2013 HABITAT MONITORING AND ASSESSMENT CD5 DEVELOPMENT PROJECT

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Cover:

Geomorphology Monitoring Photo Point looking east across the Niġliq Channel with CD4 drill pad in the background. Photograph by Aaron Wells courtesy of ConocoPhillips Alaska, Inc.

Inset: CD5 Habitat Monitoring field crew collecting vegetation data using the point count method. Photograph by Ina Timling courtesy of ConocoPhillips Alaska, Inc.

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FINAL REPORT

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February 2014

Printed on recycled paper.

EXECUTIVE SUMMARY

This report presents the results of the 2013 CD5 Habitat Monitoring Study, a long-term monitoring study designed to monitor and assess potential changes in habitat related to the CD5 Development Project on a portion of the Colville River Delta in northern Alaska. The CD5 Habitat Monitoring Study is one component of a broader long-term Monitoring Plan with an adaptive management strategy (Monitoring Plan) that has been implemented by ConocoPhillips Alaska, Inc. (CPAI) as a condition on their CD5 development permit. The objectives of the 2013 CD5 Habitat Monitoring Study were to 1) initiate the first year of monitoring, including climate, habitat, and permafrost monitoring; 2) data analysis, mapping, and reporting; and 3) present findings at an agency and stakeholder meeting in February 2014.

The CD5 Habitat Monitoring Study includes three components: climate monitoring, habitat monitoring, and permafrost monitoring. For each of these components, ABR initiated the first year of fieldwork to collect data to serve as a baseline pre-construction for future monitoring. For climate monitoring, the Alpine weather station was installed on 10 May 2013 by Polar Alpine, Inc. Climate parameters monitored include wind speed and direction, incoming solar radiation, air temperature, snow depth, precipitation, and barometric pressure. ABR summarized climate parameters for a 5-month period from May through September 2013.

For the habitat monitoring component, ABR completed several tasks. First, ABR participated in spring-breakup surveys on the Colville River Delta. Using field notes and map sketches, ABR mapped the progression of floodwater as it entered the CD5 Habitat Monitoring Study Area beginning on 30 May through 4 June when flood water peaked at the CD2 facilities. Second, ABR set up and sampled 179 Integrated Monitoring plots along 39 Monitoring Transects. Each Integrated Monitoring Plot included a Vegetation Plot, Habitat Plot, Soil Pit, and Map Verification Plot. Third, ABR classified vegetation plot data into 17 plot ecotypes (local-scale ecosystems). ABR summarized field data for plot ecotypes and used these summaries to quantify and describe the vegetation composition and environment of each. ABR used ordination analysis to test for relationships between the Vegetation Plot data and environmental parameters to elucidate the environmental gradients and ecological processes important in shaping ecosystem development in the CD5 Habitat Monitoring Study Area.

Fourth, ABR used data from Habitat Plots and Map Verification Plots to provide field verification for Integrated Terrain Unit (ITU) mapping in the CD5 Habitat Monitoring Study Area. In the ITU mapping, ABR simultaneously mapped several landscape components by photointerpretation of high-resolution (<1 ft [0.3 m]) aerial imagery. ABR used the mapping to produce maps of the individual landscape components, and aggregated the individual components to produce ecotype and wildlife habitat maps. ABR summarized areal extent of each landscape component, map ecotype, and wildlife habitat. ABR also summarized Habitat Plot data by wildlife habitat class and used the information to produce summary charts and tables of vegetation structure class and height.

Fifth, LCMF Engineering sampled Thaw Depth/Elevation Points along the 39 Monitoring Transects, including 658 thaw depth measurements and 660 elevation measurements. The Thaw Depth/ Elevation Points were used by ABR to 1) develop toposequence diagrams that illustrate some common landscape-vegetation relationships in the CD5 Habitat Monitoring Study Area, 2) plot thaw depth/elevation profiles of each Monitoring Transect, and 3) summarize elevation and thaw depth by map ecotype class. Sixth, ABR initiated three broad-scale geomorphology monitoring sub-tasks, including sedimentation and erosion monitoring using marker horizons, documentation of drift lines, and the establishment of Geomorphology Monitoring Photo Points.

For permafrost monitoring, ABR established 16 Permafrost Temperature Monitoring Plots. At each plot, ABR installed Hobo data loggers fitted with 2 temperature sensors, one placed at 11.8 in (30 cm) and the second at 39.4 in (100 cm) below the soil surface. Permafrost temperature data is being collected at hourly intervals at both depths. Permafrost temperature data is presently unavailable as the first scheduled data download is tentatively set for late June or early July 2014, at

which time the batteries in the data loggers will also be changed out. At 6 Permafrost Temperature Monitoring Plots, ABR extracted permafrost cores using a 3 in (7.62 cm) Snow, Ice and Permafrost Research Establishment (SIPRE) corer. For each core, ABR described the stratigraphy, and selectively sampled 2–4 core segments for laboratory analysis, which included volumetric ice content, bulk density, particle size, and loss on ignition. Results from the laboratory analyses were summarized and discussed in light of previous permafrost studies on the Colville River Delta.

The 2013 CD5 Habitat Monitoring Study lays the groundwork for future monitoring of potential changes in site conditions and the efficacy of the proposed mitigation measures related to the CD5 Development. The habitat monitoring components, including climate, habitat, and permafrost, and associated data summaries, descriptions and mapping follow directly from the Monitoring Plan and serve as the basis for monitoring and assessing habitats through time.

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ACKNOWLEDGMENTS

This study was funded by ConocoPhillips Alaska, Inc. and was managed by Robyn McGhee and Maggie Valentine-Graham. Many thanks to all those at Alpine whose efforts led to a safe and successful field season. Joanna Roth, Ashley Hovis, George Brady, Ina Timling, Zawisza Grabinski-Parker, Elizabeth Miner, Leah Kenney, Tony LaCortiglia, Gerald “J.J.” Frost, and James Smith provided excellent assistance in the field. Allison Zusi-Cobb and Dorte Dissing provided GIS support and created map figures. Ellen Trainor, Ina Timling, and Becky Baird prepared tables and figures, and Pam Odom produced the report. Janet Kidd, Caryn Rea, Maggie Valentine-Graham, and Anne Leggett provided a thorough review. Many thanks to you all!

1.0. INTRODUCTION

1.1. BACKGROUND

As a condition of the permit to develop CD5 in the Northeast National Petroleum Reserve-Alaska (NE NPRA) and associated infrastructure on the Colville River Delta, the U.S. Army Corp of Engineers (USACE) stipulated that ConocoPhillips Alaska, Inc. (CPAI) implement a monitoring plan with an adaptive management strategy (POA-2005-1576). The Monitoring Plan with an adaptive management strategy (Monitoring Plan) was developed to monitor changes in site conditions and the efficacy of the proposed mitigation measures (ABR and Baker 2013). The Monitoring Plan commits CPAI to 1) develop a monitoring program prior to construction; 2) prepare monitoring reports on a variety of monitoring components (see below) for review by key stakeholders; and 3) meet with federal agencies annually to review the monitoring reports and the effectiveness of the in-place mitigation measures.

1.2. MONITORING PROGRAM GOALS AND OBJECTIVES

As a result of 4 decades of development activities in North Slope wetlands, rivers, and streams, and more than 10 years of oil and gas extraction in the Colville River Delta, impacts resulting from gravel placement on tundra and in the Colville River Delta and bridges across rivers and streams are well understood. Those impacts have prompted CPAI operations to implement mitigation measures for the CD5 Project in consultation with federal agencies.

The CD5 Monitoring Plan's goal is to monitor for changes in site conditions and selected resources and to modify, if appropriate, operational practices to minimize impacts on the hydrologic function of the Colville River Delta as a result of road, bridge, and pad construction. As discussed with federal agencies in meetings during 2011, an outline of the Monitoring Plan and a table summarizing the Plan's monitoring components were provided to the USACE in a letter dated 23 November 2011. Subsequent discussions and correspondence through 30 August 2012 resulted in the following list of studies to be included in the Monitoring Plan:

- Habitat Monitoring (climate, vegetation, geomorphology, sedimentation, and permafrost)
- Hydrology Monitoring
- Erosion-Control Monitoring
- Culvert Monitoring
- Bridge Monitoring (Niġliq and Niġliagvik Bridge)

This report presents the results of the habitat monitoring component (herein, CD5 Habitat Monitoring Study) of the overall CD5 Monitoring Plan. As described in the CD5 Monitoring Plan (ABR and Baker 2013), the overall goals of the CD5 Habitat Monitoring Study include 1) determining if placement of gravel results in alteration to wildlife habitat upstream and/or downstream of the CD5 road; 2) quantifying vegetation communities and habitat in permanent plots established upstream and downstream of the road to identify changes through time based on comparison to baseline data; 3) monitoring permanent plots beginning the year before and immediately following construction and every 5 years thereafter to evaluate and identify changes in vegetation, wildlife habitat, geomorphology (soils, permafrost, thaw depth), and sedimentation/ erosion over time; and 4) through periodic monitoring of vegetation and hydrology, identify intermediate trends of change that reflect sedimentation and erosion predictions, to the extent possible.

The 2013 effort was focused on collecting the baseline information needed to allow for future monitoring of potential changes associated with the CD5 Project. The specific objectives of the 2013 CD5 Habitat Monitoring Study were to:

1. Initiate the first year of climate, habitat and permafrost monitoring in the CD5 Habitat Monitoring Study Area;
2. Analyze and summarize field data; complete the Integrated Terrain Unit (ITU) mapping update in the CD5 Habitat Monitoring Study Area; and prepare summary reports and maps; and

3. Present findings at an agency and stakeholder meeting in February 2014.

1.3. CD5 HABITAT MONITORING STUDY AREA

1.3.1. DESCRIPTION

This study focuses on the CD5 Habitat Monitoring Study Area, which is located along the Niġliq Channel in the southwestern portion of the Colville River Delta on the North Slope of Alaska (Figures 1.1 and 1.2). The Alpine Oil Facilities are located directly east of the CD5 Habitat Monitoring Study Area, and the village of Nuiqsut, established in 1971, is located several miles to the south of the CD5 Habitat Monitoring Study Area.

The CD5 Habitat Monitoring Study Area has been partitioned into 4 subareas, including test and reference areas (Figure 1.2). The "test" areas include the general area directly upstream (Test Area South) and downstream (Test Area North) of the proposed CD5 road (within approximately 1.2 mi [1.9 km]). ABR and Baker (2011) predict this area to be affected by moderate and high changes in sedimentation and erosion regime during a 200-year flood. The "reference" areas were located approximately 2–3 mi (3–5 km) upstream (Reference Area South) and downstream (Reference Area North) of the proposed CD5 road and are predicted by ABR and Baker (2011) to be unaffected by the proposed development.

1.3.2. ENVIRONMENT

The Colville River is the largest river on Alaska's North Slope and is one of 8 major rivers with significant freshwater input to the Arctic Ocean (Walker 1983, Figure 1.1). It drains approximately 29% (20,700 mi^2 [53,600 km^2]) of the North Slope of Alaska, including most of the foothills watershed (64%) and smaller areas in the Brooks Range (26%) and coastal plain (10%; Walker 1976). The Colville River enters the Beaufort Sea near the northeastern corner of the NPRA, midway between the villages of Barrow and Kaktovik; here, the river slows and spreads out across a large river delta. The head of the Colville River Delta is located about 2 miles (3 km) downstream from the mouth of the Itkillik River, and 19 miles (30 km) upstream of the Beaufort Sea (Arnborg et al. 1966).

The delta has two main distributaries, the Niġliq (western) Channel and the Colville East Channel (Figure 1.1). These two channels combined carry approximately 90% of the water through the delta during flooding and 99% during low water (Walker 1983). Smaller channels branching from the East Channel include the Sakoonang, Tamayayak, and Elaktoveach channels.

The CD5 Habitat Monitoring Study Area has a typical arctic maritime climate. Winters are cold and windy and last approximately 8 months. Summers are cool, with average daily temperatures ranging from 22° F (-6° C) in mid-May to 49° F (9° C) in July; summers are also characterized by low precipitation (less than 3 inches [in] [76 mm] on average), overcast skies, fog, and persistent winds from the northeast (NCDC 2013).

The CD5 Habitat Monitoring Study Area is bounded to the west by old alluvial terraces that are traceable from the coast to above the head of the delta (Carter and Galloway 1982). Carbon dating of fossil wood collected at the base of exposures yielded ages of 48,000–50,600 years before present (ybp), suggesting that the terraces and underlying deposits of gravelly sand were formed during the last interglacial period (Carter and Galloway 1982). These deposits are part of the Gubik Formation (Black 1964, Carter et al. 1977), a series of unconsolidated deposits that record a complex marine and alluvial history spanning approximately 3.5 million years (Carter et al. 1986). Modern sandy deltaic sediments in the delta generally range from 16–33 ft (5–10 m) below sea level and are underlain by 20–39 ft (6–12 m) of gravelly riverbed material (glaciofluvial outwash) and 66 ft (20 m) or more of interbedded silts, clays, and organics indicative of marine or deltaic sediments associated with the Gubik Formation (Miller and Phillips 1996). The surficial geology of the central Arctic Coastal Plain has been mapped (1:63,360 scale) by Carter and Galloway (1985) and Rawlinson (1993).

The CD5 Habitat Monitoring Study Area is characterized by numerous lakes and ponds, sandbars, mud flats, sand dunes, and low- and high-centered polygons (Walker 1976, 1978). Most waterbodies are shallow (<6.6 ft [2 m] deep) ponds that freeze to the bottom in winter and thaw by

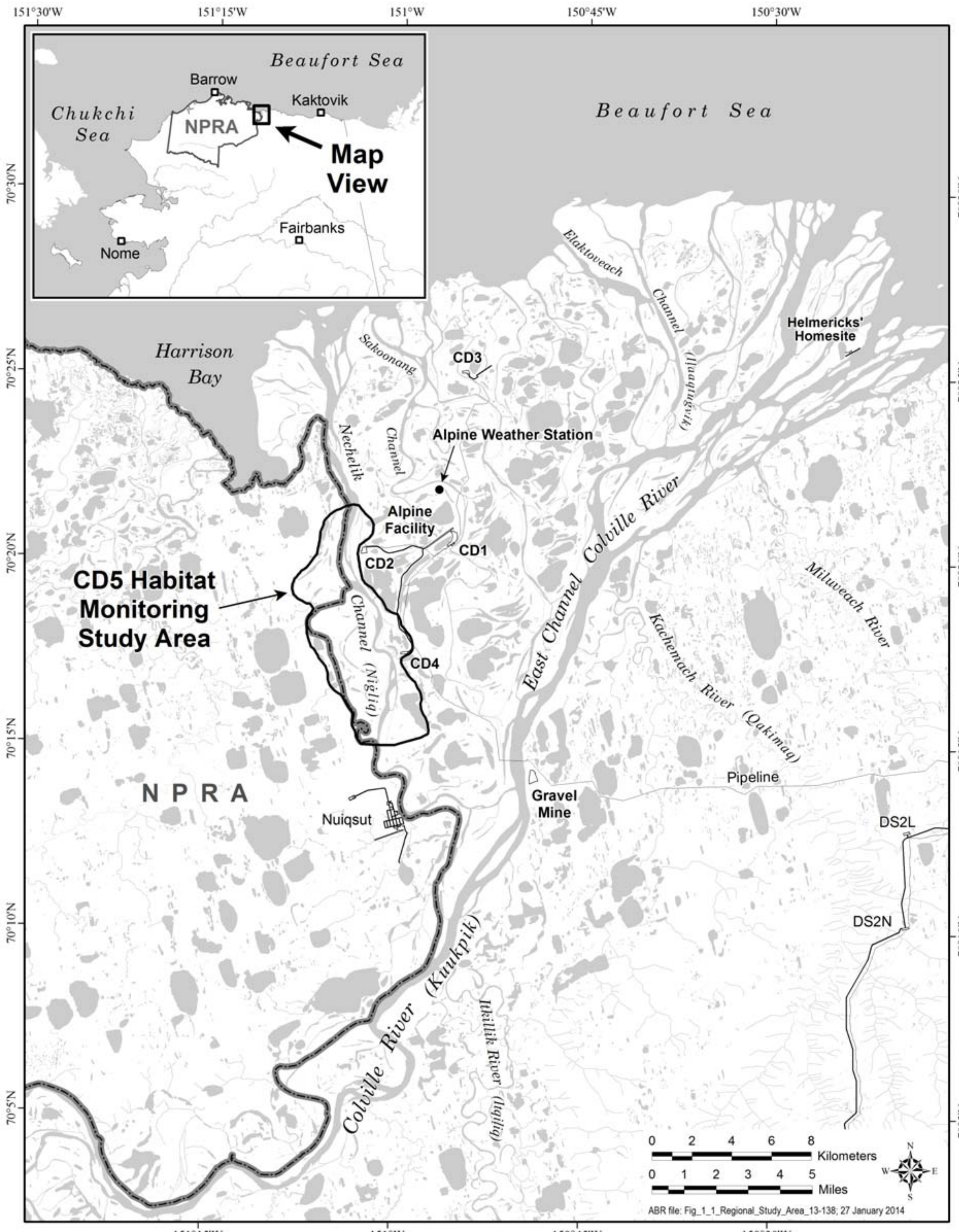


Figure 1.1. Overview map showing the location of the CD5 Habitat Monitoring Study Area on the Colville River Delta, northern Alaska, 2013.

June. Larger lakes typically are deeper (up to 33 ft [10 m]) and freeze only in the upper 6.6 ft (2 m).

Both stabilized and active dunes, which are composed mainly of fine sand, are present in the CD5 Habitat Monitoring Study Area (Walker 1976, Walker and Matsukura 1979). Stabilized dunes generally are long, narrow, vegetated ridges with smooth, rounded surfaces and few wind-eroded areas. Most of the stabilized dunes are oriented parallel to, and on the west side of, former river courses. In contrast, active dunes generally form on the western and southwestern sides of river-channel bars and along the inner edge of tidal flats in response to the prevailing winds from the northeast. Large areas of stabilized sandy material deposited during the Pleistocene also are located just west of the delta (Carter 1981).

The CD5 Habitat Monitoring Study Area is far enough from the Beaufort Sea that marine processes are limited to saltwater intrusion along river channels under ice during the winter months. The saltwater primarily influences silty barrens located along river channels, resulting in limited areas of coastal barrens and halophytic vegetation, and occasionally leading to small areas of salt-killed vegetation.

In addition to these depositional processes, the accumulation of peat has contributed substantially to deltaic deposits, thus raising the surface of the floodplain. At selected sampling sites along the Arctic Coastal Plain, Schell and Ziemann (1983) measured depths of peat accumulation of 1.6–9.8 ft (0.5–3 m) with the thickest deposit having a basal peat age of 12,610 ybp. Although formation of ice wedges and development of polygons can alter and erode the peat mat, the ubiquitous layer of peat throughout the coastal plain has contributed to the development of the arctic landscape.

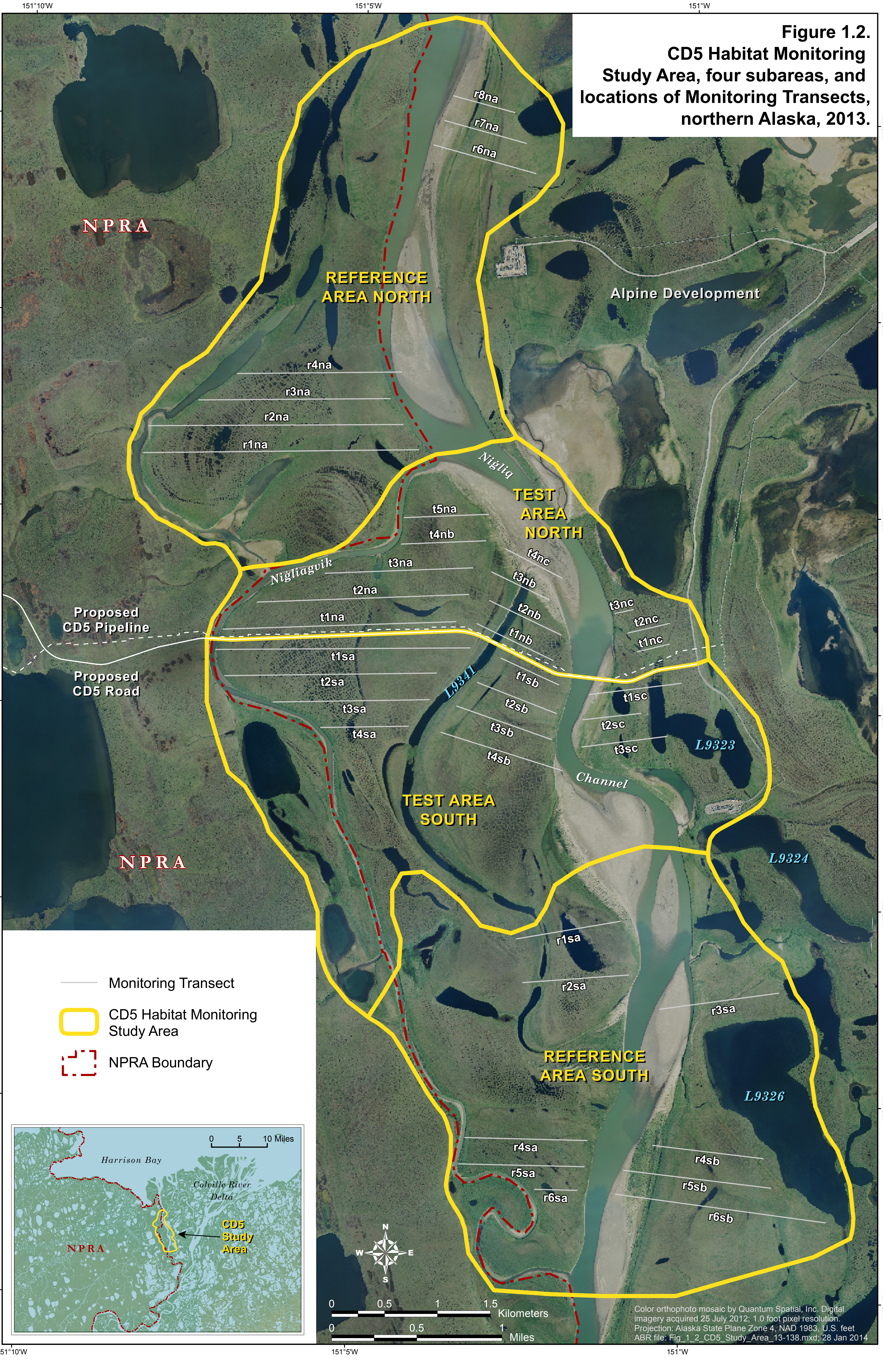


Figure 1.2. CD5 Habitat Monitoring Study Area, four subareas, and locations of Monitoring Transects, northern Alaska, 2013.

2.0. CLIMATE MONITORING

2.1. RATIONALE

Weather and climate are strongly linked to several components of the CD5 monitoring effort, including timing and magnitude of spring breakup flooding, ground and surface water levels, annual vegetation cover, active-layer thickness, and soil temperature. Also, given the long-term timeframe of the Habitat Monitoring study, naturally occurring climate variability may play a role in the outcome of monitoring efforts.

2.2. METHODS

2.2.1. WEATHER-STATION INSTALLATION

The Alpine weather station was installed on 10 May 2013 by Polar Alpine, Inc. for the purpose of monitoring weather and climate parameters in the Alpine Development area. The station is located 1.4 miles (2.3 km) NNW of the Alpine (CD1) facility (Figure 2.1). The geographical coordinates of the location are N70.36590°, W150.94639° (NAD83). The site elevation is approximately 24 ft (7.3 m) above sea level (British Petroleum mean sea level [BPMSL]).

The Alpine weather station is configured to collect the following data:

- Wind Speed and Direction,
- Incoming Solar Radiation,
- Air Temperature,
- Snow Depth,
- Precipitation, and
- Barometric Pressure.

Figure 2.2 provides an annotated photograph of the weather-station design and instrumentation. Wind speed and direction are measured using an R. M. Young Model 05103-45 Alpine Version Wind Monitor placed at 9.25 ft (2.82 m) above the ground surface. Solar radiation is measured using a Hukseflux LP02 pyranometer with a light-spectrum waveband ranging from 305–2800 nm. Air temperature is measured using a Lewellen Arctic Research, Inc. Type T Thermocouple. Snow depth is measured using a Campbell Scientific, Inc. Sonic Ranging Sensor SR50A. A Texas Electronics TE525WS Tipping Rain Bucket Rain Gauge with wind screen measures liquid precipitation. Barometric pressure is measured using a Vaisala PTB110 barometer. Appendix A provides the full specifications for the Alpine Weather Station instrumentation.

Wind speed and direction, incoming solar radiation, air temperature, and precipitation are recorded at 30-second intervals. Snow depth and barometric pressure are sampled at hourly intervals. All parameters are written to comma-delimited output files on an hourly basis.

The data are written to the output files listed below and transmitted via the AirLink Cellular Modem to Polar Alpine, Inc.'s host computer. The files are then re-transmitted to ABR, Inc.—Environmental Research and Services (hereafter, ABR). The output files are as follows:

Transmitted Hourly

- **HALP504_WX_US:** Hourly WX Data in English Units
- **HALP508_WX_SI:** Hourly WX Data in Metric Units
- **HALP503_WCT_F:** Wind Chill Data in English Units

Transmitted Daily

- **DALP500_FFDD:** Daily Freezing Degree Day Data in English Units and Temperature and Wind Data Summary
- **DALP505_CFDD:** Daily Freezing Degree Day Data in Metric Units and Temperature and Wind Data Summary

Appendix B provides example output from each of the data files and the legend for all of the data files.

2.2.2. DATA ANALYSIS

Climate data were summarized for the months during which Habitat Monitoring field work occurred, including May through September. Hourly data were ingested and summarized using the statistical software R (R Core Team 2013). Hourly data were checked to confirm that each day had 24 valid observations for the parameters of interest before producing daily summaries, and that there were the correct number of days when aggregating to month. The station was not installed until 10 May, so the May data are incomplete in this analysis.

Figure 2.1. Location of Alpine Weather Station relative to the Alpine Development on the Colville River Delta, northern Alaska, 2013.

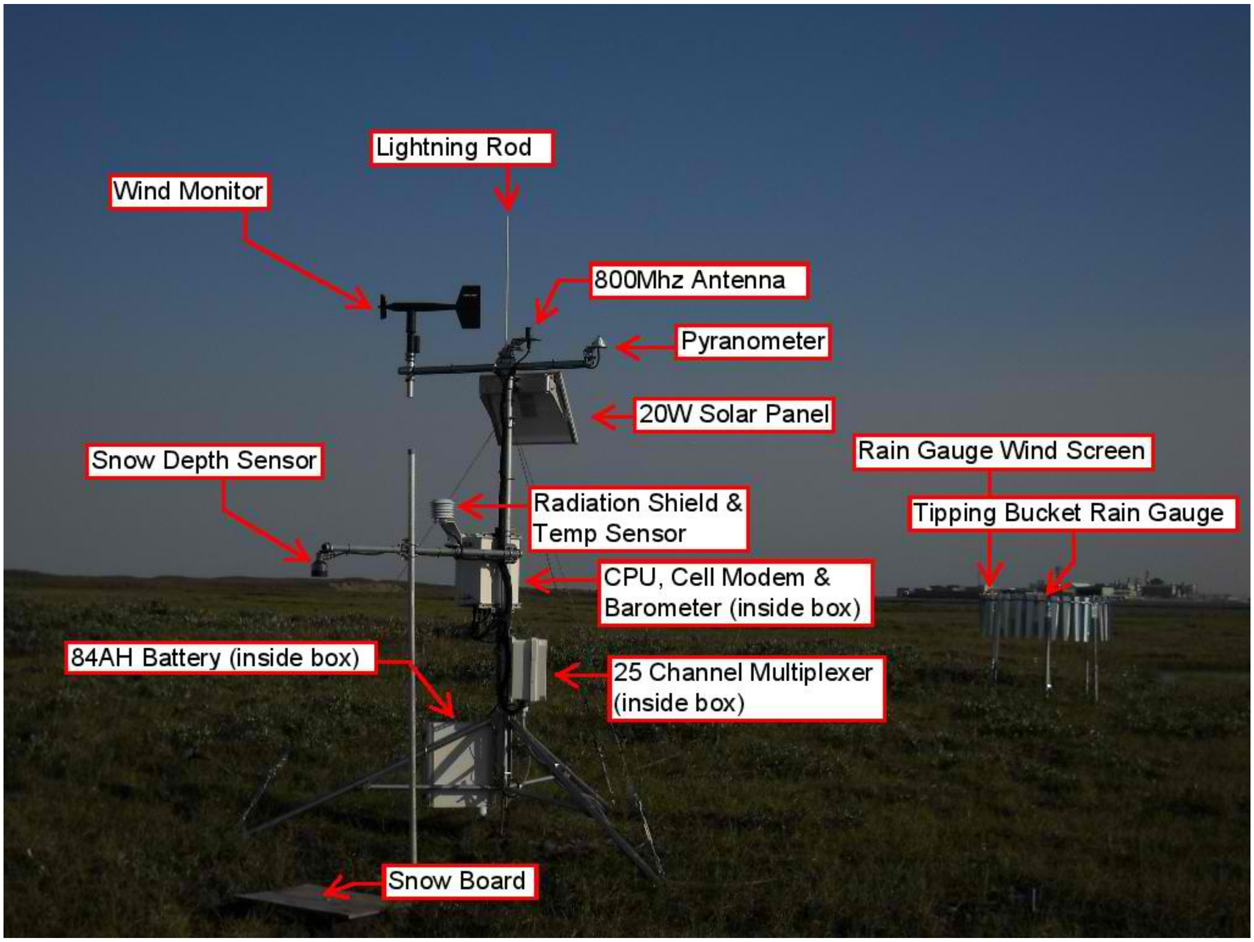


Figure 2.2. Annotated photograph of the Alpine Weather Station illustrating the station layout and instrumentation, Colville River Delta, northern Alaska, 2013.

Hourly temperature observations were aggregated to daily minimum, maximum and average temperature. Hourly wind measurements were categorized into calm (wind speed <1 miles/hour [mph] [1.6 kilometers/hour [kph]]), low (1–10 mph [1.6–16.1 kph]), moderate (10.1–20 mph [16.1–32.2 kph]), and high (>20 mph [>32.2 kph]), and placed into 22.5 degree directional bins for analysis. Hourly precipitation was aggregated to daily precipitation by calculating the daily sum. Finally, daily data were broken down into monthly periods for analysis.

2.3. RESULTS AND DISCUSSION

2.3.1. TEMPERATURE AND PRECIPITATION

Daily minimum and maximum temperature and precipitation are presented in Figure 2.3. The transition from winter to summer occurred at the end of May, with average daily temperatures rising above freezing on 20 May 2013. This day also marked the point when the cumulative thawing degree-days offset days with average temperatures below freezing. Daily maximum temperatures were above 70° F (21.1° C) for 6 days in 2013, reaching a high of 74.3° F (23.5° C) on 20 June, and except for one day in July, daily minimum temperatures remained above freezing until 20 August. There was a sharp transition to winter beginning on 15 September 2013, when the high temperature dropped below 32° F (0° C) and average daily temperatures remained below freezing.

Measurable precipitation fell on 40% of the days over the summer, with most totals <0.1 in (2.5 mm). In July, 4 rain events accrued over 0.25 in

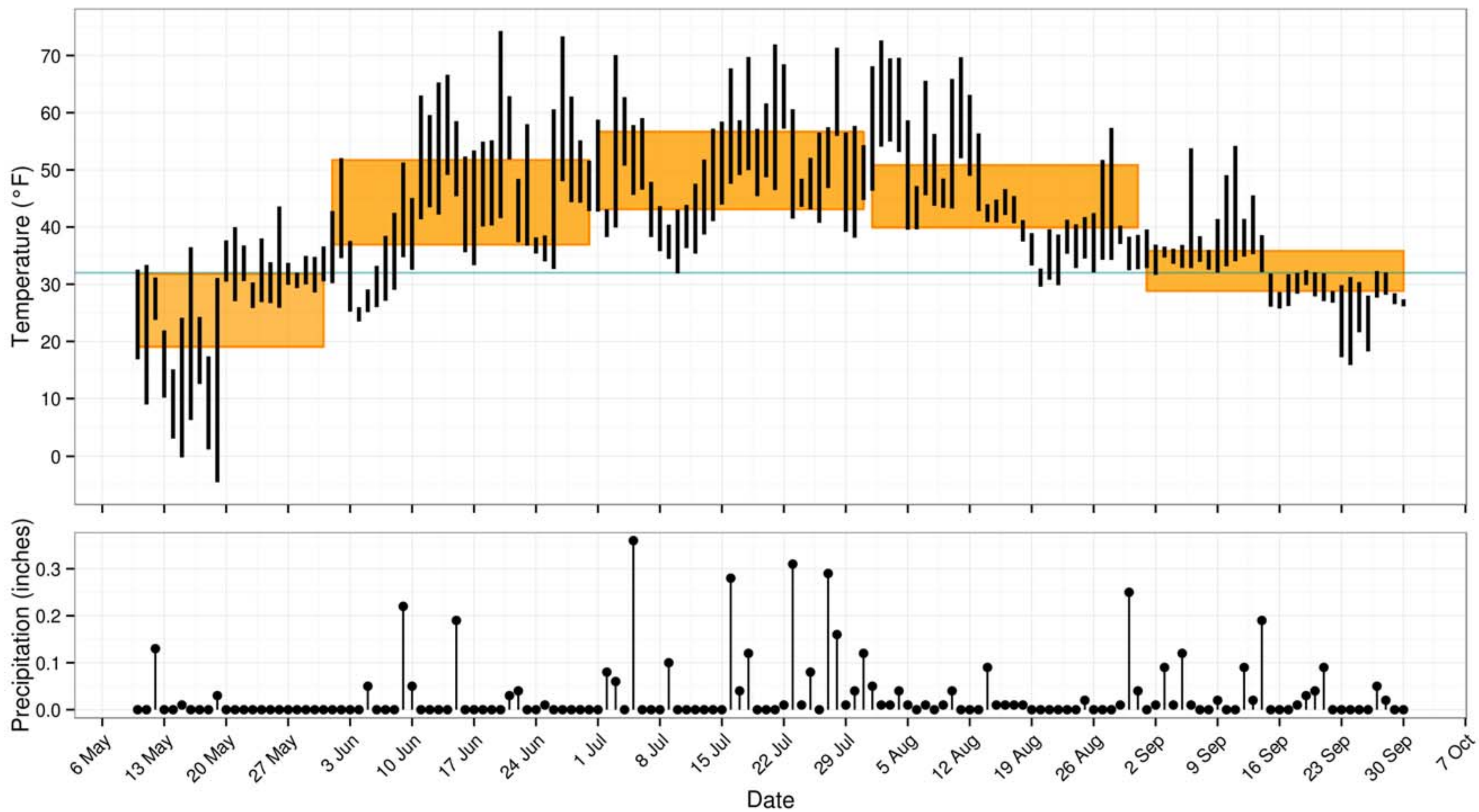


Figure 2.3. Charts summarizing temperature and precipitation data from the Alpine weather station, Colville River Delta, northern Alaska, 2013. The top figure shows daily minimum and maximum temperature (black bars), and monthly average high and low temperature (orange boxes). The freezing point is marked with a light blue line. The lower figure shows the daily precipitation totals.

(6.4 mm) water, with a maximum of 0.36 in (9.1 mm) on 5 July 2013. The total precipitation for the summer was 4.25 in (108.0 mm), more than an inch above the long-term average at nearby stations: Nuiqsut Airport (2.54 in [64.6 mm], 1998–2013), Colville Village (3.00 in [76.1 mm], 1996–2013), and Kuparuk (2.43 in [61.7 mm], 1983–2013). These stations also experienced significantly higher rainfall in 2013: Nuiqsut Airport 5.46 in (138.6 mm), Colville Village 4.02 (102.0 mm), and Kuparuk 3.41 in (86.7 mm).

The month with the highest variation in temperature was June 2013 (Figure 2.4), when daily temperatures ranged from 25°–74° F (-4°–23° C). The lowest temperature variation occurred in September 2013 (Figure 2.4). Below freezing temperatures occurred in each month except for July (Figures 2.3 and 2.4).

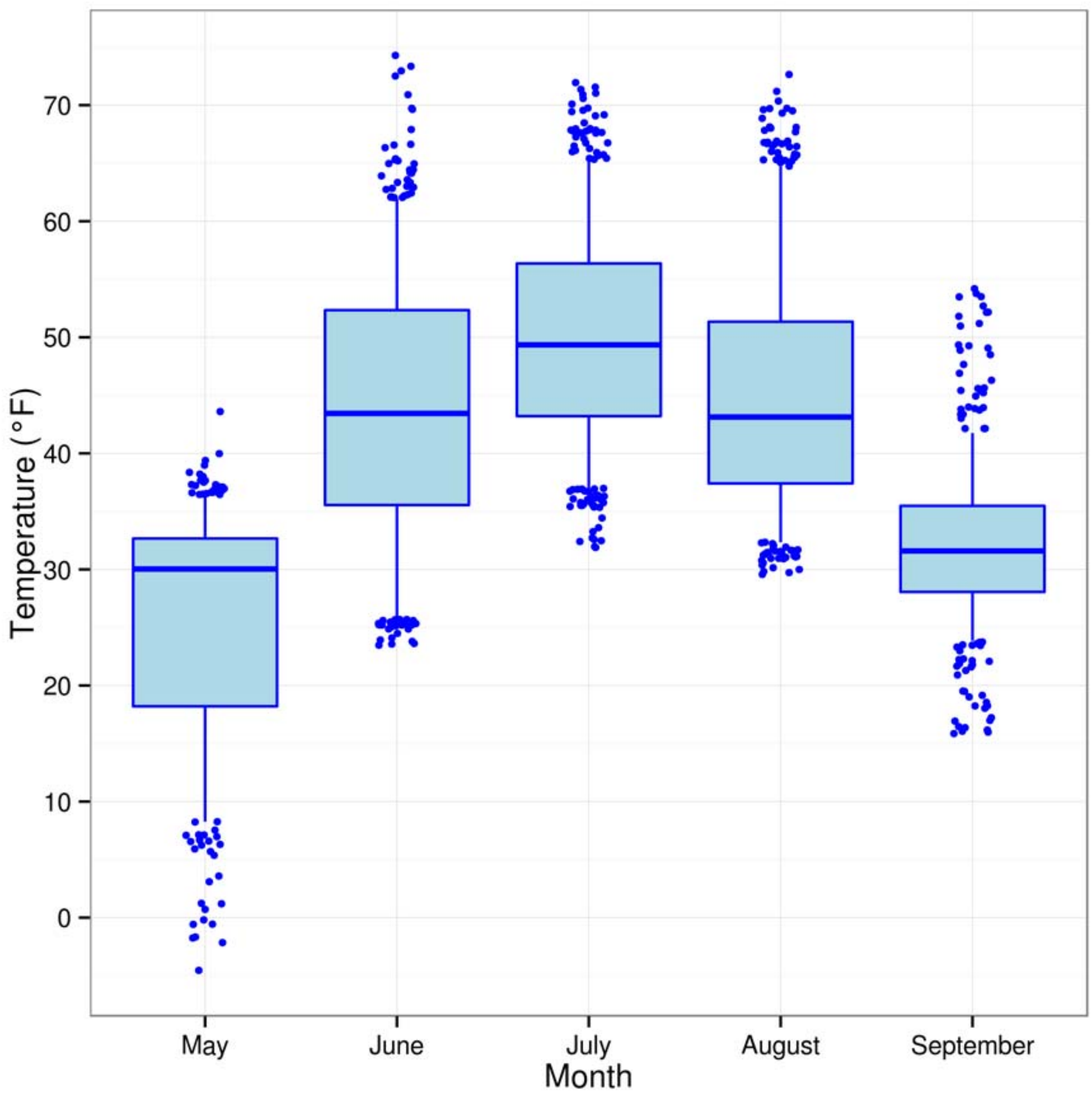


Figure 2.4. Boxplots summarizing monthly temperature distribution for the months May through September, Alpine Weather Station, Colville River Delta, northern Alaska, 2013.

2.3.2. WIND

In all summer months except May, the wind blew predominantly from an east-north-easterly direction (Figure 2.5). This was most evident in September, when more than half of the wind events came from that direction. In May, wind direction was more variable, with a significant percentage of wind events from the west in addition to the prevailing east-north-easterly winds. The frequency of calm wind events was very low, ranging from less than 1% in May to 3% in August. The highest frequency of wind events >20 mph (32 kph) occurred in May. However, these strong winds were rare and were observed less than 5% during the summer. Average monthly wind speeds were between 7.5 and 9.8 mph (12.1 to 15.8 kph) over the summer.

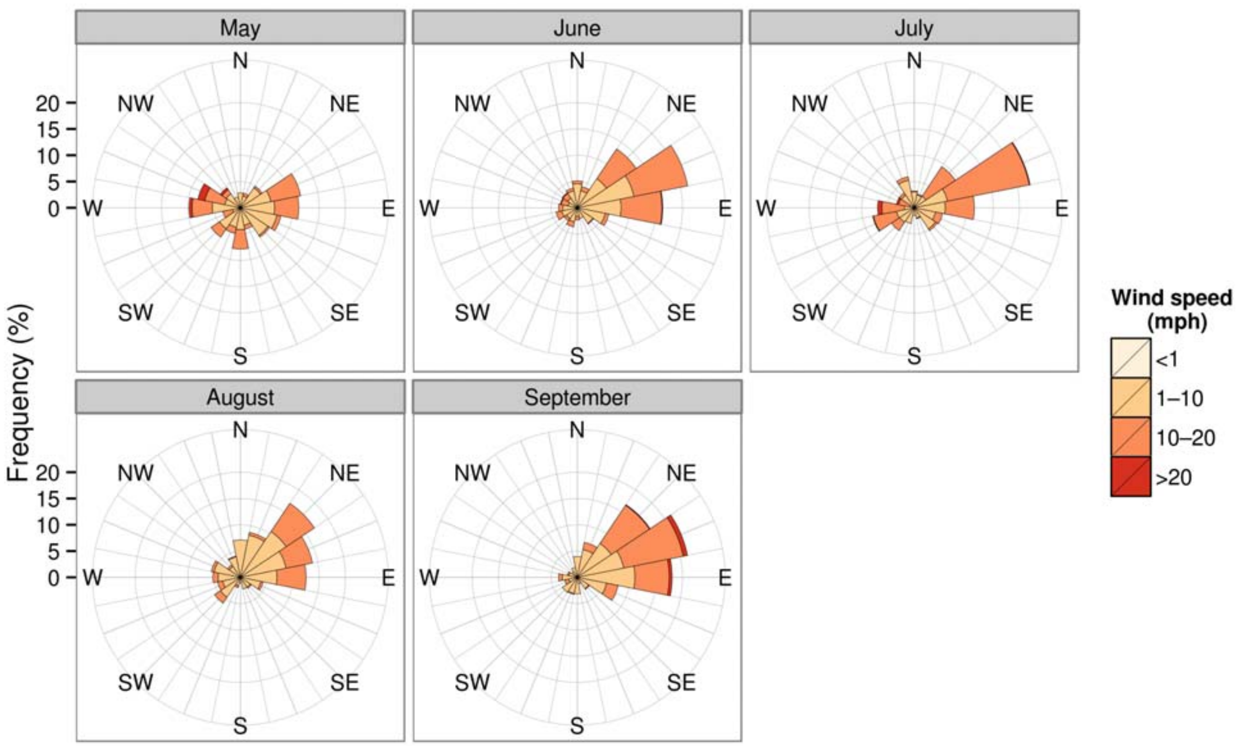


Figure 2.5. Charts summarizing monthly wind speed and direction for the months May through September, Alpine Weather Station, Colville River Delta, northern Alaska, 2013.

3.0. HABITAT MONITORING

3.1. RATIONALE

Habitat can be described as the ecological space occupied or potentially occupied by animals that includes both physical and biological features. ABR uses the term wildlife habitat to refer to the classification system that summarizes vegetation, surface forms, and geomorphology into useful categories when applied to birds and mammals (Jorgenson et al. 1997b). The Colville River Delta features a complex environment with many interacting biotic and abiotic landscape elements (Figures 3.1 and 3.2), which makes long-term habitat monitoring in this environment particularly challenging. Consequently, ABR has incorporated a broad array of biotic and abiotic features into the habitat-monitoring program, including vegetation, soils, geomorphology, permafrost, and climate. Further confounding the challenges to implementing a monitoring program in this environment, is that deltaic landscapes are highly dynamic and undergo natural landscape change through time. This makes it difficult to differentiate potential changes in sedimentation and erosion associated with the CD5 Project from natural change. Reference areas with similar environmental conditions to those areas directly upstream and downstream of the CD5 Project road have been selected for monitoring in an attempt to account for natural landscape change through time.

3.2 HABITAT MONITORING COMPONENTS

Habitat Monitoring includes several components as detailed in the Monitoring Plan. Detailed descriptions of each component and associated subcomponents are provided in the following sections. The outline below provides a guide to each of the Habitat Monitoring components with subcomponents nested within each.

- Spring Breakup Surveys
- Monitoring Transects
  - Integrated Habitat Monitoring Plots
    - Vegetation Plots
      - Vegetation Plot Photograph
    - Vegetation Lines
      - Vegetation Plot Sample Points
    - General environment data
    - Soils
  - Habitat Plots
    - Habitat Plot Line
      - Habitat Plot Line Photographs
      - Habitat Plot Points
    - Map Verification Plots
- Real Time Kinematic Surveys
  - Integrated Habitat Monitoring Plots
  - Thaw Depth/Elevation Points
- Broad-scale Monitoring of Geomorphology
  - Marker Horizons
  - Drift Lines
  - Geomorphology Monitoring Photography Points

3.3. METHODS

3.3.1. OVERALL STUDY DESIGN

The overall study design fits generally into the category of environmental impact analysis called BACI or before-after-control-impact (Stewart-Oaten et al. 1986). Sites in reference areas and impact areas (here referred to as “test” areas) are sampled before an impact occurs and resampled after the impact to compare conditions. The study design also incorporates elements of a gradient design (Ellis and Schneider 1997) in which data are collected across a range of impact levels, close to the source and far enough from the source that impacts are no longer anticipated.

3.3.2. FIELD SURVEYS

3.3.2.A. Spring Breakup

ABR joined Michael Baker, Jr., Inc. field crews during their annual spring-breakup surveys on the Colville River Delta from 27 May–6 June 2013. ABR staff participated in aerial and gage surveys and assisted with discharge measurements. During the daily aerial surveys, ABR field staff recorded observations and sketched maps detailing the progression of breakup flooding from the initiation of flooding on 30 May 2013 through the peak flow at the CD2 facilities on 4 June 2013. The field notes and map sketches were digitized by coding the approximate date of first flooding observed during spring breakup in 2013 into the 2012 Integrated Terrain Unit (ITU) map polygons (described below).

3.3.2.B. Habitat Monitoring

Habitat-monitoring field surveys were conducted 15 July–12 August 2013. Three crews of 3 people, each crew consisting of 2 botanists and one soil scientist, completed the habitat-monitoring fieldwork based out of the Alpine Oil Facilities on the Colville River Delta. Habitat-monitoring locations were accessed via helicopter, inflatable boat, and by foot. Additionally, a short-term "spike camp" was used for several days to reduce helicopter travel to and from habitat-monitoring locations.

Permanent habitat-monitoring transects (referred to herein as 'Monitoring Transects') were established upstream and downstream in both the test and reference areas (Figure 1.2). In the test areas, Monitoring Transects were oriented parallel with the proposed CD5 road (east-west) primarily between the Niġliagvik and Niġliq channels. The Monitoring Transects served as the sampling framework for habitat monitoring. Monitoring Transect orientation and placement were a function of stratification along two gradients, including distance from the CD5 road, and distance (both vertical and horizontal) from active river channels. Monitoring Transects in the test areas were located 330 ft (100 m) from the proposed CD5 road alignment to evaluate potential direct and indirect road effects (dust, gravel spray, thermokarst, impoundments, disturbance) on soils, vegetation, and habitat. Subsequent Monitoring Transects were spaced 820 ft (250 m) apart. In the test areas, Monitoring Transect length ranged between 590 ft (180 m) and 7,878 ft (2,401 m). In the reference areas, Monitoring Transects were placed perpendicular to the Niġliq channel, were spaced at least 820 ft (250 m) apart, and ranged in length from 1,312 ft (400 m) to 8,530 ft (2,600 m).

To link this report with the project database and other analytical products for the CD5 monitoring effort, the text uses the actual table and field names from the database. Database table names are written in bold and italics (e.g. ***veg_cover***) and database table field names are written in italics (e.g., *plot_id*). Values contained in text fields are enclosed in double quotes (e.g., the *plot_id* was "t1sa-0200-veg").

The following naming conventions were used to identify transects (*transect_id*):

1. Test or Reference using a "t" or "r".
2. Sequential numbering starting with 1 for the first transect north or south of the road, and then 2, 3, 4, etc. for transects farther north and south, respectively.
3. North or South using an "n" or "s".
4. Alpha-character labels for different segments along the same transect, starting with "a" for the westernmost transect segment, and then "b", "c", etc. from west to east.

For example, Monitoring Transect "t1na" would be the westernmost segment of the first transect north of the road in Test Area North. The transect segment east of the Niġliq channel in the furthest south Monitoring Transect in the southern Reference area would be "r6sb".

Permanent Integrated Habitat Monitoring Plots (herein 'Integrated Plots') were established at approximately 660-ft (200-m) increments along each transect for the first set of transects north and south of the road (i.e., t1na, t1nb, t1nc, t1sa, t1sb, and t1sb), and at approximately 1,320-ft (400-m) increments along all other transects (Figure 3.3). Integrated Plots consisted of a co-located Vegetation Plot and Habitat Plot (Figure 3.4). A Soil Pit was associated with each Vegetation Plot and a Mapping Verification Plot was associated with Habitat Plots that included more than one geomorphic surface, surface form, and/or vegetation type (Figure 3.3). The Integrated Plots were designed to monitor for changes in habitat at two spatial scales, including 1) the vegetation community scale using data from the Vegetation Plots, and 2) at the landscape scale using data from the Habitat Plots in combination with a habitat map.

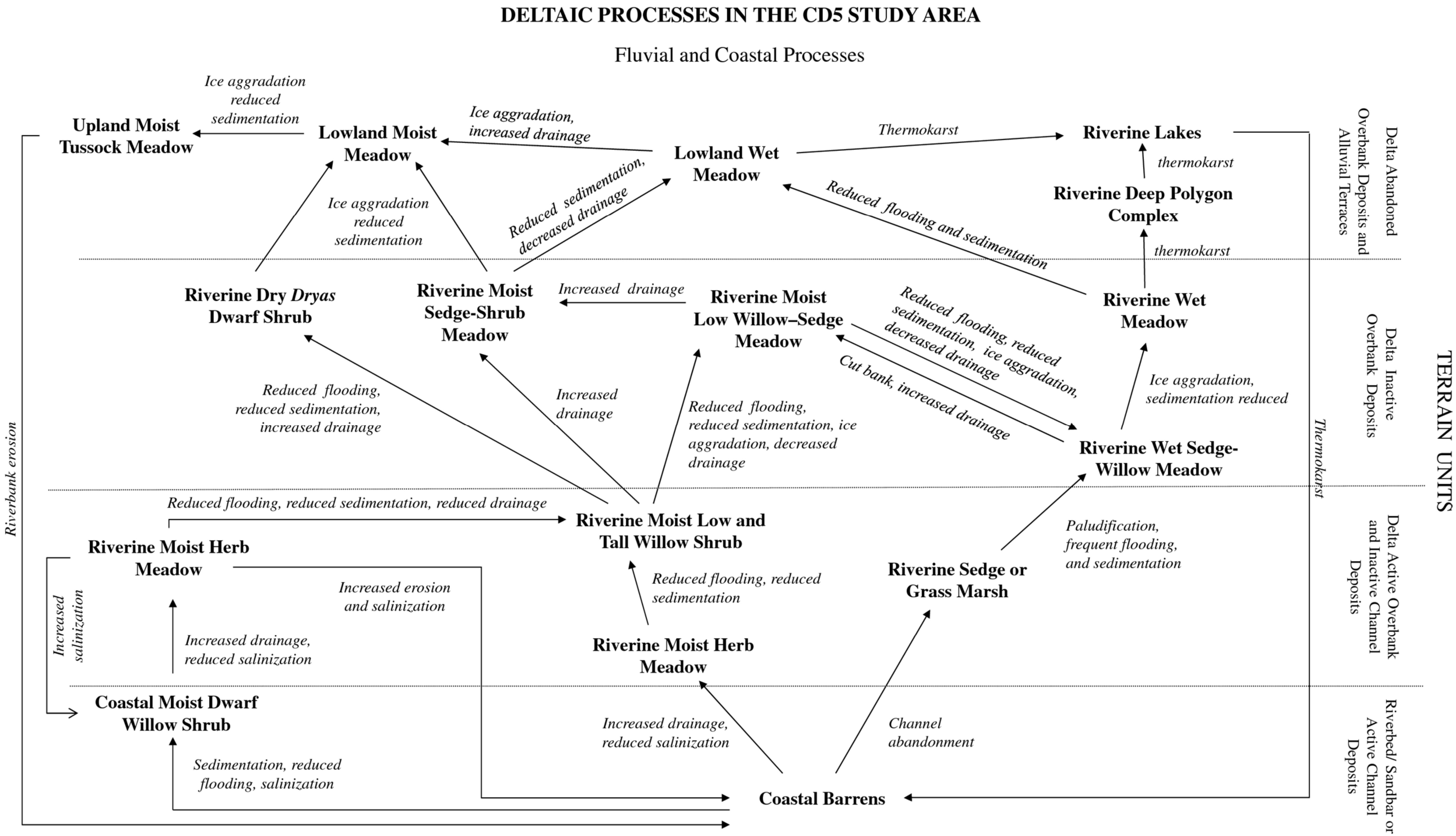


Figure 3.1. Conceptual model of fluvial and coastal processes contributing to ecosystem development in the CD5 Habitat Monitoring Study Area, Colville River Delta, northern Alaska. Adapted from Jorgenson et al. 1997.

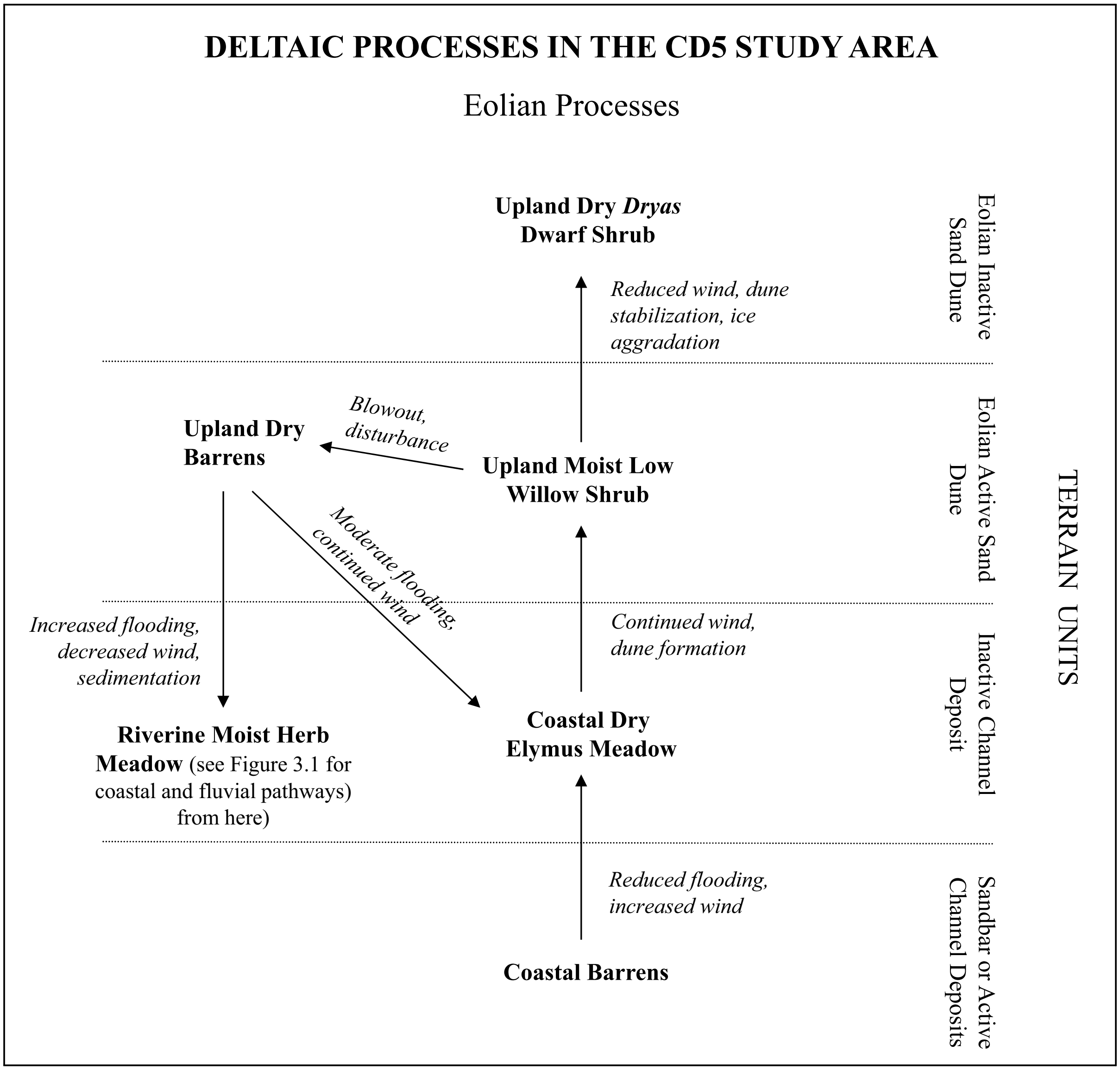


Figure 3.2. Conceptual model of eolian processes contributing to ecosystem development in the CD5 Habitat Monitoring Study Area, Colville River Delta, northern Alaska. Adapted from Jorgenson et al. 1997.

The following naming conventions were used to identify Integrated Plots (herein, *site_id*):

- The associated *transect_id*; i.e., “t1na”.
- Distance of the Vegetation Plot from the start of the transect in meters, zero-padded to 4 digits to ensure proper sorting; e.g., distance 0 became 0000, 200 became 0200, 2000 remained 2000.
- For plots nested in the Integrated Plot, a plot-type code was tagged onto the end of the *site_id* resulting in a *plot_id*:
- “-veg” was appended to *site_id* for Vegetation Plots and the associated Soil Pit.
- “-hab” was appended to *site_id* for Habitat Plots.
- “-v” was appended to *site_id* for Mapping Verification Plots.

For example, the *site_id* for the Integrated Plot at distance 0 along transect “t1na” would be “t1na-0000” and the Vegetation Plot *plot_id* would be “t1na-0000-veg”.

3.2.2.B.i. Vegetation Plots

Field-crew leaders used handheld Global Positioning System (GPS) units to navigate to pre-established Vegetation Plot Start Points. As field crews approached the Vegetation Plots, they avoided trampling in the plot area and placed backpacks and other sampling gear well away from the plot. The final location of each Vegetation Plot was determined in the field, with Vegetation Plot Start Points adjusted to fit the entire Vegetation Plot within a discrete vegetation community. Vegetation Plots measured 32.8 × 16.4 ft (10 × 5 m), with the long axis perpendicular to each habitat transect (Figure 3.4).

Monumentation

Vegetation Plot Start Points were permanently monumented by burying a Surv-Kap® magnetic marker 8 in (20 cm) below the soil surface at the Vegetation Plot Start Point by removing a small (4x4x8 in [10x10x20 cm]) soil plug, which was subsequently replaced. A survey nail was then prepared by attaching bright pink survey whiskers and an aluminum tag labeled with the *plot_id* (e.g., “t1na-0000-veg”). The nail with whiskers and tag was then inserted into the soil plug above the magnet placed at the Vegetation Plot Start Point. A wooden lath with florescent orange-painted tip was temporarily inserted into the ground directly next to the survey nail for use in photograph documentation of the Vegetation Plot. A 160 ft (50 m) tape (herein, “meter tape”) was used to temporarily establish the Vegetation Plot Central Axis as a reference for plot layout and for repeat photographs. A compass was used to align the Vegetation Plot Central Axis at 180 degrees to the habitat transect (the orientation value was stored in a handheld GPS). The meter tape was extended 36.1 ft (11 m) from the Vegetation Plot Start Point to the Vegetation Plot End Point while avoiding trampling of the plot area. Once the distance and alignment of the Vegetation Plot End Point were established, a second magnetic marker was placed as a permanent monument. Lastly, a red pin flag was placed in the soil plug above the magnet as a temporary reference. Habitat-monitoring field crews used Trimble handheld GPS units (accuracy 3 ft [1 meter] or better) to mark the locations of Vegetation Plot Start Points and End Points.

Vegetation Plot Photographs

Upon completing monumentation, a photograph was taken of the Vegetation Plot for use in future repeat photograph monitoring (Figure 3.5). Photographs were taken using a 12.1 megapixel Ricoh G700SE GPS Camera System with 5–25 mm) focal length, and 1:3.5–5.5 lens ratio, and 5x optical zoom. All photographs were taken without zoom and photograph file-size was standardized to 5MB. All equipment, packs, and humans were moved from the photograph frame before the photograph was taken. Photographs were oriented for a landscape view. The meter tape oriented along the Vegetation Plot Central Axis during monumentation was used to center the photograph horizontally. The wooden lath placed at the Vegetation Plot Start Point was used to orient the photograph vertically, i.e., the photograph was framed with the bottom of the wooden lath at the bottom center (Figure 3.5). A built-in form on the Ricoh camera was used to record the *plot_id* and other key information to associate it permanently with the electronic photograph file.

Vegetation Plot Setup

The Vegetation Plot was set up using a “tape box” design (Figures 3.4 and 3.5). Care was taken during plot setup to avoid vegetation trampling within the plot boundaries. The first plot corner was established by placing a wooden stake (12 × 2 × 1 in [30 × 5 × 2.5 cm]) in the ground 8.2 ft (2.5 m) from the Vegetation Plot Start Point towards the zero (western) end of the Monitoring Transect and securing the start of the meter tape on the stake (Figure 3.4 inset, corner “a”). Second, the first plot edge was established by extending the meter tape perpendicular across the Vegetation Plot Central Axis (over the Vegetation Plot Start Point and along the Monitoring Transect) to the 16.4 ft (5 m) mark on the meter tape. The second plot corner was established at this mark by placing a second wooden stake (Figure 3.4 inset, corner “b”). The second wooden stake was used to secure the meter tape, which was then extended parallel to the Vegetation Plot Central Axis, to the 49.2-ft (15-m) mark on the meter tape. The third plot corner was established at the 49.2-ft (15-m) mark with a

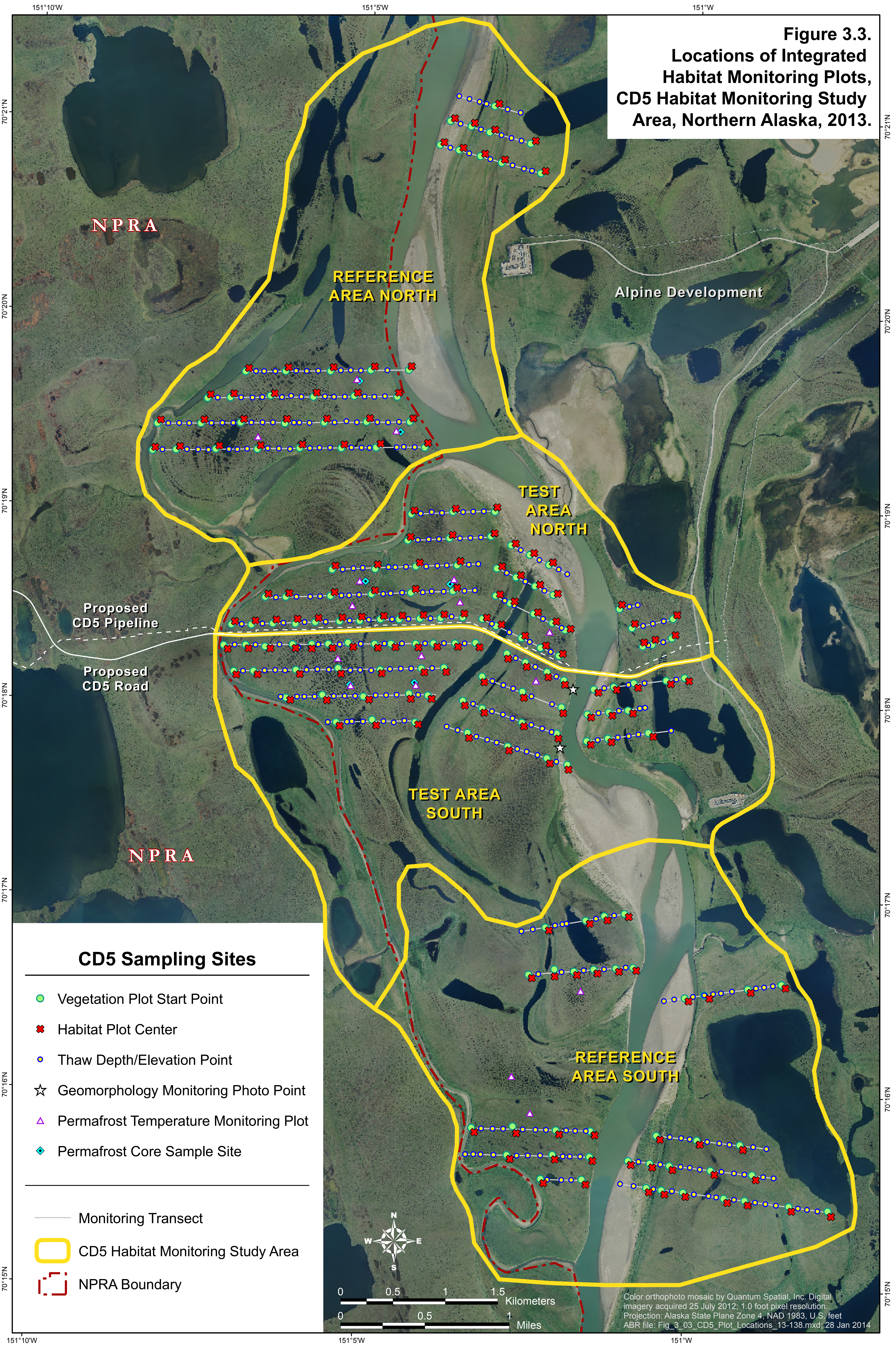


Figure 3.3. Locations of Integrated Habitat Monitoring Plots, CD5 Habitat Monitoring Study Area, Northern Alaska, 2013.

