Alaska Aviation System Plan

Appendix 2

Western Alaska Airport Resiliency Study: Cold Regions Research Annotated Bibliography

A Component of the Alaska Aviation System Plan

June 4, 2024

BUILDING RESILIENT INFRASTRUCTURE for ALASKA · ALASKA DOT&PF

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Prepared for:
Alaska Department of Transportation & Public Facilities, Statewide Aviation

Requested by:
Alaska Aviation Advisory Board

Supported by a grant from the:
Federal Aviation Administration

The preparation of this document was supported in part with financial assistance through the Airport Improvement Program from the Federal Aviation Administration (AIP Grant No. 3-02-0000-031-2022) as provided under Title 49 USC §47104. The contents do not necessarily reflect the official views or policy of the FAA. Acceptance of this report by the FAA does not in any way constitute a commitment on the part of the United States to participate in any development depicted therein, nor does it indicate that the proposed development is environmentally acceptable in accordance with appropriate public laws.

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Acronyms

ACE	air convection embankment
ACI	Airports Council International
ACROS	Airport Climate Risk Operational Screening
ACRP	Airport Cooperative Research Program
APDES	Alaska Pollutant Discharge Elimination System
BIM-CFD	Building Information Modeling-Computational Fluid Dynamics
CISA	Cybersecurity and Infrastructure Security Agency
FAA	Federal Aviation Administration
SAR	search and rescue
SWPPP	Stormwater Pollution Prevention Plan

Introduction

The following literature review summarizes recommended aviation system best practices, resilience planning strategies, and examples of implemented resilience measures with a focus on regions with cold climates. Each resource is identified as being *very relevant, relevant,* or *somewhat relevant* to the topics of Planning, Design and Construction (D&C), and Maintenance and Operations (M&O).

A central theme in recently published airport resilience guidance documents and reports of successful resilience strategies is the importance of adapting infrastructure and operational practices to climate change impacts. Areas at high latitudes are warming at a disproportionate rate. Additionally, coastal airports and airports underlain by permafrost are particularly susceptible to climate change impacts. Challenges that Alaskan airports have historically faced, such as coastal erosion, embankment failure, and extreme weather events, are projected to worsen.

Aviation resilience research has been applied to develop frameworks and guidelines that aviation professionals can use to assess which climate change-related risks specific airports face, how airport infrastructure will be impacted, and effective strategies to make infrastructure more resilient. These resources and tools can be used to identify vulnerable infrastructure and develop actions to improve resiliency. Case studies included within broader guidance documents, as well as studies and articles published by aviation providers and institutions, provide examples of effectively implemented resiliency planning approaches and specific engineering technologies that have been developed.

Resources are divided into five categories:

Section I: Guidance for Airport Resiliency Planning includes sources that provide general information about climate-related threats that airports face, introduces resilience planning frameworks, and provides case studies exemplifying how specific airports have improved resiliency. General themes in resilience planning best practice guidance are the importance of taking a proactive approach, conducting studies to understand climate change risks across all aviation system components, and broad communication and collaboration across all the different entities involved in airport operations.

Section II: Resources to Evaluate Airport Vulnerability summarizes research on how climate change impacts aviation operations. This information provides context for some specific threats that airport infrastructure faces.

Section III: Resiliency Planning Tools includes specific processes, methodologies, and tools developed for airports to conduct risk analyses, establish adaptation methods, and evaluate the financial feasibility of potential infrastructure resiliency projects.

Section IV: Examples of Cold Region Resiliency Practices cites documents that provide examples of resilience planning frameworks that aviation organizations have implemented and specific practices they have used.

Section V: Cold Climate-Specific Technologies/Methods includes research and review papers describing engineering technologies implemented by airports to cope with cold climate-related challenges, including ground subsidence from permafrost thaw and snow removal on runways.

I. Guidance for Airport Resiliency Planning

Toolbox for Resilience and Adaptation in Coastal Arctic Alaska (2017)

Planning: Very Relevant *D&C: Relevant* *M&O: Somewhat Relevant*

Synopsis: This guide includes a selection of tools and success stories from around Alaska, intended to help communities, resource managers, and decision-makers maintain resilience and adapt to change. Content is organized into six categories: Leadership and Communication, Natural Systems, Public Infrastructure, Health and Culture, Other Economic Activities, and Emergency Response. The public infrastructure section focuses on adaptation responses to erosion, flooding, and subsidence (i.e., from permafrost thaw), with a focus on rebuilding damaged infrastructure to be more resilient than what existed previously.

Relevance to Current Effort: This paper does not focus on aviation systems; however, it does provide useful information around the broader context of environmental changes and community changes that Alaska is facing. The Public Infrastructure section includes numerous examples of infrastructure adaptation stories in Alaska, such as protecting infrastructure from flooding, avalanche paths, and eroding coastlines. Additionally, aviation planners can draw from the many listed resources and tools available for resilience planning, which are organized and linked in this report.

Agnew::Beck Consulting. "A Toolbox for Resilience and Adaptation in Coastal Arctic Alaska." Adapt Alaska, October 6, 2016. https://adaptalaska.org/wp-content/uploads/2017/10/ak-adaptation-toolbox.pdf.

Airports' Resilience and Adaptation to a Changing Climate (2018)

Planning: Very Relevant *D&C: Relevant* *M&O: Relevant*

Synopsis: This policy brief includes information, insights, and guidance to assist with airport resiliency planning. Airport Council International's (ACI's) recommendations include:

- Considering climate change in the development of Master Plans
- Assessing the level of risk to or criticality of operational procedures and infrastructure
- Developing and incorporating resiliency actions early in the planning process for all airport operations
- Ensuring effective, reliable communication between airport staff, stakeholders, and relevant external entities

Relevance to Current Effort: The brief provides a framework for climate resiliency planning at airports and an overview of facilities and operations that may be vulnerable to climate stressors. The following case studies in the policy brief also provide examples of effective resiliency planning, which could be used to guide Alaska's strategy:

- Avinor, the operator of Norway's airports, approaches climate adaptation from the very beginning of project planning (e.g., selecting materials or conducting capacity assessments). Avinor conducts comprehensive risk assessments, uses lessons learned to develop new

infrastructure standards and policies, and has established standards for construction so that new infrastructure projects will have a greater emphasis on climate adaptation.

- Early planning and extensive collaboration across airport operations-related organizations are essential for mitigating disruption from storm events, as demonstrated by the Hong Kong Airport's effective response to Typhoon Hato.
- Singapore's government has implemented comprehensive strategies to address potential infrastructure damage by employing targeted approaches for individual airport assets and broader district-level protections. Preventive measures, such as building runways at a higher base elevation and improving drainage capacity, were implemented to improve resiliency.

Airports Council International. "Airports' Resilience and Adaptation to a Changing Climate," September 2018. https://store.aci.aero/wp-content/uploads/2018/10/Policy_brief_airports_adaption_climate_change_V6_WEB.pdf.

