	no data	21%
DA	-48	10	BFD	10/11/03	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	9%
DB 1	-9	1	BFD	10/11/03	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	24%
EA	-48	50	QA	10/10/03	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	15%
GA	-19	1	BFD	10/08/03	73%	0%	no data	no data	no data	no data	no data	no data	no data	no data	11%
GA	-78	10	BFD	10/08/03	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	7%
GC 2	-78	10	BFD	10/09/03	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	10%
LA	-18	10	BFD	10/02/03	80%	21%	no data	no data	no data	no data	no data	no data	no data	no data	18%
MA	-8	1	BFD	10/01/03	45%	6%	no data	no data	no data	no data	no data	no data	no data	no data	14%
MA	-30	10	BFD	10/01/03	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	9%
MA	-3	10	BFD	10/01/03	22%	18%	5%	1%	1%	12%	no data	0%	no data	no data	13%
MB	-3	10	BFD	09/30/03	5%	12%	11%	15%	7%	0%	no data	0%	no data	no data	7%
OAA	-1	10	BFD	10/09/03	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	8%
YAA	-40	1	BFD	10/14/03	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	7%
YAA	-9	10	BFD	10/14/03	11%	21%	no data	no data	no data	no data	no data	no data	no data	no data	11%
YBA	-48	10	BFD	10/20/03	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	9%
BA	-18	10	BFD	04/14/04	17%	20%	no data	no data	no data	no data	no data	no data	no data	no data	19%
EA	-18	10	BFD	04/14/04	no data	47%	no data	no data	no data	no data	no data	no data	no data	no data	24%
GA	-48	10	BFD	04/30/04	no data	no data	no data	no data	no data	no data	41%	6%	18%	9%	22%
MB	-48	10	BFD	04/30/04	no data	no data	no data	no data	no data	no data	3%	8%	8%	33%	11%
YAA	-18	10	BFD	04/14/04	118%	15%	no data	no data	no data	no data	no data	no data	no data	no data	21%
BA	-30	10	BFD	10/13/04	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	4%
BHA	-18	10	BFD	09/07/04	39%	1%	no data	no data	no data	no data	no data	no data	no data	no data	16%
DA	-30	10	BFD	10/13/04	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	13%
GA	-30	10	BFD	10/13/04	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	15%
MA	-30	10	BFD	10/12/04	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	11%
YAA	-30	10	BFD	10/13/04	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	11%
DA	-30	10	BFD	10/27/05	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	18%
EA	-30	10	BFD	10/26/05	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	25%
GA	-30	10	BFD	10/26/05	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	17%
LA	-30	10	BFD	10/25/05	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	9%
YAA	-30	50	QA	10/26/05	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	14%
YBA	-30	10	BFD	10/28/05	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	9%
BA	-30	10	BFD	12/12/06	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	56%
DA	-30	10	BFD	12/12/06	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	29%
GA	-30	50	QA	12/12/06	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	8%
LA	-30	50	QA	12/11/06	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	61%
OAA	-30	50	QA	12/12/06	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	37%
YAA	-30	10	BFD	12/13/06	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	19%
BA	-3	10	BFD	09/18/07	11%	5%	2%	50%	no data	no data	no data	no data	no data	no data	13%
BC	-18	10	BFD	09/18/07	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	22%
DA	-30	10	BFD	09/18/07	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	161%
EA	-78	10	BFD	09/18/07	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	12%
EA	-9	10	BFD	09/18/07	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	7%
GA	-9	10	BFD	09/18/07	52%	17%	no data	no data	no data	no data	no data	no data	no data	no data	19%
MA	-30	10	BFD	09/18/07	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	9%
OAA	-30	10	BFD	09/18/07	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	20%
YAA	-78	10	BFD	09/18/07	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	40%
YAA	-18	10	BFD	09/18/07	48%	31%	no data	no data	no data	no data	no data	no data	no data	no data	18%
BC	-30	50	QA	10/24/08	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	14%
EA	-1	50	QA	10/22/08	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	19%
GA	-18	50	QA	10/22/08	53%	161%	no data	no data	no data	no data	no data	no data	no data	no data	35%
GC	-48	50	QA	10/22/08	no data	no data	no data	no data	no data	no data	17%	no data	26%	no data	24%
YBA	-9	50	QA	10/24/08	46%	31%	no data	no data	no data	no data	no data	no data	no data	no data	23%
BC	-30	10	BFD	10/29/09	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	17%
EA	-1	10	BFD	10/28/09	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	9%
GA	-18	10	BFD	10/27/09	8%	68%	no data	no data	no data	no data	no data	no data	no data	no data	27%
GC	-48	10	BFD	10/27/09	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	19%
YBA	-9	10	BFD	10/29/09	16%	44%	no data	no data	no data	no data	no data	no data	no data	no data	20%
		Average RPD (%)			40.9%	29.4%	5.9%	22.2%	3.8%	6.2%	20.3%	3.6%	17.5%	20.9%	19.9%
		Completeness (%)			28%	30%	5%	5%	3%	3%	5%	7%	5%	3%	50%

Appendix C

Spatial Variability of Soils

Depth Variability of Soil Data

Variability of field measurements due to sampling and laboratory techniques was found to account for variations of up to 15% to 30%. Another source of soil variability is natural spatial variation ***that*** occurs laterally and with depth. AMPP was designed to minimize effects of spatial variability by using composite soil samples and by using standardized soil sample depths. However, it is important to understand the magnitude of spatial variability, especially when comparing AMPP data to soils data compiled from other sources.

Soil properties often vary with depth. Natural soil-forming processes and agricultural management tend to amplify differences in soil properties within the soil profile. These changes result principally from the fact that water content, water movement, temperature, and biological activity in soils all vary with depth. Surface soil layers typically have more flux of water, have more pronounced seasonal variation in water content and temperature, and have more biological activity (e.g. root mass and microbial activity) than in deeper layers. Through hundreds to thousands of years, these processes tend to increase organic matter levels, decrease pH, and remove soluble salts and lime near the soil surface. Soluble salts, lime, and clay minerals often accumulate within or near the base of the root zone at 24 to 30 inches.

Tongue River soils data were used to assess the degree of variability in soil properties with depth. Most soil properties including physical properties such as texture and chemical properties such as EC and exchangeable sodium percentage (ESP) were found to vary significantly with depth. The effect of soil depth on soil properties is important because any monitoring program which seeks to compare two or more soils, or identify trends in soil properties through time must carefully control depth. Soil properties in areas within a field that have been eroded, leveled, or have received recent sediment deposition may be significantly different than more stable portions of the same field.

Spatial Variability of Soil Data

Another important factor which influences variability of soil monitoring data is lateral spatial variability. In order to assess the degree of spatial variability in AMPP fields, each composite subsample collected in the upper 24 inches from two representative fields were individually analyzed. Field MA, which was 60 acres in size, was sampled using 12 subsamples, while field YAA (19.3 acres) had 10 subsamples.

Results of the spatial variability tests are shown for field MA in Table C-1 and Figure C-1 through C-3. Spatial location of the individual samples is shown on the X and Y axis, while the size of the symbol at each location indicates the value measured for each soil property. Results for the 0 to 6, 6 to 12, and 12 to 24 inch layer are shown on the left, middle and right, respectively. Results for selected parameters in field YAA are shown in Table C-1 and Figure C-4.

A measure of the variability of the individual samples can be obtained by determining the standard deviation, a measure of variability. Standard deviation is divided by the mean to determine the coefficient of variability (CV). A series of measurements that has a CV of 20% means that 67% of the samples will fall within 80% to 120% of the mean, while about 16% of samples will be less than 80% of the mean and 16% greater than 120% of the mean.

Results of spatial variability testing (Table C-1) showed that soil pH had little variability, soil texture had CV values from 10% to 40%, and chemical properties such as EC, SAR, and ESP had greatest variability. CV ranged from 20% to over 100%. In general, the variability of chemical properties was greatest deeper in the soil profile. The large variability that occurs within a field indicates that a reliable soil testing program designed to identify trends should use the same sampling locations each time the field is sampled.

Table C-1 Spatial variability of individual samples collected at three depths from randomly spaced locations in fields MA and YAA

Site and Depth	pH, Saturated Paste	Conduct-ivity, Paste Extract	Calcium, Saturated Paste	Magnesium, Saturated Paste	Sodium, Saturated Paste	Sodium Adsorp-tion Ratio (SAR)	Saturation	Cation Ex-change Capacity	Exchangeable Sodium Percent-age	Lime as CaCO3 (%)	Sand (%)	Silt (%)	Clay (%)
	Coefficient of Variability (Population standard deviation divided by the mean)												
MA 0-6	1.2%	14.7%	14.9%	19.3%	36.8%	35.4%	9.7%	19.1%	18.7%	20.6	30.3	11.5	10.8
MA 6-12	1.7%	21.7%	31.5%	36.0%	48.7%	52.0%	14.5%	17.6%	20.6%	18.6	44.2	12.4	20.0
MA 12-24	3.2%	55.3%	37.4%	87.3%	107.7%	96.1%	11.4%	27.8%	48.6%	19.4	53.5	17.6	17.4
YAA 0-6	1.7%	77.4%	120.2%	120.9%	55.2%	17.6%	13.7%						
YAA 6-12	1.9%	63.3%	94.1%	96.5%	48.0%	17.1%	16.9%						
YAA 12-24	1.3%	65.1%	64.2%	72.8%	88.0%	46.9%	13.7%						

Field MA is 60 acres in size and consisted of 12 subsamples, field YAA is 19.3 acres in size and consists of 10 subsamples.

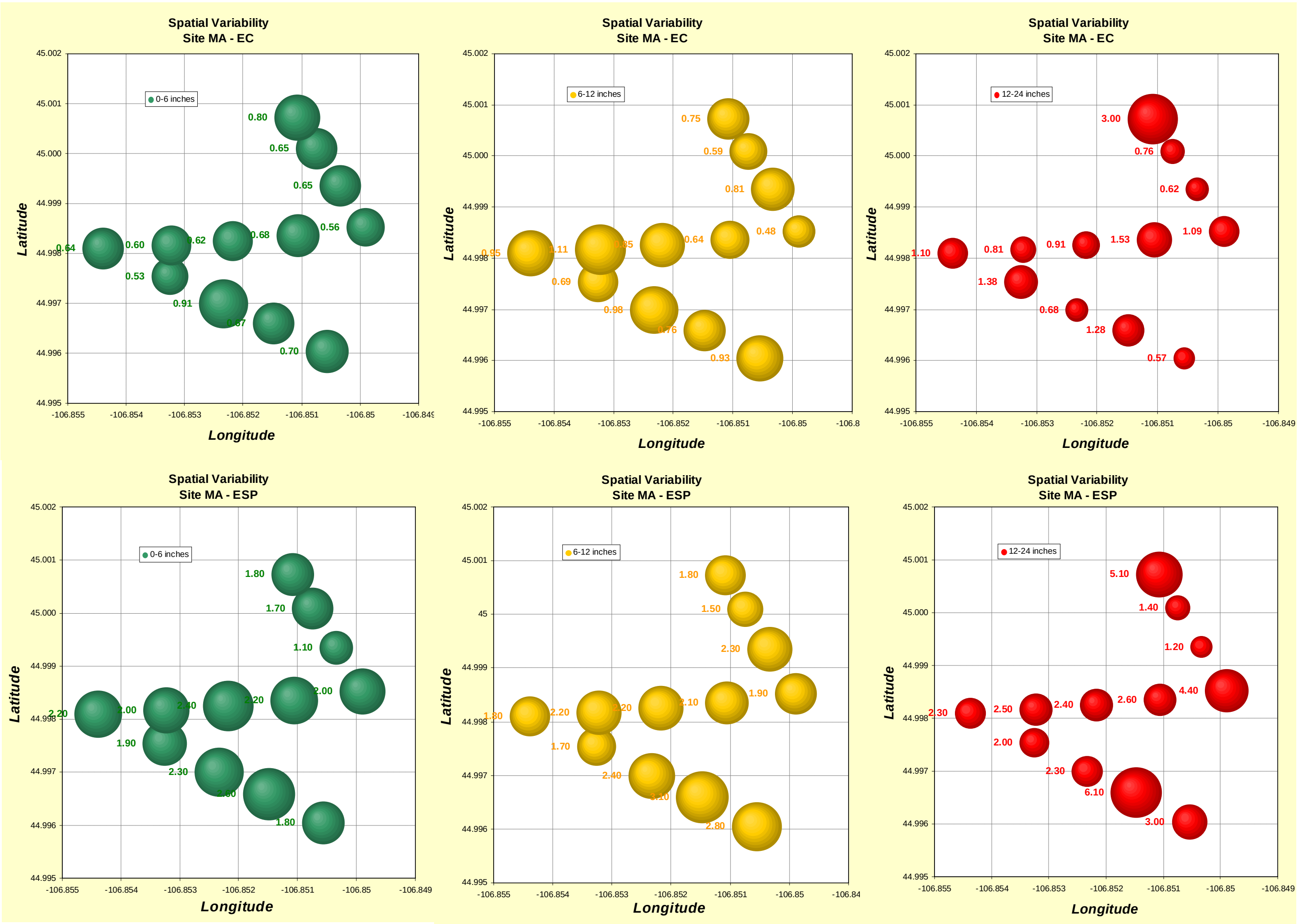


Figure C-1 Variation in electrical conductivity (dS/m) and exchangeable sodium percentage (%) for 12 composite samples from site MA collected at three depths 0 to 6 inches (green-left), 6 to 12 inches (yellow-middle), and 12 to 24 inches (red-right).

The size of the symbol indicates the EC and ESP values.

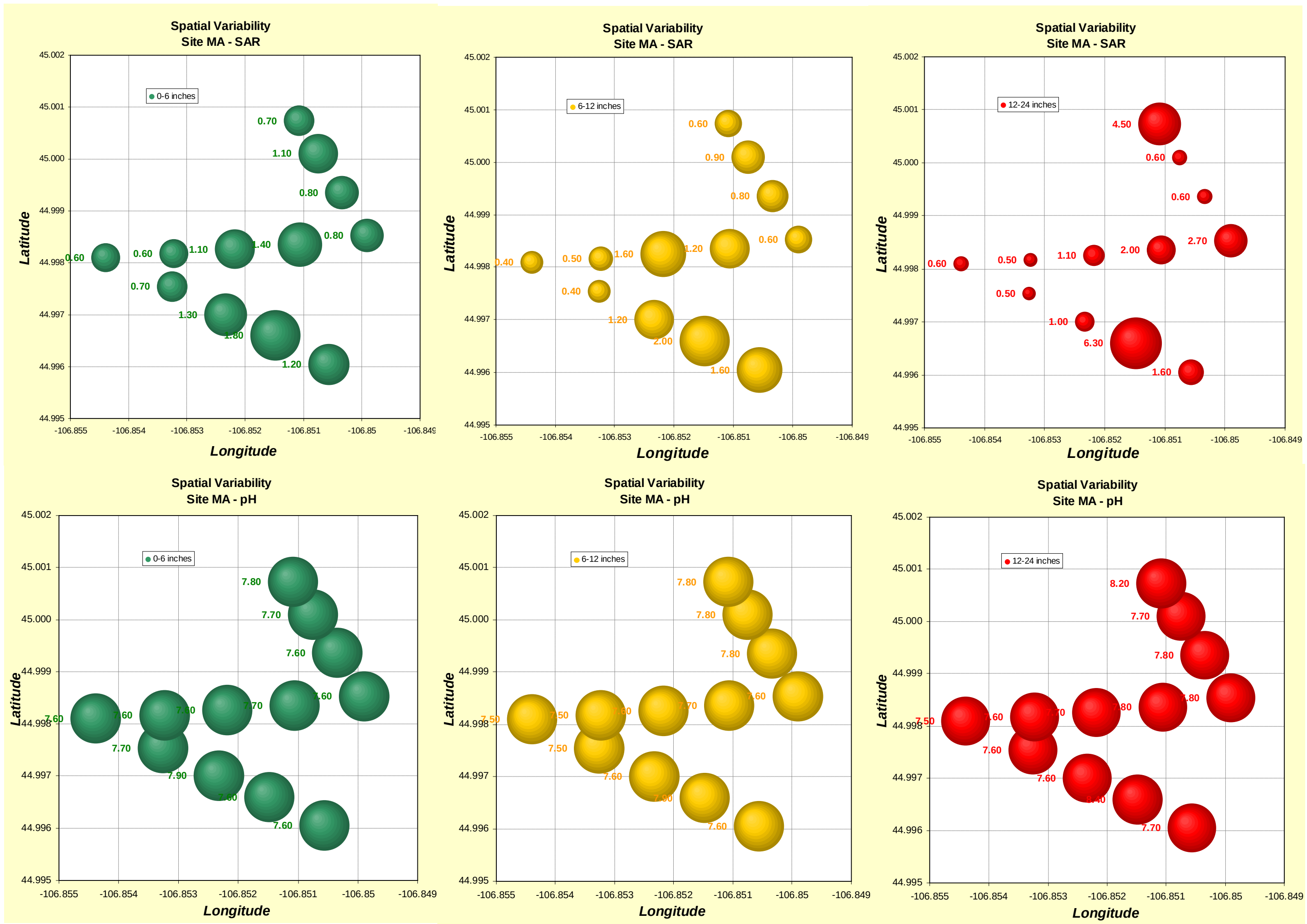


Figure C-2 Variation in sodium adsorption ratio and pH for 12 composite samples from site MA collected at three depths 0 to 6 inches (green-left), 6 to 12 inches (yellow-middle), and 12 to 24 inches (red-right).

The size of the symbol indicates the SAR and pH values.

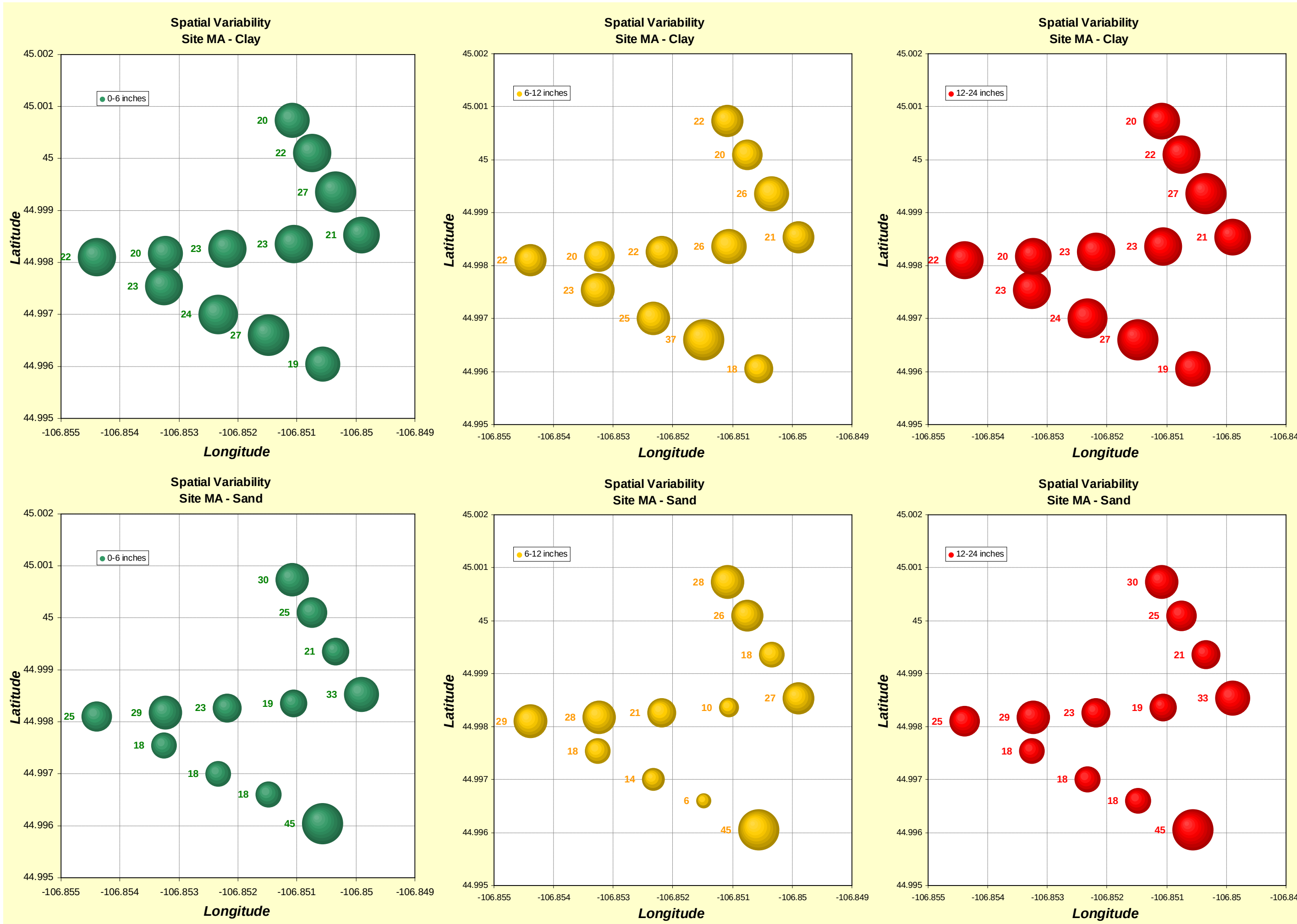


Figure C-3 Variation in clay and sand content (%) for 12 composite samples from site MA collected at three depths 0 to 6 inches (green-left), 6 to 12 inches (yellow-middle), and 12 to 24 inches (red-right).

The size of the symbol indicates the clay and sand values.

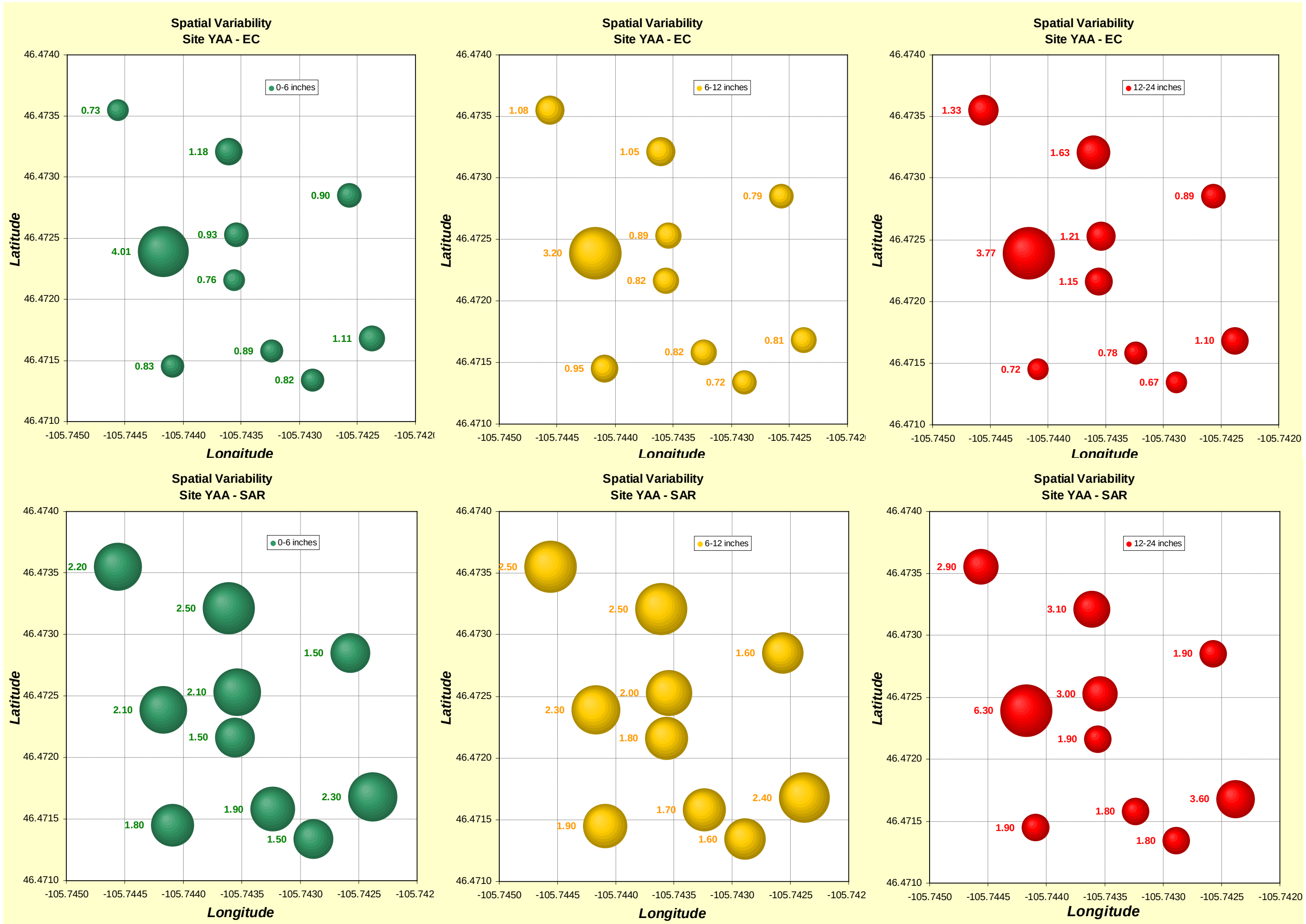


Figure C-4 Variation in electrical conductivity (dS/m) and sodium adsorption ratio for 10 composite samples from site YAA collected at three depths 0 to 6 inches (green-left), 6 to 12 inches (yellow-middle), and 12 to 24 inches (red-right).

The size of the symbol indicates the EC and SAR values.

Table C-2 illustrates the magnitude of errors that may result from selecting a single soil sample (as opposed to a composite sample as was used in the AMPP) to represent an entire field. For example, in field MA, average surface EC was 0.67 dS/m, but individual samples varied from 0.53 to 0.91 dS/m. Even greater differences occurred at depth, where in field YAA, average EC from 12 to 24 inches was 1.33 dS/m, but individual samples varied from 0.67 to 3.77 dS/m. Table C-3 provides an estimate of error associated with estimated mean EC at 0 to 6 and 12 to 24 inches in field MA for varying numbers of composite samples. Estimated mean for a field cannot be precisely derived using 10 or even 100 composite subsamples. However, 10 subsamples yield precision that is comparable to larger numbers of subsamples, and is far superior to use of a single sampling location. Additionally, when the same subsample locations are used each time a field is sampled, field variability is eliminated and chronological results should more precisely identify trends than if subsample locations are changed each sampling event.

Table C-2 Average, low, and high electrical conductivity measurements from samples collected at three depths in fields MA and YAA

Location	Average	Lowest	Highest	Std Dev	Coef Var
	Electrical Conductivity Paste (dS/m)				
MA 0-6	0.67	0.53	0.91	0.10	14.7%
MA 6-12	0.79	0.48	1.11	0.17	21.7%
MA 12-24	1.14	0.57	3.00	0.63	55.3%
YAA 0-6	1.22	0.73	4.01	0.94	77.4%
YAA 6-12	1.11	0.72	3.20	0.70	63.3%
YAA 12-24	1.33	0.67	3.77	0.86	65.1%

Field MA is 60 acres in size and consisted of 12 subsamples, field YAA is 19.3 acres in size and consists of 10 subsamples.

Table C-3 Effect of number of composite sub-samples on the potential error in measuring the electrical conductivity (dS/m) at site MA for the 0 to 6 and 12 to 24 inch depths

Location	Sample Size	Mean	Std Error	Lowest 5%	Highest 95%
MA 0-6	1	0.67	0.10	0.51	0.83
MA 0-6	2	0.67	0.07	0.55	0.78
MA 0-6	5	0.67	0.04	0.60	0.74
MA 0-6	10	0.67	0.03	0.62	0.72
MA 0-6	100	0.67	0.01	0.65	0.68
MA 12-24	1	1.14	0.63	0.10	2.19
MA 12-24	2	1.14	0.45	0.41	1.88
MA 12-24	5	1.14	0.28	0.68	1.61
MA 12-24	10	1.14	0.20	0.81	1.47
MA 12-24	100	1.14	0.06	1.04	1.25

Appendix D

Initial Soil Sampling and Characterization

Sixteen fields were selected for study in Tier 2 AMPP (Table D-1). Ten fields were irrigated with Tongue River water and were located along the entire length of the River from above the Tongue River Reservoir to the lower T&Y Irrigation District east of Miles City. Two additional Tongue River fields were selected that were non-irrigated, but were located in a similar landscape position and had similar soils as the nearby Tier 2 fields. Two fields were irrigated with water from Tongue River tributaries (Hanging Woman and Otter Creek), and two reference fields were irrigated with Yellowstone River or Big Horn River water. Throughout this report, sites are discussed in order starting with the most upstream Tongue River sites, and ending with sites irrigated with Tributary water or other irrigation sources.

Table D-1 Characteristics of Sites Selected for Tier 2 AMPP Monitoring.

Site	Irrigation	Irrigation Water Source	County	Mapped Soil Series	Mapped Classification
MA	Irrigated/Pivot	Tongue	Big Horn	Hfa - Haverson loam	fine-loamy, mixed (calcareous) mesic Ustic Torrifluvents
LA	Irrigated/Side-roll	Tongue	Big Horn	Hfa - Haverson loam	fine-loamy, mixed (calcareous) mesic Ustic Torrifluvents
GA	Irrigated/Side-roll	Tongue	Rosebud	99 - Havre loam	fine-loamy, mixed (calcareous) frigid Ustic Torrifluvents
GB	Dryland	NA	Rosebud	99 - Havre loam	fine-loamy, mixed (calcareous) frigid Ustic Torrifluvents
GC	Irrigated/Flood	Tongue	Rosebud	99 - Havre loam	fine-loamy, mixed (calcareous) frigid Ustic Torrifluvents
EA	Irrigated/Flood	Tongue	Rosebud	197 - Yamac loam	fine-loamy, mixed Borollic Camborthids
DB	Irrigated/Pivot	Tongue	Custer	901 - Sonnett thin surface	fine, montmorillonitic frigid Typic Eutroboralfs
DA	Dryland (03) then Irrigated/Pivot	Tongue	Custer	99 - Havre silty clay loam	fine-loamy, mixed (calcareous) frigid Ustic Torrifluvents
BA	Irrigated/Flood	Tongue	Custer	79A - Yamacall loam	fine-loamy, mixed, frigid Aridic Ustochrepts
BD	Dryland	NA	Custer	47A - Harlake silty clay	fine, montmorillonitic (calcareous) frigid Aridic Ustifluvents
BC	Irrigated/Flood	Tongue	Custer	47A - Harlake silty clay	fine, montmorillonitic (calcareous) frigid Aridic Ustifluvents
YAA	Irrigated/Flood	Tongue	Custer	53A - Kobase silty clay loam	fine, montmorillonitic, frigid Aridic Ustochrepts

Site	Irrigation	Irrigation Water Source	County	Mapped Soil Series	Mapped Classification
MB	Irrigated/Flood	Prairie Dog	Sheridan	171 - Kishona (50%) Cambria (30%)	fine-loamy, mixed (calcareous) Mesic Ustic Torriorthernts
OAA	Irrigated/Flood	Otter	Rosebud	99 - Havre loam	fine-loamy, mixed (calcareous) frigid Ustic Torrifluvents
YBA	Irrigated/Flood	Yellowstone	Custer	47A - Harlake silty clay	fine, montmorillonitic (calcareous) frigid Aridic Ustifluvents
BHA	Irrigated/Flood	Big Horn	Big Horn	Bs - Bew silty clay loam	fine, montmorillonitic mesic Ustollic Haplargids

Tongue River Irrigated and Dryland Sites

Site MA

Site MA is the most upstream sample in the AMPP program, and is located just north of the Wyoming-Montana boundary and about 4.1 km (2.5 miles) from the point where the Tongue River first enters Montana (Figure D-1). The site is located below most, but not all, of the Fidelity water discharge points and is above the confluence of Prairie Dog Creek, a tributary that drains nearly 25% of the upper Tongue River watershed. The center pivot sprinkler irrigated field lies on a nearly level floodplain area within a large meander bend of the Tongue River floodplain (Figure D-2). At the time of the first sampling, the field had been recently planted to alfalfa and had a poor to moderate crop stand with significant weed growth and some bare areas.

The soil mapping unit sampled within the field is Hfa - Haverson loam and Hfd - Haverson silty clay loam (Figure D-3). These soils are undeveloped floodplain soils with 18% to 35% clay. They have moderate amounts of organic matter that is stratified with depth, and contain ample amounts of lime throughout the profile. The two units differ only in that Hfd has a slightly more clayey surface layer.

The pedon described and sampled at site MA was fairly typical of soils mapped as Halverson loam (Table D-2). Clay content was variable with depth and ranged from 22% to 30%. Dominant clay minerals were illite and kaolinite, which are non-swelling clays that are not easily affected by excess sodium. Soil pH (7.6) was mildly alkaline and moderate levels of lime (10%) occurred at all depths. Both pH and lime content were unchanged with depth owing to the lack of soil profile development in these recent river deposits. EC was moderate (1 to 2 dS/m) throughout the profile. Both SAR (0.4 to 1.0) and ESP (1.8 to 2.3) were low at all depths. Nutrient levels were generally adequate except for available zinc which was moderately low, and nitrogen which was also low for crops other than alfalfa. This crop obtains its own nitrogen source from the atmosphere.

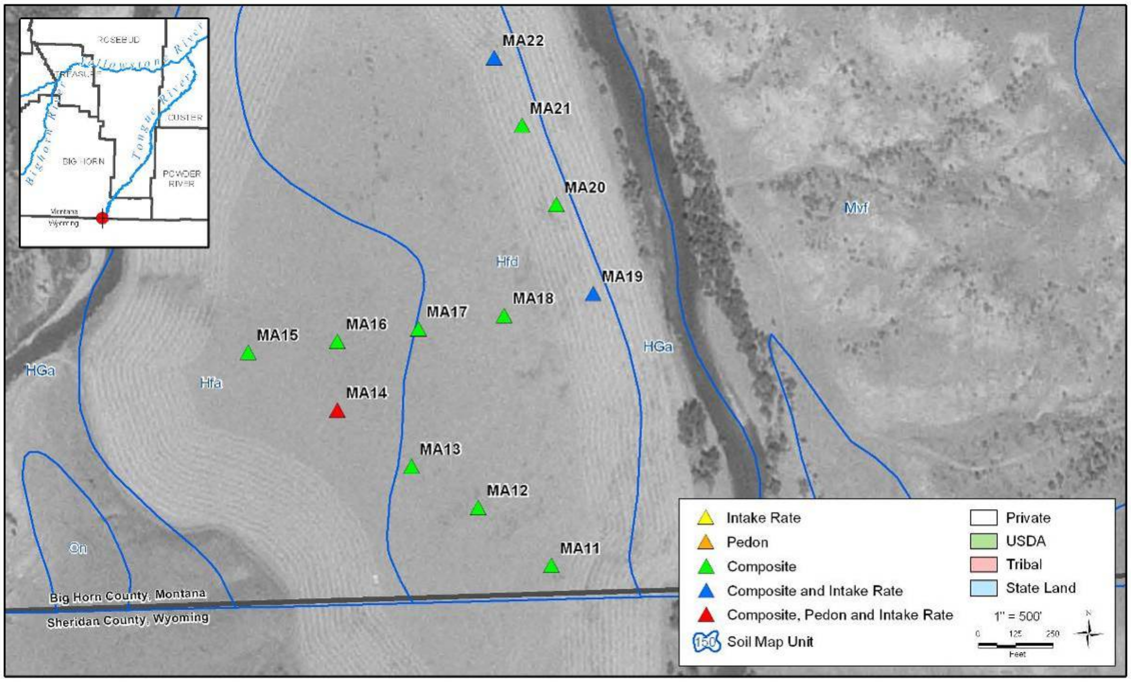


Figure D-1 Map of site MA

Figure D-2 Landscape view of site MA

Profile description for soil pit MA-14.

Landscape position:	Terrace/floodplain.	
Parent material:	Alluvium.	
County and mapped soil unit:	Bighorn County, Haverson Series.	
Vegetation:	Seeded alfalfa/weeds.	
Management Status:	Center pivot sprinkler irrigation.	
Slope and Aspect:	1% slopes with a northeast facing aspect.	
Classification:	fine-loamy, mixed (calcareous) mesic Ustic Torrifluvents	
Horizon	**Depth (inches)**	**USDA Description[1]**
Ap1	0 to 5	Brown (10YR 5/3) dry and brown (10YR 4/3) moist silt loam; weak, medium, platy parting to weak, medium, subangular blocky structure; loose, loose, slightly sticky, and non-plastic; common fine and few medium roots; common, medium, irregular, discontinuous pores; strongly effervescent; clear smooth boundary.
Ap2	5 to 10	Yellowish brown (10YR 5/4) dry and dark brown (10YR 3/3) moist silt loam; weak, medium, subangular blocky structure; slightly hard, very friable, slightly sticky, and non-plastic; common fine roots; common, medium, irregular, discontinuous pores; strongly effervescent; clear smooth boundary.
Bw	10 to 26	Light olive brown (2.5Y 5/3) dry and olive brown (2.5Y 4/3) moist silty clay loam; weak, medium, subangular blocky structure; hard, friable, slightly sticky, and slightly plastic; common fine roots; common, fine, irregular, discontinuous pores; strongly effervescent; soft white masses; clear smooth boundary.
C2k	26 to 37	Light olive brown (2.5Y 5/3) dry and light olive brown (2.5Y 5/4) moist silty clay loam; massive; hard, friable, slightly sticky, and non-plastic; few fine roots; few, fine, irregular, discontinuous pores; violently effervescent; clear smooth boundary.
C3	37 to 65	Light yellowish brown (2.5Y 6/3) dry and light olive brown (2.5Y 5/3) moist silty clay loam; massive; hard, friable, slightly sticky, and slightly plastic; few fine roots; few, fine, irregular, discontinuous pores; strongly effervescent; stratified by dark organic-like zones 1 to 6 inches thick.

Notes:

1 Soils were described using protocol defined by *Soil Survey Division Staff. 1993. Soil Survey Manual. U.S.D.A. Agriculture Handbook 18* .

2 taxonomy

Photo of Soil Pit MA-14.

Figure D-3 Soil profile description and photo of soil at site MA

Table D-2 Soil profile chemical, physical, and mineralogical data for site MA

Paste pH, Conductivity, Organic Matter, Lime and Texture											
Horizon	Upper Depth (in)	Lower Depth (in)	Dry Wt, g	pH, Saturated Paste s.u. Method ASAM10-3.2	Conductivity, Paste Extract mmhos/cm Method ASAM10-3	Organic Matter wt% Method ASA29-3	Lime as CaCO3 wt% Method USDA23c	Texture unitless Method ASA15-5	Sand wt% Method ASA15-5	Silt wt% Method ASA15-5	Clay wt% Method ASA15-5
Ap1	0	5	562	7.6	0.64	2.05	8.4	SiL	24	52	24
Ap2	5	10	529	7.6	0.72		9.6	SiL	24	54	22
Bw	10	26	603	7.6	1.45		11.1	SiCL	12	61	27
C2k	26	37	518	7.6	1.85		15.4	SiCL	16	57	27
C3	37	65	580	7.5	0.98		8.5	SiCL	16	54	30

Paste Extract and Exchangeable Ions											
Horizon	Upper Depth (in)	Lower Depth (in)	Saturation wt% Method USDA27a	Calcium, Saturated Paste meq/l Method SW6010B	Magnesium, Saturated Paste meq/l Method SW6010B	Sodium, Saturated Paste meq/l Method SW6010B	Sodium Adsorption Ratio (SAR) unitless Method Calculation	Alkalinity, Saturated Paste meq/L Method ASA10-3	Cation Exchange Capacity meq/100g Method SW6010B	Sodium, Extractable meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
Ap1	0	5	40.7	3.7	1.7	1.1	0.7	4.8	27.2	0.6	2.1
Ap2	5	10	40.6	4.7	2.3	0.8	0.4	3.2	22.3	0.6	2.3
Bw	10	26	48.4	6.8	5.1	1.5	0.6	2.6	30	0.6	1.8
C2k	26	37	45.7	9	9.3	2.8	0.9	2.1	25.3	0.6	2.1
C3	37	65	47.8	4.7	3.4	2	1	2.2	29.3	0.7	2.2

Clay Minerals and Nutrients											
Horizon	Upper Depth (in)	Lower Depth (in)	Kaolinite % Method X-ray Diffraction (based on clay fraction)	Illite % Method X-ray Diffraction (based on clay fraction)	Smectite % Method X-ray Diffraction (based on clay fraction)	Chlorite % Method X-ray Diffraction (based on clay fraction)	Nitrate as N, Saturated Paste mg/L Method ASA10-3	Phos-phorus (Olsen NaHCO3 Extract) mg/kg Method ASA24-5	Potassium, NH4OAc Extractable mg/kg Method ASA13-3	Sulfate, Saturated Paste meq/L Method ASA10-3	Zinc (DTPA Extract) mg/kg Method SW6010B
Ap1	0	5	26	52	17	5	10.9	23	502	1.8	0.38
Ap2	5	10					34.8			1.8	
Bw	10	26	37	43	17	2	124			1.1	
C2k	26	37									
C3	37	65									

Site LA

Site LA is located just upstream of the Tongue River Reservoir below all Fidelity water discharge points and below the confluence of Prairie Dog Creek (Figure D-4). The sprinkler irrigated field uses a side roll system and lies on a nearly level portion of the Tongue River floodplain. This field contains brome, orchard, and blue grasses with occasional alfalfa plants (Figure D-5).

The soil mapping unit sampled is Hfa - Haverson loam (Figure D-6), the same as was mapped at site MA. These soils are undeveloped floodplain soils with 18% to 35% clay. They have moderate amounts of organic matter that is stratified with depth, and contain ample amounts of lime throughout the profile.

The pedon described and sampled at site LA (Table D-3) was more clayey than other soils mapped as Halverson loam. Clay content was variable with depth and generally ranged from 29% to 42%, except for a horizon from 28 to 42 inches which had 50% clay. This soil was more strongly layered than at site MA. This layering is the result of successive stream sediment deposits which vary slightly in texture.