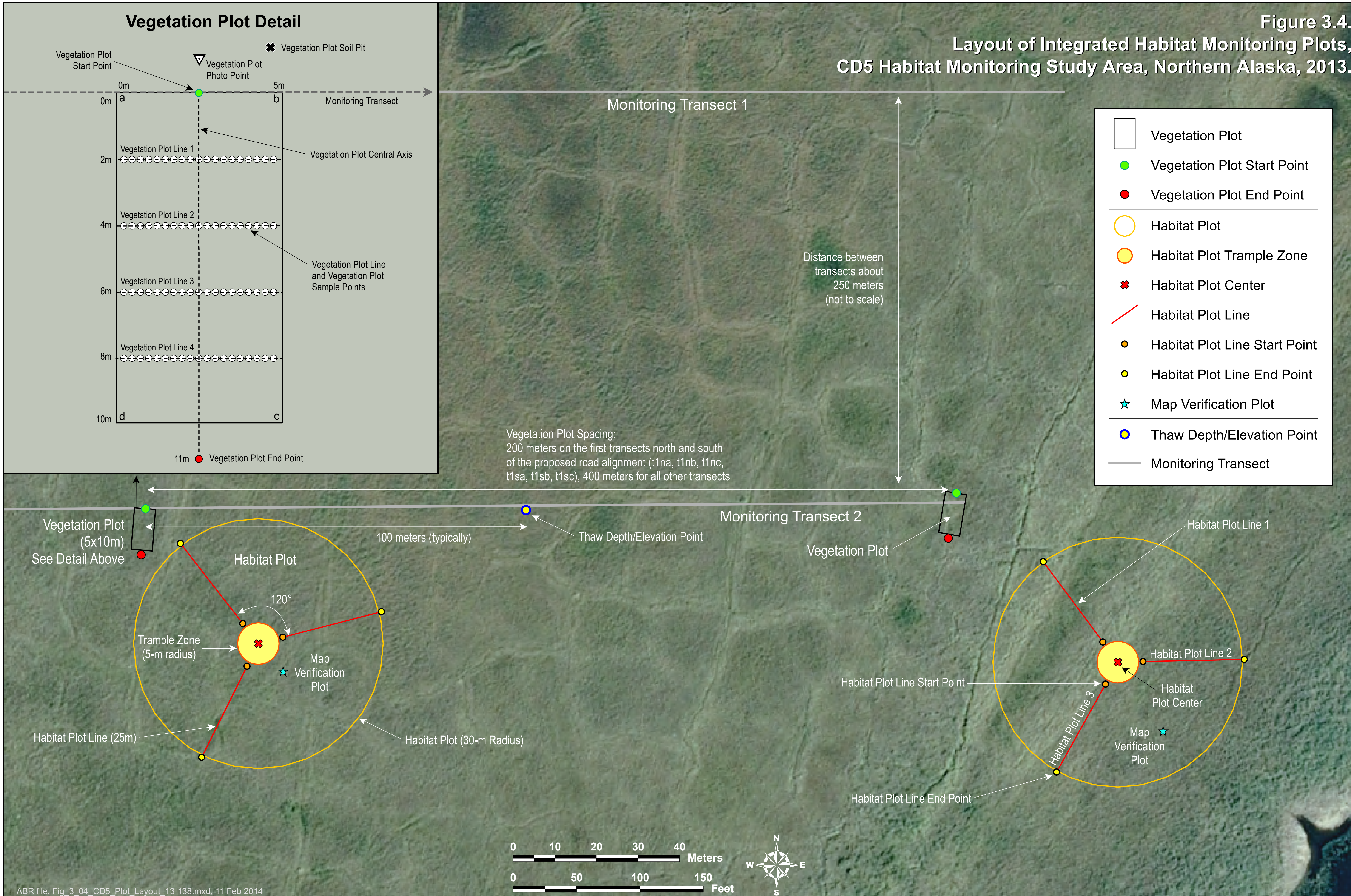
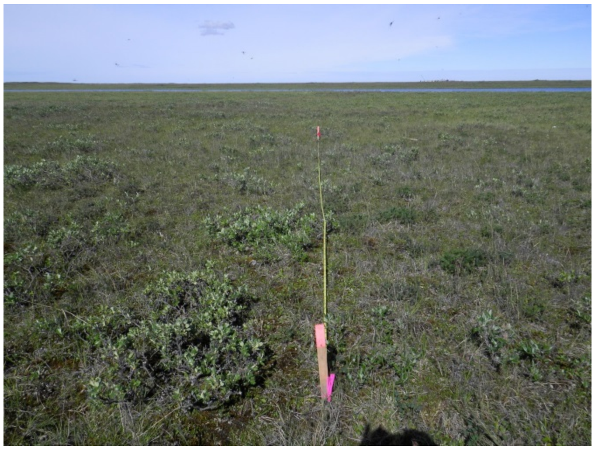
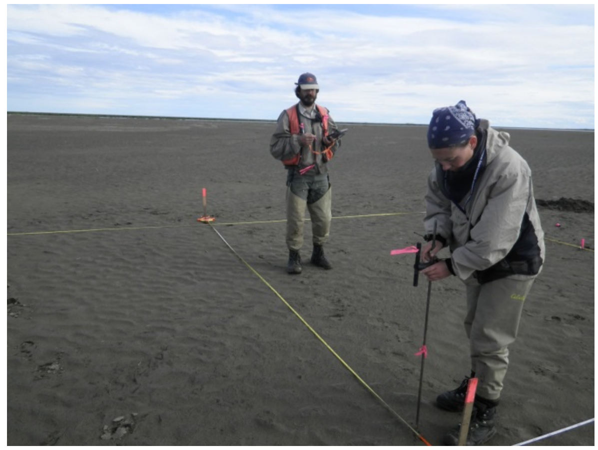


Figure 3.4. Layout of Integrated Habitat Monitoring Plots, CD5 Habitat Monitoring Study Area, Northern Alaska, 2013.



Vegetation Plot photograph with tape marking Vegetation Plot Central Axis.



Vegetation Plot Line layout.

Vegetation Plot “box plot” layout.

Data was collected on handheld tablet computers.

Typical team configuration, included botanist (foreground) and data entry technician (background).

Botanist using a laser pointer mounted on a frost probe t conduct point counts along a vegetation sampling line.

Figure 3.5. Examples of data collection using the point-count method in a Vegetation Plot, CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

wooden stake (Figure 3.4 inset, corner "c"). The tape was then extended perpendicular across the Vegetation Plot Central Axis to 65.6 ft (20 m) and the fourth plot corner was established similar to above with the "tape box" meter tape at the 65.6-ft (15-m) mark (Figure 3.4 inset, corner "d"). These corners were adjusted to ensure that the "tape box" meter tape crossed the 32.8 ft (10 m) mark on the Vegetation Plot Central Axis at exactly 57.4 ft (17.5 m). Lastly, the tape was extended to the 98.4-ft (30-m) mark back towards the first plot corner ("a"). The fourth plot corner ("d") was adjusted as needed such that it fell on the 65.6-ft (20-m) mark when the 98.4-ft (30-m) mark on the meter tape was at the first plot corner ("a").

Vegetation Plot Lines

Once photographs and plot "tape box" setup were complete, the meter tape demarcating the Vegetation Plot Central Axis and wooden lath were removed in preparation for sampling-line setup. Four Vegetation Plot Lines were sampled at each Vegetation Plot using the point-intercept method (NARSC 1999). In the point-intercept method vegetation sampling occurs by systematically sampling at discrete points in space, typically along a sampling line. At each point a very thin (0.07−0.12 in [2−3 mm]) metal rod or, in this study, a laser beam are held stationary above the vegetation. All instances in which the rod or laser beam intersected with a live or dead plant part or ground cover class (e.g., bare soil) are recorded. The process of conducting vegetation sampling using the point-intercept method is referred to as "point sampling" and the associated data is referred to as "point count data." For reference, a schematic layout of the Vegetation Plot Lines is provided in the inset on Figure 3.4, and example photographs are included on Figure 3.5.

A meter tape was used to establish the Vegetation Plot Lines at 6.6-ft (2-m) increments along the long axis of the Vegetation Plots, starting at 6.6 ft (2 m) and ending at 26.2 ft (8 m) (Figure 3.4). The Vegetation Plot Lines were set up perpendicular to the Central Axis of the Vegetation Plot using meter marks on the "tape box", and were used as the framework for point sampling. Point sampling was conducted along sampling lines using a laser pointer (GreenBeam 50) mounted on a frost probe (a 4.2-ft [1.3-m]) tile probe) that was self-supporting after being pushed into the ground vertically. To ensure repeatability in the future, laser specifications are as follows: Class III A, 532 nm wavelength, lithium batteries, and 0.07–0.12-in (2–3-mm) wide beam when held at 3.3 ft (1 m) above soil surface. Point sampling occurred along each sampling line at 0.82-ft (0.25-m) increments, beginning at 0.82 ft (0.25 m) and ending at 15.6 ft (4.75 m), for a total of 19 points per sampling line, and 76 points per plot (Figure 3.4 inset, Vegetation Plot Sample Points).

Point Sampling

All field data were recorded digitally in the field (Figure 3.5) using a standardized data entry form on an Android tablet computer designed to upload data to a relational database (PostgreSQL). Point-count protocols for Vegetation Plots were as follows:

At each sampling point:

- The laser point was oriented towards the Vegetation Plot End Point.
- Canopy Hits
  - All hits were recorded beginning at the highest hit and proceeding downward to the ground cover (last hit).
  - In plots with vegetation >3.3 ft (1.0 m) in height, point counting began with the laser pointing up, starting with highest hit and working downward to the laser. The laser was then pointed down and hits were recorded downward to ground cover.
  - Multiple hits of a single species were allowed.
  - If a dead portion of attached current annual growth was hit, it was recorded as a live hit. This was most often encountered with dead graminoid leaf tips or senescing shrub leaves.
- Standing Dead
  - Standing dead included dead vascular plants attached at the base.
  - Hits of standing dead vascular plants were recorded using the "dead" modifier

up to a maximum of 3 dead hits for a given standing-dead lifeform.

- Standing-dead hits of graminoids were recorded as lifeform only ("graminoid").
- Standing-dead hits of forbs and shrubs were recorded to species or genus when obvious; otherwise these were recorded as lifeform (forb, dwarf shrub, low shrub, etc.).

- Litter
  - Litter included any detached dead organic material.
  - Dead non-vascular plants were recorded as "litter" with no modifier.
  - Dead plants that were attached but compressed and appressed to the soil surface were also considered litter.
- Heights
  - ABR recorded heights following the Bureau of Land Management Assessment, Inventory & Monitoring (BLM AIM) protocol (BLM 2011), with modifications from NPRA (BLM 2013).
  - Height measurements were collected at every fifth sample point (starting with the first point on each line).
  - The tallest attached herbaceous and woody plant element that intersected a cylinder of 5.9-in (15-cm) diameter placed around the laser point was recorded.
  - The height was measured from where the laser intersected the ground.
    - Heights were recorded in cm, to the nearest integer.
    - The species were also recorded for the tallest woody and herbaceous vegetation at each point.
    - Plant-height minimum (when a plant was present) was set at 0.4 in (1 cm).
    - When water was present at the point, the plant heights were measured from the soil surface beneath the water.
- Water Depths
  - Water depth was recorded from the point on water surface intersected by the laser, to the ground surface directly beneath.
  - When water was measurable or visible beneath the last (non-soil) hit, a water hit was recorded as the final hit, unless live material was found below.
  - "Measurable" water was defined as water depth that could be measured using the measuring tape with a slight downward pressure to compress loose materials.
  - Water depth was measured with gentle pressure on the substratum or floc until slightly firm resistance was encountered.
  - Only live hits of vegetation were recorded below water.
  - Depths were recorded in cm, to the nearest integer.
  - Minimum water depth (when water was present) was recorded as 0.4 in (1 cm).
- In Vegetation Plots, non-vascular plants were recorded to the species level for common species that were readily and consistently identifiable (e.g., *Hylocomium splendens*, *Dactylina arctica*). For all other non-vasculars, hits were recorded in broad categories (e.g., fruticose lichen, foliose lichen, *Sphagnum*, other mosses, etc.) and then 3–5 of the most common mosses and lichens were collected as vouchers. Voucher specimens were collected from outside the plot area.
- In Habitat Plots (see below, "Habitat Plots"), hits of non-vasculars were recorded using broad categories (e.g., fruticose lichen, foliose lichen, *Sphagnum*, other mosses, etc.) and voucher specimens were not collected.

General Environment Data

Soil scientists on each crew were responsible for collecting general site data at each Vegetation Plot. Geologic, topographic, vegetation variables recorded included physiography (e.g., Riverine), surface geomorphic unit (Table 3.1), slope, aspect, surface form (Table 3.2), height of microrelief, vegetation structure (e.g., Low Shrub), Viereck et al. (1992) Level IV vegetation class (Table 3.3), and recent disturbance (Table 3.4). Ground-surface variables included percent cover of frost boils and coarse fragments.

Soils

Soil scientists described soils and hydrology from a Vegetation Plot Soil Pit at each Vegetation Plot. The Vegetation Plot Soil Pit consisted of a

Table 3.1. Standard classification system developed for classifying and mapping geomorphic units in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Classes modified from Jorgenson et al. (1997, 2003), Roth et al. (2006), Carter and Galloway (1985), and Kreig and Reger (1982). Geomorphic units that were identified in the field but not mapped are identified with an asterisk. Waterbodies (aquatic geomorphic units) are italicized.

Code	Geomorphic unit
Cs	Solifluction Deposit
Esa	Eolian Active Sand Deposit
Esda	Eolian Active Sand Dune
Esdi	Eolian Inactive Sand Dune
Esi	Eolian Inactive Sand Deposit
Fdoa	Delta Active Overbank Deposit
Fdob	Delta Abandoned Overbank Deposit
Fdoi	Delta Inactive Overbank Deposit
Fdra	Delta Active Channel Deposit
Fdri	Delta Inactive Channel Deposit
Fto	Old Alluvial Terrace
Ftr	Recent Alluvial Terrace
Hfg	Gravel Fill
Ltdi	Delta Thaw Basin, Ice-rich
Ltdn	Delta Thaw Basin, Ice-poor
Ltic	Ice-rich Thaw Basin Center
Ltim	Ice-rich Thaw Basin Margin
Ltiu	Undifferentiated Ice-rich Thaw Basin
Weldc	*Brackish Deep Tapped Lake, Connected*
Wert	*Tidal River*
Wldcrh	*Deep Tapped Riverine Lake, High-water Connection*
Wldir	*Deep Isolated Riverine Lake*
Wldit	*Deep Isolated Thaw Lake*
*Wlscr**	*Shallow Connected Riverine Lake*
Wlsir	*Shallow Isolated Riverine Lake*
Wlsit	*Shallow Isolated Thaw Lake*

Table 3.2. Standard classification system developed for classifying and mapping surface forms in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Classes modified from Jorgenson et al. (1997, 2003) and Roth et al. (2006). Surface form types that were identified in the field but not mapped are identified with an asterisk.

Code	Surface form
Dr*	Ripples
Dt	Water Tracks
Ek	Streaked Dune
Es	Small Dune
Hm	Human Modified
N	Nonpatterned
Pc*	Polygon Center
Pd	Disjunct Polygon Rims
Phh	High-centered, High-relief Polygons
Phl	High-centered, Low-relief Polygons
Plhh	Low-centered, High-relief, High-density Polygons
Plhl	Low-centered, High-relief, Low-density Polygons
Pllh	Low-centered, Low-relief, High-density Polygons
Plll	Low-centered, Low-relief, Low-density Polygons
Pm	Mixed High and Low-centered Polygons
Pr*	Polygon Rims
Sb	Bluffs or Banks
Tm	Mixed Thermokarst Pits and Polygons
Tt*	Troughs (Degraded ice-wedges)
W	Water
Wi	Lake with Islands

shallow soil plug or soil pit at least 16 in (40 cm) deep (Figure 3.6), located outside the Vegetation Plot and within 10 ft (3 m) of the Vegetation Plot Start Point (Figure 3.4). Soil plugs and excavated soils were placed on tarps to protect the ground surface during sampling. A measuring tape was placed next to the soil plug or, in the case of soil pits, oriented vertically along the pit face. The soil plug or pit was then photographed using the same camera as described for the Vegetation Plot photographs. A GPS location of the Vegetation Plot Soil Pit was obtained using a Trimble GeoXT or GeoXH GPS. Additionally, the distance and azimuth from the Vegetation Plot Start Point were recorded for each soil pit.

The following data were collected at the Vegetation Plot Soil Pit in the upper 16 in (40 cm) of the soil plug or pit:

- Description of soil horizons, including soil texture,
- Type and percentage of, and depth to, coarse fragments,
- pH and electrical conductivity (EC),

Table 3.3. Standard classification system developed for classifying and mapping vegetation in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Classes adapted from Viereck et al. (1992). Vegetation classes that were identified in the field but not mapped are identified with an asterisk.

Code	Vegetation
Bbg	Barrens
Bpv	Partially Vegetated
Hfds	Seral Herbs
Hfmm*	Mixed Herbs
Hgdl	*Elymus*
Hgmss	Moist Sedge-Shrub Tundra
Hgmswt*	Moist Sedge-Willow Tundra
Hgmt	Tussock Tundra
Hgwfg	Fresh Grass Marsh
Hgwfs	Fresh Sedge Marsh
Hgwst	Wet Sedge Meadow Tundra
Hgwswt	Wet Sedge–Willow Tundra
Sddf*	*Dryas*–Forb Dwarf Shrub Tundra
Sdds*	*Dryas*–Sedge Dwarf Shrub Tundra
Sddt	*Dryas* Dwarf Shrub Tundra
Sdec	*Cassiope* Dwarf Shrub Tundra
Sdwgh	Halophytic Willow–Graminoid Dwarf Shrub Tundra
Sdwh*	Halophytic Willow Dwarf Shrub
Sdwt*	Willow Dwarf Shrub Tundra
Slcw	Closed Low Willow
Slott*	Open Mixed Low Shrub-Sedge Tussock Tundra
Slow	Open Low Willow
Slows	Open Low Willow-Sedge Shrub Tundra
Stow	Open Tall Willow
Wb	Brackish Water
Wf	Fresh Water
Xp	Deep Polygon Complex

Table 3.4. Standard classification system developed for classifying and mapping disturbances in the CD5 Habitat Monitoring Study area, northern Alaska, 2013. Class descriptions modified from Jorgenson et al. (1997, 2003) and Roth et al. (2006). Disturbance classes that were identified in the field but not mapped are identified with an asterisk.

Code	Disturbance
A	Absent, none (mature vegetation)
Hfgp	Gravel Pad
Hfgr	Gravel Road
Hsep	Elevated Pipeline
Hti	Snow/Ice pads and roads
Nge*	Eolian (Wind)
Ngf*	Fluvial
Ngfd*	Fluvial Deposition
Ngfe	Fluvial Erosion/channel migration
Ngt	Thermokarst
Nsk	Salt killed vegetation

Figure 3.6. Examples of a soil plug (left) and soil pit (right) used to describe soil at Vegetation Plots, CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

- Dominant soil texture in the upper 16 in (40 cm),
- Depth to saturated soil,
- Depth to water table above or below ground surface,
- Thickness of surface organic matter,
- Cumulative thickness of all organic horizons,
- Depth to redoximorphic features,
- Type and percentage of coarse fragments,
- Minimum depth to coarse fragments (>15% by volume),
- Presence of cryoturbation, and
- Depth of thaw

Electrical conductivity and pH were measured in groundwater using Oakton® EC and pH meters. When water was not present in the soil pit, EC and pH were measured in a saturated soil paste using distilled water mixed with several grams of soil. A small amount of soil was collected at 4 in (10 cm) and 12 in (30 cm) for 2 EC and pH measurements each soil pit. Soil texture was assessed by estimating the percent of sand, silt, and clay using the hand-texturing method. A single simplified texture (i.e., loamy, sandy, organic) was assigned to characterize the dominant texture in the top 16 in (40 cm) at each plot. Once soil descriptions were complete, the site was restored by placing the soil plug back into the ground or backfilling the pit with excavated soil.

3.2.2.B.ii. Habitat Plots

Field-crew leaders used hand-held GPS units to navigate to pre-established Habitat Plot Center Points. Whereas the location of the Vegetation Plots was adjusted to fit the entire plot into a discrete vegetation community and ecotype, the Habitat Plot Center Points were not adjusted in the field unless they fell in a river channel or lake (in which case the location was moved to the nearest adjacent shore). The circular Habitat Plots (98.4-ft [30-m] radius) were based on the BLM AIM sample plot layout for NPRA (Figure 3.4; BLM 2011 and BLM 2013).

Monumentation

Habitat Plot Center Points were permanently monumented by burying a Surv-Kap® magnetic marker 8 in (20 cm) below the soil surface at the Habitat Plot Center Point by removing a small (4x4x8 in [10x10x20 cm]) soil plug (subsequently replaced). A survey nail was then prepared by attaching bright pink survey whiskers and an aluminum tag labeled with the *plot_id* (e.g. “t1na-0000-hab”).

Habitat Plot Setup

A 16.4-ft (5-m) radius trample zone surrounding the Habitat Plot Center Point was established using a meter tape and wooden lath (Figure 3.4). The trample zone provided space for field staff and gear while preventing the trampling of vegetation along the Habitat Plot Lines. Three Habitat Plot Lines were sampled in each Habitat Plot using the point-intercept method. The first Habitat Plot Line was established using a predetermined random azimuth and extending a meter tape out to 98.4 ft (30 m) from the Habitat Plot Center Point. The tape was then adjusted such that the zero end was moved to the Habitat Plot Line Start Point at the edge of the trample zone (i.e., 16.4 ft [5 m] from the Habitat Plot Center Point) and the end of the tape was at 83.7 ft (25.5 m) (offset 1.6 ft [0.5 m] from the actual Habitat Plot Line End Point to avoid trampling). A wooden lath labeled with the line number (Figure 3.7) was placed at the Habitat Plot Line Start Point, to which the meter tape was secured. The tape was then pulled tight and aligned along the random azimuth using a handheld compass. Once the orientation of the line was satisfactory (±3 degrees) the tape was secured at 83.7 ft (25.5 m) using a second wooden lath labeled with the line number and the letter “E” (i.e., End; Figure 3.7). A red pin flag was placed at the Habitat Plot Line End Point at the 82.0-ft (25-m) mark as a temporary reference. The second and third habitat lines were set up as above, but were offset by 120 and 240 degrees, respectively, in a clockwise direction from the first Habitat Plot Line.

Habitat Plot Line Photographs

Upon completing the layout of each Habitat Plot Line and before point sampling, photographs were taken of the Habitat Plot Line from

Figure 3.7. Examples of Habitat Plot Line Start Point (left) and Habitat Plot Line End Point (right) photographs, CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Photographs are from Habitat Plot Line 1 in Habitat Plot t2sc-0000-hab.

the Habitat Plot Line Start Point (i.e., center photograph) and Habitat Plot Line End Point (i.e. line end photograph) for use in future repeat photograph monitoring (Figure 3.7). Photographs were taken using the same Ricoh G700SE GPS Camera System used for Vegetation Plot photographs (see above for detailed specifications). The built-in form recorded the *plot_id*, Habitat Plot Line number and the direction of the photographs (center photograph vs. line end photograph). All photographs were taken without zoom and photograph file-size was standardized to 5MB. For center photographs, all equipment, packs, and humans were moved from the photograph frame, while equipment, packs, and humans may be present in line end photographs. Photographs were oriented for a landscape view. The meter tape oriented along the Habitat Plot Line during monumentation was used to center the photograph horizontally. The wooden laths placed at the Habitat Line Start and End Points were used to orient the Habitat Plot Line photographs vertically, i.e., the photograph was framed with the bottom of the wooden lath at the bottom center.

Habitat Plot Lines

Point sampling was conducted along Habitat Plot Lines using a laser pointer (see "Vegetation Plot Lines" above for specifications) mounted on a frost probe. Point sampling occurred along each sampling line at 3.3-ft (1-m) increments, beginning at 3.3 ft (1 m) and ending at 82.0 ft (25 m) for a total of 25 points per Habitat Plot Line, and 75 points per Habitat Plot. Point sampling followed the same protocols as the Vegetation Plots with few exceptions (see above, "Point Sampling"). While traversing each Habitat Plot Line the botanist and data entry technician stood on the left of the meter tape (i.e., when looking out from the Habitat Plot Center Point) and the laser was oriented toward the right side of the meter tape. Also, along each Habitat Plot Line, the approximate location along each transect where transitions occurred was noted (measured to the nearest foot [0.3 m] along the tape measure). Transitions occurred between geomorphic units (i.e., landforms and water-bodies), microtopography features (e.g. high-center polygons), and/or Alaska Vegetation Classification vegetation classes (Viereck et al. 1992). These data were used to verify the ITU mapping.

Map Verification Plots

Map Verification Plots collected basic landscape variables and photographs to inform photo-interpretation of Integrated Terrain Units (ITUs). Map Verification Plots were sampled within the Habitat-Plot boundary when the environment or vegetation differed from the Vegetation Plot in all or part of the Habitat Plot (Figure 3.4). Data collected at Map Verification

Plots include only those variables pertinent to the ITU mapping, including geomorphic unit, surface form, Viereck Level IV vegetation class, and disturbance. If a Habitat Plot encompassed more than one wildlife habitat (geomorphic units, surface forms, and vegetation types), more than one Map Verification Plot was sampled in the Habitat Plot. Two landscape and two ground-cover photographs were taken from the Map Verification Plot Center. The photographs were taken of representative views of the habitat.

3.2.2.B.iii. Real Time Kinematic (RTK) Surveys

Survey Preparation

In early August, concurrent with ABR field surveys, surveyors with LCMF Engineering used RTK satellite navigation for surveying habitat-plot locations and conducting thaw-depth and elevation surveys. Real Time Kinematic satellite navigation is a technique used to enhance the precision of position (location) data without post-processing using a satellite-based GPS.

Prior to conducting surveys, LCMF used a combination of conventional leveling and static GPS techniques to establish a broad control network that encompassed the entire CD5 Habitat Monitoring Study Area. The static survey was then processed using GPS software and the OPUS network to derive the NAD83 (2011) coordinates. Leveled elevations from local benchmarks were used to bring the vertical datum to the standard British Petroleum mean sea level (BPMSL). The strategically placed control points allowed LCMF to use GPS RTK surveying techniques and maintain the stringent horizontal and vertical tolerances required for the project. The careful planning put forth in preparing the initial survey will allow LCMF to duplicate similar results over the life of the project.

Integrated Habitat Monitoring Plots

LCMF conducted their surveys during the first week of August 2013 starting with transects already sampled by ABR. To facilitate locating the Habitat Plots, ABR supplied LCMF with Trimble GPS locations for all Vegetation Plot Start Points, Habitat Plot Centers, and Habitat Plot Line End Points before surveying began. LCMF stopped at each Integrated Plot, located the monuments (i.e., survey nails, pin flags), and used survey-grade GPS equipment (RTK, centimeter-level accuracy) to collect 3-D (latitude, longitude, and elevation) GPS locations at the Vegetation Plot Start Points, Vegetation Plot End Points, Habitat Plot Center Points, and Habitat Plot Line End Points. Thaw depth (i.e., the depth from the ground surface to frozen ground) was measured at each Vegetation Plot Start Point and Habitat Plot Center Point. Thaw depth was measured by plunging a 0.25-in (6.4-mm) diameter steel rod into the ground until it hit frozen ground. Upon completing each Integrated Plot survey, pin flags were collected and removed from the field.

Elevation and Thaw Depth

While traversing each monitoring transect, LCMF stopped at predetermined Thaw Depth/ Elevation Points spaced at 328-ft (100-m) intervals between each Habitat Plot. Three- dimensional GPS locations (latitude, longitude, elevation) and thaw depths were collected at each Thaw Depth/ Elevation Point. Thaw depths were measured as described above. A survey nail with florescent pink whiskers was placed at each Thaw Depth/Elevation Point to permanently monument the location. Surveyors also collected GPS points at Monitoring Transect Transition Points, including the edge of water along large waterbodies (e.g., riverine lakes, Niġliq channel) that occurred along transects (“Waterbody” points), and the top of the cut bank along the Niġliq channel (“Cut Bank” points).

3.2.2.B.iv. Broad-scale Monitoring of Geomorphology

Geomorphology monitoring in 2013 consisted of three tasks. First, ABR staff established marker horizons for sedimentation and erosion monitoring at the Vegetation Plot soil plugs/pits to create a baseline for future assessment of sedimentation and erosion rates along permanent transects. During Soil Pit sampling, soil plugs were cut in half lengthwise and each marker horizon was established by placing a 5-gauge nail at the upper boundary of a distinct soil horizon. When sampling was complete both halves of the plug were then placed back together and the plug was reinserted into the ground. In cases where it was not possible to remove a soil plug because of soil type (i.e., mineral dominated), ABR staff used soil pits in place of plugs and placed the nail into the vertical face of the pit at the upper boundary of the marker horizon. No marker horizons were established in soils lacking distinct horizons. Second, as ABR staff traversed monitoring transects, the location of drift lines was recorded when they occurred in the Integrated Monitoring Plots. Third, geomorphology monitoring repeat photography points (herein, Geomorphology Monitoring Photo Points) were established near the proposed CD5 road alignment (Figure 3.3). ABR staff monumented each photograph-point location by placing a survey nail with florescent pink whiskers and an aluminum tag labeled with the photograph-point name in the ground and recorded GPS locations. For each photograph, ABR staff recorded the compass direction (degrees) in which the photograph was taken relative to the survey nail. Photographs were taken while standing on the head of the survey nail.

3.3.3. OFFICE METHODS

3.3.3.A. Data Management

3.3.3.A.i. Data Storage

The Ecological Land Survey (ELS) data were downloaded from the tablet computers, reviewed, and backed up each evening while back in camp. Crew members performed additional quality assurance/quality control (QA/QC) review and data compilation during weather days or helicopter down-time. After the field season, ABR staff uploaded data directly to the ABR database server, copied backups to the ABR file server, and compiled all tablet data into a PostgreSQL database for long-term data storage and management. Field data were copied into new tables for data review, thus preserving the original data, and audit tables were created to keep detailed accounting of all changes made during the review process.

Photographs were copied to the ABR file servers and all metadata for each photograph were inserted into the database. The photographs were then joined with the field data for use in the review process. Spatial data were stored in the PostgreSQL database once they had been compiled and reviewed using ESRI ArcGIS software.

3.3.3.A.ii. Data Quality Assurance/Quality Control (QA/QC)

Vegetation, environmental, and GPS data were reviewed for integrity and consistency between study design and information collected on multiple devices. QA/QC was broken into 3 levels. During initial QA/QC, codes and naming conventions both between and within datasets were checked for consistency. During this phase, anomalous vegetation codes were highlighted to ensure that species and codes had been assigned correctly. The second level of QA/QC involved ensuring that the data were consistent with the study design. During this phase, ABR staff identified any Vegetation or Habitat Plots that were missing data due to logistical or weather problems in the field or data-collection errors. Built-in referential-integrity rules within the database were used to ensure duplicate information was not included within the database. During the third level of QA/QC, ABR staff compared spatial information among each of the data layers to identify incorrect or missing coordinates or inconsistencies between data layers. ABR used GIS software and PostgreSQL functions to overlay each of the data layers and compare spatial information from data collected in the field with the original study design.

Photographs were reviewed with the help of a form that organized all the plot photographs by *site_id*. The form facilitated review by allowing reviewers to 1) confirm that the photographs were correctly assigned to the correct *plot_id* and category (e.g., Vegetation Plot, Habitat Plot Line, Soil Pit), 2) select the best photographs among the duplicates in each category, and 3) identify any missing photographs. Photographs were also joined with the spatial information in the database so they could be used in the mapping and classification of ecosystems.

Taxonomy voucher specimens were sent for verification to Carolyn Parker at the UAF Herbarium (vasculars) and to the Komarov Botanical Institute in St. Petersburg, Russia (non-vasculars). The results of the voucher-specimen verifications were used in the PostgreSQL database to update the preliminary species codes assigned to voucher specimens in the field.

3.3.3.B. Data Analysis

3.3.3.B.i. Classification and Mapping

ABR classified and mapped ecosystems in the CD5 Habitat Monitoring Study Area at several levels. First, individual ecological components were classified for Vegetation Plots in the field and coded using standard classification systems developed for Alaska (Table 3.1–3.4). Second, ABR mapped individual ecological components simultaneously as compound codes called Integrated Terrain Units (ITUs). Third, ABR classified and mapped ecotypes and wildlife habitats based on the Central Beaufort Coastal Plain (CBCP) classification, a pre-existing classification developed by ABR for northeastern NPRA, the Colville River Delta, and the western Kuparuk Oilfield (Anderson et al. 2001; Jorgenson et al. 1997, 2003, 2004; Roth et al. 2007, 2009; Roth and Loomis 2008; Wells et al. 2012).

Ecological Components

Geomorphic units were classified according to a system based on landform–soil characteristics for Alaska (Table 3.1), developed originally by Kreig and Reger (1982) and ADGGS (1983) and modified for previous work on the coastal plain (Jorgenson et al. 1997, 2003, 2004; Roth et al. 2007). ABR relied on the classification of surficial deposits by Rawlinson (1993) and on an eco-subdistrict map produced for the CBCP (Jorgenson et al. 1997). ABR focused on soil characteristics near the surface (<3.3 ft [1 m]) because they have the greatest influence on ecological processes. For example, ABR differentiated several types of alluvial deposits (active and inactive floodplains) that were not characterized separately by Carter and Galloway (1985) in their mapping for Harrison Bay. Within the geomorphic classification, ABR also classified waterbodies based on their depth, connectivity, salinity, and genesis. Surface forms (macro-topography) were classified according to a system modified from Schoeneberger et al. (1998) (Table 3.2). Surface-form was classified according to the periglacial system of Washburn (1973). Surface-form characteristics were also assigned to waterbodies to differentiate waterbodies with islands. Vegetation was classified using the Alaska Vegetation Classification (AVC) developed by Viereck et al. (1992), with slight modifications to include information from Walker and Acevedo (1987) (Table 3.3). Soils were classified to subgroup based on the Keys to Soil Taxonomy, 11th Edition (Soil Survey Staff 2010). Disturbance was classified following a system developed by ABR (Jorgenson et al. 1997, 2002, 2003) for mapping disturbance on the Colville River Delta and in NE NPRA (Table 3.4).

2012 CD5 Integrated Terrain Unit (ITU) Mapping

Individual ecological components were mapped simultaneously as ITUs by assigning 4 parameters to each polygon describing geomorphology, surface form, vegetation, and disturbance (e.g., Delta Active Overbank Deposit/High-center Low-relief Polygons/Open Low Willow Shrub/Absent). The mapping parameters were attributed using a standard coding system (Tables 3.1–3.4); following from the above example, e.g., Fdoi/Phl/Slow/A. Polygons were delineated on-screen by aerial photo interpretation based on color orthoimagery mosaic by Quantum Spatial, Inc. (acquired 25 July 2012; 1.0 ft [0.3 m] pixel resolution). Secondary photo-interpretation was based on U.S. Geological Survey 2002 color-infrared Digital Orthophotograph Quarter-Quadrangle (DOQQ) mosaic at 8 ft [2.5 m] pixel resolution. Map polygons were delineated at a mapping scale of 1:1:1,500 for a final map scale (the scale at which the mapping is valid for landscape analysis) of 1:3,000. The minimum mapping size for polygons (a 'polygon' is defined here as an area delineated on the map as a single unit; it does not refer to polygons in the sense of polygonized landforms) was 0.25 acre (0.10 ha) for waterbodies, 2.5 acres (1.0 ha) for complexes, and 0.75 acre (0.30 ha) for all other classes. One complex vegetation class was used to map highly heterogeneous areas associated with dynamic geomorphic processes. The complex was used for polygons where at least 3 vegetation classes were present, the dominant cover type occupied <65% of the polygon, and inclusions were below the minimum size for mapping.

Waterbodies were extracted by manually thresholding the near-infrared band of the 2002 DOQQ imagery. The automatically generated waterbodies were filtered to select those that met the threshold of 0.25 acre (0.10 ha).

Individual maps were produced for each of the ecological components used to create the ITUs: geomorphology, surface forms, vegetation, and disturbance. Geomorphology was separated into terrestrial and aquatic maps to better display waterbodies. The 4 ITU component codes were concatenated for each map polygon, and the concatenated ITU code combinations (herein, ITU code) were assigned to each polygon. The ITU codes (e.g., Fdoi/Phl/Slow/A) were aggregated into map ecotypes (e.g., Riverine Moist Low Willow Shrub) and wildlife habitats (e.g., Moist Low Shrub) based on the CBCP classification as described below.

Ecotype and Wildlife Habitat Mapping

The Central Beaufort Coastal Plain (CBCP) classification and mapping represent nearly 20 years of Ecological Land Survey (ELS) classification and mapping effort in northern Alaska, including the Colville River Delta (Jorgenson et al. 1997), northeastern NPRA (Jorgenson et al. 2003; 2004), and the greater western Kuparuk Oilfield, including Drill Site 3S Development Area (Anderson et al. 2001), Central Kuparuk study area (Roth et al. 2007), and Northeast West Sak (NEWS) study area (Roth and Loomis 2008), and NEWS 2011 Addendum (Wells et al. 2012). Additionally, the classification has been applied to ITU mapping near Milne Point for BP Exploration (Alaska), Inc. (Roth et al. 2009) and in the northeastern Colville River delta and adjacent lands to the east for Pioneer Natural Resources Alaska, Inc. (Roth et al. 2011). The CBCP classification includes a classification of map ecotypes and wildlife habitats that were developed, and have been continually refined, based on field data collected as part of the above studies. The CBCP classification also provides a framework for cross-referencing between ITU polygons in new or updated mapping and the map ecotype and wildlife habitat classifications (Appendix C).

Map ecotypes are mapping classes that represent local-scale ecosystems classified by aggregating ITU map polygons with similar ecological components, including geomorphology, surface form, vegetation, and disturbance. In developing the CBCP map ecotype classification, an attempt was made to use ecological characteristics (primarily geomorphology, surface form, and vegetation structure) that could be interpreted from aerial photographs. A classification nomenclature for ecotypes was also developed that translated ecological characteristics, including physiography, moisture, vegetation structure, and dominant species into intuitive and easily understood classes (e.g., Riverine Moist Low Willow Shrub). The number of potential ecotype classes was reduced by aggregating the field data for individual ecological characteristics (e.g., soil stratigraphy and vegetation composition) using a hierarchical approach. For geomorphology, classes, textures, and layers were aggregated into geomorphic units using the approaches of Miall (1985) and Brown et al. (1997). Geomorphic units were assigned to physiographic settings based on their erosional or depositional processes. Surface forms were aggregated into a reduced set of elements (primarily driven by degree of ice development). For vegetation, the structural levels of the AVC (Viereck et al. 1992) were used because they are readily identifiable on aerial photographs. Some classes were grouped (e.g., open and closed shrub) because species composition was similar. The goal was to identify strong relationships that could be used for land management and mapping while avoiding the creation of additional classes that would lead to confusion and decrease accuracy.

Classification of map ecotypes for the CD5 Habitat Monitoring project was based on CBCP classification. Map ecotype classes were assigned to the ITU map polygons according to the CBCP classification scheme that defines map ecotypes by ITU code (Appendix C). An ecotype map was produced by recoding the ITU map using a cross reference table between ITU code and map-ecotype class as defined in Appendix C. In some cases, new ITU codes were encountered in the 2012 CD5 ITU mapping that were not present in the existing CBCP. In these cases, map-ecotype and wildlife-habitat classes were assigned to each new ITU code based on the classification of the most similar existing ITU code. In cases where there were no similar ITU codes, new map-ecotype classes were created based on the most similar plot-ecotype class (see below). Wildlife-habitat classes were then assigned to new map-ecotype classes following the methods described under Wildlife Habitat (next section).

The CBCP wildlife habitat classification was based on landscape properties considered most important to wildlife: shelter, security (or escape), and food. These factors may be directly related to the quantity and quality of vegetation, plant species composition, surface form, soils, hydrology, and microclimate. Here, habitats are not equivalent to vegetation types. In some cases, dissimilar vegetation types may be combined because selected wildlife species either do not distinguish between them or use them similarly. Conversely, wildlife may distinguish between habitats with similar vegetation on the basis of relief, soil characteristics, invertebrates, or other factors not reflected in plant-species composition. Habitat classifications for the same region may also differ, depending on the wildlife species or species groups being considered. For the CBCP classification, the focus of the habitat classification was on (1) breeding waterbirds that use waterbodies and wet and moist tundra types, and (2) mammals and upland birds that use shrublands and dry tundra types. Wildlife-habitat classes were assigned to the ITU map polygons according to the CBCP classification scheme that aggregates map ecotypes into a set of wildlife habitats (Appendix C) that have been identified in bird-habitat studies conducted in the Prudhoe Bay, Kuparuk, and Alpine oilfields and in northeastern NPRA (Anderson et al. 2001; Burgess et al. 2003; Johnson et al. 1990, 1997; Jorgenson et al. 1989; Murphy and Anderson 1993; Murphy et al. 1989). A wildlife-habitat map was produced by recoding the ITU map using the cross reference table between map ecotype and wildlife-habitat class presented in Appendix C.

3.3.3.B.ii. Vegetation Classification and Assessment

Point Count Data Summaries

Raw point count data does not correspond directly to percent cover of plant species or ground cover classes. Therefore, for each Vegetation Plot, point-count data were summarized to produce estimates of plant cover and to characterize woody and herbaceous vegetation height. The data for all the points sampled at each plot were aggregated to calculate the cover metrics by species and by vegetation-structure class for each plot. Vegetation-structure class was assigned based on lifeform for herbaceous and non-vascular vegetation (sedge, grass, forb, lichen, and moss). For woody vegetation, structure class was based on the Viereck and Little (1992) shrub species size class descriptions (e.g., low shrub). For analysis, low and tall shrubs were combined as “low and tall shrubs,” and dwarf and prostrate shrubs were grouped as “dwarf shrubs.”

Water, bare soil, and litter (including standing dead vegetation) were each summarized as separate classes in this analysis. Cover data were then summarized in three ways: 1) hit density (*hit_density)*—all hits by species and structure class at each point, 2) cover (*cover)*—first hit of each species and structure class at each point, and 3) top cover (*top_cover)*—first hit at each point.

Using BLM AIM protocol, ABR used shrub-height data collected at every fifth point along each line (BLM 2011, BLM 2013) to calculate average woody and herbaceous vegetation height (the mean height for all sampled points at which shrubs [or herbs]) were present) and frequency (the percentage of sampled points where woody [or herbaceous] vegetation was present).

Ecotype Classification of Vegetation Plots

ABR applied multivariate analyses, including Non-metric Multidimensional Scaling (NMDS) ordination (Kruskal 1964a, 1964b) and contingency table analysis, to the Vegetation-Plot data to classify plot ecotypes. ABR first assigned draft plot-ecotype classes to the Vegetation Plots using contingency table analysis. Next, species cover data calculated from the Vegetation Plot point-count data were used in the NMDS ordination. Hits of ground-cover classes (e.g., bare soil, litter, water), trace species (i.e., those species present in a plot but not hit with the laser), and any species that occurred in only one plot were excluded. Based on exploratory analysis, a log transformation of the species-cover data was determined to be most suitable for the ordination analyses. The log transformation reduced the statistical weight of dominant species with high cover relative to species with lower cover, which resulted in a more balanced representation of species composition within Vegetation Plots. Next, ABR subset the vegetation species cover by draft plot-ecotype class and plotted NMDS ordinations for each of the draft plot ecotypes. Outliers were identified as plots in the ordination that occurred well outside central grouping of plots in the ordination diagram. Outliers were either removed altogether or were moved to a more suitable plot-ecotype class, and the ordinations were re-plotted. Following the ordinations, environment data, including elevation, thaw depth, surface organic thickness, pH, electrical conductivity, and depth to water table, were summarized by ecotype class to review central tendencies and check for additional potential outliers. Potential outliers were plots with a value for any of the above variables of greater than ±2 times the standard deviation of the ecotype group. Plots with 3 or more variables flagged as outliers were considered outliers and removed from the ecotype group.

Plot ecotypes are local-scale ecosystems classified by aggregating Vegetation Plots with similar vegetation structure, species composition and environmental conditions, including geomorphology, surface form, hydrology, and soils. A classification nomenclature for plot ecotypes was used that translated ecological characteristics, including physiography, dominant soil texture, site chemistry, soil moisture, vegetation structure, and dominant species, into intuitive and easily understood classes (e.g., Riverine Loamy Alkaline Moist Low Willow Shrub). Once the classification of plot ecotypes was complete, a cross-reference table was developed between the plot ecotypes classified from the Vegetation Plot data and map ecotypes from CBCP classification.

Canonical Correspondence Analysis: Ecological Gradients and Plot Ecotypes

ABR used Canonical Correspondence Analysis (CCA, ter Braak and Verdonschot, 1995), a type of ordination analysis, to plot the Vegetation Plot species-cover data in n-dimensional ordination space and elucidate the relationships between species composition and environmental gradients in the CD5 Habitat Monitoring Study Area. In CCA, the vegetation data are regressed against the environmental variables to obtain fitted values which are then projected in the ordination as a scatter plot. Arrows are displayed in the ordination diagrams showing the importance and direction of correlation of each environmental variable relative to the vegetation scatter plot. The species-cover data calculated from the Vegetation Plot point-count data were used in the analysis, excluding hits of ground-cover classes (e.g., bare soil, litter, water), trace species (i.e., those species present in a plot but not hit with the laser), and any species that occurred in only one plot. Based on exploratory analysis, a log transformation of the species-cover data was determined to be most suitable for the ordination analyses. The log transformation reduced the statistical weight of dominant species with high cover relative to species with lower cover and resulted in a more balanced representation of species composition within Vegetation Plots. The plot ecotypes were aggregated into two groups for the CCA. The first group included ecotypes characterized by wet sedge and wet sedge-willow tundra vegetation; the second group included all other ecotypes. Plot ecotypes with a sample size of one were excluded from the CCA analysis.

Species Composition by Plot Ecotype

Plant-species composition was summarized by plot ecotype in three ways. First, average species cover and constancy were calculated for each plot ecotype. Average species cover is the average cover when a species occurs in a plot ecotype (i.e., plots where a species was absent were not factored into the average cover calculation). Constancy refers to the percentage of plots that a species occurs within a plot ecotype (e.g., plot ecotype A has a sample size of 10, and species X occurs in 9 of those plots; the constancy = 90%). Second, species richness was calculated for each plot ecotype by summing the total number of unique species occurrences in each class. Third, the cover and height data for each vegetation-structure class from the Vegetation Plots were summarized for each plot ecotype, with the exception of outliers and plot ecotypes with a sample size of one. The mean cover value for each structure class in each plot ecotype was calculated by averaging the cover values from all plots assigned to that plot ecotype. The mean height and frequency of woody and herbaceous vegetation for each plot ecotype were calculated in the same manner. The mean cover and height data were used to create stacked bar charts and summary tables for presentation. The mean cover data for each vegetation-structure class were combined with the mean top cover of the non-vegetated classes (water, soil, litter) for each plot ecotype. The top cover, or first hit, identifies points where the non-vegetated class occurred without any overtopping vegetation. These are represented as water alone, soil alone, and litter alone in the stacked bar charts and summary tables.

3.3.3.B.iii. Habitat Assessment

The Habitat Plot point count data were summarized to cover metrics following similar methods to the Vegetation Plots (see Point Count Data Summaries under section 3.3.3.B.ii., above). However, the Habitat Plots were located systematically, and the Habitat Plot Lines often covered multiple wildlife-habitat types, therefore the Habitat Plot point count data were summarized by wildlife-habitat class from the ITU mapping rather than by plot. The precise locations for each of the 25 Habitat Plot Points on each Habitat Plot Line were calculated in GIS from the survey-quality Habitat Plot Center Point and the Habitat Plot Line End Points. Next, the points were overlaid on the wildlife habitat map layer produced from the 2012 CD5 ITU Mapping, and each Habitat Line Point was assigned to the wildlife habitat class polygon within which it was located. The vegetation metrics for cover, top cover, and hit density of each vegetation structure class were then calculated for each wildlife habitat class with a sufficient sample size (75 points or more, equivalent to a full Habitat Plot). For those habitat types with sufficient data to calculate cover, the mean cover of each vegetation structure class and the mean height and frequency of woody and herbaceous vegetation were calculated for each wildlife habitat class. The mean cover and height data were used to create stacked bar charts and summary tables for presentation. Additionally, the mean cover data for each vegetation structure class were combined with the mean top cover of the non-vegetated classes (water, soil, litter) for each wildlife habitat. These are represented as water alone, soil alone, and litter alone in stacked bar charts and summary tables.

3.3.3.B.iv. Elevation and Thaw Depth

Toposequence Diagrams and Thaw/Elevation Cross Sections

Transects were generated by spatially connecting Vegetation Plot Start Points, Thaw Depth/Elevation Points, and Water Edge Points. For each location along the transect, distance (east to west), thaw depth and elevation were generated. The full transect lines were then spatially joined to the 2012 ITU Map polygons and the transitions between zones for geomorphology, surface form, and vegetation type were reported along with the distance along the transects. The Thaw Depth/ Elevation Point data were summarized in a toposequence diagram and thaw depth and elevation cross section diagrams.

For the toposequence diagram, a portion of one monitoring transect from each subarea was selected to prepare toposequence diagrams, which display a two-dimensional cross-sectional view of the landscape. The diagram was annotated using the ITU mapping data from the spatial join and the Integrated Habitat Monitoring Plot data along the transect sections.

For the thaw depth and elevation cross sections, the thaw depth and elevation point data from the Vegetation Plot Start Points, Thaw Depth/Elevation Points, and Water Edge Points for each monitoring transect were co-plotted to create two-dimensional cross sectional views. The points were then connected by lines that approximate the ground surface and lower depth of the active layer.

Thaw and Elevation Summaries by Map Ecotype

Thaw depth and elevation were summarized by map ecotype class using data collected during the RTK Surveys. A spatial join was created between the ITU Map polygons and the Vegetation Plot Start Point, Habitat Plot Center Point, and Thaw Depth/Elevation Point locations. Each point was assigned the attributes, including map ecotype class, of the ITU map polygon within which it was located. The elevation and thaw depth data were then summarized by map ecotype class that had more than 2 Thaw Depth/Elevation Points. Summary statistics included average, standard deviation, and standard error.

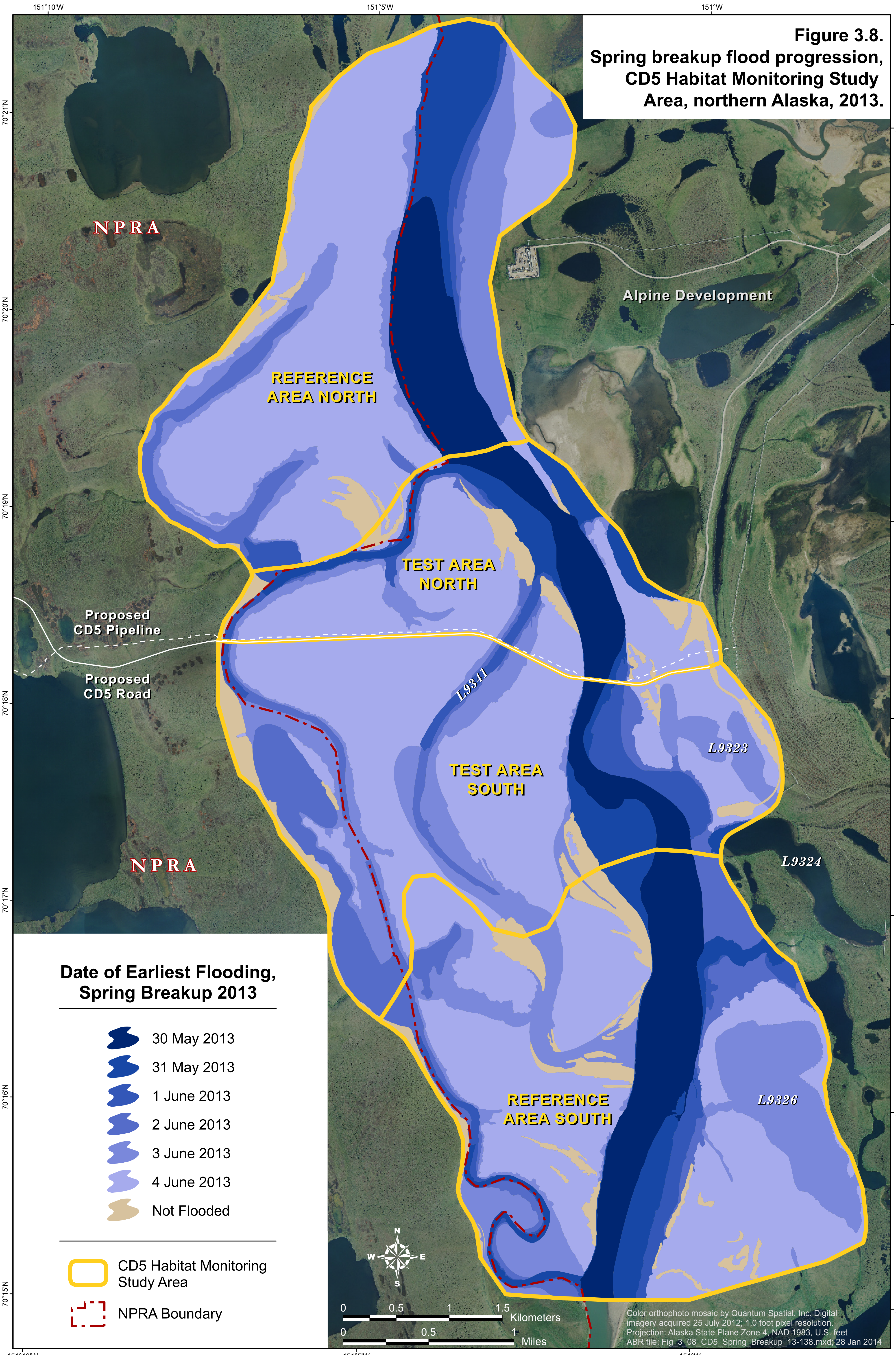


Figure 3.8. Spring breakup flood progression, CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

3.4 RESULTS AND DISCUSSION

3.4.1 SPRING BREAKUP

The spring breakup flood progression mapping depicts an approximate spatial timeline of flood waters as they moved through the CD5 Habitat Monitoring Study Area beginning on 30 May 2013, when flooding first began, through 4 June 2013, when flooding peaked at the CD2 facilities. The focus of this mapping was to capture general trends in channelized and overbank flooding during 2013 breakup in the CD5 Habitat Monitoring Study Area. Descriptions are provided below of noteworthy events for each day along the flood progression timeline. Lake codes mentioned below can be seen on Figures 1.2 and 3.8. See Baker (2013) for the complete assessment of the 2013 Colville River Delta spring breakup and monitoring.

30 May 2013

Break up flooding in the CD5 Habitat Monitoring Study Area began on this date with water entering via the Niġliq channel to just north of CD2 and flooding the lowest-lying coastal barrens (Figure 3.8).

31 May 2013

Floodwaters had filled the Niġliq Channel and all remaining coastal barrens were inundated. On this date, floodwaters began to fill the Niġliagvik Channel from both the upstream and downstream channel entrances. Flooding began in Nanuq Lake and flood water entered Lake L9324 from the east via the Sakoonang Channel.

1 June 2013

Floodwater continued to flow along the Niġliagvik Channel from both the north and south, flood water entered Lake L9341 and began flowing southwest, and an unnamed tap lake to the northwest of CD4 was flooded. Additionally, Delta Inactive Channel Deposits adjacent to major channel were flooded throughout the CD5 Habitat Monitoring Study Area.

2 June 2013

Floodwater continued to flow along the Niġliagvik Channel from both the north and south, and flood waters in Lake L9341 continued to flow southward. Floodwaters had filled an unnamed major side channel of the Niġliagvik and associated tapped lake located in the northwestern portion of the CD5 Habitat Monitoring Study Area, and floodwater filled a series of unnamed tapped lakes located along the Niġliagvik Channel in the central-western portion of the CD5 Habitat Monitoring Study Area. Lastly, flood water began covering Delta Active Overbank Deposits throughout the area.

3 June 2013

On this date, floodwaters that had been flowing from both the north and south along the Niġliagvik Channel converged, floodwaters breached the west bank of the Niġliq channel to the west of Lake L9326 and flowed northward along an inactive channel, eventually converging with floodwaters flowing southward from Lake L9341, and floodwaters entered Lakes L9326 and L9323. Overbank flooding continued to expand across Delta Active Overbank Deposits and began to inundate Delta Inactive Overbank Deposits.

4 June 2013

On this date, a large ice jam formed one mile south of CD4 in the Niġliq Channel, floodwaters peaked across the CD5 Habitat Monitoring Study Area, and all floodplain surfaces were inundated. Areas that were not flooded included sand dunes and alluvial terraces.

3.4.2 HABITAT MONITORING

3.4.2.A. Classification and Mapping

3.4.2.A.i. Plot Ecotypes

Plot ecotypes were classified using multivariate clustering routines; descriptions and summary statistics were prepared for each as per the Monitoring Plan (ABR and Baker 2013). ABR identified 17 plot ecotypes, including 2 coastal, 5 lowland, 7 riverine, and 3 upland ecotypes. A total of 9 plots, 5% of the total, were identified as outliers and were not assigned to a plot-ecotype class. Table 3.5 provides descriptions of the 17 plot ecotypes, including representative photographs, commonly associated geomorphic units and surface forms, dominant soil textures, hydrology, site chemistry, vegetation class, and dominant plant species. Tables 3.6 and 3.7 provide a summary

Table 3.5. Description of 17 plot ecotypes, including representative landscape and soil photos, CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

Coastal Loamy Brackish Moist Willow Dwarf Shrub

This plot ecotype occurs on Delta Inactive Channel Deposits and Delta Active Channel Deposits on unpatterned ground. The moist soils are somewhat poorly drained and often show hydric characteristics. Soils are brackish with an average site pH of 7.5. An organic surface mat is lacking, and the mineral soil substrate is loamy, with an average thaw depth of 2.2 ft (66.7 cm). The plant community is dominated by bare soil and *Salix ovalifolia* (avg. 32.9%). Other constant species include *Deschampsia caespitosa* and *Pedicularis sudetica*.

Coastal Sandy Moist Brackish Barrens

This plot ecotype is associated with Delta Active Channel Deposits and occurs mostly on lateral bars. The moist soils are moderately well drained. The water table is moderately deep (avg. -2.6 ft [-79.2 cm]) and is strongly linked to water levels in nearby river channels. As such water tables may fluctuate up or down with the river throughout the growing season. Soils are brackish, and sandy, and the active layer is relatively deep (avg. -4.5 ft [-138 cm]). The plot ecotype is unvegetated and dominated by bare ground. However, *Equisetum arvense* and *Leymus mollis* occur sporadically.

Table 3.5. Continued.

Lowland Lake

This plot ecotype is associated with shallow (<4.9 ft [150 cm]) thaw lakes that may feature small islands. The water is alkaline (avg. pH 7.9) and the water is fresh (EC < 800 µS). Thick organic deposits form the substrate at the lake bottom.

Lowland Organic-rich Circumneutral Moist Sedge–Shrub Meadow

This plot ecotype was sampled once on a Delta Abandoned Overbank Deposit in an area of Low-centered, Low-relief, High-density Polygons. The saturated soil is poorly drained with a circumneutral pH. A relatively thick organic horizon overlies loamy substrate. The depth to the permafrost table is shallow, and the soils showed signs of frost heaving. The dominant plant species are *Carex aquatilis*, *Eriophorum angustifolium*, and the dwarf shrub *Dryas integrifolia*.

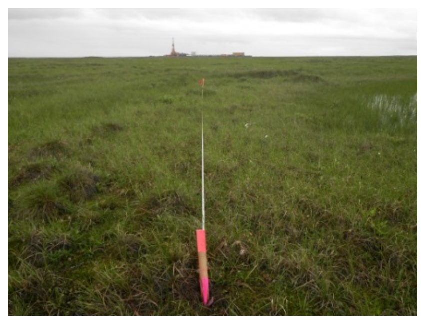
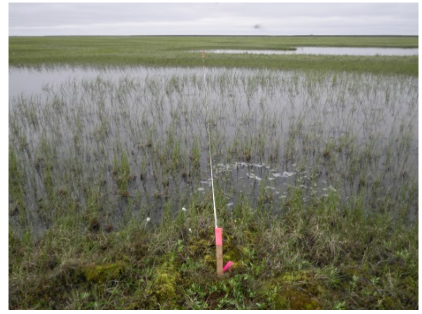


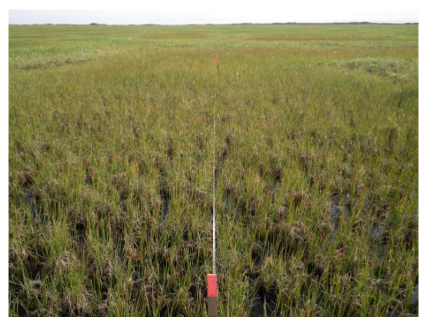
Table 3.5. Continued.

Lowland Organic-rich Circumneutral Sedge Marsh



This plot ecotype was encountered once on a Delta Abandoned Overbank Deposit in an area of Low-centered, High-relief, Low-density Polygons. The wet, circumneutral soil is permanently flooded with approximately 0.5 ft (0.15 m) of standing water. The thick surface organic horizon overlies loamy substrate, and the thaw depth is moderate. The plants *Carex aquatilis,* and unspecified algae are common below the water surface.

Lowland Organic-rich Circumneutral Wet Sedge Meadow

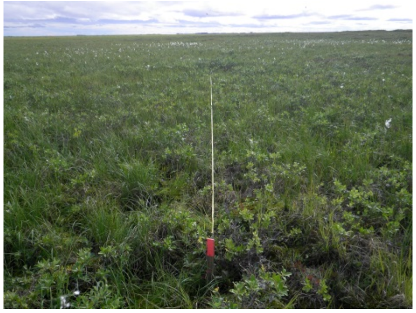


This widespread plot ecotype occurs on Delta Abandoned Overbank Deposits. The ground is generally covered with Disjunct Polygon Rims or Low-centered, Low-relief, Low-density Polygons. The soils are wet and poorly drained. The water table is often near the soil surface or slightly above (avg. 0 in). Soils are circumneutral and organic-rich. Surface organic thickness averaged 13.1 in (33.3 cm). The depth of active layer is shallow, averaging -1.3 ft (-41.0 cm). The plant community is dominated by *Carex aquatilis* and the aquatic moss *Scorpidium scorpioides*. Other characteristic species include *Carex chordorrhiza*, *C. saxatilis*, *Eriophorum angustifolium*, *E. russeolum*, *Pedicularis sudetica*, *Saxifraga hirculus*, and *Meesia triquetra*.

Table 3.5. Continued.

Lowland Organic-rich Circumneutral Wet Sedge–Willow Meadow

This plot ecotype occurs on Delta Abandoned Overbank Deposits with Low-centered, Low-relief, Low-density Polygons. The wet soils are poorly drained, and the water table is often near the soil surface or slightly above (avg. -0.1 ft [-2.8 cm]). The soils are circumneutral and have relatively thick organic mats (avg. 12.9 in [32.8 cm]) over loamy substrates. Thaw depths are shallow (average 1.4 ft [43.2 cm]). The plant community is dominated by the sedges *Carex aquatilis*, *Eriophorum angustifolium* and the mosses *Drepanocladus revolvens*, and *Tomentypnum nitens*. Willows, namely *Salix lanata* ssp. *richardsonii* occur commonly but at low abundance. Other constant taxa with lower cover values include *Eriophorum russeolum*, *Saxifraga hirculus*, *Polygonum viviparum*, *Aulacomnium turgidum*, and *Meesia triquetra*.



