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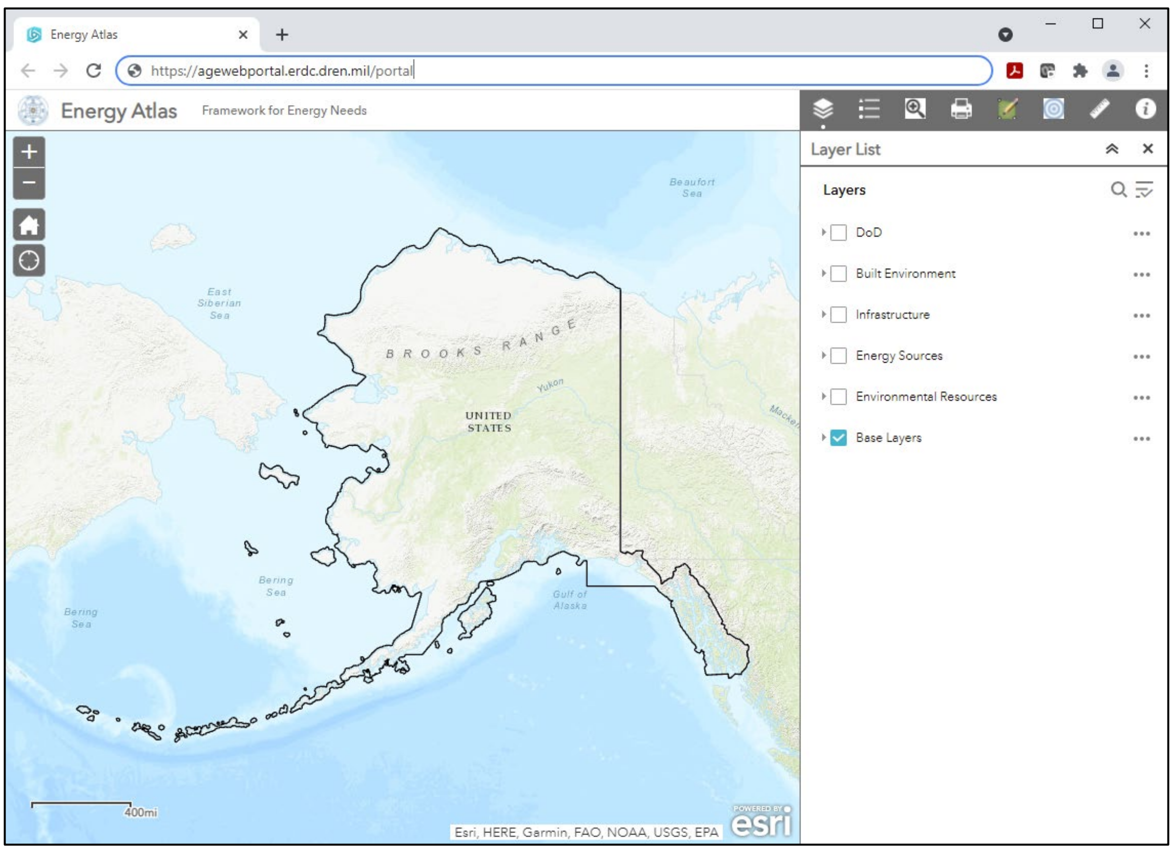
Energy Atlas—Mapping Energy-Related Data for DoD Lands in Alaska

Phase 2—Data Expansion and Portal Development

Matthew F. Bigl, Caitlin A. Callaghan, Brandon K. Booker, Kathryn P. Trubac, Jacqueline M. Willan, Paulina H. Lintsai, and Marissa J. Torres

January 2022



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Abstract

As the largest Department of Defense (DoD) land user in Alaska, the U.S. Army oversees over 600,000 hectares of land, including remote areas accessible only by air, water, and winter ice roads. Spatial information related to the energy resources and infrastructure that exist on and adjacent to DoD installations can help inform decision makers when it comes to installation planning. The *Energy Atlas–Alaska* portal provides a secure value-added resource to support the decision-making process for energy management, investments in installation infrastructure, and improvements to energy resiliency and sustainability.

The Energy Atlas–Alaska portal compiles spatial information and provides that information through a secure online portal to access and examine energy and related resource data such as energy resource potential, energy corridors, and environmental information. The information database is hosted on a secure Common Access Card–authenticated portal that is accessible to the DoD and its partners through the Army Geospatial Center's Enterprise Portal. This Enterprise Portal provides effective visualization and functionality to support analysis and inform DoD decision makers. The Energy Atlas–Alaska portal helps the DoD account for energy in contingency planning, acquisition, and life-cycle requirements and ensures facilities can maintain operations in the face of disruption.

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Preface

This study was conducted for the US Army Corps of Engineers under PE 0603119A, “Ground Advanced Technology,” Project B03, “Military Engineering Technology Demonstration,” Task SBO307, “Energy Technology Research in Cold and Arctic Regions.” The technical monitor was Dr. Thomas Douglas, U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory.

The work was performed by the Engineering Resources Branch (Dr. Caitlin A. Callaghan, chief) of the Research and Engineering Division (Dr. George W. Calfas, chief), ERDC-CRREL, with support from the Data Representation Branch (Mr. Vineet Gupta, chief) of the Topography, Imagery, and Geospatial Research Division (Mr. Jeffrey Murphy, chief), ERDC Geospatial Research Laboratory (GRL). At the time of publication Dr. Douglas Howard was the acting technical director for Cold Regions Science and Engineering. The acting deputy director of ERDC-CRREL was Mr. Bryan E. Baker, and the director was Dr. Joseph L. Corriveau. The acting director of ERDC-GRL was Ms. Valerie L. Carney.

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The Energy Atlas–Alaska is at https://agewebportal.erdc.dren.mil/portal/home/index.html.

COL Teresa A. Schlosser was commander of ERDC, and Dr. David W. Pittman was the director.

1 Introduction

1.1 Background

Geospatial data characterizing the energy resources and the related infrastructure both on and adjacent to Department of Defense (DoD) installations are critical for decision makers. Energy is a necessary consideration when conducting contingency planning, formulating acquisition requirements, and ensuring that facilities are able to maintain operations during disruptions. The ability to store, update, and access these data in a robust and timely manner ensures that the best-available information is readily accessible so decision makers can take efficient actions. This is especially important in remote DoD installations throughout Alaska where extreme conditions can cause significant disruptions to operations and planning.

As discussed in Callaghan et al. (2021), geographic information system (GIS)–based tools and frameworks provide a consistent way to collect and examine spatially resolved datasets and are increasingly assisting in decision-making. Previously developed frameworks include the Geographic Information Supporting Military Operations support tool, which Colorado State University developed in partnership with the U.S. Army Corps of Engineers. That DoD-funded project identified potential impacts from changing climate conditions on U.S. Army training lands in central Alaska (Douglas 2016). Remote-sensing techniques are also implemented to help address coastal, watershed, and landscape issues at the William and Mary's Center for Coastal Resource Management. These are both examples of resource issues that can profoundly impact DoD-managed lands if not integrated into installation resiliency planning. To support decision makers and break down information silos, there is a need for a more comprehensive database for all DoD lands in Alaska, covering not only energy and infrastructure but also the natural environment.

1.2 Objectives

The objective of this project was to take a stand-alone database of energy information related to DoD lands in Alaska, compiled in Phase 1 of this effort (Callaghan et al. 2021), and to make it more widely accessible. To achieve this, we designed and implemented a Common Access Card (CAC)–enabled online data portal, providing effective visualization and functionality that supports analysis and informs DoD decision makers and DoD partners. The *Energy Atlas–Alaska* (EA-AK) provides a value-added resource to support decision-making for investments in infrastructure and diligent energy management, helping DoD installations become more resilient and sustainable.

1.3 Approach

This effort leverages existing data, previously compiled under Phase 1; identifies additional data gaps; and makes recommendations for addressing those data gaps. Using a GIS-based online portal, we organized previously collected data. Phase 1 considered existing online data platforms to determine the most effective and efficient way to make the collected GIS data available to users.

Using this information and continued feedback from representative stakeholders, we transitioned the EA-AK from a stand-alone ArcGIS-based platform to an online system, leveraging portal infrastructure already being used by the DoD for various data sharing and digital mapping efforts. We transitioned additional functionality, previously developed during Phase 1 of the EA-AK project, to the online portal to provide continuity of functionality and to simplify access, visualization, and use of the underlying data.

Sections 2 and 3 provide more-detailed information about data collection, integration, and design of the EA-AK. These sections also address previous stakeholder engagement and subsequent improvements based on that feedback in addition to data gaps and potential improvements identified for future consideration.

1.4 Impact to DoD and the Army

As the largest DoD land user in Alaska, the U.S. Army oversees 600,000 hectares of land, including remote areas accessible only by air, water, or wintertime ice roads. The ability to securely and efficiently communicate the energy and environmental resources across these lands and how they relate to adjacent DoD installations is critical for ensuring that increased resilience and sustainability are achieved when investing and making strategic decisions at these sites. This process is complicated in Arctic regions due to the extreme conditions and remote settings of locations, requiring planning and investment.

The EA-AK portal helps the DoD account for energy in contingency planning, acquisition, and life-cycle requirements and ensures facilities can maintain operations in the face of disruption. The portal developed during this process can easily be adapted for assets in other regions or States and adjusted to the regulatory and environmental constraints. The spatial data available for resources, both built and natural, on and adjacent to DoD lands can provide critical information for investments and strategic decision-making, leading to increased resilience and sustainability across the DoD.

The EA-AK portal utilizes spatial information and leverages a secure online portal hosted by the Army Geospatial Center (AGC) to collect and examine energy-related data on DoD lands in Alaska. The database, previously developed by Callaghan et al. (2021), is accessible through the AGC Geospatial Enterprise (AGE) Portal, providing a GIS framework consistent with other Army and DoD efforts. The use of the AGE Portal ensures cross functionality between the secure portal hosting and the ability of the end user to easily access, visualize, and analyze data for decision-making. The use of this portal framework also ensures that the functionality and scope of the EA-AK can be iteratively expanded to include more data and tools to help decision makers across all DoD lands in Alaska. Within the EA-AK portal, both open-access and limited-distribution datasets are available, allowing users to directly compare both background environmental and DoD base-specific information.

2 Technical Approach Overview

Development of the EA-AK portal was a follow-on effort to expand the data coverage based on stakeholder feedback from Phase 1 and to increase ease of access through the use of a secure online portal. Sections 2.1–2.3 review the newly incorporated datasets and their sourcing. Appendix A identifies specific data sources.

2.1 Data collection

Primary data identification and collection efforts conducted during Phase 1 of this project focused on Federal, State, and open-source repositories and online tools. Phase 1 also explored data collection directly from the primary case study location (Fort Wainwright, Fairbanks, Alaska) through the U.S. Army Garrison Alaska Fort Wainwright Installation Geospatial Information and Services Program and collaborators at the U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory. The data collection described in this report will focus on the follow-on datasets that were not incorporated during the Phase 1 EA-AK stand-alone framework development. A full description of previously incorporated data is available in Callaghan et al. (2021), and Appendix A provides a comprehensive list of the currently available data at the time of writing. The focus areas of this investigation were based on stakeholder feedback from Phase 1 and include critical environmental information related to temperature and precipitation, permafrost, and sea-level rise. These collection efforts focused on spatial data (raster[1] and vector[2]) and tabular data that could be related to a spatial dataset to better portray the energy data portfolio of the case study location.

2.1.1 Temperature and precipitation

For the purposes of this study, temperature and precipitation data are defined as annual historical and temporally projected rasters for decadal time frames as opposed to a current or continuously updating data layer. We grouped the data descriptions for historical and projected precipitation and temperature because the datasets were developed using similar methods. We used the U.S. Forest Service's Climate Change Maps (USFS-

[1] A raster data model is "a regular 'grid cell' approach to defining space. Usually, square cells are arranged in rows and columns" (Bolstad 2019).

