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A Statewide Geographic Information System (GIS) as a Predictive Tool for Locating Deeply Buried Archeological Deposits in Nebraska: Phase III - The Sandhills Region

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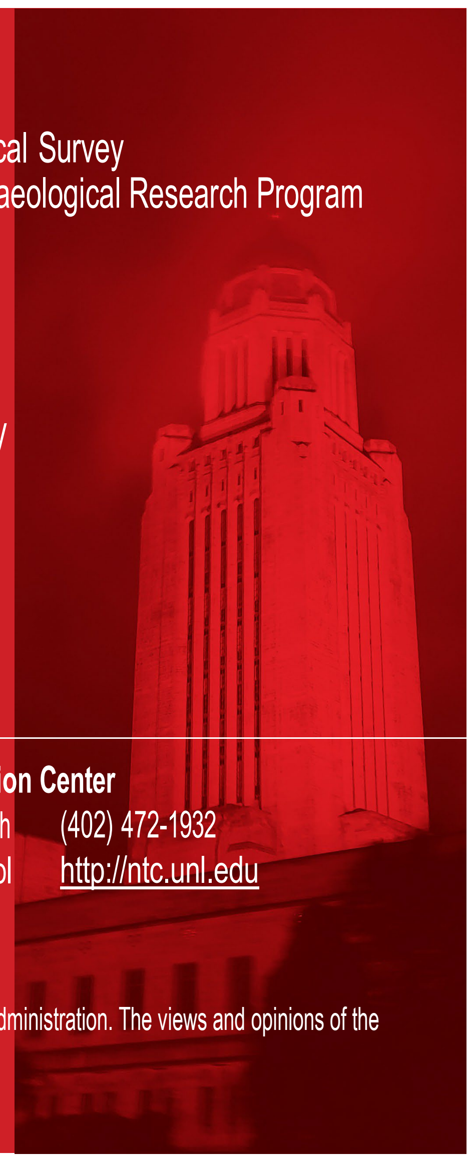

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16. Abstract

This project developed a GIS to assist with the identification of deeply buried cultural deposits in alluvial settings across the Sandhills region of Nebraska. Soil survey data, previous geoarchaeological investigations, landform position, and other information was used to rank the potential of any stream valley setting as low, low-moderate, moderate-high, or high potential to contain buried cultural deposits. While the presence of buried soils does not necessarily translate to presence of buried archeological sites, the potential for such sites is far greater in buried soils. The GIS can be used by NDOT and other agencies with statutory historic preservation obligations, to identify tracts on proposed construction projects that might require deep mechanical testing (backhoe or coring) in search of buried archeological properties.

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Abstract

This project developed a GIS to assist with the identification of deeply buried cultural deposits in alluvial settings across the Sandhills region of Nebraska. Soil survey data, previous geoarchaeological investigations, landform position, and other information was used to rank the potential of any stream valley setting as low, low-moderate, moderate-high, or high potential to contain buried cultural deposits. While the presence of buried soils does not necessarily translate to presence of buried archeological sites, the potential for such sites is far greater in buried soils. The GIS can be used by NDOT and other agencies with statutory historic preservation obligations, to identify tracts on proposed construction projects that might require deep mechanical testing (backhoe or coring) in search of buried archeological properties.

Chapter 1 Introduction

1.1 Scope and Background

This project is the third phase of an effort designed to assist cultural resource specialists involved in Nebraska Department of Transportation (NDOT) and the Federal Highway Administration (FHWA) project planning and development. The overall project goal was to develop Geographic Information System (GIS) data layers that spatially delineate different landform-sediment assemblages (LSAs) and depict the associated geologic potential for buried cultural deposits in Nebraska. The *Nebraska Buried Sites GIS* resource allows planners and cultural resource specialists to determine whether future project areas are likely to be free of deeply buried sites or whether subsurface exploration is necessary. Phase I focused on select watersheds in eastern Nebraska where a majority of groundtruth data existed (Layzell et al., 2018, 2019). In Phase II, model improvements were made, and the spatial scope was expanded across the rest of the state (Layzell et al., 2021). Phase III (this study) focused specifically on the Nebraska Sandhills, where a lot of uncertainty remains about the temporal and spatial patterns of Holocene and late-Pleistocene erosion, sedimentation, and landscape stability. To address this issue, we collected and distilled existing information about the age and distribution of buried late-Quaternary landscapes in the Sandhills and conducted field investigations in areas that lack such information. This material was used to further evaluate and improve the *Nebraska Buried Sites GIS* model which, in turn, will facilitate NDOT's cultural resource management in a vast and complex landscape.

Prior to the early 1980s, most archeologists working in Nebraska and other areas of the Midwest relied on traditional methods of surface surveys to locate prehistoric cultural deposits. Those methods, such as pedestrian surveys and shallow shovel testing, rarely detect buried cultural materials, especially in stream valleys. Bettis and Littke (1987:3) pointed out that inadequate subsurface sampling in stream valleys has led to significant gaps in the record of known prehistoric cultural resources, as well as erroneous conclusions about some aspects of regional cultural history. Many studies (e.g., Mandel, 1994, 1996, 1997, 1999, 2002, 2006a, 2009, 2010a, 2010b, 2011, 2012, 2013a, 2013b, 2014, 2015, 2016; Mandel and Bettis, 1995, 2001a, 2003) have demonstrated that stream valleys in Nebraska have extensive geomorphic surfaces that are geologically young (often post-dating 2000 yr BP), and that most of the existing record of prehistoric cultures is deeply buried. Hence there is a need for understanding the age and distribution of different LSAs to adequately evaluate the landscape for buried archeological materials.

LSAs are landforms and underlying genetically related packages of sediment and associated soils with predictable age relationships. The impetus for considering LSAs in an archeological context is the premise that the archeological record is a component of the sedimentary record; hence, physical processes that remove, modify, and bury sediments control the preservation and visibility of the record of the human past (Bettis et al., 1996). Conceptualizing the landscape in this manner provides archeologists with a range of powerful tools for locating, evaluating, and interpreting cultural resources preserved in sediments that constitute the modern landscape (Mandel, 2006a). Other factors, all described below, also must be considered in determining the potential for buried cultural deposits.

1.2 Determining the Potential for Buried Cultural Deposits

In evaluating buried site potential, it is important to consider geomorphic processes, particularly erosion, deposition, and soil development. These processes produce a complex mosaic of LSAs that are differentially but systematically preserved in the landscape, and therefore affect the distribution and detection of archeological materials. For example, LSAs representing areas of net sedimentation (e.g., stream terraces, colluvial footslopes, and alluvial fans) have thick packages of sediment that often span the Holocene. These LSAs are typically formed by pulses of sedimentation punctuated by periods of stability and soil development and are therefore more likely to contain buried cultural deposits. In contrast, LSAs such as floodplains and upland drainageways tend to have relatively thin packages of sediment and are relatively young, often post-dating Euro-American settlement in the Plains.

In this project, determining the geologic potential for buried cultural deposits considered four factors with respect to different LSAs: (1) the age of sedimentary deposits, (2) the soil stratigraphic record, (3) the depositional environment (high energy vs. low energy), and (4) the drainage conditions (poorly drained vs. well drained).

Buried cultural deposits are limited to LSAs that date to the Holocene and terminal Pleistocene. Although the time when people first arrived in mid-continental North America is uncertain, there is strong evidence of a human presence by as early as 13,500 years ago (Holliday and Mandel, 2006, 2017a). Hence, LSAs that were aggrading anytime during the past 13,500 years have potential for containing buried cultural deposits. On the other hand, LSAs that have been stable for the past 13,500 years are not likely to have *in situ* cultural materials in buried contexts. Instead, they may have cultural deposits representing Early Paleoindian through Historic period occupations on their surfaces.

The presence or absence of terminal Pleistocene and Holocene-age buried soils, especially buried A horizons, is an important factor in evaluating the potential for buried cultural deposits (Mandel, 2006a; Holliday et al., 2017). Buried soils represent previous land surfaces that were stable for a long enough period to develop recognizable soil profile characteristics (Mandel and Bettis, 2001b). If one assumes that the probability of human use of a particular landscape position was equal for each year, it follows that the surfaces that remained exposed for the longest time would represent those with the highest probability for containing cultural materials (Hoyer, 1980). In stream valleys, buried soils dating to the Holocene and terminal Pleistocene represent those surfaces, and evidence for human occupation would most likely be associated with them.

However, prehistoric cultural deposits, even rich ones, also may be found in sediment that has not been modified by soil development (Hoyer, 1980). Hence the presence or absence of buried soils cannot be used as the sole criterion for evaluating the potential for buried cultural materials. The mere presence of Holocene and terminal Pleistocene deposits beneath a geomorphic surface offers potential for buried cultural materials.

In the past, humans have been attracted to streams, often living on floodplains, terraces, or alluvial fans and exploiting the abundant resources available in alluvial settings. It is likely that prehistoric people were selective in choosing alluvial landforms for habitation, avoiding high-energy depositional environments, such as flood bars in zones of high-energy flooding and lateral accretion, but favoring relatively stable landforms elevated above the floodplain, such as terraces, alluvial fans and colluvial aprons (e.g., Mandel and Bettis, 2001b). Although alluvial landscapes are conducive to the initial accumulation of artifacts and their subsequent burial, fluvial processes may restructure the artifact patterns (Rapp and Hill, 2006: 75). For example, where sites are situated on or near the banks of stream channels, high-energy floods tend to modify cultural deposits dramatically by displacing artifacts vertically and horizontally. In some cases, stream erosion may completely remove artifacts, cultural features, and even entire sites, thereby destroying evidence of human occupation (Mandel et al., 2017). On the other hand, vertical accretion, which is a relatively low-energy process compared to lateral accretion, can result in rapid burial and preservation of cultural deposits in alluvial environments.

Drainage conditions must be considered when assessing buried site potential. Today, wetlands, including marshes, shallow lakes, and wet basins and meadows, are common on the valley floors of streams and in dune fields, and they were present at various times over the past 13,000 years. Although people undoubtedly visited wetlands for hunting and gathering during that period, it is unlikely that they would have spent much time in such wet environments, and ephemeral camps rarely produce an abundant material record. By contrast, well-drained landforms, such as alluvial fans and colluvial aprons would have been attractive locations for long-term human occupations that tend to leave a rich archeological record (e.g., Almy, 1978; Mandel and Bettis, 2001b; Saucier, 1966).

Determining the spatial pattern of buried lake deposits will be especially important, as the shores of former lakes would have attracted game and people in the past. This need is underscored by the occurrence of deeply buried Paleoindian bison kill sites, including Beacon Island (Mandel et al., 2014), Winger (Mandel and Hofman, 2003), Lubbock Lake (Holliday, 1985), and Folsom (Holliday,1997: pp. 182-185), in lacustrine deposits. However, because shorelines are not static, i.e., lakes contract and expand, it is difficult to decouple lacustrine deposits that were exposed along a relatively dry shoreline and available for human occupation from ones that were submerged and uninhabitable at specific points in time. Hence, to avoid the potential loss of cultural resources when lacustrine deposits are going to be disturbed by construction projects, those deposits should be designated as having high potential for containing cultural deposits until proven otherwise by archaeological testing.

1.3 Soil survey data and archeological research

The implementation of systematic soil surveys and soil mapping by national soil survey programs was one of the primary goals in soil-related research through much of the 20th century (Brevik et al., 2016). In the United States, the Natural Resources Conservation Service (NRCS) currently is the primary agency involved in conducting soil surveys and disseminating soil data. The NRCS Web Soil Survey provides online access to a wealth of data on landscapes and geomorphology as well as soils. Engineers, farmers, property appraisers, and others often rely on these data because they either use soil as a material or study its role in the environment (Miller, 2012). Although some scientists have used soil survey data to devise strategies for locating cultural resources (e.g., Beeton and Mandel, 2011; Bettis and Benn, 1984, Mandel, 1992, 2006b; Monger, 1995; Stafford and Creasman, 2002), these data are generally underutilized in archeology, probably because of the agricultural and land-use focus of the surveys (Holliday and Mandel, 2017c).

In Phases I and II, we used data from the NRCS Soil Survey Geographic database (SSURGO) to provide information on the spatial distribution of different LSAs and to determine the associated geologic potential for buried cultural resources. Based on this information, a GIS-based model (*Nebraska Buried Sites GIS*) was developed to identify the potential for buried archeological material in Nebraska (Layzell et al., 2018, 2019, 2021). The model is focused on stream valleys but also includes assessments of buried potential for uplands where relationships could be gleaned. Data from a large volume of field-based research conducted throughout the region, including soil stratigraphy, lithostratigraphy, and chronostratigraphy, were used to verify the model.

Chapter 2 Methodology

Research in the central Great Plains combining geomorphology with archeology (or *geoarchaeology)* has produced a large volume of data in Nebraska. However, before the *Nebraska Buried Sites GIS* project began in 2016, no collective repository or database of this geoarchaeological information existed. Hence, Phase I of the project, conducted from 2016 to 2018, involved the identification and gathering of extant technical reports, journal articles, book chapters, and other publications containing pertinent geoarchaeological data in and around Nebraska. A literature review was conducted that utilized existing databases of published and unpublished reports to identify relevant resources containing geomorphological information. All resources were converted to digital formats where applicable and compiled in a comprehensive bibliographic database. As stratigraphic profiles and associated data from select localities were used in verifying cultural resource potential based on soil survey data, related photographs and profiles were extracted from the referenced reports and added to the GIS as attachments. This geoarchaeological repository was updated as part of Phase III of the project to include new data collected from the Sandhills (Figure 2.1).

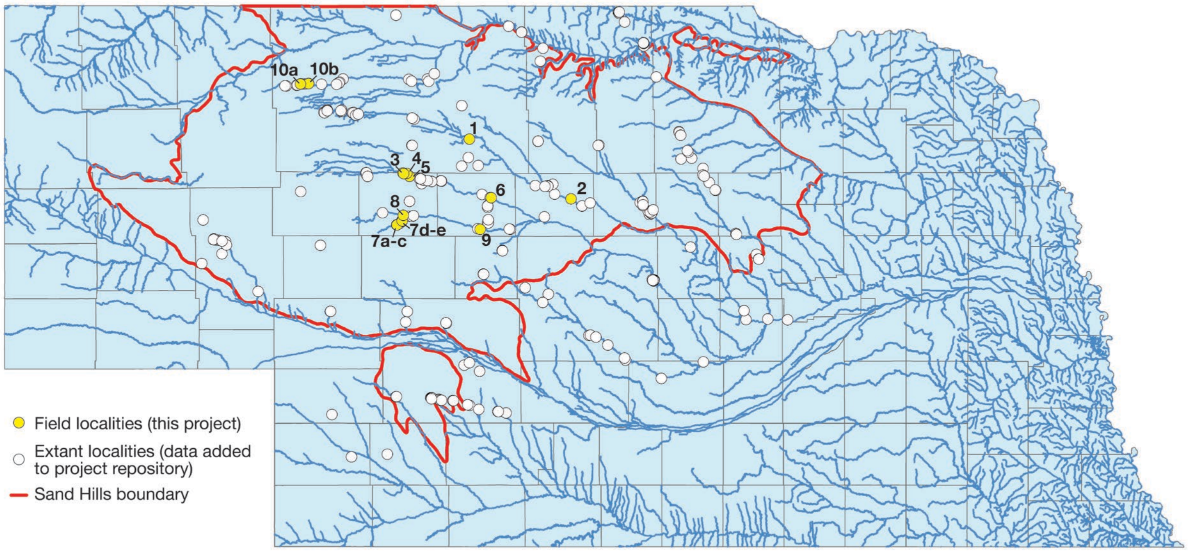

Figure 2.1 Map of Nebraska showing localities investigated in the Sandhills region. Field localities: 1. Miles, 2. Wyckoff, 3. Fits Drive, 4. Bostron, 5. O'Brien, 6. Nutter, 7a-c. Munn (Sections 1-3), 7d-e. Munn (Sections 4-5), 8. 25HO47, 9. Anderson, 10a. Sasse (Section 1), 10b. Sasse (Section 2).

In Phases I and II, GIS data files (ESRI geodatabases) were developed that spatially depict the potential for buried cultural resources by county. Determining the potential for buried cultural deposits involved consideration of four factors: (1) the age of sedimentary deposits, (2) the soil stratigraphic record, (3) the depositional environment (high energy vs. low energy), and (4) the drainage conditions (poorly drained vs. well drained). Soil data from the Soil Survey Geographic database (SSURGO) was the primary dataset used to obtain information pertaining to the four factors. Refer to the Phase II report for information on how SSURGO data (e.g., flood frequency, drainage, geomorphology, soil horizonation, parent material) were scored to provide a measure of potential for buried cultural resources (Layzell et al., 2021).

In Phase III, we evaluated the *Nebraska Buried Sites GIS* model developed in previous phases from SSURGO data for the Sandhills region. Assessment was performed by comparing predicted buried site potential with landforms (e.g., terraces, floodplains, alluvial fans) identified from Lidar data. Specifically, Lidar data was used to develop relative elevation models (REMs) for select stream valleys in the Sandhills, including the North Loup, Middle Loup, and Dismal Rivers, to help delineate LSAs and better assess the potential for buried cultural deposits predicted by the *Nebraska Buried Sites GIS*. REMs were created in ArcGIS as follows:

1. Download and mosaic Bare Earth LiDAR tiles for area of interest (AOI) (i.e., river valley).
2. Create fishnet over AOI (Create Fishnet tool). Fishnet node spacing is dictated by the scale of the project and by the stream gradient (i.e., steeper slopes need a tighter node spacing).
3. Orient the fishnet so that transects lie perpendicular to the stream channel (Rotate tool).
4. Extract the elevation of the stream channel at each individual fishnet transect.
5. Create a TIN (triangular integrated network) using the stream channel elevation field from the fishnet.
6. Use TIN to raster tool to convert the TIN to a DEM that represents the elevation of the stream channel. Specify DEM pixel resolution comparable to the original Bare Earth LiDAR data.
7. Use Clip tool to clip the stream channel DEM to the AOI to reduce computational workload.
8. Create an REM by subtracting the stream channel DEM from the original LiDAR bare earth DEM and adding 100 m to the stream bed DEM (Raster Calculator tool). Adding 100 m gives the final REM exclusively positive numbers. Note, a value of 100 in the REM represents stream channel elevation and numbers above 100 represent elevation above the stream channel (i.e., pixel value of 101 = 1 m above the channel).
9. Set values above a given threshold as null (Raster Calculator tool) to limit the AOI to the river valley. In this study, thresholds of 10 m and 15 m were used. These thresholds remove landforms such as upland dunes from the REM.
10. Classify the REM so that polygons are ranked in order of elevation above channel then reclassify the REM into 1 m bins (Reclassify tool).
11. Convert the raster classes into polygons (Raster to Polygon tool) where raster class 1 is polygon value 1, raster class 2 is polygon value 2, etc. This conversion considerably reduces the file size and allows the user to pan and zoom more easily.

In the final REM model for each stream valley, potential was symbolized based on the elevation of different LSA's above the stream channel (Table 2.1). Information pertaining to the inferred LSAs was tested by geomorphological investigation at 10 localities in the study area

(Figure 2.1). The geomorphological investigation initially involved a reconnaissance of the study area. An effort was made to locate thick, vertical sections of alluvium exposed in streambanks and roadcuts.

Table 2.1 Buried potential depicted in the REM maps based on relative elevation and associated LSA

Elevation above channel (m)	LSA	Potential
0-1	Floodplain (T-0a)	Low
1-3	Floodplain (T-0b and T-0c)	Moderate
3-8	Terrace, alluvial fan, footslope	High
8-10	Dune/interdune, alluvial fan, colluvial aprons	Variable

The next phase of the geomorphological investigation involved soil-stratigraphic studies at the 10 localities selected. Profiles at the sections were cleaned off with a hand shovel and described. Soils were described using standard procedures and terminology outlined by Birkeland (1999) and Schoeneberger et al. (2012). However, when multiple buried soils were present, the horizon nomenclature presented by Holliday (2004:339) was used. Specifically, the buried soils were numbered consecutively from the top of a section downward, with the number following the "b" suffix. For example, the A horizons of three superposed buried soils would be numbered Ab1, Ab2, and Ab3 from top to bottom.

Soils were included in the stratigraphic framework of every profile that was described. Soils are important to the subdivision of Quaternary sediments, whether the soils are at the present-day land surface or buried (Birkeland 1999). After soils were identified and described, they were numbered consecutively, beginning with 1, the modern surface soil, at the top of the profile. Graphic profiles were constructed to visually convey soil-stratigraphic information for all the sections.

Charcoal, peat, plant macrofossils, and bulk soil and sediment samples were submitted to DirectAMS, Inc., for AMS radiocarbon (^{14}C) dating. In the text of this report, radiocarbon ages are reported in median calibrated years before present (cal yr BP), and the uncalibrated radiocarbon ages are listed in Table 3.1. All radiocarbon ages were corrected for isotopic fractionation.

The numerical ages of buried landscapes were determined by radiocarbon dating soil organic matter (SOM) extracted from bulk soil samples. This approach has been used in many previous studies (e.g., May, 1989; Mandel, 1992, 2006, 2008, Rawling et al., 2003; Layzell and Mandel, 2020; Mandel et al., 2023). The radiocarbon ages determined on SOM represent mean residence times for all decalcified organic carbon in the samples (see Campbell et al., 1967). Although mean residence time does not provide the absolute age of a buried soil, it does give a minimum age for the period of soil development, and it provides a limiting age on the overlying material (Birkeland, 1999:137; Holliday, 2006; Holliday and Mandel, 2017b).

Chapter 3 Results

In Phase III, the *Nebraska Buried Sites GIS* model (hereafter SSURGO model) and the newly developed REMs were evaluated at 10 field localities in the North Loup, Middle Loup, Dismal, and Snake River valleys in the Sandhills (Figure 2.1). A total of 58 new radiocarbon ages provides chronological control for the LSAs investigated (Table 3.1).

Table 3.1 Radiocarbon sample information

River	Locality	Landform	Sedimentary Deposit	Depth (cm)	^{14}C age (^{14}Cyr BP)	Calibrated age (cal yr BP)[1] Range (2σ)	Median	Material dated	Lab ID D-AMS
North Loup	1. Miles	T-1 terrace	Alluvium	29-39	100±20	255-30	115	SOM[2]	052101
			Alluvium	94-104	1140±20	1175-960	1020	SOM	052102
			Alluvium	154-164	1540±25	1515-1355	1405	SOM	052103
			Paludal	219-223	1740±20	1705-1550	1630	Peat, TOM[3]	052104
			Paludal	278-283	1955±25	1985-1825	1880	Organic-rich sediment	052105
	2. Wyckoff	Alluvial fan	Paludal	495	590±25	645-540	605	Plant material	052097
			Paludal	528	760±25	725-670	685	Plant material	052098
			Paludal	593	1285±25	1285-1175	1225	Plant material	052096
Middle Loup	3b. Fits Drive (Sec 1)	Dune/terrace	Paludal	300	7345±35	8285-8025	8115	Organic-rich sediment	052119
			Paludal	497	8070±35	9120-8775	9000	Organic-rich sediment	052120
	3a. Fits Drive (Sec 2)	Sand dune	Eolian	88-98	1080±25	1055-930	980	SOM	052122
			Eolian	128-133	1505±25	1410-1310	1375	SOM	052123
	4. Bostron	T-0b floodplain	Alluvium	44-54	100±20	255-30	115	SOM	052117
			Alluvium	54-64	275±20	430-160	315	SOM	052118
	5. O'Brien	Alluvial fan	Alluvium	82-90	290±20	430-295	395	SOM	052111
			Alluvium	124-134	590±20	645-545	605	SOM	052112
			Paludal	710	990±25	955-795	870	Peat, TOM	052113
			Paludal	748	1360±25	1340-1180	1290	Organic-rich sediment	052114
			Paludal	763	1570±25	1520-1390	1460	Organic-rich sediment	052115
			Paludal	773	1700±25	1695-1535	1585	Organic-rich sediment	052116
	6. Nutter	T-1 terrace	Alluvium	45-55	130±20	270-10	110	SOM	050770
			Alluvium	145-155	790±20	730-675	705	SOM	050771
			Lacustrine	230	9225±30	10,500-10,260	10,385	Charcoal	050773
			Lacustrine	255	9335±40	10,690-10,415	10,545	Charcoal	050775
			Alluvium	282	9370±35	10,695-10,500	10,590	Wood	050776
			Paludal	302	9365±50	10,725-10,425	10,585	Plant material	050777
			Paludal	337	10,560±40	12,695-12,480	12,600	Charcoal	050782
South Fork Dismal	7a. Munn (Sec 1)	Dune/T-1 terrace	Alluvium	269-171	8005±40	9010-8650	8870	Organic-rich sediment	020829
			Alluvium	382	8275±55	9430-9030	9265	Charcoal	020833
			Alluvium	385-395	8585±50	9675-9485	9545	SOM	020828
	7b. Munn (Sec 2)	Sand dune	Eolian	90-95	3170±40	3460-3260	3395	SOM	022228
			Eolian	122-127	5140±50	5995-5745	5895	SOM	020831

Table 3.1 continued

River	Locality	Landform	Sedimentary Deposit	Depth (cm)	^{14}C age (^{14}Cyr BP)	Calibrated age (cal yr BP)[1] Range (2σ)	Median	Material dated	Lab ID D-AMS
	7c. Munn (Sec 3)	Sand dune	Eolian	125-130	945±40	925-745	850	SOM	022830
	7d. Munn (Sec 4)	Dune/T-1 terrace	Lacustrine	200	9030±45	10,255-9965	10,210	Charcoal	022837
			Alluvium	263	10,015±45	11,735-11,280	11,510	Charcoal	022834
			Alluvium	413	10,115±40	11,925-11,405	11,720	Charcoal	022836
	7e. Munn (Sec 5)	Dune/T-1 terrace	Lacustrine	30-40	7430±45	8370-8065	8260	Organic-rich sediment	022825
			Lacustrine	40-50	7695±55	8590-8395	8480	Organic-rich sediment	022826
			Lacustrine	50-60	8940±50	10,220-9905	10,055	Organic-rich sediment	022827
			Paludal	144	9695±40	11,225-10,810	11,135	Charcoal	022832
North Fork Dismal	8. 25HO47	T-1 terrace	Alluvium	100-110	1160±35	1175-960	1070	SOM	020822
			Alluvium	420-430	2345±40	2665-2180	2365	SOM	020823
			Alluvium	490-500	3930±35	4510-4245	4365	SOM	020824
Dismal	9. Anderson	T-1 terrace	Alluvium	40-50	470±25	535-495	515	SOM	052106
			Lacustrine	123-128	960±25	920-795	850	Organic-rich sediment	052099
			Lacustrine	138-141	1185±25	1175-1005	1105	Charcoal	052108
			Lacustrine	146-151	1320±25	1295-1175	1250	Organic-rich sediment	052108
			Lacustrine	160-165	1690±25	1690-1530	1575	Organic-rich sediment	052109
			Lacustrine	178	1975±30	1990-1830	1905	Organic-rich sediment	052110
Snake	10a. Sasse (Sec 1)	Dune/terrace	Paludal	480-490	7370±40	8320-8035	8180	Organic-rich sediment	035457
			Paludal	480-490	7705±40	8585-8410	8485	Organic-rich sediment	035458
			Paludal	555-560	8500±40	9500-9460	9505	Organic-rich sediment	035459
			Paludal	645-650	9580±40	11,140-10,735	10,930	Peat, TOM	035461
			Paludal	625-630	10195±60	12,430-11,410	11,860	Peat, TOM	035460
			Paludal	~100	10450±40	12,615-12,100	12,375	Peat, TOM	035462
	10b. Sasse (Sec 2)	Dune/T-1 terrace	Paludal	153-163	1135±35	1175-955	1025	Organic-rich sediment	035463
			Paludal	180-190	1285±30	1290-1130	1225	Organic-rich sediment	035464
			Paludal	220-230	2065±30	2115-1940	2025	Organic-rich sediment	035465
			Paludal	330-340	2750±30	2930-2765	2830	Organic-rich sediment	035466

[1]Calibration was performed with CALIB 8.2 using calibration dataset IntCal20.

[2]SOM = soil organic matter

[3]TOM = total organic matter

3.1 North Loup River

3.1.1 Miles Locality (Locality 1)

Figure 3.1 shows the potential for buried cultural deposits in the North Loup River valley at the Miles Locality. Based on SSURGO data, the Almeria and Fluvaquents soil series indicate low potential (Figure 3.1A). The low potential is attributed to (1) poor to very poor drainage conditions, (2) a floodplain setting, (3) weakly developed soils with A-C horizonation, and (4) sandy textured sediments. Overall, the SSURGO data indicate a high-energy fluvial environment proximal to the channel. It is very unlikely that any deeply buried *in situ* cultural deposits are preserved in this type of depositional environment.

The Bolent soil series indicates low-moderate potential based on (1) somewhat poorly drained conditions, (2) a floodplain setting, and (3) weakly developed soils with A-C horizonation. Bolent soils are occasionally flooded, suggesting a higher landscape position (i.e., T-0b and T-0c floodplain LSAs) relative to other floodplain soils (e.g., Almeria soils).

The SSURGO model suggests that some potential may exist for select polygons mapped as the Elsmere, Loup, and Tryon soil series. These soils have eolian parent materials but are described as “swales on interdunes” in SSURGO. Therefore, there may be some potential for buried cultural deposits on the margins of these swales.

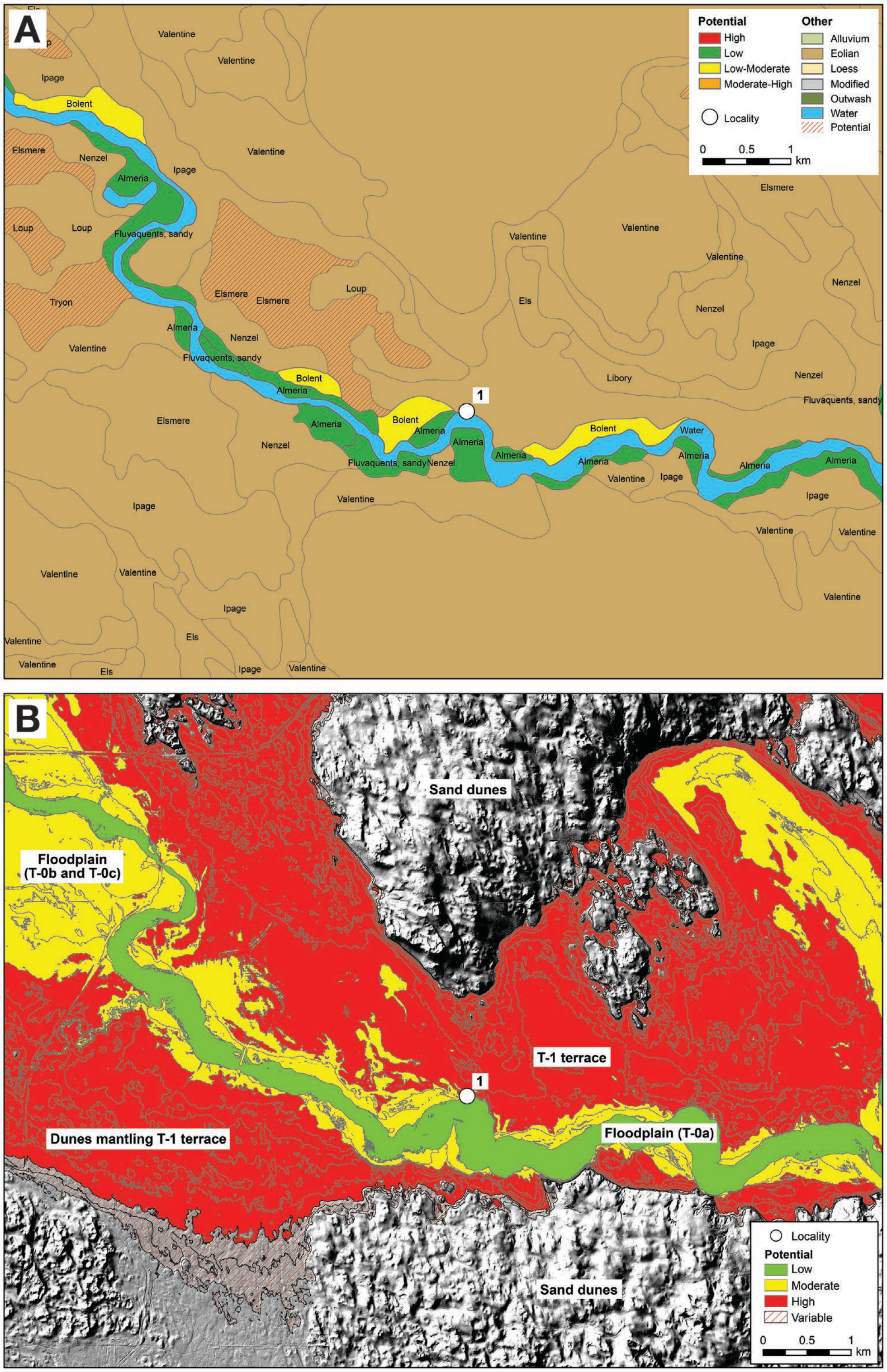

Figure 3.1 Maps of buried cultural resource potential for the North Loup River at the Miles locality (Locality 1). Potential for buried cultural deposits based on (A) SSURGO model and (B) REM data.

The REM map (Figure 3.1B) confirms that in general, SSURGO polygons mapped as having low potential (i.e., Almeria and Fluvaquents soil series) represent the T-0a floodplain, which stands less than 1 m above the modern stream channel. However, because of the spatial limitations of the SSURGO data, some of these low potential polygons include T-0b and T-0c LSAs, which are attributed moderate potential on the REM map. In the North Loup River valley, the T-0b and T-0c surfaces typically stand 1–2 m and 2–3 m above the modern stream channel, respectively. The REM map indicates that Bolent soils represent T-0b/T-0c LSAs. However, in the SSURGO model much of the T-0b and T-0c surfaces are mapped as eolian sands (e.g., Loup, Nenzel, and Ipage soil series). While T-0b and T-0c surfaces can be mantled by eolian deposits, there is still a low-moderate potential associated with these LSAs. Similarly, the T-1 terrace, which has a high potential for buried cultural deposits, is not delineated in the SSURGO model. Instead, the T-1 surface is mapped with eolian soil series (e.g., Ipage, Loup, Elsmere, Nenzel, Valentine soil series). Hence, the REM and SSURGO models should be used in conjunction to best determine the appropriate potential for a given LSA.

At the Miles Locality in the North Loup River valley (Figures 2.1 and 3.1B), the river channel has migrated laterally and is cutting into the T-1 terrace on the north side of the valley floor (Figure 3.2). The T-1 surface is about 4–5 m above the modern stream channel and spans most of the valley floor (Figure 3.1B). A 3.6 m-thick section of T-1 fill was described and sampled for radiocarbon-dateable material.

