APPENDIX J
2013 ALLUVIAL VALLEY FLOOR DETAILED SOILS REPORT

BASELINE REPORT 325A – APPENDIX J

OTTER CREEK COAL PROJECT

ALLUVIAL VALLEY FLOOR

DETAILED SOILS REPORT USING PIEZOMETER TRANSECTS

POWDER RIVER COUNTY, MONTANA

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TABLE OF CONTENTS

FIGURE

APPENDIX A - TABLES

1.0 INTRODUCTION

As part of the mine permitting process, Otter Creek Coal, LLC. conducted a comprehensive investigation of the Otter Creek floodplain to identify and characterize potential AVF areas associated with the proposed Otter Creek Coal Mine. Previous studies on this topic include a large-scale analysis of the Otter Creek floodplain using a combination of published Natural Resource Conservation Service (NRCS) soils data and site-specific data collected during the Otter Creek Coal Soils Baseline Inventory (Baker 2014). In 2013, soil samples were collected in conjunction with piezometer installation and vegetation sampling to provide a multi-discipline study of AVF hydrology, vegetation and soils. The study design was developed following discussions with the Montana Department of Environmental Quality (MDEQ) and centered on the establishment of transects across the Otter Creek floodplain.

2.0 METHODS

A total of four transects (T5, T6, T7, and T8) were located across the Otter Creek floodplain, spaced at approximately one-mile intervals and oriented perpendicular to the direction of the drainage (Figure 1). Each transect extended from slopes or upland terraces into the floodplain. At each site, a shallow (less than 15 feet) piezometer was installed targeting the fine-grained surface alluvium. Four piezometers were installed along transect T5, three along transect T6, five along transect T7, and three along transect T8. Table 1 correlates piezometer locations and soil/vegetation sampling sites. Each piezometer location was considered a sampling site, denoted with an "S" (i.e. T5S1, T5S2, etc.).

The vegetation sampling associated with the Detailed AVF Study was completed prior to the 2013 hay harvest; the results of this study are described in a separate report (Scow 2014). In addition, static water level measurements were collected on a monthly basis from each piezometer. A summary and discussion of the AVF hydrology data is also provided in the AVF Hydrology Report (Hydrometrics 2014).

During piezometer installation, soil cores were extracted and examined to identify primary soil horizons and collect representative samples from each horizon. Soil characteristics such as the depths of each horizon, coarse fragment content and rooting depth were evaluated and recorded in the field. The soil samples were submitted to the laboratory and analyzed for the following properties: pH, electrical conductivity (EC), sodium adsorption ratio (SAR), organic matter (OM), and texture (percent clay, silt, sand, coarse fragments).

Measurements of chemical soil properties, specifically salinity and sodicity, were collected on each soil horizon to determine absolute and relative changes in soil properties that could influence vegetation. Soil salinity was measured using electrical conductivity (EC) to evaluate the total concentrations of dissolved salts. Soils are generally considered saline if the EC is greater than 4 mmhos/com (Bohn et al. 1985, Brady and Weil 2008). Sodicity is reported by the sodium adsorption ratio (SAR), which compares the concentration of sodium ions, to other salt ions such as calcium and magnesium, in the soil solution. A soil with a SAR of 13 or greater is considered to be sodic (Brady and Weil 2008). Both salinity and sodicity can have a negative impact on plant growth and vitality, depending upon species tolerance or sensitivity.

To evaluate soil fertility and root density, two different methods were used for determining organic matter (OM) content from soil samples – Walkley-Black (WB) and Loss on Ignition (LOI). The WB method uses a chemical extraction process to consume decomposed OM and provides a measure of soil fertility based on plant-available OM. In contrast, the LOI method uses heat to consume and measure the content by weight of both decomposed and undecomposed OM, thus providing higher overall OM values than the WB method. By measuring differences in results between these two techniques, the amount of undecomposed OM in the soil could be estimated. These measurements primarily consist of the combination of litter and root mass in upper horizons and solely root mass in lower horizons.

Previous work on the AVF study area identified the Otter Creek floodplain boundary based on topographic information and geologic data. The floodplain boundary was used in this study to separate sites into floodplain and non-floodplain categories for the purposes of data analysis and comparison. Soil sampling locations, as they relate to the Otter Creek floodplain boundary, are presented in Table 1 of Appendix A.

