Center for Environmentally Sustainable Transportation in Cold Climates

Sustainable Construction in Remote Cold Regions

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Sustainable Construction in Remote Cold Regions

Closure Report

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The goal of this project was to identify sustainable construction techniques appropriate for remote and cold regions, some of which apply to operations and maintenance as well. The vast body of literature regarding green construction in warm regions was reviewed, and the information that might be applicable to cold and remote regions was ascertained. A hierarchal taxonomy was developed to categorize the information and reduce it to a form useful for presentation to engineering and construction managers. Twenty-two engineers and construction managers, all familiar with cold regions and remote projects, were interviewed, and the information and taxonomy were reviewed with them. This process resulted in a set of preliminary guidelines, which then were presented at two different meetings, one at AGC and one at the Alaska Department of Transportation and Public Facilities, Central Region, where the preliminary guidelines were revised slightly. The final set of guidelines, approximately 160 suggestions and notes, was used to develop a module for UAF construction management classes, although it is suitable for other learning venues. The module, the *Guidelines*, as well as a preliminary paper are available on the CESTiCC website.

DISCLAIMER

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4		mm
ft	feet	0.3048		m
yd	yards	0.914		m
mi	Miles (statute)	1.61		km
		AREA		
in^2	square inches	645.2	millimeters squared	cm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.4046	hectares	ha
		MASS (weight)		
oz	Ounces (avdp)	28.35	grams	g
lb	Pounds (avdp)	0.454	kilograms	kg
T	Short tons (2000 lb)	0.907	megagrams	mg
		VOLUME		
fl oz	fluid ounces (US)	29.57	milliliters	mL
gal	Gallons (liq)	3.785	liters	liters
ft^3	cubic feet	0.0283	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

Note: Volumes greater than 1000 L shall be shown in m^3

Symbol	When You Know	Multiply By	To Find	Symbol
		TEMPERATURE (exact)		
ºF	Fahrenheit temperature	5/9 (ºF-32)	Celsius temperature	ºC
		ILLUMINATION		
fc	Foot-candles	10.76	lux	lx
fl	foot-lamberts	3.426	candela/m^2	cd/cm^2
		FORCE and PRESSURE or STRESS		
lbf	pound-force	4.45	newtons	N
psi	pound-force per square inch	6.89	kilopascals	kPa

These factors conform to the requirement of FHWA Order 5190.1A *SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol When You Know Multiply By To Find Symbol

LENGTH

mm millimeters 0.039 inches in
m meters 3.28 feet ft
m meters 1.09 yards yd
km kilometers 0.621 Miles (statute) mi

AREA

mm^2 millimeters squared 0.0016 square inches in^2 m^2 meters
squared 10.764 square feet ft^2 km^2 kilometers squared
0.39 square miles mi^2 ha hectares (10,000 m^2) 2.471 acres
ac

MASS (weight)

g grams 0.0353 Ounces (avdp) oz
kg kilograms 2.205 Pounds (avdp) lb mg megagrams
(1000 kg) 1.103 short tons T

VOLUME

mL milliliters 0.034 fluid ounces (US) fl oz
liters liters 0.264 Gallons (liq) gal
m^3 meters cubed 35.315 cubic feet ft^3
m^3 meters cubed 1.308 cubic yards yd^3

TEMPERATURE (exact)

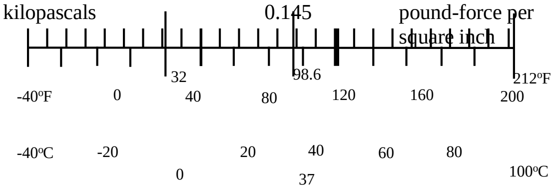
ºC Celsius temperature 9/5 ºC+32 Fahrenheit ºF
temperature

ILLUMINATION

lx lux 0.0929 foot-candles fc
cd/cm² candela/m^2 0.2919 foot-lamberts fl

FORCE and PRESSURE or STRESS

N newtons 0.225 pound-force lbf
kPa kilopascals 0.145 pound-force per psi
square inch



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EXECUTIVE SUMMARY

The goal of this project was to examine "green construction" in cold regions, with an emphasis on field construction in more remote regions. Starting with the notion of sustainable construction, which posits a balance of economic, environmental, and social factors, the authors assumed that economic and social factors are considered in project planning and design phases; thus they focused on environmental factors that are prominent during construction.

Sustainability implies projects that help meet the needs of the present without compromising the ability of future generations to meet their own needs. Projects are scrutinized in three dimensions related to their impact on the economy, the environment, and society. Sustainability requires a balance among these three aspects, often implying the need for tradeoffs and compromise between them. As regards field construction, a project's effects on the economy and society can be assumed acceptable, but the construction process offers opportunities to improve the effects on the environment. We offer a collection of tips, suggestions, and ideas, referred to as *Guidelines,* with a focus on northern regions, especially remote projects. The process of gathering these suggestions began with a search of published material, most from warmer regions. Later, interviews with Alaskan experts, listed in Appendix B, led to the content selection of the *Guidelines* presented here.

The *Guidelines* contain many ideas. All were identified in the literature search and/or were listed by Alaskan experts. Since the *Guidelines* are a collection of ideas, not specifications, many of the suggestions are applicable only in narrow circumstances. However, in vetting the suggestions with experts, none was ruled out.