Riverine Loamy Alkaline Moist Low Willow Shrub

This plot ecotype is found on Delta Active Overbank Deposits and Delta Inactive Overbank Deposits. Flooding and sedimentation are common. The ground is generally Nonpatterned, however, Disjunct Polygon Rims may sometimes be encountered on inactive surfaces. The moist soils are moderately well to somewhat poorly drained and may exhibit hydric characteristics. Soils are circumneutral to alkaline and loamy, with moderately deep to deep active layers (avg. -2.7 ft [-81.9 cm]. Soils typically feature interbedded organic and silt layers from regular flooding and sedimentation. Surface organic layers are typically thin (avg. 1.8 in [4.7 cm]), but may be moderately thick depending on the site specific flood regime. The plant community is dominated by *Salix lanata* ssp. *richardsonii* and bare soil. Other common taxa include *Astragalus alpinus*, *Equisetum variegatum*, *Petasites frigidus*, and *Polygonum viviparum*.

Table 3.5. Continued.

Riverine Loamy Alkaline Moist Mixed Herb

This plot ecotype is associated with Delta Inactive Channel Deposits. The moist soils are moderately well drained and have deep water tables and thaw depths (avg. -4.2 ft [-128.3 cm]). Soils are alkaline, loamy, and lack a surface organic horizon. The plant community is dominated by bare soil and a mixture of seral forbs, namely *Chrysanthemum bipinnatum* and *Equisetum arvense* Other common taxa include *Artemisia tilesii*, *Astragalus alpinus*, *Deschampsia caespitosa*, *Festuca rubra*, *Pedicularis verticillata*, and *Wilhelmsia physodes*. Seedlings of *Salix alaxensis* occur sporadically.

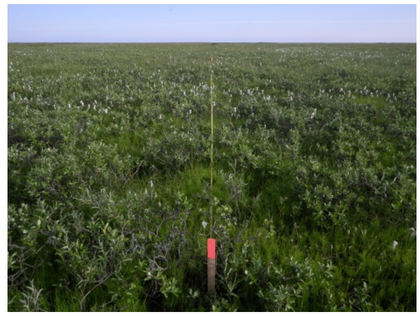
Riverine Loamy Alkaline Moist Tall Willow Shrub

This plot ecotype was sampled twice on Delta Inactive Channel Deposits. The moist soil is well drained, alkaline, and loamy. A surface organic horizon is absent, and thaw depth is deep (-4.1 ft [-125.0 cm]). The plant community is dominated by bare soil, tall willows, including *Salix alaxensis* and *Salix lanata* ssp. *richardsonii*, and *Equisetum arvense*. Other characteristic species are *Aster sibiricus*, *Chrysanthemum bipinnatum*, *Equisetum variegatum*, *Festuca rubra*, *Parnassia kotzebuei*, *Petasites frigidus*, and *Wilhelmsia physodes*.

Table 3.5. Continued.

Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow

This plot ecotype occurs most frequently on Delta Inactive Overbank Deposits, with Disjunct Polygon Rims or Low-centered, Low-relief, Low-density Polygons. The mostly wet soils are poorly to very poorly drained and show hydric characteristics. Soils are circumneutral and, at localized sites, may be brackish (EC >800 μS). The thickness of the surface organic horizon, which overlies loamy substrate, is highly variable and depends on the local-scale flooding return intervals. The active layer is moderately shallow, averaging -1.5 ft (-45.3 cm). The plant community is dominated by low willows, namely *Salix lanata* ssp. *richardsonii,* although total cover may be somewhat low (18-25%). The sedges *Carex aquatilis* and *Eriophorum angustifolium* dominate the understory. Other frequently occurring species include *Equisetum variegatum*, *Poa arctica*, *Polygonum viviparum*, *Saxifraga hirculus*, and *Salix reticulata*.



Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow

This plot ecotype is associated with Delta Inactive Overbank Deposits with Disjunct Polygon Rims or High-centered, Low-relief Polygons. The moist soils are somewhat poorly drained and show hydric characteristics. Soils are circumneutral and range from loamy to organic-rich. Surface organic horizons are relatively thin (avg. 3.8 in [9.7 cm]). The active layer is shallow (-1.1 ft. [-34.9 cm]), and signs of frost heave are common. The plot ecotype includes both Moist Sedge-Shrub Tundra and Moist Sedge-Willow Tundra vegetation types. The plant community is dominated by *Carex aquatilis*, *Dryas integrifolia*, and the moss *Tomentypnum nitens*. Other characteristic species include *Eriophorum angustifolium*, *Salix reticulata*, *S. lanata* ssp. *richardsonii*, and *Saxifraga hirculus*.

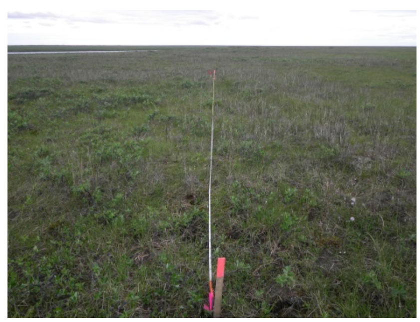


Table 3.5. Continued.

Riverine Organic-rich Circumneutral Wet Sedge Meadow

This common plot ecotype occurs on Delta Inactive Overbank Deposits with Low-centered, Low-relief, Low-density Polygons. The hydric, wet soils are very poorly drained, with the water table generally located just below the soil surface (avg. -0.1 ft [3.3 cm]). Soils are circumneutral and primarily organic-rich. The thickness of the surface organic horizon varies widely and depends on the localized flood regime. The thaw depth is shallow, averaging -1.3 ft (-39.8 cm). The plant community is dominated by *Carex aquatilis*. Other relatively constant taxa with low cover values are *Carex rariflora*, *Eriophorum angustifolium*, *E. russeolum*, *Pedicularis sudetica*, *Salix lanata* ssp. *richardsonii*, *Saxifraga hirculus*, and *Meesia triquetra*.

Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow

This widespread plot ecotype is found on Delta Inactive Overbank Deposits with Disjunct Polygon Rims or Low-centered, Low-relief, Low-density Polygons. The wet, hydric soils are very poorly drained, and the water table occurs near the soil surface (avg. -0.2 ft [-7.0 cm]). Soils are circumneutral and loamy. The thickness of the surface organic mat is wide ranging depending on the localized flood regime, and the active layer is shallow (avg. -1.4 ft [41.5 cm]). The plant community is dominated by *Carex aquatilis*, *Equisetum variegatum*, *Eriophorum angustifolium*, and the mosses *Drepanocladus revolvens, and Tomentypnum nitens*. Willows, namely *Salix lanata* ssp. *richardsonii* occur commonly but at low abundance. Other taxa common taxa include *Pedicularis sudetica*, *Polygonum viviparum*, and *Saxifraga hirculus. Dryas integrifolia* and *Salix reticulata* often occur on slightly drier microsites, including small peat mounds.

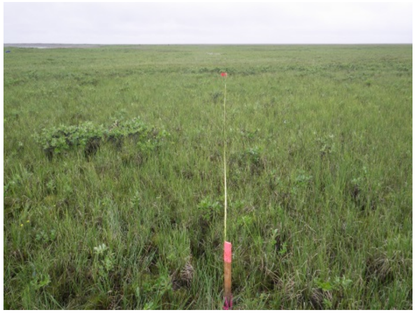


Table 3.5. Continued.

Upland Loamy-Organic Circumneutral Moist Tussock Meadow

This plot ecotype was sampled on Delta Inactive Overbank Deposits and Recent Alluvial Terraces. Both high- and low-centered ice-wedge polygons are associated with this plot ecotype. The soils are typically moist, somewhat poorly drained, and commonly show hydric characteristics. The water table, when present, is shallow (avg. -0.7 ft [-21.0 cm]). Soils are circumneutral and loamy beneath a moderately thick surface organic layer (5.5 in [14.0 cm]). Active layers are shallow and signs of frost heave are common. The plant community is dominated by the tussock-forming sedge *Eriophorum vaginatum*, along with *Carex bigelowii*, *Salix planifolia* ssp. *pulchra*, and *Hylocomium splendens*. Other characteristic species include *Arctagrostis latifolia*, *Carex aquatilis*, *Dryas integrifolia*, *Petasites frigidus*, *Pyrola grandiflora*, *Salix reticulata*, and *Tomentypnum nitens*.

Upland Sandy Alkaline Dry Barrens

This plot ecotype was sampled once on an Eolian Active Sand Dune. The moist soil is somewhat excessively drained, and the depth to the water table is deep (>3.3 ft [100 cm]). The soil is alkaline and sandy, with low electrical conductivity. A surface organic horizon is absent. The presence of permafrost is unknown. Vegetated cover is low (<5%) and bare soil predominates. *Equisetum arvense*, *Salix alaxensis*, and *S. lanata* ssp. *richardsonii* occur at low cover.

Table 3.5. Continued.

Upland Sandy Alkaline Moist Low Willow Shrub

This ecotype occurs on Eolian Active Sand Deposits and Eolian Inactive Sand Deposits. The dry to moist soils are well drained, and depth to the water table generally exceeds 5 ft (1.5 m). Soils are alkaline and sandy. A surface organic horizon is absent or very thin. If permafrost is present, the depth of the active layer is very deep (<3 ft or 1.0 m). *Astragalus alpinus*, *Oxytropis borealis*, *Salix glauca*, and *S. lanata* ssp. *richardsonii* dominate the plant community, while *Carex krausei* and *Poa arctica* are present with low cover values.

Table 3.6. Mean percent cover by plant species and species richness for moist plot ecotypes, CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Plot ecotypes with a sample size less than 3 are excluded. Bold text indicates species with constancy (frequency of occurence) ≥60%.

Ecotype Group	Species Name	Coastal Loamy Brackish Moist Willow Dwarf Shrub	Coastal Sandy Moist Brackish Barrens	Riverine Loamy Alkaline Moist Low Willow Shrub	Riverine Loamy Alkaline Moist Mixed Herb	Riverine Loamy Alkaline Moist Tall Willow Shrub	Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	Upland Loamy-Organic Circumneutral Moist Tussock Meadow
Sample Size		3	10	15	3	2	34	7	3
Deciduous Shrubs	*Alnus crispa*			7.9					
	Arctostaphylos alpina			1.3			0.1	0.1	
	Arctostaphylos rubra			2.6		0.1	0.7	0.1	
	Salix alaxensis		0.1	1.3	**3.5**	**31.8**	1.3		
	Salix arbusculoides					4.0			
	Salix arctica							1.3	
	Salix glauca			21.7	1.3	13.2	0.1	0.5	
	Salix lanata richardsonii	0.1	0.1	**30.3**	**7.3**	**8.7**	20.5	**4.9**	**2.6**
	Salix ovalifolia	**32.9**		3.7	2.6	1.3	1.1	0.1	
	Salix planifolia pulchra			1.6			5.6	6.3	**13.6**
	Salix reticulata	0.1		**2.4**			2.0	**6.8**	**3.9**
	Salix rotundifolia							0.1	
	Vaccinium uliginosum			0.1			0.1		
Evergreen Shrubs	*Andromeda polifolia*							7.9	**0.1**
	Cassiope tetragona			0.1			0.1	0.1	**12.5**
	Dryas integrifolia			**2.2**			1.4	**11.7**	**4.8**
	Empetrum nigrum			0.1			0.1		**0.7**
	Ledum decumbens								0.1
	Vaccinium vitis-idaea			0.1					**7.9**
Forbs	*Anemone parviflora*			0.1				0.1	
	Arabis lyrata kamchatica		0.1						
	Arnica lessingii			0.1					
	Artemisia tilesii		0.1		**4.9**	**0.1**			
	Aster sibiricus			0.9	**0.7**	**2.0**			
	Astragalus alpinus	0.1		**1.9**	**1.3**	1.3	0.1	0.1	
	Astragalus eucosmus	0.1		0.7		1.3	0.1	0.1	
	Astragalus eucosmus sealei			0.1					
	Astragalus umbellatus			4.2	0.1		0.1	0.1	1.3
	Caltha palustris						0.1		
	Cardamine hyperborea			0.1					1.3
	Cardamine pratensis angustifolia						0.1		0.1
	Castilleja caudata				0.1	**0.1**			
	Chrysanthemum bipinnatum		1.8		**11.8**	**0.7**			
	Epilobium latifolium		0.1	0.1	0.1				
	Equisetum arvense	**0.7**	0.1	**10.5**	**11.8**	**25.9**	9.9		

Table 3.6. Continued.

Ecotype Group	Species Name	Coastal Loamy Brackish Moist Willow Dwarf Shrub	Coastal Sandy Moist Brackish Barrens	Riverine Loamy Alkaline Moist Low Willow Shrub	Riverine Loamy Alkaline Moist Mixed Herb	Riverine Loamy Alkaline Moist Tall Willow Shrub	Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	Upland Loamy-Organic Circumneutral Moist Tussock Meadow
Forbs (continued)	*Equisetum scirpoides*			7.9			4.9	**6.1**	5.3
	Equisetum variegatum		1.3	**9.3**		**1.3**	6.1	5.0	
	Gentiana propinqua				**0.1**	**0.1**			
	Hedysarum alpinum	0.1		0.5	3.9				
	Hedysarum mackenzii				0.1	0.1			
	Lupinus arcticus			22.4			0.4	4.0	7.9
	Oxytropis borealis			0.1			0.1		
	Oxytropis campestris								
	Oxytropis deflexa								
	Oxytropis maydelliana					0.1			
	Parnassia kotzebuei			0.7	**0.1**	**0.7**			
	Parnassia palustris			0.1	0.1				
	Pedicularis capitata			0.4			0.1	0.1	**0.5**
	Pedicularis langsdorffii			0.1			0.1	0.4	**0.1**
	Pedicularis langsdorffii arctica							0.1	
	Pedicularis sp.						0.3		
	Pedicularis sudetica	**0.5**		0.8		0.1	0.4	0.1	**0.1**
	Pedicularis sudetica albolabiata						0.7		
	Pedicularis verticillata			0.3	**0.5**	2.6	0.1		
	Petasites frigidus	0.1	0.1	**5.1**	**1.4**	**0.7**	0.2	**0.3**	**1.8**
	Platanthera hyperborea					0.1			
	Polygonum bistorta			0.9		1.3	0.1	0.1	**2.0**
	Polygonum viviparum	**2.0**		**0.3**	0.1	**0.1**	0.4	**0.3**	**0.1**
	Potentilla palustris			0.1			4.0	1.8	0.1
	Pyrola grandiflora			2.6			0.1	0.1	**2.6**
	Pyrola secunda			0.1			0.1	0.7	
	Pyrola secunda secunda						0.1		
	Ranunculus lapponicus								0.1
	Rubus chamaemorus						0.1		
	Rumex arcticus	0.1							
	Saussurea angustifolia			0.1				0.1	**0.5**
	Saxifraga cernua						0.5		
	Saxifraga hieracifolia							0.1	0.1
	Saxifraga hirculus	0.1		0.7			0.6	**0.1**	**0.5**
	Saxifraga punctata			0.1			0.1	0.1	**0.5**
	Sedum rosea integrifolium	0.1							
	Senecio atropurpureus			0.1			0.1	**0.1**	**0.1**
	Silene acaulis						0.1		

Table 3.6. Continued.

Ecotype Group	Species Name	Coastal Loamy Brackish Moist Willow Dwarf Shrub	Coastal Sandy Moist Brackish Barrens	Riverine Loamy Alkaline Moist Low Willow Shrub	Riverine Loamy Alkaline Moist Mixed Herb	Riverine Loamy Alkaline Moist Tall Willow Shrub	Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	Upland Loamy-Organic Circumneutral Moist Tussock Meadow
Forbs (continued)	*Stellaria humifusa*		0.1						
	Stellaria longipes	1.3		0.8	1.3		0.1	**0.1**	**0.1**
	Valeriana capitata	0.1		2.0			0.5	0.1	**0.5**
	Wilhelmsia physodes	0.1	0.1	0.1	**0.5**	**1.3**			
Grasses	*Agropyron macrourum*				0.1	**0.1**			
	Alopecurus alpinus	**0.7**		0.1		0.1	0.1	0.1	
	Arctagrostis latifolia	**0.7**	0.1	**1.8**	0.1	1.3	1.1	**1.4**	**2.6**
	Arctophila fulva		0.1						
	Bromus pumpellianus		1.3		**0.7**	0.1			
	Calamagrostis canadensis			10.5					
	Deschampsia caespitosa	**1.4**	1.4		**2.2**				
	Dupontia fischeri	17.1		2.6			0.4	0.1	
	Festuca baffinensis			0.1					
	Festuca brachyphylla						0.1		0.1
	Festuca richardsonii			0.1					
	Festuca rubra	1.3	0.1	1.2	**5.7**	**4.0**	0.1	0.1	
	Hierochloe odorata				**0.1**				
	Hierochloe pauciflora			0.1	2.6		0.6		
	Leymus mollis		0.7		0.1				
	Poa alpina			0.1					
	Poa arctica	**0.1**	0.1	**1.6**	0.1		0.4	**0.1**	**0.5**
	Puccinellia vaginata			0.1					
	Trisetum spicatum spicatum			0.1	0.1	**0.1**		0.1	1.3
Sedges	*Carex amblyorhynca*			0.1			1.3		
	Carex aquatilis	3.9		**4.0**			15.4	**7.0**	**3.6**
	Carex bigelowii			2.1			1.1	**9.0**	**10.6**
	Carex capillaris			1.4		0.1			
	Carex chordorrhiza			0.1			1.8	0.9	
	Carex krausei			0.4		0.1	0.7	0.1	
	Carex maritima	**1.4**							
	Carex membranacea						0.1		
	Carex misandra							1.3	
	Carex rariflora			2.2			1.4	0.1	
	Carex rotundata						0.1		
	Carex saxatilis						0.1		
	Carex subspathacea	0.1							
	Carex williamsii							3.9	
	Eriophorum angustifolium	15.8	0.1	**4.1**		0.1	17.6	**6.6**	17.1
	Eriophorum russeolum			0.1			2.0	0.1	

Table 3.6. Continued.

Ecotype Group	Species Name	Coastal Loamy Brackish Moist Willow Dwarf Shrub	Coastal Sandy Moist Brackish Barrens	Riverine Loamy Alkaline Moist Low Willow Shrub	Riverine Loamy Alkaline Moist Mixed Herb	Riverine Loamy Alkaline Moist Tall Willow Shrub	Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	Upland Loamy-Organic Circumneutral Moist Tussock Meadow
Sedges (continued)	*Eriophorum scheuchzeri*						2.6		
	Eriophorum vaginatum						0.5	**0.3**	**11.8**
	Juncus arcticus				0.1	1.3			
	Luzula arcuata unalaschensis							0.1	
	Luzula kjellmaniana			0.1				0.1	
	Luzula multiflora			0.1					
	Luzula tundricola			0.4			0.1	**1.4**	**0.9**
Mosses and Liverworts	*Aulacomnium palustre*			0.7			1.3	**1.1**	**3.3**
	Aulacomnium turgidum			0.1			0.7	**1.5**	**2.7**
	Blepharostoma trichophyllum							0.1	
	Brachythecium mildeanum			8.6		1.3	5.3		
	Brachythecium turgidum			0.1			0.1		
	Bryum pseudotriquetrum			0.7			0.6	0.1	
	Calliergon giganteum			11.4			3.6		
	Campylium arcticum	19.7		4.4		0.1	18.5		
	Campylium polygamum			6.6					
	Campylium stellatum			20.7			10.3	2.6	
	Catoscopium nigritum			0.1					
	Ceratodon purpureus			0.1					
	Cinclidium latifolium						0.9		
	Cirriphyllum cirrosum			0.1					
	Dicranum elongatum						0.1		
	Dicranum laevidens							0.1	
	Distichium capillaceum			15.5			0.7	4.9	
	Ditrichum flexicaule			0.1				0.1	
	Drepanocladus aduncus	7.9							
	Drepanocladus brevifolius			5.3			6.7	0.1	
	Drepanocladus revolvens			0.1			10.3	2.6	
	Drepanocladus sendtneri						0.1		
	Encalypta rhaptocarpa			0.1					
	Entodon concinnus			0.1					
	Hamatocaulis vernicosus						23.7		
	Hylocomium splendens			5.3			0.7	**3.8**	**13.2**
	Hypnum bambergeri			0.1					
	Hypnum lindbergii						0.1		
	Marchantia polymorpha			0.1					0.1
	Meesia longiseta						0.1		
	Meesia triquetra						2.9		
	Meesia uliginosa						0.1		

Table 3.6. Continued.

Ecotype Group	Species Name	Coastal Loamy Brackish Moist Willow Dwarf Shrub	Coastal Sandy Moist Brackish Barrens	Riverine Loamy Alkaline Moist Low Willow Shrub	Riverine Loamy Alkaline Moist Mixed Herb	Riverine Loamy Alkaline Moist Tall Willow Shrub	Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	Upland Loamy-Organic Circumneutral Moist Tussock Meadow
Mosses and Liverworts (continued)	*Myurella julacea*			0.1			0.1		
	Oncophorus virens							0.1	
	Oncophorus wahlenbergii						0.1	3.4	
	Orthothecium chryseon			0.1					
	Philonotis tomentella							13.2	
	Plagiomnium ellipticum			1.3			0.1		
	Polytrichum commune						0.1		
	Polytrichum juniperinum							1.3	**1.4**
	Polytrichum strictum			1.3					
	Pseudocalliergon turgescens	0.1						0.1	
	Rhytidium rugosum								**2.0**
	Sanionia uncinata			10.6					
	Timmia austriaca						0.1		
	Tomentypnum nitens			**13.4**			12.8	**32.7**	**4.8**
	Tortula ruralis			1.3					
Lichens	*Cetraria cf. islandica*							0.1	
	Cetraria islandica islandica								0.1
	Cladonia cornuta							0.1	
	Cladonia ecmocyna			2.6					
	Cladonia furcata								1.3
	Cladonia pyxidata						0.1	0.1	
	Cladonia squamosa							0.1	
	Dactylina arctica							0.1	**0.1**
	Flavocetraria cucullata							0.1	**1.4**
	Flavocetraria nivalis								
	Lobaria linita							0.1	**1.3**
	Masonhalea richardsonii							0.1	
	Nephroma arcticum								0.1
	Nephroma expallidum							0.1	
	Peltigera aphthosa			0.1			0.1	**1.4**	**4.6**
	Peltigera canina							0.1	
	Peltigera didactyla						0.1	0.1	
	Peltigera leucophlebia							2.7	9.2
	Peltigera rufescens							0.1	
	Stereocaulon alpinum							0.1	0.1
	Thamnolia vermicularis							0.1	

Table 3.6. Continued.

Ecotype Group	Species Name	Coastal Loamy Brackish Moist Willow Dwarf Shrub	Coastal Sandy Moist Brackish Barrens	Riverine Loamy Alkaline Moist Low Willow Shrub	Riverine Loamy Alkaline Moist Mixed Herb	Riverine Loamy Alkaline Moist Tall Willow Shrub	Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	Upland Loamy-Organic Circumneutral Moist Tussock Meadow
	Species Richness[1] Summaries								
	Vascular Species Richness	26	19	72	33	35	64	55	39
	Non-Vascular Species Richness	3	0	30	0	2	29	33	16
	Total Species Richness	29	19	102	33	37	93	88	55

[1] Species richness is the total number of unique species occurrences in each plot ecotype.

of species composition by plot ecotype. Environmental data summaries by plot ecotype are provided in Tables 3.8 and 3.9, and a cross-reference between each plot ecotype class and the equivalent map ecotype class is provided in Table 3.10.

In coastal areas, the most commonly sampled plot ecotype was Coastal Sandy Moist Brackish Barrens (n = 10), which occurs on Delta Active Channel Deposit. In lowlands, Lowland Organic-rich Circumneutral Wet Sedge Meadow is the most commonly sampled plot ecotype (n = 29). This ecotype is associated with Low-center, Low-relief Polygons on Inactive or Abandoned Delta Overbank Deposits. These areas on the landscape are characterized by water-logged soils, accumulations of thick surface organic horizons, and shallow thaw depths. In riverine habitats, both Riverine Organic-rich Circumneutral Wet Sedge Meadow (n = 34) and Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow (n = 34) were most commonly sampled. These plot ecotypes are found on Delta Inactive Overbank Deposit showing ice-wedge formation, with relatively shallow active layers and depth to water table. For both of these plot ecotypes, the sedge *Carex aquatilis* ssp. *aquatilis* is a dominant species. Other common riverine plot ecotypes include Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow (n = 16), and Riverine Loamy Alkaline Moist Low Willow Shrub (n = 15), both of which are associated with Active to Inactive Delta Overbank Deposits and are dominated by *Salix lanata* ssp. *richardsonii*. In upland areas, Upland Sandy Alkaline Moist Low Willow Shrub (n = 4) and Upland Loamy-Organic Circumneutral Moist Tussock Meadow (n = 3) are the most commonly sampled plot ecotypes. Upland Sandy Alkaline Moist Low Willow Shrub occurs on Active and Inactive Eolian Sand Dunes. Upland Loamy-Organic Circumneutral Moist Tussock Meadow is found on Delta Abandoned Overbank Deposit and Recent Alluvial Terraces with ice-wedge polygonization and is dominated by the tussock-forming sedge *Eriophorum vaginatum*.

3.4.2.A.ii. Integrated Terrain Unit (ITU) Mapping

The ITU mapping places the CD5 Habitat Monitoring Study within a spatial and temporal context. Multiple landscape components, including geomorphic units, surface forms, vegetation classes, and recent disturbance were mapped simultaneously providing for a multivariate view of the landscape. The multiple landscape components were aggregated to map ecotypes which represent local-scale ecosystems with similar vegetation, soils, and landscape processes. The map ecotypes were further aggregated to wildlife habitat classes that represent areas on the

Table 3.7. Mean percent cover by plant species and species richness for wet plot ecotypes, CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Plot ecotypes with a sample size of less than 3 are excluded. Bold text indicates species with constancy (frequency of occurence) ≥60%.

Ecotype Group	Species Name	Lowland Lake	Lowland Organic-rich Circumneutral Wet Sedge Meadow	Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	Riverine Organic-rich Circumneutral Wet Sedge Meadow	Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow
Sample Size		2	29	5	34	34
Deciduous Shrubs	*Arctostaphylos alpina*		0.1		0.1	0.1
	Arctostaphylos rubra		1.3	0.1	0.1	0.1
	Salix arbusculoides		0.1			
	Salix arctica				0.1	0.9
	Salix fuscescens		0.1			
	Salix lanata richardsonii		**0.6**	**8.7**	**1.4**	**7.9**
	Salix ovalifolia		0.1		0.2	2.7
	Salix planifolia pulchra		**0.2**	**5.2**	**1.0**	**4.9**
	Salix reticulata		0.1	**1.3**	0.2	**1.5**
	Vaccinium uliginosum				1.3	0.1
Evergreen Shrubs	*Andromeda polifolia*		0.1		0.5	2.0
	Cassiope tetragona		0.1		0.1	0.3
	Dryas integrifolia		0.1	**0.9**	1.4	**2.4**
	Ledum decumbens					0.1
	Vaccinium vitis-idaea				0.1	0.1
Forbs	*Anemone parviflora*				0.1	
	Anemone richardsonii					0.1
	Astragalus alpinus				0.1	0.1
	Astragalus eucosmus		0.1		0.1	0.1
	Astragalus eucosmus sealei					0.1
	Astragalus umbellatus			1.3	0.7	0.1
	Caltha palustris		0.1	0.1	0.1	0.5
	Cardamine hyperborea					0.7
	Cardamine pratensis angustifolia		0.1		0.6	0.1
	Equisetum arvense				0.7	0.5
	Equisetum scirpoides		2.2	2.6	3.9	3.2
	Equisetum variegatum		0.8	**3.3**	**5.5**	**9.5**
	Hedysarum alpinum		0.1			0.1
	Hippuris vulgaris				1.3	
	Lupinus arcticus		0.1		0.4	0.3

Table 3.7. Continued.

Ecotype Group	Species Name	Lowland Lake	Lowland Organic-rich Circumneutral Wet Sedge Meadow	Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	Riverine Organic-rich Circumneutral Wet Sedge Meadow	Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow
Forbs (continued)	*Melandrium apetalum*				0.1	
	Pedicularis capitata		0.1	0.1	0.1	0.1
	Pedicularis langsdorffii			0.1	0.1	0.1
	Pedicularis langsdorffii langsdorffii				0.1	1.3
	Pedicularis sp.		2.0	0.1	1.4	0.1
	Pedicularis sudetica		**0.3**	**0.1**	**0.5**	**0.5**
	Pedicularis sudetica albolabiata		0.1			
	Pedicularis verticillata				0.1	0.1
	Petasites frigidus			0.1	0.4	0.2
	Platanthera hyperborea					0.1
	Polygonum viviparum		0.2	**0.3**	**0.8**	**0.6**
	Potentilla palustris		0.2	1.3	0.5	1.0
	Pyrola grandiflora		0.1	0.1	0.1	0.3
	Pyrola secunda		0.1	0.1	0.1	0.1
	Ranunculus gmelini		0.1			
	Ranunculus lapponicus			0.1	0.1	0.1
	Ranunculus pallasii				0.1	1.3
	Rubus chamaemorus		0.1		0.1	0.1
	Saxifraga cernua				0.1	0.1
	Saxifraga foliolosa				0.1	0.1
	Saxifraga hieracifolia				0.1	
	Saxifraga hirculus		**0.3**	**0.3**	**0.4**	**0.4**
	Saxifraga punctata				0.1	0.1
	Saxifraga tricuspidata		0.1			
	Senecio atropurpureus				0.1	0.1
	Stellaria longipes				0.1	0.1
	Tofieldia pusilla				0.1	0.1
	Utricularia intermedia		0.1		0.1	
	Utricularia minor		2.7		5.3	
	Utricularia vulgaris macrorhiza		0.1		0.5	
	Valeriana capitata					0.8
Grasses	*Alopecurus alpinus*		0.1		1.3	0.1
	Alopecurus pratensis					0.1

Table 3.7. Continued.

Ecotype Group	Species Name	Lowland Lake	Lowland Organic-rich Circumneutral Wet Sedge Meadow	Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	Riverine Organic-rich Circumneutral Wet Sedge Meadow	Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow
Grasses	*Arctagrostis latifolia*		1.3	0.1	2.6	0.1
(continued)	*Dupontia fischeri*			**0.1**	0.9	1.1
	Festuca rubra					3.9
	Hierochloe pauciflora		0.1	0.1	1.2	0.5
	Poa alpina					0.1
	Poa arctica			0.1	0.1	0.4
Sedges	*Carex amblyorhynca*		0.1	0.1	0.4	2.0
	Carex aquatilis	0.1	**16.0**	**13.7**	**12.5**	**13.0**
	Carex atrofusca		0.2		0.5	0.5
	Carex bicolor				6.8	0.1
	Carex bigelowii		1.3		0.7	2.1
	Carex capillaris				0.1	0.1
	Carex chordorrhiza		**3.1**	0.1	**5.8**	1.5
	Carex krausei		0.1		0.1	0.5
	Carex maritima		0.1			
	Carex membranacea		4.0		1.4	1.3
	Carex misandra				0.1	
	Carex praticola		2.7			
	Carex rariflora		1.4	**0.7**	**2.5**	**1.7**
	Carex rotundata		0.5		0.7	0.1
	Carex saxatilis		**1.1**	0.1	**1.1**	0.2
	Carex vaginata				1.3	
	Carex williamsii		0.1		0.1	0.8
	Eriophorum angustifolium		**3.9**	**10.3**	**3.2**	**11.5**
	Eriophorum russeolum		**1.6**	**2.6**	**2.1**	**2.3**
	Eriophorum scheuchzeri		0.6		0.8	4.0
	Eriophorum vaginatum		0.1	2.6	2.3	3.3
	Juncus arcticus		0.1			
	Juncus biglumis		0.1		0.6	0.1
	Juncus triglumis		0.1		**0.7**	4.0
	Luzula kjellmaniana					0.1
	Luzula multiflora					0.1
	Luzula spicata					0.1
	Luzula tundricola				0.1	0.3

Table 3.7. Continued.

Ecotype Group	Species Name	Lowland Lake	Lowland Organic-rich Circumneutral Wet Sedge Meadow	Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	Riverine Organic-rich Circumneutral Wet Sedge Meadow	Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow
Mosses and Liverworts	*Aulacomnium palustre*		0.1	**3.5**	1.2	2.2
	Aulacomnium turgidum		0.4	**1.1**	0.3	1.2
	Brachythecium mildeanum					7.9
	Brachythecium turgidum					12.6
	Bryum pseudotriquetrum		0.1	0.1	0.1	3.8
	Calliergon giganteum		2.4	11.8	**3.2**	**7.5**
	Campylium arcticum		0.1		0.1	10.2
	Campylium stellatum		1.1	**6.0**	2.3	6.1
	Catoscopium nigritum		0.1			0.1
	Cinclidium latifolium		4.8	1.3	3.0	2.5
	Cinclidium subrotundum					3.9
	Climacium dendroides					0.1
	Dicranum spadiceum				0.1	
	Distichium capillaceum		0.1	**0.1**	0.1	0.6
	Distichium inclinatum					10.7
	Ditrichum flexicaule				0.1	0.1
	Drepanocladus brevifolius		0.7	15.2	7.1	7.7
	Drepanocladus revolvens		**12.7**	**11.3**	**19.5**	**9.0**
	Drepanocladus sendtneri		0.1			0.1
	Fissidens adiantoides				0.1	
	Hamatocaulis vernicosus		5.3			13.9
	Hylocomium splendens			2.6	0.1	0.1
	Hypnum bambergeri		8.0		0.1	6.7
	Marchantia polymorpha				1.3	0.7
	Meesia longiseta		0.1			
	Meesia triquetra		**3.7**	**5.2**	**5.1**	**3.5**
	Meesia uliginosa				0.1	0.1
	Oncophorus virens				0.1	
	Oncophorus wahlenbergii		0.1	0.1	2.8	8.3
	Orthothecium chryseon				0.1	0.3
	Paludella squarrosa					1.3
	Philonotis tomentella					0.1
	Plagiomnium ellipticum					1.3
	Polytrichum jensenii		0.1		2.0	0.1
	Polytrichum juniperinum		0.1	1.3	0.3	0.9

Table 3.7. Continued.

Ecotype Group	Species Name	Lowland Lake	Lowland Organic-rich Circumneutral Wet Sedge Meadow	Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	Riverine Organic-rich Circumneutral Wet Sedge Meadow	Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow
Mosses and Liverworts (continued)	*Pseudocalliergon turgescens*				0.1	
	Rhizomnium magnifolium				2.7	5.3
	Rhytidium rugosum				0.1	
	Sanionia uncinata					0.1
	Scorpidium scorpioides		**22.8**		14.3	1.3
	Timmia austriaca				0.1	0.1
	Tomentypnum nitens		1.4	**17.1**	2.5	**13.1**
	Tortella tortuosa		0.1		1.4	
	Warnstorfia sarmentosa			0.1		0.1
Lichens	*Cetraria cf. islandica*					1.4
	Cladonia cariosa					1.3
	Cladonia squamosa					0.1
	Dactylina arctica					0.1
	Flavocetraria cucullata				1.3	0.1
	Nephroma expallidum					1.3
	Peltigera aphthosa			0.1	0.7	0.8
	Peltigera canina					1.4
	Peltigera didactyla					1.3
	Peltigera leucophlebia					0.1
	Species Richness[1] Summaries					
	Vascular Species Richness		56	32	76	80
	Non-Vascular Species Richness		22	16	32	47
	Total Species Richness		78	48	108	127

[1] Species richness is the total number of unique species occurrences in each plot ecotype.

Table 3.8. Mean surface organic thickness, pH, and electrical conductivity for plot ecotypes with sample size greater than one in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

	Surface Organic Thickness (in [cm])		pH		Electrical Conductivity (µS)	
Plot Ecotype	Mean	sd	Mean	sd	Mean	sd
Coastal Loamy Brackish Moist Willow Dwarf Shrub	0 [0]	0 [0]	7.5	0.5	1,346.7	644.9
Coastal Sandy Moist Brackish Barrens	0 [0]	0 [0]	7.6	0.5	3,420.0	5,457.3
Lowland Lake	12.8 [32.5]	0.8 [2.1]	7.9	0.2	275.0	7.0
Lowland Organic-rich Circumneutral Wet Sedge Meadow	13.1 [33.3]	2.4 [6.1]	6.6	0.3	404.1	104.5
Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	12.9 [32.8]	3 [7.7]	6.7	0.3	298.0	89.6
Riverine Loamy Alkaline Moist Low Willow Shrub	1.8 [4.7]	3.3 [8.4]	7.2	0.8	494.7	277.0
Riverine Loamy Alkaline Moist Mixed Herb	0 [0]	0 [0]	8.1	0.1	520.0	45.0
Riverine Loamy Alkaline Moist Tall Willow Shrub	0 [0]	0 [0]	8.2	0.0	430.0	175.3
Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	3.9 [10]	3.3 [8.4]	6.8	0.5	711.9	560.8
Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	3.8 [9.7]	2.9 [7.4]	6.7	0.5	428.4	175.9
Riverine Organic-rich Circumneutral Wet Sedge Meadow	6.9 [17.5]	5.1 [12.9]	6.5	0.3	489.4	192.9
Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow	4.3 [10.8]	3.7 [9.4]	6.7	0.3	475.6	271.0
Upland Loamy-Organic Circumneutral Moist Tussock Meadow	5.5 [14.0]	3 [7.7]	6.4	0.3	310.0	214.4
Upland Sandy Alkaline Moist Low Willow Shrub	0.1 [0.4]	0.2 [0.4]	8.1	0.2	237.5	178.2

Table 3.9. Mean elevation, thaw depth, and water table depth summarized for plot ecotypes with sample size greater than one in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Elevation is referenced to British Petroleum mean sea level (BPMSL).

Plot Ecotype	Elevation (ft [cm])		Thaw Depth (ft [cm])		Water Table Depth (ft [cm])	
	Mean	sd	Mean	sd	Mean	sd
Coastal Loamy Brackish Moist Willow Dwarf Shrub	6.2 [189.3]	3.5 [105.6]	-2.2 [-66.7]	0.1 [4.2]	-1.5 [-45.3]	0.6 [19.1]
Coastal Sandy Moist Brackish Barrens	3.3 [101.6]	1.6 [48.4]	-4.5 [-138]	0.8 [25.3]	-2.6 [-80.0]	2.0 [62.1]
Lowland Lake	NA	NA	NA	NA	0.7 [23.0]	0.1 [2.8]
Lowland Organic-rich Circumneutral Wet Sedge Meadow	10 [303.9]	1.8 [55.8]	-1.3 [-41.0]	0.1 [3.9]	0 [0.20]	0.1 [4.1]
Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	10.3 [313.7]	2.0 [59.5]	-1.4 [-43.2]	0.2 [4.7]	-0.1 [-2.8]	0.1 [2.9]
Riverine Loamy Alkaline Moist Low Willow Shrub	9.0 [274.6]	2.2 [68.6]	-2.7 [-81.9]	1.7 [50.7]	-2.3 [-71.1]	1.9 [58.0]
Riverine Loamy Alkaline Moist Mixed Herb	7.5 [229.9]	1.3 [39.3]	-4.2 [-128.3]	1.2 [37.5]	-4.2 [-128.3]	1.1 [32.5]
Riverine Loamy Alkaline Moist Tall Willow Shrub	8.2 [250.7]	1.2 [36.2]	-4.1 [-125]	1.2 [35.4]	-4.1 [-125]	0.9 [27.4]
Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	8.6 [261.8]	2.4 [73.7]	-1.5 [-45.3]	0.4 [11.4]	-0.4 [-11.1]	0.3 [10.4]
Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	9.6 [291.7]	1.6 [49.5]	-1.1 [-34.9]	0.2 [6.3]	-0.9 [-27.4]	0.2 [5.3]
Riverine Organic-rich Circumneutral Wet Sedge Meadow	10.2 [310.5]	1.6 [47.6]	-1.3 [-39.8]	0.1 [3.8]	-0.1 [-3.3]	0.1 [4.1]
Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow	10.3 [315.3]	1.8 [54.3]	-1.4 [-41.5]	0.2 [6.3]	-0.2 [-7.0]	0.2 [6.1]
Upland Loamy-Organic Circumneutral Moist Tussock Meadow	10.7 [324.8]	1.3 [40.0]	-1.0 [-32.0]	0.3 [8]	-0.7 [-21.0]	0.3 [9.1]
Upland Sandy Alkaline Moist Low Willow Shrub	14.5 [443.0]	2.8 [86.4]	-4.5 [-138.0]	0.8 [24]	-4.5 [-138]	0.7 [21.7]

Table 3.10. Cross-reference table for plot ecotype and map ecotype classes, CD5 Habitat Monitoring Study, northern Alaska, 2013.

Plot Ecotype	Map Ecotype
Coastal Loamy Brackish Moist Willow Dwarf Shrub	Coastal Moist Willow Dwarf Shrub
Coastal Sandy Moist Brackish Barrens	Coastal Barrens
Lowland Lake	Lowland Lake
Lowland Organic-rich Circumneutral Moist Sedge-Shrub Meadow	Lowland Moist Sedge-Shrub Meadow
Lowland Organic-rich Circumneutral Sedge Marsh	Lowland Sedge Marsh
Lowland Organic-rich Circumneutral Wet Sedge Meadow	Lowland Wet Sedge Meadow
Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	Lowland Wet Sedge-Willow Meadow
Riverine Loamy Alkaline Moist Low Willow Shrub	Riverine Moist Low Willow Shrub
Riverine Loamy Alkaline Moist Mixed Herb	Riverine Moist Herb Meadow
Riverine Loamy Alkaline Moist Tall Willow Shrub	Riverine Moist Tall Willow Shrub
Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	Riverine Moist Low Willow-Sedge Meadow
Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	Riverine Moist Sedge-Shrub Meadow
Riverine Organic-rich Circumneutral Wet Sedge Meadow	Riverine Wet Sedge Meadow
Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow	Riverine Wet Sedge-Willow Meadow
Upland Loamy-Organic Circumneutral Moist Tussock Meadow	Upland Moist Tussock Meadow
Upland Sandy Alkaline Dry Barrens	Upland Dry Barrens
Upland Sandy Alkaline Moist Low Willow Shrub	Upland Moist Low Willow Shrub

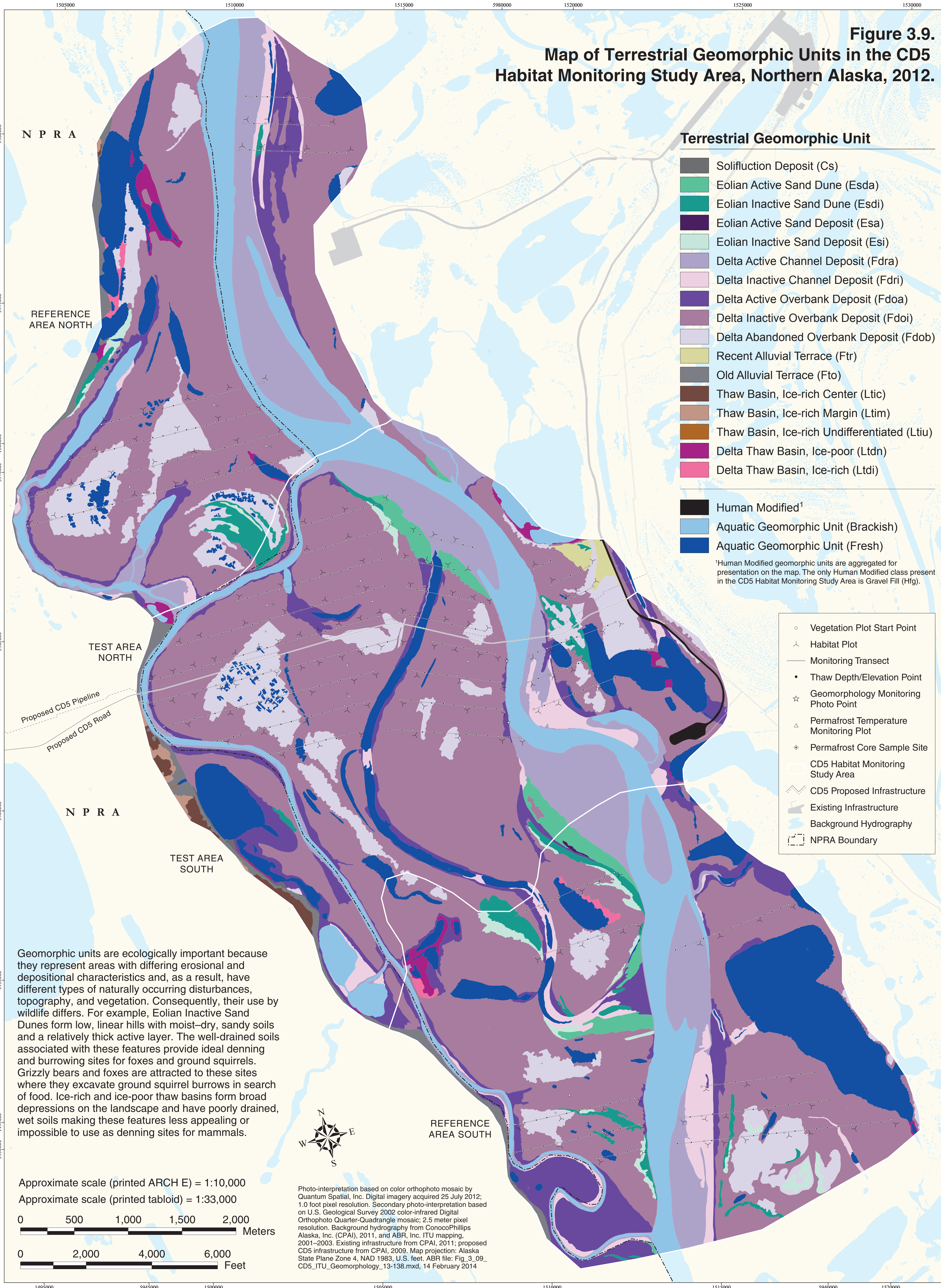


Figure 3.9. Map of Terrestrial Geomorphic Units in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2012.

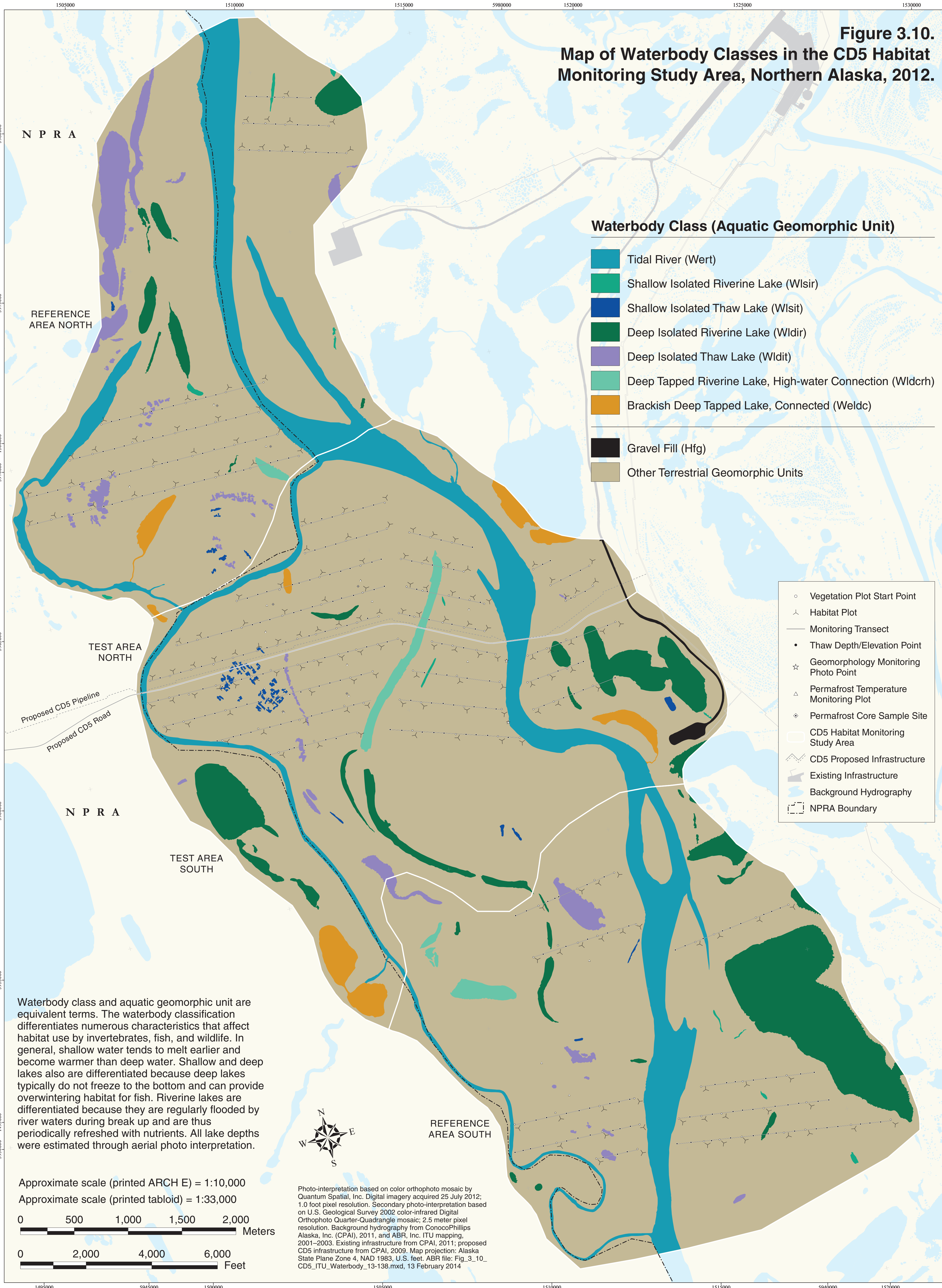
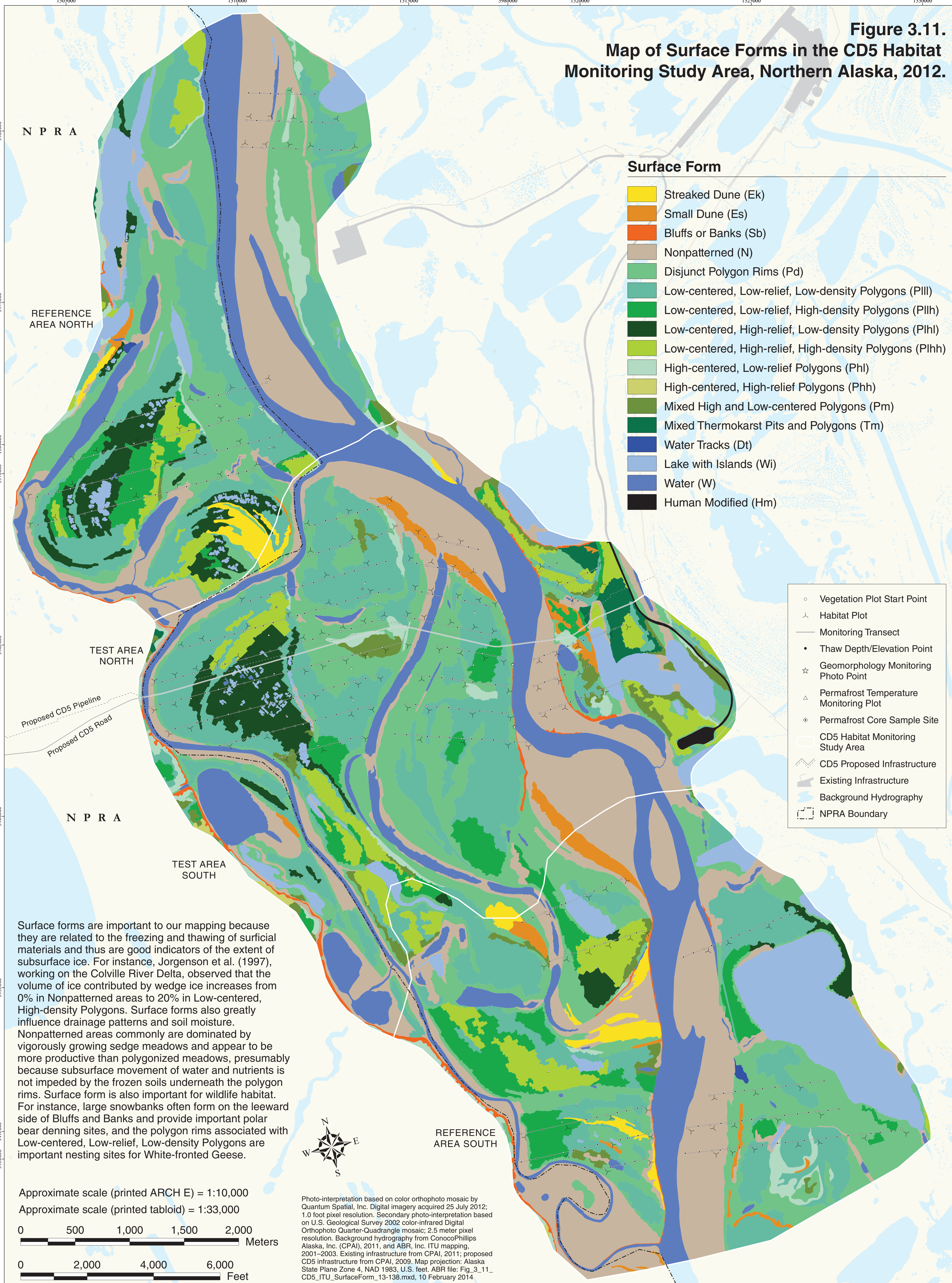


Figure 3.10. Map of Waterbody Classes in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2012.

Waterbody class and aquatic geomorphic unit are equivalent terms. The waterbody classification differentiates numerous characteristics that affect habitat use by invertebrates, fish, and wildlife. In general, shallow water tends to melt earlier and become warmer than deep water. Shallow and deep lakes also are differentiated because deep lakes typically do not freeze to the bottom and can provide overwintering habitat for fish. Riverine lakes are differentiated because they are regularly flooded by river waters during break up and are thus periodically refreshed with nutrients. All lake depths were estimated through aerial photo interpretation.

Photo-interpretation based on color orthophoto mosaic by Quantum Spatial, Inc. Digital imagery acquired 25 July 2012; 1.0 foot pixel resolution. Secondary photo-interpretation based on U.S. Geological Survey 2002 color-infrared Digital Orthophoto Quarter-Quadrangle mosaic; 2.5 meter pixel resolution. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2011, and ABR, Inc. ITU mapping, 2001–2003. Existing infrastructure from CPAI, 2011; proposed CD5 infrastructure from CPAI, 2009. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_3_10_CD5_ITU_Waterbody_13-138.mxd, 13 February 2014

Figure 3.11. Map of Surface Forms in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2012.



Surface forms are important to our mapping because they are related to the freezing and thawing of surficial materials and thus are good indicators of the extent of subsurface ice. For instance, Jorgenson et al. (1997), working on the Colville River Delta, observed that the volume of ice contributed by wedge ice increases from 0% in Nonpatterned areas to 20% in Low-centered, High-density Polygons. Surface forms also greatly influence drainage patterns and soil moisture. Nonpatterned areas commonly are dominated by vigorously growing sedge meadows and appear to be more productive than polygonized meadows, presumably because subsurface movement of water and nutrients is not impeded by the frozen soils underneath the polygon rims. Surface form is also important for wildlife habitat. For instance, large snowbanks often form on the leeward side of Bluffs and Banks and provide important polar bear denning sites, and the polygon rims associated with Low-centered, Low-relief, Low-density Polygons are important nesting sites for White-fronted Geese.

Photo-interpretation based on color orthophoto mosaic by Quantum Spatial, Inc. Digital imagery acquired 25 July 2012; 1.0 foot pixel resolution. Secondary photo-interpretation based on U.S. Geological Survey 2002 color-infrared Digital Orthophoto Quarter-Quadrangle mosaic; 2.5 meter pixel resolution. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2011, and ABR, Inc. ITU mapping, 2001–2003. Existing infrastructure from CPAI, 2011; proposed CD5 infrastructure from CPAI, 2009. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_3_11_CD5_ITU_SurfaceForm_13-138.mxd, 10 February 2014

landscape with similar biological and physical attributes important for wildlife. For future monitoring, the ITU mapping provides a quantifiable baseline for assessing potential landscape change over time. For instance, in 2016 (the next scheduled study year), the ITU mapping, based on 2012 imagery, will be compared to new ITU mapping delineated on imagery collected in 2016. The 2012 and 2016 ITU mapping will be compared spatially to monitor for landscape change as detailed in the "Landscape Change Analysis" section of the Monitoring Plan (ABR and Baker 2013).

Geomorphic Units

Eighteen terrestrial geomorphic units were mapped within the overall CD5 Habitat Monitoring Study Area (Figure 3.9, Table 3.11). A map of terrestrial geomorphic units revealed that the region is characterized by delta overbank and channel deposits. Delta Inactive Overbank Deposit is the dominant geomorphic unit, with an areal cover of 44.7% (Table 3.12). Delta Active Channel Deposit, Delta Active Overbank Deposit, and Delta Abandoned Overbank Deposit have areal cover values ranging from 7.4 to 9.9%. All other terrestrial geomorphic units cover <3% of the CD5 Habitat Monitoring Study Area.

Geomorphic units are ecologically important because they represent areas with differing erosional and depositional characteristics and, as a result, have different types of naturally occurring disturbances, topography, and vegetation. Consequently, their use by wildlife differs. For example, Eolian Inactive Sand Dunes form low, linear hills with moist–dry, sandy soils and a relatively thick active layer. The well-drained soils associated with these features provide ideal denning and burrowing sites for foxes and ground squirrels. Grizzly bears and foxes are attracted to these sites where they excavate ground squirrel burrows in search of food. Ice-rich and ice-poor thaw basins form broad depressions on the landscape and have poorly drained, wet soils making these features less appealing or impossible to use as denning sites for mammals.

Seven aquatic geomorphic units were mapped across the overall CD5 Habitat Monitoring Study Area (Figure 3.10, Table 3.13), which accounted for 20.8% of the areal cover (Table 3.12). Tidal River water is a relatively widespread geomorphic unit with 9.8% areal cover. In addition, Deep Isolated Riverine Lakes make up a substantial portion of the landscape with 6.7% areal cover. The remaining aquatic geomorphic units occur at or less than 2%.

The waterbody classification differentiated numerous characteristics that affect habitat use by invertebrates, fish, and wildlife. In general, shallow water tends to melt earlier and become warmer than deep water. Shallow and deep lakes also are differentiated because deep lakes typically do not freeze to the bottom and can provide overwintering habitat for fish. Riverine lakes are differentiated because they are regularly flooded by river waters during breakup and are thus refreshed with nutrients periodically. All lake depths were estimated through aerial photo-interpretation.

Surface Forms

Seventeen surface forms were mapped in the overall CD5 Habitat Monitoring Study Area (Figure 3.11, Table 3.14). The dominant surface forms were Disjunct Polygon Rims; Low-centered, Low-relief, Low-density Polygons; and Nonpatterned, with each of these surface forms covering approximately 20% of the CD5 Habitat Monitoring Study Area (Table 3.15). With regards to massive ice-related surface forms, low-centered ice-wedge polygons occur frequently, with a combined total of 32.1% areal cover for all types of low-centered polygons, while high-centered polygon types are far less common (combined areal cover of 2.2%). Water accounts for 13.4% of the total area, and Lakes with Islands 7.4%. All other surface forms are relatively rare, with areal coverage of less than 2%.

Examples of common ice-wedge polygon surface forms are provided in Figure 3.12. ABR characterized ice-wedge polygon surface forms in the mapping because they are related to the freezing and thawing of surficial materials (Leffingwell 1919, Black 1952, Washburn 1956, Lachenbruch 1962, Hartwell 1973, NWWG 1988) and thus are good indicators of the extent of subsurface ice (Sellman et al. 1972, Billings and Peterson 1980, Walker et al. 1980, Jorgenson et al. 1997). For instance, Jorgenson et al. (1997), working on the Colville River Delta, observed that the volume of ice contributed by wedge ice

Table 3.11. Classification and description of terrestrial geomorphic units in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Classes modified from Jorgenson et al. (1997, 2003), Roth et al. (2006), Carter and Galloway (1985), and Kreig and Reger (1982).

Terrestrial Geomorphic Unit	Description
Delta Abandoned Overbank Deposit (Fdob)	Peat, silt, or fine sand (or mixtures or interbeds of all 3), deposited in a deltaic overbank environment by fluvial, eolian, and organic processes. These deposits generally consist of an accumulation of peat 0.7-2.0 ft (20–60 cm) thick overlying cover and riverbed alluvium. Because these are older surfaces, eolian silt and sand may be common as distinct layers or as intermixed sediments. The surface layer, however, usually lacks interbedded silt layers associated with occasional sedimentation during extreme floods. Lenticular and reticulate forms of segregated ice, and massive ice in the form of ice wedges, are common in these deposits. The surface is characterized by high density, low-relief polygons and represents the oldest surface on the floodplain.
Delta Active Channel Deposit (Fdra)	Silty and sandy channel or lateral accretion deposits laid down from the bed load of a river in a deltaic environment at low water velocities. This unit includes point bars, lateral bars, mid-channel bars, unvegetated high-water channels, and broad sandbars exposed during low water. Generally, sediment texture becomes finer in a seaward direction along the distributaries. Organic matter, including driftwood, peat shreds, and other plant remains, usually is interbedded with the sediments. Only those riverbed deposits that are exposed at low water are mapped, but they also occur under rivers and cover deposits. Frequent flooding (every 1–2 years) prevents the establishment of vegetation.
Delta Active Overbank Deposit (Fdoa)	Thin (0.3-1.6 ft [10–50 cm] fine-grained, horizontally stratified cover deposits (primarily silt) that are laid down over sandier channel deposits during flood stages. Relatively frequent deposition (every 3–4 years) prevents the development of a surface organic horizon. Supra-permafrost groundwater generally is absent or occurs only at the bottom of the active layer during mid-summer. This unit usually occurs on the upper portions of point and lateral bars and supports low and tall willow vegetation.
Delta Inactive Channel Deposit (Fdri)	Delta deposits in channels that are only flooded during periods of high flow. These "high-water" channels are no longer active during low-flow conditions because of the migration of active channels. Generally, there is little indication of ice-wedge development, although a few older channels have begun to develop polygon rims. Very old channels with well-developed low-centered polygons are not included in this unit.
Delta Inactive Overbank Deposit (Fdoi)	Fine-grained cover or vertical accretion deposits laid down over coarser channel deposits during floods. The surface layers are a sequence (0.7-2.0 ft [20–60 cm] thick) of interbedded organic and silt horizons, indicating occasional flood deposition. Under the organic horizons is a thick layer (~1.0 ft [~0.3 m] thick) of silty cover deposits overlying channel deposits. Surface forms range from nonpatterned to disjunct and low-density, low-centered polygons. Lenticular and reticulate forms of segregated ice, and massive ice in the form of ice wedges, are common.
Delta Thaw Basin, Ice-poor (Ltdn)	Deposits in thaw lakes within deltaic deposits. They usually are connected to a river or to nearshore water (tapped lake). Most connections occur when a meandering distributary cuts through a lake's bank; once connected, the lake is influenced by changes in river level. During breakup, large quantities of sediment-laden water flow into the lake, forming a lake delta at the point of breakthrough. Sediments generally consist of brackish fine sands, silts, and clays.

Table 3.11. Continued.

Terrestrial Geomorphic Unit	Description
Delta Thaw Basin, Ice-rich (Ltdi)	Similar to the above unit, except that sediments are ice-rich, as indicated by the development of ice-wedge polygons. Typically, the sediments contain a sequence of a thick (0.7–2.0 ft [20-60 cm]) layer of interbedded silt and peat, fine-grained cover deposits, and silty clay lacustrine deposits. They still are subject to flooding.
Eolian Active Sand Deposit (Esa)	Deposits of fine to very fine, well-sorted sand that has not formed into distinct dunes. The sands typically contain abundant quartz with minor dark minerals. Sand is stratified with large-scale cross bedding in places. These active sandy deposits are barren or partially vegetated and are undergoing active accretion and deflation. Eolian Active Sand Deposits usually occur adjacent to Eolian Active Sand Dune.
Eolian Active Sand Dune (Esda)	Unconsolidated, wind-deposited accumulations of primarily very fine and fine sand. Surficial patterns associated with ice aggradation are absent. The sand dunes are built by deposition of sand from adjacent sandbars and are prone to wind erosion, giving them distinctive, highly dissected patterns. Active dunes primarily occur along river corridors or within recently drained lake basins. Active dunes are barren or partially vegetated and are undergoing active accretion and deflation.
Eolian Inactive Sand Deposit (Esi)	Deposits of fine to very fine, well-sorted sand that has not formed into distinct dunes. The sands typically contain abundant quartz with minor dark minerals. Sand is stratified with large-scale cross bedding in places. Often contains buried soils and peat beds in upper few meters. These inactive sandy deposits are vegetated, typically have thin to thick organic soil horizons at the surface, and are not subject to active scouring or movement. Inactive Eolian Sandy Deposits typically occur adjacent to Eolian Active Sand Dunes and Eolian Inactive Sand Dunes.
Eolian Inactive Sand Dune (Esdi)	Unconsolidated, wind-deposited accumulations of primarily very fine and fine sand. Surficial patterns associated with ice-aggradation generally are absent. Inactive dunes primarily occur along river corridors where the inter-dune areas are still subject to infrequent flooding from the river. Inactive dunes are well vegetated and are not subject to active scouring or movement.
Gravel Fill (Hfg)	Gravel and sandy gravel that has been placed as fill for roads and pads in the Alpine Development. The gravel is obtained from deep riverbed deposits or gravelly coastal plain deposits.
Ice-rich Thaw Basin Center (Ltic)	The sediments are similar to those of ice-poor thaw lake deposits but have much more ground ice, as indicated by the development of low-centered or high-centered polygons. The centers of basins usually have organic-rich silty sediments that have high-potential for ice segregation and often are raised by ice aggradation. Surface morphology ranges from low-center polygons at early stages of development to high-centered polygons on distinctly raised domes.
Ice-rich Thaw Basin Margin (Ltim)	The sediments are similar to those of ice-poor thaw lake deposits but have much more ground ice, as indicated by the development of low-centered or high-centered polygons. Waterbodies within these basins tend to be rectangular, to have smooth, regular shorelines, and to be poorly interconnected. Soils generally have a moderately thick organic layer overlying sand or sandy loam.
Old Alluvial Terrace (Fto)	Old alluvial terraces are ancient and are not subject to flooding under the current flood regime. A distinct bluff typically separates this geomorphic unit from Deltaic depostis. The characteristic morphology of a terrace with a riser and a flat tread is often no longer expressed due to weathering events over time. In regions that support permafrost,

Table 3.11. Continued.