Eco Airport Toolkit: Climate Resilient Airports (2021)

Planning: Very Relevant *D&C: Relevant* *M&O: Relevant*

Synopsis: This toolkit provides a high-level overview of the issues climate change may cause for airports and some strategies for anticipating and preparing for contingencies. The toolkit reiterates the resiliency measures recommended in the Airport Council International policy brief and discusses typical steps to develop a master plan or separate resiliency plan that accounts for climate impacts.

The toolkit also provides guidance on additional considerations, such as establishing communication systems and emergency plans. Communication systems tied to the airlines, tenants, and relevant external parties must be maintained with an accurate and updated contact list. Airports should also have emergency plans and standard operating procedures to address potential storm-related events and regularly engage stakeholders in these efforts.

Relevance to Current Effort: The document introduces tools and several strategies for design and construction that could be employed in Alaska airport resiliency planning, such as using a risk matrix and climate change risk assessment. The toolkit supports the ACI recommendation to address resilience in an airport master plan and provides a discussion and resources for developing climate adaptation measures.

The toolkit also includes case studies of various airports—several of those particularly relevant to cold-climate airports, like the following:

- The Iqaluit International Airport Improvement Project included extensive research and employed a variety of techniques, such as ground-penetrating radar, permafrost core analysis, surficial mapping, and remote sensing, to generate site-specific knowledge about permafrost properties. The data collected have been used to inform infrastructure decision-making. A key finding of this work is that permafrost tends to be subject to greater warming under pavement than embankments (and other "naturalized" surfaces).
- In 2014, the Toronto Lester B. Pearson International Airport experienced significant operational impacts from extreme cold and ice buildup. In response, the Greater Toronto Airports Authority recommended changes, such as improving communication protocols, developing tools to improve communications with passengers, and establishing an Airport Updates webpage.

International Civil Aviation Organization. "Eco Airport Toolkit: Climate Resilient Airports," April 22, 2021. https://www.icao.int/environmental-protection/Documents/Climate%20resilient%20airports.pdf.

A Guide for Resilience Planning at Airports (2021)

Planning: Very Relevant *D&C: Somewhat Relevant* *M&O: Relevant*

Synopsis: This article emphasizes the significance of resilience planning within the aviation industry, especially considering the challenges posed by climate change and the growing complexity of airport systems. Environmental Science Associates recommend developing a resilience management plan using a risk-based approach. The article highlights the importance of addressing shock events (major failures that demand immediate attention) and chronic stressors (smaller events that lead to and exacerbate these significant disruptions). The following principles inform the development of a resilience management plan:

- Create a Project Framework
- Conduct Resilience Management Plan Visioning
- Inventory Strategic Assets and Infrastructure
- Determine Requirements
- Conduct a Risk Assessment
- Identify Strategic Focus Areas
- Develop Focused Management Plans and Processes
- Perform Stakeholder Outreach
- Develop a System for Resilience Management
- Develop Resilience Promotion/Education Programs
- Develop Electronic Resilience Management Tools
- Create a Structure for Regular Reviews

Relevance to Current Effort: The article provides a strategy for mitigating risks to airports from stress events and chronic stressors. In addition to the list of principles, this article also provides general guidance. For instance, resiliency planning should complement existing planning efforts and, instead of starting from scratch, can build off established master plans. The guide also emphasizes that the resiliency planning process requires collaboration across airport departments, airport tenants, and other key external stakeholders, such as the Federal Aviation Administration's (FAA's) Airports District Office, communities surrounding the airport, and regional planning organizations.

Wolfe, N. "A Guide for Resilience Planning at Airports." Environmental Science Associates, 2021. https://esassoc.com/wp-content/uploads/2022/02/Resilience-at-Airports_Full-Article_ESA.pdf.

Statewide Threat Assessment: Identification of Threats from Erosion, Flooding, and Thawing Permafrost in Remote Alaska Communities (2019)

Planning: Very Relevant *D&C: Somewhat Relevant* *M&O: Somewhat Relevant*

Synopsis: This document assesses the relative risk to public infrastructure in rural Alaskan communities from erosion, permafrost thaw, flooding, and the compounded threats arising from the interconnected dynamics of these factors. Additionally, it provides guidance for decision makers to develop effective mitigation or adaptation strategies in response to these challenges. An overview of each threat and a

description of the available data are provided. There is a lack of long-term spatially or temporally discrete monitoring throughout Alaska. The paper recommends additional data collection and provides templates outlining the types of data that should be recorded for community resiliency planning. It emphasizes the need for central data repositories, organized by community, and standardized data collection methodology and terminology.

Relevance to Current Effort: Research into the relative threat from flooding, erosion, and permafrost thaw that communities face can help to identify threats that airport infrastructure is exposed to, which can inform mitigation and resiliency considerations. Airport resiliency research and evaluation would also benefit from strategies such as central data repositories and standardized data collection.

II. Resources to Evaluate Airport Vulnerability

Key Climate Change Vulnerabilities for Aviation Organizations (2022)

A component of Climate Change: Climate Risk Assessment, Adaptation and Resilience

Planning: Very Relevant *D&C: Very Relevant* *M&O: Very Relevant*

Synopsis: This guidance document provides a table describing how climate change-related impacts (higher average and extreme temperatures, changing precipitation, increased intensity of storms, and sea level rise) are affecting airports, air navigation service providers, and aircraft operations.

Relevance to Current Effort: The guidance document can be used as a reference to evaluate the types of infrastructure damage that Alaskan airports and aircraft operations are susceptible to. This information can be used to identify and prioritize vulnerabilities that Alaska's aviation systems face, such as changing precipitation patterns that will cause flooding and flood damage to runways and infrastructure or increased storm surges and permafrost thaw that threaten airport infrastructure. In addition to ground assets like runways and access roads, vulnerable infrastructure includes power supplies, navigation and communication equipment, and other electronic systems.

International Civil Aviation Organization. "Key Climate Change Vulnerabilities for Aviation Organisations." Climate Change: Climate Risk Assessment, Adaptation and Resilience, 2022. https://www.icao.int/environmental-protection/Documents/Climate%20Risk%20Assessment%20and%20Adaptation%20Report_Key%20Vulnerablities_final.pdf.

Reviewing the Impacts of Climate Change on Air Transport Operations (2022)

Planning: Very Relevant *D&C: Very Relevant* *M&O: Relevant*

Synopsis: This journal review article summarizes evidence that climate change has already impacted air transport and is expected to accelerate in the future. Changing wind direction, reducing wind strength, and increasing temperatures impact airplane take-off performance by increasing take-off distances where a surplus of runway length exists and decreasing available payload where it does not. The paper also discusses research indicating a general trend of increased air turbulence and changes to wildlife patterns, particularly bird activity, which may also impact airplane operations.

Relevance to Current Effort: The article provides an overview of some major aviation operation trends that many airports will experience because of climate change.

Gratton, G. B., P. D. Williams, A. Padhra, and S. Rapsomanikis. "Reviewing the Impacts of Climate Change on Air Transport Operations." *The Aeronautical Journal* 126, no. 1295 (January 2022): 209–21. https://doi.org/10.1017/aer.2021.109.