3.0 RESULTS

Soils within the floodplain are primarily Haverson and Havre soils, as mapped by the NRCS in the Powder River County soil survey (NRCS, 2013). Some isolated areas of Farland, Fort Collins, Heldt, Hesper and McRae are found at the toe of alluvial fans or slopes along the floodplain boundary. Typically the soils within the floodplain are 0 to 2 percent slopes with distinct terrace breaks and small depressional features indicative of abandoned stream channels.

Generally, soils both within and adjacent to the floodplain consisted of finely textured silty to clayey loam soils in the upper horizons, grading to a loamy soil texture in the lower horizons. Coarse fragments were uncommon and primarily confined isolated to gravel lenses in deeper horizons.

A total of 92 soil samples were collected from the 15 piezometer sites and submitted to the laboratory for analysis. Appendix A of this report contains: soil properties for each soil horizon in Table 2, averaged soil data for each sample site in Table 3, and summarized data for floodplain versus non-floodplain sites in Table 4.

3.1 Root Analysis

The organic matter concentrations ranged from 0.4 percent to 6.8 percent in floodplain samples, and in non-floodplain sites from 0.3 percent to 5.9 percent. Weighted averages for organic matter were very similar between the two soil categories. Decomposed OM (using the WB method) averaged 0.9 percent for the floodplain and 1.0 percent outside of the floodplain. Total organic material content (calculated using the LOI method) for floodplain and non-floodplain soils averaged 2.3 and 2.5 percent, respectively. The relative differences in organic matter between the LOI and WB methods were indicative of the field evaluations of root size and abundance, confirming the qualitative field observations.

The maximum rooting depth in the floodplain ranged from 30 to 82 inches, while rooting depths at non-floodplain sites ranged from 44 to 115 inches. Groundwater was detected at all piezometer sites within the floodplain sites, ranging in depth from 45 to 84 inches at these sites. At non-floodplain sites groundwater was detected at six of eight sites, with a range of 101 to 162 inches. At two floodplain sites (T5S1 and T7S3) the roots extended approximately 11 inches deeper than the 2013/2014 average groundwater level. At the remaining five floodplain sites the rooting depth was similar to, or shallower than, the average groundwater depth.

3.2 Soil Salinity

Saline soils were identified at all seven sampling locations within the floodplain boundary and at four of seven non-floodplain sites. EC values in these sites ranged from 4.2 mmhos/cm (T6S3 and T7S2) to 14.5 mmhos/cm (T6S2). The average EC of sites in the floodplain ranged from 3.29 to 7.24 mmhos/cm and ranged from 0.97 to 8.08 mmhos/cm outside of the floodplain.

Elevated SAR was detected at 4 sites within the floodplain and 4 sites outside of the floodplain. Within the floodplain, SAR values ranged from 12.8 to 16.8. The elevated SAR values for non-floodplain sampling locations were higher than within the floodplain, ranging from 15.7 to 22.1. However, the weighted average SAR values were less than 13 overall for all floodplain sites and most non-floodplain sites. The non-floodplain sites with high sodicity were sites T7S1 and T8S3, which contained weighted SAR averages of 13.3 and 16.0, respectively.

Saline soils were found at an average minimum depth of 11 inches within the floodplain and 103 inches at non-floodplain sites. Similarly, the minimum depth of sodic soils was 66 inches in the floodplain and 123 inches outside of the floodplain. The range of minimum depths for elevated EC in the floodplain was 0 (soil surface) to 30 inches. At floodplain sites with elevated EC at shallow depths the saline conditions typically extended throughout most of the soil column.

The distribution of salinity within the soil profile was notably different between floodplain and non-floodplain soils. Several non-floodplain sites contained saline and/or sodic conditions in isolated horizons at mid-profile or deeper depths in the soil column. However, soil salinity in the floodplain varied from a fully saline soil profile to isolated horizons, although in general there were broad distributions of salts throughout all floodplain soils.

4.0 DISCUSSION

Many of the physical soil properties were similar between floodplain and non-floodplain soils, including soil texture, coarse fragment content, pH and organic matter content (Table 3). Although the distribution of roots within the soil profile does not appear to be associated with variation in salt concentrations, the relationship between maximum rooting depths and groundwater is notable. Average maximum rooting depths were 15 inches deeper at non-floodplain sites than they were within the floodplain. Indicating that vegetation in non-floodplain areas is utilizing more of the soil column to extract nutrients and moisture than the floodplain soils.