Terrestrial Geomorphic Unit	Description
	thermokarst lakes may form on the tread and small drainage channels may weather and dissect the riser escarpment face. The surficial geomorphology of these deposits is typically no longer alluvium, but rather loess or thick organic deposits.
Recent Alluvial Terrace (Ftr)	Recent alluvial terraces are old (millennia) and flooding is very rare. Return intervals for flooding are upwards of 500 to >1000 years. These surfaces represent the highest surface that may be flooded under the current flood regime (albeit extremely rarely), and often feature a distinct rise of one to several meters in elevation that separates it from Delta Abandoned Overbank Deposits. Soils will have been stable long enough for weakly to moderately developed subsurface diagnostics to form, such as thick organic mats and ice-rich permafrost.
Solifluction Deposit (Cs)	Unconsolidated fine-grained, sandy or gravelly material, resulting from movement of saturated materials. Usually associated with gelifluction processes at the base of slopes and in snowbeds.
Undifferentiated Ice-rich Thaw Basin (Ltiu)	Sediments similar to ice-rich thaw lake deposits but having less ground ice with poorly developed low-centered or high-centered polygons. This type is used when the thaw lake centers and margins are poorly differentiated.

Table 3.12. Areal extent of geomorphic units in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Area is reported in acres, hectares (ha), and percent of the CD5 Habitat Monitoring Study Area.

Geomorphic Unit	Acres	ha	%
Terrestrial			
Delta Abandoned Overbank Deposit	866.4	350.6	8.2
Delta Active Channel Deposit	1,046.2	423.4	9.9
Delta Active Overbank Deposit	783.7	317.1	7.4
Delta Inactive Channel Deposit	278.0	112.5	2.6
Delta Inactive Overbank Deposit	4,716.1	1,908.5	44.7
Delta Thaw Basin, Ice-poor	62.4	25.3	0.6
Delta Thaw Basin, Ice-rich	18.5	7.5	0.2
Eolian Active Sand Deposit	1.3	0.5	<0.1
Eolian Active Sand Dune	122.8	49.7	1.2
Eolian Inactive Sand Deposit	75.9	30.7	0.7
Eolian Inactive Sand Dune	157.3	63.7	1.5
Gravel Fill	19.6	7.9	0.2
Ice-rich Thaw Basin Center	29.8	12.1	0.3
Ice-rich Thaw Basin Margin	13.8	5.6	0.1
Old Alluvial Terrace	125.0	50.6	1.2
Recent Alluvial Terrace	25.3	10.3	0.2
Solifluction Deposit	8.1	3.3	0.1
Undifferentiated Ice-rich Thaw Basin	0.5	0.2	<0.1
Aquatic (Waterbodies)			
Brackish Deep Tapped Lake, Connected	125.1	50.6	1.2
Deep Isolated Riverine Lake	704.5	285.1	6.7
Deep Isolated Thaw Lake	211.4	85.6	2.0
Deep Tapped Riverine Lake, High-water Connection	84.2	34.1	0.8
Shallow Isolated Riverine Lake	20.6	8.3	0.2
Shallow Isolated Thaw Lake	20.2	8.2	0.2
Tidal River	1,029.4	416.6	9.8
TOTAL	10,546.3	4,267.9	100.0
AGGREGATED SUBTOTALS			
Terrestrial Geomorphic Units	8,350.8	3,379.4	79.2
Aquatic Geomorphic Units	2,195.5	888.5	20.8

Table 3.13. Classification and description of waterbodies (aquatic geomorphic units) in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Classes modified from Jorgenson et al. (1997, 2003) and Roth et al. (2006). Waterbody classes that were identified in the field but not mapped are identified with an asterisk.

Waterbody class	Description
Brackish Deep Tapped Lake, Connected (Weldc)	Deep (≥4.9 ft [1.5 m]) brackish waterbodies that have been partially drained through erosion of banks by adjacent river channels, and are connected to river channels during flooding events. The water typically is brackish because the lakes are usually within the delta and subject to flooding every year. Because water levels have dropped after tapping, the lakes generally have broad flat shorelines with silty clay sediments. Salt-marsh vegetation is common along the shores. Lakes do not freeze to the bottom during the winter.
Deep Isolated Riverine Lake (Wldir)	Deep (≥4.9 ft [1.5 m]) waterbodies formed in old river channels. They do not freeze to the bottom during winter. These lakes have no distinct outlets. They are connected to rivers only during flood events. Sediments are fine-grained silt and clay.
Deep Isolated Thaw Lake (Wldit)	Deep (≥4.9 ft [1.5 m]) waterbodies that do not freeze to the bottom during winter. These lakes have no distinct outlets, and are not connected to rivers. The lakes develop from thawing of ice-rich permafrost. Sediments are fine-grained silt and clay
Deep Tapped Riverine Lake, High-water Connection (Wldcrh)	Deep (≥4.9 ft [1.5 m]) waterbodies that have been partially drained through erosion of banks by adjacent river channels, and are connected to rivers by channels that are dry during low water as these lakes are connected only during flooding events. Water tends to be fresh. Because water levels have dropped after tapping, the lakes generally have broad flat shorelines with silty clay sediments and small deltaic fans are common near the connecting channels due to deposition during seasonal flooding. These lakes do not freeze to the bottom during winter. Sediments are fine-grained silt and clay with some sand.
Shallow Connected Riverine Lake (Wlscr)*	Shallow (<4.9 ft [1.5 m]) ponds or small lakes with or without emergent vegetation. Lakes form in abandoned channels and old oxbows and have a channel or outlet to the adjacent stream. Water freezes to the bottom during winter, thaws by early to mid-June, and is warmer than water in deep lakes. Sediments are sand, silt, and clay.
Shallow Isolated Riverine Lake (Wlsir)	Shallow (<4.9 ft) [1.5 m] ponds or small lakes with or without emergent vegetation. Lakes form in abandoned channels and old oxbows. Water freezes to the bottom during winter, thaws by early to mid-June, and is warmer than water in deep lakes. Sediments are sand, silt, and clay.
Shallow Isolated Thaw Lake (Wlsit)	Shallow (<4.9 ft [1.5 m]) ponds or small lakes with or without emergent vegetation. Water freezes to the bottom during winter, thaws by early to mid-June, and is warmer than water in deep lakes. Sediments are fine-grained silt and clay. These ponds most commonly are found within Ice-rich Thaw Basins
Tidal River (Wert)	Permanently flooded channels of the Colville River that are affected by daily tidal fluctuations and have correspondingly variable salinity. The channels generally experience peak flooding during spring breakup and lowest water levels during mid-summer. During winter unfrozen water in deeper channels can become hypersaline

Table 3.14. Classification and description of surface form types in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Classes modified from Jorgenson et al. (1997, 2003) and Roth et al. (2006). Surface form types that were identified in the field but not mapped are identified with an asterisk.

Surface Form	Description
Bluffs or Banks (Sb)	Moderate to steep slopes of unconsolidated material. Banks form from undercutting by streams and rivers or thermal erosion due to transfer of heat by water and wind at lake margins.
Disjunct Polygon Rims (Pd)	Disjunct Polygon Rims are found where ice-wedge development is not sufficiently advanced to create closed polygons. This surface form is common in recently-drained thaw basins and isolated depressions in older basins where ice wedges are actively developing.
High-centered, High-relief Polygons (Phh)	These units are comprised of high-centered polygons in which progressive thawing of the ice wedge causes subsidence, resulting in the development of deep (>4.9 ft [0.5 m]) troughs. This thermokarst process frequently is related to changes in drainage adjacent to river and lake banks or surface disturbance.
High-centered, Low-relief Polygons (Phl)	Similar to above, but polygon centers are only slightly raised (<1.5 ft [50 cm]) with respect to the troughs. This class also includes “flat-centered” polygons where the relief between centers and troughs is barely noticeable. This surface form is common on old surfaces such as Delta Abandoned Overbank Deposits, or older ice-rich drained basins.
Human Modified (Hm)	Actively maintained and recently abandoned gravel roads, pads, and fill.
Lake with Islands (Wi)	Lakes with one or more islands present. Island s must be at least 3.3 ft (1 m) across and 9.8 ft (3 m) from the shore to be included in this class.
Low-centered, High-relief, High-density Polygon (Plhh)	Low-centered polygons are composed of a low-lying, often wet or flooded "center" surrounded by a “rim” that separates the center from adjacent polygons. Rims are underlain by ice wedges. Low-centered polygons in this class have rims that exceed 1.5 ft (50 cm) in height with respect to centers. High-relief polygons are more likely to have well-developed troughs between polygon rims. Relief can be accentuated by thaw settlement of the polygon center. High-density polygons are relatively small (~26.2–49.2 ft [~8 to 15 m] across), resulting in high microtopographic variability.
Low-centered, High-relief, Low-density Polygons (Plhl)	Similar to the above, with rims greater than 1.6 ft (50 cm) tall, but the individual polygons are larger (~49.2–98.4 ft [~15 to 30 m] across).
Low-centered, Low relief, High-density Polygons (Pllh)	Similar to the preceding class, with rims less than 50 cm tall, but individual polygons are relatively small (~26.2–49.2 ft [~8 to 15 m] across).
Low-centered, Low-relief, Low-density Polygons (Plll)	Similar to the preceding Low-centered Polygon classes, but rims are less than 1.6 ft (50 cm) tall. Low-density polygons are relatively large (~49.2–98.4 ft [~15 to 30 m] across). Larger polygons often are partially bisected by indistinct rims, which overlie newly-developing ice wedges.

Table 3.14. Continued.

Surface Form	Description
Mixed High- and Low-centered Polygons (Pm)	This surface form refers to a polygonal network in which individual features are transitioning from low- to high centers. This is caused when the ice wedges between low center polygons begin to melt, and drainage is altered. Also, the accumulation of organic matter and ground ice in the low centers can raise the surface to high-centers.
Mixed Thermokarst Pits and Polygons (Tm)	This class contains elements of both high- and low-centered polygons and is characterized by flooded, often deep 6.6 ft (2 m) thermokarst pits at the intersections of polygon troughs. The pits form due to thaw of the uppermost parts of ice wedges, resulting in surface subsidence.
Nonpatterned (N)	Flat areas that lack polygonal rims caused by the development of ice wedges. Ice wedges may be present, but are not expressed in the surface form. Small, elevated microsites (if present) generally are <1.0 ft (30 cm) high and compose less than 5% of the surface area. Nonpatterned ground includes some of the youngest portions of the tundra landscape, such as recently drained thaw lakes or young floodplains, where ground ice is not abundant.
Polygon Center (Pc)*	The center of well-developed ice-wedge polygons, including wet depressions bounded by rims formed by ice wedges (low-center), or flat to slightly convex surfaces bounded by ice wedge troughs (high-center)
Polygon Rims (Pr)*	The outer rim of defined ice-wedges. Polygon rims are often associated with low-centered ice-wedge polygons. These rims form when frozen material is forced upwards, thus raising the rims.
Ripples (Dr)*	Small scale features formed in sandy and silty deposits on Delta Active Channel Deposits or Eolian Active Sand Dunes. This surface form feature is characterized by repeating, sinuous, linear form created by wind or water movement. Ripples on active channels were mapped as Nonpatterned.
Small Dune (Es)	Elongated mounds or low ridges composed of wind-blown sand. This surface is found adjacent to Delta Active Channel Deposits, generally found on the west (prevailing downwind) side of the Colville River.
Streaked Dune (Ek)	A form of dune surface characterized by thin, elongate strips or stringers.
Troughs (Degraded ice-wedges) (Tt)*	A shallow (<4.9 ft [1.5 m]), narrow (1.6–3.3 ft [0.5 to 1 m]), linear wet depression formed by the melting ice wedges that typically form the outer boundary of high-center polygons.
Water (W)	Permanent waterbodies without islands.
Water Tracks (Dt)	Found in areas where elevation and drainage are sufficient to cause small swales and ephemeral drainage ways but not an incised drainage. Most water tracks are connected polygon troughs in depressed areas of gentle slopes, but they also form short flooded connections between lakes. Water commonly is present throughout the summer months.

Table 3.15. Areal extent of surface forms in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Area is reported in acres, hectares (ha), and percent of the CD5 Habitat Monitoring Study Area.

Surface Form	Acres	ha	%
Bluffs or Banks	69.2	28.0	0.7
Disjunct Polygon Rims	2,064.9	835.7	19.6
High-centered, High-relief Polygons	8.3	3.4	0.1
High-centered, Low-relief Polygons	222.2	89.9	2.1
Human Modified	19.6	7.9	0.2
Lake with Islands	781.3	316.2	7.4
Low-centered, High-relief, High-density Polygons	470.0	190.2	4.5
Low-centered, High-relief, Low-density Polygons	401.1	162.3	3.8
Low-centered, Low-relief, High-density Polygons	476.2	192.7	4.5
Low-centered, Low-relief, Low-density Polygons	2,042.1	826.4	19.4
Mixed High and Low-centered Polygons	161.1	65.2	1.5
Mixed Thermokarst Pits and Polygons	58.7	23.8	0.6
Nonpatterned	2,106.8	852.6	20.0
Small Dune	124.9	50.6	1.2
Streaked Dune	120.6	48.8	1.1
Water	1,414.2	572.3	13.4
Water Tracks	5.0	2.0	<0.1
TOTAL	10,546.3	4,267.9	100.0

increases from 0% in nonpatterned areas to 20% in low-centered, high-density polygons.

Surface forms also greatly influence drainage patterns and soil moisture. Nonpatterned areas commonly are dominated by vigorously growing sedge meadows and appear to be more productive than polygonized meadows, presumably because subsurface movement of water and nutrients is not impeded by the frozen soils underneath the polygon rims. Surface form is also important for wildlife habitat. For instance, large snowbanks often form on the leeward side of Bluffs and Banks and, when located within several miles of the Beaufort Sea Coast, provide important polar bear denning sites. Additionally, polygon rims associated with Low-centered, Low-relief, Low-density Polygons are important nesting sites for White-fronted Geese. Surface forms specific to water were differentiated because they are important for mapping waterbird habitat. For example, Lakes with Islands were mapped separately from rivers and lakes without islands because several species of waterbirds prefer nesting on islands.

Vegetation

Twenty vegetation classes (Level IV, AVC) were identified in the overall CD5 Habitat Monitoring Study Area (Figure 3.13, Table 3.16). Wet Sedge Meadow Tundra, Fresh Water, and Wet Sedge–Willow Tundra represent the dominant cover classes, totaling 22.6%, 19.2%, and 17.6% areal cover, respectively, across the entire CD5 Habitat Monitoring Study Area (Table 3.17). Other relatively common vegetation classes include Open Low Willow (7.9%), Deep Polygon Complex (6.4%), Barrens (6.1%), and Open Low Willow–Sedge Shrub Tundra (5.7%). All other vegetation classes account for less than 4% of the CD5 Habitat Monitoring Study Area.

Classifying the vegetation is important as vegetation provides food and cover for wildlife, both of which are essential for wildlife habitat. In

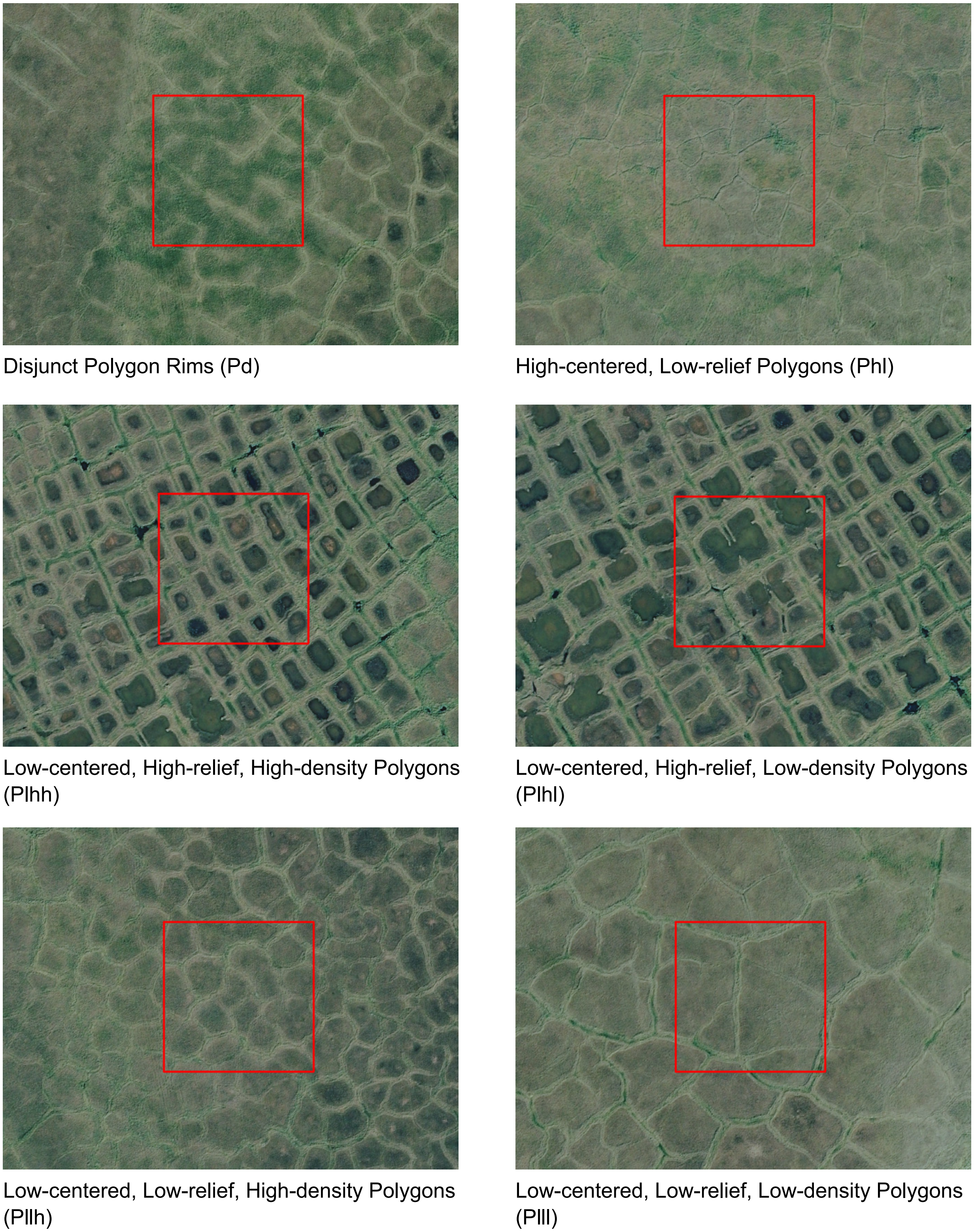
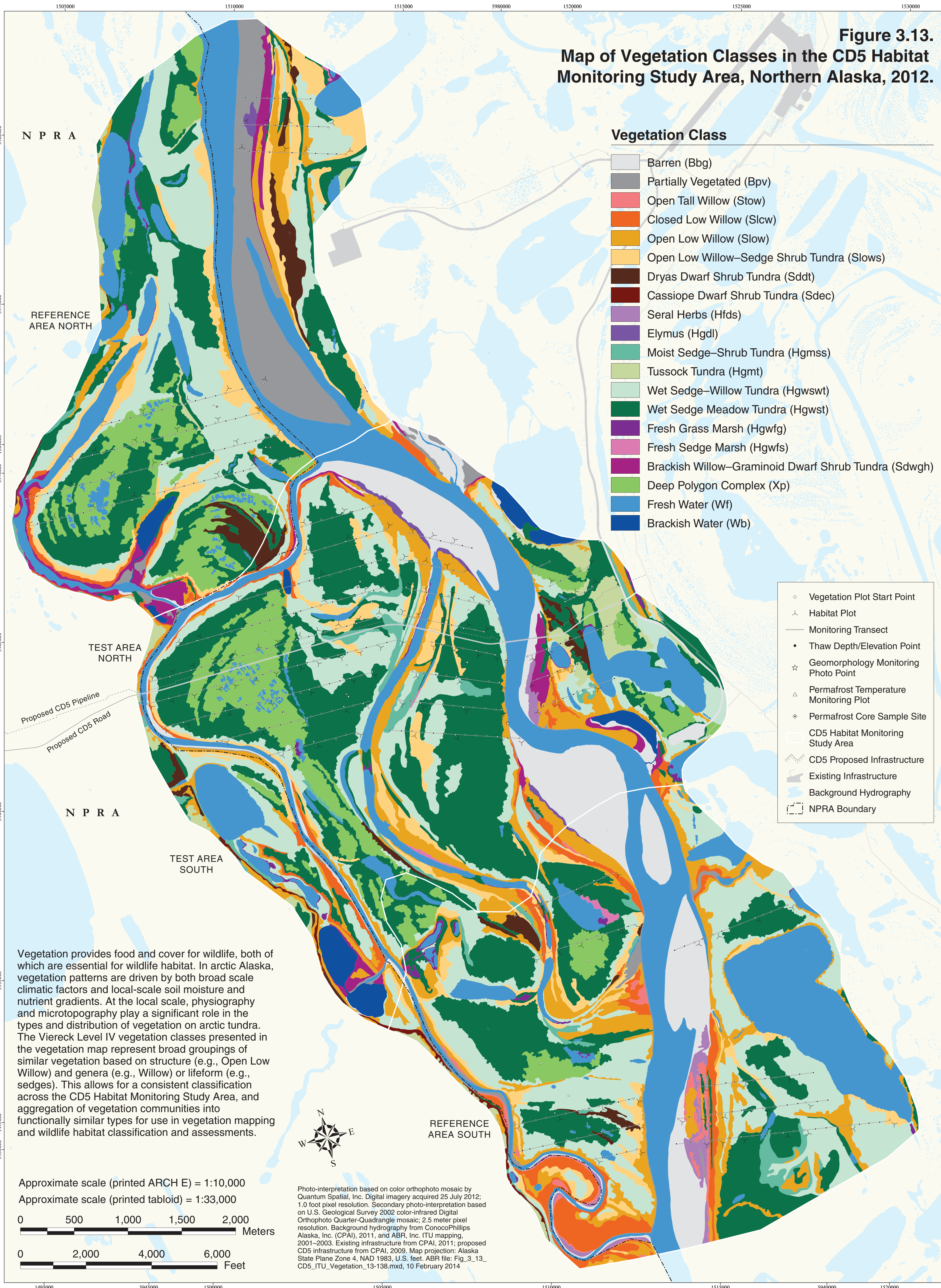


Figure 3.12. Examples of common ice-wedge polygon surface forms in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Red bounding box highlights each respective type and provides scale; bounding box represents an area of approximately 328×328 ft (100×100 m) on the ground. Background imagery is a color orthophotograph mosaic by Quantum Spatial, Inc. Digital imagery acquired 25 July 2012; 1.0-ft pixel resolution.

Figure 3.13. Map of Vegetation Classes in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2012.



Vegetation provides food and cover for wildlife, both of which are essential for wildlife habitat. In arctic Alaska, vegetation patterns are driven by both broad scale climatic factors and local-scale soil moisture and nutrient gradients. At the local scale, physiography and microtopography play a significant role in the types and distribution of vegetation on arctic tundra. The Viereck Level IV vegetation classes presented in the vegetation map represent broad groupings of similar vegetation based on structure (e.g., Open Low Willow) and genera (e.g., Willow) or lifeform (e.g., sedges). This allows for a consistent classification across the CD5 Habitat Monitoring Study Area, and aggregation of vegetation communities into functionally similar types for use in vegetation mapping and wildlife habitat classification and assessments.

Photo-interpretation based on color orthophoto mosaic by Quantum Spatial, Inc. Digital imagery acquired 25 July 2012; 1.0 foot pixel resolution. Secondary photo-interpretation based on U.S. Geological Survey 2002 color-infrared Digital Orthophoto Quarter-Quadrangle mosaic; 2.5 meter pixel resolution. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2011, and ABR, Inc. ITU mapping, 2001–2003. Existing infrastructure from CPAI, 2011; proposed CD5 infrastructure from CPAI, 2009. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_3_13_CD5_ITU_Vegetation_13-138.mxd, 10 February 2014

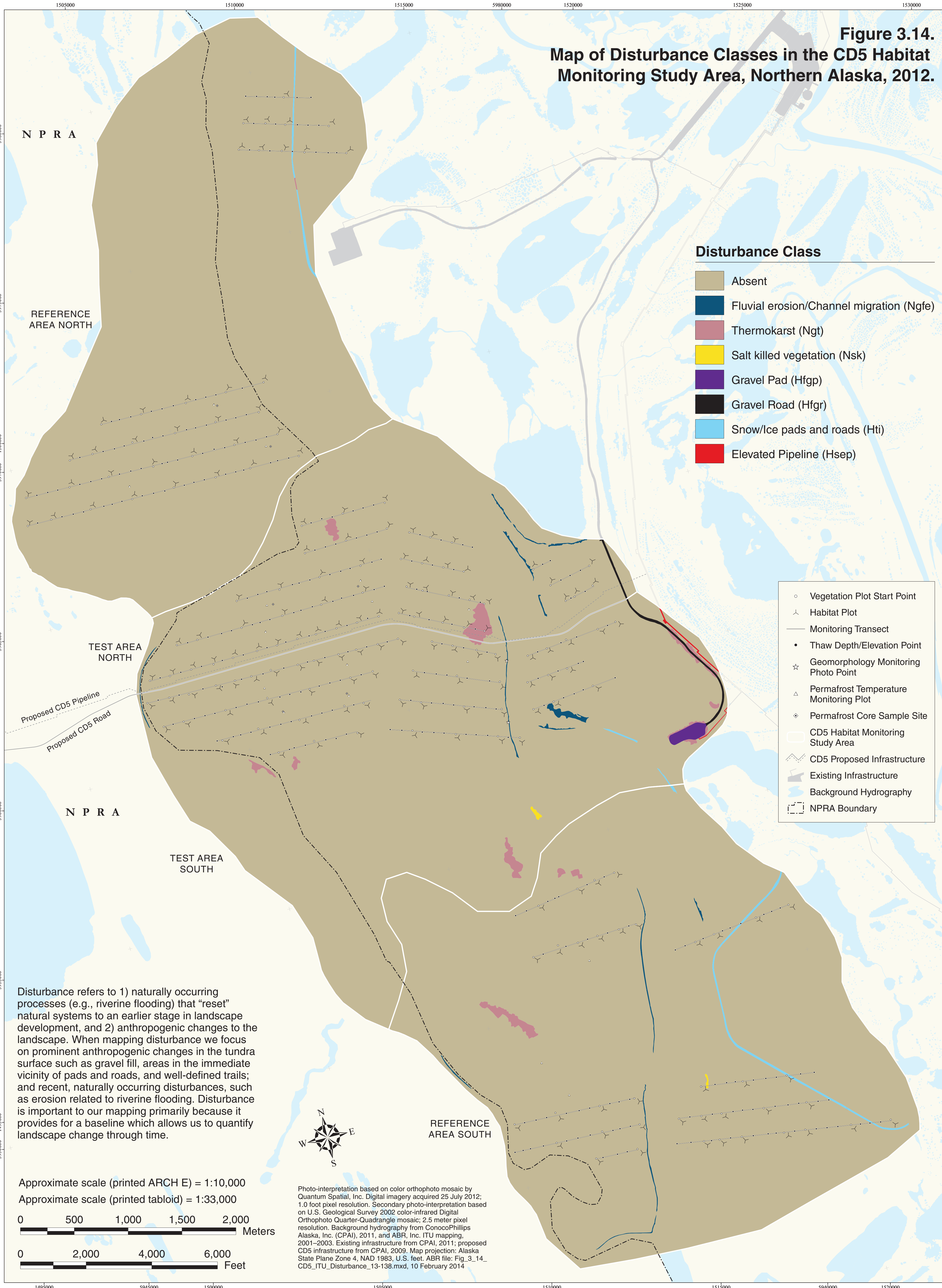


Figure 3.14. Map of Disturbance Classes in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2012.

Disturbance refers to 1) naturally occurring processes (e.g., riverine flooding) that "reset" natural systems to an earlier stage in landscape development, and 2) anthropogenic changes to the landscape. When mapping disturbance we focus on prominent anthropogenic changes in the tundra surface such as gravel fill, areas in the immediate vicinity of pads and roads, and well-defined trails; and recent, naturally occurring disturbances, such as erosion related to riverine flooding. Disturbance is important to our mapping primarily because it provides for a baseline which allows us to quantify landscape change through time.

Approximate scale (printed ARCH E) = 1:10,000

Approximate scale (printed tabloid) = 1:33,000

Photo-interpretation based on color orthophoto mosaic by Quantum Spatial, Inc. Digital imagery acquired 25 July 2012; 1.0 foot pixel resolution. Secondary photo-interpretation based on U.S. Geological Survey 2002 color-infrared Digital Orthophoto Quarter-Quadrangle mosaic; 2.5 meter pixel resolution. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2011, and ABR, Inc. ITU mapping, 2001–2003. Existing infrastructure from CPAI, 2011; proposed CD5 infrastructure from CPAI, 2009. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_3_14_CD5_ITU_Disturbance_13-138.mxd, 10 February 2014

Table 3.16. Classification and description of vegetation classes in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Classes adapted from Viereck et al. (1992). Vegetation classes that were identified in the field but not mapped are identified with an asterisk.

Vegetation Class	Description
Barrens (Bbg)	Nonvegetated areas on river bars and active sand dunes that are too young or unstable or to support more than a few pioneering plants (<5% cover). Typical pioneer species include *Salix alaxensis, Festuca rubra*, *Deschampsia caespitosa,* and *Elymus arenarius* ssp. *mollis*.
Brackish Water (Wb)	Permanently flooded, non-vegetated, brackish waterbodies, including isolated and connected brackish lakes, tidal lakes, tidal guts, and tidal rivers. Saltwater incursions are limited to storm- and wind-driven marine water in non-tidal lakes.
Cassiope Dwarf Shrub Tundra (Sdec)	Old dunes and banks on Eolian Inactive Sand Deposits, and steep bluffs along Old Alluvial Terraces. Compared with *Dryas* Dwarf Shrub Tundra, with which this class shares some species, *Cassiope* Dwarf Shrub Tundra is less well drained, has shallower thaw depths, and can occur on sandy or loamy soils. *Cassiope* dominated sites typically are very species rich. Common associated species include *Dryas integrifolia, S. phlebophylla, Salix reticulata, Vaccinium vitis-idaea, Carex bigelowii, Hierochloe alpina*, and *Arctagrostis latifolia*. Cryptogams present include crustose lichens, *Hylocomium splendens*, *Dicranum* sp*., Tomentypnum nitens, and Rhytidium rugosum*. All sites have a wide variety of forbs.
Closed Low Willow (Slcw)	Thickets of low-growing willows that form a dense, closed canopy (>75% cover). This class occurs on well-drained overbank deposits or inactive sand dunes. Dominant willows include one or more of *Salix alaxensis, S. glauca,* and *S. richardsonii*. The understory commonly includes dwarf shrubs such as *Arctostaphylos rubra, Dryas integrifolia, S. reticulata;* forbs such as *Lupinus arcticus;* and mosses such as *Tompentypnum nitens.*
Deep Polygon Complex (Xp)	Mosaic of vegetation on inactive and abandoned floodplains where low-centered polygons have particularly deep (>1.6 ft [0.5 m]) centers formed by thaw settlement of ice-rich soils. Permanently flooded nonvegetated polygon centers are fringed by Fresh Grass or Sedge Marsh. Broad, low, rims of Wet Sedge Meadow or Moist Sedge–Shrub Tundra separate the centers. While water forms a substantial portion of this class, no single vegetation type or water is dominant.
Dryas Dwarf Shrub Tundra (Sddt)	Dry, upland, sandy slopes, crests, and well-drained river terraces dominated by *Dryas integrifolia*. Most commonly associated with Inactive Eolian Sand Deposits and small dunes, *Dryas* Dwarf Shrub Tundra also is found on nonpatterned ground and high-centered polygons on Delta Inactive Overbank Deposits. Inactive dune sites are strongly dominated by *Dryas* and occasionally co-dominated by lichens. Associated species include *Salix glauca, S. reticulata, Arctostaphylos alpina, Arctagrostis latifolia, Thamnolia vermicularis,* and *Cetraria cuculata*. Riverine sites may have co-dominant species such as *Equisetum variegatum* and *Salix reticulata*, with *S. lanata richardsonii, Arctostaphylos rubra, Oxytropis deflexa, Tomentypnum nitens*, and *Thamnolia vermicularis* as associated species. Sedges (e.g. *Carex scirpoidea*) may be present on moist sites but are never co-dominant. Soils are sandy, well to somewhat excessively drained, and thaw depths often exceed 1.0 m.
Dryas–Forb Dwarf Shrub Tundra (Sddf)*	Similar to *Dryas*–Sedge Dwarf Shrub tundra, but forb cover is very prominent above the dwarf shrub mat. Common forbs include *Lupinus arcticus* and *Petasites frigidus*. This class was only found once, on a well-drained overbank deposit. This vegetation class was aggregated with *Dryas* Dwarf Shrub Tundra for mapping.

Table 3.16. Continued.

Vegetation Class	Description
Dryas–Sedge Dwarf Shrub Tundra (Sdds)*	Well-drained tops of high-centered polygons dominated by *Dryas integrifolia.* These communities are co-dominated by sedges, although vegetation cover is often discontinuous in exposed sites. Associated species include *Carex bigelowii*, *Salix reticulata, Arctagrostis latifolia, Poa arctica, Tomenthypnum nitens*. This class is rare in the study area and is restricted to well-drained overbanks and stabilized dunes. This vegetation class was aggregated with *Dryas* Dwarf Shrub Tundra for mapping.
Elymus (Hgdl)	This vegetation class is uncommon in the study area and was found only on active sand dunes. Vegetation cover is discontinuous and is dominated by the grass *Leymus mollis*. Associate species vary widely by site and can include scattered willows, forbs such as as *Parnassia Kotzebuei, Oxytropis borealis* and *Hedysarum alpinum*, and sedges such as *Carex krausei.* Mosses are scarce.
Fresh Grass Marsh (Hgwfg)	Shallow marshes dominated by the aquatic emergent grass *Arctophila fulva*. This class was occasionally found in small flooded areas on older overbank deposits, and along pond margins. Water depths generally are <3.3 ft (1.0 m). *Hippuris vulgaris, Utricularia intermedia* and *Carex aquatilis* may be present in water <1.6 ft (0.5 m) deep.
Fresh Sedge Marsh (Hgwfs)	Permanently flooded shallow water on overbank deposits dominated by *Carex aquatilis*. Water depth mostly is ≤1.6 ft (0.5m) deep. Common associates include the mosses *Scorpidium scorpioides* and *Calliergon giganteum*, and vascular plants *Eriophorum angustifolium, Caltha palustris*, and *Ranunculus* spp.
Fresh Water (Wf)	Permanently flooded waterbodies that lack emergent vegetation, including lakes, ponds, and distributaries of the Colville River Delta.
Halophytic Willow Dwarf Shrub (Sdwh)*	Similar to Willow Dwarf Shrub Tundra, this class is rare and was found on an inactive river channel in the northern (seaward) part of the study area that is occasionally affected by saltwater intrusion. Vegetation cover is discontinuous; the grass *Deschampsia caespitosa* and the sedge *Carex maritima* are common associates. This vegetation class was aggregated with Brackish Willow–Graminoid Dwarf Shrub Tundra for mapping.
Halophytic Willow–Graminoid Dwarf Shrub Tundra (Sdwgh)	This rare class is similar to Halophytic Willow Dwarf Shrub, except that dwarf willows are less abundant and there is extensive cover of the salt-tolerant grass, *Dupontia fisheri*. Sedges such as *Eriophorum angustifolium* and *Carex aquatilis* are also common.
Mixed Herbs (Hfmm)*	This forb-dominated class is found on frequently flooded or disturbed sites on active and inactive river channels, as well as active sand dunes. Species composition varies considerably by site but commonly includes *Artemisia tilesii, Chrysanthemum bipinnatum, Equisetum arvense*, *Hedysarum alpinum*, and *Astragalus alpinus*. Common associates include grasses, such as *Deschampsia caespitosa* and *Festuca rubra*, and scattered willows. Vegetation cover is discontinuous; mosses and lichens are scarce or absent.
Moist Sedge–Shrub Tundra (Hgmss)	This class is occasionally found on mesic overbank deposits, usually in association with the elevated rims of low-center polygons. Vegetation is co-dominated by dwarf shrubs and sedges, particularly *Dryas integrifolia, Salix reticulate, Carex bigelowii,* and *Eriophorum angustifolium.* Associate species include *S. pulchra, C. membranacea, C. aquatilis, Lupinus arcticus, Tomentypnum nitens, Flavocetraria nivalis, Hylocomium splendens,* and *Thamnolia vermicularis*. Soils have a shallow surface organic layer, and are saturated at intermediate depths (>0.7 ft [20 cm]).

Table 3.16. Continued.

Vegetation Class	Description
Moist Sedge–Willow Tundra (Hgmswt)*	Similar to Moist Sedge–Shrub Tundra except vegetation is co-dominated specifically by willows. This class is also found on older overbank deposits, usually in association with mesic microsites on the rims of low-center polygons. Dominant plants include *Salix pulchra*, *S. arctica*, *Eriophorum angustifolium*, *Carex aquatilis*, *C. maritima* and *Tomentypnum nitens*. Included in Moist Sedge–Shrub Tundra class for mapping.
Open Low Willow (Slow)	Low-growing willows that form an open canopy (25–75% cover). This class is common primarily on mesic overbank deposits and inactive sand dunes. Several willow species may be dominant, including *Salix richardsonii, S. glauca,* and *S. pulchra.* On overbank deposits, common associates include forbs such as *Artemisia tilesii, Equisetum arvense,* and *Lupinus arcticus*. On dunes, *Salix glauca* is usually dominant and common associates include *Arctostaphylos alpina, Festuca rubra,* and *Oxytropis borealis.* Sedges, such as *Carex bigelowii*, can be common but they do not provide much live cover.
Open Low Willow–Sedge Shrub Tundra (Slows)	Similar to Open Low Willow, but soils are usually wet and there is considerable cover of sedges, such as *Carex aquatilis* and *Eriophorum angustifolium*, and hydrophytic mosses such as *Calliergon giganteum* and *Drepanocladus* spp. *Salix richardsonii* is the dominant willow. This class is very common on inactive and abandoned overbank deposits of the Colville River, usually in nonpatterned areas.
Open Mixed Low Shrub–Sedge Tussock Tundra (Slott)*	This class is co-dominated by the tussock-forming sedge *Eriophorum vaginatum* and a mixture of low- and dwarf shrubs with >25% total cover, including *Salix pulchra*, *Ledum decumbens*, and *Vaccinium vitis-idaea*. Mosses also may be abundant including *Dicranum* sp., *Polytrichum strictum, Hylocomium splendens, Aulacomnium palustre*, and *Sphagnum* spp. This class is restricted to old surfaces associated with Delt Abandoned Overbank Deposits and Alluvial Terraces. Soils are acidic and organic-rich, with shallow thaw depth (<1.6 ft [50 cm]). This vegetation class was aggregated with Tussock Tundra for mapping.
Open Tall Willow (Stow)	Tall (≥4.9 ft [1.5 m]) riparian willows, mostly *Salix alaxensis*, that form an open canopy (25–75% cover). This class occurs locally on inactive channel deposits of the Colville River. The understory commonly includes the forbs *Aster sibiricus, Astragalus alpinus, Hedysarum alpinum,* and *Equisetum arvense*, as well as grasses including *Bromus pumpellianus, Deschampsia caespitosa,* and *Festuca rubra*.
Partially Vegetated (Bpv)	Sparsely vegetated areas on river bars and active sand dunes that are too young or disturbed to support continuous cover of vegetation (<30% cover). Typical species on river bars include *Salix alaxensis, Festuca rubra*, *Deschampsia caespitosa, Elymus arenarius* ssp. *mollis, Chrysanthemum bipinnatum,* and *Equisetum arvense*. On sand dunes, *Salix richardsonii, S. alaxensis, Astragalus alpinus, D. caespitosa,* and *Leymus mollis* are more common.
Seral Herbs (Hfds)	Partially vegetated (5–30% cover) to vegetated (>30%) areas on Inactive Channel Deposits supporting a diverse mixture of early successional forb species, most notably *Chrysanthemum bipinnatum* and *Equisetum arvense*. Bare soil cover is typically high (>75%). Other common taxa include *Artemisia tilesii, Astragalus alpinus, Deschampsia caespitosa, Festuca rubra, Pedicularis verticillata,* and *Wilhelmsia physodes*. Willow (*Salix* spp.) seedlings are common at low abundance.

Table 3.16. Continued.

Vegetation Class	Description
Tussock Tundra (Hgmt)	This vegetation class is dominated by the tussock-forming sedge *Eriophorum vaginatum*. It is uncommon in the study area but is occasionally present on old abandoned overbank deposits and terraces. Common vascular species also include *Salix pulchra, E. angustifolium, Ledum decumbens, Vaccinium vitis-idaea, Poa arctica, Hierochloe alpina, Luzula confusa,* and *Cassiope tetragona.* Soils are moist, circumneutral, and thaw depth is usually <1.6 ft [50 cm] from the surface.
Wet Sedge Meadow Tundra (Hgwst)	Low-lying, poorly drained areas with vegetation dominated by *Carex aquatilis, Eriophorum angustifolium,* and hydrophytic mosses. Wet Sedge Meadow Tundra is widespread in the study area on poorly-drained overbank deposits, often in low-center polygon centers. Associate vascular plants include *C. saxatilis*, *C. misandra*, *Salix pulchra, Saxifraga hirculis,* and *Pedicularis sudetica.* Common mosses include *Scorpidium scorpioides*, *Tomentypnum nitens, Drepanocladus* spp., and *Aulacomnium turgidum*. Wet Sedge Meadow Tundra generally is flooded during early summer (depth <1.0 ft [0.3m]) and water remains close to the surface throughout the growing season. Soils usually have a moderately thick organic layer.
Wet Sedge–Willow Tundra (Hgwswt)	Similar to Wet Sedge Meadow Tundra, but dwarf- and low willow shrubs such as *Salix richardsonii* and *S. pulchra* are common on better-drained microsites associated with the rims of low-center polygons. Soils usually have a moderately thick organic layer.
Willow Dwarf Shrub Tundra (Sdwt)*	Dwarf willows, primarily *Salix ovalifolia*, form an open to closed, prostrate mat. Associate species include *Arctagrostis latifolia, Festuca rubra,* and *Polygonum viviparum,*. This class is uncommon in the study area and was occasionally found on abandoned overbanks and channels, as well as sandy deposits. This vegetation class was aggregated with *Dryas* Dwarf Shrub Tundra for mapping.

Arctic Alaska, vegetation patterns are driven by both broad-scale climatic factors and local-scale soil moisture and nutrient gradients. At the local scale, physiography and microtopography play a significant role in the types and distribution of vegetation on arctic tundra. The Viereck Level IV vegetation classes presented in the vegetation map (Figure 3.13) represent broad groupings of similar vegetation based on structure (e.g., Open Low Willow) and genera (e.g., willow) or lifeform (e.g., sedges). This allows for a consistent classification across the CD5 Habitat Monitoring Study Area, and for aggregating vegetation communities into functionally similar types for use in vegetation mapping and wildlife habitat classification and assessments.

Disturbance

Disturbance refers to both naturally occurring processes (e.g., riverine flooding) that "reset" natural systems to an earlier stage in landscape development, and anthropogenic changes to the landscape. When mapping disturbance, ABR focuses on prominent anthropogenic changes to the tundra surface, such as areas in the immediate vicinity of pads and roads, and well-defined trails; and recent, naturally occurring disturbances, such as riverine flooding, wind erosion, and thermokarsting. Disturbance is important to mapping primarily because it provides a baseline for quantifying landscape change through time.

ABR identified and mapped 8 disturbance categories within the overall CD5 Habitat Monitoring Study Area (Figure 3.14, Table 3.18). Limited evidence of anthropogenic or natural disturbance is present in the vast majority of the area. The areal extent of undisturbed ground is 98.9% (Table 3.19). Thermokarst, which refers to the pitted landscape in permafrost regions resulting from the subsidence of thawing, ice-rich ground related to either natural or anthropogenic causes, is the most common disturbance type (0.5% areal

Table 3.17. Areal extent of vegetation classes in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Area is reported in acres, hectares (ha), and percent of the CD5 Habitat Monitoring Study Area.

Vegetation Class	Acres	ha	%
Barren	642.3	259.9	6.1
Brackish Water	125.1	50.6	1.2
Cassiope Dwarf Shrub Tundra	22.0	8.9	0.2
Closed Low Willow	301.4	122.0	2.9
Deep Polygon Complex	671.9	271.9	6.4
Dryas Dwarf Shrub Tundra	159.3	64.4	1.5
Elymus	23.3	9.4	0.2
Fresh Grass Marsh	37.5	15.2	0.4
Fresh Sedge Marsh	9.9	4.0	0.1
Fresh Water	2,030.1	821.6	19.2
Halophytic Willow–Graminoid Dwarf Shrub Tundra	129.0	52.2	1.2
Moist Sedge–Shrub Tundra	134.5	54.4	1.3
Open Low Willow	838.3	339.3	7.9
Open Low Willow–Sedge Shrub Tundra	604.8	244.8	5.7
Open Tall Willow	38.2	15.5	0.4
Partially Vegetated	341.5	138.2	3.2
Seral Herbs	52.7	21.3	0.5
Tussock Tundra	139.6	56.5	1.3
Wet Sedge Meadow Tundra	2,386.4	965.8	22.6
Wet Sedge–Willow Tundra	1,858.5	752.1	17.6
TOTAL	10,546.3	4,267.9	100.0

Table 3.18 Classification and description of disturbance regime categories in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Class descriptions modified from Jorgenson et al. (1997, 2003) and Roth et al. (2006). Disturbance regime classes that were identified in the field but not mapped are identified with an asterisk.

Disturbance regime	Description
Absent (A)	No disturbance within approximately a 5-year period.
Elevated Pipeline (Hsep)	Pipelines which are all elevated to a minimum height of 5 ft (1.5 m) above ground level and supported by Vertical Support Members (VSMs).
Eolian Wind (Nge)*	Common along the western, downwind side of the Colville River, this category refers to the evolution of active dunes, or the remobilization of vegetated dunes due to eolian processes.
Fluvial (Ngf)*	Undifferentiated fluvial disturbance processes along active river channels and overbanks. Disturbances can be annual (e.g., flooding of active channels during peak flow in spring), but episodic events (e.g., large floods with low return periods) can affect much larger areas.
Fluvial Deposition (Ngfd)*	Fluvial disturbance associated with sediment deposition during and after flood events.
Fluvial Erosion/Channel Migration (Ngfe)	Fluvial disturbance associated with the evolution of distributary channels on the Colville River delta, such as cutbank erosion.
Gravel Pad (Hfgp)	Gravel and sandy gravel that has been placed as fill for pads. The gravel is obtained from deep riverbed deposits or gravelly coastal plain deposits.
Gravel Road (Hfgr)	Similar to above but the gravel here is placed as fill for roads.
Salt Killed Vegetation (Nsk)	Coastal areas where saltwater intrusions from storm surges have killed much of the original terrestrial vegetation and where salt-tolerant plants are actively colonizing.
Snow/Ice pads and Roads (Hti)	Disturbed vegetation due to previous placement of snow (from plowed gravel pads) or ice roads and pads on tundra.
Thermokarst (Ngt)	The processes associated with the thawing permafrost that leads to local or widespread collapse, subsidence, erosion and instability of the ground surface.

Table 3.19. Areal extent of disturbance classes in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Area is reported in acres, hectares (ha), and percent of the CD5 Habitat Monitoring Study Area.

Disturbance Class	Acres	ha	%
Absent	10425.0	4218.8	98.9
Elevated Pipeline	3.0	1.2	<0.1
Fluvial erosion/Channel migration	21.3	8.6	0.2
Gravel Pad	9.8	4.0	0.1
Gravel Road	9.9	4.0	0.1
Salt killed vegetation	1.7	0.7	<0.1
Snow/Ice pads and roads	23.9	9.7	0.2
Thermokarst	51.8	21.0	0.5
TOTAL	10546.3	4267.9	100.0

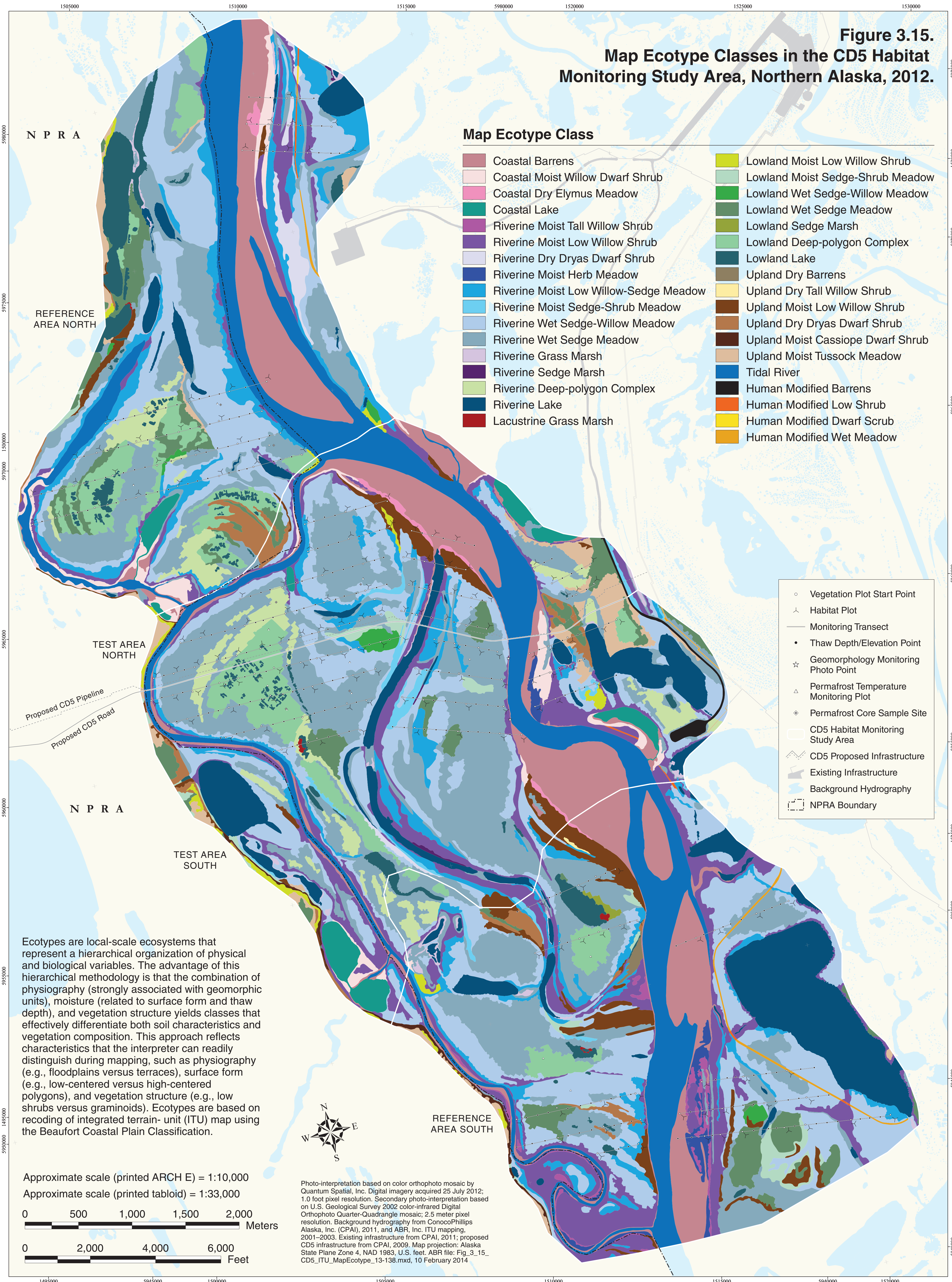


Figure 3.15.
Map Ecotype Classes in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2012.
Map Ecotype Class
Coastal Barrens
Coastal Moist Willow Dwarf Shrub
Coastal Dry Elymus Meadow
Coastal Lake
Riverine Moist Tall Willow Shrub
Riverine Moist Low Willow Shrub
Riverine Dry Dryas Dwarf Shrub
Riverine Moist Herb Meadow
Riverine Moist Low Willow-Sedge Meadow
Riverine Moist Sedge-Shrub Meadow
Riverine Wet Sedge-Willow Meadow
Riverine Wet Sedge Meadow
Riverine Grass Marsh
Riverine Sedge Marsh
Riverine Deep-polygon Complex
Riverine Lake
Lacustrine Grass Marsh
Lowland Moist Low Willow Shrub
Lowland Moist Sedge-Shrub Meadow
Lowland Wet Sedge-Willow Meadow
Lowland Wet Sedge Meadow
Lowland Sedge Marsh
Lowland Deep-polygon Complex
Lowland Lake
Upland Dry Barrens
Upland Dry Tall Willow Shrub
Upland Moist Low Willow Shrub
Upland Dry Dryas Dwarf Shrub
Upland Moist Cassiope Dwarf Shrub
Upland Moist Tussock Meadow
Tidal River
Human Modified Barrens
Human Modified Low Shrub
Human Modified Dwarf Scrub
Human Modified Wet Meadow
Vegetation Plot Start Point
Habitat Plot
Monitoring Transect
Thaw Depth/Elevation Point
Geomorphology Monitoring Photo Point
Permafrost Temperature Monitoring Plot
Permafrost Core Sample Site
CD5 Habitat Monitoring Study Area
CD5 Proposed Infrastructure
Existing Infrastructure
Background Hydrography
NPRA Boundary
N P R A
REFERENCE AREA NORTH
TEST AREA NORTH
Proposed CD5 Pipeline
Proposed CD5 Road
N P R A
TEST AREA SOUTH
REFERENCE AREA SOUTH
N
E
W
S
Ecotypes are local-scale ecosystems that represent a hierarchical organization of physical and biological variables. The advantage of this hierarchical methodology is that the combination of physiography (strongly associated with geomorphic units), moisture (related to surface form and thaw depth), and vegetation structure yields classes that effectively differentiate both soil characteristics and vegetation composition. This approach reflects characteristics that the interpreter can readily distinguish during mapping, such as physiography (e.g., floodplains versus terraces), surface form (e.g., low-centered versus high-centered polygons), and vegetation structure (e.g., low shrubs versus graminoids). Ecotypes are based on recoding of integrated terrain- unit (ITU) map using the Beaufort Coastal Plain Classification.
Approximate scale (printed ARCH E) = 1:10,000
Approximate scale (printed tabloid) = 1:33,000
0 500 1,000 1,500 2,000 Meters
0 2,000 4,000 6,000 Feet
Photo-interpretation based on color orthophoto mosaic by Quantum Spatial, Inc. Digital imagery acquired 25 July 2012; 1.0 foot pixel resolution. Secondary photo-interpretation based on U.S. Geological Survey 2002 color-infrared Digital Orthophoto Quarter-Quadrangle mosaic; 2.5 meter pixel resolution. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2011, and ABR, Inc. ITU mapping, 2001–2003. Existing infrastructure from CPAI, 2011; proposed CD5 infrastructure from CPAI, 2009. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_3_15_CD5_ITU_MapEcotype_13-138.mxd, 10 February 2014

Table 3.20. Description of map ecotypes in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Class descriptions modified from Jorgenson et al. (1997, 2003) and Roth et al. (2006).

Ecotype	Descriptions
Coastal Barrens	Barren or partially vegetated (<30% cover) Delta Active Channel Deposits where frequent sedimentation restricts vegetation establishment. Sediments usually are saline, alkaline, have deep thaw depths and little organic accumulation. Common colonizing plants include *Deschampsia caespitosa, Elymus arenarius, Salix ovalifolia* and *Stellaria humifusa* in well-drained areas and *Puccinellia phryganodes, Dupontia fisheri,* and *Carex subspathacea* in wetter areas.
Coastal Dry *Elymus* Meadow	Somewhat poorly vegetated, well-drained meadows on Delta Active Channel Deposits characterized by the presence of *Leymus mollis*. Soils are brackish sands with little organic material and deep active layers. Commonly associated species include *Salix ovalifolia* and *Deschampsia caespitosa*.
Coastal Lake	Coastal waterbodies that are flooded periodically with saltwater during high tides or storm surges. Salinity levels often are increased by subsequent evaporation of impounded saline water. The substrate is loamy or sandy and occasionally contains peat. Shorelines usually have halophytic vegetation. Some Coastal Lakes have distinct outlets or have been partially drained (tapped) through erosion of adjacent banks. Shallow lakes (<5.0 ft [1.5m]) freeze to the bottom during winter.
Coastal Moist Willow Dwarf Shrub	Delta Active Channel Deposits and Delta Active Overbank Deposits with vegetation dominated by dwarf willow and graminoids. Soils on Delta Active Overbank Deposits are brackish, loamy (with variable organic horizons), saturated soils, with ground water depths ~0.8 ft (~25 cm) and active layer depths ~1.6 ft (~50 cm). Vegetation is dominated by *Salix ovalifolia, Carex subspathacea,* and *Deschampsia caespitosa*. On sandy sites *Leymus mollis* is a codominant. On Delta Active Overbank Deposits, soils are loamy, less brackish, and associated species include *Carex aquatilis,* and *Dupontia fisheri*.
Human Modified Barrens	Actively maintained and recently abandoned gravel roads, pads and fill.
Human Modified Dwarf Scrub	Dwarf shrub on ice road routes and areas adjacent to existing roads, pads and commercial or industrial developments that have been affected by the placement of ice roads, and dust and leaching from gravels. These are naturally occurring *Dryas* Dwarf ShrubTunda communities that may show signs of nutrient enhancement, thermokarst or other disturbance due to proximity to human development.
Human Modified Low Shrub	Low shrub on ice road routes that have been affected the placement of ice roads. These are naturally occurring Open Low Willow communities that may show signs damage, including broken and damaged stems.
Human Modified Wet Meadow	Wet meadow communities adjacent to roads and pads that are affected by dust, impoundment and leaching from gravels. These are naturally occurring communities that show signs of nutrient enhancement or thermokarst due to proximity to human development.

Table 20. Continued.

Ecotype	Descriptions
Lacustrine Grass Marsh	Vegetated, depressions and lakes (depth <3.3 ft [1m]), in Ice-poor Basins and shallow margins of deeper Lowland Lakes defined by the presence of *Arctophila fulva*. Water is alkaline to circumneutral and sediments have a variable peat layer (0.3-1.3 ft [10–40 cm] deep) overlying sands. *Hippuris vulgaris* and *Carex aquatilis* may be present in shallow water.
Lowland Lake	Deep (≥4.9 ft [1.5 m]) and shallow (<4.9 ft [1.5m]) lakes and ponds that form in low-lying basins and from thawing of ice-rich permafrost. These lakes lack riverine or coastal influences and emergent vegetation. In deep lakes, a substantial volume of deep water remains unfrozen through the winter. In shallow lakes, water freezes to the bottom during winter, thaws by early to mid-June, and is warmer than water in deep lakes. Sediments are sandy to loamy. Lowland lakes may or may not have distinct outlets or connections to rivers.
Lowland Moist Low Willow Shrub	Flats and gentle slopes with high-centered polygons or drainage tracks on Delta Abandoned Overbank Deposits and Ice-rich Thaw Basin deposits. Soils typically are somewhat poorly drained, and acidic with moderate to thick organic horizons. Vegetation is dominated by low willows (0.7-4.9 ft [0.2–1.5 m] tall), most commonly *Salix planifolia pulchra*. Common associated species include *S. reticulata, Carex bigelowii, C. aquatilis, Eriophorum angustifolium* and mosses.
Lowland Moist Sedge-Shrub Meadow	Typically High-centered, Low-relief Polygons on Delta AbandonedOverbank Deposits. Soils are saturated at intermediate depths (>0.5 ft [15cm]) but generally are free of surface water during summer. The active layer is relatively shallow and the organic horizon is moderate (0.3-0.5 ft [10–15 cm]). Vegetation is dominated by *Dryas integrifolia, Carex aquatilis* and *C. bigelowii*. Other common species include *C. misandra, Eriophorum angustifolium, E. vaginatum, Salix reticulata, S. rotundifolia, S. arctica* and the moss *Tomentypnum nitens*.
Lowland Sedge Marsh	Vegetated, permanently flooded, shallow (<1.6 ft [50 cm]) basins, most commonly on lake margins and the flooded centers of Low-center, High-relief, Low-Density Polygons. Surface waters are alkaline to circumneutral, sediments commonly are organic. Vegetation is dominated by *Carex aquatilis*, with *C. membranacea, Eriophorum angustifolium* and *Scorpidium scorpioides*.
Lowland Wet Sedge Meadow	Low-centered, Low-relief polygons, with water near the surface on Delta Abandoned Overbank Deposits. Overbank flooding is rare to infrequent and when it does occur is of short duration. However, the surface generally is flooded by rain and snow melt during early summer, soils are saturated throughout the growing season, and are circumneutral to acidic, with moderate to thick (0.7-1.3 ft [20–40 cm]) organic layers and moderately deep active layer depths (>1.3 ft [40 cm]). Vegetation is dominated by sedges, usually *Carex aquatilis* and *Eriophorum angustifolium*, with *C. saxatilis, Salix arctica, E. russeolum* and *S. planifolia* ssp. *pulchra*. Mosses typical of wet conditions are common, including *Limprichtia revolvens, Aulacomnium turgidum, Scorpidium scorpioides, Drepanocladus* spp. and *Sphagnum* spp. Drier polygon rims are populated by species typical of moist meadows including *Dryas integrifolia, Salix reticulata, Carex bigelowii* and *Cassiope tetragona*.

Table 20. Continued.

Ecotype	Descriptions
Lowland Wet Sedge-Willow Meadow	Delta Abandoned Overbank Deposits with Low-centered, Low-relief, Low-density Polygons. The wet soils are poorly drained, with the water table located close beneath the soil surface. Overbank flooding is rare to infrequent and when it does occur is of short duration. However, the surface generally is flooded rain and snow melt during early summer . Soils are saturated throughout the growing season and are organic-rich. The plant community is dominated by sedges, including *Carex aquatilis, Eriophorum* angustifolium. Low willows, most notably *Salix lanata* ssp. *richardsonii,* occur frequently at low abundance. Other characteristic taxa include *Eriophorum russeolum, Saxifraga hirculus, Polygonum viviparum, Aulacomnium turgidum*, and *Meesia triquetra*.
Riverine Deep-polygon Complex	This class is associated with natural permafrost degradation on Delta Inactive Overbank Deposits. Most polygon centers are deep (up to 6.6 ft [2 m]) and rims are broad and flat. Deep polygons support a fringe of marsh species such as *Arctophila fulva, Caltha palustris, Hippuris vulgaris* and *Carex aquatilis*. Rims are dominated by *Eriophorum angustifolium, Carex aquatilis, Dryas integrifolia*, and *Salix ovalifolia*. Shallow (<1.6 ft [0.5 m]) polygons support wet meadow vegetation dominated by *Carex aquatilis* and *Eriophorum angustifolium*.
Riverine Dry *Dryas* Dwarf Shrub	Delta Inactive Overbank Deposits of meander rivers with nonpatterned ground or high-centered polygons dominated by dwarf (<0.7 ft [0.2 m]) shrubs. The loamy to sandy soils are well-drained and alkaline with shallow (<0.5 ft [15 cm]) organic horizons and deep (>2.6 ft [80 cm]) active layer depths. The dwarf shrub *Dryas integrifolia* is dominant with *Salix reticulata*, *Equisetum variegatum, Oxytropis deflexa, Arctostaphylos rubra,* and lichens as common associates. This community is rare in the study area.
Riverine Grass Marsh	This class occurs along margins of shallow waterbodies on Delta Active- and Inactive Overbank Deposits. Due to shallow water depths (1.0-3.3 ft [0.3-1.0 m]), the water freezes to the bottom in the winter and the ice melts by early June. These sites usually have low pH values. The emergent vegetation is dominated by *Arctophila fulva, Dupontia* fisheri, and *Hippuris vulgaris* are common associates.
Riverine Lake	Shallow (<4.9 ft [1.5m]) and deep (≥4.9 ft [1.5m]) lakes associated with old river channels, point bars and meander scrolls and that lack emergent vegetation. Some may have connecting channels that flood during high water. Water freezes to the bottom during winter in shallow, but not in deep lakes. Water is alkaline to circumneutral and sediments are fine-grained.
Riverine Moist Herb Meadow	Active and Inactive Delta Channel deposits with sandy, moist, moderately well drained soil. The ground surface is dominated by bare soil. *Chrysanthemum bipinnatum*, and *Equisetum arvense* are the dominant species. Other characteristic taxa include *Artemisia tilesii*, *Astragalus alpinus*, *Deschampsia caespitosa*, *Festuca rubra*, *Pedicularis verticillata*, *Salix alaxensis*, and *Wilhelmsia physodes*
Riverine Moist Low Willow Shrub	Delta Active and Inactive Overbank Deposits with Nonpatterned ground or high-centered polygons dominated by low (<4.9 ft [1.5 m]) shrubs. Frequently flooded sites are well drained with little organic accumulation whereas infrequently flooded areas are moderately well drained with interbedded layers of fine mineral soil and organic material. Soils are circumneutral with relatively deep (>1.3 ft [40 cm]) active layer depths. Either *Salix lanata* ssp. *richardsonii* or *S. planifolia* ssp. *pulchra* is dominant with *Eriophorum angustifolium, Carex aquatilis* and mosses in the understory.