Outcomes of the 2020 Survey on the Impacts of Climate Change and Variability on Aviation (2020)

Planning: Relevant *D&C: Relevant* *M&O: Somewhat Relevant*

Synopsis: This article reviews the outcomes of the 2020 Survey on the Impacts of Climate Change and Variability on Aviation. Most respondents evaluated the degree of impact of future climate change and variability on aviation to be moderate or greater and believed that climate change impacts may be felt within the next 10 years. Some major trends that were identified include:

- Increased likelihood of airfield flooding caused by heavy rain and/or storm surge
- Longer take-off and landing distances in a warming climate and a reduced runway capacity
- Frequent disruption from extreme weather events and increased fuel consumption because of longer routings
- Increased frequency and severity of turbulence

Relevance to Current Effort: The article provides additional evidence that aviation professionals are concerned about climate change and are experiencing or expect to experience impacts within the near term. The article helps identify some key vulnerabilities that airports and the overall aviation system will likely face.

Standing Committee on Services for Aviation. "Outcomes of the 2020 Survey on the Impacts of Climate Change and Variability on Aviation." World Meteorological Organization, October 2020. https://library.wmo.int/doc_num.php?explnum_id=10387.

Effect of Warmer Minnesota Winters on Freeze-Thaw Cycles (2022)

Planning: Somewhat Relevant *D&C: Somewhat Relevant* *M&O: Somewhat Relevant*

Synopsis: Minnesota winters have been getting warmer, and there are increasing periods with winter temperatures around freezing (32 degrees Fahrenheit). This study investigated how these changes in temperature patterns impact freeze-thaw events of pavement and, consequently, pavement conditions and longevity. The study assessed historical air, pavement, and subsurface temperatures, precipitation, and freeze-thaw depth data collected from Minnesota roads and runways. The study also analyzed correlations between air, pavement, and subsurface temperatures and the occurrence of freeze-thaw events. Climate data indicated a trend of later onsets of freezing temperatures and increased precipitation. Pavement freeze-thaw patterns showed a decrease in freeze-thaw events during early and late winter months, and freeze-thaw events remained sporadic, with more shallow freezing during the middle winter months. The report recommends a follow-up study into how precipitation influences freeze-thaw events for pavement and the integration of pavement condition projections into vulnerability mapping of the state road networks.

Relevance to Current Effort: This study provides an example of collecting data and conducting research to understand how climate change impacts pavement conditions, which is important for sustainable pavement management planning, especially in the context of a changing climate. Further study should be conducted in Alaska as the state continues to experience increased thawing, especially of permafrost.

Ceylan, H., M. Mahedi, D. Rajewski, S. Kim, I. Cho, and E. S. Takle. "Effect of Warmer Minnesota Winters on Freeze-Thaw Cycles." Office of Innovation and Research, Minnesota Department of Transportation, July 2022. https://www.researchgate.net/profile/Masrur-Mahedi/publication/372763895_Effect_of_Warmer_Minnesota_Winters_on_Freeze-Thaw_Cycles_-_Minnesota_Department_of_Transportation/links/64c6d608545060019e3ed8bd/Effect-of-Warmer-Minnesota-Winters-on-Freeze-Thaw-Cycles-Minnesota-Department-of-Transportation.pdf.

III. Resiliency Planning Tools

Key Steps in Aviation Organisation Climate Change Risk Assessment and Adaptation Planning (2022)

A component of Climate Change: Climate Risk Assessment, Adaptation and Resilience

Planning: Very Relevant *D&C: Very Relevant* *M&O: Very Relevant*

Synopsis: This guidance document was produced for carrying out a climate change risk assessment and subsequently developing and implementing an adaptation plan intended for use by airports, aircraft operators, and air navigation service providers.

The guide includes step-by-step flowcharts for carrying out a climate change risk assessment and a discussion of each key step, ranging from staff organization and identification of scope, to data collection and assessment of climate impacts, and to identification and assessment of at-risk infrastructure. The guide recommends using a risk matrix to analyze the consequence of potential impacts alongside the probability of occurrence, followed by assessing the existing adaptive capacity of infrastructure and systems that may be impacted to quantify overall airport vulnerability.

Next, the document describes how to apply the risk assessment to climate change adaptation planning. The process is divided into four key steps, with a detailed description of sub-steps for each key stage:

1) Define adaptation and resilience objectives
2) Identify adaptation and resilience measures to address prioritized vulnerabilities
3) Develop and implement a climate adaptation plan
4) Conduct periodic monitoring and review

Relevance to Current Effort: The guidance includes step-by-step information about how to develop a risk assessment, how to develop and implement a climate adaptation plan, and additional planning tools and resources that can be integrated into this process.

The document is also supplemented with best practices/lessons learned during the risk assessment process. For example, when developing a risk assessment scope, less visible or obvious threats are often overlooked. To achieve a more comprehensive approach and avoid overlooking threats, the risk assessment team should engage with asset operators, operational staff, facility managers, and decision-makers at an early stage in the process. Similarly, during the identification of climate impacts stage, engaging the organization's personnel is essential, such as asset operators, operational staff, and facility managers who have hands-on experience to assess expected impacts.

International Civil Aviation Organization. "Key Steps in Aviation Organisation Climate Change Risk Assessment and Adaptation Planning." Climate Change: Climate Risk Assessment, Adaptation and Resilience, 2022. https://www.icao.int/environmental-protection/Documents/Climate%20Risk%20Assessment%20and%20Adaptation%20Report_Key%20Steps%20Risk%20Assessment_final.pdf.

Menu of Adaptation Options (2022)

A component of Climate Change: Climate Risk Assessment, Adaptation and Resilience

Planning: Very Relevant *D&C: Very Relevant* *M&O: Very Relevant*

Synopsis: This document is a supplement to Climate Risk Assessment, Adaptation and Resilience: Key Steps in Aviation Organisation Climate Change Risk Assessment and Adaptation Planning, with information targeted toward the adaptation action selection process. The document lists operational and infrastructure adaptation practices in response to different climate change impacts and emphasizes the importance of broad collaboration for strengthening climate change resilience.

Relevance to Current Effort: The document offers examples and suggestions for resilience actions that can help airports address the impacts of climate change. Applying this checklist to specific airports will identify which airports are already implementing resilience measures, which can create a baseline for individual airports and be used to evaluate the efficacy of specific strategies for Alaskan airports. Relevant climate impacts that are addressed include increased intensity of storms, changing precipitation patterns, and sea level rise. For example, recommended responses to severe weather events and storm surges include ensuring clear and functional drainage networks, relocating critical infrastructure to higher floors, installing backup power sources, implementing groundwater storage measures, designing facilities to withstand extreme precipitation events, and safeguarding wiring and connections from flooding through relocation, burial, or elevation.

International Civil Aviation Organization. "Menu of Adaptation Options." Climate Change: Climate Risk Assessment, Adaptation and Resilience, 2022. https://www.icao.int/environmental-protection/Documents/Climate%20Risk%20Assessment%20and%20Adaptation%20Report_Menu%20of%20Adaptation%20Measures_final.pdf.