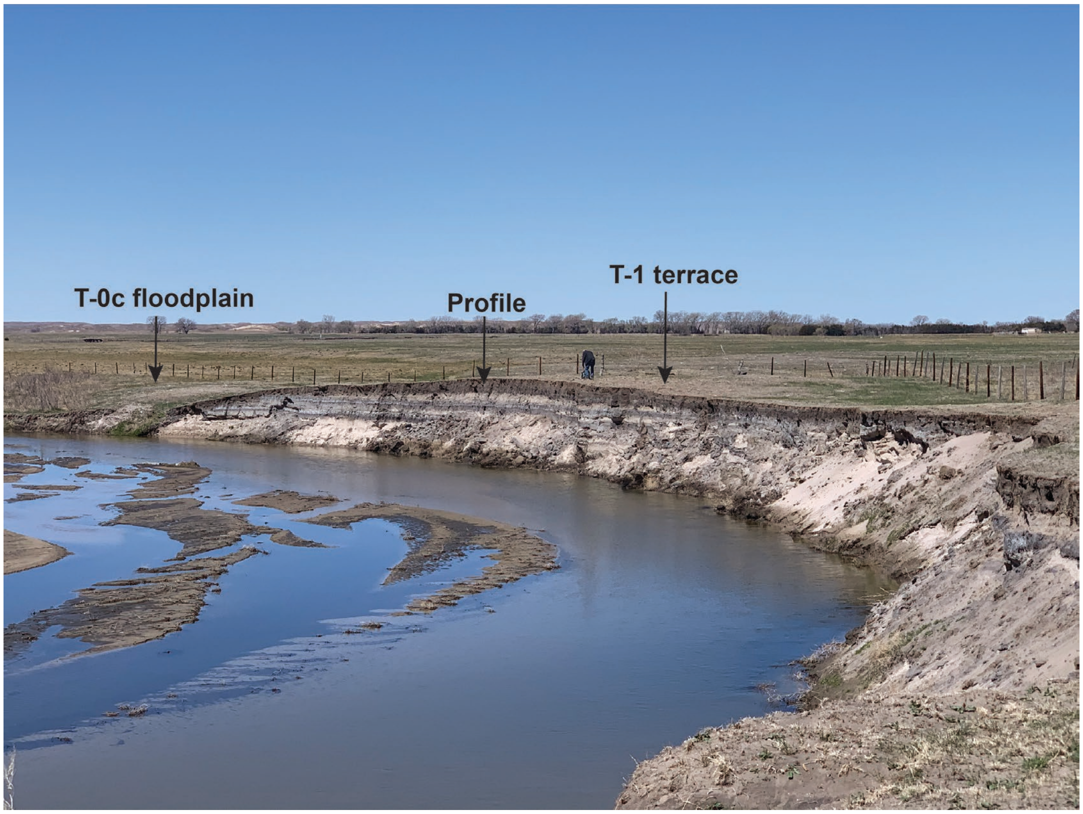

Figure 3.2 Photograph of the Miles Locality in the North Loup River valley.

The lower 59 cm of the section at the Miles Locality consists of sandy channel fill (Figure 3.3; Table A.1). Sandy alluvium at a depth of 180 to 301 cm below the T-1 surface is interbedded with thick and thin organic-rich deposits, including peaty muck and gyttja that accumulated in a paludal environment. The gyttja is a black mud that formed from the partial decay of peat and has a gel-like or rubbery consistency. Many of the beds of organic-rich sediment at a depth of 180 to 301 cm are slightly wavy to folded or overturned (Figure 3.4A). The convoluted beds represent soft-sediment deformation that occurred during or shortly after deposition of alluvium on top of the beds. Samples of organic-rich material from the upper 5 cm of the gyttja near the top of the sequence of paludal deposits and the upper 5 cm of the peaty muck near the bottom of the sequence yielded radiocarbon ages of 1630 cal yr BP and 1880 cal yr BP, respectively.

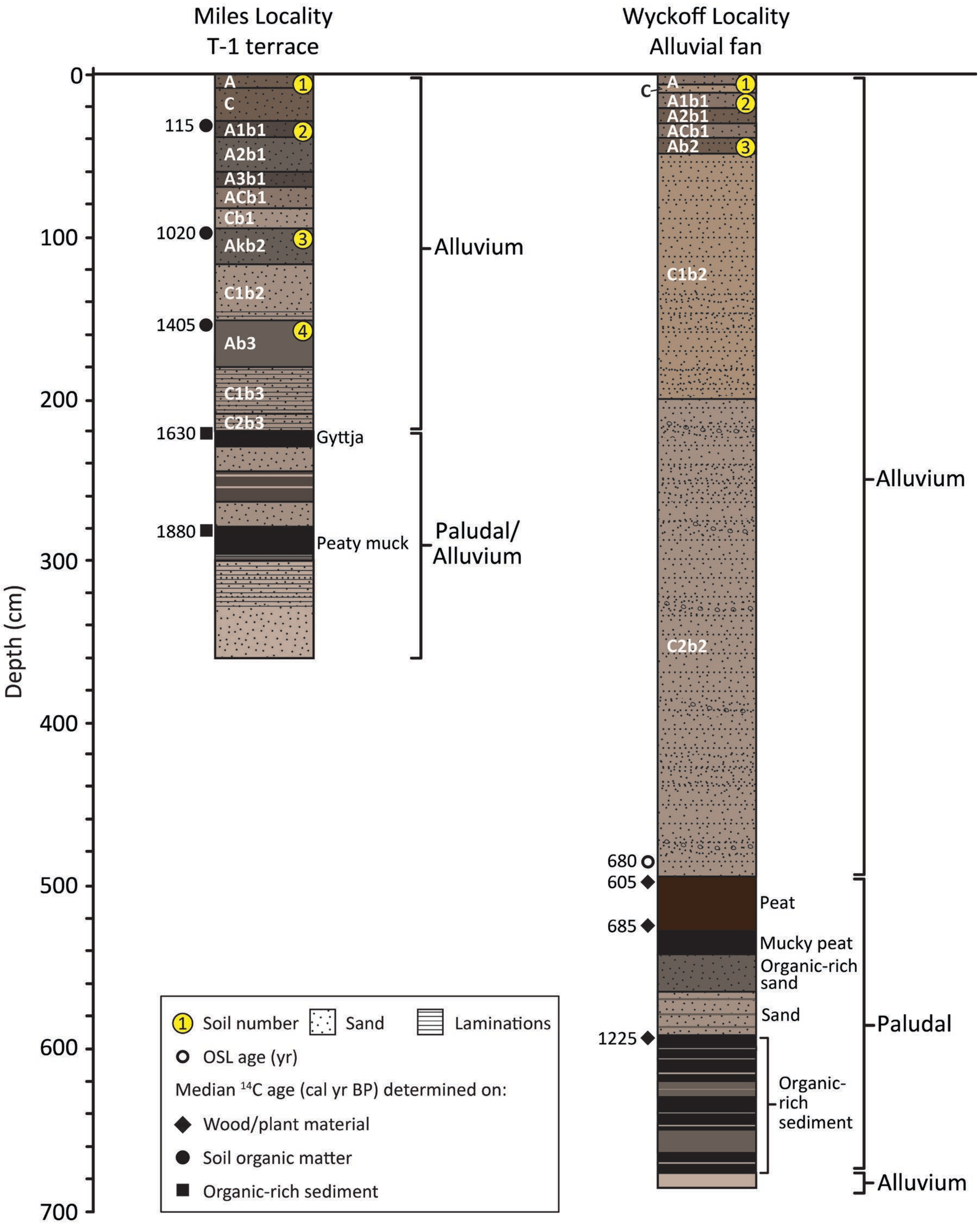

Figure 3.3 Diagram of the soil-stratigraphy from the Miles and Wyckoff localities in the North Loup River valley.

The sequence of paludal deposits in the lower half of the section is mantled by sandy and loamy vertical accretion deposits that continue to the top of the T-1 terrace. The modern surface soil (Soil 1) and three buried soils (soils 2, 3, and 4) are developed in the upper 180 cm of the T-1 fill (Figures 3.3 and 3.4). All these soils have weakly expressed A-C, A-AC-C, or Ak-C profiles suggesting that they are products of relatively short episodes of landscape stability. This interpretation of the soils evidence is supported by the radiocarbon ages determined on SOM. Soil organic matter from the upper 10 cm of the A1b1 horizon of Soil 2, the upper 10 cm of the Akb2 horizon of Soil 3, and the upper 10 cm of the Ab3 horizon of Soil 4 yielded radiocarbon ages of 115 cal yr BP, 1020 cal yr BP, and 1405 cal yr BP, respectively.

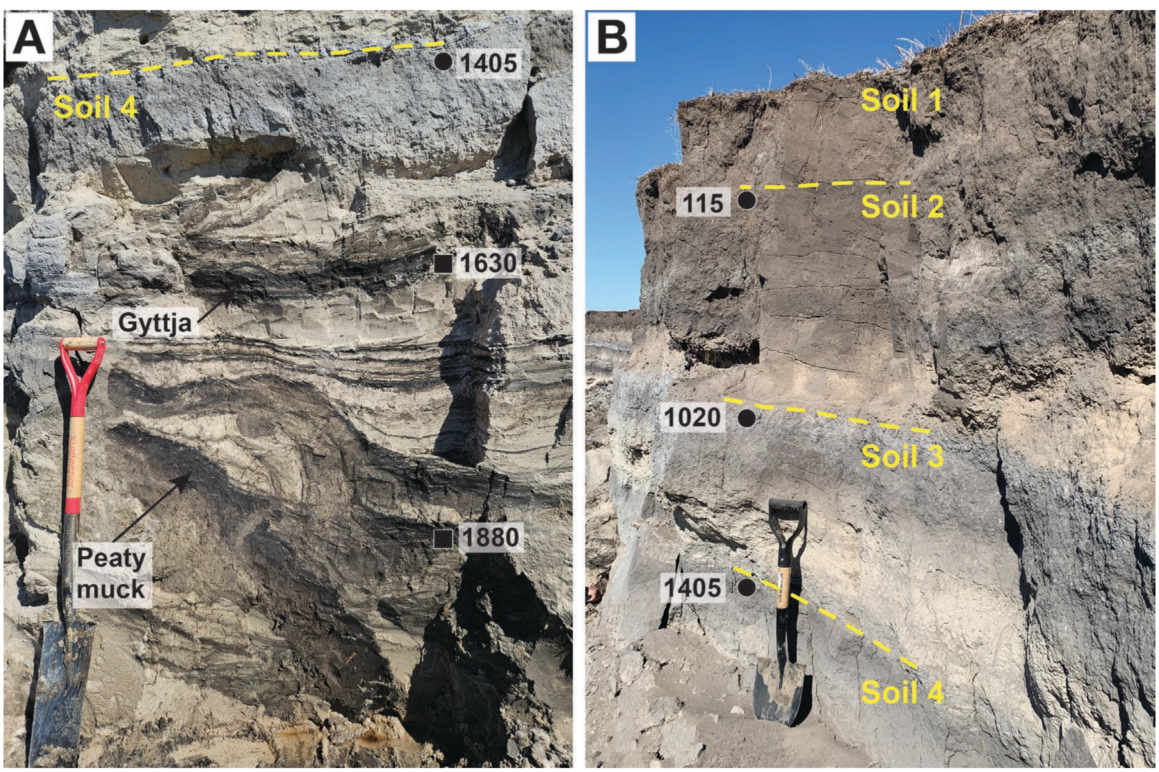

Figure 3.4 Photograph of the profile described at the Miles Locality in the North Loup River valley. (A) lower part of the profile, (B) upper part of the profile.

Based on the numerical ages and the characteristics of the deposits in the Miles section, a paludal environment was in place on the valley floor of the North Loup River between ca. 1880 and 1630 cal yr BP. Rapid aggradation was underway on the late Holocene floodplain (now the T-1 terrace) soon after ca. 1630 cal yr BP and was punctuated by two brief episodes of landscape stability and soil development (soils 3 and 4) between ca. 1,600 and 1,000 years ago. The shallowest buried soil (Soil 2) formed sometime between ca. 1,000 and 100 years ago and is mantled by a thin veneer of modern alluvium that is the parent material of the surface soil (Soil 1).

The timing of stream incision that transformed the late Holocene floodplain of the North Loup River into a terrace (T-1) is unknown. However, based on the regional alluvial chronology (Mandel 2006), it probably occurred around 1,000 years ago.

The sequence of paludal and alluvial deposits in the lower half of the section at the Miles Locality has relatively low potential for containing buried cultural deposits. Rapid alluviation on an unstable late-Holocene floodplain (now the T-1 terrace) was followed by slow sedimentation and the establishment of a wetland between about 1,900 and 1,600 years ago. As previously noted, it is likely that people visited wetlands for hunting and gathering, but unlikely that they would have spent much time in such wet environments. Instead, they would have occupied well-drained landforms adjacent to the wetlands. At the Miles Locality, the T-1 fill above the paludal deposits is well drained and has three weakly developed buried soils with moderate potential for containing cultural deposits. Soils 4 and 3 formed between about 1,600 and 1,000 years ago and have potential for containing Plains Woodland cultural deposits. Soil 2 is the shallowest buried soil in the stratigraphic sequence and formed sometime between about 1,000 and 100 years ago and has potential for containing Plains Village and younger cultural deposits.

3.1.2 Wyckoff Locality (Locality 2)

Figure 3.5 shows the potential for buried cultural deposits in the North Loup River valley at the Wyckoff Locality. Based on SSURGO data, the Almeria and Fluvaquents soil series indicate low potential (Figure 3.5A). The low potential is attributed to (1) poorly (Almeria) to very poorly (Fluvaquents) drained conditions, (2) a floodplain setting that is either occasionally (Almeria) or frequently (Fluvaquents) flooded, (3) weakly developed soils with A-C-Cg horizonation (Almeria) or Oe-Cg (Fluvaquents) horizonation, and (4) sandy textured sediments.

The Bolent and Calamus soil series indicate low-moderate potential based on (1) somewhat poorly drained (Bolent) to moderately well drained (Calamus) conditions, (2) a floodplain setting, (3) weakly developed soils with A-C horizonation, and (4) sandy textures. In this study reach, Bolent soils are occasionally flooded and Calamus soils are never flooded, suggesting relatively higher landscape positions (i.e., T-0b and T-0c floodplain LSAs) relative to other floodplain soils (e.g., Almeria and Fluvaquent soil series).

The Vetal soil series indicates high potential and is associated with the T-1 terrace in the North Loup River valley. The assignment of high potential from SSURGO data is based on (1) well drained conditions, (2) association with stream terrace LSAs, (3) moderately developed soils with overthickened A horizons, and (4) loamy soil texture.

The SSURGO model suggests that some potential may exist for select polygons mapped as the Ipage soil series. These soils have eolian parent materials but are described as “stream terraces” in SSURGO. Hence, these polygons likely represent T-1 terrace LSAs mantled by sand dunes and, therefore, have a high potential for buried cultural resources.

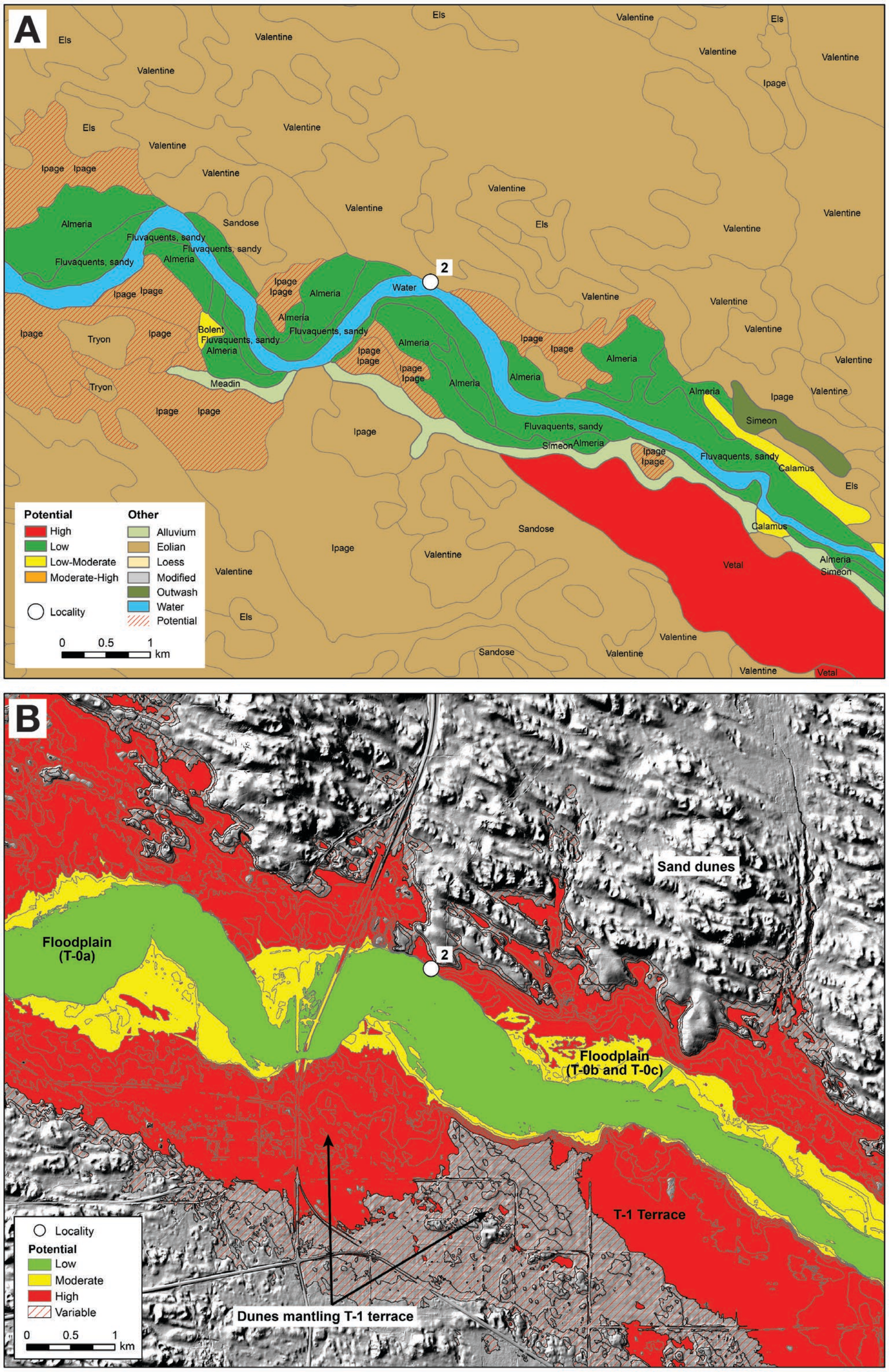

Figure 3.5 Maps of buried cultural resource potential for the North Loup River at the Wyckoff locality (Locality 2). Potential for buried cultural deposits based on (A) SSURGO model and (B) REM data.

The REM map (Figure 3.5B) confirms that in general SSURGO polygons mapped as having low potential (i.e., Almeria and Fluvaquents soil series) represent the T-0a floodplain. However, the SSURGO model does not appear to adequately map the extent of T-0b and T-0c LSAs. For example, some of these LSAs as depicted on the REM map are mapped as Almeria soils (T-0a; low potential) in the SSURGO model while others are mapped by polygons representing eolian sands (e.g., Ipage). While T-0b and T-0c surfaces can be mantled by eolian deposits, there is still a low-moderate potential associated with these floodplain LSAs. Similarly, the T-1 terrace, which has a high potential for buried cultural deposits, is only partially mapped in the SSURGO model. In most areas where the T-1 terrace is mapped by the REM, the SSURGO model maps this LSA with eolian soil series (e.g., Ipage soils) because the T-1 surface is typically mantled by dune sand. Some of the Ipage soils have geomorphic descriptors associating them with stream terraces and are therefore attributed as having some potential in the SSURGO model. However, other Ipage polygons do not have a stream terrace descriptor, even though the REM map indicates the presence of the T-1 LSA beneath these eolian deposits. Hence, the REM and SSURGO models should be used in conjunction to best determine the appropriate LSA and the likely associated potential.

At the Wyckoff Locality (Figures 2.1 and 3.5B), a long, steep cutbank on the north side of the North Loup River provided an opportunity to study a thick section of alluvium (Figure 3.6). The land surface is relatively flat and resembles a terrace in the immediate area of the cutbank. However, other lines of evidence, as described below, strongly suggest that an alluvial fan mantles late-Holocene floodplain deposits at Wyckoff. A detailed description of the stratigraphic sequence was completed to a depth of 6.85 m below the surface at the Wyckoff section (Figure 3.3; Table A.2), and the analysis of the section is supported by OSL and radiocarbon dating.

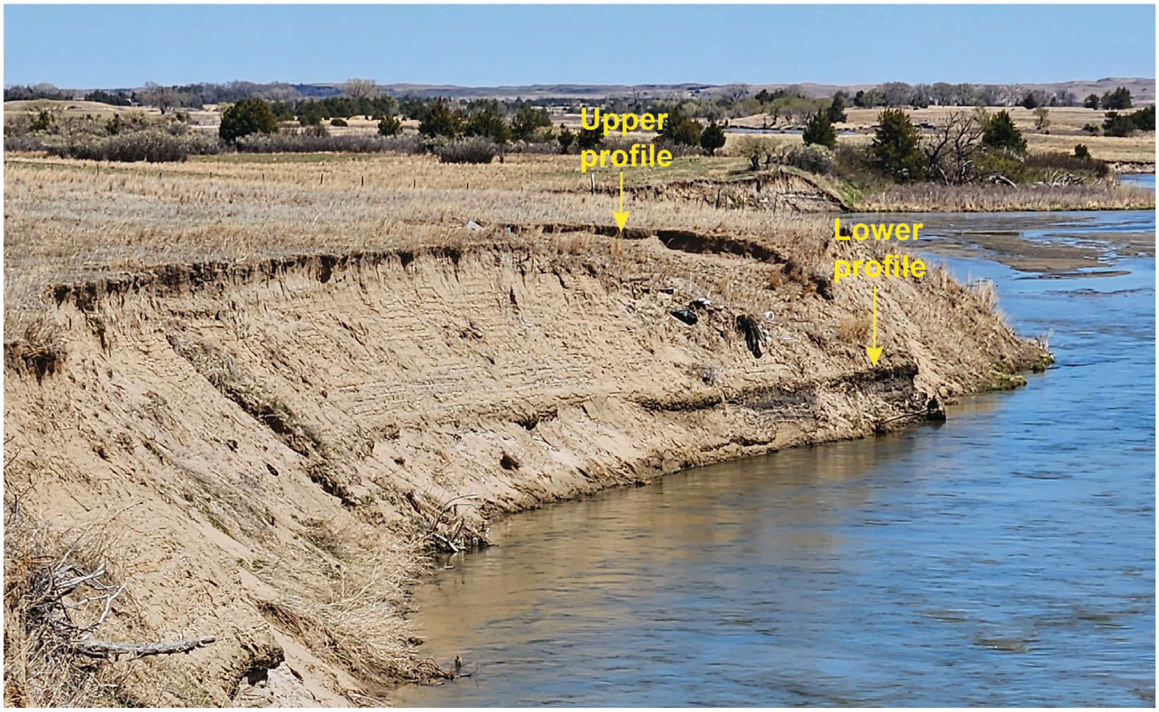

Figure 3.6 Photograph of the Wyckoff Locality in the North Loup River valley.

In the lower profile, a prominent brown fibrous peat occurs at a depth of 495–528 cm below the fan surface, and other organic-rich paludal deposits span most of the 157 cm below the peat, almost to the bottom of the section (Figures 3.3 and 3.7A). Plant material collected from the upper 5 cm and lower 5 cm of the brown peat, at depths of 495 cm and 528 cm below the surface, yielded radiocarbon ages of 605 and 685 cal yr BP, respectively. Plant macrofossils collected at a depth of 593 cm below the surface, from the top of a unit of stratified organic-rich sediment below the peat, yielded a radiocarbon age of 1225 cal yr BP.

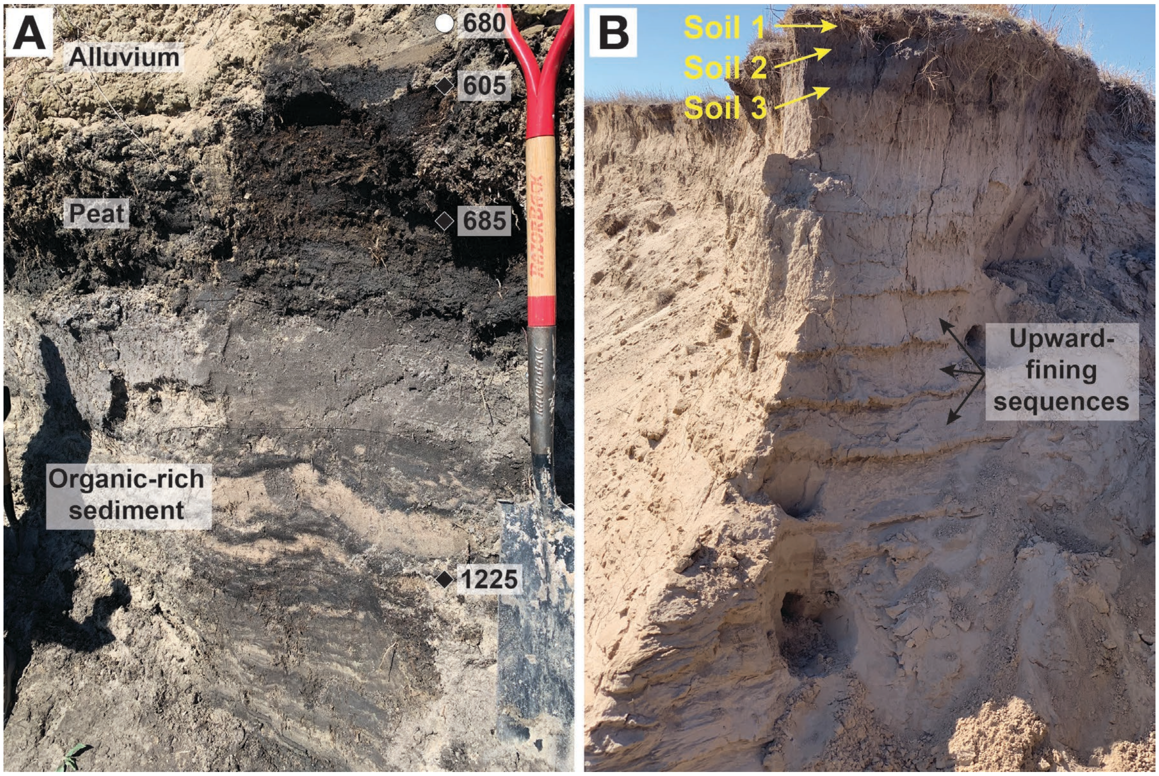

Figure 3.7 Photograph of the profiles described at the Wyckoff Locality in the North Loup River valley. (A) lower profile, (B) upper profile.

The peat and underlying organic-rich deposits spanning the lower ~2 m of the Wyckoff section are mantled by nearly 5 m of stratified sandy alluvium. The alluvium is characterized by upward-fining sequences (graded bedding), and thin beds of granules and fine pebbles are common. Two weakly developed buried soils occur in the upper 50 cm of the section (Figures 3.3 and 3.7B): Soil 2 with A-AC horizonation and Soil 3 with an A-C profile. The surface soil (Soil 1) also is weakly developed (A-C profile). The radiocarbon age of 605 cal yr BP determined on plant material from the upper 5 cm of the brown peat in the lower part of the section indicates that the ~5 m-thick body of sand above the peat accumulated over the past 600 years. This chronology is supported by an OSL age of 680±270 yr BP determined on quartz grains collected near the base of the sandy unit, at a depth of 4.90 m below the surface (Figure 3.3).

Based on the numerical ages and the characteristics of the deposits in the Wyckoff section, a paludal environment was in place on the valley floor of the North Loup River between ca. 1,225 and 600 years ago. Rapid aggradation occurred on the floodplain after ca. 600 cal yr BP. To account for the accumulation of nearly 5 m of sandy alluvium in about 600 years, we suggest that an alluvial fan prograded across the floodplain, burying a wetland. Although the land surface at the Wyckoff section is relatively flat and resembles the T-1 terrace, deposits of late-Holocene alluvium burying a former wetland beneath what is clearly the T-1 terrace upstream at the Miles locality are no more than about 2 m thick (Figure 3.3). Similarly, Brice (1964) identified an early-Holocene peat deposit (9000±200 ^{14}C yr BP; 10,100 cal yr BP) mantled by ~2.9 m of alluvium beneath a terrace about six miles upstream of the Wyckoff locality. Brice (1964) also documented a terrace (the Elba terrace) about five miles downstream of the Wyckoff locality. This terrace fill contained an early Holocene peat deposit (8400±250 ^{14}C yr BP; 9400 cal yr BP) that was mantled by ~1.5 m of alluvium.

In sum, based on the evidence presented from other localities in the North Loup River valley, it seems unlikely that the Wyckoff section represents rapid aggradation of the T-1 fill during the late Holocene. The rapid accumulation of about 5 m of sandy alluvium can, however, occur via localized deposition, i.e., the development of an alluvial fan. The alluvial fan at the O'Brien Locality (Locality 5) in the Middle Loup River valley is a case in point (see Section 3.2.2). There are potential drainage elements immediately north of the Wyckoff section that may have provided sediment to an alluvial fan, and the lack of fan geometry may be attributed to either being obscured by eolian deposits or to the position of the Wyckoff section on the fan. Distal segments of fans tend to be relatively flat, and at Wyckoff, a distal segment may have been near the point where it merged with T-1 fill that has been removed by lateral migration of the North Loup River.

Overall, there is relatively low potential for buried, in situ cultural deposits in the alluvial fan and underlying paludal deposits at the Wyckoff Locality. Although plant and animal resources may have attracted people to the late-Holocene wetland represented by the paludal deposits, it is likely that those people would have occupied well-drained LSAs adjacent to the wetland. Hence little, if any, of the material record of human occupation would not be in the paludal deposits. Also, the rapid, high-energy deposition that emplaced the alluvial fan above the paludal deposits would have been unfavorable for human occupation and preservation of cultural deposits. Although there are two buried soils in the upper 50 cm of the fan, they are products of very brief (a few tens of years) of landscape stability that probably occurred during the past 200-300 years.

3.2 Middle Loup River valley

3.2.1 Fits Drive Locality (Locality 3) and Bostron Locality (Locality 4)

Figure 3.8 shows the potential for buried cultural deposits in the Middle Loup River valley at the Fits Drive and Bostron localities. In this study reach, the Bolent soil series in the SSURGO model indicates low potential (Figure 3.8A). Here, the low potential is attributed to (1) poorly drained conditions, (2) a channeled, frequently flooded, floodplain setting, (3) weakly developed soils with A-C-Cg horizonation, and (4) sandy textured sediments.

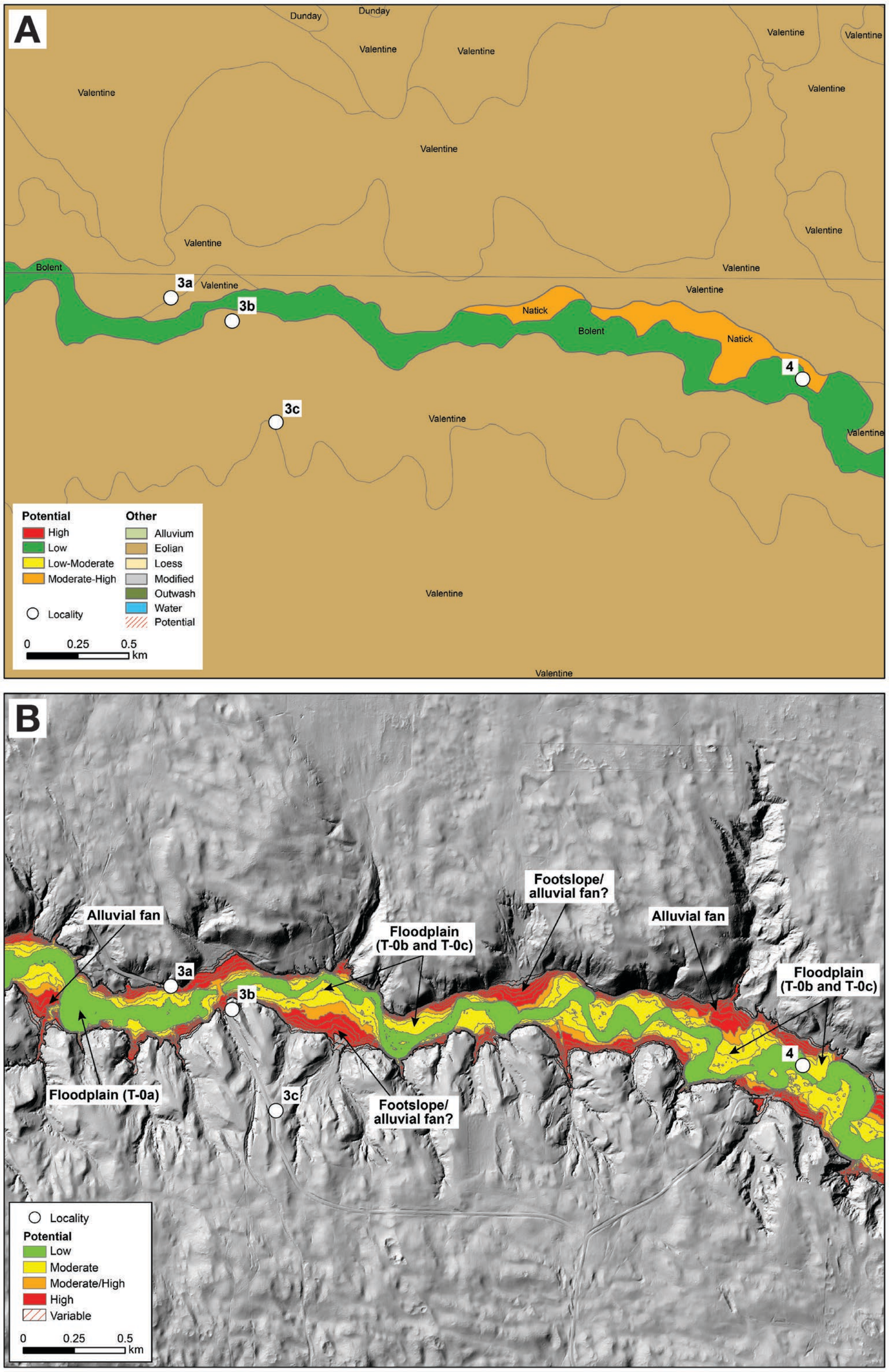

Figure 3.8 Maps of buried cultural resource potential for the Fits Drive Locality (Locality 3: 3a = Section 1, 3b = Section 2, 3c = Section 3) and Bostron Locality (Locality 4). Potential for buried cultural deposits based on (A) SSURGO model and (B) REM data.

The REM map (Figure 3.8B) highlights the spatial limitations of the SSURGO model, particularly in narrow stream valleys. For example, polygons attributed with low potential (i.e., Bolent soils) in the SSURGO model mostly represent T-0a floodplain LSAs but also include portions of T-0b and T-0c floodplain LSAs (moderate potential in REM) according to the REM map.