[2] A vector data model is "a representation of spatial data based on coordinate location storage for shape-defining points and associated attribute information" (Bolstad 2019).

CCM) repository to collect geospatial data on temperature and precipitation projections for Alaska (USFS, n.d.). USFS developed all data layers from the Scenario Network for Alaska and Arctic Planning (SNAP) datasets at 771 × 771 m[3] resolution (University of Alaska Fairbanks, n.d.). The projection data utilizes Representative Concentration Pathway (RCP) modeling scenarios that incorporated time series of emissions for most greenhouse gases and land use and cover types (Moss et al. 2007). The current version of the EA-AK incorporates RCP 8.5 for each projected temperature and precipitation scenario. The RCP 8.5 is the highest emission scenario and represents a trajectory that assumes no curtailment of global greenhouse emissions rate over the next century (Moss et al. 2007). The specific modifications USFS made for each SNAP dataset used in the EA-AK include the following:

Temperature

- USFS developed historical annual temperatures for Alaska by averaging mean monthly temperature (in degree Celsius) for 1975–2005. The downscaling process leveraged the PRISM (Parameter-Elevation Regressions on Independent Slopes Model) climatological datasets from 1971 to 2000 (USFS 2019).
- Projected annual temperatures for Alaska are downscaled projections from the RCP 8.5 climate model and cover 2006–2100 at 771 × 771 m spatial resolution. The RCP model is calculated as a five-model average from the top-ranked global circulation models (NCAR-CCSM4, GFDL-CM3, GISS-E2-R, IPSL-CM5A-LR, and MRI-CGCM3).[4] The projected mean monthly temperatures were average for 2071–2090 (USFS 2019).
- USFS developed absolute annual temperature changes for Alaska by subtracting historical annual temperatures from projected annual temperatures (USFS 2019).

Precipitation

- USFS developed historical annual precipitation for Alaska by averaging mean monthly precipitation (in millimeters) for 1975–2005, then these

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[3] For a full list of the spelled-out forms of the units of measure used in this document, please refer to *U.S. Government Publishing Office Style Manual*, 31st ed. (Washington, DC: U.S Government Publishing Office, 2016), 248–252, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

[4] The National Center for Atmospheric Research's Community Climate System Model Version 4, the Geophysical Fluid Dynamics Laboratory's General Coupled Circulation Model Version 3, the Goddard Institute for Space Studies ModelE2 using the Russell ocean model, the Institut Pierre Simon Laplace Climate Model 5A, and the Meteorological Research Institute's Coupled Global Climate Model Version 3.

values were summated for total annual precipitation. The downscaling process leveraged PRISM climatological datasets from 1961 to 1990 (USFS 2019).

- Projected annual precipitation data for Alaska are downscaled projections from the RCP 8.5 climate model and cover 2006–2100 at 771 × 771 m spatial resolution. The RCP model is calculated as a five-model average from the top-ranked global circulation models (NCAR-CCSM4, GFDL-CM3, GISS-E2-R, IPSL-CM5A-LR, and MRI-CGCM3). The projected mean monthly precipitation data were averaged (in millimeters) for 2071–2090, then these values were summated for total annual precipitation (USFS 2019).
- USFS developed absolute annual precipitation changes for Alaska by subtracting historical annual precipitation from projected annual precipitation (USFS 2019).

We incorporated the geospatial data for historical and projected temperature and precipitation into the EA-AK as raster data. The project team did not make any additional modifications to the data retrieved from the USFS-CCM repository.

2.1.2 Permafrost

Permafrost is a critical environmental factor in Arctic regions and will only become more important as the changing climate leads to increased permafrost thaw. Permafrost as defined by Woo (2012) is soil or rock that is frozen for more than two consecutive years. Generally, it includes soil and rock material that remains frozen year-round and can include an active layer, which experiences seasonal thaws. The warming of regions underlain with permafrost is a topic of great concern because as the permafrost thaws, the ground becomes unstable and can damage critical infrastructure and lead to significant costs (Melvin et al. 2017; Larsen et al. 2008). We examined Federal, State, and academic data repositories and publications and considered datasets covering Alaska and the entire North American Arctic.

The Global Terrestrial Network for Permafrost (GTN-P) provides an archive of both continuous and discontinuous data from global permafrost monitoring sites (GTN-P 2021). It hosts information related to borehole temperature measurements and active layer thicknesses for many sites within Alaska and provides the ability to download maps and graphics.

Although there is a wealth of data available through the GTN-P data repository, the majority is information from individual sites and is not specifically related to permafrost coverage or projections for large areas.

The National Snow and Ice Data Center (NSIDC) has an extensive amount of permafrost data covering various locations throughout the Arctic and Antarctic (NSIDC 2021). However, only 14 datasets have coverage in Alaska; and of those, only one has statewide coverage, yet it is over 23 years old at the time of publication.

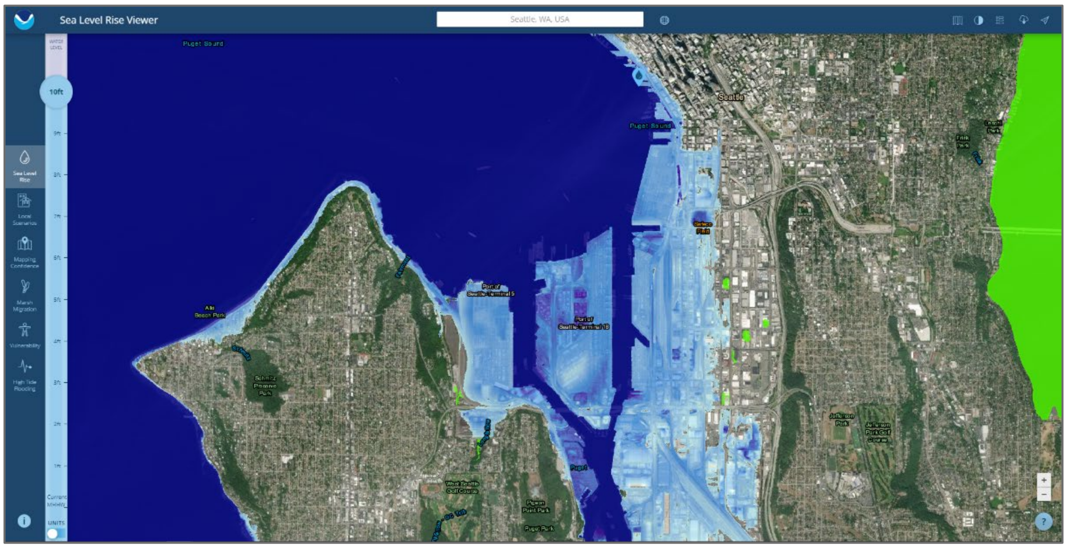
The Alaska Department of Natural Resources (DNR) provides an overview of geologic hazards located in Alaska, including permafrost and periglacial hazards (Alaska DNR 2021). It notes that the permafrost within Alaska is at its thickest and is most extensive north of the Brooks Range, where it can extend as much as 610 m below the surface (Alaska DNR 2021). Research by Jorgenson et al. (2008) and Pastick et al. (2015a, 2015b) has resulted in full coverage estimates of permafrost probability across the entire State of Alaska. These data are available in raster format through the U.S. Geological Survey (USGS) ScienceBase catalog and represent the most recent permafrost probability datasets that we identified during this project (Pastick et al. 2015a, 2015b).

In addition to collecting existing likelihood of permafrost, we were also interested in projections of permafrost coverage throughout Alaska. The future degradation of permafrost because of a changing climate will have drastic effects on infrastructure planning and implementing in the coming decades. Researchers and partners with the Permafrost Laboratory at the Geophysical Institute, University of Alaska Fairbanks, have been working to refine a landscape-scale permafrost model. The Geophysical Institute Permafrost Lab (GIPL) model simulates the dynamics of permafrost, including active layer thickness, soil temperature, and permafrost extent. The outputs of the Intergovernmental Panel on Climate Change's Fifth Assessment Report (AR5) climate model projections, under the RCP8.5 emission scenario from 2010 to 2100, drive the changes in the simulated permafrost dynamics (University of Alaska Fairbanks 2020).

2.1.3 Sea-level rise

This study investigated many sources of sea-level-rise data. The National Oceanic and Atmospheric Administration (NOAA) has a large database for current water levels and tidal predictions across the U.S. and has a tool to view sea-level-rise predictions. The NOAA Sea Level Rise Viewer allows users to interactively see the potential flooding due to sea-level rise at any location in the contiguous U.S. Users can adjust the height of the water level up to 3 m above the current mean higher high water datum. The tool then shows what areas could potentially be submerged due to an increase in sea level, shown in light blue in Figure 1 below (NOAA 2021b).

Figure 1. Example of the NOAA Sea Level Rise Viewer looking at an increase of 10 ft (3 m) to the current water level in Seattle, Washington. (Image reproduced from NOAA 2021b. Public domain.)



NOAA also has data on the global average sea level for the years between 1880 and 2020. The Global Climate Dashboard available from NOAA (Figure 2) shows that the trend of sea-level rise over the twentieth century has accelerated from 1.7 mm/year to 3.2 mm/year (NOAA 2021a).

However, these particular data sites do not include geospatial water-level data for locations outside the contiguous U.S., meaning there is no GIS sea-level data available for the State of Alaska. A number of other sites, including NOAA, contain data sets of historical measurements of water levels in Alaska but only at a few specific locations along the coast, and no statewide predictions currently exist.

While the global average sea level is on the rise, sea levels in Alaska have actually been decreasing (Figure 3). This is because the land beneath Alaska is rising due to ice loss and block motion in the regional tectonic plates. So even though the increase in glacial and ice-sheet melting contributes to an increase in global sea-level rise, it is decreasing the sea level in Alaska because reduced ice levels are lessening the weight on the land, allowing it to rise further (Elliott et al. 2010; Sato et al. 2010; SeaLevelRise.org 2021).

Figure 2. NOAA Global Climate Dashboard showing the global average sea-level rise between 1880 and 2020. (Image reproduced from NOAA 2021a. Public domain.)