Climate Change Adaptation Planning: Risk Assessment for Airports (2015)

Planning: Very Relevant *D&C: Very Relevant* *M&O: Very Relevant*

Synopsis: This guidebook helps airport practitioners identify specific climate change impacts, develop adaptation actions, and incorporate actions into the overall airport planning process. The guidebook is organized into the following four parts:

Part 1: Provides an overview and introduces the Airport Climate Risk Operational Screening (ACROS) tool, which offers a streamlined approach to developing a climate adaptation plan (see Part 3 for a description of the ACROS tool) and describes the process of initiating climate adaptation planning. Initiation involves identifying crucial leaders, establishing a stakeholder advisory committee, and setting climate resilience goals.

Part 2: Provides an overview of climate change projections and how airports will be impacted, with a description of commonly used climate change metrics. This section also includes guidance for developing a climate change adaptation strategy independent of the ACROS tool.

Part 3: User guide for the ACROS tool, which is used to provide a screening-level investigation of climate change risks. The ACROS tool contains site-specific information on airport assets for 500 airports nationwide, climate change projection data, and expert-recommended adaptation options.

Part 4: Describes how climate change planning can be integrated into existing planning frameworks. For example, climate impacts can be addressed within Safety Management Systems, disaster, business recovery, emergency response planning, and risk management processes. Climate adaptation planning can be incorporated throughout Airport Master Plan and Airport Layout Plan development and should be done in coordination with broader regional transportation planning efforts.

Relevance to Current Effort: The guidebook outlines the process and provides a tool to guide airports through the Airport Cooperative Research Program's climate adaptation planning process. In particular, the ACROS tool can help airports determine what aspects of climate change will most likely impact them, how these impacts will affect operations and infrastructure, and potential adaptation responses. This tool saves airport staff time and resources when evaluating and prioritizing potential adaptation options and initiating the airport adaptation process. This guidebook also contains tools for developing an adaptation plan without using the ACROS tool. Appendix A of the guidebook includes a list of possible climate stressors and how they will impact specific assets; Appendix E includes a list of resources that provide supplemental information on climate change adaptation planning.

National Academies of Sciences, Engineering, and Medicine. "Climate Change Adaptation Planning: Risk Assessment for Airports." *The National Academies Press*, 2015. https://nap.nationalacademies.org/catalog/23461/climate-change-adaptation-planning-risk-assessment-for-airports

Climate Resilience and Benefit-Cost Analysis: A Handbook for Airports (2019)

Planning: Very Relevant *D&C: Very Relevant* *M&O: Relevant*

Synopsis: This handbook is designed to help airport practitioners assess the benefits, costs, and financial feasibility of infrastructure projects designed to improve resilience to climate change and extreme weather events.

The handbook recommends using an existing software tool, ACROS (see Climate Change Adaptation Planning: Risk Assessment for Airports for more information), to access future climate projections, identify vulnerable infrastructure, and consider ways to reduce impacts through investments in infrastructure or operational changes. The handbook directs users to a tool that will run Monte Carlo simulations using climate model data to evaluate the probability of specific climate events and consequential infrastructure damage. This tool calculates the probability of various severities of infrastructure damage and related costs if no mitigation occurs, compared to the cost of climate impacts to infrastructure if mitigation is implemented. This analysis can help users predict whether a climate mitigation measure will save money.

Relevance to Current Effort: Alaskan airports will likely need to continue to invest in resiliency projects. This handbook and associated software and tools can be used to identify and evaluate the economic feasibility and potential cost savings of climate resilience-oriented infrastructure projects. Following the guidance in the handbook provides a method for making data-supported decisions about which resiliency measures to invest in.

National Academies of Sciences, Engineering, and Medicine. "Climate Resilience and Benefit-Cost Analysis: A Handbook for Airports." *The National Academies Press*, 2019. https://doi.org/10.17226/25497.

An Airport Climate Resilience Assessment Scan (2020)

Planning: Relevant *D&C: Relevant* *M&O: Somewhat Relevant*

Synopsis: This article is a thesis that describes the development of the Airport Climate Resilience Assessment Scan (AirCRAS). This digital method is used to assess airport resiliency at the airport level to gain a holistic view of the climate resilience status of an airport. The tool requires that users provide answers to assessment questions, identifying what climate risks are relevant to the airport in question, and providing details about airport organizations, operations, and infrastructure. The tool will then output a rose diagram describing the airport's resilience status and provide discussion questions aimed at facilitating additional resilience planning.

Relevance to Current Effort: The article describes a method that synthesizes existing airport resilience research into an assessment tool that will evaluate the resiliency status of individual airports. Potential applications of this method include providing insights into the resilience of specific airports in Alaska, providing baseline data for resilience planning, and helping with efforts to identify airports that are most vulnerable to climate change.

Verdijk, P. F. M. "An Airport Climate Resilience Assessment Scan." Netherland Airport Consultants, 2020. http://essay.utwente.nl/85464/1/Verdijk_MA_ET.pdf.

IV. Examples of Cold Region Resiliency Practices

Adapting Airports to a New Climate (2016)

Planning: Relevant *D&C: Relevant* *M&O: Relevant*

Synopsis: This document discusses risk assessment and climate change adaptation implemented by Avinor, a Norwegian airport operator. It mentions specific challenges and considerations, such as changing wind directions, drainage issues, the vulnerability of navigation infrastructure to flooding, and changes in requirements for runway elevations to combat rising sea levels. The document emphasizes the importance of considering climate change impacts and integrating climate adaptation measures into infrastructure planning and maintenance. The document also highlights the need for conducting risk assessments of airports, including navigation systems and surface access, to identify vulnerabilities and take appropriate actions.

Relevance to current effort: The document provides relevant insights and considerations for Alaska aviation system planning and improving safety in the face of climate change. Alaska has similarities in geography and climate to Norway and is facing similar climate change-related challenges. The emphasis on conducting risk assessments and integrating climate change considerations into infrastructure planning can be valuable for Alaska's aviation systems.

Larsen, O. M. and K. Fjellheim. "Adapting Airports to a New Climate." International Civil Aviation Organization, 2016. https://www.icao.int/environmental-protection/Documents/EnvironmentalReports/2016/ENVReport2016_pg211-213.pdf.

Climate Risks & Adaptation Practices for the Canadian Transportation Sector (2016)

Planning: Very Relevant *D&C: Very Relevant* *M&O: Very Relevant*

Synopsis: This report reviews climate risks to the Canadian transportation sector and describes different climate vulnerabilities, priorities, practices, and opportunities across Canada's national transportation system. It is organized into chapters based on geographic region, each of which has a dedicated air transportation section. Summaries of the air transportation information provided in Chapter 3 (Northern Territories) and Chapter 4 (British Columbia) are included herein.