The REM map indicates that the polygons mapped as the Natick soil series in the SSURGO model correspond with T-0b and T-0c LSAs, as well as colluvial footslope and alluvial fan deposits that grade to these surfaces. However, in other portions of this study reach, these same LSAs are mapped in the SSURGO model as eolian deposits (i.e., Valentine soil series). It is difficult to delineate terraces from the REM data in narrow stream valleys because only isolated remnants of terrace fills are preserved against valley walls. Furthermore, the SSURGO model maps these isolated LSAs as eolian deposits (e.g., Valentine soil series) as they tend to be mantled by thick sand dunes. A case in point is Section 1 at the Fits Drive Locality (Locality 3a).

The Fits Drive Locality is the westernmost study site in the Middle Loup River valley (Figures 2.1 and 3.8B). Two deep roadcuts along Fits Drive provided an opportunity to examine thick sections consisting of alluvium and lacustrine deposits beneath sand dunes. Section 1 in the south-facing roadcut was described, and bulk soil samples were collected for radiocarbon dating. The stratigraphy in Section 2 in the west-facing roadcut was identified but not described in detail, and sediment samples were collected for radiocarbon and OSL dating. In addition, eolian deposits beneath a sand dune were examined in Section 3 in a west-facing roadcut upslope from Section 2.

Figure 3.9 Photograph of Section 1 described at the Fits Road Locality in the Middle Loup River valley.

In Section 1 (Figure 3.9), a 6.5 m-thick package of mostly sandy T-1 alluvium is mantled by about 3 m of eolian sand. However, only the alluvial stratigraphy was described (Figure 3.10; Table A.3). The contact between the eolian sand and the alluvium stands more than 10 m above the elevation of the modern stream channel, suggesting that the T-1 terrace tread is at notably higher elevations in narrow, upstream reaches of the Middle Loup River valley. The lower 4.31 m of the section consists of stratified alluvium that appears to have steadily aggraded, i.e., there are no buried soils in that portion of the section. By contrast, four buried soils, all with A-AC or A-C horizonation, occur in the upper ~2.2 m of the alluvium. The deepest buried soil, Soil 5, has an overthickened, cumulic A horizon. With cumulic soils, pedogenesis and sedimentation occur simultaneously because the rate of sedimentation is very slow (Birkeland, 1999). In other words, soil development keeps pace with sedimentation. The A horizons of the other buried soils are relatively thin and are products of short episodes of landscape stability.

Soil organic matter from the upper 10 cm of the A1b4 horizon of Soil 5 and upper 10 cm of the Ab1 horizon of Soil 2 yielded radiocarbon ages of 9000 cal yr BP and 8115 cal yr BP, respectively. Based on these ages, aggradation of the T-1 alluvium slowed around 9,000 years ago, allowing a soil (Soil 5) with a cumulic A horizon to form. Between about 9,000 and 8,100 years ago, relatively slow alluviation was punctuated by brief episodes of landscape stability and concomitant soil development. Sometime after 8115 cal yr BP, Soil 2 at the top of the T-1 fill was mantled by eolian sand.

The stratigraphy recorded in Section 1 is repeated in the upper half of Section 2. In the lower half of Section 2, beneath the alluvium, the stratigraphic sequence includes a 2 m-thick diatomite (Figure 3.11). The diatomite is mantled by a ~10 cm-thick bed of organic-rich lacustrine mud, and stratified sand and gravel occur beneath the diatomite. Organic carbon from the upper 5 cm of the lacustrine mud yielded a radiocarbon age of > 45,000 ^{14}C B.P., and quartz grains from a bed of sand immediately below the diatomite yielded an OSL age of > 75 ka.

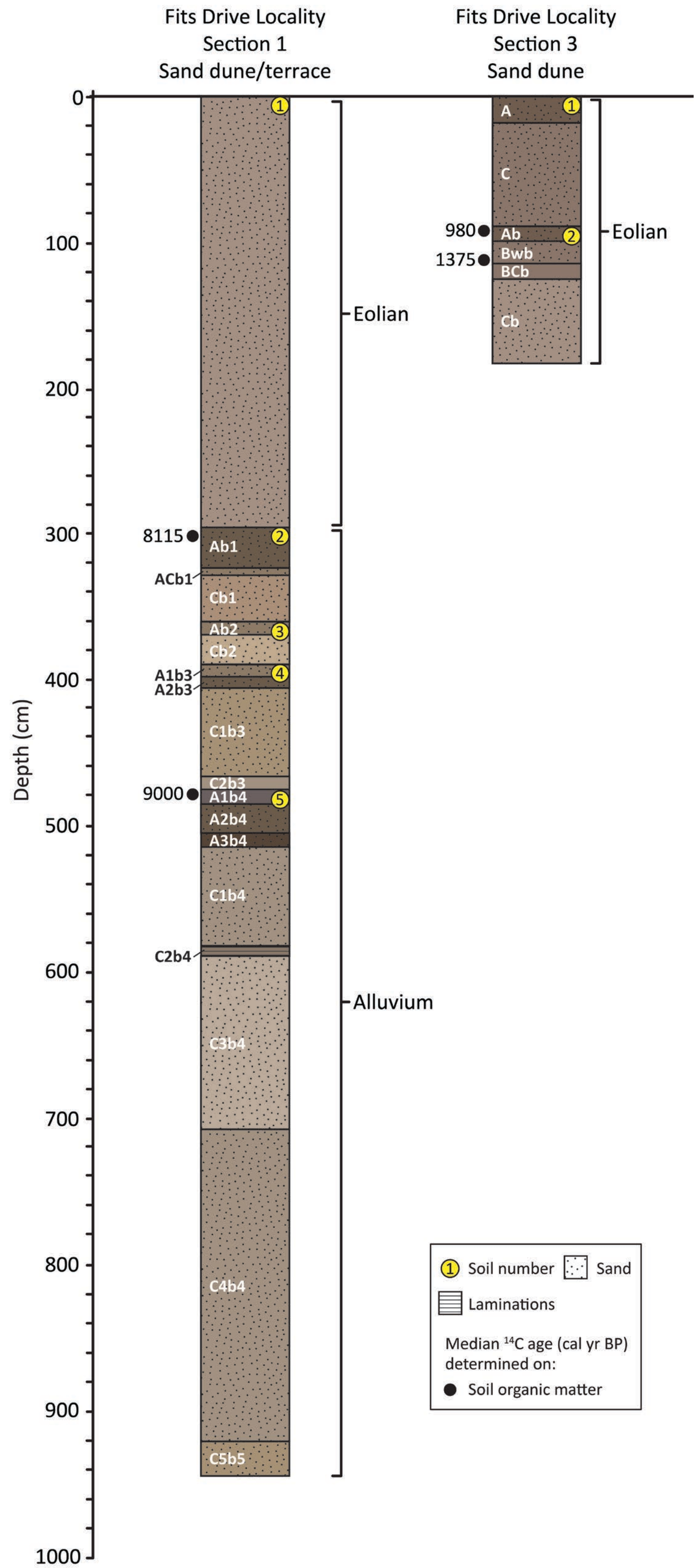

Figure 3.10 Diagram of the soil-stratigraphy from the Fits Drive Locality in the Middle Loup River valley.

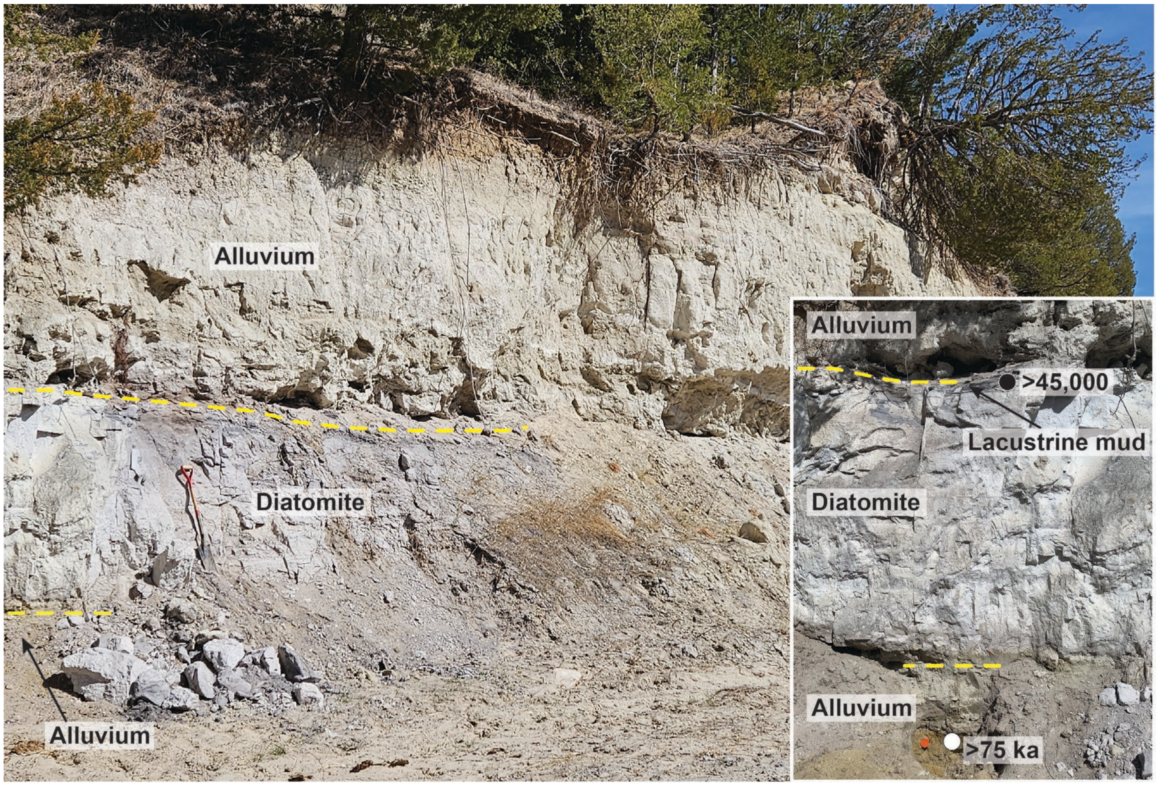

Figure 3.11 Photograph of Section 2 at the Fits Drive Locality in the Middle Loup River valley. Inset picture shows location and ages of radiocarbon and OSL samples.

In Section 3, a nearly 2 m-thick sequence of eolian sand was examined beneath a dune that formed on the uplands adjacent to Section 2 (Figure 3.10, Table A.4). A buried soil (Soil 2) with A-Bw-BC horizonation occurs at a depth of 88–143 cm below the surface of the dune. Soil organic matter from the upper 10 cm of the Ab horizon and lower 5 cm of the Bwb horizon of Soil 2 yielded radiocarbon ages of 980 cal yr BP and 1375 cal yr BP, respectively. Eolian sands above Soil 2 accumulated after 980 cal yr BP, and a surface soil with a thin A-C horizonation developed on the dune.

Based on the information gleaned from the three sections at the Fits Drive Locality, coarse-grained alluvium was accumulating on the valley floor of the Middle Loup River before 75 ka. Also, sometime before 45,000 ^{14}C years B.P., a lake occupied the valley floor. Because the valley is narrow, a dune could have easily dammed the river and created that lake. Although the rate at which diatoms accumulate can vary, given the thickness of the diatomite (~2 m), the lake probably persisted for decades and perhaps hundreds of years. The time when the diatomite and overlying bed of lacustrine mud were buried by alluvium is unknown. However, it occurred sometime before ca. 9000 cal yr BP. Initially, the aggradation of the alluvium above the lacustrine mud was rapid. However, it slowed by 9000 cal yr BP, allowing a cumulic soil (Soil 5) to form. Between ca. 9000 and 8115 cal yr BP, aggradation of the T-1 fill continued, but at a relatively slow rate and was punctuated by landscape stability and soil development, as indicated by multiple buried soils in the upper ~2.2 m of the T-1 fill.

There is evidence in Section 3 that during the late Holocene, eolian sands were accumulating on the upland landscape adjacent to the Middle Loup River. Accumulation of the eolian sand that forms the upper 2 m of the dune in Section 3 was interrupted by landscape stability and soil formation (Soil 2) around 1,400 to 1,000 years ago. Eolian sands above Soil 2 accumulated after 980 cal yr BP.

From an archeological perspective, there is low potential for buried cultural deposits in most of the alluvium exposed in sections 1 and 2. However, there is at least moderate potential for Late Paleoindian and Early Archaic cultural deposits in the weakly developed buried soils that occur in the upper 2.2 m of the T-1 fill. Also, there is high potential for Plains Woodland and Plains Village cultural deposits in the shallow buried soil that occurs in the sand dune on the uplands at the Fits Drive Locality.

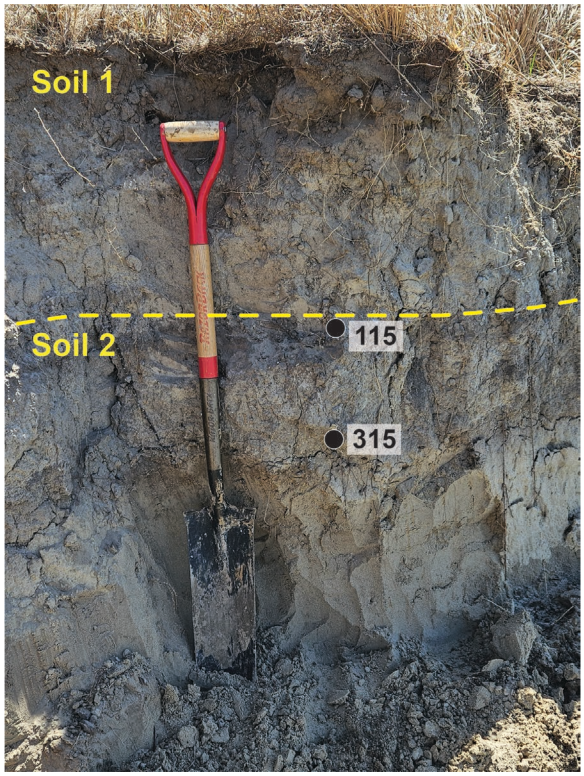

Figure 3.12 Photograph of profile described at the Bostron Locality in the Middle Loup River valley.

The Natick soil series, mapped in the downstream portion of this study reach and investigated at the Bostron Locality (Locality 4; Figure 3.8A), indicates moderate-high potential based on (1) moderately well drained conditions, (2) association with stream terrace LSAs, (3) weakly developed soils with A-AC-C horizonation, and (4) sandy textures. However, based on field observations and the REM map (Figure 3.8B), the LSA at the Bostron locality is not a stream terrace but rather the T-0b floodplain, which stands ~1.8 m above the stream channel.

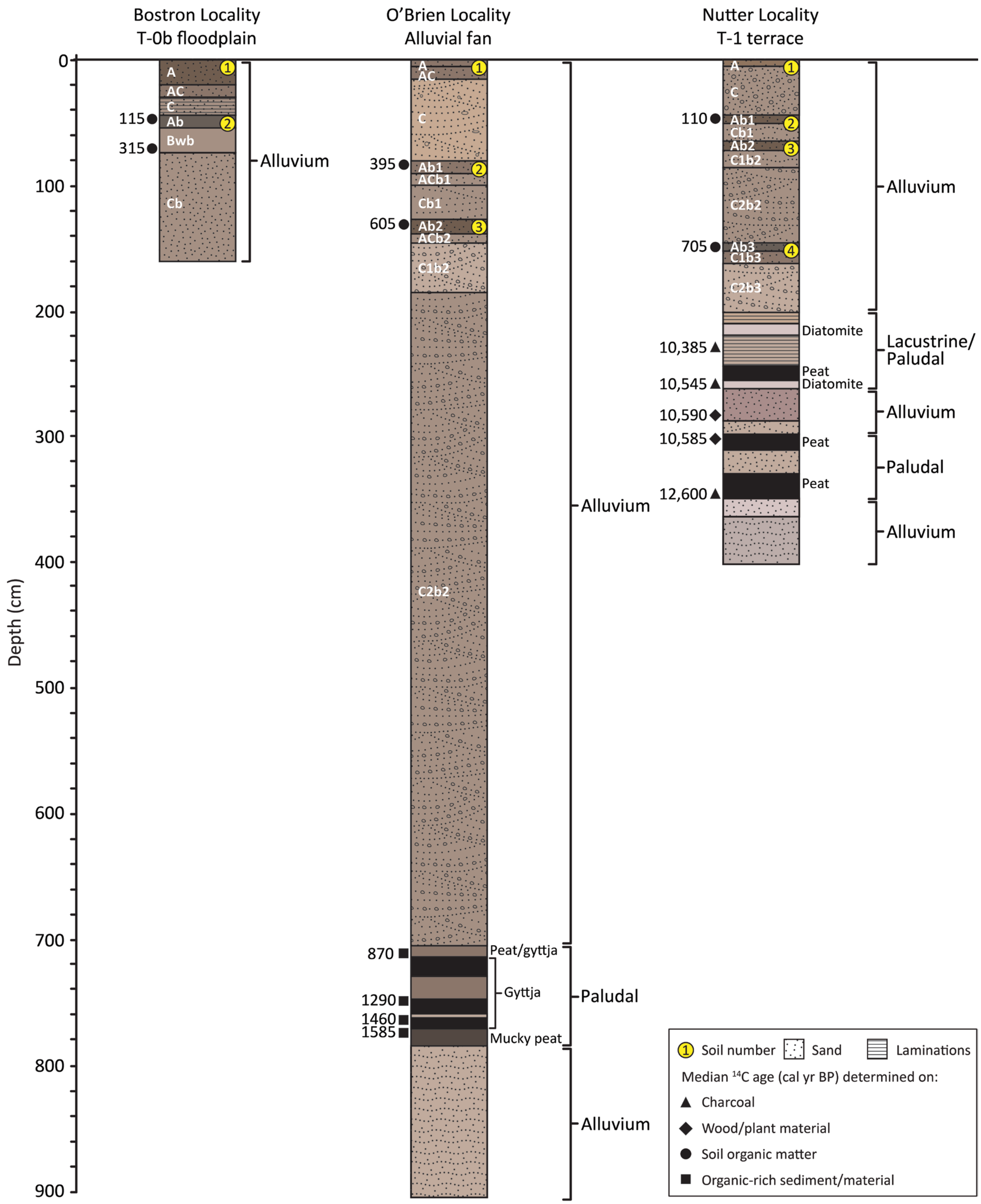

Figure 3.13 Diagram of the soil-stratigraphy from the Bostron (Locality 4), O'Brien (Locality 5), and Nutter (Locality 6) localities in the Middle Loup River valley.

A 1.6 m-thick section of T-0b fill was studied in a cutbank on the north side of the river (Figure 3.12). Two soils were recorded in the section: a buried soil (Soil 2) with A-Bw horizonation occurs at a depth of 44–74 cm below the T-0b surface, and a surface soil (Soil 1) with an A-AC-C profile is developed in sandy alluvium in the upper 44 cm of the section (Figure 3.13; Table A.5).

Soil organic matter from the upper 10 cm of the Ab horizon and lower 10 cm of the Bwb horizon of Soil 2 yielded radiocarbon ages of 115 cal yr BP and 315 cal yr BP, respectively. Based on these radiocarbon ages, aggradation of the upper 1.6 m of the T-0b fill slowed soon before 315 cal yr BP and the surface of the floodplain became relatively stable between ca. 300 and 100 yr BP, allowing Soil 2 to form. Aggradation resumed soon after ca. 100 yr BP, resulting in burial of Soil 2, but ceased sometime after ca. 100 yr B and Soil 1 formed.

Given the soil-stratigraphic and chronological information gleaned from the section at the Bostron Locality, there is high potential for Plains Tradition and Late Plains Village cultural deposits associated with Soil 2 in the upper 1.6 m of the T-0b fill. The potential for pre-contact cultural deposits below Soil 2, at least within the exposed portion of the T-0b fill at Bostron, is low because the floodplain was unstable before ca. 300 yr BP.

3.2.2 O'Brien Locality (Locality 5)

Figure 3.14 shows the potential for buried cultural deposits in the Middle Loup River valley at the O-Brien Locality. The SSURGO model maps much of this reach of river as the Bolent soil series, which indicates low potential (Figure 3.14A). Here, the low potential is attributed to (1) somewhat poorly drained conditions, (2) a channeled, frequently flooded, floodplain setting, (3) weakly developed soils with A-C-Cg horizonation, and (4) sandy textured sediments.

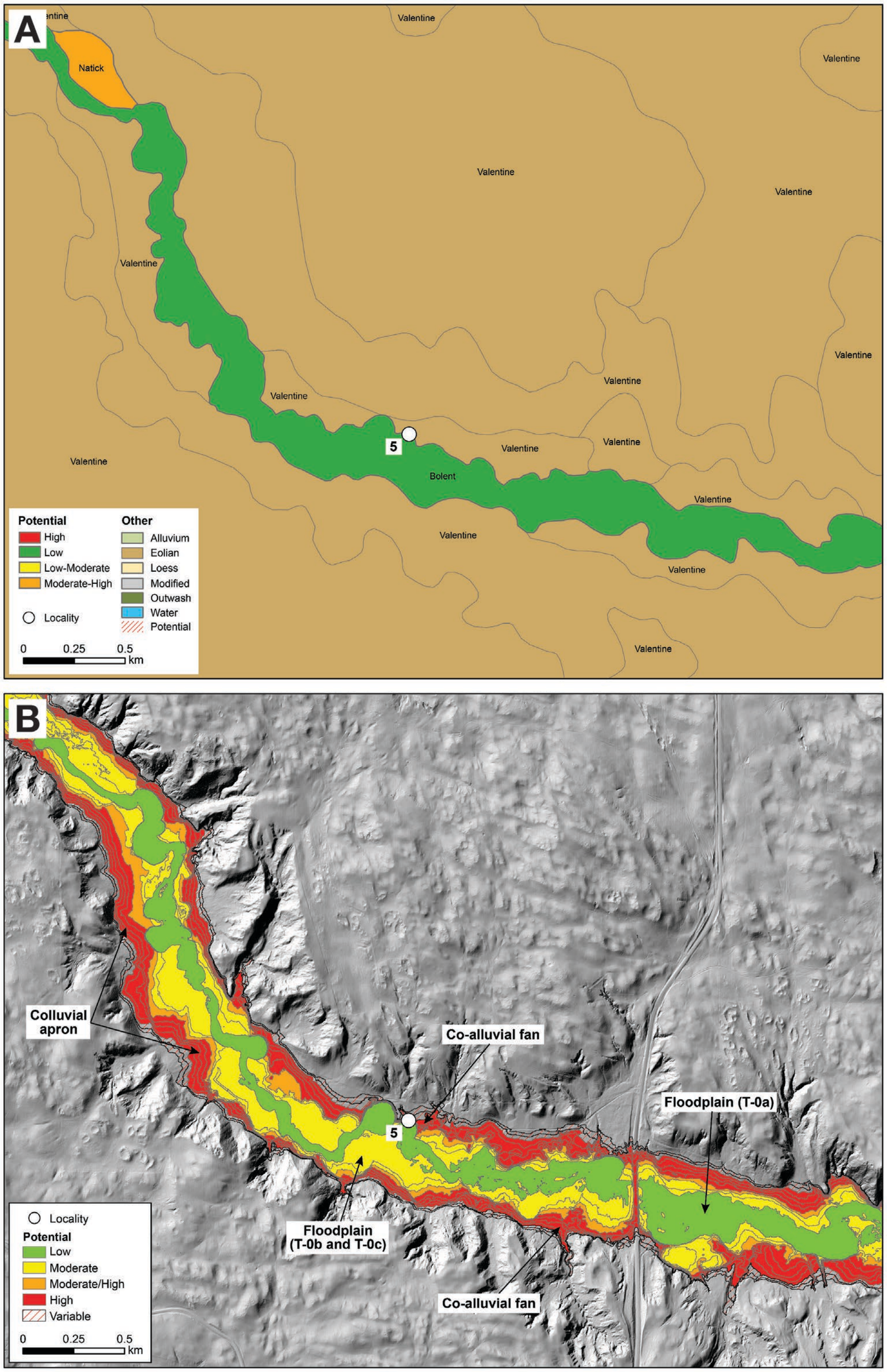

Figure 3.14 Maps of buried cultural resource potential for the Middle Loup River at the O'Brien locality (Locality 5). Potential for buried cultural deposits based on (A) SSURGO model and (B) REM data.

At this locality, the REM map (Figure 3.14B) further highlights the spatial limitations of the SSURGO model. Whereas the SSURGO map suggests that the river valley is dominated by floodplain deposits with low potential (i.e., Bolent soils), field observations and the REM map indicate that multiple different LSAs with varying potential are present. In particular, the Bolent soil series appears to predominantly map T-0a, T-0b, and T-0c LSAs. Along this study reach, the SSURGO model maps one polygon of the Natick soil series. As previously noted, this soil series is attributed moderate-high potential partly based on an association with stream terrace LSAs. However, based on the REM map, the associated LSA along this study reach is actually the T-0b/T-0c floodplain. Co-alluvial fans and colluvial aprons are present in this portion of the river valley and commonly grade to the T-0b/T-0c floodplain. A geomorphological investigation was conducted on one of the alluvial fans.

At the O'Brien Locality (Locality 5), the Middle Loup River has migrated laterally into a large, high-angle alluvial fan on the north side of the valley floor, creating a steep cutbank that exposes a 9 m-thick package of fan and floodplain deposits (Figure 3.15A). A section at the distal end of the fan was described and sampled for radiocarbon-dateable material (Figure 3.15B).

Figure 3.15 Photographs of the section described at the O'Brien Locality in the Middle Loup River valley.

The lower 1.2 m of the section (7.80–9.00 m below surface) at O'Brien consists of stratified, sandy, floodplain deposits. The stratified alluvium is mantled by a nearly 1 m-thick unit of organic-rich deposits, including mucky peat, gyttja, and peat interbedded with gyttja (from the bottom to the top of the unit) that accumulated in a paludal floodplain environment (Figures 3.13 and 3.16; Table A.6). An abrupt boundary separates the unit of paludal floodplain deposits from stratified alluvial fan deposits that span the upper 7 m of the section. Two buried soils occur in the upper 1.5 m of the section: Soil 2 at a depth of 82–98 cm and Soil 3 at a depth of 124–146 cm. A thin, weakly expressed surface soil (Soil 1) with A-C horizonation is developed at the top of the section.

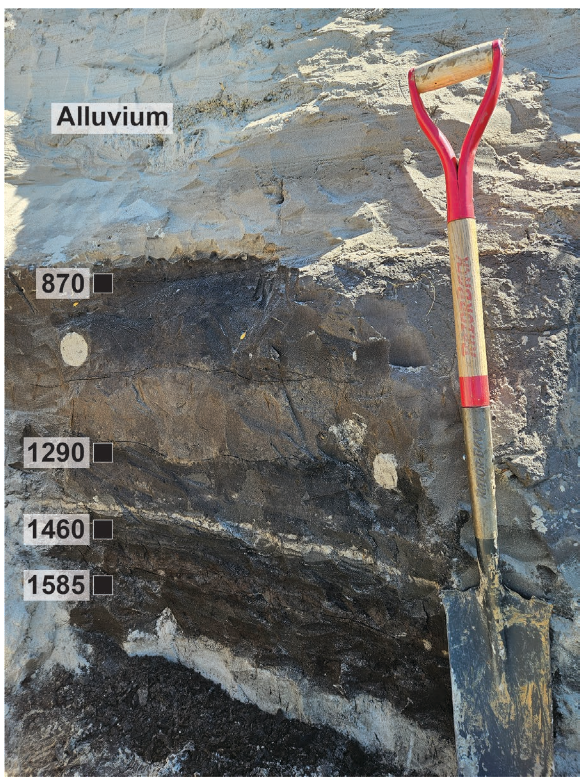

Figure 3.16 Photograph of lower part of the profile described at the O'Brien Locality in the Middle Loup River valley.

Organic-rich material collected at depths of 773 cm, 763 cm, 748 cm and 710 cm below the surface in the unit of paludal deposits yielded radiocarbon ages of 1585 cal yr BP, 1460 cal yr BP, 1290 cal yr BP, and 870 cal yr BP, respectively. Also, SOM from the upper 10 cm of the Ab2 horizon of Soil 3 and upper 10 cm of the Ab1 horizon of Soil 2 yielded radiocarbon ages of 605 cal yr BP and 395 cal yr BP, respectively.

Based on the radiocarbon chronology and the characteristics of the deposits in the O'Brien section, a paludal environment was in place on the valley floor of the Middle Loup River between 1585 and 870 cal yr BP. Soon after 870 cal yr BP, an alluvial fan prograded across the valley floor and buried the floodplain wetland. The fan rapidly aggraded, with ~7 m of fan deposits accumulating in less than about 850 years. Sedimentation slowed on the surface of the fan around 600 and 400 years ago, allowing soils 3 and 2 to form, respectively. The surface soil (Soil 1) formed sometime after 395 cal yr BP.

The results of the investigation at the O'Brien Locality indicate that there is low potential for buried cultural deposits in the paludal deposits that occur at a depth of 7.00–7.80 m and in most of the overlying fan deposits. However, soils 2 and 3 in the upper 1.5 m of the fan have the potential to contain Plains Village cultural deposits.

3.2.3 Nutter Locality (Locality 6)

Figure 3.17 shows the potential for buried cultural deposits in the Middle Loup River valley at the Nutter Locality. Based on SSURGO data, the Fluvaquents and Almeria soil series indicate low potential (Figure 3.17A). The low potential is attributed to (1) very poorly drained (Fluvaquents) to poorly drained (Almeria) conditions, (2) a floodplain setting that is frequently (Fluvaquents) or occasionally (Almeria) flooded, (3) very weakly developed soils with O-Cg (Fluvaquents) or A-Cg (Almeria) horizonation, and (4) sandy textured sediments.

The Bolent soil series indicates low-moderate potential based on (1) somewhat poorly drained conditions, (2) a floodplain setting that is rarely flooded, and (3) weakly developed soils with A-AC-Cg horizonation, and (4) sandy textured sediments. Because Bolent soils are rarely flooded they most likely represent T-0c floodplain LSAs in this portion of the Middle Loup River.

Polygons mapped as the Natick and Pivot soil series in the SSURGO model indicate moderate-high potential (Figure 3.17A). Natick soils are (1) moderately well drained, (2) associated with stream terrace LSAs, (3) weakly developed with A-AC-C horizonation, and (4) developed in sandy alluvium. Pivot soils are similar except they are somewhat excessively drained and have A-C horizonation.

The REM map (Figure 3.17B) indicates that SSURGO polygons mapped as having low potential (i.e., Fluvaquents and Almeria soil series) represent floodplain LSAs, however, there is poor differentiation between T-0a and T-0b/T-0c LSAs in the SSURGO model. For example, some T-0b/T-0c LSAs (moderate potential) depicted on the REM map are mapped as Fluvaquent soils (low potential) in the SSURGO model. However, the Bolent soil series (low-moderate potential in SSURGO) accurately depicts T-0b/T-0c LSAs (moderate potential) on the REM map. In downstream reaches of the Middle Loup River, the T-0c surface can stand 3-4 m above the modern stream channel. In these instances, the SSURGO model maps these LSAs as the Pivot soil series. T-1 terrace LSAs on the REM map are accurately depicted by Natick and Pivot soils in the SSURGO model. The REM data indicate that the T-1 terrace stands 4–5 m above the modern channel, however, the terrace tread is mantled in some areas by dune sands that are up to 2 m thick.

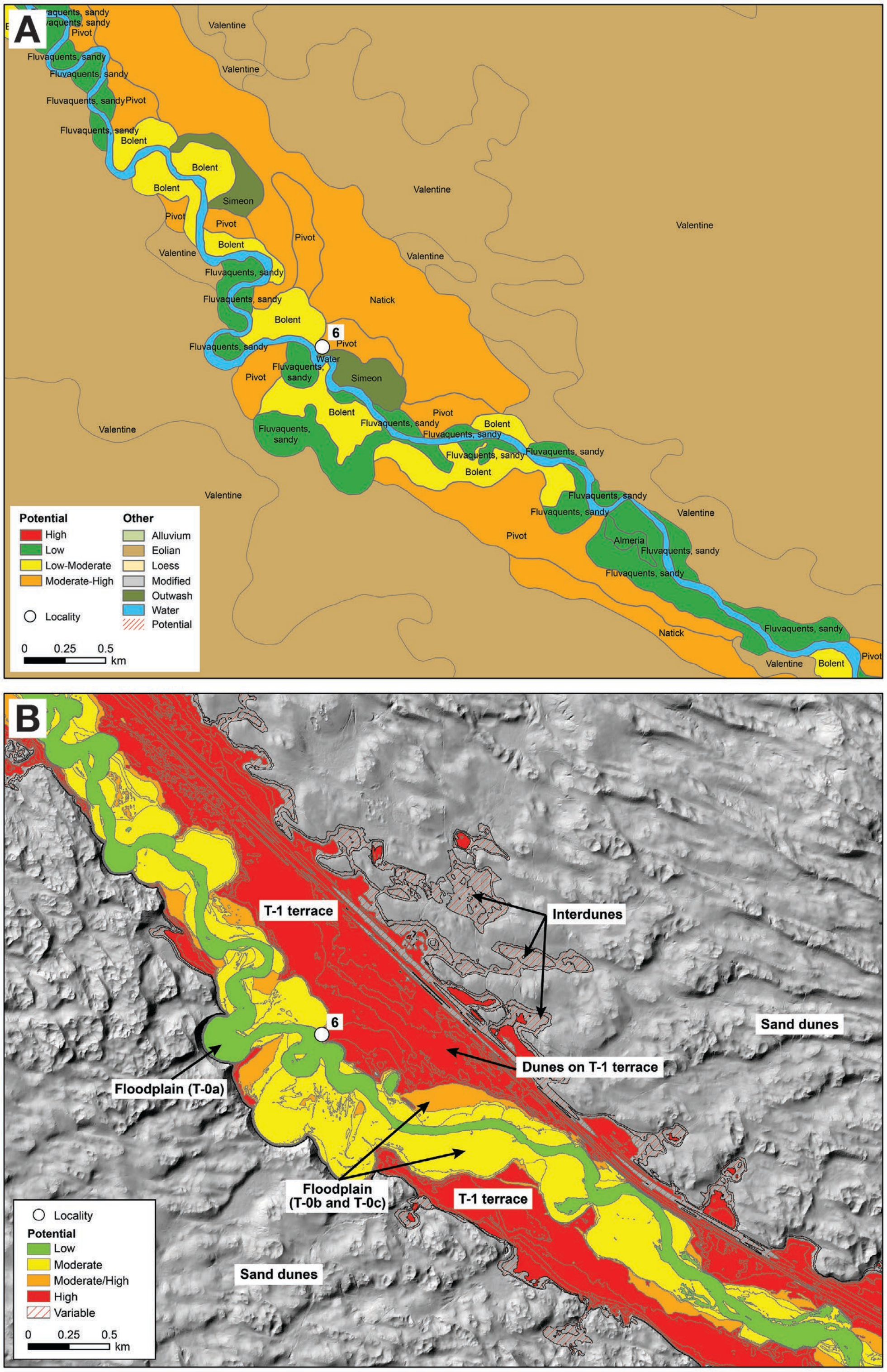

Figure 3.17 Maps of buried cultural resource potential for the Middle Loup River at the Nutter Locality (Locality 6). Potential for buried cultural deposits based on (A) SSURGO model and (B) REM data.