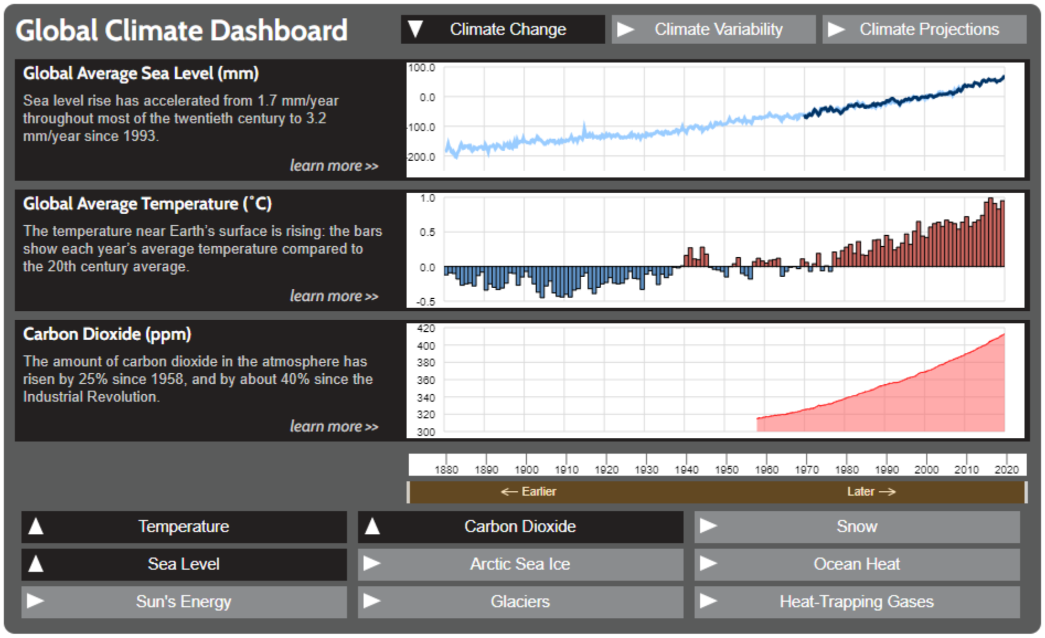
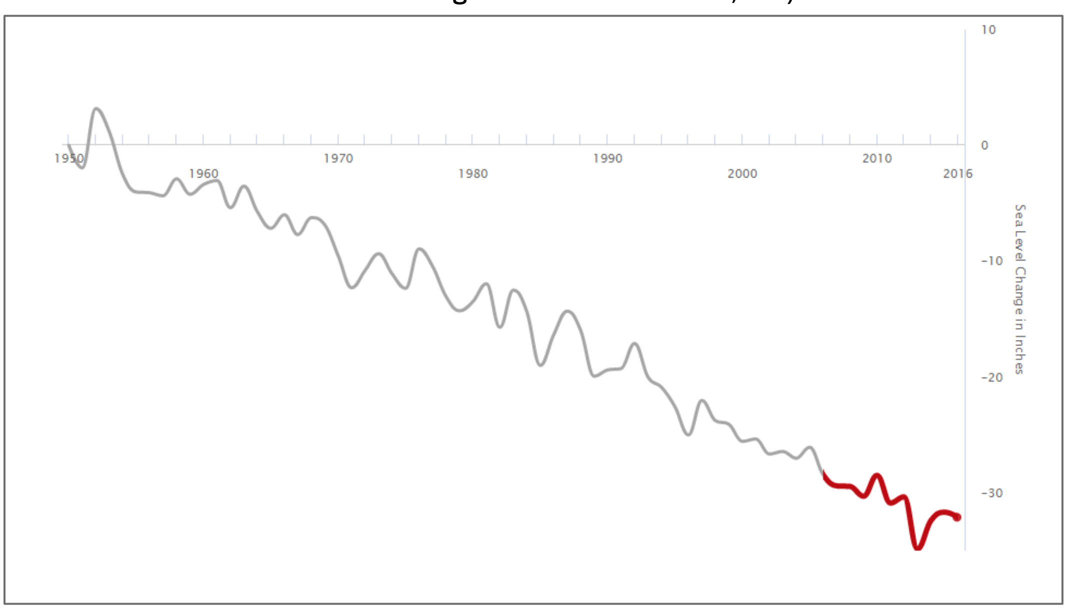


Figure 3. Sea levels in Juneau since 1950. (Image reproduced with permission from SeaLevelRise.org 2021. Data from NOAA, n.d.)



The Woods Hole Oceanographic Institute (WHOI), along with the Arctic and Antarctic Research Institute and NOAA, have also investigated Arctic sea-level rise. Various research entities have collected measurements of sea level throughout the Arctic Seas, dating back to the 1920s (WHOI, n.d.). WHOI and the Antarctic Research Institute monitored the sea-level gauges, and if a vertical geodetic change was detected, they adjusted to compensate for this. However, this data investigates the change in global sea-level rise, which does not consider the particular situation of Alaska, as discussed previously. Since these values were averaged, the unique variability of each location was removed, meaning the change of sea-level rise at each location is somewhat uncertain (Proshutinsky 2004). In addition, these were historical measurements at specific locations, so there is no GIS data for the whole coastline of Alaska and no detailed projections for these locations.

2.2 Data Integrated into the Energy Atlas–Alaska

2.2.1 Temperature and precipitation

We incorporated into the EA-AK geospatial data for historical and projected temperature and precipitation. This informs the potential magnitude of climate change at a relevant scale that DoD rangeland and installation development planning efforts can leverage. Temperatures play a vital role in determining the energy load requirements to maintain indoor operational temperature with heat and cooling systems. Projections in temperature can also be used to estimate equipment requirements to successfully sustain missions in historically cold climates, such as Alaska. Temperature will also greatly affect soil conditions in permafrost landscapes (see section 2.2.2), and any resulting changes in permafrost will have a direct impact on geotechnical stability for both buildings and roads.

As the climate changes over the coming decades and century, precipitation rates are likely to change. This could mean more rainfall with an increased risk of flooding or longer droughts for different regions. In Alaska, precipitation models will help predict the amount of snowfall each year. Understanding seasonal change in precipitation will facilitate planning mobility logistics in historically cold regions as snow conditions will dictate the traction requirements for each vehicle. Additionally, seasonal change in precipitation can be used to estimate flood risk and water-table levels in a region where new installations or energy generation plants are being developed.

The historical and projected temperature and precipitation data provide a foundational understanding of what to expect in the next century for the

Alaskan climate if the globe continues down the current emissions trajectory. Although current advancements in low-emission electrical generators and vehicles will likely reduce the impact of global warming, the data incorporated for this version of the EA-AK will provide guidance on the worst-case scenario. A future version of the EA-AK is likely to include a range of RCP models for temperature and precipitation with increases temporal resolution.

2.2.2 Permafrost

We incorporated geospatial data for permafrost probability and projected minimum and maximum active layer thickness into the EA-AK portal. Although the presence of permafrost does not exclude an area from consideration for infrastructure development, it does greatly affect how that infrastructure is planned and the ultimate cost to construct and maintain it into the future. By incorporating both a probability dataset and projected active layer thickness datasets, it is our goal to provide a useful resource for infrastructure planning. The projected active layer thicknesses are based on the same climate scenarios included for temperature and precipitation so that investigations based on these datasets will be directly comparable.

As the climate continues to change over the coming decades, the presence and thickness of permafrost throughout Alaska will also change, making it important to factor these potential changes into installation planning.

2.2.3 Sea-level rise

We found no useable sea-level-rise data during the data collection process; therefore, it is not part of the EA-AK. See the section 2.4 for more information about data gaps.

2.3 Stakeholder engagement

The EA-AK portal is primarily for DoD decision-maker use but can support other DoD-related reviews, analyses, and activities. The enterprise portal framework utilized for this project can easily be adapted to serve other States and the requirements therein. To inform the development of the EA-AK, we sought input and feedback during Phase 1 from a variety of intended and potential users:

- Installation energy manager
- Installation energy and water plan developers
- Academic research partners
- DoD researchers

The EA-AK project team provided a demonstration to a representative set of stakeholders during Phase 1 and an in-progress review presentation during Phase 2. Feedback from the stakeholders was documented and, as appropriate, integrated into the EA-AK. The feedback from 38 stakeholders across 6 separate organizations provided guidance that we incorporated where time and resources allowed.

2.3.1 Dataset and function expansion

There was significant discussion with stakeholders regarding how the EA-AK could be expanded to include additional datasets and functions. The primary focus for dataset expansion moving into potential future versions of the EA-AK will be to expand the detailed installation dataset coverage from Fort Wainwright to all other DoD installations in the State. The focus of Phases 1 and 2 was on Fort Wainwright, and it is clear that enough spatial information exists to be able to expand coverage to the entire State. Future functionality improvements include troubleshooting, expansion of printing functionality, and incorporating additional planning tools for decision makers identified in ongoing stakeholder discussions.

2.3.2 Ease of access—public portal

Another item frequently discussed by academic research partners is the potential to develop a version of the EA-AK portal that is publicly accessible without the use of CAC authentication. A number of datasets collected throughout this project are publicly available and should be readily accessible by nongovernmental research partners. While we believe that a public-access portal would be useful when stakeholders are partnering with external private and academic entities for installation planning, it is not something that the AGE Portal can currently host. When external entities partnering with DoD stakeholders need these data, they should be accessible through a specific data-sharing agreement between those partners.

2.4 Data gaps

We assessed data gaps and future data needs based on discussions with stakeholders and within the EA-AK project team. The most important data gap identified during this phase is sea-level rise.

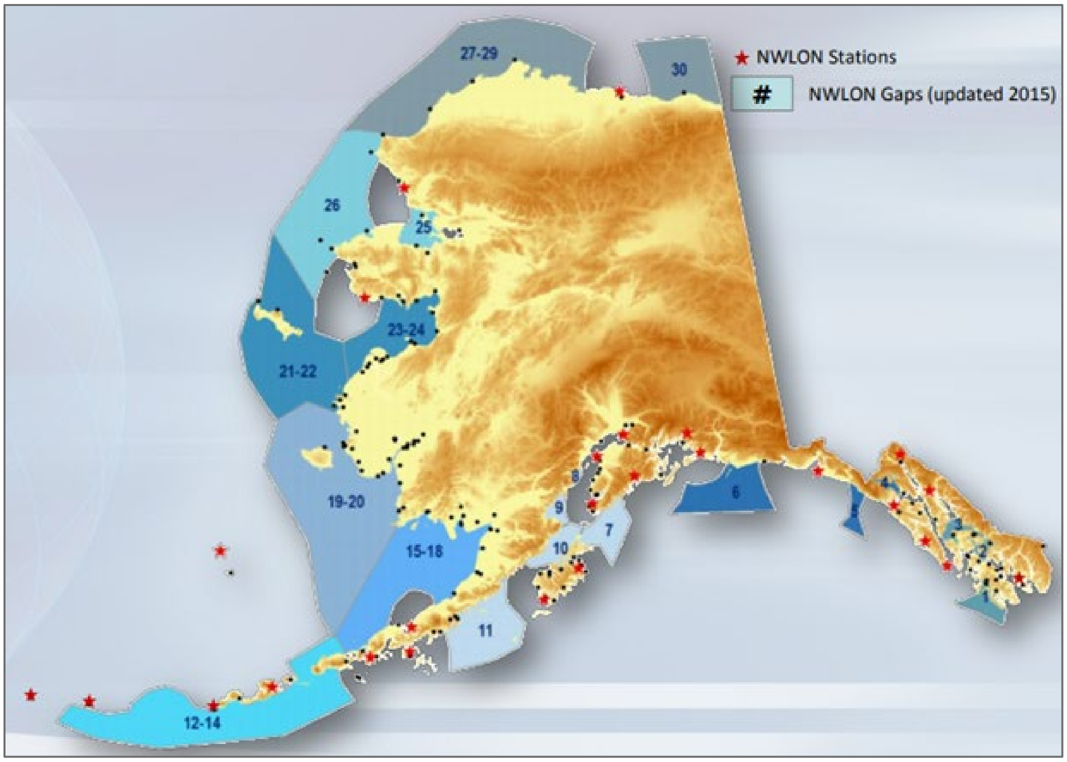
There is a significant lack of GIS data for the coast of Alaska, specifically for elevation, tidal ranges, erosion, etc. Since many parts of the Alaskan coast are very remote, there has not been an extensive effort to survey the relative elevation of the shoreline. Even for more populated areas, there is very little information.

Lidar data is the most useful for elevation data; however, there are only a few areas in Alaska with large lidar coverage, such as Anchorage and the Kenai Peninsula. Most of the nonlidar elevation data available in Alaska is derived from USGS topological maps, which have contour intervals that can range from 4.5 to 30.5 m, providing lower vertical resolution. Because of this lower resolution, these datasets are not suitable for modeling the effects of sea-level rise (Clough 2010).

The issue with the data for tidal ranges is that they are collected at only specific locations. As discussed earlier in section 2.1.3, data from NOAA does not include geospatial water-level data for locations outside the contiguous U.S. The NOAA data repositories reviewed for this work contain data sets of only historical measurements of water levels in Alaska at only a few specific locations along the coast. This makes it very difficult to develop a statewide prediction for sea-level rise (NOAA 2021a). In addition, there many locations where the tide gauges are a significant distance apart, sometimes 80 km or more (Figure 4). This leads to long-distance interpolation, which can cause inaccuracies (Clough 2010).