Chapter 3 Northern Territories, Section 6 Aviation System identifies the following key climate issues that northern airports are facing:

- Air Temperature – Permafrost degradation can damage and degrade runways/taxiways.
- Snow – Increased snowfall may cause flooding in the thaw seasons, damaging permafrost under runways/taxiways.
- Blizzards – Blowing snow and winter storms can reduce visibility and delay flight operations.
- Rainfall – Increased rainfall can reduce traction on runways/taxiways. Intense periods of freezing rain can cause delays to flights and could cause airplanes to experience issues with braking and sliding off airstrips.
- Fog – Increased fog episodes may require additional training and procedures for airport personnel to ensure safety. Intense periods of fog can delay flights until visibility improves.

This section also provides an overview of adaptation practices and rationales that are implemented at Northern Canadian airports. For example, ground settlement from permafrost thaw can be more easily corrected in gravel runways by adding embankment material or more easily reconstructed than paved runways. This section also notes that the grooving of paved runways has improved drainage and traction; however, it is relatively costly, and removing snow as quickly as possible can mitigate the risk of permafrost thaw from heavier snowfall.

Chapter 4 British Columbia, Section 6 Air Transportation: This section identifies the key hazards for coastal airports as storm surges increase and sea levels rise. The Vancouver Airport is addressing risks of climate change in a Master Plan update, whereas other airports in the region are taking a more reactive adaptation approach by monitoring weather conditions on an ongoing basis and adjusting practices as changes in weather phenomena are observed.

Relevance to Current Effort: Alaska shares many climate characteristics with Canada and faces similar threats from climate change. The adaptation practices and case studies can provide insight into Alaska's adaptation planning. For instance, the Northwest Territory chapter describes how the Iqaluit International Airport collected data on underlying permafrost conditions to inform infrastructure protection decisions. Extensive maps were produced to identify potentially problematic locations for existing and proposed infrastructure (e.g., thaw-sensitive soils and/or difficult terrain for construction); a taxiway was relocated with an insulated barrier to reduce permafrost damage; the importance of removing thick snow cover in key areas was recognized; thermosyphons were installed beneath airport buildings; and drainage was improved to reduce the infiltration of surface water into permafrost.

Palko, K. G. and D. S. Lemmen. "Climate Risks and Adaptation Practices – For the Canadian Transportation Sector 2016." Transport Canada, 2016. https://natural-resources.canada.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2016/ClimatRisk-E-ACCESSIBLE.pdf.

Arctic Airports and Aerodromes as Critical Infrastructure (2020)

Planning: Very Relevant *D&C: Relevant* *M&O: Relevant*

Synopsis: This policy primer provides an overview of airport conditions and trends in Nunavut, Canada, and highlights the significance of aviation infrastructure for remote communities, such as the critical role of airports in supporting public health through medical flights. The article provides an overview of aviation infrastructure in the region and discusses challenges faced by airports, including ground instability caused by permafrost thaw and deficiencies in runway lighting and power supply. The policy primer recommends that remoteness be factored into assessments of the importance of existing infrastructure assets and the significance of future investments and the Index of Remoteness, which uses several variables to quantify the remoteness of communities. Remoteness and the conditions of airport infrastructure are both important considerations to inform approaches to community resupply, medical evacuation, and search and rescue (SAR) operations.

Relevance to Current Effort: Many communities in Alaska are similarly remote and reliant on airport infrastructure, making this approach of quantifying remoteness into infrastructure planning decisions relevant. The following additional broad recommendations from this overview may offer insight into Alaska aviation planning:

- Recognizing the increasing frequency of intense storms caused by climate change, it is important to note that navigation system upgrades may facilitate safer landings in difficult weather. For many northern airports and aerodromes, 24-hour weather reporting is not yet available. Runway lighting is absent at many smaller gravel-surfaced airports and NAV CANADA lists many of these same runways as having clearing and surface maintenance concerns. As storms worsen and community pressures grow, investments in technologies are prudent to ensure the safe operation of existing air transportation patterns.
- Investments in weather-monitoring capabilities will be essential as climate change advances.
- Thoughtful analyses of medical travel and SAR operations represent important considerations for the planning of aeronautical infrastructure.

Bouchard, C. "Arctic Airports and Aerodromes as Critical Infrastructure." North American and Arctic Defence and Security Network, October 30, 2020. https://www.naadsn.ca/wp-content/uploads/2020/11/Airports_CI_2020_11_05.pdf.

Yukon Aviation System Review (2017)

Planning: Relevant *D&C: Somewhat Relevant* *M&O: Relevant*

Synopsis: The Yukon Aviation System Review includes a description of existing conditions, aviation forecasting, and the results from a compliance assessment of buildings and airfields for the Yukon Territories. The report then introduces evaluation criteria for infrastructure investment prioritization using a triple bottom line approach. Airports are ranked based on social, environmental, and economic performance; then, airport projects are evaluated to determine investment priority. The model considers the role of the airport, its triple bottom line ranking and scores, the severity of compliance issues, and the general condition and impact on future operations and capacity.

Relevance to Current Effort: The review provides an example of a methodology for assessing safety and performance issues of aviation infrastructure and a framework for prioritizing infrastructure investment decisions. The Yukon Aviation System Review exemplifies how a structured process for determining which aviation projects to invest in has the potential to maximize safety and performance within the broader aviation system.

Thompson, W. "Yukon Aviation System Review." Department of Highway and Public Works – Aviation Branch, Government of Yukon, May 23, 2017. https://yukonflying.com/Documents/YTG%20Aviation%20Review.pdf.

Cambridge Bay Airport Climate Change Vulnerability Assessment (2016)

Planning: Very Relevant *D&C: Very Relevant* *M&O: Very Relevant*

Synopsis: This report summarizes the Cambridge Bay Airport vulnerability assessment, which followed a standardized protocol prepared by the Public Infrastructure Engineering Vulnerability Committee. The assessment used historical data and climate models to assess climate conditions over the next 30 years. It identified five climate events that may affect airport operations and infrastructure performance: rainfall, visibility, frost, ground thawing index, and climate variability. Current environmental and maintenance baseline data were inadequate for a detailed engineering assessment; this lack of understanding was considered a moderate risk. The following actions were recommended:

- Evaluate the capacity of drainage systems to assess the resiliency of culverts and ditches against higher flows and measure runoff and changes in surface water bodies.
- Systematically collect information on visibility using a detailed logbook/database. Document weather conditions and characteristics of limited-visibility events.
- Collect data on frost formation, such as climate parameters, timing, location, and extent.
- Review frost management procedures.
- Update or develop an asset management system, including an evaluation of current infrastructure service life.
- Monitor local snow accumulation, including spatial (re)distribution, and note limitations to operations.
- Automate measurement of ground temperatures across the airport property.
- Document in a logbook/database climate-related flight delays/cancellations, as well as maintenance and repair activities, including date, location, type, and extent.
- Carry out an initial climate change vulnerability assessment with involvement from several stakeholder groups, including the airport operators, owners, and users, and re-evaluate it every 5 years as new baseline data, infrastructure performance information, and improved climate models become available.

Relevance to Current Effort: The report provides an example of a vulnerability assessment conducted at a northern, coastal airport and stresses the importance of collecting baseline data necessary for engineering and vulnerability assessments of airport infrastructure.