Therefore, in the SSURGO model, some of the T-1 LSAs shown in the REM map are mapped as eolian deposits (i.e., Valentine soil series).

In upstream reaches of the Middle Loup River (e.g., localities 3–5) where the river valley is comparatively narrow, relative elevations above the stream channel of 8–10 m typically represent alluvial fan or colluvial apron LSAs. However, in downstream reaches (e.g., the Nutter Locality) where the river valley is relatively wide, relative elevations of 8–10 m depict interdune areas on the adjacent uplands. There is likely some potential associated with the margins of these interdunal areas.

The Nutter Locality is about 50 km downstream from the O'Brien Locality (Figure 2.1). At Nutter, the T-1 terrace spans most of the valley floor and is 4–5 m above the modern stream channel. The Middle Loup River has migrated laterally into the T-1 terrace, creating a steep cutbank on the north side of the channel (Figure 3.18A). A 4 m-thick section of the T-1 fill was described and sampled for dateable materials (Figure 3.18B).

The lower 2 m of the section at the Nutter Locality consists of a complex stratigraphic sequence consisting of sandy alluvium, diatomite (lacustrine), and paludal deposits, including peat and gyttja (Figure 3.13; Table A.7). The stratigraphic sequence, from the bottom to the top of the section, is as follows: 348–400 cm, sandy alluvium interbedded with very fine and fine pebbles; 302–348 cm, paludal deposits consisting mostly of black peat and gyttja; 262–287 cm, sandy and loamy alluvium; 255–262 cm, diatomite (lacustrine); 245–255 cm, black peat (paludal); 220–245 cm, sandy and loamy alluvium; 210–220 cm, diatomite (lacustrine); 200–210 cm, sandy alluvium; 0–200 cm, sandy alluvium interbedded with gravel. Three buried alluvial soils (soils 2, 3, and 4) occur in the upper 2 m of the section, all with A-C profiles, and a very thin surface soil (Soil 1) with an A-C profile is developed at the top of the T-1 fill (Figure 3.13).

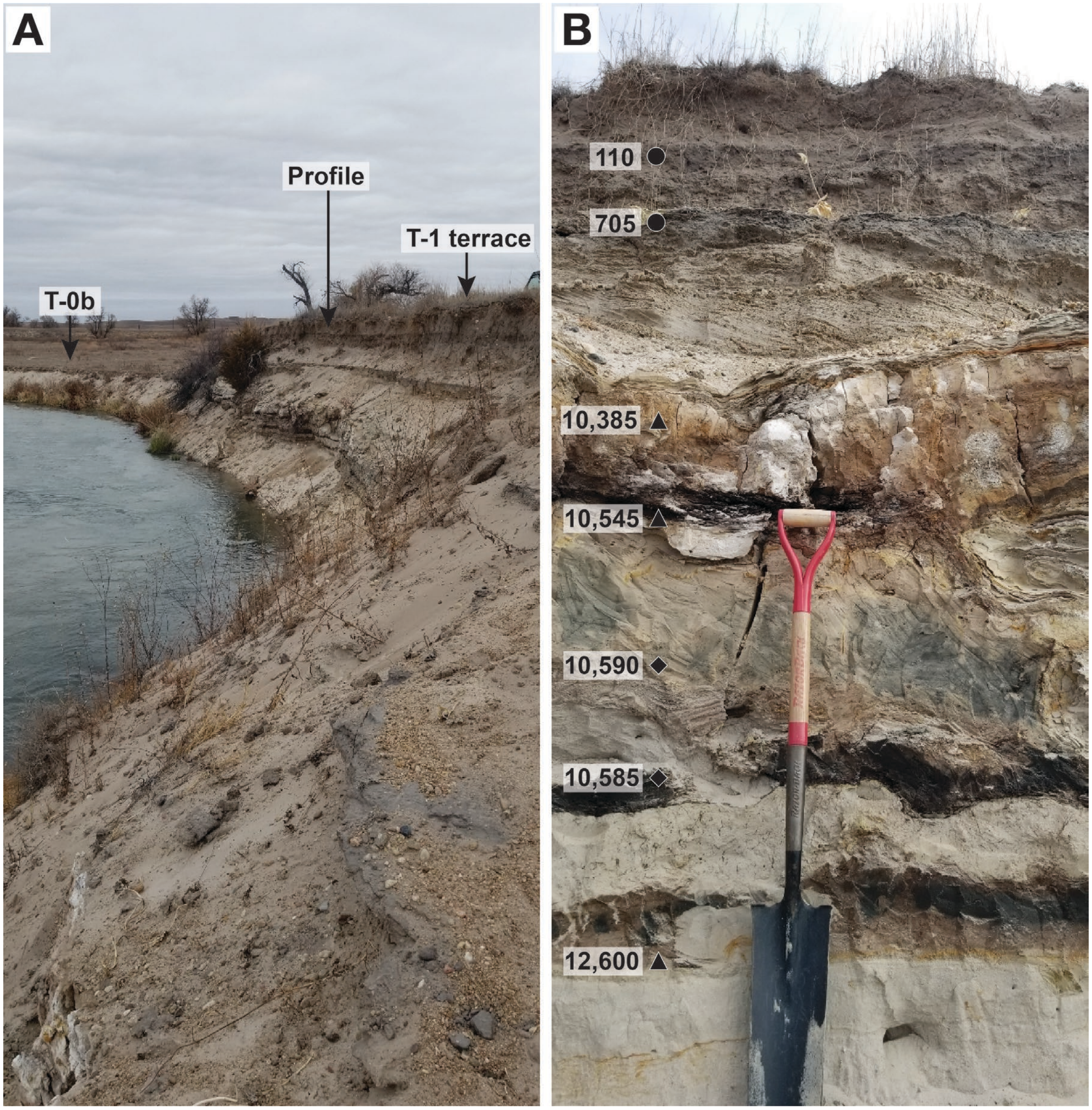

Figure 3.18 Photographs of the Nutter Locality in the Middle Loup River valley. (A) LSAs and profile location. (B) Profile of the T-1 fill described and sampled.

A suite of seven radiocarbon ages provides a robust alluvial chronology for the T-1 fill at the Nutter Locality. Charcoal collected at a depth of 337 cm below the surface in a peat/gyttja deposit yielded a radiocarbon age of 12,600 cal yr BP, and plant macrofossils collected slightly higher in the section, at a depth of 302 cm below the surface in a peat deposit, yielded a radiocarbon age of 10,585 cal yr BP. Wood collected at a depth of 282 cm in sandy alluvium yielded a radiocarbon age of 10,590 cal yr BP, and charcoal collected at a depth of 255 cm at the top of a diatomite yielded a radiocarbon age of 10,545 cal yr BP. Charcoal collected at a depth of 230 cm in lacustrine deposits yielded a radiocarbon age of 10,385 cal yr BP. Finally, SOM from the upper 10 cm of the Ab3 horizon of Soil 4 and the upper 10 cm of the Ab1 horizon of Soil 2 yielded radiocarbon ages of 705 cal yr BP and 110 cal yr BP, respectively.

Stratigraphic and chronological information gleaned from the Nutter Locality indicates that rapid aggradation of the T-1 fill was occurring before 12,600 cal yr BP. However, alluviation slowed dramatically by 12,600 cal yr BP, allowing establishment of a wetland on the terminal Pleistocene floodplain. From 12,600 cal yr BP to 10,385 cal yr BP, the environment on the valley floor of the Middle Loup River fluctuated between paludal (marsh) and lacustrine (lake). The lacustrine deposits may represent lakes that formed behind sand dunes that temporarily dammed the river. Also, there were occasional episodes of rapid deposition of sandy alluvium, perhaps because of high-magnitude floods. An erosional unconformity separates the package of organic-rich terminal Pleistocene/early Holocene paludal and lacustrine deposits from late-Holocene alluvium that accumulated over the past 1,000 years. That episode of alluviation was interrupted by three brief periods of floodplain stability and soil formation between ca. 700 and 100 years ago. The weakly-expressed surface soil (Soil 1) developed at the top of the T-1 fill after ca. 110 cal yr BP.

The potential for buried cultural deposits at the Nutter Locality is variable. Specifically, there is low potential for buried cultural deposits in the alluvial and paludal deposits that occur 2-4 m below the T-1 surface, but high potential for cultural materials on the surfaces of lacustrine deposits at that depth. Within the upper 1.5 m of the T-1 fill, there is high potential for Plains

Village cultural deposits in Soil 4, and cultural deposits post-dating ca. 700 yr BP may occur in Soil 3. Only post-contact cultural deposits may occur within and above Soil 2.

3.3 Dismal River valley

3.3.1 Munn Locality (Locality 7)

Figure 3.19 shows the potential for buried cultural deposits in the South Fork of the Dismal River valley at the Munn Locality. Along this study reach, the SSURGO map (Figure 3.19A) depicts the entire stream valley as comprising eolian deposits (i.e., Valentine soil series), again underscoring the spatial resolution limitations of SSURGO data in narrow stream valleys.

The REM map, however, indicates the presence of a variety of different LSAs in the stream valley, including floodplain (T-0a and T-0b/T-0c), co-alluvial fan, and colluvial apron LSAs (Figure 3.19B). In this study reach, the REM map does not depict the T-1 terrace because it stands ~12 m above the modern stream channel based on field investigations (i.e., the Munn Locality, Section 1) and only elevations up to 10 m above the channel are depicted. Even so, terrace LSAs are only preserved in isolated remnants along the valley walls and are difficult to identify in narrow river valleys. Furthermore, they are often mantled by eolian deposits (e.g., the Munn Locality, Section 1).

The Munn Locality consists of five stratigraphic sections, all in roadcuts, that were studied on the Munn Ranch in the South Fork Dismal River valley (Figure 3.20). The results of investigations at Munn sections 1, 2, and 3 (localities 7a, 7b and 7c) are presented first and are followed by the results of investigations at Munn sections 4 and 5 (localities 7d and 7e).

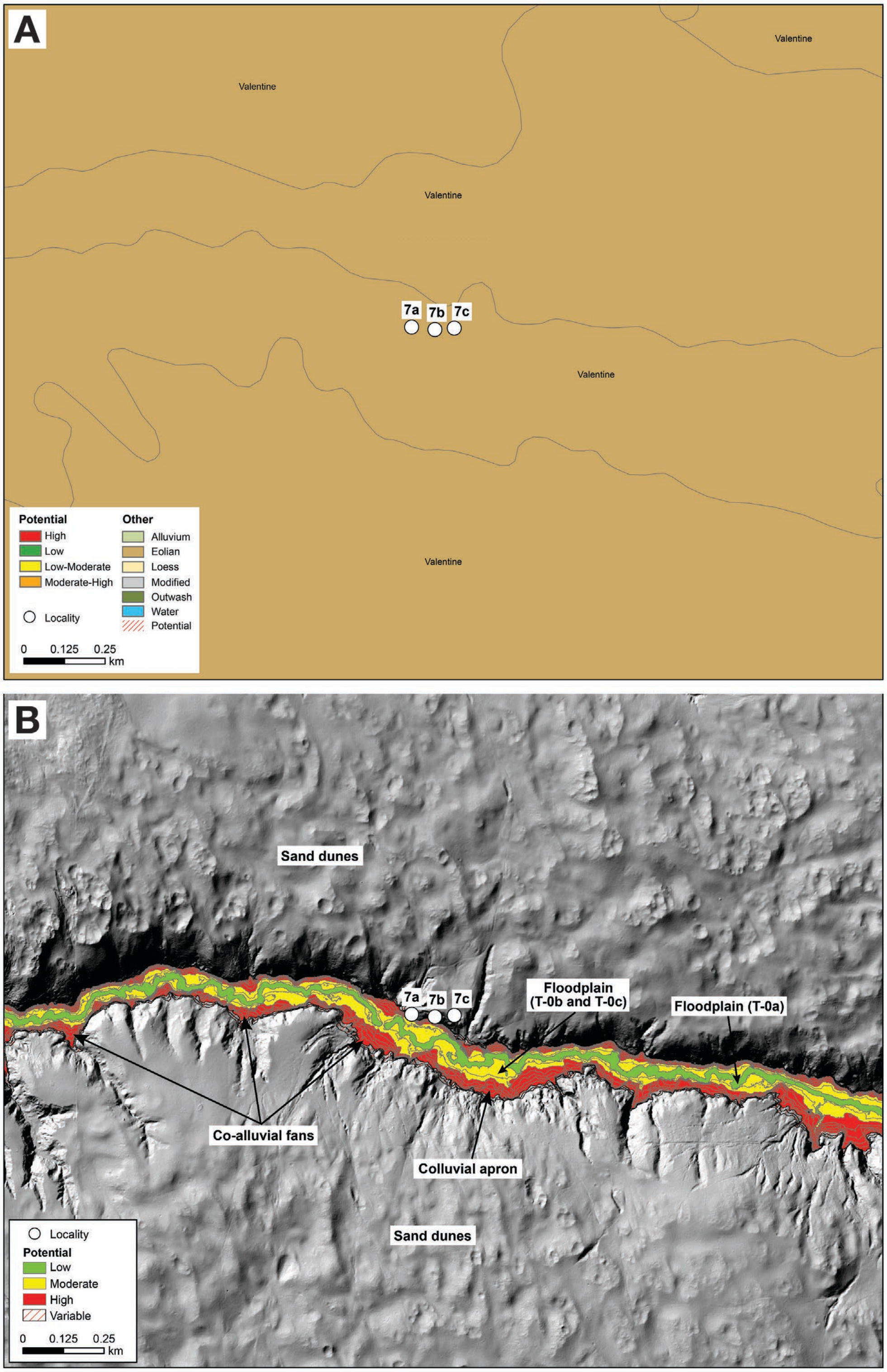

Figure 3.19 Maps of buried cultural resource potential for the South Fork Dismal River at the Munn Locality (Locality 7). Potential for buried cultural deposits based on (A) SSURGO model and (B) REM data.

3.3.1.1 Munn Locality, Sections 1–3 (localities 7a-c)

Munn sections 1, 2, and 3 (localities 7a, 7b, and 7c) are in a long roadcut that extends from the uplands to the valley floor of the South Fork Dismal River (Figures 3.19B and 3.20). Five profiles were described along the roadcut: profiles 1 and 2 in Section 1, profiles 3 and 4 in Section 2, and Profile 5 in Section 3.

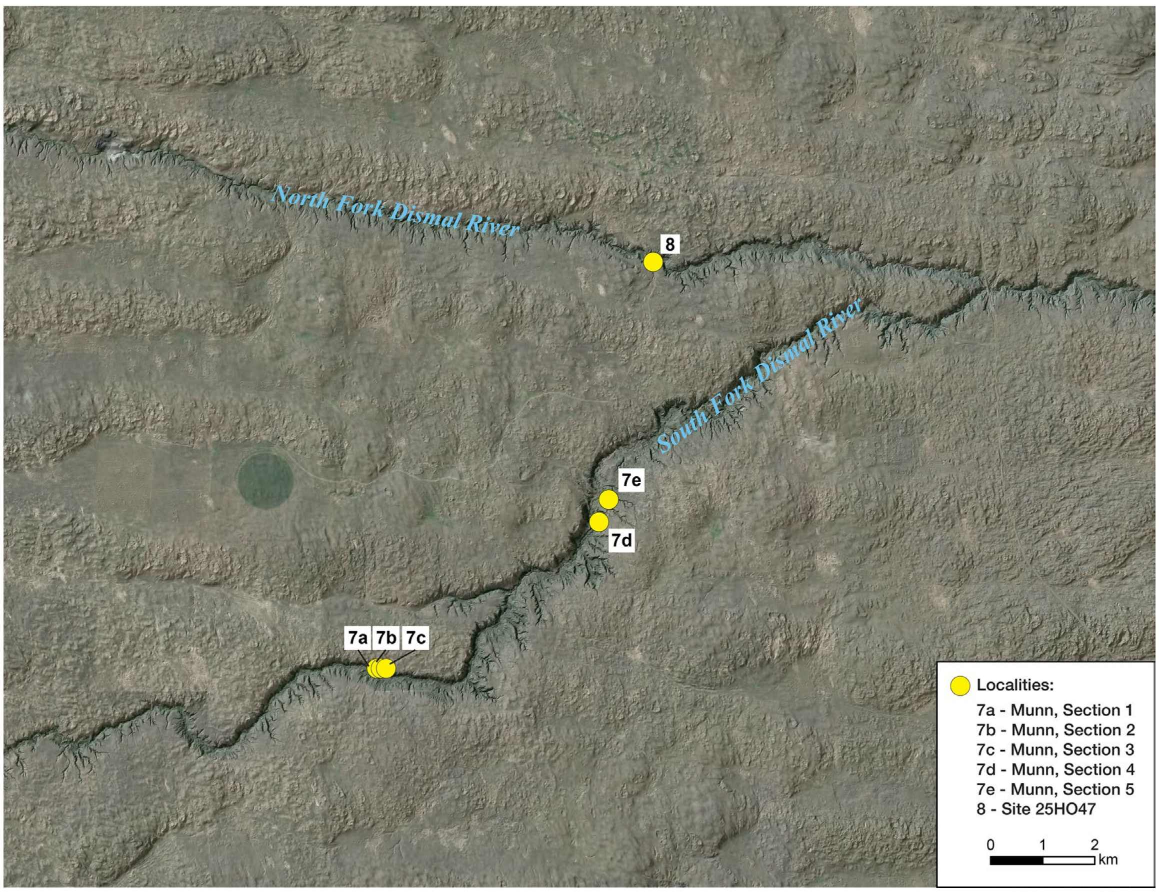

Figure 3.20 Map of localities in the North Fork Dismal River and South Fork Dismal River valleys.

Section 1 is at the lowest landscape position in the roadcut and provided an opportunity to examine valley fill beneath a dune-mantled alluvial terrace (T-1) of the South Fork Dismal River. The surface of the terrace is about 12 m above the surface of the modern floodplain.

Profiles 1 and 2 were cleaned off next to each other, with the upper 3.2 m of the section exposed in Profile 1, and the lower 1.5 m of the section exposed in Profile 2 (Figures 3.21A and 3.21B, respectively). A composite of profiles 1 and 2 is shown in the soil-stratigraphic diagram (Figure 3.22) and is described in Table A.8.

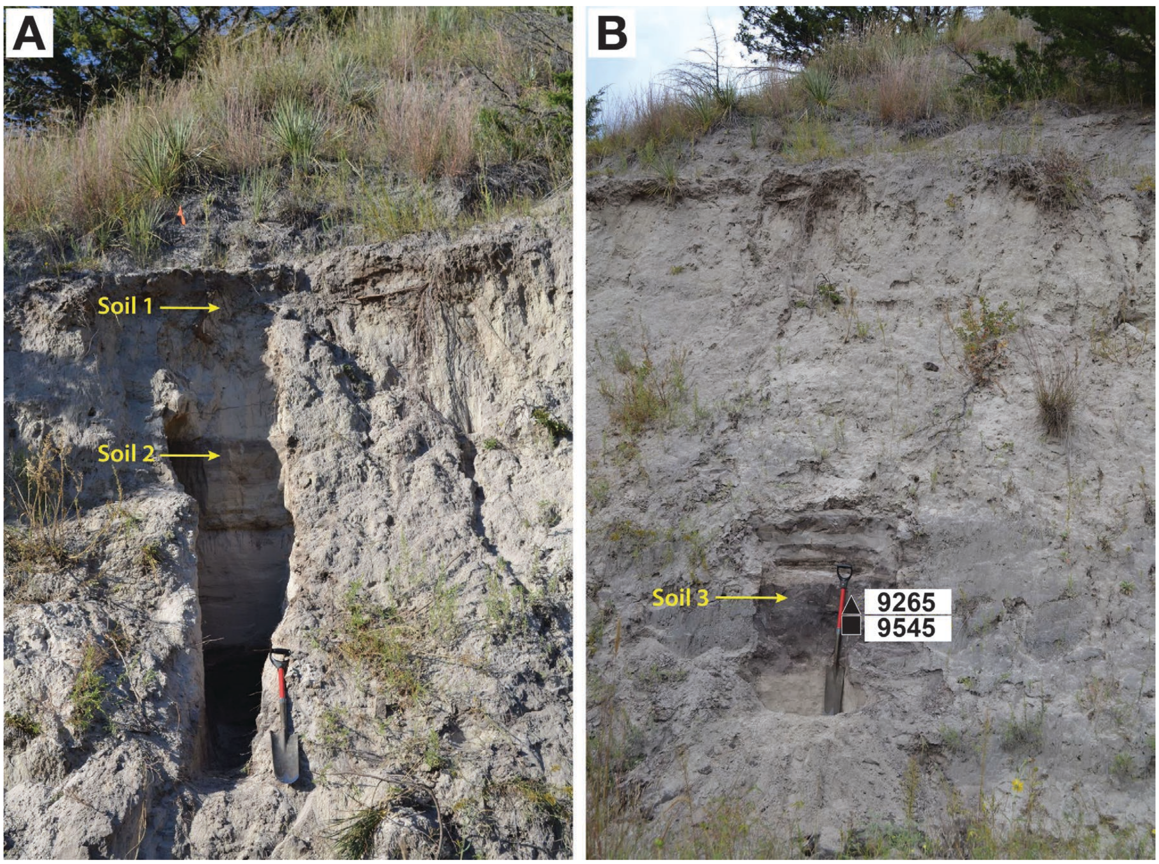

Figure 3.21 Photographs of the Munn Locality, Section 1 in the South Fork Dismal River valley. (A) profile 1 and (B) profile 2.

In Section 1, a soil (Soil 3) with an overthickened A horizon is developed in fine-grained, organic-rich paludal deposits at a depth of 269–423 cm below the surface (Figure 3.21B). The paludal deposits accumulated on the margins of a paleolake (see Munn sections 4 and 5) or in a backwater area on the early-Holocene floodplain of the South Fork Dismal River. The multistoried A horizon (4A1b2 + 4A2b2 + 4A3b2) is 58 cm thick and typical of a cumulic soil. Charcoal from a lens of carbonized plant fragments in the lower 3 cm of the 4A1b2 horizon of Soil 3 yielded a radiocarbon age of 9265 cal yr BP, and soil organic matter from the upper 5 cm of the 4A2b2 horizon yielded a radiocarbon age of 9545 cal yr BP (Figures 3.21B and 3.22).

Soil 3 is mantled by an 83 cm-thick unit of stratified organic-rich paludal deposits interbedded with alluvium (Figure 3.21A). The upper 69 cm of the unit consists of thinly bedded black to dark grayish brown very fine sandy loam, fine sandy loam, and loamy fine sand. Despite the abundance of organic matter, there is no evidence of soil development. Instead, there is excellent preservation of primary sedimentary features, including millimeter-thick laminae within the individual beds. Organic matter from the upper 2 cm of an organic-rich bed that caps the unit yielded a radiocarbon age of 8870 cal yr BP (Figure 3.22).

The package of paludal/alluvial deposits is mantled by a 72 cm-thick unit of cross-bedded eolian sand, which in turn is mantled by a 62 cm-thick unit of laminated sediment (Figure 3.22). The laminated sediment may be alluvium deposited by the South Fork Dismal River or re-deposited eolian sand that accumulated as sheetwash in a former low, interdunal area. A thin soil (Soil 2) with a weakly expressed A-C profile is developed at the top of the unit of laminated sediment. Soil 2 is mantled by a unit of eolian sand that spans the upper 135 cm of Section 1.

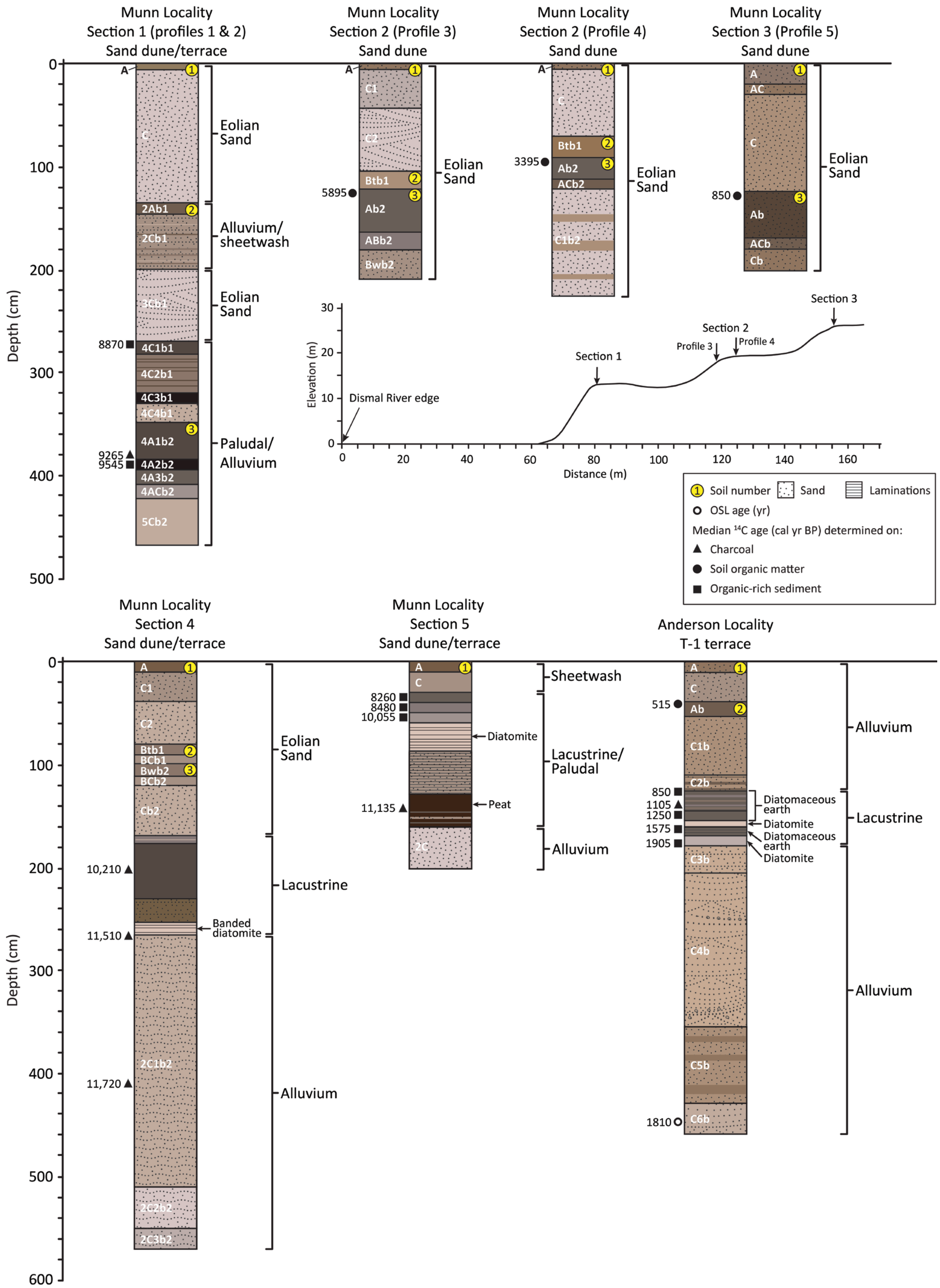

Figure 3.22 Diagram of the soil-stratigraphy from the Munn (Locality 7) and Anderson (Locality 9) localities in the Dismal River valley.

Munn Section 2 is about 36 m upslope from Section 1 (see cross-sectional profile in Figure 3.22) and consists entirely of eolian sand beneath a dune. At Section 2, two profiles were described: profiles 3 and 4. Profile 3, which spans the lower 2.1 m of Section 2, includes two buried soils (Figures 3.22 and 3.23A; Table A.9). The lowest buried soil (Soil 3) has a weakly developed A-AB-Bw profile. Soil organic matter from the upper 5 cm of the Ab2 horizon of Soil 3 yielded a radiocarbon age of 5895 cal yr BP. Soil 2 is immediately above Soil 3 and is represented by a truncated Bt horizon; the A horizon was stripped off by erosion before Soil 2 was buried. Cross-bedded eolian sands mantle Soil 2, and a thin, weakly expressed surface soil (Soil 1) with A-C horizonation is developed at the top of the profile.

Profile 4 is about 6 m upslope from Profile 3 and spans the upper 2.25 m of Section 2. The surface of the sand dune at Profile 4 is 1.8 m higher than the surface at Profile 3. Three soils occur in Profile 4: a surface soil (Soil 1) and two buried soils (soils 2 and 3) (Figures 3.22 and 3.23B; Table A.10). Soil 3, the deepest buried soil, has an A-AC-C profile. Soil organic matter from the upper 5 cm of the Ab2 horizon of Soil 3 yielded a radiocarbon age of 3395 cal yr BP. Soil 2 is immediately above Soil 3 and is represented by a truncated Bt horizon; the A horizon was stripped off by erosion before Soil 2 was buried beneath eolian sands. The modern surface soil, Soil 1, has a thin, weakly expressed A-C profile.

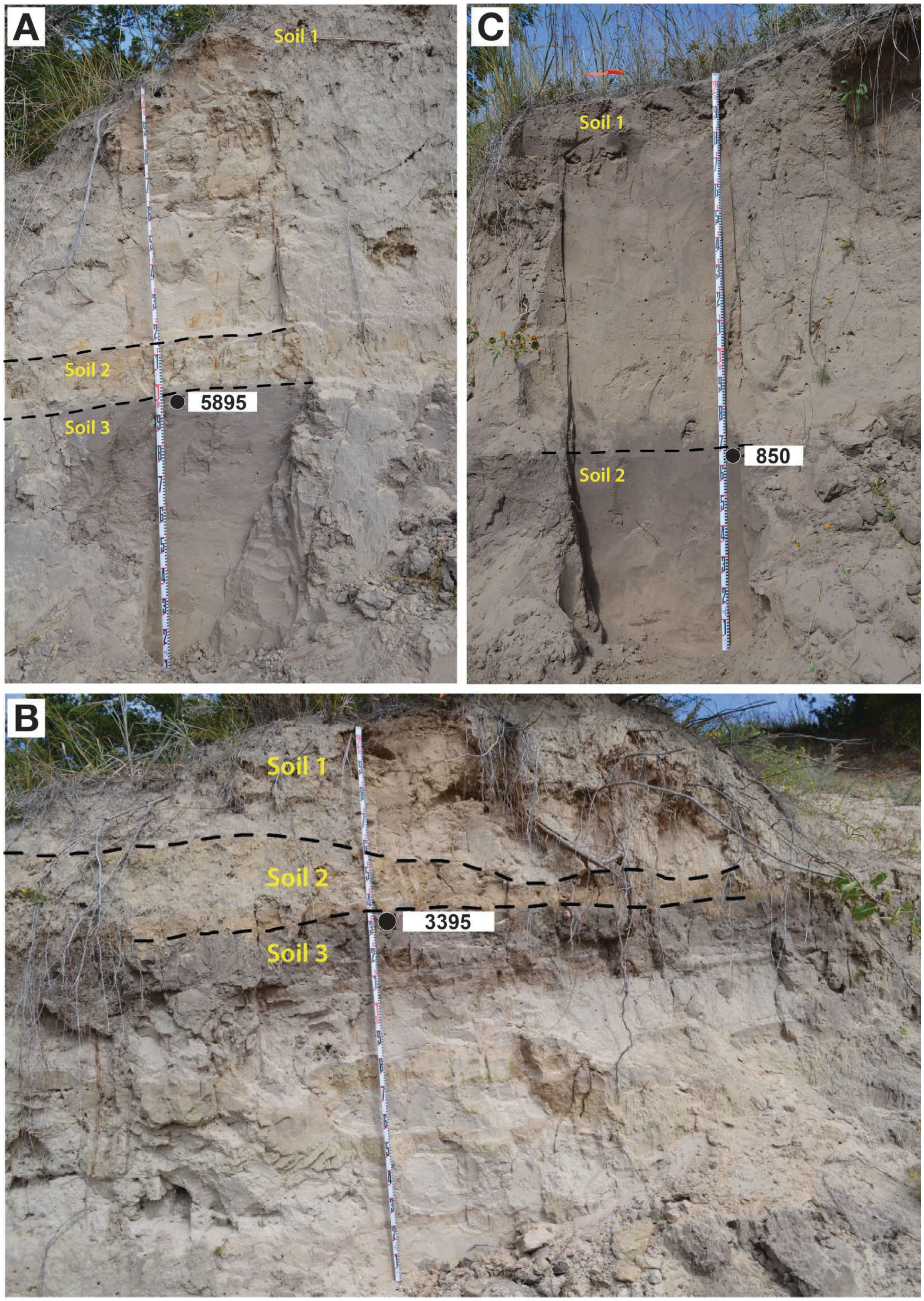

Figure 3.23 Photographs of the Munn Locality, Section 2 and 3 in the South Fork Dismal River valley. (A) Profile 3, Section 2, (B) Profile 4, Section 2, and (C) Profile 5, Section 3.

Section 3 is approximately 31 m upslope from Section 2 and is at the highest position in the valley landscape (see cross-sectional profile in Figure 3.22). At Section 3, the upper 2 m of a sand dune was described (Profile 5).

In Profile 5, a buried soil (Soil 2) with A-AC horizonation occurs at a depth of 125–180 cm below the surface (Figures 3.22 and 3.23C; Table A.11). The Ab horizon of Soil 2 is 45 cm thick and consists of very dark grayish brown sand. Soil organic matter from the upper 5 cm of the Ab horizon yielded a radiocarbon age of 850 cal yr BP; hence, burial of the soil occurred soon after that time. A thin, weakly expressed surface soil (Soil 1) with A-AC horizonation formed in the upper 30 cm of the sand dune.

Munn sections 1, 2, and 3 reveal a complex sequence of landscape evolution that spans almost the entire Holocene. Shortly before ca. 9545 cal yr BP, alluviation occurred on the early Holocene floodplain (now a terrace) of the South Fork Dismal River. By ca. 9545 cal yr BP, alluviation slowed or ceased. A cumulic soil (Soil 3 in Section 1) with an overthickened A horizon formed either in near-shore lacustrine or distal floodplain deposits. Soil 3 was buried by paludal/alluvial deposits sometime between ca. 9265 and 8870 cal yr BP. Soon after 8870 cal yr BP, dunes encroached on the early Holocene floodplain. There also is evidence of dune activity during the middle and late Holocene, though higher in the valley landscape. In Section 2, four buried soils were recorded in a sand dune, two of which have intact A horizons and two are represented by truncated Bt horizons. Soil organic matter from the A horizon of the deepest buried soil in the section yielded a radiocarbon age of 5895 cal yr BP, placing it firmly in the middle Holocene. Soil 3 in Profile 4 of Section 2 is characterized by a thick, prominent A horizon. Soil organic matter from the upper 5 cm of Soil 3 yielded a radiocarbon age of 3395 cal yr BP. At the highest position of the valley landscape, a buried soil occurs almost 1.3 m below the surface of a sand dune. Soil organic matter from the upper 5 cm of that soil yielded a radiocarbon age of 850 cal yr BP.