There are 26 active NOAA tide gauges in Alaska, and only 17 of them have extended records. Shown in Figure 4, the northern shores of Alaska have very few tide gauges, making it even more difficult to provide an accurate set of data for sea level (Kinsman 2016).

Figure 4. NOAA tide gauge locations in Alaska. (Image reproduced from Kinsman 2016. Public domain.)



3 Energy Atlas–Alaska Portal

3.1 Hosting and design

The EA-AK portal functions within Esri's ArcGIS Enterprise Portal software and is hosted by the AGE Portal. A valid DoD CAC is required to sign in. The EA-AK portal system consists of a web application created with Esri's Web AppBuilder. Within the web application, we used Python code to create several tools shown below (Figure 5).

Figure 5. EA-AK web application toolbar listing the available functions, including (*left to right*) Layers tool, Legend tool, Zoom to Base tool, Print tool, AOI (Area of Interest) tool, Buffer tool, Measure tool, and Query tool.

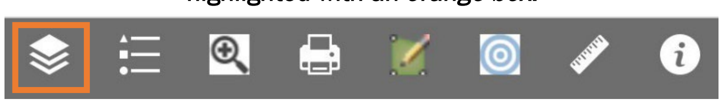
Data is stored in ArcGIS File geodatabases and symbolized with layer files. The data layers are then published as web layers to the hosting server.

3.2 Functions

3.2.1 Layers tool

The Layers tool allows the user to check layers on, making the layer visible in the map (Figure 6). If the layer is within a group, then the group layer must also be checked on for the layer to be visible.

Figure 6. EA-AK web application toolbar with the Layers tool highlighted with an *orange box*.



3.2.2 Legend tool

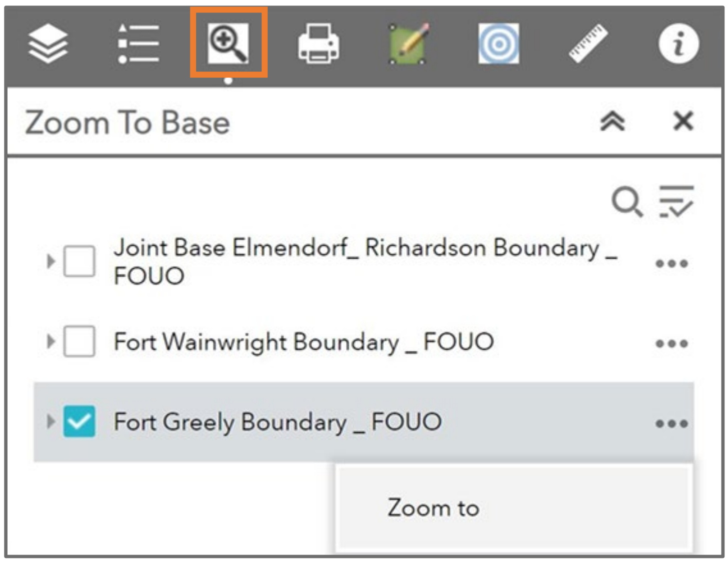
The Legend tool allows the user to view the legend for the layers that are turned on (Figure 7).

Figure 7. EA-AK web application toolbar with the Legend tool highlighted with an *orange box*.

3.2.3 Zoom to Base tool

The Zoom to Base tool allows user to easily zoom in to the extent of the base selected by right-clicking and selecting “Zoom to” from the drop-down menu (Figure 8).

Figure 8. EA-AK web application toolbar with the Zoom to Base tool highlighted with an *orange box* and the dropdown selection options shown underneath.



3.2.4 Print tool

The Print tool allows the user to print the current layers and visible extent of their map view to several different file formats (Figure 9). The tool automatically adds an inset map, legend, scale bar, and north arrow. The user also has the option to specify a title.

If desired, the user can specify an author under the “Advanced” settings. Other settings listed under “Advanced” are not used in the default “Atlas Template” that has been set for creating a file. The default figure settings automatically include a legend and a scale bar. The user can specify the output format with choices of GIF, JPEG, PNG32, PNG8, or SVG. After the format is specified, and the “Print” command has been selected, a file is created in the format specified (Figure 10). To print or save, the user then clicks on the file name, and the file will open in the web browser.

Figure 9. EA-AK web application toolbar with the Print tool highlighted with an *orange box* and the dropdown formatting and output options shown underneath.

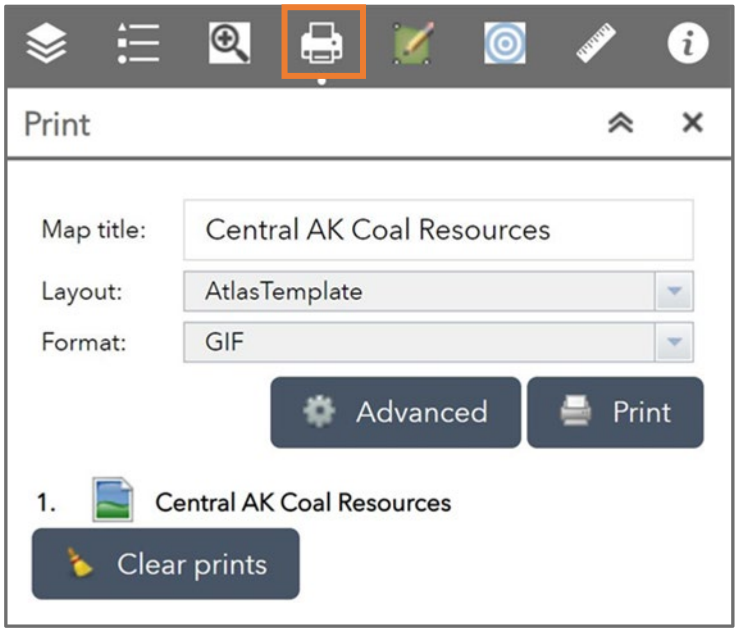
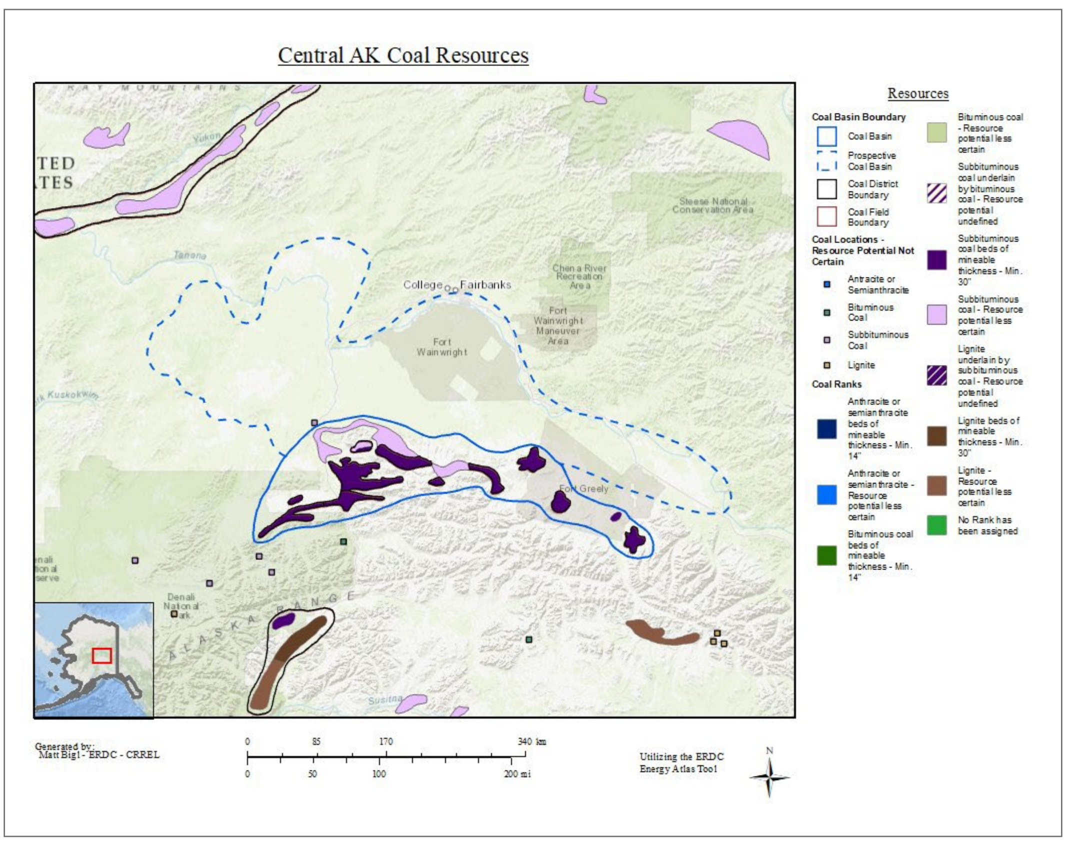
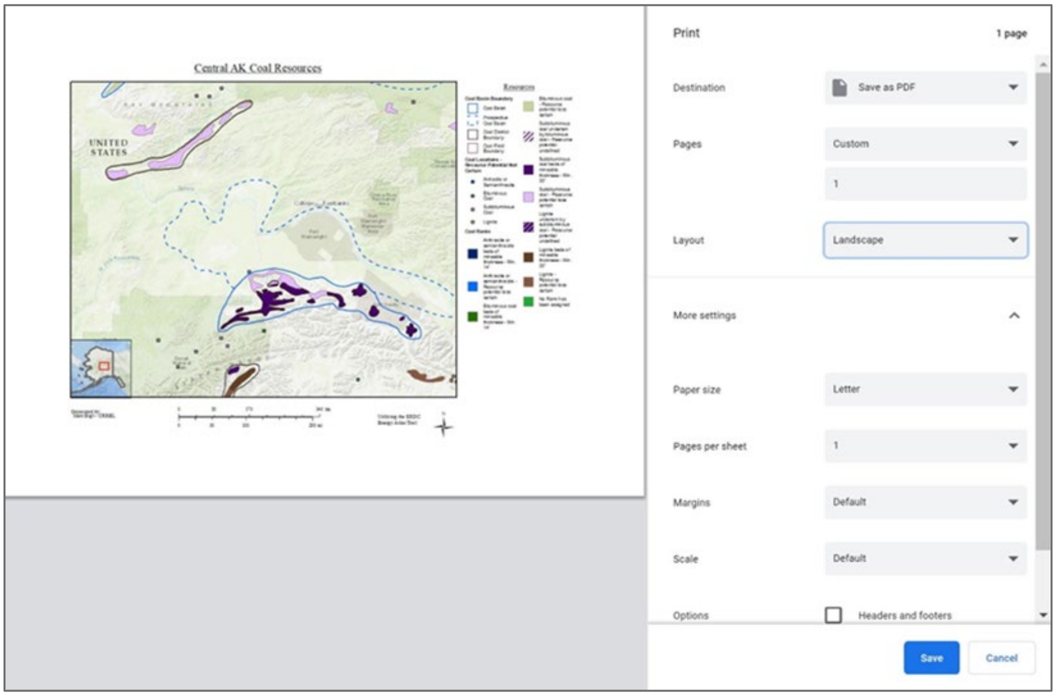


Figure 10. Example figure resulting from the use of the Print tool built into the EA-AK toolbar.



The user can then right-click on the image, and select "Save image as" to save the image file. Alternatively, the browser's print function can be used to send the file to a printer or to save as a PDF file (Figure 11).

Figure 11. View of Print tool menu (*right*) and figure to be printed (*left*).



3.2.5 AOI tool

The AOI (Area of Interest) Tool allows the user to draw an AOI on the map to begin a site selection analysis or just as a reference for data layer review. This AOI can then be displayed with other data layers to start an analysis of an area. To run the tool, a user selects a shape to interactively draw the AOI (Figure 12). The user then clicks "Run," after which, an AOI polygon layer is drawn on the map and added as a layer to the layer list. The polygon will remain on the screen for visual comparison to other layers within the area. To delete the AOI polygon from the screen, select the Input tab, then click the red button, which will clear the AOIs from the screen.

