E. Anthropogenic Change Agents

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Summary

Section E. *Anthropogenic Change Agents* provides the detailed descriptions, methods, datasets, results, and limitations for the assessments of changes due to human activities including natural resource extraction, infrastructure, and subsistence.

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1. Introduction

Anthropogenic change agents assessed in this project include several human activities ranging from oil production and mining, to livelihood activities such as subsistence. This section describes the current extent of human activity in the North Slope study area and attempts to assess potential change in these factors projected into the future.

Anthropogenic activities in the North Slope study area are diverse. Although natural resource extraction dominates the footprint, subsistence as a competing use is an important activity for consideration in making land use decisions. Small communities separated by large distances, located primarily along the northern coast, are vulnerable to changing climate conditions, which creates complex challenges for near and long-term regional management. Ownership and control of land is fragmented among several federal agencies, state, and local bodies. Ecoregional boundaries cross jurisdictional boundaries, thus creating the need for robust inter-agency cooperation and coordinated management of resources. With subsistence being a critical part of the local social, cultural, and economic fabric, local participation in resource management is, and will continue to be, critical in sustainable management practices.

Owing to the breadth of such factors, this section is necessarily limited to general information, guided by the MQs, and covers the following:

- Subsistence: All communities in the region depend on subsistence resources. Subsistence species harvested include various species of fish, whales, birds, plants, and big game animals, primarily caribou. Development of any kind impacts the land available for subsistence. People in the region constantly strive to balance these two priorities, allowing them the ability to have both a subsistence lifestyle and a cash economy.
- Natural Resource Extraction: Prudhoe Bay is home to the largest oil field in the United States and produces approximately 40% of the oil extracted in Alaska. Oil extraction has substantial impacts on transportation infrastructure, energy supply, community populations, employment, and subsistence. Additionally, mining activities are either proposed or currently exist in a smaller part of the study area.
- Transportation and Communications Infrastructure: The majority of the transportation infrastructure is related to oil industry activities. Other community transportation infrastructure – existing and planned – is small in comparison to the oil industry's activities, as well as small in comparison to other U.S. communities. Transportation infrastructure includes local roads, airports, ports, and local summer and winter trails. Communication infrastructure includes broadband and cellular service towers.
- Recreation: This includes visitors to remote lodges and dispersed and centralized facilities in state and national recreation areas. Visitors to this region are mostly seasonal.
- Community Energy Development: Diesel generators are the main source of electricity in communities, with an increasing emphasis on renewable sources of energy. Renewable energy projects in this region are small scale and designed to replace some of the energy produced by

diesel generators. Lack of transmission infrastructure and a small customer base limit the size of these projects.

In addition to assessing the current and future anthropogenic activities, we also provide a social and economic profile of the region. Assessing the extent of anthropogenic activities required an extensive process of discovery, collection, and cleaning of data on various social and economic indicators from multiple data sources, and mapping and analyzing the various types of activities in the region. This section also identifies various data sources used in the analysis, and identifies various limitations to availability and accessibility of required data. The ecoregions correspond closely to the administrative boundaries of the North Slope Borough with the exception of two communities, Kivalina and Noatak, and the Red Dog Mine, all located in the Northwest Arctic Borough (NWAB).

Although the BLM requests project results to be reported at the 5th-level hydrologic unit, social and economic data are only available by political and administrative jurisdictions and do not correspond to HUCs. Where possible and meaningful, data were aggregated to the 5th-level hydrologic unit, but most data is presented at its native resolution.

1.1. General Land Status

With almost 70% of the land in the North Slope study area monitored and regulated by federal agencies, federal government is the largest landowner in the study area (Table E-1). More than half of this federal land is regulated/monitored by the Bureau of Land Management (BLM), including the National Petroleum Reserve – Alaska (NPR-A). Overall, the BLM is the largest landowner/regulator in the North Slope study area, regulating 38.98% (97,364.321 sq. km) of total land in the study area.

Table E-1. Distribution of land ownership in the North Slope study area.

Land Ownership	Area (km^2)	Percent of Total Study Area
Bureau of Land Management	97,364	39%
State Patent or TA	49,493	20%
US Fish and Wildlife Service	45,834	18%
National Park Service	29,165	12%
Native Patent or IC	23,134	9%
State Selected	3,009	1.2%
Native Selected	1,674	0.7%
Military	81	0.03%
Private	0.05	0.00%
Total	**249,754**	

The State of Alaska with 19.82% (49,493.086 sq. km) is the second largest landowner in the study area. This was part of the land entitlement accrued as part of its Statehood Act. Approximately 447,582 km^2, or 96.3% of the state's entitlement was selected since statehood. This selection includes 149,976 km^2 of

land that was tentatively approved for selection (Bradner 2013). The State selected areas it believed would provide the necessary resources for the state's development, and to convey control over the state's internal affairs from the federal government. These selections were based on the principles of encouraging development and settlement, development of natural resources, and development of recreational uses of land (Alaska Department of Natural Resources 2000). Much of the oil development in the North Slope study area is on state-owned land. Figure E-1 shows land ownership in the study area.

In addition to the State Patent or Temporarily Approved (TA) selection, the State of Alaska also selected lands that are yet to be approved by the federal government, and has not yet been conveyed either through a patent or temporary approval. Approximately 3,008.827 sq. km of land is marked as state selected lands in the North Slope study area, not all of which may be eventually conveyed under the authorizing legislation. While the state files a claim and the land is marked as "state selected", the land is closed for federal mining claims, however, the State of Alaska accepts mining claims on this land. There is considerable risk associated with such claims since the federal government may restrict such claims or may decide not to convey the selected land to the state (Alaska Department of Natural Resources 2014).

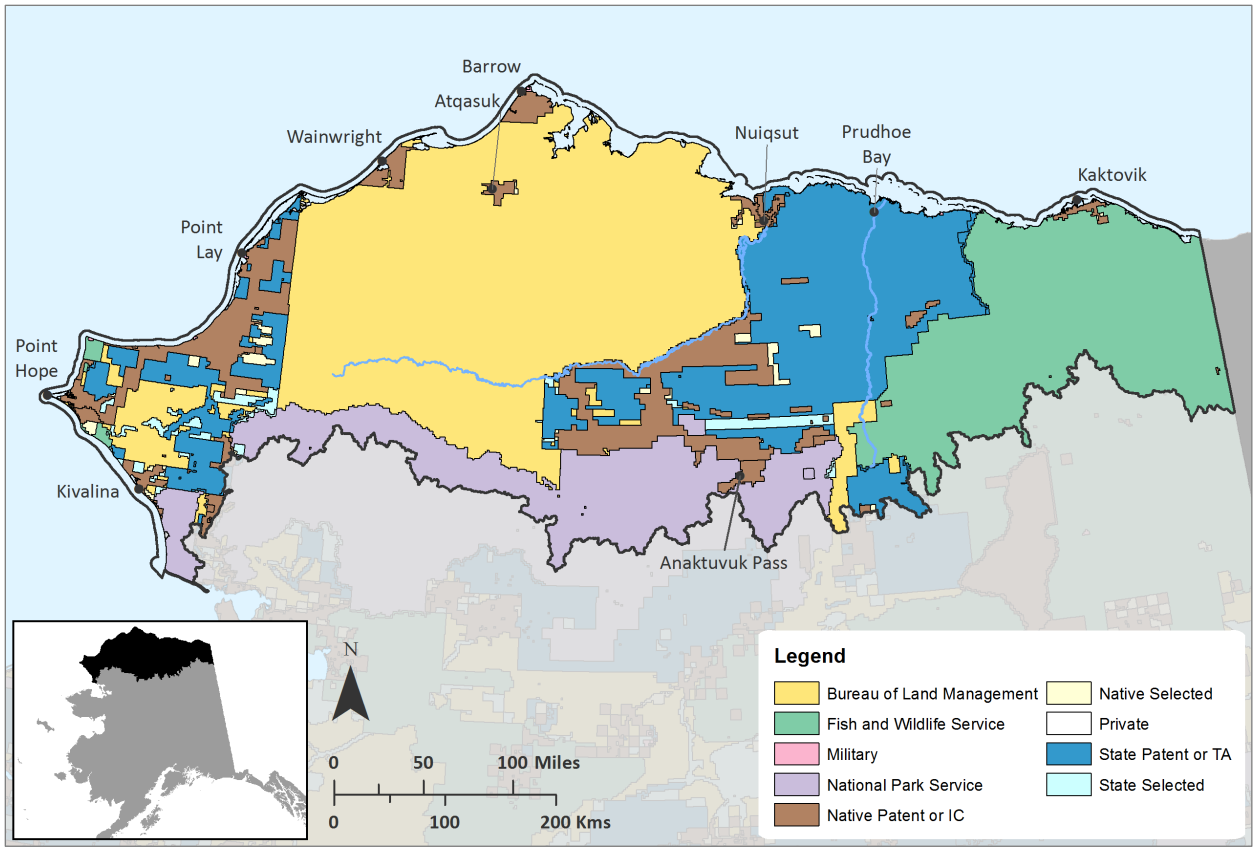


Figure E-1. Land status in the North Slope study area.

Similar to the state selection, Alaska Native corporations were entitled to land selections through the Alaska Native Claims Settlement Act of 1971. A total of 23,133.629 sq. km^2 of land is either conveyed or

in interim conveyance (IC), and another 1,674.189 sq. km of land was selected but yet to be conveyed. Recipients of conveyances under ANCSA are a mixture of regional and Alaska Native village corporations, and the majority of this land will be conveyed as private landholdings to them. A small portion of this land is to be conveyed as a land base for communities. These conveyances for community lands (up to 1200 acres) will first be transferred from local Alaska Native corporations to the state, in trust for a future municipal body to be incorporated under state law. Upon incorporation of such a municipal entity, these conveyed trust lands will be conveyed to the local municipal entity. Such lands are selected by each community through an extensive public process involving members of that community and other stakeholders in the lands around that community. Most communities in the North Slope study area region have not completed their land selections.

The ten communities in the study area have a combined footprint of 22.485 sq. km. While the area occupied by each community is extremely small compared to any other landowners in the area, subsistence activities of the resident population require a significantly large area, potentially extending to the entire study area. As shown in Figure E-2, resident population has camps and cabins throughout the region, signifying their use of the region's vast land resources. A majority of the trails outside the vicinity of Prudhoe Bay are used to access subsistence resources of the region. Despite the density of camps and cabins, the remoteness of the region and sparse population mean relatively low impact of this use on the ecological resources.

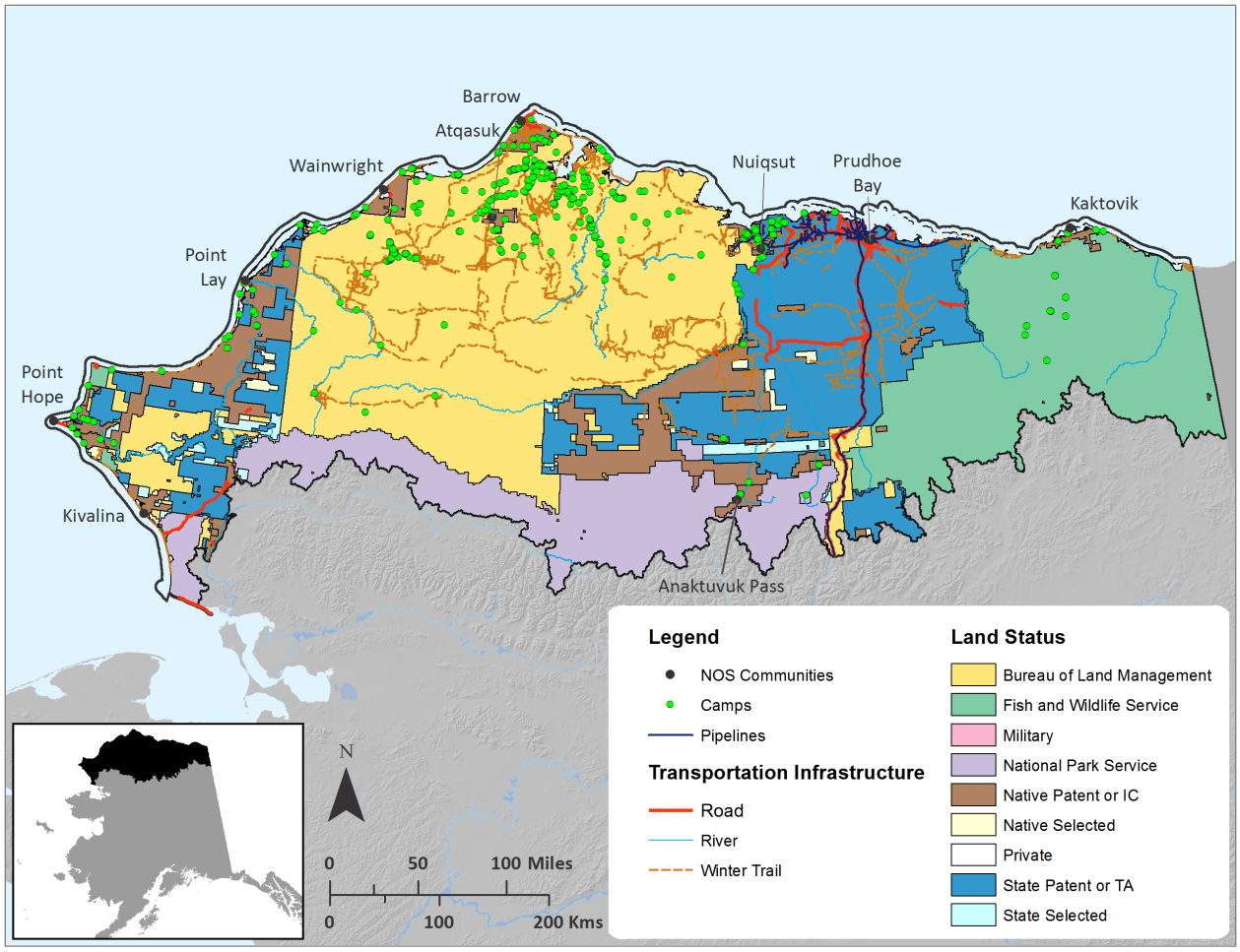


Figure E-2. Locations of camps and cabins in the North Slope study area.

2. Current Human Footprint

This section describes the current human footprint in the North Slope study area. Human activity in this area dates back centuries. However, this narrative is limited to the recent human footprint beginning with the military installations following World War II. Many trails used for inter-village transportation and access to subsistence existed far before any contact with non-residents of this region. These access and transportation routes changed over time, and documentation of such routes is a relatively recent effort.

Ten communities, two industrial complexes with substantial transient populations, a number of fishing camps, around the Teshekpuk Lake and along all rivers, transportation routes (trails, roads, and river transportation routes), oil fields, pipelines and associated infrastructure, and mines comprise the bulk of the current human footprint. In addition, this region saw increased activity during the heady days of the Cold War, with several military installations that still dot the landscape. Radar sites at Barrow, Oliktok, and Barter Island are active North Warning System Long Range Radars The region is home to some of the largest parks and preserves in the nation, and abundant natural resources.

2.1. Methods

The human footprint includes all major human activities ranging from individual community footprints, subsistence use areas, transportation networks, defense installations, and industrial infrastructure. We identified current human footprint in the region by using several data layers. Figure E-3 shows the process model for computing the current human footprint in the region.

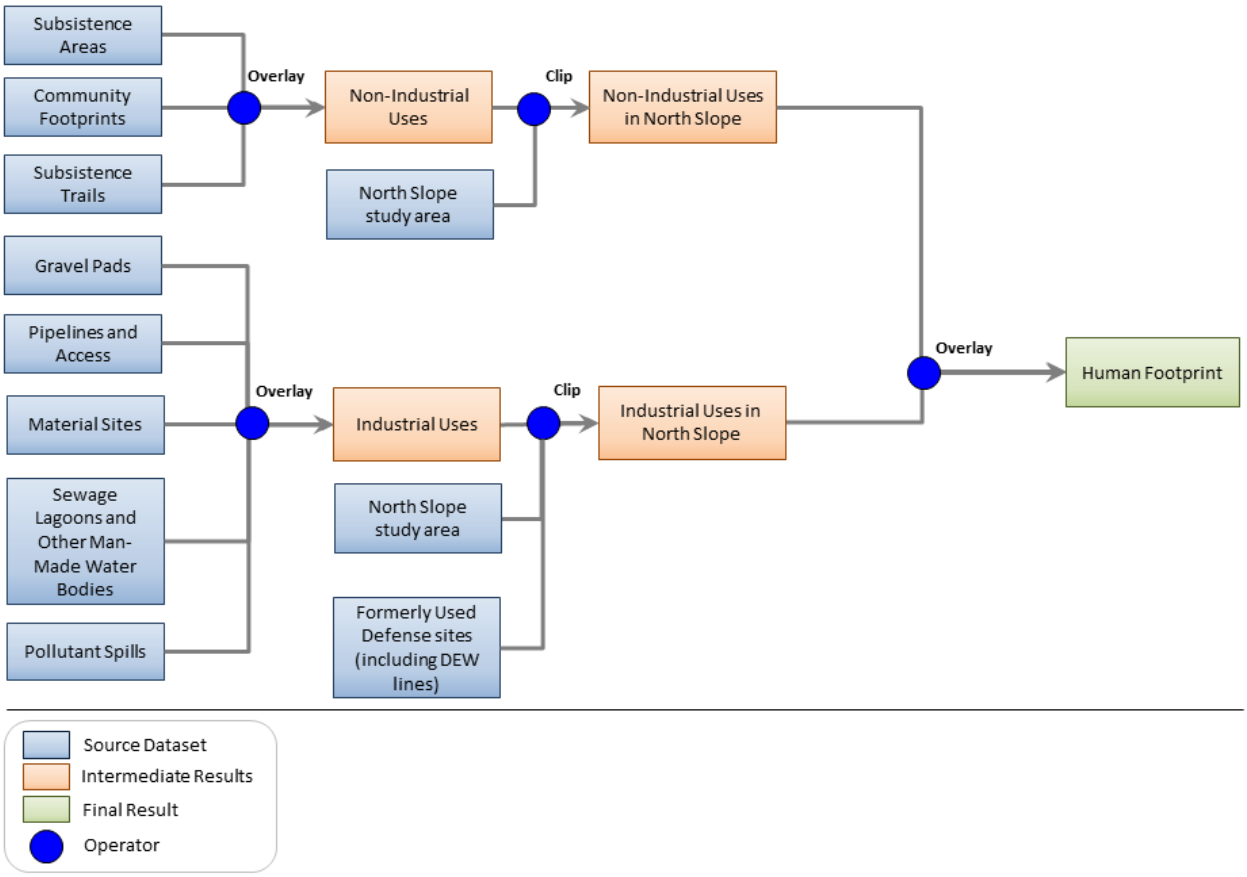


Figure E-3. Process Model for computing human footprint in the North Slope study area.

Datasets

Table E-2 lists the datasets that were included in computing the human footprint in the region. All original datasets were cropped to the North Slope study area boundary. A combined human footprint map was used to generate the Landscape Condition Model, and was produced by overlaying all individual layers described below. Some of the datasets that were more challenging are also described below.

Table E-2. Source datasets for analysis of current and future human footprints.

Dataset Name	Data Source
Community Footprints	Digitized from aerial and satellite imagery
General Land Status - October 2013 - All Attributes - Clipped to 1:63,360 Coastline	ADNR Information Resources Management
Alaska DNR RS2477 Trails	ADNR Information Resources Management
Alaska Roads 1:63,360	ADNR Information Resources Management
Rolligon Routes	Bureau of Land Management

Dataset Name	Data Source
Ice Roads	Bureau of Land Management
Alaska Resource Data File (ARDF)	U.S. Geological Survey
Mineral Potential Data	U.S. Geological Survey
Federal Mining Claims in Alaska	Bureau of Land Management
Alaska DNR State Mining Claims	ADNR Information Resources Management
Alaska DNR State Prospecting Sites	ADNR Information Resources Management
Renewable energy infrastructure	Alaska Energy Authority (AEA)
Contaminated sites program database	Alaska Department of Environmental Conservation
Oil and gas infrastructure, transportation infrastructure, camp sites	Mapmakers Alaska
Distant Early Warning sites and Formerly Used Defense Sites (FUDs)	U.S. Army Corps of Engineers
Subsistence Use Areas	Bureau of Land Management
Kivalina evacuation route	Digitized from reports prepared by WH Pacific, a private consulting engineering firm

All uses of the land are broadly classified into industrial and non-industrial use areas. Industrial use areas include all infrastructure associated with oil, gas, and mining industries in the North Slope study area. Non-industrial use areas include community footprints and subsistence use areas. There is an obvious overlap between industrial and non-industrial uses. While several facilities in Prudhoe Bay and surrounding oil and gas fields are strictly used for residential purposes, these are classified as industrial uses for two reasons: (1) these facilities are expected to be temporary, and (2) only serve the needs of the workforce and do not serve any permanent population in the study area. Within the community footprints, there can be several facilities that could be classified under industrial uses. However, since all these facilities are located within community footprints, and the individual footprint of these facilities is relatively insignificant, they are classified as non-industrial.

Communities

Community footprints were produced by digitally tracing the built areas from satellite imagery. This was done to represent the actual footprints more accurately than would have been possible from the U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) files. TIGER files are geospatial files with information on several political and administrative units. These shapefiles include polygon boundaries of geographic areas and features, linear features including roads and hydrography, and point features. The communities in Alaska were released as a polygon shapefile, with each community's boundary identified. However, there were two major concerns with this file:

i. Community boundary polygons represent the legal boundaries and not the actual developed areas. The actual developed area for each community in the region is much smaller than its legal boundary. Moreover in many instances, boundaries as identified in TIGER files are not

legal boundaries recognized under state law. Therefore, these polygon boundaries are not accurate representations of existing communities, and over-represent the actual community footprints.

ii. Many of the maps produced for this project show community-level social and demographic information. For better representation in such maps, a point file was used instead of a polygon file to identify communities. Generation of a point file from a polygon file is done by locating the point at the center of gravity of the polygon. Given the large polygons in the community TIGER file, centers of gravity are often well outside the actual community footprints.

As a result, Census TIGER files were not used in identifying community footprints. Instead, each community's footprint was digitized from satellite imagery. Communities in the North Slope study area are small and their footprints are concentrated in small areas with some activities scattered around each communities' central location. Population in each community is low and activity beyond identified footprint boundaries is limited to subsistence-use and inter-community trails.

Total population numbers from the years 1990 to 2013 were used. Population in Prudhoe Bay was counted as resident population of the North Slope starting with the Census 2010. Since Prudhoe Bay numbers are unavailable for prior years, we excluded Prudhoe Bay population from 2010 to 2013. Decennial population data (for the years 1990, 2000, and 2010) were obtained from U.S. Census. Data for other years were obtained from estimates provided by the AK-DOLWD.

Table E-3. Population projection models considered for projecting population of the North Slope study area.

Model Name	MAPE	Adjusted R-square
Trend Linear Regression (Method1)	3.97%	
Holts Exponential Smoothing (Method2)	1.40%	
Time Series Decomposition (Method3)	0.96%	
Multiple Regression with Method1, Method2, and Method3	0.89%	96.01%
Multiple Regression with Method2 and Method3	0.88%	96.06%

Three different models (Table E-3) were used - Trend Linear Regression, Holts Exponential Smoothing, and Time Series Decomposition. Mean Percentage Absolute Error (MAPE) was for individual and combination of models to identify the model that provides the best projection. Multiple regression with Holts Exponential Smoothing and Time Series Decomposition had the highest adjusted R-square of 96.06% and lowest Mean Absolute Percentage Error (MAPE) of 0.88%, and therefore this method was selected for the base population projection.

Community Energy Infrastructure

Both gas and diesel are used to produce electricity in the North Slope study area. Alaska Energy Data Gateway (AEDG) maintained and managed by the Institute of Social and Economic Research (ISER) is a comprehensive source of data on production and consumption of energy from all sources in the state.

The AEDG was explored to obtain relevant data for this project. Energy infrastructure in the study area includes several diesel power plants and some gas powered generators.

Renewable energy infrastructure includes several types of energy production installations: wind, hydro, thermal, and biomass. Through multiple waves over the last decade, the Alaska Energy Authority - Renewable Energy Fund funded, or is considering funding, several of these installations. All renewable energy sites are small scale and are within community footprints. Future potential for renewable energy in the region was obtained from the Alaska Energy Atlas produced by the Alaska Energy Authority.

Transportation Infrastructure

The transportation network in the region includes airstrips, few paved or gravel roads within communities, and a network of trails to subsistence use areas and those that connect communities. Most communities in the region are located along the northern coast of Alaska, with Noatak, Nuiqsut, Prudhoe Bay, and Atqasuk located inland, along rivers. Travel to and from communities in the region is largely limited to air travel. While many rivers in the region are navigable, these are not treated as regular transportation routes. The transportation data used in the North Slope study was obtained from two sources – North Slope Borough Planning Department and Alaska Department of Natural Resources (ADNR). Alaska trails from Revised Statute (RS) 2477 of the Mining Act of 1866 are rights-of-way for the construction of highways over public lands, not reserved for public uses. The Act granted public right-of-way across unreserved federal land to guarantee access as land transferred to state or private ownership. Rights-of-way were created and granted under RS 2477 until its repeal in 1976. The combined dataset used for this project does not include subsistence access trails on Native land.

Natural Resource Extraction

As of 2003, there were more than 4,800 exploratory and production wells, 223 production and exploratory drill pads, over 500 miles of roads, 28 production plants, gas processing facilities, seawater treatment plants, and power plants on the North Slope and in the adjacent Beaufort and Chukchi Seas (National Research Council 2003), and approximately 989 miles of flowline and oil transmission pipelines (Robertson et al. 2010). Although no comprehensive listing of facilities supporting the oil and gas industry was available, several sources list the following as common industrial facilities associated with the North Slope oil and gas industry:

- Drill Site
  - Well Pads
  - Ice Pads
  - Production Pads
  - Injection Pads
- Wells
  - Exploratory
  - Development (exploitation or production)
  - Disposal
- Production facilities (NPR-A, 2013)
  - Docks and bottom-founded structures
  - Seawater treatment plants
  - Material sites such as gravel and sand pits
  - Temporary platforms
  - Pump stations
- Processing facilities
  - Above-ground oil storage tanks
  - Building modules
  - Facility oil piping
  - Crude oil transmission pipeline
  - Drilling mud plant (2014 GMT1 EIS)
  - Flow lines
  - Pipelines
- Maintenance Complex
- Emergency response center
- Warehouse facilities
- Vibroseis (thumper truck)
- Transportation
  - Gravel roads
  - Ice roads
  - Airports
  - Bridges
  - Power plants
  - Refineries
  - Residential centers
  - Solid waste

Data on mining activities in the region were obtained from the Alaska Resource Data File (ARDF), a compilation of mining activity maintained by the U.S. Geological Survey (USGS). It is a subset of the National Mineral Resource Data System (MRDS), "a collection of reports describing metallic and non-metallic mineral resources throughout the world" (U.S. Geological Survey 2014). All mines, prospects, and mineral occurrences are recorded with descriptions, types of minerals and ores, last reported date, current status of the site, and location.

The following process was followed to prepare the ARDF mining dataset to be included in the human footprint:

1. Main data file had quadrangle codes, and quadrangle code descriptions were given in another file (http://ardf.wr.usgs.gov/explain.pdf). The quadrangle code descriptions have been added in the main dataset.
2. Address the considerable uncertainty in several key fields in the dataset.
    a. 'Site status' had the following values: 'active,' 'active?,' 'inactive,' 'inactive?,' 'probably inactive,' 'not determined,' 'undetermined.' These were recoded and defined as follows:
        i. Active (some work was reported at the time of last report date) - 'active', 'active?'
        ii. Inactive (no work was reported at the time of last report date)– 'inactive' 'inactive?,' 'probably inactive'
        iii. 'undetermined' (no information was available) – 'undetermined', 'not determined,' 'undetermined' and blank cells
    b. 'Site type' refers generally to the current status or potential for the site to yield a mineral. Three distinct values seem to be valid – 'mine', 'occurrence', and 'prospect'. This classification of reporting mineral occurrences is not congruent with the industry standard set by the Society for Mining, Metallurgy & Exploration (SME), or other

international organizations. No certain definitions could be obtained from USGS. This field had the following recorded values: 'mine', 'mine?', 'mines', 'mine (?)', 'occurrence', 'occurrence(?)', 'occurrence?', 'occurrences', 'prospect', 'prospect(?)','prospect?', 'prospects(?)', ‘prospect', 'mine', and ‘mine and prospect’. These were recoded and defined as follows:

i. Mine (where a mineral was or is being extracted) – 'mine', 'mine?', 'mines', 'mine (?)'
ii. Occurrences (a location where a useful mineral or material is or was found) – 'occurrence', 'occurrence(?)', 'occurrence?', 'occurrences'
iii. Prospect – (prospect is any occurrence that has been developed to determine the extent of mineralization) – 'prospect', 'prospect(?)', 'prospect?', 'prospects(?)', 'prospect; mine', and 'mine and prospect'.

c. Commodities or minerals at each site were recorded in two separate columns – 'commodities-main', and 'commodities-other':
   i. 'Commodities-main' is the main mineral resource that was, is or is expected to be mined at the site. Multiple commodities (up to 21) were listed in this column for many sites.
   ii. 'Commodities-other' are ancillary minerals that may be extracted depending on the technological and economic feasibility. There was more than one commodity listed in this column.
d. 'Deposit model' field contained a brief description of the deposit. These descriptions indicated if a particular site was a placer gold mining site. If the site listed gold in the 'commodities-main' field, these sites were marked as placer gold mining sites, whether in the past, present, or in the future.
e. 'Production' field recorded any production activity at each site as of the last reported date. A variety of values were used. They were all recoded into the following options:
   i. 'No' – 'No', 'None'
   ii. 'Yes' – 'Small'; 'Yes', 'Large', 'Yes', 'medium', 'Yes, small', 'Yes, Very small', 'Yes: small', 'Yes: large', 'Yes, medium', 'Yes, small?', 'Yes: unknown', 'Yes?'
   iii. ‘Undetermined’ – 'Undet.', 'Undetermined', 'Unknown')
f. 'Last report date' is the only date field in the dataset. This field reports the date of last update on any activity at each site. Date of last update on each site varies, and not all sites are updated annually or periodically.