Based on the soil stratigraphy and geochronology of the alluvial, paludal, and eolian deposits in the immediate area of Munn sections 1, 2, and 3, there is high potential for Plains Village, Plains Woodland, and Archaic cultural materials in stratified contexts. Those materials are likely to be associated with the buried soils that have intact A horizons. Specifically, at Section 1, Soil 3 has potential for containing Early Archaic cultural deposits. At Section 2, Soil 3 in Profile 3 has potential for containing Middle Archaic cultural materials, and Soil 3 in Profile 4 has potential for containing Late Archaic cultural deposits. At Section 3, there is high potential for Plains Woodland and/or Plains Village cultural deposits in Soil 2.

3.3.1.2 Munn Locality, Sections 4 and 5 (localities 7d and 7e)

Sections 4 and 5 at the Munn Locality are in the South Fork Dismal River valley about 4 km northeast of Munn sections 1–3 (Figure 3.20). Sections 4 and 5 are about 275 m apart and exposed in roadcuts.

Section 4 is about 5 m thick and extends from the bottom of the valley wall to nearly halfway up a steep ranch road that goes to the top of the bluff. A sequence of alluvial, lacustrine, and eolian deposits as well as three buried soils are exposed in the section (Figure 3.24; Table A.12). The lower 2.5 m of Section 4 consists of stratified alluvium characterized by multiple upward-fining sequences, with each sequence capped by a bed of very dark gray sandy clay loam that often contains charcoal fragments. Charcoal from a bed of fine-grained alluvium about 50 cm above the bottom of the exposed alluvium yielded a radiocarbon age of 11,720 cal yr BP (Figure 3.24). Also, charcoal from a bed of fine-grained alluvium at the top of the alluvial sequence yielded a radiocarbon age of 11,510 cal yr BP.

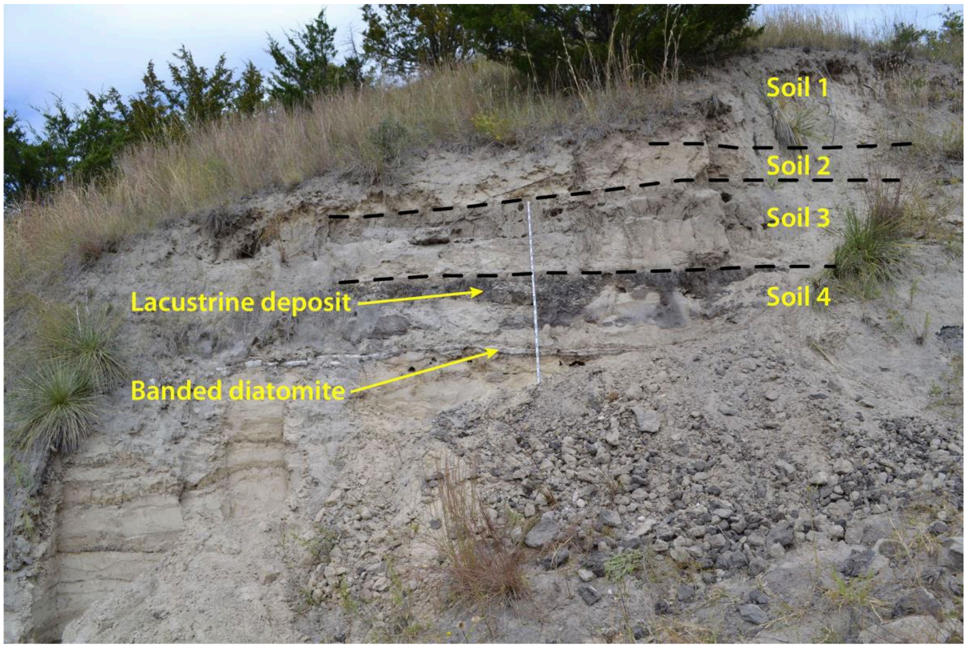

Figure 3.24 Photograph of the Munn Locality, Section 4.

Figure 3.25 Stratified alluvium beneath the banded diatomite in Munn Section 4.

The most prominent feature in Section 4 is a deposit of dark gray, fine-grained lacustrine sediment (Figure 3.24). Charcoal from the middle of the thickest part of the organic-rich lacustrine deposit yielded a radiocarbon age of 10,210 cal yr BP (Figure 3.25). Immediately below the dark gray lacustrine deposit is a 59–20 cm-thick unit of very dark gray sandy clay loam interbedded with 2–4 mm-thick laminae of light gray fine sand. The very dark gray sediment overlies a 22 cm-thick bed of laminated sand. A 10–15 cm-thick banded diatomite occurs beneath the laminated sand. Charcoal from the boundary between the banded diatomite and underlying alluvium yielded a radiocarbon age of 11,510 cal yr BP.

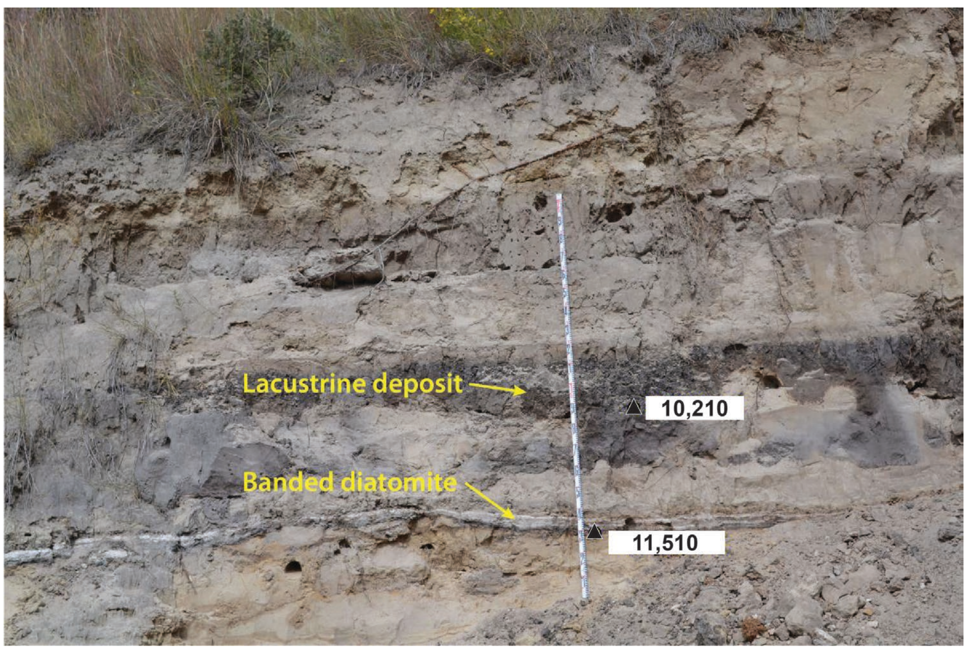

Figure 3.26 Close-up of the dark gray lacustrine deposit and banded diatomite in Munn Section 4.

The package of lacustrine deposits is mantled by eolian sand that comprises a dune. A surface soil (Soil 1) and two buried soils (soils 2 and 3) are developed in the eolian deposits (Figure 3.24). The top of soils 2 and 3 are at depths of 0.80 m and 0.97 m, respectively, and this portion of the section resembles Profile 3 at Munn Section 2. Soil 2 is represented by a truncated Bt horizon, and Soil 3 has an A-AB-Bw profile. The numerical ages of soils 2 and 3 are unknown.

Section 5 is at the lower end of a former ranch road that extended up the valley wall to the uplands. Although considerable slumping of sediment has occurred in the roadcut, a small outcrop provided an opportunity to examine the stratigraphy at the foot of the valley wall (Figure 3.27). Section 5 is 2 m thick and consists of a complex sequence of alluvium, degraded peat, diatomite, and organic-rich lacustrine sediment mantled by sandy slopewash (Figure 3.28; Table A.13). In the lower 60 cm of the section, a 30 cm-thick bed of degraded brown peat mantles light gray fine sand that probably is alluvium, though an eolian origin cannot be ruled out. The peat consists mostly of plant impressions and casts, and small fragments of carbonized plant remains in a silty (perhaps loess) matrix. A piece of charcoal recovered from the middle of the peat bed yielded a radiocarbon age of 11,135 cal yr BP.

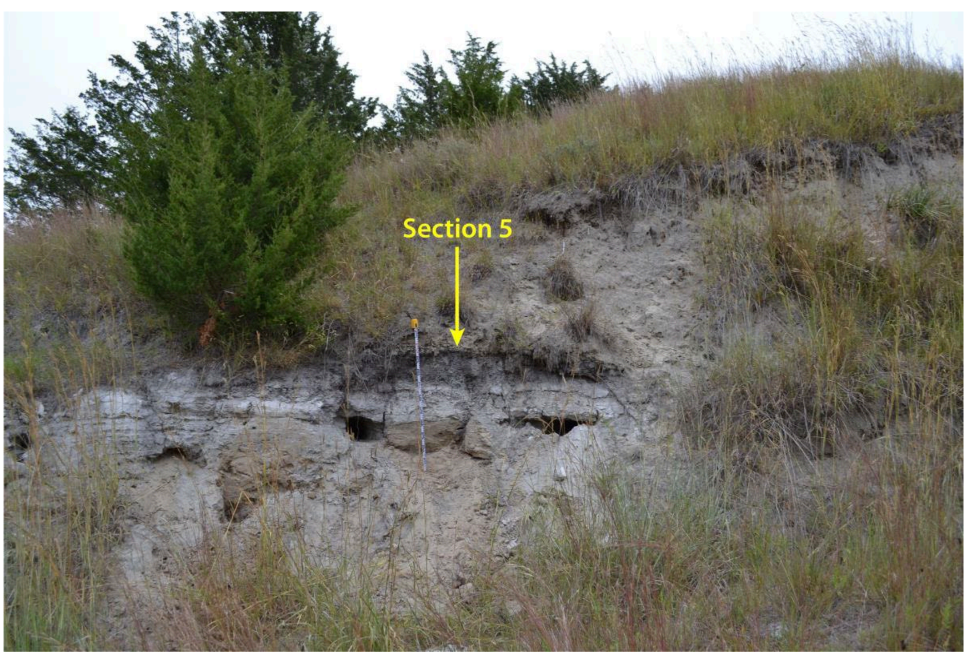

Figure 3.27 Photograph of Munn Section 5.

The peat is mantled by a 40 cm-thick unit of stratified sandy alluvium (Figure 3.28). Most of the alluvium consists of fine and medium sand, and upward-fining sequences occur within this package of sediment. A 30 cm-thick white diatomite accumulated above the stratified alluvium. The diatomite is interbedded with laminae of dark gray fine-grained sediment, and very fine fragments of charcoal are common in the lower half of the bed of deposit.

A 30 cm-thick lacustrine deposit consisting of fine-grained, organic-rich sediment mantles the diatomite. The color (10YR 6/1 and 6/2, dry), low bulk density, and brittleness of the deposit suggest that it has high diatom content. Organic matter from the lower, middle, and upper 10 cm of the deposit yielded radiocarbon ages of 10,055 cal yr BP, 8480 cal yr BP, and 8260 cal yr BP, respectively (Figure 3.28). Sandy slopewash derived from the adjacent dune mantles the lacustrine deposit.

Munn sections 4 and 5 yielded valuable information about landscape evolution in the South Fork Dismal River valley during the Pleistocene-Holocene transition and into the early Holocene. Based on the sequence of deposits and radiocarbon ages at Munn Section 4, rapid alluviation occurred in the South Fork Dismal River valley at that locality between ca. 11,720 cal yr BP. and 11,510 cal yr BP. In Section 5, a brown peat indicates that at ca. 11,135 cal yr BP. a marsh was present on the early Holocene landscape at that locality. The marsh was either associated with a floodplain wetland or the margins of a pond. The marsh was buried by alluvium sometime between ca. 11,135 cal yr BP and 10,005 cal yr BP. During that same period, sand dunes formed a dam across the South Fork Dismal River, thereby creating a lake behind the dam. At Section 5, a thick bed of diatomite accumulated on the floor of the paleolake and was subsequently buried beneath an organic-rich lacustrine deposit that accumulated between ca. 10,005 cal yr BP and 8260 cal yr BP. It is likely that the bed of diatomite in Section 5 is a thicker component of the banded diatomite in Section 4. Also, the organic-rich lacustrine deposits in sections 4 and 5 appear to be coeval. At the Section 4 locality, a radiocarbon age determined on charcoal from the organic-rich lacustrine deposit indicates that lake sediments were accumulating around 10,200 cal yr BP. The stratigraphic record in Section 5 indicates that the paleolake was present until at least ca. 8260 cal yr BP. However, soon after 8260 cal yr BP., the dune dam failed, and water drained out of the lake.

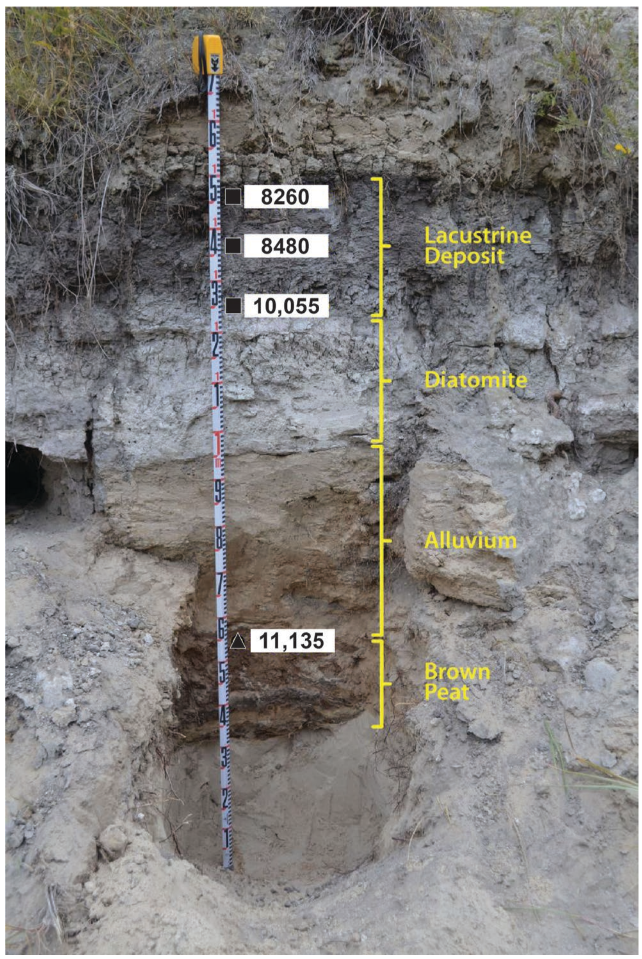

Figure 3.28 Photograph of Munn Section 5 showing stratigraphy and radiocarbon ages.

Late Paleoindian and Early Archaic cultural deposits are likely to occur on the margins of the former lake represented by the early Holocene lacustrine deposits at Munn sections 4 and 5.

Finding those margins, however, will be difficult because of the thick mantle of slopewash and/or eolian sand above the lacustrine deposits. Also, soils 2 and 3 in the sand dune at Section 4 have high potential for buried cultural deposits post-dating 10,210 cal yr BP.

3.3.2 25HO47 Site (Locality 8)

Figure 3.29 shows the potential for buried cultural deposits in the North Fork of the Dismal River valley at archeological site 25HO47 (Locality 8; Figure 3.20). As noted previously for the South Fork Dismal River at the Munn Locality (Locality 7), the SSURGO map (Figure 3.29A) depicts the North Fork Dismal River valley as being comprised of eolian deposits (i.e., Valentine soil series).

The REM map, however, indicates the presence of T-0a floodplain, colluvial apron, and co-alluvial fan LSAs in the stream valley (Figure 3.29B). Like the Munn Locality, the REM map for this study reach does not depict the T-1 terrace because based on field investigations at site 25HO47 it stands >10 m above the modern channel. Only elevations up to 10 m above the channel are depicted on the REM maps. As previously noted, terrace LSAs are only preserved in isolated remnants along the valley walls and are difficult to identify in narrow river valleys.

Site 25HO47 is in the North Fork Dismal River valley about 3.75 km northeast of Munn Section 5 (Figure 3.20). Remnants of a prominent, unpaired alluvial terrace (T-1) occur along this segment of the river (Figure 3.30).

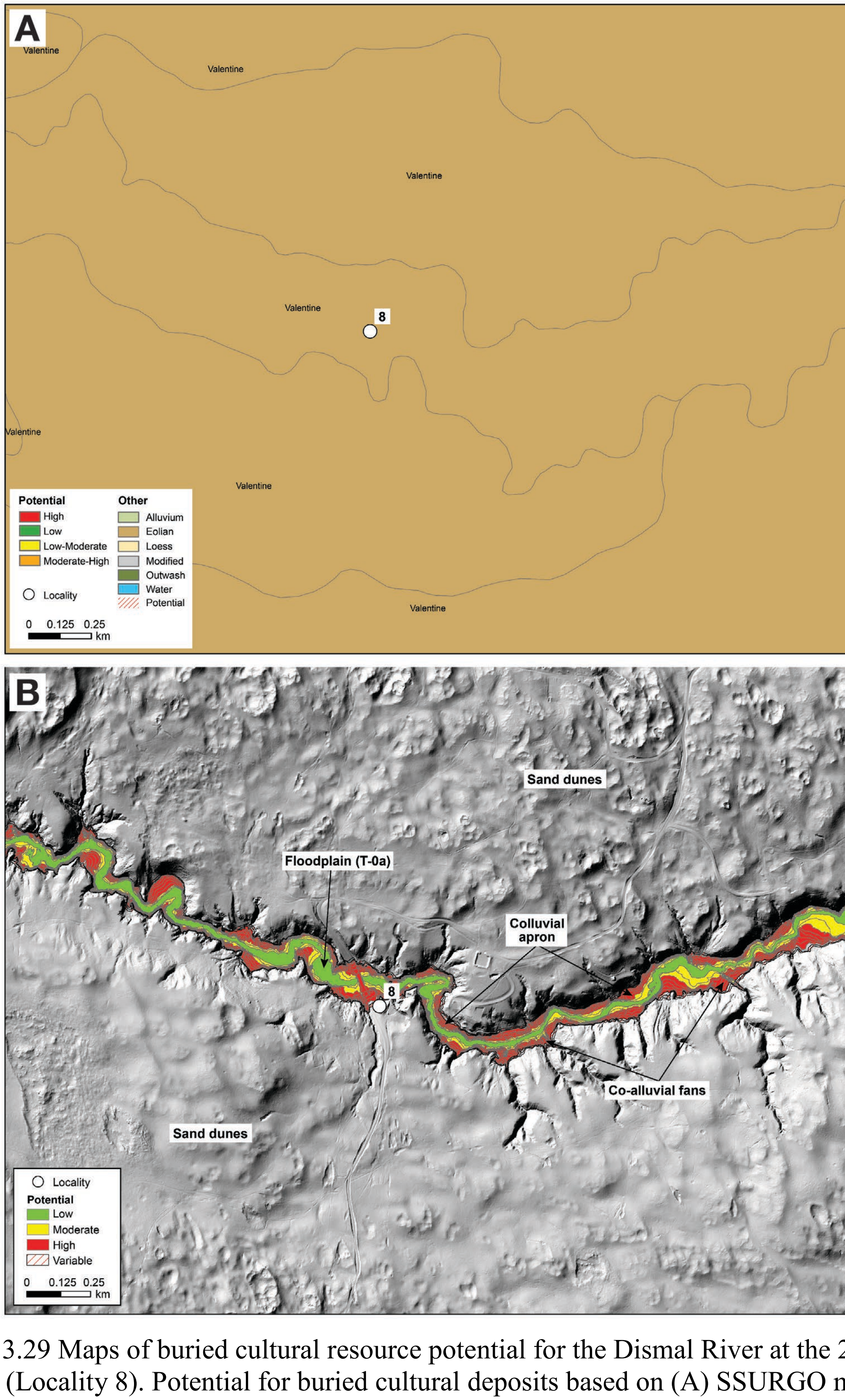

Figure 3.29 Maps of buried cultural resource potential for the Dismal River at the 25HO47 Locality (Locality 8). Potential for buried cultural deposits based on (A) SSURGO model and (B) REM data.

Figure 3.30 Photograph of the South Fork Dismal River valley near site 25HO47. Note sloping tread of T-1 terrace.

A borrow pit on the south side of the river provided an opportunity to examine a thick section of the T-1 fill (Figure 3.31). Although the section was not described in detail, the depths of buried soils were recorded, and bulk soil samples were collected for radiocarbon dating.

Three buried soils occur in the section at site 25HO47 (Figure 3.31). The top of the shallowest buried soil, Soil 2, is 1.00 m below the T-1 surface. Soil organic matter from the upper 10 cm of Soil 2 yielded a radiocarbon age of 1070 cal yr BP. The top of the next deepest soil, Soil 3, is 4.20 m below the T-1 surface. Soil organic matter from the upper 10 cm of Soil 3 yielded a radiocarbon age of 2365 cal yr BP. The top of the deepest buried soil, Soil 4, is 4.90 m below the T-1 surface. Soil 4 is developed in a fine-grained channel fill, and soil organic matter from the upper 10 cm of the A horizon of Soil 4 yielded a radiocarbon age of 4365 cal yr BP.

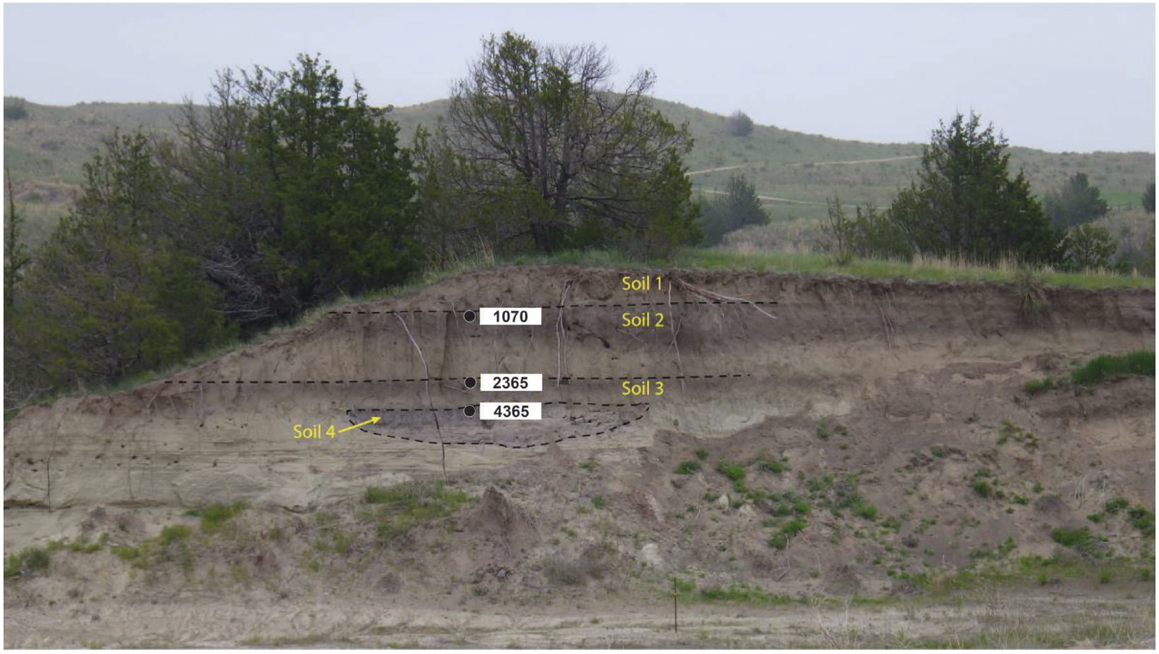

Figure 3.31 Photograph of the stratigraphic section exposed in the borrow pit at site 25HO47.

Based on soil-stratigraphic and chronologic information gleaned from the section at site 25HO47, most of the upper 5 m of the T-1 fill of the North Fork Dismal River aggraded between ca. 4500 and 1000 yr BP. Aggradation was punctuated by three episodes of landscape stability and related soil development. A final pulse of T-1 aggradation occurred after ca. 1150 ^{14}C yr BP, emplacing about 50–100 cm of alluvium on the late-Holocene floodplain (now the T-1 terrace). Taking regional alluvial chronologies into account (see Mandel 1995, 2006), the river probably downcut around 1000 ^{14}C yr BP (Medieval Warm Period), transforming its late-Holocene floodplain into a terrace.

The results of the geomorphological investigation at site 25HO47 indicate that there is high potential for Middle Archaic and younger cultural deposits in the T-1 fill of the North Fork Dismal River. Specifically, Middle and Late Archaic cultural deposits are likely to be associated with Soil 4, and Late Archaic and Plains Woodland archeological materials may occur on and within Soil 3. Plains Woodland and Plains Village cultural deposits are likely to be associated with Soil 2.

3.3.3 Anderson Locality (Locality 9)

Figure 3.32 shows the potential for buried cultural deposits in the Dismal River valley at the Anderson locality. Based on SSURGO data, the Bolent soil series in this study reach indicates low potential (Figure 3.31A). Here, the low potential is attributed to (1) somewhat poorly drained conditions, (2) a channeled floodplain setting that is frequently flooded, (3) very weakly developed soils with A-C-Cg horizonation, and (4) sandy textured sediments. In the study reach, one Bolent soil polygon was attributed with low-moderate potential based on its description as representing a floodplain setting that is rarely flooded. Hence, this polygon likely maps a T-0c LSA.

Polygons mapped as the Natick soil series in the SSURGO model indicate moderate-high potential (Figure 3.32A). The potential for Natick soils is based on (1) moderately well drained conditions, (2) association with stream terrace LSAs, (3) weakly developed soils with A-AC-C horizonation, and (4) development in sandy alluvium.

The REM map (Figure 3.32B) indicates that the Bolent soil series, mapped as having low potential in the SSURGO model, appropriately maps floodplain LSAs. However, there is very little differentiation between T-0a and T-0b/T-0c surfaces. The only exception in this study reach is the isolated Bolent soil polygon mapped with low-moderate potential, which correctly represents the T-0c LSA.

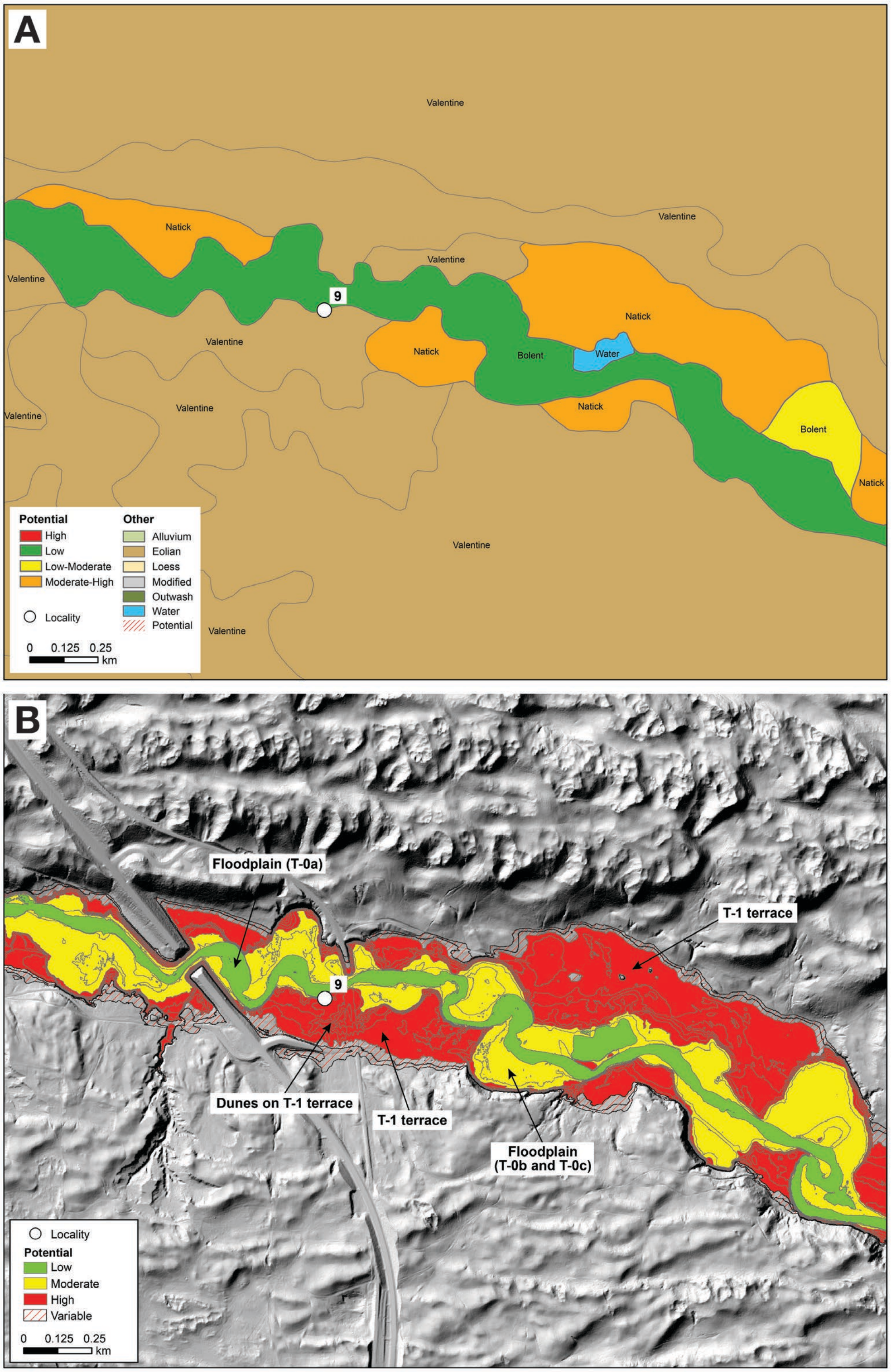

Figure 3.32 Maps of buried cultural resource potential for the Dismal River at the Anderson Locality (Locality 9). Potential for buried cultural deposits based on (A) SSURGO model and (B) REM data.

T-1 terrace LSAs on the REM map are accurately depicted by the Natick soil series in the SSURGO model. The REM data indicate that the T-1 terrace stands ~5 m above the modern channel, however, the terrace tread is mantled in some areas by sand dune deposits that are up to 2 m thick. Therefore, in the SSURGO model, some of the T-1 terrace LSAs delineated in the REM map are mapped as eolian deposits (i.e., Valentine soil series). A case in point is the T-1 terrace at the Anderson Locality.

Figure 3.33 Photograph of the Anderson Locality in the Dismal River valley. T-1 terrace and floodplain LSAs shown. View looking south.

The Anderson Locality is in the Dismal River valley about 60 km downstream from the Munn Locality (Figure 2.1). At Anderson, the T-1 surface spans most of the valley floor on the south side of the river channel and is partly mantled by sand dunes (Figures 3.32B and 3.33). The

Dismal River has migrated laterally into the T-1 terrace, exposing alluvium and lacustrine deposits in a cutbank on the south side of the valley floor (Figure 3.33). A 4.6 m-thick section of the T-1 fill was described and sampled for radiocarbon-dateable materials (Figure 3.34; Table A.14).

The lower 2.82 m of the T-1 fill in the Anderson section consists of stratified sandy alluvium with horizontal and trough cross-bedding typical of a high-energy channel or near-channel depositional environment. A distinct bed of stratified lacustrine deposits consisting of diatomite and organic-rich lacustrine mud occurs above the sandy alluvium, at a depth of 123-178 cm below the T-1 surface (Figures 3.22 and 3.33). Sandy alluvium spans the upper 123 cm of the T-1 fill, with a weakly developed buried soil (Soil 2, A-C profile) occurring at a depth of 40-46 cm. A thin surface soil (Soil 1) with A-C horizonation occurs at the top of the T-1 fill.

A suite of six radiocarbon ages and one OSL date provides a numerical chronology for the T-1 fill at the Anderson section. Quartz grains collected at a depth of 450 cm below the T-1 surface yielded an OSL age of 1810±70 yr BP, and charcoal collected at a depth of 138–141 cm in an organic-rich deposit of lacustrine mud yielded a radiocarbon age of 1905 cal yr BP. Organic matter from a bed of organic-rich lacustrine mud at a depth of 178 cm, directly below a thin bed of diatomite, yielded a radiocarbon age of 1575 cal yr BP. Also, organic matter from bulk sediment samples collected at depths of 123–128 cm, 146–151 cm, and 160–165 cm below the surface in lacustrine deposits yielded radiocarbon ages of 850 cal yr BP, 1105 cal yr BP, and 1250 cal yr BP, respectively. Finally, soil organic matter from the upper 10 cm of the Ab horizon of Soil 2 yielded a radiocarbon age of 515 cal yr BP.

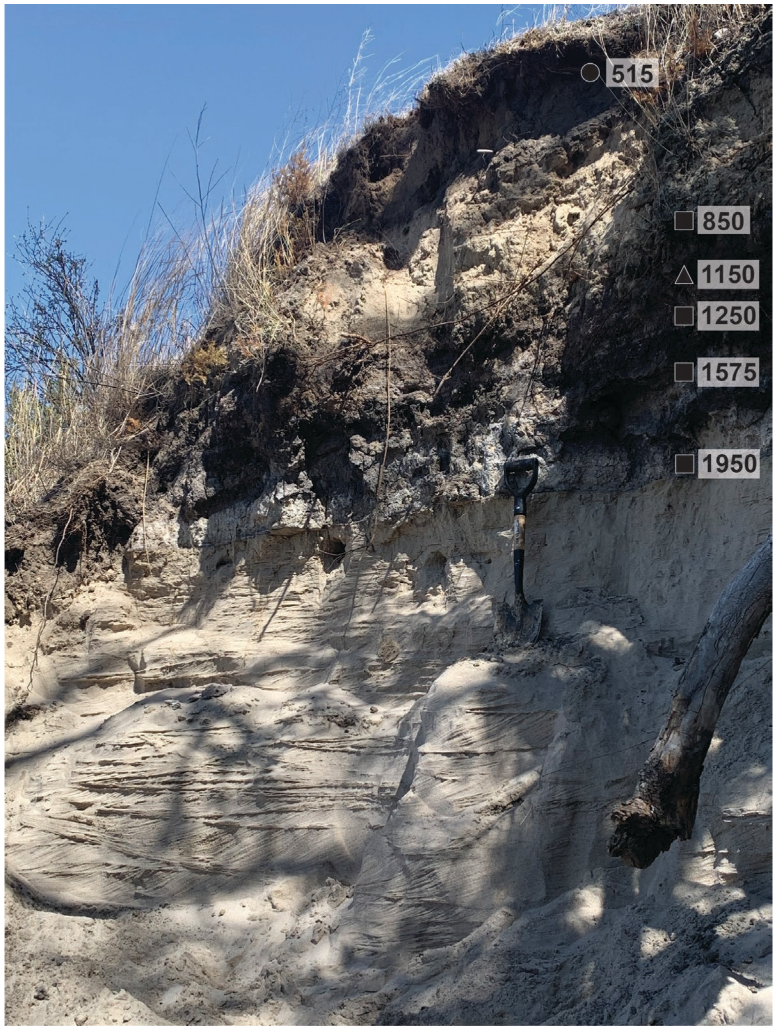

Figure 3.34 Photograph of the profile described at the Anderson Locality in the Dismal River valley.