To delete the AOI from the layer list, select the Output tab, then click the light gray "x" next to the three dots (Figure 13).

Figure 12. EA-AK web application toolbar with the AOI tool highlighted with an *orange box* and the Input tab open with options shown underneath.

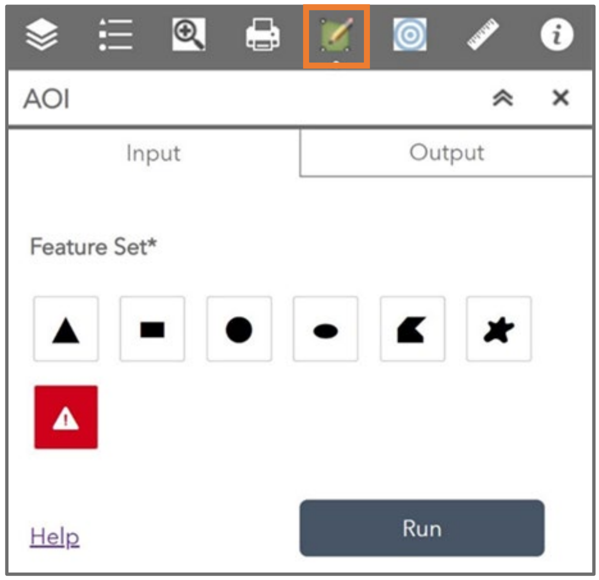
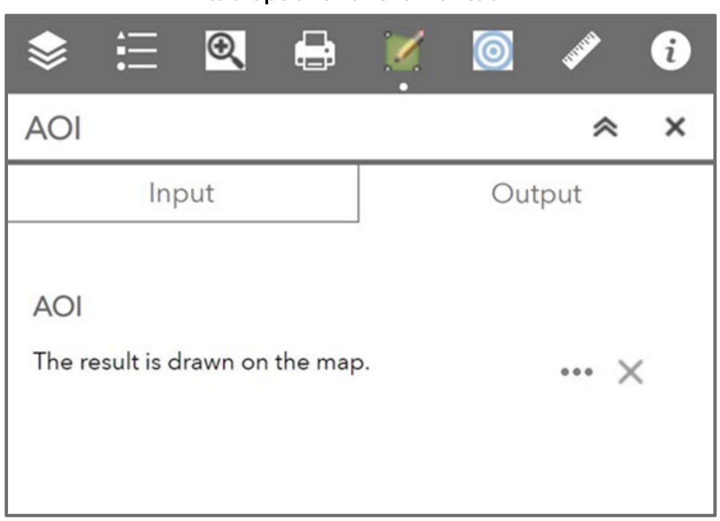


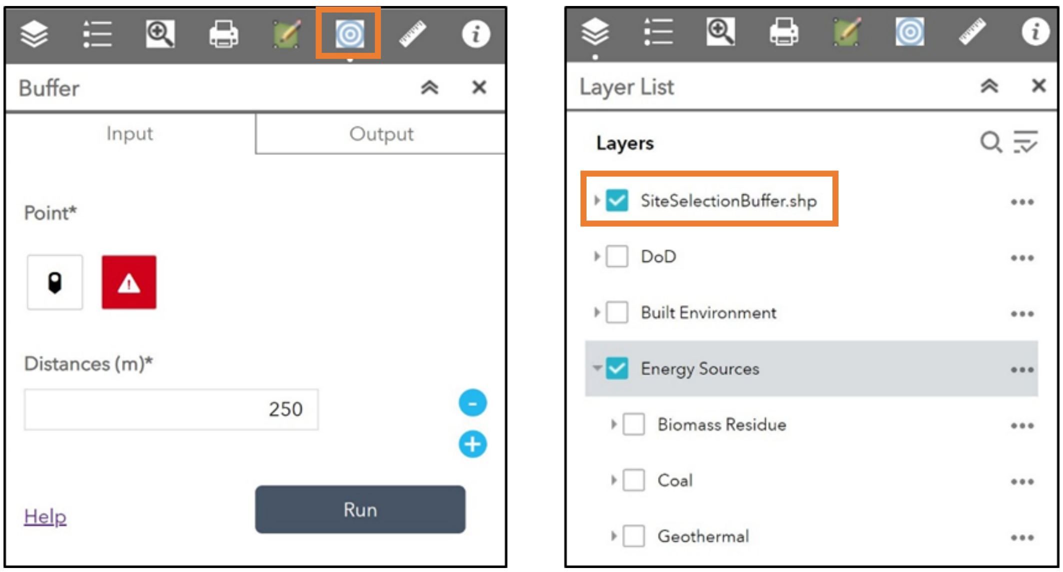
Figure 13. EA-AK web application toolbar showing the Output tab options for the AOI tool.



3.2.6 Buffer tool

The Buffer Tool allows the user to specify one or more distances for buffer analysis of a proposed site. This could assist the user in determining proximity of a possible site to existing infrastructure. To run the tool, a user clicks the Point button to draw a point on the map. The user then adds the distance in meters for the buffer (Figure 14). Next, the user clicks “Run” to execute the tool. After running the tool, a buffer polygon layer is drawn on the map and added to the layer list. The polygon will remain on the screen for visual comparison to other layers within the area. To delete the site selection buffer from the screen, select the Input tab, then click the red button, which will clear the AOIs from the screen. To delete the point from the screen, select the Input tab, then click the red button, which will clear the point from the screen. To delete the buffer layer from the layer list, select the Output tab, then click the "x."

Figure 14. EA-AK web application toolbar with the Buffer tool highlighted with an *orange box* and the Input tab open with options shown underneath (*left*). The layers list shown on the *right* highlights the output layer from the Buffer tool with an *orange rectangle*.



3.2.7 Measure tool

The Measure tool allows the user to measure distances and areas on the map (Figures 15 and 16). The tool also allows the user to click on a point and obtain the latitude and longitude of the location in degrees.

Figure 15. EA-AK web application toolbar with the Measure tool highlighted with an *orange box*.

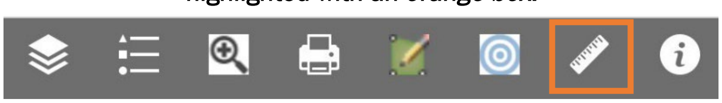
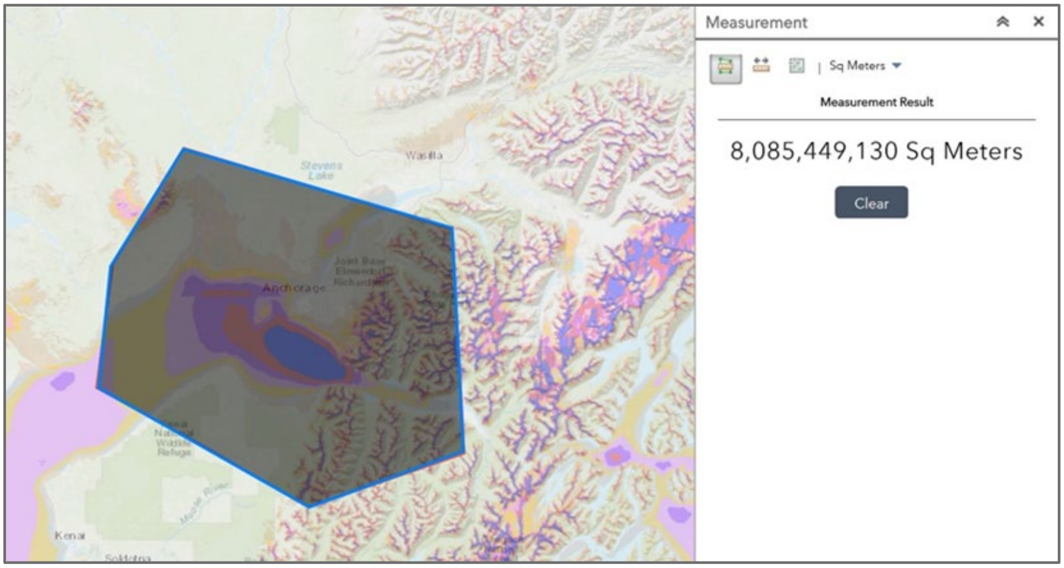


Figure 16. Example of the Measure tool being used with the area function within the EA-AK web application.



3.2.8 Map navigational tools

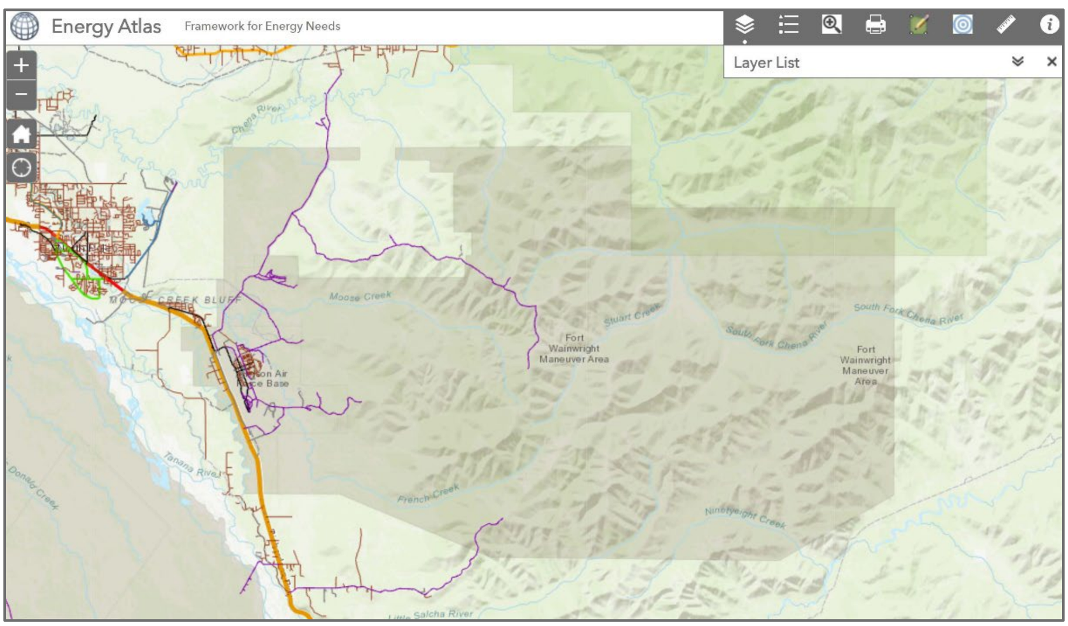
Three tools can be used for navigating around the map. The Default Extent tool allows the user to click on the home button to zoom to the custom extent of Alaska. The "+" and "–" tools zoom in and out.

4 Use Case: Avoidance of Current and Projected Permafrost

This scenario demonstrates use of the EA-AK portal to assist in the site selection process for a building, such as a supply building added to a training area.