A relatively sharp decrease in root density at shallow depths within the floodplain was noted in field observations and quantitatively estimated using organic matter extractions. The changes in root densities are likely a function of low species diversity as well as saline soils influenced by low quality groundwater. At most floodplain sites, the root size decreased to fine or very fine and the density decreased to a rating of few within the top 15 – 20 inches of the profile. Similarly the LOI organic matter content often decreased to less than 1.5 percent below a depth of 30 inches. Furthermore, the average rooting depth of plants within the floodplain was shallower than the average depth of the groundwater; indicating that floodplain vegetation is not actively utilizing groundwater.

In regards to soil chemistry, the average total salinity of the soil profiles is similar between floodplain and non-floodplain sites; however, there are some notable differences in the vertical distribution of salts within these soils. In the floodplain, moderate concentrations of salts are commonly found at shallow depths and extend throughout the soil profile. Outside of the floodplain, moderate to strong concentrations of salts are less common and are found in discreet, often isolated, horizons within the soil. These two contrasting salt profiles indicate that soil salinity outside of the floodplain is primarily derived from the chemistry of associated geologic deposits or leaching of near-surface salinity to deeper horizons. In contrast, soil salinity in the floodplain appears to be a function of groundwater fluctuations and seasonal overbank flooding from Otter Creek.

In summary, soils within the Otter Creek floodplain exhibit many similar physical and chemical properties to the soils adjacent to the floodplain. However, analysis of the soil sample data identified the following trends:

- Non-floodplain soils tend to contain isolated horizons of high salinity at mid- to deep depths. These soils also exhibit a gradual decrease in root density with depth.
- Floodplain soils contain variable salt concentrations at shallow to mid- depths of the profile, occasionally including the soil surface. The root density within floodplain soils tends to decrease sharply below approximately 20 inches in depth.

These observations indicate that vegetation within the floodplain is more heavily utilizing the upper soil horizons to provide moisture and minerals than the deeper horizons, including those intersecting groundwater.

5.0 REFERENCES CITED

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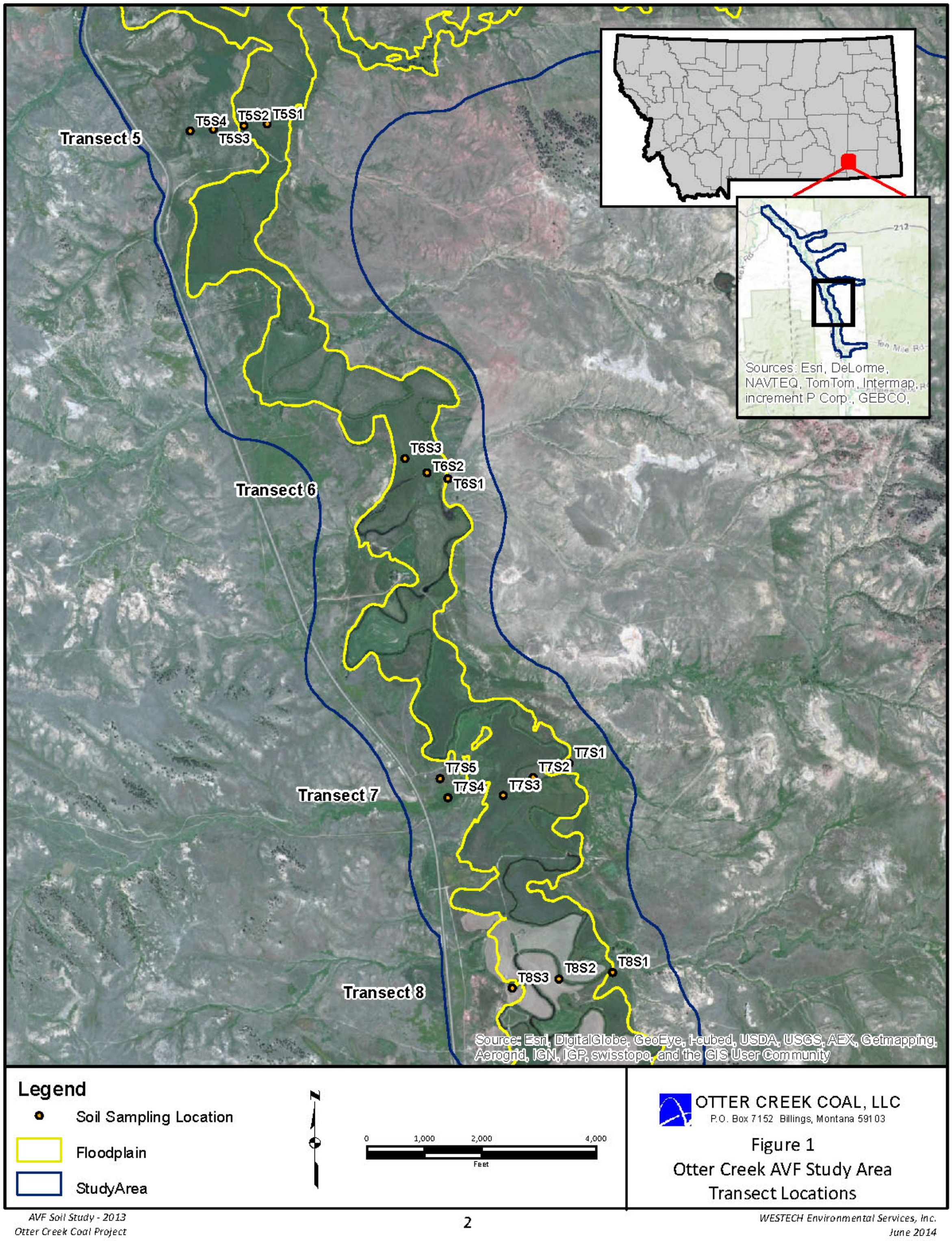
Figure 1. Otter Creek Coal – Detailed AVF Study Map