The ARDF file is not updated in a systematic way. Data contained in the ARDF are largely a result of voluntary reporting and collection efforts. The last report date for the ARDF file are between 2001 and 2012 have been considered in the final data set. There were only four (4) prospects that had a report date prior to 2001, all were last updated on May 4, 1999.

Mineral potential data was available for the eastern part of the study area from the BLM. Six mineral deposit models were used to generate the data:

1) REE-Th-Y-Nb deposits associated with peralkaline to carbonatitic intrusive rocks,

2) Placer and paleoplacer Au,
3) PGE (-Co-Cr-Ni-Ti-V) deposits associated with mafic-to-ultramafic intrusive rocks,
4) Carbonate-hosted Cu (-Co-Ag-Ge-Ga) deposits,
5) Sandstone U (-V-Cu) deposits, and
6) Sn-W-Mo (-Ta-In-fluorspar) deposits in specialized granites.

12-digit HUC areas were used to display the data. Each polygon contains an estimate of potential and uncertainty of a particular mineral deposit model to be found in that polygon. Estimates are based on the proximity of certain favorable geologic conditions found in multiple statewide datasets.

2.2. Results

Communities

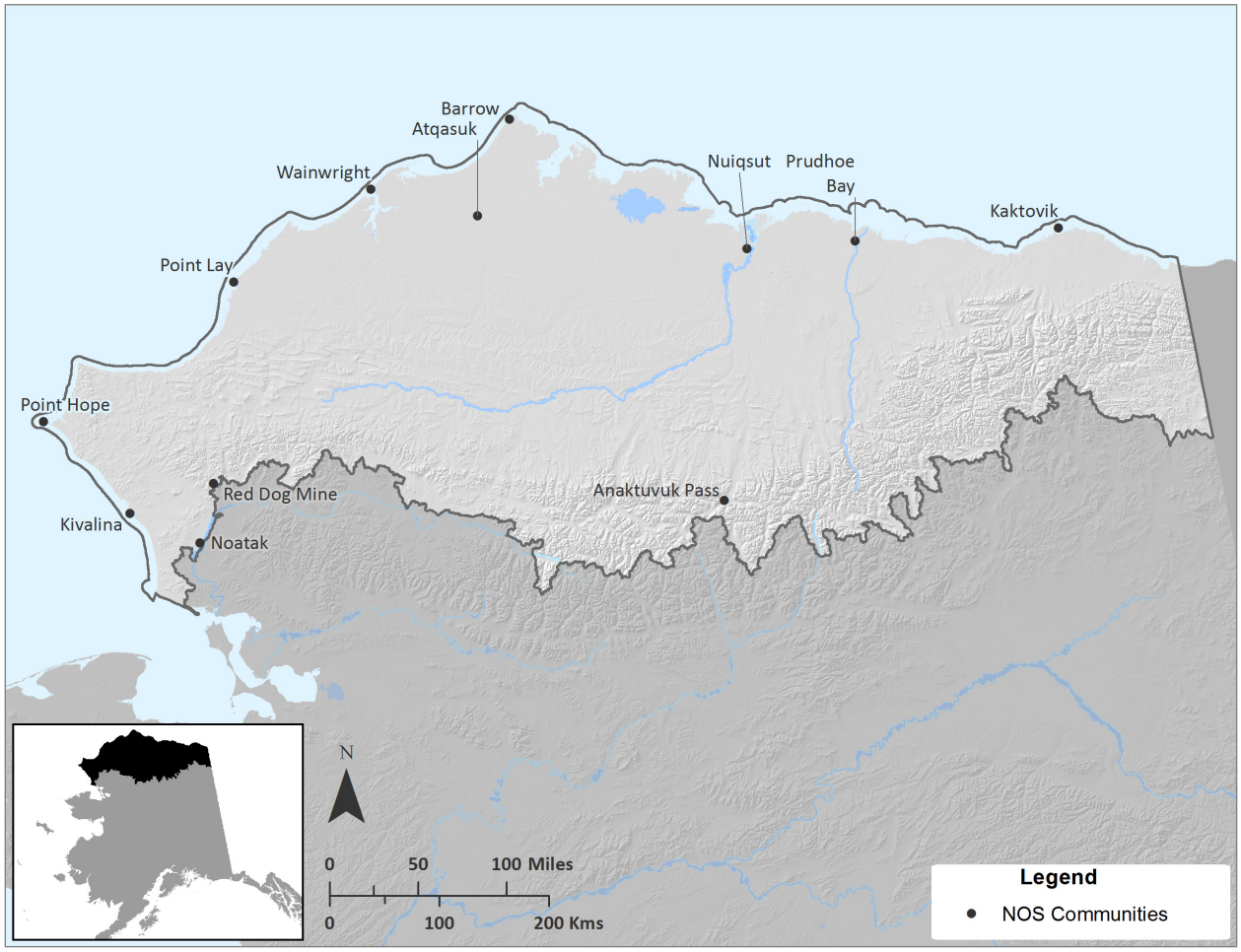


Figure E-4. Footprints of communities and populated places in the North Slope study area. Prudhoe Bay is not treated as a community, and its footprint is discussed in a separate section.

Table E-4. Total population counts of communities and group quarters in the North Slope study area.

Community	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
North Slope Borough														
Anaktuvuk Pass	282	302	308	326	311	321	314	293	303	309	324	324	344	358
Atqasuk	228	236	234	232	224	233	245	231	229	212	233	243	235	248
Barrow	4,581	4,450	4,449	4,428	4,388	4,201	4,095	4,067	4,082	4,171	4,212	4,324	4,445	4,514
Kaktovik	293	273	295	280	265	252	259	252	237	245	239	247	245	262
Nuiqsut	433	427	445	419	436	415	422	408	389	410	402	427	428	452
Point Hope	757	708	699	706	706	694	703	666	646	660	674	668	668	683
Point Lay	247	250	245	248	232	218	208	216	218	196	189	184	196	215
Wainwright	546	560	532	546	526	511	506	525	519	536	556	571	565	543
Northwest Arctic Borough														
Kivalina	377	380	374	374	372	363	365	366	370	370	374	384	402	402
Noatak	428	438	456	469	451	475	471	490	515	490	514	547	568	562
Group Quarters (data available since 2010)														
Prudhoe Bay											2,174	2,174	2,174	2,174
Red Dog Mine											309	309	309	309
Total	8,172	8,024	8,037	8,028	7,911	7,683	7,588	7,514	7,508	7,599	10,200	10,402	10,579	10,413

Data Source: U.S. Decennial Census: 2000 and 2010 population; Alaska Department of Labor and Workforce Development: 2001-2009 and 2011-2013.

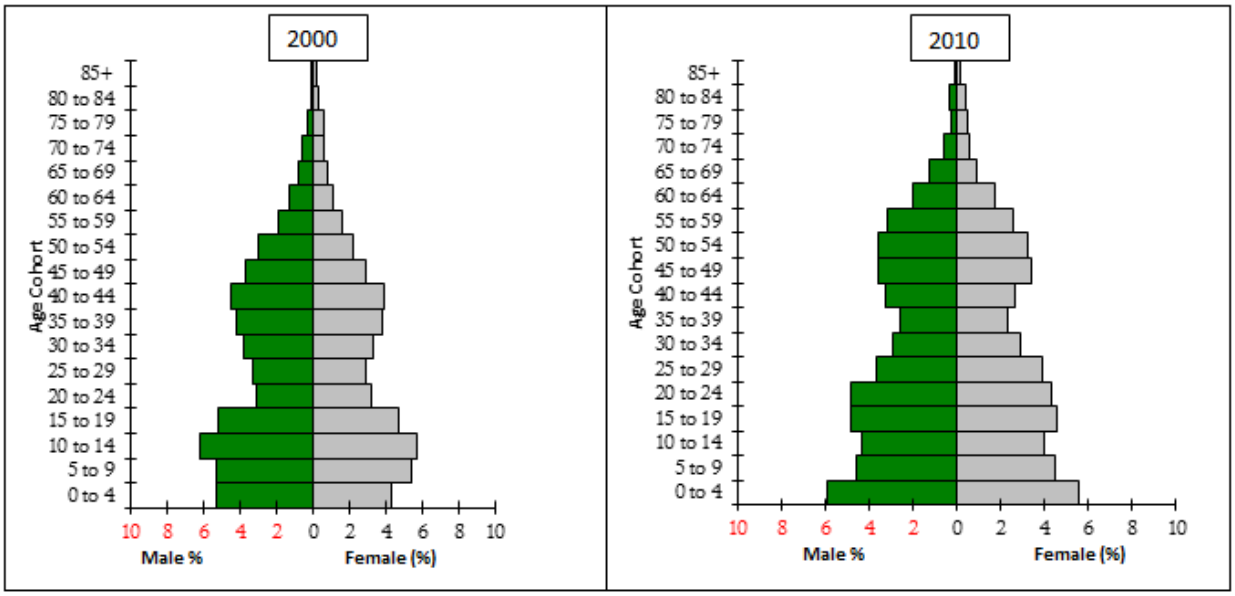


Figure E-5. Population structure of the North Slope study area (excluding group quarters; 2000 and 2010).

Figure E-4 shows the locations of communities. Table E-4 shows Barrow (pop. 4,514 in 2013), with the largest population, which also has the largest footprint among the communities in the region. Remaining communities' populations range from 683 in Point Hope to 215 in Point Lay. All communities except Noatak in the Northwest Arctic Borough, and Atqasuk, Anaktuvuk Pass, and Nuiqsut in the North Slope Borough are located on an island off the coast, or on the coast. Figure E-5 shows the gender and age distribution of the population in the study area excluding Prudhoe Bay and Red Dog Mine for the years 2000 and 2010. Although the total population in 2000 (pop. 8,172) is less compared to 2010 (pop. 7,717), higher proportion of younger cohorts in 2010 indicates likely sustained growth in the future. Total estimated resident population of the study area, excluding Prudhoe Bay and Red Dog Mine, in 2013 is 8,239. If the present trends continue (Table E-5; Figure E-6) the region's population is likely to be more than 9,500 by year 2025 and over 12,000 by year 2050.

Table E-5. Projected population for the North Slope study area (excluding Prudhoe Bay and Red Dog Mine).

Year	Base Projection	Low Projection	High Projection
2020	9,047	9,001	9,137
2025	9,500	9,452	9,595
2030	10,028	9,978	10,129
2035	10,529	10,477	10,634
2040	11,038	10,983	11,149
2045	11,486	11,429	11,601
2050	12,017	11,957	12,137
2055	12,518	12,456	12,644
2060	13,028	12,963	13,158

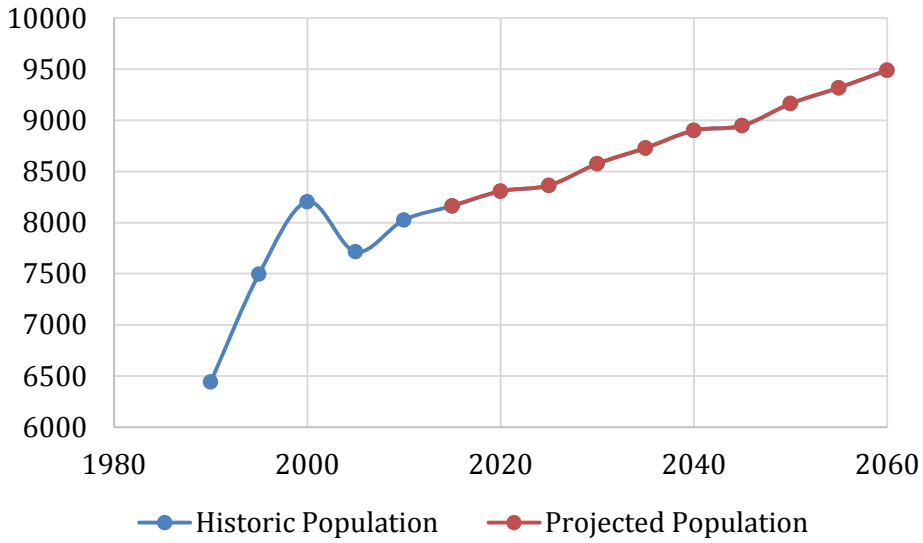


Figure E-6. Population projection of the North Slope study area (excluding Prudhoe Bay and Red Dog Mine).

Alaska Natives comprise approximately 70% of the local resident population in the region, and more than 90% of the population in a majority of the communities (Figure E-7).

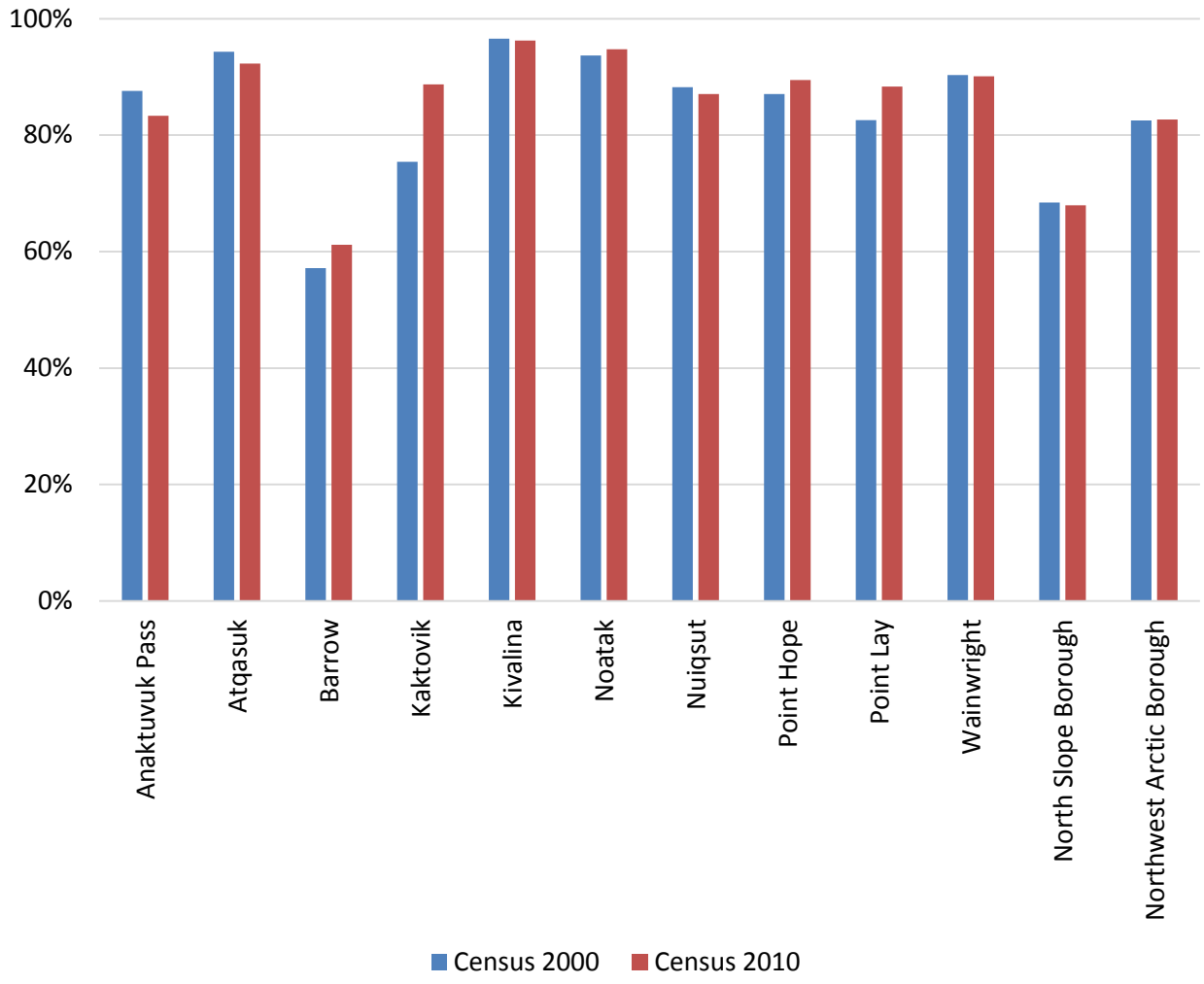


Figure E-7. Percentage of population reported as Alaska Native in each community in the North Slope study area.

Prudhoe Bay and Red Dog Mine are large industrial developments. Prudhoe Bay (pop. 2,714 in 2013) is home to the largest oil industry complex on the North Slope. Several oil fields in the vicinity also operate their logistics from Prudhoe Bay. Red Dog (pop. 309 in 2013) is a zinc and lead mine. Population in these industrial developments is entirely composed of transient workers on a two-week or three-week shift. Residential facilities built to serve this population include large hotels and lodges owned or contracted by oil companies. No permanent residence is allowed in either place. Population from both places is excluded from the population projections above.

Community Energy Infrastructure

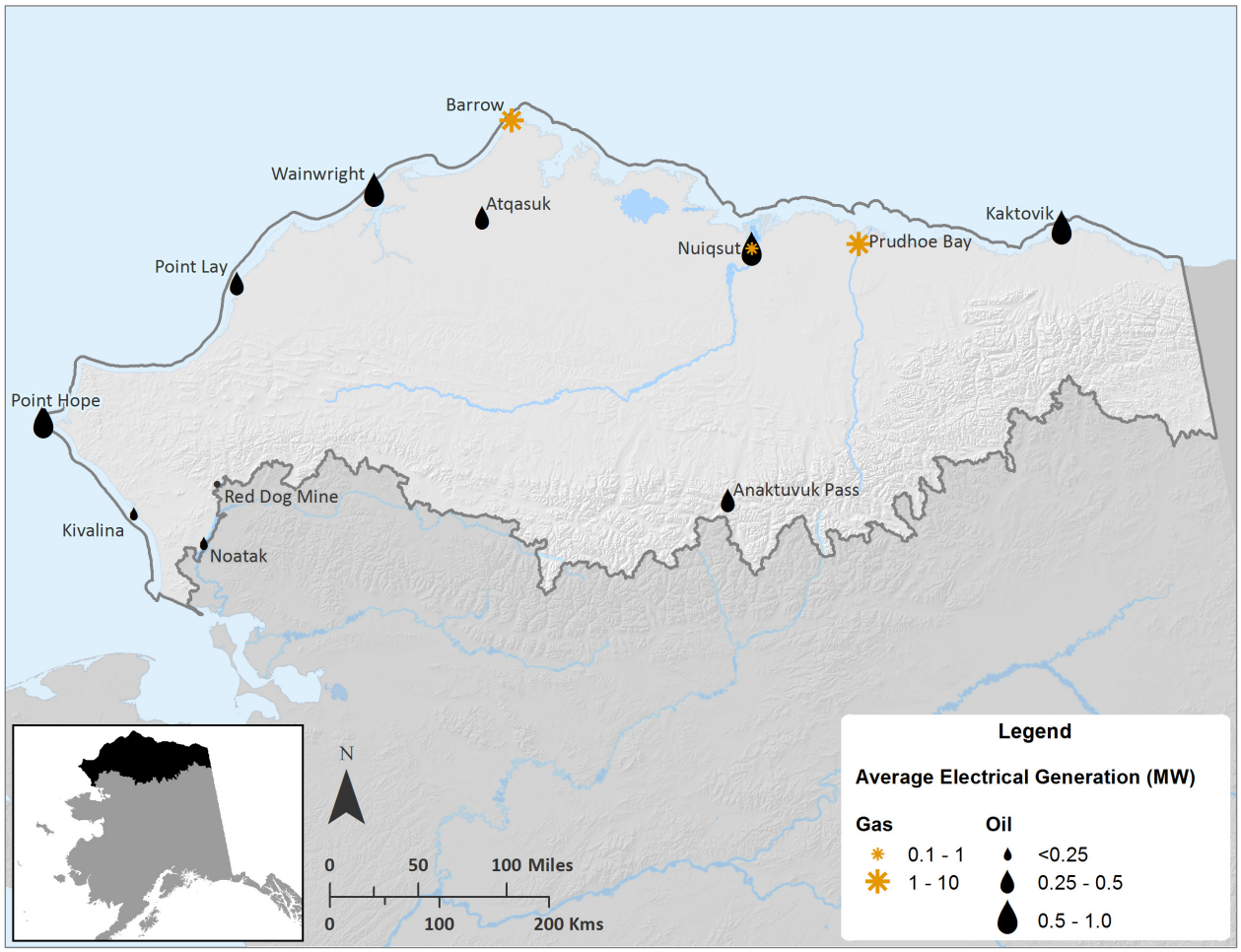


Figure E-8. Electricity generation capacity and source for each community in the North Slope study area.

This section only covers the energy infrastructure serving the region's resident communities, and does not discuss the energy infrastructure of Prudhoe Bay oil and gas industry complex in any detail. Each community in the study area is served by an isolated grid, with its own generation and distribution infrastructure. All energy infrastructure in each community is within the community's footprint. Barrow and Prudhoe Bay, the two largest population centers, rely completely on natural gas for generating electricity. Nuiqsut relies both on natural gas and diesel. Other than Barrow and Prudhoe Bay, all other communities have small demand loads, and thus only generate less than a megawatt. Figure E-8 shows the locations and generation capacity of electricity infrastructure in the North Slope study area.

Renewable energy infrastructure includes several types of energy production installations: wind, hydro, thermal, and biomass. Through multiple waves over the last decade these projects were funded or are being considered for funding by the Alaska Energy Authority - Renewable Energy Fund. All renewable energy sites are small scale and are within community footprints (Figure E-9). We obtained the data for

the area's renewable energy potential from the Alaska Energy Atlas produced by the Alaska Energy Authority (Figure E-10).

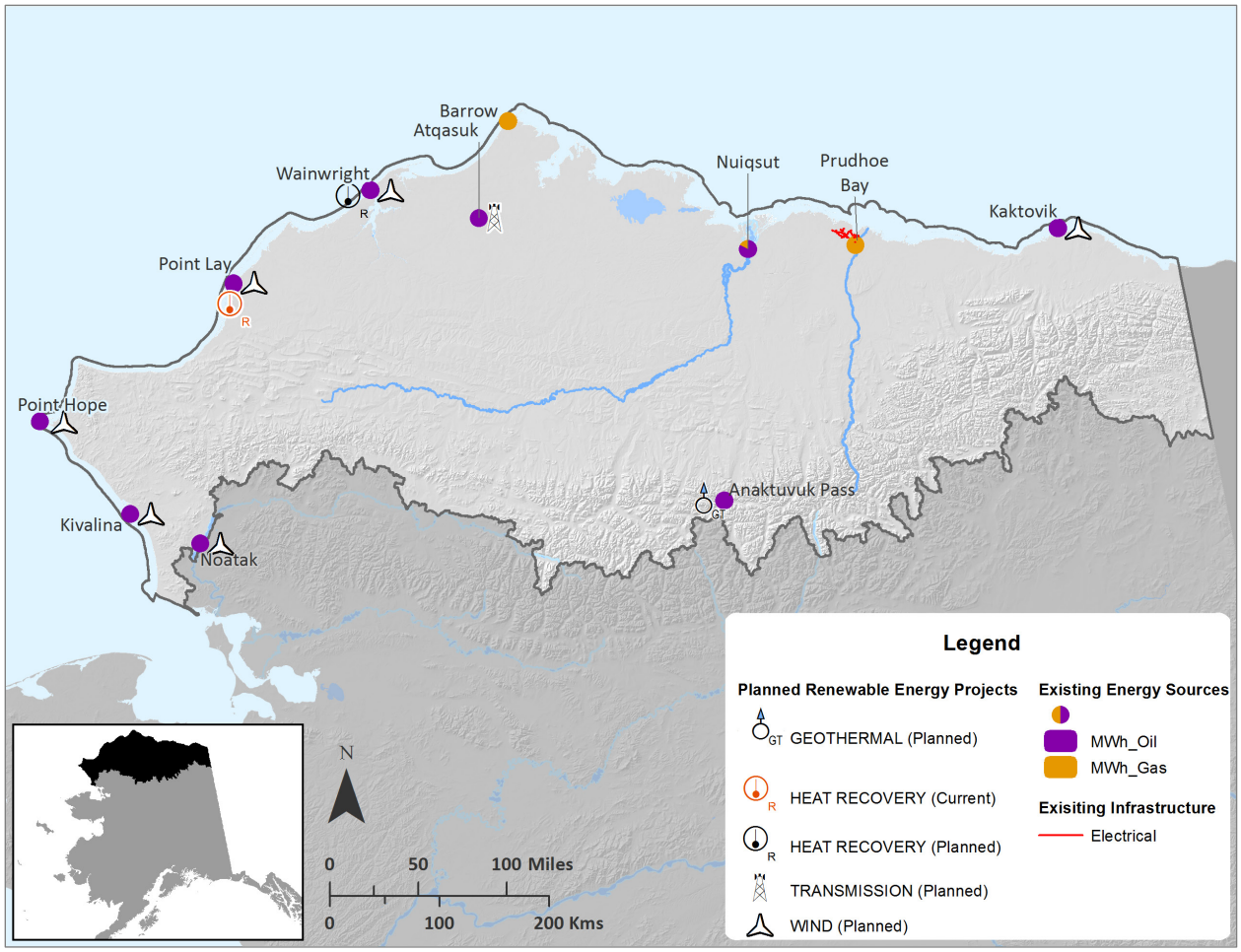


Figure E-9. Planned renewable energy projects in the North Slope study area.

While several renewable energy projects are in the planning stages, the only active project is a heat recovery system in Point Lay. Most proposed projects use wind energy for electricity generation; they are all small scale, with the capacity to meet only a fraction of the local energy demand in their respective communities.

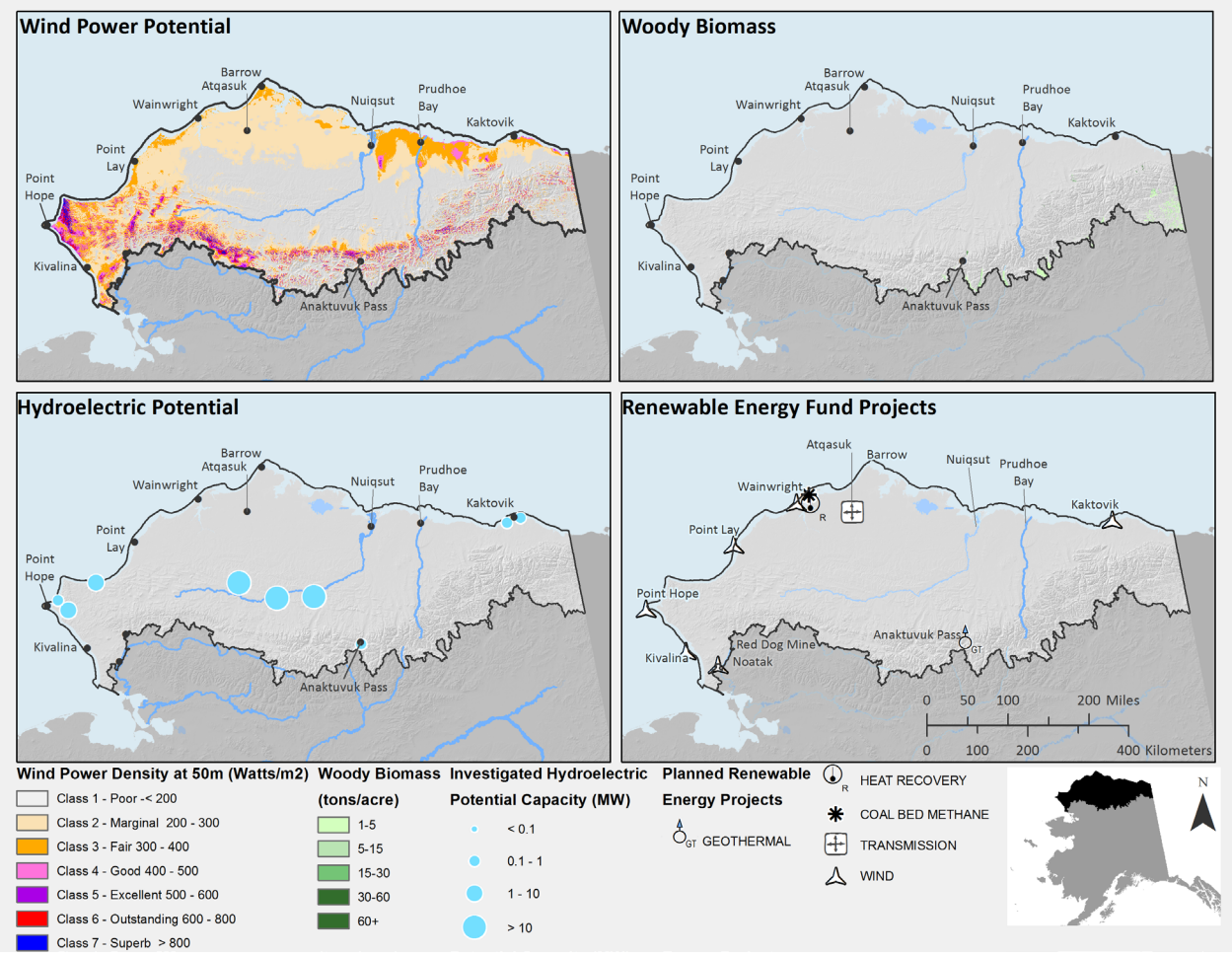


Figure E-10. Renewable energy potential in the North Slope study area.