Table 20. Continued.

Ecotype	Descriptions
Riverine Moist Low Willow-Sedge Meadow	Delta Active and Inactive Overbank Deposits commonly with Disjunct Polygon Rims and Low-centered, Low-relief Polygons. The soils are predominantly loamy with thin interbedded organic layers, moist to wet, and somewhat poorly to poorly drained. Sites in this class are flooded in early spring and soils become successively drier throughout the growing season. The plant community is dominated by the low willow *Salix lanata* ssp. *richardsonii. Carex aquatilis,* and *Eriophorum angustifolium* dominate the herbaceous layer. Other frequently occurring species include *Equisetum variegatum, Poa arctica, Polygonum viviparum, Saxifraga hirculus, and Salix reticulata*.
Riverine Moist Sedge-Shrub Meadow	This class occurs on Delta Inactive Overbank Deposits. The surface form usually is Nonpatterned, High-centered, Low-relief Polygons or Mixed High- and Low-centered Polygons. Soils are somewhat poorly drained, alkaline to circumneutral, with shallow organic horizons and moderately deep (1.3–2.6 ft [40–80 cm]) active layer depths. Vegetation is dominated by *Dryas integrifolia, Carex bigelowii*, *Salix planifolia* ssp. *pulchra,* and *S. reticulata,* with *Carex aquatilis, Eriophorum angustifolium,* and *Equisetum variegatum*. Common mosses include *Tomentypnum nitens* and *Dicranum* spp.
Riverine Moist Tall Willow Shrub	Delta Active Overbank Deposits dominated by tall (≥4.9 ft [1.5 m]) shrubs. Sites are Nonpatterned and subject to variable flooding frequency, soils are well-drained, alkaline to circumneutral, and lack organic material. Vegetation is defined by an open canopy of *Salix alaxensis*. Understory species include *Equisetum arvense, Gentiana propinqua, Chrysanthemum bipinnatum, Festuca rubra* and *Aster sibiricus*.
Riverine Sedge Marsh	Vegetated, permanently flooded, shallow (<1.6 ft [50 cm]) margins along Riverine Lakes. Water is circumneutral to alkaline and sediments have moderate organic horizons. Thaw depths typically exceed 2.0 ft (60 cm). Vegetation is dominated by *Carex aquatilis, Eriophorum angustifolium*, *C. chordorrhiza*, and *Scorpidium scorpioides.*
Riverine Wet Sedge Meadow	Delta Active and Inactive Overbank Deposits with variable surface forms, including Nonpatterned to Low-relief, Low-centered polygons; the latter are indicative of progressive ice-wedge development and are common on Delta Inactive Overbank Deposits. Sites in this class are flooded in early spring and soils remain saturated with ground water close to the surface throughout the growing season. Soils usually have a moderately thick organic layer (0.3-1.3 ft [10–40 cm]) over sand or loam, and are alkaline to circumneutral. Thaw depths are approximately 1.3-2.0 ft (40–60 cm). Vegetation is dominated by the sedges *Carex aquatilis* and *Eriophorum angustifolium*. Common associated species include *C. saxatilis*, *S. reticulata,* and mosses.
Riverine Wet Sedge-Willow Meadow	Delta Inactive Overbank Deposits with Disjunct Polygon Rims or Low-centered, Low-relief Polygons. The wet, hydric soils are very poorly drained and feature prominent interbedded organic and mineral layers indicative of frequent sedimentation. Sites in this class are flooded in early spring and soils remain saturated with ground water close to the surface throughout the growing season. The plant community is dominated by sedges, including *Carex aquatilis, Eriophorum* angustifolium. Low willows, most notably *Salix lanata ssp. richardsonii,* occur frequently at low abundance. Other characteristic species include *Dryas integrifolia, Pedicularis sudetica, Polygonum viviparum, Salix reticulata, and Saxifraga hirculus*.

Table 20. Continued.

Ecotype	Descriptions
Tidal River	Unvegetated, permanently flooded channels of the Colville River that are affected by daily tidal fluctuations and have correspondingly variable salinity. The channels generally experience peak flooding during spring breakup and lowest water levels during mid-summer. During winter unfrozen water in deeper channels can become hypersaline.
Upland Dry Barrens	Eolian Active Sand Dunes with partial vegetative cover (<50%). These deposits are well drained, with high pH, deep active layers, and little to no organic accumulation. The dunes are too steep and unstable to support full vegetation cover. Typical species include *Salix alaxensis, Salix glauca, Leymus mollis* and *Chrysanthemum bipinnatum*.
Upland Dry *Dryas* Dwarf Shrub	Dwarf shrub (<0.7 ft [0.2 m] tall) communities on Eolian Inactive Sand Dunes and Eolian Inactive Sand Deposits dominated by *Dryas integrifolia*. Soils are sandy to loamy, excessively to well drained, alkaline to circumneutral, and lack surface organic accumulation. Associated species include *Salix reticulata, S. rotundifolia, S. arctica, Cassiope tetragona, Eriophorum vaginatum, Carex bigelowii, Arctagrostis latifolia* and lichens.
Upland Dry Tall Willow Shrub	Areas of Eolian Active Sand Deposits (dunes) with vegetation dominated by the tall willow *Salix alaxensis*. Soils are sandy, excessively drained, alkaline to circumneutral, with deep active layers (>3.3 ft [1 m]) and no surface organic horizons. The shrub canopy usually is open with dominant shrubs >3.3 ft (1 m) tall. Other common species include *Chrysanthemum bipinnatum, Festuca rubra*, and *Equisetum arvense*.
Upland Moist *Cassiope* Dwarf Shrub	Steep bluffs along Old Alluvial Terraces. Soils are well-drained, loamy to sandy, and circumneutral to acidic. Vegetation is species rich, dominated by the dwarf shrub *Cassiope tetragona***,** with *Dryas integrifolia, Salix reticulata, S. arctica, Carex bigelowii, and C. membranacea.* Lichens and mosses also are common.
Upland Moist Low Willow Shrub	Upper, well-drained, protected slopes of Old Alluvial Terraces and Eolian Active and Inactive Sand Dunes and Deposits. Soils are sandy, alkaline to circumneutral with deep active layers, and have little organic accumulation. Low shrubs (0.7-4.9 ft [0.2–1.5 m] tall) are dominant, typically *Salix glauca*, with *Dryas integrifolia, Salix lanata richardsonii, Arctostaphylos rubra*, and mosses.
Upland Moist Tussock Meadow	Gentle slopes and ridges of Eolian Inactive Sand Deposits, Old Alluvial Terraces, and Ice-rich Thaw Basin Centers. Vegetation is dominated by tussock-forming plants, most commonly *Eriophorum vaginatum.* High-centered polygons of low or high relief are associated with this ecotype. Soils are loamy to sandy, somewhat well-drained, acidic to circumneutral, with moderately thick (0.3-1.0 ft [10–30 cm]) organic horizons and shallow (<1.3 ft [40 cm]) active layer depths. On acidic sites, associated species include *Ledum decumbens, Betula nana, Salix planifolia pulchra, Cassiope tetragona* and *Vaccinium vitis-idaea*. On circumneutral sites common species include *Dryas integrifolia, S. reticulata, Carex bigelowii,* and lichens. Mosses are common at most sites.

Table 3.21. Areal extent of map ecotypes in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Area is reported in acres, hectares (ha), and percent of the CD5 Habitat Monitoring Study Area.

Ecotype	Acres	ha	%
Terrestrial			
Coastal Barrens	956.5	387.1	9.1
Coastal Dry *Elymus* Meadow	23.3	9.4	0.2
Coastal Moist Willow Dwarf Shrub	129.0	52.2	1.2
Human Modified Barrens	19.6	7.9	0.2
Human Modified Dwarf Scrub	0.5	0.2	<0.1
Human Modified Low Shrub	5.9	2.4	0.1
Human Modified Wet Meadow	20.4	8.3	0.2
Lacustrine Grass Marsh	3.5	1.4	<0.1
Lowland Deep-polygon Complex	427.4	173.0	4.1
Lowland Moist Low Willow Shrub	44.3	17.9	0.4
Lowland Moist Sedge–Shrub Meadow	78.5	31.7	0.7
Lowland Sedge Marsh	5.5	2.2	0.1
Lowland Wet Sedge Meadow	328.6	133.0	3.1
Lowland Wet Sedge–Willow Meadow	30.3	12.2	0.3
Riverine Deep-polygon Complex	244.2	98.8	2.3
Riverine Dry *Dryas* Dwarf Shrub	53.4	21.6	0.5
Riverine Grass Marsh	34.0	13.8	0.3
Riverine Moist Herb Meadow	52.7	21.3	0.5
Riverine Moist Low Willow Shrub	850.4	344.1	8.1
Riverine Moist Low Willow–Sedge Meadow	601.4	243.4	5.7
Riverine Moist Sedge-Shrub Meadow	56.1	22.7	0.5
Riverine Moist Tall Willow Shrub	36.9	14.9	0.3
Riverine Sedge Marsh	4.3	1.8	<0.1
Riverine Wet Sedge Meadow	2,050.1	829.7	19.4
Riverine Wet Sedge–Willow Meadow	1,815.8	734.8	17.2
Upland Dry Barrens	7.7	3.1	0.1
Upland Dry *Dryas* Dwarf Shrub	105.3	42.6	1.0
Upland Dry Tall Willow Shrub	1.3	0.5	<0.1
Upland Moist *Cassiope* Dwarf Shrub	22.0	8.9	0.2
Upland Moist Low Willow Shrub	242.5	98.1	2.3
Upland Moist Tussock Meadow	139.6	56.5	1.3
Waterbodies			
Coastal Lake	125.1	50.6	1.2
Lowland Lake	228.2	92.3	2.2
Riverine Lake	772.5	312.6	7.3
Tidal River	1,029.4	416.6	9.8
TOTAL	10,546.3	4,267.9	100.0
AGGREGATED SUBTOTALS			
Terrestrial Map Ecotypes	8,390.9	3,395.4	79.6
Waterbody Map Ecotypes	2,155.2	872.1	20.4

cover). The anthropogenic disturbance of Snow/Ice Pads and Roads, and the natural disturbance Fluvial Erosion and Channel Migration, each make up 0.2% areal cover.

Map Ecotypes

Map ecotypes are mapping classes that represent local-scale ecosystems classified by aggregating ITU map polygons with similar ecological components, including geomorphology, surface form, vegetation, and disturbance. The advantage of this approach is that the combination of physiography (strongly associated with geomorphic units), moisture (related to surface form), and vegetation structure yields classes that effectively differentiate both soil characteristics and vegetation composition. This approach reflects characteristics that the interpreter can readily distinguish during mapping, such as physiography (e.g., floodplains versus uplands), surface form (e.g., low-centered versus high-centered polygons), and vegetation structure (e.g., low shrubs versus graminoids). Map ecotypes are derived from recoding the Integrated Terrain Unit (ITU) map using the Beaufort Coastal Plain Classification. Map ecotypes were summarized in two ways. First, the areal extent of each map ecotype class was summarized across the entire CD5 Habitat Monitoring Study Area. Second, the areal extent of map ecotypes in each of the 4 subareas was summarized to compare the proportion of map ecotypes within each subarea.

Thirty-five ecotypes were mapped in the overall CD5 Habitat Monitoring Study Area (Figure 3.15, Table 3.20). Riverine Wet Sedge Meadow and Riverine Wet Sedge–Willow Meadow represent the dominant ecotypes, with 19.4% and 17.2% areal cover, respectively (Table 3.21). Other common map ecotypes include Tidal River (9.8% areal cover), Coastal Barrens (9.1%), Riverine Moist Low Willow Shrub (8.1%), Riverine Lake (7.3%), and Riverine Moist Low Willow–Sedge Meadow (5.7%). All other map ecotypes account for less than 5% of the total area.

Twenty-eight map ecotypes were mapped in Reference Area North, 31 in Reference Area South, 23 in Test Area North, and 31 in Test Area South (Figure 3.15, Table 3.22). The map ecotypes Riverine Wet Sedge Meadow and Riverine Wet Sedge-Willow Meadow are the most common map ecotypes in all subareas. Tidal River is the next most common map ecotype, accounting for less than 5% of the area in Reference Area North, Reference Area South, and Test Area North. Coastal Barrens account for less than 5% of the areal cover in all subareas, with a maximum of 14% areal cover in Test Area North. Riverine Moist Low Willow Shrub has comparable areal coverage in Reference Area South (11.9%) and Test Area South (9.2%), but also is present in the other 2 subareas with 4–5% areal coverage. Lowland Deep Polygon Complex is common in Reference Area North and Test Area South. Lowland Lake is common in Reference Area North. Lastly, Riverine Moist Low Willow-Sedge Meadow is common in Reference Area North but uncommon in all other subareas. All other map ecotypes occur at less than 5% areal cover in all subareas. The results indicate that the 4 subareas share the same common map ecotypes, and that, in general, map ecotypes within the subareas have similar proportions across the landscape.

Wildlife Habitat

The habitat classification is based on landscape properties that ABR considers most important to wildlife: shelter, security (or escape), and food. These factors may be directly related to the quantity and quality of vegetation, vegetation structure and species composition, surface form, soils, hydrology, and microclimate. ABR emphasizes that habitats are not necessarily equivalent to vegetation types. In some cases, dissimilar vegetation types may be combined because selected wildlife species use them similarly. Conversely, wildlife may distinguish between habitats with similar vegetation on the basis of microrelief, soil characteristics, invertebrates, or other factors not reflected in plant species composition. For the CD5 wildlife habitat classification, ABR concentrated on 1) breeding waterbirds that use water bodies and wet and moist tundra types; and 2) mammals and upland birds that use shrublands and dry tundra types. Habitats are based on recoding of the ITU map using the Beaufort Coastal Plain Classification (Appendix C). ABR summarized wildlife-habitat classes in two ways: First, the areal extent of each wildlife-habitat class was summarized across the entire CD5 Habitat Monitoring Study Area.

Table 3.22. Areal extent of map ecotypes in the 4 CD5 Habitat Monitoring Study subareas, northern Alaska, 2013. Area is reported in acres, hectares (ha), and percent of the respective test or reference area. Bold text denotes map ecotypes occurring at ≥5% areal cover within a subarea.

	Reference Area North			Test Area North			Reference Area South			Test Area South		
Map Ecotype	Acres	ha	%	Acres	ha	%	Acres	ha	%	Acres	ha	%
Coastal Barrens	284.8	115.2	**9.7**	196.9	79.7	**14.0**	301.9	122.2	**8.8**	173.0	70.0	**6.3**
Coastal Dry *Elymus* Meadow	6.2	2.5	0.2	12.3	5.0	0.9	1.1	0.5	<0.1	3.7	1.5	0.1
Coastal Lake	20.9	8.5	0.7	31.8	12.9	2.3				72.4	29.3	2.6
Coastal Moist Willow Dwarf Shrub	73.9	29.9	2.5	13.8	5.6	1.0	0.7	0.3	<0.1	40.7	16.5	1.5
Human Modified Barrens				2.5	1.0	0.2				17.1	6.9	0.6
Human Modified Dwarf Scrub	0.5	0.2	<0.1									
Human Modified Low Shrub	3.1	1.3	0.1				1.3	0.5	<0.1	1.5	0.6	0.1
Human Modified Wet Meadow	3.7	1.5	0.1				13.7	5.5	0.4	3.0	1.2	0.1
Lacustrine Grass Marsh	0.6	0.2	<0.1				1.8	0.7	0.1	1.2	0.5	<0.1
Lowland Deep-polygon Complex	194.6	78.8	**6.6**	28.5	11.5	2.0	66.5	26.9	1.9	137.8	55.8	**5.0**
Lowland Lake	150.1	60.7	**5.1**	1.5	0.6	0.1	43.6	17.6	1.3	33.0	13.4	1.2
Lowland Moist Low Willow Shrub	7.4	3.0	0.3	9.7	3.9	0.7	7.6	3.1	0.2	19.5	7.9	0.7
Lowland Moist Sedge–Shrub Meadow	7.6	3.1	0.3	6.0	2.4	0.4	40.0	16.2	1.2	24.9	10.1	0.9
Lowland Sedge Marsh							5.5	2.2	0.2			
Lowland Wet Sedge Meadow	104.4	42.2	3.5	48.0	19.4	3.4	101.7	41.2	3.0	74.5	30.1	2.7
Lowland Wet Sedge–Willow Meadow	7.1	2.9	0.2				7.0	2.8	0.2	16.1	6.5	0.6
Riverine Deep-polygon Complex	74.9	30.3	2.5	67.3	27.2	4.8	21.1	8.5	0.6	81.0	32.8	2.9
Riverine Dry *Dryas* Dwarf Shrub	46.5	18.8	1.6							7.0	2.8	0.3
Riverine Grass Marsh	10.1	4.1	0.3	2.3	0.9	0.2	12.2	4.9	0.4	9.3	3.8	0.3
Riverine Lake	81.0	32.8	2.7	18.4	7.4	1.3	400.6	162.1	**11.7**	272.6	110.3	**9.9**
Riverine Moist Herb Meadow							43.0	17.4	1.3	9.7	3.9	0.4
Riverine Moist Low Willow Shrub	117.9	47.7	4.0	71.0	28.7	**5.0**	408.0	165.1	**11.9**	253.5	102.6	**9.2**
Riverine Moist Low Willow–Sedge Meadow	260.4	105.4	**8.8**	65.6	26.6	4.7	159.5	64.5	4.6	116.0	46.9	4.2
Riverine Moist Sedge-Shrub Meadow				10.6	4.3	0.8	10.3	4.2	0.3	35.1	14.2	1.3
Riverine Moist Tall Willow Shrub												
Riverine Sedge Marsh	0.8	0.3	<0.1							3.5	1.4	0.1

Table 3.22. Continued.

Map Ecotype	Reference Area North			Test Area North			Reference Area South			Test Area South		
	Acres	ha	%	Acres	ha	%	Acres	ha	%	Acres	ha	%
Riverine Wet Sedge Meadow	513.6	207.9	**17.4**	287.8	116.5	**20.4**	561.4	227.2	**16.3**	687.4	278.2	**24.9**
Riverine Wet Sedge–Willow Meadow	517.8	209.5	**17.6**	214.0	86.6	**15.2**	675.0	273.2	**19.7**	409.0	165.5	**14.8**
Tidal River	369.2	149.4	**12.5**	204.4	82.7	**14.5**	320.4	129.7	**9.3**	135.4	54.8	4.9
Upland Dry Barrens							7.7	3.1	0.2			
Upland Dry *Dryas* Dwarf Shrub	35.9	14.5	1.2	19.4	7.8	1.4	28.3	11.5	0.8	21.8	8.8	0.8
Upland Dry Tall Willow Shrub							1.3	0.5	<0.1			
Upland Moist *Cassiope* Dwarf Shrub							13.8	5.6	0.4	8.2	3.3	0.3
Upland Moist Low Willow Shrub	23.4	9.5	0.8	49.6	20.1	3.5	129.4	52.4	3.8	40.1	16.2	1.5
Upland Moist Tussock Meadow	29.9	12.1	1.0	47.7	19.3	3.4	13.2	5.3	0.4	48.8	19.8	1.8
TOTAL AREA	2,946.2	1,192.3	100.0	1,409.1	570.2	100.0	3,434.4	1,389.9	100.0	2,756.6	1,115.5	100.0
TOTAL CLASSES MAPPED			28			23			31			31

Table 3.23. Classification and description of wildlife habitats in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Class descriptions modified from Jorgenson et al. (1997, 2003) and Roth et al. (2006).

Habitat Class	Description
Barrens (BAR)	Includes barren and partially vegetated (<30% plant cover) areas related to riverine or thaw lake processes. Riverine Barrens on river flats and bars are flooded seasonally and can have either silty or gravelly sediments. The margins frequently are colonized by *Deschampsia caespitosa, Festuca rubra, Salix alaxensis,* and *Equisetum arvense.* Lacustrine Barrens occur along margins of drained lakes and ponds and may support *Arctophila fulva,* and *Carex aquatilis*. These areas may be flooded seasonally or can be well drained.
Deep Open Water with Islands or Polygonized Margins (DOWIP)	Similar to above except that they have islands or complex shorelines formed by thermal erosion of low-center polygons. The complex shorelines and islands are important features of nesting habitat for many species of waterbirds.
Deep Open Water without Islands (DOWA)	Deep (≥4.9 ft [1.5 m]) waterbodies range in size from small ponds in ice-wedge polygons to large open lakes. Most deep open lakes have resulted from thawing of ice-rich sediments, although some are associated with old river channels. They do not freeze to the bottom during winter. These lakes usually are not connected to rivers. Sediments are fine-grained silt and clay. Deep Open Waters without Islands are differentiated from those with islands because of the lack of nest sites for waterbirds that prefer islands.
Deep Polygon Complex (DPC)	A complex of terrestrial and aquatic habitats formed by the thermokarst of ice-rich soil which has produced deep (>3.3 ft [1 m]), permanently flooded polygon centers. Emergent vegetation, mostly *Carex aquatilis*, usually is found around the margins of the polygon centers. Occasionally, centers will have the emergent grass *Arctophila fulva*. Polygon rims are moderately well drained and dominated by sedges and dwarf shrubs, including *C. bigelowii, C. aquatilis*, *Dryas integrifolia*, *Salix reticulata*, and *S. phlebophylla*.
Dry Dwarf Shrub (DDS)	*Dryas* tundra on Eolian Inactive Sand Dunes and Eolian Inactive Sand Deposits. *Dryas* tundra is dominated by *D. integrifolia* but may include *Salix reticulata, S. rotundifolia, S. arctica, Cassiope tetragona, Eriophorum vaginatum, Carex bigelowii, Arctagrostis latifolia* and lichens. The soils generally have a thin (<0.2 ft [5 cm]) organic horizon.
Dry Halophytic Meadow (DHM)	Somewhat sparsely vegetated areas of Delta Inactive Channel Deposits and Eolian Active Sand Dunes characterized by a high cover bare soil (sand), litter, and the presence of the grass *Leymus mollis* and scattered forbs.
Dry Tall Shrub (DTS)	Open to closed stands of tall (>4.9 ft [1.5 m] high) shrub dominated *by Salix alaxensis* found in sheltered areas on Eolian Active and Inactive Sand Dunes.
Grass Marsh (GRMA)	Shallow lakes and lake margins with the emergent grass *Arctophila fulva.* Due to shallow water depths (<3.3 ft [1 m]), the water freezes to the bottom in the winter, and thaws by early June. *Arctophila fulva* stem densities and annual productivity can vary widely among sites. Sediments generally lack peat. This type usually occurs as an early successional stage in the thaw lake cycle and is more productive than Aquatic Sedge Marshes. This habitat tends to have abundant invertebrates and is important to many waterbirds.

Table 3.23. Continued.

Habitat Class	Description
Moist Halophytic Dwarf Shrub (MHDS)	The dwarf willow *Salix ovalifolia* forms an open to closed mat along margins of Delta Active Channel Deposits. Other common species include *Deschampsia caespitosa, Puccinellia andersonii, Dupontia fisheri, Arctagrostis latifolia, Alopecurus alpinus, Chrysanthemum bipinnatum,* and *Petasites frigidus*. Usually found on Delta Active Overbank Deposits subject to flooding and sedimentation nearly every year.
Moist Herb Meadow (MHEM)	Somewhat sparsely vegetated areas of Delta Inactive Channel Deposits characterized by a high cover of bare soil (sand and silt) and a mixture of seral forbs, including *Chrysanthemum bipinnatum*, *Equisetum arvense*, *Artemisia tilesii*, *Astragalus alpinus*, *Deschampsia caespitosa*, *Festuca rubra*, *Pedicularis verticillata*, and *Wilhelmsia physodes.*
Moist Low Shrub (MLS)	This class includes both open and closed stands of Riverine, Lacustrine and Lowland Moist Low Willow Shrub. Low willow stands are infrequent in the study area and generally dominated by *Salix planifolia pulchra*, though *S. lanata richardsonii* may be present in riverine communities. Understory plants include sedges *(Carex aquatilis, C. bigelowii*, and *Eriophorum angustifolium*), *Salix reticulata,* and mosses*.* Soils vary from interbedded riverine deposits to sands and loams with shallow to moderate organic horizons.
Moist Sedge–Shrub Meadow (MSSM)	Occurs on better-drained Delta Inactive Overbank Deposits and Delta Abandoned Overbank Deposits, and generally associated with High-centered or Mixed High- and Low-Centered Polygons. Vegetation is dominated by *Dryas integrifolia, Carex aquatilis* and *C. bigelowii*. Other common species include *C. misandra*, *Eriophorum angustifolium*, *E. vaginatum*, *Salix reticulata, S. rotundifolia, S. arctica* and the moss *Tomentypnum nitens.* Soils generally have a moderate layer (0.7-1.0 ft [20–30 cm]) of organic matter over silt loam or sands.
Moist Tall Shrub (MTS)	This habitat is dominated by large willows (*Salix alaxensis, S. lanata* ssp. *richardsonii*) that form a canopy that is >4.9 ft (1.5 m) in height. Riverine Tall Willow Shrub is not common and occurs locally on active and inactive overbanks of the Colville River. The high vertical structure of these shrubs is distinctive on the Colville Delta, making these habitats important for birds and mammals.
Moist Tussock Tundra (MTT)	Vegetation is characterized by the tussock-forming sedge *Eriophorum vaginatum. Carex bigelowii,* the willow *Salix planifolia pulchra,* ericaceous shrubs and a nearly continuous carpet of mosses dominated by *Hylocomium splendens, Aulacomnium* spp., *Dicranum* spp. and lichens of the genus *Cladina* also are typical.

Table 3.23. Continued.

Habitat Class	Description
Non-patterned Wet Meadow (NWM)	Sedge-dominated meadows that typically occur Delta Active and Inactive Overbank Deposits. Disjunct Polygon Rims cover <5% of the ground surface. The surface generally is flooded during early summer (depth <1.0 ft [0.3 m]) and drains later, but remains saturated within 0.5 ft (15 cm) of the surface throughout the growing season. The uninterrupted movement of water (and dissolved nutrients) in Non-patterned ground results in more robust growth of sedges than occurs in polygonized habitats. Usually dominated by *Carex aquatilis* and *Eriophorum angustifolium,* although other sedges may be present. Low and dwarf willows (*Salix arctica,* and *S. planifolia pulchra*) occasionally are present, but are not co-dominant. Soils generally have a moderately thick (0.3–1.0 ft [10–30 cm]) organic horizon overlying fine-grained silt.
Patterned Wet Meadow (PWM)	Occurs in lowland areas primarily on Delta Inactive- and Abandoned Overbank Deposits, associated with Low-centered Polygons and Disjunct Polygon Rims. Water depth varies through the season (<1.0 ft [0.3 m] maximum). Polygon rims interrupt surface and groundwater flow, so only interconnected polygon troughs receive downslope flow and dissolved nutrients; in contrast, the input of water to polygon centers is limited to precipitation. As a result, vegetation growth typically is more robust in polygon troughs than in centers. Vegetation is dominated by sedges, usually *Carex aquatilis* and *Eriophorum angustifolium,* although other sedges may be present, including *C. rotundata, C. saxatilis, C. membranacea, C. chordorrhiza,* and *E. russeolum*. Willows, including *Salix arctica* and *S. planifolia* ssp. *pulchra* maybe co-dominant.
River or Stream (RS)	All permanently flooded river channels. Rivers generally experience peak flooding during spring breakup and lowest water levels during mid-summer.
Sedge Marsh (SEMA)	Permanently flooded, low lying areas and lake margins dominated by *Carex aquatilis*. Typically, emergent sedges occur in water ≤1.0 ft (0.3 m) deep. Water and bottom sediments of this shallow habitat freeze completely during winter, but the ice melts in early June. The sediments generally consist of a peat layer (0.7–1.6 ft [0.2–0.5 m] deep) overlying fine-grained silt.
Shallow Open Water with Islands or Polygonized Margins (SOWIP)	Shallow lakes with islands or complex low-center polygon shorelines. Distinguished from Shallow Open Water without Islands because presence of islands and shoreline complexity appear to be an important feature of nesting habitat for many species of waterbirds.
Shallow Open Water without Islands (SOWA)	Small lakes <4.9 ft (1.5 m) deep with emergent vegetation covering <5% of the waterbody's surface. Due to the shallow depth, water freezes to the bottom during winter and thaws by early to mid-June. Maximal summer temperatures are higher than those in deep water. These lakes generally are surrounded by wet and moist tundra. Sediments are fine-grained silt and clay.

Table 3.23. Continued.

Habitat Class	Description
Tapped Lake with High-water Connection (TLHWC)	Connecting channels are dry during low water and the lakes are connected only during flooding events. Water tends to be fresh. Small deltaic fans are common near the connecting channels due to deposition during seasonal flooding.
Tapped Lake with Low-water Connection (TLLWC)	Deep (>4.9 ft [1.5 m]) waterbodies that have been partially drained through erosion of banks by adjacent river channels, and are connected to rivers by distinct, permanently flooded channels. The water typically is brackish because the lakes are usually within the delta and subject to flooding every year. Because water levels have dropped after tapping, the lakes generally have broad flat shorelines with silty clay sediments. Salt-marsh vegetation is common along the shorelines. These lakes do not freeze to the bottom during winter. Sediments are fine-grained silt and clay with some sand.

Second, the areal extent of wildlife-habitat classes in each of the subareas was summarized in order to compare the proportion of wildlife-habitat classes within each subarea.

Twenty-four wildlife-habitat classes were mapped in the overall CD5 Habitat Monitoring Study Area (Figure 3.16, Table 3.23). The dominant habitat type is Patterned Wet Meadow, with an areal cover of 26.1% (Table 3.24). Other widespread, important wildlife-habitat classes include Moist Low Shrub (16.5% areal cover), Nonpatterned Wet Meadow (14.0%), Barrens (9.1%), and Deep Polygon Complex (6.4%). In addition, the aquatic habitat classes River or Stream and Deep Open Water with Islands or Polygonized Margins, with 9.8% and 6.8% areal cover, respectively, are common. All other wildlife habitat classes were mapped at less than 2% areal cover.

Twenty wildlife-habitat classes were mapped in Reference Area North, 22 in Reference Area South, 19 in Test Area North, and 22 in Test Area South (Figure 3.16, Table 3.25). The wildlife habitat Patterned Wet Meadow is the most common wildlife habitat in all subareas, encompassing approximately 25% (23.1–28.8%) of the areal extent of each subarea. Other widespread wildlife habitats in all 4 subareas include Nonpatterned Wet Meadow, Moist Low Shrub, and Barrens. River or Stream is common in 3 of the 4 subareas, including Reference Area North, Reference Area South, and Test Area North. Deep Polygon Complex is common in all subareas with the exception of Reference Area South, while Deep Open Water with Islands or Polygonized Margins is common in all subareas with the exception of Test Area North. The results indicate that the 4 subareas share the same common wildlife-habitat classes, and that in general, wildlife-habitat classes within the subareas have similar proportions across the landscape.

3.4.2.B. Vegetation Assessment

ABR sampled 39 Monitoring Transects, including 7 in Reference Area North, 9 in Reference Area South, 12 in Test Area North, and 11 in Test Area South. Along these transects ABR sampled: 179 Integrated Plots, including 36 in Reference Area North, 38 in Reference Area South, 51 in Test Area North, and 54 in Test Area South; and 306 Thaw/Elevation Points, including 78 in Reference Area North, 76 in Reference Area South, 71 in Test Area North, and 81 in Test Area South (Figure 1.2).

3.4.2.B.i. Vegetation Plot Sampling Adequacy

To assess the adequacy of the study design and sampling effort in the CD5 Habitat Monitoring Study Area, ABR 1) compared the number of Vegetation Plots sampled in each of the 17 plot

Table 3.24. Areal extent of wildlife habitat classes in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Area is reported in acres, hectares (ha), and percent of the CD5 Habitat Monitoring Study Area.

Habitat Class	Acres	ha	%
Terrestrial			
Barrens	964.2	390.2	9.1
Deep Polygon Complex	671.7	271.8	6.4
Dry Dwarf Shrub	158.7	64.2	1.5
Dry Halophytic Meadow	23.3	9.4	0.2
Dry Tall Shrub	1.3	0.5	<0.1
Grass Marsh	37.5	15.2	0.4
Human Modified	46.5	18.8	0.4
Moist Dwarf Shrub	22.0	8.9	0.2
Moist Halophytic Dwarf Shrub	129.0	52.2	1.2
Moist Herb Meadow	52.7	21.3	0.5
Moist Low Shrub	1,738.6	703.6	16.5
Moist Sedge-Shrub Meadow	134.5	54.4	1.3
Moist Tall Shrub	36.9	14.9	0.3
Moist Tussock Tundra	139.6	56.5	1.3
Nonpatterned Wet Meadow	1,476.0	597.3	14.0
Patterned Wet Meadow	2,748.7	1,112.4	26.1
Sedge Marsh	9.9	4.0	0.1
Waterbodies			
Deep Open Water with Islands or Polygonized Margins	714.9	289.3	6.8
Deep Open Water without Islands	182.7	73.9	1.7
River or Stream	1,029.4	416.6	9.8
Shallow Open Water with Islands or Polygonized Margins	18.5	7.5	0.2
Shallow Open Water without Islands	12.1	4.9	0.1
Tapped Lake with High-water Connection	72.6	29.4	0.7
Tapped Lake with Low-water Connection	125.1	50.6	1.2
TOTAL	10,546.3	4,267.9	100.0
AGGREGATED SUBTOTALS			
Terrestrial Wildlife Habitats	8,391.2	3,395.6	79.6
Waterbody Wildlife Habitats	2,155.3	872.2	20.4

Table 3.25. Areal extent of wildlife habitats in the 4 CD5 Habitat Monitoring Study subareas, northern Alaska, 2013. Area is reported in acres, hectares (ha), and percent of the respective test or reference area. Bold text denotes wildlife habitats occurring at ≥5% areal cover within a subarea.

	Reference Area North			Test Area North			Reference Area South			Test Area South		
Habitat Class	Acres	ha	%	Acres	ha	%	Acres	ha	%	Acres	ha	%
Barrens	284.8	115.2	**9.7**	196.9	79.7	**14.0**	309.6	125.3	**9.0**	173.0	70.0	**6.3**
Deep Open Water with Islands or Polygonized Margins	187.0	75.7	**6.3**	<0.1	<0.1	<0.1	388.5	157.2	**11.3**	139.4	56.4	**5.1**
Deep Open Water without Islands	28.3	11.4	1.0	5.3	2.1	0.4	25.6	10.3	0.7	123.5	50.0	4.5
Deep Polygon Complex	269.5	109.1	**9.1**	95.8	38.8	**6.8**	87.6	35.4	2.5	218.8	88.6	**7.9**
Dry Dwarf Shrub	82.3	33.3	2.8	19.4	7.8	1.4	28.3	11.5	0.8	28.7	11.6	1.0
Dry Halophytic Meadow	6.2	2.5	0.2	12.3	5.0	0.9	1.1	0.5	<0.1	3.7	1.5	0.1
Dry Tall Shrub							1.3	0.5	<0.1			
Grass Marsh	10.7	4.3	0.4	2.3	0.9	0.2	14.0	5.7	0.4	10.5	4.2	0.4
Human Modified	7.4	3.0	0.3	2.5	1.0	0.2	15.0	6.1	0.4	21.6	8.7	0.8
Moist Dwarf Shrub							13.8	5.6	0.4	8.2	3.3	0.3
Moist Halophytic Dwarf Shrub	73.9	29.9	2.5	13.8	5.6	1.0	0.7	0.3	<0.1	40.7	16.5	1.5
Moist Herb Meadow							43.0	17.4	1.3	9.7	3.9	0.4
Moist Low Shrub	409.0	165.5	**13.9**	196.0	79.3	**13.9**	704.5	285.1	**20.5**	429.1	173.6	**15.6**
Moist Sedge-Shrub Meadow	7.6	3.1	0.3	16.6	6.7	1.2	50.3	20.4	1.5	60.0	24.3	2.2
Moist Tall Shrub							36.9	14.9	1.1			
Moist Tussock Tundra	29.9	12.1	1.0	47.7	19.3	3.4	13.2	5.3	0.4	48.8	19.8	1.8
Nonpatterned Wet Meadow	462.8	187.3	**15.7**	143.3	58.0	**10.2**	466.3	188.7	**13.6**	403.3	163.3	**14.6**
Patterned Wet Meadow	680.1	275.2	**23.1**	406.5	164.5	**28.8**	878.8	355.6	**25.6**	783.4	317.0	**28.4**
River or Stream	369.2	149.4	**12.5**	204.4	82.7	**14.5**	320.4	129.7	**9.3**	135.4	54.8	4.9
Sedge Marsh	0.8	0.3	<0.1				5.5	2.2	0.2	3.5	1.4	0.1
Shallow Open Water with Islands or Polygonized Margins	4.6	1.9	0.2	1.2	0.5	0.1				12.7	5.1	0.5
Shallow Open Water without Islands	4.3	1.7	0.1	0.3	0.1	<0.1	3.7	1.5	0.1	3.8	1.5	0.1
Tapped Lake with High-water Connection	7.0	2.8	0.2	13.1	5.3	0.9	26.4	10.7	0.8	26.2	10.6	0.9
Tapped Lake with Low-water Connection	20.9	8.5	0.7	31.8	12.9	2.3				72.4	29.3	2.6
TOTAL AREA	2,946.2	1,192.3	100.0	1,409.1	570.2	100.0	3,434.4	1,389.9	100.0	2,756.6	1,115.5	100.0
TOTAL CLASSES MAPPED			20			19			22			22

Table 3.26. Sample size (n) of plot ecotypes within 4 subareas of the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Bold text denotes 3 most commonly sampled plot ecotypes within each subarea.

	Reference Area North		Test Area North		Reference Area South		Test Area South		Grand Total	
Plot Ecotype	n	%	n	%	n	%	n	%	n	%
Coastal Loamy Brackish Moist Willow Dwarf Shrub	2	5.6	0	0.0	0	0.0	1	1.9	3	1.7
Coastal Sandy Moist Brackish Barrens	3	8.3	2	3.9	2	5.3	3	5.6	10	5.6
Lowland Lake	0	0.0	0	0.0	0	0.0	2	3.7	2	1.1
Lowland Organic-rich Circumneutral Moist Sedge-Shrub Meadow	0	0.0	0	0.0	0	0.0	1	1.9	1	0.6
Lowland Organic-rich Circumneutral Sedge Marsh	0	0.0	0	0.0	0	0.0	1	1.9	1	0.6
Lowland Organic-rich Circumneutral Wet Sedge Meadow	**5**	**13.9**	5	9.8	**7**	**18.4**	**12**	**22.2**	**29**	**16.2**
Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	0	0.0	1	2.0	2	5.3	2	3.7	5	2.8
Riverine Loamy Alkaline Moist Low Willow Shrub	3	8.3	3	5.9	**5**	**13.2**	4	7.4	15	8.4
Riverine Loamy Alkaline Moist Mixed Herb	0	0.0	0	0.0	1	2.6	2	3.7	3	1.7
Riverine Loamy Alkaline Moist Tall Willow Shrub	0	0.0	0	0.0	2	5.3	0	0.0	2	1.1
Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	**7**	**19.4**	**6**	**11.8**	1	2.6	2	3.7	**16**	**8.9**
Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	2	5.6	3	5.9	0	0.0	2	3.7	7	3.9
Riverine Organic-rich Circumneutral Wet Sedge Meadow	3	8.3	**15**	**29.4**	**5**	**13.2**	**11**	**20.4**	**34**	**19.0**
Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow	**7**	**19.4**	**10**	**19.6**	**9**	**23.7**	**8**	**14.8**	**34**	**19.0**
Upland Loamy-Organic Circumneutral Moist Tussock Meadow	1	2.8	1	2.0	0	0.0	1	1.9	3	1.7
Upland Sandy Alkaline Dry Barrens	0	0.0	1	2.0	0	0.0	0	0.0	1	0.6
Upland Sandy Alkaline Moist Low Willow Shrub	0	0.0	3	5.9	1	2.6	0	0.0	4	2.2
Outlier	3	8.3	1	2.0	3	7.9	2	3.7	9	5.0
Grand Total	36	100.0	51	100.0	38	100.0	54	100.0	179	100.0

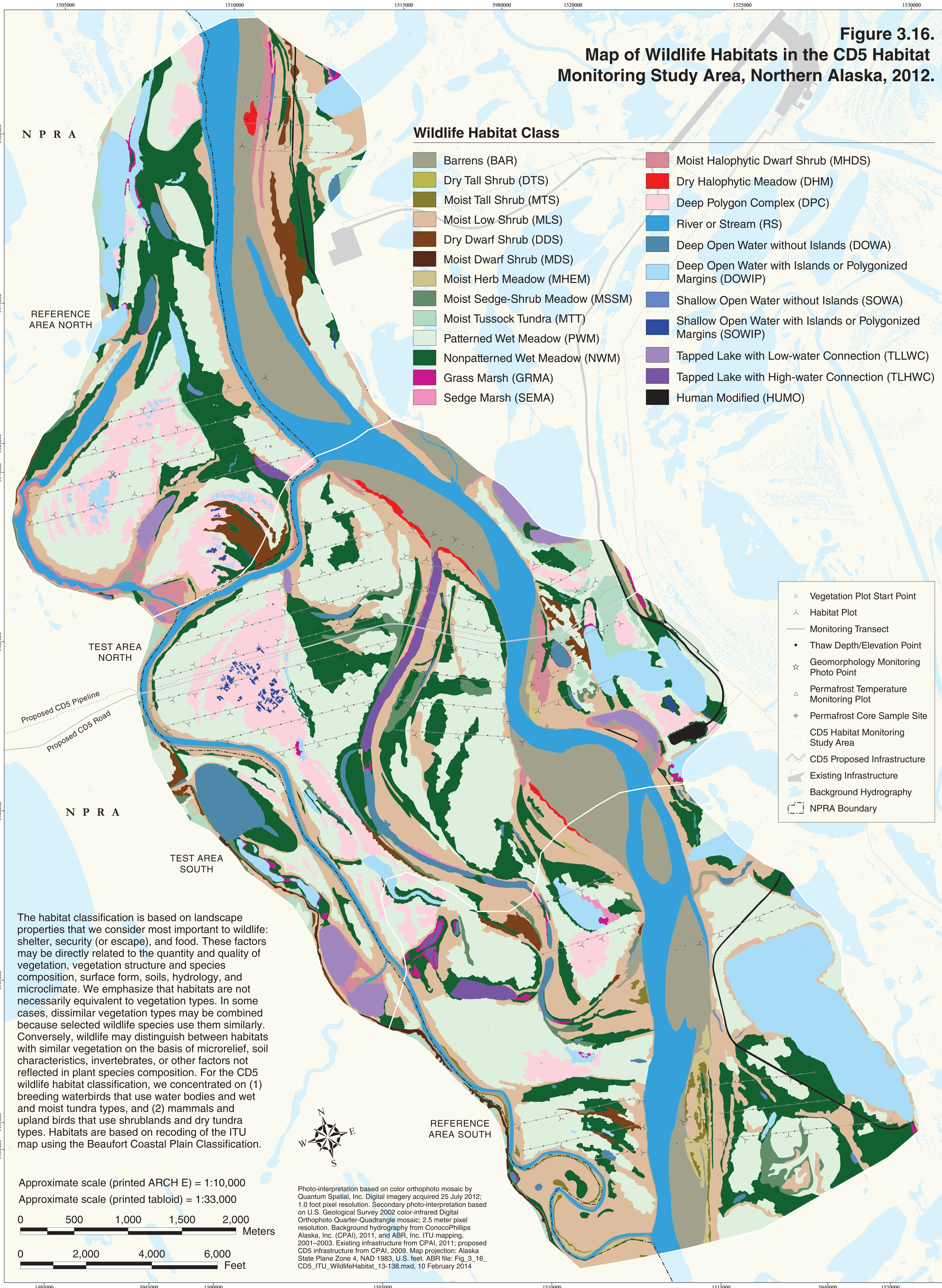


Figure 3.16.
Map of Wildlife Habitats in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2012.

The habitat classification is based on landscape properties that we consider most important to wildlife: shelter, security (or escape), and food. These factors may be directly related to the quantity and quality of vegetation, vegetation structure and species composition, surface form, soils, hydrology, and microclimate. We emphasize that habitats are not necessarily equivalent to vegetation types. In some cases, dissimilar vegetation types may be combined because selected wildlife species use them similarly. Conversely, wildlife may distinguish between habitats with similar vegetation on the basis of microrelief, soil characteristics, invertebrates, or other factors not reflected in plant species composition. For the CD5 wildlife habitat classification, we concentrated on (1) breeding waterbirds that use water bodies and wet and moist tundra types, and (2) mammals and upland birds that use shrublands and dry tundra types. Habitats are based on recoding of the ITU map using the Beaufort Coastal Plain Classification.

ecotypes within each of the subareas, and 2) compared the areal extent of map ecotypes to the sample size of the equivalent plot ecotypes within each subarea.

Three plot ecotypes consistently ranked in the top 3 most commonly sampled across the 4 subareas including Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow, Lowland Organic-rich Circumneutral Wet Sedge Meadow, and Riverine Organic-rich Circumneutral Wet Sedge Meadow (Table 3.26). The primary exceptions to this included Reference Area North and Test Area North, in which Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow replaced Riverine Organic-rich Circumneutral Wet Sedge Meadow and Lowland Organic-rich Circumneutral Wet Sedge in the rankings, respectively. Additionally, in Reference Area South, Riverine Loamy Alkaline Moist Low Willow Shrub tied with Riverine Organic-rich Circumneutral Wet Sedge Meadow in the rankings for the third most commonly sampled plot ecotype. Riverine Loamy Alkaline Moist Low Willow Shrub was also one of the more commonly sampled plot ecotypes in the other 3 subareas, ranking 4th, 5th, and 4th in Reference Area North, Test Area North, and Test Area South, respectively. The ecotype Riverine Organic-rich Circumneutral Wet Sedge Meadow is ranked 4th in the Reference Area North, while in all other subareas it is ranked in the top 3. The equivalent map ecotype, Riverine Wet Sedge Meadow, encompasses 17.4% of reference area north (Table 3.22) and thus, is not rare in this subarea. However, much of this map ecotype is located to the north and south of the monitoring transects in Reference Area North (Figure 3.15); thus, the low sample size of this plot ecotype in Reference Area North is largely related to the location of the monitoring transects and systematic sample design relative to the spatial distribution of this map ecotype across the landscape.

As another means of assessing the study design, ABR compared the sample size of plot ecotypes against the area of their equivalent map ecotypes from the ITU mapping in each subarea (Table 3.22). It is important to note that when comparing between the number of plot ecotypes sampled and the area of map ecotype classes, there is not always a one-to-one relationship. For instance, several map ecotype classes are not assigned to plot ecotypes. An example of this is the map ecotype classes Lowland Deep-polygon Complex and Riverine Deep-polygon Complex. These map ecotype classes are not assigned to plot ecotypes because they represent complex areas on the landscape characterized by 3 or more vegetation types that co-occur at a spatial scale that prohibits mapping each vegetation type separately. However, following from the field protocols, Vegetation Plots were placed such that the plot boundaries encompassed a single, discreet vegetation community. Hence, Vegetation Plots located in areas mapped as complexes represent a single plot ecotype at the spatial scale of the Vegetation Plot, while the mapping represents the complex vegetation at a broader spatial scale. As such, a plot may be assigned a plot ecotype class based on the vegetation and environment at the spatial scale of the vegetation plot, which may be too small an area to be delineated in the ITU mapping based on the minimum delineation. In these cases the plot ecotype will differ from the map ecotype within which it was mapped. Given these caveats, ABR did not attempt a direct comparison, but rather compared the relative areal proportion of map ecotypes to the sample size proportion of each plot ecotype in the 4 subareas.

Four of the 5 most commonly sampled plot ecotypes in the 4 subareas, including Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow, Riverine Organic-rich Circumneutral Wet Sedge Meadow, Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow, and Riverine Loamy Alkaline Moist Low Willow Shrub (Table 3.26) also had the highest areal extent of their respective equivalent map ecotypes, including Riverine Wet Sedge-Willow Meadow, Riverine Wet Sedge Meadow, Riverine Moist Low Willow-Sedge Meadow, and Riverine Moist Low Willow Shrub (Table 3.22). These 4 map ecotypes combined accounted for 47.8%, 45.3%, 52.5%, and 53.1% in Reference Area North, Test Area North, Reference Area South, and Test Area South, respectively.

Coastal Barrens was one of the most common map ecotypes in the 4 subareas, accounting for 9.7%, 14.0%, 8.8%, and 6.3% of the area in

Reference Area North, Test Area North, Reference Area South, and Test Area South, respectively (Table 3.22). In Reference Area North, and Test Area South, the equivalent plot ecotype, Coastal Sandy Moist Brackish Barrens, was sampled approximately proportionate to the areal extent in each subarea (8.3% and 5.6%, respectively). However, in Test Area North and Reference Area South, the plot ecotype Coastal Sandy Moist Brackish Barrens was sampled disproportionate to the areal extent (3.9% and 5.3%, respectively). Lastly, the plot ecotype Lowland Organic-rich Circumneutral Wet Sedge Meadow was one of the most commonly sampled plot ecotypes. However, the equivalent map ecotype, Lowland Wet Sedge Meadow, accounted for less than 5% of the area in each subarea. This is in part related to the map ecotype class Lowland Deep-polygon Complex, in which Lowland Wet Sedge Meadow was mapped as a complex.

The assessment of sampling adequacy indicates that while the relative proportion of the plot ecotypes sampled in each of the 4 subareas are not equal, the relative rankings are similar across the 4 subareas. With few exceptions, the most widely sampled plot ecotypes also had the most common equivalent map ecotypes, which accounted for approximately 50% of the areal extent of each subarea. However, 2 plot ecotypes, Riverine Organic-rich Circumneutral Wet Sedge Meadow and Coastal Sandy Moist Brackish Barrens, were under-sampled relative to the areal extent of their equivalent map ecotype in 3 subareas. Additionally, differences in scale between the Vegetation Plots and ITU mapping resulted in difficultly making direct comparisons between sample size and areal extent for some plot ecotype and equivalent map ecotypes.

This assessment suggests that plot ecotypes were sampled approximately equivalent to their areal extent in each subarea, and that overall the study design is reasonably robust and well balanced, especially considering that the study design is not a tightly controlled laboratory experiment, but rather includes elements of both field and natural experiments (Diamond 1983). In field experiments, experimental controls are limited to a single variable, in this case, the placement of the test and reference areas relative to the CD5 road. In natural experiments, experimental control is solely from placement of sample plots, with the goal of placing plots in locations that differ naturally in one or several factors. In the case of the CD5 Habitat Monitoring Study, the study design is based on the premise that Test and Reference Areas are similar environments, the difference being that Reference Areas are located further from the CD5 road alignment than the Test Areas and will thus be less impacted by the placement of the CD5 road. The primary advantages of natural experiments include efficiency in data collection relative to highly controlled experiments, and the ability to use natural ecological patterns as the premise for monitoring for changes in habitat through time. The primary disadvantage is that in natural experiments the researcher must rely on the uncontrolled natural environment as the "laboratory" for the experiment. Hence, the discussion of sampling adequacy for this study must be kept within the context of the variability within the natural landscape, with a recognition that a perfectly balanced study design would be difficult if not impossible to achieve.

3.4.2.B.ii. Canonical Correspondence Analysis (CCA)

Ordination diagrams are presented in the following section that charts Vegetation Plot data in two dimensions (Figures 3.17 and 3.18). Individual plots are represented as a single point in the diagrams, and the points are symbolized (e.g., in Figure 3.17 either circles, triangles, crosses, or "×"), with each symbol representing the plot ecotype class to which each plot was assigned. The location of plots to one another in the ordination diagrams corresponds to the similarity in vegetation species composition. Plots that are more similar to one another in species composition are located closer to one another in the ordination, while plots that are dissimilar are located further apart. The arrows overlaid on the ordination diagrams indicate the environmental characteristics (e.g., water table depth) that explain the distribution of plots in the ordination, i.e., differences and similarities in species composition between Vegetation Plots. For future monitoring, vegetation data from subsequent years will be displayed in ordination space using CCA or similar as explained in the Monitoring Plan. Data will be

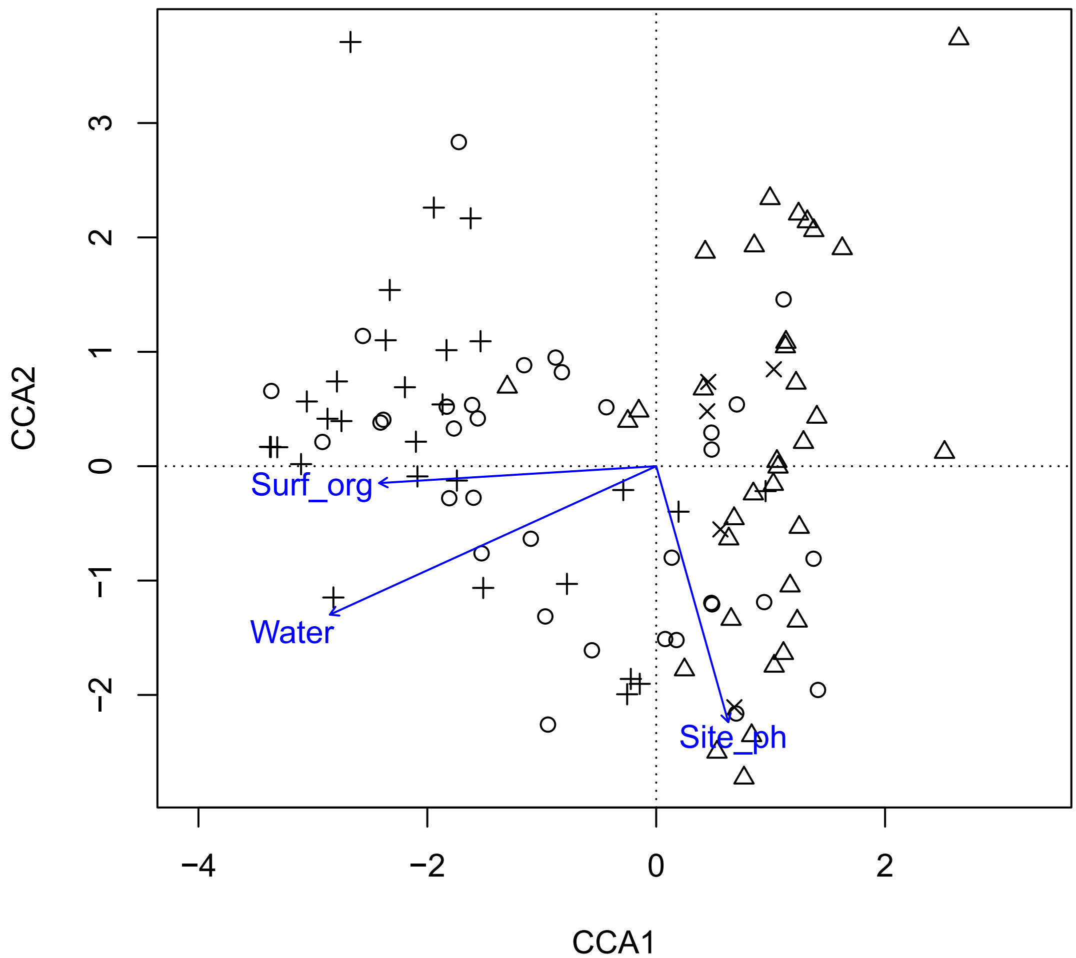


Figure 3.17. Canonical Correspondence Analysis of 4 wet plot ecotypes, CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Plot ecotypes include Riverine Organic-Rich Circumneutral Wet Sedge Meadow (circles), Riverine Organic-Rich Circumneutral Wet-Sedge Willow Meadow (triangles), Lowland Organic-Rich Circumneutral Wet Sedge Meadow (crosses), and Lowland Organic-Rich Circumneutral Wet Sedge-Willow Tundra ("x").

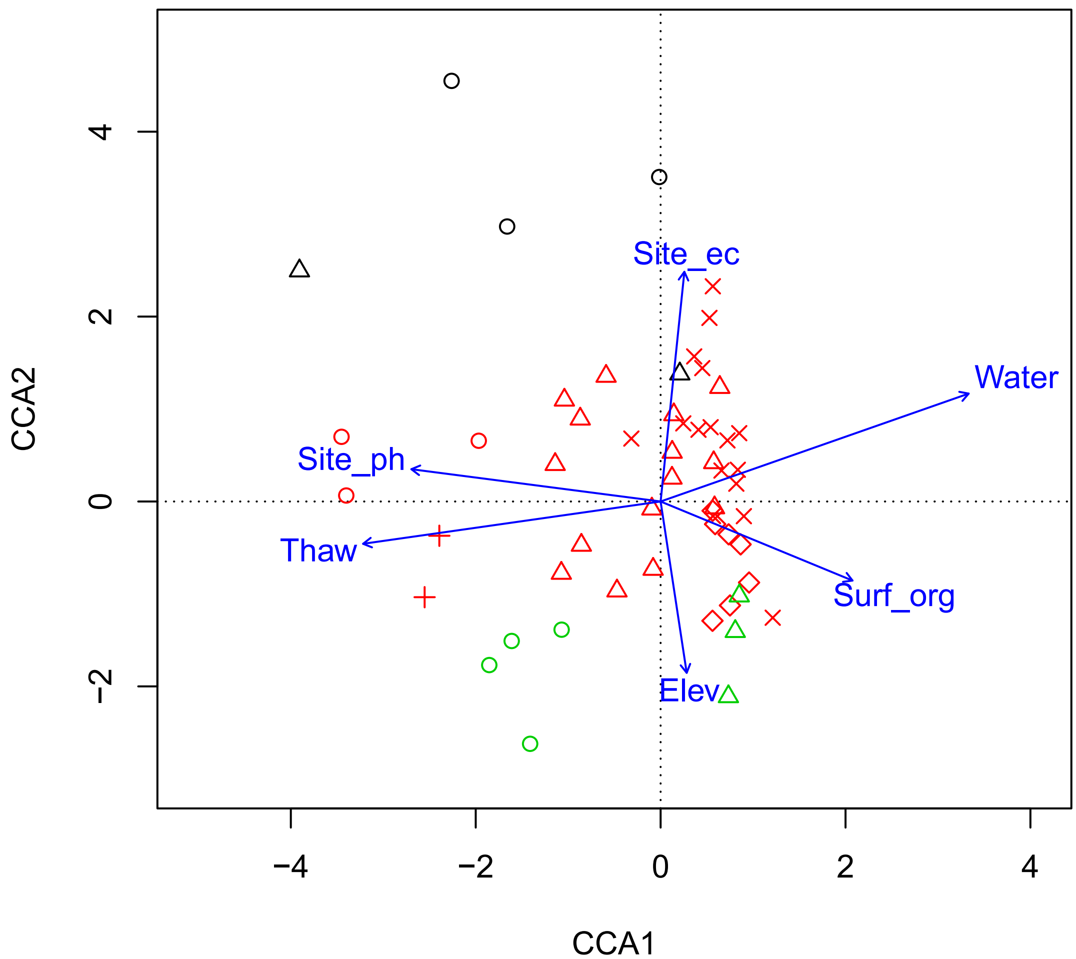


Figure 3.18. Canonical Correspondence Analysis of 9 moist plot ecotypes, CD Habitat Monitoring Study Area, northern Alaska, 2013. Plot ecotypes include Coastal Loamy Brackish Moist Willow Dwarf Shrub (black circles), Coastal Sandy Moist Brackish Barrens (black triangles), Riverine Loamy Alkaline Moist Mixed Herb (red circles), Riverine Loamy Alkaline Moist Low Willow Shrub (red triangles), Riverine Loamy Alkaline Moist Tall Willow Shrub (red crosses), Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow (red "x"), Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow (red diamond), Upland Sandy Alkaline Moist Low Willow Shrub (green circles), and Upland Loamy-Organic Circumneutral Moist Tussock Meadow (green triangles).

Table 3.27. Correlation (CCA1 and CCA2), model fit (R2), and p-value for 3 environmental variables significant at the 0.001 level in the Canonical Correspondence Analysis (CCA) of wet sedge and wet sedge–willow ecotypes, CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

Environmental Variable	Code	CCA1	CCA2	R^2	*p*-value
Surface Organic Thickness	Surf_org	-1.00	-0.06	0.29	0.001
pH	Site_ph	0.27	-0.96	0.27	0.001
Water Table Depth	Water	-0.91	-0.41	0.49	0.001

Table 3.28. Correlation (CCA1 and CCA2), model fit (R2), and p-value for 6 environmental variables significant at the 0.001 level in the Canonical Correspondence Analysis (CCA) of moist ecotypes, CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

Environmental Variable	Code	CCA1	CCA2	R^2	*p*-value
Elevation	Elev	0.15	-0.99	0.23	0.001
Thaw Depth	Thaw	-0.99	-0.14	0.69	0.001
Surface Organic Thickness	Surf_org	0.92	-0.38	0.33	0.001
pH	Site_ph	-0.99	0.13	0.48	0.001
Electrical Conductivity	Site_ec	0.10	0.99	0.41	0.001
Water Table Depth	Water	0.94	0.33	0.81	0.001

analyzed following the general methods underpinning the reference condition approach to monitoring ecological communities as per Reynoldson et al. (2001). Vegetation data from both test and reference areas from post-construction monitoring years will be ordinated with the pre-construction data to determine if a shift in species composition (i.e., as indicated by the location of the plots in the ordination diagrams) has occurred over time.

The environment in the CD5 Habitat Monitoring Study Area is complex, with many interacting biotic and abiotic landscape elements (Figures 3.1 and 3.2). The CCA revealed that ecotypes in the CD5 Habitat Monitoring Study Area are oriented along environmental gradients of elevation above sea level, thaw depth, soil moisture, soil chemistry, and frequency of sedimentation (Tables 3.27 and 3.28, Figures 3.17 and 3.18).

In the CCA of wet sedge and wet sedge-willow ecotypes, 3 environmental variables were significant (p = 0.001), including thickness of the surface organic layer (*surf_org*), pH (*site_pH*), and water table depth (*water_depth*, Table 3.27). Of these 3 variables, water table depth had the highest model fit (R^2) value. Site pH was negatively correlated with Axis 2, while surface organic thickness and water table depth were negatively correlated with Axis 1 (Figure 3.17). Thus, decreasing surface organic thickness and water table depth (i.e., deeper water tables) are predicted from left to right along Axis 1 in the CCA diagram, while decreasing pH is predicted from bottom to top along Axis 2. Surface organic thickness is the thickness of organic soil material from the soil surface down to the first mineral soil layer (≥0.02 in [0.5 mm]). Surface organic layer is used as a proxy for frequency and intensity of sedimentation, given the assumption that a thicker surface organic layer equates to a longer period since the last sedimentation event, relative to a soil with a thinner surface organic layer. The ecotypes Riverine Wet Sedge Meadow, Riverine Wet Sedge-Willow Meadow, and Lowland Wet Sedge-Willow Meadow are clustered predominantly in center right of the CCA diagram corresponding to thinner surface organic layers, and hence more sedimentation, and deeper water tables. The ecotype Lowland Wet Sedge Meadow is clustered predominantly on the left side of the CCA diagram, corresponding to thicker surface organic layers and hence less frequent sedimentation and shallower water tables. Similar trends in surface organic thickness and water table depth for Riverine and Lowland Wet Meadows were reported for the Colville River Delta by Jorgenson et al. (1997).

In the CCA of moist ecotypes, 6 environmental variables were significant (p = 0.001), including thickness of surface organic layer (*surf_org*), elevation above sea level, thaw depth (*thaw_depth*), pH (*site_ph*), electrical conductivity (*site_ec*), and water table depth (*water_depth)* (Table 3.28). Of these 6 variables, thaw depth, water table depth, and pH had the highest model fit (R^2) values. Site pH and thaw depth were negatively correlated with Axis 1, while water table depth and surface organic thickness were positively correlated with Axis 1 (Figure 3.18). Higher pH, deeper thaw depths, thinner surface organic layers, and deeper water tables are predicted on the left side of Axis 1 corresponding to the ecotypes that receive frequent overbank flooding and sedimentation. These include Riverine Loamy Alkaline Moist Mixed Herb, Riverine Loamy Alkaline Moist Tall Willow Shrub, and Riverine Loamy Alkaline Moist Low Willow Shrub. Lower pH, shallower thaw and water table depths, and thicker surface organic layers are predicted on the right side of Axis 1, corresponding to ecotypes that receive less frequent flooding and sedimentation, including Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow and Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow.