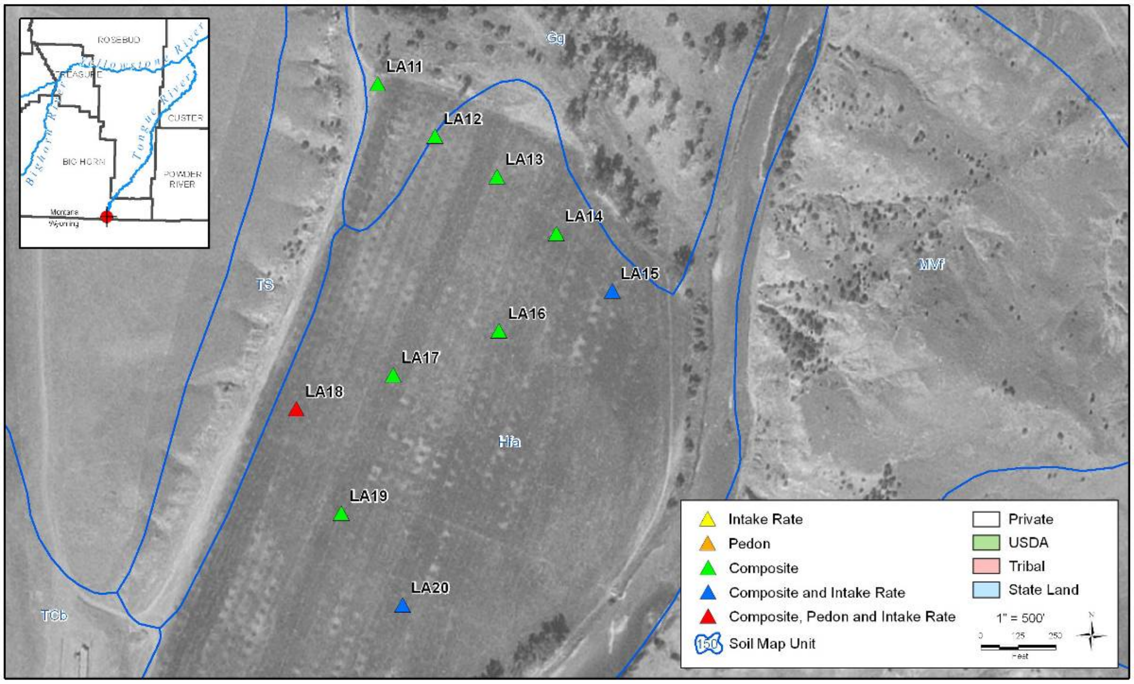


Figure D-4   Map of site LA

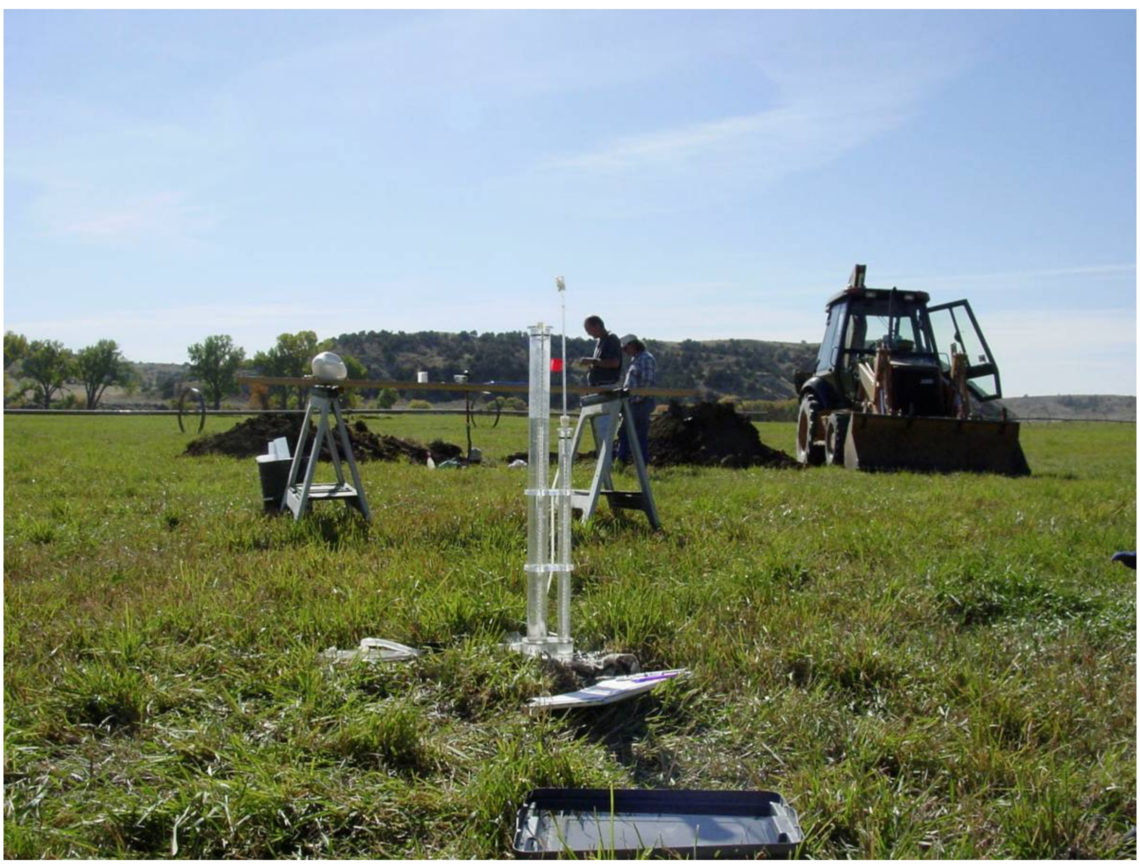


Figure D-5   Landscape view of site LA

Profile description for soil pit LA-18.

Landscape position:	Terrace/floodplain.	
Parent material:	Alluvium.	
County and mapped soil unit:	Bighorn County, Haverson Series.	
Vegetation:	Mixed pasture grasses with small amount of alfalfa.	
Management Status:	Sideroll sprinkler irrigation.	
Slope and Aspect:	1% slopes with an east facing aspect.	
Classification:	fine, mixed (calcareous) frigid Ustic Torrifluvents	
Horizon	**Depth (inches)**	**USDA Description[1]**
Ap	0 to 6	Dark grayish brown (10YR 4/2) dry and brown (10YR 4/3) moist silty clay loam; weak, medium, platy parting to moderate, medium, granular structure; soft, very friable, slightly sticky, and slightly plastic; many fine and few medium roots; common, fine, continuous pores; strongly effervescent; clear, smooth boundary.
C	6 to 18	Brown (10YR 5/3) dry and dark brown (10YR 3/3) moist clay loam; moderate, medium, subangular blocky structure; hard, friable, sticky, and plastic; many fine and few medium roots; few, fine, discontinuous pores; strongly effervescent; clear, smooth boundary.
2C1	18 to 24	Brown (10YR 5/3) dry and brown (10YR 4/3) moist silty clay; moderate, medium, subangular blocky structure; hard, friable, sticky, and plastic; common, fine roots; interstitial pores; strongly effervescent; common, fine, threads and seams of gypsum; abrupt, wavy boundary.
2C2	24 to 28	Light olive brown (2.5Y 5/3) dry and olive brown (2.5Y 4/3) moist clay loam; massive; soft, very friable, slightly sticky, and slightly plastic; few, fine roots; interstitial pores; common, medium, distinct mottles; strongly effervescent; abrupt, smooth boundary.
3C1	28 to 42	Light yellowish brown (2.5Y 6/3) dry and very dark grayish brown (2.5Y 3/2) moist silty clay; weak, medium, subangular blocky structure; very friable, sticky, and plastic; few, fine roots; interstitial pores; common, medium, distinct mottles; strongly effervescent; gradual, smooth boundary.
3C2	42 to 60+	Olive brown (2.5Y 4/3) moist loam; massive; very friable, nonsticky, and nonplastic; interstitial pores; strongly effervescent.

Notes:
1 Soils were described using protocol defined by *Soil Survey Division Staff. 1993. Soil Survey Manual. U.S.D.A. Agriculture Handbook 18*.

Photo of Soil Pit LA-18.

Figure D-6 Soil profile description and photo of soil at site LA

Layered soils may have slower internal drainage than unlayered soils. Dominant clay minerals were kaolinite and illite, which are non-swelling clays that are not easily affected by excess sodium. Swelling clays (smectite) accounted for 20% to 23% of the clay minerals. Soil pH was weakly alkaline (7.4 to 8.0) and moderate levels of lime (6% to 13%) at all depths. Both pH and lime content were unchanged with depth owing to the lack of soil profile development. EC was moderately low at this location (0.8 to 1.1 dS/m), but was higher at other locations in the field. Both SAR (1.3 to 1.9) and ESP (1.2 to 2.7) were low at all depths. Nutrient levels were variable with nitrogen deficient for irrigated grass. Soil test levels of phosphorus, potassium, sulfur and zinc were generally adequate.

Table D-3 Soil profile chemical, physical, and mineralogical data for site LA

Paste pH, Conductivity, Organic Matter, Lime and Texture												
Horizon	Upper Depth (in)	Lower Depth (in)	Dry Wt, g	pH, Saturated Paste s.u. Method ASAM10-3.2	Conductivity, Paste Extract mmhos/cm Method ASAM10-3	Organic Matter wt% Method ASA29-3	Lime as CaCO3 wt% Method USDA23c	Texture unitless Method ASA15-5	Sand wt% Method ASA15-5	Silt wt% Method ASA15-5	Clay wt% Method ASA15-5
Ap	0	6	241	7.4	0.93	3.9	8.5	SiCL	19	52	29
C	6	18	205	7.5	0.79		8.3	CL	27	41	32
2C1	18	24	237	7.8	1.02		6.5	SiC	7	52	41
2C2	24	28	210	7.9	1.07		7.5	CL	27	45	28
3C1	28	42	231	8	1.11		6.5	SiC	ND	50	50
3C2	42	60	212	8	0.95		12.9	L	49	38	13

Paste Extract and Exchangeable Ions												
Horizon	Upper Depth (in)	Lower Depth (in)	Saturation wt% Method USDA27a	Calcium, Saturated Paste meq/l Method SW6010B	Magnesium, Saturated Paste meq/l Method SW6010B	Sodium, Saturated Paste meq/l Method SW6010B	Sodium Adsorption Ratio (SAR) unitless Method Calculation	Alkalinity, Saturated Paste meq/L Method ASA10-3	Cation Exchange Capacity meq/100g Method SW6010B	Sodium, Extractable meq/100g Method SW6010B	Exchang-eable Sodium Percentage % Method USDA20b
Ap	0	6	57.3	4.9	2.6	2.5	1.3	5.9	46.1	0.8	1.3
C	6	18	53.2	3.7	1.7	2.7	1.7	4.3	49	0.8	1.2
2C1	18	24	55	3.7	2.5	3.1	1.8	3.4	42.9	0.9	1.8
2C2	24	28	48.2	3.6	3.9	2.7	1.4	3	39.5	0.6	1.2
3C1	28	42	70.6	3	5	3.1	1.6	2.9	44.2	1.1	2
3C2	42	60	37	2.3	3.8	3.3	1.9	3	20	0.7	2.7

Clay Minerals and Nutrients												
Horizon	Upper Depth (in)	Lower Depth (in)	Kaolinite % Method X-ray Diffraction (based on clay fraction)	Illite % Method X-ray Diffraction (based on clay fraction)	Smectite % Method X-ray Diffraction (based on clay fraction)	Chlorite % Method X-ray Diffraction (based on clay fraction)	Nitrate as N, Saturated Paste mg/L Method ASA10-3	Phos-phorus (Olsen NaHCO3 Extract) mg/kg Method ASA24-5	Potassium, NH4OAc Extractable mg/kg Method ASA13-3	Sulfate, Saturated Paste meq/L Method ASA10-3	Zinc (DTPA Extract) mg/kg Method SW6010B
Ap	0	6	45	32	20	4	0.9	19	365	3	1
C	6	18					1			2.8	
2C1	18	24	35	39	23	2	1.4			5.5	
2C2	24	28									
3C1	28	42									
3C2	42	60									

Site GA

For several miles downstream of the Tongue River Reservoir, the floodplain is narrow and little irrigation occurs. Site GA is about 25 miles downstream of the Tongue River Reservoir, and is below the confluence of Hanging Woman Creek near Birney (Figure D-7). The sprinkler-irrigated field uses a side roll system and straddles the Tongue River floodplain and a low terrace situated a few feet above the active floodplain. At the time of the first sampling, this field had an older stand of alfalfa-grass on the north half and a newer alfalfa stand~~s~~ in the south half (Figure D-8).

The soil mapping unit sampled is 99 – Havre loam (Figure D-9), the dominant soil mapped throughout most of the Tongue River floodplain. These soils mapped in both Rosebud and Custer Counties are similar to Haverson soils mapped in Big Horn County. They are undeveloped floodplain soils with 18% to 35% clay, which have moderate amounts of organic matter that is stratified with depth, and contain ample amounts of lime throughout the profile.

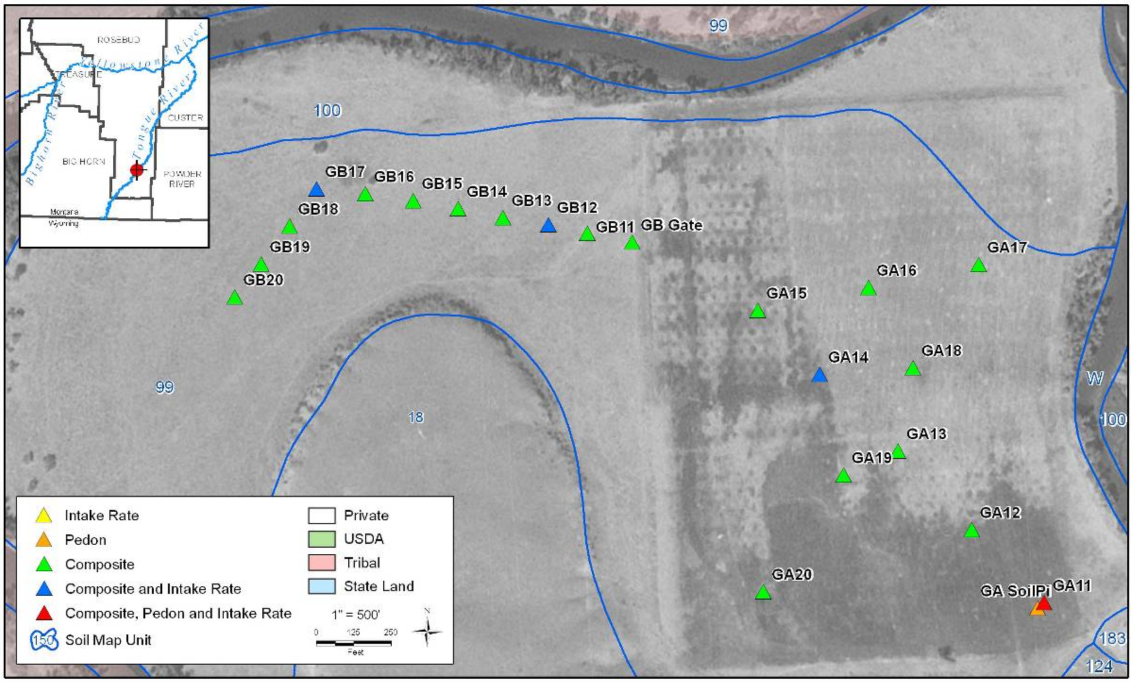


Figure D-7 Map of site GA and GB

Figure D-8 Landscape view of site GA

Profile description for soil pit GA-11

Landscape position:	Floodplain.
Parent material:	Alluvium.
County and mapped soil unit:	Rosebud County, Havre loam, 0 to 2%.
Vegetation:	Alfalfa/grass hayfield; greasewood on field margins.
Management Status:	Sideroll sprinkler irrigation.
Slope and Aspect:	0 to 2% slopes with a west facing aspect.
Classification:	fine, mixed (calcareous) frigid Ustic Torrifluvents

Horizon	Depth (inches)	USDA Description[1]
Ap	0 to 6	Yellowish brown (10YR 5/4) dry and dark yellowish brown (10YR 4/4) moist silty clay; moderate, medium, granular structure; slightly hard, very friable, sticky, and slightly plastic; common coarse and many fine roots; very slightly effervescent; clear smooth boundary.
C1	6 to 12	Brown (10YR 4/3) moist silty clay; moderate, medium, subangular blocky structure; hard, firm, sticky, and slightly plastic; common coarse and many fine roots; common fine tubular pores; very slightly effervescent; abrupt smooth boundary.
C2	12 to 26	Dark brown (10YR 3/3) moist silty clay; weak, coarse, columnar structure; hard, firm, sticky, and slightly plastic; few coarse and common fine roots; many fine tubular pores; slightly effervescent; gradual smooth boundary.
C3	26 to 42	Very dark grayish brown (10YR 3/2) moist silty clay; weak, medium, subangular blocky structure; slightly hard, friable, sticky, and slightly plastic; few fine roots; many fine tubular pores; slightly effervescent; common fine threads and seams of gypsum; clear smooth boundary.
C4	42 to 49	Olive brown (2.5Y 4/4) moist silty clay loam; massive; very friable, sticky, and slightly plastic; common fine tubular pores; strongly effervescent; common fine threads and seams of gypsum; abrupt wavy boundary.
C5	49 to 72+	Olive brown (2.5Y 4/3) moist silty clay; massive; friable, sticky, and plastic; common fine tubular pores; common medium distinct mottles; strongly effervescent; common fine threads and seams of gypsum.

Notes:

1 Soils were described using protocol defined by *Soil Survey Division Staff. 1993. Soil Survey Manual. U.S.D.A. Agriculture Handbook 18*.

2 taxonomy

Photo of Soil Pit GA-11.

Figure D-9 Soil profile description and photo of soil at site GA

The pedon described and sampled at site GA (Table D-4) was much higher in clay content than soils typically mapped as Havre loam and represents an inclusion of a different soil series. Clay content was variable with depth and generally ranged from 32% to 48%. Composite samples collected across the entire field had an average clay content of only 23%, which is typical of Havre loam. Dominant clay minerals were kaolinite and illite, which are non-swelling clays that are not easily affected by excess sodium. Soil pH was mildly alkaline (7.7 to 8.0) and moderate levels of lime (5% to 8%) at all depths. Both pH and lime content were relatively unchanged with depth owing to the lack of soil profile development. EC was low at this location (0.6 to 0.9 dS/m) throughout the profile, but was higher at other locations in the field. Both SAR (0.9 to 1.4) and ESP (1.2 to 1.8) were low at all depths. Patches of greasewood were found near an irrigation ditch a few hundred feet from this site indicating that higher sodium levels occur in the vicinity. Nutrient levels were variable with nitrogen deficient for irrigated alfalfa-grass. Soil test levels of phosphorus, sulfur, potassium and zinc were generally adequate.

Table D-4 Soil profile chemical, physical, and mineralogical data for site GA

Paste pH, Conductivity, Organic Matter, Lime and Texture											
Horizon	Upper Depth (in)	Lower Depth (in)	Dry Wt, g	pH, Saturated Paste s.u. Method ASAM10-3.2	Conductivity, Paste Extract mmhos/cm Method ASAM10-3	Organic Matter wt% Method ASA29-3	Lime as CaCO3 wt% Method USDA23c	Texture unitless Method ASA15-5	Sand wt% Method ASA15-5	Silt wt% Method ASA15-5	Clay wt% Method ASA15-5
Ap	0	6	548	7.7	0.62	3.1	5.4	SiC	5	47	48
C1	6	12	575	7.8	0.69		6.8	SiC	4	51	45
C2	12	26	592	7.9	0.63		6.2	SiC	ND	54	46
C3	26	42	630	7.9	0.58		7.1	SiC	ND	54	46
C4	42	49	538	7.9	0.67		7.3	SiCL	5	63	32
C5	49	72	624	8	0.89		7.2	SiC	ND	58	42

Paste Extract and Exchangeable Ions											
Horizon	Upper Depth (in)	Lower Depth (in)	Saturation wt% Method USDA27a	Calcium, Saturated Paste meq/l Method SW6010B	Magnesium, Saturated Paste meq/l Method SW6010B	Sodium, Saturated Paste meq/l Method SW6010B	Sodium Adsorption Ratio (SAR) unitless Method Calculation	Alkalinity, Saturated Paste meq/L Method ASA10-3	Cation Exchange Capacity meq/100g Method SW6010B	Sodium, Extractable meq/100g Method SW6010B	Exchang-eable Sodium Percentage % Method USDA20b
Ap	0	6	66.3	3.4	1.7	1.5	0.9	4.9	35.1	0.5	1.2
C1	6	12	55.9	3.5	1.7	2.2	1.4	3.8	34.9	0.7	1.6
C2	12	26	61.3	2.7	1.3	1.8	1.3	2	40.1	0.7	1.5
C3	26	42	59.1	2.5	1.4	1.8	1.3	2.2	36.7	0.6	1.2
C4	42	49	51.2	2.8	2	1.9	1.2	2.2	38	0.6	1.4
C5	49	72	64.7	2.8	2.9	2.4	1.4	2.4	31.4	0.7	1.8

Clay Minerals and Nutrients											
Horizon	Upper Depth (in)	Lower Depth (in)	Kaolinite % Method X-ray Diffraction (based on clay fraction)	Illite % Method X-ray Diffraction (based on clay fraction)	Smectite % Method X-ray Diffraction (based on clay fraction)	Chlorite % Method X-ray Diffraction (based on clay fraction)	Nitrate as N, Saturated Paste mg/L Method ASA10-3	Phos-phorus (Olsen NaHCO3 Extract) mg/kg Method ASA24-5	Potassium, NH4OAc Extractable mg/kg Method ASA13-3	Sulfate, Saturated Paste meq/L Method ASA10-3	Zinc (DTPA Extract) mg/kg Method SW6010B
Ap	0	6	42	42	3	12	4.8	21	299	1.4	0.7
C1	6	12					21.5			3.1	
C2	12	26	38	31	25	7	3.3			3.6	
C3	26	42									
C4	42	49									
C5	49	72									

Site GB

Site GB (Figure D-7) was located adjacent to and southwest of field MA. Site GB was a dryland soil, which had the same soil mapping unit as field GA. The field is in a native range condition (Figure D-10) and contains a mixture of perennial grasses (blue grama, crested wheatgrass, needle-and-thread, red three-awn, and smooth brome), forbs (yellow sweetclover) and shrubs (silver sagebrush and greasewood). A separate soil profile description was not performed on this field because it was thought to be similar to field GA.

Figure D-10 Landscape view of site GB

Site GC

Site GC is located a few miles further north of sites GA and GB, and is about 30 miles downstream of the Tongue River Reservoir (Figure D-11). The flood-irrigated field has been leveled and contains border dykes to facilitate even distribution of water. The field lies on the Tongue River floodplain and had an established alfalfa stand at the time of the first sampling (Figure D-12).

The soil mapping unit sampled within the field is 99 – Havre loam (Figure D-13), the same soil mapped at sites GA and GB just upstream. Havre loam is an undeveloped floodplain soil with 18% to 35% clay, which has moderate amounts of organic matter that is stratified with depth, and contains ample amounts of lime throughout the profile. The soil profile was lighter in color than GA soil, indicating that the soil pit may have been located in a portion of the field that was scalped of much of the surface soil during leveling. Measured organic matter content (4.2%) seems excessive given the light soil color. High lime content may have interfered with the organic matter measurement.

The pedon described and sampled at site GC (Table D-5) was higher in clay content than soils typically mapped as Havre loam. Like the soil pedon at site GA, it represents an inclusion of a different soil series.

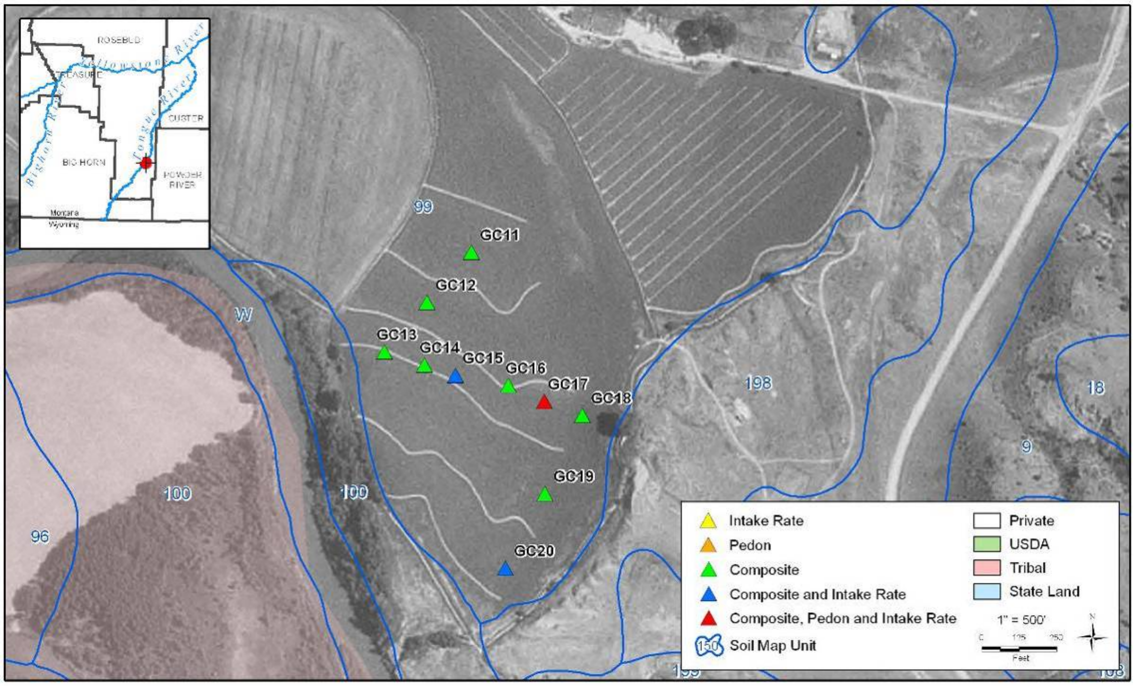


Figure D-11 Map of site GC

Figure D-12 Landscape view of site GC

Profile description for soil pit GC-17.

Landscape position:	Floodplain.
Parent material:	Alluvium.
County and mapped soil unit:	Rosebud County, Havre Series.
Vegetation:	Alfalfa.
Management Status:	Flood irrigation.
Slope and Aspect:	0 to 1% leveled slopes with a west facing aspect.
Classification:	fine, mixed (calcareous) frigid Ustic Torrifluvents

Horizon	Depth (inches)	USDA Description[1]
Ap	0 to 5	Yellowish brown (10YR 5/4) dry and dark brown (10YR 3/3) moist silty clay loam; medium, platy parting to fine, granular structure; slightly hard, very friable, sticky, and slightly plastic; common coarse and few fine roots; few fine vesicular pores; strongly effervescent; clear smooth boundary.
C1	5 to 18	Very pale brown (10YR 7/3) dry and dark grayish brown (10YR 4/2) moist silty clay; weak, medium, subangular blocky structure; slightly hard, friable, sticky, and slightly plastic; common coarse and few fine roots; few fine vesicular pores; strongly effervescent; gradual smooth boundary.
C2	18 to 30	Brownish yellow (10YR 6/6) dry and dark yellowish brown (10YR 3/4) moist silty clay; massive; hard, friable, sticky, and slightly plastic; few coarse and few fine roots; common fine vesicular pores; violently effervescent; gradual smooth boundary.
C3	30 to 60+	Yellow (10YR 7/8) dry and brown (10YR 4/3) moist silty clay loam; massive; slightly hard, friable, sticky, and slightly plastic; few coarse and few fine roots; few fine vesicular pores; violently effervescent; common fine threads and masses of gypsum.

Notes:

1 Soils were described using protocol defined by *Soil Survey Division Staff. 1993. Soil Survey Manual. U.S.D.A. Agriculture Handbook 18*.

2 taxonomy

Photo of Soil Pit GC-17.

Figure D-13 Soil profile description and photo of soil at site GC

Clay content was variable with depth and generally ranged from 30% to 47%, with an average of around 40% in the upper 40 inches. Composite samples collected across the entire field had an average clay content of only 32%, which is at the upper end of the Havre loam. The dominant clay minerals were kaolinite and illite, which are non-swelling clays that are not easily affected by excess sodium. The soil had a mildly alkaline pH (7.7 to 8.1) and moderate levels of lime (8% to 10%) at all depths. Both pH and lime content were relatively unchanged with depth owing to the lack of soil profile development. EC was very low and uniform at this location (0.7 to 1.1 dS/m) and was low at other locations in the field as well. Both SAR (0.7 to 0.9) and ESP (1.4 to 2.0) were low in the pedon and in the field composite samples. Site GC had the lowest EC, SAR and ESP of any soils sampled. Nutrient levels were generally adequate for alfalfa production.

Table D-5 Soil profile chemical, physical, and mineralogical data for site GC

Paste pH, Conductivity, Organic Matter, Lime and Texture

Horizon	Upper Depth (in)	Lower Depth (in)	Dry Wt, g	pH, Saturated Paste s.u. Method ASAM10-3.2	Conductivity, Paste Extract mmhos/cm Method ASAM10-3	Organic Matter wt% Method ASA29-3	Lime as CaCO3 wt% Method USDA23c	Texture unitless Method ASA15-5	Sand wt% Method ASA15-5	Silt wt% Method ASA15-5	Clay wt% Method ASA15-5
Ap	0	5	489	7.7	0.71	4.2	8.1	SiCL	6	64	30
C1	5	18	617	8	0.72		8.6	SiC	ND	59	41
C2	18	30	551	7.9	1.08		9.5	SiC	ND	53	47
C3	30	60	598	8.1	0.72		8.8	SiCL	19	43	38

Paste Extract and Exchangeable Ions

Horizon	Upper Depth (in)	Lower Depth (in)	Saturation wt% Method USDA27a	Calcium, Saturated Paste meq/l Method SW6010B	Magnesium, Saturated Paste meq/l Method SW6010B	Sodium, Saturated Paste meq/l Method SW6010B	Sodium Adsorption Ratio (SAR) unitless Method Calculation	Alkalinity, Saturated Paste meq/L Method ASA10-3	Cation Exchange Capacity meq/100g Method SW6010B	Sodium, Extractable meq/100g Method SW6010B	Exchang-eable Sodium Percentage % Method USDA20b
Ap	0	5	63.9	4.2	2.4	1.8	1	5.6	45.3	0.9	1.7
C1	5	18	59.4	3.9	2.1	2.2	1.3	3.8	38.9	0.9	2
C2	18	30	63.5	5.5	3.8	2.4	1.1	4.8	41.5	0.7	1.4
C3	30	60	55.8	2.8	2.4	1.8	1.1	2.4	40.8	0.8	1.6

Clay Minerals and Nutrients

Horizon	Upper Depth (in)	Lower Depth (in)	Kaolinite % Method X-ray Diffraction (based on clay fraction)	Illite % Method X-ray Diffraction (based on clay fraction)	Smectite % Method X-ray Diffraction (based on clay fraction)	Chlorite % Method X-ray Diffraction (based on clay fraction)	Nitrate as N, Saturated Paste mg/L Method ASA10-3	Phos-phorus (Olsen NaHCO3 Extract) mg/kg Method ASA24-5	Potassium, NH4OAc Extractable mg/kg Method ASA13-3	Sulfate, Saturated Paste meq/L Method ASA10-3	Zinc (DTPA Extract) mg/kg Method SW6010B
Ap	0	5	38	35	16	11	4.8	24	219	1.8	0.61
C1	5	18					26.5			3.5	
C2	18	30	38	31	21	11	6.4			8.1	
C3	30	60									

Site EA

Site EA is located just upstream of the Brandenburg Bridge on the west side of the Tongue River (Figure D-14). The site is located on a low terrace above the floodplain, and is flood-irrigated. At the time of the first sampling, the field contained hay millet stubble (Figure D-15). The field was not planted, irrigated or harvested in 2004. It was planted to alfalfa in the spring of 2005.

The soil mapping unit sampled within the field is 197 - Yamac loam (Figure D-16). This soil differs from soils typically mapped lower on the floodplain in that it has a subsurface horizon enriched in clay. The soil was higher in clay content (averaging greater than 35% clay) than typical floodplain soils.

The pedon described and sampled at site EA (Table D-6) was probably typical of soils mapped as Yamac, except that lime content was higher in the surface layer than typical values, and the subsurface layers were darker than usually observed. Additionally, clay content was slightly higher than occurs in Yamac soils. These differences may indicate that the clay-enriched subsoil may have resulted from more deposition of texturally contrasting layers rather than soil development processes. Clay content was variable with depth and ranged from 13% to 50%.

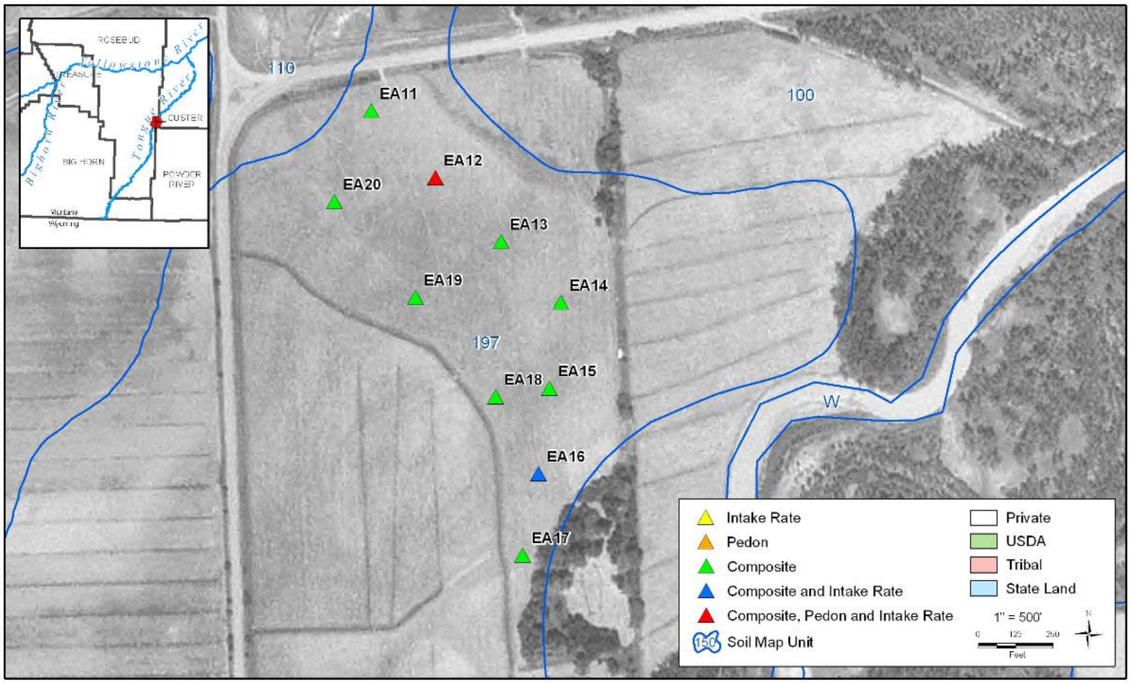


Figure D-14 Map of site EA

Figure D-15 Landscape view of site EA

Profile description for soil pit EA-12.

Landscape position:	Floodplain/terrace.	
Parent material:	Alluvium.	
County and mapped soil unit:	Rosebud County, Yamac Series.	
Vegetation:	Alfalfa/grass/weeds.	
Management Status:	Flood irrigation.	
Slope and Aspect:	0 to 2% slopes with an east facing aspect.	
Classification:	fine, mixed (calcareous) Borollic Camborthids	
Horizon	**Depth (inches)**	**USDA Description[1]**
Ap	0 to 4	Light gray (2.5Y 7/2) moist silty clay loam; moderate, medium, platy structure; firm, sticky, and plastic; common fine roots; common medium pores; strongly effervescent; abrupt irregular boundary.
Bw	4 to 18	Light yellowish brown (2.5Y 6/4) moist silty clay; strong, very coarse, angular blocky structure; extremely firm, sticky, and plastic; few fine roots; common fine pores; strongly effervescent; very few, small, organic bands throughout; clear smooth boundary.
C1	18 to 33	Dark olive brown (2.5Y 3/3) moist silty clay; massive; firm, sticky, and plastic; few fine roots; common fine pores; violently effervescent; many, medium, soft white masses and threads; gradual smooth boundary.
C2	33 to 50	Very dark grayish brown (2.5Y 3/2) moist silty clay; massive; friable, sticky, and plastic; few fine roots; common fine pores; few fine faint mottles; violently effervescent; clear smooth boundary.
C3	50 to 60	Light olive brown (2.5Y 5/3) moist loam; massive; loose, nonsticky, and nonplastic; few fine roots; common medium pores; few fine faint mottles; violently effervescent to noneffervescent.

Notes:

1 Soils were described using protocol defined by *Soil Survey Division Staff. 1993. Soil Survey Manual. U.S.D.A. Agriculture Handbook 18*.

2 taxonomy

Photo of Soil Pit EA-12.

Figure D-16 Soil profile description and photo of soil at site EA

The soil was strongly layered as a result of successive stream sediment deposition, creating layers which varied in texture. Layered soils may have slower internal drainage than unlayered soils. Dominant clay minerals were kaolinite and illite, which are non-swelling clays that are not easily affected by excess sodium. Swelling clays (smectite) accounted for 13% to 14% of clay minerals. The soil had a mildly alkaline pH (7.5 to 8.6) and moderate levels of lime (6% to 9%) at all depths. EC was higher than average at this location (1.4 to 8 dS/m) with higher levels found at depth. EC levels were slightly lower in the composite samples. SAR (1.5 to 17) and ESP (1.8 to 8.4) were also higher than average for the Tongue River and increased with depth. Soil test levels of nitrogen were low for irrigated grass, but since the field was seeded to alfalfa in 2005, nitrogen content was not a concern. Levels of phosphorus, potassium, sulfur and zinc were generally adequate.

Table D-6 Soil profile chemical, physical, and mineralogical data for site EA

Paste pH, Conductivity, Organic Matter, Lime and Texture											
Horizon	Upper Depth (in)	Lower Depth (in)	Dry Wt, g	pH, Saturated Paste s.u. Method ASAM10-3.2	Conductivity, Paste Extract mmhos/cm Method ASAM10-3	Organic Matter wt% Method ASA29-3	Lime as CaCO3 wt% Method USDA23c	Texture unitless Method ASA15-5	Sand wt% Method ASA15-5	Silt wt% Method ASA15-5	Clay wt% Method ASA15-5
Ap	0	4		7.5	1.4	4.5	6.9	SiCL	1	66	33
Bw	4	18	618	7.8	3.25		6.3	SiC	1	55	44
C1	18	33	645	8.1	10		9.6	SiC	2	48	50
C2	33	50	623	8.5	7.37		9	SiC	1	58	41
C3	50	60	595	8.6	8		8.5	L	42	45	13

Paste Extract and Exchangeable Ions											
Horizon	Upper Depth (in)	Lower Depth (in)	Saturation wt% Method USDA27a	Calcium, Saturated Paste meq/l Method SW6010B	Magnesium, Saturated Paste meq/l Method SW6010B	Sodium, Saturated Paste meq/l Method SW6010B	Sodium Adsorption Ratio (SAR) unitless Method Calculation	Alkalinity, Saturated Paste meq/L Method ASA10-3	Cation Exchange Capacity meq/100g Method SW6010B	Sodium, Extractable meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
Ap	0	4	70	7	4	3.5	1.5	8.4	45.6	1.1	1.8
Bw	4	18	69.3	11.3	11.7	16.1	4.8	3.6	50.2	2.5	2.8
C1	18	33	78.5	18.1	46.3	56.4	9.9	2.4	50.6	6.5	4.1
C2	33	50	72.2	3.8	28.1	61.2	15	2.8	42.8	7	6.1
C3	50	60	40	3.2	28.9	70	17	3	12.7	3.9	8.4

Clay Minerals and Nutrients											
Horizon	Upper Depth (in)	Lower Depth (in)	Kaolinite % Method X-ray Diffraction (based on clay fraction)	Illite % Method X-ray Diffraction (based on clay fraction)	Smectite % Method X-ray Diffraction (based on clay fraction)	Chlorite % Method X-ray Diffraction (based on clay fraction)	Nitrate as N, Saturated Paste mg/L Method ASA10-3	Phosphorus (Olsen NaHCO3 Extract) mg/kg Method ASA24-5	Potassium, NH4OAc Extractable mg/kg Method ASA13-3	Sulfate, Saturated Paste meq/L Method ASA10-3	Zinc (DTPA Extract) mg/kg Method SW6010B
Ap	0	4	38	40	14	8	0.5	22	522	6	0.64
Bw	4	18					0.5			38	
C1	18	33	39	36	13	11	1.8			47.1	
C2	33	50									
C3	50	60									

Site DA

Site DA is located between Brandenburg Bridge and the T&Y Irrigation Diversion Dam (Figure D-17) and is near the mouth of Foster Creek, an ephemeral tributary that joins the Tongue River from the east. The field is somewhat sub-irrigated and has been sporadically irrigated with event water. It was brought under full irrigation when a pivot was constructed in August 2003. The field lies on the Tongue River floodplain and had an established alfalfa/grass stand at the time of the first sampling (Figure D-18).

The soil mapping unit sampled within the field is 99 – Havre loam (Figure D-19), the same soil mapped extensively along the Tongue River. The soil profile was much sandier in texture at this site owing to sediment from Foster Creek. The pedon described and sampled at site DA (Table D-7) was lower in clay content than soils typically mapped as Havre loam and represents an inclusion of a different soil series that has from 18% to 35% clay. The soil very nearly fits the sandy particle size class, especially deeper in the profile. Clay content was variable with depth and averaged less than 10% in the upper 40 inches. Dominant clay minerals consisted of nearly equal parts of kaolinite and smectite with lesser amounts of illite.