Transportation Infrastructure

Although a complex network of trails, roads, and other ground transportation infrastructure exists in the study area, they are not useable year-round. All resident communities are remote and isolated, and rely on air transport services. Every community has an airstrip within its community boundary. Barrow, the largest community in the region, serves as the commercial and services hub for the region. The communities of Point Hope, Kivalina, and Noatak are served from Kotzebue due to better logistics.

The Dalton Highway connects Prudhoe Bay to Livengood, 75 miles north of Fairbanks, and parallels the Trans-Alaska Pipeline carrying crude oil from Prudhoe Bay oil fields to the Port of Valdez located on the Gulf of Alaska. The Highway is 28 ft. wide with an average of 3-6 ft. of gravel surfacing. The majority of traffic on the Highway is commercial freight trucks serving the oil and gas industry in and around Prudhoe Bay. The Highway was opened to public use in 1995. Summer traffic counts are substantially higher than during winter months. Another major gravel road in the North Slope study area with high usage is the 52-mile road connecting the Red Dog Mine to its port site on the Chukchi Sea. Ore is trucked to the port for export during the 100-day open shipping routes.

In addition to the Dalton Highway, Prudhoe Bay oil fields are also served by three major airstrips – a state owned and operated airport at Deadhorse and two privately owned airstrips. The Deadhorse airstrip is 6,500 ft. long and 150 ft. wide, and accommodates large aircraft. This airport is served by several scheduled flights operated by commercial airline companies. The two privately owned airstrips are of similar capacity at Deadhorse, and are exclusively served by Shared Services, a joint flight operation of ConocoPhillips and British Petroleum. The Wiley Post-Will Rogers Memorial Airport in Barrow is also state-owned and is similar in capacity to the Deadhorse Airport. Barrow is also served by commercial airline companies from Anchorage and Fairbanks. Kotzebue's Ralph Wien Memorial Airport is also state-owned, and is 5,900 ft. long to accommodate large aircraft. Nuiqsut, Wainwright, and Atqasuk are the other primary airports in the region with approximately 4500 ft. long gravel airstrips, and are also state owned.

Table E-6. Extent of transportation routes in the North Slope study area.

Type of route	Length in Km.
Trails	9725.58
Ice Roads/Rolligon Routes	4975.71
Rivers	4568.92
Secondary Roads	2187.23
Pipelines access roads	1633.41
Highways	569.96

In addition to the Dalton Highway and the airstrips that serve the most major transportation needs in the region, an extensive trail network developed over generations plays a significant role for inter-community travel and for access to subsistence use areas. As shown in Table E-6, the total length of the trail system far exceeds the other modes of transportation in the study region. This trail network includes several that were built to access various infrastructure facilities in the oil and gas fields around Prudhoe Bay. Work on assessing long-term impacts of these trails is still underway. Figure E-11 shows the extent of various transportation infrastructure facilities in the North Slope study area.

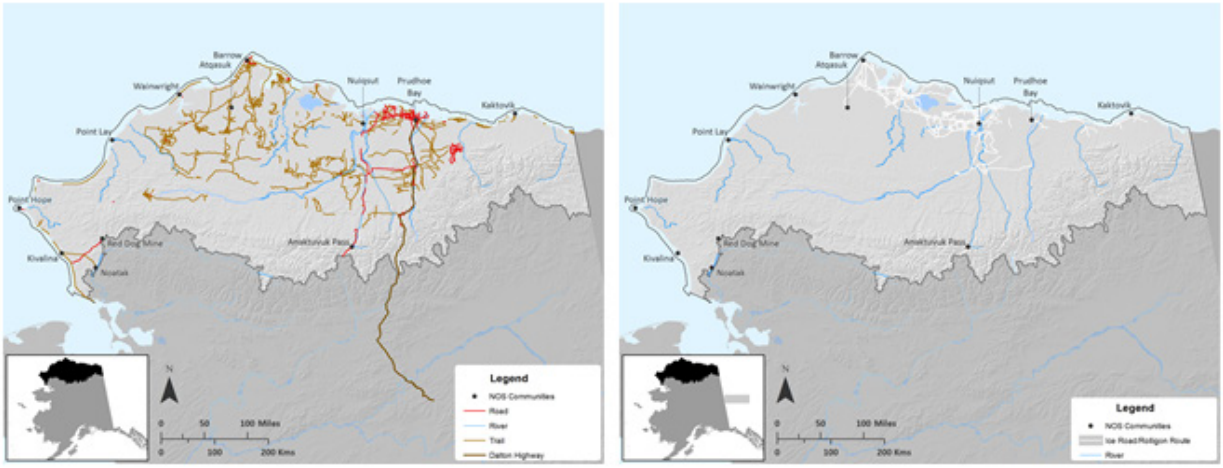


Figure E-11. Transportation infrastructure in the North Slope study area.

A major concern in the study area is the disturbance caused by activities on trails associated with increased seismic exploration requiring ground transport. During the early days of oil exploration, when concerns of environmental impacts were not acute, exploration activities were not as regulated. Damages to the slow-growing tundra and permafrost can still be seen 60 years later. Better land management practices and regulations starting in the 1970s minimized further damages to a large extent. Short-term (2-8 years) studies did not find any major impacts, and thus activities as conducted now, during winter months when the ground is frozen, are considered harmless. However, increased exploration activities both in frequency and geographic extent during the last decade brought back concerns of their impact. The cumulative impacts of seismic exploration are considered higher than all other human activities combined (National Research Council 2003). There is an increased effort to assess these long-term impacts (Janet et al. 2010).

The almost 5,000 km. long network of ice roads/Rolligon routes is used to serve the oil and gas infrastructure facilities in the study area. State of Alaska regulations allow ice roads to be built in areas with 6” to 9” of snow depth and with soil temperature of -5C at 30cm depth. The short-term impacts on the environment have been studied, and the impacts are reported to be more severe than seismic trails (National Research Council 2003). Rolligon trails are pioneered in the study area to transport freight to remote drilling sites, and for travel between Barrow and Atqasuk and Nuiqsut. These trails are built for special vehicles called Rolligons, equipped with large inflatable bags for wheels. Rolligons can carry large loads (approximately 40 tons) and can travel for up to 250 miles at 12 mph. An inconclusive study in 2004 reported some impacts from insufficient data (Roth et al. 2004). Many rivers and streams in the region are navigable. They are used for access to subsistence use areas, and recreation purposes. However, given the sparse population and remoteness of the region, rivers are not major transportation routes in the region. None of the rivers in the region offer inter-community connectivity.

Natural Resource Extraction

The natural resource economic potential from the North Slope of Alaska is well recognized. Continuous exploration for and extraction of oil, gas, and minerals had a sustained impact on the ecosystems of the region over the course of the last century. While such activities were limited in scope before the discovery of oil at Prudhoe Bay, since then the region has experienced phenomenal growth in these activities. Landscape-scale disturbances are due to an accumulation of a number of smaller, related activities over a long period of time. For example, an oil field can have one small gravel pad with an access road, and this likely does not have a perceivable impact as an isolated activity. However, when there are a number of these activities, such as gravel pads, access roads, associated pipelines, transportation infrastructure including trails, vehicular traffic, dust accumulation, material sites, gravel mines, sewage lagoons, reserve pits, small and large pollutant spills, seismic trails, and snow pads, they can have a sustained impact on the natural ecosystem.

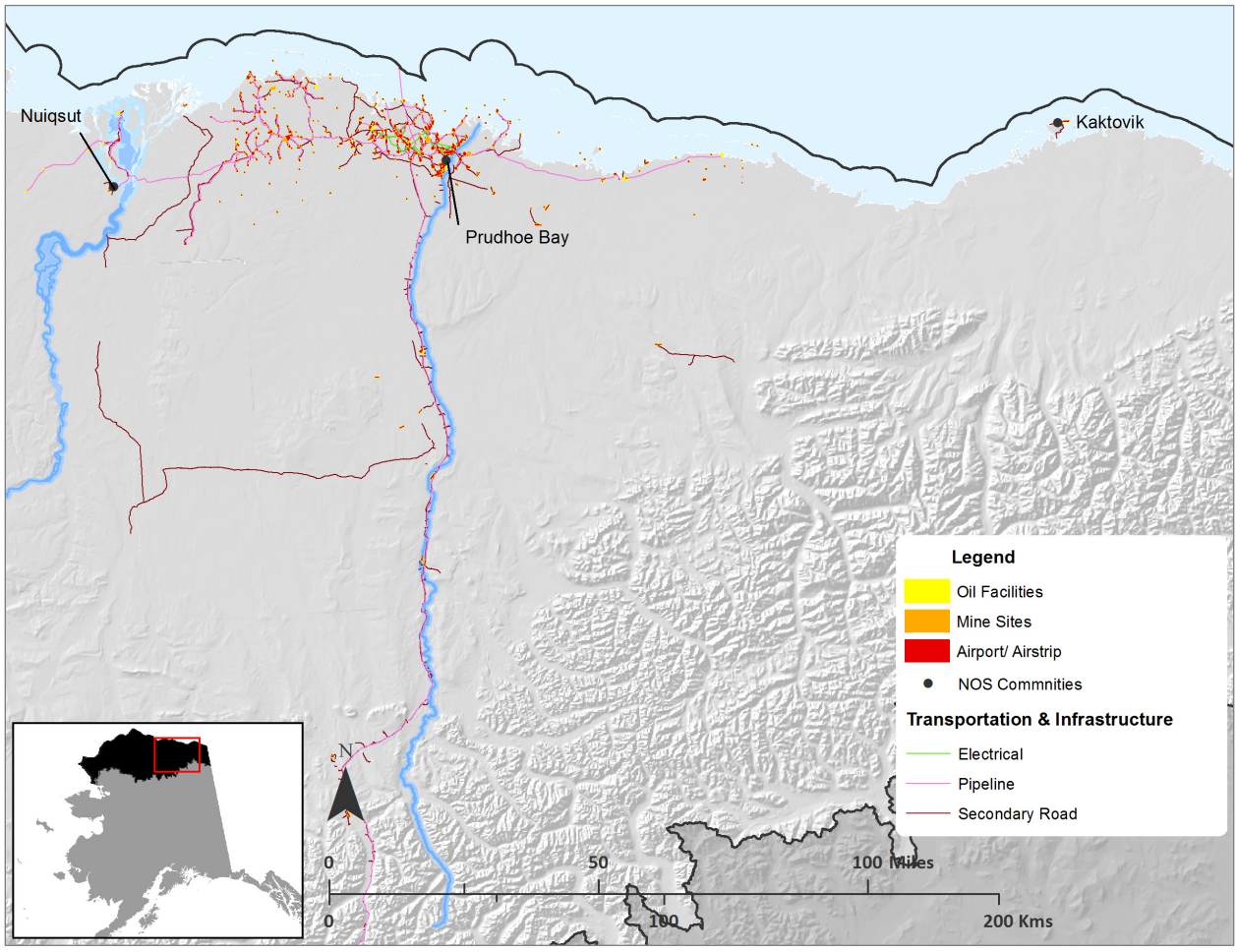


Figure E-12. Oil and gas infrastructure in the North Slope study area.

By 2001, the total area covered by oil and gas infrastructure in the North Slope study area was approximately 17,354 acres. This estimate includes areas affected by year-round structures and does

not include seasonal and occasional activities such as ice roads or off-road travel. While technology improvements over the last three decades have decreased the amount of year-round infrastructure being built, it still remains high. In addition to extensive presence of oil and gas deposits, there are rich deposits of some of the best grade coal, and several minerals. Similar data is not readily available for mining as they are for oil and gas activities in the region (National Research Council 2003).

Patterns of land ownership in the North Slope study area are unique, and play a major role in the patterns of natural resource extraction. The study area can be broadly classified into state owned/controlled, federally owned/controlled, native regional corporations-which are privately controlled-tribally owned/controlled, and other private land. Federal ownership and control dominates the region. Approximately 70% of the land is owned and controlled by the federal government through its various agencies. Most oil and gas development is concentrated between the National Petroleum Reserve – Alaska (NPR-A) and the Arctic National Wildlife Refuge (ANWR), between the Colville River in the west and Canning River in the east. This land is largely owned by the State of Alaska and is subdivided into two lease zones: the North Slope (20,639 sq. km.) and the North Slope foothills (30,756 sq. km.). A third leasing zone consists of the territorial waters of the Beaufort Sea. Owing to the scale used in this report, this section only discusses the dense development of oil and gas infrastructure present on the state-owned land. Several past attempts at exploration in the NPR-A were included in the human foot print section.

Although exploration in the region began in the 1920's, economically feasible extraction began in the late 1970's after the completion of the Trans-Alaska Pipeline System (TAPS) and the Dalton Highway. Natural resource development in the North Slope study area can be described as approximately 423 miles of gravel road/causeway, 189 miles of peat roads, tractor trails, and exploration roads, 166 miles of TAPS, 491 miles of other pipeline, 336 miles of power transmission lines, 400 facility pads, 13 airstrips, gravel mines covering 21.7 sq. km., 2,037 culverts, 27 bridges dot the landscape directly disturbing 74.2 sq. km. of land in this region (Hillmer-Pegram 2014). Figure E-12 shows the footprint of this infrastructure.

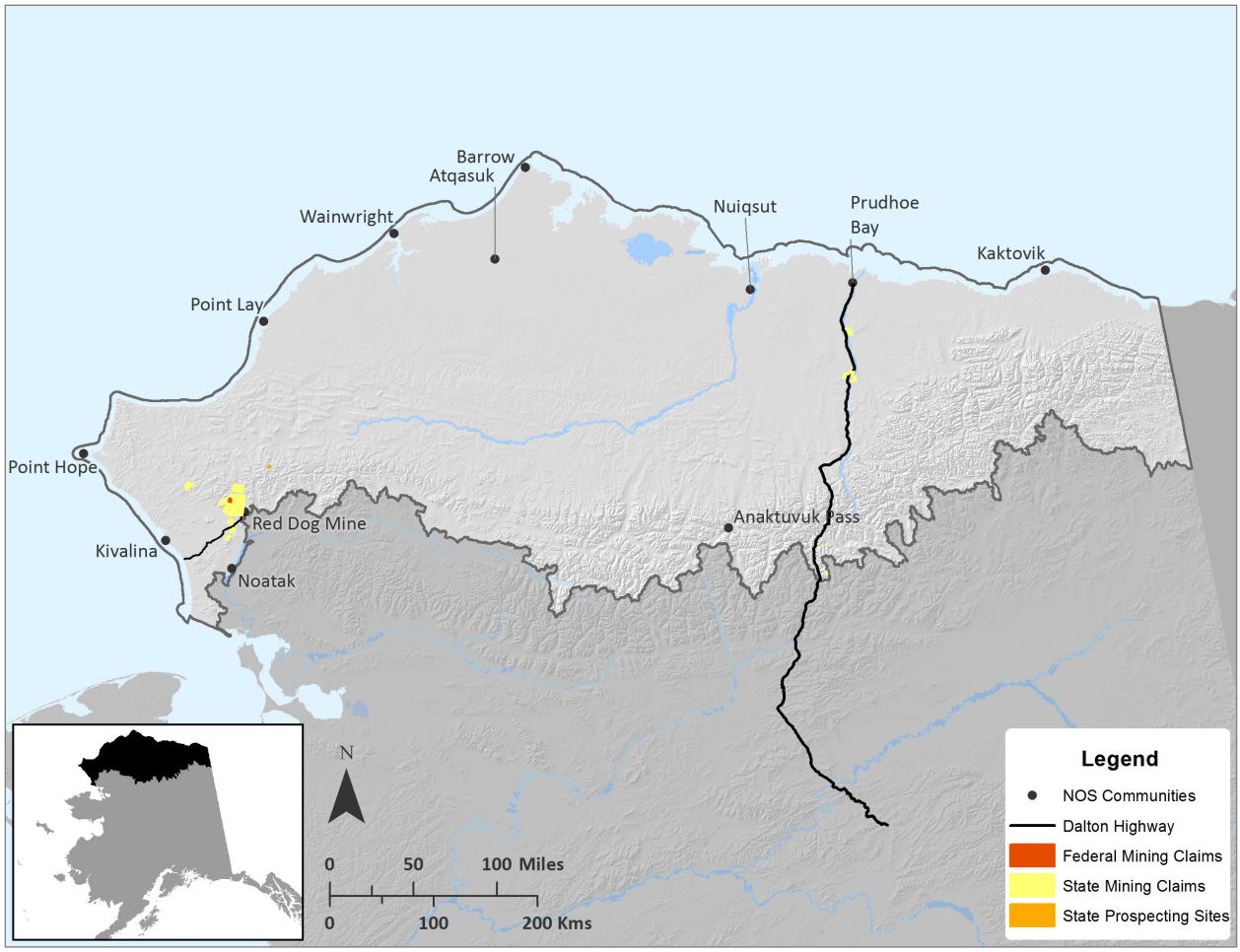


Figure E-13. Mining claims in the North Slope study area.

Mining in the North Slope study area can be discussed in two primary parts. The first part, mining for precious minerals, is mostly restricted to Red Dog Mine in the western part of the region. Several areas in the region-particularly in the foothills of the Brooks Range-are rich in several valuable minerals. However, the economic feasibility of mining these materials is low, limiting current exploration and extraction. The second part is mining for gravel. Gravel is used to construct everything from drilling pads to roads, community facilities, and airports. A substantial amount of gravel is mined in the North Slope study area.

Gravel mining at substantial levels in the region parallels the development of oil and gas industry in the region. During the first decade of oil industry development, gravel was primarily mined from active river waterbeds. There was little monitoring and the permitting process was weak. Gravel mining and water withdrawal from active rivers and overwintering lakes caused concern, resulting in new regulations in late 1970s restricting such use between the Canning and Colville Rivers. This led to innovative multiuse deep gravel pits that supplied gravel for the numerous needs of the oil and gas industry operations in addition to serving as deep lakes for overwintering of fish. Studies over the years by ADF&G found that the winter water quality of these lakes is very conducive for healthy fish habitat (Ott et al. 2014).

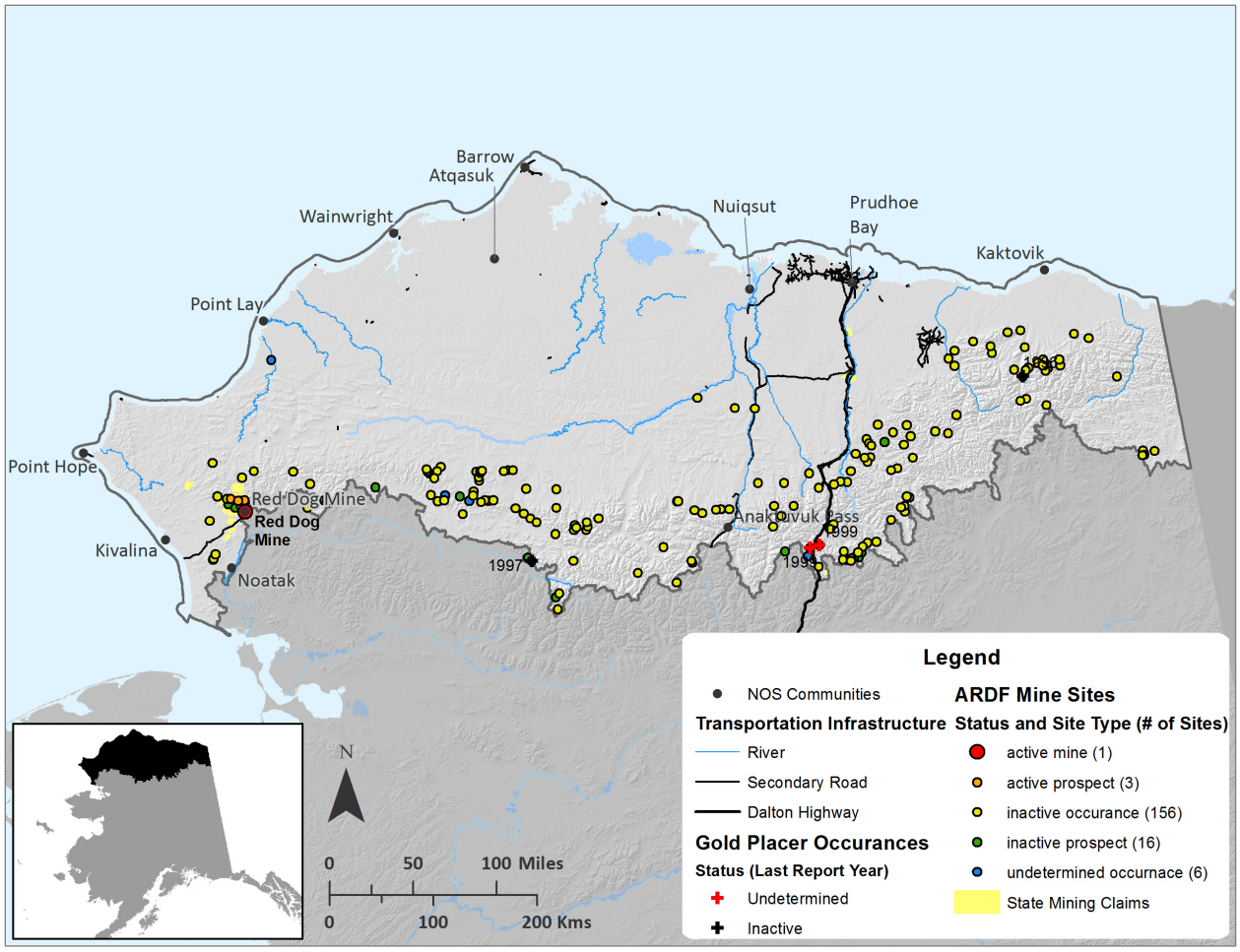


Figure E-14. Placer and hard rock mine sites from the Alaska Resource Data File (ARDF).

Mining in the region is limited to the Red Dog Mine in the Northwest Arctic Borough. It is an open pit zinc and lead mine, and uses the truck and shovel method. The mine site is accessed year round by air. Mine facilities include the main Red Dog pit, Aqqaluk pit, tailings pond, mill, and the personnel accommodation complex (PAC). The DeLong Mountain Transportation System (DMTS), the transportation network around the mine, includes several access roads to various facilities at the site, a terminal port on the Chukchi Sea coast, and a 52-mile gravel road connecting the mine site with the port.

In addition to the mining claims around the Red Dog Mine, there are minor active mining claims along the Dalton Highway (Figure E-13). The Alaska Resource Development File (ARDF) mine site database displayed in Figure E-14 shows several inactive occurrences all along the northern foothills of the Brooks Range. Very few of these potential mine sites, principally in the vicinity of the Red Dog Mine, are located on active mine claims.

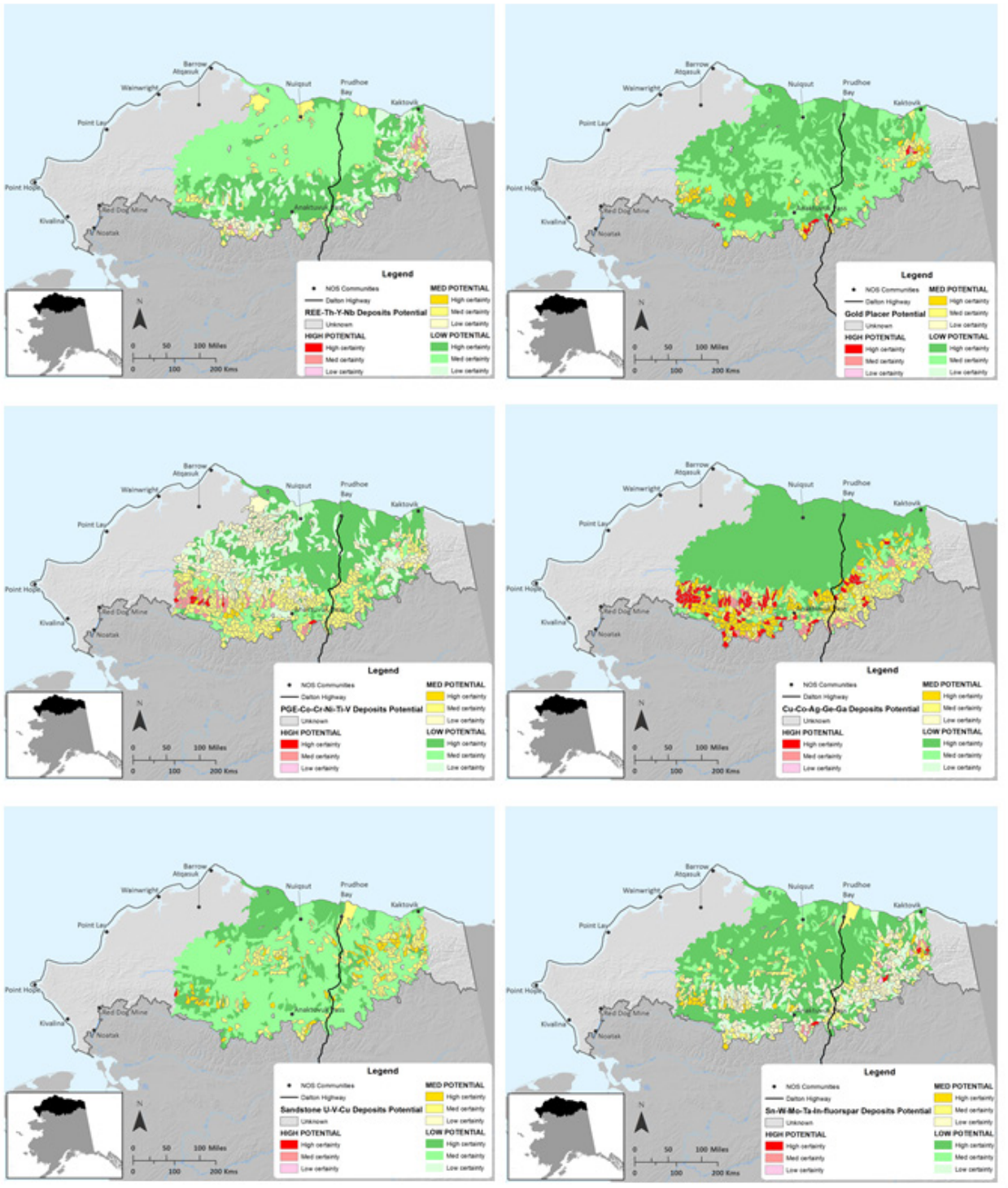


Figure E-15. Mineral potential for six deposit groups in the eastern part of the North Slope study area.

Data on mineral potential in the study area was available from the U. S. Geological Survey (USGS) (Jones III et al. 2015). This data was compiled as part of a mineral resource potential study for the Bureau of Land Management Central Yukon Planning Area. Data was compiled on six selected deposit groups:

- Rare Earth Elements (REE): Th-Y-Nb deposits associated with peralkaline to carbonatitic intrusive rocks
- Placer and Paleoplacer Gold: Gold
- Platinum Group Elements (PGE): Co-Cr-Ni-Ti-V deposits associated with mafic-to-ultramafic intrusive rocks
- Carbonate-hosted Copper Deposits: Cu-Co-Ag-Ge-Ga
- Sandstone Uranium Deposits: U-V-Cu
- Tin-Tungsten-Molybdenum-Fluorspar deposits: Sn-W-Mo-Ta-In-fluorspar deposits in specialized granites

Based on proximity of certain geologic conditions found in multiple state-wide datasets, potential for various deposits was estimated in polygons and displayed at a 12-digit HUC level. The intensity score of occurrence depended on a variety of characteristics: the presence of certain elements in sediment geochemistry; the presence of samples of each type in the ARDF; igneous indices for ASI (aluminum saturation index), 10,000*Ga/Al (gallium over aluminum) or displacement of Fe#; presence of ARDF samples of Th/K from aerorad data set. Figure E-15 shows the potential for each deposit group.

The potential for future mining of any of the minerals is distinct from the potential for existence of a mineral deposit. The economic and regulatory environments are significant drivers in the feasibility of mining. Several non-local factors including the international market dynamics for a mineral influences the feasibility of mining. Assessing the potential for a mine is nearly impossible without extensive data collection and is well beyond the scope of this project.

3. Future Human Footprint

3.1. Methods

The future human footprint of the region was developed concurrent to the REA through the North Slope Science Initiative (NSSI) Scenarios Project (NSSI 2015). The primary goal of the project is to identify plausible future development scenarios on Alaska's North Slope and adjacent seas using a stakeholder driven approach. Since the project is ongoing the development scenarios should be considered interim products and may change. Additionally, the NSSI Scenarios Project is focused just on oil and gas development scenarios; no future residential or commercial development is considered. Given the opportunity to integrate with a more robust approach to future human development, we relied upon the scenario project for all future human development estimates. More information about the project can be found on the North Slope Science Initiative's website (http://northslope.org/scenarios/).