Elevation was negatively correlated with Axis 2, while EC was positively correlated with Axis 1. Thus, higher EC and lower elevations are predicted on the upper end of Axis 2, while lower EC and higher elevations are predicted on the lower end of Axis 2. EC is a measure a material's ability to conduct electricity. For instance, water with higher concentrations of dissolved salts has a higher EC. Hence, EC is used as a proxy for salinity here, with higher electrical conductivities corresponding to higher salinity. Along Axis 2, ecotypes that occur at lower elevations across the floodplain and that are associated with higher EC occur along upper end of Axis 1, including Coastal Loamy Brackish Moist Willow Dwarf Shrub and Coastal Sandy Moist Brackish Barrens. Ecotypes that occur at the highest elevations and low EC occur along the lower end of Axis 2, including Upland Sandy Alkaline Moist Low Willow Shrub and Upland Loamy-Organic Circumneutral Moist Tussock Meadow.

3.4.2.B.iii. Species Composition by Plot Ecotype

The species composition summaries by plot ecotype were prepared as indicated in the Monitoring Plan (ABR and Baker 2013). Species composition was summarized by plot ecotype in three ways, including species constancy/cover tables, species richness, and vegetation structure class and height summaries. These summaries provide baseline data on vegetation species composition and structure for use in describing the vegetation communities and ground cover classes associated with each plot ecotype.

Tables 3.6 and 3.7 provide a summary of species composition by plot ecotype, including an indication of the most frequently occurring species in each plot ecotype, the average cover when a species occurs in a plot ecotype, and species richness. The summary tables were used in Table 3.5 to report on the dominant and characteristic species in each plot ecotype description. Species richness is one component of species diversity and is a count of the total number of unique species occurrences. In this case, species richness was summarized for each plot ecotype, including vascular species richness, non-vascular species richness, and total species richness. Appendices D and E provide a comprehensive list of all vegetation species encountered during the 2013 Habitat Monitoring effort.

Species Richness

The plot ecotypes with the highest total species richness included Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow (127 species), Riverine Organic-rich Circumneutral Wet Sedge Meadow (108), and Riverine Loamy Alkaline Moist Low Willow Shrub (102). The aquatic plot ecotype Lowland Lake (1) had the lowest species richness of all plot ecotypes. Terrestrial plot ecotypes with the lowest total species richness included Coastal Sandy Moist Brackish Barrens (19), Coastal Loamy Brackish Moist Willow Dwarf Shrub (29), and Riverine Loamy Alkaline Moist Mixed Herb (33). The plot ecotypes with the highest total species richness are two of the most commonly sampled plot ecotypes, while the plot ecotypes with the lowest total species richness had a sample size of ≤5 plots, suggesting that species richness may be correlated with sample size. To address this, ABR plotted species richness as a function of sample size (Figure 3.19) and found that for plot ecotypes with sample sizes of ≤5, species richness increased rapidly as the number of plots increased. When sample size was >5, species richness generally increased, but in a non-linear fashion, with several plot ecotypes featuring lower species richness than those with lower sample size. The results suggest that species richness is sensitive to low sample size (approximately ≤5), but is generally robust at sample sizes >5.

Vegetation Structure Class Summaries by Plot Ecotype

Another component of species composition is vegetation structure, which incorporates the species life form (e.g., grass, forb, shrub, etc.) as well as height class for woody classes (e.g. dwarf shrub, low shrub). A summary of vegetation structure class cover and non-vegetated top cover by plot ecotype is presented in Figure 3.20 and Table 3.29.

Plot ecotypes with the highest cover of water alone include Lowland Lake and Lowland Organic-rich Circumneutral Wet Sedge Meadow. Soil Alone had the highest cover in Coastal Sandy Moist Brackish Barrens, Coastal Loamy Brackish Moist Willow Dwarf Shrub, and Riverine Loamy Alkaline Moist Mixed Herb. Litter Alone was highest in Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow, Lowland Organic-rich Circumneutral Wet Sedge Meadow, and Riverine Organic-rich Circumneutral Wet Sedge Meadow. Cover of mosses was highest in Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow, Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow, and Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow. Lichen cover was generally absent to low across all plot ecotypes, but was highest in Upland

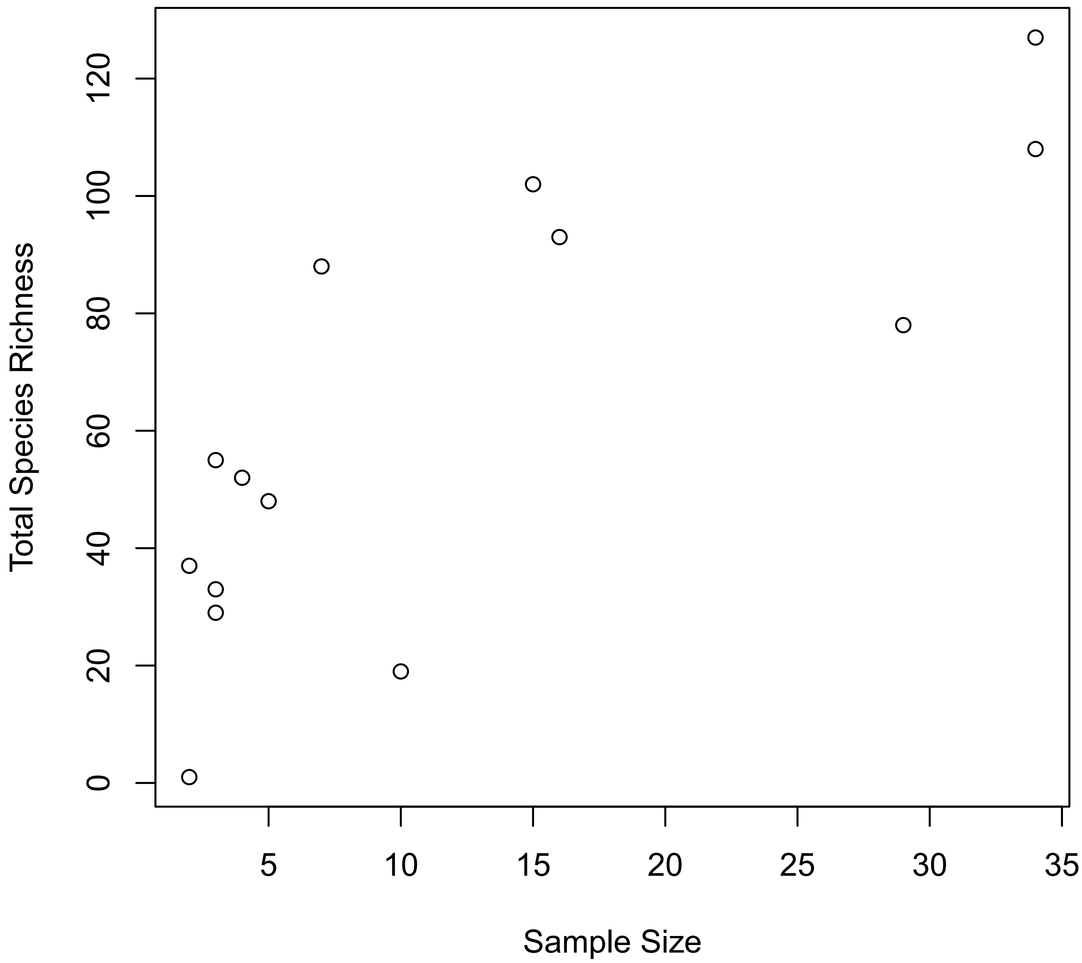


Figure 3.19. Species richness as a function of sample size for plot ecotypes in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

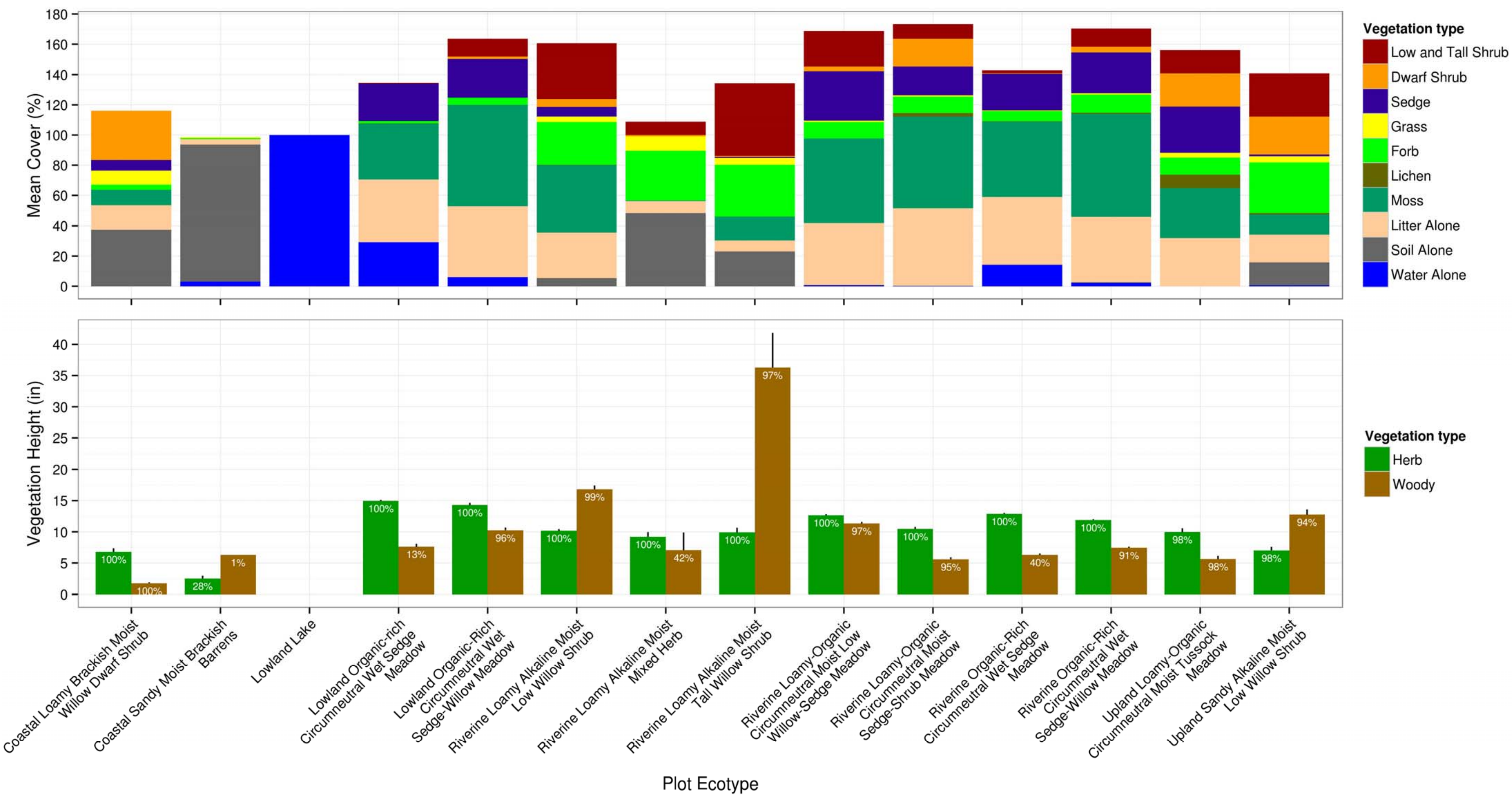


Figure 3.20. Mean cover by vegetation structure class and herbaceous and woody plant height for plot ecotypes with a sample greater than one in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. For vegetation height plot (bottom), the bar represents the vegetation height, the black line represents the standard error of the height, and the percentage value represents the frequency of occurrence.

Table 3.29. Mean cover by vegetation structure class and herbaceous and woody plant height for plot ecotypes with sample size greater than one in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

		Top Cover (%)			Vegetation Cover (%)							Vegetation Heights					
Plot Ecotype	Number of Vegetation Plots	Water Alone	Soil Alone	Litter Alone	Moss and Liverwort	Lichen	Forb	Grass	Sedge	Dwarf Shrub	Low And Tall Shrub	Woody Height (in)	Woody Height (cm)	Woody Frequency (%)	Herb Height (in)	Herb Height (cm)	Herb Frequency (%)
Coastal Loamy Brackish Moist Willow Dwarf Shrub	3	0.0	37.3	16.2	10.1	0.0	3.5	9.2	7.0	32.9	0.0	1.8	4.5	100.0	6.8	17.2	100.0
Coastal Sandy Moist Brackish Barrens	10	3.1	90.6	3.5	0.0	0.0	0.8	0.7	0.0	0.0	0.0	6.3	16.0	0.6	2.5	6.4	28.1
Lowland Lake	2	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lowland Organic-rich Circumneutral Wet Sedge Meadow	29	29.2	0.0	41.3	37.1	0.1	1.6	0.1	24.7	0.1	0.4	7.6	19.3	12.6	14.9	38.0	100.0
Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	5	6.1	0.0	46.8	67.1	0.0	4.7	0.0	25.5	1.6	11.8	10.3	26.1	96.3	14.3	36.3	100.0
Riverine Loamy Alkaline Moist Low Willow Shrub	15	0.0	5.4	30.1	44.6	0.2	28.3	3.6	6.3	5.3	36.8	16.8	42.7	99.2	10.2	25.8	100.0
Riverine Loamy Alkaline Moist Mixed Herb	3	0.0	48.3	7.9	0.4	0.0	32.9	9.7	0.0	0.9	8.8	7.0	17.9	41.7	9.2	23.4	100.0
Riverine Loamy Alkaline Moist Tall Willow Shrub	2	0.0	23.0	7.2	15.8	0.0	34.2	4.6	0.7	0.7	48.0	36.3	92.1	96.9	9.9	25.2	100.0
Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	16	0.6	0.2	41.3	55.7	0.0	10.8	0.9	32.7	2.9	23.7	11.3	28.8	97.3	12.6	32.1	100.0
Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	7	0.2	0.2	51.1	60.7	2.4	10.7	0.9	18.8	18.4	9.8	5.6	14.2	94.6	10.5	26.6	100.0
Riverine Organic-rich Circumneutral Wet Sedge Meadow	34	14.2	0.0	44.7	49.9	0.2	6.9	0.5	24.3	0.3	1.9	6.3	16.0	39.5	12.9	32.7	99.8
Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow	34	2.1	0.5	43.2	68.3	0.7	11.9	0.9	26.8	4.0	12.1	7.4	18.9	91.2	11.9	30.2	100.0
Upland Loamy-Organic Circumneutral Moist Tussock Meadow	3	0.0	0.0	32.0	32.9	8.8	11.4	3.1	30.7	21.9	15.4	5.6	14.3	97.9	10.0	25.3	97.9
Upland Sandy Alkaline Moist Low Willow Shrub	4	0.7	15.1	18.4	13.2	1.0	33.6	4.0	1.3	25.0	28.6	12.7	32.4	93.8	7.0	17.8	98.4

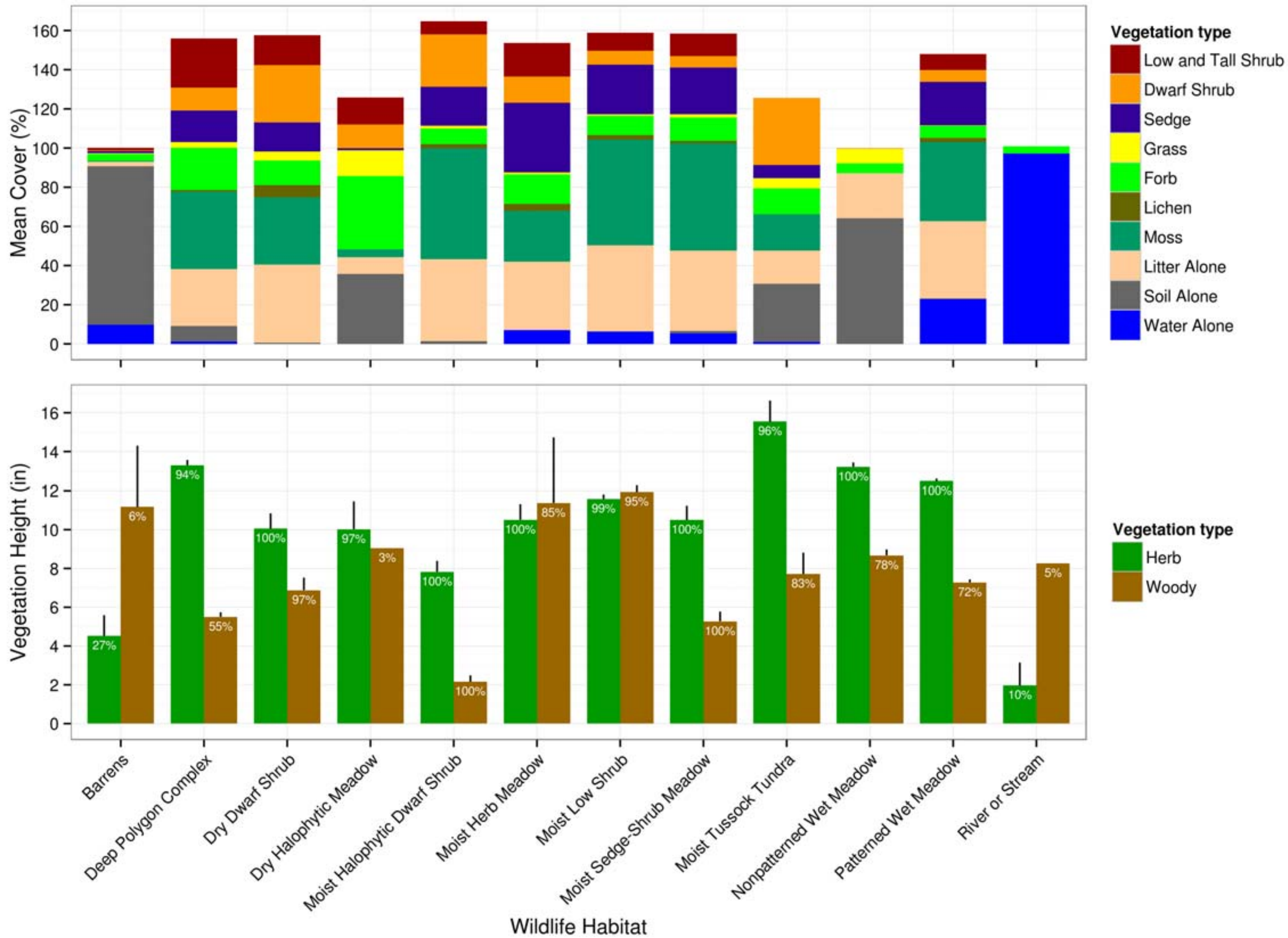


Figure 3.21. Mean cover by vegetation structure class and herbaceous and woody plant height for wildlife habitat classes with at least 75 Habitat Plot Sample Points in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. For vegetation height plot (bottom), the bar represents the vegetation height, the black line represents the standard error of the height, and the percentage value represents the frequency of occurrence.

Loamy-Organic Circumneutral Moist Tussock Meadow.

Forbs were most abundant in upland and riverine willow plot ecotypes, including Riverine Loamy Alkaline Moist Tall Willow Shrub, Upland Sandy Alkaline Moist Low Willow Shrub, and Riverine Loamy Alkaline Moist Low Willow Shrub; and in Riverine Loamy Alkaline Moist Mixed Herb. Grasses had the highest cover in Riverine Loamy Alkaline Moist Mixed Herb and Coastal Loamy Brackish Moist Willow Dwarf Shrub. Sedges predominated in several plot ecotypes, with the highest average cover in Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow and Upland Loamy-Organic Circumneutral Moist Tussock Meadow. Dwarf shrubs (< 8 in. [20 cm]) were most abundant in Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow, Upland Sandy Alkaline Moist Low Willow Shrub, and Upland Loamy-Organic Circumneutral Moist Tussock Meadow. Lastly, low and tall shrub was most common in willow-dominated plot ecotypes, most notably, Riverine Loamy Alkaline Moist Tall Willow Shrub and Riverine Loamy Alkaline Moist Low Willow Shrub.

A summary of herbaceous ("herb," i.e., non-woody) and woody vegetation heights by plot ecotype is presented in Figure 3.21 and Table 3.29. Woody vegetation frequency was highest in willow-dominated plot ecotypes and lowest in Lowland Lake, wet sedge-dominated ecotypes, and Coastal Sandy Moist Brackish Barrens. Woody vegetation heights were highest in Riverine Loamy Alkaline Moist Tall Willow Shrub, Riverine Loamy Alkaline Moist Low Willow Shrub, and Upland Sandy Alkaline Moist Low Willow Shrub; and were lowest in Lowland Lake and Coastal Loamy Brackish Moist Willow Dwarf Shrub. Herbaceous vegetation was ≥97% in all but 2 plot ecotypes: Lowland Lake and Coastal Sandy Moist Brackish Barrens.

3.4.2.C. Habitat Assessment

Summaries of vegetation structure cover, non-vegetated top cover, and herb and woody vegetation heights by wildlife habitat class are provided below. These summaries provide 1) quantitative cover and height values of general vegetation structural classes and ground cover types for wildlife habitat map classes for use in describing the mapping classes; and 2) a quantitative baseline for long-term habitat monitoring. In future monitoring years, data from repeat sampling of Habitat Plots will be summarized as below and compared to the baseline as detailed in the Monitoring Plan (ABR and Baker 2013).

Habitat Plot data were summarized by wildlife habitat class for all wildlife habitats with at least 75 points. Of the 24 wildlife habitats in the CD5 Habitat Monitoring Study Area, 12 had sufficient data. The sampling design avoided placing Habitat Plot Center Points in waterbodies, and as such, waterbody habitats were not frequently sampled. Thus, of the 7 waterbody habitats, only the "River or Stream" class met the 75 point criteria. The 6 terrestrial wildlife habitat classes with insufficient data from the Habitat Plots were all rare. The 11 terrestrial wildlife habitat classes with sufficient data cover 98.2% of the non-water portion of the study area (Table 3.20).

Summaries of vegetation structure class cover and non-vegetated top cover by wildlife habitat class are presented in Figure 3.21 and Table 3.30. Wildlife habitats with the highest cover of water alone include River or Stream and Deep Polygon Complex. Soil alone had the highest cover in Barrens, Dry Halophytic Meadow, and Moist Herb Meadow. Moist Low Shrub and Moist Halophytic Dwarf Shrub also had appreciable soil alone cover. Litter alone was highest in Patterned Wet Meadow, Nonpatterned Wet Meadow, Moist Sedge-Shrub Meadow, and Dry Dwarf Shrub. Cover of mosses was highest in Moist Sedge-Shrub Meadow, Patterned Wet Meadow, and Nonpatterned Wet Meadow. Lichen cover was generally absent to low across all wildlife habitats, but was highest in Dwarf Low Shrub and Moist Tussock Tundra. Forbs were most abundant in Moist Herb Meadow and Moist Low Shrub, while grasses had the highest cover in Moist Herb Meadow and Dry Halophytic Meadow. Wildlife habitats with the highest cover of sedges included Moist Tussock Tundra, Patterned Wet Meadow, and Nonpatterned Wet Meadow. Dwarf shrubs were most common in Moist Halophytic Dwarf Shrub, Dry Dwarf Shrub, and Moist Sedge-Shrub Meadow. Lastly, low and tall shrub cover was highest in Moist Low Shrub, Tussock Tundra, and Dry Dwarf Shrub.

Table 3.30. Mean cover by vegetation structure class and herbaceous and woody plant height for wildlife habitat classes with at least 75 Habitat Plot Sample Points in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

	Top Cover (%)				Vegetation Cover (%)						Vegetation Heights					
Wildlife Habitat	Water Alone	Soil Alone	Litter Alone	Moss & Liverwort	Lichen	Forb	Grass	Sedge	Dwarf Shrub	Low And Tall Shrub	Woody Height (in)	Woody Height (cm)	Woody Frequency (%)	Herb Height (in)	Herb Height (cm)	Herb Frequency (%)
Barrens	9.8	81.0	2.2	0.5	0.0	3.4	0.6	0.9	0.5	1.3	11.2	28.4	6.1	4.5	11.5	27.5
Deep Polygon Complex	22.9	0.1	39.6	40.3	2.2	6.3	0.1	22.2	6.2	8.0	5.5	14.0	55.0	13.3	33.8	93.6
Dry Dwarf Shrub	0.0	0.6	40.0	34.3	6.3	12.6	4.6	14.9	29.2	15.4	6.9	17.5	96.9	10.1	25.5	100.0
Dry Halophytic Meadow	0.0	64.3	22.8	0.0	0.0	5.2	7.3	0.0	0.5	0.0	9.1	23.0	2.6	10.0	25.5	97.4
Moist Halophytic Dwarf Shrub	1.0	29.7	16.9	18.5	0.0	13.3	5.1	6.7	34.4	0.0	2.2	5.5	100.0	7.8	19.9	100.0
Moist Herb Meadow	0.0	35.6	8.6	4.0	0.0	37.4	13.2	1.2	12.1	13.8	11.4	28.9	84.8	10.5	26.7	100.0
Moist Low Shrub	1.1	8.1	29.0	39.6	0.8	21.5	3.0	16.1	11.7	25.2	11.9	30.3	95.2	11.6	29.4	99.1
Moist Sedge-Shrub Meadow	0.0	1.3	42.0	56.7	2.0	8.0	1.3	20.0	26.7	6.7	5.3	13.4	100.0	10.5	26.7	100.0
Moist Tussock Tundra	7.1	0.0	34.8	25.9	3.6	15.2	0.9	35.7	13.4	17.0	7.7	19.6	83.3	15.5	39.5	95.8
Nonpatterned Wet Meadow	5.3	1.3	41.1	54.8	1.2	11.8	1.7	23.9	5.8	11.5	8.7	22.0	77.6	13.2	33.6	99.6
Patterned Wet Meadow	6.3	0.1	43.9	54.1	2.3	9.8	0.9	25.2	7.1	9.2	7.3	18.5	72.0	12.5	31.7	99.7
River or Stream	97.2	0.0	0.0	0.0	0.0	3.7	0.0	0.0	0.0	0.0	8.3	21.0	5.0	2.0	5.0	10.0

Summaries of herbaceous and woody vegetation heights by wildlife habitat class at Habitat Plot Points are presented in Figure 3.21 and Table 3.30. Woody vegetation frequency was highest in Moist Sedge-Shrub Meadow, Moist Halophytic Dwarf Shrub, Dry Dwarf Shrub, and Moist Low Shrub. Moist Low Shrub and Moist Herb Meadow were associated with some of the highest woody vegetation heights. Barrens also had high average woody vegetation heights, although frequency of woody vegetation was low. Note that Tall Shrub habitat classes were relatively rare and were excluded from these results due to insufficient sample points. Herb frequency was greater than 93% in all but 2 habitats, Barrens and River or Stream. Herb heights were highest in Moist Tussock Tundra, Nonpatterned Wet Meadow, Patterned Wet Meadow, and Deep Polygon Complex.

3.4.2.D. Elevation and Thaw Depth

3.4.2.D.i. Toposequence Diagrams

The toposequence diagrams illustrate some common geomorphology, surface form, and vegetation relationships in the CD5 Habitat Monitoring Study Area, which were used as the basis for classifying and mapping ecotypes.

Reference Area North, Transect 1, Segment A (r1na)

Figure 3.22 shows a toposequence diagram of the westernmost ~738 ft (225 m) portion of Monitoring Transect r1na. The transect begins at the water's edge of the Niġliagvik Channel and crosses an area regularly flooded by channelized flow (Delta Active Channel Deposit) with a non-patterned surface form and vegetation dominated by Halophytic Willow-Graminoid Dwarf Shrub Tundra and Closed Low Willow. The end of the toposequence crosses a higher floodplain surface, where ice-wedge development is fully expressed as ice-wedge polygons and the vegetation is dominated by Wet Sedge Meadow Tundra and Deep Polygon Complex (permanently flooded polygon centers bordered by marsh and wet and moist meadow vegetation). The toposequence reflects a gradient from high frequency and duration of flooding, and high sedimentation to lower frequency and duration of flooding, and lower sedimentation.

Reference Area South, Transect 6, Segment B (r6sb)

The toposequence for Monitoring Transect r6sb (Figure 3.23; approximately 1,900 ft [600 m] long) borders the east side of the Niġliq Channel and initially crosses mostly Barrens and Delta Active Channel Deposit. In contrast to Monitoring Transect r1na, however, Monitoring Transect r6sb moves into Delta Inactive Channel Deposit, which reflects a land surface that experiences high frequency flooding. The vegetation comprises mostly Seral Herbs, although bands of Tall Open Willow and Closed Low Willow are also present. The transect portion shown ends in Eolian Inactive Sand Dune, which is dominated by Open Low Willow. The toposequence reflects a gradient from an area with mostly well-drained soils, deep active layers and relatively high frequency of flooding to an area affected less by flooding and greater amounts of ground ice and shallower active layers.

Test Area North, Transect 5, Segment A (t5na)

Figure 3.24 shows a toposequence diagram of an approximately 1,600 ft (488 m) section of Monitoring Transect t5na. The transect starts at the cut-bank of the Niġliagvik Channel and crosses Delta Inactive Overbank Deposit. Ground ice is present and expressed as Disjunct Polygon Rims or fully-formed Low-Centered, Low-Relief, Low-Density ice-wedge polygons at the surface. The associated vegetation is dominated by willows closer to the river, and by sedges as the transect advances to the east. The toposequence represents an area of predominantly wet soils with shallow active layers and intermediate ice-wedge polygonization, reflecting a relatively long disturbance-free period that has allowed for *in situ* permafrost development and expression of massive-ice features.

Test Area South, Transect 1, Segment A (t1sa)

Figure 3.25 shows a toposequence diagram of an approximately 1,394 ft (425 m) section of Monitoring Transect t1sa. Similar to Monitoring Transect t5ba, this Monitoring Transect begins at the Niġliagvik Channel. The beginning of the toposequence crosses Barrens on Delta Active Channel Deposit, with a Non-patterned surface form. Further east the transect crosses willow-dominated Delta Active Overbank Deposit with relatively deep active layers. The middle portion of the toposequence runs through poorly-drained areas featuring Low-centered, Low-relief, Low-density ice-wedge polygons with Wet Sedge Meadow Tundra and shallow active layers. Towards the end of the toposequence, Low-centered, High-relief, Low-density ice-wedge polygons with the complex vegetation type Deep Polygon Complex, indicating large amounts of massive ground ice.

3.4.2.D.ii. Thaw/Elevation Cross Sections

Cross sections of ground surface elevation and thaw depth along the 39 monitoring transects are presented in Appendices F–I. The cross sections represent baseline conditions for thaw depth and elevation. In the future, the transects will be re-surveyed and thaw depth and elevation re-measured at the same locations. This repeat data will be overlaid on the baseline cross section diagrams to visually assess potential changes in thaw depth and elevation through time, as per the Monitoring Plan (ABR and Baker 2013).

3.4.2.D.iii. Thaw Depth and Elevation Summaries by Map Ecotype

Thaw Depth/Elevation Point data were summarized by map ecotype class for all map ecotypes with at least 2 Thaw Depth/Elevation Points. Of the 31 terrestrial map ecotypes in the CD5 Habitat Monitoring Study Area, 18 had sufficient data. The sampling design avoided placing Thaw Depth/Elevation Points in waterbodies and as such, waterbody ecotypes were not sampled. The 13 terrestrial map ecotype classes with insufficient data from the Thaw Depth/Elevation Points were all rare. The 18 terrestrial map ecotype classes with sufficient data cover 96.7% of the non-water portion of the CD5 Habitat Monitoring Study Area (Table 3.31).

Map ecotypes were generally organized along an elevation gradient from coastal ecotypes at the lowest elevations, riverine ecotypes at moderate elevations, and lowland and upland ecotypes at the highest elevations. Map ecotypes with the highest average elevation above sea level (13.5–14.9 ft [4.1–4.5 m]) included Upland Dry Dryas Dwarf Shrub and Upland Moist Low Willow Shrub (Table 3.31, Figure 3.26). These ecotypes are typical of active and inactive sand dunes and feature some the highest elevations in the CD5 Habitat Monitoring Study Area. Map ecotypes with the lowest average elevation included Coastal Barrens and Coastal Moist Willow Dwarf Shrub. These ecotypes occur on active channel deposits along river channels and are regularly subjected to coastal and fluvial processes, including saltwater intrusion, channelized flooding, sedimentation, and erosion.

The map ecotypes with shallow thaw depths included Upland Moist Tussock Meadow, Riverine Moist Sedge-Shrub Meadow, Lowland Wet Sedge-Willow Meadow, Lowland Deep-polygon Complex, and Lowland Wet Sedge Meadow (Table 3.31, Figure 3.27). These ecotypes typically occur on older landscape surfaces or are associated with convex surface forms (High-center, Low-relief Polygons). The deepest thaw depths occurred in ecotypes with sandy, well-drained soils, or in ecotypes located near river channels where seasonal melt is amplified due to the close proximity of flowing water during the summer months. Ecotypes with the deepest thaw depths included Riverine Moist Tall Willow Shrub (-4.4 ft [-1.3 m]), Coastal Dry Elymus Meadow (-3.5 ft [-1.1 m]), Coastal Barrens (-3.2 ft [-1.0 m]), and Riverine Moist Herb Meadow (-3.2 ft [-1.0 m]). Similar trends in thaw depth and elevation by ecotype were reported by Jorgenson et al. (1997) for the Colville River Delta.

In deltaic environments, elevation is a major factor affecting the flood regime (frequency and magnitude) at a site. Flood regime influences sedimentation and erosion, which in turn influences the types and abundance of wildlife habitat across the landscape. Ecotypes positioned at lower elevation across the landscape typically experience more frequent flooding and sedimentation than those ecotypes that occur higher elevations. Thaw depth influences soil drainage, groundwater level, soil nutrient status, and is a strong indicator of subsurface ice aggradation. The summary of Thaw Depth/Elevation Point data by map ecotype class provides a quantitative assessment of elevation and thaw depth for the map ecotype classes, as per the Monitoring Plan (ABR and Baker 2013).

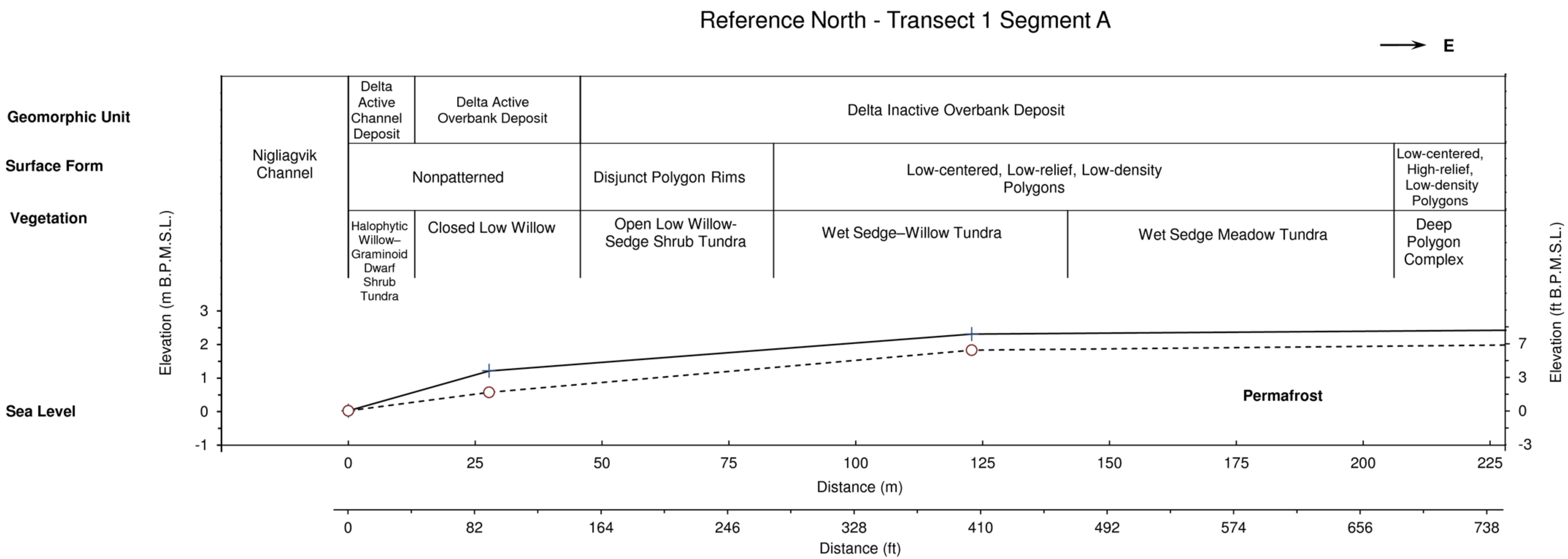


Figure 3.22. Toposequence illustrating relationships between topography, geomorphology, permafrost, soils, and vegetation along Monitoring Transect r1na, Reference Area North, CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

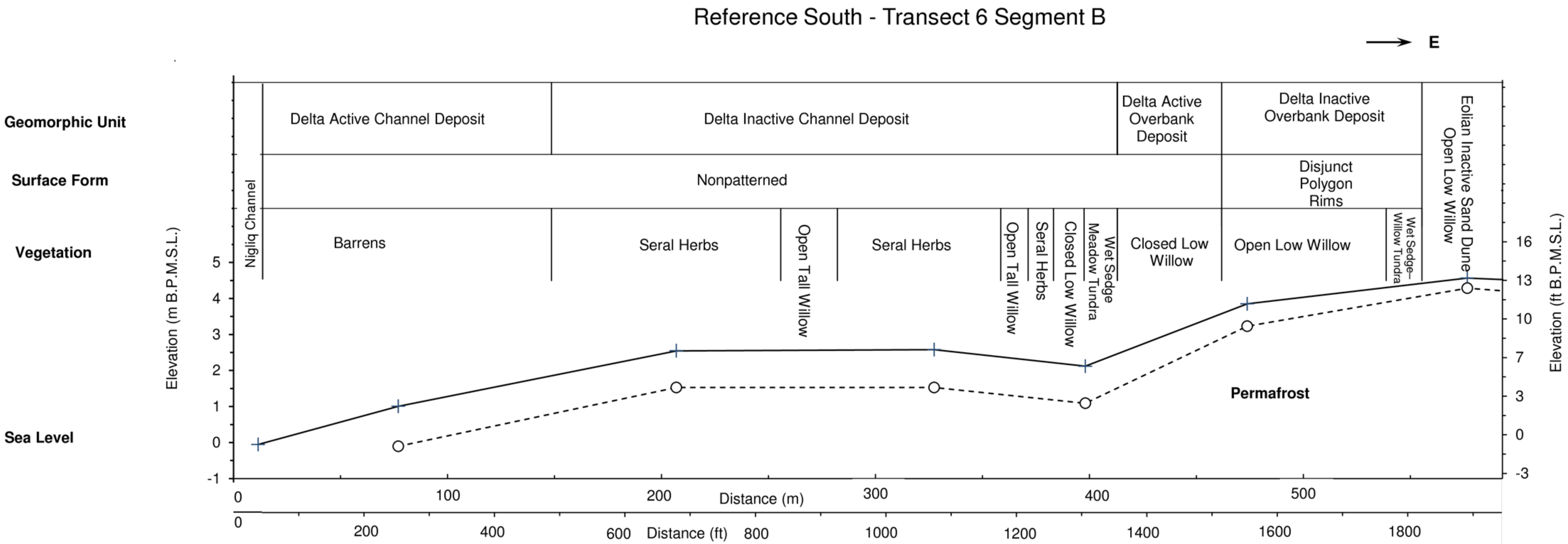


Figure 3.23. Toposequence illustrating relationships between topography, geomorphology, permafrost, soils, and vegetation along Monitoring Transect r6sa, Reference Area South, CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

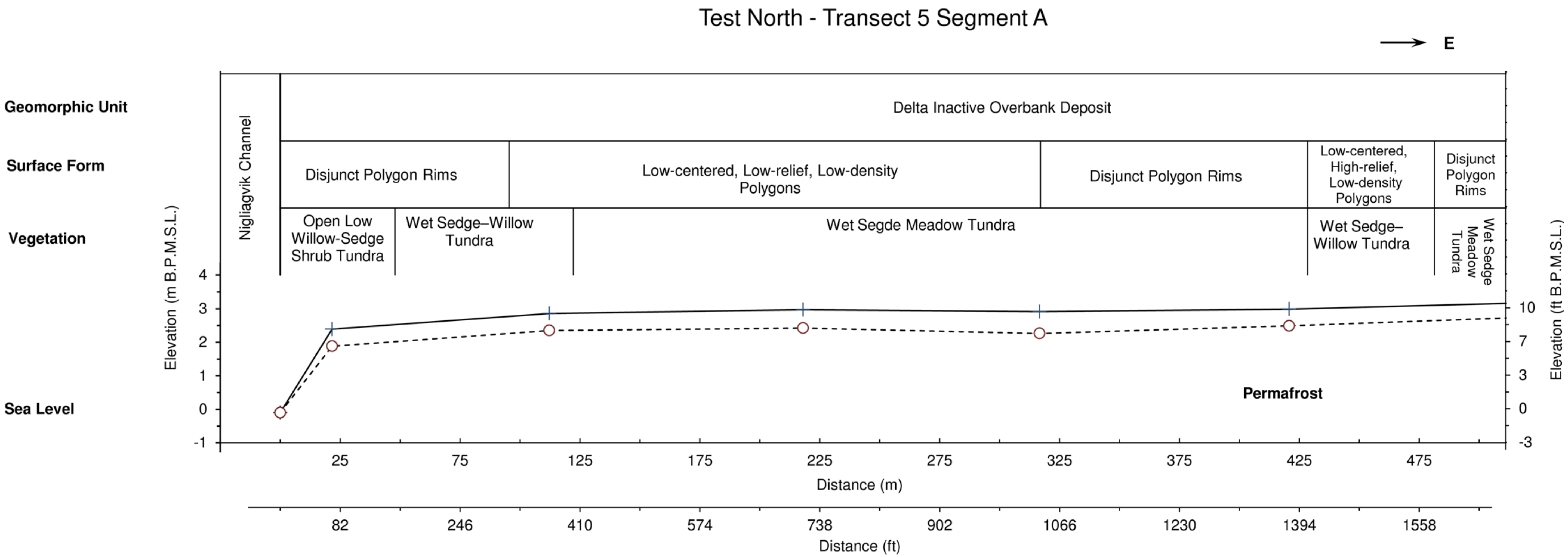


Figure 3.24. Toposequence illustrating relationships between topography, geomorphology, permafrost, soils, and vegetation along Monitoring Transect t5na, Test Area North, CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

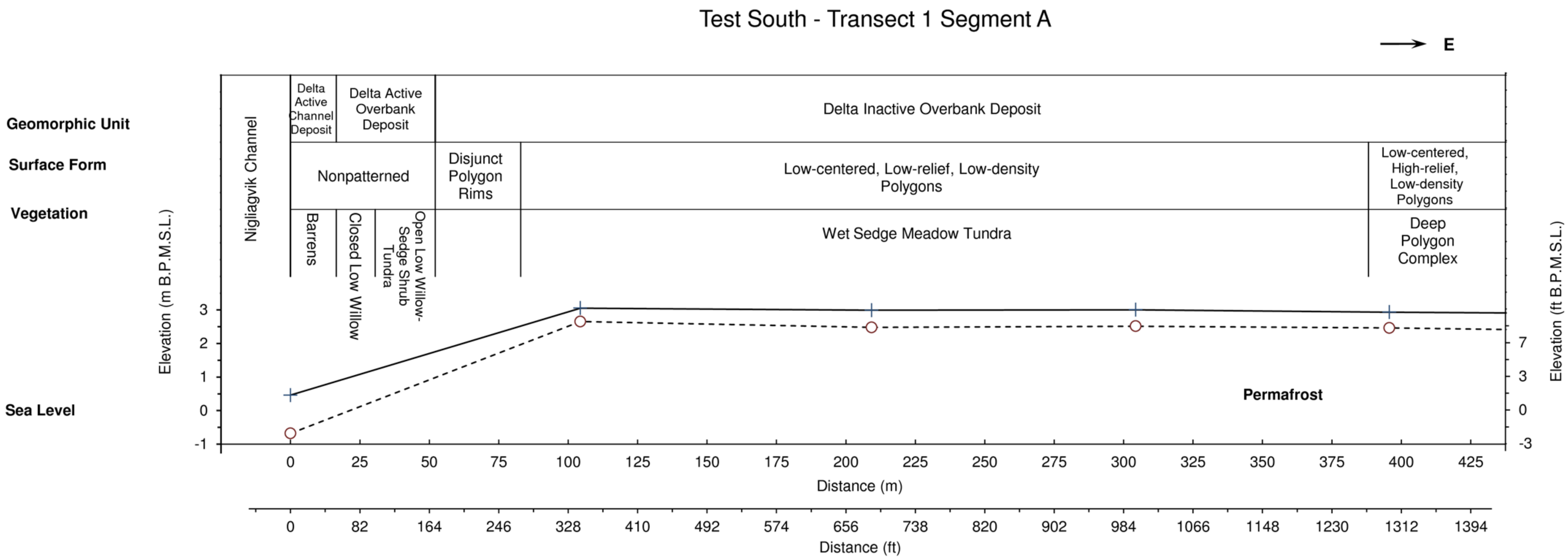


Figure 3.25. Toposequence illustrating relationships between topography, geomorphology, permafrost, soils, and vegetation along Monitoring Transect t1sa, Test Area South, CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

Table 3.31. Elevation and thaw depth summarized by map ecotype class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Elevation is referenced to British Petroleum mean sea level (BPMSL). Sample size and standard deviations are also presented.

	Elevation above BPMSL					Thaw depth				
Map Ecotype Class	Mean (ft)	sd (ft)	Mean (m)	sd (m)	n	Mean	sd	Mean (m)	sd (m)	n
Coastal Barrens	4.1	1.9	1.2	0.6	30	-3.2	0.4	-1.0	0.1	30
Coastal Dry Elymus Meadow	8	2.9	2.4	0.9	5	-3.5	0.8	-1.1	0.2	5
Coastal Moist Willow Dwarf Shrub	6.8	2.6	2.1	0.8	9	-2.5	0.6	-0.8	0.2	9
Human Modified Wet Meadow	12.3	0.7	3.7	0.2	2	-1.7	0	-0.5	0.0	2
Lowland Deep-polygon Complex	9.5	1.3	2.9	0.4	56	-1.5	0.2	-0.5	0.1	55
Lowland Wet Sedge Meadow	11.2	2.2	3.4	0.7	39	-1.5	0.2	-0.5	0.1	38
Lowland Wet Sedge-Willow Meadow	10.7	1.3	3.3	0.4	5	-1.4	0.1	-0.4	0.0	5
Riverine Deep-polygon Complex	8.8	1.1	2.7	0.3	28	-1.5	0.2	-0.5	0.1	28
Riverine Moist Herb Meadow	8.1	1.1	2.5	0.3	7	-3.2	0.4	-1.0	0.1	7
Riverine Moist Low Willow-Sedge Meadow	8.8	2.6	2.7	0.8	43	-1.7	0.4	-0.5	0.1	43
Riverine Moist Low Willow Shrub	9.4	2.7	2.9	0.8	58	-2.2	0.7	-0.7	0.2	58
Riverine Moist Sedge-Shrub Meadow	10	1.2	3.0	0.4	7	-1.4	0.2	-0.4	0.1	7
Riverine Moist Tall Willow Shrub	7.5	0.5	2.3	0.2	2	-4.4	0	-1.3	0.0	2
Riverine Wet Sedge Meadow	10.2	1.6	3.1	0.5	193	-1.6	0.3	-0.5	0.1	193
Riverine Wet Sedge-Willow Meadow	10.4	2.1	3.2	0.6	148	-1.6	0.3	-0.5	0.1	148
Upland Dry Dryas Dwarf Shrub	14.9	1.6	4.5	0.5	3	-2.1	1.1	-0.6	0.3	3
Upland Moist Low Willow Shrub	13.5	3	4.1	0.9	17	-2.9	1	-0.9	0.3	17
Upland Moist Tussock Meadow	9.9	1.3	3.0	0.4	8	-1.4	0.2	-0.4	0.1	8

3.4.2.E. Broad-scale Monitoring of Geomorphology

Per Monitoring Plan requirements (ABR and Baker 2013), three tasks were initiated in 2013 to monitor sedimentation and erosion processes within the CD5 Study Area over time. Baseline sedimentation and erosion monitoring marker horizons were established at Vegetation Plot soil plugs/pits to assess potential changes in sedimentation and erosion between monitoring years. Examples of marker horizons in soil plugs and pits are presented in Figure 3.28. ABR also documented the location of drift lines when they occurred in habitat monitoring transects as a means of documenting spring breakup flooding extent, relative to habitat monitoring plots. For example, the location of a drift line in a monitoring plot in the northern test sub-area is presented in Figure 3.29. Finally, ABR established 2 Geomorphology Monitoring Photograph Points near the proposed CD5 road alignment (Figure 3.3), which are displayed in Figure 3.30. In future monitoring years, repeat photographs will be taken from the same location and compared to the 2013 photographs. The photographic comparison will be used as a qualitative means of assessing changes in sedimentation and erosion through time.

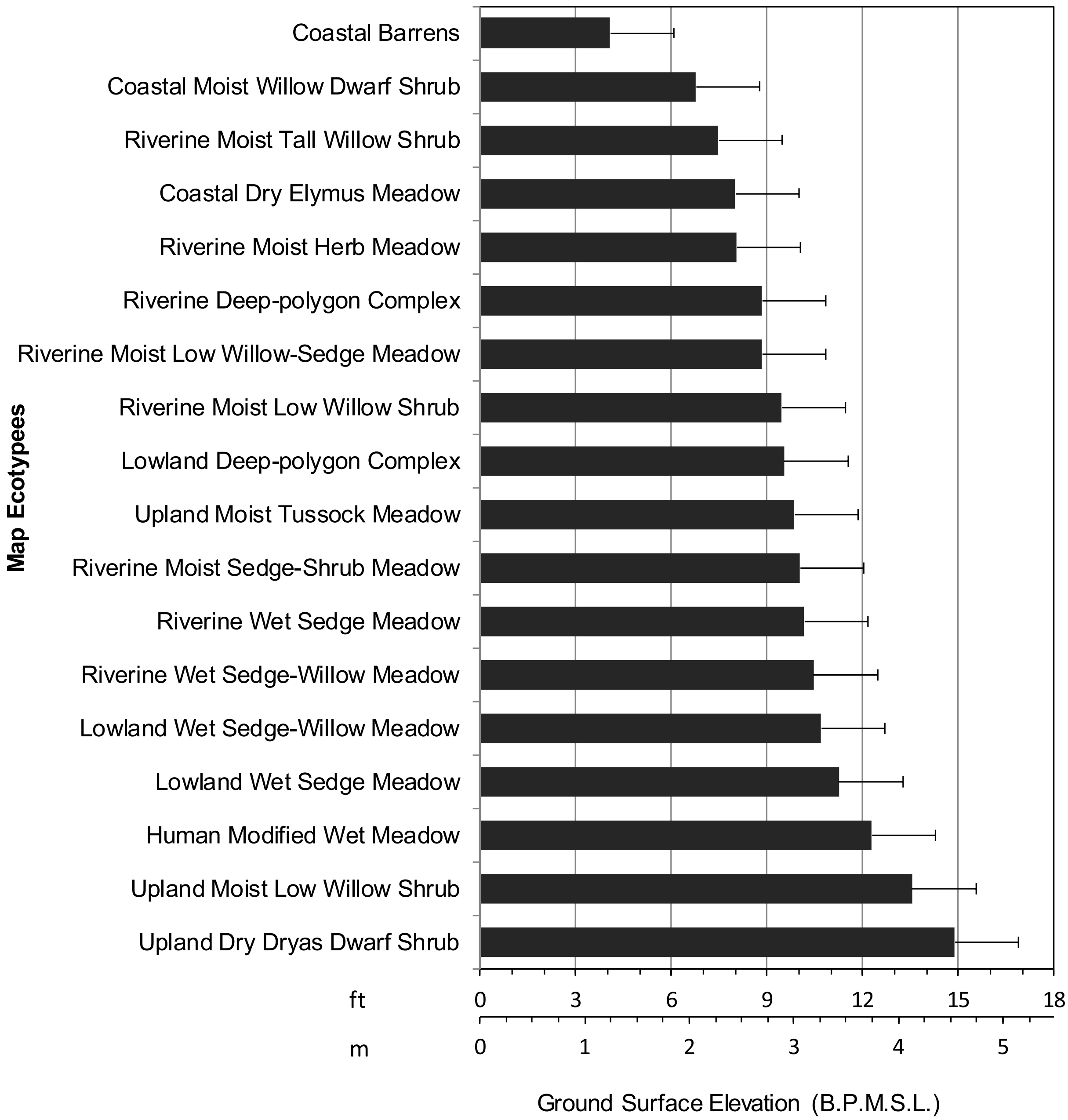


Figure 3.26. Barchart illustrating average elevation and standard error for map ecotype classes in the CD5 Habitat Monitoring Study Area, northern Alaska 2013. Elevations are referenced to British Petroleum mean sea level (BPMSL).

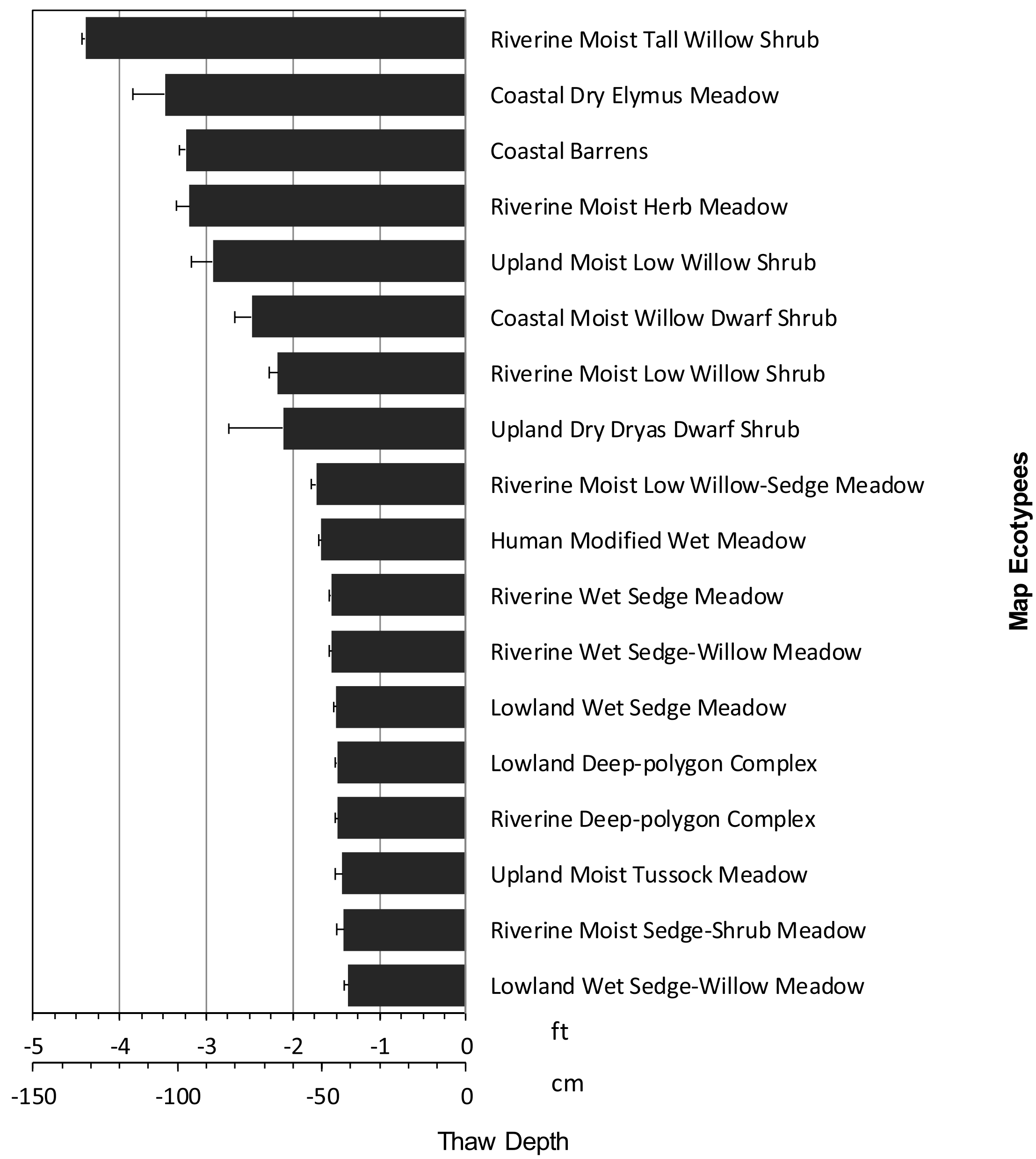


Figure 3.27. Barchart illustrating average thaw depth and standard error for map ecotype classes in the CD5 Habitat Monitoring Study Area, northern Alaska 2013.

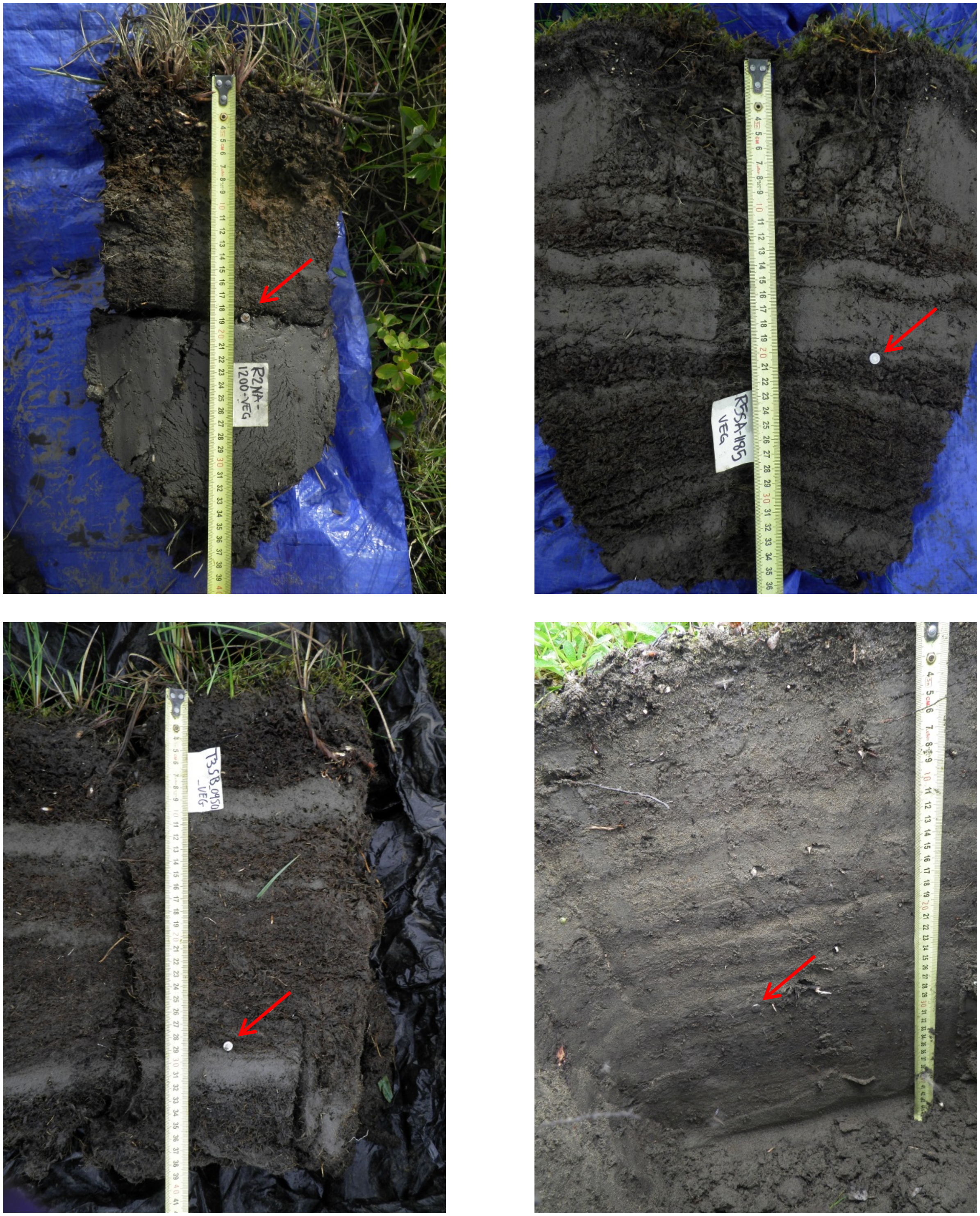


Figure 3.28. Examples of sedimentation and erosion monitoring marker horizons, including a 5-gauge nail (red arrow) placed at the upper boundary of the horizon, CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

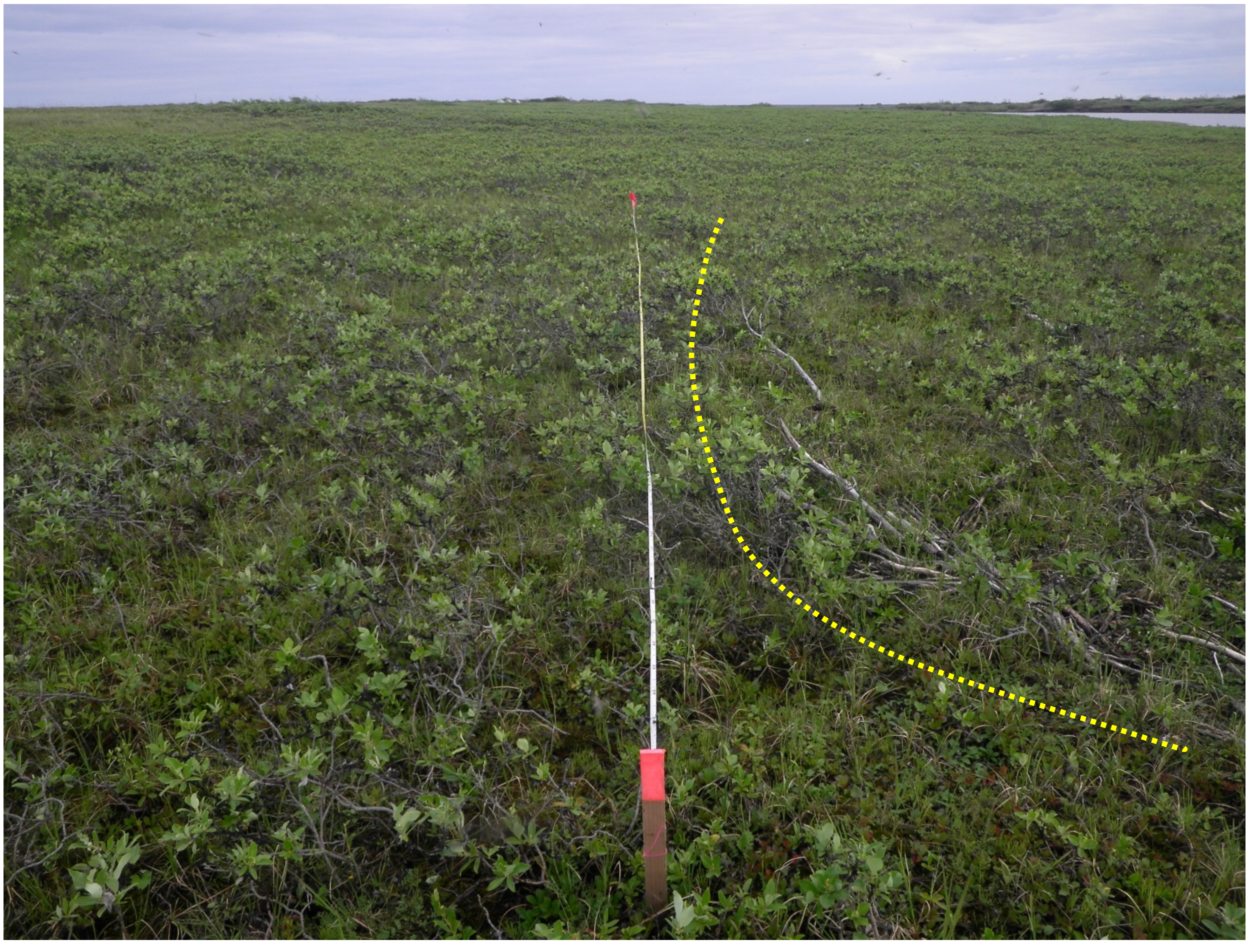


Figure 3.29. Photograph of vegetation plot number t2nb-0150-veg documenting 2013 drift line, CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Dashed yellow line shows approximate edge of drift.

a

b

c

Figure 3.30. Photographs from the Geomorphology Monitoring Photo Points, CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Photographs include a) Photo Point 1 at 110º, b) Photo Point 1 at 190º, and c) Photo Point 2 at 154º.

4.0. PERMAFROST MONITORING

4.1. RATIONALE

Shallow permafrost (within 3.3 ft [1 m] of the soil surface) underlies nearly the entire CD5 Habitat Monitoring Study Area, with the exception of active river channels. Permafrost plays a primary role in shaping the landscape of the Colville River Delta, including surface form and soil drainage, which in turn influences vegetation and wildlife habitat. Shallow permafrost is also sensitive to perturbations in thermal regime potentially related to climate change or other landscape changes. Previous permafrost studies by Jorgenson et al. (1996, 2002, 2003, 2004, and 2005), including those within the Colville River Delta and NE NPRA, provide baseline data on ice volume and ice structure by geomorphic unit. The Colville River Delta includes Delta Inactive and Abandoned Overbank Deposits that are ice-rich (>50% volumetric ice content) and feature prominent ice-wedge development (Shur and Jorgenson 1998). Because permafrost properties are temperature dependent and ice-rich permafrost settles upon thawing, the degradation of the permafrost in response to thermal perturbation has important consequences for human infrastructure and vice versa (Shur and Jorgenson 1998). The permafrost monitoring component is designed to compare differences in subsurface ice content, type of subsurface ice, permafrost temperature across the broader time period (decadal) that would be associated with climate change or gradual changes related to potentially altered soil drainage patterns or flooding related to the CD5 road.