The results of the investigation at the Anderson Locality indicate that late-Holocene alluvium deposited under high-energy conditions was buried by lacustrine deposits around 1,900 years ago. It is likely that dune damming occurred in the Dismal River valley at that time and that a lake persisted until about 850 years ago. After 850 cal yr BP, rapid alluviation resumed on the late-Holocene floodplain, resulting in burial of the lacustrine deposits. During the final phase of T-1 aggradation, a brief episode of landscape stability and soil development (Soil 2) occurred around 500 years ago. The T-1 surface stabilized and the surface soil (Soil 1) formed soon after 515 cal yr BP.

Based on the findings described above, most of the upper 4.6 m of the T-1 fill at the Anderson Locality has low potential for containing buried cultural deposits. High-energy fluvial deposits spanning the lower 2.82 m of the section are unfavorable for the preservation of in situ cultural deposits. However, the lake margins represented by the lacustrine deposits at a depth of 123–178 cm have high potential for Plains Woodland cultural deposits. Also, there is moderate potential for buried Plains Village cultural deposits in association with Soil 2 in the alluvium above the lacustrine deposits.

3.4 Snake River valley

3.4.1 Sasse Locality (Locality 10)

Figure 3.35 shows the potential for buried cultural deposits in the Snake River valley at the Sasse locality. Based on the SSURGO model, the valley floor is dominated by Fluvaquents and Almeria soil series indicating low potential. The low potential for these soils is attributed to (1) very poorly drained conditions, (2) a floodplain setting that is channeled (Almeria) and frequently flooded, (3) very weakly developed soils with Oe-Cg (Fluvaquents) or A-C-Cg (Almeria) horizonation, and (4) sandy textured sediments. In the study reach there is one polygon representing the Bolent soil series that also has low potential. Bolent soils are similar to Almeria soils except they are somewhat poorly drained and occasionally flooded.

The Calamus soil series indicates low-moderate potential based on (1) moderately well drained conditions, (2) a floodplain setting, (3) weakly developed soils with A-C horizonation, and (4) sandy textured sediments. These soils likely represent the T-0c floodplain LSA.

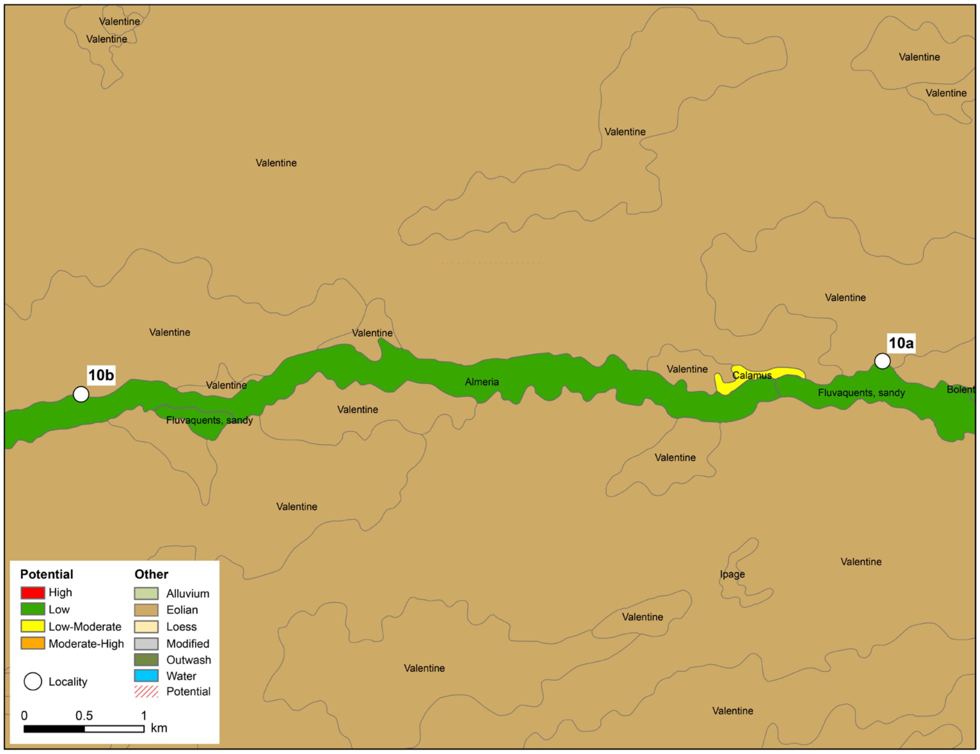

Figure 3.35 Map of buried cultural resource potential for the Snake River at the Sasse Locality (Locality 10) based on SSURGO model. Locality 10a = Section 1; Locality 10b = Section 2

No REM was developed for the Snake River valley; however, two stratigraphic sections were studied on the Sasse Ranch (Locality 10, Figure 2.1) where an alluvial terrace is mantled by almost 5 m of eolian sand. Because of the thickness of the eolian sand, both sections are mapped as the Valentine soils series in the SSURGO model (Figure 3.35).

At Section 1 (Locality 10a), the river channel has migrated laterally and is cutting into a dune-mantled terrace on the north side of the valley floor (Figure 3.36). Detailed descriptions were completed for two profiles: Profiles 1 and 2. A brown peat exposed in that another profile (Profile 3) was sampled and radiocarbon dated but was not described.

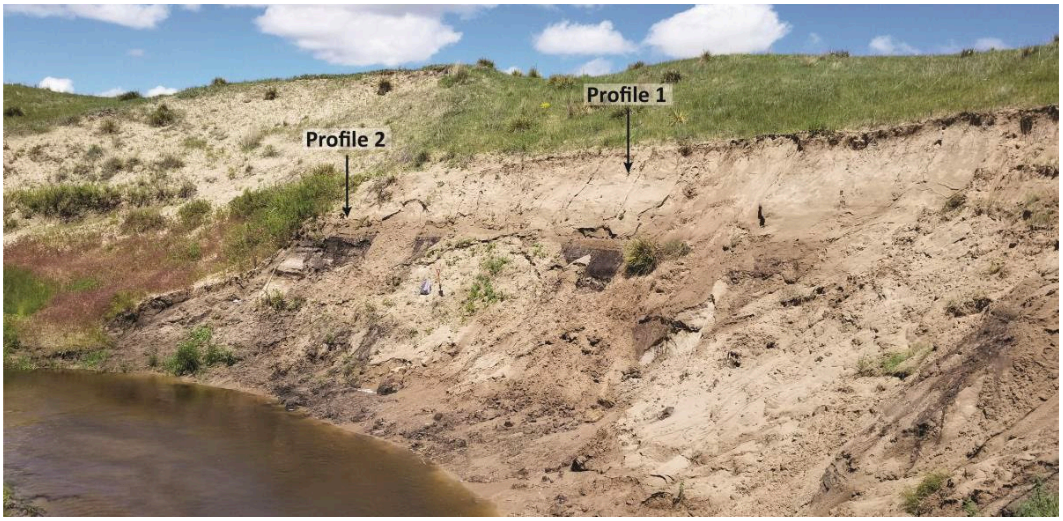

Figure 3.36 Photograph of profiles 1 and 2 described at the Sasse Locality, Section 1 in the Snake River valley.

In Profile 1 of Sasse Section 1, a 4.80 m-thick deposit of eolian sand mantles a peaty muck at the top of an alluvial sequence (Figures 3.37A and 3.38; Table A.15). The peaty muck consists of fine textured, nonfibrous organic matter derived from aquatic vegetation. A few small remains of sedges, reeds, and grass-like plants are scattered through the muck. An "H" was used to designate the soil horizons associated with the muck. By definition, an H master horizon is formed from accumulations of undecomposed or partially decomposed organic material at the original land surface (Chesworth 2008: 668). All H horizons are saturated with water for prolonged periods or were once saturated but are now drained. An H horizon may be on top of mineral soils or at any depth beneath the surface if it is buried.

The 2H1b-2H4b horizons comprising the muck have a combined thickness of 1.06 m. The muck formed as organic matter accumulated in a wetland, probably a marsh or a shallow pond like the ones that presently occur on the floodplain of the Snake River and was buried by sand dunes. Organic matter from the upper 5 cm of the 2H1b horizon (480–485 cm below surface), upper 5 cm of the 2H3b horizon (555 cm below surface), and the peat bed at 625–630 cm below the surface yielded radiocarbon ages of 8485, 9505, and 11,860 cal yr BP, respectively (Figures 3.37A).

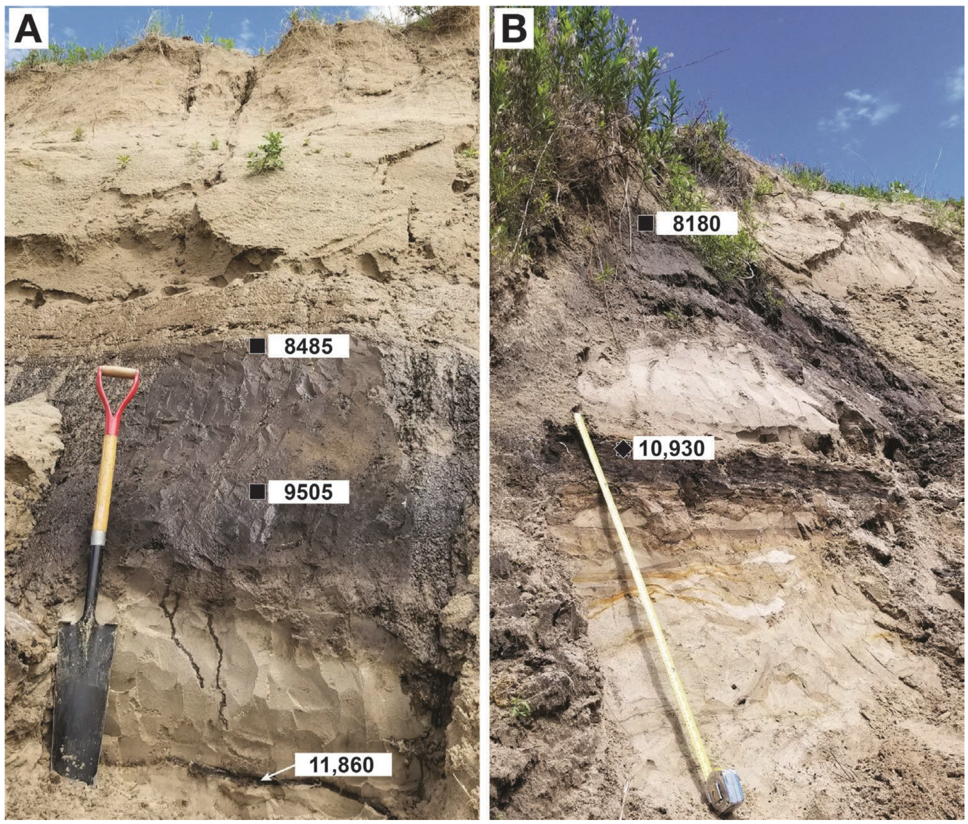

Figure 3.37 Photograph of (A) Profile 1 and (B) Profile 2 described at the Sasse Locality, Section 1.

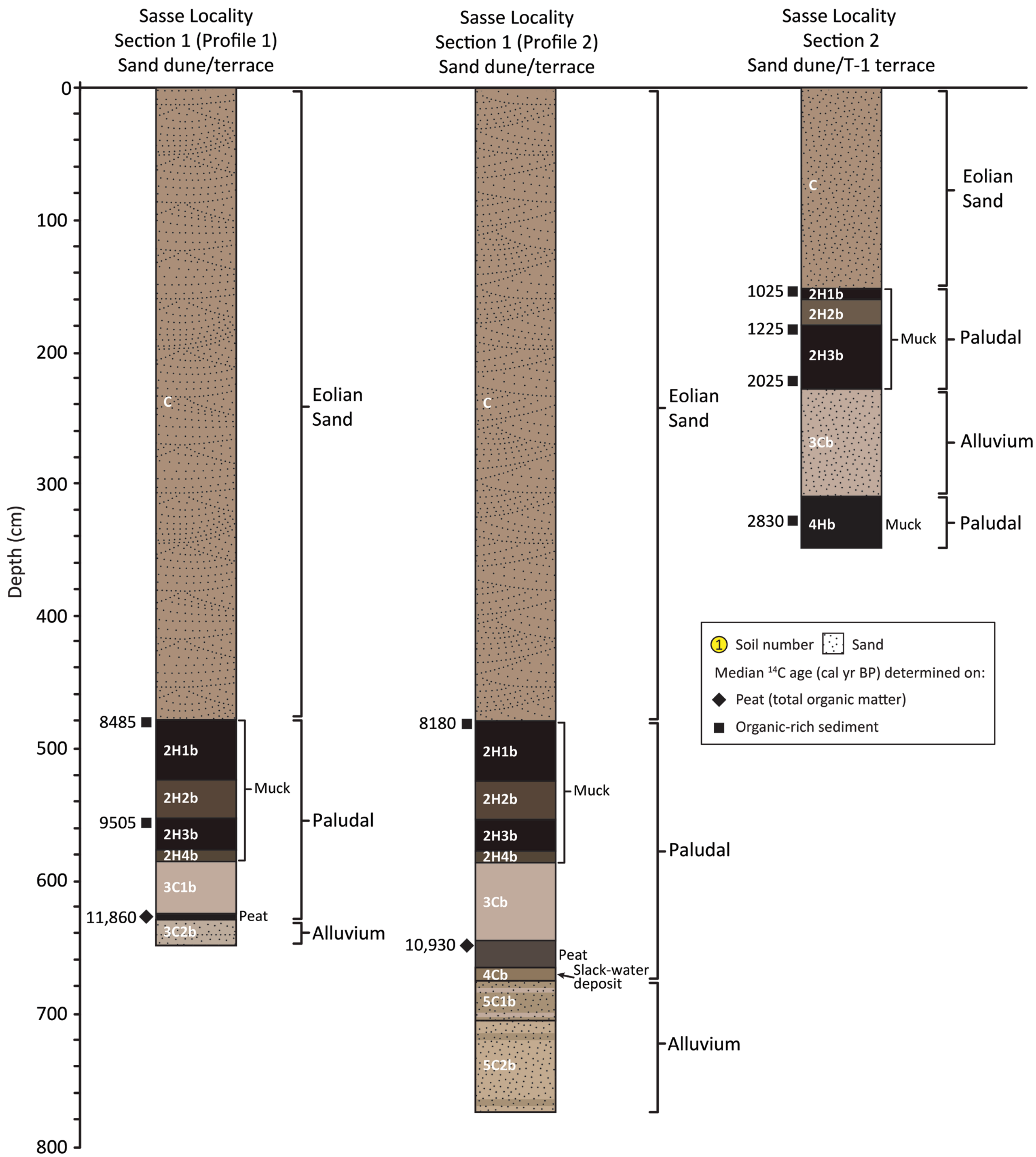

Figure 3.38 Diagram of the soil-stratigraphy from the Sasse Locality (Locality 10) in the Snake River valley.

Profile 2 in the Sasse Section is located about 20 m west of Profile 1. The sequence of deposits recorded in Profile 1 is mostly repeated in Profile 2: a 4.80 m-thick deposit of eolian sand mantles a 1.06 m-thick bed of organic-rich muck at the top of an alluvial sequence (Figures 3.37B and 3.38; Table A.16). In Profile 2, organic matter from the upper 5 cm of the 2H1b horizon (480–485 cm below surface) yielded a radiocarbon age of 8180 cal yr BP, which is similar to the age determined on organic carbon from the upper 5 cm of the muck in Profile 1. However, organic matter from the upper 5 cm of the peat bed at 645–665 cm below surface yielded radiocarbon age of 10,930 cal yr BP, which is about 600 years younger than the peat in Profile 1. It is important to note that (1) the peat bed in Profile 1 is only 5 cm thick, whereas the peat bed in Profile 2 is 20 cm thick, and (2) the upper 5 cm of the peat in Profile 2 was dated, whereas the full thickness (5 cm) of the peat was dated in Profile 1. Hence, the accumulation of organic material that forms the peat in the area of Profile 2 may have spanned the period ca. 11,860 to 10,930 cal yr BP, but the basal age is unknown.

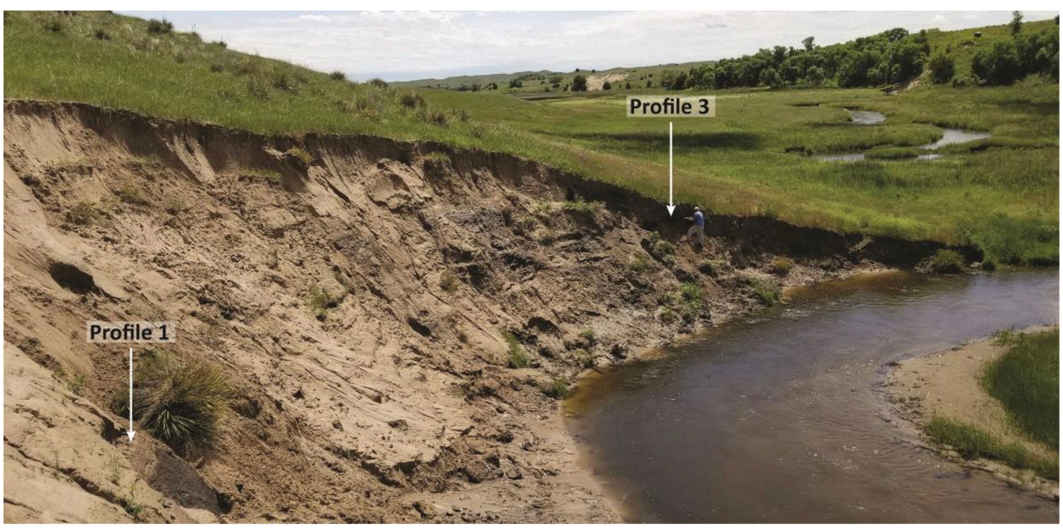

Figure 3.39 Photograph of profiles 1 and 3 at the Sasse Locality, Section 1 in the Snake River valley.

Profile 3 in the Sasse Section 1 is located about 30 m east of Profile 1. In the area of Profile 3, the Snake River has stripped off most of the deposits recorded in profiles 1 and 2, leaving stratified brown and dark gray peat beneath a 35 cm-thick surface veneer of slopewash (Figure 3.39). The upper-most peat deposit is about 15–35 cm thick. A sample of peat from the upper 5 cm of that organic deposit yielded a radiocarbon age of 12,375 cal yr BP, which is about 500 years older than the peat sample collected at a depth of 625–630 cm below the surface in Profile 1.

Based on the stratigraphic and temporal information gleaned from the three profiles at Sasse Section 1, rapid aggradation on the terminal Pleistocene floodplain of the Snake River was followed by slow sedimentation and the establishment of a paludal (marsh) depositional environment by ca. 11,860 cal yr BP. Although there was an episode of rapid sedimentation sometime between ca. 10,930 and 9505 cal yr BP, the paludal environment mostly persisted until ca. 8180 cal yr BP. Sometime after ca. 8180 cal yr BP, the paludal deposits were buried by a sand dune.

At Sasse Section 2 (Locality 10b; Figures 2.1 and 3.35), which is located about 5 km upstream of Sasse Section 1, the valley floor of the Snake River consists of a floodplain complex (T-0a and T-0b) and a low alluvial terrace (T-1) (Figure 3.40). Narrow surfaces of modern point and channel bar deposits that are at or slightly above the water-surface elevation comprise T-0a. T-0b is a broad floodplain surface that stands about 2 m above T-0a and is frequently flooded. The T-1 terrace is an unpaired geomorphic surface about 2 m above the T-0b surface and is occasionally flooded. The channel of the Snake River has migrated laterally into the T-1 terrace on the north side of the valley floor, exposing a 3.5 m-thick package of deposits in a steep cutbank designated as Sasse Section 2).

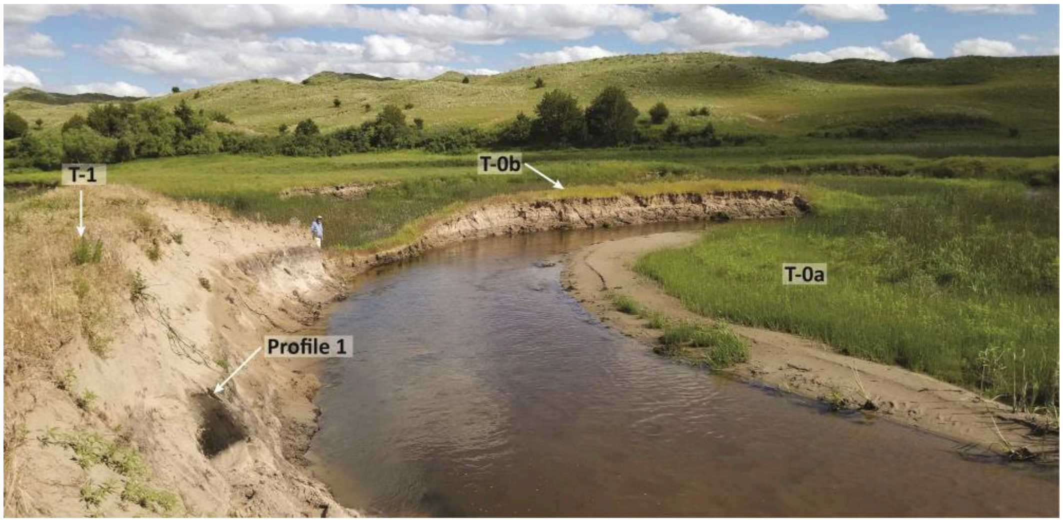

Figure 3.40 Photograph of the Sasse Locality, Section 2 in the Snake River valley showing LSAs.

Figure 3.41 Photograph of the profile described at the Sasse Locality, Section 2 in the Snake River valley.

In Sasse Section 2, a 1.53 m-thick deposit of eolian sand mantles an organic-rich muck at the top of an alluvial sequence (Figures 3.38 and 3.41; Table A.17). Like the muck in Sasse Section 1, it consists of fine textured, nonfibrous organic matter derived from aquatic vegetation. The 2H1b-2H3b horizons have a combined thickness of 77 cm, and an underlying unit of sandy alluvium overlies a bed of laminated muck that spans the lower 40 cm of the section (Figure 3.38).

Organic matter from the upper 5 cm of the 2H1b horizon (153–158 cm below the surface), upper 5 cm of the 2H3b horizon (180–185 cm below the surface), lower 5 cm of the 2H3b horizon 225–230 cm below the surface), and upper 5 cm of the 3Hb horizon (310–315 cm below the surface) yielded radiocarbon ages of 1025, 1225, 2025, and 2830 cal yr BP, respectively. Based on these ages, there was a marsh on the late-Holocene floodplain (now the T-1 terrace) at ca. 2830 cal yr BP. The marsh was buried by alluvium soon after that time, but a marsh was reestablished on the late-Holocene floodplain by ca. 2025 cal yr BP and remained there until it was buried by eolian sand soon after ca. 1025 cal yr BP.

Overall, there is low potential for buried cultural deposits at sections 1 and 2 in the Snake River valley. Both sections have thick paludal deposits that represent former wetlands. Although people may have occupied well drained landforms adjacent to the wetlands, it is unlikely that they would have camped within the wetlands. Also, the alluvial and eolian deposits in sections 1 and 2 lack buried soils and, therefore, have low potential for cultural deposits in buried contexts.

Chapter 4 Discussion and conclusions

4.1 Landscape evolution and buried site potential in river valleys of the Sandhills

A suite of 58 radiocarbon ages was used to assess landscape evolution in river valleys of the Sandhills. Ages span the entire Holocene and range from 12,600–110 cal yr BP. All radiocarbon ages were ranked and plotted from youngest to oldest (Figure 4.1). Larger vertical gaps between ages (i.e., fewer ages over a given period) in Figure 4.1 correspond to periods of landscape instability (i.e., sediment erosion, transport, and aggradation) whereas small vertical gaps between ages (i.e., more ages for a given period) correspond to periods of relative landscape stability (i.e., soil development, wetland formation, limited erosion and aggradation).

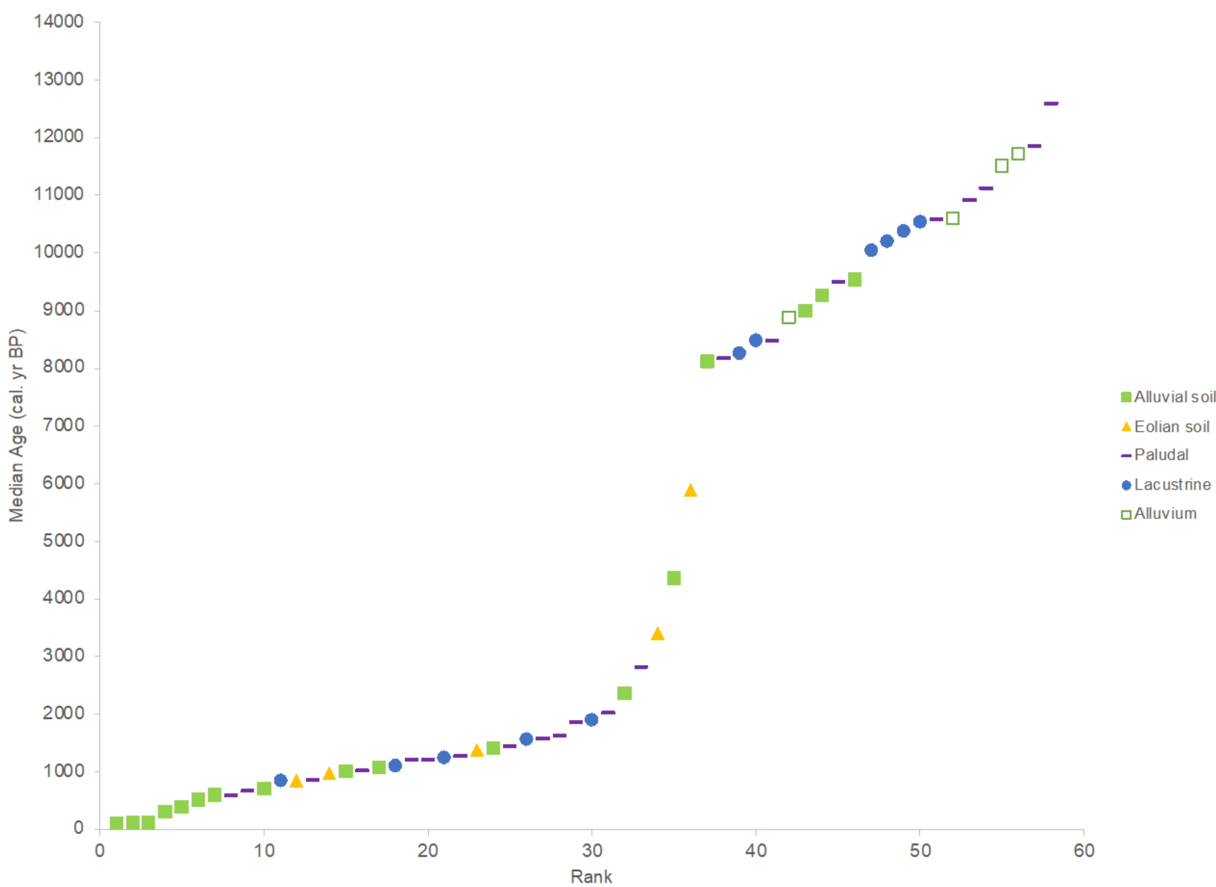

Figure 4.1 Plot of radiocarbon ages collected in this study ranked from youngest to oldest.

The period from ca. 12,600–8000 cal yr BP is dominated by ages derived from lacustrine (lake) and paludal (wetland) deposits. Hence, paleoenvironmental conditions were likely wet, with high water tables in river valleys of the Sandhills. It is possible that the formation of lakes and wetlands was facilitated by increased precipitation during this period. However, it is also possible that the formation of lakes and wetlands resulted from dune damming during dry periods (e.g., Loupe et al., 1995; Mason et al., 1997). In this scenario, prevailing periods of aridity could have resulted in landscape instability and dune migration across river valleys, thereby blocking stream channels and raising water tables. Increasingly arid conditions during the later part of the Younger Dryas (ca. 12,900–11,500 cal yr BP) and into the early Holocene have been documented throughout the western Great Plains (i.e., High Plains) (e.g., Holliday, 2000; Mandel, 2008). However, additional paleoenvironmental investigations, using a variety of different proxies, are warranted to decouple these two potential mechanisms of lake and wetland formation during the early Holocene in river valleys of the Sandhills.

The latter part of the period from ca. 12,600–8000 cal yr BP also was a time of quasi-stability in upstream reaches of rivers in the Sandhills. Specifically, buried cumulic soils in the T-1 fill at the Munn (Section 1, Soil 3) and Fits Drive (Section 1, Soil 5) localities date to ca. 9500–9000 cal yr BP. Because cumulic soils indicate slow aggradation accompanied by soil development, there is no evidence for episodic large magnitude flooding at this time. Alluvial and paludal soils dating to the early Holocene were only found in narrow, upstream reaches of river valleys. In contrast, only early Holocene lacustrine and paludal deposits were identified in downstream reaches where the river valleys widen. However, it is likely that the lake and wetland deposits grade into alluvial and paludal soils, which represent greater landscape stability, in these downstream locations, i.e., pedofacies occur on the valley floors.

The period from ca. 8000–3000 cal yr BP is characterized by very few radiocarbon ages suggesting landscape instability at that time in river valleys of the Sandhills. Only three radiocarbon samples yielded ages that date to this period. Two ages are from buried soils in eolian sand dunes, and the other age is from an alluvial soil developed in a paleochannel fill that represents a localized period of stability. Regional studies have shown that the middle Holocene (i.e., Altithermal, ca. 8000–4000 yr BP) was a period of significant bioclimatic change in the central Great Plains (Layzell et al., 2020; Mandel et al., 2023). At that time stronger zonal airflow restricted the northward penetration of moist tropical air from the Gulf of Mexico into the central Great Plains, resulting in a warm, dry climate. Studies have suggested that these prevailing climatic conditions destabilized the uplands by changing the vegetation composition, resulting in high rates of erosion and transport of sediment from uplands and hillslopes to valley floors in the region (Layzell and Mandel, 2020). This would have resulted in aggradation of valley fills and would explain the lack of buried alluvial soils dating to this period.

The period from ca. 3000–0 cal yr BP is characterized by ages from a variety of different deposits. For example, from ca. 3000–1000 cal yr BP, most ages are from lacustrine and paludal deposits suggesting wetter conditions and higher water tables. Regional paleoenvironmental records support the presence of wetter conditions in the Central Plains during the late Holocene (e.g., Baker et al, 2000; Grimm et al., 2011). Wetter conditions were likely facilitated by a change in atmospheric circulation patterns during the late Holocene from zonal flow to meridional flow (Knox, 1983). Meridional flow allowed for the penetration of warm, moist, tropical air masses from the Gulf of Mexico into the Central Plains, resulting in more frequent frontal activity and increased precipitation. A few ages from ca. 3000–1000 cal yr BP are from buried alluvial soils, but after ca. 1000 cal yr BP the chronological record is dominated by alluvial soils. Increased precipitation from frontal activity during the late Holocene would have resulted in episodic, large magnitude floods in river valleys, resulting in cycles of incision and aggradation. For example, Layzell and Mandel (2020) showed that low frequency, high magnitude flooding resulted in episodic aggradation of both floodplain and terrace LSAs in the Republican River valley after ca. 2000 yr BP. Regional incision in stream valleys of the Central Plains after ca. 1000 yr BP has also been widely documented (e.g., Hall, 1990; Mandel 1995, 2006a; Daniels and Knox, 2005; Layzell and Mandel, 2020).

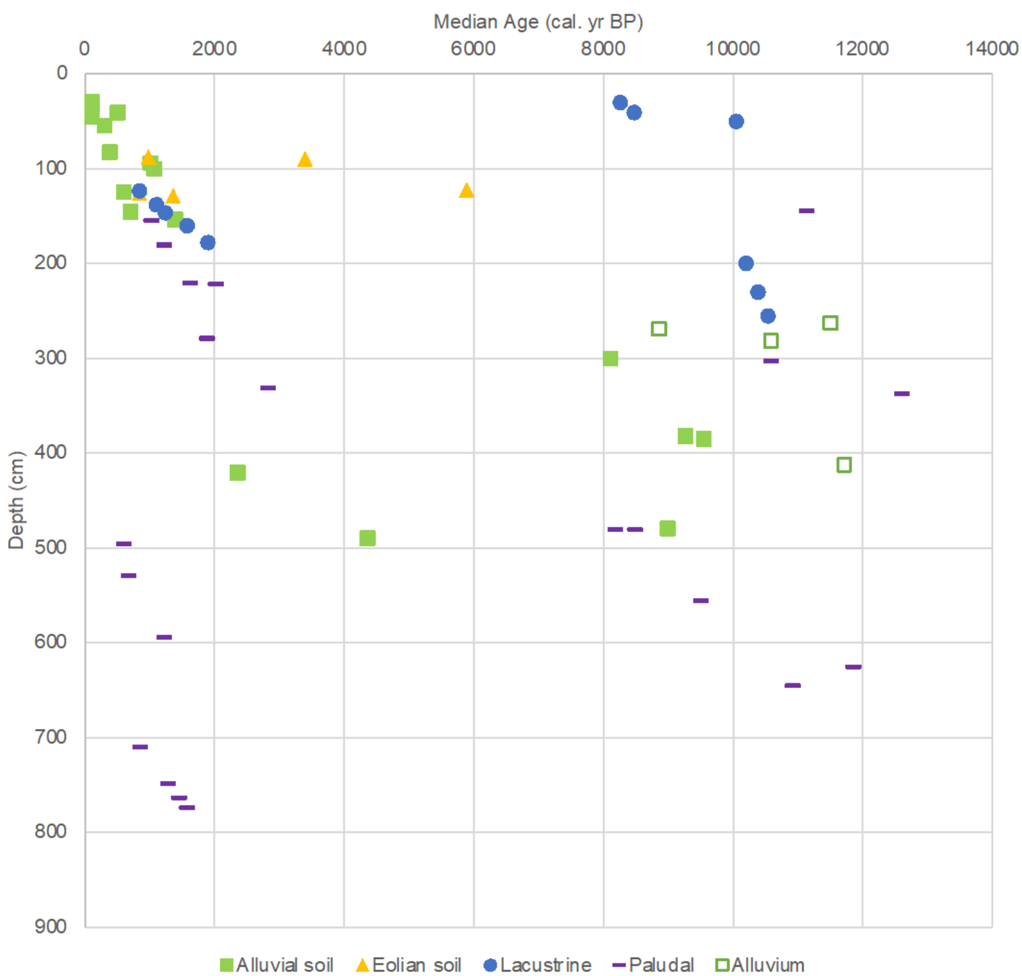

Figure 4.2 Plot of radiocarbon ages collected in this study as a function of depth below surface.

Figure 4.2 shows radiocarbon ages plotted as a function of sample depth below the surface. The majority of buried alluvial soils are less than 2 m below the surface and date to less than 1500 cal yr BP. These buried soils are found in T-0b fill (e.g., Bostron Locality), T-1 fill (Miles, Nutter, and Anderson localities), and alluvial fan deposits (i.e., O'Brien Locality). Therefore, depending on the degree of soil development, there is potential for Plains Woodland and younger cultural deposits in the upper 2 m of these LSAs. It should be noted that these spatial patterns should be used as a general approximation as these landforms can be mantled by 1–2 m of eolian sand, thereby increasing the potential depth to buried cultural resources.