3.2. Results

Geospatial data for three scenarios were delivered to us showing plausible oil and gas development futures (low, medium, and high scenario). The low scenario was not considered in the REA as it depicted the removal of oil and gas infrastructure, and while that future is certainly plausible, we did not feel it provided value to the REA process. Future oil and gas infrastructure associated with the medium development scenario includes development in part of the Greater Moose's Tooth region of NPR-A, and further expands the development currently at Point Thompson (Figure E-16). Drilling pads at Liberty are expanded, and there is a new pipeline built connecting offshore activities to the Point Thompson region. In addition to the oil and gas development, we also included the road and relocation of Kivalina in the medium development scenario. The high development scenario included all the same infrastructure of the medium development scenario, but expanded the Greater Moose's Tooth development to include a pipeline connecting to Smith Bay, a pipeline and road from the potential Chukchi Sea facilities, and a pipeline connecting Umiat to other oil and gas infrastructure (Figure E-17). Although offshore activities are included in the NSSI scenarios, we did not include those developments given our terrestrial focus. Additionally, we assumed all current oil infrastructure would continue to operate into the future. Given the uncertainty in future human footprint models, especially in the high development scenario, the results should be considered representative of potential changes in human land use and development.

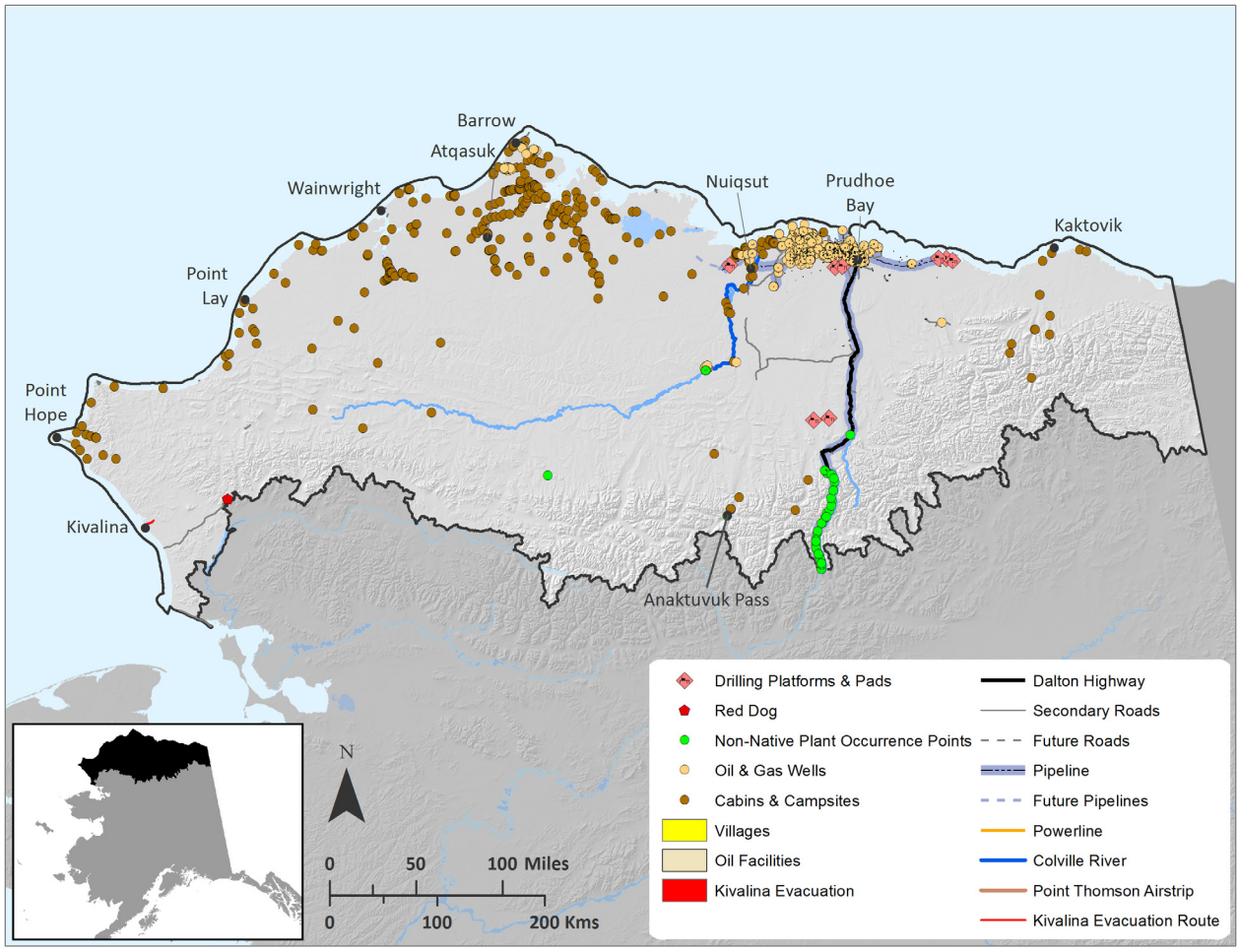


Figure E-16. Medium development scenario (2040) of human footprint in the North Slope study area.

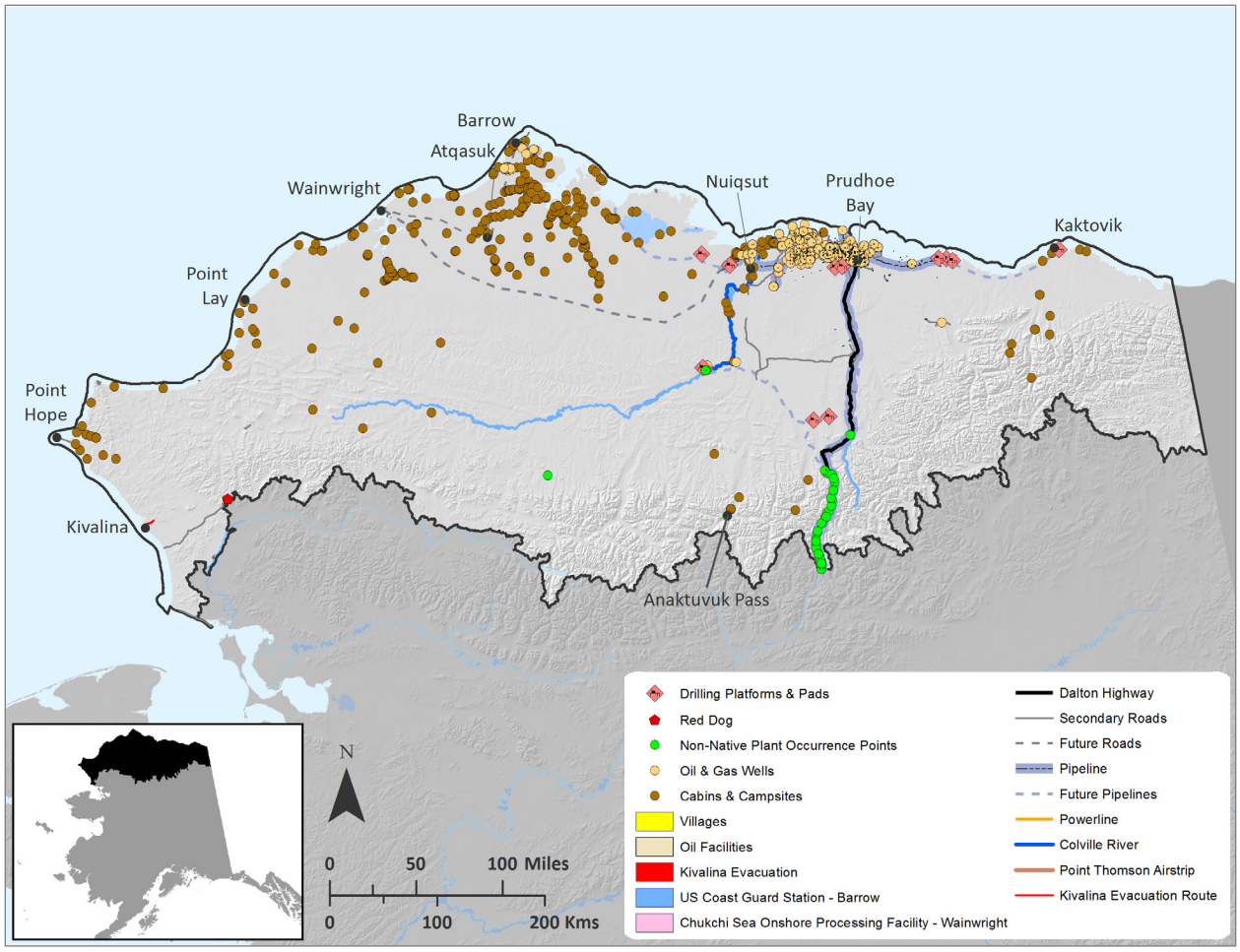


Figure E-17. High development scenario (2040) of human footprint in the North Slope study area.

4. Social and Economic Conditions

4.1. Methods

We attempted to assess the social and economic conditions of the North Slope study area and individual communities using a framework developed for the Arctic Social Indicators (ASI) Report (Larsen et al. 2013). Data in the ASI include commonly used, publicly available sources. Most of the literature used in the ASI is gray literature, such as ADF&G community harvest studies, newspaper articles, and reports from individual research grants.

A comprehensive index of various indicators was attempted to describe the socioeconomic conditions of the region. Such an index would allow relative comparisons between this region and other similar regions in the state. The ASI Report identified a list of indicators organized into seven domains of life in the Arctic. Domains were identified through extensive interviews across the circumpolar north to reflect the lifestyle circumstances of the region. The seven domains are: health, population and demographics, material wellbeing, education, cultural wellbeing, closeness to nature, and fate control. Several indicators identified are relevant to multiple domains. We reorganized the list of indicators identified to represent these overlaps. Figure E-18 shows the reorganized list of ASI domains and indicators, and intersections between domains.

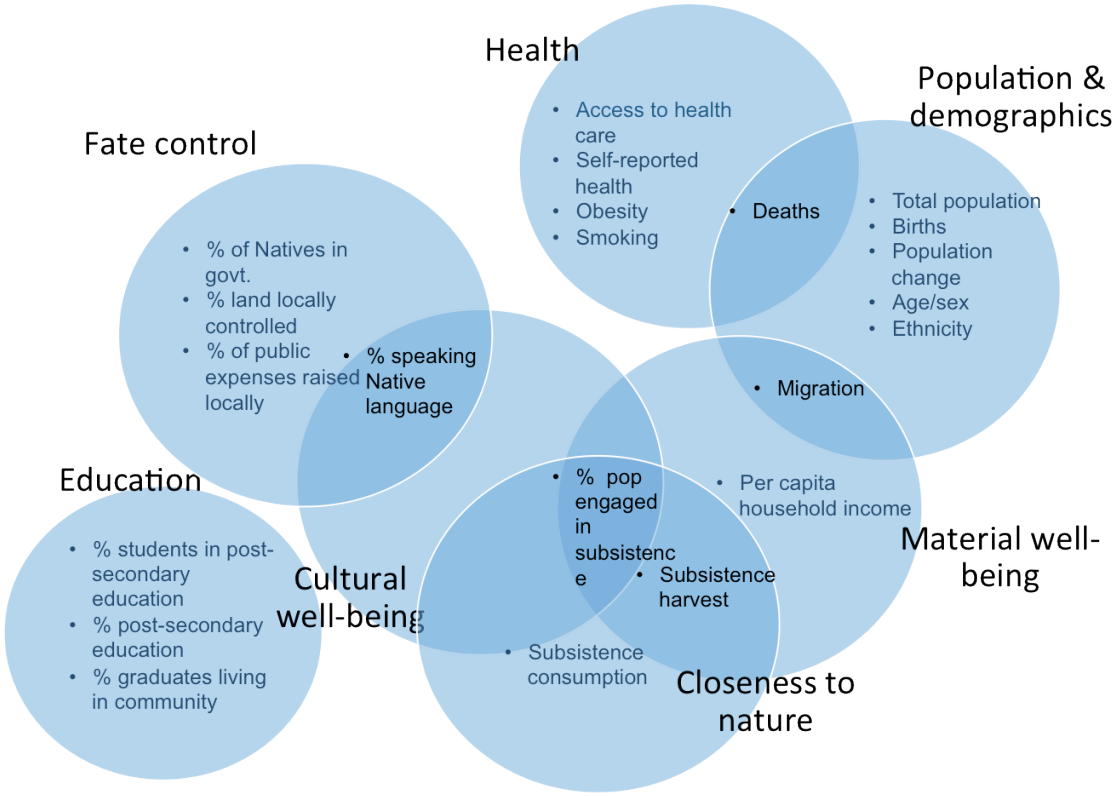


Figure E-18. Arctic Social Indicators (ASI) organized into seven domains.

Table E-7 identifies all domains and indicators suggested by the ASI Report, whether or not data are available, and suggested proxy variables. The ASI Report suggested a single variable per domain that would best represent each of the seven domains; these variables include such statistics as infant mortality rate for the health domain, net migration rate for population/demography domain, per capita income for material well-being, ratio of students successfully completing post-secondary education for the education domain, and language retention for the cultural well-being domain. Data for several variables are not systematically collected in Alaska. We identified proxy variables for only a few.

Table E-7. Indicators identified in ASI Report. Key variables that according to the ASI report best represent the domain are indicated with an asterisk.

Domain	Variables suggested by Nordic Council	Community level data availability	Used
Health	Access to health care	Unavailable.	N
	Self-assessed health		
	Smoking rate		
	Obesity rate	Community level data are confidential.	
	Child mortality rate	Community level data are confidential.	
	Infant mortality rate*		
	Suicide rate		
Population/ Demography	Total population	Alaska Department of Labor and Workforce Development (AK-DOLWD) and U.S. Census.	Y
	Population growth or decline rates and projections	Calculated.	Y
	Number of births	Annual community level data are not available. We assumed that these rates do not vary significantly among communities.	N
	Age/sex/ethnicity composition of the population including age and sex ratios		
	Birth rates		
	Mortality rates		
	Infant or child mortality rates		
	Net migration*		
	Number of death		
Material Well-being	Per capita household income *	ACS 2006-2010 moving average. *Proxy variable:* Per capita income (past 12 months) for total population and for AIAN (ACS 2006-2010). AK-DOLWD estimates of annual per capita earnings by community.	Y
	Per capita gross domestic product	GDP data for Alaska is available at U.S. Government Federal Reserve.	Y
	Unemployment rate	AK-DOLWD–ALARI provides unemployment insurance claimants by community.	
	Poverty rate	Community level data are not available.	

Domain	Variables suggested by Nordic Council	Community level data availability	Used
	Subsistence harvest per person	ADF&G subsistence harvest data are not collected every year in every community, nor for every species in every year. However, they are available for nearly all of the North Slope communities.	
	Net migration rate	Community level data are not available. State and census area level are available.	
	A composite index that takes into account three sectors: Per capita household income, Net migration rate, Subsistence harvest	Lacking complete data.	
Education	Proportion of students pursuing post-secondary education	*Proxy variable:* Proportion of students pursuing secondary education (Alaska Department of Education and Early Development (AK-DEED); National Center Educational Statistics (NCES).	Y
	Ratio of students successfully completing post-secondary education *	*Proxy variable:* Ratio of students successfully completing secondary education (AK-DEED; NCES).	Y
	Proportion of graduates who are still in their own community (or have returned to it) 10 years later	Unavailable.	N
Cultural Well-being	Cultural autonomy	Unavailable.	N
	Do laws and policies recognize institutions that exist to advocate for cultural autonomy or national minority populations?		
	Do institutions representing national minority cultures exist?		
	What is the proportion of such institutions to minority peoples, e.g. are all peoples represented through such organizations?		
	Are resources available to such institutions?		
	Are funding policies in place and how well-resourced are they?		
	Language retention* (e.g. what percentage of a population speaks its ancestral language?)	*Proxy variable*: Multiple variables from community level language data from US Census.	Y

Domain	Variables suggested by Nordic Council	Community level data availability	Used
	Belonging (e.g. what percentage of people are engaged in recreational or subsistence activities?)	ADF&G subsistence harvest data report the number of people attempting to harvest, successfully harvesting, and using each species. However, data are not available for all communities.	N
	A composite index that takes into account above three sectors	To be computed but data unavailable.	N
Closeness to Nature	Harvest of country foods*	Partial subsistence data available from ADF&G.	Y
	Consumption of country foods*	Partial subsistence data available from ADF&G.	
	Number of people or households engaged in the traditional economy	ADF&G subsistence harvest data report the number of people attempting to harvest, successfully harvesting, and using each species. However, data are not available for all communities.	Y
Fate Control	Percentage of indigenous members in governing bodies (municipal, community, regional) relative to the percentage of the indigenous people in the total population	*Proxy variable:* native corporations' earnings.	Y
	Percentage of surface lands legally controlled by the inhabitants through public governments, Native corporations, and Community governments*	Acres of land owned by native corporations.	
	Percentage of public expenses within the region (regional government, municipal taxes, community sales taxes) raised locally	*Proxy variable:* Municipal taxation, State of Alaska Department of Commerce, Community and Economic Development (AK-DCCED), Alaska Taxable.	Y
	Percentage of individuals who speak a mother tongue (whether Native or not) in relation to the percentage of individuals reporting corresponding ethnicity	U.S. Census collects the data that shows how many people speak only English in the community.	Y

*Key variables to use as indicators – According to authors of the Arctic Social Indicator report.

Many of the domains share indicators. For example, subsistence is a component of three different domains. Because of this overlap we used available data in a principal components analysis and attempted to identify similar but mutually exclusive domains. We compiled the available data and

conducted a principal component analysis (PCA) to identify factors that would explain the economic and social conditions of various communities. However, the data was not sufficient to meaningfully interpret the results. For meaningful results, the number of items or variables in a PCA should be sufficiently large in comparison to the number of cases, or communities in this situation. The general convention is 15 cases for each variable. We had only 12 communities in the North Slope study area. We tried the analysis with all rural communities in the state to increase the number of communities in the analysis. However, due to lack of consistent variables across communities, the results were not meaningful to interpret. Therefore, we resorted to a descriptive analysis of the social and economic conditions of communities in the region.

Datasets

Data on most indicators identified by the ASI Report are not available at the community level. For the purposes of the North Slope REA, we retained the domains as a conceptual framework and identified proxies for indicators, for those variables where local level data were available.

Data from diverse sources were compiled for the North Slope REA. Table E-8 lists the datasets and sources. Much of the demographic data was obtained from the U.S. Census and the Alaska Department of Labor and Workforce Development (AK-DOLWD). The decennial census from the U.S. Census collects only demographic information (age, sex, and race/ethnicity of household members). Starting with Census 2000, the Census Bureau eliminated the long form, which contained questions about income, occupation, education, migration, language use, and disabilities. The census long form was replaced by the American Community Survey (ACS), which is used to collect long form equivalent information every year. ACS is a sample survey, with a sample size of less than 10,000 for the entire state, and as such is highly unreliable for small population centers. To compensate for this, data are pooled over a 3-year or 5-year period. However, margins of error on the estimates are often larger than the estimates. AK-DOLWD uses data from the Permanent Fund Dividend records to estimate population for inter-censual years and reconciles these numbers with the decennial census numbers. AK-DOLWD numbers are used to compute several demographic details of the NOA REA study area.

Table E-8. Source datasets for analysis of community socio-economic conditions.

Dataset Name	Data Source
Demographic information – population, gender, race (2000-2010)	U.S. Census Bureau, Alaska Department of Labor and Workforce Development (AK-DOLWD)
Status of distressed communities 2013	Denali Commission
Fuel prices (1990-2010)	Alaska Energy Authority (AEA)
School enrollment data (2000-2014)	National Center Educational Statistics (NCES)
Alaska Game Management Units (GMUs)	Alaska Department of Fish and Game (ADF&G)
Alaska harvest statistics	Alaska Department of Fish and Game (ADF&G)
Alaska sport fish harvest	Alaska Department of Fish and Game (ADF&G)
Alaska visitor statistics	McDowell Group
Subsistence use areas	Bureau of Land Management

The Denali Commission releases a status list of communities every two years, identifying if a community is economically distressed. This rating was used in assessing social and economic conditions of the communities in the region. The Alaska Fuel Price Projections are developed for the Alaska Energy Authority (AEA) to assist in evaluating the economic feasibility of proposed renewable energy projects.

4.2. Results

Current socio-economic conditions in North Slope communities were shaped by three major events during the late 1960s and early 1970s: discovery and commercial production of oil starting in the late 1960s, the Alaska Native Claims Settlement Act (ANCSA) enacted in 1971, and the establishment of the North Slope Borough in 1972. This profile provides an overview about the demographic structure and economy of the region and sets the context regarding the impact of development on key ecological elements in the region.

ANCSA established 12 regional land-based share-holding corporations across the state and distributed rights to 44 million acres of land along with almost a billion dollars in cash compensation in exchange for aboriginal land rights. A thirteenth regional corporation was established in 1975 for Alaska Natives who live outside of Alaska. Two of these corporations are located in the North Slope study area: the Arctic Slope Regional Corporation (ASRC) and NANA, Inc. These corporations received surface and subsurface rights. ASRC received subsurface rights to nearly 5 million acres of land (the combined acreage is about the size of Massachusetts), and NANA[1] Inc. received approximately 2.3 million acres. A local village corporation was created in each village and rights to surface estate was conveyed to the corporation. ASRC began paying biannual shareholder dividends in 1972. The corporation's 2014 shareholder base is approximately 11,000, about three times more than the 3,700 in 1971. In 2014, dividends were $50 per share. Shareholders owned 100 shares each, on average. Since 1972, ASRC has paid out over three

[1] Northwest Arctic Native Association was NANA's predecessor, and played a key role in the enactment of ANCSA.

quarters of a billion dollars in dividends (Alaska Business Monthly 2014). NANA paid out approximately $9.4 million to its more than 13,600 shareholder in 2014.

Both North Slope Borough and Northwest Arctic Borough (NWAB) used their taxation authority to levy taxes on the natural resource extraction industries located on borough land. To quickly generate cash however, the North Slope Borough issued bonds, and over time used tax revenue to repay them. Bond revenues provided funding for major infrastructure improvement projects in the North Slope Borough area. Since its inception, nearly all residents have worked for the North Slope Borough rather than directly for oil companies or oil support industries. Local and borough government jobs allow for subsistence leave and schedule work around community calendars. Fuel subsidies provided by the North Slope Borough are an additional source of economic support. Compared to the rest of rural Alaska, the North Slope study area has higher employment rates, higher earnings, lower rates of out-migration, and more subsistence activity.

Abundance of oil and the ability to tax its production through the establishment of the North Slope Borough created a much more robust local economy over the last four decades than in most rural Alaska areas. Until the advent of the oil industry, the region's economy was dominated exclusively by external interests. Commercial whaling was the economic driver in the western Arctic during the years when baleen and whale oil were in high demand before the 1920. However, residents of the region had minimal participation in the industry. Demand for whale oil collapsed in the 1920s as whale oil was replaced by petroleum products. At the same time, high demand for fur in the 1920s drove the economy into the fur trade, which at times proved more profitable than whaling. During and immediately following World War II, there was a federal infusion of cash from heightened military activities. Inupiat, the major population in the North Slope study area, adapted well over the last century and a half to the external changes that brought major local economic impacts. Local populations actively engaged in economic opportunities presented by each boom period, and reverted back to their traditional economy and subsistence during the bust periods characterized by severe unemployment (Northern Economics 2006).

During postwar years prior to statehood, and through some major political and administrative reorganization of the state and its economic contours after statehood, the region's population had a major and most direct stake in the region's natural resources and its development. Statehood paved the way for three major structural changes – discovery of Prudhoe Bay, ANCSA, and formation of North Slope Borough – that fundamentally transformed the region's economy, and allowed for greater self-determination. Although North Slope Borough initially borrowed against future revenues, it also accumulated surplus revenues over the years. This allowed North Slope Borough to strengthen its local village economies through infrastructure development, local jobs, and considerable energy subsidies. The North Slope Borough is the largest employer of residents in the North Slope study area, with unique provisions for subsistence leave. This has several positive effects such as higher employment rates, higher earnings, more subsistence activities, and lower rates of out-migration than in any other parts of rural Alaska.

This fundamental transformation of the economic structure also affected the social structure. Having a consistent cash income meant increased time and resources to expand subsistence activities. The North Slope Borough government provided the basic structure that transformed the economy and provided the basic governance in the region, while it strived to reflect the traditional Inupiaq values. Despite the adoption of modern life styles (ex: standard housing and settled communities), economic behaviors (ex: consumerism and wage employment) and cultural traits (ex: main stream American sports and other popular entertainment), the local population adopted a remarkably grounded approach to their abundance, striving to ensure the maintenance and continuity of their traditional worldview. This is illustrated by one of the leaders in the region referring to ANCSA as a harpoon, meaning that this recent federal law has had significant socio-economic impacts, much like the ancient whaling weapon effective enough to hunt and kill one of the largest known mammals in the world.

Employment

The majority of the employment in the North Slope study area is provided by the oil and gas industry – the oil companies themselves, and the many supporting service organizations. While a majority of the jobs in the region are in the oil industry, most of these jobs are filled by non-residents who commute from outside the region. Approximately 10 - 15% of the local residents are directly employed by the oil and gas companies or their contractors. Both the North Slope oil industry and the Red Dog Mine provide employment and earnings for other Alaskans and others who live outside the state. Unlike the North Slope oil industry, Red Dog Mine is owned by NANA, Inc. and in partnership with the Mine's operator Teck, implements preferential policies to hire NANA shareholders ahead of non-shareholders (Haley and Fisher 2012). Not all NANA shareholders who work at the mine live in the region. Both Prudhoe Bay and Red Dog Mine are equipped with large airports, allowing easy commute for workers who live elsewhere in the state and the nation.

Despite the natural resource industry and other associated supporting employment sectors, local government is the largest employer of the resident population, accounting for approximately 50%-60% of the total jobs held by residents of the region. Trade, transportation, education, health services, professional services form the major private sector employers. Figure E-19 shows the distribution of employment by sector for the years 2001-2014. A substantial percentage of the workforce continues to be employed in trade, transportation, and utilities and construction sectors. Jobs in the educational, health, professional and business services increased over the same period.

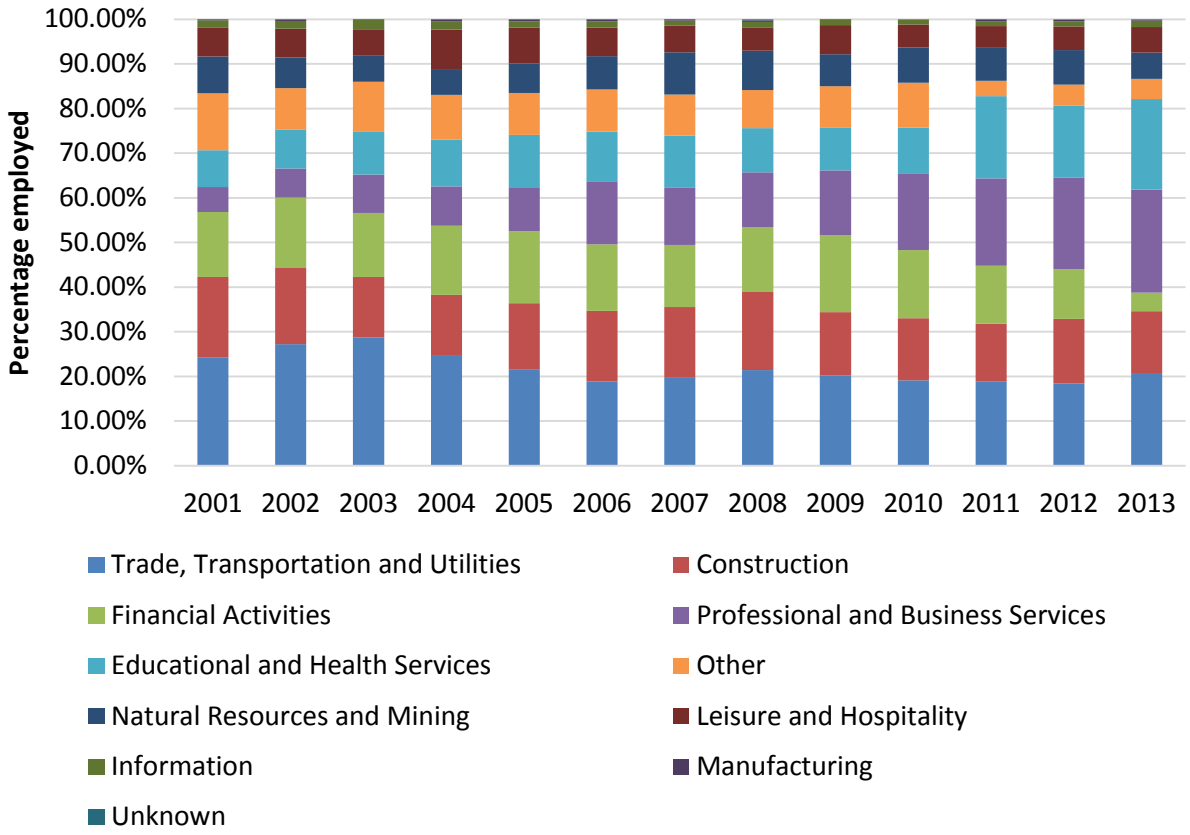


Figure E-19. Employment by industry in the private sector – North Slope study area including the oil industry and Red Dog Mine (2001-2013).