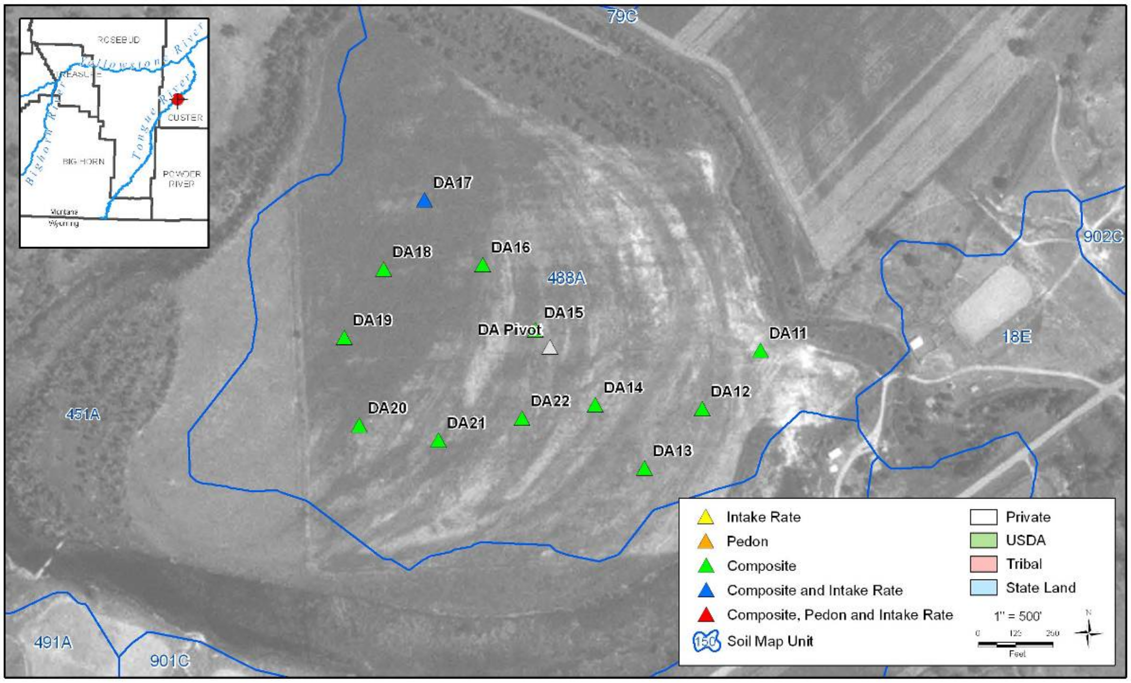


Figure D-17 Map of site DA

Figure D-18 Landscape view of site DA

Profile description for soil pit DA-14.

Landscape position:	Floodplain/terrace.
Parent material:	Alluvium.
County and mapped soil unit:	Custer County, Havre Series.
Vegetation:	Alfalfa/grass/weeds.
Management Status:	Center pivot sprinkler irrigation.
Slope and Aspect:	0 to 2% slopes with a northwest facing aspect.
Classification:	coarse-loamy, mixed (calcareous) frigid Ustic Torrifluvents

Horizon	**Depth (inches)**	**USDA Description[1]**
Ap	0 to 8	Light yellowish brown (10YR 6/4) dry and dark yellowish brown (10YR 4/4) moist loam; weak, medium, platy structure; soft, loose, nonsticky, and nonplastic; common fine and common coarse roots; few fine pores; strongly effervescent; abrupt smooth boundary.
C1	8 to 21	Pale brown (10YR 6/3) dry and brown (10YR 4/3) moist loam; single grain; loose, loose, nonsticky, and nonplastic; common fine and common coarse roots; many fine interstitial pores; very abrupt wavy boundary.
C2	21 to 37	Yellowish brown (10YR 5/4) dry and dark yellowish brown (10YR 4/4) moist sand; massive; soft, loose, nonsticky, and nonplastic; few fine and few coarse roots; few fine pores; common medium faint mottles; strongly effervescent; common medium soft white threads and masses from 21 to 27 inches; abrupt wavy boundary.
C3	37 to 60+	Brown (10YR 5/3) moist sand; single grain; loose, loose, nonsticky, and nonplastic; few coarse roots; many fine interstitial pores; 20 percent coarse fragments.

Notes:
1 Soils were described using protocol defined by *Soil Survey Division Staff. 1993. Soil Survey Manual. U.S.D.A. Agriculture Handbook 18*.
2 taxonomy

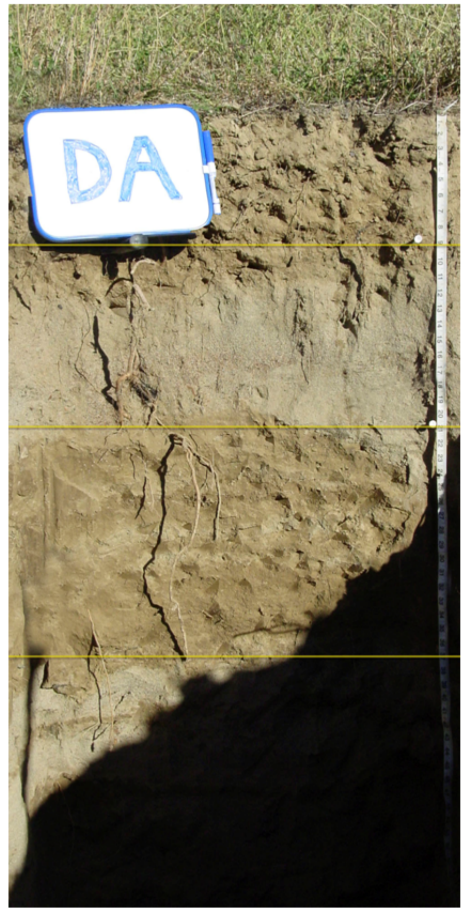


Photo of Soil Pit DA-14.

Figure D-19 Soil profile description and photo of soil at site DA

Dominant clays are non-swelling clays that are not easily affected by excess sodium. The soil had a mildly alkaline pH and moderate levels of lime at all depths. Both the pH and lime content were relatively unchanged with depth owing to the lack of soil profile development. EC was widely variable with the highest value (EC = 8.9 dS/m) occurring at a depth of 8 to 21 inches. SAR (1 to 19) and ESP (5 to 24) were also much higher than other Tongue River soils, ~~low~~, probably as a result of runoff of high EC and sodium-enriched water from the nearby tributary. This soil was so recently placed under irrigation that its soil chemical status had not reached equilibrium with Tongue River irrigation water. As of fall 2005, EC, SAR, and ESP had significantly decreased in the 6-12 and 12-24 inch depths due to 24 inches of irrigation water in 2004 and 15 inches of irrigation water plus above normal precipitation in 2005. Nutrient levels were generally very low for nitrogen, phosphorus and potassium.

Table D-7 Soil profile chemical, physical, and mineralogical data for site DA

Paste pH, Conductivity, Organic Matter, Lime and Texture

Horizon	Upper Depth (in)	Lower Depth (in)	Dry Wt, g	pH, Saturated Paste s.u. Method ASAM10-3.2	Conductivity, Paste Extract mmhos/cm Method ASAM10-3	Organic Matter wt% Method ASA29-3	Lime as CaCO3 wt% Method USDA23c	Texture unitless Method ASA15-5	Sand wt% Method ASA15-5	Silt wt% Method ASA15-5	Clay wt% Method ASA15-5
Ap	0	8	568	7.7	0.69	1.4	7.7	L	51	39	10
C1	8	21	610	8.3	8.9		8.5	L	46	45	9
C2	21	37	678	7.9	1.26		3.5	S	95	4	1
C3	37	60	623				4.3	S	92	8	ND

Paste Extract and Exchangeable Ions

Horizon	Upper Depth (in)	Lower Depth (in)	Saturation wt% Method USDA27a	Calcium, Saturated Paste meq/l Method SW6010B	Magnesium, Saturated Paste meq/l Method SW6010B	Sodium, Saturated Paste meq/l Method SW6010B	Sodium Adsorption Ratio (SAR) unitless Method Calculation	Alkalinity, Saturated Paste meq/L Method ASA10-3	Cation Exchange Capacity meq/100g Method SW6010B	Sodium, Extractable meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
Ap	0	8	34.7	3.4	2	1.6	1	4.6	13.6	0.7	4.8
C1	8	21	37.4	13.6	24	82.5	19	2.6	13.4	4.4	9.9
C2	21	37	29.5	3.7	3.2	5.4	2.9	2.4	6.6	0.8	10
C3	37	60	29.6	0.9	1.1	9.4	9.3	2.8	4	1.2	24

Clay Minerals and Nutrients

Horizon	Upper Depth (in)	Lower Depth (in)	Kaolinite % Method X-ray Diffraction (based on clay fraction)	Illite % Method X-ray Diffraction (based on clay fraction)	Smectite % Method X-ray Diffraction (based on clay fraction)	Chlorite % Method X-ray Diffraction (based on clay fraction)	Nitrate as N, Saturated Paste mg/L Method ASA10-3	Phosphorus (Olsen NaHCO3 Extract) mg/kg Method ASA24-5	Potassium, NH4OAc Extractable mg/kg Method ASA13-3	Sulfate, Saturated Paste meq/L Method ASA10-3	Zinc (DTPA Extract) mg/kg Method SW6010B
Ap	0	8	33	27	36	4	0.3	2.2	136	2.7	0.32
C1	8	21					1.3			124	
C2	21	37	39	20	30	11	1.3			11.5	
C3	37	60									

Site DB

Site DB is located a few miles further north of site DA, and is situated between Brandenburg Bridge and the T&Y Irrigation Diversion Dam (Figure D-20). The center pivot sprinkler-irrigated field lies on a terrace above the Tongue River floodplain and had an established alfalfa stand at the time of the first sampling (Figure D-21).

The soil mapping unit sampled within the field is 901 – Sonnett (Figure D-22), which is classified as a fine-textured smectite-dominant soil with a pronounced subsurface layer with elevated clay content. These soils are atypical of others mapped in the floodplain. The mapped soil differed substantially from the soil that actually occurred in the field.

The pedon described and sampled at site DB (Table D-8) was lower in clay content than Sonnett soils and did not have a clayey subsoil horizon. Soils at site DB resembled the Havre loam mapped extensively elsewhere along the floodplain. Clay content generally decreased with depth and varied from 8% to 35%.

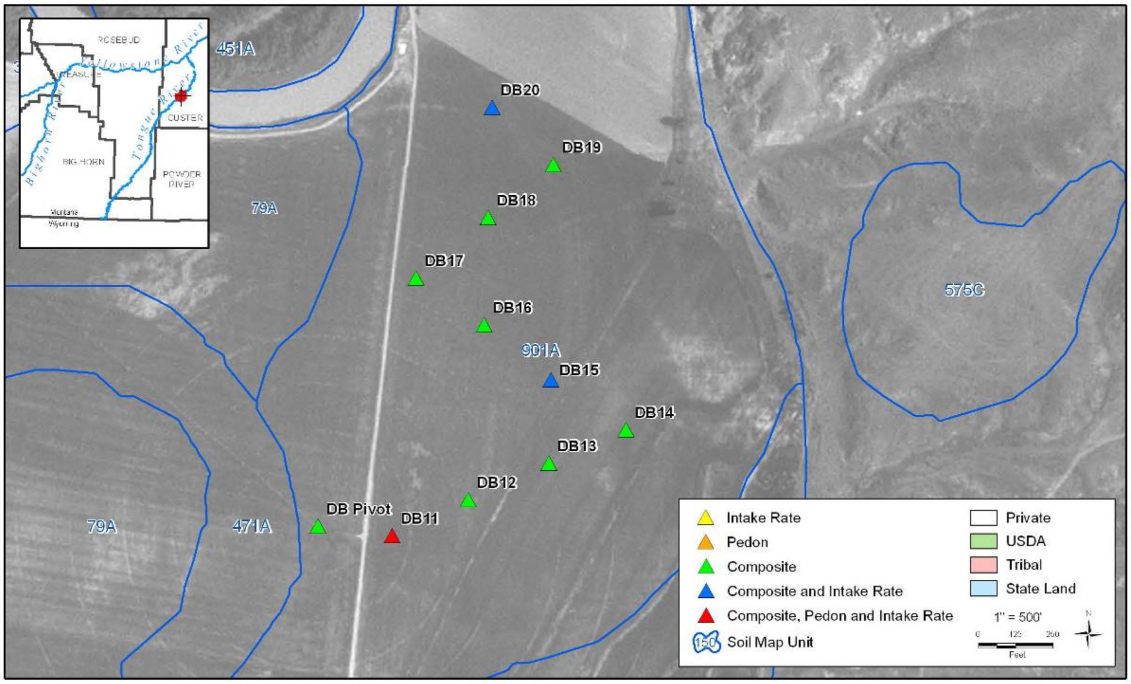
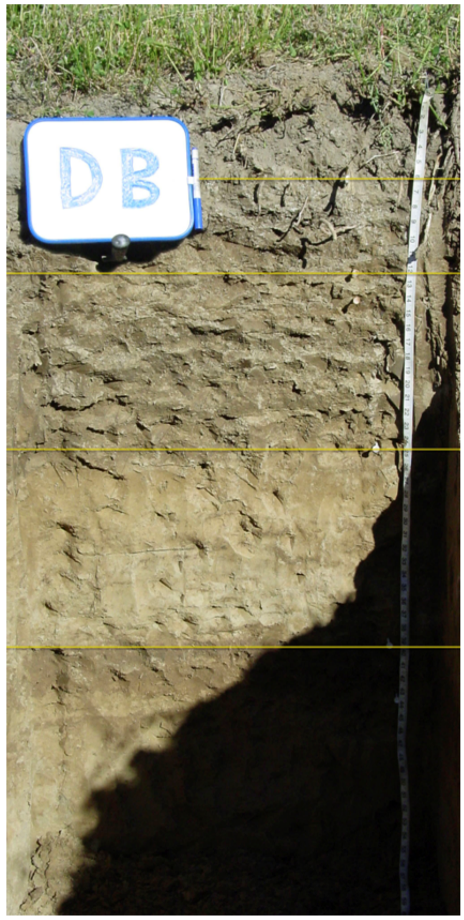


Figure D-20 Map of site DB

Figure D-21 Landscape view of site DB

Profile description for soil pit DB-11.

Landscape position:	Floodplain.	
Parent material:	Alluvium.	
County and mapped soil unit:	Custer County, Sonnett Series.	
Vegetation:	Alfalfa.	
Management Status:	Center pivot sprinkler irrigation.	
Slope and Aspect:	0 to 4% slopes with a west facing aspect.	
Classification:	fine-loamy, mixed (calcareous) frigid Ustic Torrifluvents	
Horizon	**Depth (inches)**	**USDA Description[1]**
Ap	0 to 6	Gray (10YR 6/1) dry and very dark brown (10YR 2/2) moist silty clay loam; moderate, medium, platy parting to weak, fine, granular structure; slightly hard, friable, slightly sticky, and slightly plastic; common fine and common coarse roots; common fine pores; slightly effervescent; clear smooth boundary.
C1	6 to 12	Grayish brown (10YR 5/2) dry and very dark grayish brown (10YR 3/2) moist silty clay loam; weak, medium, angular blocky structure; slightly hard, friable, slightly sticky, and slightly plastic; common fine and common coarse roots; common fine pores; strongly effervescent; many fine and many medium soft white threads and masses; clear wavy boundary.
C2	12 to 14	Yellowish brown (10YR 5/6) moist sandy loam; massive; loose, nonsticky and nonplastic; few fine roots; common fine pores; strongly effervescent; few fine soft white masses; clear wavy boundary.
C3	14 to 25	Brown (10YR 5/3) dry and brown (10YR 4/3) moist silty clay loam; massive; friable, sticky and plastic; few fine roots; common fine pores; strongly effervescent; clear smooth boundary.
C4	25 to 39	Pale yellow (2.5Y 7/4) dry and light olive brown (2.5Y 5/4) moist silt loam; massive; very friable, nonsticky and nonplastic; common fine pores; few medium faint mottles; strongly effervescent; abrupt smooth boundary.
C5	39 to 44	Yellowish brown (10YR 5/6) dry and dark yellowish brown (10YR 4/4) moist silt loam; massive; very friable, slightly sticky and nonplastic; common fine pores; strongly effervescent; abrupt smooth boundary.



Notes:
1 Soils were described using protocol defined by *Soil Survey Division Staff. 1993. Soil Survey Manual. U.S.D.A. Agriculture Handbook 18*.

Photo of Soil Pit DB-11.

2 taxonomy

Figure D-22 Soil profile description and photo of soil at site DB

Composite samples collected across the entire field had an average clay content of only 21%, which is similar to the pedon location and is typical of the Havre loam. Dominant clay minerals were non-swelling clays that are not easily affected by excess sodium. Swelling clays (smectite) accounted for 35% of the clay minerals. Soil pH ranged from moderately to strongly alkaline (7.8 to 9.2) and had moderate levels of lime (5% to 10%) at all depths. EC was higher than average at this location (2.8 to 18.9 dS/m) with higher levels found at depth. EC levels were the highest of any soil sampled with EC varying from 3 dS/m near surface to over 18 dS/m, which was much higher than the soil EC based on composite sampling, which averaged 1.43 dS/m in the upper 36 inches. SAR (11 to 66) and ESP (6 to 23) were also higher than average for the Tongue River and increased with depth. By contrast, SAR and ESP of composite samples was 3 and 6, respectively, in the upper 36 inches. The large difference between the site DB pedon and composite samples provides a striking example of natural soil spatial variability. Nutrient levels were variable with nitrogen deficient for irrigated grass, but adequate for alfalfa. Soil test levels of nitrogen, phosphorus, potassium, sulfur and zinc were generally adequate.

Table D-8 Soil profile chemical, physical, and mineralogical data for site DB

Horizon	Upper Depth (in)	Lower Depth (in)	Dry Wt 0 Method FIELD	pH (Paste) S.U. Method ASAM10-3.2	Electrical Conductivity (Paste) mmhos/cm Method ASAM10-3	Organic Matter % Method ASA29-3	Lime as CaCO3 wt% Method USDA23c	Texture unitless Method ASA15-5	Sand % Method ASA15-5	Silt % Method ASA15-5	Clay % Method ASA15-5
Ap	0	6	496	7.8	2.8	3.2	4.9	SiCL	6	59	35
C1	6	12	602	8.4	18.9		7.9	SiCL	8	62	30
C3	14	25	612	8.9	16.5		10.3	SiCL	4	69	27
C4	25	39	645	9.1	12.8		10.3	SiL	16	76	8
C5	39	44	638	9.2	14.6		10	SiL	24	60	16

Horizon	Upper Depth (in)	Lower Depth (in)	Saturation Percentage wt% Method USDA27a	Calcium (Paste) meq/l Method SW6010B	Magnesium (Paste) meq/l Method SW6010B	Sodium (Paste) meq/l Method SW6010B	Sodium Adsorption Ratio unitless Method Calculation	Alkalinity (Paste) meq/L Method ASA10-3	Cation Exchange Capacity meq/100g Method SW6010B	Extractable Sodium meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
Ap	0	6	70.3	3.8	2.9	20.9	11	8.7	33.7	3.8	6.8
C1	6	12	70.8	24.6	29.4	169	33	5.2	26.7	13.7	6.6
C3	14	25	83.3	7.3	13.2	160	50	5.6	19.3	17.9	23
C4	25	39	47	1.2	5.9	115	61	5.7	10.5	7.2	17
C5	39	44	60.3	1.2	7.3	136	66	6.3	15.2	10.8	17

Horizon	Upper Depth (in)	Lower Depth (in)	Kaolinite % Method X-ray Diffraction	Illite % Method X-ray Diffraction	Smectite % Method X-ray Diffraction	Chlorite % Method X-ray Diffraction	Nitrate as N mg/L Method ASA10-3	Phosphorus mg/kg Method ASA24-5	Potassium mg/kg Method ASA13-3	Sulfate (Paste) meq/L Method ASA10-3	Zinc mg/kg Method SW6010B
Ap	0	6	36	22	35	7	2.4	31	303	18.5	0.56
C1	6	12					1.9			228	
C3	14	25	33	26	35	6	2.8			187	

Site BA

Site BA is located just downstream of the T& Y Irrigation Dam (Figure D-23), and is flood-irrigated from the T&Y Canal. The field lies on the Tongue River floodplain and had recently disked-under corn stubble at the time of the first sampling (Figure D-24).

The soil mapping unit sampled within the field is 79A – Yamacall loam (Figure D-25), which is somewhat similar to the Havre and differs mostly by having a weakly developed subsurface horizon. The subsurface horizon that is diagnostic of the Yamacall series was lacking at this location. The soil most resembled the abundant Havre. They are undeveloped floodplain soils with 18% to 35% clay, which have moderate amounts of organic matter that is stratified with depth, and contain ample amounts of lime throughout the profile.

The pedon described and sampled at site BA (Table D-9) had clay content around 28% except for a thin layer of loamy fine sand from 27 to 36 inches in depth.

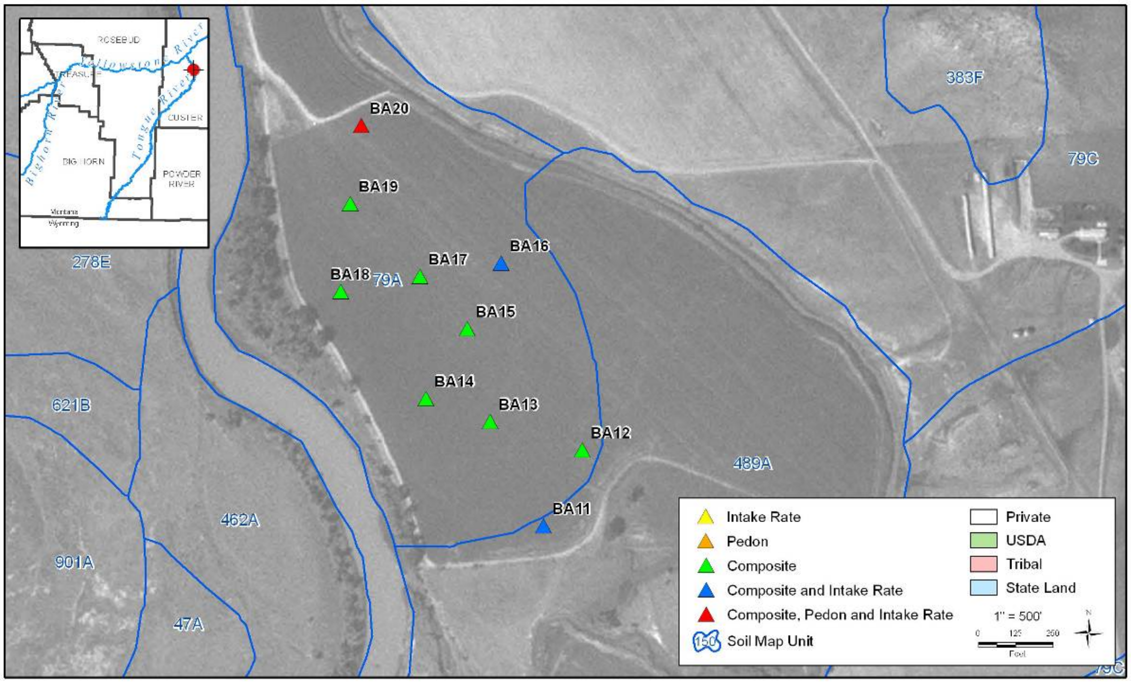


Figure D-23 Map of site BA

Figure D-24 Landscape view of site BA

Profile description for soil pit BA-20.

Landscape position:		Floodplain/terrace.
Parent material:		Alluvium.
County and mapped soil unit:		Custer County, Yamacall Series.
Vegetation:		Corn.
Management Status:		Flood irrigation.
Slope and Aspect:		0 to 2% slopes with a west facing aspect.
Classification:		fine-loamy, mixed (calcareous) frigid Ustic Torrifluvents
Horizon	**Depth (inches)**	**USDA Description[1]**
Ap	0 to 6	Yellow (10YR 7/6) dry and yellowish brown (10YR 5/6) moist silty clay loam; moderate, medium, platy parting to weak, fine, granular structure; slightly hard, friable, slightly sticky, and slightly plastic; many fine and few coarse roots; common very fine pores; slightly effervescent; clear smooth boundary.
C1	6 to 15	Dark yellowish brown (10YR 4/4) dry and very dark gray (10YR 3/1) moist silty clay loam; weak, fine, subangular blocky structure; friable, sticky, and plastic; common fine and few coarse roots; common fine pores; strongly effervescent; clear smooth boundary.
C2	15 to 27	Dark yellowish brown (10YR 3/4) moist silt loam; massive; very friable, slightly sticky, and slightly plastic; common fine roots; common fine pores; violently effervescent; clear smooth boundary.
C3	27 to 36	Pale yellow (2.5Y 7/4) dry and light olive brown (2.5Y 5/4) moist sandy loam; massive; loose, nonsticky, and nonplastic; few fine roots; interstitial pores; gradual wavy boundary.
C4	36 to 45	Very dark grayish brown (10YR 3/2) moist silt loam; massive; very friable, slightly sticky, and slightly plastic; few very fine roots; common fine pores; common fine faint mottles; strongly effervescent; gradual wavy boundary.
C5	45 to 60+	Yellowish brown (10YR 5/4) moist loam; massive; loose, nonsticky, and nonplastic; few very fine roots; common fine pores; few fine faint mottles.

Notes:
1 Soils were described using protocol defined by *Soil Survey Division Staff. 1993. Soil Survey Manual. U.S.D.A. Agriculture Handbook 18*.
2 taxonomy

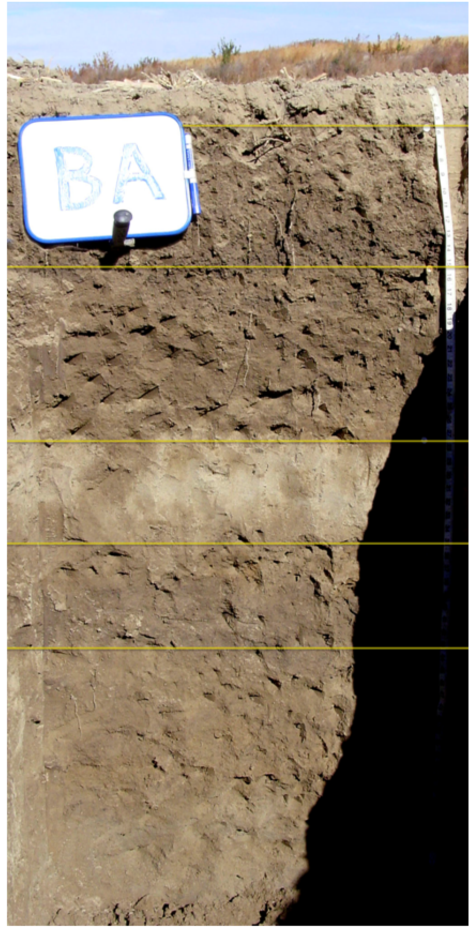


Photo of Soil Pit BA-20.

Figure D-25 Soil profile description and photo of soil at site BA

Composite samples collected across the entire field had an average clay content of only 19%, which is at the lower end of the Havre loam and was coarser textured than the pedon sample. Smectite was the most abundant clay mineral, but non-swelling clays that are not easily affected by excess sodium still accounted for more than 50% of the clay mineral abundance. The soil had a uniform pH (7.7 to 7.9) and moderate levels of lime (6% to 7%) at all depths. EC was very low (less than 1 dS/m) with somewhat higher levels found in composite samples. SAR (1 to 2) and ESP (2 to 4) were also low. Nutrient levels were variable with low nitrogen following the corn crop while levels of phosphorus, potassium, sulfur and zinc were generally adequate.

Table D-9 Soil profile chemical, physical, and mineralogical data for site BA

Paste pH, Conductivity, Organic Matter, Lime and Texture											
Horizon	Upper Depth (in)	Lower Depth (in)	Dry Wt, g	pH, Saturated Paste s.u. Method ASAM10-3.2	Conductivity, Paste Extract mmhos/cm Method ASAM10-3	Organic Matter wt% Method ASA29-3	Lime as CaCO3 wt% Method USDA23c	Texture unitless Method ASA15-5	Sand wt% Method ASA15-5	Silt wt% Method ASA15-5	Clay wt% Method ASA15-5
Ap	0	6	550	7.7	0.73	2.2	5.9	SiCL	10	62	28
C1	6	15	605	7.7	0.8		6.2	SiCL	8	64	28
C2	15	27	578	7.8	0.73		6.4	SiL	24	54	22
C3	27	36	596	7.9	0.45		5.2	SL	74	22	4
C4	36	45	602	7.8	0.71		6.5	SiL	9	71	20
C5	45	60	585	7.8	0.62		6.9	L	40	42	18

Paste Extract and Exchangeable Ions											
Horizon	Upper Depth (in)	Lower Depth (in)	Saturation wt% Method USDA27a	Calcium, Saturated Paste meq/l Method SW6010B	Magnesium, Saturated Paste meq/l Method SW6010B	Sodium, Saturated Paste meq/l Method SW6010B	Sodium Adsorption Ratio (SAR) unitless Method Calculation	Alkalinity, Saturated Paste meq/L Method ASA10-3	Cation Exchange Capacity meq/100g Method SW6010B	Sodium, Extractable meq/100g Method SW6010B	Exchang-eable Sodium Percentage % Method USDA20b
Ap	0	6	55.3	3.1	1.8	2.5	1.6	4.3	33.7	1	2.5
C1	6	15	53.8	3.5	2	2.5	1.5	4.2	28.1	1	3.2
C2	15	27	45.2	2.6	1.5	2.8	2	3	24.7	0.8	2.7
C3	27	36	34	1.4	0.7	1.7	1.6	2.6	11.7	0.6	4.3
C4	36	45	50.2	2.4	1.2	2.8	2.1	3.2	28	0.9	2.6
C5	45	60	37.4	2.1	1.1	2.4	1.9	2.9	21.5	0.8	3.2

Clay Minerals and Nutrients											
Horizon	Upper Depth (in)	Lower Depth (in)	Kaolinite % Method X-ray Diffraction (based on clay fraction)	Illite % Method X-ray Diffraction (based on clay fraction)	Smectite % Method X-ray Diffraction (based on clay fraction)	Chlorite % Method X-ray Diffraction (based on clay fraction)	Nitrate as N, Saturated Paste mg/L Method ASA10-3	Phos-phorus (Olsen NaHCO3 Extract) mg/kg Method ASA24-5	Potassium, NH4OAc Extractable mg/kg Method ASA13-3	Sulfate, Saturated Paste meq/L Method ASA10-3	Zinc (DTPA Extract) mg/kg Method SW6010B
Ap	0	6	29	20	46	5	1.6	47	267	2.9	0.9
C1	6	15	36	18	42	4	1.1			3.2	
C2	15	27	34	23	39	4	1.6			3.3	
C3	27	36									
C4	36	45									
C5	45	60									

Site BC

Site BC is located a few miles south of Miles City, and is flood-irrigated using water from the T&Y Canal (Figure D-26). The field lies on the Tongue River floodplain and had an established alfalfa/grass stand at the time of the first sampling (Figure D-27). Orchardgrass was inter-seeded spring of 2004 so the stand is now grass/alfalfa.

The soil mapping unit sampled within the field is 47A – Harlake silty clay (Figure D-28), indicating a higher clay content than most other soils mapped in the Tongue River floodplain. Finer textured soils may be expected to occur on lower portions of the river floodplain where stream gradient decreases near the confluence with the Yellowstone River. Harlake soils have greater than 35% clay, and smectite is the dominant clay.

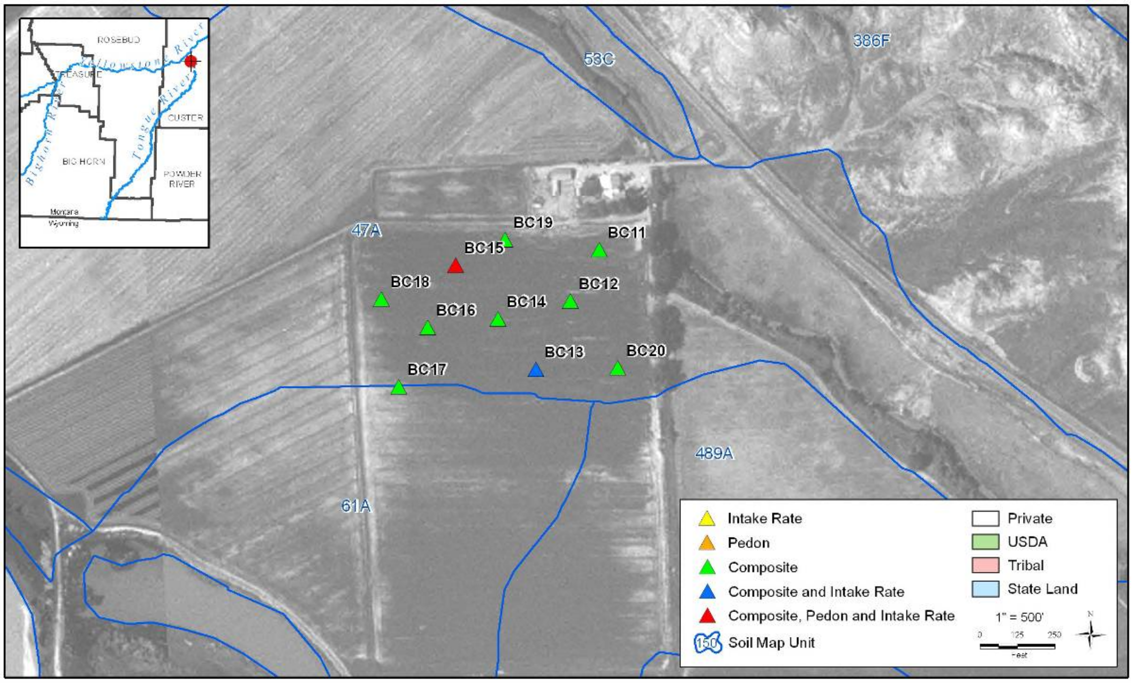


Figure D-26 Map of site BC

Figure D-27 Landscape view of site BC

Profile description for soil pit BC-15.

Landscape position:	Floodplain.	
Parent material:	Alluvium.	
County and mapped soil unit:	Custer County, Harlake Series.	
Vegetation:	Alfalfa.	
Management Status:	Flood irrigation.	
Slope and Aspect:	0 to 2% slopes with a west facing aspect.	
Classification:	fine, mixed (calcareous) frigid Ustic Torrifluvents	
Horizon	**Depth (inches)**	**USDA Description[1]**
Ap	0 to 5	Yellowish brown (10YR 5/4) dry and very dark grayish brown (10YR 3/2) moist silty clay loam; moderate, medium, platy parting to moderate, medium, subangular blocky structure; slightly hard, friable, slightly sticky, and slightly plastic; many fine and few coarse roots; many fine and common coarse pores; slightly effervescent; gradual smooth boundary.
AB	5 to 15	Dark grayish brown (2.5Y 4/2) moist silty clay loam; moderate, medium, subangular blocky parting to weak, medium, prismatic structure; hard, firm, slightly sticky, and slightly plastic; many fine and few coarse roots; many fine and common coarse pores; strongly effervescent; many fine soft white threads; clear smooth boundary.
1C	15 to 26	Olive brown (2.5Y 4/3) moist silty clay; massive; firm, sticky, and plastic; common fine and common medium roots; common fine and few medium pores; strongly effervescent; abrupt smooth boundary.
2C	26 to 60+	Olive brown (2.5Y 4/3) moist clay; massive; very firm, very sticky, and very plastic; common very fine roots; common fine pores; slightly effervescent; nodules and white masses.

Notes:

1 Soils were described using protocol defined by *Soil Survey Division Staff. 1993. Soil Survey Manual. U.S.D.A. Agriculture Handbook 18*.

2 taxonomy

Photo of Soil Pit BC-15.

Figure D-28 Soil profile description and photo of soil at site BC

The pedon described and sampled at site BC (Table D-10) was similar in clay content to the Harlake series, but smectite was not the dominant clay mineral. Mineralogy was mixed and calcareous. Soil pH was mildly alkaline (7.4 to 8.0) and had moderate levels of lime (5% to 8%) at all depths. EC was low at all depths except below 5 feet where the EC was 11.6 dS/m. SAR (2 to 20) and ESP (2 to 12) were about average within the upper 5 feet, but increased at depth as did EC. Nutrient levels were variable with adequate nitrogen, phosphorus, sulfur and zinc and moderate levels of potassium.

Table D-10 Soil profile chemical, physical, and mineralogical data for site BC

Paste pH, Conductivity, Organic Matter, Lime and Texture

Horizon	Upper Depth (in)	Lower Depth (in)	Dry Wt, g	pH, Saturated Paste s.u. Method ASAM10-3.2	Conductivity, Paste Extract mmhos/cm Method ASAM10-3	Organic Matter wt% Method ASA29-3	Lime as CaCO3 wt% Method USDA23c	Texture unitless Method ASA15-5	Sand wt% Method ASA15-5	Silt wt% Method ASA15-5	Clay wt% Method ASA15-5
Ap	0	5	601	7.4	1.23	2.9	8	SiCL	17	52	31
AB	5	15	635	7.8	1.19		8.1	SiCL	15	53	32
1C	15	26	646	8.1	3.9		6.6	SiC	ND	48	52
2C	26	60	615	8	11.6		4.8	C	ND	36	64

Paste Extract and Exchangeable Ions

Horizon	Upper Depth (in)	Lower Depth (in)	Saturation wt% Method USDA27a	Calcium, Saturated Paste meq/l Method SW6010B	Magnesium, Saturated Paste meq/l Method SW6010B	Sodium, Saturated Paste meq/l Method SW6010B	Sodium Adsorption Ratio (SAR) unitless Method Calculation	Alkalinity, Saturated Paste meq/L Method ASA10-3	Cation Exchange Capacity meq/100g Method SW6010B	Sodium, Extractable meq/100g Method SW6010B	Exchang-eable Sodium Percentage % Method USDA20b
Ap	0	5	50.3	4.7	3.8	4.6	2.2	9.7	45.8	1	1.7
AB	5	15	48.1	3.3	2.9	5.6	3.2	6.7	38.2	1.4	2.9
1C	15	26	70.3	4.4	5.7	31.7	14	4.4	48.3	5.7	7.1
2C	26	60	82.6	17.8	19.9	87.5	20	2.8	49.3	13.1	12

Clay Minerals and Nutrients

Horizon	Upper Depth (in)	Lower Depth (in)	Kaolinite % Method X-ray Diffraction (based on clay fraction)	Illite % Method X-ray Diffraction (based on clay fraction)	Smectite % Method X-ray Diffraction (based on clay fraction)	Chlorite % Method X-ray Diffraction (based on clay fraction)	Nitrate as N, Saturated Paste mg/L Method ASA10-3	Phos-phorus (Olsen NaHCO3 Extract) mg/kg Method ASA24-5	Potassium, NH4OAc Extractable mg/kg Method ASA13-3	Sulfate, Saturated Paste meq/L Method ASA10-3	Zinc (DTPA Extract) mg/kg Method SW6010B
Ap	0	5	34	22	39	5	1	32	190	3.6	
AB	5	15					2.9			4.6	
1C	15	26	35	26	30	9	1.9			35.9	
2C	26	60									

Site BD

Site BD (Figure D-29).is located close to BC, but is situated on the west side of the Tongue River in a dryland field (Figure D-30). Several prominent spreader dikes crossed the field and served to distribute runoff from tributary drainages across the field. Vegetation consisted of perennial native (western wheatgrass) and introduced (crested wheatgrass) species, annual grassy weeds (cheatgrass) and scattered stands of silver sage and western snowberry.

The soil mapping unit sampled within the field is 47A – Harlake silty clay (Figure D-31), the same as mapped across the river at BC. However, the pedon described and sampled at site BD (Table D-11) was lower in clay content than Harlake soils and was more representative of the Havre series. Clay content was variable with depth and generally ranged from 22% to 36%, with an average of around 28% in the upper 40 inches. Composite samples collected also had an average clay content of 28%, which is typical of the Havre loam. Dominant clay minerals were a mixture of non-swelling clays (kaolinite and illite) that are not easily affected by excess sodium.

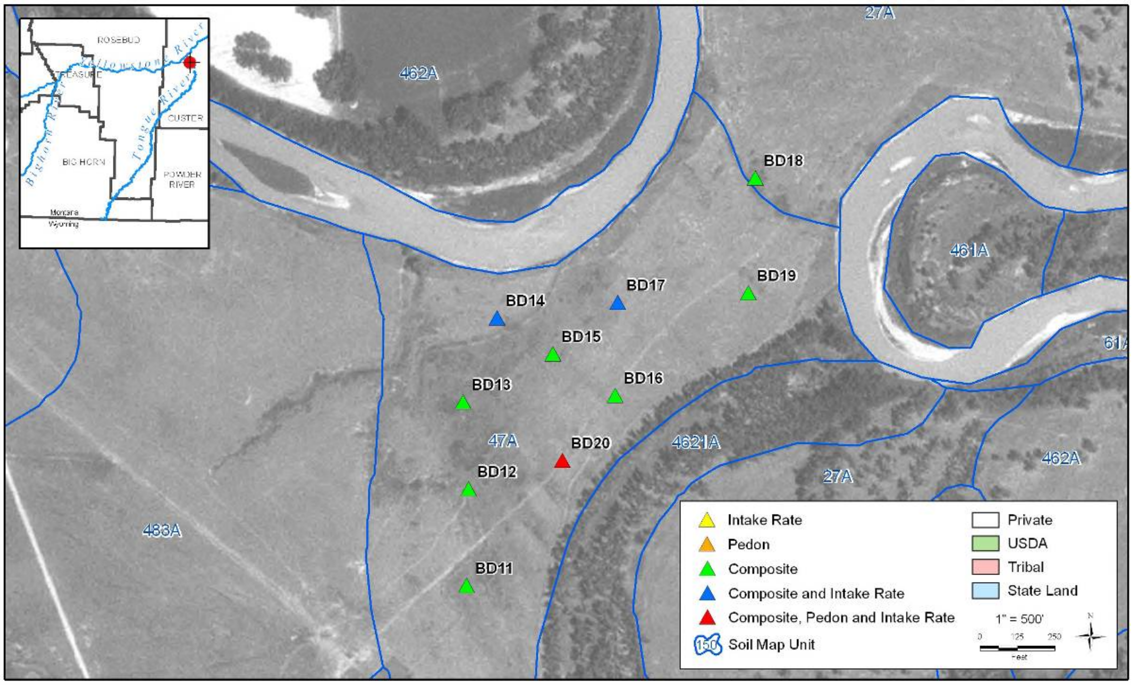


Figure D-29 Map of site BD

Figure D-30 Landscape view of site BD

Profile description for soil pit BD-20.

Landscape position:	Floodplain.
Parent material:	Alluvium/lacustrine.
County and mapped soil unit:	Custer County, Harlake Series.
Vegetation:	Pasture grasses (wheat grasses).
Management Status:	Dryland farming.
Slope and Aspect:	0 to 3% slopes with an east facing aspect.
Classification:	fine-loamy, mixed (calcareous) frigid Ustic Torrifluvents

Horizon	Depth (inches)	USDA Description[1]
Ap	0 to 8	Yellowish brown (10YR 5/4) dry and dark brown (10YR 3/3) moist silty clay loam; moderate, coarse, subangular blocky parting to moderate, medium, platy structure; hard, very friable, slightly sticky, and nonplastic; many fine and common medium roots; common fine discontinuous pores; slightly effervescent; clear irregular boundary.
C1	8 to 17	Light yellowish brown (2.5Y 6/4) dry and olive brown (2.5Y 4/3) moist silt loam; moderate, medium, platy parting to weak, medium, subangular blocky structure; hard, very friable, nonsticky, and nonplastic; common fine and few medium roots; common fine discontinuous pores; strongly effervescent; clear wavy boundary.
C2	17 to 24	Light yellowish brown (2.5Y 6/4) dry and olive brown (2.5Y 4/3) moist silty clay loam; massive; slightly hard, friable, slightly sticky, and slightly plastic; common fine roots; few very fine discontinuous pores; strongly effervescent; varves; clear smooth boundary.
C3	24 to 60+	Pale yellow (2.5Y 7/4) dry and light olive brown (2.5Y 5/4) moist silt loam; massive; slightly hard, very friable, nonsticky, and nonplastic; few fine roots; few fine discontinuous pores; strongly effervescent; varves.