The majority of radiocarbon ages determined on materials below 2 m depth are from lacustrine and paludal deposits. Therefore, any cultural record associated with the margins of these deposits is deeply buried. Some of the radiocarbon ages determined on materials deeper than 2 m below the surface are from alluvial/paludal soils. However, those soils were only found in narrow, upstream reaches of the studied river systems. For example, the youngest two ages are from site 25HO47 (Locality 8), whereas the early Holocene ages are from the Munn and Fits Drive localities (localities 7a and 3a, respectively). The soils are more deeply buried in these reaches because the valley fills are thicker. For example, the T-1 terrace stands greater than 10 m above the stream channel in these narrow, upstream reaches compared to 4–5 m in wider, downstream reaches. This spatial pattern can be explained by considering the relationship between sediment supply and stream discharge. For example, thicker valley fills in upstream reaches may result from higher sediment inputs, lower stream discharges, and/or less accommodation space in the narrow valleys. Because the deeply buried soils at the Munn and Fits Drive localities comprise intact, cumulic A horizons that are very weakly developed, there is at least moderate potential for Late Paleoindian and Early Archaic cultural deposits associated with the T-1 fill in narrow, upstream portions of the studied river valleys.

4.2 Strengths and limitations of SSURGO and REM data

Previous phases of this study indicated the ability to readily identify LSAs from SSURGO data as one of its main strengths. Specifically, certain SSURGO tables included descriptions of where particular soil series occur in the landscape, e.g., floodplains, alluvial fans, terraces, upland drainageways, colluvial footslopes, etc. This information is valuable because geoarchaeological studies have shown that specific LSAs are more likely to contain buried soils and therefore buried cultural deposits than others. However, in the Sandhills region, delineation of different LSAs from SSURGO datasets is often hindered by the presence of eolian deposits that mantle a variety of different LSAs. One of the major limitations of SSURGO data is that only the upper 1–2 m of soil parent materials are considered. Because certain LSAs (i.e., stream terraces) are often mantled by 1–2 m of eolian material, key information pertaining to underlying LSAs and, specifically, the presence or absence of buried soils is missing. Information on types of deposits below ~2 m is important because of the nature of the alluvial stratigraphic record. For instance, unconformable stratigraphic relationships are often present in alluvial deposits (e.g., Locality 6) and therefore the age of sediments at depth may be significantly greater than at the surface (Mandel, 2008).

Delineation of LSAs from SSURGO data is also hampered by a second major limitation, namely, the spatial scale of the soil survey mapping. The prioritization of different landscape features and soil types is inherently different at different spatial scales (Hudson and Culver, 1994; Miller and Schaetzl, 2015). The SSURGO database contains information collected at scales ranging from 1:12,000 to 1:63,360. These scales permit a minimum size for delineating map units of 0.57 ha to 16.2 ha (Soil Survey Division Staff, 1993). Consequently, the scale of most map units as well as the variability inherent in those mapping units is greater than the scale of many archeological sites (Holliday and Mandel, 2017c). Also, the discrete borders of map units may not denote actual soil boundaries because soils do not have sharp contacts and typically grade from one type into another (Holliday and Mandel, 2017c). Finally, many mapping decisions are subjective because soil survey mappers are called upon to make judgment calls based on whether a particular soil can be mapped consistently and whether it meets the objectives of the survey. For example, having too many map unit delineations may reduce the overall usefulness of a soil map. Therefore, the degree to which soil survey data accurately depicts soil-geomorphic relationships will vary depending on the training and experience of the soil mapper. In sum, the fundamental issue of scale in soil survey mapping is that the actual soils associated with a given map unit may not necessarily be those indicated on the map. In the Sandhills, this is most evident in narrow stream valleys that are mapped with soil series comprising eolian deposits (e.g., localities 7 and 8).

The two major limitations of SSURGO data described above have hindered their use in archeological surveys. In this study, we attempted to overcome these limitations by developing a REM dataset as well as continuing to groundtruth the assignments of potential for buried cultural deposits that are based on soil survey data. The REM data provides a ready means to identify LSAs based on their relative elevation above the channel (e.g., floodplain and terraces LSAs) and slope (e.g., co-alluvial fans). Our groundtruthing supports the identification of these LSAs, but more groundtruthing would continue to improve the predictive power of both the SSURGO and REM GIS resources presented here. More field data is particularly needed for LSAs that are buried by eolian deposits, identifying terrace deposits in narrow stream valleys, delineating the margins of buried wetlands, and differentiating colluvial hillslopes and alluvial fans.

In sum, by using the REM and SSURGO datasets in conjunction with the detailed repository of geoarchaeological information that has been developed from extant studies in the Sandhills as part of this project, the Buried Sites GIS can be used as a helpful screening tool to determine whether certain areas are likely to be free of deeply buried cultural deposits or whether subsurface exploration is necessary. Because soil survey data are generalized, they should only be used to establish first approximations of buried-site potential. Detailed field investigations are necessary to confirm and elaborate on those approximations and to establish more appropriate spatial and temporal scales.

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Appendix A Soil descriptions

Table A.1 Description of Miles Ranch section, North Loup River.

Landform: T-1 terrace

Parent material: Alluvium and lacustrine

Land Cover: Grass

Remarks: Soil organic matter from the upper 10 cm of the A1b1 horizon of Soil 2, the Akb2 horizon of Soil 3, and the Ab3 horizon of Soil 4 yielded radiocarbon ages of 100±20 ^{14}C yr BP (115 cal yr BP), 1140±20 ^{14}C yr BP (1020 cal yr BP), and 1540±25 ^{14}C yr BP 1405 cal yr BP), respectively. Organic matter collected at a depth of 219-223 cm below the surface in a peat deposit yielded a radiocarbon age of 1740±20 ^{14}C yr BP (1630 cal yr BP).

Organic-rich material collected at a depth of 278-283 cm below the surface in a peaty muck deposit yielded a radiocarbon age of 1955±25 ^{14}C yr BP (1880 cal yr BP).

Depth (cm)	Soil Horizon	Description
		ALLUVIUM
		Soil 1
0-7	A	Dark grayish brown (10YR 4/2) very fine to fine sand, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; slightly hard, very friable; many very fine and fine roots; common open work burrows; gradual smooth boundary.
7-29	C	Dark grayish brown (10YR 4/2) very fine to fine sand, very dark grayish brown (10YR 3/2) moist; massive parting to single grain; slightly hard, very

friable; many very fine and fine, few medium roots; abrupt wavy boundary.

Soil 2

29-48	A1b1	Very dark gray (10YR 3/1) loamy fine sand, black (10YR 2/1) moist; weak medium and fine subangular blocky structure parting to weak fine granular; slightly hard, friable; many very fine and fine roots; common open work burrows; clear smooth boundary.
48-59	A2b1	Dark gray (10YR 4/1) loamy sand, very dark gray (10YR 3/1); weak medium subangular blocky structure parting to weak fine granular; slightly hard, friable; common very fine and fine roots; many very fine pores; clear smooth boundary.
59-68	A3b1	Very dark gray (10YR 3/1) loamy sand, black (10YR 2/1) moist; weak fine subangular blocky structure parting to weak fine granular; slightly hard, friable; common very fine and fine roots; many very fine pores; clear smooth boundary.
68-83	ACb1	Grayish brown (10YR 5/2) very fine to fine sand, dark grayish brown (10YR 4/2) moist; weak fine subangular blocky structure parting to very weak fine granular; slightly hard, very friable; common very fine and fine roots; many very fine pores; abrupt wavy boundary.
83-94	Cb1	Light brownish gray (10YR 6/2) fine sand, grayish brown (10YR 5/2) moist; massive parting to single grain; slightly hard to loose, friable; few very fine and fine roots; abrupt smooth boundary.

Soil 3

94-117	Akb2	Dark gray (10YR 4/1) loam, very dark gray (10YR 3/1); moderate medium and fine subangular blocky structure; hard, friable; common very fine and fine roots; many very fine pores; many fine and very fine carbonate threads in upper 10 cm, decreasing in abundance with depth; clear smooth boundary.
117-148	C1b2	Light brownish gray (10YR 6/2) very fine sand, grayish brown (10YR 5/2) moist; massive parting to single grain; slightly hard to loose, friable; few very fine roots; abrupt smooth boundary.
148-154	C2b2	Thinly-bedded light brownish gray (10YR 6/2) fine sand, grayish brown (10YR 5/2) moist; contains thin beds of dark gray (10YR 4/1) silty clay loam; massive parting to single grain; slightly hard to loose; abrupt smooth boundary.

Soil 4

154-180	Ab3	Dark gray (10YR 4/1) sandy loam, very dark gray (10YR 3/1); moderate fine subangular blocky structure parting to weak fine granular; slightly hard, friable; few very fine roots; many very fine pores; gradual smooth boundary.
180-210	C1b3	Laminated light brownish gray (10YR 6/2) fine to medium sand, grayish brown (10YR 5/2) moist; interbedded with 1-3 cm-thick, internally laminated wavy beds of dark gray (10YR 3/1) silty clay loam; massive parting to single grain; soft to loose, friable; few very fine and fine roots; abrupt wavy boundary.

210-218	C2b3	Laminated dark gray (10YR 3/1) silty clay loam, black (10YR 2/1) moist; interbedded with 1-3 cm-thick, internally laminated wavy beds of light brownish gray (10YR 6/2) fine to medium sand; massive parting to single grain; slightly hard to soft, friable; few very fine and fine roots; abrupt wavy boundary.
		PALUDAL
218-230	---	Gyttja; rubbery; organic matter heavily decayed; very hard, firm; many fine and very fine roots; abrupt irregular boundary.
230-245	---	Light brownish gray (10YR 6/2) fine to medium sand, grayish brown (10YR 5/2) moist; massive parting to single grain; loose to soft, very friable; few very fine roots; abrupt wavy boundary.
245-259	---	Thinly-bedded very dark gray (10YR 3/1) silty clay loam, black (10YR 2/1) moist; massive; hard, friable to firm; interbedded with 2-20 mm-thick wavy beds of light brownish gray (10YR 6/2) and grayish brown (10YR 5/2) very fine to fine sand; few very fine roots; horizon thickness varies from 7-14 cm; abrupt wavy boundary.
259-278	---	Interbedded grayish brown (10YR 5/2) very fine to fine sand, dark grayish brown (10YR 4/2) moist; massive parting to single grain; loose, friable; interbedded with 1-10 mm-thick very wavy beds of very dark gray (10YR 3/1) silty clay loam; few very fine roots; horizon thickness varies from 3-19 cm; abrupt wavy boundary.

278-291	---	Black (10YR 2/1) peaty muck; mineral portion consists of loam to very fine sandy loam; interspersed with brown peat; horizon thickness varies from 2-13 cm; abrupt wavy boundary.
291-301	---	Black (10YR 2/1) peaty muck interbedded with 4-10 mm-thick beds of grayish brown (10YR 5/2) very fine to fine sand; contains inclusions of brown peat; abrupt wavy boundary.
		ALLUVIUM
301-329	C3b3	Channel fill consisting of laminated light brownish gray (10YR 6/2) medium sand, grayish brown (10YR 5/2) moist; interbedded with laminae of dark gray (10YR 4/1) organic-rich sediment; massive parting to single grain; loose to soft, friable; abrupt wavy boundary (check photo).
329-360+	C4b3	Channel fill consisting of light brownish gray (10YR 6/2) fine to medium sand that fines upward, grayish brown (10YR 5/2) moist; massive parting to single grain; loose to soft, friable.

Note - channel fill (301-360 cm) laterally inset against black (10YR 2/1) peaty muck on west side of section.

Table A.2 Description of Wyckoff Ranch section, North Loup River.

Landform: Alluvial

Parent material: Alluvium and paludal

Land Cover: Grass

Remarks: Quartz grains collected from a depth of 490 cm below the surface yielded an OSL age of 680±270 yr.

Plant material collected from the top and bottom of a peat deposit at depths of 495 cm and 528 cm below the surface yielded radiocarbon ages of 590±25 ^{14}C yr BP (605 cal yr BP) and 760±25 ^{14}C yr BP (685 cal yr BP), respectively.

Plant macrofossils collected at a depth of 593 cm below the surface, from the top of a unit of organic-rich sediment, yielded a radiocarbon age of 1285±25 ^{14}C yr BP (1225 cal yr BP).

Depth (cm)	Soil Horizon	Description
		ALLUVIUM
		Soil 1
0-7	A	Grayish brown (10YR 5/2) loamy fine sand, dark grayish brown (10YR 4/2) moist; very weak fine granular structure; slightly hard, very friable; many very fine and fine roots; clear smooth boundary.
7-12	C	Pale brown (10YR 6/3) very fine sand, brown (10YR 5/3) moist; massive parting to single grain; very soft, very friable; many very fine and fine roots; abrupt smooth boundary.

		Soil 2
12-19	A1b1	Grayish brown (10YR 5/2) loamy fine sand, dark grayish brown (10YR 4/2) moist; weak fine granular structure; slightly hard, very friable; many very fine and fine roots; abrupt smooth boundary.
19-31	A2b1	Dark grayish brown (10YR 4/2) loamy fine sand, very dark grayish brown (10YR 3/2) moist; very weak fine granular structure; soft, very friable; many very fine and fine roots; abrupt smooth boundary.
31-38	ACb1	Grayish brown (10YR 5/2) loamy fine sand, dark grayish brown (10YR 4/2) moist; very weak fine granular structure; soft, very friable; many very fine and fine roots; common dark grayish brown (10YR 4/2) organic stains; abrupt smooth boundary.
		Soil 3
38-47	Ab2	Grayish brown (10YR 5/2) loamy fine sand, dark grayish brown (10YR 4/2) moist; very weak fine granular structure; soft, very friable; many very fine and fine roots; heavily bioturbated with many inclusions of grayish brown (10YR 5/2) loamy fine sand; diffuse boundary.
47-197	C1b2	Stratified, planar cross-beds 5-20 cm-thick, pale brown (10YR 6/3) very fine to coarse sand, brown (10YR 5/3) moist; massive parting to single grain; loose, very friable; common very fine and fine roots in upper 25 cm, decreasing in abundance with depth; abrupt smooth boundary.
197-495	C2b2	Stratified, planar cross-beds 5-20 cm-thick, light brownish gray (10YR 6/2)

and pale brown (10YR 6/3) very fine to coarse sand, grayish brown (10YR 5/2) and brown (10YR 5/3) moist; massive parting to single grain; loose to soft, friable; abrupt wavy boundary. Contains internal ripple laminations and interbedded with lenses of granular gravel (2–4 mm).

PALUDAL

495-528	-	Brown, fibrous peat; ~90% plant material; abrupt wavy boundary.
528-542	-	Black (10YR 2/1) mucky peat; ~60% plant material; mineral fraction consists of loam to silty clay loam; abrupt wavy boundary.
542-564	-	Dark gray (10YR 4/1) organic-rich fine to medium sand, very dark gray (10YR 3/1) moist; massive parting to single grain; soft to loose, very friable; many very fine and few medium roots; abrupt wavy boundary.
564-593	-	Stratified light brownish gray (10YR 6/2) fine sand, grayish brown (10YR 5/2) moist; interbedded with 1-3 cm-thick wavy beds of dark gray (10YR 4/1) silty clay loam; massive parting to single grain; loose to soft, very friable; abrupt wavy boundary.
593-677	-	Stratified black (10YR 2/1) and dark gray (10YR 4/1) organic-rich silty clay loam; interbedded with 3-20 mm-thick wavy beds of light brownish gray (10YR 6/2) fine sand; slightly hard, friable; abrupt wavy boundary; contains many inclusions of brown peat.

ALLUVIUM

677-685+	C1b2	Light brownish gray (10YR 6/2) medium to coarse sand, grayish brown (10YR 5/2) moist; massive parting to single grain; loose, very friable.

Table A.3 Description of Fits Drive Locality Section 1.

Landform: Sand dune/T-1 terrace.

Parent material: Alluvium

Land Cover: Grass

Remarks: Soil organic matter from the upper 10 cm of the Ab1 horizon of Soil 2 and the upper 10 cm of the A1b4 horizon of Soil 5 yielded radiocarbon ages of 7345±35 ^{14}C yr BP (8115 cal yr BP) and 8070±30 ^{14}C yr BP (9000 cal yr BP), respectively.

Depth (cm)	Soil Horizon	Description
		Note – Alluvium is mantled by 3 m of eolian sand in which the surface soil (Soil 1) developed.
		ALLUVIUM
		Soil 2
300-327	Ab1	Dark grayish brown (10YR 4/2) loamy fine sand, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to weak fine granular structure; very soft, very friable; common very fine and fine roots; common insect and worm burrows; gradual smooth boundary.
327-333	ACb1	Grayish brown (10YR 5/2) loamy fine sand, dark grayish brown (10YR 4/2) moist; very weak fine granular structure; very soft, very friable; common very fine and fine roots; common insect and worm burrows; gradual smooth boundary.

333-365	Cb1	Pale brown (10YR 6/3) very fine to fine sand, brown (10YR 5/3) moist; massive parting to single grain; very soft, very friable; common very fine and fine roots; abrupt smooth boundary.
		Soil 3
365-372	Ab2	Grayish brown (10YR 5/2) loamy fine sand, dark grayish brown (10YR 4/2) moist; very weak fine granular structure; very soft, very friable; few very fine and fine roots; few insect burrows; gradual smooth boundary.
372-395	Cb2	Pale brown (2.5Y 7/3) very fine to medium sand, light yellowish brown (2.5Y 6/3) moist; massive parting to single grain; very soft, very friable; few very fine and fine roots; abrupt smooth boundary. Lower 7 cm is cross-bedded.
		Soil 4
395-401	A1b3	Grayish brown (10YR 5/2) loamy fine sand, dark grayish brown (10YR 4/2) moist; very weak fine subangular blocky structure parting to weak fine granular structure; slightly hard, friable; common very fine and fine roots; clear smooth boundary.
401-409	A2b3	Dark grayish brown (10YR 4/2) loamy fine sand, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; soft, friable; many very fine and fine roots; few fine distinct strong brown (7.5YR 5/6) redoximorphic concentrations in pores and root paths; gradual wavy boundary.
409-470	C1b3	Light yellowish brown (2.5Y 6/3) very fine to fine sand, light olive brown

		(2.5Y 5/3) moist; massive parting to single grain; very soft, very friable; few very fine and fine roots; abrupt smooth boundary.
470-479	C2b3	Light brownish gray (2.5Y 6/2) loam, grayish brown (2.5Y 5/2) moist; weak fine platy structure; slightly hard, friable; common very fine and fine roots; few fine distinct redoximorphic concentrations in pores; abrupt smooth boundary.
		Soil 5
479-490	A1b4	Dark gray (2.5Y 4/1) loam, very dark gray (2.5Y 3/1) moist; very weak fine subangular blocky structure parting to weak fine and medium granular structure; slightly hard, friable; common very fine and fine roots; clear smooth boundary.
490-509	A2b4	Dark grayish brown (10YR 4/2) loamy fine sand, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; slightly hard, friable; few very fine and fine roots, many insect burrows; abrupt smooth boundary. Upper 5 cm is heavily bioturbated and filled with sediment from above (A1b4 horizon).
509-519	A3b4	Very dark grayish brown (10YR 3/2) loamy fine sand, very dark brown (10YR 2/2) moist; weak fine granular structure; slightly hard, friable; few very fine and fine roots, many insect burrows; gradual diffuse boundary. Lower boundary is heavily bioturbated and filled with sediment from above (A2b4 horizon) and below (C1b4 horizon). Lower 2 cm contains 1-2 mm gravel.

519-587	C1b4	Light brownish gray (2.5Y 6/2) very fine to medium sand, grayish brown (2.5Y 5/2) moist; massive parting to single grain; very soft, very friable; few very fine and fine roots; abrupt smooth boundary.
587-595	C2b4	Internally laminated, grayish brown (10YR 5/2) clay loam, dark grayish brown (10YR 4/2) moist; moderate fine subangular blocky structure; slightly hard, friable; common distinct redoximorphic concentrations along bedding planes; abrupt smooth boundary. Contains plant macrofossils.
595-715	C3b4	Light gray (2.5Y 7/2) fine to medium sand, light brownish gray (2.5Y 6/2) moist; massive parting to single grain; soft, very friable; abrupt smooth boundary.
715-925	C4b4	Light brownish gray (2.5Y 6/2) loamy sand, grayish brown (2.5Y 5/2) moist; massive; soft, friable; abrupt smooth boundary. Contains gastropods.
925-950+	C5b4	Light yellowish brown (2.5Y 6/3) very fine to medium sand, light olive brown (2.5Y 5/3) moist; massive parting to single grain; soft, very friable.

Table A.4 Description of Fits Drive Locality Section 3

Landform: Sand dune

Parent material: Eolian sand

Land Cover: Grass

Remarks: Soil organic matter from the upper 10 cm of the Ab horizon and the lower 5 cm of the Bwb horizon of Soil 2 yielded radiocarbon ages of 1080±25 ^{14}C yr BP (980 cal yr BP) and 1505±25 ^{14}C yr BP (1375 cal yr BP), respectively.

Depth (cm)	Soil Horizon	Description
		EOLIAN
		Soil 1
0-18	A	Dark grayish brown (10YR 4/2) very fine sand, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; soft, friable; many very fine and fine roots; many insect and worm burrows; common worm casts; gradual smooth boundary.
18-88	C	Stratified grayish brown (10YR 5/2) very fine to fine sand, dark grayish brown (10YR 4/2) moist; massive parting to single grain; very soft, very friable; many very fine and fine roots in upper 25 cm, decreasing to common very fine and fine, and few medium roots beneath; few open worm burrows; common worm casts; abrupt smooth boundary.

		Soil 2
88-116	Ab	Dark grayish brown (10YR 4/2) very fine sand, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; soft, very friable; common very fine and fine, few medium roots; few open worm burrows; gradual smooth boundary.
116-133	Bwb	Grayish brown (10YR 5/2) very fine sand, dark grayish brown (10YR 4/2) moist; weak medium and fine subangular blocky structure; hard, friable; few very fine, fine, and medium roots; gradual smooth boundary.
133-143	BCb	Grayish brown (10YR 5/2) very fine to fine sand, dark grayish brown (10YR 4/2) moist; very weak fine subangular blocky structure; hard, friable; few very fine, fine, and medium roots; gradual smooth boundary.
143-183+	Cb	Light brownish gray (10YR 6/2) very fine sand, grayish brown (10YR 5/2) moist; massive parting to single grain; soft, very friable; few very fine, fine, and medium roots.

Table A.5 Description of the Bostron Locality

Landform: T-0b floodplain

Parent material: Alluvium

Land Cover: Grass

Remarks: Soil organic matter from the upper 10 cm of the Ab horizon and the lower 10 cm of the Bwb horizon of Soil 2 yielded radiocarbon ages of100±20 ^{14}C yr BP (115 cal yr BP) and 275±20 ^{14}C yr BP (315 cal yr BP), respectively.

Depth (cm)	Soil Horizon	Description
		ALLUVIUM
		Soil 1
0-21	A	Dark grayish brown (10YR 4/2) loamy fine sand, very dark grayish brown (10YR 3/2) moist; weak medium and fine granular structure; slightly hard, very friable; many very fine and fine roots; many insect and worm burrows; common worm casts; gradual smooth boundary.
21-34	AC	Faintly bedded grayish brown (10YR 5/2) fine sandy loam, dark grayish brown (10YR 4/2) moist; contains beds of light brownish gray (10YR 6/2) very fine loamy sand, grayish brown (10YR 5/2) moist; weak medium and fine granular structure; soft, very friable; many very fine and fine roots; many insect and worm burrows; common worm casts; gradual smooth boundary.

34-44	C	Laminated light brownish gray (10YR 6/2) very fine sand, grayish brown (10YR 5/2) moist; massive parting to single grain; soft, very friable; few very fine and fine roots; few very fine pores; abrupt smooth boundary.
		Soil 2
44-54	Ab	Dark gray (10YR 4/1) loam, very dark gray (10YR 3/1) moist; weak fine subangular blocky structure parting to moderate medium and fine granular structure; hard, friable; many very fine and fine roots; many very fine pores and biogenic features; gradual smooth boundary.
54-74	Bwb	Grayish brown (10YR 5/2) loam, dark grayish brown (10YR 4/2) moist; weak coarse prismatic structure parting to weak fine subangular blocky structure; hard, friable; common very fine and fine roots; common very fine pores; very few fine carbonate threads; common distinct reddish yellow (7.5YR 6/6 and 6/8) redoximorphic concentrations along root paths; clear smooth boundary.
74-160+	Cb	Light brownish gray (10YR 6/2) very fine sand, grayish brown (10YR 5/2) moist; massive parting to single grain; very soft, very friable; common fine and medium roots; common distinct reddish yellow (7.5YR 6/6 and 6/8) redoximorphic concentrations along root paths.

Table A.6 Description of O'Brien Locality.

Landform: Alluvial fan.

Parent material: Alluvium and lacustrine

Land Cover: Grass

Remarks: Soil organic matter from the upper 10 cm of the Ab1 horizon of Soil 2 and the Ab2 horizon of Soil 3 yielded radiocarbon ages of 290±20 ^{14}C yr BP (395 cal yr BP) and 590±20 ^{14}C yr BP (605 cal yr BP), respectively. Organic material collected at a depth of 710 cm below the surface, from a peat deposit, yielded a radiocarbon age of 990±25 ^{14}C yr BP (870 cal yr BP). Organic-rich sediment collected at depths of 748 cm, 763 cm, and 773 cm below the surface in deposits of gyttja yielded radiocarbon ages of 1360±25 ^{14}C yr BP (1290 cal yr BP), 1570±25 ^{14}C yr BP (1460 cal yr BP), and 1700±25 ^{14}C yr BP (1585 cal yr BP), respectively.

Depth (cm)	Soil Horizon	Description
		ALLUVIUM
		Soil 1
0-5	A	Grayish brown (10YR 5/2) fine sand, dark grayish brown (10YR 4/2) moist; very weak fine subangular blocky structure parting to weak fine granular structure; soft, very friable; many very fine and fine roots; clear smooth boundary.
5-15	AC	Grayish brown (10YR 5/2) fine sand, dark grayish brown (10YR 4/2) moist; weak medium and fine granular structure parting to single grain; soft, very friable; many very fine and fine roots; clear smooth boundary.

15-82	C	Faintly cross-bedded, very pale brown (10YR 7/3) fine to medium sand, pale brown (10YR 6/3) moist; contains few isolated fine to medium gravel clasts; massive; soft, friable; few very fine and fine roots; abrupt smooth to wavy boundary.
		Soil 2
82-90	Ab1	Grayish brown (10YR 5/2) loamy fine sand, dark grayish brown (10YR 4/2) moist; moderate fine subangular blocky structure parting to weak medium and fine granular structure; slightly hard, friable; few very fine and fine roots; many very fine pores; clear smooth boundary.
90-98	ACb1	Light brownish gray (10YR 6/2) fine sand, grayish brown (10YR 5/2) moist; weak fine subangular blocky structure parting to single grain; soft, very friable; few very fine and fine roots; few very fine pores; clear smooth boundary.
98-124	Cb1	Faintly cross-bedded, light brownish gray (10YR 6/2) fine sand, grayish brown (10YR 5/2) moist; contains beds of coarse sand and very fine gravel; massive parting to single grain; loose, very friable; few very fine and fine roots; abrupt smooth to wavy boundary.
		Soil 3
124-138	Ab2	Grayish brown (10YR 5/2) loamy fine sand, dark grayish brown (10YR 4/2) moist; moderate medium and fine subangular blocky structure parting to weak medium and fine granular structure; slightly hard, friable; few very fine

		roots; many very fine pores; clear smooth boundary.
138-146	ACb2	Light brownish gray (10YR 6/2) fine sand, grayish brown (10YR 5/2) moist; weak fine subangular blocky structure parting to single grain; soft, very friable; few very fine pores; clear smooth boundary.
146-185	C1b2	Faintly cross-bedded light gray (10YR 7/2) sand, light brownish gray (10YR 6/2) moist; contains fine and medium gravel along bedding planes; massive parting to single grain; loose, very friable; abrupt smooth to wavy boundary.
185-704	C2b2	Stratified, cross- and horizontally-bedded light brownish gray (10YR 6/2) and light gray (10YR 7/2) fine to medium sand and gravel, grayish brown (10YR 5/2) moist; massive parting to single grain; soft, friable; abrupt smooth to wavy boundary.
		PALUDAL
704-710	---	Stratified grayish brown (10YR 5/2) gyttja and brown peat; abrupt wavy boundary.
710-730	---	Black (10YR 2/1) gyttja; contains crotovina up to 8cm in diameter filled with light brownish gray (10YR 6/2) fine sand; abrupt wavy boundary.
730-748	---	Mottled grayish brown (10YR 5/2) gyttja; contains common redoximorphic iron stains along root paths; abrupt wavy boundary.
748-761	---	Black (10YR 2/1) gyttja; abrupt wavy boundary.

761-763	---	Light gray (10YR 7/2) very fine sand, light brownish gray (10YR 6/2) moist; abrupt wavy boundary.
763-773	---	Black (10YR 2/1) gyttja; contains inclusions of rubbery brown peat; abrupt wavy boundary.
773-786	---	Brown mucky peat in very dark gray (10YR 3/1) silty clay loam matrix; abrupt wavy boundary.
		ALLUVIUM
786-863+	---	Light gray (10YR 7/2) bedded fine sand, light brownish gray (10YR 6/2) moist; single grain; loose, very friable.

Table A.7 Description of Nutter Locality

Landform: T-1 terrace

Parent material: Alluvium and lacustrine

Land Cover: Grass

Remarks: Soil organic matter from the upper 10 cm of the Ab1 horizon of Soil 2 and the Ab3 horizon of Soil 4 yielded radiocarbon ages of 130±20 ^{14}C yr BP (110 cal yr BP) and 790±20 ^{14}C yr BP (705 cal yr BP), respectively. Charcoal collected at a depth of 230 cm below surface in lacustrine deposits yielded a radiocarbon age of 9225±35 ^{14}C yr BP (10,385 cal yr BP). Charcoal collected at a depth of 255 cm below surface at the top of a diatomite yielded a radiocarbon age of 9355±40 ^{14}C yr BP (10,545 cal yr BP). Wood collected at a depth of 282 cm below surface in alluvium yielded a radiocarbon age of 9370±35 ^{14}C yr BP (10,590 cal yr BP). Plant material collected at a depth of 302 cm below surface in a peat deposit yielded a radiocarbon age of 9365±50 ^{14}C yr BP (10,585 cal yr BP). Charcoal collected from a depth of 337 cm below surface in a peat/gyttja deposit yielded a radiocarbon age of 10,560±40 ^{14}C yr BP (12,600 cal yr BP).

Depth (cm)	Soil Horizon	Description
		ALLUVIUM
		Soil 1
0-5	A	Brown (10YR 5/3) fine sand, brown (10YR 4/3) moist; very weak fine granular structure; soft, very friable; many very fine and fine and common medium roots; clear smooth boundary.
5-45	C	Light brownish gray (10YR 6/2) fine to medium sand and fine to medium

		gravel, grayish brown (10YR 5/2) moist; massive parting to single grain; loose to soft, very friable; common very fine and fine roots; abrupt smooth boundary.
		Soil 2
45-53	Ab1	Dark grayish brown (10YR 4/2) fine sand, very dark grayish brown (10YR 3/2) moist; very weak fine subangular blocky structure; soft, friable; common very fine and fine roots; clear smooth boundary.
53-64	Cb1	Light brownish gray (10YR 6/2) fine sand, grayish brown (10YR 5/2) moist; massive parting to single grain; loose to soft, very friable; interbedded with fine gravel; few very fine and fine roots; abrupt smooth boundary.
		Soil 3
64-73	Ab2	Dark grayish brown (10YR 4/2) fine sand, very dark grayish brown (10YR 3/2) moist; very weak fine subangular blocky structure; soft, friable; few very fine and fine roots; clear smooth boundary.
73-85	C1b2	Light brownish gray (10YR 6/2) fine sand, grayish brown (10YR 5/2) moist; massive parting to single grain; loose to soft, very friable; interbedded with fine gravel; few very fine and fine roots; abrupt smooth boundary.
85-145	C2b2	Cross-bedded light brownish gray (10YR 6/2) sand and fine gravel, grayish brown (10YR 5/2) moist; single grain; loose, very friable; abrupt smooth boundary.

		Soil 4
145-151	Ab3	Dark grayish brown (10YR 4/2) fine to medium sand with some fine gravel, very dark grayish brown (10YR 3/2) moist; very weak fine graular structure; soft, friable; few very fine and fine roots; clear smooth boundary.
151-163	C1b3	Grayish brown (10YR 5/2) fine to medium sand with some fine gravel, dark grayish brown (10YR 4/2) moist; contains ~5 cm-thick bed of dark grayish brown (10YR 4/2) and dark gray (10YR 4/1) organic-rich sand; massive parting to single grain; loose to soft, friable; abrupt wavy boundary.
163-200	C2b3	Cross-bedded light brownish gray (10YR 6/2) medium and coarse sand and fine to medium gravel, grayish brown (10YR 5/2) moist; massive parting to single grain; loose to soft, friable; common prominent strong brown (7.5YR 5/8) and reddish yellow (7.5YR 6/8) redoximorphic concentrations along bedding planes; abrupt wavy boundary.
200-210	-	Finely laminated very pale brown (10YR 7/3 and 7/4) very fine sand, pale brown (10YR 6/3) moist; massive parting to single grain, wavy beds; soft, friable; common prominent yellowish red (5YR 5/8) and red (2.5YR 5/8) redoximorphic concentrations along bedding planes; abrupt wavy boundary.
		LACUSTRINE/PALUDAL
210-220	-	Very pale brown (10YR 8/2) diatomite; abrupt wavy boundary.
220-245	-	Finely laminated light brownish gray (10YR 6/2) loam to fine sandy loam, grayish brown (10YR 5/2) moist; massive, interbedded with many wood and

plant macrofossils; soft, friable; common prominent strong brown (7.5YR 5/8), reddish yellow (7.5YR 6/8 and 7/8) and yellowish red (5YR 5/8) redoximorphic concentrations along root paths and macropores; abrupt wavy boundary.

245-255 - Stratified black (10YR 2/1) peat, abrupt wavy boundary.

255-262 - Very pale brown (10YR 8/2) diatomite; laterally discontinuous; contains plant macrofossils; abrupt wavy boundary.

ALLUVIUM

262-287 - Pale red (2.5YR 6/2) fine sandy loam, weak red (2.5YR 5/2) moist; massive; soft, friable; common prominent strong brown (7.5YR 5/8), reddish yellow (7.5YR 6/8 and 7/8) and yellowish red (5YR 5/8) redoximorphic concentrations along root paths and macropores, common prominent medium pale brown (10YR 6/3) and grayish brown (2.5Y 5/2) mottles; abrupt wavy boundary.

287-297 - Cross-bedded very pale brown (10YR 7/3), pale brown (10YR 6/3), and brown (10YR 5/3 and 7.5YR 5/4) loamy fine sand, (10YR 4/3) moist; massive parting to single grain; soft, friable; common prominent brownish yellow (10YR 6/8) and reddish yellow (7.5 YR 6/8) redoximorphic concentrations along bedding planes; abrupt wavy boundary.