The majority of the jobs outside Prudhoe Bay and Red Dog Mine are located in Barrow. The North Slope Borough government and the school district are the community's largest employers, accounting for almost half the workforce in the community. Other major employers include Alaska Native for-profit corporations, regional non-profit corporations, and several state and federal agencies with offices in Barrow. During the period from 2001 through 2013, Barrow accounted for over 50% of all local government jobs in the North Slope study area. The other 50% of local government jobs were distributed among the other communities. Point Hope and Wainwright accounted for 10% and 7% respectively over the same period. Although several federal and state government agencies have offices in the regions' communities, employment in this sector is minimal compared to all other sectors identified in this report.

The gender distribution among those employed in the region varies by sector. Education and health services being dominated by women; while the financial services, leisure / hospitality, and professional services are fairly balanced. And predictably, construction trades, transportation, utilities, and information sectors are dominated by male employees.

Table E-9. Total employment by quarter (2010), by community.

Community or Political Entity	Jan-Mar	April-June	July-Sept	Oct-Nov	All 4 quarters
Alaska	253,557	270,292	269,839	256,722	213,657
North Slope-study area (excluding Prudhoe Bay and Red Dog Mine)	2,994	3,245	3,313	3,066	2,394
North Slope Borough	2,701	2,919	2,981	2,750	2,175
Anaktuvuk Pass city	135	138	146	131	101
Atqasuk city	86	97	99	86	67
Barrow city	1,673	1,816	1,829	1,715	1,407
Kaktovik city	111	114	125	120	94
Nuiqsut city	153	176	175	158	106
Point Hope city	260	273	292	259	182
Point Lay CDP	85	90	99	86	63
Wainwright city	185	202	204	183	143
Northwest Arctic Borough	2,372	2,558	2,667	2,499	1,818
Kivalina city	122	136	135	124	83
Noatak CDP	184	203	209	204	148

Revenue and Income

Revenue sources for local governments in the North Slope study area are dominated by taxes from the oil and gas industry. Other major sources of revenues include federal funds for health and education services, and revenue sharing funds from the state. Civic infrastructure built since the mid-1970s have largely been within the boundaries of the communities. Figure E-20 shows the percentage of workers in the North Slope study area by their annual per capita wage income. This does not include dividends and other non-employment income. Approximately 45% of the workforce earned less than $20,000. With an average household size of 3.59 in 2010, and based on per capita wage income only, a substantial amount of the population may have lived below the poverty line.

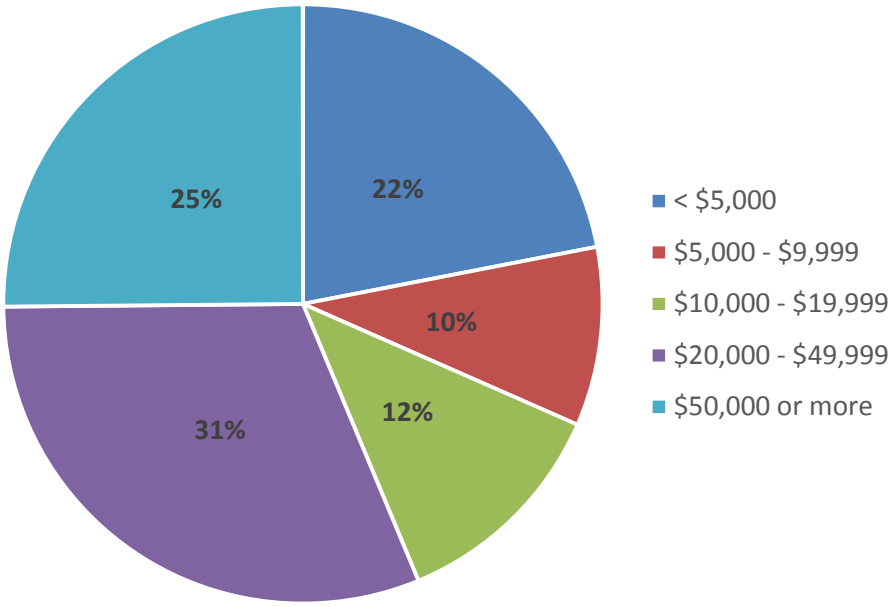


Figure E-20. Percentage of workers by annual per capita wage income (2001-2010 average) in the North Slope study area.

Socio-economic conditions can also be understood using the designation of 'distressed communities' as defined by the Denali Commission (Denali Commission 2013). Distressed communities meet at least two of three criterion: (1) Average market income in 2012 less than $16,120 (half-time employment at $7.75 minimum wage); (2) More than 70% of residents 16 and over earned less than $16,120; and (3) Less than 30% of residents 16 and over worked all four quarters of 2013. Increased revenue for the borough/regional governments, and increased per-capita incomes are reflected in the 'distressed communities' classification of communities in the region. Based on this criteria, Kivalina is the only community in the North Slope study area categorized as distressed.

Kivalina has been identified by the U.S. Army Corps of Engineers as being at risk from erosion damage and will need to move or implement major projects to mitigate damage from erosion and permafrost thaw. The U.S. Army Corps of Engineers estimates that without major mitigation efforts Kivalina will remain above ground for 10-15 years. Relocation will be expensive, at an estimated $400 million, and could disrupt cultural traditions, limit access to subsistence and other resources, and require complicated government agency and community coordination (Glenn Gray and Associates 2010).

Planning has started for an evacuation road. The community has had three emergency evacuations in the past five years. Currently, planes or boats are the only evacuation means. An evacuation road is also a first step in relocation. Residents have identified a site eight miles inland as the location for a new school and destination for the road.

Energy Prices

Costs of electricity in most rural Alaska communities are prohibitive due to the high fuel prices, primarily driven by the cost of delivery, and are indicative of the severe economic conditions and high cost of living. North Slope study area communities face the same challenge. North Slope Borough village corporations provide heating fuel, charging only a per-gallon delivery fee. This is possible due to fuel subsidies provided by the North Slope Borough. However, the North Slope Borough does not subsidize heating fuel for commercial use.

The energy picture in rural Alaska can be best understood as comprised of three key components – electricity, heating, and transportation. Alaska had 2,197 MW of installed capacity for electricity generation and approximately 6.6 million MW-hours of electricity were generated. While a majority (58%) of the state's electricity is generated with natural gas, almost all of this was consumed in the rail belt region (Wilson et al. 2008).

Most remote rural communities were eligible for the Power Cost Equalization (PCE) program in 2014. PCE was instituted by the state to offset the high fuel prices in rural Alaskan communities. The program pays 95% of residential electricity cost. However, the program has not been fully funded by the Legislature in 15 out of its 25 years of existence, and electricity rates in rural Alaska with PCE are still higher than in urban Alaska (Fay et al. 2013). Due to this, the PCE program increases the economic vulnerability of rural households to changes in state spending.

Table E-10. Fuel prices by community in the North Slope study area.

Community	Community Retailer	Residential	Commercial	Gasoline
Anaktuvuk Pass	Nunamiut Corporation	$1.55	$9.25	$9.49
Atqasuk	Atqasuk Corporation	$1.40	$4.10	$4.10
Barrow	BUEC, Inc.	Natural Gas	Natural Gas	$7.00
Kaktovik	Kaktovik Inupiat Corporation	$3.00	$9.00	$7.50
Nuiqsut	Kuukpik Corporation	Natural Gas	Natural Gas	$5.00
Point Hope	Tigara Corporation	$1.99	$7.99	$5.76
Wainwright	Olgoonik Corporation	$1.50	$7.30	$6.87

Source: DCCED, DCRA 2015. Alaska Fuel Price Report, January 2015.

Heating houses and other buildings is a necessity in Alaska. Communities across the state rely on a variety of fuel sources for heating: natural gas, diesel, electricity, wood, and other sources such as geothermal energy. Saylor and Haley reported 79% of the houses in remote rural Alaska are heated using diesel fuel. Between 2000 and 2005, cost of diesel for home heating increased by 83% in these remote rural communities. While natural gas is not available for transport to most rural Alaska communities, especially those beyond the railbelt, the primary fuel source for heating in two of the North Slope communities, Barrow and Nuiqsut, is natural gas. On average, outside of the North Slope

Borough, heating fuel retailed at $5.71 per gallon (Table E-10) shows fuel prices in the North Slope Borough communities in 2015 (Division of Community and Regional Affairs 2015).

Transportation consumes both gasoline and diesel. In addition to commuting between villages, transportation to and from subsistence areas is extremely important to sustain the cultural lifestyle and to supplement cash incomes of residents in the region. Although outside of the North Slope study area, in a survey of 54 households in Norton Sound, Schwoerer (2013) reported that on average each household travels 774 miles on snow machines, 416 miles on boats, and 172 miles on all-terrain vehicles (ATVs), one-way to access subsistence resources. These households consume approximately 1,291 gallons of gasoline per year. In addition, these households also consume 886 gallons of diesel oil and four cords of wood per year for various other purposes.

With perhaps an exception in 2014-15, there has been a recent dramatic increase in fuel prices throughout Alaska. Looking only at changes from 2000 through 2006, Saylor and Haley (2007) used census data to document total utility costs – including heat, electricity, water, and sewer – paid by residents of remote Alaska communities increased from a median value of 6.6% of total income to 9.9% of total income. By comparison, the median amount spent by Anchorage households increased from 2.6% to 3.1% of household income during this same period.

5. Non-Industrial Activities

5.1. Methods

All non-industrial activities result from general living of the local population in the region. The 2010 Census reports a total of 10,200 people live in the North Slope study area, including 2,174 workers at Prudhoe Bay. The remaining population lives in ten different communities. Barrow, the largest community, with a population of 4,212, serves as the regional communication, transportation, and administrative hub. Point Hope, with 674 people, is the next largest and Atqasuk, with 233 people, is the smallest. Few communities are connected by ground transportation but all can be reached by air year-round. More than 80% of the population in all communities are Alaska Native, with the exception of Barrow. In Barrow, Alaska Natives comprise 61% of the population. While wage employment is higher in the region compared to other parts of rural Alaska, reliance on subsistence is high. Subsistence is of both economic and cultural value to the population. Non-industrial activities are generally confined to the community footprints. They include general community infrastructure such as housing units, transportation facilities such as roads and airports within the community footprint, and commercial and public facilities. Subsistence and recreation access trails extend beyond the community boundaries to reach hunting and fishing camps. Rivers provide access to interior regions. Although the acreage under industrial development is large (approximately 2,500 sq. km.), it is much less than the area required for subsistence. All four herds of caribou that range in the region are harvested for subsistence uses. Additionally, several other animal and bird species, plants, and berries are harvested.

Subsistence use areas are computed from data obtained from the Bureau of Land Management (BLM). Spatial data was collected through surveys by private contractors for various projects, and was made available for this project. The Alaska Department of Fish and Game (ADF&G) also collects similar data during their community household subsistence surveys. However spatial data for subsistence use areas for communities in the North Slope study area were not available from ADF&G in time for this report. Thus, we relied on survey data collected for specific projects such as environmental impact statements of various development proposals in the region.

Data were obtained through household surveys conducted during sporadic years over a long period of time. For example, data for Atqasuk is from 1978. Data for Nuiqsut dates as far back as 1985, and is more substantial than for any other community. Only a small sample of households is interviewed during these survey attempts, thus raising questions about the sample size and representativeness of the sample. One household member in a household is typically asked to identify the areas and locations that the household hunted or fished during the previous year. These areas and locations are digitized and combined with responses from other households in the community. Such data is collected for each major subsistence species.

We used this data to compute subsistence use areas for the North Slope study area. We computed areas and locations by species, and by community. Thus we derived a polygon file for each species for each community. We then overlapped each community's polygon file for a particular species. Respondents from multiple communities sometimes identified common areas and locations. Overlaps are rated by

the number of such overlaps. Areas with respondents from only one community were assigned a rating of 1, areas with two communities were assigned a rating of 2, and areas with three communities were rated as 3. All maps are color coded. Thus, subsistence use area maps represent a simple use intensity for each species across the study area.

5.2. Results

Recreation

Recreation in the North Slope study area is distinct from what is considered recreation elsewhere. The region is remote and much of it is inaccessible by major modes of transport. Much of the region is not connected by roads, and recreational visitors either arrive by air, or use the trails and rivers. Recreation activities in the region include wildlife viewing, camping, and sport hunting. Tourism in the region is minimal although there is increased interest in recent years. The tourism visitor statistics program of the State of Alaska does not provide detailed visitor statistics for any place within the study area. The most recent assessment of tourism development needs in the North Slope Borough was conducted by the Arctic Development Council in collaboration with the State Department of Commerce in 1997, and identified the lack of facilities in the region and along the Dalton Highway. Several independent touring companies offer tours of specific communities or custom planned trips to remote parts of the region for wildlife viewing, camping, river travel, and sport hunting. There is a general lack of data available regarding the number of visitors to conduct an analysis. Figure E-21 shows all the protected areas in the study area. While NPR-A is not a recreational park, it is a protected area from most other development.

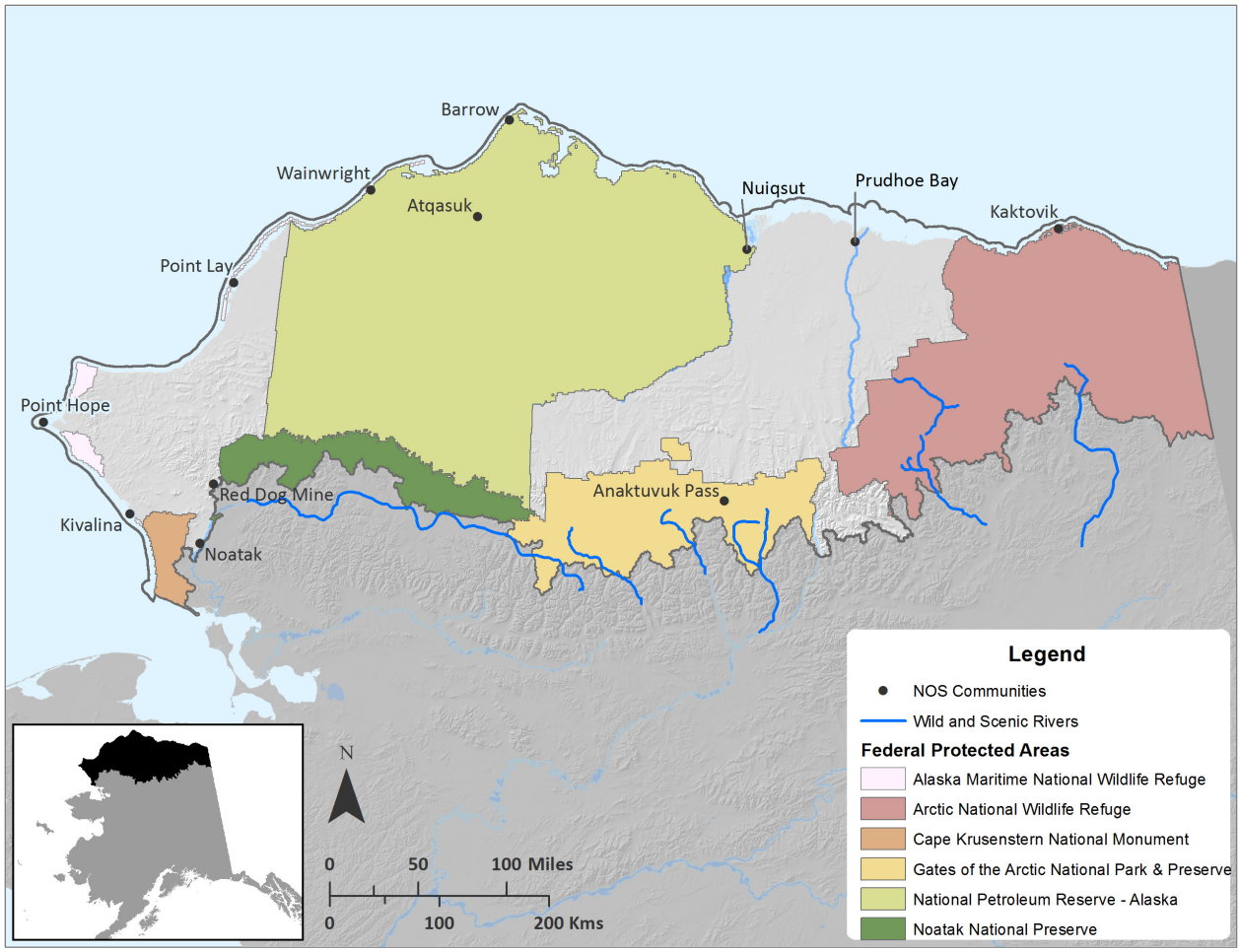
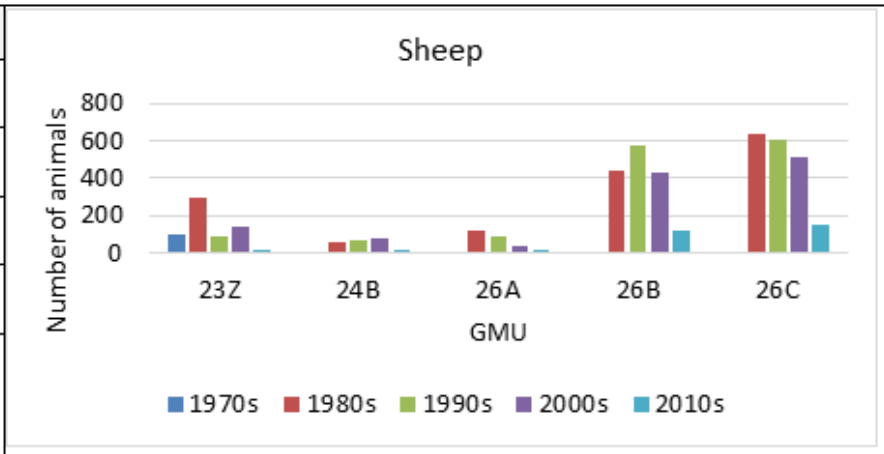


Figure E-21. Federal protected areas in the North Slope study area.

Sport hunting data is available at a game management unit level for the region. Sheep are most harvested around Anaktuvuk Pass and Kaktovik. Moose are most harvested around the Northwest Arctic

Borough communities of Kivalina, Noatak, and Red Dog Mine (

NS Community	GMU
Anaktuvuk Pass	24B
Atqasuk	26A
Barrow	26A
Kaktovik	26C
Kivalina	23Z
Noatak	23Z
Nuiqsut	26A
Point Hope	23Z
Point Lay	26A
Prudhoe Bay	26B
Red Dog	23Z
Wainwright	26A



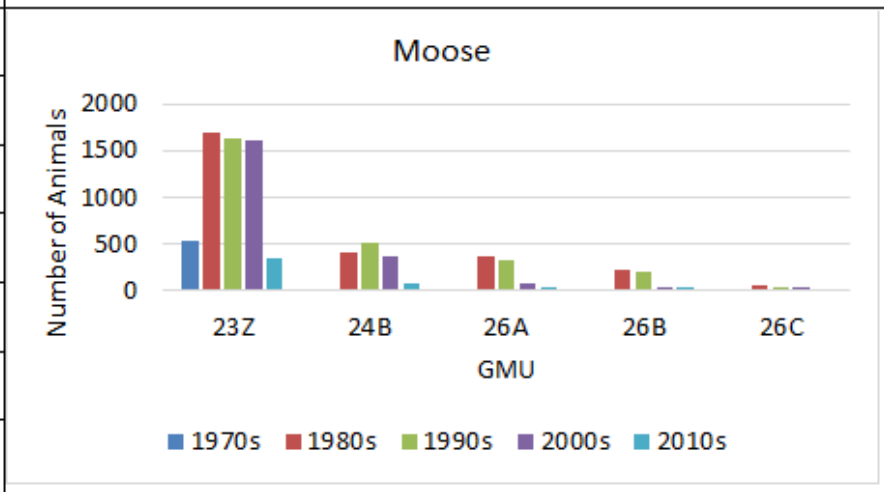
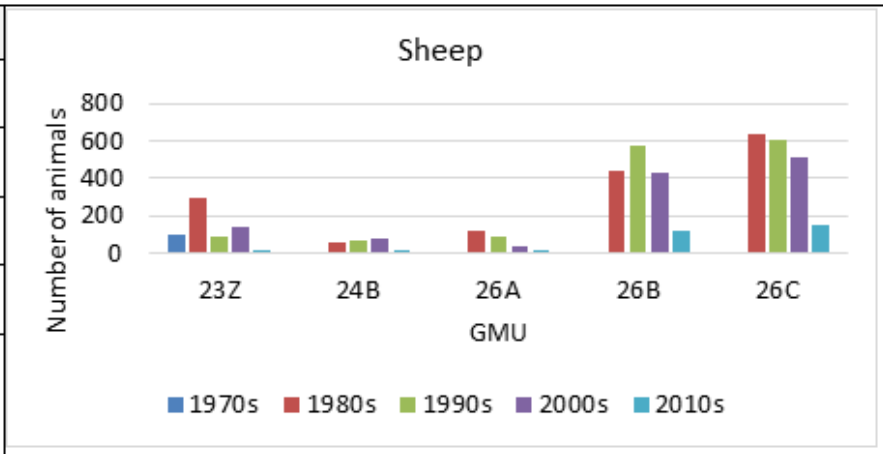


Figure **E-22**). Caribou are mostly harvested around Prudhoe Bay and along the Dalton Highway corridor. Muskox, brown bear, and black bear are other species harvested by sport hunters in the region.

NS Community	GMU
Anaktuvuk Pass	24B
Atqasuk	26A
Barrow	26A
Kaktovik	26C
Kivalina	23Z
Noatak	23Z
Nuiqsut	26A
Point Hope	23Z
Point Lay	26A
Prudhoe Bay	26B
Red Dog	23Z
Wainwright	26A



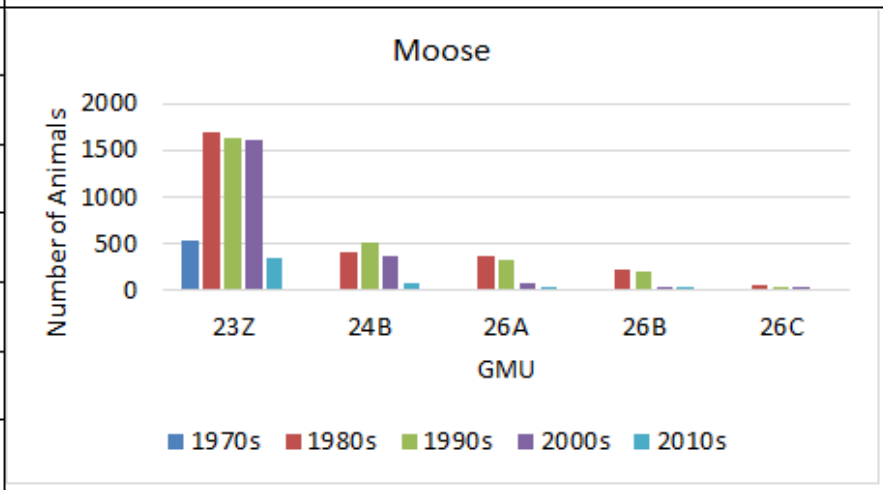


Figure E-22. Sport harvest of sheep and moose in the North Slope study area (1970s – 2010s).

Subsistence

Subsistence practices are closely linked to the natural cycles of the environment. Such practices include hunting, fishing, and gathering of various animal and plant species in the region. The majority of the population in remote rural Alaska depends substantially on subsistence to supplement their wages (Goldsmith 2007). Fishing and hunting are essential parts of local livelihoods in the North Slope study area. Subsistence forms a substantial part of the household and community economy in the region. As shown in Table E-11. Annual cycle of subsistence activities in the vicinity of Anaktuvuk Pass., local population in the study area uses a large portion of the region's land for subsistence. We computed subsistence use areas from survey data collected for other projects and data available from the Bureau of Land Management.

Subsistence foods are a large part of household food consumption. According to the Survey of Living Conditions in the Arctic, subsistence foods make up between half and three-quarters of all food consumed by Alaska Native households (Martin 2012). Higher income households are also high

subsistence-producing households, and have been termed "super households" (Wolfe et al. 2009). This report identified what has become known as the "30:70 rule," where 30% of households produce 70% or more of a community's subsistence food. Even though only 30% hunt, nearly everyone reports using subsistence foods, illustrating widespread sharing and the significance of the role hunters have as part of a community's holistic system. Subsistence traditions connect people to each other, the animals, and land they have used for thousands of years. This is especially true of Alaska Natives, who are among the very few aboriginal groups in the world that have not been displaced from their traditional lands.

Many species are harvested by the local population. Among the conservation elements considered for this REA, the following are frequently considered subsistence species:

- Caribou – *Rangifer tarandus* – Tuttu
- Greater White-Fronted Goose – *Anser albifrons* – Nibliq
- Willow Ptarmigan – *Lagopus lagopus* – Aqargiq
- Dolly Varden – *Salvelinus malma* – Iqalukpik
- Broad Whitefish – *Coregonus nasus* – Aanaakliq
- Chum Salmon – *Oncorhynchus keta* – Iqalugruaq
- Arctic Grayling – *Thymallus arcticus* – Sulukpaugaq
- Burbot – *Lota lota* – Tittaaliq
- Arctic Fox – *Vulpes lagopus*

While all the above species are harvested, only a few of them are harvested in significant amounts, and are discussed below. Data on subsistence harvest is limited. Available ADF&G surveys are dated, and some of it was useable for REA purposes. Information on all species was not always collected.

Table E-11. Annual cycle of subsistence activities in the vicinity of Anaktuvuk Pass.

Species	Winter					Spring		Summer			Fall	
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Caribou												
Sheep												
Moose												
Grizzly Bear												
Ptarmigan												
Furbearers												
Fish												
Berries												

	No to very low levels of subsistence activity
	Low to medium levels of subsistence activity
	High levels of subsistence activity

Animal and plant species used as subsistence resources may vary from community to community and from year to year. Each community has a general seasonal cycle of harvest, informed by tradition, personal experience of elders in the community, and observations of harvesters during the current and immediate previous harvest seasons. Natural and human factors such as river conditions, ice, weather, migratory patterns, species abundance, technology, economic opportunities, and other factors have an impact on the harvest cycles (Georgette & Loon 1991). Table E-11 shows the seasonal cycle of subsistence activities for Anaktuvuk Pass, a community at the foothills of the Brooks Range, far from the coast. Almost all subsistence harvest in the community is land-based. On the other hand, Table E-12 shows the seasonal subsistence cycle for Barrow, a coastal community. Marine mammals are a substantial source of subsistence foods for this community.

Table E-12. Annual cycle of subsistence activities in the vicinity of Barrow.

Species	Winter					Spring		Summer			Fall	
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Fish												
Birds												
Berries												
Furbearers												
Caribou												
Polar Bear												
Seals												
Walrus												
Bowhead Whale												
	No to very low levels of subsistence activity											
	Low to medium levels of subsistence activity											
	High levels of subsistence activity											

Regardless of the location in the region, all communities rely heavily on some common species. Caribou are harvested by all communities across the study area. The only harvest data available for this study area was from ADF&G household subsistence surveys. The survey data is sporadic, with data missing for many years for each community. Only eight out of the ten resident communities were ever surveyed. Of those surveyed, the earliest available data is from 1982. Kaktovik was surveyed eight times, most among the ten communities. Wainwright, Point Lay, Nuiqsut, and Barrow were each only surveyed twice during the three decades since 1982. Therefore, this analysis is severely limited by the sparse data available on subsistence harvest amounts in the region.

Figure E-23 shows the per capita caribou harvest in pounds across eight communities, over three decades. The numbers represent average amounts over the years for which data was available during the decade. Since data was available only for a few years for any community, these numbers are very

limited and do not represent the average harvest amounts. Variation in per capita harvest amounts can be due to many reasons associated with harvesters or the species being harvested. Factors influencing subsistence harvests were explored in response to MQ TF 3. However, sparseness of the available data severely limited our ability to explore possible explanations of observed variability in per capita subsistence harvests. ADF&G data available for grayling, with similar limitations, is presented in Figure E-24.