Notes:

1 Soils were described using protocol defined by *Soil Survey Division Staff. 1993. Soil Survey Manual. U.S.D.A. Agriculture Handbook 18*.

Photo of Soil Pit BD-20.

Figure D-31 Soil profile description and photo of soil at site BD

Swelling clays (smectite) accounted for 36% to 43% of the clay minerals, which is greater than is typical farther upriver. The increased proportion of smectite clays at this location may be due to changes in geologic parent material. The Lebo Shale member of the Fort Union formation, which outcrops near Miles City, may contain more abundant smectite than the Tongue River member that occurs further upstream. Soil pH was mildly alkaline (7.3 to 7.8) and had moderate levels of lime (4% to 8%) at all depths. EC was relatively low (1 to 3 dS/m) with higher levels found in the middle of the profile near the base of the root zone. SAR (1 to 2) and ESP (1 to 3) were also low. As expected for native range or tame pasture, nitrogen levels were low but other nutrients were generally adequate.

Table D-11 Soil profile chemical, physical, and mineralogical data for site BD

Paste pH, Conductivity, Organic Matter, Lime and Texture											
Horizon	Upper Depth (in)	Lower Depth (in)	Dry Wt, g	pH, Saturated Paste s.u. Method ASAM10-3.2	Conductivity, Paste Extract mmhos/cm Method ASAM10-3	Organic Matter wt% Method ASA29-3	Lime as CaCO3 wt% Method USDA23c	Texture unitless Method ASA15-5	Sand wt% Method ASA15-5	Silt wt% Method ASA15-5	Clay wt% Method ASA15-5
Ap	0	8	483	7.3	0.88	5	4.4	SiCL	5	59	36
C1	8	17	518	7.3	2.9		7.5	SiL	12	65	23
C2	17	24	552	7.7	0.7		8.1	SiCL	1	70	29
C3	24	60	574	7.8	0.64		8.3	SiL	7	71	22

Paste Extract and Exchangeable Ions											
Horizon	Upper Depth (in)	Lower Depth (in)	Saturation wt% Method USDA27a	Calcium, Saturated Paste meq/l Method SW6010B	Magnesium, Saturated Paste meq/l Method SW6010B	Sodium, Saturated Paste meq/l Method SW6010B	Sodium Adsorption Ratio (SAR) unitless Method Calculation	Alkalinity, Saturated Paste meq/L Method ASA10-3	Cation Exchange Capacity meq/100g Method SW6010B	Sodium, Extractable meq/100g Method SW6010B	Exchang-eable Sodium Percentage % Method USDA20b
Ap	0	8	75.1	4.2	2	0.9	0.5	7.1	42.1	0.5	1
C1	8	17	35.5	21.2	9.4	3.2	0.8	3.7	31.9	0.7	2
C2	17	24	40.1	2.1	1.6	2	1.4	4.3	36.2	0.8	1.9
C3	24	60	36.4	1.3	1.3	2.3	2	4.3	27	0.9	2.9

Clay Minerals and Nutrients											
Horizon	Upper Depth (in)	Lower Depth (in)	Kaolinite % Method X-ray Diffraction (based on clay fraction)	Illite % Method X-ray Diffraction (based on clay fraction)	Smectite % Method X-ray Diffraction (based on clay fraction)	Chlorite % Method X-ray Diffraction (based on clay fraction)	Nitrate as N, Saturated Paste mg/L Method ASA10-3	Phos-phorus (Olsen NaHCO3 Extract) mg/kg Method ASA24-5	Potassium, NH4OAc Extractable mg/kg Method ASA13-3	Sulfate, Saturated Paste meq/L Method ASA10-3	Zinc (DTPA Extract) mg/kg Method SW6010B
Ap	0	8	32	32	36	<2	ND	16	520	1.6	1.13
C1	8	17					0.2			32.2	
C2	17	24	33	19	43	4	ND			1.7	
C3	24	60									

Site YAA

Site YAA is actually within the Yellowstone River floodplain and is located about 10 miles northeast of Miles City (Figure D-32). The field is in the T&Y Irrigation District so receives Tongue River water as an irrigation source. The flood-irrigated field uses border dikes to facilitate even distribution of water and had an established alfalfa stand at the time of the first sampling (Figure D-33).

The soil mapping unit sampled within the field is 53 A – Kobase silty clay loam (Figure D-34), which is similar to the Harlake series mapped upstream on the Tongue River, differing only in having a weakly develop subsoil horizon. The Kobase series has more than 35% clay, moderate soil profile development, and smectite is the dominant clay mineral.

The pedon described and sampled at site YAA (Table D-12) was much lower in clay content than typical Kobase soils and more closely resembles the Havre loam. Clay content was variable with depth and generally ranged from 22% to 44%, with an average of 28% in the composite samples, which is typical of Havre loam.

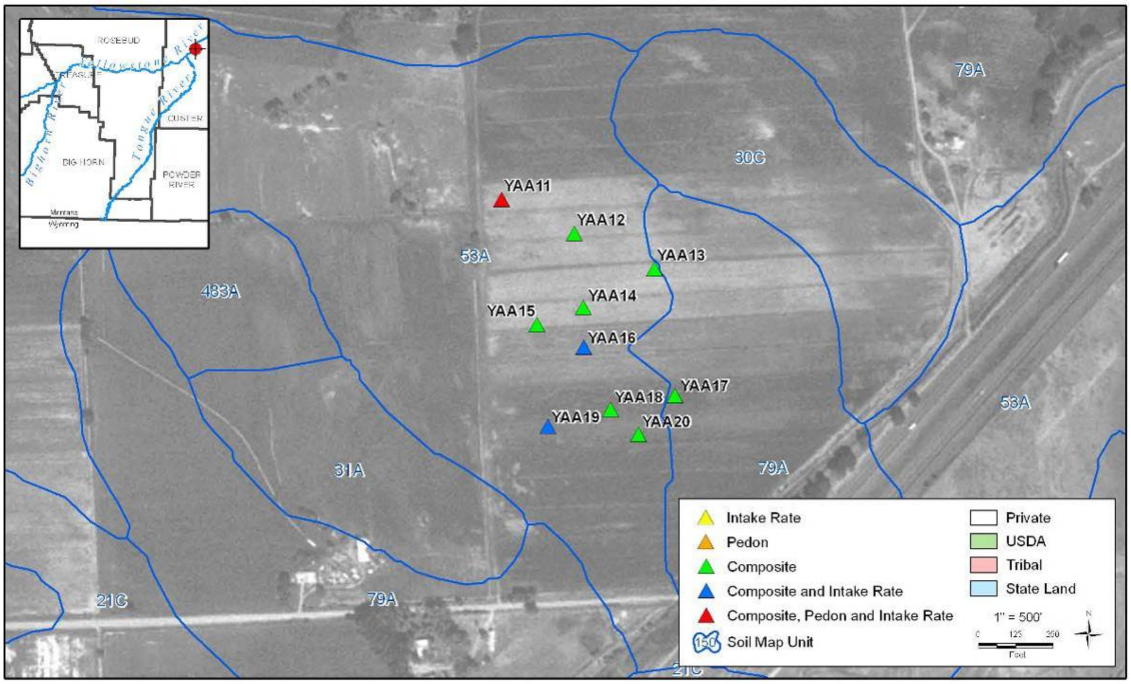


Figure D-32 Map of site YAA

Figure D-33 Landscape view of site YAA

Profile description for soil pit YAA-11.

Landscape position:	Terrace.	
Parent material:	Alluvium.	
County and mapped soil unit:	Custer County, Kobase Series.	
Vegetation:	Alfalfa.	
Management Status:	Flood irrigation.	
Slope and Aspect:	0 to 2% slopes with a north facing aspect.	
Classification:	fine-loamy, mixed (calcareous) frigid Ustic Torrifluvents	
Horizon	**Depth (inches)**	**USDA Description[1]**
Ap	0 to 6	Dark grayish brown (10YR 4/2) dry and very dark grayish brown (10YR 3/2) moist loam; strong, coarse, subangular blocky parting to moderate, fine, granular structure; slightly hard, firm, sticky, and plastic; many fine and few coarse roots; many fine and few coarse pores; strongly effervescent; clear smooth boundary.
E	6 to 12	Brown (10YR 5/3) dry and very dark grayish brown (10YR 3/2) moist silt loam; weak, fine, subangular blocky structure; soft, friable, slightly sticky, and slightly plastic; common fine roots; many fine and common coarse pores; common, fine, faint mottles; strongly effervescent; clear smooth boundary.
Bw	12 to 15	Yellowish brown (10YR 5/4) dry and dark brown (10YR 3/3) moist loam; weak, fine, angular blocky structure; soft, friable, slightly sticky, and slightly plastic; common fine roots; many fine and common coarse pores; common, fine, faint mottles; strongly effervescent; abrupt smooth boundary.
C1	15 to 34	Brown (10YR 4/3) dry and very dark grayish brown (10YR 3/2) moist silt loam; massive; slightly hard, very friable, sticky, and plastic; common fine roots; many fine and common coarse pores; common, fine, faint mottles; strongly effervescent; clear irregular boundary.
C2	34 to 47	Very dark grayish brown (2.5Y 3/2) moist loam; massive; very friable, nonsticky, and nonplastic; few very fine roots; interstitial pores; few, fine, distinct mottles; diffuse and strongly effervescent; clear smooth boundary.
C3	47 to 60+	Very dark grayish brown (10YR 3/2) moist silty clay; massive; very friable, sticky, and plastic; many fine pores; strongly effervescent.

Photo of Soil Pit YAA-11.

Notes:

1 Soils were described using protocol defined by *Soil Survey Division Staff. 1993. Soil Survey Manual. U.S.D.A. Agriculture Handbook 18*.

2 taxonomy

Figure D-34 Soil profile description and photo of soil at site YAA

The dominant clay mineral was smectite, at 51% to 62%t of the clays. Soil pH was mildly alkaline (7.8 to 8.1) and the soil had moderate levels of lime (5% to 7.5%) at all depths. EC was similar to levels found in flood irrigated soils in the Tongue River floodplain (1 to 3.7 dS/m) with higher levels found at depth. SAR (2.2 to 13) and ESP (2.5 to 9.6) were moderate and generally increased with depth. Soil test levels of nitrogen, sulfur and zinc were adequate for alfalfa while phosphorus and potassium were low.

Table D-12 Soil profile chemical, physical, and mineralogical data for site YAA

Paste pH, Conductivity, Organic Matter, Lime and Texture

Horizon	Upper Depth (in)	Lower Depth (in)	Dry Wt, g	pH, Saturated Paste s.u. Method ASAM10-3.2	Conductivity, Paste Extract mmhos/cm Method ASAM10-3	Organic Matter wt% Method ASA29-3	Lime as CaCO3 wt% Method USDA23c	Texture unitless Method ASA15-5	Sand wt% Method ASA15-5	Silt wt% Method ASA15-5	Clay wt% Method ASA15-5
Ap	0	6	587	7.8	1.06	2.7	6.5	L	28	48	24
E	6	12	635	7.8	0.92		6.5	SiL	26	52	22
C1	15	34	608	8	1.57		6.6	SiL	24	53	23
C2	34	47	588	8.1	2.07		7.6	L	44	38	18
C3	47	60	608	8.1	3.65		4.7	SiC	8	48	44

Paste Extract and Exchangeable Ions

Horizon	Upper Depth (in)	Lower Depth (in)	Saturation wt% Method USDA27a	Calcium, Saturated Paste meq/l Method SW6010B	Magnesium, Saturated Paste meq/l Method SW6010B	Sodium, Saturated Paste meq/l Method SW6010B	Sodium Adsorption Ratio (SAR) unitless Method Calculation	Alkalinity, Saturated Paste meq/L Method ASA10-3	Cation Exchange Capacity meq/100g Method SW6010B	Sodium, Extractable meq/100g Method SW6010B	Exchang-eable Sodium Percentage % Method USDA20b
Ap	0	6	40.9	3.8	2.9	4.5	2.4	6.6	33	1.2	2.9
E	6	12	40.2	3	2.5	3.6	2.2	4.8	30.4		2.5
C1	15	34	41.2	4.5	6.1	5.3	2.3	4.2	30.7	1.2	3.2
C2	34	47	32.9	2.4	3.9	13.4	7.5	5.8	26.2	2.1	6.2
C3	47	60	63.2	4	5.2	28.3	13	4.2	35.6	5.2	9.6

Clay Minerals and Nutrients

Horizon	Upper Depth (in)	Lower Depth (in)	Kaolinite % Method X-ray Diffraction (based on clay fraction)	Illite % Method X-ray Diffraction (based on clay fraction)	Smectite % Method X-ray Diffraction (based on clay fraction)	Chlorite % Method X-ray Diffraction (based on clay fraction)	Nitrate as N, Saturated Paste mg/L Method ASA10-3	Phos-phorus (Olsen NaHCO3 Extract) mg/kg Method ASA24-5	Potassium, NH4OAc Extractable mg/kg Method ASA13-3	Sulfate, Saturated Paste meq/L Method ASA10-3	Zinc (DTPA Extract) mg/kg Method SW6010B
Ap	0	6	25	11	62	2	0.5	1.2	149	3.8	0.39
E	6	12	24	20	51	5	1			4	
C1	15	34									
C2	34	47									
C3	47	60									

Tongue River Tributary AMPP Sites

Site MB

Site MB is located near the confluence of Prairie Dog Creek and the Tongue River in Sheridan County, Wyoming (Figure D-35). The irrigated field lies on a gently sloping upper terrace about 15 feet above the Tongue River floodplain, and is flood-irrigated using water diverted from Prairie Dog Creek. At the time of the first sampling, the field contained hay millet stubble with significant weed growth consisting of kochia, Russian thistle, lambsquarter, field bindweed, and Canada thistle (Figure D-36).

The soil mapping unit sampled within the field is 171 - Kishona (50%) Cambria (30%) (Figure D-37). These soils are weakly developed floodplain soils with 18% to 35% clay, which have moderate amounts of organic matter that is stratified with depth, and contain ample amounts of lime throughout the profile.

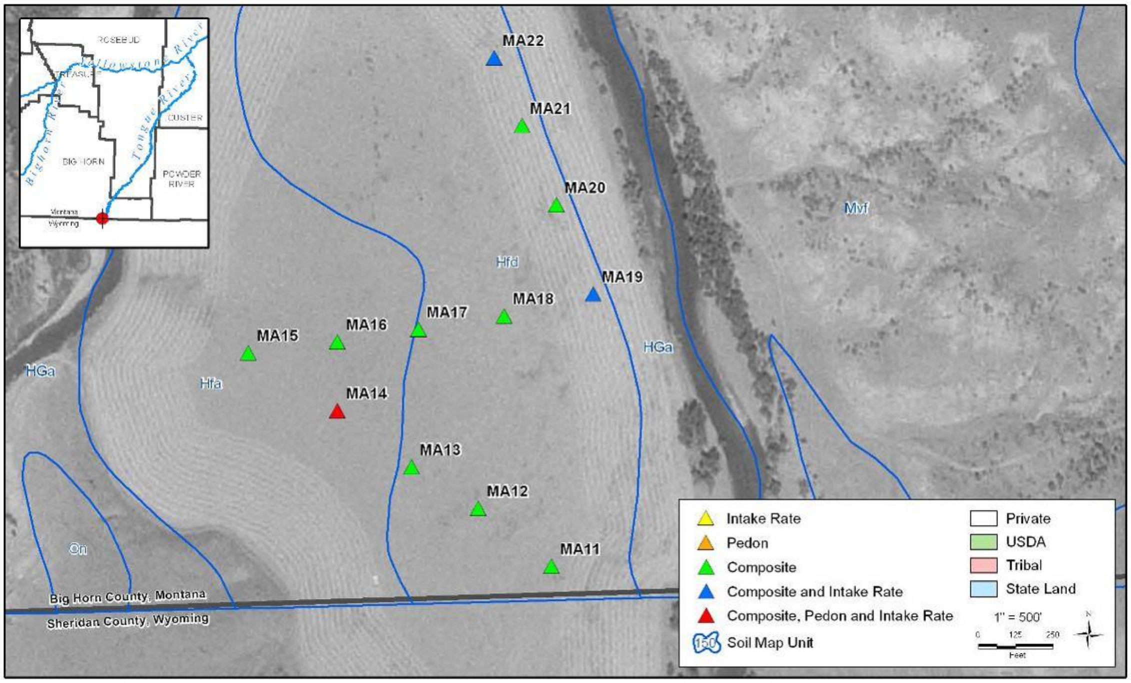


Figure D-35 Map of site MB

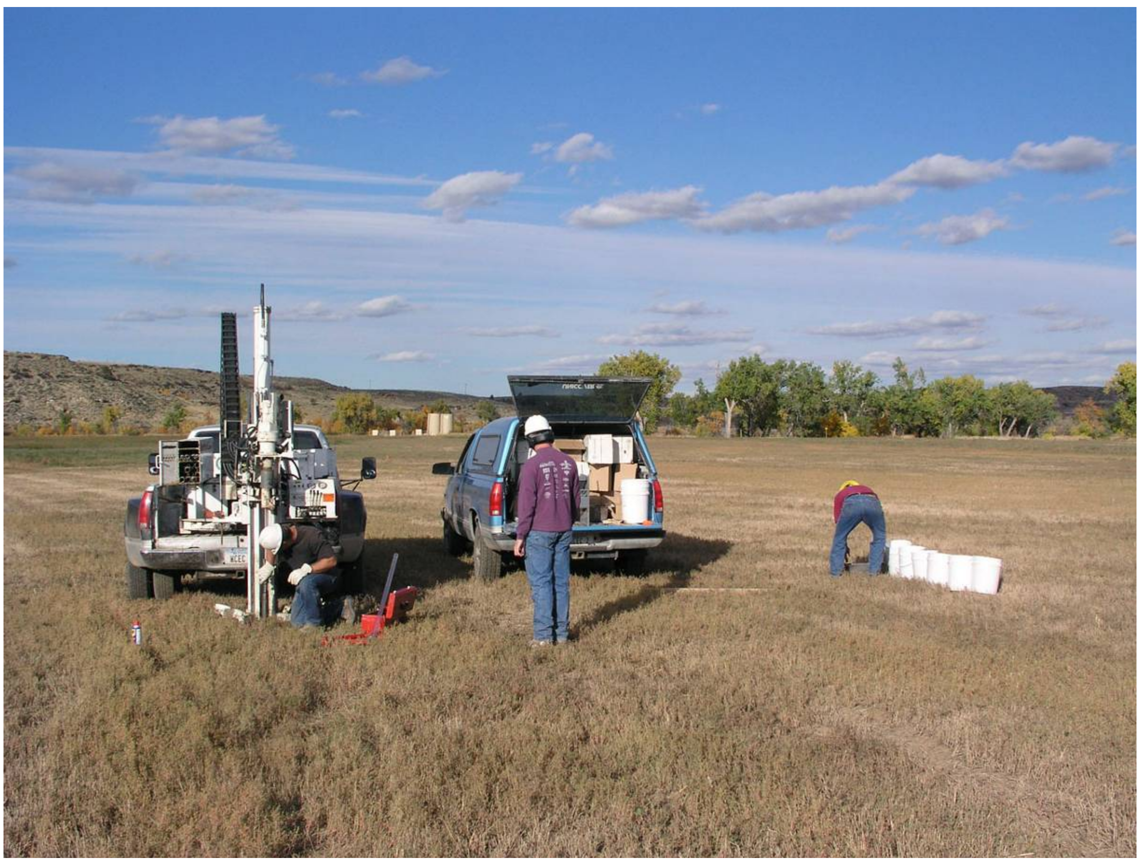


Figure D-36 Landscape view of site MB.

Profile description for soil pit MB-14.

Landscape position:	Terrace.	
Parent material:	Alluvium.	
County and mapped soil unit:	Bighorn County, Kishona/Cambria Series.	
Vegetation:	Russian Thistle and other weed species.	
Management Status:	Flood irrigation.	
Slope and Aspect:	1% slopes with a north facing aspect.	
Classification:	fine-loamy, mixed (calcareous) Borollic Camborthids	
Horizon	**Depth (inches)**	**USDA Description[1]**
Ap	0 to 3	Yellowish brown (10YR 5/4) dry and dark brown (10YR 3/3) moist clay loam; weak, medium, granular structure; soft, very friable, slightly sticky, and slightly plastic; common fine and common medium roots; common very fine pores; very slightly effervescent; clear smooth boundary.
Bt	3 to 7	Brown (10YR 5/3) dry and brown (10YR 4/3) moist silty clay; moderate, medium platy parting to moderate, medium subangular blocky structure; hard, very friable, slightly sticky, and slightly plastic; common fine and common medium roots; few fine pores; slightly effervescent; clear smooth boundary.
Bk1	7 to 17	Brown (10YR 5/3) dry and dark yellowish brown (10YR 4/4) moist silty clay; moderate, medium prismatic structure; hard, friable, sticky, and slightly plastic; common fine roots; common very fine pores; strongly effervescent; clear smooth boundary.
Bk2	17 to 31	Brown (10YR 5/3) dry and brown (10YR 4/3) moist clay loam; moderate, medium prismatic parting to moderate, medium, subangular blocky structure; hard, friable, slightly sticky, and slightly plastic; common fine roots; few fine pores; violently effervescent; clear smooth boundary.
C	31 to 66+	Light olive brown (2.5Y 5/3) dry and olive brown (2.5Y 4/3) moist loam; massive; hard, friable, slightly sticky, and slightly plastic; few very fine and few fine roots; few fine pores; strongly effervescent; common soft white threads and masses.

Notes:

1 Soils were described using protocol defined by *Soil Survey Division Staff 1993. Soil Survey Manual. U.S.D.A. Agriculture Handbook 18*.

2 taxonomy

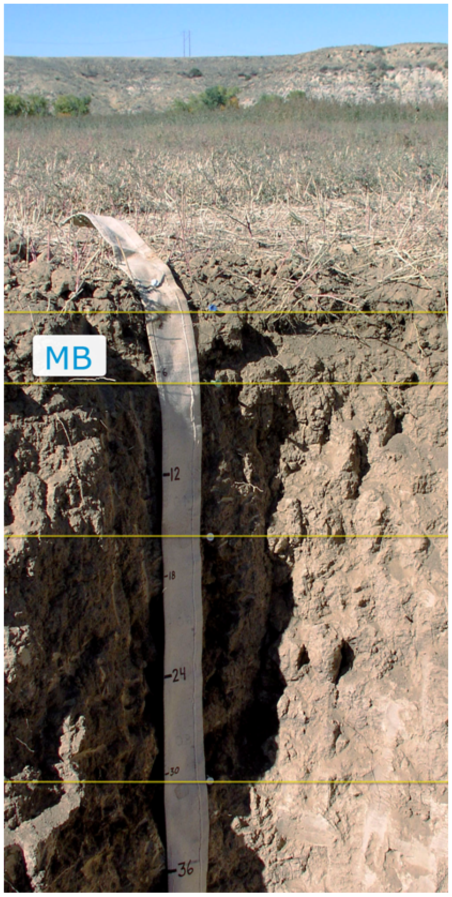


Photo of Soil Pit MB-14.

Figure D-37 Soil profile description and photo of soil at site MB

The pedon described at site MB differed slightly from the typical soils mapped in unit 171 (Table D-13). The soil profile contained higher than average clay content ranging from 33% near the surface to 40% in a subsoil layer (3 to 17 inches). This soil profile zone contained increased clay content called an argillic horizon. Dominant clay minerals were kaolinite and illite, which are non-swelling clays that are not easily affected by excess sodium. Soil pH was mildly alkaline (7.6) and lime content was low for surface soil (1.3%), and both pH and lime content increased with depth. EC was moderately low (< 1 dS/m) in the upper 30 inches and increased to 3.0 dS/m in the deepest horizon (31 to 66 inches). Both SAR (0.5 to 2.3) and ESP (1.6 to 3.8) were low throughout all depths. Nutrient levels were generally adequate, except for available zinc which was low.

The composite soil samples collected from site MB were similar to most soils irrigated with Tongue River water despite the slightly higher average salinity found in Prairie Dog Creek. Owing to irrigation management, average salinity (based on a weighted average in the upper 36 inches of the profile) was slightly lower than average for the Tongue River soils. Site MB also had lower than average SAR and ESP. While clay content was slightly higher in these soils, they were in other aspects similar to most soils irrigated with Tongue River water.

Table D-13 Soil profile chemical, physical, and mineralogical data for site MB

Paste pH, Conductivity, Organic Matter, Lime and Texture

Horizon	Upper Depth (in)	Lower Depth (in)	Dry Wt, g	pH, Saturated Paste s.u. Method ASAM10-3.2	Conductivity, Paste Extract mmhos/cm Method ASAM10-3	Organic Matter wt% Method ASA29-3	Lime as CaCO3 wt% Method USDA23c	Texture unitless Method ASA15-5	Sand wt% Method ASA15-5	Silt wt% Method ASA15-5	Clay wt% Method ASA15-5
Ap	0	3	2090	7.6	0.69	2.1	1.3	CL	25	42	33
Bt	3	7	1850	7.8	0.43		4.8	SiC	15	44	41
Bk1	7	17	1940	8	0.43		12.4	SiC	16	44	40
Bk2	17	31	1860	8	0.54		11.2	CL	39	33	28
C	31	66	2030	7.9	2.99		7.4	L	39	39	22

Paste Extract and Exchangeable Ions

Horizon	Upper Depth (in)	Lower Depth (in)	Saturation wt% Method USDA27a	Calcium, Saturated Paste meq/l Method SW6010B	Magnesium, Saturated Paste meq/l Method SW6010B	Sodium, Saturated Paste meq/l Method SW6010B	Sodium Adsorption Ratio (SAR) unitless Method Calculation	Alkalinity, Saturated Paste meq/L Method ASA10-3	Cation Exchange Capacity meq/100g Method SW6010B	Sodium, Extractable meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
Ap	0	3	42.5	3.6	2.4	0.9	0.5	4.5	29.2	0.5	1.6
Bt	3	7	49.8	2.1	1.6	1.1	0.8	3.2	36.6	0.6	1.4
Bk1	7	17	47.6	2.3	1.8	1.1	0.8	3.7	32.3	0.5	1.4
Bk2	17	31	39	1.9	1.6	2.4	1.8	3.8	26	0.8	2.7
C	31	66	41.6	12.6	18.8	9.1	2.3	1.6	24.7	1.3	3.8

Clay Minerals and Nutrients

Horizon	Upper Depth (in)	Lower Depth (in)	Kaolinite % Method X-ray Diffraction (based on clay fraction)	Illite % Method X-ray Diffraction (based on clay fraction)	Smectite % Method X-ray Diffraction (based on clay fraction)	Chlorite % Method X-ray Diffraction (based on clay fraction)	Nitrate as N, Saturated Paste mg/L Method ASA10-3	Phosphorus (Olsen NaHCO3 Extract) mg/kg Method ASA24-5	Potassium, NH4OAc Extractable mg/kg Method ASA13-3	Sulfate, Saturated Paste meq/L Method ASA10-3	Zinc (DTPA Extract) mg/kg Method SW6010B
Ap	0	3	33	54	5	8	34.9	16	533	1.3	0.24
Bt	3	7					12.6			0.6	
Bk1	7	17	39	29	23	9	5.6			1	
Bk2	17	31									
C	31	66									

Site OAA

Site OAA is located near the mouth of Otter Creek, a tributary that joins the Tongue River near Ashland (Figure D-38). The field is flood-irrigated using Otter Creek water, which has a higher average EC and SAR than water from the Tongue River mainstem. At the time of the first sampling, the field had a stand of crested wheat and brome grasses with sparse patches of alfalfa (Figure D-39).

The soil mapping unit sampled within the field is 99 – Havre loam (Figure D-40), the dominant soil series found in the Tongue River floodplain. The pedon described and sampled at site OAA (Table D-14) averaged just 18% clay, which is at the lower limit for Havre loam. Clay content was variable with depth and was somewhat finer near the surface, decreasing to only 13%t at depth.

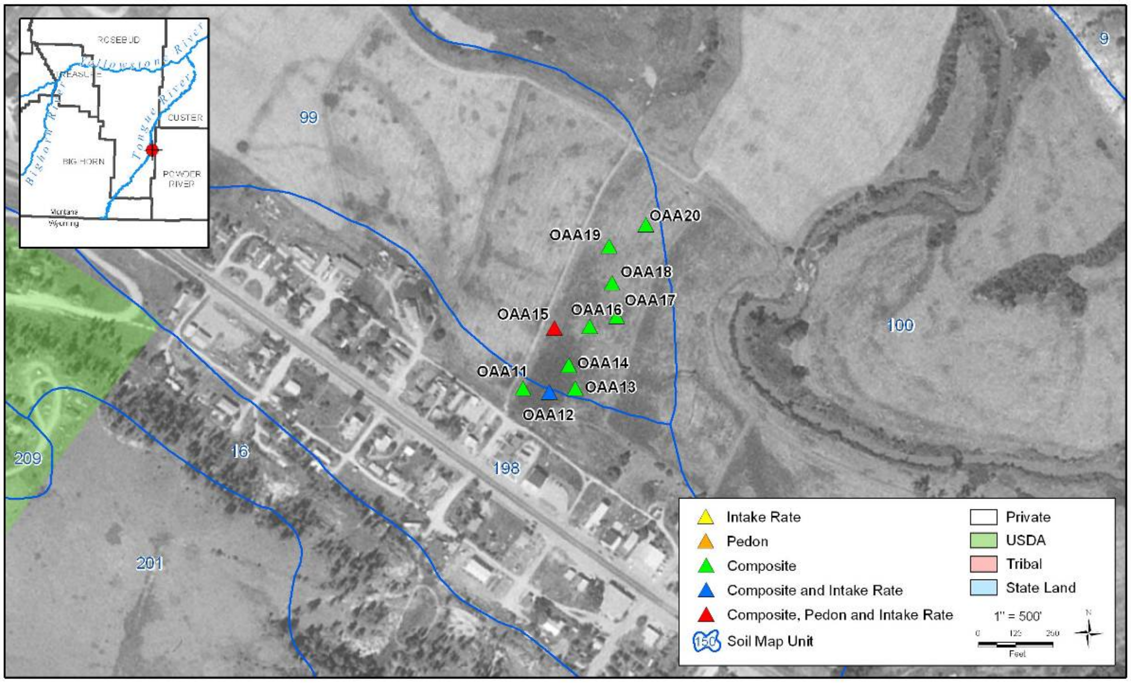


Figure D-38 Map of site OAA

Figure D-39 Landscape view of site OAA.

Profile description for soil pit OAA-15

Landscape position:	Floodplain.
Parent material:	Alluvium.
County and mapped soil unit:	Rosebud County, Havre Series.
Vegetation:	Alfalfa/grass.
Management Status:	Flood irrigation.
Slope and Aspect:	0 to 1% slopes with a northwest facing aspect.
Classification:	fine-loamy, mixed (calcareous) frigid Ustic Torrifluvents

Horizon	Depth (inches)	USDA Description[1]
Ap	0 to 6	Dark yellowish brown (10YR 4/4) dry and brown (10YR 4/3) moist loam; moderate, medium, prismatic parting to weak, fine, granular structure; slightly hard, friable, nonsticky, and nonplastic; many fine and few coarse roots; common fine vesicular pores; strongly effervescent; clear smooth boundary.
C1	6 to 15	Brown (10YR 5/3) dry and dark yellowish brown (10YR 4/4) moist silt loam; moderate, medium, subangular blocky structure; slightly hard, firm, slightly sticky, and slightly plastic; many fine and few coarse roots; common fine vesicular pores; strongly effervescent; abrupt smooth boundary.
C2	15 to 39	Brown (10YR 5/3) dry and dark yellowish brown (10YR 4/4) moist loam; massive; soft, loose, nonsticky, and nonplastic; many fine and few coarse roots; common very fine vesicular pores; very slightly effervescent; clear smooth boundary.
C3	39 to 60	Brown (10YR 4/3) moist silty clay loam; massive; friable, slightly sticky, and slightly plastic; common fine and few coarse roots; common very fine vesicular and common fine tubular pores; common fine faint mottles; violently effervescent; soft white threads and masses.

Notes:
1 Soils were described using protocol defined by *Soil Survey Division Staff 1993. Soil Survey Manual. U.S.D.A. Agriculture Handbook 18*.
2 taxonomy

Photo of Soil Pit OAA-15.

Figure D-40 Soil profile description and photo of soil at site OAA

Dominant clay minerals were kaolinite and illite, which are non-swelling clays that are not readily affected by elevated levels of sodium. Smectite content was only 14% of the clays. The soil had mildly alkaline pH (7.7 to 8.2) and moderate levels of lime (7.5% to 8.6%) at all depths. EC was quite low (0.5 to 0.9 dS/m) when compared to Tongue River soils despite the higher average EC of Otter Creek. This may indicate that the field is only irrigated during the early part of the season when salinity is lower in Otter Creek. SAR (<1 to 4) and ESP (1 to 4) were moderately low as well, similar to EC. Soil test levels of nitrogen and phosphorus were low while other nutrients had generally adequate levels of abundance.

Table D-14 Soil profile chemical, physical, and mineralogical data for site OAA

Paste pH, Conductivity, Organic Matter, Lime and Texture											
Horizon	Upper Depth (in)	Lower Depth (in)	Dry Wt, g	pH, Saturated Paste s.u. Method ASAM10-3.2	Conductivity, Paste Extract mmhos/cm Method ASAM10-3	Organic Matter wt% Method ASA29-3	Lime as CaCO3 wt% Method USDA23c	Texture unitless Method ASA15-5	Sand wt% Method ASA15-5	Silt wt% Method ASA15-5	Clay wt% Method ASA15-5
Ap	0	6	510	7.7	0.87	3.3	7.5	L	28	47	25
C1	6	15	568	8.1	0.5		8.2	SiL	20	54	26
C2	15	39	586	7.9	0.87		8.6	L	51	36	13
C3	39	60	613	8.2	0.69		8.4	SiCL	15	55	30

Paste Extract and Exchangeable Ions											
Horizon	Upper Depth (in)	Lower Depth (in)	Saturation wt% Method USDA27a	Calcium, Saturated Paste meq/l Method SW6010B	Magnesium, Saturated Paste meq/l Method SW6010B	Sodium, Saturated Paste meq/l Method SW6010B	Sodium Adsorption Ratio (SAR) unitless Method Calculation	Alkalinity, Saturated Paste meq/L Method ASA10-3	Cation Exchange Capacity meq/100g Method SW6010B	Sodium, Extractable meq/100g Method SW6010B	Exchang-eable Sodium Percentage % Method USDA20b
Ap	0	6	49.9	4.4	4.4	0.7	0.3	8.1	31	0.5	1.6
C1	6	15	43.4	1.5	2.1	1.2	0.9	4.1	29.3	0.4	1.2
C2	15	39	32.7	2.9	3	1.8	1.1	2.9	15.7	0.6	3.5
C3	39	60	44.8	1	0.8	3.9	4.1	3.7	33.8	1.4	3.6

Clay Minerals and Nutrients											
Horizon	Upper Depth (in)	Lower Depth (in)	Kaolinite % Method X-ray Diffraction (based on clay fraction)	Illite % Method X-ray Diffraction (based on clay fraction)	Smectite % Method X-ray Diffraction (based on clay fraction)	Chlorite % Method X-ray Diffraction (based on clay fraction)	Nitrate as N, Saturated Paste mg/L Method ASA10-3	Phos-phorus (Olsen NaHCO3 Extract) mg/kg Method ASA24-5	Potassium, NH4OAc Extractable mg/kg Method ASA13-3	Sulfate, Saturated Paste meq/L Method ASA10-3	Zinc (DTPA Extract) mg/kg Method SW6010B
Ap	0	6	36	32	14	18	0.4	13	294	0.6	0.41
C1	6	15					3.6			0.6	
C2	15	39					3.5			0.6	
C3	39	60	37	41	14	9					

Reference AMPP Sites in Other River Basins

Site YBA

Site YBA is located on a low bench above the Yellowstone River (Figure D-41) just west of Miles City on the Fort Keogh Research Center. The field is flood-irrigated with Yellowstone River water which is generally similar in quality to the Tongue River. At the time of the first sampling, the field had a stand of volunteer barley and weeds following a barley grain crop harvested earlier in 2003 (Figure D-42).

The soil mapping unit sampled within the field is 47A – Harlake silty clay loam, the same soil mapped upstream on the lower Tongue River (in Custer County) at sites BC and BD (Figure D-43). The Harlake series differs from Havre by having more than 35% clay with smectite as the dominant clay mineral. The Harlake series, like the Havre, does not exhibit significant soil development and is typical of recent floodplain soils (e.g. variable texture and organic matter content with depth).

The pedon described and sampled at site YBA (Table D-15) averaged just 22% clay, which is much less than is found in Harlake soils and is near the lower limit for Havre loam. Clay content varied from 24% in the upper 20 inches and decreased to 18% at 20 to 40 inches.

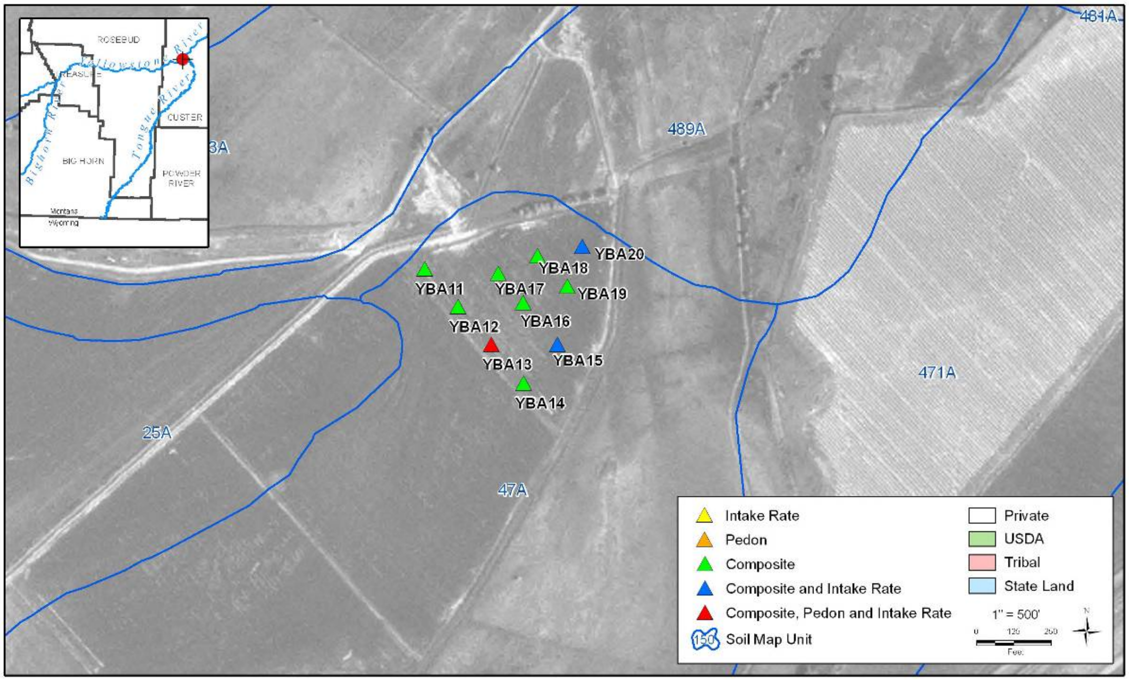


Figure D-41 Map of site YBA

Figure D-42 Landscape view of site YBA

Profile description for soil pit YBA-13

Landscape position:	Floodplain.	
Parent material:	Alluvium/lacustrine.	
County and mapped soil unit:	Custer County, Harlake Series.	
Vegetation:	Fallow.	
Management Status:	Flood irrigation.	
Slope and Aspect:	0 to 2% slopes with a north facing aspect.	
Classification:	fine-loamy, mixed (calcareous) frigid Ustic Torrifluvents	
Horizon	**Depth (inches)**	**USDA Description[1]**
Ap	0 to 15	Pale brown (10YR 6/3) dry and dark brown (10YR 3/3) moist silt loam; weak, medium, subangular blocky parting to weak, fine, granular structure; slightly hard, very friable, slightly sticky, and slightly plastic; common fine roots; common fine and common medium pores; slightly effervescent; abrupt smooth boundary.
C1	15 to 22	Yellow (2.5Y 7/6) dry and light olive brown (2.5Y 5/3) moist silt loam; moderate, medium, platy structure; hard, very friable, slightly sticky, and slightly plastic; few fine roots; common fine pores; common, fine, distinct mottles; violently effervescent; clear smooth boundary.
C2	22 to 41	Pale yellow (2.5Y 7/4) dry and light olive brown (2.5Y 5/6) moist silt loam; massive; slightly hard, very friable, slightly sticky, and slightly plastic; few fine roots; common fine and few coarse pores; common, fine, distinct mottles; strongly effervescent; gradual smooth boundary.
C3	41 to 60+	Very dark grayish brown (2.5Y 3/2) moist silty clay loam; massive; very friable, slightly sticky, and slightly plastic; few fine roots; common fine and few coarse pores; common, fine, distinct mottles; strongly effervescent.

Notes:

1 Soils were described using protocol defined by *Soil Survey Division Staff. 1993. Soil Survey Manual. U.S.D.A. Agriculture Handbook 18*.