TABLES

Table 1. Sample Site Location Floodplain vs Non-Floodplain

Transect	Sampling Location
T5	T5S1 – Floodplain
	T5S2 – Floodplain
	T5S3 – Non-Floodplain
	T5S4 – Non-Floodplain
T6	T6S1 – Non-Floodplain
	T6S2 – Floodplain
	T6S3 – Floodplain
T7	T7S1 – Non-Floodplain
	T7S2 – Floodplain
	T7S3 – Floodplain
	T7S4 – Non-Floodplain
	T7S5 – Non-Floodplain
T8	T8S1 – Non-Floodplain
	T8S2 – Floodplain
	T8S3 – Non-Floodplain

Location[1]	Site	Depth Range (in)	Texture[2]	pH	EC (mmhos/cm)[3]	SAR (unitless)	OM-WB (%)	OM-LOI (%)	Roots[5]
Floodplain	T5S1	0-5	SiCL	7.5	0.9	0.4	4.89	7.7	MF/CM
		5-15	SiCL	7.8	0.6	0.9	2.22	4.2	CF/FM
		15-30	L	8.2	2.5	3.8	0.92	2.0	FF
		30-56	L	8.3	6.0	12.5	0.95	2.2	VFF
		56-110	SiCL	8.2	5.1	10.8	0.74	2.4	X
Floodplain	T5S2	0-6	SiCL	7.6	0.8	0.9	3.85	6.6	MF/CM/FC
		6-17	SiC	7.9	0.7	2.5	1.72	4.3	MF/CM/FC
		17-30	L	8.2	7.1	9.7	1.05	2.3	FF
		30-60	SL	8.3	5.6	16.8	0.80	1.4	X
		60-132	SL	8.3	5.3	11.7	0.58	1.2	X
Floodplain	T6S2	0-8	SiCL	7.9	7.7	10.9	3.43	6.3	MF/CM
		8-20	L	8.1	9.5	12.8	1.61	3.1	CF/FM
		20-38	L	8.4	14.5	16.2	0.79	1.9	FF
		38-64	SiL	8.3	7.5	11.3	0.79	2.1	X
		64-110	SiL	8.1	5.9	9.3	0.76	2.0	X
		110-165	L	8.2	5.3	9.3	0.79	1.9	X
Floodplain	T6S3	0-4	L	7.3	2.3	2.0	2.97	8.6	MF/CM
		4-14	CL	7.8	6.6	6.8	1.70	5.3	CF/FM
		14-40	SiCL	8.0	7.8	9.8	1.61	3.2	FF
		40-62	SL	8.1	4.7	7.7	0.36	1.1	FF
		62-90	L	8.1	4.2	8.6	0.70	1.4	X
Floodplain	T7S2	0-5	SiL	7.6	0.6	0.2	0.77	5.0	CF/FM
		5-16	L	7.8	0.9	0.4	1.19	2.9	CF
		16-40	L	7.9	5.4	6.8	1.23	2.4	FF
		40-75	SL	8.2	7.9	13.9	0.31	1.3	FF
		75-115	L	8.6	4.2	12.0	0.34	1.1	X
		115-144	SL	8.3	3.5	9.2	0.25	0.9	X
Floodplain	T7S3	0-6	SiC	7.4	1.4	1.2	1.07	7.9	MF/CM/FC
		6-20	SiCL	8.0	7.3	10.6	1.16	4.5	CF/FM
		20-50	CL	8.3	9.6	13.1	0.83	2.5	FF
		50-82	SiCL	8.4	2.2	7.1	0.67	3.4	FF
		82-118	SiL	8.2	2.3	5.4	1.75	2.1	X
		118-144	L	8.2	3.3	6.7	0.80	1.2	X
Floodplain	T8S2	0-7	SiCL	7.8	0.8	1.4	3.47	6.2	CF
		7-20	SiC	8.0	5.3	5.6	1.38	3.4	FF
		20-54	C	8.2	5.1	7.3	0.77	2.1	FF
		54-92	C	8.3	2.8	7.2	0.80	2.5	X
		92-140	L	8.2	3.5	8.4	0.53	1.6	X
		140-164	L	8.1	4.8	8.7	0.23	1.2	X