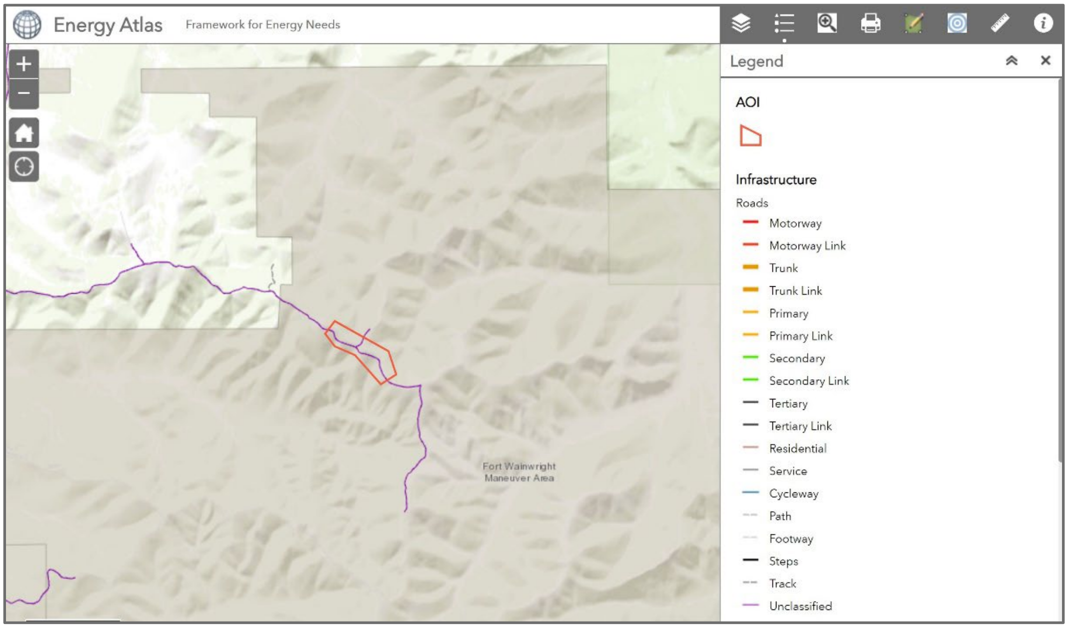
When selecting a new site for building in an area subject to permafrost, it would be useful to use the Energy Atlas's Environmental Permafrost layers (Figure 17). In particular, the Projected Annual Maximum Active Layer Thickness layers could be viewed in the desired area.

Figure 17. Overview of the use-case region with the roads layer overlain on the background topo map.



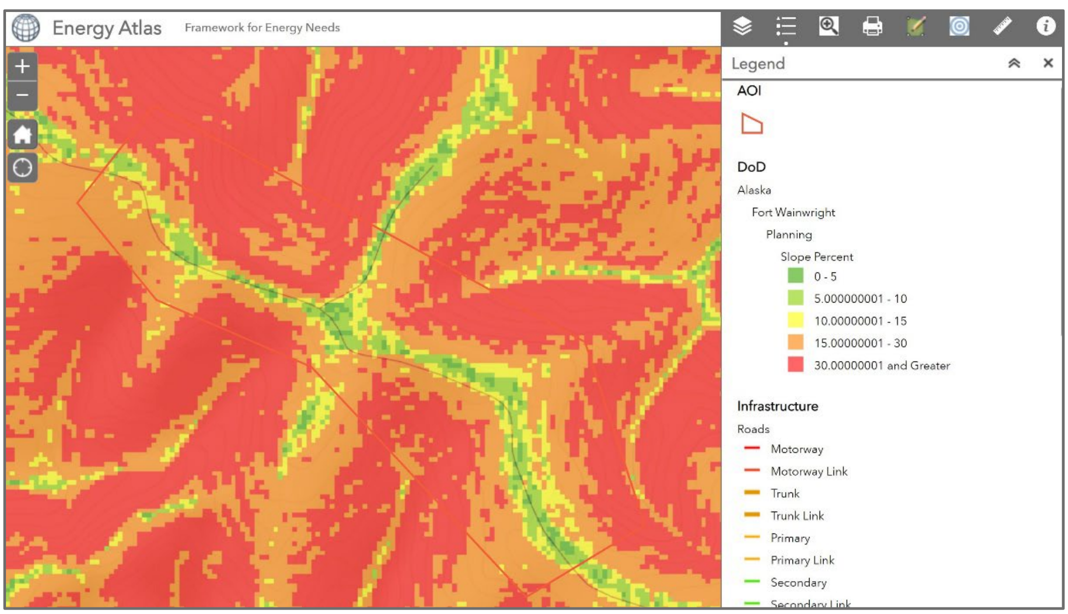
Other considerations would be the existence of nearby roads and the slope of the area. The AOI tool could be used to select an initial area (Figure 18).

Figure 18. Detail figure of use-case area with example AOI drawn for further investigation.



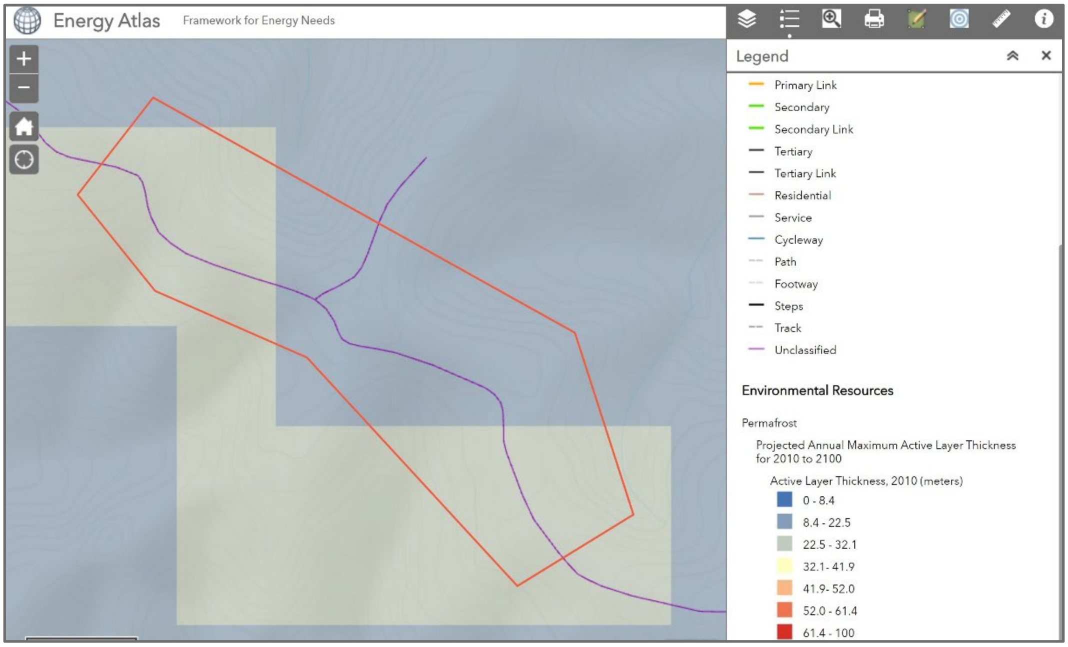
The slope along the road would then be considered (Figure 19).

Figure 19. Detail figure of use-case area with the slope raster layer selected.



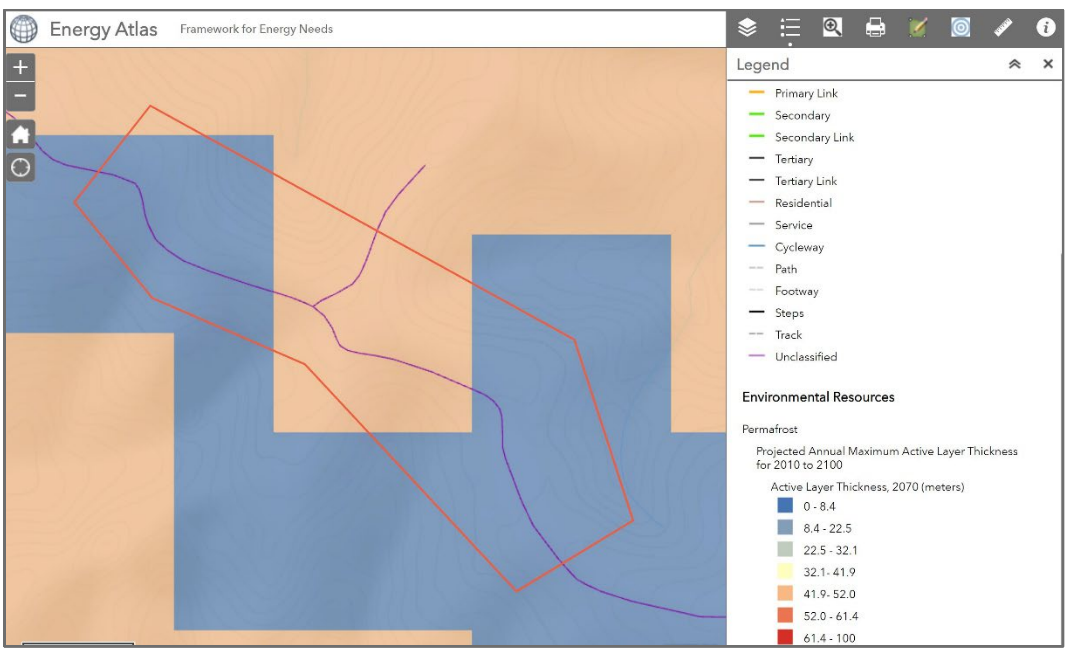
Next, the Active Layer Thickness for Permafrost in the current time (2020s) is overlain on the map to consider the effect of the current active layer thickness (Figure 20).

Figure 20. Detail figure of use-case area with 2020s Active Layer Thickness data overlain.



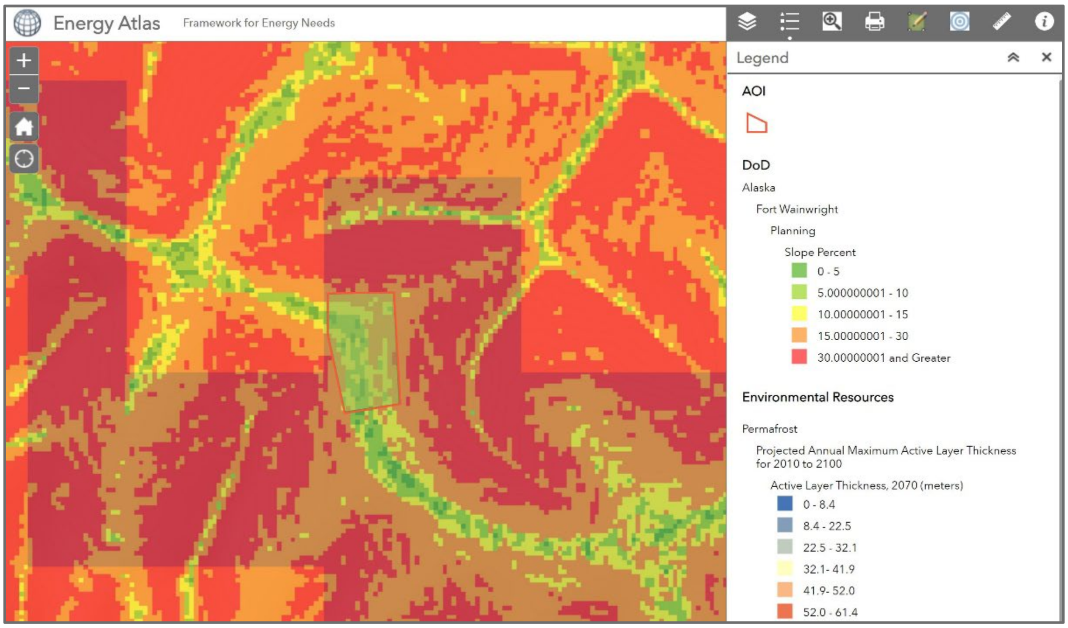
Next, the future projection for Active Layer Thickness in the 2070s could be considered (Figure 21).

Figure 21. Detail figure of use-case area with 2070s Active Layer Thickness data overlain.



Next, the slope percent layer is turned on and then the AOI tool run again for the area in which the Active Layer Thickness stays below 22.5 m and the slope is less than 10%. By analyzing this series of layers, the user can locate a potential site for new construction and then investigate it further in person to confirm suitability (Figure 22). Using the layers within the EA-AK saves during this process and allows additional in-depth site suitability analyses on these layers to identify other sites for field investigations.