2 taxonomy

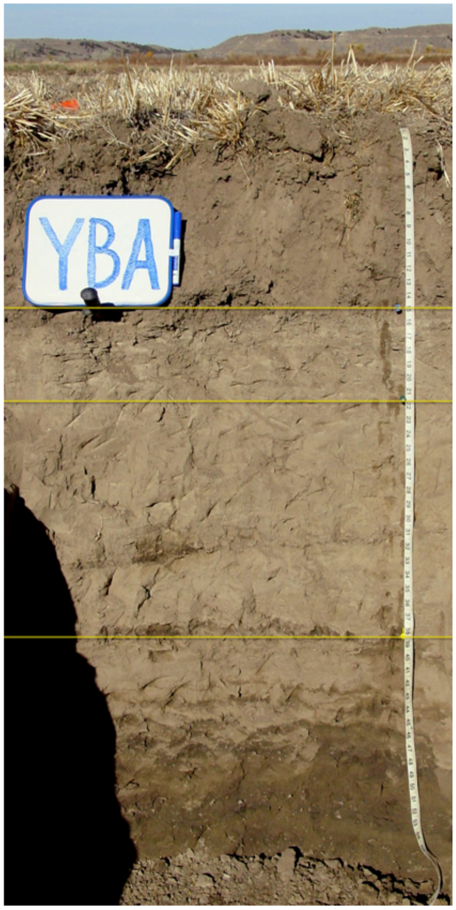


Photo of Soil Pit YBA-13.

Figure D-43 Soil profile description and photo of soil at site YBA

The dominant clay mineral was smectite (54%), with the remainder composed of kaolinite and illite. The soil was mildly alkaline in pH (7.7 to 8.0) and had moderate levels of lime (6% to 9%) at all depths. EC had a similar range within the profile found in typical flood-irrigated Tongue River soils (0.8 to 3 dS/m), which was low near the surface and increased with depth. SAR (1 to 5) and ESP (2 to 6) were moderately low as well, similar to the pattern for EC. Soil test levels of phosphorus and potassium were low while other nutrients were generally adequate.

Table D-15 Soil profile chemical, physical, and mineralogical data for site YBA

Paste pH, Conductivity, Organic Matter, Lime and Texture											
Horizon	Upper Depth (in)	Lower Depth (in)	Dry Wt, g	pH, Saturated Paste s.u. Method ASAM10-3.2	Conductivity, Paste Extract mmhos/cm Method ASAM10-3	Organic Matter wt% Method ASA29-3	Lime as CaCO3 wt% Method USDA23c	Texture unitless Method ASA15-5	Sand wt% Method ASA15-5	Silt wt% Method ASA15-5	Clay wt% Method ASA15-5
Ap	0	15	620	7.7	0.83	2	7	SiL	16	60	24
C1	15	22	637	7.9	1.28		9.8	SiL	4	72	24
C2	22	41	593	8	1.59		7.5	SiL	16	66	18
C3	41	60	583	8	3.16		6.1	SiCL	14	57	29

Paste Extract and Exchangeable Ions											
Horizon	Upper Depth (in)	Lower Depth (in)	Saturation wt% Method USDA27a	Calcium, Saturated Paste meq/l Method SW6010B	Magnesium, Saturated Paste meq/l Method SW6010B	Sodium, Saturated Paste meq/l Method SW6010B	Sodium Adsorption Ratio (SAR) unitless Method Calculation	Alkalinity, Saturated Paste meq/L Method ASA10-3	Cation Exchange Capacity meq/100g Method SW6010B	Sodium, Extractable meq/100g Method SW6010B	Exchang-eable Sodium Percentage % Method USDA20b
Ap	0	15	57	3.2	1.4	2.5	1.6	5.2	33.3	0.9	2.2
C1	15	22	56.4	3.4	3.4	4.7	2.6	3.6	30.8	1.3	3.3
C2	22	41	51.2	3.2	4	7.6	4	3.3	24.6	1.6	5
C3	41	60	62	5.5	9.1	14	5.2	2.8	33.6	2.9	6.2

Clay Minerals and Nutrients											
Horizon	Upper Depth (in)	Lower Depth (in)	Kaolinite % Method X-ray Diffraction (based on clay fraction)	Illite % Method X-ray Diffraction (based on clay fraction)	Smectite % Method X-ray Diffraction (based on clay fraction)	Chlorite % Method X-ray Diffraction (based on clay fraction)	Nitrate as N, Saturated Paste mg/L Method ASA10-3	Phos-phorus (Olsen NaHCO3 Extract) mg/kg Method ASA24-5	Potassium, NH4OAc Extractable mg/kg Method ASA13-3	Sulfate, Saturated Paste meq/L Method ASA10-3	Zinc (DTPA Extract) mg/kg Method SW6010B
Ap	0	15	23	22	54	2	3	10	170	2.5	0.57
C1	15	22	19	22	54	4	5			7	
C2	22	41					5.1			11.4	
C3	41	60									

Site BHA

Site BHA is located on the west side of the Big Horn River just south of Hardin, Montana (Figure D-44). The field is flood-irrigated with Big Horn River water, which has a slightly higher average EC than the Tongue River. Sugar beets were grown at site BHA in 2003, and were harvested just prior to sampling.

The soil mapped within the field is Bs – Bew silty clay loam. The Bew series, which is mapped in Big Horn County, has more than 35% clay, is dominated by smectite, and contains a lime-depleted and clay-enriched subsoil horizon (Figure D-45). The pedon described and sampled at site BHA (Table D-16) averaged more than 40% clay, but did not contain evidence of secondary clay accumulation or lime removal by weathering. Consequently, this site contained a slightly different soil that, while similar to Bew, was less developed. The dominant clay mineral was illite with lesser amounts of kaolinite, with smectite comprising only 10% of the clay fraction.

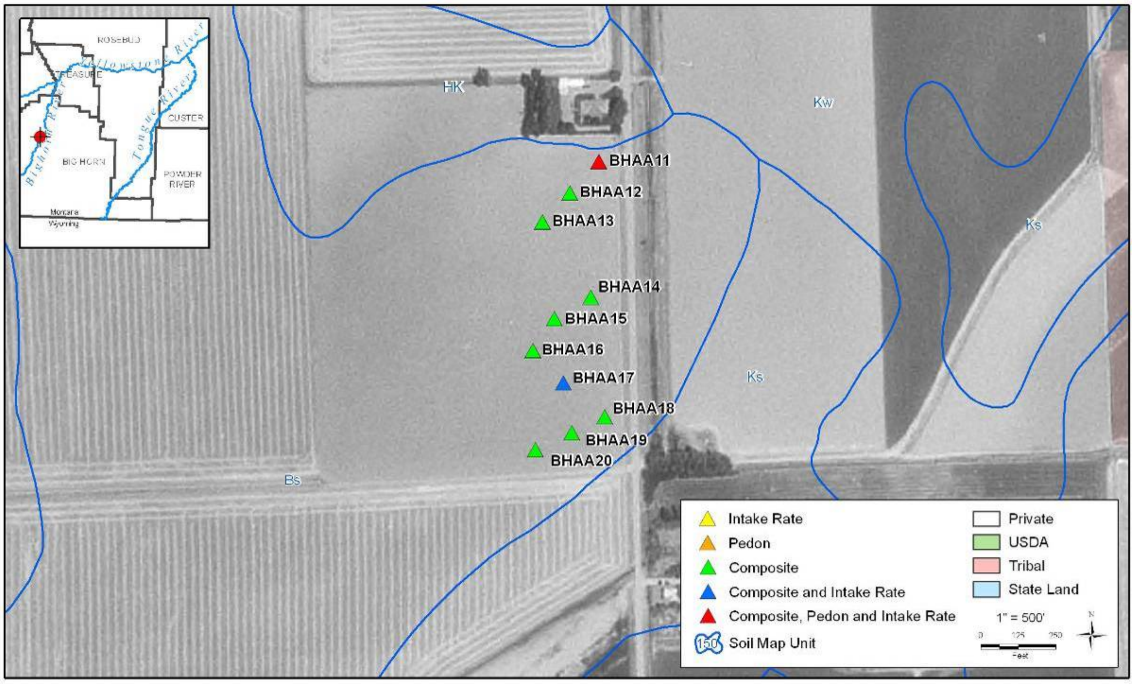


Figure D-44 Map of site BHA

Profile description for soil pit BHA-11.

Landscape position:	Floodplain.
Parent material:	Alluvium.
County and mapped soil unit:	Big Horn County, Bew Series.
Vegetation:	Sugarbeets.
Management Status:	Flood irrigation.
Slope and Aspect:	0 to 1% slopes with a south facing aspect.
Classification:	fine, mixed (calcareous) frigid Ustic Torrifluvents

Horizon	Depth (inches)	USDA Description[1]
Ap	0 to 8	Dark brown (10YR 3/3) moist silty clay; moderate, medium, subangular blocky structure; firm, sticky, and plastic; common fine roots; many fine continuous pores; abrupt smooth boundary.
A2	8 to 15	Brown (10YR 4/3) moist silty clay; moderate, medium, subangular blocky parting to weak, fine, granular structure; firm, sticky, and plastic; few fine roots; many fine continuous pores; 5% coarse fragments; abrupt smooth boundary.
C1	15 to 30	Olive brown (2.5Y 4/4) moist silty clay; weak, medium, subangular blocky structure; very firm, very sticky, and very plastic; few fine roots; common fine discontinuous pores; strongly effervescent; clear smooth boundary.
C2	30 to 60+	Dark grayish brown (2.5Y 4/2) moist silt loam; massive; firm, slightly sticky, and nonplastic; few fine roots; common fine discontinuous pores; violently effervescent.

Notes:

1 Soils were described using protocol defined by *Soil Survey Division Staff. 1993. Soil Survey Manual. U.S.D.A. Agriculture Handbook 18*.

2 taxonomy

Photo of Soil Pit BHA-11.

Figure D-45 Soil profile description and photo of soil at site BHA.

Table D-16 Soil profile chemical, physical, and mineralogical data for site BHA

Paste pH, Conductivity, Organic Matter, Lime and Texture

Horizon	Upper Depth (in)	Lower Depth (in)	Dry Wt, g	pH, Saturated Paste s.u. Method ASAM10-3.2	Conductivity, Paste Extract mmhos/cm Method ASAM10-3	Organic Matter wt% Method ASA29-3	Lime as CaCO3 wt% Method USDA23c	Texture unitless Method ASA15-5	Sand wt% Method ASA15-5	Silt wt% Method ASA15-5	Clay wt% Method ASA15-5
Ap	0	8	499	7.5	1.21	1.8	2.4	SiC	10	43	47
A2	8	15	534	7.5	0.8		2.6	SiC	11	42	47
C1	15	30	663	7.7	1.05		6.3	SiC	9	43	48
C2	30	60	641	7.7	1.24		4.1	SiL	20	55	25

Paste Extract and Exchangeable Ions

Horizon	Upper Depth (in)	Lower Depth (in)	Saturation wt% Method USDA27a	Calcium, Saturated Paste meq/l Method SW6010B	Magnesium, Saturated Paste meq/l Method SW6010B	Sodium, Saturated Paste meq/l Method SW6010B	Sodium Adsorption Ratio (SAR) unitless Method Calculation	Alkalinity, Saturated Paste meq/L Method ASA10-3	Cation Exchange Capacity meq/100g Method SW6010B	Sodium, Extractable meq/100g Method SW6010B	Exchangeable Sodium Percentage % Method USDA20b
Ap	0	8	47	3.2	1.3	4.5	3	6	44.5	1.5	2.9
A2	8	15	47.6	2.6	1	2.8	2.1	3.3	33.3	1	2.7
C1	15	30	43	3.3	1.7	3.1	1.9	3	33.1	1.3	3.4
C2	30	60	34.7	3.4	2.2	4.3	2.6	2.2	24.5	0.9	3

Clay Minerals and Nutrients

Horizon	Upper Depth (in)	Lower Depth (in)	Kaolinite % Method X-ray Diffraction (based on clay fraction)	Illite % Method X-ray Diffraction (based on clay fraction)	Smectite % Method X-ray Diffraction (based on clay fraction)	Chlorite % Method X-ray Diffraction (based on clay fraction)	Nitrate as N, Saturated Paste mg/L Method ASA10-3	Phos-phorus (Olsen NaHCO3 Extract) mg/kg Method ASA24-5	Potassium, NH4OAc Extractable mg/kg Method ASA13-3	Sulfate, Saturated Paste meq/L Method ASA10-3	Zinc (DTPA Extract) mg/kg Method SW6010B
Ap	0	8	20	66	10	5	11.2	92	332	3.6	1.69
A2	8	15					3.3			3.7	
C1	15	30	27	49	9	15	13.8			5.7	
C2	30	60									

The soil had a mildly alkaline pH (7.5 to 7.7) and had lower levels of lime (2.4% to 6.3%) typically found in the Tongue River soils. The lower lime content probably results from differences in the stream sediments from which the soils formed. EC was low (0.8 to 1.2 dS/m), and was similar to many of the lower EC, flood-irrigated Tongue River soils. SAR (2 to 3 dS/m) and ESP (2.7 to 3.4) were relatively uniform and were moderately low, indicating that amply applied irrigation water has leached excessive salts from the profile. SAR and ESP in the 0-2 inch depth of the composite samples were 5.4 and 6.1, respectively. Both had significantly been reduced to 3.8 and 2.8 by April 2004 and 3.0 and 3.3 by fall 2005, respectively. Most likely, SAR and ESP were elevated due to the warm dry fall prior to initial sampling. When the beet tops were removed, soil moisture rapidly moved to the surface and evaporated, leaving salts behind in the top 2 inches of soil. This field was planted to winter wheat in 2004 and 2005, so the plant canopy was more open and the soil drier at harvest than what is normal for beets. When the wheat was harvested, moisture did not rapidly move to the soil surface. Plant available nutrient levels were abundant.

Appendix E

Tier 2 Analysis of Variance Results

Appendix E-1 Soil chemical temporal trend analysis.

Modeling Approach

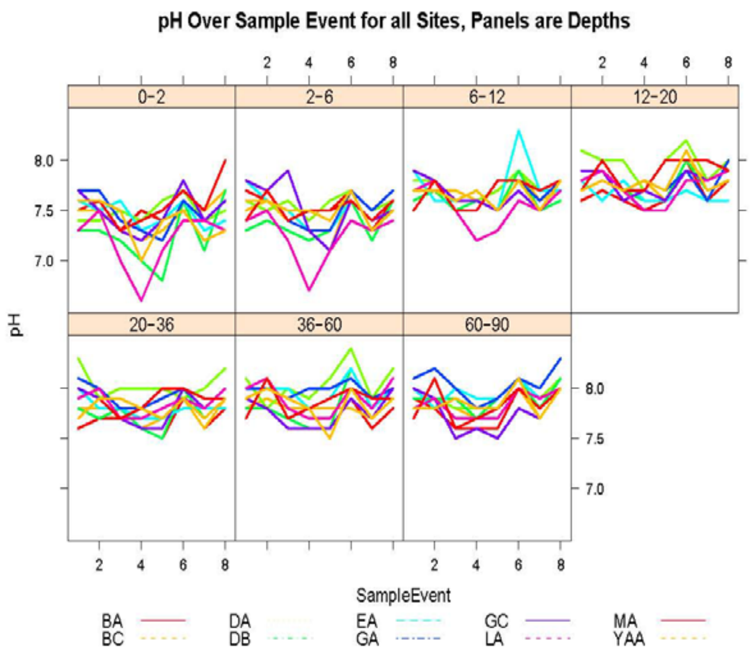
Sites are assumed to be a random sample of all possible sites, justifying the use of a random effect for the site covariate. We examined a model that included both random intercepts and random slopes for each site. Since sample events (year) are repeatable (that is, we could have collected more data each year), it was treated as a fixed effect, as was clay. Separate models were fit for each depth and each response variable (pH, Conductivity, Saturation, etc.) was modeled separately. Modeling was carried out using the `R` statistical environment (R Core Development Team), and specifically the `nlme` package (Pinheiro and Bates, 2000).

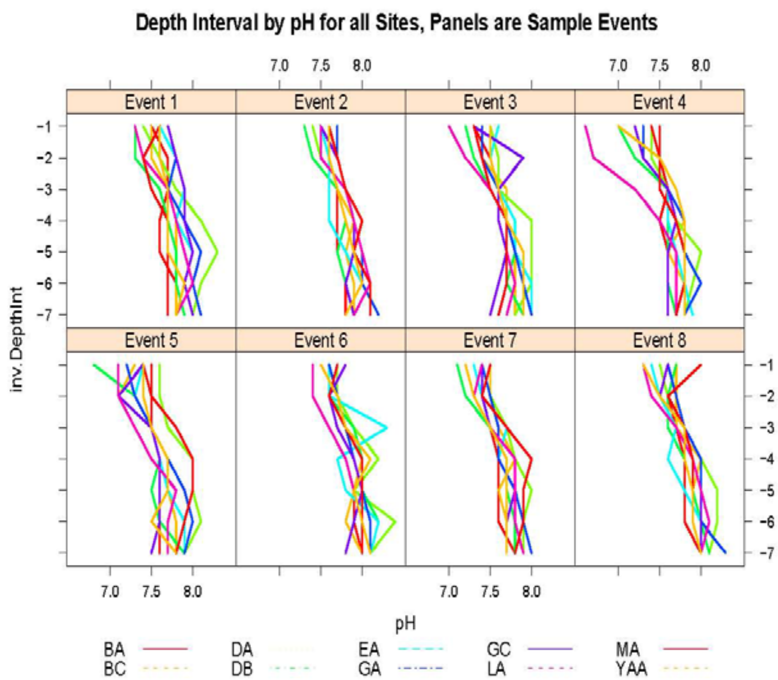
Results

pH

Analysis

Based on preliminary plotting, pH appeared to have similar (positive) trends over depth at all sites.



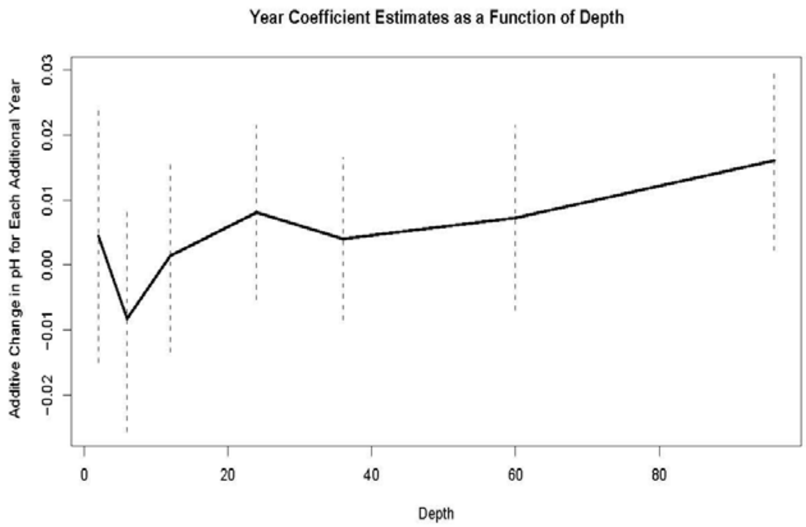


pH was modeled as a function of Clay and Sample Event, with random intercepts and slopes included for Site, as stated below:

$$\mu_{pH\ at\ site\ i} = \beta_0 + \beta_1 x_{sample\ event} + \beta_2 x_{clay} + b_{0i} + b_{1i} x_{sample\ event}$$

This model, as well as various subsets of this model, was fit using maximum likelihood, optimized iteratively through Expectation-Maximization and Newton-Raphson methods (Lindstrom and Bates, 1988). Model selection was performed using Akaike's Information Criterion (AIC; Burnham and Anderson, 2003), with favor given to the parsimonious model in situations where AIC scores were within two points of one another. Tables containing all models fit, as well as AIC values for each model and an indication of which model was selected are included at the end of this document. For pH (see Table 1), clay was dropped from the model as insignificant at all depths. Estimates from the best model at each depth are shown below:

Depth	β-Sample Event Estimate	Standard Error	Degrees of freedom	Test Statistic	p-value
0-2 inches	0.004524	0.00988880	69	0.45747	0.6488
2-6 inches	-0.008214	0.00883170	69	-0.93009	0.3556
6-12 inches	0.001429	0.00752645	69	0.18981	0.85
12-20 inches	0.008095	0.00683780	69	1.18389	0.2405
20-36 inches	0.004048	0.00633524	69	0.63891	0.525
36-60 inches	0.007262	0.00722220	69	1.0055	0.3182
60-96 inches	0.016071	0.00700677	69	2.2937	0.0249



Interpretation

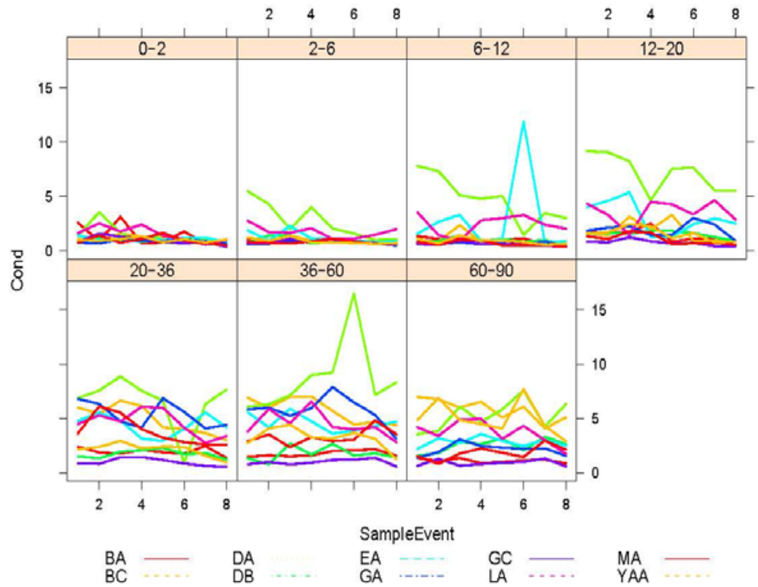
In general, pH did not show strong trends over sample events at shallower soil depths. However, a significant trend was detected at the lowest depth, where pH was found to increase significantly ($p = 0.0249$) over sample events. Clay was not significantly related to pH at any depth modeled here, and was excluded from all models based on likelihood ratio tests. The positive trend in beta-estimates over depth corresponds with the preliminary plotting of the data in the first figure.

Conductivity

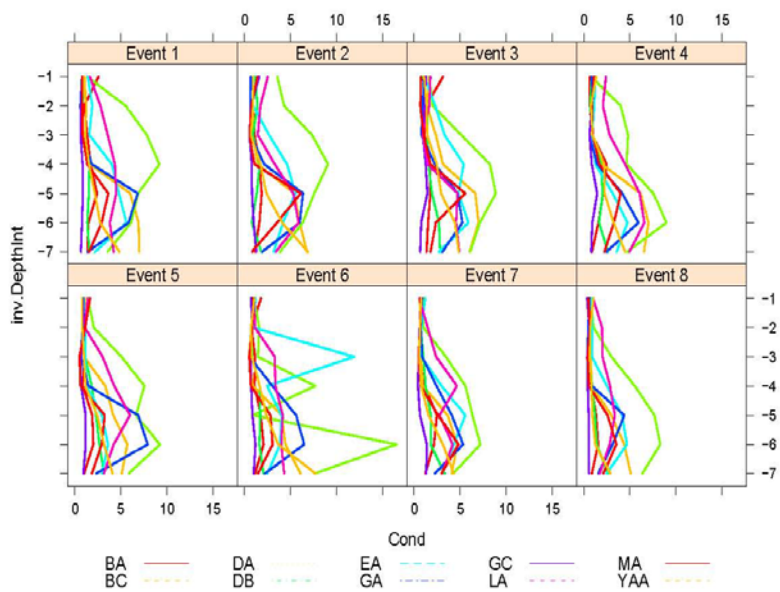
Analysis

Preliminary plotting suggested common within-site relationships between conductivity and depth for some sites, with substantial differences from site to site and quadratic effects present at certain sites.

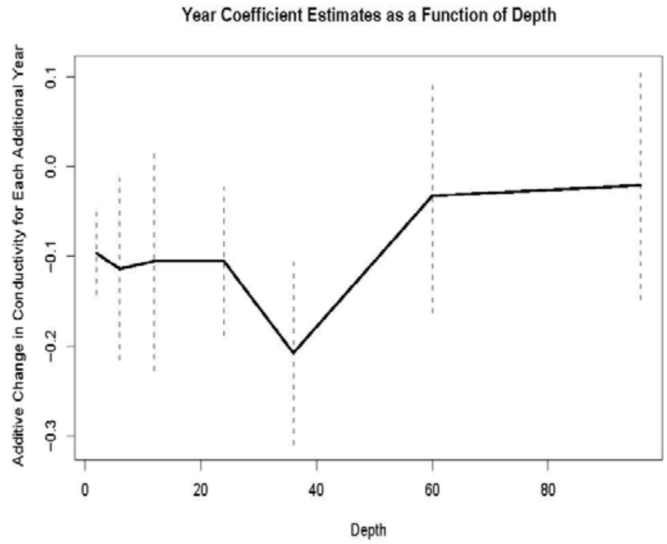
Conductivity Over Sample Event for all Sites, Panels are Depths



Depth Interval by Conductivity for all Sites, Panels are Sample Events



This complexity rendered a slightly more complicated model selection process for conductivity, with different model structures deemed appropriate at different depths. In general, conductivity was modeled as a function of Clay and Sample



Event, with random intercepts and slopes included for Site, as stated below:

$$\mu_{Conductivity\ at\ site\ i} = \beta_0 + \beta_1 x_{sample\ event} + \beta_2 x_{clay} + b_{0i} + b_{1i} x_{sample\ event}$$

This model, as well as various subsets of this model shown in Table 2, was fit using iterative maximum likelihood, as described for pH above at each depth. Estimates from the best model at each depth are shown below:

Depth	β-Sample Event Estimate	Standard Error	Degrees of freedom	Test Statistic	p-value
0-2 inches	-0.0963929	0.0232867	69	-4.139395	1e-04
2-6 inches	-0.1139881	0.0517342	69	-2.203342	0.0309
6-12 inches	-0.105326	0.0620785	68	-1.696655	0.0943
12-20 inches	-0.1582619	0.0420583	69	-3.762918	3e-04
20-36 inches	-0.207774	0.0522731	69	-3.974774	2e-04
36-60 inches	-0.032476	0.0666025	69	-0.487612	0.6274
60-96 inches	-0.020619	0.0652015	69	-0.316236	0.7528

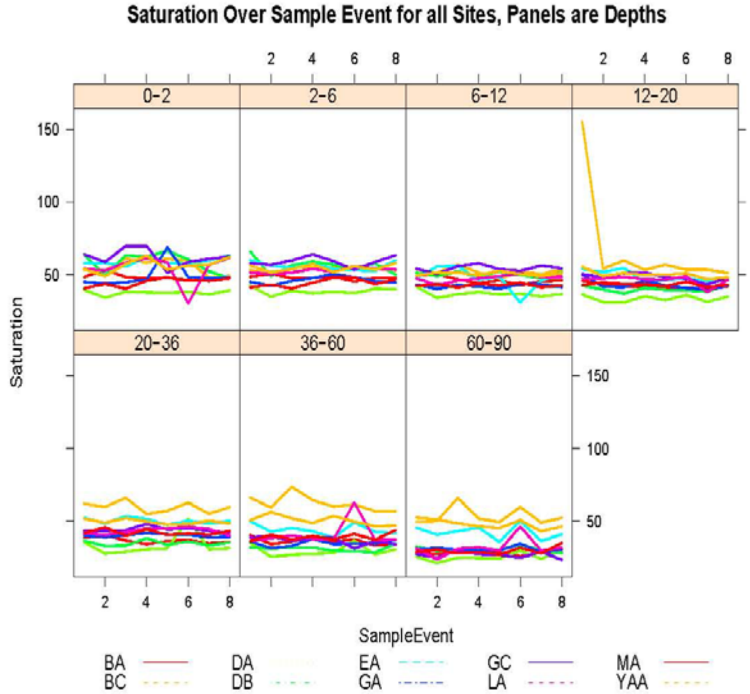
Interpretation

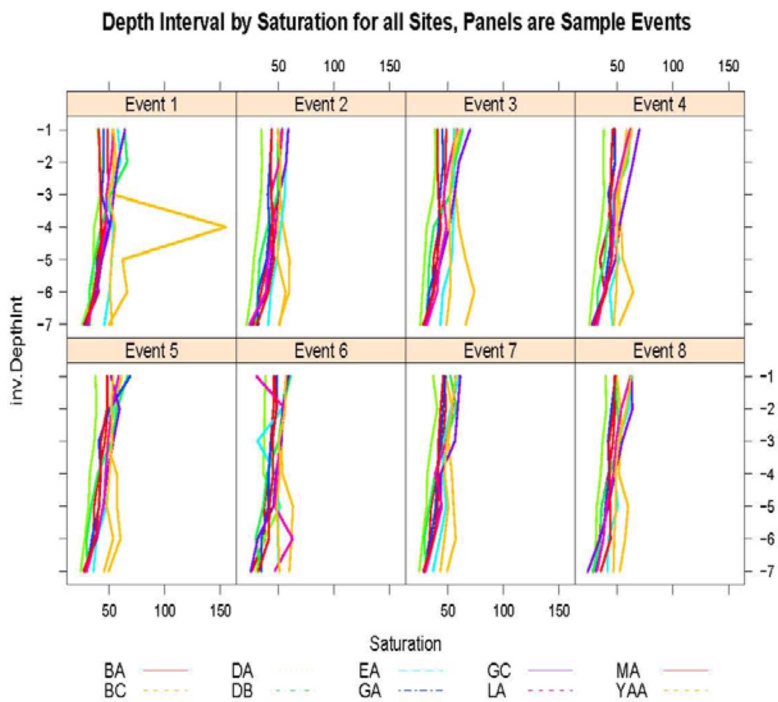
While conductivity did not appear to impacted much by depth, or by Clay (Clay was only significant in the model at the 6-12 inch depth), conductivity did decrease significantly at the shallow depths over the sample period (p-values ¡= .05 for all depths shallower than 36 inches except at the 6-12 inch depth). At deeper levels, the change in conductivity was not found to be significant. The plot suggests no substantial trend in Sample Event coefficient estimates over depths.

Saturation

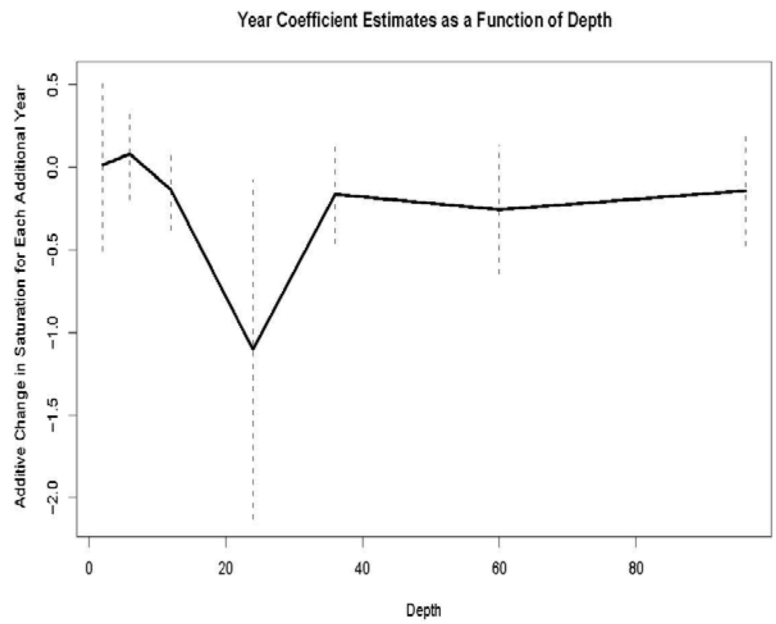
Analysis

Preliminary plotting suggested common within-site relationships between saturation and depth for sites, with differences from site to site.





Clay was included in the model for all cases save one: it was excluded from the 2-6 inch depth model. In general, saturation was modeled as a function of Clay and Sample Event, with random intercepts and slopes included for Site, as



stated below:

$$\mu_{Saturation\ at\ site\ i} = \beta_0 + \beta_1 x_{sample\ event} + \beta_2 x_{clay} + b_{0i} + b_{1i} x_{sample\ event}$$

This model, as well as various subsets of this model shown in Table 3, was fit using iterative maximum likelihood at each depth, as described for pH. Estimates from the best model at each depth are shown below:

Depth	β-Sample Event Estimate	Standard Error	Degrees of freedom	Test Statistic	p-value
0-2 inches	0.013320	0.264785	68	0.050304	0.96
2-6 inches	0.08107	0.1419399	69	0.571167	0.5697
6-12 inches	-0.136230	0.1238183	68	-1.100239	0.2751
12-20 inches	-1.102946	0.523928	68	-2.105149	0.039
20-36 inches	-0.16410	0.1534908	68	-1.069149	0.2888
36-60 inches	-0.255673	0.1977630	68	-1.292825	0.2004
60-96 inches	-0.142551	0.1688508	68	-0.844242	0.4015

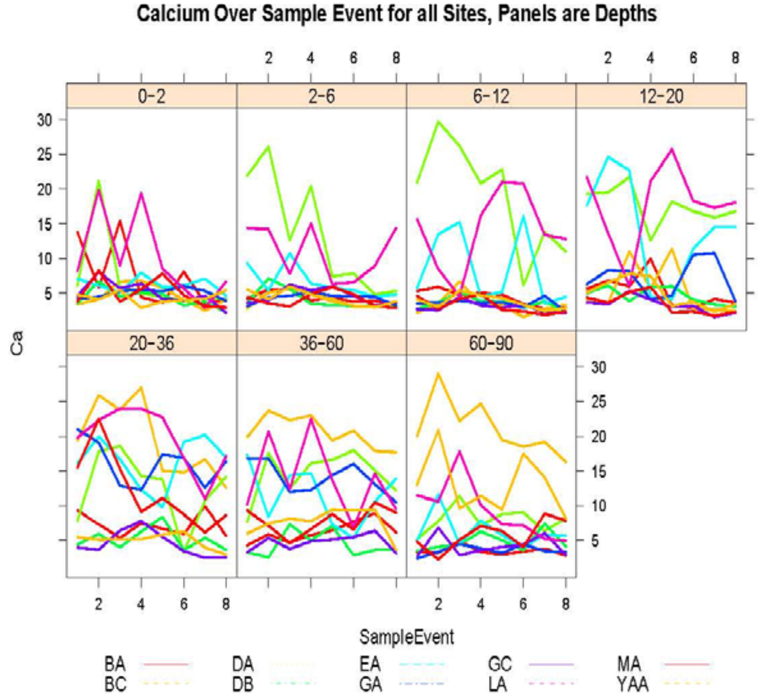
Interpretation

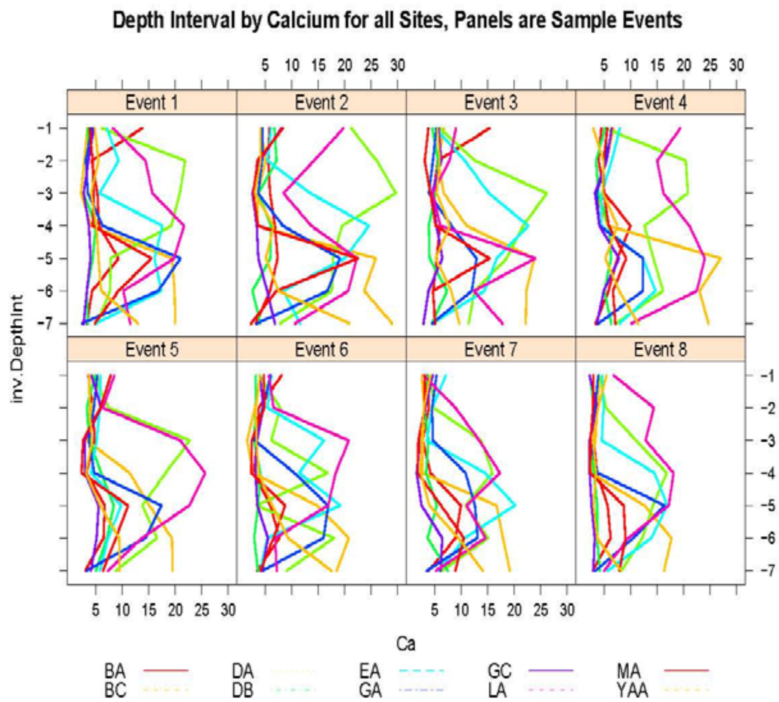
Saturation was strongly impacted by Clay, which was significant in every model except at a depth of 2-6 inches. However, a significant relationship was detected between Saturation and Sample Event was detected only at a depth of 12-20 inches (p-value = .039). No strong trend between depth and saturation was detected, as depicted in the plot above.

Calcium

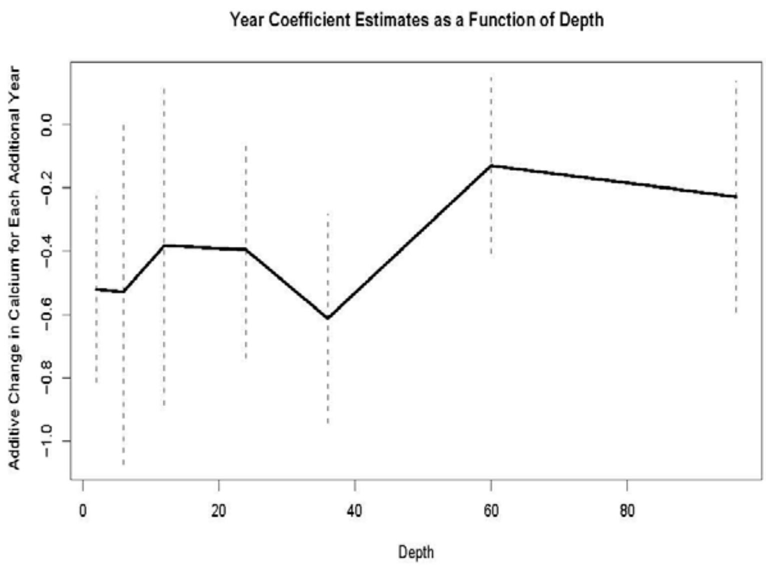
Analysis

Initial plots showed trends of varying order for Calcium as a function of depth at different sites. Given the amount of data available, only a first order relationship was considered.





Clay was dropped from all models for Calcium. In general, Calcium was modeled as a function of Clay and Sample Event, with random intercepts and slopes included for Site, as stated below:



$$\mu_{Calcium\ at\ site\ i} = \beta_0 + \beta_1 x_{sample\ event} + \beta_2 x_{clay} + b_{0i} + b_{1i} x_{sample\ event}$$

This model, as well as various subsets of this model shown in Table 4, was fit using iterative maximum likelihood at each depth, as described for pH above. Estimates from the best model at each depth are shown below:

Depth	β-Sample Event Estimate	Standard Error	Degrees of freedom	Test Statistic	p-value
0-2 inches	-0.521607	0.1501773	69	-3.473276	9e-04
2-6 inches	-0.528155	0.2784986	69	-1.896436	0.0621
6-12 inches	-0.382667	0.2560985	69	-1.494217	0.1397
12-20 inches	-0.395452	0.1748476	69	-2.261697	0.0269
20-36 inches	-0.612881	0.1680296	69	-3.647459	5e-04
36-60 inches	-0.129119	0.1422673	69	-0.907581	0.3673
60-96 inches	-0.228060	0.1865104	69	-1.222771	0.22565

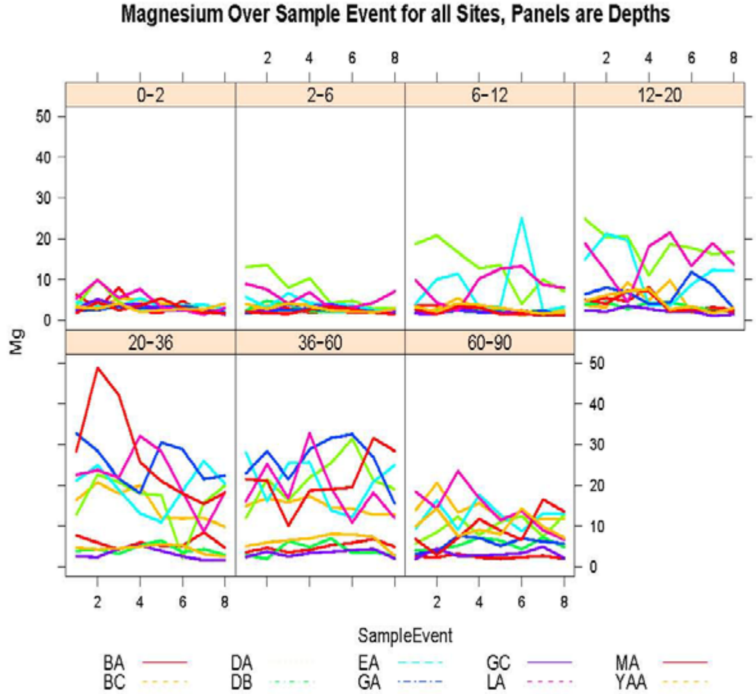
Interpretation

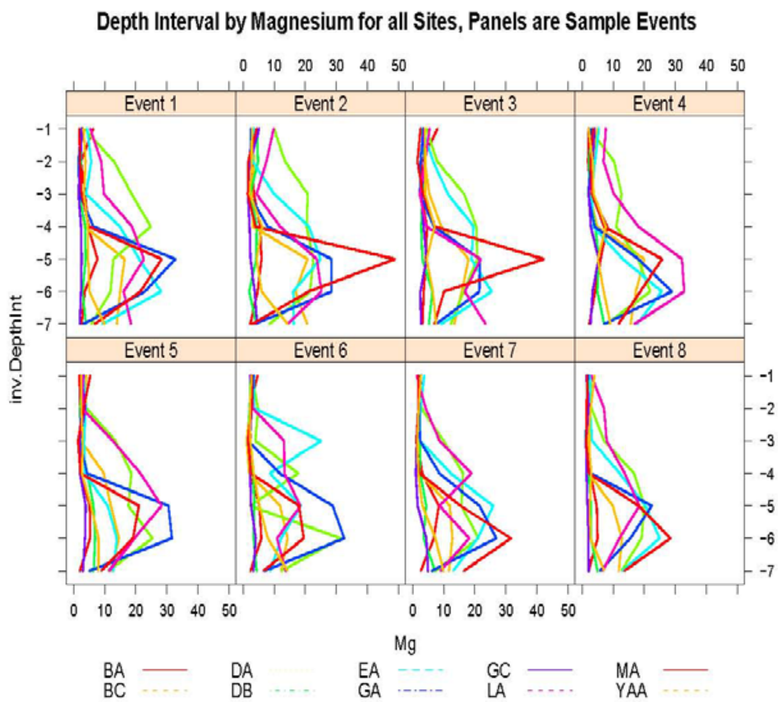
Calcium consistently declined over the sampling period at all depths, however only certain depths (0-2 inches, 12-20 inches and 20-36 inches) showed decreases that were statistically significant. The plot of beta-coefficients over depth suggests that perhaps Calcium concentrations increased slightly with increasing depth.