BGC Engineering and Transport Canada. "Cambridge Bay Airport – Climate Change Vulnerability Assessment." Public Infrastructure Engineering Vulnerability Committee, May 17, 2016. https://pievc.ca/wp-content/uploads/2016/05/cambridge_bay_climate_vulnerability_assessment_web.pdf.

Churchill Airport Climate Change Vulnerability Assessment (2016)

Planning: Very Relevant *D&C: Very Relevant* *M&O: Very Relevant*

Synopsis: This report summarizes the Churchill Airport vulnerability assessment, which followed a standardized protocol prepared by the Public Infrastructure Engineering Vulnerability Committee. The report found that the infrastructure component likely to be most vulnerable to climate change is the natural foundation on which airports are constructed because of heterogeneity in permafrost conditions. Poor visibility caused by changes in atmospheric moisture (e.g., fog, frost, precipitation) was determined to be the climate event most likely to be problematic for airport operations in the future. The precise extent of disruptions from poor visibility or other climate events was difficult to determine because of an inadequate baseline of environmental data and maintenance records. This lack of data and records prevented the performance of a detailed engineering assessment; therefore, the report recommends developing a database that combines infrastructure performance, air traffic operation, and climate events. Recommendations are as follows:

- Develop a database of infrastructure performance and environmental data to assess conditions during climate change-related challenges and document the severity of events.
- Document maintenance and repair efforts in a systematic manner to note changes and highlight infrastructure performance.

- Perform a procedural review by reviewing current operation and maintenance practices and standard operational procedures and evaluating their robustness against future climate conditions.
- Systematically collect information on visibility (e.g., fog and cloud ceiling) to identify potential trends and inform whether upgrades in the current instrumentation are required.
- Evaluate the capacity of culverts and ditches to assess the resiliency of existing drainage systems.
- Monitor local snow accumulation, including spatial (re)distribution, to assess current snow management plans and plan for future requirements.
- Reassess climate change vulnerability every 5 years with involvement from several stakeholder groups, including the airport operators, owners, and users, as more baseline data, infrastructure performance information, and improved climate models become available.

Relevance to Current Effort: Like the Cambridge Bay Airport Climate Change Vulnerability Assessment, this report emphasizes the importance of collecting baseline data for assessing climate change vulnerability and improving resiliency. The report provides an additional example of a vulnerability assessment and airport-specific resiliency actions for a cold climate airport with a gravel strip, though the climate is likely more similar to Southeast Alaska than Western Alaska.

BGC Engineering and Transport Canada. "Churchill Airport – Climate Change Vulnerability Assessment." Public Infrastructure Engineering Vulnerability Committee, May 17, 2016. https://pievc.ca/wp-content/uploads/2021/01/churchill_climate_vulnerability_assessment_web-1.pdf.

V. Cold Climate-Specific Technologies and Methods

Review of Thermosyphon Applications (2014)

Planning: Relevant *D&C: Relevant* *M&O: Relevant*

Synopsis: This review document describes the history of thermosyphon use in Alaska, the different applications they can be used for, and how the technology has evolved. This review notes that thermosyphon use will likely become increasingly important as temperatures warm and permafrost degrades because of climate change.

Relevance to Current Effort: The review provides a broad overview and insights into thermosyphon use in Alaska. Thermosyphons are already used for permafrost stabilization of runway and airport facilities (for example, Bethel is included as a case study in this review) and will likely become increasingly important. The review discusses the use of buried and hairpin thermosyphons, which may be a viable technology for new airport construction.

Note that this paper is from 2014, so recent advances in technology and applicability are not included.

Wagner, A. M. "Review of Thermosyphon Applications." US Army Corps of Engineers, February 2014. https://dot.alaska.gov/stwddes/research/assets/pdf/erdc-crrel-tr-14-1.pdf.

Loftus Road Extension: ACE & Thermosyphon Design Features (2003)

Planning: Relevant *D&C: Relevant* *M&O: Relevant*

Synopsis: This article describes the experimental features used in the construction of Thompson Drive in Fairbanks, Alaska. The design of the road included the novel use of hairpin thermosyphons, which are filled with liquid carbon dioxide and buried under the roadbed. It also used air convection embankments (ACE), which utilizes uniformly sized rocks with no fines to allow airflow within the embankment. The article includes diagrams to illustrate how these technologies and techniques were used throughout the road embankment.

Relevance to Current Effort: Hairpin thermosyphons and air convection embankments could be considered for use in the design of new airports. Retrofitting existing airports with thermosyphons would be more difficult.

Local Technical Assistance Program, "." Alaska Department of Transportation and Public Facilities, 2003. https://dot.alaska.gov/stwddes/research/assets/pdf/03v28n1.pdf

BIM-CFD Integrated Sustainable and Resilient Building Design for Northern Architecture (2020)

Planning: Somewhat Relevant *D&C: Relevant* *M&O: Somewhat Relevant*

Synopsis: The practice of elevating buildings is commonly used to decrease permafrost degradation from building heat transfer. Heat from buildings can be transferred into the ground (and the permafrost below) either by physical contact or by wind moving heated air from the building toward the ground; the latter process is known as the downwash effect and is influenced by wind speed and direction. This

study analyzed the relationship between building height, wind velocity, and wind direction to determine their impacts on northern building architecture and permafrost. Results revealed that the building downwash effect is a key factor in heat transfer to the ground and raising a building by at least 1 meter reduces the impact of the downwash effect. The study also found, however, that raising a building by 1.5 meters or more increases building heat loss through convective heat transfer.

The study also noted that a building's shadow area (i.e., the area of the ground around the building that is cast in shadow by the building) is highly susceptible to convective heat transfer.

Relevance to Current Effort: Many airport facilities in Alaska must be built on permafrost. This study provides design considerations for preventing damage to permafrost from transfer of heat to ground from buildings. The following design recommendations from this study can be considered for airport facilities on permafrost in northern Alaska:

- Raise buildings 1 meter above the ground to reduce the thermal stresses on the permafrost.
- Avoid implementing pilings foundation and screw jacks in the shadow area under the building frames because they are exposed to the highest heat transfer. Note that these methods are imperfect solutions for permafrost regions because thawing ground can disrupt the structure.
- Use special insulation in building edges and corners to enhance energy savings and significantly reduce the heat transfer from the buildings to the permafrost underneath.
- Consider building orientation in the early design stages to alleviate the building downwash effect on the permafrost.

Younis, M., M. Kahsay, and G. Bitsuamlak. "BIM-CFD Integrated Sustainable and Resilient Building Design for Northern Architecture." In *ASHRAE Topical Conference Proceedings*, 584–91. American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc., 2020.

Climate Change Impacts on Frost and Thaw Considerations: Case Study of Airport Pavement Design in Canada (2023)

Planning: Relevant *D&C: Relevant* *M&O: Relevant*

Synopsis: This study focused on investigating the potential impacts of climate change on frost/thaw depths and frost heaves in multiple locations across Canada. The study analyzed existing methods to estimate frost penetration depth and used these models to project future frost depth patterns. This information is important to inform the design of resilient pavements in future airport projects.