Figure 22. Detail figure of potential building site with 2070s Active Layer Thickness data overlain.



5 Conclusion and Next Steps

The EA-AK portal is an evolving tool that we expect to expand in terms of data coverage and functionality based on user feedback, the needs of decision makers, and the availability of new and more accurate datasets and geospatial capabilities. The second phase of this effort focused on expanding relevant data sources to include historical and predicted temperature, precipitation, and permafrost probability and thickness. We identified a large knowledge gap related to sea-level-rise predictions across the State of Alaska and identified relevant research partners who can help garner funding and serve as subject matter experts for follow-on research efforts related to filling this critical gap. Moving forward, we intend to continue expanding through collaborative research efforts the installation data coverage from the case study of Fort Wainwright to all DoD installations within Alaska. Beyond Alaska, the portal framework developed for the EA-AK can easily be applied to other States and territories as the majority of databases used for this study contain national datasets that were down sampled for research and hosting purposes.

The project team, pending follow-on funding, plans to address the following opportunities in subsequent phases of the EA-AK effort:

First, we will expand the current web-based ArcGIS Enterprise Portal to cover all DoD facilities within Alaska as opposed to solely focusing on Fort Wainwright. By continuing to communicate with the GIS professionals that support Fort Wainwright, Joint Base Elmendorf Richardson, Fort Greely, and the AGC, we will expand the data coverage and ensure consistent visualization.

Second, we will expand the data available through the EA-AK. Data gaps identified through further stakeholder engagement will continue to be sourced and integrated into the EA-AK, depending on resources available. Stakeholder input will inform the prioritization of this effort.

Finally, the project team will investigate additional funding sources and engage additional research partners to evaluate the potential for collecting detailed coastline elevation data to serve as a basis for future sea-level-rise research and modeling.

The development of the EA-AK portal collected and organized relevant information related to energy, infrastructure, and the environment for DoD lands across Alaska and made it accessible through an easy and secure portal system. In addition to this, by hosting the EA-AK portal through the AGE portal, we can efficiently expand not only the available datasets but also the coverage. This breaks down data silos and organizes all these data in one easy-to-use resource, saving time and money while making our Arctic DoD installations more efficient, resilient, and cost effective as we move into the future.

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Appendix A: Data Sources

Table A-1. Data sources integrated into the Energy Atlas–Alaska.

Data	Description	Sources/Citations & URLs
DOD Site Locations—FOUO	Locations of DoD sites	Defense Information Spatial Data Infrastructure (DISDI)—Homeland Infrastructure Foundation-Level Data (HIFLD) Secure Data Portal. Retrieved 4/2/2020 from https://gii.dhs.gov/gii/home/
DOD Buildings—FOUO	Locations of buildings and structures on DoD sites	DISDI—HIFLD Secure Data Portal. Retrieved 4/2/2020 from https://gii.dhs.gov/gii/home/
DOD Site Boundaries—FOUO	Boundaries of DoD sites, installations, ranges, and training areas	DISDI—HIFLD Secure Data Portal. Retrieved 4/2/2020 from https://gii.dhs.gov/gii/home/
Roads on Installations—FOUO	Road centerlines located on DoD sites	DISDI—HIFLD Secure Data Portal. Retrieved 4/3/2020 from https://gii.dhs.gov/gii/home/
Roads—FOUO	Major roads and roads located on DoD sites	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Fort Greely Space Missile Command—FOUO	Created from Installation layer, which was split into two layers (Fort Greely Space Missile Command and Installation boundaries near Fort Wainwright)	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Helipad—FOUO	Pavement section airline—helipads on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Levee—FOUO	Levees on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Railroad—FOUO	Rail segment—railroads on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Fence—FOUO	Fence on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Landuse—FOUO	Landuse on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Vehicle Parking—FOUO	Vehicle parking on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Pavement Section Road—FOUO	Pavement section road on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Pavement Section Airfield—FOUO	Pavement section airfield on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Airfield / Helipad Markings—FOUO	Airfield / helipad markings on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Electrical Utility Outlet—FOUO	Electrical utility outlet on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Electrical Utility Generator—FOUO	Electrical utility generator on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)

Data	Description	Sources/Citations & URLs
Electrical Utility Node Junction—FOUO	Electrical utility node junction on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Electrical Utility Meter—FOUO	Electrical utility meter on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Electrical Utility Substation—FOUO	Electrical utility substation on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Electrical Utility Switch—FOUO	Electrical utility switch on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Electrical Utility Transformer—FOUO	Electrical utility transformer on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Electrical Utility Segment—FOUO	Electrical utility segment on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Utility Feature Support—FOUO	Utility feature support on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
POL Utility Junction—FOUO	Petroleum, oil, and lubricants utility junction on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
POL Storage Tank—FOUO	Petroleum, oil, and lubricants storage tank on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
POL Utility Pipeline—FOUO	Petroleum, oil, and lubricants utility pipeline on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Thermal Utility Node—FOUO	Thermal utility node on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Thermal Utility Fitting—FOUO	Thermal utility fitting on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Thermal Utility Valve—FOUO	Thermal utility valve on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Thermal Utility Line—FOUO	Thermal utility line on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Future Projects Location—FOUO	Future projects location on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Future Projects Pavement—FOUO	Future projects pavement on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Future Projects Building—FOUO	Future projects building on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Future Projects Area—FOUO	Future projects area on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Towers—FOUO	Towers on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Access control—FOUO	Access control on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Building Location—FOUO	Building location on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Land Management Zone—FOUO	Land management zone on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Structure—FOUO	Structure on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)

Data	Description	Sources/Citations & URLs
Land Parcel—FOUO	Land parcel on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Installation—FOUO	Installation layer was split into 2 layers (Fort Greely Space Missile Command and Installation boundaries near or on Fort Wainwright)	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Outside Installation—FOUO	Outside installations near Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Building Footprint—FOUO	Building footprint on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Site—FOUO	Site on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Stormwater Utility Inlet—FOUO	Stormwater utility inlet on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Stormwater Utility Discharge—FOUO	Stormwater utility discharge on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Stormwater Utility Junction—FOUO	Stormwater utility junction on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Culvert—FOUO	Culvert on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Stormwater Utility—FOUO	Stormwater utility on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Stormwater Utility Open Drainage—FOUO	Stormwater utility open drainage on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Wastewater Utility Sludge Bed—FOUO	Wastewater utility sludge bed on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Wastewater Utility Fitting—FOUO	Wastewater utility fitting on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Wastewater Utility Junction—FOUO	Wastewater utility junction on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Wastewater Utility Pump—FOUO	Wastewater utility pump on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Wastewater Utility Valve—FOUO	Wastewater utility valve on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Wastewater Utility Segment—FOUO	Wastewater utility segment on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Water Utility Fitting—FOUO	Water utility fitting on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Water Utility Hydrant—FOUO	Water utility hydrant on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Water Utility Meter—FOUO	Water utility meter on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Water Utility Pump—FOUO	Water utility pump on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Water Utility Tank—FOUO	Water utility tank on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)

Data	Description	Sources/Citations & URLs
Water Utility Treatment Plant—FOUO	Water utility treatment plant on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Water Utility Valve—FOUO	Water utility valve on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Water Utility Segment—FOUO	Water utility segment on Fort Wainwright	Fort Wainwright, Fairbanks, AK (Ostrom 2019)
Power Plants	Electric power plants	DISDI—HIFLD secure data portal. Retrieved 4/2/2020 from https://gii.dhs.gov/gii/home/
Biomass	Biomass	National Renewable Energy Laboratory (NRL). Retrieved 5/19/2020 from https://maps-data.nrel.gov/ows?outputFormat=SHAPEZIP&propertyName=name%2Cstate_name%2Ccrops%2Cmanure%2Cforest%2Cprimm ill%2Csecmill%2Curban%2Clandfill%2Ctotal%2Cthe_geom_4326&request=GetFeature&service=WFS&typeName=re_atlas%3AReAtlas_biomass&version=1.0.0
Coal District Boundary	Coal district boundary	Alaska Department of Natural Resources (DNR) Division of Geological and Geophysical Surveys (DGGS). Retrieved 5/4/2020 from https://dggs.alaska.gov/pubs/id/2636
Coal Basin Boundary	Coal basin boundary	Alaska DNR DGGS. Retrieved 5/4/2020 from https://dggs.alaska.gov/pubs/id/2636
Coal Field Boundary	Coal field boundary	Alaska DNR DGGS. Retrieved 5/4/2020 from https://dggs.alaska.gov/pubs/id/2636
Coal Locations	Coal locations—location of coal occurrence of unknown extent	Alaska DNR DGGS. Retrieved 5/4/2020 from https://dggs.alaska.gov/pubs/id/2636
Coal Ranks	Coal ranks	Alaska DNR DGGS. Retrieved 5/4/2020 from https://dggs.alaska.gov/pubs/id/2636
Heat Flow	Heat Flow—geothermal gradient test hole	Alaska DNR DGGS. Retrieved 4/28/2020 from https://dggs.alaska.gov/pubs/id/671
Thermal Springs	Thermal springs—hot springs data file was split into two feature classes using symbol field, based on map published by DGGS: thermal springs and thermal wells	Alaska DNR DGGS. Retrieved 4/28/2020 from https://dggs.alaska.gov/pubs/id/671
Volcanic Rocks	Volcanic rocks—Quaternary or Quaternary-Tertiary volcanic rocks	Alaska DNR DGGS. Retrieved 5/4/2020 from https://dggs.alaska.gov/pubs/id/2636
Volcanic Vents	Volcanic vents	Alaska DNR DGGS. Retrieved 4/28/2020 from https://dggs.alaska.gov/pubs/id/671
Oil and Gas Reservoirs	Oil and gas reservoirs	Argonne National Laboratory (ANL)—Energy Zones Mapping Tool (EZMT). Retrieved 3/17/2020 from https://ezmt.anl.gov/viewer

Data	Description	Sources/Citations & URLs
Oil and Natural Gas Fields	Oil and natural gas fields	Oak Ridge National Laboratory / ANL—HIFLD Open Data Portal. Retrieved 4/2/2020 from https://gii.dhs.gov/gii/home/
Petroleum Product Terminals	Petroleum product terminals	ANL—EZMT. Retrieved 6/4/2020 from https://ezmt.anl.gov/viewer
Petroleum Refineries	Petroleum refineries	ANL—EZMT. Retrieved 5/28/2020 from https://ezmt.anl.gov/viewer
Wind Resource Potential at 50 m	Wind resource potential at 50 meters—data layer had over 1.3 million polygons without any attribute information so a DISSOLVE operation was performed, reducing the number of polygons to 9	NRL—Wind Energy Resource Atlas of the United States. Retrieved 1/28/2020 from http://www.nrel.gov/gis/wind_maps.html
Wind Speed at 100 m	Wind speed at 100 meters	ANL—EZMT. Retrieved 5/11/2020 from https://ezmt.anl.gov/viewer
Wind Speed at 80 m	Wind speed at 80 meters	ANL—EZMT. Retrieved 5/11/2020 from https://ezmt.anl.gov/viewer
Solar Photovoltaic	Solar photovoltaic	NRL—Renewable Energy Atlas. Retrieved 5/20/2020 from https://maps.nrel.gov/re-atlas/?aL=AMzVXM%255Bv%255D%3Dt&bL=clight&cE=0&lR=0&mC=63.421030654064175%2C-141.6796875&zL=5
Climate Reference Network Sites	Climate reference network sites—added URLs for sensor site data, which includes daily data at that site	National Oceanic and Atmospheric Administration (NOAA)—National Centers for Environmental Information (NCEI) portal. Retrieved 6/9/2020 from https://gis.ncdc.noaa.gov/maps/ncei/
Hourly Climate Normals Sites	Hourly climate normals sites	NOAA—NCEI portal. Retrieved 6/9/2020 from https://gis.ncdc.noaa.gov/maps/ncei/
Daily Climate Normals Sites	Daily climate normals sites—added URLs for station site data, which includes daily data at that site	NOAA—NCEI portal. Retrieved 6/9/2020 from https://gis.ncdc.noaa.gov/maps/ncei/
Absolute Change in Average Annual Precipitation between (1975–2005) and (2071–2090) (mm)	Absolute change in average annual precipitation between (1975–2005) and (2071–2090) (millimeters)	U.S. Forest Service (USFS)—National Forest Climate Change Maps. Retrieved 1/8/2021 from https://www.fs.fed.us/rm/boise/AWAE/projects/NFS-regional-climate-change-maps/categories/us-raster-layers.html
Historical Annual Average Precipitation for 1975 to 2005 (mm)	Historical annual average precipitation for 1975 to 2005 (millimeters)	USFS—National Forest Climate Change Maps. Retrieved 1/8/2021 from https://www.fs.fed.us/rm/boise/AWAE/projects/NFS-regional-climate-change-maps/categories/us-raster-layers.html
Percent Change in Average Annual Precipitation between (1975–2005) and (2071–2090) (mm)	Percent change in average annual precipitation between (1975–2005) and (2071–2090) (millimeters)	USFS—National Forest Climate Change Maps. Retrieved 1/8/2021 from https://www.fs.fed.us/rm/boise/AWAE/projects/NFS-regional-climate-change-maps/categories/us-raster-layers.html