Magnesium

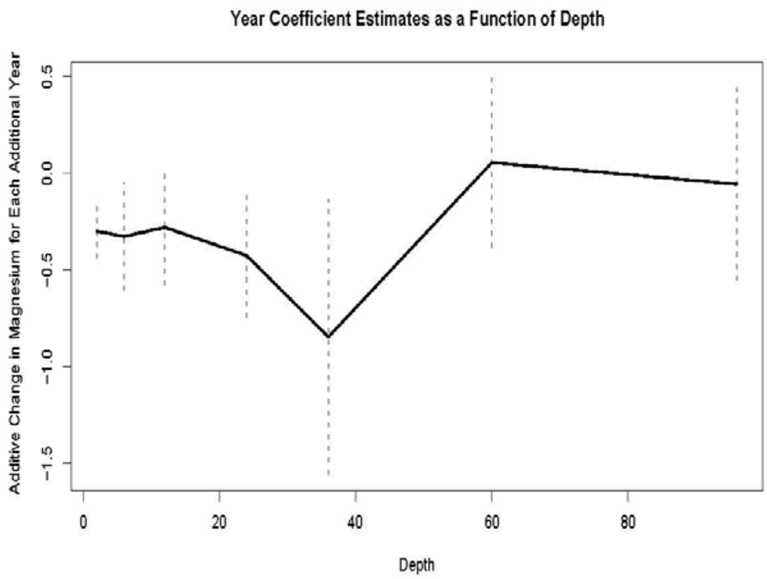
Analysis

Initial plots showed trends of varying order for Magnesium as a function of depth at different sites (see for example GA as compared to GC in the lattice below). Given the amount of data available, only a first order relationship was considered.





Clay was included in models for Magnesium at depths of 6-12 inches and 60-90 inches, but dropped from all other models. In general, Magnesium was modeled as a function of Clay and Sample Event, with random intercepts and slopes included



for Site, as stated below:

$$\mu_{Magnesium\ at\ site\ i} = \beta_0 + \beta_1 x_{sample\ event} + \beta_2 x_{clay} + b_{0i} + b_{1i} x_{sample\ event}$$

This model, as well as various subsets of this model shown in Table 5, was fit using iterative maximum likelihood at each depth, as described for pH above. Estimates from the best model at each depth are shown below:

Depth	β-Sample Event Estimate	Standard Error	Degrees of freedom	Test Statistic	p-value
0-2 inches	-0.298429	0.0725144	69	-4.115437	1e-04
2-6 inches	-0.325774	0.1418845	69	-2.296049	0.0247
6-12 inches	-0.279077	0.1525309	68	-1.829640	0.0717
12-20 inches	-0.424905	0.1643311	69	-2.585662	0.0118
20-36 inches	-0.845976	0.362800	69	-2.331796	0.0226
36-60 inches	0.055964	0.2239125	69	0.249938	0.8034
60-96 inches	-0.055633	0.2542568	68	-0.218807	0.8275

Interpretation

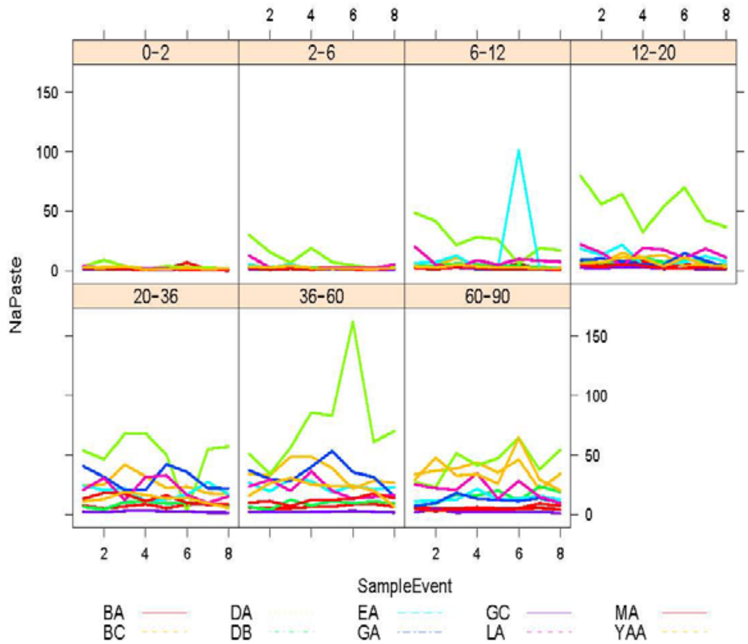
Magnesium consistently declined over the sampling period at all depths except 60-90 inches (where clay was present in the model, and the trend over sample events was not found to be significant). The declines over the sampling period were significant or marginally significant at all depths up to 36 inches. The plot of beta-coefficients over depth shows little evidence of temporal trend changes at different depths.

Sodium Paste

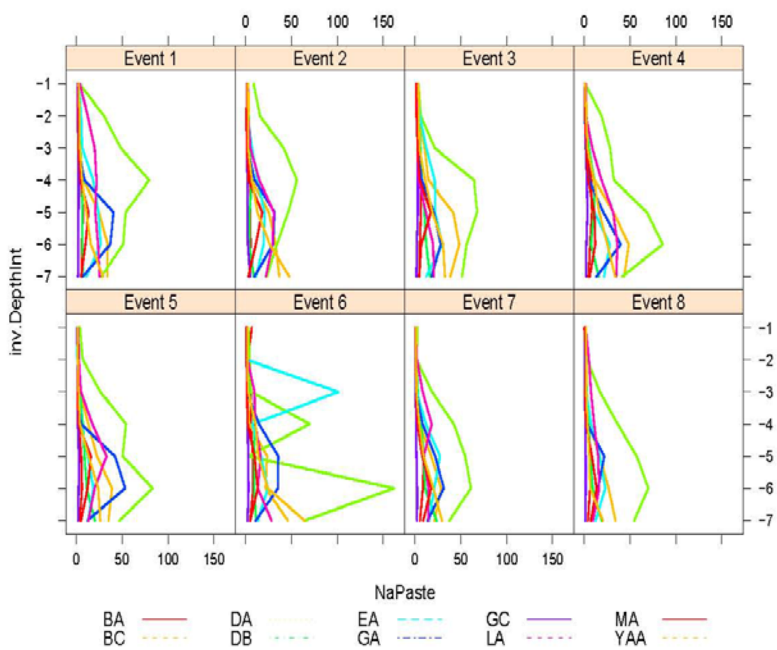
Analysis

Initial plots generally showed fairly linear trends for Sodium over sampling period, with the exception of the GA site, which showed some quadrature. Given the amount of data available, only a first order random effect was considered.

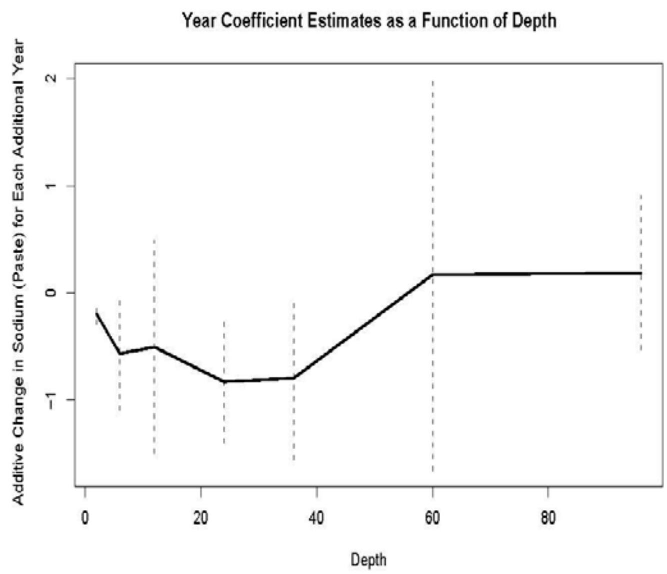
Sodium (Paste) Over Sample Event for all Sites, Panels are Depths



Depth Interval by Sodium (Paste) for all Sites, Panels are Sample Events



Clay was included in models for Sodium paste at depths of 6-12 inches, 20-36 inches, and 60-90 inches, but dropped from all other models. In general, Sodium paste was modeled as a function of Clay and Sample Event, with random intercepts



and slopes included for Site, as stated below:

$$\mu_{Sodium\ (Paste)\ at\ site\ i} = \beta_0 + \beta_1 x_{sample\ event} + \beta_2 x_{clay} + b_{0i} + b_{1i} x_{sample\ event}$$

This model, as well as various subsets of this model shown in Table 6, was fit using iterative maximum likelihood at each depth. Estimates from the best model at each depth are shown below:

Depth	β-Sample Event Estimate	Standard Error	Degrees of freedom	Test Statistic	p-value
0-2 inches	-0.1965476	0.0521912	69	-3.765917	3e-04
2-6 inches	-0.566821	0.1515409	69	-3.740386	4e-04
6-12 inches	-0.50640	0.506658	68	-0.999490	0.3211
12-20 inches	-0.830845	0.291282	69	-2.852370	0.0057
20-36 inches	-0.79741	0.386252	68	-2.064478	0.0428
36-60 inches	0.169083	0.932838	69	0.181257	0.8567
60-96 inches	0.184573	0.366911	68	0.5030465	0.6166

Interpretation

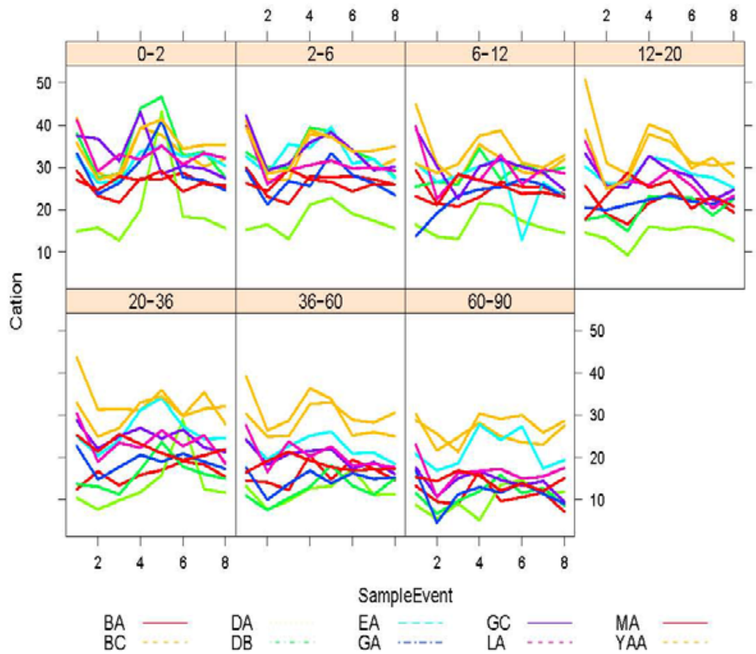
Sodium paste consistently declined over the sampling period at all depths except those beyond 36 inches, and at a depth of 6-12 inches, where clay was present in the model. The plot of beta-coefficients over depth shows little evidence of temporal trend changes at different depths.

Cation Exchange Capacity

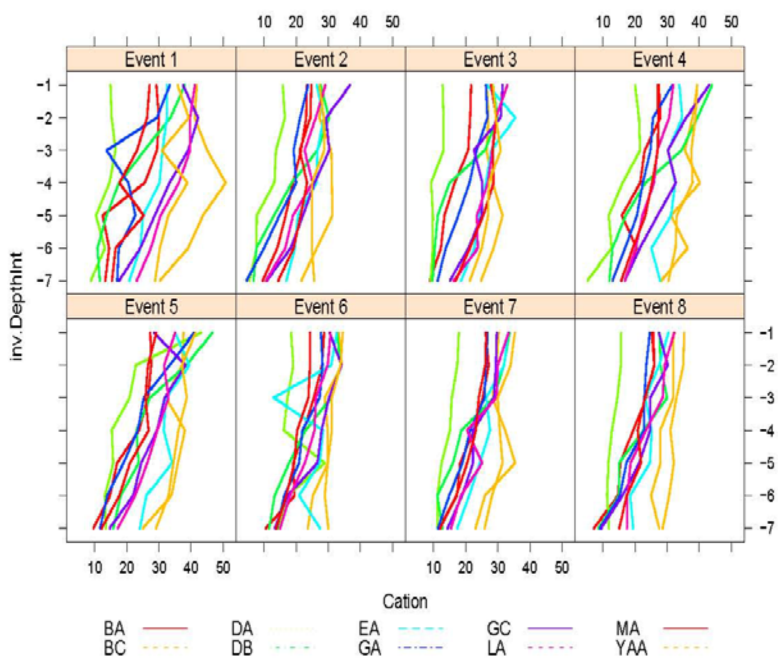
Analysis

Initial plots generally showed fairly linear trends for cation exchange capacities over sampling period, except at the shallowest depth. Given the amount of data available, a first order random effect was considered.

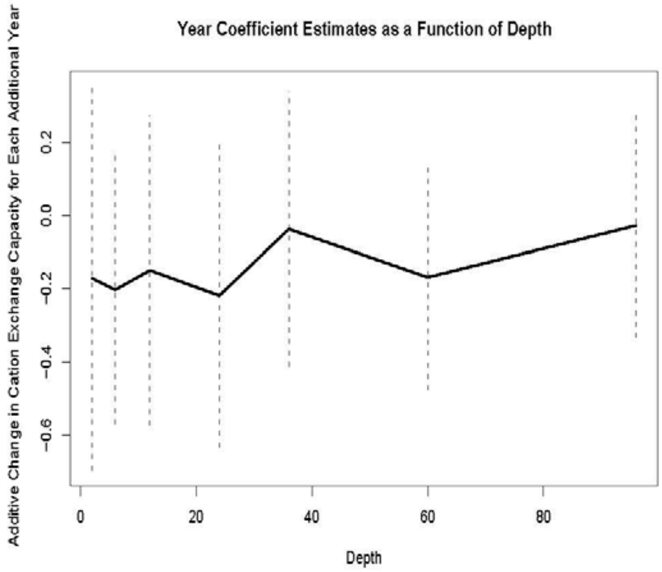
Cation Exchange Capacity Over Sample Event for all Sites, Panels are Depths



Depth Interval by Cation Exchange Capacity for all Sites, Panels are Sample Events



Clay was included in models for cation exchange capacity for all depths except 2-6 inches and depths beyond 36 inches. In general, cation exchange capacity was modeled as a function of Clay and Sample Event, with random intercepts and slopes



included for Site, as stated below:

$$\mu_{Cation\ Exchange\ Capacity\ at\ site\ i} = \beta_0 + \beta_1 x_{sample\ event} + \beta_2 x_{clay} + b_{0i} + b_{1i} x_{sample\ event}$$

This model, as well as various subsets of this model shown in Table 7, was fit using iterative maximum likelihood at each depth, as described for pH above. Estimates from the best model at each depth are shown below:

Depth	β-Sample Event Estimate	Standard Error	Degrees of freedom	Test Statistic	p-value
0-2 inches	-0.171603	0.2674069	68	-0.641731	0.5232
2-6 inches	-0.203095	0.1870917	69	-1.085538	0.2815
6-12 inches	-0.150252	0.215425	68	-0.697467	0.4879
12-20 inches	-0.219023	0.2106678	68	-1.039662	0.3022
20-36 inches	-0.037255	0.1915220	68	-0.194523	0.8463
36-60 inches	-0.16925	0.1568508	69	-1.079051	0.2843
60-96 inches	-0.02744	0.1562108	69	-0.175663	0.8611

Interpretation

Cation exchange capacity was not found to be significantly related to sample event at any depth. Additionally, the plot of beta-coefficients over depth shows little evidence of temporal trend changes at different depths.

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Lindstrom, M.J. and D.M. Bates. "Newton-Raphson and EM algorithms for linear mixed-effects models for repeated measures data". 1988. Journal of the American Statistical Association, **83**(404), pp. 1014-1022.

Pinheiro, J.C. and D.M. Bates. *Mixed-Effects Models in S and S-PLUS.* 2000. Springer

Pinheiro, J.C., D. M. Bates, S. DebRoy, D. Sarkar and the R Core team (2008). nlme: Linear and Nonlinear Mixed Effects Models. R package version 3.1-89.

R Development Core Team (2008). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Table 1: Models fit for pH

Depth	Fixed Effects	Random Effects	Covariance Structure	AIC	Comment
0-2	Sample Event, Clay	Slope, Intercept	Unstructured	13.53	
0-2	Sample Event, Clay	Slope, Intercept	Diagonal	11.53	
0-2	Sample Event, Clay	Intercept	Unstructured	9.53	
0-2	Sample Event	Slope, Intercept	Unstructured	3.43	
0-2	Sample Event	Slope, Intercept	Diagonal	1.43	
0-2	Sample Event	Intercept	Unstructured	-0.57	Selected
2-6	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
2-6	Sample Event, Clay	Slope, Intercept	Diagonal	-5.80	
2-6	Sample Event, Clay	Intercept	Unstructured	-7.80	
2-6	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
2-6	Sample Event	Slope, Intercept	Diagonal	-16.92	
2-6	Sample Event	Intercept	Unstructured	-18.92	Selected
6-12	Sample Event, Clay	Slope, Intercept	Unstructured	-36.59	
6-12	Sample Event, Clay	Slope, Intercept	Diagonal	-38.59	
6-12	Sample Event, Clay	Intercept	Unstructured	-40.59	
6-12	Sample Event	Slope, Intercept	Unstructured	-46.72	
6-12	Sample Event	Slope, Intercept	Diagonal	-48.72	
6-12	Sample Event	Intercept	Unstructured	-50.61	Selected
12-20	Sample Event, Clay	Slope, Intercept	Unstructured	-39.95	
12-20	Sample Event, Clay	Slope, Intercept	Diagonal	-41.95	
12-20	Sample Event, Clay	Intercept	Unstructured	-43.95	
12-20	Sample Event	Slope, Intercept	Unstructured	-51.42	
12-20	Sample Event	Slope, Intercept	Diagonal	-53.42	
12-20	Sample Event	Intercept	Unstructured	-55.42	Selected
20-36	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
20-36	Sample Event, Clay	Slope, Intercept	Diagonal	-51.69	
20-36	Sample Event, Clay	Intercept	Unstructured	-53.69	
20-36	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
20-36	Sample Event	Slope, Intercept	Diagonal	-62.71	
20-36	Sample Event	Intercept	Unstructured	-64.71	Selected
36-60	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
36-60	Sample Event, Clay	Slope, Intercept	Diagonal	-32.46	
36-60	Sample Event, Clay	Intercept	Unstructured	-34.46	
36-60	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
36-60	Sample Event	Slope, Intercept	Diagonal	-44.23	
36-60	Sample Event	Intercept	Unstructured	-46.23	Selected
60-90	Sample Event, Clay	Slope, Intercept	Unstructured	-37.29	
60-90	Sample Event, Clay	Slope, Intercept	Diagonal	-39.29	
60-90	Sample Event, Clay	Intercept	Unstructured	-41.29	
60-90	Sample Event	Slope, Intercept	Unstructured	-49.14	
60-90	Sample Event	Slope, Intercept	Diagonal	-51.14	
60-90	Sample Event	Intercept	Unstructured	-53.14	Selected

Table 2: Models fit for Conductivity

Depth	Fixed Effects	Random Effects	Covariance Structure	AIC	Comment
0-2	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
0-2	Sample Event, Clay	Slope, Intercept	Diagonal	139.05	
0-2	Sample Event, Clay	Intercept	Unstructured	137.05	
0-2	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
0-2	Sample Event	Slope, Intercept	Diagonal	133.56	Selected
0-2	Sample Event	Intercept	Unstructured	131.56	Selected
2-6	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
2-6	Sample Event, Clay	Slope, Intercept	Diagonal	162.70	
2-6	Sample Event, Clay	Intercept	Unstructured	174.65	
2-6	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
2-6	Sample Event	Slope, Intercept	Diagonal	154.06	Selected
2-6	Sample Event	Intercept	Unstructured	167.20	
6-12	Sample Event, Clay	Slope, Intercept	Unstructured	300.15	
6-12	Sample Event, Clay	Slope, Intercept	Diagonal	300.39	
6-12	Sample Event, Clay	Intercept	Unstructured	298.39	Selected
6-12	Sample Event	Intercept, Slope	Unstructured	NA	Failed to Converge
6-12	Sample Event	Intercept, Slope	Diagonal	313.28	
6-12	Sample Event	Intercept	Unstructured	311.28	
12-20	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
12-20	Sample Event, Clay	Slope, Intercept	Diagonal	258.25	
12-20	Sample Event, Clay	Intercept	Unstructured	256.25	
12-20	Sample Event	Slope, Intercept	Unstructure	NA	Failed to Converge
12-20	Sample Event	Slope, Intercept	Diagonal	251.47	
12-20	Sample Event	Intercept	Unstructured	249.47	Selected
20-36	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
20-36	Sample Event, Clay	Slope, Intercept	Diagonal	285.39	
20-36	Sample Event, Clay	Intercept	Unstructured	283.39	
20-36	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
20-36	Sample Event	Slope, Intercept	Diagonal	280.94	
20-36	Sample Event	Intercept	Unstructured	278.94	Selected
36-60	Sample Event, Clay	Slope, Intercept	Unstructured	322.60	
36-60	Sample Event, Clay	Slope, Intercept	Diagonal	320.92	
36-60	Sample Event, Clay	Intercept	Unstructured	320.88	
36-60	Sample Event	Slope, Intercept	Unstructured	318.64	
36-60	Sample Event	Slope, Intercept	Diagonal	316.65	
36-60	Sample Event	Intercept	Unstructured	316.75	Selected by Parsimony
60-90	Sample Event, Clay	Slope, Intercept	Unstructured	257.11	
60-90	Sample Event, Clay	Slope, Intercept	Diagonal	257.31	
60-90	Sample Event, Clay	Intercept	Unstructured	257.04	
60-90	Sample Event	Slope, Intercept	Unstructured	252.14	Selected
60-90	Sample Event	Slope, Intercept	Diagonal	253.34	
60-90	Sample Event	Intercept	Unstructured	253.96	

Table 3: Models fit for Saturation

Depth	Fixed Effects	Random Effects	Covariance Structure	AIC	Comment
0-2	Sample Event, Clay	Slope, Intercept	Unstructured	522.44	
0-2	Sample Event, Clay	Slope, Intercept	Diagonal	520.44	
0-2	Sample Event, Clay	Intercept	Unstructured	518.44	Selected
0-2	Sample Event	Slope, Intercept	Unstructured	536.96	
0-2	Sample Event	Slope, Intercept	Diagonal	NA	Failed to Converge
0-2	Sample Event	Intercept	Unstructured	536.96	
2-6	Sample Event, Clay	Slope, Intercept	Unstructured	446.27	
2-6	Sample Event, Clay	Slope, Intercept	Diagonal	445.11	
2-6	Sample Event, Clay	Intercept	Unstructured	443.11	
2-6	Sample Event	Slope, Intercept	Unstructured	442.28	
2-6	Sample Event	Slope, Intercept	Diagonal	441.238	
2-6	Sample Event	Intercept	Unstructured	439.238	Selected
6-12	Sample Event, Clay	Slope, Intercept	Unstructured	404.75	
6-12	Sample Event, Clay	Slope, Intercept	Diagonal	403.94	
6-12	Sample Event, Clay	Intercept	Unstructured	401.94	Selected
6-12	Sample Event	Slope, Intercept	Unstructured	450.16	
6-12	Sample Event	Slope, Intercept	Diagonal	448.27	
6-12	Sample Event	Intercept	Unstructured	446.39	
12-20	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
12-20	Sample Event, Clay	Slope, Intercept	Diagonal	614.66	
12-20	Sample Event, Clay	Intercept	Unstructured	612.66	Selected
12-20	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
12-20	Sample Event	Slope, Intercept	Diagonal	632.34	
12-20	Sample Event	Intercept	Unstructured	630.34	
20-36	Sample Event, Clay	Slope, Intercept	Unstructured	451.42	
20-36	Sample Event, Clay	Slope, Intercept	Diagonal	449.42	
20-36	Sample Event, Clay	Intercept	Unstructured	447.42	Selected
20-36	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
20-36	Sample Event	Slope, Intercept	Diagonal	458.88	
20-36	Sample Event	Intercept	Unstructured	456.88	
36-60	Sample Event, Clay	Slope, Intercept	Unstructured	479.13	
36-60	Sample Event, Clay	Slope, Intercept	Diagonal	477.13	
36-60	Sample Event, Clay	Intercept	Unstructured	475.19	Selected
36-60	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
36-60	Sample Event	Slope, Intercept	Diagonal	500.97	
36-60	Sample Event	Intercept	Unstructured	498.97	
60-90	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
60-90	Sample Event, Clay	Slope, Intercept	Diagonal	456.21	
60-90	Sample Event, Clay	Intercept	Unstructured	454.21	Selected
60-90	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
60-90	Sample Event	Slope, Intercept	Diagonal	484.63	
60-90	Sample Event	Intercept	Unstructured	482.63	

Table 4: Models fit for Calcium

Depth	Fixed Effects	Random Effects	Covariance Structure	AIC	Comment
0-2	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
0-2	Sample Event, Clay	Slope, Intercept	Diagonal	429.72	
0-2	Sample Event, Clay	Intercept	Unstructured	427.72	
0-2	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
0-2	Sample Event	Slope, Intercept	Diagonal	426.25	
0-2	Sample Event	Intercept	Unstructured	424.25	Selected
2-6	Sample Event, Clay	Slope, Intercept	Unstructured	402.43	
2-6	Sample Event, Clay	Slope, Intercept	Diagonal	422.41	
2-6	Sample Event, Clay	Intercept	Unstructured	430.31	
2-6	Sample Event	Slope, Intercept	Unstructured	397.055	Selected
2-6	Sample Event	Slope, Intercept	Diagonal	417.15	
2-6	Sample Event	Intercept	Unstructured	425.98	
6-12	Sample Event, Clay	Slope, Intercept	Unstructured	461.29	
6-12	Sample Event, Clay	Slope, Intercept	Diagonal	465.91	
6-12	Sample Event, Clay	Intercept	Unstructured	465.20	
6-12	Sample Event	Slope, Intercept	Unstructured	459.94	Selected
6-12	Sample Event	Slope, Intercept	Diagonal	464.88	
6-12	Sample Event	Intercept	Unstructured	463.94	
12-20	Sample Event, Clay	Slope, Intercept	Unstructured	474.35	
12-20	Sample Event, Clay	Slope, Intercept	Diagonal	472.35	
12-20	Sample Event, Clay	Intercept	Unstructured	470.35	
12-20	Sample Event	Slope, Intercept	Unstructured	470.25	
12-20	Sample Event	Slope, Intercept	Diagonal	468.25	
12-20	Sample Event	Intercept	Unstructured	466.25	Selected
20-36	Sample Event, Clay	Slope, Intercept	Unstructured	466.03	
20-36	Sample Event, Clay	Slope, Intercept	Diagonal	467.55	
20-36	Sample Event, Clay	Intercept	Unstructured	465.55	
20-36	Sample Event	Slope, Intercept	Unstructured	461.39	
20-36	Sample Event	Slope, Intercept	Diagonal	463.41	
20-36	Sample Event	Intercept	Unstructured	461.41	Selected for Parsimony
36-60	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
36-60	Sample Event, Clay	Slope, Intercept	Diagonal	438.99	
36-60	Sample Event, Clay	Intercept	Unstructured	436.99	
36-60	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
36-60	Sample Event	Slope, Intercept	Diagonal	437.92	
36-60	Sample Event	Intercept	Unstructured	435.92	Selected for Parsimony
60-90	Sample Event, Clay	Slope, Intercept	Unstructured	416.85	
60-90	Sample Event, Clay	Slope, Intercept	Diagonal	423.80	
60-90	Sample Event, Clay	Intercept	Unstructured	421.93	
60-90	Sample Event	Slope, Intercept	Unstructured	417.49	Selected for Parsimony
60-90	Sample Event	Slope, Intercept	Diagonal	424.68	
60-90	Sample Event	Intercept	Unstructured	423.61	

Table 5: Models fit for Magnesium

Depth	Fixed Effects	Random Effects	Covariance Structure	AIC	Comment
0-2	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
0-2	Sample Event, Clay	Slope, Intercept	Diagonal	312.55	
0-2	Sample Event, Clay	Intercept	Unstructured	310.55	
0-2	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
0-2	Sample Event	Slope, Intercept	Diagonal	306.69	
0-2	Sample Event	Intercept	Unstructured	304.69	Selected
2-6	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
2-6	Sample Event, Clay	Slope, Intercept	Diagonal	325.83	
2-6	Sample Event, Clay	Intercept	Unstructured	335.57	
2-6	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
2-6	Sample Event	Slope, Intercept	Diagonal	319.21	Selected
2-6	Sample Event	Intercept	Unstructured	329.69	
6-12	Sample Event, Clay	Slope, Intercept	Unstructured	438.54	
6-12	Sample Event, Clay	Slope, Intercept	Diagonal	440.99	
6-12	Sample Event, Clay	Intercept	Unstructured	439.24	Selected on Parsimony
6-12	Sample Event	Slope, Intercept	Unstructured	446.45	
6-12	Sample Event	Slope, Intercept	Diagonal	449.77	Selected
6-12	Sample Event	Intercept	Unstructured	447.77	
12-20	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
12-20	Sample Event, Clay	Slope, Intercept	Diagonal	463.18	
12-20	Sample Event, Clay	Intercept	Unstructured	461.18	
12-20	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
12-20	Sample Event	Slope, Intercept	Diagonal	458.94	
12-20	Sample Event	Intercept	Unstructured	456.94	Selected
20-36	Sample Event, Clay	Slope, Intercept	Unstructured	526.57	
20-36	Sample Event, Clay	Slope, Intercept	Diagonal	533.50	
20-36	Sample Event, Clay	Intercept	Unstructured	531.94	
20-36	Sample Event	Slope, Intercept	Unstructured	522.79	Selected
20-36	Sample Event	Slope, Intercept	Diagonal	529.61	
20-36	Sample Event	Intercept	Unstructured	527.93	
36-60	Sample Event, Clay	Slope, Intercept	Unstructured	514.30	
36-60	Sample Event, Clay	Slope, Intercept	Diagonal	512.30	
36-60	Sample Event, Clay	Intercept	Unstructured	510.59	
36-60	Sample Event	Slope, Intercept	Unstructured	511.24	
36-60	Sample Event	Slope, Intercept	Diagonal	509.27	
36-60	Sample Event	Intercept	Unstructured	507.60	Selected
60-90	Sample Event, Clay	Slope, Intercept	Unstructured	429.31	Selected
60-90	Sample Event, Clay	Slope, Intercept	Diagonal	435.96	
60-90	Sample Event, Clay	Intercept	Unstructured	438.34	
60-90	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
60-90	Sample Event	Slope, Intercept	Diagonal	433.06	
60-90	Sample Event	Intercept	Unstructured	436.70	

Table 6: Models fit for Sodium (Paste)

Depth	Fixed Effects	Random Effects	Covariance Structure	AIC	Comment
0-2	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
0-2	Sample Event, Clay	Slope, Intercept	Diagonal	271.51	
0-2	Sample Event, Clay	Intercept	Unstructured	269.51	
0-2	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
0-2	Sample Event	Slope, Intercept	Diagonal	266.08	
0-2	Sample Event	Intercept	Unstructured	264.08	Selected
2-6	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
2-6	Sample Event, Clay	Slope, Intercept	Diagonal	432.77	
2-6	Sample Event, Clay	Intercept	Unstructured	438.71	
2-6	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
2-6	Sample Event	Slope, Intercept	Diagonal	427.24	Selected
2-6	Sample Event	Intercept	Unstructured	434.01	
6-12	Sample Event, Clay	Slope, Intercept	Unstructured	622.81	
6-12	Sample Event, Clay	Slope, Intercept	Diagonal	620.81	
6-12	Sample Event, Clay	Intercept	Unstructured	618.81	Selected
6-12	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
6-12	Sample Event	Slope, Intercept	Diagonal	638.93	
6-12	Sample Event	Intercept	Unstructured	636.93	
12-20	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
12-20	Sample Event, Clay	Slope, Intercept	Diagonal	559.04	
12-20	Sample Event, Clay	Intercept	Unstructured	557.04	Selected
12-20	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
12-20	Sample Event	Slope, Intercept	Diagonal	556.10	
12-20	Sample Event	Intercept	Unstructured	554.10	Selected
20-36	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
20-36	Sample Event, Clay	Slope, Intercept	Diagonal	596.15	
20-36	Sample Event, Clay	Intercept	Unstructured	594.15	Selected
20-36	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
20-36	Sample Event	Slope, Intercept	Diagonal	601.13	
20-36	Sample Event	Intercept	Unstructured	599.13	
36-60	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
36-60	Sample Event, Clay	Slope, Intercept	Diagonal	674.92	
36-60	Sample Event, Clay	Intercept	Unstructured	676.23	
36-60	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
36-60	Sample Event	Slope, Intercept	Diagonal	673.89	Selected on Parsimony
36-60	Sample Event	Intercept	Unstructured	675.45	
60-90	Sample Event, Clay	Slope, Intercept	Unstructured	586.70	
60-90	Sample Event, Clay	Slope, Intercept	Diagonal	585.14	
60-90	Sample Event, Clay	Intercept	Unstructured	584.71	Selected on Parsimony
60-90	Sample Event	Slope, Intercept	Unstructured	588.77	
60-90	Sample Event	Slope, Intercept	Diagonal	586.79	
60-90	Sample Event	Intercept	Unstructured	586.86	

Table 7: Models fit for Cation Exchange Capacity

Depth	Fixed Effects	Random Effects	Covariance Structure	AIC	Comment
0-2	Sample Event, Clay	Slope, Intercept	Unstructured	517.96	
0-2	Sample Event, Clay	Slope, Intercept	Diagonal	515.96	
0-2	Sample Event, Clay	Intercept	Unstructured	513.96	Selected
0-2	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
0-2	Sample Event	Slope, Intercept	Diagonal	523.65	
0-2	Sample Event	Intercept	Unstructured	521.65	
2-6	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
2-6	Sample Event, Clay	Slope, Intercept	Diagonal	479.12	
2-6	Sample Event, Clay	Intercept	Unstructured	477.12	
2-6	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
2-6	Sample Event	Slope, Intercept	Diagonal	475.90	
2-6	Sample Event	Intercept	Unstructured	473.90	Selected
6-12	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
6-12	Sample Event, Clay	Slope, Intercept	Diagonal	488.85	
6-12	Sample Event, Clay	Intercept	Unstructured	486.85	Selected
6-12	Sample Event	Slope, Intercept	Unstructured	491.08	
6-12	Sample Event	Slope, Intercept	Diagonal	491.50	
6-12	Sample Event	Intercept	Unstructured	489.50	
12-20	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
12-20	Sample Event, Clay	Slope, Intercept	Diagonal	484.66	
12-20	Sample Event, Clay	Intercept	Unstructured	482.66	Selected
12-20	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
12-20	Sample Event	Slope, Intercept	Diagonal	486.29	
12-20	Sample Event	Intercept	Unstructured	484.29	
20-36	Sample Event, Clay	Slope, Intercept	Unstructured	NA	Failed to Converge
20-36	Sample Event, Clay	Slope, Intercept	Diagonal	470.10	
20-36	Sample Event, Clay	Intercept	Unstructured	468.10	Selected
20-36	Sample Event	Slope, Intercept	Unstructured	NA	Failed to Converge
20-36	Sample Event	Slope, Intercept	Diagonal	482.35	
20-36	Sample Event	Intercept	Unstructured	480.35	
36-60	Sample Event, Clay	Slope, Intercept	Unstructured	454.89	
36-60	Sample Event, Clay	Slope, Intercept	Diagonal	456.57	
36-60	Sample Event, Clay	Intercept	Unstructured	454.57	
36-60	Sample Event	Slope, Intercept	Unstructured	450.23	
36-60	Sample Event	Slope, Intercept	Diagonal	454.34	
36-60	Sample Event	Intercept	Unstructured	452.74	Selected
60-90	Sample Event, Clay	Slope, Intercept	Unstructured	456.41	
60-90	Sample Event, Clay	Slope, Intercept	Diagonal	454.41	
60-90	Sample Event, Clay	Intercept	Unstructured	452.41	
60-90	Sample Event	Slope, Intercept	Unstructured	456.36	
60-90	Sample Event	Slope, Intercept	Diagonal	454.36	
60-90	Sample Event	Intercept	Unstructured	452.36	Selected on Parsimony

Appendix E-2 Soils Tongue River Report

Modeling Approach

Sites are assumed to be a random sample of all possible sites, justifying the use of a random effect for the site covariate. We examined a model that included both random intercepts and random slopes for each site. Since sample events (year) are repeatable (that is, we could have collected more data each year), it was treated as a fixed effect, as was clay. Separate models were fit for each depth and each response variable (pH, Conductivity, Saturation, etc.) was modeled separately. Modeling was carried out using the R statistical environment (R Core Development Team), and specifically the **nlme** package (Pinheiro and Bates, 2000).

Calcium

Analysis

Clay was dropped from all models for Calcium. In general, Calcium was modeled as a function of Clay and Sample Event, with random intercepts and slopes included for Site, as stated below:

$$\mu_{Calcium\ at\ site\ i} = \beta_0 + \beta_1 x_{sample\ event} + \beta_2 x_{clay} + b_{0i} + b_{1i} x_{sample\ event}$$

In this portion of the study, I compared the best model from the previous set of fits at each depth to the best model with the following additions (which correspond to one additional β term a piece in the model stated above):

1. Fixed effect for Streamflow
2. Fixed effect for November-June Rainfall in Miles City
3. Fixed effect for Water Calcium content below the Tongue River Dam
4. Fixed effects for Streamflow and Rainfall
5. Fixed effects for Streamflow and Water Calcium
6. Fixed effects for Rainfall and Water Calcium
7. Fixed effects for Streamflow, Rainfall, and Water Calcium

Models were compared based on AIC values and p-values associated with likelihood ratio tests (LRTs), since all the new models fit here are nested in the previous best model. LRT p-values and AIC scores are included for each model fit in Table 1.

Findings

Streamflow, Rainfall, and Water Calcium did not significantly model fits for soil Calcium in models that already included Clay (if previously selected) and Year (Sample Event) at any depth. However, Water Calcium did marginally improve model fit at a depth of 20-36 inches (p-value on LRT = .083; AIC value of 461.74 for model with Water Calcium, as opposed to 461.41 without). Output for that model is included here.

Fixed Effects for 20-36 inches:

```
Fixed effects: Ca ~ SampleEvent + BTR_Ca
                 Value Std.Error DF   t-value p-value
(Intercept)  7.918915  4.366422 68  1.813593  0.0742
SampleEvent -0.455914  0.188964 68 -2.412699  0.0185
BTR_Ca       0.130935  0.075822 68  1.726885  0.0887
```

The coefficient estimate associated with Water Calcium suggests that increasing Water Calcium corresponds to increased soil Calcium, as we might expect ($\beta = .1309$; p-value = .0887).

Sodium

Findings

The new covariates did not substantially improve the model for soil sodium paste at a depth of 0-2 inches. At 2-6 inches, the model with Streamflow and Water Sodium signficantly improved model fit. At depths of 12-20 inches, 20-36 inches, and 36-60 inches, the new covariates did not improve model fit signficantly. At 60-90 inches, rainfall marginally improved model fit.

Fixed Effects for 2-6 inches:

```
Fixed effects: NaPaste ~ SampleEvent + BTR_flow + BTR_Na
                Value Std.Error DF   t-value p-value
(Intercept) 14.280167  3.978327 67  3.589490  0.0006
SampleEvent -0.581207  0.285604 67 -2.035010  0.0458
BTR_flow    -0.003753  0.001991 67 -1.884890  0.0638
BTR_Na      -0.246937  0.096701 67 -2.553613  0.0129
```

Fixed Effects for 60-90 inches:

```
Fixed effects: NaPaste ~ SampleEvent + RainMCNJ
                Value Std.Error DF   t-value p-value
(Intercept) 14.212004  5.064650 68 2.8061177  0.0065
SampleEvent  0.154089  0.482781 68 0.3191693  0.7506
RainMCNJ     0.573461  0.336445 68 1.7044719  0.0929
```

At 2-6 inches, increase streamflow corresponded to a marginally significant decrease in soil sodium ($\beta = -.00375$; p-value = .0638). Increased water sodium corresponded to a signficant decrease in soil sodium ($\beta = -.2469$; p-value = .0129). At 60-90 inches, increased November-June rainfall in Miles City corresponded with a marginally signficant increase in soil sodium ($\beta = .5734$; p-value = .0929).

Magnesium

At a depth of 0-2 inches, inclusion of Water Magnesium marginally improved model fit. At depths of 2-6 inches, 12-20 inches, 20-36 inches, and 36-60 inches, the new covariates did not substantially improve model fit.

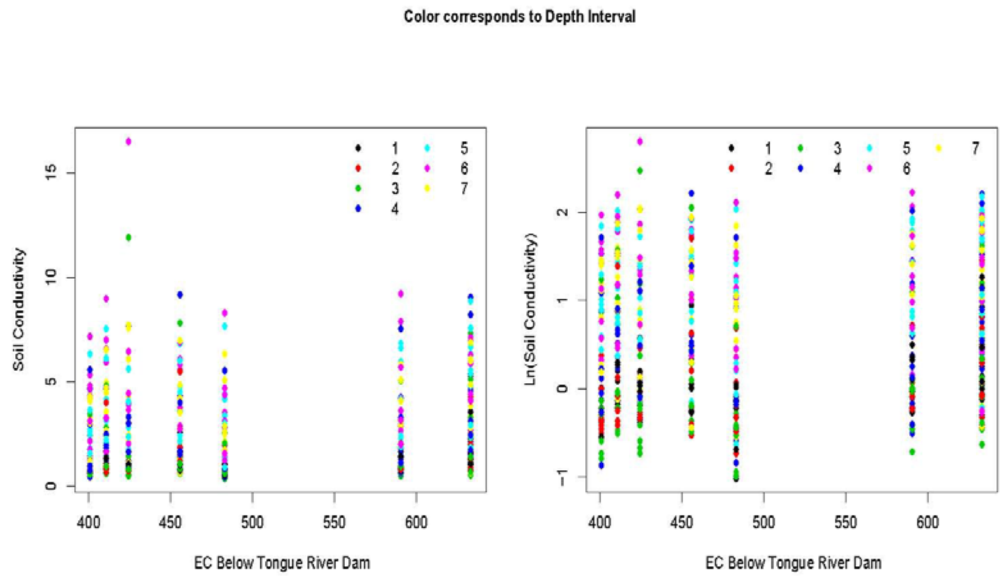
Fixed Effects for 2-6 inches:

```
Fixed effects: Mg ~ SampleEvent + BTR_Mg
                 Value Std.Error DF   t-value p-value
(Intercept)  2.7330552 1.1708464 68  2.334256  0.0225
SampleEvent -0.2286841 0.0807241 68 -2.832910  0.0061
BTR_Mg       0.0617338 0.0335210 68  1.841644  0.0699
```

Increases in Water Magnesium corresponded with marginally significant increases in soil Magnesium ($\beta = .0617$; p-value = .0699).