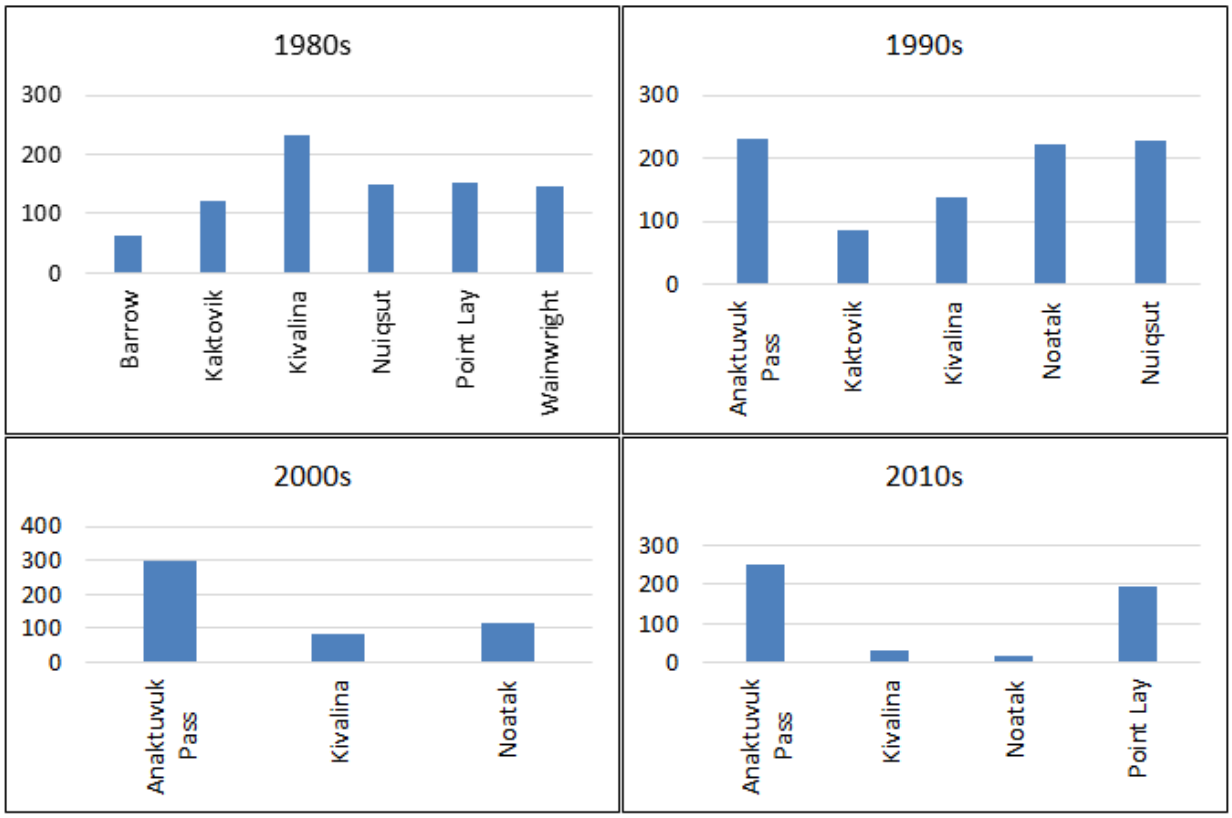


Figure E-23. Average per capita subsistence harvest of caribou (in pounds) for communities surveyed (1982 – 2013).

While ADF&G data is very limited, the North Slope Borough has been working diligently for more than two decades to collect and compile subsistence harvest patterns and practices. The Subsistence Harvest Documentation Project (SHDP) (North Slope Borough 2015) is part of a larger 4-part Subsistence Harvest Documentation Project initiated in 1994. The larger project includes mapping, migratory bird survey, and hunter education, and is designed to collect, compile and analyze subsistence data to inform management practices. SHDP is designed to collect survey data from each household in each community within the North Slope Borough every six months. Due to Barrow's relatively large population, a sample of households is randomly picked for the survey.

Bacon et al. (2011) report subsistence harvest numbers between the years 1993 and 2003 from the data collected through the SHDP. SHDP conducted two surveys in each village – a one year recall survey, and a six-month recall survey. During the period between 1994 and 2003, only 13 one-year surveys and 17

six-month surveys were conducted in the eight communities of the North Slope Borough, indicating challenges in conducting subsistence surveys. Other limitations of this data included difficulty in identifying the right species, non-availability of households for the survey, inaccuracy of recall. All these errors are not uncommon in similar efforts such as the ADF&G surveys. The SHDP data was not available to be analyzed for the North Slope REA.

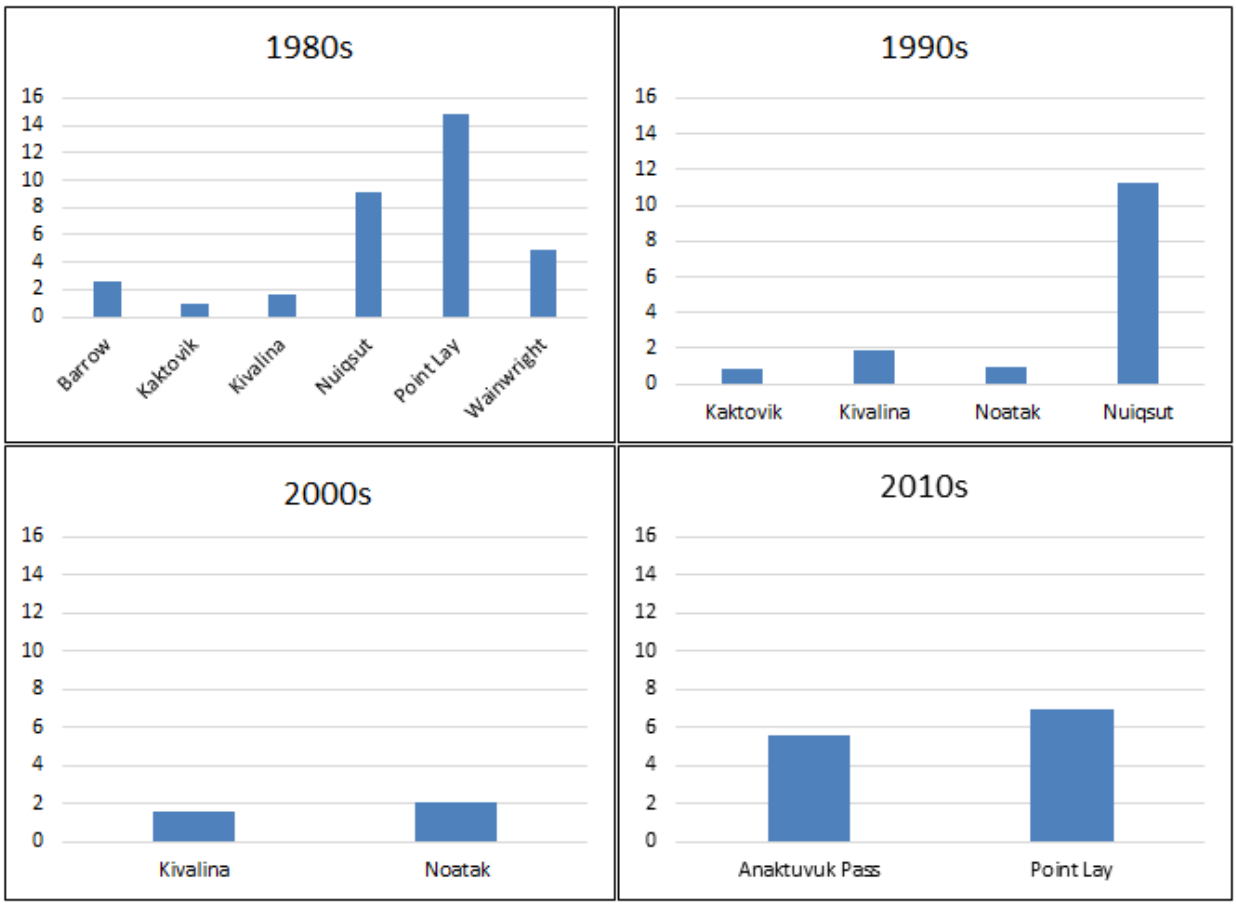


Figure E-24. Average per capita subsistence harvest of grayling (in pounds) for communities surveyed (1982 – 2013).

Other disparate efforts to collect similar survey data include attempts by independent contractors to conduct surveys as part of a specific proposed or current development project. Data from these one-time projects may extend over a few years, are often proprietary, and are not available in public domain. The Bureau of Land Management shared spatial data from such projects for the purposes of this study. This data was utilized to compute subsistence use areas in the North Slope study area. This data is very limited in several ways. Some of the data is not dated, leading us to believe it is quite old. Nevertheless, we developed a method to spatially identify areas that may be valuable for subsistence. This data is limited to communities in the North Slope Borough.

Figure E-25 shows subsistence use areas for caribou, moose, vegetation, fish, furbearers, and wildfowl. The largest concentration of human population in the region is in the communities of Barrow, Atqasuk,

and Wainwright. The region surrounding these communities seems most used for subsistence purposes. However, it should be noted that the level of use is a simple overlapping count of the number of communities that identified a particular area as important for subsistence use. The number of hunters that identified a particular area, or the count or pounds of subsistence harvest is not considered in preparing these maps. This is a severe limitation considering the distances between the communities.

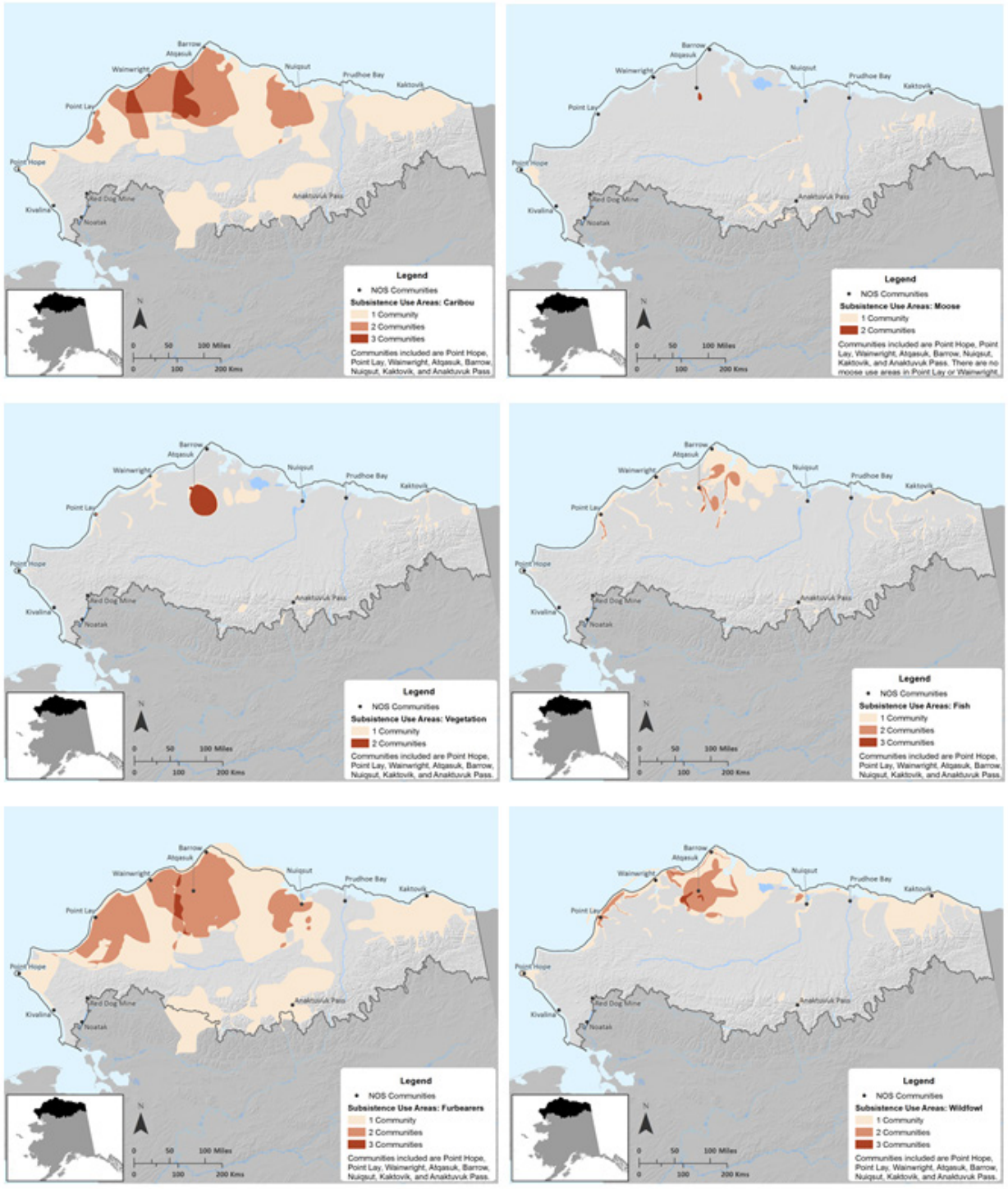


Figure E-25. Subsistence use areas within the North Slope study area.

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7. Measurable and Perceived Impacts of Development

The North Slope study area includes three distinct but overlapping management questions regarding impacts of development on subsistence resources. All three questions are addressed in this section. Although the resource of focus differed between TF 3 and AF 2, both questions were very similar, with similar methodologies and results. Limitations to access (AP 1), whether physical or perceptual, are closely related to the impacts of development. Many of the impacts identified in TF 3 and AF 2 are adverse, and are either real or perceived barriers to access.

MQ TF 3	What are the measurable and perceived impacts of development on subsistence harvest of caribou?
MQ AF 2	What are the measurable and perceived impacts of development on subsistence harvest of fish?
MQ AP 1	What physical and perceptual limitations to access to subsistence resources by local residents are caused by oil/gas activities?

Impacts due to measurable factors and perceived factors may have similar effect on subsistence outcomes whether measured in pounds harvested or access to subsistence. However, both sets of factors are distinct and owing to the methodological differences in identifying them, are discussed separately in response to these question.

7.1. Definitions

Subsistence: Alaska National Interest Lands Conservation Act (ANILCA) defines subsistence as "the customary and traditional uses by rural Alaska residents of wild renewable resources for direct personal or family consumption as food, shelter, fuel, clothing, tools, or transportation". Subsistence as an important component of the food supply chain as well as an integral part of the population's cultural identity and social life (Woods 2013). Therefore, subsistence can mean a diverse set of activities that contribute to the physical, emotional, social, and cultural wellbeing of the population.

Measurable impacts: Measurable impacts are interpreted as anything that could be quantified.

Subsistence harvest: Although 'subsistence harvest' can be defined quite broadly, we used a narrow definition to allow measurement – per capita harvest of caribou in pounds.

Factors affecting subsistence: There are many different factors that can affect subsistence harvests including land use restrictions by the local, state, and federal authorities; restriction of access to subsistence areas due to development activities; contaminations due to oil spills and other development activities; fuel cost; wage earning jobs; available time for subsistence activities; subsistence equipment costs; distance to travel for harvests; change of animal migration patterns; total population number and population density of both the humans depending on subsistence and the resource being harvested; distance of the villages from the urban markets; vehicular traffic and other noises due to development activities; water quality and water withdrawal for oil and gas and other development activities; and loss

of vegetation due to contamination and space used for development activities. We limited our analysis to factors relevant to development activities.

Development: Many types of development are identified in the literature – principal among them are social development, economic development, and physical development. Each type of development has several, often overlapping sets of indicators. Social development indicators may include population demography, life expectancy, infant mortality rate, maternal mortality rate, literacy rate, percentage of population with post-secondary education, etc. Economic development indicators may include real wages per worker, unemployment rate, local revenues from taxes and fees, new businesses created, new jobs created, mean and median income, etc. Physical development indicators may include road (paved) length per square kilometer of surface area; railroad length per square kilometer of surface area; per capita electricity consumption; annual fresh water withdrawal for domestic, agriculture, and industrial use; secure internet servers (per 1 million people), etc. We considered physical, social, and economic indicators.

7.2. Methods

Measurable Impacts

Figure E-26 shows the process model to assess the measurable impacts on subsistence harvest of caribou. Two primary elements impact subsistence harvest: physical alterations to landscape, and social and economic factors of the population that enhance or hinder their abilities to harvest. Physical alterations include any development activities such as construction of roads or industrial infrastructure. Social and economic factors include increased income that may allow hunters to acquire new and more efficient modes of transport that can enhance their ability to harvest while also leaving them less time for subsistence activities, impeding their ability to harvest.

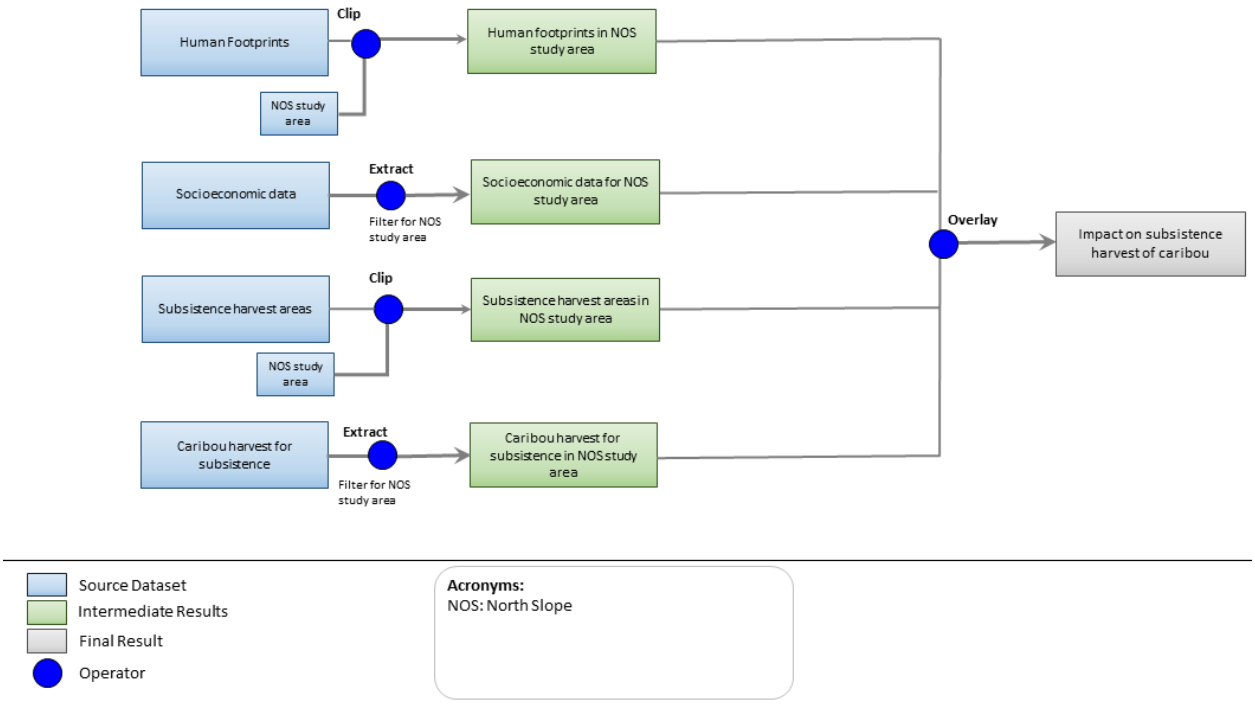

Figure E-26. Process model identifying measurable impacts of development on subsistence harvest.

Several agency reports and peer-reviewed journal articles were retrieved from multiple sources. 'North Slope Alaska', 'Subsistence', 'Socioeconomics', 'Oil and Gas' were used as search terms singularly and in combination. We identified the following variables (and corresponding data availability) as having an impact on subsistence harvest:

- **Per capita harvest amount in pounds (available):** Data were obtained from the Alaska Department of Fish and Game subsistence harvest surveys. These surveys are conducted sporadically in various communities across the state.
- **Distance from Subsistence Use Areas (unavailable):** Subsistence use areas for various species. Use areas may change over time, and thus temporal data is important. From the use area maps we intended to calculate the distance between each community (hunter's home) to the nearest subsistence area by species.
- **Intensity of Contamination (unavailable):** An overlay of the map showing intensity of contaminants and subsistence use area maps would yield the proportion of the subsistence use areas impacted by contamination.
- **Human Traffic and Vehicular Traffic (unavailable):** Number of people and vehicles passing by the subsistence use areas during the harvest season each year. Number and type of aircrafts flying by the subsistence use areas, their altitudes and noise levels during the harvest season each year.
- **Animal Migration Pattern (available):** Number of animals (caribou) moved in the harvest area and moved out of the harvest area; i.e. net migration number or net migration rate.

- **Physical Barrier (available):** Physical infrastructure (ft^2 or m^2) between the community and subsistence use area.
- **Transportation Infrastructure (available):** Road access from the community to subsistence use area (in mile or meter), paved road or ice road during harvest season.
- **Road Network (available):** Distance of the community from the major road network.
- **Price of Store Bought Foods (available):** Community level commodity price index or consumer price index.
- **Animal Count (available):** Number of caribou per square meter (before harvest) in subsistence use area.
- **Number of Substitute Species (partially available):** Number of other CE species per square meter (before harvest) in subsistence use area.
- **Urban Market Distance (available):** Distance to the closest urban market (hub community) from the rural community.
- **Population (available):** Ratio of native population to total population.
- **Income (available):** Per capita aggregate income or income from wages (per capita).
- **Available Time (available):** Number of employees who worked all 4 quarters of a year in relation to the total population of those age 16 and over.
- **Fuel Price (available):** Diesel fuel price, based on cost per gallon.

We used the subsistence per capita harvest of caribou in pounds as the dependent variable and used several combinations of the above variables as independent variables in a multiple regression to examine the impacts of each variable on per capita subsistence harvest amounts. Several independent variables had to be eliminated from the analysis due to co-linearity.

Perceived Impacts

Perceived impacts of development on subsistence were assessed using qualitative methods. A review of literature combined with content analysis of primary sources revealed factors perceived by the local population that impact subsistence harvest.

At the first Assessment Management Team (AMT) meeting on June 27, 2013 we were advised to closely examine the meeting minutes of the Subsistence Advisory Panel (SAP) for the National Petroleum Reserve-Alaska (NPR-A) to identify specific species or habitats of interest to the North Slope study area. A two-phase project was designed. Phase I consisted of an exploratory survey of the SAP documents for key issues and themes using frequency and co-occurrence analyses. Phase II entailed a more in-depth examination of those themes and issues identified during Phase I, in order to identify substantive knowledge components potentially useful in answering management questions. Although Phase II of the analysis was abandoned in light of the findings of Phase I, the results of Phase I analysis are applicable to management questions addressing perceived impacts to fish and/or caribou.

- Reading the entire set of transcripts
- Simple Text Retrieval – frequency count for every term used in the documents

- Identifying search categories – picking out potential CEs, CAs. We used preliminary list of CEs, and CAs from the North Slope REA to identify search categories. This list included variants of the stated CEs and CAs.
- Coding – The entire document set was searched using each of the items in the search category list. Blocks of text containing the search term was filtered for coding based on the following rules:
    - Speaker identity and role – the speakers were self-identified subsistence users in the region, devoid of their official role with any organized agency or private entity operating in the region, or as industry representatives.
    - Context of the conversation – Conversations initiated by subsistence users and not in response to comments, reports and/or presentations made by industry or agency representatives were coded.
- Frequency Analysis – Each code in the above step was counted.
- Co-occurrence Analysis – Pairings of CE-CA codes were counted.

During the coding process, specific attention was paid to comments initiated by subsistence users. If a person acted in multiple capacities (i.e. as a subsistence representative in the industry but also as a participant in workshops and meetings), only those comments made in the context of meeting/workshop participation were included. This was because the reports made by these individuals in their official capacities as subsistence representatives were reflective of the context of their employment, and were considered biased by that context. There was a risk of skewing the data based upon term repetition within single comments. To account for this, terms were searched as single hard returns, rather than exact word-matches. Thus, when the same category was mentioned multiple times in the context of a single comment-response interchange, that conversation was coded as a single occurrence.

In addition to the above, some identified categories were referenced in-text using variants, misspelled in transcription, or identified within a specific subgroup. Those identified during the initial reading process were organized as additional search terms and sorted as subcategories within the established categories. For example, specific caribou herds mentioned by subsistence users (Teshekpuk Herd, Central Arctic Herd, etc.) were coded using the broader category “caribou”.

Following coding, the retrieval process consisted of both frequency and co-occurrence analyses, employed to identify the relative importance of particular categories based on repetition and also to assess which categories aligned more frequently than others. For purposes of presenting these analyses, similar categories were grouped together. The appended tables reflect select categories (presented by group), their term frequency as established in Phase I, and their filtered frequency after the coding scheme was applied.

For the purposes of this analysis, each of the issues and recommendations in the document were reviewed for pertinence to fish, caribou, or access. In addition, the issues/recommendations were also associated with CAs identified in the North Slope study area where possible.

Further supplementing the above analysis, and following it, an extensive review of the extant literature was conducted:

- Consortium Library database search (peer-reviewed journal articles) and Google Scholar and Google (articles and webpages) were conducted using these search terms alone and in combination
- Following terms were used in the context of caribou: "oil, production, gas, subsistence, perceived, perceptual, perception, mental, sensed, observe, observed, observation, resources, activities, barriers, development, exploration, extraction, pipeline, hunters, villagers, Alaska Natives, impacts, harvest, caribou, Teshekpuk Herd, Central Arctic Herd"
- Following terms were used in the context of fish: "oil, production, gas, subsistence, perceived, perceptual, perception, mental, sensed, observe, observed, observation, resources, activities, barriers, development, exploration, extraction, pipeline, hunters, villagers, Alaska Natives, impacts, fish, fishing, harvest, dolly varden, broad whitefish, chum salmon, arctic grayling, burbot"
- Following terms were used in the context of access to either fish or caribou: "access, oil, production, gas, subsistence, perceived, perceptual, perception, mental, sensed, observe, observed, observation, resources, activities, barriers, development, exploration, extraction, pipeline, hunters, villagers, Alaska Natives, impacts"
- Special attention was paid to the following documents (identified either for the comprehensive nature of the documentation or the importance of the document to community/communities in the region:
    - Full-text review and bibliographic search of "Synthesis: Three Decades of Research on Socioeconomic Effects Related to Offshore Petroleum Development in Coastal Alaska" (Braund and Kruse 2009)
    - Full-text review and bibliographic search of "Subsistence Mapping of Nuiqsut, Kaktovik, and Barrow" (Braund and Associates 2010)
    - Full-text review and bibliographic search of "Impacts and Benefits of Oil and Gas Development to Barrow, Nuiqsut, Wainwright, and Atqasuk Harvesters" (Braund and Associate 2009)
    - Full-text review and bibliographic search of "Aggregate Effects of Oil Industry Operations on Inupiaq Subsistence Activities, Nuiqsut, Alaska: A History and Analysis of Mitigation and Mointoring" (Braund and Associates 2013)
    - Full-text review of "The Inupiat View. National Petroleum Reserve in Alaska 105(c) Final Study, Volume 1(b)" (Inupiat Community of the Arctic Slope 1979)

7.3. Results for Measurable Impacts

The final dataset consisted of very few records mainly due to the small number of communities in the North Slope study area. Because only 10 communities were surveyed sporadically over the last several decades, there were only 17 records. To increase the power of the analysis, we included all rural communities in the state, and all resources instead of just caribou. The final regression model included

four independent variables – wage per capita in nominal dollars, percentage of American Indian and Alaska Native population, diesel fuel price in nominal dollars, and Gini index. These variables were chosen because of data availability.

A backward step-wise regression tested five different models, each subsequent model with one variable removed. Unfortunately, none of the models were a good fit. Nevertheless, the variables identified were considered to have a significant impact on the subsistence harvest of species, and would have yielded meaningful results with sufficient data.

Impacts of physical development

Impacts of development on the natural environment have been documented extensively. Development activities may create noise, contamination, and land use restriction due to regulation or alteration of physical features. All these may cause loss of vegetation area, loss or transformation of natural habitat, change in migration pattern, and other changes that affect subsistence harvests (Bureau of Ocean Energy Management 2011, Braund et al. 2009, Woods 2013).

For example, migration patterns of caribou near Noatak had an unusual pattern in 2009 and 2010 - narrow along the east-west corridor centered on the Anisak River drainage. Harvest numbers for Kotzebue, Kivalina, and Noatak during those years were lower (Braem and Kostick 2014). Similarly, residents of Nuiqsut, surrounded by oil development on the North Slope, reported traveling longer distances for subsistence hunting: "A few residents also reported hunting substantial distances east and west of the community, although several people commented that hunting has declined east of the community due to activities associated with oil and gas development. Respondents commonly indicated that they look for caribou while hunting wolf and wolverine by snow machine over a large expanse. Residents generally did not travel past the Sagavanirktok River to the east in search of caribou, but one individual reported venturing as far west as Barrow in the last 10 years" (Braund et al. 2010).

In addition to these immediate affects, changes in migration patterns may have long-term negative impacts on subsistence harvest due to loss of calving grounds and consequent decline in herd (U.S. Army Corps of Engineers 1980). Changes in migratory pattern may prove fatal to very old or very young members of a herd due to unfamiliar conditions (Tetra Tech, Inc. 2009). Central Arctic Herd (CAH) of caribou in the North Slope is the most affected herd due to the expansion of industrial activities around Prudhoe Bay oil fields. "The CAH traditionally calved between the Colville and Kuparuk Rivers on the west side of the Sagavanirktok River and between the Sagavanirktok and the Canning Rivers on the east side. During the 1990s, the greatest concentration of caribou calving in the western portion of Unit 26B shifted southwest as development of infrastructure related to oil production [began] in what was originally a major calving area" (Braem et al. 2011). Other studies documented similar patterns. Continued expansion of the Prudhoe Bay oil field eastward displaced caribou further eastward toward the coast, affecting their calving habitat as well as their migration route and grazing areas (Bureau of Ocean Energy Management 2011, Pedersen and Caulfield 1980).

In addition to physical barriers, development is a major source of contaminants that affects habitat and individual species. Most common sources of contaminants in the North Slope include oil spill and

fugitive dusts, affecting both land and water (Tetra Tech, Inc. 2009, Bureau of Ocean Energy Management 2001) through multiple pathways (Galginaitis and Patterson 1990, Alaska Native Science Commission 2009).