Evaluation of Frost Depth Calculation Methods: The accuracy of three frost depth calculation methods (developed by the Ministry of Transportation of Ontario, the Ministry of Transportation of Quebec, and Transport Canada Civil Aviation) was assessed. The measured frost depths in nine northern cities in Canada and the United States were compared to the frost depths estimated by these statistical models. The study revealed that the accuracy of the models varied, and the type of soil influenced their ability to predict frost penetration depth accurately.

Frost Depth Projections: The evaluated frost depth models were then used to project future frost/thaw depths and frost heave events under a high emission scenario (RCP8.5). The results indicated a decrease in frost depth penetration across the models.

Implications for Pavement Design: The article concludes that the warming winter temperatures associated with climate change may positively affect pavement conditions in southern areas of Canada. However, northern regions are likely to face challenges because of increased differential thaw settlement, frost heaves, and a decrease in overall pavement strength caused by permafrost thawing and a higher number of freeze-thaw cycles.

Relevance to Current Effort: Knowing how climate change can impact airport pavements' frost and seasonal frost-thaw conditions is essential for planning future transportation infrastructure projects. This study provides insights into the accuracy of some commonly used methods to evaluate frost penetration depth and recommendations for developing more mechanistic methods that better account for site-specific soil properties, to improve accuracy.

When considering pavement design that will be resilient to future warming freeze-thaw patterns, areas underlain by permafrost should be regarded differently than those not underlain by permafrost. For pavement underlain with permafrost, changes to the active layer thickness is the main concern because of projected increases in thaw depth.

Barbi, P. S. R., P. Tavassoti, and S. L. Tighe. "Climate Change Impacts on Frost and Thaw Considerations: Case Study of Airport Pavement Design in Canada." *Applied Sciences* 13, no. 13 (January 2023): 7801. https://doi.org/10.3390/app13137801.

Evaluation Of Airport Pavement Designs for Seasonal Frost and Permafrost Conditions (2023)

Planning: Very Relevant *D&C: Very Relevant* *M&O: Very Relevant*

Synopsis: Information was gathered and reviewed on the pavement performance issues of three runways with asphalt pavement (Nome, Kotzebue, and Utqiaġvik) and one runway with gravel surface (Noorvik). Data sources included pavement design and construction records, geotechnical investigations, pavement condition surveys, and environmental investigations. The loss of permafrost and thawing of the frost-susceptible pavement layers was the root cause of most airport performance issues. Some failures were attributed to issues with guidance, design assumptions, and construction techniques incompatible with a warming trend. The report presents recommendations for how FAA guidance can be updated to improve airport resiliency to frost and permafrost thaw, including:

- How and to what extent warming temperature trends need to be considered for calculating thaw depth and associated design decisions
- How to assess frost condition of subgrade
- How to base design and construction decisions on the presence, extent, and conditions of underlying permafrost
- How to implement complete frost protection and reduced subgrade strength methods
- When and how to construct insulating panels

Relevance to Current Effort: The evaluation provides an analysis of what causes runway performance issues in Alaskan airports underlain with permafrost and assessment of design considerations and construction best practices that could mitigate frost and permafrost-related performance issues.

Ashtiani, A. Z. and T. Parsons. "Evaluation of Airport Pavement Designs for Seasonal Frost and Permafrost Conditions." U.S. Department of Transportation Federal Aviation Administration, March 1, 2023. https://doi.org/10.21949/1528206.

Use of Cellular Concrete for Air Convection Embankment to Protect Permafrost Foundations in Cold Regions: Feasibility Study (2019)

Planning: Somewhat Relevant *D&C: Very Relevant* *M&O: Relevant*

Synopsis: The use of air convection embankment (ACE) has been demonstrated to provide passive cooling for roadway embankments in permafrost zones. However, in many areas of Interior Alaska, the coarse gravel or crushed rocks needed for ACE construction are not readily available and shipping them to remote areas is cost prohibitive. This research paper investigated the feasibility of using cellular concrete as an alternative to crushed rocks to take full advantage of the ACE design.

The paper included a literature review, testing of different material combinations of cement to assess optimal mixture proportions and material combinations, a simulation to assess the performance of cellular concrete, and an economic analysis. Results indicated that cellular concrete ACE is more effective than crushed rock ACE, and economically more feasible.

Relevance to Current Effort: The use of ACE is also applicable to airport runways that are underlain with permafrost. This study demonstrates that the use of cellular concrete ACE is a structurally- and cost-effective way to address problems related to thaw settlement and ground instability from permafrost thaw. The study also includes insights into the optimum combination of materials for developing cellular concrete considering ACE construction on permafrost foundations in Alaska.

Liu, J. and H. Wu. "Use of Cellular Concrete for Air Convection Embankment to Protect Permafrost Foundations in Cold Regions: Feasibility Study." Center for Environmentally Sustainable Transportation in Cold Climates, University of Alaska Fairbanks, August 2019. http://hdl.handle.net/11122/10673

Laboratory Performance of Wicking Fabric H2Ri in Silty Gravel, Sand and Organic Silt (2016)

Planning: Relevant *D&C: Very Relevant* *M&O: Very Relevant*

Synopsis: The moisture-wicking geotextile fabric, H2Ri, has been used to remove moisture from roadway embankment. This study tested soil types in which H2Ri is effective. H2Ri was tested using a highly permeable sand and an impermeable organic silt soil. The study also tested if H2Ri will work when length requirements exceed the width of the wicking fabric. A 73-foot flume was used to measure the distance that the H2Ri can move water. Results indicated that the fabric is effective at moving water through a sand soil but ineffective for organic silt; and, in a crushed surface course with 14 percent fines, the H2Ri fabric could move water 73 feet.

Relevance to Current Effort: This study specifically tested the applicability of H2Ri at airports. Airports are wider than roads; the study reasoned that for H2Ri to be effective, it must transport water at least 75 feet for a 150-foot embankment. Using a material that is likely to be encountered at airports (a

well-graded material was used with 14 percent fines), this study demonstrated that H2Ri does have the potential to effectively remove water from airport runways.

Connor, B. and X. Zhang. "Laboratory Performance of Wicking Fabric H2Ri in Silty Gravel, Sand and Organic Silt." Alaska Department of Transportation Research, Development, and Technology and Alaska University Transportation Center, May 2016. http://hdl.handle.net/11122/10383

A Bio-Wicking System to Mitigate Capillary Water in Base Course (2016)

Planning: Relevant *D&C: Very Relevant* *M&O: Very Relevant*

Synopsis: H2Ri geotextile is used to wick moisture from pavement, which is important to mitigate frost heaving and pavement distress. However, long-term issues are associated with using H2Ri and include degradation from sunlight exposure, mechanical damage from grass mowing, loss of function under high suction conditions, and clogging and salt concentration that influence drainage efficiency. This research paper assesses an alternative application of H2Ri geotextile. The previous use of H2Ri involved exposing the fabric along the roadway. In this new approach, the geotextile is buried several inches below the soil surface in the road shoulder and covered with hydroseed. Evaporation then occurs at the leaves of the vegetation instead of directly from the wicking fabric. The article demonstrates that this method improves effectiveness and longevity compared to the traditional H2Ri application method.