Conductivity

EC in water was never a significant predictor of soil conductivity, nor were streamflow or rainfall at any depth. I generated the plot below, which contains water and soil conductivity measures. I'm not struck by a strong trend here.



It appears that conductivity does vary with depth (as evidenced by the grouped colors), but no trend between water and soil conductivity jumps out at me.

References

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R Development Core Team (2008). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Table 1: Models fit for Calcium

Depth Interval	Fixed Effects	LRT P-value	AIC
0-2	Previous	NA	424.25
0-2	Flow	0.3333	424.01
0-2	Rainfall	0.5322	424.56
0-2	Water Chemistry	0.1769	423.13
0-2	Flow + Rain	0.6217	426
0-2	Flow + Water Chemistry	0.3531	424.87
0-2	Rain + Water Chemistry	0.3877	425.05
0-2	Flow + Rain + Water Chemistry	0.5397	426.79
2-6	Previous	NA	397.06
2-6	Flow	0.7173	398.88
2-6	Rainfall	0.907	399
2-6	Water Chemistry	0.983	399.01
2-6	Flow + Rain	0.8736	400.74
2-6	Flow + Water Chemistry	0.7534	400.45
2-6	Rain + Water Chemistry	0.9861	400.99
2-6	Flow + Rain + Water Chemistry	0.8991	402.43
6-12	Previous	NA	459.94
6-12	Flow	0.229	462.11
6-12	Rainfall	0.8836	463.53
6-12	Water Chemistry	0.1236	461.19
6-12	Flow + Rain	0.4038	463.74
6-12	Flow + Water Chemistry	0.2867	463.06
6-12	Rain + Water Chemistry	0.1776	462.1
6-12	Flow + Rain + Water Chemistry	0.3071	463.95
12-20	Previous	NA	466.25
12-20	Flow	0.5405	469.22
12-20	Rainfall	0.4064	468.9
12-20	Water Chemistry	0.4485	469.02
12-20	Flow + Rain	0.6953	470.87
12-20	Flow + Water Chemistry	0.7435	471
12-20	Rain + Water Chemistry	0.6749	470.81
12-20	Flow + Rain + Water Chemistry	0.8491	472.79
20-36	Previous	NA	461.41
20-36	Flow	0.1135	462.24
20-36	Rainfall	0.2125	463.19
20-36	Water Chemistry	0.083	461.74
20-36	Flow + Rain	0.2557	464.01
20-36	Flow + Water Chemistry	0.2216	463.73
20-36	Rain + Water Chemistry	0.2168	463.68
20-36	Flow + Rain + Water Chemistry	0.3812	465.67
36-60	Previous	NA	435.92
36-60	Flow	0.9083	438.63
36-60	Rainfall	0.6754	438.47
36-60	Water Chemistry	0.5271	438.24
36-60	Flow + Rain	0.908	440.45
36-60	Flow + Water Chemistry	0.2666	438
36-60	Rain + Water Chemistry	0.4774	439.16
36-60	Flow + Rain + Water Chemistry	0.2791	438.8

Table 2: Models fit for Calcium (Continued)

Depth Interval	Fixed Effects	LRT P-value	AIC
60-90	Previous	NA	417.49
60-90	Flow	0.7828	420.06
60-90	Rainfall	0.2386	418.75
60-90	Water Chemistry	0.154	418.11
60-90	Flow + Rain	0.4546	420.56
60-90	Flow + Water Chemistry	0.0301	415.13
60-90	Rain + Water Chemistry	0.3364	419.96
60-90	Flow + Rain + Water Chemistry	0.068	417.01

Table 3: Models fit for Sodium (Paste)

Depth Interval	Fixed Effects	LRT P-value	AIC
0-2	Previous	NA	264.08
0-2	Flow	0.5759	260.76
0-2	Rainfall	0.1139	258.58
0-2	Water Chemistry	0.3917	260.34
0-2	Flow + Rain	0.2693	260.45
0-2	Flow + Water Chemistry	0.6285	262.15
0-2	Rain + Water Chemistry	0.286	260.57
0-2	Flow + Rain + Water Chemistry	0.4226	262.27
2-6	Previous	NA	427.24
2-6	Flow	0.4218	430.94
2-6	Rainfall	0.4863	431.1
2-6	Water Chemistry	0.0641	428.16
2-6	Flow + Rain	0.6898	432.84
2-6	Flow + Water Chemistry	0.0308	426.62
2-6	Rain + Water Chemistry	0.1623	429.95
2-6	Flow + Rain + Water Chemistry	0.0697	428.52
12-20	Previous	NA	554.1
12-20	Flow	0.3243	559.42
12-20	Rainfall	0.7448	560.29
12-20	Water Chemistry	0.523	559.99
12-20	Flow + Rain	0.5966	561.36
12-20	Flow + Water Chemistry	0.5377	561.15
12-20	Rain + Water Chemistry	0.8143	561.98
12-20	Flow + Rain + Water Chemistry	0.7396	563.14
20-36	Previous	NA	599.13
20-36	Flow	0.2915	604.8
20-36	Rainfall	0.837	605.87
20-36	Water Chemistry	0.2992	604.84
20-36	Flow + Rain	0.5212	606.61
20-36	Flow + Water Chemistry	0.5596	606.76
20-36	Rain + Water Chemistry	0.5187	606.6
20-36	Flow + Rain + Water Chemistry	0.701	608.5
60-90	Previous	NA	586.79
60-90	Flow	0.3328	592.95
60-90	Rainfall	0.089	590.99
60-90	Water Chemistry	0.7608	593.79
60-90	Flow + Rain	0.235	592.99
60-90	Flow + Water Chemistry	0.2949	593.44
60-90	Rain + Water Chemistry	0.1654	592.29
60-90	Flow + Rain + Water Chemistry	0.1294	592.22

Table 4: Models fit for Magnesium

Depth Interval	Fixed Effects	LRT P-value	AIC
0-2	Previous	NA	304.69
0-2	Flow	0.1698	299.92
0-2	Rainfall	0.3591	300.97
0-2	Water Chemistry	0.0649	298.4
0-2	Flow + Rain	0.3811	301.88
0-2	Flow + Water Chemistry	0.1574	300.11
0-2	Rain + Water Chemistry	0.1769	300.35
0-2	Flow + Rain + Water Chemistry	0.2897	302.06
2-6	Previous	NA	319.21
2-6	Flow	0.7815	320.97
2-6	Rainfall	0.9447	321.05
2-6	Water Chemistry	0.8968	321.03
2-6	Flow + Rain	0.9299	322.9
2-6	Flow + Water Chemistry	0.6979	322.33
2-6	Rain + Water Chemistry	0.9916	323.03
2-6	Flow + Rain + Water Chemistry	0.8686	324.33
12-20	Previous	NA	456.94
12-20	Flow	0.9163	460.06
12-20	Rainfall	0.4859	459.59
12-20	Water Chemistry	0.7606	459.98
12-20	Flow + Rain	0.7441	461.48
12-20	Flow + Water Chemistry	0.898	461.86
12-20	Rain + Water Chemistry	0.7762	461.57
12-20	Flow + Rain + Water Chemistry	0.887	463.43
20-36	Previous	NA	522.79
20-36	Flow	0.11	525.29
20-36	Rainfall	0.1825	526.07
20-36	Water Chemistry	0.1077	525.26
20-36	Flow + Rain	0.2375	526.97
20-36	Flow + Water Chemistry	0.2548	527.11
20-36	Rain + Water Chemistry	0.2461	527.04
20-36	Flow + Rain + Water Chemistry	0.4005	528.9
36-60	Previous	NA	507.6
36-60	Flow	0.4448	511.65
36-60	Rainfall	0.1955	510.55
36-60	Water Chemistry	0.9059	512.22
36-60	Flow + Rain	0.4313	512.55
36-60	Flow + Water Chemistry	0.3658	512.22
36-60	Rain + Water Chemistry	0.3044	511.85
36-60	Flow + Rain + Water Chemistry	0.2271	511.89

Table 5: Models fit for Conductivity

Depth Interval	Fixed Effects	LRT P-value	AIC
0-2	Previous	NA	131.56
0-2	Flow	0.2929	123.49
0-2	Rainfall	0.5034	124.15
0-2	Water Chemistry	0.1529	122.55
0-2	Flow + Rain	0.571	125.48
0-2	Flow + Water Chemistry	0.2532	123.85
0-2	Rain + Water Chemistry	0.3125	124.27
0-2	Flow + Rain + Water Chemistry	0.2244	124.23
2-6	Previous	NA	154.06
2-6	Flow	0.8918	151.85
2-6	Rainfall	0.7467	151.77
2-6	Water Chemistry	0.8225	151.82
2-6	Flow + Rain	0.8861	153.63
2-6	Flow + Water Chemistry	0.5849	152.8
2-6	Rain + Water Chemistry	0.9491	153.77
2-6	Flow + Rain + Water Chemistry	0.7366	154.6
12-20	Previous	NA	249.47
12-20	Flow	0.8971	247.7
12-20	Rainfall	0.5416	247.34
12-20	Water Chemistry	0.5815	247.41
12-20	Flow + Rain	0.8065	249.29
12-20	Flow + Water Chemistry	0.4524	248.13
12-20	Rain + Water Chemistry	0.8197	249.32
12-20	Flow + Rain + Water Chemistry	0.6194	249.94
20-36	Previous	NA	278.94
20-36	Flow	0.0879	274.65
20-36	Rainfall	0.2502	276.24
20-36	Water Chemistry	0.1164	275.1
20-36	Flow + Rain	0.2243	276.58
20-36	Flow + Water Chemistry	0.2323	276.65
20-36	Rain + Water Chemistry	0.2915	277.1
20-36	Flow + Rain + Water Chemistry	0.3639	278.38
36-60	Previous	NA	316.75
36-60	Flow	0.5695	316.02
36-60	Rainfall	0.159	314.36
36-60	Water Chemistry	0.6892	316.18
36-60	Flow + Rain	0.3613	316.31
36-60	Flow + Water Chemistry	0.7888	317.87
36-60	Rain + Water Chemistry	0.2456	315.53
36-60	Flow + Rain + Water Chemistry	0.091	313.88

Table 6: Models fit for Conductivity (Continued)

Depth Interval	Fixed Effects	LRT P-value	AIC
60-90	Previous	NA	252.14
60-90	Flow	0.5887	250.68
60-90	Rainfall	0.3725	250.18
60-90	Water Chemistry	0.9431	250.97
60-90	Flow + Rain	0.6703	252.18
60-90	Flow + Water Chemistry	0.3829	251.05
60-90	Rain + Water Chemistry	0.472	251.47
60-90	Flow + Rain + Water Chemistry	0.0339	246.3

Appendix F

Tier 2 Forage Analysis Results

Table F-1 Forage analysis for site MA

AMPP

MA Location Yields, Forage Quality, Mineral Content, and Fertilizer Applied

Year	Crop	Cutting	Date	Harvest Wt.lbs	% Water	Wt. @ 12%	Ft^2 Harvest	Yield	% Cr. Protein	% ADF	% Calc Digest Protein	% TDN	Energy (mcal/lb) Lact	Main	Gain	Mineral Content, % Ca	P	K	Mg	Na	S	Mineral Content, ppm Fe	Mn	Zn	Cu	Act. Nutrients App./Ac., lbs
2004	Alfalfa	1st	7/1	2.60	10.0	2.7	52.27	1.11	15.3	43.7	7.8	53.6	0.54	0.50	0.25	1.53	0.29	4.33	0.37	0.07	0.42	138	24.6	32.8	14.8	12-70-0-0-4
		2nd	9/30	3.20	33.5	2.4	52.27	1.01	23.0	28.1	16.4	68.6	0.71	0.72	0.45	1.34	0.29	2.99	0.25	0.06	0.38	125	24.7	16.5	12.4	0-0-0-0-0
					TOTAL YIELD			**2.12 T/Ac**	**19.2**	**35.9**	**12.1**	**61.1**	**0.63**	**0.61**	**0.35**	**1.44**	**0.29**	**3.66**	**0.31**	**0.07**	**0.40**	**131**	**24.7**	**24.7**	**13.6**	**12-70-0-0-4**
2005	Alfalfa	1st	6/20	5.20	9.3	5.4	52.27	**2.23 T/Ac**	**18.3**	**37.2**	**13.0**	**58.9**	**0.60**	**0.58**	**0.32**	**1.16**	**0.33**	**3.26**	**0.27**	**0.07**	**0.30**	**106**	**37.1**	**27.0**	**13.5**	**0-0-0-0-0**
		2nd	Did not get a second cutting due to pivot wheel tracks too deep.																							
2006	Alfalfa	1st	8/8	2.30	9.0	2.4	52.27	**0.99 T/Ac**	**18.4**	**30.3**	**n/a**	**66.3**	**0.68**	**0.69**	**0.42**	**1.59**	**0.26**	**2.74**	**0.31**	**0.04**	**0.38**	**280**	**32.4**	**35.4**	**8.80**	**0-0-0-0-0**
2007	Alfalfa	1st	6/16	6.40	10.4	6.5	52.27	**2.72 T/Ac**	**15.2**	**40.1**	**10.8**	**55.8**	**0.57**	**0.53**	**0.28**	**0.70**	**0.30**	**2.64**	**0.33**	**0.07**	**0.30**	**145**	**37.0**	**37.9**	**11.0**	**0-0-0-0-0**
				Grams		Grams																				
2008	Alfalfa	1st	6/23	1,213	8.3	1,264	52.27	**1.16 T/Ac**	**19.7**	**35.4**	**n/a**	**60.8**	**0.62**	**0.61**	**0.35**	**1.13**	**0.22**	**3.19**	**0.29**	**0.08**	**0.25**	**326**	**32.8**	**37.9**	**12.6**	**0-0-0-0-0**
2009	Alfalfa	1st	6/23	1,893	14.0	1,850	52.27	**1.70 T/Ac**	**11.4**	**38.2**	**n/a**	**57.9**	**0.59**	**0.56**	**0.31**	**0.65**	**0.16**	**1.90**	**0.22**	**0.02**	**0.16**	**130**	**53.5**	**30.6**	**7.60**	**0-0-0-0-0**
2010	Alfalfa	1st	6/30	1,793	21.5	1,599	52.27	**1.47 T/Ac**	**11.9**	**31.9**	**n/a**	**43.3**	**0.44**	**0.41**	**0.21**	**0.67**	**0.13**	**1.81**	**0.18**	**0.03**	**0.14**	**61.5**	**27.2**	**23.6**	**7.22**	**0-0-0-0-0**

Forage quality data and mineral content are on a dry matter basis.
Crop yields collected and sheet compiled by: Neal E. Fehringer, Certified Professional Agronomist, C.C.A. revised on 6/15/10.

Table F-2 Forage analysis for site MB.

AMPP

MB Location Yields, Forage Quality, Mineral Content, and Fertilizer

Year	Crop	Cutting	Date	Harvest Wt.lbs	% Water	Wt. @ 12%	Ft^2 Harvest	Yield	% Cr. Protein	% ADF	% Calc Digest Protein	% TDN	Energy (mcal/lb) Lact	Main	Gain	Mineral Content, % Ca	P	K	Mg	Na	S	Mineral Content, ppm Fe	Mn	Zn	Cu	Act. Nutrients App./Ac., lbs
2004	Barley	Planted but was not irrigated much and was not sprayed or harvested.									n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0-0-0-0-0
2005	Fallow	Field was not planted.				n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	**0-0-0-0-0**
2006	New Grass	Seeded to grass in June.				n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	**0-0-0-0-0**
2007	Weeds	Grass did not take.				n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	**0-0-0-0-0**
				Grams		Grams																				
2008	H Millet	1st	9/10	1,053	13.3	1,037	43.56	**1.14 T/Ac**	**7.30**	**38.5**	**n/a**	**59.4**	**0.61**	**0.59**	**0.33**	**0.57**	**0.25**	**1.94**	**0.35**	**0.03**	**0.21**	**919**	**82.3**	**34.8**	**13.4**	0-0-0-0-0
		Yield compromised by neighbor's cattle repeatedly getting into field and grazing crop.																								
2009	Grn Hay	1st	7/14	577	17.2	543	43.56	**0.60 T/Ac**	**9.80**	**38.4**	**n/a**	**59.5**	**0.61**	**0.59**	**0.33**	**0.36**	**0.40**	**2.15**	**0.21**	**0.06**	**0.23**	**234**	**40.8**	**29.9**	**8.20**	0-0-0-0-0
2010	Grn Hay	1st	6/30	962	16.1	917	43.56	**1.01 T/Ac**	**6.00**	**34.5**	**n/a**	**47.4**	**0.48**	**0.45**	**0.24**	**0.13**	**0.23**	**1.32**	**0.10**	**0.01**	**0.12**	**111**	**30.1**	**22.6**	**5.62**	0-0-0-0-0

Forage quality data and mineral content are on a dry matter basis.
Crop yields collected and sheet compiled by: Neal E. Fehringer, Certified Professional Agronomist, C.C.A. revised on 6/15/10.

Table F-3 Forage analysis for site LA.

AMPP

LA Location Yields, Forage Quality, Mineral Content, and Fertilizer Applied

Year	Crop	Cutting	Date	Harvest Wt.lbs	% Water	Wt. @ 12%	Ft² Harvest	Yield	% Cr. Protein	% ADF	% Calc Digest Protein	% TDN	Energy (mcal/lb) Lact	Main	Gain	Mineral Content, % Ca	P	K	Mg	Na	S	Mineral Content, ppm Fe	Mn	Zn	Cu	Act. Nutrients App./Ac., lbs
2004	Grs/Alf	1st	6/28	5.00	9.6	5.1	52.27	2.14	10.2	40.9	5.2	56.8	0.58	0.55	0.29	0.30	0.21	2.52	0.15	0.04	0.18	103	37.8	19.6	9.10	38-12-0-0-0
		2nd	9/16	3.40	13.7	3.3	52.27	1.39	15.8	31.0	8.0	67.9	0.70	0.71	0.44	0.41	0.38	3.19	0.24	0.08	0.32	256	67.0	4.20	11.2	70-40-30-0-0
					TOTAL YIELD			**3.53 T/Ac**	**13.0**	**36.0**	**6.6**	**62.4**	**0.64**	**0.63**	**0.37**	**0.36**	**0.30**	**2.86**	**0.20**	**0.06**	**0.25**	**179**	**52.4**	**11.9**	**10.2**	**118-82-0-0-0**
2005	Grs/Alf	1st	6/20	7.40	9.2	7.6	52.27	3.18	8.9	40.7	6.3	55.1	0.56	0.52	0.27	0.25	0.32	2.56	0.12	0.07	0.20	79.7	40.6	21.9	10.9	95-40-40-0-0
		2nd	8/26	2.80	10.8	2.8	52.27	1.18	17.5	30.7	8.9	68.1	0.70	0.72	0.44	0.44	0.46	3.59	0.22	0.03	0.32	364	68.5	34.2	21.9	45-0-0-0-0
					TOTAL YIELD			**4.36 T/Ac**	**13.2**	**35.7**	**7.6**	**61.6**	**0.63**	**0.62**	**0.36**	**0.35**	**0.39**	**3.08**	**0.17**	**0.05**	**0.26**	**222**	**54.6**	**28.1**	**16.4**	**140-40-40-0-0**
2006	Grass	1st	6/21	24.2	6.9	25.6	270.00	2.07	9.1	35.9	n/a	62.4	0.64	0.63	0.37	0.31	0.25	2.78	0.13	0.03	0.24	104	49.8	26.3	8.80	100-35-50-0-0
		2nd	8/16	18.3	14.5	17.8	270.00	1.43	14.9	34.3	n/a	64.1	0.66	0.66	0.39	0.41	0.31	3.16	0.20	0.04	0.26	89.9	64.2	25.7	7.70	45-0-0-0-0
					TOTAL YIELD			**3.50 T/Ac**	**12.0**	**35.1**	**n/a**	**63.3**	**0.65**	**0.65**	**0.38**	**0.36**	**0.28**	**2.97**	**0.17**	**0.04**	**0.25**	**96.9**	**57.0**	**26.0**	**8.25**	**145-35-50-0-0**
2007	Grass	1st	6/15	6.05	10.1	6.2	32.20	4.18	10.1	44.0	7.5	52.4	0.53	0.48	0.23	0.29	0.23	2.88	0.13	0.02	0.17	144	67.5	24.7	9.32	140-0-50-0-0
		2nd	8/24	2.60	16.9	2.5	43.56	1.23	18.9	31.0	13.8	67.2	0.69	0.70	0.43	0.48	0.37	4.04	0.25	0.03	0.35	170	85.6	38.9	15.7	45-0-0-0-0
					TOTAL YIELD			**5.41 T/Ac**	**14.5**	**37.5**	**10.7**	**59.8**	**0.61**	**0.59**	**0.33**	**0.39**	**0.30**	**3.46**	**0.19**	**0.03**	**0.26**	**157**	**76.5**	**31.8**	**12.5**	**165-0-50-0-0**
				Grams		Grams																				
2008	Grass	1st	6/23	3,302	8.7	3,426	52.27	3.14	10.8	38.4	n/a	59.5	0.61	0.59	0.33	0.25	0.21	2.71	0.14	0.02	0.14	239	36.9	25.6	11.4	140-0-50-0-0
		2nd	8/23	1,065	14.2	1,038	52.27	0.95	15.1	40.5	n/a	57.2	0.58	0.55	0.30	0.40	0.31	4.76	0.23	0.02	0.32	157	59.8	37.0	14.2	45-0-0-0-0
					TOTAL YIELD			**4.10 T/Ac**	**13.0**	**39.5**	**n/a**	**58.4**	**0.60**	**0.57**	**0.32**	**0.33**	**0.26**	**3.74**	**0.19**	**0.02**	**0.23**	**198**	**48.4**	**31.3**	**12.8**	**165-0-50-0-0**
2009	Grs/Alf	1st	6/18	3,208	13.3	3,161	52.27	2.90	10.2	42.9	n/a	54.6	0.55	0.51	0.26	0.21	0.23	2.65	0.10	0.01	0.15	87.2	42.1	21.0	6.00	140-0-50-0-0
		2nd	*	1.28	11.0	1.29 T/Ac		1.29	16.5	35.3	n/a	63.0	0.65	0.64	0.38	0.47	0.33	3.77	0.20	0.02	0.26	120	59.8	22.8	11.4	45-0-0-0-0
					TOTAL YIELD			**4.20 T/Ac**	**13.4**	**39.1**	**n/a**	**58.8**	**0.60**	**0.58**	**0.32**	**0.34**	**0.28**	**3.21**	**0.15**	**0.02**	**0.21**	**103**	**51.0**	**21.9**	**8.70**	**165-0-50-0-0**
2010	Grs/Alf	1st	6/30	3,986	17.7	3,728	52.27	3.42	8.8	32.6	n/a	48.0	0.49	0.47	0.26	0.21	0.18	2.27	0.11	0.01	0.15	69.5	33.6	14.4	7.16	140-0-50-0-0
		2nd	*	1.40	12.6	1.39 T/Ac		1.39	14.9	29.6	n/a	56.5	0.58	0.58	0.35	0.38	0.25	3.24	0.18	0.02	0.23	152	57.1	19.8	12.4	45-0-0-0-0
					TOTAL YIELD			**4.81 T/Ac**	**11.9**	**31.1**	**n/a**	**52.3**	**0.54**	**0.53**	**0.31**	**0.30**	**0.22**	**2.76**	**0.15**	**0.02**	**0.19**	**111**	**45.3**	**17.1**	**9.79**	**165-0-50-0-0**

* Yield based on bale count. Bales sampled with Penn State forage sampler.
Forage quality data and mineral content are on a dry matter basis.
Crop yields collected and sheet compiled by: Neal E. Fehringer, Certified Professional Agronomist, C.C.A. revised on 6/15/10.

Table F-4 Forage analysis for site GA.

AMPP

GA Location Yields, Forage Quality, Mineral Content, and Fertilizer Applied

Year	Crop	Cutting	Date	Harvest Wt.lbs	% Water	Wt. @ 12%	Ft² Harvest	Yield	% Cr. Protein	% ADF	% Calc Digest Protein	% TDN	Energy (mcal/lb) Lact	Main	Gain	Mineral Content, % Ca	P	K	Mg	Na	S	Mineral Content, ppm Fe	Mn	Zn	Cu	Act. Nutrients App./Ac., lbs
2004	Alf/Grs	1st	6/28	2.60	9.4	2.7	43.56	1.34	16.5	39.5	8.4	58.4	0.60	0.57	0.31	1.04	0.27	2.78	0.36	0.12	0.31	111	32.0	28.6	11.8	0-0-0-0-0
		2nd	8/20	3.20	20.1	2.9	43.56	1.45	18.7	38.7	13.3	57.3	0.58	0.55	0.30	0.95	0.27	2.74	0.31	0.10	0.33	199	24.5	32.7	10.9	0-0-0-0-0
					TOTAL YIELD			**2.79 T/Ac**	**17.6**	**39.1**	**10.9**	**57.9**	**0.59**	**0.56**	**0.31**	**1.00**	**0.27**	**2.76**	**0.34**	**0.11**	**0.32**	**155**	**28.3**	**30.7**	**11.4**	**0-0-0-0-0**
2005	Alf/Grs	1st	6/7	1.10	8.4	1.1	21.78	1.15	20.7	34.9	12.4	62.8	0.64	0.64	0.37	1.66	0.56	4.82	0.42	0.16	0.49	375	51.2	44.4	17.1	90-60-60-0-0
		2nd	7/29	1.80	12.4	1.8	21.78	1.79	21.4	32.1	12.8	65.9	0.68	0.68	0.41	1.18	0.30	2.77	0.42	0.12	0.33	801	31.2	44.0	17.0	0-0-0-0-0
					TOTAL YIELD			**2.94 T/Ac**	**21.1**	**33.5**	**12.6**	**64.4**	**0.66**	**0.66**	**0.39**	**1.42**	**0.43**	**3.80**	**0.42**	**0.14**	**0.41**	**588**	**41.2**	**44.2**	**17.1**	**90-60-60-0-0**
2006	Alf/Grs	1st	6/21	1.50	7.7	1.6	21.78	1.57	16.2	34.3	n/a	64.2	0.66	0.66	0.39	0.99	0.22	2.23	0.26	0.09	0.31	235	31.8	31.8	10.1	15-30-40-0-0
		2nd	8/8	1.71	17.6	1.6	21.80	1.60	21.1	35.5	n/a	60.7	0.62	0.61	0.34	1.23	0.32	2.73	0.45	0.09	0.36	140	29.2	32.1	11.7	0-0-0-0-0
					TOTAL YIELD			**3.17 T/Ac**	**18.7**	**34.9**	**n/a**	**62.5**	**0.64**	**0.64**	**0.37**	**1.11**	**0.27**	**2.48**	**0.36**	**0.09**	**0.34**	**188**	**30.5**	**32.0**	**10.9**	**15-30-40-0-0**
2007	Alf/Grs	1st	6/15	1.85	9.5	1.9	21.78	1.90	16.1	40.4	11.4	56.5	0.57	0.54	0.29	0.88	0.22	2.48	0.29	0.12	0.26	229	29.1	26.1	12.9	15-30-40-0-0
		2nd	7/30	1.65	11.4	1.7	21.78	1.66	18.6	35.7	13.1	61.8	0.63	0.62	0.36	1.13	0.25	2.74	0.34	0.08	0.34	252	23.6	29.4	11.7	0-0-0-0-0
					TOTAL YIELD			**3.56 T/Ac**	**17.4**	**38.1**	**12.3**	**59.2**	**0.60**	**0.58**	**0.33**	**1.01**	**0.24**	**2.61**	**0.32**	**0.10**	**0.30**	**240**	**26.3**	**27.8**	**12.3**	**15-30-40-0-0**
				Grams		Grams																				
2008	Alf/Grs	1st	6/30	5,555	7.8	5,820	230.00	1.21	16.7	40.4	n/a	56.5	0.57	0.54	0.29	0.79	0.25	2.65	0.26	0.05	0.21	200	23.9	23.9	10.6	15-30-40-0-0
		2nd	Yield based on bale count.				n/a	1.88	14.8	36.3	n/a	61.1	0.63	0.61	0.35	0.77	0.19	2.72	0.28	0.11	0.23	310	27.7	28.2	11.3	0-0-0-0-0
					TOTAL YIELD			**3.09 T/Ac**	**15.8**	**38.4**	**n/a**	**58.8**	**0.60**	**0.58**	**0.32**	**0.78**	**0.22**	**2.69**	**0.27**	**0.08**	**0.22**	**255**	**25.8**	**26.1**	**11.0**	**15-30-40-0-0**
2008	Barley	1st	Yield based on bale count.					**3.76 T/Ac**	**13.2**	**32.2**	**n/a**	**66.5**	**0.69**	**0.69**	**0.42**	**0.36**	**0.32**	**2.66**	**0.21**	**0.22**	**0.19**	**175**	**70.6**	**36.7**	**11.3**	**15-30-40-0-0**
2009	Alfalfa	1st	6/19	1,368	13.8	1,340	43.56	1.48	15.3	42.5	n/a	54.1	0.55	0.50	0.25	0.78	0.26	2.10	0.28	0.06	0.25	121	28.3	23.2	7.70	15-30-40-0-0
		2nd	*	0.94	12.9	0.93 T/Ac		0.93	17.9	36.6	n/a	60.8	0.62	0.61	0.35	1.20	0.24	2.71	0.31	0.08	0.26	158	31.5	21.0	7.90	0-0-0-0-0
					TOTAL YIELD			**2.41 T/Ac**	**16.6**	**39.6**	**n/a**	**57.5**	**0.59**	**0.56**	**0.30**	**0.99**	**0.25**	**2.41**	**0.30**	**0.07**	**0.26**	**139**	**29.9**	**22.1**	**7.80**	**15-30-40-0-0**
2010	Barley	1st	8/4	2,177	17.7	2,036	58.30	**1.68 T/Ac**	**106.0**	**32.8**	**n/a**	**47.1**	**0.48**	**0.45**	**0.24**	**0.40**	**0.20**	**2.07**	**0.24**	**0.26**	**0.16**	**100**	**26.4**	**24.4**	**8.15**	**0-0-0-0-0**

* Yield based on bale count. Bales sampled with Penn State forage sampler.
Forage quality data and mineral content are on a dry matter basis.
Crop yields collected and sheet compiled by: Neal E. Fehringer, Certified Professional Agronomist, C.C.A. revised on 6/15/10.

Table F-5 Forage analysis for site GC.

AMPP

GC Location Yields, Forage Quality, Mineral Content, and Fertilizer Applied

Year	Crop	Cutting	Date	Harvest Wt.lbs	% Water	Wt. @ 12%	Ft^2 Harvest	Yield	% Cr. Protein	% ADF	% Calc Digest Protein	% TDN	Energy (mcal/lb) Lact	Main	Gain	Mineral Content, % Ca	P	K	Mg	Na	S	Mineral Content, ppm Fe	Mn	Zn	Cu	Act. Nutrients App./Ac., lbs
2004	Alf/Grs	1st	6/15	2.10	9.3	2.2	43.56	1.08	15.8	36.1	8.1	62.2	0.64	0.63	0.36	1.27	0.31	3.44	0.43	0.18	0.36	149	49.0	32.7	22.9	15-40-100-0-3
		2nd	7/30	2.10	8.6	2.2	43.56	1.09	21.7	34.3	11.1	64.2	0.66	0.66	0.39	1.54	0.28	3.02	0.40	0.07	0.34	175	31.1	28.7	13.1	0-0-0-0-0
		3rd	9/23	2.00	15.6	1.9	43.56	0.96	22.6	27.4	16.0	69.4	0.72	0.73	0.46	1.15	0.31	2.53	0.30	0.05	0.34	135	31.7	26.2	10.9	0-0-0-0-0
					TOTAL YIELD			**3.13 T/Ac**	**20.0**	**32.6**	**11.7**	**65.3**	**0.67**	**0.67**	**0.40**	**1.32**	**0.30**	**3.00**	**0.38**	**0.10**	**0.35**	**153**	**37.3**	**29.2**	**15.6**	**15-40-100-0-3**
2005	Alf/Grs	1st	6/7	2.50	8.8	2.6	43.56	1.30	15.4	38.1	10.9	58.0	0.59	0.56	0.31	1.04	0.43	2.63	0.30	0.08	0.38	186	42.2	28.1	14.1	30-40-50-0-0
		2nd	8/26	2.40	11.1	2.4	43.56	1.21	23.2	32.4	13.9	65.6	0.68	0.68	0.41	1.34	0.31	2.66	0.36	0.07	0.32	438	41.0	36.6	17.6	0-0-0-0-0
					TOTAL YIELD			**2.51 T/Ac**	**19.3**	**35.3**	**12.4**	**61.8**	**0.64**	**0.62**	**0.36**	**1.19**	**0.37**	**2.65**	**0.33**	**0.08**	**0.35**	**312**	**41.6**	**32.4**	**15.9**	**30-40-50-0-0**
2006	Alf/Grs	1st	6/21	2.25	8.4	2.3	43.56	1.17	17.6	32.9	n/a	65.7	0.68	0.68	0.41	1.38	0.24	2.03	0.29	0.05	0.29	124	33.2	27.5	8.70	30-40-60-0-0
		2nd	8/8	3.80	10.2	3.9	43.56	1.94	15.9	39.8	n/a	56.2	0.57	0.54	0.28	1.17	0.28	2.66	0.37	0.08	0.30	140	35.0	23.3	8.80	0-0-0-0-0
					TOTAL YIELD			**3.11 T/Ac**	**16.8**	**36.4**	**n/a**	**61.0**	**0.63**	**0.61**	**0.35**	**1.28**	**0.26**	**2.35**	**0.33**	**0.07**	**0.30**	**132**	**34.1**	**25.4**	**8.75**	**30-40-60-0-0**
2007	H Bar.	1st	9/19	2.78	12.5	2.8	43.56	**1.38 T/Ac**	**19.0**	**30.2**	**n/a**	**68.7**	**0.71**	**0.72**	**0.45**	**0.97**	**0.25**	**2.58**	**0.41**	**0.16**	**0.33**	**557**	**72.8**	**39.2**	**11.2**	**0-0-0-0-0**
				Grams		Grams																				
2008	Grs/Alf	1st	9/2	12,610	14.9	12,194	330.00	**1.77 T/Ac**	**17.7**	**40.0**	**n/a**	**57.0**	**0.58**	**0.55**	**0.29**	**0.65**	**0.23**	**2.88**	**0.35**	**0.06**	**0.26**	**201**	**57.6**	**31.5**	**14.3**	**0-0-0-0-0**
2009	Grs/Alf	1st	6/19	2,270	14.5	2,206	43.56	2.43	11.3	41.2	n/a	55.6	0.56	0.53	0.27	0.30	0.21	2.54	0.15	0.03	0.16	104	74.1	20.8	8.90	80-40-0-0-0
		2nd	*	0.60	11.3	0.60 T/Ac		0.60	13.8	37.7	n/a	59.5	0.61	0.59	0.33	0.67	0.27	3.09	0.30	0.04	0.37	151	151	20.3	8.70	0-0-0-0-0
					TOTAL YIELD			**3.03 T/Ac**	**12.6**	**39.5**	**n/a**	**57.6**	**0.59**	**0.56**	**0.30**	**0.49**	**0.24**	**2.82**	**0.23**	**0.04**	**0.27**	**127**	**112**	**20.6**	**8.80**	**80-40-0-0-0**
2010	Grs/Alf	1st	6/25	2,177	17.7	2,036	43.56	2.24	7.3	34.2	n/a	45.4	0.46	0.43	0.22	0.26	0.17	1.88	0.14	0.02	0.14	55.7	74.2	14.8	5.60	100-20-0-0-0
		2nd	*	0.55	12.2	0.55 T/Ac		0.55	13.4	31.2	n/a	54.5	0.56	0.55	0.32	0.84	0.25	2.05	0.28	0.03	0.31	102	119	16.7	8.34	0-0-0-0-0
					TOTAL YIELD			**2.79 T/Ac**	**10.4**	**32.7**	**n/a**	**50.0**	**0.51**	**0.49**	**0.27**	**0.55**	**0.21**	**1.97**	**0.21**	**0.03**	**0.23**	**78.9**	**96.5**	**15.7**	**6.97**	**100-20-0-0-0**

* Yield based on bale count. Bales sampled with Penn State forage sampler.
Forage quality data and mineral content are on a dry matter basis.
Crop yields collected and sheet compiled by: Neal E. Fehringer, Certified Professional Agronomist, C.C.A. revised on 6/15/10.

Table F-6 Forage analysis for site OAA.

AMPP

OAA Location Yields, Forage Quality, Mineral Content, and Fertilizer

Year	Crop	Cutting	Date	Harvest Wt.lbs	% Water	Wt. @ 12%	Ft^2 Harvest	Yield	% Cr. Protein	% ADF	% Calc Digest Protein	% TDN	Energy (mcal/lb) Lact	Main	Gain	Mineral Content, % Ca	P	K	Mg	Na	S	Mineral Content, ppm Fe	Mn	Zn	Cu	Act. Nutrients App./Ac., lbs
2004	Grs/Alf	1st	6/28	2.21	9.1	2.3	43.56	**1.14 T/Ac**	**8.0**	**37.8**	**4.1**	**60.2**	**0.62**	**0.60**	**0.34**	**0.44**	**0.14**	**1.43**	**0.14**	**0.03**	**0.14**	**111**	**38.9**	**30.4**	**7.30**	**0-0-0-0-0**
2005	Grs/Alf	1st	7/5	2.40	7.0	2.5	43.56	**1.27 T/Ac**	**9.6**	**34.1**	**5.8**	**63.7**	**0.65**	**0.65**	**0.38**	**0.43**	**0.20**	**1.22**	**0.15**	**0.06**	**0.16**	**115**	**44.6**	**27.7**	**7.70**	**0-0-0-0-0**
2006	Grass	1st	6/21	1.80	5.9	1.9	43.56	**0.96 T/Ac**	**7.80**	**32.8**	**n/a**	**65.9**	**0.68**	**0.68**	**0.41**	**0.40**	**0.11**	**1.59**	**0.14**	**0.02**	**0.18**	**62.3**	**38.6**	**35.6**	**5.90**	**0-0-0-0-0**
2007	Grass	1st	6/15	2.15	10.3	2.2	43.56	**1.10 T/Ac**	**11.2**	**38.8**	**8.4**	**58.4**	**0.60**	**0.57**	**0.31**	**0.45**	**0.17**	**1.86**	**0.14**	**0.01**	**0.18**	**85.8**	**40.9**	**33.9**	**7.51**	**0-0-0-0-0**
				Grams		Grams																				
2008	Grass	1st	6/30	1316	7.8	1379	43.56	**1.52 T/Ac**	**10.6**	**37.0**	**n/a**	**61.1**	**0.63**	**0.61**	**0.35**	**0.48**	**0.16**	**1.86**	**0.15**	**0.06**	**0.17**	**93.8**	**26.4**	**41.0**	**8.80**	**0-0-0-0-0**
2009	Grs/Alf	1st	6/19	1456	12.9	1441	43.56	**1.59 T/Ac**	**8.50**	**39.0**	**n/a**	**58.1**	**0.59**	**0.57**	**0.31**	**0.36**	**0.12**	**1.49**	**0.10**	**0.01**	**0.12**	**63.3**	**26.4**	**31.6**	**7.90**	**0-0-0-0-0**
2010	Grs/Alf	1st	6/25	905	17.5	848	43.56	**0.93 T/Ac**	**10.90**	**32.4**	**n/a**	**47.7**	**0.49**	**0.46**	**0.25**	**0.49**	**0.13**	**1.55**	**0.15**	**0.02**	**0.13**	**98.6**	**49.3**	**24.7**	**7.43**	**0-0-0-0-0**

Forage quality data and mineral content are on a dry matter basis.
Crop yields collected and sheet compiled by: Neal E. Fehringer, Certified Professional Agronomist, C.C.A. revised on 6/15/10.

Table F-7 Forage analysis for site EA.