297-302 - Cross-bedded light gray (10YR 7/2) very fine sand, light brownish gray (10YR 6/2) moist; massive parting to single grain; loose to soft, very friable;

abrupt wavy boundary.

PALUDAL

302-312	-	Black (10YR 2/1) peat/gyttja; massive; firm; upper 5 cm contains few plant macrofossils; abrupt wavy boundary.
312-332	-	Light gray (10YR 7/2) fine sand, light brownish gray (10YR 6/2) moist; single grain; loose to soft, very friable; many root traces filled with black and (10YR 2/1) and brown (7.5 YR 4/4) silty clay; abrupt wavy boundary.
332-348	-	Black (10YR 2/1) peat/gyttja; massive; firm; upper 5 cm contains few plant macrofossils; abrupt wavy boundary; bounded by 3-5 cm-thick finely laminated brown (7.5YR 4/4) loam to fine sandy loam with irregular boundaries.

ALLUVIUM

348-363	-	Faintly laminated light gray (10YR 7/2) very fine to fine sand, light brownish gray (10YR 6/2) moist; single grain; loose to soft, very friable; common prominent yellowish red (5YR 5/8) and reddish yellow (5YR 6/8) redoximorphic concentrations along bedding planes, abrupt wavy boundary.
363-400+	-	Light gray (10YR 7/2) fine to medium sand, light brownish gray (10YR 6/2) moist; single grain; interbedded with very fine and fine pebbles; loose to soft, very friable; few to common prominent yellowish red (5YR 5/8) and reddish yellow (5YR 6/8) discontinuous wavy redoximorphic lenses.

Table A.8 Description of profiles 1 and 2 (composite), Section 1 at the Munn Locality.

Landform: Sand dune on an alluvial terrace

Vegetation: Riparian woodland

Remarks: Organic matter from an organic-rich bed of alluvium 269-271 cm below surface yielded a radiocarbon age of 8005±40 ^{14}C yr BP (8870 cal yr BP). Charcoal recovered 30 cm below the top of Soil 3 formed in paludal deposits, or 382 cm below surface, yielded a radiocarbon age of 8275±55 ^{14}C yr BP (9265 cal yr BP). Soil organic matter from the upper 10 cm of the 4A2b2 horizon of Soil 3, or 385-395 cm below surface, yielded a radiocarbon age of 8585±50 ^{14}C yr BP (9545 cal yr BP).

Depth (cm)	Soil Horizon	Description
		EOLIAN SAND
		Soil 1
0-6	A	Brown (10YR 5/3) sand, brown (10YR 4/3) moist; very weak fine granular structure; soft, very friable; predominantly very fine sand; many very fine and fine and common medium roots; clear smooth boundary.
6-135	C	White (10YR 8/1) sand, light gray (10YR 7/2) moist; single grain, loose; predominantly very fine sand; common very fine and fine and few medium roots; abrupt smooth boundary.
		ALLUVIUM OR SHEETWASH
		Soil 2

135-144	2Ab1	Dark grayish brown (10YR 4/2) very fine sandy loam, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; slightly hard, friable; common worm casts and open worm and insect burrows; many very fine and fine and common medium roots; gradual smooth boundary.
144-197	2Cb1	Horizontally laminated vary pale brown (10YR 8/2) and light gray (10YR 7/1 and 7/2) very fine, fine and medium sand, light gray (10YR 7/2), gray (10YR 6/1) and light grayish brown (10YR 6/2) moist, interbedded with grayish brown (10YR 5/2) and dark grayish brown 10YR 4/2) very fine sandy loam, dark grayish brown (10YR 4/2) and very dark grayish brown (10YR 3/2) moist; massive parting to single grain; soft, very friable to loose; few very fine, fine and medium roots; abrupt wavy boundary.
		EOLIAN SAND
197-269	3Cb1	Cross-bedded white (10YR 8/1) and light gray (10YR 7/1) very fine sand and fine sand, light gray (10YR 7/1) and gray (10YR 6/1) moist; single grain, loose; few very fine and fine roots; abrupt smooth boundary.
		PALUDAL/ALLUVIUM
269-283	4C1b1	Thinly bedded black (10YR 2/1) and very dark brown (10YR 3/1) fine sandy loam, black (10YR 2/1) moist; individual beds are 1-3 cm thick; massive; slightly hard, friable; few very fine and fine roots; abrupt smooth boundary.

283-319	4C2b1	Thinly bedded grayish brown (10YR 5/2) and dark grayish brown (10YR 4/2) very fine sandy loam and loamy fine sand, grayish brown (10YR 4/2) and very dark grayish brown (10YR 3/2) moist; individual beds are 1-5 cm thick; massive; slightly hard, friable; few very fine and fine roots; abrupt smooth boundary.
319-330	4C3b1	Thinly bedded black (10YR 2/1) fine sandy loam, black (10YR 2/1) moist, and light gray (10YR 7/2) and light brownish gray (10YR 6/2) very fine sand, light brownish gray (10YR 6/2) and grayish brown (10YR 5/2) moist; individual beds are 1-6 cm thick; beds of fine sandy loam are massive, slightly hard, friable; beds of very fine sand are single grain, loose; common fine faint yellowish brown (10YR 5/4) mottles; beds are internally laminated; common worm and insect burrows filled with black (10YR 2/1) very fine sandy loam; few very fine and fine roots; abrupt wavy boundary.
330-352	4C4b1	Light gray (10YR 7/2) sand, light brownish gray (10YR 6/2) moist; single grain; loose; predominantly very fine sand; common worm and insect burrows filled with very dark gray (10YR 3/1) very fine sand; few very fine and fine roots; abrupt wavy boundary.
		Soil 3
352-385	4A1b2	Very dark gray (10YR 3/1) sandy clay loam, black (10YR 2/1) moist; massive to very fine granular structure; very hard, firm; few thin lenses of fine charcoal; few lenses of light gray (10YR 7/2) very fine sand; common fine and very fine roots; abrupt wavy boundary.

385-395	4A2b2	Black (10YR 2/1) sandy clay loam, massive to very fine granular structure; very hard, firm; common fine and very fine roots; abrupt wavy boundary.
395-410	4A3b2	Dark gray (10YR 4/1) very fine sandy loam, very dark gray (10YR 3/1) moist; massive to very fine granular structure; hard, friable; common fine and very fine roots; gradual smooth boundary.
410-423	4ACb2	Gray (10YR 6/1) loamy fine sand, gray (10YR 5/1) moist; massive to very fine granular structure; slightly hard, friable; common fine inclusions of light brownish gray (10YR 6/2) fine sandy loam; common fine and very fine roots; gradual smooth boundary.
423-470	4Cb2	Laminated white (10YR 8/1) and light gray (10YR 7/2) sand, light gray (10YR 7/1) and light brownish gray (10YR 6/2) moist; single grain, loose; predominantly very fine sand; few fine and very fine roots.

Table A.9 Description of profile 3, Section 2 at the Munn Locality.

Landform: Sand dune on an alluvial terrace

Vegetation: Riparian woodland

Remarks: Soil organic matter from the upper 10 cm of the Ab2 horizon of Soil 3, or 122-132 cm below surface, yielded a radiocarbon age of 5140±50 ^{14}C yr BP (5985 cal yr BP).

Depth (cm)	Soil Horizon	Description
		EOLIAN SAND
		Soil 1
0-5	A	Brown (10YR 5/3) sand, brown (10YR 4/3) moist; weak fine granular structure; soft, very friable; predominantly very fine sand; many fine and very fine roots; clear smooth boundary.
5-45	C1	Light gray (10YR 7/1) sand, gray (10YR 6/1) moist; common inclusions of white (10YR 8/1), light gray (10YR 7/2), vary pale brown (10YR 7/3), and pale brown (10YR 6/3) sand; massive parting to single grain, slightly hard to loose; predominantly very fine sand; many fine and very fine and common medium and coarse roots; abrupt wavy boundary.
45-104	C2	Cross-bedded white (10YR 8/1) sand, light gray (10YR 7/1) moist; common fine and medium distinct reddish yellow (7.5YR 6/8) and fine faint reddish yellow (7.5YR 7/6) coatings along root paths and in macro-pores; massive parting to single grain; slightly hard to loose;

		predominantly very fine sand; many fine and very fine and common medium and coarse roots; abrupt wavy boundary.
		Soil 2
104-122	Btb1	Pale brown (10YR 6/3) very fine sandy loam, brown (10YR 5/3) moist; many fine and medium faint yellowish brown (10YR 5/4) and fine and medium distinct reddish yellow (7.5YR 6/8) mottles; moderate medium and fine angular blocky structure; very hard, friable; few patchy dark grayish brown (10YR 4/2) clay films on ped faces and clay bridges between sand grains; many fine and very fine and common medium and coarse roots; abrupt smooth boundary.
		Soil 3
122-165	Ab2	Dark gray (10YR 4/1) very fine sandy loam, very dark gray (10YR 3/1) moist; few fine distinct reddish yellow (7.5YR 6/8) and brownish yellow (10YR 6/8) mottles; weak fine granular structure; very hard, friable; common open insect burrows; many fine and very fine roots; gradual smooth boundary.
165-180	ABb2	Gray (10YR 5/1) very fine sandy loam, dark gray (10YR 4/1) moist; few fine distinct reddish yellow (7.5YR 6/8) and brownish yellow (10YR 6/8) mottles; weak fine subangular blocky structure; very hard, friable; few open insect burrows; common fine and very fine roots; gradual smooth boundary.

180-210	Bwb2	Light brownish gray (10YR 6/2) loamy fine sand, grayish brown (10YR 5/2) moist; weak medium prismatic structure parting to weak fine subangular blocky; slightly hard, friable; few open insect burrows; few fine and very fine roots.

Table A.10 Description of profile 4, Section 2 at the Munn Locality.

Landform: Sand dune on an alluvial terrace

Vegetation: Riparian woodland

Remarks: Soil organic matter from the upper 10 cm of the Ab2 horizon of Soil 3, or 90-100 cm below surface, yielded a radiocarbon age of 3170±40 ^{14}C yr BP (3395 cal yr BP).

Depth (cm)	Soil Horizon	Description
		EOLIAN SAND
		Soil 1
0-5	A	Brown (10YR 5/3) sand, brown (10YR 4/3) moist; weak fine granular structure; soft, very friable; predominantly very fine sand; many fine and very fine roots; clear smooth boundary.
5-70	C	White (10YR 8/1) sand, light gray (10YR 7/1) moist; few wavy light yellowish brown (10YR 6/4) and brownish yellow (10YR 6/6) wavy lamellae; single grain, loose; predominantly very fine sand; many fine and very fine and common medium and coarse roots; abrupt wavy boundary.
		Soil 2
70-90	Btb1	Yellowish brown (10YR 5/4) fine sandy loam, dark yellowish brown (10YR 4/4) moist; weak medium prismatic structure parting to weak medium and fine subangular blocky; very hard, friable; few patchy

		brown (10YR 5/3) clay films on ped faces and as clay bridges between sand grains; common open insect burrows; many fine and very fine and common medium and coarse roots; abrupt wavy boundary.
		Soil 3
90-110	Ab2	Dark gray (10YR 4/1) very fine sandy loam, very dark gray (10YR 3/1) moist; weak medium and coarse subangular blocky structure parting to weak medium and coarse granular; hard, friable; common open insect burrows; many fine and very fine and common medium roots; gradual smooth boundary.
110-120	ACb2	Dark grayish brown (10YR 4/2) very fine sandy loam, very dark grayish brown (10YR 3/2) moist; weak medium and coarse subangular blocky structure parting to weak medium and coarse granular; hard, friable; faint bedding; few open insect burrows; many fine and very fine and common medium roots; gradual smooth boundary.
120-145	C1b2	White (10YR 8/1) sand, light gray (10YR 7/1) moist; few fine distinct brownish yellow (10YR 6/6 and 6/8) mottles; single grain; loose; predominantly very fine sand; common fine and very fine roots; abrupt wavy boundary.
145-153	C2b2	Pale brown (10YR 6/3) very fine sandy loam, brown (10YR 5/3) moist; many fine and very fine distinct brownish yellow (10YR 6/8) and yellowish brown (10YR 5/8) mottles; few yellowish red (5YR 5/8)

		coatings along root paths; massive; slightly hard, friable; few fine and very fine roots; abrupt wavy boundary.
153-173	C3b2	White (10YR 8/1) sand, light gray (10YR 7/1) moist; few fine distinct brownish yellow (10YR 6/6 and 6/8) mottles; single grain; loose; predominantly very fine sand; few fine and very fine roots; abrupt wavy boundary.
173-182	C4b2	Pale brown (10YR 6/3) very fine sandy loam, brown (10YR 5/3) moist; many fine and very fine distinct brownish yellow (10YR 6/8) and yellowish brown (10YR 5/8) mottles; few yellowish red (5YR 5/8) coatings along root paths; massive; slightly hard, friable; few fine and very fine roots; clear smooth boundary.
182-203	C5b2	White (10YR 8/1) sand, light gray (10YR 7/1) moist; few fine faint brownish yellow (10YR 6/6) mottles; single grain; loose; predominantly very fine sand; few fine and very fine roots; clear wavy boundary.
203-207	C6b2	Pale brown (10YR 6/3) very fine sandy loam, brown (10YR 5/3) moist; massive; slightly hard, friable; few fine and very fine roots; abrupt irregular to very wavy boundary.
207-225	C7b2	White (10YR 8/1) sand, light gray (10YR 7/1) moist; single grain; loose; predominantly very fine sand; few fine and very fine roots.

Table A.11 Description of Profile 5, Section 3 at the Munn Locality.

Landform: Sand dune

Vegetation: Mixture of trees and native grasses

Remarks: Soil organic matter from the upper 10 cm of the Ab horizon of Soil 2, or 125-135 cm below surface, yielded a radiocarbon age of 945±40 ^{14}C yr BP (850 cal yr BP).

Depth (cm)	Soil Horizon	Description
		EOLIAN SAND
		Soil 1
0-20	A	Grayish brown (10YR 5/2) sand, dark grayish brown (10YR 4/2) moist; weak fine granular structure; soft, very friable; predominantly very fine sand; many worm casts and open worm and insect burrows; many fine and very fine and common medium roots; gradual smooth boundary.
20-30	AC	Brown (10YR 5/3) sand, brown (10YR 4/3) moist; very weak fine granular structure; very soft, very friable; predominantly very fine sand; common worm casts and open worm and insect burrows; common krotovina 3-5 cm in diameter filled with grayish brown (10YR 5/2) or pale brown (10YR 6/3) sand; common fine and very fine and few medium and coarse roots; gradual smooth boundary.
30-125	C	Pale brown (10YR 6/3) sand, brown (10YR 5/3) moist; massive parting to single grain; very soft, loose; predominantly very fine sand; common

		open insect burrows; common krotovina 3-25 cm in diameter filled with brown (10YR 5/3) very fine sand; common fine and very fine and few medium and coarse roots; diffuse irregular boundary.
		Soil 2
125-170	Ab	Very dark grayish brown (10YR 3/2) sand, very dark brown (10YR 2/2) moist; very weak fine granular structure; slightly hard, very friable; predominantly very fine sand; few worm casts and open worm and insect burrows; common fine and very fine and few medium roots; gradual smooth boundary.
170-180	ACb	Dark grayish brown (10YR 4/2) sand, very dark grayish brown (10YR 3/2) moist; very weak fine granular structure; slightly hard, very friable; predominantly very fine sand; few worm casts and open worm and insect burrows; common fine and very fine and few medium roots; gradual smooth boundary.
180-200	Cb	Brown (10YR 5/3) sand, brown (10YR 4/3) moist; single grain, loose; predominantly very fine sand; few fine and very fine roots.

Table A.12 Description of Section 4, Munn Locality.

Landform: Sand dune on an alluvial terrace.

Vegetation: Mixture of trees and native grasses

Remarks: Charcoal collected at a depth of 200-201 cm below surface in lacustrine deposits yielded a radiocarbon age of 9030±45 ^{14}C yr BP (10,210 cal yr BP). Charcoal collected at the boundary between the top of the alluvial sequence and the overlying banded diatomite (263-264 cm below surface) yielded a radiocarbon age of 10,015±45 ^{14}C yr BP (11,510 cal yr BP). Charcoal from a wavy, 3-cm-thick bed of very dark gray (10YR 3/1, dry) sandy clay loam, 413 cm below surface yielded a radiocarbon age of 10,120±40 ^{14}C yr BP (11,720 cal yr BP).

		EOLIAN SAND
		Soil 1
0-11	A	Brown (10YR 4/3) sand, dark brown (10YR 3/3) moist; weak fine granular structure; soft, very friable; predominantly very fine sand; many fine and very fine roots; clear smooth boundary.
11-40	C1	Light brownish gray (10YR 6/2) sand, grayish brown (10YR 5/2) moist; single grain, loose; predominantly very fine sand; common fine and very fine roots; clear smooth boundary.
40-80	C2	Light gray (10YR 7/2) sand, light brownish gray (10YR 6/2) moist; single grain, loose; predominantly very fine sand; common fine and very fine roots; clear smooth boundary.

		Soil 2
80-90	Btb1	Grayish brown (10YR 5/2) sandy clay loam, dark grayish brown (10YR 4/2) moist; coarse prismatic structure; very hard, friable; few thin faint discontinuous gray (10YR 5/1) clay films on ped faces and in macro-pores; common open worm and insect burrows; common fine and very fine pores; many very fine and common fine roots; gradual smooth boundary.
90-97	BCb1	Light brownish gray (10YR 6/2) loamy fine sand, grayish brown (10YR 5/2) moist; very weak medium prismatic structure parting to very weak fine subangular blocky; slightly hard, friable; common open worm and insect burrows; common fine and very fine pores; many very fine and common fine roots; abrupt smooth boundary.
		Soil 3
97-110	Bwb2	Grayish brown (10YR 5/2) sand, dark grayish brown (10YR 4/2) moist; weak fine subangular blocky structure; hard, friable; predominantly very fine sand; common open worm and insect burrows; common fine and very fine pores; many very fine and fine roots; gradual smooth boundary.
110-120	BCb2	Light brownish gray (10YR 6/2) sand, grayish brown (10YR 5/2) moist; very weak fine subangular blocky structure; hard, friable; predominantly very fine sand; common open worm and insect burrows; common fine and very fine pores; many very fine and fine roots; gradual smooth boundary.

120-167	Cb2	Light gray (10YR 7/2) sand, light brownish gray (10YR 6/2) moist; single grain, loose; predominantly very fine sand; common fine and very fine roots; clear smooth boundary.
		LACUSTRINE
167-174	- -	Gray (10YR 5/1) sandy clay loam, dark gray (10YR 4/1) moist, interbedded with laminae of light gray (10YR 7/2) very fine sand, light brownish gray (10YR 6/2) moist, that are a 2-4 mm thick; massive; hard; abrupt wavy boundary.
174-233	- -	Very dark gray (10YR 3/1) sandy clay loam, black (10YR 2/1) moist; interbedded with 2-4 mm-thick laminae of light gray (10YR 7/2) very fine sand, light brownish gray (10YR 6/2) moist; massive; hard; abrupt wavy boundary.
233-255	- -	Laminated light gray (10YR 7/2) sand, light brownish gray (10YR 6/2) moist; massive parting to single grain; soft to loose; abrupt wavy boundary.
255-263	- -	**BANDED DIATOMITE** White (10YR 8/2) diatomite interbedded with gray (10YR 5/1) and dark gray (10YR 4/1) beds of decomposed organic matter 1-4 mm thick; common charcoal fragments; abrupt wavy boundary.
		ALLUVIUM

263-512	- -	Light gray (10YR 7/2) sand, light brownish gray (10YR 6/2) moist; single grain, loose; common wavy beds 1-4 cm thick of very dark gray (10YR 3/1) sandy clay loam containing common charcoal fragments, black (10YR 2/1) moist; common prominent coarse yellowish brown (10YR 6/8) mottles along the upper and lower boundaries of the wavy beds of very dark gray (10YR 3/1) sandy clay loam; abrupt wavy boundary.
512-551	- -	White (10YR 8/1) sand, white (10YR 8/1) moist; single grain, loose; common wavy beds 0.5-5.0 cm thick of very dark gray (10YR 3/1) sandy clay loam containing common charcoal fragments, black (10YR 2/1) moist; common prominent coarse yellowish brown (10YR 6/8) mottles along the upper and lower boundaries of the wavy beds of very dark gray (10YR 3/1) sandy clay loam; abrupt wavy boundary.
551-571	- -	Light gray (10YR 7/1) sand, gray (10YR 6/1) moist; single grain, loose; common wavy beds 0.5-5.0 cm thick of very dark gray (10YR 3/1) sandy clay loam containing common charcoal fragments, black (10YR 2/1) moist; common prominent coarse yellowish brown (10YR 6/8) mottles along the upper and lower boundaries of the wavy beds of very dark gray (10YR 3/1) sandy clay loam.

Table A.13 Description of Section 5, Munn Locality.

Landform: Sand dune on an alluvial terrace.

Vegetation: Mixture of trees and native grasses

Remarks: Total organic matter (TOM) collected at a depth of 30-40 cm, 40-50 cm, 50-60 cm below surface in lacustrine deposit yielded radiocarbon age of 7030±45 ^{14}C yr BP (8260 cal yr BP), 7695±55 ^{14}C yr BP (8480 cal yr BP) and 8940±50 ^{14}C yr BP (10,005 cal yr BP). Charcoal collected at a depth of 144 cm below surface in a degraded brown peat yielded a radiocarbon age of 9695±40 ^{14}C yr BP (11,135 cal yr BP).

		SANDY SHEETWASH
0-8	A	Grayish brown (10YR 5/2) sand, dark grayish brown (10YR 4/2) moist; weak fine granular structure; soft, very friable; predominantly very fine sand; common open worm and insect burrows; many fine and very fine and common medium roots; clear smooth boundary.
8-30	C	Light gray (10YR 7/2) sand, light brownish gray (10YR 6/2) moist; single grain, loose; predominantly very fine sand; common open worm and insect burrows; many fine and very fine and common medium roots; abrupt smooth boundary.
		LACUSTRINE DEPOSIT
30-40	- -	Dark gray (10YR 4/1) silty clay loam, very dark gray (10YR 3/1) moist; massive to coarse platy structure; brittle; low bulk density; common fine and very fine roots; gradual smooth boundary.

40-50	- -	Gray (10YR 5/1) silty clay loam, dark gray (10YR 4/1) moist; massive to coarse platy structure; brittle; low bulk density; common fine and very fine roots; gradual smooth boundary.
50-60	- -	Gray (10YR 6/1) silty clay loam, gray (10YR 5/1) moist; massive to coarse platy structure; brittle; low bulk density; common fine and very fine roots; abrupt wavy boundary.
		DIATOMITE
60-88	- -	White (10YR 8/1) laminated diatomite.
		LAMINATED SAND
88-128	- -	Laminated light brownish gray (10YR 6/2) and gray (10YR 6/1) fine and medium sand, brownish gray (10YR 5/2) and gray (10YR 5/1) moist; common to many fine faint yellowish brown (10YR 5/6) and brownish yellow (10YR 6/6) mottles in the lower 20 cm of the bed; single grain; loose; abrupt wavy boundary.
		PEAT
128-148	- -	Brown degraded peat.
148-161	- -	Stratified brown and dark gray degraded peat with a bed of light brownish gray (10YR 6/2, dry) sand at a depth of 153-157 cm below surface; abrupt wavy boundary.

		ALLUVIUM
161-200+	- -	White (10YR 8/1) sand, white (10YR 8/1) moist; single grain, loose.

Table A.14 Description of Anderson Locality

Landform: T-1 terrace

Parent material: Alluvium and lacustrine

Land Cover: Grass

Remarks: Soil organic matter from the upper 10 cm of the Ab horizon of Soil 2 yielded a radiocarbon age of 470±25 ^{14}C yr BP (515 cal yr BP). Organic-rich sediment collected at depths of 123-128 cm, 146-151 cm, and 160-165 cm below the surface in deposits of diatomaceous earth yielded radiocarbon ages of 960±25 ^{14}C yr BP (850 cal yr BP), 1320±25 ^{14}C yr BP (1250 cal yr BP), and 1690±25 ^{14}C yr BP (1575 cal yr BP), respectively. Organic-rich sediment collected at a depth of 178 cm below the surface, from an organic bed beneath a unit of diatomite, yielded a radiocarbon age of 1975±30 ^{14}C yr BP (1905 cal yr BP). Charcoal collected at a depth of 138-141 cm below the surface in a deposit of diatomaceous earth yielded a radiocarbon age of 1185±25 ^{14}C yr BP (1105 cal yr BP). Quartz grains collected from a depth of 450 cm below the surface yielded an OSL age of 1810±70 yr.

Depth (cm)	Soil Horizon	Description
		ALLUVIUM
		Soil 1
0-7	A	Brown (10YR 5/3) fine sand, brown (10YR 4/3) moist; very weak fine granular structure; soft, very friable; clear smooth boundary.
7-40	C	Light brownish gray (10YR 6/2) fine sand, grayish brown (10YR 5/2) moist; massive parting to single grain; soft, friable; abrupt wavy boundary.

Soil 2

40-56	Ab	Dark grayish brown (10YR 4/2) sandy loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine granular structure; soft, very friable; abrupt irregular boundary.
56-108	C1b	Pale brown (10YR 6/3) sand, brown (10YR 5/3) moist; massive parting to single grain; loose to soft, very friable; abrupt wavy boundary.
108-123	C2b	Stratified pale brown (10YR 6/3) sand, brown (10YR 5/3) moist; massive parting to single grain; loose to soft, very friable; contains 1-4 cm-thick beds of dark grayish brown (10YR 4/2) sandy loam, very dark grayish brown (10YR 3/2) moist; weak medium and fine granular structure; friable; abrupt wavy boundary.

LACUSTRINE

123-146	---	Stratified diatomaceous earth containing 3-7 cm-thick beds of very dark gray (10YR 4/1), gray (10YR 5/1) and grayish brown (10YR 5/2) very fine sandy loam; common fine and medium carbonate threads along root paths; common, very fine plant macrofossil fragments from 138-141 cm, abrupt wavy boundary.
146-156	---	Diatomaceous earth; dark gray (10YR 4/1) and gray (10YR 5/1) very fine sandy loam; organic rich, common fine and medium carbonate threads along root paths; abrupt wavy boundary.

156-160	---	Very pale brown (10YR 8/2) diatomite; abrupt wavy boundary.
160-168	---	Diatomaceous earth; laminated dark gray (10YR 4/1) and gray (10YR 5/1) silty loam; abrupt wavy boundary.
168-178	---	Light gray (10YR 7/1) diatomite; thickness highly variable, typically ranging between 10-15 cm, can be up to 25 cm-thick; parts of section contain 2-3 cm-thick bed of gray (10YR 5/1) diatomaceous earth beneath diatomite, abrupt wavy boundary.
		ALLUVIUM
178-205	C3b	Horizontally-bedded very pale brown (10YR 7/3) fine sand, pale brown (10YR 6/3) moist; massive parting to single grain; soft, very friable; abrupt smooth boundary.
205-355	C4b	Cross-bedded very pale brown (10YR 7/3) fine and medium sand, pale brown (10YR 6/3) moist; massive parting to single grain; loose to soft, friable; contains beds of coarse sand and fine gravel; abrupt wavy boundary.
355-430	C5b	Stratified pale brown (10YR 6/3) sand, brown (10YR 5/3) moist; massive parting to single grain; friable; contains 15-25 cm-thick beds of faintly laminated brown (10YR 5/3) silt loam, brown (10YR 4/3) moist; massive; loose to soft, friable; of abrupt wavy boundary.
430-460+	C6b	Cross-bedded light gray (10YR 7/2) fine and medium sand, light brownish gray (10YR 6/2) moist; massive parting to single grain; loose to soft, friable;

abrupt wavy boundary.

Table A.15 Description of Sasse Locality Section 1, Profile 1.

Landform: Sand dune on an alluvial terrace

Vegetation: Rangeland

Remarks: Organic matter from the upper 5 cm of the 2H1b horizon, the 2H3b horizon, and the peat bed at 625-630 cm below surface yielded radiocarbon ages of 7705±45 ^{14}C yr BP (8485 cal yr BP), 8500±40 ^{14}C yr BP (9505 cal yr BP), and 10,195±60 ^{14}C yr BP (11,860 cal yr BP), respectively.

Depth (cm)	Soil Horizon	Description
		EOLIAN SAND
0-480	C	Pale brown (10YR 6/3) cross-bedded dune sand, brown (10YR 5/3) moist; single grain, loose; predominantly very fine sand; common to few fine and very fine roots; abrupt smooth boundary.
		MUCK/ALLUVIUM
480-525	2H1b	Black (10YR 2/1) sandy clay loam, black (10YR 2/1) moist; massive; elastic when moist, brittle when dry; few very fine plant fragments; clear smooth boundary.
525-555	2H2b	Very dark grayish brown (10YR 3/2) sandy clay loam, very dark brown (10YR 3/1) moist; massive when moist, brittle when dry; elastic when moist, brittle when dry; few very fine plant fragments; clear smooth boundary.

555-578	2H3b	Black (10YR 2/1) sandy clay loam, black (10YR 2/1) moist; massive; elastic when moist, brittle when dry; few very fine plant fragments; gradual smooth boundary.
578-586	2H4b	Very dark grayish brown (2.5Y 3/2) loamy fine sand, very dark grayish brown (2.5Y 3/2) moist; massive; elastic when moist, brittle when dry; gradual smooth boundary.
586-625	2Cb	Light gray (2.5Y 7/2) sand, light brownish gray (2.5Y 6/2) moist; single grain, loose; very faint bedding; abrupt wavy boundary.
		PEAT
625-630	- - -	Black (10YR 2/1) peat; abrupt wavy boundary.
		ALLUVIUM
630-650	3Cb	Stratified light gray (2.5Y 7/2) sand, light brownish gray (2.5Y 6/2) moist; single grain, loose; predominantly very fine and fine sand.

Table A.16 Description of Sasse Locality Section 1, Profile 2.

Landform: Sand dune on an alluvial terrace

Vegetation: Rangeland

Remarks: Organic matter from the upper 5 cm of the 2H1b horizon and the peat bed at 645-665 cm below surface yielded radiocarbon ages of 7370±40 ^{14}C yr BP (8190 cal yr BP) and 9580±40 ^{14}C yr BP (10,930 cal yr BP), respectively.

Depth (cm)	Soil Horizon	Description
		EOLIAN SAND
0-480	C	Pale brown (10YR 6/3) cross-bedded sand, brown (10YR 5/3) moist; single grain, loose; predominantly very fine sand; common to few fine and very fine roots; abrupt smooth boundary.
		MUCK
480-525	2H1b	Black (10YR 2/1) sandy clay loam, black (10YR 2/1) moist; massive; elastic when moist, brittle when dry; few very fine plant fragments; clear smooth boundary.
525-555	2H2b	Very dark grayish brown (10YR 3/2) sandy clay loam, very dark brown (10YR 3/1) moist; massive; elastic when moist, brittle when dry; few very fine plant fragments; clear smooth boundary.

555-578	2H3b	Black (10YR 2/1) sandy clay loam, black (10YR 2/1) moist; massive; elastic when moist, brittle when dry; few very fine plant fragments; gradual smooth boundary.
578-586	2H4b	Very dark grayish brown (2.5Y 3/2) loamy fine sand, very dark grayish brown (2.5Y 3/2) moist; massive; elastic when moist, brittle when dry; gradual smooth boundary.
		ALLUVIUM
586-645	3Cb	Light gray (10YR 7/2) sand, light brownish gray (10YR 6/2) moist; single grain, loose; very faint bedding; abrupt wavy boundary.
		PEAT
645-665	- - -	Very dark gray (10YR 3/1) peat; abrupt wavy boundary.
		SLACK-WATER DEPOSIT
665-675	4C1b	Bed of light olive brown (2.5Y 5/3) silty clay loam, olive brown (10YR 4/3) moist; hard, firm; abrupt wavy boundary.
		ALLUVIUM
675-705	5C2b	Wavy beds of light yellowish brown (2.5Y 6/3) sand, light olive brown (2.5Y 5/3) moist, interbedded with light gray (10YR 7/2) sand, light brownish gray (10YR 6/2) moist; many prominent coarse, wavy yellowish brown (10YR 5/8) and strong brown (7.5YR 5/8 and 4/6) mottles along boundaries between the beds; single grain, loose; abrupt wavy boundary.

705-775	5C3b	Wavy beds of light gray (2.5Y 7/2) sand, light brownish gray (2.5Y 6/2) moist, with few beds 3-4 cm thick of light yellowish brown (2.5Y 6/3) sand, light olive brown (2.5Y 5/3) moist; single grain, loose.

Table A.17 Description of Sasse Locality Section 2.

Landform: T-1 terrace

Parent material: Eolian sand, paludal, alluvium

Vegetation: Rangeland

Remarks: Organic matter from the upper 5 cm of the 2H1b horizon and 2H3b horizon, lower 5 cm of the 2H3b horizon, and upper 5 cm of the 3Hb horizon yielded radiocarbon ages of 1140±35 ^{14}C yr BP (1025 cal yr BP), 1285±30 ^{14}C yr BP (1225 cal yr BP), 2065±30 ^{14}C yr BP (2025 cal yr BP), and 2750±30 yr BP (2830 cal yr BP), respectively.

Depth (cm)	Soil Horizon	Description
		EOLIAN SAND
0-153	C	Pale brown (10YR 6/3) sand, brown (10YR 5/3) moist; single grain, loose; predominantly very fine sand; common fine and very fine roots; abrupt smooth boundary.
		MUCK/ALLUVIUM
153-159	2H1b	Very dark gray (10YR 3/1) sandy clay loam, black (10YR 2/1) moist; common faint, fine and medium, strong brown (7.5YR 5/6) and yellowish red (5YR 4/6) mottles; massive; elastic when moist, brittle when dry; common fine and very fine roots; abrupt irregular boundary.
159-180	2H2b	Dark grayish brown (10YR 4/2) sandy clay loam, very dark grayish brown (10YR 3/2) moist; common distinct, fine and medium strong brown (7.5YR

		5/6) and yellowish red (5YR 4/6) mottles; massive; elastic when moist, brittle when dry; few fine and very fine roots; abrupt wavy boundary.
180-230	2H3b	Black (10YR 3/1) sandy clay loam, black (10YR 3/1) moist; common distinct, fine and medium strong brown (7.5YR 5/6) and yellowish red (5YR 4/6) mottles; massive; elastic when moist, brittle when dry; few fine and very fine roots; clear irregular boundary.
230-310	3Cb	Light gray (10YR 7/2) sand, light brownish gray (10YR 6/2) moist; common distinct brownish yellow (10YR 6/8) mottles along root paths; common brown (7.5YR 4/3), wavy, lamellae between 250 and 275 cm below surface; single grain, loose; few fine and very fine roots; abrupt wavy boundary.
		MUCK
310-350	4Hb	Laminated black (10YR 2/1) sandy clay loam, black (10YR 2/1) moist; massive; firm; laminated; few very fine roots.