Relevance to Current Effort: Application of H2Ri geotextile fabric also has the potential to remove water from airport runways and improve pavement performance. This research article provides insights into a method for applying H2Ri that can improve its effectiveness, which can be considered during runway design to improve the resiliency of paved runways.

Lin, C. and X. Zhang. "A Bio-Wicking System to Mitigate Capillary Water in Base Course." Center for Environmentally Sustainable Transportation in Cold Climates, University of Alaska Fairbanks, November 2016. http://hdl.handle.net/11122/9577

Sustainable Construction in Remote Cold Regions (2015)

Planning: Relevant *D&C: Very Relevant* *M&O: Relevant*

Synopsis: This article identifies sustainable (green) construction techniques appropriate for remote and cold regions, some of which also apply to operations and maintenance. Information is gathered from a review of existing research and guidance about green construction methods and interviews with experts in remote Alaskan construction. The article also evaluates how methods applied to vertical construction projects can also be applied to horizontal construction. It provides a set of 160 guidelines related to construction and a construction management training module.

Construction techniques discussed in the guidelines address environmental issues and cover topics such as energy use, ground clearing, working in permafrost, stormwater management, wildlife protection, and hazardous and solid waste management.

Relevance to Current Effort: Some of the guidelines are directly related to airport construction and maintenance. Consulting and implementing these guidelines, as applicable, during the planning and construction phases of airport projects can reduce negative environmental consequences related to construction and reduce the life cycle cost.

Perkins, R. "Sustainable Construction in Remote Cold Regions." Center for Environmentally Sustainable Transportation in Cold Climates, University of Alaska Fairbanks, December 31, 2015. http://hdl.handle.net/11122/9586

Long-term Stabilization of Disturbed Slopes Resulting from Construction Operations (2018)

Planning: Relevant *D&C: Very Relevant* *M&O: Relevant*

Synopsis: Stabilizing disturbed slopes at construction sites is mandated by law, regulations, and a permitting system. However, establishing vegetation in northern Alaska is challenging and often ineffective because of the arid and cold climate.

Extending the establishment periods may improve success, but it also presents challenges. This study reviewed practices from other states and found that extending the establishment period has not been consistently successful. Nevertheless, the article recommends that ADOT&PF consider experimenting with an additive bid item to assess the cost of extending the establishment period.

This study also provided evidence that, in northern Alaska, there is minimal erosion on embankment slopes where vegetation has failed, which suggests that vegetation may have a limited impact on particulate pollution in nearby waters and wetlands. The article recommends gathering additional data and observations regarding the role of grass establishment in preventing pollution from construction projects in northern Alaska. It also suggests modifying the Construction General Permit to allow for the closure of the Alaska Pollutant Discharge Elimination System (APDES) Stormwater Pollution Prevention Plan (SWPPP) without the requirement of revegetation in regions where sustainable revegetation with grasses is not practical and the erosion potential is low.

Relevance to Current Effort: These recommendations apply to airport construction projects in northern Alaska that must undergo permitting and meet federal Clean Water Act requirements. The article provides recommendations for modifying the stormwater management permitting system to address unique climate challenges related to vegetation establishment, which can improve long-term erosion control.

Perkins, R. A., F. L. Benett, and E. C. Packee Jr. "Long-term Stabilization of Disturbed Slopes Resulting from Construction Operations." Center for Environmentally Sustainable Transportation in Cold Climates, University of Alaska Fairbanks, March 20, 2018. http://hdl.handle.net/11122/9592

Geosynthetics Used to Support Embankments Over Voids: A Thesis (1991)

Planning: Somewhat relevant *D&C: Very Relevant* *M&O: Somewhat relevant*

Synopsis: Geosynthetics can be used to reinforce road embankments and bridge voids in embankment material. The proper geosynthetic material must be selected and multiple layers of material may be required.

Relevance to Current Efforts: Geosynthetics, or geotextiles, can be used to bridge voids in runway embankments caused by excavation or organics or ice lenses.

Neogi, D. “Geosynthetics Use to Support Embankments Over Voids: A Thesis.” University of Alaska Fairbanks, February 1991. https://dot.alaska.gov/stwddes/research/assets/pdf/19910203.pdf

Additional, Non-Climate-Related Resiliency Research

Washington State Airports Seismic Resilience Project (2021)

Planning: Relevant *D&C: Relevant* *M&O: Relevant*

Synopsis: Airports are crucial for post-earthquake disaster response. The Cybersecurity and Infrastructure Security Agency carried out an analysis of the ability of Washington State’s aviation system to support post-disaster response, recovery, and mobility needs. The research team performed three analytical tasks to evaluate the airport system’s capacity and reliance on external infrastructure in responding to earthquakes:

1. An analysis to determine the airport systems’ vulnerability to potential impacts related to the Cascadia Subduction Zone (CSZ)
2. A screening analysis to assess the risk of runway pavements being disrupted by liquefaction
3. Discussions with airport personnel

The project revealed that Washington airports would play an important role as post-disaster logistic supply chain hubs to receive, organize, and distribute disaster relief supplies and equipment from around the country to local communities, but that the full resilience of their facilities is not well understood at a local level.

Relevance to Current Effort: The framework and methodology from this study can be applied to evaluate the resiliency of Alaskan airports to earthquakes and the ability of airports to function as critical hubs post-disaster. The study identified a need for better analyses of site-specific geotechnical vulnerabilities to seismic impacts at airports to characterize how ground failures may disrupt airport pavements and facilities. The study also found that airports consistently depend on electric power and external fuel supplies to support their operations; therefore, airports should increase the resilience of on-site fuel storage and fuel supply chains and develop more infrastructure for backup energy generation.

Cybersecurity & Infrastructure Security Agency, Washington State Department of Transportation, and Washington Emergency Management Division. “Washington State Airports Seismic Resilience Project,” October 2021. https://mil.wa.gov/asset/634989baeb821.

Guidelines for the Use of Synthetic Fluid Dust Control Palliatives on Unpaved Roads (2017)

Planning: Relevant *D&C: Very Relevant* *M&O: Very Relevant*

Synopsis: This paper developed guidelines for the application and maintenance of synthetic fluid dust control palliatives on unpaved roads. A study was conducted using field and laboratory methods to test the effectiveness of dust palliatives and develop recommendations for effective use. These recommendations focus on guidance-related road design, including considerations for good drainage and material selection, application methodology, and maintenance practices.

Relevance to Current Effort: Although this study focused on roads, dust management is also an important issue for unpaved runways, making this technical guidance applicable to airports as well. The article presents background information about the use of dust control palliatives, including context about why they are needed and in which situations they are necessary. Some of the guidelines provided for road synthetic fluid dust control are also relevant for runways, such as the importance of good drainage design and application methods.

Barns, D. and B. Connor. "Guidelines for the Use of Synthetic Fluid Dust Control Palliatives on Unpaved Roads." Center for Environmentally Sustainable Transportation in Cold Climates, University of Alaska Fairbanks, July 6, 2017. http://hdl.handle.net/11122/8812