AMPP

EA Location Yields, Forage Quality, Mineral Content, and Fertilizer Applied

Year	Crop	Cutting	Date	Harvest Wt.lbs	% Water	Wt. @ 12%	Ft² Harvest	Yield	% Cr. Protein	% ADF	% Calc Digest Protein	% TDN	Energy (mcal/lb) Lact	Energy (mcal/lb) Main	Energy (mcal/lb) Gain	Mineral Content, % Ca	Mineral Content, % P	Mineral Content, % K	Mineral Content, % Mg	Mineral Content, % Na	Mineral Content, % S	Mineral Content, ppm Fe	Mineral Content, ppm Mn	Mineral Content, ppm Zn	Mineral Content, ppm Cu	Act. Nutrients App./Ac., lbs
2004	Fallow	Not planted, irrigated, sprayed, or harvested.							n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0-0-0-0-0
2005	New Alf	1st	7/29	4.6	11.1	4.6	43.56	2.32 T/Ac	13.8	33.9	8.7	63.9	0.66	0.65	0.39	0.51	0.27	2.98	0.34	0.05	0.19	257	36.5	39.5	14.6	11-52-30-0-0
2006	Alfalfa	1st	6/5	3.25	9.5	3.3	43.56	1.67	18.4	37.7	n/a	59.5	0.60	0.59	0.33	1.37	0.24	3.22	0.24	0.06	0.31	119	20.5	35.2	10.3	0-0-0-0-0
		2nd	7/17	3.25	11.2	3.3	43.56	1.64	17.5	41.1	n/a	56.6	0.58	0.54	0.29	1.13	0.25	2.76	0.31	0.04	0.27	166	23.8	32.7	11.9	0-0-0-0-0
		3rd	10/4	2.55	43.3	1.6	43.56	0.82	22.4	32.6	n/a	63.8	0.66	0.65	0.39	1.90	0.34	2.33	0.68	0.36	0.64	372	36.6	36.6	14.1	0-0-0-0-0
					TOTAL YIELD			4.13 T/Ac	19.4	37.1	n/a	60.0	0.61	0.59	0.34	1.47	0.28	2.77	0.41	0.15	0.41	219	27.0	34.8	12.1	0-0-0-0-0
2007	Alfalfa	1st	6/15	3.15	9.7	n/a	n/a	2.22	16.6	40.6	11.4	55.3	0.56	0.52	0.27	1.14	0.31	3.02	0.38	0.04	0.24	120	19.7	35.8	13.7	0-0-0-0-0
		2nd	7/23	Baled	11.2	n/a	n/a	1.00	19.1	30.0	13.5	66.6	0.69	0.69	0.42	1.53	0.22	2.73	0.27	0.05	0.37	280	22.5	36.5	15.3	0-0-0-0-0
					TOTAL YIELD			3.22 T/Ac	17.9	35.3	12.5	61.0	0.63	0.61	0.35	1.34	0.27	2.88	0.33	0.05	0.31	200	21.1	36.2	14.5	0-0-0-0-0
				Grams		Grams																				
2008	Alfalfa	1st	6/17	1,392	7.1	1,470	43.56	1.62	19.3	37.5	n/a	58.6	0.60	0.57	0.32	0.91	0.20	2.91	0.30	0.03	0.26	137	18.8	34.8	10.7	0-0-0-0-0
		2nd	7/29	663	14.3	646	43.56	0.71	23.1	30.4	n/a	66.1	0.68	0.69	0.42	1.01	0.22	3.52	0.37	0.03	0.29	218	23.0	46.9	13.8	0-0-0-0-0
					TOTAL YIELD			2.33 T/Ac	21.2	34.0	n/a	62.4	0.64	0.63	0.37	0.96	0.21	3.22	0.34	0.03	0.28	177	20.9	40.9	12.3	0-0-0-0-0
2009	Alfalfa	1st	6/19	1,372	17.0	1,294	43.56	1.43	16.6	33.7	n/a	62.7	0.64	0.64	0.37	1.23	0.19	2.61	0.34	0.04	0.26	134	21.9	32.9	11.0	0-0-0-0-0
		2nd	10/26	372	11.0	376	43.56	0.41	12.1	49.7	n/a	45.6	0.45	0.37	0.12	0.94	0.11	1.31	0.23	0.09	0.14	264	15.0	24.0	9.00	0-0-0-0-0
					TOTAL YIELD			1.84 T/Ac	14.4	41.7	n/a	54.2	0.55	0.51	0.25	1.09	0.15	1.96	0.29	0.07	0.20	199	18.5	28.5	10.0	0-0-0-0-0
2010	Alfalfa	1st	6/25	1,277	19.0	1,175	43.56	1.29	16.1	31.6	n/a	46.1	0.47	0.44	0.24	0.92	0.15	2.07	0.27	0.04	0.19	90.0	18.4	20.5	10.2	0-0-0-0-0
		2nd	9/13	566	18.0	527	43.56	0.58	12.5	29.4	n/a	49.4	0.51	0.49	0.28	0.89	0.10	1.62	0.29	0.06	0.19	135	17.1	24.7	9.51	0-0-0-0-0
					TOTAL YIELD			1.88 T/Ac	14.3	30.5	n/a	47.8	0.49	0.47	0.26	0.91	0.13	1.85	0.28	0.05	0.19	112	17.7	22.6	9.9	0-0-0-0-0

Forage quality data and mineral content are on a dry matter basis.
Crop yields collected and sheet compiled by: Neal E. Fehringer, Certified Professional Agronomist, C.C.A. revised on 6/15/10.

Table F-8 Forage analysis for site DA.

AMPP

DA Location Yields, Forage Quality, Mineral Content, and Fertilizer Applied

Year	Crop	Cutting	Date	Harvest Wt.lbs	% Water	Wt. @ 12%	Ft² Harvest	Yield @12%	% Cr. Protein	% ADF	% Calc Digest Protein	% TDN	Energy (mcal/lb) Lact	Main	Gain	Mineral Content, % Ca	P	K	Mg	Na	S	Mineral Content, ppm Fe	Mn	Zn	Cu	Act. Nutrients App./Ac., lbs
2004	Alf/Grs	1st	6/22	1.10	9.7	1.1	47.92	0.51	19.8	32.1	10.1	66.6	0.69	0.69	0.42	1.22	0.30	3.92	0.49	0.21	0.42	214	62.6	42.2	14.5	100-70-40-0-3
		2nd	8/2	2.50	18.0	2.3	47.92	1.06	12.2	39.7	6.2	58.1	0.59	0.57	0.31	1.10	0.25	3.80	0.49	0.33	0.44	96.0	30.3	26.9	11.8	0-0-0-0-0
				TOTAL YIELD				**1.57 T/Ac**	**16.0**	**35.9**	**8.2**	**62.4**	**0.64**	**0.63**	**0.37**	**1.16**	**0.28**	**3.86**	**0.49**	**0.27**	**0.43**	**155**	**46.5**	**34.6**	**13.2**	**100-70-40-0-3**
						@ 70%		Yield @ 70%																		
2005	Corn	Chop	9/13	253.5	58.9	347.3	240.00	**31.5 T/Ac**	**7.5**	**31.4**	**4.0**	**66.2**	**0.65**	**0.69**	**0.42**	**0.16**	**0.25**	**1.28**	**0.20**	**0.02**	**0.10**	**269**	**25.5**	**32.2**	**17.5**	**170-80-50-0-2**
						@ 12%		Yield @12%																		
2006	Peas	1st	7/17	1.31	12.0	1.3	52.27	18.20 **Bu/Ac**	Did not test peas for feed and mineral content.																	0-0-0-0-0
	H. Millet	2nd	10/4	2.25	16.0	2.1	52.27	0.89 **T/Ac**	**14.5**	**33.7**	**n/a**	**64.8**	**0.67**	**0.67**	**0.40**	**0.55**	**0.25**	**2.82**	**0.41**	**0.22**	**0.23**	**263**	**39.8**	**37.2**	**8.00**	**0-0-0-0-0**
								Yield @12%																		
2007	Alf/Grs	1st	7/1	Yield based on bale count.				1.49	18.0	30.1	13.0	68.3	0.71	0.72	0.44	0.92	0.2	3.59	0.59	0.81	0.41	135	35.1	33.1	10.4	40-40-0-3-0
		2nd	8/20	1.95	12.1	1.9	52.27	0.81	22.1	31.7	15.6	66.5	0.69	0.69	0.42	1.23	0.3	3.86	0.50	0.25	0.41	102	27.5	35.0	13.5	0-0-0-0-0
				TOTAL YIELD				**2.30 T/Ac**	**20.1**	**30.9**	**14.3**	**67.4**	**0.70**	**0.71**	**0.43**	**1.08**	**0.25**	**3.73**	**0.55**	**0.53**	**0.41**	**119**	**31.3**	**34.0**	**11.9**	**40-40-0-3-0**
				Grams		Grams		Yield @12%																		
2008	Alf/Grs	1st	6/17	1,993	7.9	2,086	52.27	1.91	21.6	35.9	n/a	60.3	0.62	0.60	0.34	1.27	0.25	3.32	0.30	0.10	0.32	312	35.0	55.3	11.7	50-26-0-0-0
		2nd	7/29	1,780	12.9	1,762	52.27	1.62	24.0	32.5	n/a	63.9	0.66	0.65	0.39	1.29	0.29	3.42	0.35	0.13	0.39	171	26.4	36.9	13.2	0-0-0-0-0
		3rd	8/25	1,124	12.9	1,113	52.27	1.02	25.6	29.6	n/a	67.0	0.69	0.70	0.43	1.25	0.30	4.21	0.36	0.12	0.45	153	23.8	34.4	13.2	0-0-0-0-0
				TOTAL YIELD				**4.55 T/Ac**	**23.7**	**32.7**	**n/a**	**63.7**	**0.66**	**0.65**	**0.39**	**1.27**	**0.28**	**3.65**	**0.34**	**0.12**	**0.39**	**212**	**28.4**	**42.2**	**12.7**	**50-26-0-0-0**
2009	Alfalfa	1st		1,869	14.9	1,807	52.27	1.66	16.9	36.5	n/a	59.7	0.61	0.59	0.33	0.91	0.22	3.09	0.26	0.12	0.24	98.8	20.3	29.1	8.70	17-80-80-0-0
		2nd		11,257	14.1	10,988	408	1.29	12.3	47.8	n/a	47.6	0.48	0.40	0.16	0.57	0.19	3.02	0.20	0.11	0.18	67.3	11.2	30.8	19.6	0-0-0-0-0
				TOTAL YIELD				**2.95 T/Ac**	**14.6**	**42.2**	**n/a**	**53.7**	**0.55**	**0.50**	**0.25**	**0.74**	**0.21**	**3.06**	**0.23**	**0.12**	**0.21**	**83.1**	**15.8**	**30.0**	**14.2**	**17-80-80-0-0**
2010	Alfalfa	1st	6/21	2,547	21.1	2,284	52.27	2.10	16.1	27.7	n/a	48.2	0.49	0.48	0.28	0.99	0.17	2.21	0.24	0.13	0.20	95.9	22.3	20.0	8.92	17-80-80-0-0
		2nd	8/2	1,723	18.0	1,606	52.27	1.47	16.0	30.0	n/a	48.8	0.50	0.48	0.27	0.79	0.16	2.09	0.25	0.11	0.22	82.6	17.0	23.3	10.6	0-0-0-0-0
				TOTAL YIELD				**3.57 T/Ac**	**16.1**	**28.9**	**n/a**	**48.5**	**0.50**	**0.48**	**0.28**	**0.89**	**0.17**	**2.15**	**0.25**	**0.12**	**0.21**	**89.2**	**19.6**	**21.7**	**9.8**	**17-80-80-0-0**

Forage quality data and mineral content are on a dry matter basis.
Crop yields collected and sheet compiled by: Neal E. Fehringer, Certified Professional Agronomist, C.C.A. revised on 6/15/10.

Table F-9 Forage analysis for site DB.

AMPP

DB Location Yields, Forage Quality, Mineral Content, and Fertilizer Applied

Year	Crop	Cutting	Date	Harvest Wt.lbs	% Water	Wt. @ 12%	Ft² Harvest	Yield	% Cr. Protein	% ADF	% Calc Digest Protein	% TDN	Energy (mcal/lb) Lact	Main	Gain	Mineral Content, % Ca	P	K	Mg	Na	S	Mineral Content, ppm Fe	Mn	Zn	Cu	Act. Nutrients App./Ac., lbs
2004	Alfalfa	1st	6/15	18.3	9.0	18.9	340.00	1.21	21.0	36.4	10.7	61.8	0.63	0.62	0.36	1.37	0.23	2.46	0.40	0.16	0.30	474	18.3	26.8	11.3	20-50-80-0-3
		2nd	7/22	4.45	9.0	4.6	43.56	2.30	19.7	41.6	10.0	56.0	0.57	0.53	0.28	1.39	0.33	3.78	0.49	0.14	0.38	133	17.0	35.8	15.3	0-0-0-0-0
		3rd	9/1	2.60	31.2	2.0	43.56	1.02	20.7	31.4	14.7	65.1	0.67	0.67	0.40	1.74	0.32	3.11	0.46	0.15	0.49	168	26.7	20.8	14.8	0-0-0-0-0
					TOTAL YIELD			**4.53 T/Ac**	**20.5**	**36.5**	**11.8**	**61.0**	**0.62**	**0.61**	**0.35**	**1.50**	**0.29**	**3.12**	**0.45**	**0.15**	**0.39**	**258**	**20.7**	**27.8**	**13.8**	**20-50-80-0-3**
2005	Alf/Grs	1st	6/7	1.90	8.4	2.0	43.56	0.99	21.7	31.7	13.0	66.4	0.69	0.69	0.42	1.74	0.46	3.05	0.45	0.13	0.46	274	35.6	40.3	15.5	11-52-30-0-0
		2nd	7/29	2.60	11.4	2.6	43.56	1.31	20.7	32.8	12.4	65.1	0.67	0.67	0.40	1.44	0.30	2.27	0.46	0.12	0.38	414	28.5	32.7	17.1	0-0-0-0-0
		3rd	9/13	2.20	11.8	2.2	43.56	1.10	21.8	31.7	13.1	66.4	0.68	0.69	0.42	1.75	0.28	2.33	0.45	0.15	0.42	250	27.8	33.6	16.1	0-0-0-0-0
					TOTAL YIELD			**3.40 T/Ac**	**21.4**	**32.1**	**12.8**	**66.0**	**0.68**	**0.68**	**0.41**	**1.64**	**0.35**	**2.55**	**0.45**	**0.13**	**0.42**	**313**	**30.6**	**35.5**	**16.2**	**11-52-30-0-0**
2006	Alf/Grs	1st	6/5	2.40	9.1	2.5	43.56	1.24	20.7	32.8	n/a	63.6	0.65	0.65	0.38	1.27	0.28	2.32	0.35	0.11	0.37	158	25.6	35.5	9.90	0-42-70-0-2
		2nd	7/17	2.00	8.2	2.1	43.56	1.04	19.4	32.7	n/a	63.8	0.66	0.65	0.39	1.22	0.29	2.24	0.38	0.06	0.28	112	24.6	27.3	8.20	0-0-0-0-0
		3rd	8/21	2.25	16.9	2.1	43.56	1.06	22.5	32.8	n/a	63.6	0.65	0.65	0.38	1.26	0.35	2.91	0.47	0.08	0.35	170	26.8	32.8	8.90	0-0-0-0-0
					TOTAL YIELD			**3.35 T/Ac**	**20.9**	**32.8**	**n/a**	**63.7**	**0.65**	**0.65**	**0.38**	**1.25**	**0.31**	**2.49**	**0.40**	**0.08**	**0.33**	**147**	**25.7**	**31.9**	**9.00**	**0-42-70-0-2**
2007	Grs/Alf	1st	6/4	3.25	10.5	3.3	43.56	1.65	19.1	37.1	13.3	60.3	0.62	0.60	0.34	1.35	0.29	2.61	0.41	0.14	0.33	249	23.0	34.1	10.5	13-60-27-5-0
		2nd	8/6	4.25	12.5	4.2	43.56	2.11	22.0	30.4	15.5	67.9	0.70	0.71	0.44	1.12	0.29	3.06	0.44	0.24	0.39	100	21.0	33.7	10.6	0-0-0-0-0
		3rd	9/20	1.30	37.5	0.9	43.56	0.46	24.2	29.5	n/a	68.9	0.71	0.73	0.45	1.62	0.36	2.77	0.45	0.14	0.44	437	43.4	49.2	14.5	0-0-0-0-0
					TOTAL YIELD			**4.23 T/Ac**	**21.8**	**32.3**	**n/a**	**65.7**	**0.68**	**0.68**	**0.41**	**1.36**	**0.31**	**2.81**	**0.43**	**0.17**	**0.39**	**262**	**29.1**	**39.0**	**11.9**	**13-60-27-5-0**
				Grams		Grams																				
2008	S. Wht.	Harv	7/29	1,295	12.0	1,295	43.56	**47.5 Bu/Ac**	Did not have grain analyzed for feed parameters and mineral content.																	**140-40-0-0-0**
2009	H Bar.	1st	7/6	2,569	13.3	2,531	43.56	**2.79 T/Ac**	**13.1**	**42.6**	**n/a**	**54.9**	**0.56**	**0.52**	**0.26**	**0.43**	**0.29**	**2.68**	**0.19**	**0.48**	**0.24**	**154**	**23.2**	**34.7**	**12.1**	**55-70-0-0-0**
2010	Alfalfa	1st	8/2	1,097	18.8	1,012	43.56	**1.11 T/Ac**	**20.1**	**28.3**	**n/a**	**49.9**	**0.51**	**0.5**	**0.29**	**0.91**	**0.25**	**2.43**	**0.32**	**0.15**	**0.26**	**136**	**21.4**	**27.2**	**11.7**	**30-150-150-0-0**

Forage quality data and mineral content are on a dry matter basis.
Crop yields collected and sheet compiled by: Neal E. Fehringer, Certified Professional Agronomist, C.C.A. revised on 6/15/10.

Table F-10 Forage analysis for site BA.

AMPP

BA Location Yields, Forage Quality, Mineral Content, and Fertilizer Applied

Year	Crop	Cutting	Date	Harvest Wt.lbs	% Water	Wt. @ 70%	Ft^2 Harvest	Yield	% Cr. Protein	% ADF	% Calc Digest Protein	% TDN	Energy (mcal/lb) Lact	Main	Gain	Mineral Content, % Ca	P	K	Mg	Na	S	Mineral Content, ppm Fe	Mn	Zn	Cu	Act. Nutrients App./Ac., lbs
2004	Corn	Chop	9/16	279.2	76.8	215.9	250.00	18.81 T/Ac	8.8	35.3	4.8	63.6	0.61	0.65	0.38	0.31	0.22	1.02	0.42	0.02	0.10	246	34.0	5.40	9.50	200-70-0-0-0
2005	Corn	Chop	9/6	331.0	70.9	321.1	250.00	27.97 T/Ac	8.2	37.5	4.4	62.2	0.58	0.63	0.36	0.32	0.20	0.91	0.42	0.02	0.10	167	32.5	26.6	8.90	170-40-60-0-2
2006	S. Wht	Harv	7/17	3.35	12.0	3.35	43.56	55.83 Bu/Ac	Did not have wheat analyzed for feed and mineral content.																	80-70-60-0-3
2007	Corn	1st	9/5	215.4	58.0	301.6	250.00	26.27 T/Ac	7.0	22.4	n/a	77.4	0.81	0.85	0.56	0.22	0.18	1.01	0.25	0.02	0.11	312	30.5	27.9	5.10	220-80-90-0-3
				Grams		Grams																				
2008	Bar/Alf	1st	7/25	2,694	13.8	2,639	43.56	2.91	12.2	33.4	n/a	64.5	0.66	0.66	0.40	0.78	0.19	2.77	0.27	0.39	0.23	134	18.7	26.7	10.7	16-78-0-0-0
		2nd	Did not get a harvest for yield.						22.5	28.1	n/a	68.6	0.71	0.72	0.45	1.64	0.27	2.28	0.37	0.12	0.35	316	66.4	30.4	13.8	0-0-0-0-0
					TOTAL YIELD			2.91 T/Ac	17.4	30.8	n/a	66.6	0.69	0.69	0.43	1.21	0.23	2.53	0.32	0.26	0.29	225	42.6	28.6	12.3	16-78-0-0-0
2009	Alfalfa	1st	6/16	2,542	15.3	2,447	43.56	2.69	17.0	46.0	n/a	49.5	0.50	0.43	0.18	1.05	0.30	2.61	0.28	0.11	0.23	89.4	14.4	20.2	7.24	11-52-30-0-0
		2nd	7/25	1,562	16.0	1,491	43.56	1.64	19.3	47.2	n/a	48.2	0.48	0.41	0.16	1.22	0.37	3.23	0.32	0.17	0.36	99.4	19.9	28.4	8.65	0-0-0-0-0
		3rd	*	0.98	13.1	0.97 T/Ac		0.97	22.5	30.8		65.8	0.68	0.68	0.41	1.59	0.26	2.01	0.43	0.29	0.40	209	32.4	26.5	12.2	0-0-0-0-0
					TOTAL YIELD			5.30 T/Ac	19.6	41.3	n/a	54.5	0.55	0.51	0.25	1.29	0.31	2.62	0.34	0.19	0.33	133	22.2	25.0	9.37	11-52-30-0-0
2010	Alfalfa	1st	6/21	2,427	19.4	2,223	43.56	2.45	14.3	33.2	n/a	44.0	0.45	0.41	0.21	0.85	0.20	1.76	0.22	0.10	0.15	149	11.5	16.1	6.93	18-46-0-0-0
		2nd	8/2	1,648	17.8	1,539	43.56	1.70	17.4	31.8	n/a	47.1	0.48	0.46	0.24	1.02	0.22	1.80	0.25	0.09	0.19	62.0	15.5	17.4	9.70	0-0-0-0-0
		3rd	9/13	1,027	21.2	920	43.56	1.01	18.1	26.8	n/a	49.1	0.5	0.5	0.29	1.21	0.24	1.80	0.29	0.16	0.27	76.8	15.8	20.3	11.3	0-0-0-0-0
					TOTAL YIELD			5.16 T/Ac	16.6	30.6	n/a	46.7	0.48	0.46	0.25	1.03	0.22	1.79	0.25	0.12	0.20	96.1	14.3	18.0	9.30	18-46-0-0-0

* Yield based on bale count. Bales sampled with Penn State forage sampler.
Wheat yield is based on as is moisture content.
Forage quality data and mineral content are on a dry matter basis.
Crop yields collected and sheet compiled by: Neal E. Fehringer, Certified Professional Agronomist, C.C.A. revised on 6/15/10.

Table F-11 Forage analysis for site BC.

AMPP

BC Location Yields, Forage Quality, Mineral Content, and Fertilizer Applied

Year	Crop	Cutting	Date	Harvest Wt.lbs	% Water	Wt. @ 12%	Ft^2 Harvest	Yield @ 12%	% Cr. Protein	% ADF	% Calc Digest Protein	% TDN	Energy (mcal/lb) Lact	Main	Gain	Mineral Content, % Ca	P	K	Mg	Na	S	Mineral Content, ppm Fe	Mn	Zn	Cu	Act. Nutrients App./Ac., lbs
2004	Grs/Alf	1st	6/22	2.30	9.0	2.4	43.56	1.19	15.2	42.5	7.7	55.0	0.56	0.52	0.27	1.17	0.23	3.36	0.41	0.07	0.29	96.0	31.6	22.8	12.6	100-40-0-0-0
		2nd	8/2	7.80	9.2	8.0	260.00	0.67	12.8	40.7	6.5	57.0	0.58	0.55	0.29	0.90	0.22	2.30	0.31	0.15	0.25	82.0	18.8	21.9	9.40	0-0-0-0-0
		3rd	9/16	1.80	17.1	1.7	43.56	0.85	18.4	31.0	13.1	65.5	0.67	0.68	0.41	1.00	0.30	2.29	0.35	0.18	0.36	346	39.7	11.5	11.5	0-0-0-0-0
					TOTAL YIELD			**2.71 T/Ac**	**15.5**	**38.1**	**9.1**	**59.2**	**0.60**	**0.58**	**0.32**	**1.02**	**0.25**	**2.65**	**0.36**	**0.13**	**0.30**	**175**	**30.0**	**18.7**	**11.2**	**100-40-0-0-0**
2005	Grs/Alf	1st	6/7	2.00	9.9	2.0	43.56	1.02	17.2	36.5	10.3	61.0	0.62	0.61	0.35	1.09	0.43	2.98	0.38	0.15	0.34	159	39.0	33.0	12.0	35-20-35-0-0
		2nd	7/29	1.30	12.9	1.3	43.56	0.64	19.3	33.4	11.6	64.5	0.66	0.66	0.40	1.09	0.29	2.15	0.37	0.09	0.31	429	50.5	43.3	15.9	0-0-0-0-0
		3rd	Grazed				n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					TOTAL YIELD			**1.67 T/Ac**	**18.3**	**35.0**	**11.0**	**62.8**	**0.64**	**0.64**	**0.38**	**1.09**	**0.36**	**2.57**	**0.38**	**0.12**	**0.33**	**294**	**44.8**	**38.2**	**14.0**	**35-20-35-0-0**
2006	Grs/Alf	1st	6/5	6.00	9.4	6.2	43.56	3.09	14.6	33.5	n/a	62.9	0.65	0.64	0.37	1.11	0.25	2.31	0.31	0.09	0.29	81.0	36.8	32.4	8.80	0-0-0-0-0
		2nd	7/18	1.50	8.6	1.6	43.56	0.78	19.0	33.1	n/a	63.2	0.65	0.64	0.38	1.22	0.27	2.05	0.35	0.12	0.33	86.5	26.8	29.8	8.90	0-0-0-0-0
					TOTAL YIELD			**3.87 T/Ac**	**16.8**	**33.3**	**n/a**	**63.1**	**0.65**	**0.64**	**0.38**	**1.17**	**0.26**	**2.18**	**0.33**	**0.11**	**0.31**	**83.8**	**31.8**	**31.1**	**8.85**	**0-0-0-0-0**
2007	Grs/Alf	1st	6/12	1.85	10.8	1.9	43.56	0.94	11.1	42.6	8.0	54.0	0.55	0.50	0.25	0.54	0.24	1.91	0.20	0.06	0.20	99.4	29.8	23.8	8.11	0-0-0-0-0
		2nd	9/5	1.30	15.2	1.3	43.56	0.63	17.5	34.9	n/a	62.8	0.64	0.64	0.37	1.06	0.34	1.06	0.33	0.10	0.37	395	63.5	40.4	11.5	0-0-0-0-0
					TOTAL YIELD			**1.56 T/Ac**	**14.3**	**38.8**	**n/a**	**58.4**	**0.60**	**0.57**	**0.31**	**0.80**	**0.29**	**1.49**	**0.27**	**0.08**	**0.29**	**247**	**46.7**	**32.1**	**9.81**	**0-0-0-0-0**
2008	Grass	1st	6/17	756	7.6	794	43.56	**0.87 T/Ac**	**13.7**	**32.1**	**n/a**	**65.9**	**0.68**	**0.68**	**0.41**	**0.63**	**0.26**	**2.39**	**0.25**	**0.11**	**0.21**	**212**	**31.8**	**23.9**	**10.6**	**0-0-0-0-0**
				Pounds		Pounds		@ 70%																		
2009	Corn	Silage	9/16	295	60.3	390	250	**34.01 T/Ac**	**6.9**	**31.3**	**n/a**	**66.2**	**0.66**	**0.69**	**0.42**	**0.21**	**0.18**	**1.27**	**0.18**	**0.10**	**0.02**	**340**	**32.6**	**38.0**	**10.9**	**200-100-60-0-0**
2010	S. Wht. Grain		8/4	2,116	12.0	2,116	58.30	**72.6 Bu/Ac**	Did not have grain analyzed for feed parameters and mineral content.																	**60-50-30-0-0**

Forage quality data and mineral content are on a dry matter basis.
Crop yields collected and sheet compiled by: Neal E. Fehringer, Certified Professional Agronomist, C.C.A. revised on 6/15/10.

Table F-12 Forage analysis for site YAA.

AMPP

YAA Location Yields, Forage Quality, Mineral Content, and Fertilizer

Year	Crop	Cutting	Date	Harvest Wt.lbs	% Water	Wt. @ 12%	Ft² Harvest	Yield	% Cr. Protein	% ADF	% Calc Digest Protein	% TDN	Energy (mcal/lb) Lact	Main	Gain	Mineral Content, % Ca	P	K	Mg	Na	S	Mineral Content, ppm Fe	Mn	Zn	Cu	Act. Nutrients App./Ac., lbs
2004	Alfalfa	1st	6/15	14.8	9.3	15.3	180.00	1.85	17.0	40.1	8.7	57.7	0.59	0.56	0.30	1.36	0.20	2.28	0.41	0.12	0.29	174	12.4	26.4	12.4	0-0-0-0-0
		2nd	7/22	3.40	10.8	3.4	39.20	1.91	17.6	45.0	9.0	52.2	0.53	0.47	0.22	1.07	0.29	2.82	0.41	0.09	0.31	151	13.0	34.1	13.0	22-104-0-0-0
		3rd	10/6	16.6	20.4	15.0	270.00	1.21	20.0	29.7	14.2	66.9	0.69	0.70	0.43	1.13	0.26	1.84	0.33	0.19	0.33	63.1	15.1	23.3	12.3	0-0-0-0-0
					TOTAL YIELD			**4.97 T/Ac**	**18.2**	**38.3**	**10.6**	**58.9**	**0.60**	**0.58**	**0.32**	**1.19**	**0.25**	**2.31**	**0.38**	**0.13**	**0.31**	**129**	**13.5**	**27.9**	**12.6**	**22-104-0-0-0**
2005	Alfalfa	1st	6/7	2.10	9.1	2.2	39.20	1.21	17.9	37.4	10.7	60.0	0.61	0.59	0.33	1.18	0.39	2.80	0.39	0.13	0.34	186	34.0	34.0	16.2	15-65-75-0-0
		2nd	7/29	3.90	11.9	3.9	39.20	2.17	18.9	38.8	13.4	57.2	0.58	0.55	0.30	1.31	0.27	1.93	0.41	0.12	0.32	511	24.4	47.3	15.8	0-0-0-0-0
		3rd	Did not have 3rd cutting due to lateness of 2nd. Second was actully harvested in late August.											n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					TOTAL YIELD			**3.37 T/Ac**	**18.4**	**38.1**	**12.1**	**58.6**	**0.60**	**0.57**	**0.32**	**1.25**	**0.33**	**2.37**	**0.40**	**0.13**	**0.33**	**348**	**29.2**	**40.7**	**16.0**	**15-65-75-0-0**
2006	Alfalfa	1st	6/5	3.20	7.9	3.3	39.20	1.86	15.2	35.2	n/a	61.1	0.63	0.61	0.35	1.19	0.22	2.13	0.26	0.06	0.29	80.3	22.3	26.8	8.90	12-55-55-0-0
		2nd	8/1	2.70	9.1	2.8	39.20	1.55	20.4	35.7	n/a	60.5	0.62	0.60	0.34	1.43	0.30	2.27	0.46	0.07	0.42	124	29.7	35.1	10.8	0-0-0-0-0
		3rd	10/4	9.00	16.1	8.6	164.00	1.14	19.4	32.4	n/a	64.0	0.66	0.66	0.39	2.40	0.22	1.59	0.49	0.17	0.41	170	26.6	23.9	10.6	0-0-0-0-0
					TOTAL YIELD			**4.55 T/Ac**	**18.3**	**34.4**	**n/a**	**61.9**	**0.64**	**0.62**	**0.36**	**1.67**	**0.25**	**2.00**	**0.40**	**0.10**	**0.37**	**125**	**26.2**	**28.6**	**10.1**	**12-55-55-0-0**
2007	Alfalfa	1st	6/4	2.30	11.4	2.3	39.20	1.29	14.4	36.9	10.4	59.3	0.61	0.58	0.33	0.41	0.29	2.29	0.42	0.12	0.33	249	36.0	33.1	12.3	0-0-75-0-0
		2nd	7/30	3.05	10.2	3.1	39.20	1.73	16.9	34.9	11.9	61.4	0.63	0.62	0.35	1.11	0.27	1.78	0.33	0.16	0.35	127	18.3	34.0	14.4	0-0-0-0-0
		3rd	9/10	1.35	15.8	1.3	39.20	0.72	23.1	27.7	n/a	69.1	0.71	0.73	0.46	1.58	0.36	2.23	0.44	0.13	0.49	118	23.0	38.4	12.8	0-0-0-0-0
					TOTAL YIELD			**3.73 T/Ac**	**18.1**	**33.2**	**n/a**	**63.3**	**0.65**	**0.64**	**0.38**	**1.03**	**0.31**	**2.10**	**0.40**	**0.14**	**0.39**	**164**	**25.8**	**35.2**	**13.2**	**0-0-75-0-0**
				Grams		Grams																				
2008	Alf/Grs	1st	6/17	1,554	7.7	1,630	39.20	1.99	18.0	32.2	n/a	64.2	0.66	0.66	0.39	1.19	0.25	1.91	0.41	0.15	0.29	147	18.8	29.5	10.7	11-52-0-0-0
		2nd	8/25	1,066	13.1	1,053	39.20	1.29	18.1	33.4	n/a	62.9	0.65	0.64	0.37	1.11	0.24	1.90	0.36	0.12	0.28	102	13.5	26.9	10.8	0-0-0-0-0
					TOTAL YIELD			**3.28 T/Ac**	**18.1**	**32.8**	**n/a**	**63.6**	**0.66**	**0.65**	**0.38**	**1.15**	**0.25**	**1.91**	**0.39**	**0.14**	**0.29**	**125**	**16.2**	**28.2**	**10.8**	**11-52-0-0-0**
2009	Alfalfa	1st	6/10	1,849	15.7	1,771	43.56	1.95	14.5	40.5	n/a	55.4	0.56	0.52	0.27	0.78	0.24	1.93	0.30	0.07	0.23	97.8	32.6	27.2	10.3	
		2nd	9/16	720	15.0	695	43.56	0.77	14.7	34.8	n/a	61.5	0.63	0.62	0.36	1.00	0.21	1.96	0.34	0.08	0.30	113	32.2	21.5	8.97	
					TOTAL YIELD			**2.72 T/Ac**	**14.6**	**37.7**	**n/a**	**58.5**	**0.60**	**0.57**	**0.32**	**0.89**	**0.23**	**1.95**	**0.32**	**0.08**	**0.27**	**105**	**32.4**	**24.4**	**9.63**	
2010	Alfalfa	1st	6/14	1,542	18.1	1,542	39.20	1.89	11.4	29.4	n/a	49.4	0.51	0.49	0.28	0.43	0.16	1.72	0.16	0.03	0.17	78.1	22.6	16.5	6.14	60-0-0-0-0
		2nd	9/13	804	18.8	804	39.20	0.98	15.0	26.5	n/a	51.8	0.53	0.53	0.31	0.76	0.18	1.81	0.25	0.06	0.24	109	27.2	16.3	9.09	0-0-0-0-0
					TOTAL YIELD			**2.87 T/Ac**	**13.2**	**28.0**	**n/a**	**50.6**	**0.52**	**0.51**	**0.30**	**0.60**	**0.17**	**1.77**	**0.21**	**0.05**	**0.21**	**93.4**	**24.9**	**16.4**	**7.62**	**60-0-0-0-0**

Forage quality data and mineral content are on a dry matter basis.
Crop yields collected and sheet compiled by: Neal E. Fehringer, Certified Professional Agronomist, C.C.A. revised on 6/15/10.

Table F-13 Forage analysis for site YBA.

AMPP

YBA Location Yields, Forage Quality, Mineral Content, and Fertilizer

Year	Crop	Cutting	Date	Harvest Wt.lbs	% Water	Wt. @ 12%	Ft² Harvest	Yield	% Cr. Protein	% ADF	% Calc Digest Protein	% TDN	Energy (mcal/lb) Lact	Main	Gain	Mineral Content, % Ca	P	K	Mg	Na	S	Mineral Content, ppm Fe	Mn	Zn	Cu	Act. Nutrients App./Ac., lbs
2004	Barley	1st	7/3	5.20	9.1	5.4	43.56	2.69 T/Ac	11.6	44.0	5.9	53.4	0.54	0.49	0.24	0.36	0.30	3.20	0.20	0.47	0.21	129	30.3	25.5	9.60	35-40-20
2005	Bar/Alf	1st	7/7	7.70	35.2	5.7	43.56	2.84	13.0	41.6	7.8	55.1	0.56	0.52	0.27	0.37	0.34	2.50	0.14	0.59	0.26	116	28.6	177	10.5	0-0-0-0-0
	Alfalfa	2nd	9/6	2.40	11.4	2.4	43.56	1.21	17.7	30.5	12.6	66.0	0.68	0.68	0.42	1.93	0.24	2.13	0.41	0.17	0.43	208	33.0	34.4	17.2	0-0-0-0-0
		TOTALS		10.1				4.04 T/Ac																		0-0-0-0-0
2006	Alfalfa	1st	7/10	4.00	9.50	4.1	43.56	2.06	20.9	32.9	n/a	63.5	0.65	0.65	0.38	2.15	0.27	2.99	0.25	0.10	0.36	104	22.8	31.4	11.4	0-60-60-0-2-1B
		2nd	8/21	4.65	8.70	4.8	43.56	2.41	13.8	47.3	n/a	48.1	0.48	0.41	0.16	1.01	0.27	2.57	0.23	0.14	0.24	88.4	20.6	20.6	5.90	0-0-0-0-0
		3rd	10/4	4.00	15.0	3.9	43.56	1.93	17.9	37.0	n/a	59.1	0.60	0.58	0.32	1.53	0.27	2.26	0.32	0.19	0.35	113	24.8	24.8	8.30	0-0-0-0-0
		TOTALS		12.7				6.40 T/Ac	17.5	39.1	n/a	56.9	0.58	0.55	0.29	1.56	0.27	2.61	0.27	0.14	0.32	102	22.7	25.6	8.53	0-60-60-0-2-1B
2007	Alfalfa	1st	6/4	2.90	9.70	3.0	43.56	1.49	18.2	37.3	12.7	58.8	0.60	0.58	0.32	1.27	0.38	2.65	0.39	0.12	0.27	109	15.1	31.7	11.4	0-55-20-0-1-1B
		2nd	7/17	3.60	7.80	3.8	43.56	1.89	18.6	34.2	12.9	62.1	0.64	0.63	0.36	1.50	0.41	2.83	0.35	0.14	0.36	86.4	18.1	31.9	12.6	0-0-0-0-0
		3rd	9/5	3.30	19.4	3.0	43.56	1.51	20.4	35.5	n/a	60.7	0.62	0.61	0.34	1.79	0.32	3.44	0.40	0.22	0.49	101	20.3	37.6	14.5	0-0-0-0-0
		TOTALS		9.80				4.89 T/Ac	19.1	35.7	n/a	60.5	0.62	0.61	0.34	1.52	0.37	2.97	0.38	0.16	0.37	99	17.8	33.7	12.8	0-55-20-0-1-1B
				Grams		Grams																				
2008	Alfalfa	1st	6/17	1,864	8.1	1,947	43.56	2.14	19.4	36.0	n/a	60.2	0.62	0.60	0.34	1.26	0.25	2.46	0.29	0.18	0.24	114	8.30	27.8	11.1	0-55-20-0-1-1B
		2nd	7/28	1,747	14.2	1,703	43.56	1.88	21.3	32.7	n/a	63.7	0.65	0.65	0.38	1.36	0.28	2.54	0.34	0.16	0.30	113	12.8	28.2	10.3	0-0-0-0-0
		3rd	9/16	1,395	19.0	1,284	43.56	1.41	22.6	28.7	n/a	68.0	0.70	0.71	0.44	1.40	0.26	2.73	0.32	0.22	0.32	148	16.4	24.6	10.9	0-0-0-0-0
					TOTAL YIELD			5.43 T/Ac	21.1	32.5	n/a	64.0	0.66	0.65	0.39	1.34	0.26	2.58	0.32	0.19	0.29	125	12.5	26.9	10.8	0-55-20-0-1-1B
2009	Alfalfa	1st	6/10	1,615	15.4	1,553	43.56	1.71	20.4	39.0	n/a	57.0	0.58	0.55	0.29	1.58	0.31	2.42	0.41	0.20	0.34	128	22.7	28.4	9.66	0-0-0-0-0
		2nd	7/25	1,794	18.3	1,666	43.56	1.83	19.9	41.9	n/a	53.8	0.55	0.50	0.25	1.31	0.28	2.68	0.34	0.15	0.31	96.0	19.8	31.1	10.5	0-0-0-0-0
		3rd	9/16	1,368	15.2	1,318	43.56	1.45	18.8	39.6	n/a	56.3	0.57	0.54	0.28	1.39	0.27	2.83	0.33	0.16	0.35	102	17.0	25.5	11.3	0-0-0-0-0
					TOTAL YIELD			5.00 T/Ac	19.7	40.2	n/a	55.7	0.57	0.53	0.27	1.43	0.29	2.64	0.36	0.17	0.33	109	19.8	28.3	10.5	0-0-0-0-0
2010	Alfalfa	1st	6/14	2,394	19.7	2,185	43.56	2.41	14.3	33.1	n/a	43.9	0.44	0.41	0.21	0.98	0.18	1.68	0.21	0.10	0.17	61.0	11.1	14.8	7.4	0-75-60-0-0
		2nd	8/2	1,536	17.5	1,440	43.56	1.59	16.6	32.7	n/a	46.5	0.47	0.44	0.23	0.97	0.22	2.14	0.26	0.10	0.20	51.3	14.2	19.5	8.8	0-0-0-0-0
		3rd	9/13	783	18.7	723	43.56	0.80	21.1	27.6	n/a	50.7	0.52	0.51	0.30	1.23	0.28	2.25	0.33	0.15	0.28	86.0	16.8	24.3	11.2	0-0-0-0-0
					TOTAL YIELD			4.79 T/Ac	17.3	31.1	n/a	47.0	0.48	0.45	0.25	1.06	0.23	2.02	0.27	0.12	0.22	66	14.0	19.5	9.1	0-75-60-0-0

Barley results. Rest of tests are for alfalfa which has a lower sodium content.
Forage quality data and mineral content are on a dry matter basis.
Crop yields collected and sheet compiled by: Neal E. Fehringer, Certified Professional Agronomist, C.C.A. revised on 6/15/10.

Table F-14 Forage analysis for site BHA.

AMPP

BHA Location Yields, Forage Quality, Mineral Content, and Fertilizer Applied

Year	Crop	Cutting	Date	Harvest Wt.lbs	% Water	Wt. @ 12%	Ft^2 Harvest	Yield	% Cr. Protein	% ADF	% Calc Digest Protein	% TDN	Energy (mcal/lb) Lact	Main	Gain	Mineral Content, % Ca	P	K	Mg	Na	S	Mineral Content, ppm Fe	Mn	Zn	Cu	Act. Nutrients App./Ac., lbs
2004	W Wht	Harv	7/22	7.5	12.0	7.5	43.56	**125.0 Bu/Ac**	Did not have grain analyzed for feed parameters and mineral content.																	**200-30-20-0-0**
2005	W Wht	Harv	7/22	4.6	12.0	4.6	43.56	**76.7 Bu/Ac**	Did not have grain analyzed for feed parameters and mineral content.																	**200-40-30-0-0**
2006	Beets	Harv	10/6	208.3	As Is	n/a	100	**45.4 T/Ac**	**w/ 16.09% sugar.** Did not have beets analyzed for feed parameters and mineral content.																	**200-130-0-0-0**
2007	M. Bar		Did not take a harvest because field combined before arrived.																							**90-30-20-0-0**
				Grams		Grams																				
2008	M. Bar.	Harv	7/16	2,501	12.0	2,501	43.56	**114.8 Bu/Ac**	Did not have grain analyzed for feed parameters and mineral content.																	**90-30-20-0-0**
				Pounds		Pounds																				
2009	Beets	Harv	10/17	176.8	As Is	n/a	96	**40.1 T/Ac**	**w/ 16.03% sugar.** Did not have beets analyzed for feed parameters and mineral content.																	
2010	W. Wht.	Grain	7/30	4,207	12.0	4,207	62.50	**107.6 Bu/Ac**	Did not have grain analyzed for feed parameters and mineral content.																	**90-30-20-0-0**

Forage quality data and mineral content are on a dry matter basis.
Crop yields collected and sheet compiled by: Neal E. Fehringer, Certified Professional Agronomist, C.C.A. revised on 6/15/10.