Data	Description	Sources/Citations & URLs
Projected Annual Precipitation for 2006 to 2100 (mm)	Projected annual precipitation for 2006 to 2100 (millimeters)	USFS—National Forest Climate Change Maps. Retrieved 1/8/2021 from https://www.fs.fed.us/rm/boise/AWAE/projects/NFS-regional-climate-change-maps/categories/us-raster-layers.html
Absolute Change in Average Annual Temperature between (1975–2005) and (2071–2090) (°C)	Absolute change in average annual temperature between (1975–2005) and (2071–2090) (degrees Celsius)	USFS—National Forest Climate Change Maps. Retrieved 1/8/2021 from https://www.fs.fed.us/rm/boise/AWAE/projects/NFS-regional-climate-change-maps/categories/us-raster-layers.html
Historical Annual Average Temperature for 1975 to 2005 (°C)	Historical annual average temperature for 1975 to 2005 (degrees Celsius)	USFS—National Forest Climate Change Maps. Retrieved 1/8/2021 from https://www.fs.fed.us/rm/boise/AWAE/projects/NFS-regional-climate-change-maps/categories/us-raster-layers.html
Projected Annual Average Temperature for 2006 to 2100 (°C)	Projected annual average temperature for 2006 to 2100 (degrees Celsius)	USFS—National Forest Climate Change Maps. Retrieved 1/8/2021 from https://www.fs.fed.us/rm/boise/AWAE/projects/NFS-regional-climate-change-maps/categories/us-raster-layers.html
Active Layer Thickness, 2100 (meters)	Projected active layer thickness in 2100 under RCP 8.5 scenario (meters)	University of Alaska Fairbanks (UAF), Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Active Layer Thickness, 2090 (meters)	Projected active layer thickness in 2090 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Active Layer Thickness, 2080 (meters)	Projected active layer thickness in 2080 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Active Layer Thickness, 2070 (meters)	Projected active layer thickness in 2070 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Active Layer Thickness, 2060 (meters)	Projected active layer thickness in 2060 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Active Layer Thickness, 2050 (meters)	Projected active layer thickness in 2050 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Active Layer Thickness, 2040 (meters)	Projected active layer thickness in 2040 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from

Data	Description	Sources/Citations & URLs
		http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Active Layer Thickness, 2030 (meters)	Projected active layer thickness in 2030 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Active Layer Thickness, 2020 (meters)	Projected active layer thickness in 2020 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Active Layer Thickness, 2010 (meters)	Projected active layer thickness in 2010 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Permafrost Base, 2100 (meters)	Projected annual minimum depth of permafrost base, 2100 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Permafrost Base, 2090 (meters)	Projected annual minimum depth of permafrost base, 2090 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Permafrost Base, 2080 (meters)	Projected annual minimum depth of permafrost base, 2080 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Permafrost Base, 2070 (meters)	Projected annual minimum depth of permafrost base, 2070 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Permafrost Base, 2060 (meters)	Projected annual minimum depth of permafrost base, 2060 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Permafrost Base, 2050 (meters)	Projected annual minimum depth of permafrost base, 2050 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Permafrost Base, 2040 (meters)	Projected annual minimum depth of permafrost base, 2040 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Permafrost Base, 2030 (meters)	Projected annual minimum depth of permafrost base, 2030 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual

Data	Description	Sources/Citations & URLs
Permafrost Base, 2020 (meters)	Projected annual minimum depth of permafrost base, 2020 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Permafrost Base, 2010 (meters)	Projected annual minimum depth of permafrost base, 2010 under RCP 8.5 scenario (meters)	UAF Geophysical Institute Permafrost Laboratory. Retrieved 11/25/2020 from http://ckan.snap.uaf.edu/dataset/gipl-model-outputs-linear-coupled-annual
Rivers/Streams	Rivers/streams from Open Street Map	U.S. Army Geospatial Center (AGC)—Common Map Background Online Portal. Retrieved 3/9/2020 from https://agcwfs.agc.army.mil/CMB_Online/default.html
Surface Water	Surface water	U.S. Geological Survey (USGS)—National Water Information System Portal. Retrieved 3/24/2020 from https://waterdata.usgs.gov/ak/nwis
Water Bodies	Waterbodies from Open Street Map	AGC—Common Map Background Online Portal. Retrieved 3/9/2020 from https://agcwfs.agc.army.mil/CMB_Online/default.html
Natural Gas Pipelines	Natural gas pipelines	U.S. Department of Homeland Security—HIFLD Open Data Portal. Retrieved 3/13/2020 from https://gii.dhs.gov/gii/home/
Oil and Natural Gas Wells	Oil and natural gas wells	U.S. Department of Homeland Security—HIFLD Open Data Portal. Retrieved 3/31/2020 from https://gii.dhs.gov/gii/home/
Roads	Roads from Open Street Map	AGC—Common Map Background Online Portal. Retrieved 3/9/2020 from https://agcwfs.agc.army.mil/CMB_Online/default.html
Land Cover	Land cover	Multi-Resolution Land Characteristics Consortium—2016 National Land Cover Database. Retrieved 5/22/2020 from https://www.mrlc.gov/data?f%5B0%5D=region%3Aalaska&f%5B1%5D=region%3Aalaska
Slope Percent	Slope Percent for each cell of the raster. Created from 30 meter resolution digital terrain elevation data Level 2 for Fort Wainwright area	AGC—Common Map Background Online Portal. Retrieved 5/22/2020 from https://agcwfs.agc.army.mil/CMB_Online/default.html
County Boundary	County boundary—Topologically Integrated Geographic Encoding and Referencing Line file	U.S. Census Bureau. Retrieved 3/10/200 from https://www.census.gov/cgi-bin/geo/shapefiles/index.php

Data	Description	Sources/Citations & URLs
State Boundary	State Boundary— Topologically Integrated Geographic Encoding and Referencing Line file	U.S. Census Bureau. Retrieved 3/10/200 from https://www.census.gov/cgi-bin/geo/shapefiles/index.php
CADRG TLM50—Fort Greely, Fort Wainwright, Joint Base Elmendorf-Richardson	Compressed arc digital raster graphics of topographic line maps 1:50,000 scale for three areas: Fort Greely, Fort Wainwright, Joint Base Elmendorf-Richardson	AGC Common Map Background Online Portal. Retrieved 4/4/2020 from https://agcwfs.agc.army.mil/CMB_Online/default.html
USGS Topographic Reference Map	USGS topographic reference map	USGS—The National Map. Retrieved 3/11/2020 from https://basemap.nationalmap.gov/arcgis

Table A-2. Data sources not integrated into the Energy Atlas–Alaska.

Source	Consideration	Sources/Citations & URLs
Military Installations, Ranges, and Training Areas (MIRTA) Boundary Data	Compared the Defense Information Spatial Data Infrastructure site boundaries file and the MIRTA boundaries file and found that the files are essentially the same except the DIDSI file also includes training sites and training areas, which are not in the MIRTA file	DoD—Data.gov portal. Retrieved 4/14/2020 from https://catalog.data.gov/dataset/military-installations-ranges-and-training-areas
Rivers/Streams, Waterbodies	Rivers/streams, waterbodies—not used because data was not as detailed as the Open Street Map data	Alaska Department of Natural Resources. Retrieved 3/26/2020 from http://www.asgdc.state.ak.us/#30

Acronyms and Abbreviations

AGC	Army Geospatial Center
AGE	AGC Geospatial Enterprise
ANL	Argonne National Laboratory
AOI	Area of Interest
AR5	Intergovernmental Panel on Climate Change's Fifth Assessment Report
CAC	Common Access Card
CCM	Climate Change Map
CRREL	Cold Regions Research and Engineering Laboratory
DGGS	Division of Geological & Geophysical Surveys
DISDI	Defense Installation Spatial Data Infrastructure
DNR	Department of Natural Resources
DoD	Department of Defense
EA-AK	Energy Atlas–Alaska
ERDC	U.S. Army Engineer Research and Development Center
EZMT	Energy Zones Mapping Tool
FOUO	For Official Use Only
GFDL-CM3	Geophysical Fluid Dynamics Laboratory's General Coupled Circulation Model Version 3
GIPL	Geophysical Institute Permafrost Lab
GIS	Geographic Information System
GISS-E2-R	Goddard Institute for Space Studies ModelE2 using the Russell Ocean Model
GRL	Geospatial Research Laboratory

GTN-P	Global Terrestrial Network for Permafrost
HIFLD	Homeland Infrastructure Foundation-Level Data
IPSL-CM5A-LR	Institut Pierre Simon Laplace Climate Model 5A
MRI-CGCM3	Meteorological Research Institute's Coupled Global Climate Model Version 3
NCAR-CCSM4	National Center for Atmospheric Research's Community Climate System Model Version 4
NCEI	National Centers for Environmental Information
NOAA	National Oceanic and Atmospheric Administration
NSIDC	National Snow and Ice Data Center
PRISM	Parameter-Elevation Regressions on Independent Slopes Model
RCP	Representative Concentration Pathway
SNAP	Scenario Network for Alaska and Arctic Planning
UAF	University of Alaska Fairbanks
USACE	U.S. Army Corps of Engineers
USFS	United States Forest Service
USGS	United States Geological Survey
WHOI	Woods Hole Oceanographic Institute

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14. ABSTRACT
As the largest Department of Defense (DoD) land user in Alaska, the U.S. Army oversees over 600,000 hectares of land, including remote areas accessible only by air, water, and winter ice roads. Spatial information related to the energy resources and infrastructure that exist on and adjacent to DoD installations can help inform decision makers when it comes to installation planning. The *Energy Atlas–Alaska* portal provides a secure value-added resource to support the decision-making process for energy management, investments in installation infrastructure, and improvements to energy resiliency and sustainability.

The Energy Atlas–Alaska portal compiles spatial information and provides that information through a secure online portal to access and examine energy and related resource data such as energy resource potential, energy corridors, and environmental information. The information database is hosted on a secure Common Access Card–authenticated portal that is accessible to the DoD and its partners through the Army Geospatial Center's Enterprise Portal. This Enterprise Portal provides effective visualization and functionality to support analysis and inform DoD decision makers. The Energy Atlas–Alaska portal helps the DoD account for energy in contingency planning, acquisition, and life-cycle requirements and ensures facilities can maintain operations in the face of disruption.

15. SUBJECT TERMS
ArcGIS, Energy conservation, Geographic information systems, Land use, Renewable energy sources--Alaska, United States--Department of Defense

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