Location[1]	Site	Depth Range (in)	Texture[2]	pH	EC (mmhos/cm)[3]	SAR (unitless)	OM-WB (%)	OM-LOI (%)	Roots[5]
Non-Floodplain	T5S3	0-9	SiCL	7.3	0.6	0.1	3.75	5.7	MF/FM
		9-23	SiCL	7.6	0.5	0.2	2.00	3.9	CF/FM
		23-48	SiCL	8.0	0.4	0.2	0.95	2.3	CF/FM
		48-84	SiCL	8.2	0.3	0.3	0.58	1.7	FF
		84-108	L	8.3	1.0	1.7	0.52	1.2	X
		108-140	LS	8.5	2.8	8.8	0.18	0.5	X
		140-215	SL	8.9	2.8	9.1	0.23	0.6	X
Non-Floodplain	T5S4	0-8	SiCL	7.4	0.6	0.1	3.17	4.5	MF/CM
		8-20	SiCL	7.4	0.6	0.1	2.71	4.1	MF/CM
		20-50	SiCL	8.4	0.4	1.4	3.45	1.9	CF/FM
		50-85	SiCL	8.2	0.3	0.3	0.58	3.0	FF
		85-115	SiCL	8.6	0.4	3.9	0.65	3.1	FF
		115-140	L	8.6	1.8	10.2	0.34	1.7	X
		140-180	SL	8.9	2.1	11.2	0.17	1.0	X
Non-Floodplain	T6S1	0-6	CL	7.3	1.7	0.4	6.34	9.5	MF/FM
		6-18	SiCL	8.0	2.2	4.3	1.38	3.9	CF
		18-44	L	8.3	21.8	22.1	0.74	2.7	FF
		44-76	SiCL	7.9	5.3	5.9	1.21	3.7	X
		76-112	SiCL	8.0	3.2	6.7	1.03	2.9	X
		112-130	L	8.0	3.2	7.0	0.85	2.1	X
		130-160	SL	7.9	3.5	6.9	2.64	4.1	X
Non-Floodplain	T7S1	0-4	SiCL	6.5	0.3	0.2	3.95	6.0	MF/FM/FC
		4-16	SiC	7.4	0.5	0.1	2.23	4.3	MF/CM
		16-34	SiCL	7.8	4.3	1.7	1.86	3.7	CF/FM
		34-62	L	8.4	16.0	11.0	0.41	1.8	FF
		62-118	L	8.5	9.4	15.7	0.32	1.9	X
		118-148	L	8.6	6.6	19.2	0.29	1.8	X
		148-196	L	8.8	4.6	16.9	0.35	1.5	X
Non-Floodplain	T7S4	0-8	SiCL	7.8	0.6	1.0	1.12	7.1	MF/CM/FC
		8-20	L	7.8	1.0	1.0	0.58	2.9	CF/FM
		20-48	L	7.9	0.5	0.4	1.27	2.4	CF/FM
		48-72	L	8.0	0.7	0.9	0.97	2.4	FF
		72-112	SiL	7.9	0.8	1.3	0.88	2.9	FF
		112-150	SL	7.9	1.6	0.5	0.34	1.7	X
		150-192	L	8.0	1.1	0.8	0.43	2.2	X
Non-Floodplain	T7S5	0-6	L	7.0	1.0	0.4	1.90	6.6	MF/FM
		6-16	CL	7.7	0.6	0.3	1.16	4.5	CF
		16-30	CL	8.1	0.8	0.6	0.74	3.8	FF
		30-64	CL	8.0	5.1	4.2	0.64	2.9	FF
		64-144	L	8.2	10.3	9.4	0.43	2.1	X
		144-192	L	8.3	9.8	12.9	1.32	1.8	X
Non-Floodplain	T8S1	0-6	SiCL	7.6	0.7	1.1	3.16	6.8	CF/FM
		6-22	L	7.8	0.7	0.8	1.29	3.0	CF/FM
		22-50	CL	7.8	0.6	0.8	1.29	3.1	FF
		50-78	CL	7.9	0.8	1.0	1.20	3.1	X
		78-108	C	8.0	0.5	1.0	1.01	2.8	X
		108-156	SiCL	8.0	0.9	2.0	1.04	3.3	X