4.2. FIELD METHODS

The permafrost monitoring field survey was conducted from 9–18 September 2013 with a field team of 5 people. The crew consisted of 2 soil scientists, 2 vegetation ecologists, and one mechanical technician. Fieldwork was based out of the Alpine Oil Facilities on the Colville River Delta and all permafrost monitoring locations were accessed via helicopter.

Permafrost Temperature Monitoring Plots were established in Delta Inactive and Abandoned Overbank Deposits within north and south reference and test areas, for a total of 16 plots (Figure 4.1). Each Permafrost Temperature Monitoring Plot included a soil temperature monitoring station and Map Verification Plot. Map Verification Plot methods are provided in Section 3 of this document under “Field Methods”.

Permafrost cores were extracted and described at 6 Permafrost Core Sample Sites co-located with Permafrost Temperature Monitoring Plots. Extracting additional permafrost cores was planned; however, ABR was unable to obtain these due to low visibility, helicopter icing, and rapidly deteriorating weather conditions.

4.2.1. SOIL TEMPERATURE MONITORING

Soil temperature is being recorded using HOBO U23 Data Loggers equipped with 2 soil temperature sensors permanently attached to each logger. The HOBO data loggers were launched (activated) according to the manufacturer’s instructions using a HOBO U-DTW-1 Waterproof Shuttle in the office prior to fieldwork. Each of the 2 sensors had a label affixed by the manufacturer identifying them as Channel 1 or Channel 2. Channels 1 and 2 were pre-measured from the tip of the metal sensor to a length of 11.8 in (30 cm) and 39.4 in (100 cm) respectively, and the depth was marked with a permanent marker. To ensure the appropriate sampling depth from the soil surface was being measured, ABR secured each channel sensor with putty at the pre-measured length to the top of the connector box (at the soil surface) between the waterproof box with the data logger and the PVC tube with the sensor cables. Prior to deployment in the field, each HOBO Data Logger was calibrated in an ice-water bath to within ±0.9°F (0.5°C), and offsets from 32°F (0°C) were recorded.

In the field, each HOBO Data Logger was deployed inside a waterproof box and polyvinyl chloride (PVC) tube system (Figure 4.2). Soil temperature is being recorded once every hour at a depth of 11.8 in (30 cm) and 39.4 in (100 cm) from the soil surface. Permafrost Temperature Monitoring locations include 5 plots in the Test Area North, 5 plots in the Test Area South, 3 plots in the Reference Area North, and 3 plots in the Reference Area South (Figure 4.1).

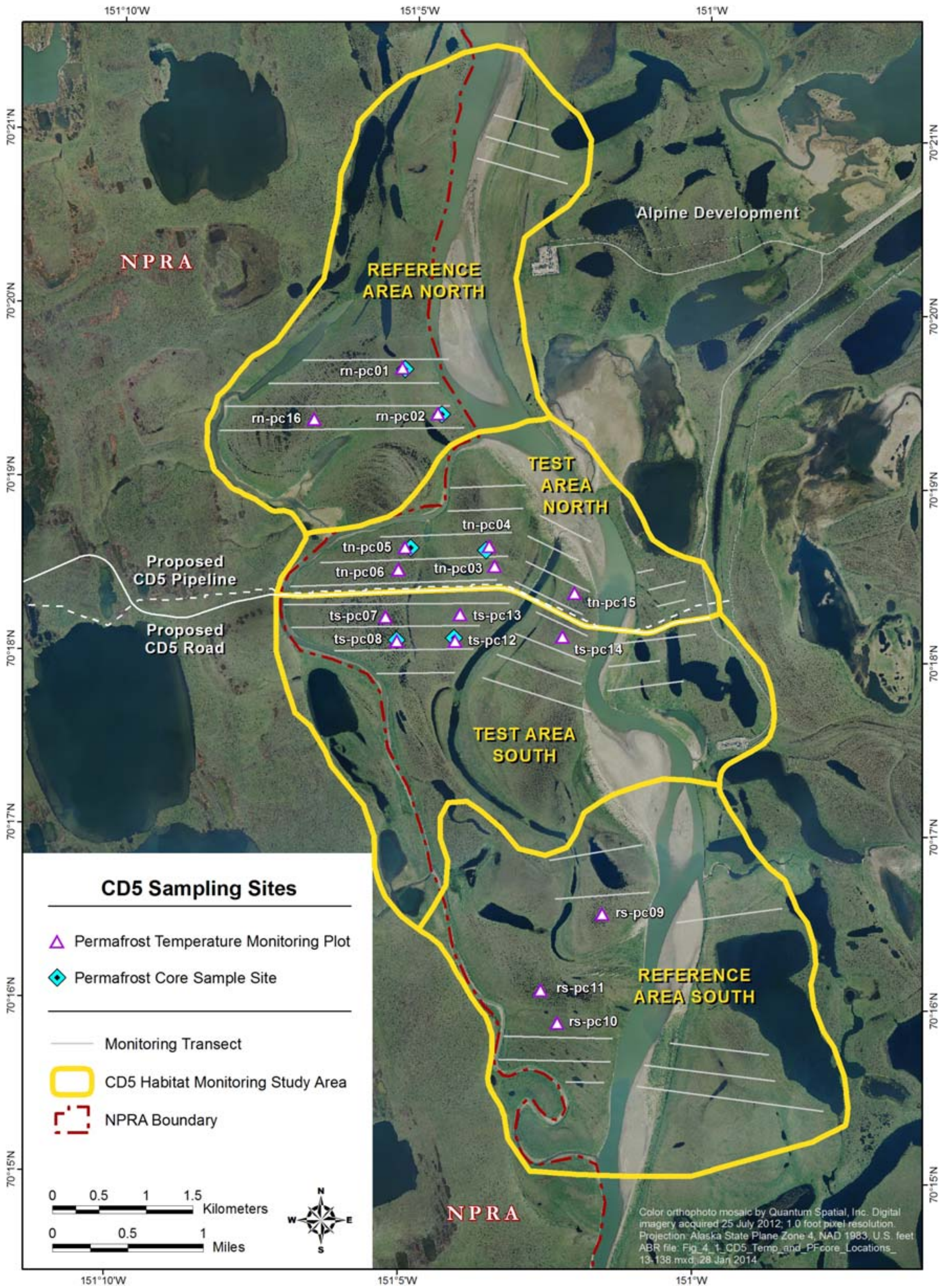


Figure 4.1. Locations of Permafrost Temperature Monitoring Plots and Permafrost Core Sample Sites in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

Figure 4.2. A selection of images showing the HOBO Temperature Logger installation and field deployment, CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Installation includes a) drilling a 1-m deep hole with a power drill; b) feeding the HOBO logger cables through the water proof box and into the PVC tube to a depth of 11.8 in (30 cm) and 39.4 in (100 cm) from the soil surface; c) sealing the box and PVC tube and reinforcing connections with waterproof tape; d) removing and restoring the surface organic mat; and e) an image of the final logger installation.

4.2.2. PERMAFROST CORES

Permafrost Core Sample Sites were co-located with 6 of the Permafrost Temperature Monitoring Plots (Figure 4.1). ABR collected field data for the Permafrost Core Sample sites by describing the active layer and SIPRE core samples on a paper field form. ABR recorded soil horizon, horizon thickness, soil texture, and ice structure (Figure 4.3, Table 4.1) for each unique horizon. Materials below the active layer were described by coring moderately deep (3.3–5.5 ft [1–1.7 m]) permafrost cores using a 3 in (7.62 cm) Snow, Ice and Permafrost Research Establishment (SIPRE) corer (Figure 4.4). Detailed photographs of the permafrost cores were recorded using Panasonic Lumix DMC-TS4 cameras. Spatial information for permafrost monitoring plots was recorded in tablets and with a DeLorme PN60 GPS device. Detailed photographs of the HOBO installation, vegetation, and site and soil characteristics were recorded using Panasonic Lumix DMC-TS4 cameras. Field photographs were downloaded and backed up each night.

Several (2–4) unique soil horizons from each Permafrost Core Sample Site were collected to measure and analyze soil properties, including bulk density, volumetric ice content, particle size (texture), and loss on ignition (estimated percent organic matter content). The length and circumference of soil core samples were measured and recorded. Soil samples were double bagged in Ziploc plastic bags in the field and wet weights (minus plastic bag tare weight) were recorded each evening in camp. These data were used for calculating volumetric ice content for core samples.

Permafrost Core Sample Sites included 2 cores in Test Area North, 2 cores in Test Area South, and 2 cores in Reference Area North. Due to weather, no cores were extracted in Reference Area South (Figure 4.1). In subsequent years (10 year sampling intervals), cores will be extracted near the location of the original core and the methods described above repeated as per the Monitoring Plan (ABR and Baker 2013).

4.3 OFFICE METHODS

4.3.1. SOIL TEMPERATURE MONITORING

ABR collected field data for Map Verification Plots associated with the Permafrost Temperature Monitoring Plots on tablet computers. After the field season, the data were uploaded to the ABR data server and were compiled in a PostgreSQL database for long-term data storage and management.

The first HOBO Data Loggers download is scheduled for late June or early July in 2014, at which time the batteries in the data loggers will be refreshed, and the Permafrost Temperature Monitoring Plots will continue to record soil temperature once every hour. Permafrost temperature will be plotted to determine annual and seasonal trends. Soil temperatures that were recorded during the first 5–7 days after loggers were deployed in the field will be omitted from analysis to allow for ground temperature stabilization to occur.

4.3.2. PERMAFROST CORES

Original stratigraphy field sheets were scanned and backed up on the ABR server. Stratigraphy data were uploaded to the ABR data server and compiled in a PostgreSQL database for long-term data storage and management.

Soil samples were oven dried at 221° F (105° C) and dry weights were recorded (minus plastic bag tare weight). Soil volume was determined using core sample length and the circumference of the core. Bulk density was calculated by dividing oven dry weight by core volume. Volumetric ice content was calculated by multiplying core moisture weight (wet weight minus dry weight) by the bulk density of the soil divided by the density of frozen water (Black 1965). Oven-dried soil samples were passed through a 0.080 in (2 mm) sieve to retain the <0.080 in (2 mm) fraction. Sieved samples were sent to the Palmer Research Station Soils Laboratory (Palmer, AK) for particle size analysis (texture) and loss on ignition (estimated percent organic matter). ABR cross-referenced laboratory data with soil stratigraphy descriptions to ensure proper horizonation and soil texture were recorded in the field.

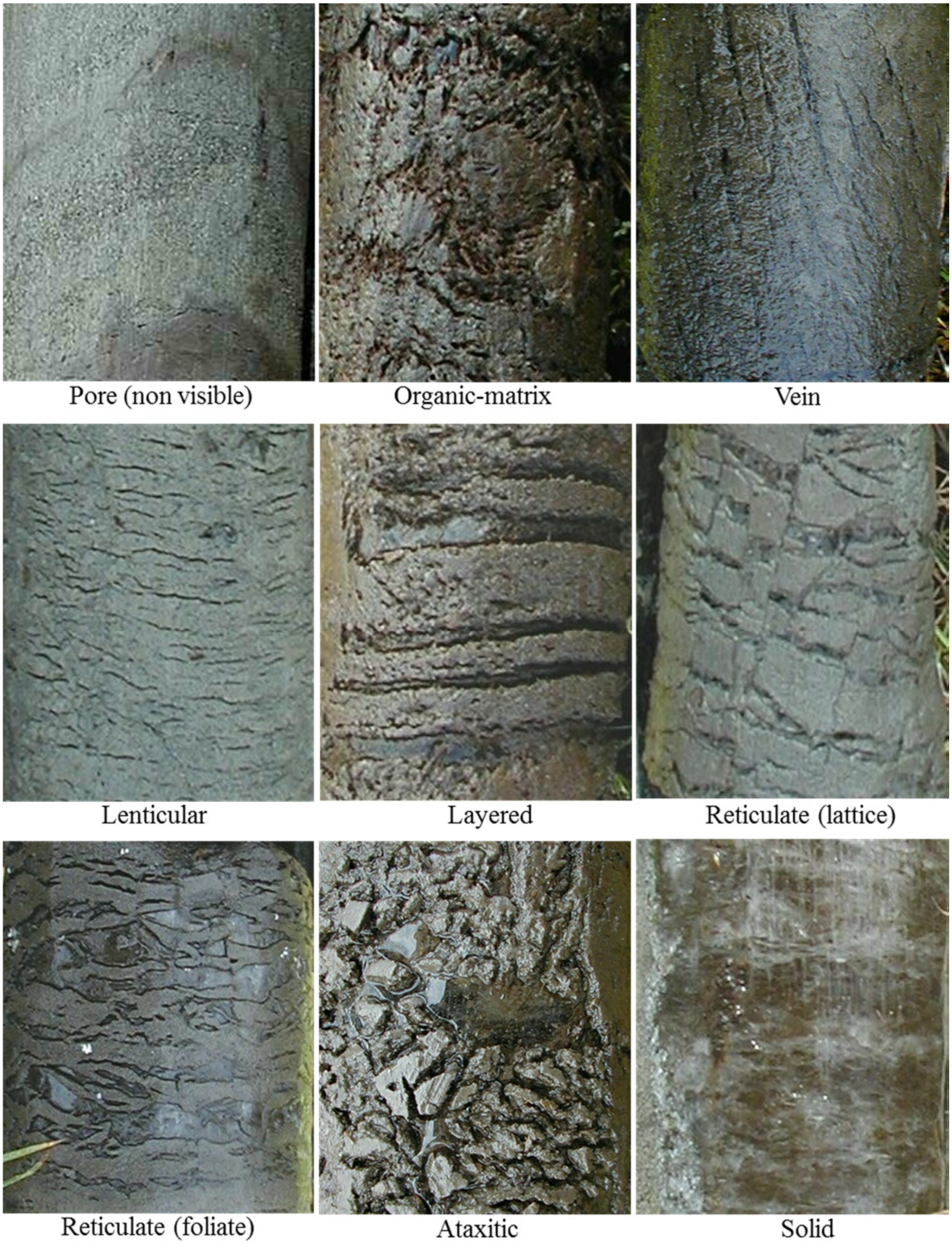


Figure 4.3. Photographs of ice structures found in permafrost in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013. From Jorgenson et al. (2002).

Table 4.1. Classification and description of ground ice observed in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

Cryostructure	Definition
Pore	Ice in minute holes, or pores, within mineral soil matrix that has an almost structureless appearance. May be visible (without hand lens) or non-visible. Visual impression is that ice does not exceed original voids in soil. Forms where pore water freezes *in situ*.
Organic-matrix	Ice formed within organic matrix and has a structureless appearance. May be visible or non-visible. Mostly formed where pore water freezes *in situ*.
Lenticular	Lens-shaped, thin (generally <0.02 in [0.5 mm]), short bodies of ice within a soil matrix. The orientation is generally perpendicular to the freezing front and usually reflects the structure of the sediments.
Vein	Isolated, thin lens, needle-like, or sheet-like structures, or particles visible in the soil matrix. Usually inclined and bisecting sedimentary structures that are associated with interbedded layers of alluvium. Differs from layered ice in that they are solitary and do not have a repeated, parallel pattern.
Layered	Laterally continuous bands of ice less than 3.9 inches (10cm) thick. Usually parallel, repeating sequences that follow with sedimentary structure or are normal to freezing front. Thicker layers (>3.9 in [10 cm]) are described as solid ice.
Reticulate, Foliate	Net-like structure of ice veins surrounding fine-grained blocks of soil. Ice occupies up to 50% of surface area. Foliated reticulate ice is irregular horizontally dominated ice giving the soil a platy structural appearance.
Reticulate, Lattice	Net-like structure of ice veins surrounding fine-grained blocks of soil. Ice occupies up to 50% of surface area. Lattice-like reticulate ice exhibits regular, rectangular, or square framework.
Ataxitic	Ice occupies 50–99% of cross-sectional area, giving the soil inclusions a suspended appearance. When present, ataxitic ice is near the upper part of the permafrost table.
Solid	Ice (>3.9 in [10cm] thick) where soil inclusions occupy <1% of the cross-sectional area. Sheet ice is cloudy or dirty, horizontally bedded ice exhibiting indistinct to distinct stratification. Wedge ice is V-shaped masses of vertically foliated or stratified ice resulting from infilling of frost.

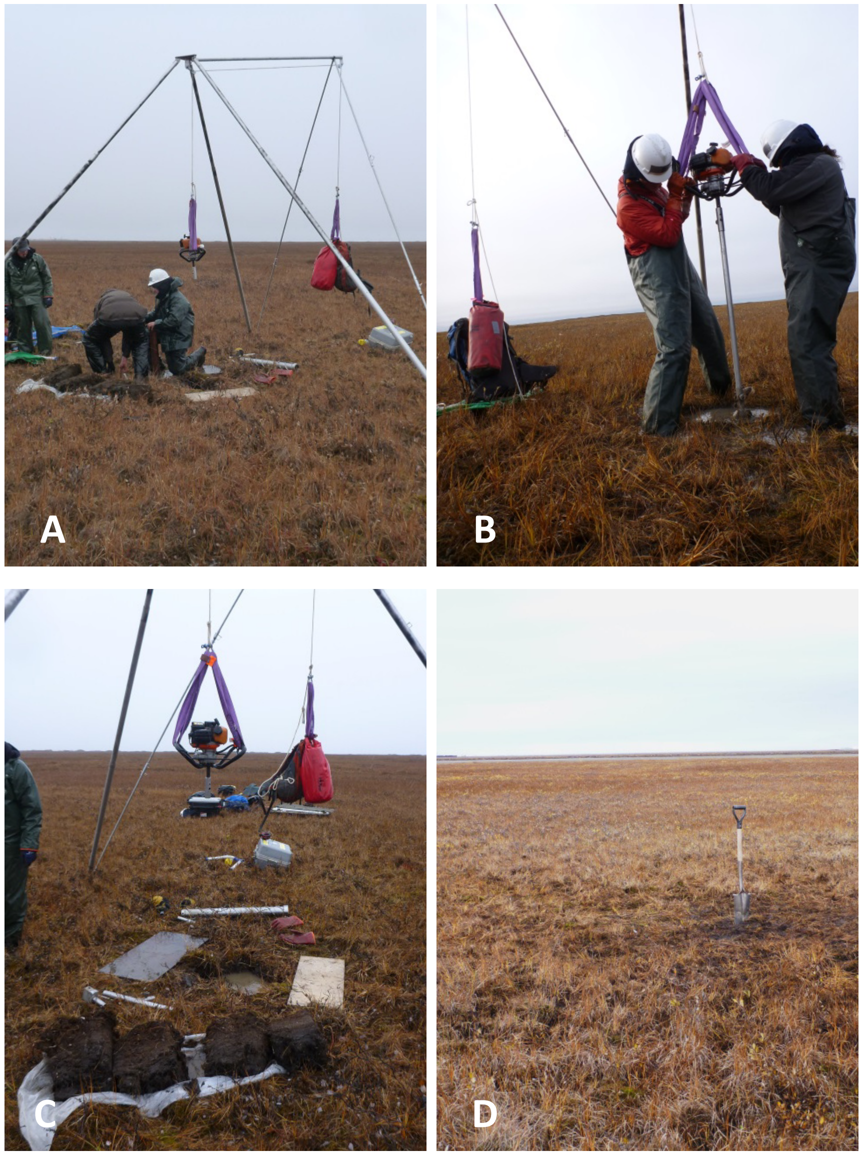


Figure 4.4. A series of images showing the SIPRE permafrost core extraction, CD5 Habitat Monitoring Study Area, northern Alaska, 2013. The process includes a) the tripod setup, b) two personnel operating the SIPRE core tool with counter weight suspended from bags to alleviate fatigue and back injury, c) the extraction of the surface organic mat to be used in site restoration and the use of wooden platforms at the drill site to both protect the tundra and provide user stability, and d) an illustration of the impact to the tundra after the drilling is complete, the permafrost cores have been returned to the auger hole, and the organic mat has been returned to the surface.

4.4. RESULTS AND DISCUSSION

4.4.1 PERMAFROST CORES

A comprehensive investigation into the geomorphology and hydrology of the Colville River Delta was conducted by ABR, Inc. in 1995 (Jorgenson et al. 1996). This report includes summaries of soil genesis and permafrost development by geomorphic unit (e.g. Delta Active, Inactive and Abandoned Overbank Deposits), which were used in classification and mapping of the Colville River Delta. The Permafrost Core Sample Sites for the CD5 Habitat Monitoring Study were designed to establish baseline information about surface and cumulative organic mat thickness, particle size distribution, and ice structure type and volume for both Delta Inactive Overbank Deposits and Delta Abandoned Overbank Deposits (Table 3.11) in the north and south reference and test areas. The CD5 Habitat Monitoring permafrost data were compared to the 1995 data on similar geomorphic deposits to establish similarities or differences between the soil stratigraphy profiles.

Three processes dominate soil genesis and ice morphology on the Colville River Delta: flooding frequency, syngenetic permafrost development, and ice-wedge formation. The flooding frequency for inactive-floodplain cover deposits is 5–25 years, and for abandoned-floodplain deposits it is estimated to be 26–150 years (Jorgenson 1996). The flooding return interval and discharge velocity determine the particle size class distribution and the degree of interbedding of mineral and organic horizons in deltaic deposits. The recurrence interval also impacts surface and cumulative organic mat thickness. Frequently flooded sandbars and Delta Active Overbank Deposits usually lack surface organic material, while Delta Inactive Overbank Deposits typically have a somewhat thick and highly stratified surface organic mat (Figures 4.5 and 4.6). Overbank flooding is rare in Delta Abandoned Overbank Deposits, and the long time periods between disturbances allow for the accumulation of thick organic mats (≥15.7 in [40 cm]) at the surface. The result is the development of an organic-dominated soil, as opposed to a mineral-dominated soil (e.g., Terric Fibristels). Periodic flooding and sedimentation play a role in permafrost development on the floodplain of the Colville River Delta. Flooding events deposit fresh sediment at the surface, which temporarily increases the thickness of the active layer in the soil profile. Syngenetic permafrost formation takes place synchronously with the deposition of alluvial soil, resulting in the permafrost table freezing upward to adjust to the new conditions (Shur and Jorgenson 1998). The formation of syngenetic permafrost always results in ice-rich permafrost (>50% ice content), which means the ground ice is in excess of the pore volume in an unfrozen state (Shur and Jorgenson 1998). Ice wedge formation in syngenetic permafrost occurs in later stages of floodplain evolution (Figure 4.5). Ice wedge formation affects surface topology and the elevation of the floodplain, which in turn influences hydrology, sedimentation, and organic matter accumulation (Shur and Jorgenson 1998).

4.4.1.A. Accumulation of Organic Matter

Jorgenson et al. (1996) calculated the mean averages for surface organic horizon thickness since the last significant fluvial deposition event on the Colville River Delta as absent for riverbed/sandbar deposits, <0.4 in (1 cm) for Delta Active Overbank Deposits, 3.0 in (7.6 cm) for Delta Inactive Overbank Deposits, and 7.1 in (18.0 cm) for Delta Abandoned Overbank Deposits (Jorgenson et al. 1996). For the CD5 Habitat Monitoring Study Area, the mean surface organic mat thickness was 1.8 in (4.6 cm) for the 5 Delta Inactive Overbank Deposits. Surface organic mat thickness was 7.9 in (20 cm) for the single Delta Abandoned Overbank Deposit sampled. The 5 Permafrost Core Sample Sites on Delta Inactive Overbank Deposits featured a silt loam layer mixed with peat ranging from 1.2–3.1 in (3–8 cm) below the soil surface (Figures 4.6 and 4.7). This was attributed to a major flooding event that would have occurred 10–15 years ago.

4.4.1.B. Sediment Characteristics

Particle size analysis of soil samples from permafrost cores extracted at the 6 Permafrost Core Sample Sites revealed a dominant silt loam texture across all core samples (Appendix J). The higher percentage of clay (mean = 17.7%) and lower percentage of sand (mean = 18.8%) is indicative of a low-velocity deltaic depositional environment (Figure 4.5). These results are consistent with

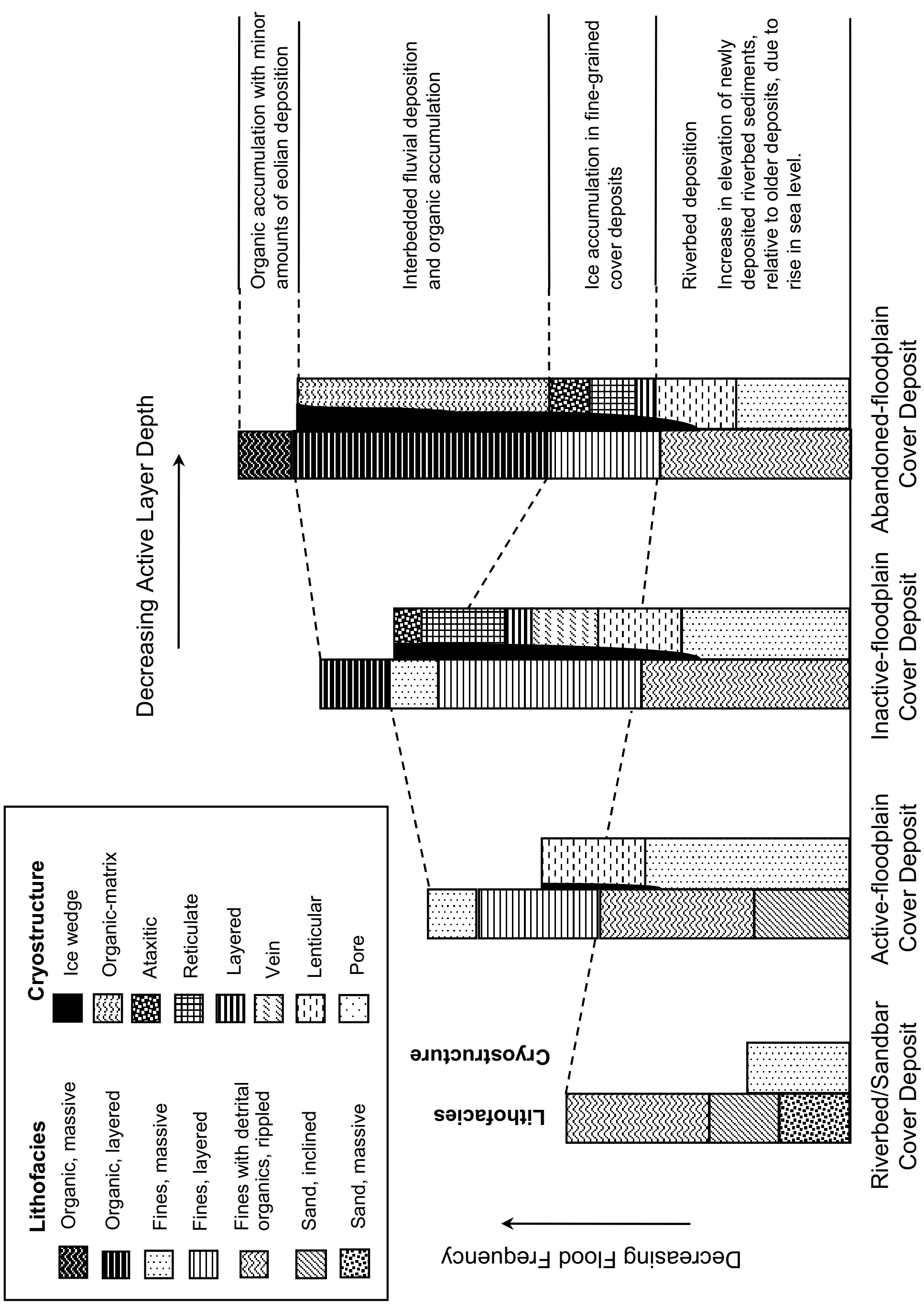


Figure 4.5. A conceptual model of changes in soil texture, active layer thickness, and cryogenic structure during evolution of floodplain deposits on the Colville River Delta. From Jorgenson et al. (1996).

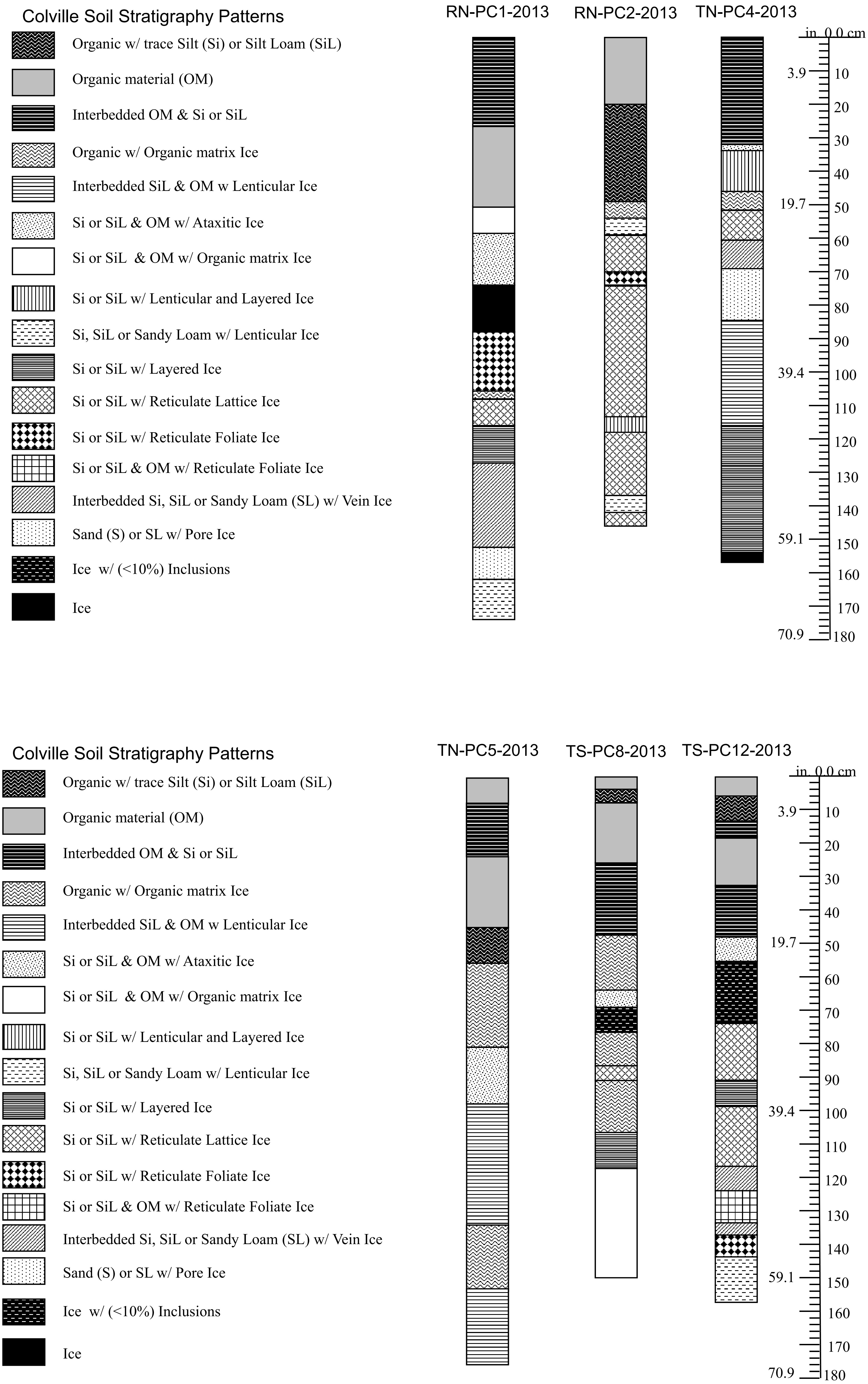


Figure 4.6. Soil stratigraphy profiles of permafrost cores from the CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

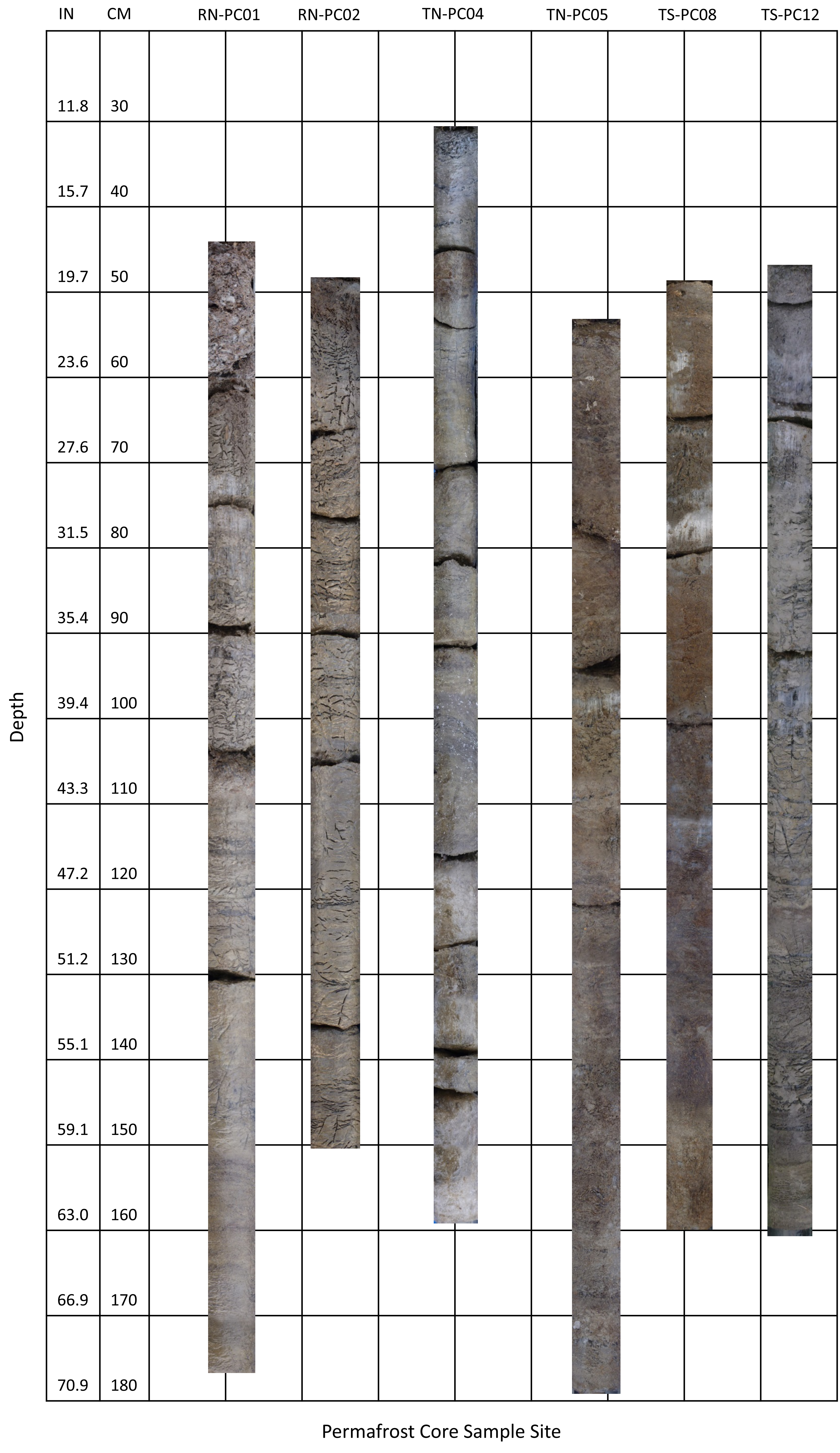


Figure 4.7. Composite core profiles illustrating stratigraphy and ice structures of permafrost cores sampled in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

earlier studies on the Colville River Delta. For instance, Jorgenson et al. (1996) showed consistent decreases in sand, and substantial increases in clay from more frequently flooded surfaces (e.g., Delta Active Overbank deposits) to infrequently flooded surfaces (e.g. Delta Inactive Overbank deposits). Jorgenson et al (1996) found an increase in sand from Delta Inactive Overbank Deposits to Delta Abandoned Overbank Deposits. The majority of this sand, however, was believed to be attributed to eolian deposition in the surface organic mat, as opposed to fluvial deposition lower in the core profile.

4.4.1.C. Ice Structures and Volumes

On the Colville River Delta, soils that are deposited in the early stages of floodplain succession (e.g., Delta Active Channel Deposit and Delta Active Overbank Deposits) typically have a higher concentration of sand (Figure 4.5). On Inactive and Abandoned Overbank Deposits, these sandier alluvial deposits are the oldest materials lowest in the core profiles, and are dominated by pore, lenticular and layered ice structures (Figure 4.3, Table 4.1). As a site transitions from an active depositional environment to an inactive depositional environment, the frequency between flooding events decreases, allowing vegetation to establish and organic matter to accumulate. These processes were evident in the Delta Inactive Overbank Deposit permafrost cores as interbedded organic horizons with silts overlying finer textured mineral soil (lower sand, higher clay and silt). Ice structures that typify Delta Inactive Overbank Deposits include reticulate lattice, organic-matrix, and layered ice. Solid ice (>3.9 in [10cm] thick) may also be present in inactive environments as ice wedge polygons develop through syngenetic ice wedge formation. Ataxitic ice (Table 4.1) was present in all 5 of the Delta Inactive Overbank Deposits, but was not described in the Delta Abandoned Overbank Deposit. Ataxitic ice, when present, is typically located at or near the contact of the permafrost table. The ice structure of the Delta Abandoned Overbank Deposit core differed from the Delta Inactive Overbank Deposit cores by having the greatest proportion of reticulate lattice ice (Figures. 4.5 and 4.7).

Volumetric ice content was calculated for 18 permafrost core sections from the 6 Permafrost Core Sample Sites (Appendix J). Soils from the active layer were not included in the laboratory testing. The active layer depth is best illustrated in Figure 4.7, where the top of the core is the end of the 2013 active layer and the beginning of the perennially frozen soil.

Results of volumetric ice analysis found a correlation between percent ice, ice structure, and particle size distribution. Sandier textures (>50% sand) exclusively occurred with pore ice structures (Appendix J). French (2007) describe pore ice as water that has frozen *in situ*, while other ice structures are segregated ice that has formed along a thermal gradient (Figure 4.3, Table 4.1). Soils with 25–50% sand were most commonly associated with lenticular and layered ice structures. Soils with 5–25% sand most commonly expressed ataxitic, organic-matrix, and reticulate lattice ice structures. Soils with <5% sand had reticulate foliate ice. The data revealed that the sandy mineral soils with pore ice had the lowest volume of ice (47.9%), while organic soil horizons with organic-matrix ice had the greatest volume of ice (mean = 85.6%). Of the remaining ice structures that were analyzed, reticulate lattice (mean = 66.2%) and reticulate foliate (mean = 69.4%) had slightly less ice volume then layered (mean = 74.1 %) and lenticular (mean = 76.2%) ice. The highest volume of ground ice is usually concentrated in the upper 3.3–9.8 ft (1–3 m) of permafrost and begins to decline with depth due to the upward thermal gradient moving towards the freezing front (French 2007). Ataxitic ice, which is usually at the freezing front, or near the contact with the permafrost table, had a mean ice volume of 69.2%, which is roughly in between that of the reticulate ice structures and the layered and lenticular structures. Jorgenson et al. (2006) reported that ice contents by geomorphic unit increased over time with floodplain evolution. They calculated mean ice volumes to be lowest for riverbed/sandbar deposits (61.1%), intermediate for Delta Active Overbank Deposits (67.7%), and highest for Delta Inactive Overbank Deposits (73.4%). Jorgenson et al. (2006) were unable to determine ice volumes for Delta Abandoned Overbank Deposits. It is assumed that Delta Abandoned Overbank Deposits would have the highest ice content, and hence the greatest susceptibility to thaw, because these deposits would likely have a high percentage of ice-rich, organic-matrix ice.

The permafrost monitoring component of this study is designed to compare differences in ice structure and ice volume across a broad time period (decadal). The Permafrost Temperature Monitoring Plots will allow monitoring of thermal (temperature) changes in the permafrost associated with broader climate change, or more localized gradual changes related to altered soil drainage patterns from flooding. Permafrost monitoring will occur again in 2024, and every 10 years thereafter through 2044.

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Appendix A. Alpine Weather Station instrumentation specifications, CD5 Habitat Monitoring Study, Colville River Delta, northern Alaska, 2013.

Wind Monitor	
Make	R. M. Young
Model	05103-45 Alpine Version Wind Monitor
Operating Temperatures	-50°C to +50°C
Range	0 to 224 mph
Accuracy	60.6 mph or 1% of reading
Starting Threshold	2.2 mph
Wind Direction Range	0 to 360°
Accuracy	65°
Height	9.25 ft. above the ground surface
Pyranometer	
Make	Hukseflux
Model	LP02
Light Spectrum Waveband	305 to 2800 nm
Maximum Irradiance	2000 W/m^2
Sensitivity (nominal)	15 $\mu V/(W/m^2)$
Operating Temperature	-40° to +80°C
Temperature Dependence	<0.15%/°C
ISO Classification	Second Class
Air Temperature Sensor	
Make	Lewellen Arctic Research, Inc.
Model	Type T Thermocouple
Sensitivity	17 to 58 µV/°C
Temperature Range	-250 to +400°C
Barometer	
Make	Vaisala
Model	PTB110
Accuracy	±0.3 mb @ +20°C
	±0.6 mb @ 0° to 40°C
	±1.0 mb @ -20° to +45°C
	±1.5 mb @ -40° to +60°C
Linearity	60.25 mb
Hysteresis	60.03mb
Repeatability	60.03mb
Snow Depth Sensor	
Make	Campbell Scientific, Inc.
Model	Sonic Ranging Sensor SR50A
Measurement Range	1.6 to 32.8 ft.
Resolution	0.01 in
Accuracy	60.4 in or 0.4% of distance to target (whichever is greater)
Operating Temperature	-45 to +50°C

Appendix A. Continued.

Wind Monitor	
Rain Gauge	
Make	Texas Electronics
Model	TE525WS Tipping Bucket Rain Gauge[1]
Temperature Rating	0° to +50°C
Resolution	1 tip
Accuracy	Up to 1 in/hr: ±1%; Up to 2 in/hr: 0 to 2.5% Up to 3 in/hr: 0 to 3.5%
Wind screen	Installed

[1] Conforms to the National Weather Service recommendation for an 8 in. funnel orifice

Appendix B. Example output and legends from each of the data files produced by the Alpine Weather Station, Colville River Delta, northern Alaska, 2013.

Appendix B-1. Example of HALP504_WX_US_Hourly Weather Observations data in English units, Colville River Delta, northern Alaska, 2013.

TIMESTAMP (TS)[a]	RECORD (RN)[b]	DOY[c]	Array[d]	AirT2_F[e]	BP_inHg[f]	WS_mph[g]	WD[h]	WS_mph_Avg[i]	WS_mph_Max[j]	WD_Avg[k]	WD_Std[l]	SD[m]	Rain_in_Tot[n]	TTLRain_in[o]	SlrW_Avg[p]	BattV_Avg[q]
												in.		Since MN	W/m^2	Volts
		Smp	Smp	Smp	Smp	Smp	Smp	Avg	Max	Avg	Std	Smp	Tot	Smp	Avg	Avg
1/11/2014 8:55	792	11	504	-7.838	29.56	14.26	247.2	14.35	16.43	243.3	4.947	7.077	0	0	0.042	12.21
1/11/2014 9:55	793	11	504	-7.464	29.54	16.27	260.7	15.56	18.26	254.5	5.469	7.042	0	0	-0.065	12.27
1/11/2014 10:55	794	11	504	-7.809	29.53	15.74	258.7	17.04	20.30	258.6	4.642	7.041	0	0	-0.177	12.28
1/11/2014 11:55	795	11	504	-7.529	29.51	14.37	253.8	15.15	17.41	256.8	4.599	7.045	0	0	0.117	12.29
1/11/2014 12:55	796	11	504	-7.444	29.48	15.84	248.2	14.29	17.21	248.9	6.248	7.049	0	0	0.545	12.29
1/11/2014 13:55	797	11	504	-7.859	29.45	15.94	260.4	15.53	17.86	258.9	5.398	7.083	0	0	0.693	12.30
1/11/2014 14:55	798	11	504	-7.428	29.44	14.71	259.1	15.39	17.41	262.1	4.207	7.374	0	0	0.297	12.30
1/11/2014 15:55	799	11	504	-6.984	29.43	14.61	271.9	14.54	16.56	264.5	5.847	7.496	0	0	0.092	12.30

[a] TS Time Stamp
[b] RN Record Number
[c] DOY Day of Year
[d] Array Unique Array Number Associated with this Data File
[e] AirT2_F Air Temperature (°F) Recorded at 55 minutes After the hour
[f] BP_inHg Barometric Pressure (in-Hg) Recorded at 55 minutes after the hour
[g] WS_mph Wind Speed (mph) Recorded at 55 at 55 minutes after the hour
[h] WD Wind Direction (° True) Recorded at 55 minutes after the hour
[i] WS_mph_Avg Average Hourly Wind Speed (mph)
[j] WS_mph_Max Maximum Hourly Wind Speed (mph)
[k] WD_Avg Average Hourly Wind Direction (° True)
[l] WD_Std Hourly Standard Deviation of the Wind Direction (°)
[m] SD Snow Depth (in.)
[n] Rain_in_Tot Rain Fall in the previous hour in.)
[o] TTLRain_in Total Rain Fall since Midnight (in.)
[p] SlrW_Avg Average Hourly Solar Radiation (W/m^2)
[q] BattV_Avg Battery Voltage hourly average

Appendix B-2. Example of HALP508_WX_SI_Hourly Weather Observations data in metric units, Colville River Delta, northern Alaska, 2013.

TIMESTAMP (TS)[a]	RECORD (RN)[b]	DOY[c]	Array[d]	AirT2_C[e] DegC	BP_mbar[f]	WS_mps[g]	WD[h]	WS_mps_Avg[i]	WS_mps_Max[j]	WD_Avg[k]	WD_Std[l]	SD_cm[m]	Rain_cm_Tot[n]	TTLRain_cm[o] Since MN	SlrW_Avg[p] W/m^2	BattV_Avg[q] Volts
		Smp	Smp	Smp	Smp	Smp	Smp	Avg	Max	Avg	Std	Smp	Tot	Smp	Avg	Avg
1/11/2014 8:55	792	11	508	-22.13	1000.9130	6.376	247.2	6.416	7.343	243.3	4.947	17.97	0	0	0.042	12.21
1/11/2014 9:55	793	11	508	-21.92	1000.3370	7.274	260.7	6.955	8.160	254.5	5.469	17.89	0	0	-0.065	12.27
1/11/2014 10:55	794	11	508	-22.12	999.8312	7.036	258.7	7.619	9.070	258.6	4.642	17.88	0	0	-0.177	12.28
1/11/2014 11:55	795	11	508	-21.96	999.1835	6.425	253.8	6.771	7.784	256.8	4.599	17.90	0	0	0.117	12.29
1/11/2014 12:55	796	11	508	-21.91	998.2518	7.081	248.2	6.387	7.692	248.9	6.248	17.90	0	0	0.545	12.29
1/11/2014 13:55	797	11	508	-22.14	997.4330	7.124	260.4	6.941	7.983	258.9	5.398	17.99	0	0	0.693	12.30
1/11/2014 14:55	798	11	508	-21.90	997.0622	6.575	259.1	6.882	7.784	262.1	4.207	18.73	0	0	0.297	12.30
1/11/2014 15:55	799	11	508	-21.66	996.5944	6.533	271.9	6.499	7.402	264.5	5.847	19.04	0	0	0.092	12.30

[a] TS — Time Stamp
[b] RN — Record Number
[c] DOY — Day of Year
[d] Array — Unique Array Number Associated with this Data File
[e] AirT2_C — Air Temperature (°C) Recorded at 55 minutes After the hour
[f] BP_mbar — Barometric Pressure (millibars) Recorded at 55 minutes after the hour
[g] WS_mps — Wind Speed (mps) Recorded at 55 at 55 minutes after the hour
[h] WD — Wind Direction (° True) Recorded at 55 minutes after the hour
[i] WS_mps_Avg — Average Hourly Wind Speed (mps)
[j] WS_mps_Ma — Maximum Hourly Wind Speed (mps)
[k] WD_Avg — Average Hourly Wind Direction (° True)
[l] WD_Std — Hourly Standard Deviation of the Wind Direction (°)
[m] SD — Snow Depth (cm.)
[n] Rain_in_Tot — Rain Fall in the previous hour (cm)
[o] TTLRain_in — Total Rain Fall since Midnight (cm)
[p] SlrW_Avg — Average Hourly Solar Radiation (W/m^2)
[q] BattV_Avg — Battery Voltage hourly average

Appendix B-3. Example of HALP503_WCT_F_Wind Chill Temperature (°F) data calculated at 55 minutes after the hour, Colville River Delta, northern Alaska, 2013.

TIMESTAMP (TS)[a]	RECORD (RN)[b]	DOY[c]	Array[d]	AirT2_F[e]	WS_mph[f]	WCT_F[g]
		Smp	Smp	Smp	Smp	Smp
1/10/2014 14:55	774	10	503	-26.46	9.07	-47.68
1/10/2014 15:55	775	10	503	-26.08	9.49	-47.71
1/10/2014 16:55	776	10	503	-23.65	11.46	-46.75
1/10/2014 17:55	777	10	503	-24.73	9.26	-45.79
1/10/2014 18:55	778	10	503	-22.26	14.31	-47.44
1/10/2014 19:55	779	10	503	-18.51	12.09	-40.86
1/10/2014 20:55	780	10	503	-16.78	13.28	-39.63
1/10/2014 21:55	781	10	503	-18.67	10.27	-39.39
1/10/2014 22:55	782	10	503	-19.47	10.09	-40.16
1/10/2014 23:55	783	10	503	-17.35	11.24	-38.62

[a] TS Time Stamp
[b] RN = Record Number
[c] DOY Day of Year
[d] Array Unique Array Number Associated with this Data File
[e] AirT2_F Air Temperature (°F) Recorded at 55 minutes After the Hour
[f] WS_mph Wind Speed (mph) Recorded at 55 Minutes after the Hour
[g] WCT_F Wind Chill Temperature (°F) Calculated at 55 Minutes After the Hour

Note:
Wind Chill Temperature is calculated according to the Equation:
WCT_F = 35.74 + 0.6215*AirT2_F -35.75*(WS_mph^0.16) + 0.4275*AirT2_F*(WS_mph^0.16)

Wind Chill Equation is Valid for: A temperature range Between 645°F and for Wind Speeds from 3 to 60 mph

Appendix B-4. Example of DALP500_FFDD_Daily Weather Measurement Summary data in English Units, Colville River Delta, northern Alaska, 2013.

TS[a]	RN[b]	DOY[c] Smp	Array[d] Smp	FDD2_F_Avg[e] Avg	AirT2_F_Avg[f] Avg	AirT2_F_Max[g] Max	AirT2_F_TMx[h] TMx	AirT2_F_Min[i] Min	AirT2_F_TMn[j] TMn	WS_mph_Avg[k] Avg	WS_mph_Max[l] Max	WS_mph_TMx[m] TMx	WS_mph_Min[n] Min	WS_mph_TMn[o] TMn	WD_Avg[p] Avg	WD_Std[q] Std	SD[r] in. Smp	Rain_in_Tot[s] Tot	SlrW_Avg[t] W/m^2 Avg	BattV_Avg[u] Volts Avg
1/1/2014 23:55	23	1	500	29.48	2.515	4.753	1/1/2014 17:01	-3.768	1/1/2014 0:50	24.700	36.18	1/1/2014 21:35	11.050	1/1/2014 0:31	74.01	5.111	6.99	0	-0.346	12.38
1/2/2014 23:55	24	2	500	30.01	1.987	6.261	1/2/2014 9:58	-1.155	1/2/2014 19:19	23.780	33.76	1/2/2014 3:15	9.520	1/2/2014 16:24	84.60	13.790	7.031	0	-0.139	12.39
1/3/2014 23:55	25	3	500	30.39	1.610	4.214	1/3/2014 23:30	-1.311	1/3/2014 16:59	23.540	33.33	1/3/2014 3:57	14.680	1/3/2014 0:50	85.90	6.649	7.037	0	-0.027	12.38
1/4/2014 23:55	26	4	500	30.40	1.595	3.805	1/3/2014 23:55	-1.352	1/4/2014 22:28	16.090	27.60	1/4/2014 0:17	7.767	1/4/2014 11:54	78.41	11.400	7.049	0	-0.291	12.38
1/5/2014 23:55	27	5	500	34.30	-2.296	4.446	1/5/2014 23:04	-6.818	1/5/2014 16:04	7.851	22.99	1/5/2014 23:31	0.694	1/5/2014 2:26	82.80	18.420	7.038	0	-0.684	12.35
1/6/2014 23:55	28	6	500	30.04	1.964	4.559	1/6/2014 0:32	-1.983	1/6/2014 7:19	16.910	27.45	1/6/2014 5:19	3.916	1/6/2014 8:32	77.01	19.120	7.058	0	-0.049	12.37
1/7/2014 23:55	29	7	500	43.40	-11.400	2.212	1/6/2014 23:56	-26.140	1/7/2014 23:54	7.840	19.56	1/7/2014 1:22	0.044	1/7/2014 20:22	168.50	147.700	7.051	0	-1.236	12.33
1/8/2014 23:55	30	8	500	57.30	-25.300	-13.990	1/8/2014 23:55	-31.190	1/8/2014 4:56	1.549	5.54	1/8/2014 1:07	0.000	1/8/2014 6:02	241.40	70.680	7.068	0	-0.876	12.18
1/9/2014 23:55	31	9	500	46.45	-14.450	-8.750	1/9/2014 5:22	-19.780	1/9/2014 17:53	8.800	19.73	1/9/2014 20:16	0.000	1/9/2014 4:37	237.60	86.100	7.038	0	-0.390	12.26
1/10/2014 23:55	32	10	500	54.32	-22.320	-16.710	1/10/2014 20:49	-27.550	1/10/2014 13:56	9.160	16.28	1/10/2014 20:35	4.903	1/10/2014 5:11	265.20	13.560	7.080	0	-0.576	12.21

[a] TS	Time Stamp
[b] RN	Record Number
[c] DOY	Day of Year
[d] Array	Unique Array Number Associated with this Data File
[e] FDD2_F_Avg	Freezing Degrees for the Day (°F). Note a FDD = 32- Average Air Temperature for the Day
[f] AirT2_F_Avg	Avearge Air Temperature for the Day (°F)
[g] AirT2_F_Max	Maximum Air Temperature for the Day (°F)
[h] AirT2_F_TMx	Time of Maximum Air Temperature
[i] AirT2_F_Min	Minimum Air Temperaturefor the Day (°F)
[j] AirT2_F_TMn	Time of Minimum Air Temperature
[k] WS_mph_Avg	Average Wind Speed (mph)
[l] WS_mph_Max	Maximum Wind Speed for the Day (mph)
[m] WS_mph_TMx	Time of Maximum Wind
[n] WS_mph_Min	Minimum Wind Speed for the Day (mph)
[o] WS_mph_TMn	Time of Minimum Wind
[p] WD_Avg	Average Wind Direction (° True)
[q] WD_Std	Wind Direction Standard Deviation (°)
[r] SD	Snow Depth in (in)
[s] Rain_in_Tot	Total Rain for the Day (in)
[t] SlrW_Avg	Average Daily Solar Flux (W/m^2)
[u] BattV_Avg	Average Battery Voltage

Appendix B-5. Example of DALP505_CFDD_ Daily Weather Measurements Summary in Metric Units, Colville River Delta, northern Alaska, 2013.

		DOY[c]	Array[d]	FDD2_C_Avg[e]	AirT2_C_Avg[f]	AirT2_C_Max[g]	AirT2_C_TMx[h]	AirT2_C_Min[i]	AirT2_C_TMn[j]	WS_mps_Avg[k]	WS_mps_Max[l]	WS_mps_TMx[m]	WS_mps_Min[n]	WS_mps_TMn[o]	WD_Avg[p]	WD_Std[q]	SD_cm_Tot[r]	Rain_cm_Tot[s]	SlrW_Avg[t]	BattV_Avg[u]
						DegC	DegC	DegC	DegC								in		W/m²	Volts
TS[a]	RN[b]	Smp	Smp	Avg	Avg	Max	TMx	Min	TMn	Avg	Max	TMx	Min	TMn	Avg	Std	Tot	Tot	Avg	Avg
1/1/2014 23:55	23	1	505	16.38	-16.38	-15.14	1/1/2014 17:01	-19.87	1/1/2014 0:50	11.040	16.180	1/1/2014 21:35	4.942	1/1/2014 0:31	74.01	5.111	7999	0	-0.346	12.38
1/2/2014 23:55	24	2	505	16.67	-16.67	-14.30	1/2/2014 9:58	-18.42	1/2/2014 19:19	10.630	15.090	1/2/2014 3:15	4.256	1/2/2014 16:24	84.60	13.790	7999	0	-0.139	12.39
1/3/2014 23:55	25	3	505	16.88	-16.88	-15.44	1/3/2014 23:30	-18.51	1/3/2014 16:59	10.520	14.900	1/3/2014 3:57	6.562	1/3/2014 0:50	85.90	6.649	7999	0	-0.027	12.38
1/4/2014 23:55	26	4	505	16.89	-16.89	-15.66	1/3/2014 23:55	-18.53	1/4/2014 22:28	7.192	12.340	1/4/2014 0:17	3.472	1/4/2014 11:54	78.41	11.400	7999	0	-0.291	12.38
1/5/2014 23:55	27	5	505	19.05	-19.05	-15.31	1/5/2014 23:04	-21.57	1/5/2014 16:04	3.510	10.280	1/5/2014 23:31	0.310	1/5/2014 2:26	82.80	18.420	7999	0	-0.684	12.35
1/6/2014 23:55	28	6	505	16.69	-16.69	-15.24	1/6/2014 0:32	-18.88	1/6/2014 7:19	7.560	12.270	1/6/2014 5:19	1.751	1/6/2014 8:32	77.01	19.120	7999	0	-0.049	12.37
1/7/2014 23:55	29	7	505	24.11	-24.11	-16.55	1/6/2014 23:56	-32.30	1/7/2014 23:54	3.505	8.740	1/7/2014 1:22	0.020	1/7/2014 20:22	168.50	147.700	7999	0	-1.236	12.33
1/8/2014 23:55	30	8	505	31.84	-31.84	-25.55	1/8/2014 23:55	-35.11	1/8/2014 4:56	0.692	2.479	1/8/2014 1:07	0.000	1/8/2014 6:02	241.40	70.680	7999	0	-0.876	12.18
1/9/2014 23:55	31	9	505	25.81	-25.81	-22.64	1/9/2014 5:22	-28.76	1/9/2014 17:53	3.933	8.820	1/9/2014 20:16	0.000	1/9/2014 4:37	237.60	86.100	7999	0	-0.390	12.26
1/10/2014 23:55	32	10	505	30.18	-30.18	-27.06	1/10/2014 20:49	-33.08	1/10/2014 13:56	4.097	7.277	1/10/2014 20:35	2.192	1/10/2014 5:11	265.20	13.560	7999	0	-0.576	12.21

[a] TS Time Stamp
[b] RN Record Number
[c] DOY Day of Year
[d] Array Unique Array Number Associated with this Data File
[e] DD2_C_Avg Freezing Degrees for the Day (°C). Note a FDD = 0.0 - Average Air Temperature for the Day
[f] AirT2_C_Avg Avearge Air Temperature for the Day (°C)
[g] AirT2_C_Max Maximum Air Temperature for the Day (°C)
[h] AirT2_C_TMx Time of Maximum Air Temperature
[i] AirT2_C_Min Minimum Air Temperaturefor the Day (°C)
[j] AirT2_C_TMn Time of Minimum Air Temperature
[k] WS_mps_Avg Average Wind Speed (mps)
[l] WS_mps_Max Maximum Wind Speed for the Day (mps)
[m] WS_mps_TMx Time of Maximum Wind
[n] WS_mps_Min Minimum Wind Speed for the Day (mps)
[o] WS_mps_TMn Time of Minimum Wind
[p] WD_Avg Average Wind Direction (° True)
[q] WD_Std Wind Direction Standard Deviation (°)
[r] SD Snow Depth in (cm)
[s] Rain_in_Tot Total Rain for the Day (cm)
[t] SlrW_Avg Average Daily Solar Flux (W/m²)
[u] BattV_Avg Average Battery Voltage

Appendix C. Cross-reference table of aggregated Integrated Terrain Unit (ITU) code combinations with map ecotype and wildlife habitat class from the Central Beaufort Coastal Plain ITU classification, CD5 Habitat Monitoring Study, northern Alaska, 2013.

MAP ECOTYPE	WILDLIFE HABITAT	ITU CODE	
Coastal Barrens	Barrens	Fdoa/N/Bpv/Nsk	Fdra/Sb/Bpv
		Fdoi/N/Bpv/Nsk	Fdra/Sb/Bpv/Ngfe
		Fdra/N/Bbg	Ltdn/N/Bbg
		Fdra/N/Bpv	Ltdn/N/Bpv
Coastal Dry Elymus Meadow	Dry Halophytic Meadow	Esda/Es/Hgdl	
		Fdra/N/Hgdl	
Coastal Lake	Tapped Lake with Low-water Connection	Weldc/W/Wb	
		Weldc/Wi/Wb	
Coastal Moist Willow Dwarf Shrub	Moist Halophytic Dwarf Shrub	Fdra/N/Sdwgh	
		Fdri/N/Sdwgh	
		Ltdn/N/Sdwgh	
Human Modified Barrens	Human Modified	Hfg/Hm/Bbg/Hfgp	
		Hfg/Hm/Bbg/Hfgr	
Human Modified Dwarf Scrub	Human Modified	Fdoi/Phl/Sddt/Hti	
Human Modified Low Shrub	Human Modified	Fdoa/N/Slow/Hti	Fdoi/Pd/Slows/Hti
		Fdoa/N/Slows/Hti	Fdri/N/Slcw/Hti
		Fdoa/Pd/Slows/Hti	Fdri/N/Slow/Hti
		Fdoi/Pd/Slow/Hti	
Human Modified Wet Meadow	Human Modified	Fdoa/Pd/Hgwswt/Hti	Fdoi/Plll/Hgwst/Hsep
		Fdob/Plhh/Hgwst/Hsep	Fdoi/Plll/Hgwst/Hti
		Fdoi/Pd/Hgwst/Hsep	Fdoi/Plll/Hgwswt/Hti
		Fdoi/Pd/Hgwswt/Hti	Fdri/N/Hgwst/Hti
		Fdoi/Plhh/Xp/Hsep	
Lacustrine Grass Marsh	Grass Marsh	Wldit/W/Hgwfg	
		Wldit/Wi/Hgwfg	
Lowland Deep-polygon Complex	Deep Polygon Complex	Fdob/Plhh/Xp	
		Fdob/Plhl/Xp	
Lowland Lake	Deep Open Water with Islands or Polygonized Margins	Wldit/Wi/Wf	
	Deep Open Water without Islands	Wldit/W/Wf	
	Shallow Open Water with Islands or Polygonized Margins	Wlsit/Wi/Wf	

Appendix C. Continued.

MAP ECOTYPE	WILDLIFE HABITAT	ITU CODE	
	Shallow Open Water without Islands		
Lowland Moist Low Willow Shrub	Moist Low Shrub	Esi/Phl/Slow	Ltdi/Plll/Slow
		Fdob/Phl/Slow	Ltic/Pd/Slow
		Fto/N/Slcw	Ltic/Phh/Slow
		Fto/N/Slow	Ltic/Pllh/Slow
		Fto/Pd/Slow	Ltic/Pm/Slow
		Fto/Phl/Slow	
Lowland Moist Sedge-Shrub Meadow	Moist Sedge-Shrub Meadow	Cs/N/Hgmss	Ltim/Pd/Hgmss
		Esi/Pd/Hgmss	Ltim/Phl/Hgmss
		Fdob/Phl/Hgmss	Ltim/Pm/Hgmss
		Fto/N/Hgmss	Ltiu/Pd/Hgmss
		Fto/Phl/Hgmss	
Lowland Sedge Marsh	Sedge Marsh	Ltdi/Pd/Hgwfs	
Lowland Wet Sedge Meadow	Nonpatterned Wet Meadow	Esi/Pd/Hgwst	Ltdi/Pd/Hgwst
		Fto/Pd/Hgwst	Ltiu/Pd/Hgwst
		Ltdi/N/Hgwst	
	Patterned Wet Meadow	Fdob/Plhh/Hgwst	Fto/Plll/Hgwst
		Fdob/Pllh/Hgwst	Ftr/Plhh/Hgwst
		Fdob/Plll/Hgwst	Ltdi/Plhh/Hgwst
		Fdob/Plll/Hgwst/Ngt	Ltic/Pllh/Hgwst
		Fdob/Pm/Hgwst	Ltim/Plll/Hgwst
		Fto/Plhh/Hgwst	
Lowland Wet Sedge-Willow Meadow	Patterned Wet Meadow	Fdob/Pllh/Hgwswt	
		Fdob/Plll/Hgwswt	
		Fdob/Pm/Hgwswt	
Riverine Deep-polygon Complex	Deep Polygon Complex	Fdoi/Plhh/Xp	
		Fdoi/Plhl/Xp	
Riverine Dry Dryas Dwarf Shrub	Dry Dwarf Shrub	Fdoi/Phl/Sddt	
Riverine Grass Marsh	Grass Marsh	Wldcrh/W/Hgwfg	
		Wldcrh/Wi/Hgwfg	
		Wldir/W/Hgwfg	
		Wldir/Wi/Hgwfg	
		Wlsir/W/Hgwfg	
		Wlsir/Wi/Hgwfg	

Appendix C. Continued.