Impact of social and economic development

Short and long-term development activities create opportunities for wage-paying jobs (Pedersen and Caulfield 1980). The economy of North Slope communities transformed since the beginning of the oil and gas industry in the region, with dramatic rise in per capita incomes. Increased incomes have both positive and negative impacts on subsistence harvests. Time available for subsistence hunting is limited due to obligations of a paid job. People with full-time well-paying jobs may be limited to weekends, after hours, or vacation time. Time restrictions often force shorter commutes to subsistence harvest areas. On the other hand, the ability to purchase hunting and fishing tools, including transportation vehicles such as ATV's or snow machines is often greatly improved. Barrow residents tend to fish at Elson Lagoon, Chipp, Ikpikpuk, and/or some other local rivers where they catch salmon, whitefish, Arctic grayling, least cisco, burbot, and some other fish as opposed to established subsistence harvest areas (Carothers 2013).

Table E-13. Factors impacting subsistence harvest in the North Slope study area.

Caribou	Fish
Noise	Contamination (i.e. oil spill, fugitive dust): death of fish, destruction of fish habitat
Road traffic, human traffic, air traffic	Change of migration patterns due to contamination and water withdrawal for development activities
Contamination (i.e. oil spill, fugitive dust)	Access to subsistence area: legal restriction, transportation infrastructure, distance to subsistence area
Change of animal migration pattern	Income from wages
Access to subsistence area: perception/belief, legal restriction, physical barrier, transportation infrastructure, distance to subsistence area	Available time
Loss of vegetation area and calving habitat	Material inputs: Oil price, hunting gears, snow-machines
Income from wages	Price and availability of substitute store foods
Available time	Legal restriction imposed by local, state, and federal authorities on fishing specific species
Material inputs: Oil price, hunting gears, snow-machines	Availability of substitute harvest species
Price and availability of substitute store foods	Access/distance to urban markets

Caribou	Fish
Legal restriction imposed by local, state, and federal authorities on hunting specific species	Number of total people
Availability of substitute harvest species	Number of native people
Access/distance to urban markets	Water withdrawal for development activities
Communities along the road networks	Communities along the road networks
Number of total people	
Number of native people	

Other major factors associated with development that impact subsistence harvest include higher demand due to increased community populations, their proximity and access to urban markets, higher energy prices, and applicable game management regulations. Development activities may cause increase in community populations due to in-migration, which may increase the total harvest amounts. However, higher population can result in lower per capita harvest amount. Per capita harvest declined by half from almost 1,300 pounds per capita in 1964 to almost 750 pounds per capita in 1992 in Kivalina (Magdanz et al. 2002) as the community's population increased from 142 in 1960 to 317 in 1990. Alaska Native communities traditionally relied on subsistence, and place a higher social and cultural value on subsistence activity (Tetra Tech, Inc. 2009). The impacts of increased population are higher and more pronounced in larger communities than in smaller communities.

Easy or affordable access to urban markets that offer multiple food choices tend to have a negative effect on per capita harvest amounts. Communities along the road networks harvest less than the communities that are off the road networks. Higher fuel prices have mixed impacts on subsistence harvest amounts. While the increased transport costs may decrease subsistence harvests, costs increase to import foods from otherwise accessible and affordable urban markets. Applicable game management regulations at all levels during, after, or before development have a direct impact on harvest amounts and patterns. The 1970 declaration of bowhead whale as an endangered species criminalized bowhead whale hunting. Summer caribou harvest near Nuiqsut was restricted in the late 1970s. The local government in Arctic Village restricted caribou harvest in 1981 (Pederson and Caulfield 1980). In 1970s the lack of walrus and bowhead in Wainwright caused more hunting for fish and seal, but the total amount of harvest may have stayed the same. Table E-13 shows the list of factors impacting subsistence harvest of caribou and fish.

7.4. Results for Perceived Impacts

SAP Minutes for Caribou

A textual analysis of 13 years of SAP minutes conducted in 2013-2014 revealed that for the NPR-A, caribou and fish were considered at risk from three primary sources of disturbance: air traffic, contamination, and seismic activities. More generally, areas of concern with regards to oil and gas development included erosion, contamination, oil spills, ice roads, air traffic, and seismic activities. This

analysis was reassessed to identify pertinent themes. These themes were used as guidance during the literature review.

Table E-14. Results of co-occurrence analysis of "caribou" with factors perceived to be impacting subsistence harvest of caribou.

Factor	Co-occurrence count
Air Traffic	38
Contamination	3
Erosion	1
Ice Roads	4
Seismic	17
Spills	1
Subsistence	58

"Caribou" was one of the two most commonly occurring categories in the transcripts (N=223). "Caribou" co-occurred with all six of the "areas of concern" which may be easily categorized within the identified CAs for this project. "Caribou" likewise co-occured with "air traffic" (38) and "seismic activities" (17). Unsurprisingly "caribou" co-occurred with "subsistence" (58) reflecting the strong association between these two categories (Table E-14).

The collection of SAP issues and recommendations collected over the course of the 13-year documented period show similar patterns to those identified in the SAP Minutes analysis, which also includes notations on the result/solution of the concerns cited. The document was used to identify concerns relating to caribou, and then tie them to CAs. Of the 182 issues and recommendations listed in the document, twenty-two pertain directly to caribou (Table E-15).

Table E-15. Specific threats to subsistence harvest of caribou.

Threat factor	Co-occurrence count
Energy Development	2
Natural Resource Extraction	8
Transportation and Communication Infrastructure	4
Air Traffic	4
General/unspecified Concern	8

SAP Minutes for Fish

"Fish" was the other commonly occurring category in the dataset (N=339). "Fish" co-occurred with all six of the "areas of concern". "Fish" most frequently co-occurred with "seismic activities" (28) and "air traffic" (19). Unsurprisingly "fish" co-occurred with "subsistence" (51) reflecting the strong association between these two categories. Importantly, "lakes" (60), "rivers" (45), and "creeks" (49) were discussed

with similar frequency (Table E-16), and more so than any other CEs, barring “fish” and “caribou”. This is indicative of a concern not only for the water resources but the subsistence resources living in them as well.

Table E-16. Results of co-occurrence analysis of “fish” with factors perceived to be impacting subsistence harvest of fish.

Factor	Co-occurrence counts			
	Fish: General	Creeks	Lakes	Rivers
Air Traffic	19	5	3	2
Contamination	15	0	3	3
Erosion	3	0	1	3
Ice Roads	9	0	4	1
Seismic	28	0	3	4
Spills	6	1	4	3
Subsistence	51	4	10	9

Of the 182 issues and recommendations listed in the document, twelve pertain directly to fish (Table E-17). Perceived threats to fish were spread equally amongst concerns comprised of energy development (3), natural resource extraction (3), transportation and communication infrastructure (3) and general or unspecified (3). More specific areas of concern included: contamination (2), infrastructure (4), seismic activities (3), pipelines (1), and general/unspecified concerns (as below).

Table E-17. Specific threats to subsistence harvest of fish.

Threat Factor	Co-occurrence count
Energy Development	3
Natural Resource Extraction	3
Transportation and Communication Infrastructure	3
General/unspecified Concern	3

In addition, there were also six references to subsistence practice in general and forty-five references wherein the species of concern is not identified or pertains to an animal other than fish or caribou.

Literature Review

The literature search produced few articles pertinent to the “perceived impacts” of oil and gas activity on the subsistence harvest of caribou. Primary results included material on subsistence harvest numbers, caribou health and articles specifically addressing caribou behavior or health vis a vis

particular oil and gas activities (such as air traffic). In addition, those reports and articles selected for further review were also identified during database searches of ADF&G, BLM, and BOEM.

Document sources utilized in the literature review generally fell into two categories: subsistence harvest reports and subsistence documentation contained within environmental impact statements (EIS), environmental assessments (EAs) and/or findings of no significant impact (FONSI). The major limitation of these types of documents is that although they identify current and past subsistence activities, numbers, and locations, they are rarely designed to take into account the perceptions of subsistence users. For example, one of the most comprehensive of these documents, "Subsistence Mapping of Nuiqsut, Kaktovik, and Barrow" (Braund and Associates 2010) states that "[r]esidents' observations about changes in resource use, abundance, quality, distribution, and migration are a key indicator of changes related to development," and that "[a]although traditional knowledge about resource change is beyond the scope of this study, the study team recommends that future studies include systematic documentation of observed resource changes" (p. 29). A secondary but equally important limitation is that although the author(s) of these documents may have synthesized documentation regarding the perceived impacts of the oil and gas industry on subsistence resources, it is not always clear whether the "perception" is that of the subsistence user or the author.

A complete list of sources used for this exercise is included in the database of literature compiled and delivered as a final product.

Physical and Perceptual Limitations to Access

Participation in subsistence is integral to the lifestyle of people who live on the North Slope, daily and seasonal activities revolve around the availability of particular resources (Brower Jr. and Hepa 1998). Subsistence activities also have a seasonal component, meaning that changes in climate, hydrology, and weather events will influence different subsistence activities more than others. Residents of the North Slope have expressed concern about access disruptions to subsistence areas and resources (Bureau of Land Management 2005).

Ability to access subsistence resources is influenced by both availability of physical access and the abundance and location of the resource. In addition to limitations caused by development, access to land mammals and their harvest are also subject to climate change. Fires, freeze-thaw events, and snow depths all influence caribou availability; with snow depths also influencing physical access by hunters. In addition, changes in the timing of freeze up and breakup have been shown to inhibit the ability of hunters to access caribou (Gustine et al. 2014, Dau 2004, Rattenbury et al. 2009). Both coastal and inland communities are influenced by erosion, which can prevent river and sea access to areas (Brubaker et al. 2014). The ability to travel by snow machine likely will be reduced due to the decreasing frozen season on the tundra in Alaska (Hayes 2013). Changes in season also influence phenology and the timing of production which in turn affect when waterfowl arrive on the North Slope (Sweet et al. 2015).

Anthropogenic activities are likely to influence access and availability to subsistence resources (Lawhead et al. 2006, Reeves et al. 2012). As identified and described earlier in this report from the analysis of the SAP meeting minutes and other documents, air traffic is perceived as the most severe threat to

subsistence harvest. Air and road traffic can spook caribou. Whereas pipelines, if not constructed properly, can influence caribou movements (Lawhead et al. 2006). The most perceived threat related to ground traffic is from seismic exploration activities. While these activities are not actual physical barriers to accessing any part of the study area, strong perceptions of the threat make them physical barriers for subsistence hunters. Pipelines, roads and other infrastructure facilities fragment the habitat and potentially alter migration patterns, thereby creating access issues and availability of subsistence resources.

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8. Parameters for Determining Natural and Anthropogenic Change

MQ AT 1	What parameters can help measure impacts from anthropogenic activities independently of natural cycles and vice-versa?

It is well recognized that most environmental drivers (climate, wildfire, biogeochemistry, etc.) are constantly changing, operating on various time scales, and creating multiple 'stages' of environmental setting. These natural cycles are often the cause of major environmental change operating on relatively short ("flickering switch" from Taylor et al. 1993) to very long timescales (interglacial periods). Thus, it is increasingly important to identify the role human activity has independent of larger natural phenomenon.

Disentangling the impact of anthropogenic activities from natural cycles has been a crux of conservation biology, and ecology in general. The original goal of monitoring cumulative effects came from the recognition that environmental change comes from multiple stressors acting at the same time. However, quantifying the cumulative impact has been extremely difficult for the same reason this arose as a management question: there is no clear answer.

Several studies have been conducted in the region that identify the impacts of anthropogenic activities on wildlife species and other ecological processes, including impacts on nest survival of tundra birds on the arctic coastal plain, arctic fox, and caribou. Although many models have been built to try and isolate the impact of different stressors, there is no standard set of parameters or indicators that have been developed to specifically disentangle the impact of human activity versus natural cycles.

Given the ongoing debate over the role of anthropogenic emissions and activities on climate change, we interpreted this question as only those human activities that occur in the North Slope study area. Using the landscape integrity estimates (see Section F), it is clear that the effect of anthropogenic activities on the broader North Slope ecosystems is very limited. It is safe to assume then that natural cycles can be considered the primary drivers of ecosystem change at the ecoregional-level. With this observation, we suggest that the attributes and indicators (see Section G, H, I, J) tables that have been developed for each CE will be a useful guide for establishing monitoring parameters to help disentangle the impacts from anthropogenic activities and natural cycles. In some cases, CE status includes a weighted impact of different stressors based on the best available literature. This information can help managers identify the most important parameters to measure impacts from anthropogenic versus natural cycles.

Additionally, we suggest using the Cumulative Impacts (CI) model to identify those areas that are most likely to change due to the abiotic (climate, wildfire, permafrost) vs. anthropogenic-driven (development, invasive species) CAs. Strategically designing monitoring procedures to occur in watersheds with all CAs changing, versus those with only abiotic changes, and those with only anthropogenic changes, would help identify the relative impact of the different stressors on local and regional ecosystem resources.

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9. Impacts of Oil and Gas Development on CE Habitats

MQ AT 2	What potential impacts will oil/gas exploration and development have on CE habitat?

Oil and gas development may potentially impact CE habitat through direct loss or fragmentation of habitat from the footprint of associated infrastructure development, including roads, pipelines, drilling pads, and residential facilities, or contamination of habitat through toxic spills. These effects to habitats impact wildlife CEs through direct mortality and displacement, reduced reproductive rates, and creating more suitable conditions for predators. Furthermore, significant effects to wildlife (CEs) and habitat will likely accumulate as industry expands in the future.

Resource extraction and infrastructure development have caused the fragmentation of caribou habitat throughout Alaska. Patch sizes are likely to decrease as development increases. While a previous study in Prudhoe Bay found that caribou cows and calves did not avoid drilling areas (Fancy 1983), more recent studies have found that caribou generally avoid areas of human activity (up to 50 - 95% reduced presence; Vistnes and Nellemann 2008) and can be displaced from preferred calving grounds by human disturbance (Joly and Klein 2011, Wolfe et al. 2000). When caribou cows are displaced from preferred calving areas, their calves are smaller at birth and may not grow as fast or survive as well.

The calving areas and summer habitat of the Central Arctic Herd coincide with industrial development in the North Slope study area. The construction of roads, pipelines, and facilities has changed the spatial distribution patterns of the herd by splitting aggregations to an eastern group and a western group. East-west movement across the developed corridors decreased by at least 90% compared to pre-development observations from the 1970s (Cameron et al. 2005).

While some caribou have occasionally used gravel pads and roads as insect relief areas (Fancy 1983), infrastructure can typically delay or redirect caribou moving towards coastal areas to seek mosquito relief. If displacement from foraging and relief habitats causes energetic stress, then affected cows will likely respond with lower fecundity (Murphy and Lawhead 2000, Vistnes and Nellemann 2008).

Greater white-fronted geese are loyal to breeding and molting sites, which may hinder a population's ability to relocate if breeding or molting habitats are negatively impacted or destroyed by development. All-weather roads, necessitated by a warming climate and shortened ice road season, associated with energy extraction activities could impact Greater white-fronted geese and other waterfowl, especially near important molting areas around Teshekpuk Lake (Liebezeit et al. 2009). Because geese concentrate at pre-nesting and molting sites, the effects of severe but rare local disturbance events, such as oil spills or toxic contamination, will likely have large negative impacts on populations (Schoen and Senner 2002). During years of late snow melt, geese nest on drier upland sites (Ely and Raveling 1984) that are more likely to be restricted by future development. Greater white-fronted geese and cliff nesting raptors are sensitive to machine noise (Barry and Spencer 1976 *in* Ely and Dzubin 1994) and aircraft disturbance (Derksen et al. 1979) which can result in habitat avoidance and nest abandonment (Ritchie et al. 1997, Palmer et al. 1988).

These are just a few specific examples of how oil and gas activities impact wildlife habitat. For more in-depth discussion, please see Section H. Terrestrial Fine-Filter Conservation Elements.

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10. Contaminants

MQ AT 3	What additional contaminants baseline data are needed for fish, birds, marine and terrestrial species, particularly those that affect the health and safety of subsistence foods?

We focused on synthesizing baseline information related to contaminants of concern for marine and terrestrial organisms within the North Slope study area, with emphasis on subsistence species. This information will help with current and future contaminant monitoring and management programs. For this MQ, we focused on the contaminants of greatest concern to humans through use of subsistence resources to include: heavy metals, petroleum products (PAHs), persistent organic pollutants (POPs), and radionuclides. Data on most frequently harvested species per community were obtained from Alaska Department of Fish and Game (ADF&G) household subsistence harvest surveys. For this review, we included the five most commonly harvested species per community (Table E-18). We provide a brief overview of these species, contaminants of most concern to subsistence users, and a detailed discussion on the baseline contaminants data that exists for each subsistence species.

Terrestrial and freshwater species that are frequently harvested in communities within the North Slope study area include: caribou, greater-white fronted geese, Dolly Varden, broad whitefish, chum salmon, grayling, and burbot (Table E-18). Marine mammals comprise a significant proportion of the harvest of subsistence resources for communities within the North Slope study area, especially coastal communities, and include: bowhead whale, beluga whale, pacific walrus, bearded seal, ringed seal, spotted seal, and polar bear (Table E-18).

Table E-18. Top five most harvested subsistence species (taken from Sum of Estimated Pounds Harvested not in the order of amount of harvest) in North Slope communities. Data for missing North Slope communities are not available. These data were obtained from ADF&G.

Species	Barrow	Kaktovik	Kivalina	Noatak	Nuiqsut	Point Lay	Wainwright	Anaktuvuk Pass
Terrestrial and fresh water species								
Caribou	x	x	x	x	x	x	x	x
Greater white-fronted goose	x	x	x	x	x	x	x	x
Grayling	x	x	x	x	x	x	x	x
Dolly Varden/Char		x				x		x
Broad whitefish	x				x			x
Burbot	x		x	x	x			

Chum salmon			x	x		x		
Marine mammals								
Bowhead whale	x	x			x	x	x	
Walrus	x		x	x		x	x	
Bearded seal	x	x	x	x	x	x	x	
Ringed seal	x	x	x	x	x	x	x	
Polar Bear	x	x			x		x	
Beluga			x	x	x	x		
Spotted seal		x	x	x				

10.1. Current Status of Contaminants

Studies on contaminants in the region cover spills from industrial activities, general living of the population, and presence of contaminants in natural food sources. This study was limited to identifying contaminants on the ground as part of the human footprint in the North Slope study area. The Department of Environmental Conservation of the State of Alaska tracks contaminated sites and monitors clean up activity. Figure E-27 shows contaminated sites identified in the North Slope study area.

Every community is identified as a contaminated site. This is largely owing to the presence of bulk fuel storage tanks in each community for local supply needs through the year. Several spills in the Prudhoe Bay area are petroleum products associated with the oil and gas industry. A total of 141 contaminated sites are identified in the region.

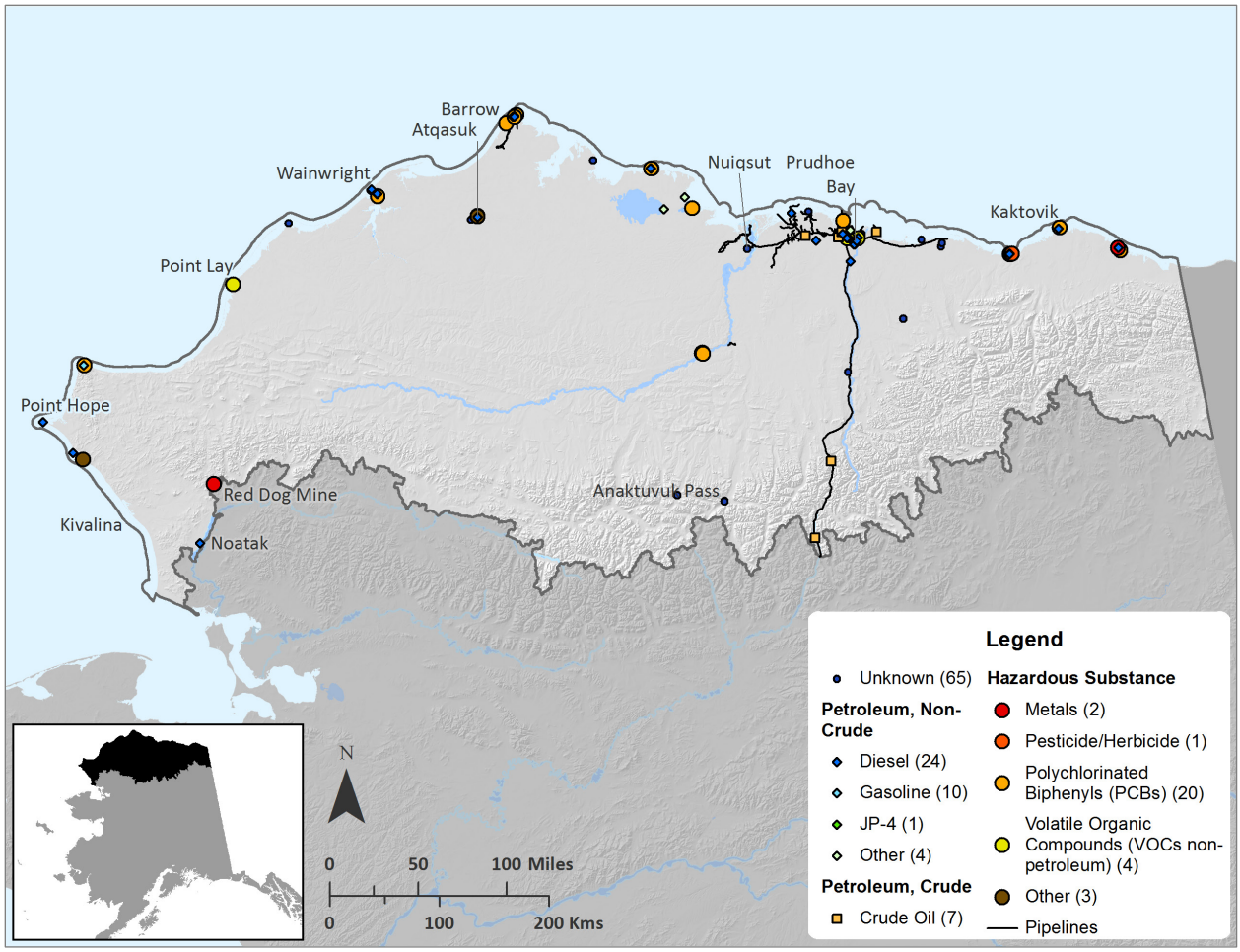

Figure E-27. Sites with known contaminants in the North Slope study area.

10.2. Overview of Contaminants of Concern

Petroleum Products with Emphasis on Polycyclic aromatic Hydrocarbons (PAHs)

PAHs are a group of organic contaminants that form from the incomplete combustion of hydrocarbons, such as coal and gasoline. PAHs are an environmental concern because they are toxic to aquatic life and because several are suspected human carcinogens. Pollution from oilfield activities is a major threat to habitats within the North Slope study area, and exposure to petroleum oil from natural sources such as seeps or coal bed areas are also a concern for fish and wildlife. Regardless of the source, establishing baseline levels in subsistence species is important.

Terrestrial wildlife may be exposed to PAHs, but the biggest concern is for aquatic fish and waterbirds. PAHs do not accumulate in tissues, thus monitoring for these contaminants must happen within a short window of time after exposure (about 2 weeks) or when there is longer-term chronic exposure as in more highly polluted areas. PAHs are a concern for subsistence users because direct ingestion of tissues

contaminated by PAHs are possible, in addition to the effects that exposure to PAHs could have to wildlife including carcinogenesis, endocrine disruption and dermal irritation (Eisler 1987).

Heavy Metals

Heavy metals, including mercury, cadmium, selenium, arsenic, copper, nickel, and lead are of greatest concern to subsistence species and can be attributed to both local natural sources and anthropogenic activities, as well as long-range transport. Some of these heavy metals provide essential micronutrients (e.g., selenium), while others have no known biological benefit and are considered toxic to biota (e.g., mercury). All metals can have serious negative health consequences at elevated levels. Additionally, heavy metals are a concern for subsistence species because they can bioaccumulate within individuals and biomagnify through food webs. Thus, humans that rely on subsistence species may be exposed to greater levels of toxic metals due to exposure through diet. Heavy metals can affect both terrestrial and aquatic wildlife and have been documented in several important subsistence species within the North Slope study area.

Radionuclides

Radioactivity is a concern for subsistence species within the North Slope study area because contamination within plants and animals can persist for long periods and can lead to high exposure rates to subsistence users (AMAP 2010). Fallout from nuclear weapons tests is the primary source of contamination to arctic regions, but nuclear fuel reprocessing plants are additional anthropogenic sources of radionuclides. The Chernobyl accident in 1986 and more recently the 2011 partial nuclear reactor failures in Fukushima are a concern as potential sources of radionuclide contamination to arctic communities. Though levels of this contaminant have been declining over the last couple of decades, potential for contamination and movement through food webs still exists and may pose a health threat to humans. Cesium-137 can accumulate in animal muscle and is the most commonly studied radionuclide. Thus, we focused our review on baseline Cesium-137 data.

Persistent Organic Pollutants (POPs)

POPs are organic compounds that are resistant to environmental degradation. For this reason, they often persist in the environment, are capable of long-range transport, bioaccumulate in human and animal tissue, and biomagnify in food chainshttp://en.wikipedia.org/wiki/Persistent_organic_pollutant - cite_note-ritter-1. Most POPs are the result of anthropogenic sources (e.g., pesticides, pharmaceuticals, and solvents), but POPs also occur naturally in very low levels from volcanic activity and fires. Some of the more common and well-known POPs include polychlorinated biphenyl (PCB), dichlorodiphenyltrichloroethane (DDT), mirex, and dioxins. Similar to heavy metals, POPs have the potential to bioaccumulate within individuals and biomagnify through food webs, thus these chemicals pose a risk to wildlife and humans that rely on wildlife for subsistence.

10.3. Subsistence Species and Baseline Contaminants

Caribou (*Rangifer tarandus*)

The summer diet of caribou consists largely of grasses, sedges, twigs, leaves, and mushrooms, which generally tend to have lower levels of contaminates. The winter diet is composed mainly of lichens, which are known to accumulate contaminants from air and precipitation, especially radionuclides (AMAP 2010).

Baseline data for most heavy metals of concern have been collected for caribou within the North Slope study area (Table E-19). Though baseline levels of cadmium in caribou tissues within the North Slope study area exist, further study of this contaminant may be warranted. Cadmium is a particular concern for subsistence users given that relatively high levels were documented in caribou from communities sampled within the North Slope study area (O'Hara et al. 2003). Studies from other regions have also documented similarly high levels (AMAP 1998, Aastrup et al., 2000, Elkin, 2001; Odsjö, 2002). Although O'Hara et al. 2003 documented relatively high levels of cadmium in caribou tissues from areas within the North Slope study area, they did not find corresponding histological effects and advise caution when interpreting these data in the context of subsistence use. For these reasons, further studies on exposure rates of subsistence users to cadmium in caribou tissues and the potential impacts on human health may be warranted. Similarly, iron levels in caribou from Cape Thompson, Barrow, and Point Hope (O'Hara et al. 2003) were relatively high and may warrant further data collection.

Baseline data on radionuclides for caribou within the North Slope study area are lacking. Other arctic countries including Norway, Greenland, Iceland, and Russia have documented relatively high levels of radionuclides in caribou (AMAP 2004, MacDonald et al. 2007, AMAP 2010). Given that these other arctic countries documented relatively high levels of radionuclides, and caribou are an important subsistence species in every community included in this review (Table E-19) baseline data on caribou radionuclide data are needed.

Baseline data for POPs, particularly DDTs, and PCBs are lacking. Braune et al. (1999) found a decreasing trend in PCB levels in caribou from eastern Canada to western Canada. Although levels were found to be low in caribou from Canada, there is no baseline data for the North slope study area. The North Slope Borough 2006 reported collection of baseline data for POPs in caribou within the North Slope study area, but these data are currently not publicly available.

Greater White-Fronted Goose *(Anser albifrons)*

The Greater white-fronted goose is primarily a grazer and feeds on terrestrial and aquatic sedges and grasses, berries (e.g., crowberry), and aquatic insects and their larvae (Ely and Dzubin 1994, Rothschild and Duffy 2005).

Baseline data for all contaminants are lacking for Greater-white fronted goose within the North Slope study area (Table E-19). Given its importance as a subsistence species in communities throughout the

North Slope study area, in addition to its aquatic foraging habits, baseline data for heavy metals and PAH's in particular are recommended.

Rothschild and Duffy (2005) reported low levels of mercury in tissues of Greater-white fronted goose from western Alaska. The diet of Greater-white fronted goose is similar between these regions, but point sources of mercury contamination may differ. Thus, baseline data should be collected to confirm that Greater white-fronted goose within the North Slope study area also have low levels of mercury. Similarly, Braune et al. (1999) found relatively low levels of cadmium, mercury, selenium, and radionuclides for other goose species in Canada.

Dolly Varden (Salvelinus malma)

Dolly Varden occur within the North Slope study area as lake-resident, stream resident, and anadromous populations although they are considered to be predominantly anadromous within the North Slope study area. Larger juvenile and adult fish consume salmon fry, salmon eggs, invertebrates, and small fish. Juveniles feed primarily on macroinvertebrates. Due to their largely piscivorous diet, Dolly Varden may be more susceptible to exposure to contaminants as well as biomagnification of contaminants.

Baseline data for many of the heavy metals of concern exist for this species (Table E-19). However, we are not aware of any studies that have looked at radionuclides, mercury, POPs, or PAHs within Dolly Varden sampled from the North Slope study area. Low levels of mercury have been reported in Dolly Varden from Canada (Braune et al. 1999), but baseline levels from Dolly Varden within the North Slope study area have not been reported.