Table 2. Physical and Chemical Soils Data

Location[1]	Site	Depth Range (in)	Texture[2]	pH	EC (mmhos/cm)[3]	SAR (unitless)	OM-WB (%)	OM-LOI (%)	Roots[5]
Non-Floodplain	T8S3	0-5	SiCL	7.5	0.7	0.3	2.86	8.2	CF/FM
		5-15	SiCL	8.0	0.7	1.0	2.44	4.5	FF
		15-46	SiCL	8.1	19.1	17.6	1.74	3.5	FF
		46-90	SiC	8.3	13.8	19.2	1.20	2.3	*X*
		90-144	SiCL	8.7	5.1	21.2	0.56	1.6	*X*
		144-196	SiCL	8.6	1.9	11.5	0.32	1.4	*X*

Notes:

[1] Location based on floodplain map developed as part of Otter Creek Coal AVF Analysis, 2014.

[2] C = clay, CL = clay loam, L = loam, LS = loamy sand, LFS = loamy fine sand, SiL =silty loam,
SiCL = silty clay loam, SiC = silty clay, S = sand, SL = sandy loam, SCL = sandy clay loam, SC = sandy clay

[3] Electrical Conductivity meaured in millimohs per centimeter

[4] Sodium Absorption Ratio - unitless

[5] Abundance: F = few, C = common, M = many.
Size: VF = very fine, F = fine, M = medium, CO = coarse.

Table 3. Soils Data Summarized by Sample Site

Sampling Site	Avg Groundwater Depth (inches)	Maximum Rooting Depth (inches)	Minimum Depth of EC >4 (inches)	Minimum Depth of SAR >13 (inches)	Weighted Average EC (mmhos/cm)	Weighted Average SAR	Weighted Average OM - WB (%)	Weighted Average OM - LOI (%)
Floodplain Sites								
T5S1	45	56	30	110	4.4	8.9	1.1	2.7
T5S2	47	30	17	30	5.0	11.4	0.9	1.9
T6S2	47	38	0	8	7.2	10.7	1.0	2.3
T6S3	61	62	4	90	5.5	8.2	1.1	2.6
T7S2	84	75	16	40	4.8	9.7	0.5	1.6
T7S3	71	82	6	20	4.4	7.9	1.1	2.8
T8S2	56	54	7	164	3.9	7.4	0.8	2.2
Floodplain Averages	***59***	***57***	***11***	***66***	***5.0***	***9.2***	***0.9***	***2.3***
Non-floodplain Sites								
T5S3	114	84	215	215	1.7	4.8	0.7	1.5
T5S4	126	115	180	180	1.0	4.9	1.2	2.3
T6S1	101	44	18	18	6.6	8.7	1.5	3.5
T7S1	162	62	16	62	7.5	13.3	0.7	2.2
T7S4	186	112	192	192	1.0	0.8	0.7	2.5
T7S5	192	64	30	144	7.8	8.0	0.8	2.6
T8S1	133	50	156	156	0.7	1.3	1.2	3.2
T8S3	112	46	15	15	8.1	16.0	1.0	2.3
Non-floodplain Averages	***141***	***72***	***103***	***123***	***4.3***	***7.2***	***1.0***	***2.5***