MAP ECOTYPE	WILDLIFE HABITAT	ITU CODE	
Riverine Lake	Deep Open Water with Islands or Polygonized Margins	Wldir/Wi/Wf	
	Deep Open Water without Islands	Wldir/W/Wf	
	Shallow Open Water with Islands or Polygonized Margins	Wlsir/Wi/Wf	
	Shallow Open Water without Islands	Wlsir/W/Wf	
	Tapped Lake with High-water Connection	Wldcrh/W/Wf	
		Wldcrh/Wi/Wf	
Riverine Moist Herb Meadow	Moist Herb Meadow	Fdri/N/Hfds	
Riverine Moist Low Willow Shrub	Moist Low Shrub	Fdoa/N/Slcw	Fdoi/Pm/Slow
		Fdoa/N/Slow	Fdoi/Sb/Slcw
		Fdoa/Pd/Slow	Fdoi/Sb/Slow
		Fdoa/Sb/Slow	Fdoi/Sb/Slow/Ngfe
		Fdoi/N/Slcw	Fdra/N/Slow
		Fdoi/N/Slow	Fdri/N/Slcw
		Fdoi/Pd/Slcw	Fdri/N/Slow
		Fdoi/Pd/Slow	Fdri/N/Slow/Ngfe
		Fdoi/Phl/Slcw	Fdri/Sb/Slow/Ngfe
		Fdoi/Phl/Slow	Ltdn/N/Slow
Riverine Moist Low Willow-Sedge Meadow	Moist Low Shrub	Fdoa/Dt/Slows	Fdoi/Phl/Slows
		Fdoa/N/Slows	Fdoi/Pllh/Slows
		Fdoa/Pd/Slows	Fdoi/Plll/Slows
		Fdoi/N/Slows	Fdoi/Pm/Slows
		Fdoi/Pd/Slows	Fdri/N/Slows
Riverine Moist Sedge-Shrub Meadow	Moist Sedge-Shrub Meadow	Fdoi/Pd/Hgmss	
		Fdoi/Phl/Hgmss	
		Fdoi/Pm/Hgmss	
		Ltdn/N/Hgmss	
Riverine Moist Tall Willow Shrub	Moist Tall Shrub	Fdoa/N/Stow	
		Fdri/N/Stow	
Riverine Sedge Marsh	Sedge Marsh	Fdoi/N/Hgwfs	
		Wldcrh/W/Hgwfs	
Riverine Wet Sedge Meadow	Nonpatterned Wet Meadow	Fdoa/N/Hgwst	Fdoi/Pd/Hgwst/Ngt
		Fdoa/Pd/Hgwst	Fdra/N/Hgwst
		Fdoi/N/Hgwst	Fdri/N/Hgwst
		Fdoi/N/Hgwst/Ngt	Ltdn/N/Hgwst
		Fdoi/Pd/Hgwst	

Appendix C. Continued.

MAP ECOTYPE	WILDLIFE HABITAT	ITU CODE	
	Patterned Wet Meadow	Fdoi/Plhh/Hgwst	Fdoi/Plll/Hgwst/Ngt
		Fdoi/Plhl/Hgwst	Fdoi/Pm/Hgwst
		Fdoi/Pllh/Hgwst	Fdoi/Pm/Hgwst/Ngt
		Fdoi/Plll/Hgwst	
Riverine Wet Sedge-Willow Meadow	Nonpatterned Wet Meadow	Fdoa/N/Hgwswt	Fdoi/Pd/Hgwswt
		Fdoa/Pd/Hgwswt	Fdoi/Pd/Hgwswt/Ngt
		Fdoa/Pd/Hgwswt/Ngt	Fdri/N/Hgwswt
		Fdoi/N/Hgwswt	Ltdn/N/Hgwswt
	Patterned Wet Meadow	Fdoi/Dt/Hgwswt	Fdoi/Pllh/Hgwswt
		Fdoi/Plhh/Hgwswt	Fdoi/Plll/Hgwswt
		Fdoi/Plhl/Hgwswt	Fdoi/Pm/Hgwswt
Tidal River	River or Stream	Wert/W/Wf	
Upland Dry Barrens	Barrens	Esda/Ek/Bpv	
Upland Dry Dryas Dwarf Shrub	Dry Dwarf Shrub	Cs/Sb/Sddt	Esi/Phl/Sddt
		Esdi/Ek/Sddt	Fto/Phl/Sddt
		Esdi/Es/Sddt	Fto/Sb/Sddt
		Esi/Pd/Sddt	
Upland Dry Tall Willow Shrub	Dry Tall Shrub	Esa/N/Stow	
Upland Moist Cassiope Dwarf Shrub	Moist Dwarf Shrub	Fto/Sb/Sdec	
Upland Moist Low Willow Shrub	Moist Low Shrub	Cs/N/Slow	Esdi/N/Slow
		Esda/Ek/Slow	Esi/Es/Slow
		Esda/Es/Slow	Esi/N/Slcw
		Esda/N/Slcw	Esi/N/Slow
		Esda/N/Slow	Esi/Pd/Slow
		Esdi/Ek/Slow	Esi/Pm/Slow
		Esdi/Es/Slcw	Fto/Sb/Slcw
		Esdi/Es/Slow	Fto/Sb/Slow
		Esdi/N/Slcw	Ltim/Sb/Slcw
Upland Moist Tussock Meadow	Moist Tussock Tundra	Fdob/Phl/Hgmt	Fto/Pm/Hgmt
		Fdob/Phl/Hgmt/Ngt	Fto/Tm/Hgmt
		Fdob/Pm/Hgmt	Ftr/Tm/Hgmt
		Fdob/Tm/Hgmt	Ltic/Phh/Hgmt
		Fto/Phh/Hgmt	Ltic/Phl/Hgmt
		Fto/Phl/Hgmt	Ltic/Pm/Hgmt

Appendix D. Comprehensive list of all vascular plant species encountered in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

Vascular Species	Vascular Species
Betulaceae	*Carex praticola* Rydb.
Alnus crispa (Ait.) Pursh	*Carex rariflora* (Wahlenb.) Smith
Caryophyllaceae	*Carex rotundata* Wahlenb.
Melandrium apetalum (L.) Fenzl.	*Carex saxatilis* L.ssp. *laxa* (Trautv.) Kalela
Silene acaulis L.	*Carex subspathacea* Wormsk.
Stellaria humifusa Rottb.	*Carex vaginata* Tausch
Stellaria longipes Goldie	*Carex williamsii* Britt.
Wilhelmsia physodes (Fisch.) McNeill	*Eriophorum angustifolium* Honck. ssp. *subarcticum* (V. Vassiljev) Hult.
Compositae (Asteraceae)	*Eriophorum russeolum* Fries
Arnica lessingii Greene	*Eriophorum scheuchzeri* Hoppe
Artemisia arctica Less. ssp. arctica	*Eriophorum vaginatum* L.
Artemisia tilesii Ledeb.	*Kobresia myosuroides* (Vill.) Fiori & Paol.
Aster sibiricus L.	Empetraceae
Cacalia auriculata DC. ssp. *kamtschatica* (Maxim.) Hult.	*Empetrum nigrum* L.
Chrysanthemum bipinnatum L.	Equisetaceae
Petasites frigidus (L.) Franchet	*Equisetum arvense* L.
Saussurea angustifolia (Willd.) DC.	*Equisetum fluviatile* L. ampl. Ehrh.
Senecio atropurpureus (Ledeb.) Fedtsch.	*Equisetum scirpoides* Michx.
Crassulaceae	*Equisetum variegatum* Schleich.
Sedum rosea (L.) Scop. ssp. *integrifolium* (Raf.) Hult.	Ericaceae
Cruciferae (Brassicaceae)	*Andromeda polifolia* L.
Arabis lyrata L. ssp. *kamchatica* (Fisch.) Hult.	*Arctostaphylos alpina* (L.) Spreng.
Cardamine hyperborea O.E. Schulz	*Arctostaphylos rubra* (Rehd. & Wilson) Fern.
Cardamine pratensis L. ssp. *angustifolia* (Hook.) O.E. Schultz	*Cassiope tetragona* (L.) D. Don
Parrya nudicaulis (L.) Regel	*Ledum decumbens* (Ait.) Lodd.
Cyperaceae	*Vaccinium uliginosum* L.
Carex amblyorhynca Krecz.	*Vaccinium vitis-idaea* L.
Carex aquatilis Wahlenb. ssp. *aquatilis*	Gentianaceae
Carex atrofusca Schkuhr	*Gentiana propinqua* Richards. ssp. *propinqua*
Carex bicolor All.	Graminae (Poaceae)
Carex bigelowii Torr.	*Agropyron macrourum* (Turcz.) Drobov
Carex capillaris L.	*Agropyron violaceum* (Hornem.) Lange ssp. *violaceum*
Carex chordorrhiza Ehrh.	*Alopecuris alpinus* Sm. ssp. *alpinus*
Carex krausei Boeck.	*Alopecurus pratensis* L.
Carex maritima Gunn.	*Arctagrostis latifolia* (R. Br.) Griseb.
Carex membranacea Hook.	*Arctophila fulva* (Trin.) Anderss.
Carex misandra R. Br.	*Bromus pumpellianus* SL

Appendix D. Continued.

Vascular Species	Vascular Species

Calamagrostis canadensis (Michx.) Beauv.
Calamagrostis inexpansa Gray
Deschampsia caespitosa (L.) P. Beauv.
Dupontia fischeri R.Br.
Elymus arenarius L. ssp. *mollis* (Trin.) Hult.
Festuca baffinensis Polunin
Festuca brachyphylla Schult.
Festuca richardsonii Hook.
Festuca rubra L.
Hierochloe odorata (L.) P. Beauv.
Hierochloe pauciflora R. Br.
Poa alpina L.
Poa arctica R. Br.
Poa glauca M. Vahl.
Poa lanata Scribn. & Merr.
Puccinellia vaginata (Lange) Fern. & Weath.
Trisetum spicatum (L.) Richter ssp. *spicatum*

Haloragaceae
Hippuris vulgaris L.
Myriophyllum spicatum L.

Juncaceae
Juncus arcticus Willd.
Juncus biglumis L.
Juncus triglumis L.
Luzula arctica Blytt.
Luzula arcuata (Wahlenb.) Sw. ssp. *unalaschensis* (Buchenau) Hult.
Luzula multiflora (Retz.) Lej.
Luzula multiflora (Retz.) Lej. ssp. *multiflora* var. *kjellmaniana* (Miyabe & Kudo) Sam.
Luzula spicata (L.) DC.
Luzula tundricola Gorodk.

Leguminosae (Fabaceae)
Astragalus alpinus L.
Astragalus eucosmus Hornem. ssp. *sealei* (LePage) Hult.
Astragalus eucosmus Robins. ssp. *eucosmus*
Astragalus umbellatus Bunge
Hedysarum alpinum L.
Hedysarum mackenzii Richards.
Lupinus arcticus S. Wats.
Oxytropis borealis DC.
Oxytropis campestris (L.) DC.
Oxytropis deflexa (Pall.) DC.
Oxytropis maydelliana Trautv.
Oxytropis viscida Nutt.

Lentibulariaceae
Utricularia intermedia Hayne
Utricularia minor L.
Utricularia vulgaris L. ssp. *macrorhiza* (LeConte) Clauson

Liliaceae
Tofieldia pusilla (Michx.) Pers.

Onagraceae
Epilobium latifolium L.

Orchidaceae
Platanthera hyperborea (L.) Lindl.

Papaveraceae
Papaver macounii Greene

Polemoniaceae
Polemonium boreale Adams

Polygonaceae
Polygonum bistorta L. ssp. *plumosum* (Small)
Polygonum viviparum L.
Rumex arcticus Trautv.

Primulaceae
Androsace chamaejasme Host ssp. *lehmannia* (Spr Hult.

Pyrolaceae
Pyrola grandiflora Radius
Pyrola secunda L.
Pyrola secunda L. ssp. *secunda*

Ranunculaceae
Anemone parviflora Michx.
Anemone richardsonii Hook.
Caltha palustris L.
Ranunculus gmelini DC. ssp. *gmelini*
Ranunculus hyperboreus Rottb.
Ranunculus lapponicus L.
Ranunculus pallasii Schlect.

Appendix D. Continued.

Vascular Species	Vascular Species
Rosaceae	*Parnassia palustris* L.
Dryas integrifolia Vahl.	*Saxifraga cernua* L.
Potentilla palustris (L.) Scop.	*Saxifraga foliolosa* R. Br.
Rubus chamaemorus L.	*Saxifraga hieracifolia* Waldst. & Kit.
Sibbaldia procumbens L.	*Saxifraga hirculis* L.
Salicaceae	*Saxifraga punctata* L.
Salix alaxensis (Anderss.) Cov.	*Saxifraga tricuspidata* Rottb.
Salix arbusculoides Anderss.	Scrophulariaceae
Salix arctica Pall.	*Castilleja caudata* (Pennell) Rebr.
Salix brachycarpa Nutt. ssp. *niphoclada* (Rydb.) Argus	*Pedicularis capitata* Adams.
Salix fuscescens Anderss.	*Pedicularis langsdorffii* Fisch.
Salix glauca L.	*Pedicularis langsdorffii* Fisch. ssp. *arctica* (R. Br. Pennell
Salix lanata L. ssp. *richardsonii* (Hook.) Skvort.	*Pedicularis langsdorffii* Fisch. ssp. *langsdorffii*
Salix ovalifolia Trautv.	*Pedicularis sudetica* Willd.
Salix phlebophylla Anderss.	*Pedicularis sudetica* Willd. ssp. *albolabiata*
Salix planifolia Pursch. ssp. *pulchra* (Cham.) Argus	*Pedicularis verticillata* L.
Salix reticulata L.	Valerianaceae
Salix rotundifolia Trautv.	*Valeriana capitata* Pall.
Saxifragaceae	
Parnassia kotzebuei Cham. & Schlecht.	

Appendix E. Comprehensive list of all non-vascular plant species encountered in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013.

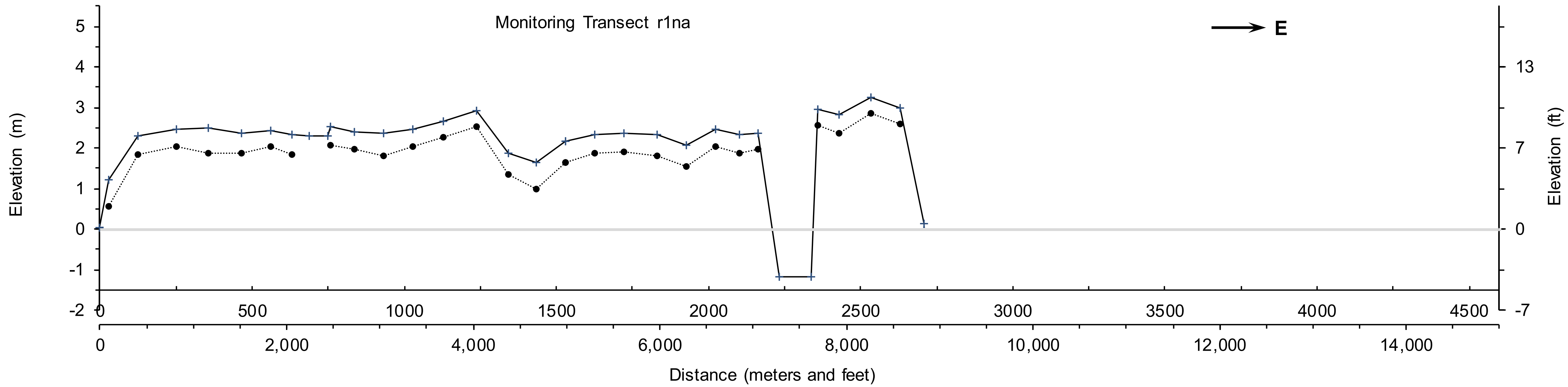
Non-Vascular Species
Lichen
Cetraria islandica (L.) Ach.
Cetraria islandica (L.) Ach. ssp. *islandica*
Cladonia cariosa (Ach.) Spreng.
Cladonia cornuta (L.) Hoffm.
Cladonia ecmocyna Leighton
Cladonia furcata (Hudson) Schrader
Cladonia pyxidata (L.) Hoffm.
Cladonia squamosa Hoffm.
Dactylina arctica (Richardson) Nyl.
Flavocetraria cucullata (Bellardi) Kärnefelt & Thell
Flavocetraria nivalis (L.) Kärnefelt & Thell
Lobaria linita (Ach.) Rabenh.
Masonhalea richardsonii (Hook.)
Nephroma arcticum (L.) Torss.
Nephroma expallidum (Nyl.) Nyl.
Parmelia saxatilis (L.) Ach.
Peltigera aphthosa (L.) Willd.
Peltigera canina (L.) Willd.
Peltigera didactyla (With.) J. R. Laundon
Peltigera leucophlebia (Nyl.) Gyelnik
Peltigera rufescens (Weiss) Humb.
Stereocaulon alpinum Laurer ex Funck
Thamnolia vermicularis (Sw.) Ach. ex Schaerer
Moss and Liverwort
Abietinella abietina (Hedw.) Fleisch.
Aulacomnium acuminatum (Lindb. & Arnell)
Aulacomnium palustre (Hedw.) Schwaegr.
Aulacomnium turgidum (Wahlenb.) Schwaegr.
Blepharostoma trichophyllum (L.) Dum.
Brachythecium mildeanum (Schimp.) Schimp. ex Milde
Brachythecium turgidum (Hartm.) Kindb.
Sphagnum squarrosum Crome

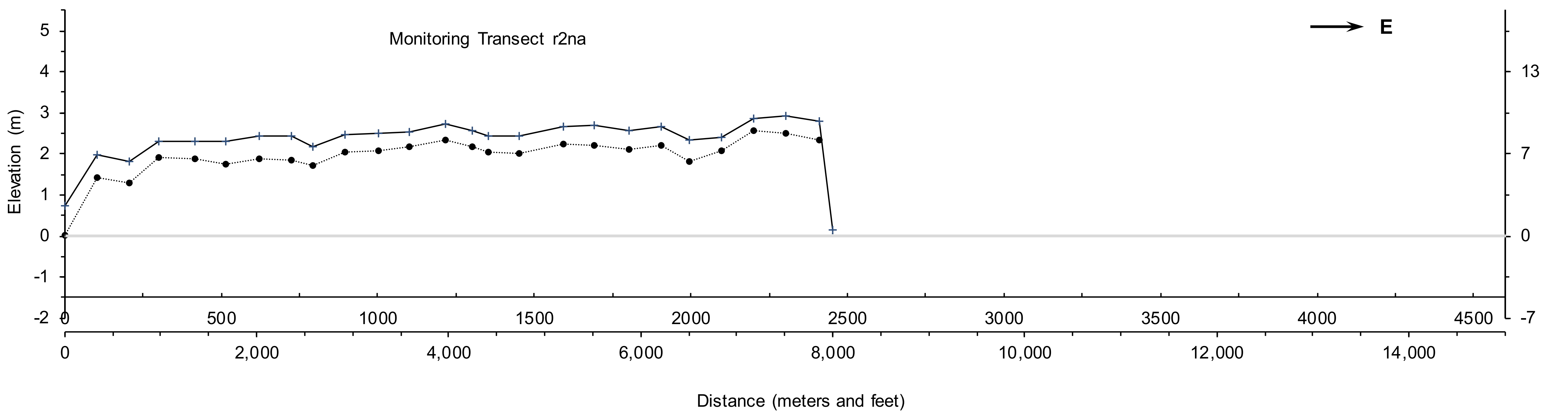
Non-Vascular Species
Bryum pseudotriquetrum (Hedw.) Gaertn. et al.
Calliergon giganteum (Schimp.) Kindb.
Calliergon stramineum (Brid.) Kindb.
Campylium arcticum Williams
Campylium polygamum (B.S.G.) C.Jens.
Campylium stellatum (Hedw.) C.Jens.
Catoscopium nigritum (Hedw.) Brid.
Ceratodon purpureus (Hedw.) Brid.
Cinclidium latifolium Lindb.
Cinclidium subrotundum Lindb.
Cirriphyllum cirrosum (Schwaegr.) Grout
Climacium dendroides (Hedw.) Web. et Mohr.
Dicranum elongatum Schleich. ex Schwaegr.
Dicranum laevidens Williams
Dicranum majus Sm.
Dicranum spadiceum Zett.
Distichium capillaceum (Hedw.) B.S.G.
Distichium inclinatum (Hedw.) B.S.G.
Ditrichum flexicaule (Schwaegr.) Hampe
Drepanocladus aduncus (Hedw.) Warnst. s.l.
Drepanocladus brevifolius (Lindb.) Warnst.
Drepanocladus revolvens (Sw.) Warnst.
Drepanocladus sendtneri (Schimp. ex C.Muell.) Warnst.
Encalypta alpina Sm.
Encalypta rhaptocarpa Schwägr.
Entodon concinnus (De Not.) Par.
Eurhynchium pulchellum (Hedw.) Jenn.
Fissidens adiantoides Hedw. (one stem)
Hamatocaulis vernicosus (Mitt.) Hedenaes
Hylocomium splendens (Hedw.) B.S.G.
Hypnum bambergeri Schimp.
Hypnum lindbergii Mitt.
Marchantia polymorpha L
Meesia longiseta Hedw.

Appendix E. Continued.

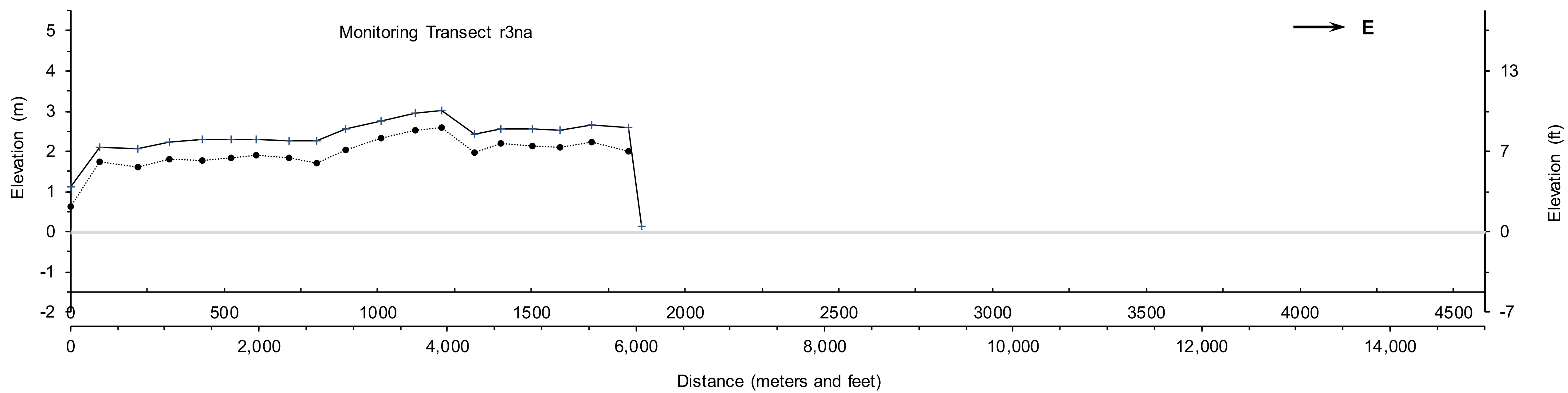
Non-Vascular Species
Meesia triquetra (Richter) Aongstr.
Meesia uliginosa Hedw.
Myurella julacea (Schwaegr.) B.S.G.
Oncophorus virens (Hedw.) Brid.
Oncophorus wahlenbergii Brid.
Orthothecium chryseon (Schwaegr. ex Schultes) Schimp.
Paludella squarrosa (Hedw.) Brid.
Philonotis tomentella Molendo
Plagiomnium ellipticum (Brid.) T.Kop.
Polytrichum commune Hedw.
Polytrichum jensenii Hag.
Polytrichum juniperinum Hedw.
Polytrichum strictum Brid.

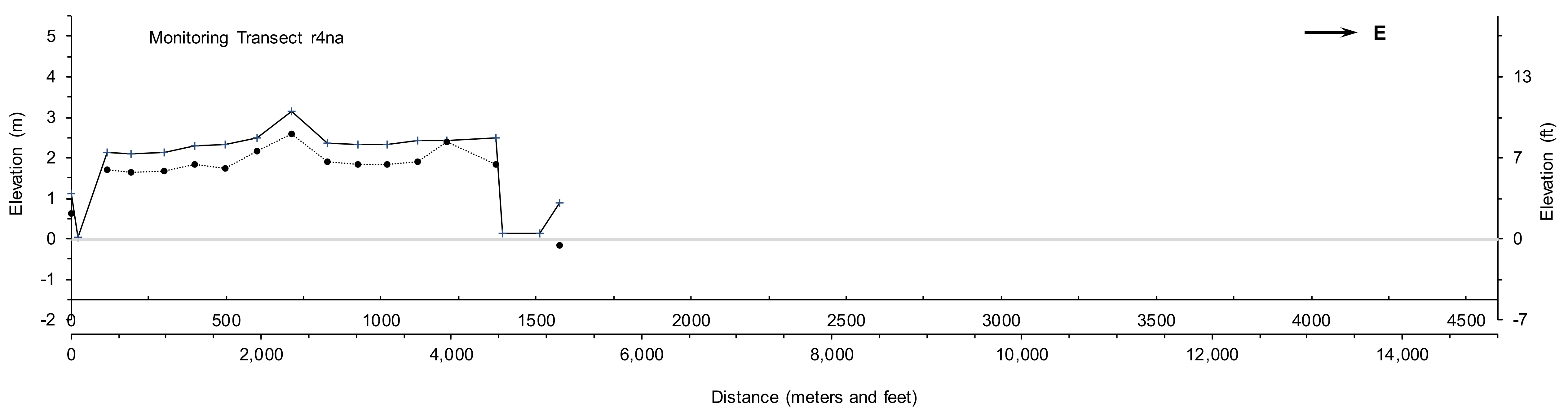
Non-Vascular Species
Pseudocalliergon turgescens (T.Jens.) Loeske
Rhizomnium andrewsianum (Steere) T. Kop.
Rhizomnium magnifolium (Horik.) T. Kop.
Rhytidium rugosum (Hedw.) Kindb.
Sanionia uncinata (Hedw.) Loeske
Scorpidium scorpioides (Hedw.) Limpr.
Sphagnum squarrosum Crome
Sphagnum subsecundum Nees ex Sturm
Timmia austriaca Hedw.
Tomentypnum nitens (Hedw.) Loeske
Tortella tortuosa (Hedw.) Limpr.
Tortula ruralis (Hedw.) Gaertn., Meyer, & Scherb.
Warnstorfia sarmentosa (Wahlenb.) Hedenaes



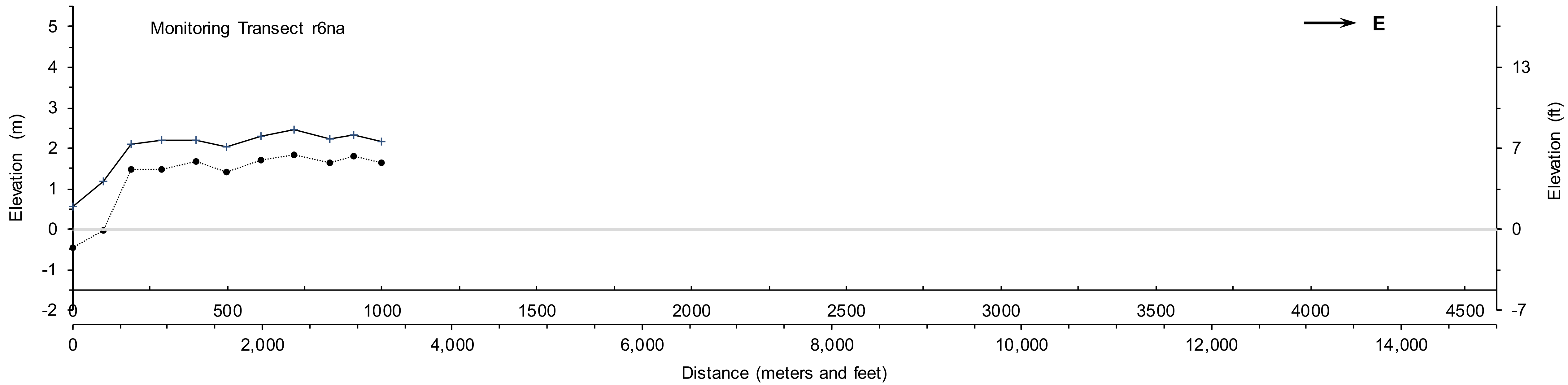


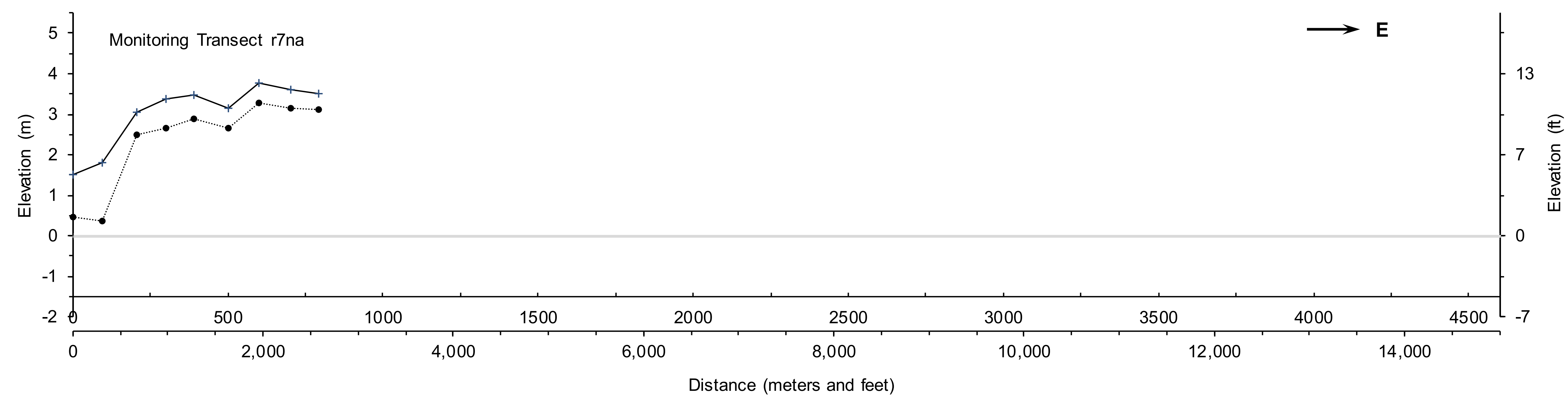
Appendix F. Cross sections of ground surface elevation and thaw depth along Monitoring Transects in Reference Area North, CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Elevations are referenced to British Petroleum mean sea level (BPMSL).





Appendix F. Continued.





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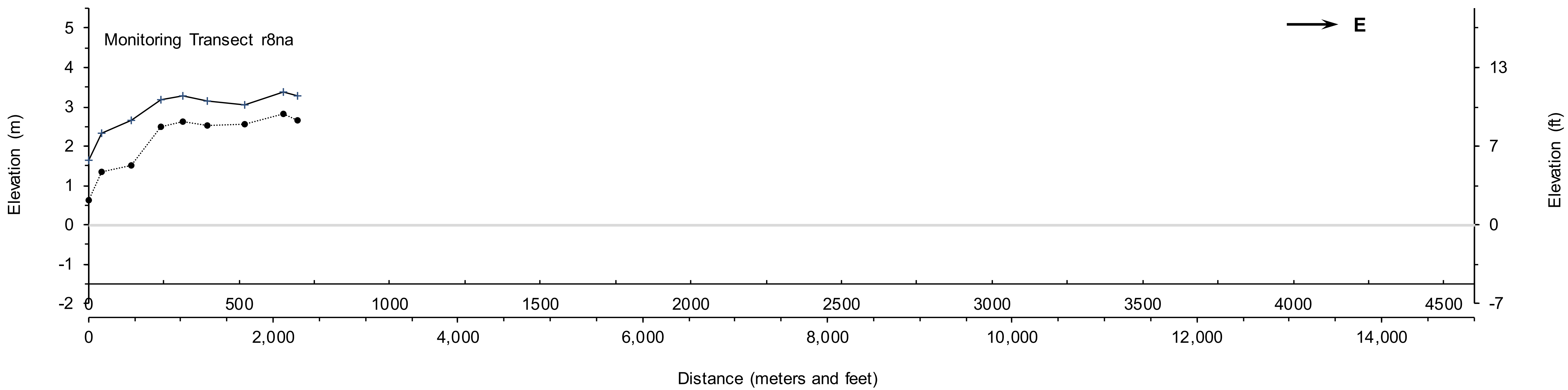

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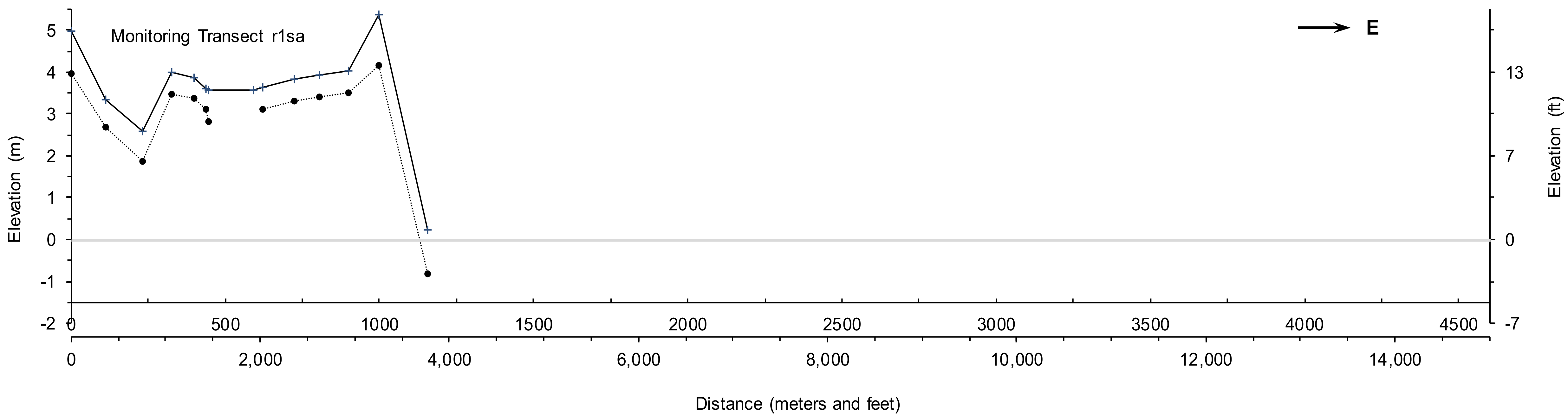
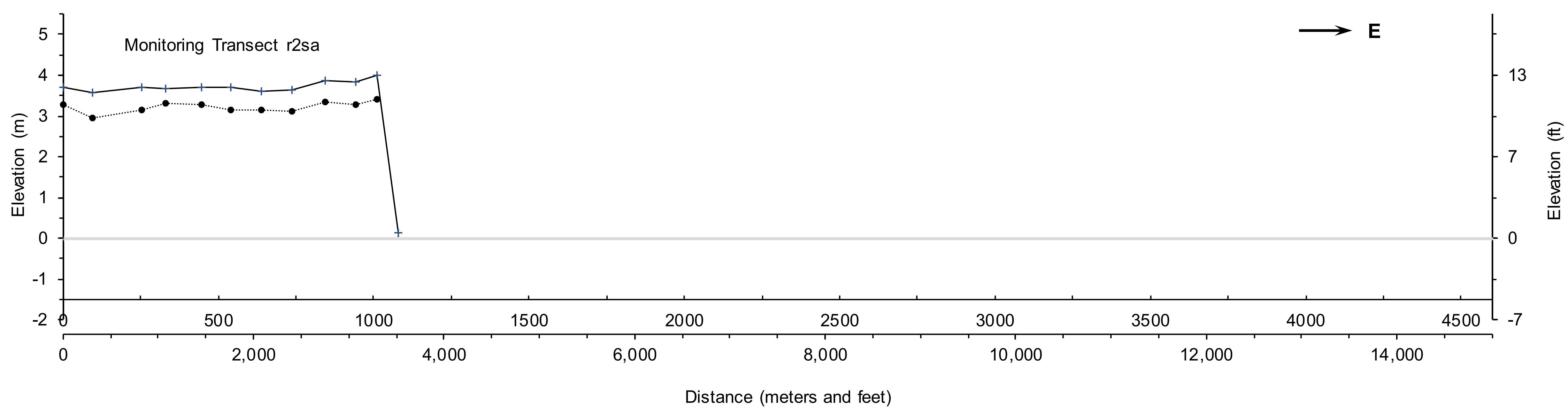
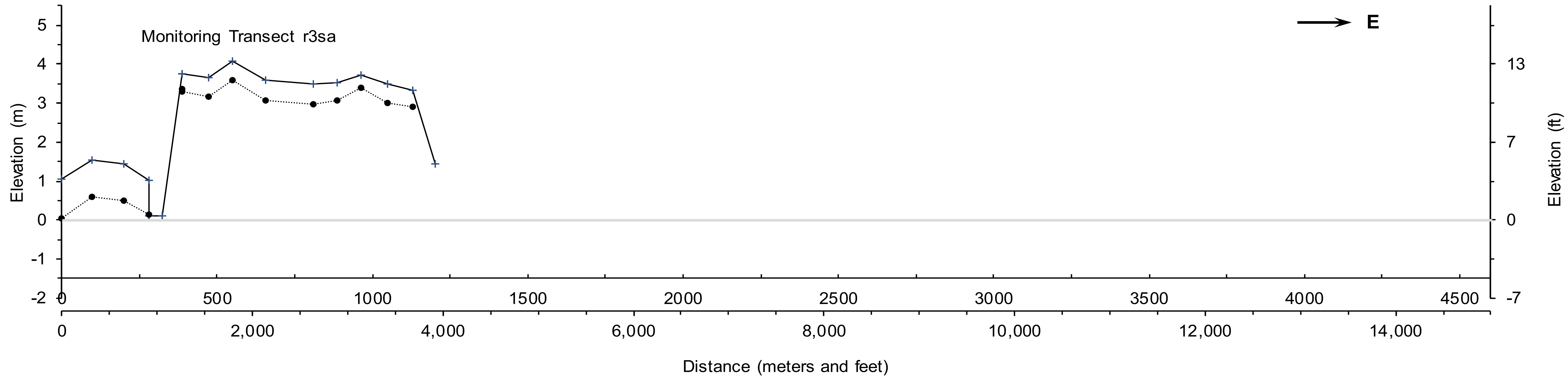
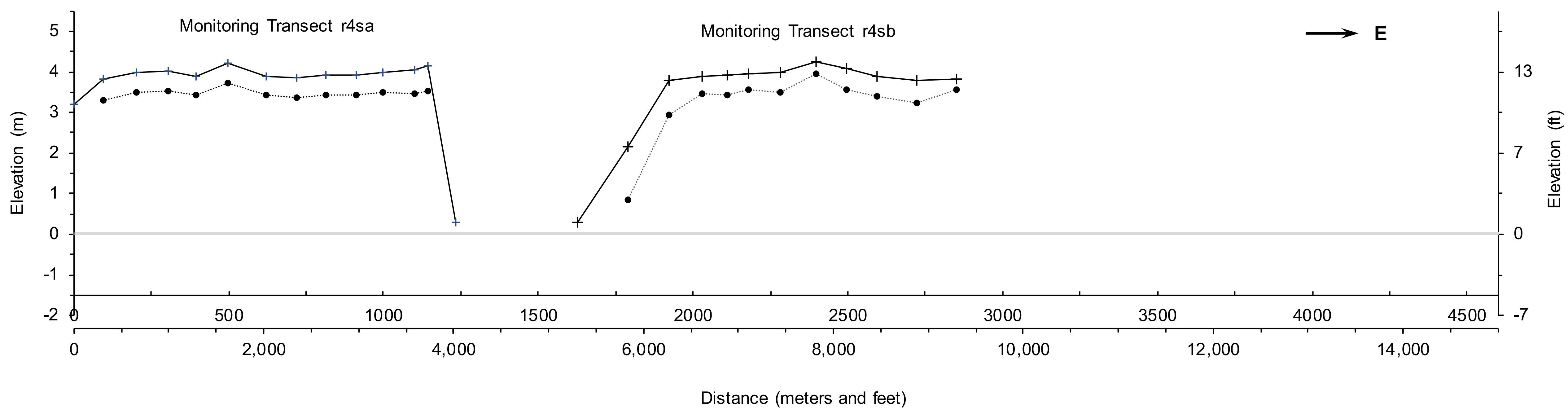




Appendix G. Cross sections of ground surface elevation and thaw depth along Monitoring Transects in Reference Area North, CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Elevations are referenced to British Petroleum mean sea level (BPMSL).





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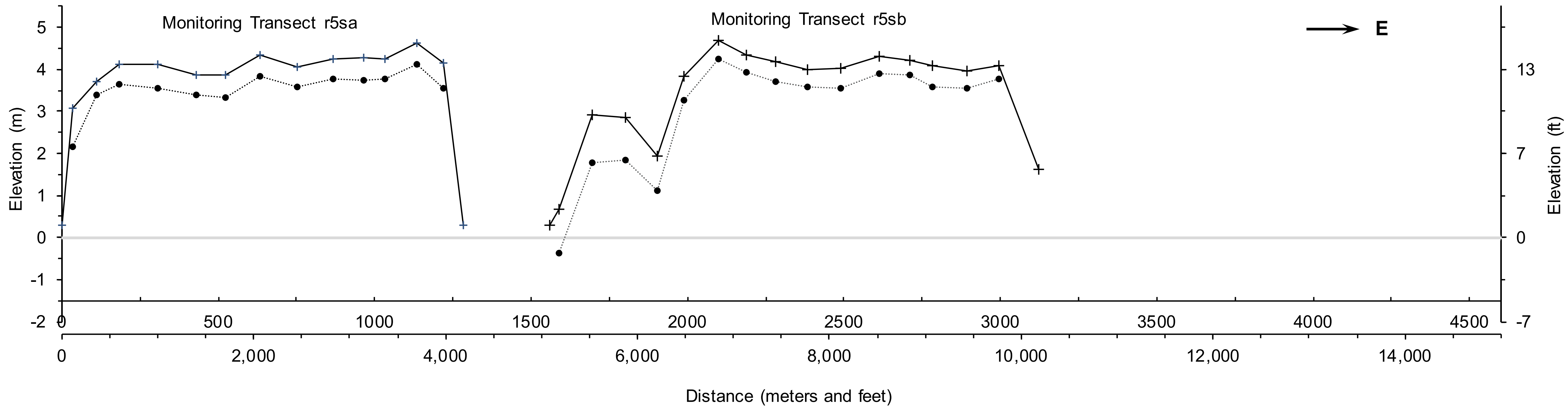

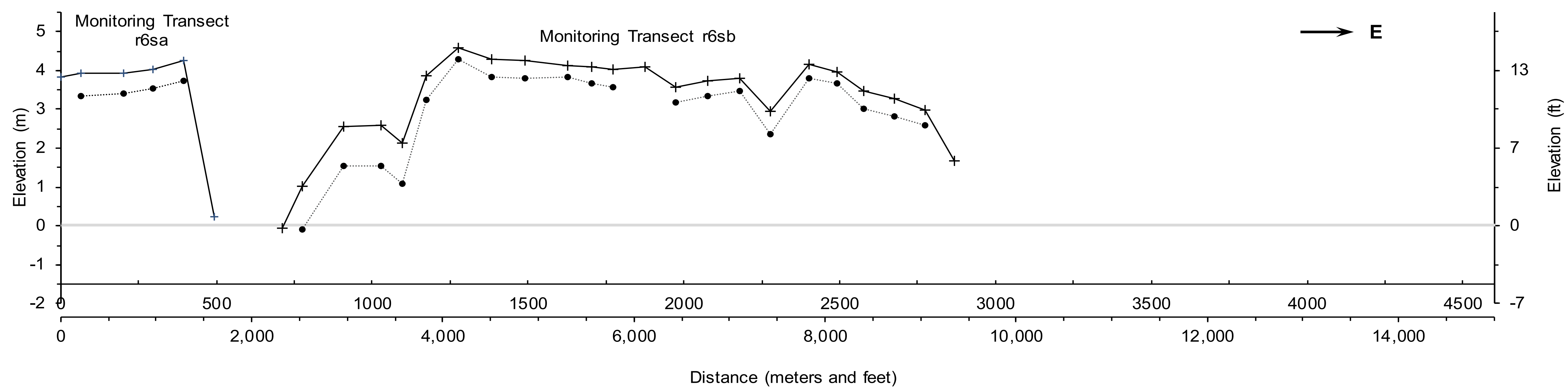

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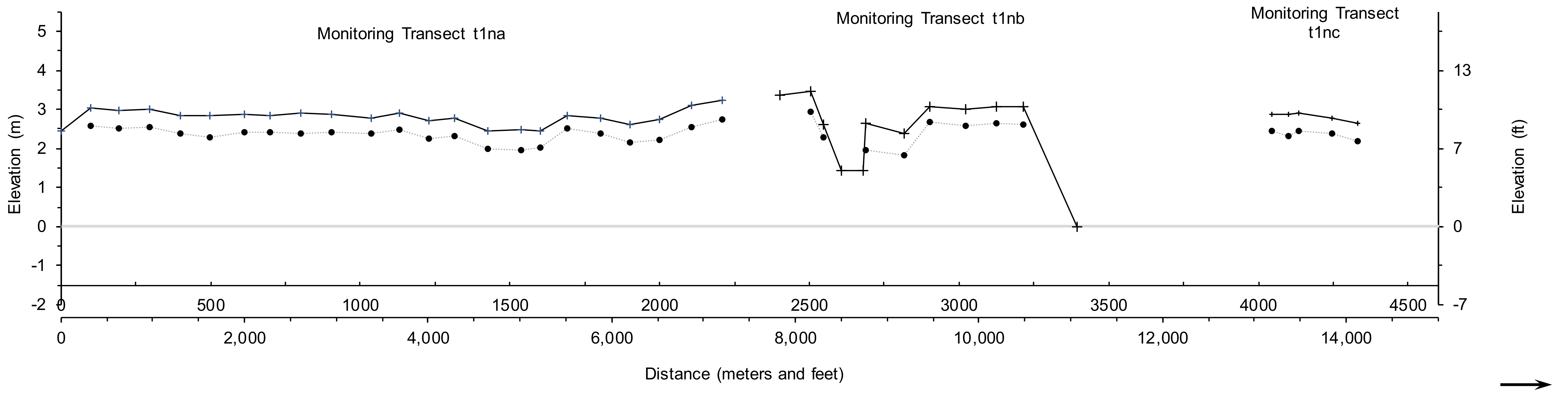
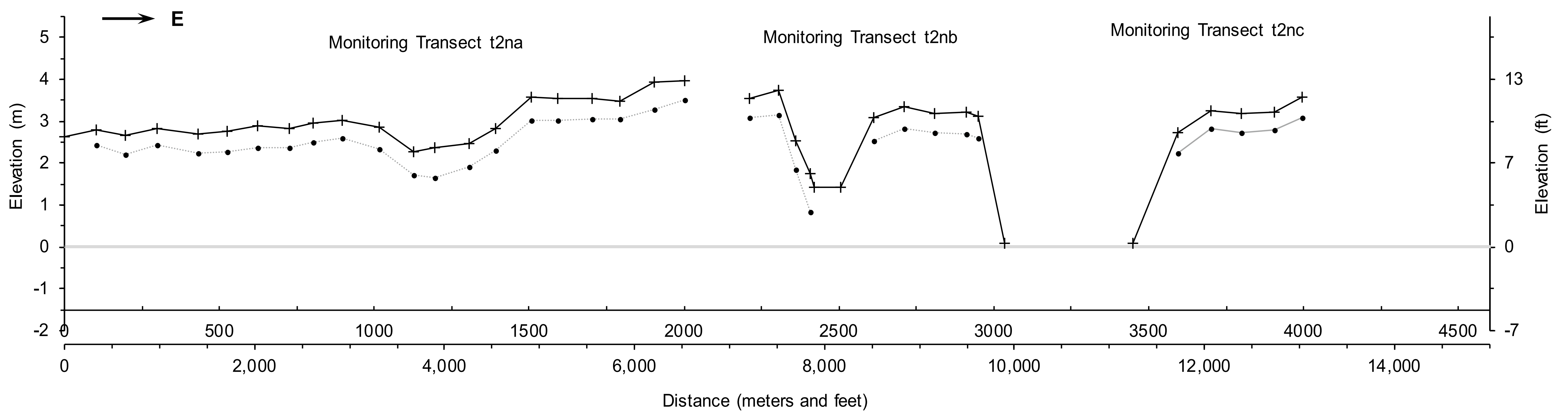
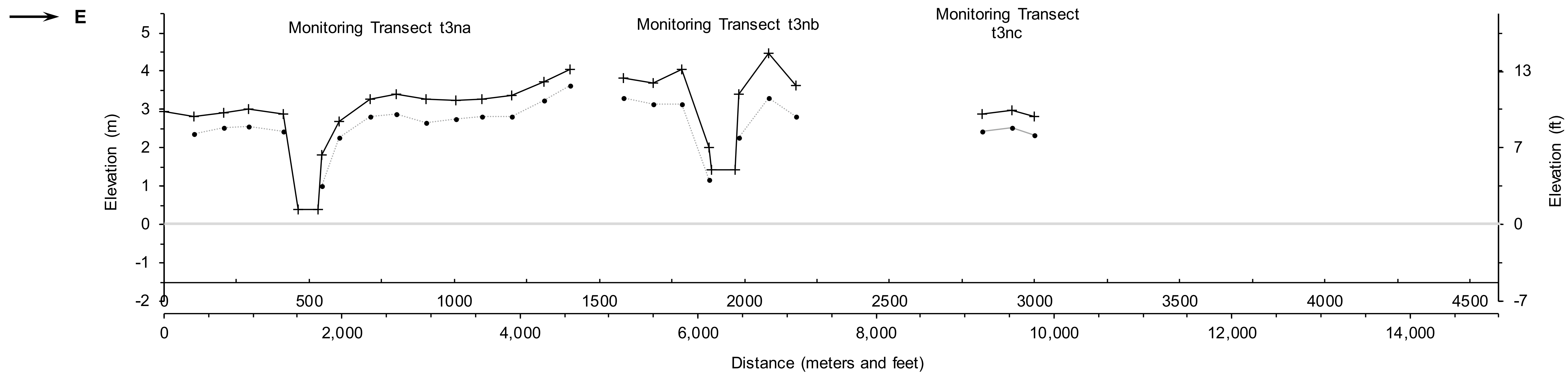
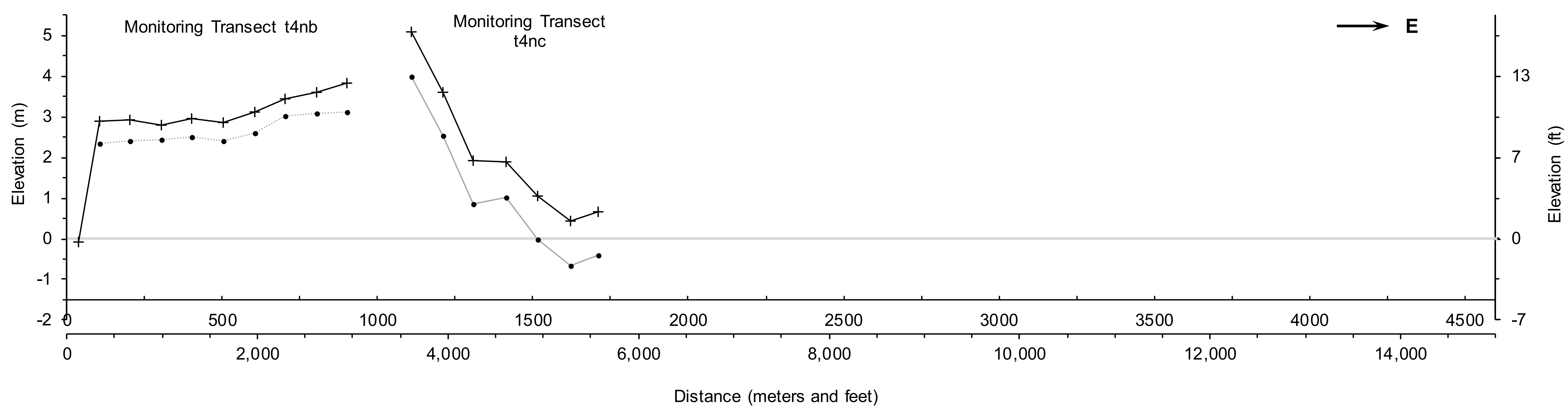




Appendix H. Cross sections of ground surface elevation and thaw depth along Monitoring Transects in Test Area North, CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Elevations are referenced to British Petroleum mean sea level (BPMSL).





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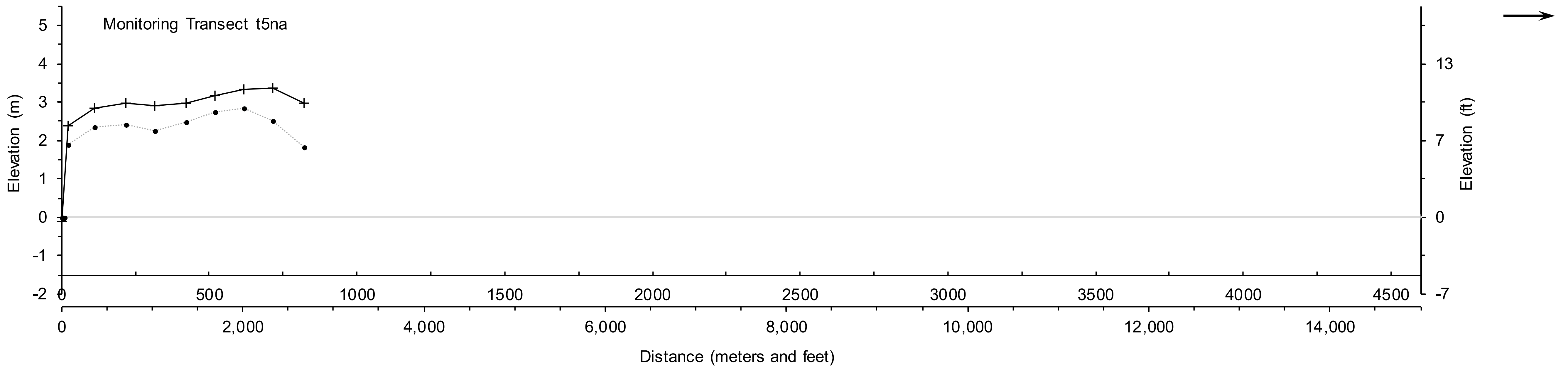

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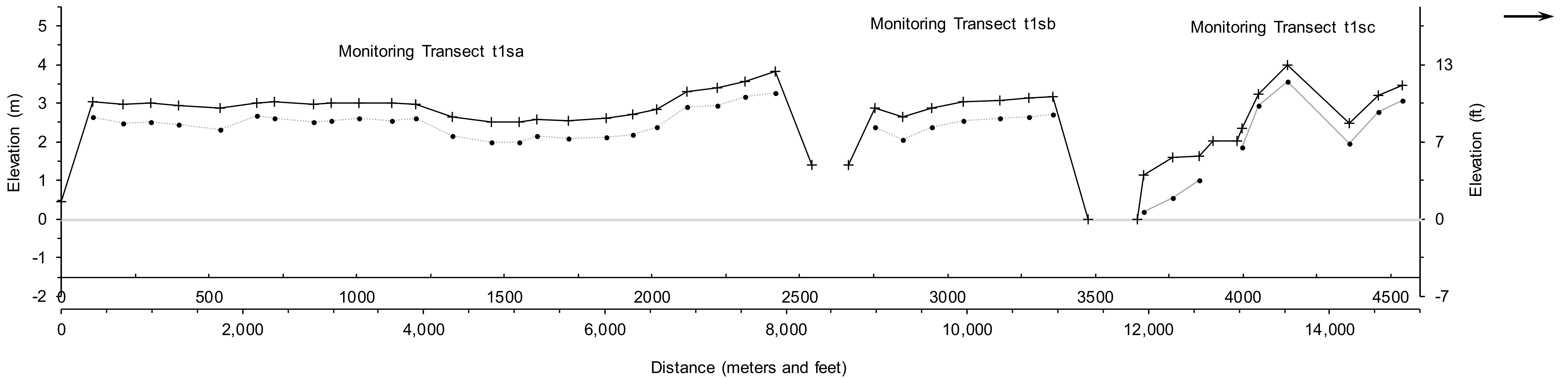
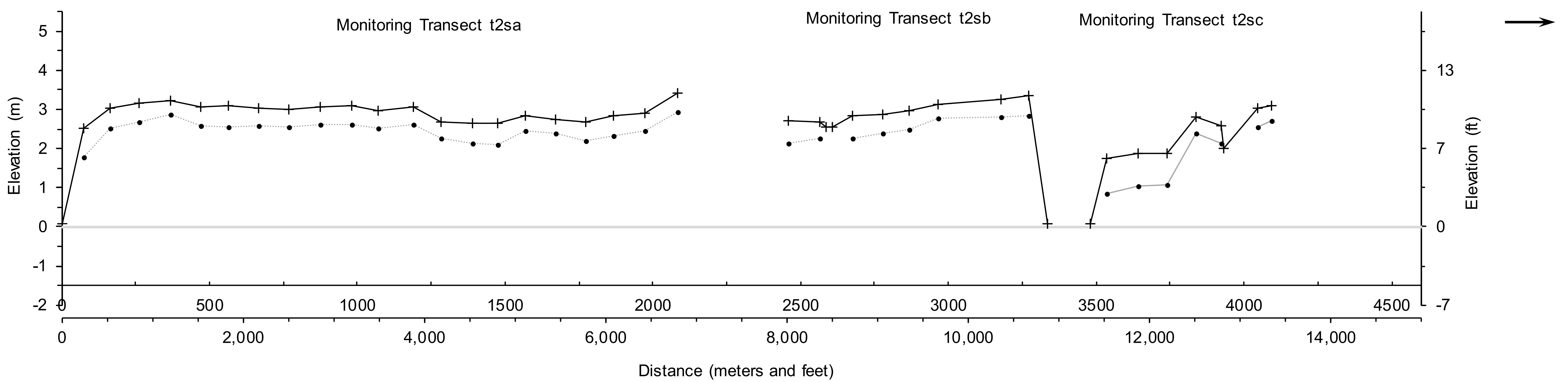
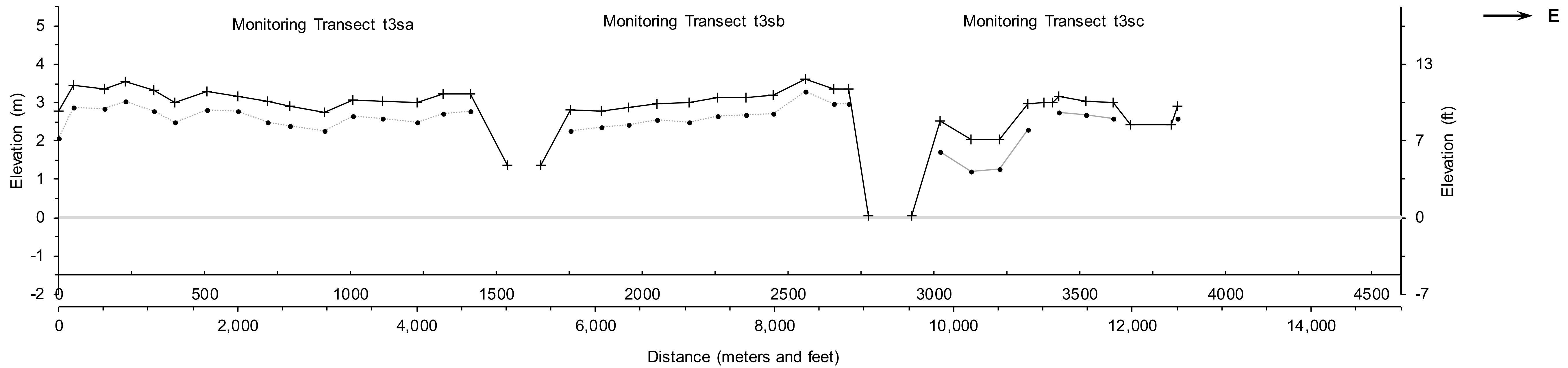
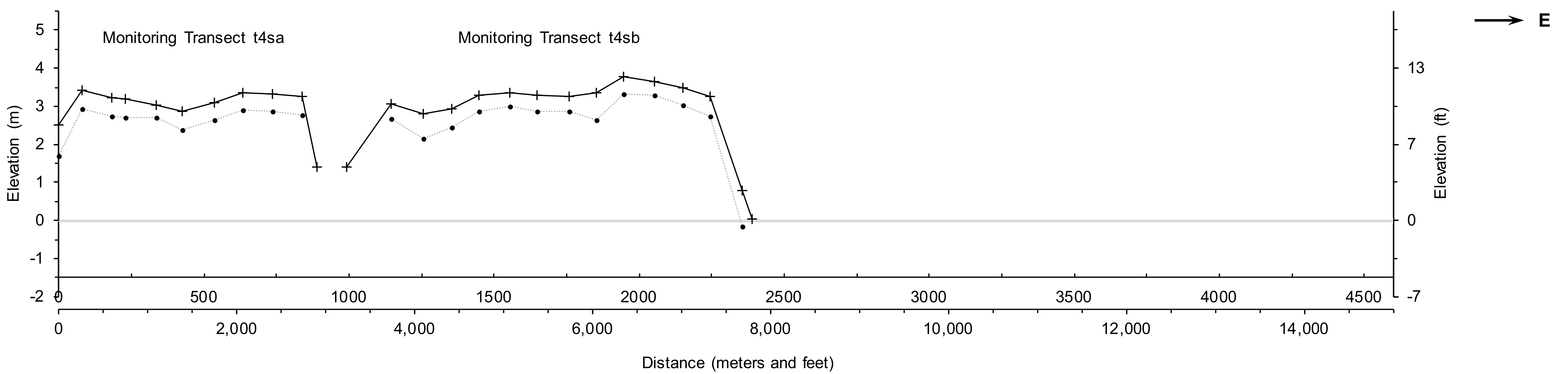




Appendix I. Cross sections of ground surface elevation and thaw depth along Monitoring Transects in Test Area South, CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Elevations are referenced to British Petroleum mean sea level (BPMSL).





Appendix I. Continued.

Appendix J. Summary of soil laboratory data CD5 Habitat Monitoring Study Area, northern Alaska, 2013. Data for particle size and loss on ignition from Palmer Research Station Soils Laboratory. Bulk density and volumetric ice content from ABR, Inc.

		Based on 100 C° Oven Dry					Based on 105 C° Oven Dry	
Plot ID	Soil Depth (cm)	% Sand	% Silt	% Clay	Texture[1]	% Loss On Ignition	Bulk Density (g/cm^3)	% Volumetric Ice Content
RN-PC01-2013	88–106	4.40	71.00	24.60	SIL	5.87	0.34	62.0
RN-PC01-2013	108–116	11.40	69.00	19.60	SIL	4.52	0.63	62.4
RN-PC01-2013	116–128	12.40	70.00	17.60	SIL	4.38	0.55	60.2
RN-PC01-2013	153–162	60.40	28.00	11.60	SL	4.40	0.76	47.9
RN-PC02-2013	84–113	23.06	60.00	16.94	SIL	4.54	0.48	36.1[2]
RN-PC02-2013	142–146	8.00	76.40	15.60	SIL	4.70	0.46	50.0
TN-PC04-2013	54–60	31.60	53.80	14.60	SIL	3.96	1.03	72.8
TN-PC04-2013	97–117	27.20	61.20	11.60	SIL	4.34	0.73	72.6
TN-PC04-2013	130–147	35.60	52.80	11.60	SIL	2.92	0.12	88.1
TN-PC05-2013	81–99	17.20	65.20	17.60	SIL	12.33	0.32	69.2
TN-PC05-2013	99–116	28.33	59.58	12.08	SIL	19.99	0.39	73.6
TN-PC05-2013	155–177	11.20	64.20	24.60	SIL	11.11	0.30	82.4
TS-PC08-2013	49–73	19.60	65.80	14.60	SIL	16.10	0.23	81.0
TS-PC08-2013	91–107	19.60	62.80	17.60	SIL	12.79	0.20	86.8
TS-PC08-2013	141–158	12.00	61.00	27.00	SICL	19.88	0.28	89.0
TS-PC12-2013	74–91	5.60	70.80	23.60	SIL	5.00	0.59	71.2
TS-PC12-2013	99–113	7.60	74.80	17.60	SIL	4.86	0.70	74.6
TS-PC12-2013	135–142	2.60	76.80	20.60	SIL	6.66	0.41	76.8

[1] Soil Textures: SIL = Silt Loam, SL = Sandy Loam, SICL = Silty Clay Loam
[2] The value for Volumetric Ice Content for Plot RN-PC2-2013, 84-113 cm, was omitted from analysis because this section of the core was mishandled in the field.