Broad Whitefish (*Coregonus nasus*)

Broad whitefish are bottom feeders that primarily feed on snails, bivalves and other mollusks, as well as aquatic insect larvae. Due to their lower trophic level diet, their exposure to contaminants especially, POPs and heavy metals, is assumed to be low. Most contaminants of concern have been studied at baseline levels for broad whitefish except radionuclides (Table E-19). All contaminants studied have been reported at relatively low levels. Studies in Canada also found relatively low levels of PCBs in broad whitefish (Lockart et al. 1993).

Chum Salmon (Oncorhynchus keta)

Chum salmon only feed in freshwater during a short period of time as juveniles (2-3 weeks). As adults they feed at sea on copepods and mollusks and a variety of fish. Thus, their piscivorous diet at sea makes them more susceptible to exposure to contaminants as well as biomagnification of contaminants.

Most contaminants of concern have been studied at least at baseline levels for chum salmon within the North Slope study area, except radionuclides, POPs, and PAHs (Table E-19). Most contaminates studied are reported at relatively low levels. Additionally, relatively low levels of PCBs, DDTs, and heavy metals (specific metals not reported) were reported for chum salmon from the Yukon-Kuskokwim region (USFWS 2004). Levels of POPs for chum salmon within the North Slope study area may differ from chum

salmon sampled within the Kuskokwim region. Thus baseline levels of these contaminants are recommended. Similarly, baseline levels of radionuclides and PAHs in chum salmon within the North Slope study area are recommended.

Grayling (Thymallus thymallus)

Arctic grayling are considered generalists, but primarily consume macroinvertebrates. They will also eat salmon eggs and out-migrating salmon smolts. Most contaminants of concern have been studied at least at baseline levels for Arctic grayling, except radionuclides and mercury (Table E-19). Most contaminates studied are reported at relatively low levels and do not appear to pose a risk to subsistence users. Furthermore, extensive studies elsewhere in Alaska have documented relatively low levels of mercury (Jewett and Duffy 2007, Jewett et al. 2003, Duffy et al. 1999, Mueller and Matz 2002, Synder-Conn et al. 1992), and PCBs (Mueller and Matz 2000) in grayling tissues. Thus, it is likely that grayling within the North Slope study area also have low levels of mercury. However, to confirm this assumption, baseline mercury tissue data should be collected. We are not aware of any studies within Alaska that have looked at radionuclides in grayling tissues and baseline data are recommended.

Burbot (Lota lota)

Burbot are a long-lived freshwater fish found in deep lakes and rivers. Juveniles feed on insects for the first few years, and then shift to a mostly piscivorous diet as adults (Morrow 1980). Because they feed higher on the food chain, burbot are expected to have higher levels of contaminants.

Most contaminants of concern have been studied at least at baseline levels, except mercury, and radionuclides (Table E-19). PCB and DDT levels in burbot, collected near Nuquist and Umiat slough, have been documented at relatively high levels. As a consequence, recommendations on consumption levels have been suggested (Hanns 2006). In Canada, burbot PCB and DDT levels were also relatively high (Braune et al. 1999, Kidd et al. 1995). Given these high levels, further study of burbot PCBs and DDT from other areas within the North Slope study area that are regularly used by subsistence users may be warranted.

Mercury levels in burbot from elsewhere in Alaska (Jewett and Duffy 2007, Duffy et al. 1999, Hinck et al. 2006) and Canada (Braune et al. 1999) have been reported at relatively high levels. Hinck et al. (2006) found that burbot from the Yukon River in Alaska had mercury levels high enough to warrant concern for piscivorous wildlife. Because burbot feed higher on the food chain, are more susceptible to accumulating contaminants and because they represent an important subsistence resource, it should be a priority to obtain baseline levels of this contaminant within the North Slope study area.

Bowhead whale (Balaena mysticetus)

All contaminants of concern have been studied for bowhead whales and most contaminants have been documented at low levels (Table E-19). For an excellent review of knowledge about contaminants in bowhead whale tissues see O'Hara et al. (2004).

Beluga whale (*Delphinapterus leucas*)

Most contaminants of concern have been studied for beluga whales, except for PAHs (Table E-19). Mercury, cadmium, and selenium were reported at intermediate to relatively high levels, but are consistent with other studies in Alaska and other arctic regions and do not appear to warrant concern for subsistence users (Becker et al. 1995, Woshner et al.2001, Wagemann et al. 1996, Koeman et al. 1973, Dietz et al., 1990). Baseline data on PAHs in beluga whale tissues are recommended.

Pacific Walrus (Odobenus rosmarus divergens)

Most contaminants of concern have been studied for Pacific walrus, except for PAHs (Table E-19). Robards 2009 provide a thorough review of contaminant studies in Pacific walrus. Concentrations of most contaminants studied are relatively low. However, high levels of cadmium have been reported in walrus tissues (Taylor et al. 1989, Lipscomb 1995), though no histopathological effects in Pacific walrus tissues were reported (Lipscomb 1995). Similarly, Taylor et al. (1989) reported relatively high levels of mercury and recommend further study of both cadmium and mercury to better understand the effects of these contaminants on walrus populations and subsistence users.

Bearded seal (Erignathus barbatus)

Most contaminants of concern have been studied for bearded seals, except PAHs (Table E-19), and most contaminants have been documented at relatively low levels. However, concentrations of cadmium and mercury from bearded seals collected near Barrow, Wainwright, and Kaktovik where relatively high (Quakenbush et al. 2011) compared to bearded seals collected near Nome (Mackey et al. 1996), but lower than another study that sampled liver of bearded seals near Barrow (Dehn et al. 2006). Bearded seals from northern Alaska have especially low levels of POPs when compared to seals from other arctic countries (Weis and Muir 1997, Nakata et al. 1998).

Ringed seal (*Pusa hispida*)

Most contaminants of concern have been studied for ringed seals, except PAHs (Table E-19), and most contaminants have been documented at relatively low levels.

Spotted seal (*Phoca largha*)

Most contaminants of concern have been studied for spotted seals, except PAHs (Table E-19), and most contaminants have been documented at relatively low levels.

Polar bear (Ursus maritimus)

Most contaminants of concern have been studied for polar bears, except PAHs (Table E-19), and most contaminants have been documented at relatively low levels.

Table E-19. Baseline data collection for select contaminants and subsistence species within the North Slope study area.

Species	Contaminant	Baseline Data (Y/N)	Reference
Mammals			
Caribou	Radionuclides	N	Robillard et al. 2002
	Cadmium	Yes	O'Hara et al. 2003
	Arsenic	Yes	O'Hara et al. 2003
	Copper	Yes	O'Hara et al. 2003
	Lead	Yes	O'Hara et al. 2003
	Mercury	Yes	Gerlach et al. 2006
	Selenium	No	
	POPs	No	
	PAHs	No	
Birds			
Greater White-Fronted Goose	Radionuclides	No	
	Cadmium	No	
	Arsenic	No	
	Copper	No	
	Lead	No	
	Mercury	No	
	Selenium	No	
	POPs	No	
	PAHs	No	
Fish			
Dolly Varden	Radionuclides	No	
	Cadmium	Yes	DEC Fish Monitoring Program 2011
	Arsenic	Yes	DEC Fish Monitoring Program 2011
	Copper	Yes	DEC Fish Monitoring Program 2011
	Lead	Yes	DEC Fish Monitoring Program 2011
	Mercury	No	
	Selenium	Yes	DEC Fish Monitoring Program 2011
	POPs	No	
	PAHs	No	
Broad Whitefish	Radionuclides	No	
	Cadmium	Yes	DEC Fish Monitoring Program 2011; Spies et al. 2003

Species	Contaminant	Baseline Data (Y/N)	Reference
	Arsenic	Yes	DEC Fish Monitoring Program 2011; Spies et al. 2003
	Copper	Yes	DEC Fish Monitoring Program 2011; Spies et al. 2003
	Lead	Yes	DEC Fish Monitoring Program 2011; Spies et al. 2003
	Mercury	Yes	Jewett and Duffy 2007; Spies et al. 2003
	Selenium	Yes	DEC Fish Monitoring Program 2011; Spies et al. 2003
	POPs	Yes	Hanns 2006; Spies et al. 2003
	PAHs	Yes	Wetzel and Mercurio 2007; Spies et al. 2003
Chum	Radionuclides	No	
	Cadmium	Yes	DEC Fish Monitoring Program 2011
	Arsenic	Yes	DEC Fish Monitoring Program 2011
	Copper	Yes	DEC Fish Monitoring Program 2011
	Lead	Yes	DEC Fish Monitoring Program 2011
	Mercury	Yes	Jewett and Duffy 2007
	Selenium	Yes	DEC Fish Monitoring Program 2011
	POPs	No	
	PAHs	No	
Arctic grayling	Radionuclides	No	
	Cadmium	Yes	DEC Fish Monitoring Program 2011
	Arsenic	Yes	DEC Fish Monitoring Program 2011; Mueller and Matz 2002
	Copper	Yes	DEC Fish Monitoring Program 2011
	Lead	Yes	DEC Fish Monitoring Program 2011
	Mercury	Yes	Jewett and Duffy 2007; AMAP 2011
	Selenium	Yes	DEC Fish Monitoring Program 2011
	POPs	Yes	Hanns 2006; Wilson et al. 1995; Verbrugge and Middaugh 2004
	PAHs	Yes	Wetzel and Mercurio 2007
Burbot	Radionuclides	No	
	Cadmium	Yes	DEC Fish Monitoring Program 2011
	Arsenic	Yes	DEC Fish Monitoring Program 2011
	Copper	Yes	DEC Fish Monitoring Program 2011
	Lead	Yes	DEC Fish Monitoring Program 2011
	Mercury	No	Jewett and Duffy 2007; AMAP 2011
	Selenium	Yes	DEC Fish Monitoring Program 2011

Species	Contaminant	Baseline Data (Y/N)	Reference
	POPs	Yes	Hanns 2006; Meuller and Matz 2000
	PAHs	Yes	Wetzel and Mercurio 2007
Marine mammals			
Beluga whale	Radionuclides	Yes	Cooper et al. 2000
	Cadmium	Yes	Dehn et al. 2006
	Arsenic	Yes	Dehn et al. 2006
	Copper	Yes	Dehn et al. 2006
	Lead	Yes	Dehn et al. 2006
	Mercury	Yes	Dehn et al. 2006; Woshner et al. 2001
	Selenium	Yes	Dehn et al. 2006
	POPs	Yes	O'Hara et al. 2004; Hoekstra et al. 2003
	PAHs	No	
Pacific walrus	Radionuclides	Yes	Hamilton et al. 2008
	Cadmium	Yes	Taylor et al. 1989; Lipscomb 1995
	Arsenic	Yes	Taylor et al. 1989
	Copper	No	
	Lead	Yes	Taylor et al. 1989
	Mercury	Yes	Taylor et al. 1989
	Selenium	Yes	Taylor et al. 1989
	POPs	Yes	Cooper et al. 2000, Taylor et al. 1989; Seagars and Garlich-Miller 2001
	PAHs	No	
Bearded seal	Radionuclides	Yes	Cooper et al. 2000; Hamilton et al. 2005; Hamilton et al. 2008
	Cadmium	Yes	Quakenbush et al. 2011; Dehn et al. 2005; Mackey et al. 1996
	Arsenic	Yes	Quakenbush et al. 2011
	Copper	Yes	Dehn et al. 2005
	Lead	Yes	Quakenbush et al. 2011
	Mercury	Yes	Quakenbush et al. 2011; Dehn et al. 2005
	Selenium	Yes	Dehn et al. 2005
	POPs	Yes	Quakenbush et al. 2011; Hoekstra et al. 2003; Krahn et al. 1997
	PAHs	No	
Ringed seal	Radionuclides	Yes	Cooper et al. 2000

Species	Contaminant	Baseline Data (Y/N)	Reference
	Cadmium	Yes	AMAP 2011; Dehn et al. 2005; Becker et al. 1995; Woshner et al. 2001
	Arsenic	Yes	Woshner et al. 2001
	Copper	Yes	Dehn et al. 2005; Woshner et al. 2001
	Lead	Yes	Woshner et al. 2001
	Mercury	Yes	Dehn et al. 2005; Woshner et al. 2001
	Selenium	Yes	Dehn et al. 2005; Woshner et al. 2001
	POPs	Yes	Kucklick et al. 2002; Krahn et al. 1997
	PAHs	No	
Spotted Seal	Radionuclides	Yes	Whoshner et al. 2001
	Cadmium	Yes	Moses et al. 2009; Dehn et al. 2005
	Arsenic	Yes	Moses et al. 2009
	Copper	Yes	Whoshner et al. 2001; Dehn et al. 2005; Moses et al. 2009
	Lead	Yes	Moses et al. 2009; Quakenbush et al. 2011
	Mercury	Yes	Moses et al. 2009; Dehn et al. 2005
	Selenium	Yes	Dehn et al. 2005
	POPs	Yes	Moses et al. 2009
	PAHs	No	
Polar Bear	Radionuclides	Yes	Cooper et al. 2000
	Cadmium	Yes	Evans 2004; Woshner et al. 2001; Kannan et al. 2007
	Arsenic	Yes	Woshner et al. 2001
	Copper	Yes	Evans 2004; Woshner et al. 2001; Kannan et al. 2007
	Lead	Yes	Evans 2004; Woshner et al. 2001; Kannan et al. 2007
	Mercury	Yes	Evans 2004; Woshner et al. 2001; Kannan et al. 2007
	Selenium	Yes	Evans 2004; Woshner et al. 2001
	POPs	Yes	Bentzen et al. 2008; Kucklick et al. 2002; Kannan et al. 2005; Verreault et al. 2005
	PAHs	No	

10.4. Conclusion

Other potential contaminants of concern include phthalates, plutonium, polybrominated diphenyl ethers (PBDEs) and brominated compounds. In general, for species that have some baseline contaminants data, there are large spatial and temporal gaps. While studies show that many of these

contaminants are attributed to point sources (military activities, oil and gas industry, infrastructure, etc), recent focus on long-range transport of contaminants to Arctic environments is a growing concern and should be studied to better understand sources of these contaminants. Most subsistence species covered for this review have at least some baseline contaminants data. However, we are not aware of any contaminants data related to greater-white fronted goose within the study area. In general, most species were lacking baseline data on PAHs. Baseline data for all these contaminants provides information on contaminant levels in these important subsistence species and may serve as a reference point for future changes. Although the focus of this MQ was on subsistence species and thus the potential impact on human health, the biological implications for the animals themselves is relatively unknown and should also be a point of further study.

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11. Air Quality

MQ AP 2	How are oil, gas, and mineral development on the North Slope impacting near- and far-field air quality, with particular emphasis on communities and "sensitive class 2" areas such as Arctic National Wildlife Refuge, Gates of the Arctic National Park, and Noatak National Preserve?

The BLM modeled air quality for the 2012 Integrated Activity Plan/Environmental Impact Statement (IAP/EIS) for NPR-A based on meteorological data and emissions scenarios (BLM 2012). Input data was spatially limited and therefore the outputs had high uncertainty. However, the results indicated that oilfield development could fail to meet both Clean Air Act (CAA) ambient air standards and air quality related value standards in National Parks and National Wildlife Refuges hundreds of miles away. Further air quality modeling is needed to determine potential effects of increased oil and gas extraction on air quality in the North Slope study area and surrounding lands.

11.1. Methods

MQ AP 2 is a data gap and requires extensive modeling to be answered. **This section does not provide any further information directly related to MQ AP 2**, as it is beyond the scope of the REA. No spatial or mathematical modeling was conducted for this question nor is the question explored by literature review. At the request of BLM, the remainder of this section is a description of factors and processes affecting air quality in the North Slope study area.

A conceptual model of factors affecting air quality in the North Slope study area was developed. This conceptual model is explained by the brief, introductory literature review provided in the text below. A database of existing literature and publicly available datasets related to air quality and air quality modeling on the North Slope was provided to BLM to help land managers review available information, data, and tools for future modelling efforts aimed at exploring MQ AP 2.

11.1. Processes Affecting Air Quality on the North Slope

The conceptual model below (Figure E-28) is a general summary of processes affecting air quality in the North Slope study area. The model focuses on emissions sources, meteorological influences on transport and diffusion, chemical transformation of emissions, and contaminant fate.

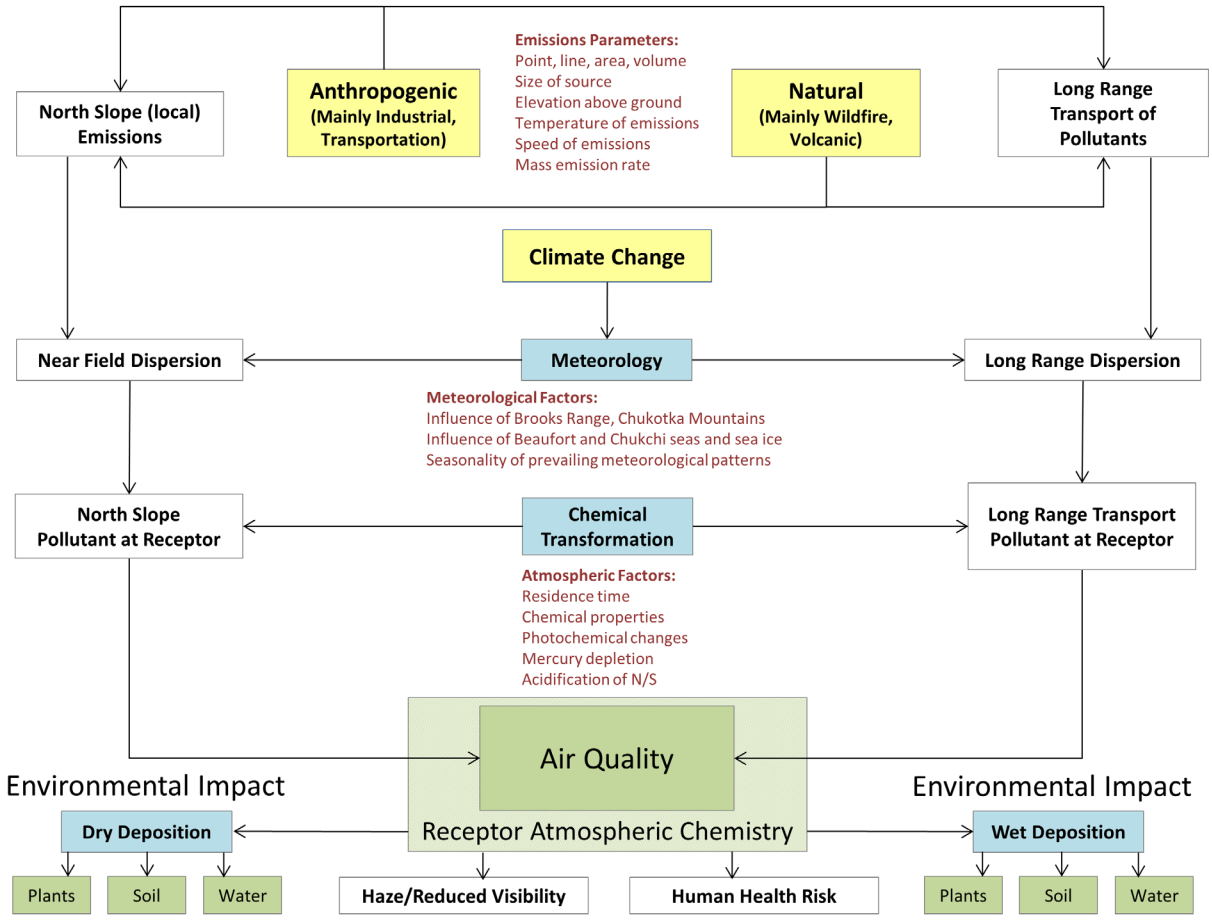

Figure E-28. Conceptual model for air quality in the North Slope study area.

Emissions Sources

Emission sources of airborne pollutants and contaminants are either anthropogenic in origin or natural in origin. Anthropogenic emissions are determined by economy, population sizes, technology, land use plans, and emissions reduction strategies. In the North Slope study area, industrial activities and transportation to these activities are the primary sources of emissions (Roe et al. 2007). Currently, the majority of industrial emissions sources are located in the Prudhoe Bay region. Additional industrial development is approved at the Greater Moose's Tooth Unit 1 of NPR-A. The medium- and high-development scenarios for landscape condition suggest that industrial activity, and therefore emissions, are likely to increase in the North Slope study area by 2040. Increase in industrial activity will likely be compounded by an associated increase in transportation. Additional, but less significant, emissions are generated by rural communities (Delaney and Dulla 2007).

Natural emissions depend on fuel loads and burn frequencies for wildfires or are stochastic for volcanic activity. Fires within and outside Alaska are significant sources of emissions in the North Slope study area (Larkin et al. 2012, Warneke 2009). Fire frequency within the North Slope study area has historically been low and is projected to remain low in the near-term and long-term futures (see Section C. Abiotic

Change Agents); however, fire frequency elsewhere in Alaska is expected in increase in the next 50 years (Fresco et al. 2014). Smoke from wildfires originating in the contiguous U.S. and Canada can be transported to the North Slope study area given proper atmospheric conditions (Figure E-29). Future increases in fire frequency in Alaska south of the Brooks Range, Canada, and the contiguous U.S. will reduce air quality in the North Slope study area. Biotic emissions of Environmental Protection Agency (EPA) criteria pollutants have also been documented in the Arctic (*e.g.* Sharma et al. 2012).

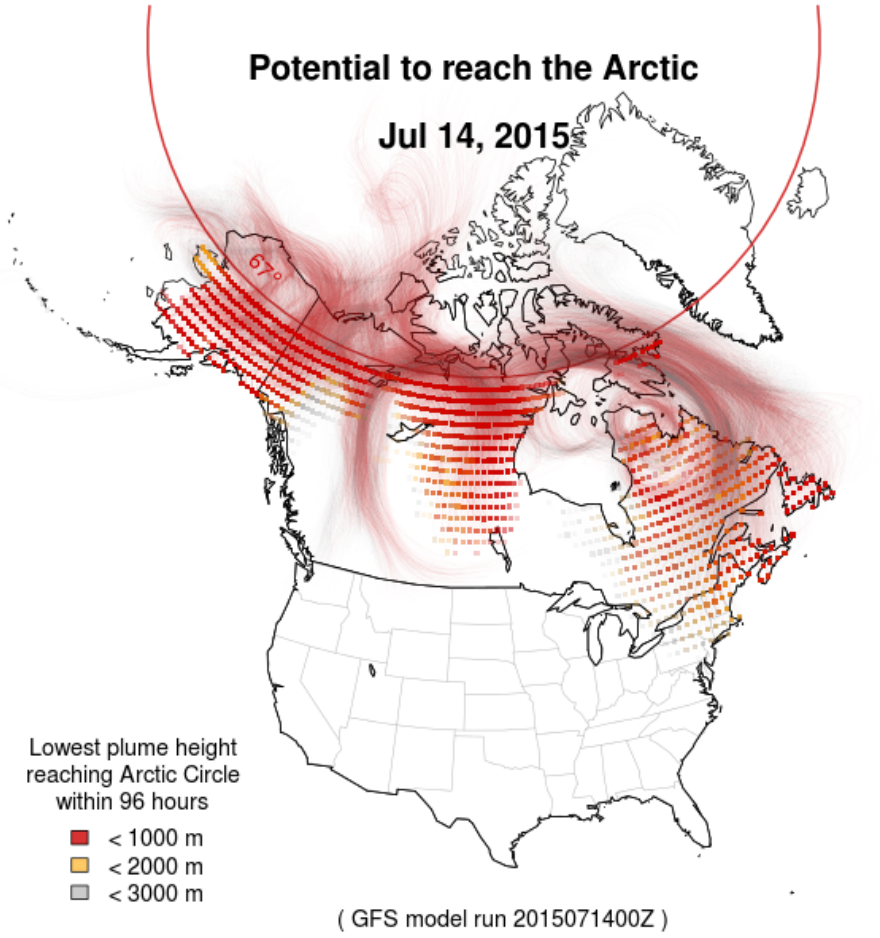

Figure E-29. Daily Arctic transport forecast showing potential for atmospheric transportation of smoke from wildfires to the Arctic (available from **http://www.airfire.org/**).

Particulate material, usually in the form of dust from roads, also affects air quality in the North Slope study area. The prevalence of dirt roads and ATVs in communities contributes to increased airborne dust locally (ADEC 2011). Traffic along the dirt portions of the Dalton Highway increases airborne dust along the highway corridor (see Section G. Terrestrial Coarse-Filter Conservation Elements for discussion of impacts on vegetation).

Both anthropogenic and natural emissions are treated by dispersion models as point, line, area, or volume sources. The source geometry is an important modeling consideration, as well as source

strength (emission rate), release height, and exit temperature and velocity (influence buoyancy). The temporal pattern of emission is another important factor considered by dispersion models.

Meteorology

The mechanics of dispersion of near-field emissions and long-range emissions that reach the study area are determined by the prevailing meteorological patterns of the region. The North Slope study area includes both the polar maritime climate subtype along the coast, which is strongly influenced by the Beaufort and Chukchi seas, and the continental maritime subtype in and towards the Brooks Range, which is strongly influenced by the large land mass of North America (Wilcox and Velkamp 2007).

In winter, prevailing winds blow onshore from the ocean. Temperatures are cold, and storms and temperature inversions are common. In summer months, the Brooks Range and Chukotka Mountains generate seaward winds. While the coastal plain is largely flat, meteorological patterns within the Brooks Range are substantially altered by the extreme topographic texture. Even within individual ecoregions, meteorological patterns vary. For example, the Brooks Range exerts a stronger influence over the nearshore weather of the northeastern Beaufort Coastal Plain than that of the northwestern Beaufort Coastal Plain because of its greater proximity on the eastern side. Onshore winds become more dominant to the west and north (Wilcox and Velkamp 2007).

During the ice-free season for the Beaufort and Chukchi seas, pollutants can concentrate at ground level from the process of coastal fumigation. The coastal thermal internal boundary layer forms during daylight hours because of the temperature difference between the water and land. Offshore pollutants in a stable air layer are transported onshore and encounter the coastal thermal internal boundary layer, which forces the pollutants to mix downwards to ground level. As a result, the surface concentrations of pollutants increase (Luhar 2002). From November to early June, the Beaufort and Chukchi seas freeze over (MACTEC 2011). The coastal fumigation process does not occur in winter while the seas are frozen; thus if the duration of the sea ice decreases (see Section C. Abiotic Change Agents) in the future then the length of time during which coastal fumigation can occur would be expected to increase.

Long-range transport potential to the North Slope is influenced by the release height of the emissions and the timing of emissions in relation to meteorological interactions at circumarctic or trans/intercontinental scales (Larkin et al. 2012). For example, wildfires in Central Asia have been documented to have air quality impacts on the Arctic in Alaska (Warneke 2009). Air quality in the North Slope study area is therefore significantly influenced by emissions outside the region.

Chemical Transformation

The chemicals released at emissions sources are often volatile and react with other chemicals while in residence in the atmosphere. Gaseous forms of mercury (Hg), when transported to the Arctic, are photochemically oxidized into a form that precipitates and accumulates in the snowpack. This results in a flush of mercury when the snow melts in spring and early summer (Lindberg et al. 2002). Nitrates and sulfates are also commonly transformed while in the atmosphere. Sulfuric oxides (SO_x) eventually

convert to sulfuric acid via oxidation pathways. Nitric oxides participate in ozone formation through photochemical reactions with reactive volatile organic compounds.

Impacts

Impairment of air quality lowers visibility distance and can cause, or aggravate, adverse human health conditions. Increased oil and gas extraction activity is likely to cause episodic events of decreased air quality near oil field facilities. This may cause a subsequent decrease in air quality affecting people (e.g. at subsistence camps). A reduction in air quality in the North Slope study area could have health consequences such as a resulting increase in rates of pulmonary disease. Inupiat populations have high baseline rates of pulmonary disease (Wernham 2007), making them especially sensitive.

11.2. Limitations

Air quality monitoring data within the North Slope study area are sparse due to the high cost and difficult logistics of monitoring air quality in Arctic Alaska. A BLM-maintained air quality monitoring station was installed at Inigok in 2014 and will be the first permanent, public air quality monitoring station in the study area. Other air quality monitoring in the study area has been conducted by private industries associated with oil and gas extraction, e.g., Nuiqsut monitoring site (maintained by ConocoPhillips). Public air quality monitoring data useful for the North Slope study area currently exist only for Bettles (originally located at Ambler) just south of the study area boundary. The general lack of monitoring hinders accurate air quality modeling in the region. Additional monitoring sites, especially arranged along terrain gradients such as elevational transects, would be beneficial to a better understanding of air quality issues in the study area.

Existing meteorological data are also sparse within the North Slope study area. There is only one upper air meteorological station within the study area, at Point Barrow. Upper air stations provide the vertical profiles necessary to prepare surface meteorological data for input to air quality models. Surface meteorological stations are also limited and often do not contain full data for all years of operation. The Bureau of Ocean Energy Management (BOEM) has developed a modeled meteorological dataset, the Beaufort and Chukchi Sea Mesoscale Meteorological dataset, to serve as a meteorological input to some of the dispersion models. However, the accuracy of this modeled dataset is limited by the paucity of observational data. Additional upper air and surface meteorological stations, especially in the northern Brooks Range and eastern half of the study area, are necessary for more complete spatial coverage of meteorological conditions across the study area.

Existing air dispersion models vary in their purpose, scale, resolution, inputs, computing requirements, and cost. Not all existing meteorological and emissions datasets include the necessary parameters required for input to various existing models.

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