The *Guidelines* have already been presented at an international conference, propounded at a webinar, distributed to the 22 interviewees, distributed to the Alaska Department of Transportation and Public Facilities (Alaska DOT&PF) design and construction supervisors and

professionals, including environmental staff, and placed on the CESTiCC web site. A model course has been prepared, based on the *Guidelines*.

CHAPTER 1.0 INTRODUCTION

1.1 Problem Statement

Remoteness and cold climate make construction in rural Alaska challenging and expensive. Sustainable construction practices serve to reduce the negative environmental consequences of construction projects and often reduce their life cycle cost. While such practices are commonly considered in warm climate construction, especially for horizontal construction, little knowledge has been accumulated about sustainable construction in cold regions.

1.2 Background

Sustainable construction, also referred to as “green” construction, has been an essential part of the building construction process for many decades. The contemporary interest in green practices arose in the 1970s, when rapid increases in world oil prices instigated improvements in building energy efficiency. Furthermore, the environmental movement that began in the 1960s and 1970s spurred the development of environmentally friendly and energy efficient buildings and other structures (EPA 2014).

A review of sustainable construction practices to date indicates at least two significant aspects: (1) Sustainable construction embraces all phases of the project life cycle, from early planning to operations, maintenance, and even decommissioning. (2) Emphasis to date has been on buildings and similar structures (vertical construction), with much less consideration of green practices in heavy construction (horizontal construction), such as roadways, pipelines, and airfields. Thus, a typical Internet entry (GSC 2014) that explains sustainable construction suggests the following:

> These terms [sustainable or green construction] refer to a structure and building process that is environmentally responsible and resource efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and demolition. Green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by: 1. efficiently using energy, water and other resources, 2. protecting occupant health and improving employee productivity, 3. reducing waste, pollution and environmental degradation.

Note the emphasis on "a building" and "throughout a building's life cycle."

While we do treat vertical construction, buildings in Alaska are either built in the warmer season or "closed in" for cold season construction. Construction of transportation facilities, the major construction industry in the North, has a horizontal emphasis. The effects of seasonality on horizontal construction and arctic and subarctic conditions—permafrost, for example—contrast with warmer climates.

Two realities affected our research. (1) Sustainable construction embraces all phases of the project life cycle, but the greatest emphasis has been on design and material specifications and, to date, buildings and similar structures, with much less consideration of green practices in heavy construction: roadways, pipelines, boardwalks, and airfields. (2) There is a need, especially in remote cold regions like rural Alaska, for a compilation of guidelines to assist construction contractors, particularly those involved with horizontal construction, in conducting their operations to maximize sustainability and increase the net benefit of a project.

The focus of this project was primarily on one aspect of the construction project life cycle: the construction process itself – the assembly of the project in the field. However, unlike vertical construction, which has a definite occupancy phase, in horizontal construction, operations and maintenance (O&M) are often ongoing, and construction-like operations such as road grading occur. We included these ongoing O&M operations that parallel initial construction. With this focus, we avoided a dilution of effort that an investigation into the totality of the life cycle process would require. Important as well for ongoing O&M is that rural residents are often involved in that phase of construction.

We distinguished “rural” Alaska (also known as “the bush”) and non-rural Alaska (also known as “on the highway system”). Although not connected by highways, most of rural Alaska is connected by small airports and river landings, and sometimes by short roads and four-wheeler tracks. Rural Alaska provides a well-suited setting for this a study. Many airfield and roadway projects are constructed in rural Alaska each year, using a variety of construction methods. We learned much about sustainable construction methods that are, and are not, used on these projects. Harsh climatic conditions, logistical challenges, scarcity of some materials, and other conditions affect the degree to which construction methods are sustainable. Many approaches used successfully in vertical construction may apply to horizontal construction, and some of them may apply to remote projects in harsh climates similar to those in Alaska. We did not exclude these.

The efficiency and effectiveness of the construction process in rural Alaska must be improved, but also operations must be conducted in a responsibly sustainable way. Thus, one outcome of this project is a program by which lessons learned can be made available to those persons who plan and perform construction operations in rural Alaska, including rural residents and residents of more developed areas.

Regarding sustainable construction in cold regions—the subject of this research—little about research and implementation has been published or made its way into standard specifications or standard operating procedures (SOP), although there are exceptions. One exception is the Alyeska Pipeline Environmental Protection Manual. However, in talks with experts, we noted some issues that need closer investigation. For example, SWPPP (storm water pollution prevention plans) require many temporary structures to divert or minimize storm water runoff from construction. Could these structures be left in place semi-permanently to minimize runoff in later years? Material selection can likewise affect both runoff and dust control. Disposal of construction debris such as concrete washout could be used in semi-permanent structures related to storm water, driver safety, or perhaps aesthetics. Alaska rural roads are often unpaved, and rural airport runways are usually unpaved. These surfaces must be constantly regraded, and the grading often involves water acquisition and disposal. Use and disposal of oil, debris, and potentially hazardous materials during construction are construction issues, but lead to sustainability issues, for example, deteriorating temporary landfills.

Construction of snow and ice roads is a novel idea in its own right, but bears on the construction of new conventional roads and work pads, since ice roads are sometimes used during the construction phase. Ice roads over rivers are, of course, not sustainable after breakup, but ice and snow roads over permafrost are sustainable in the sense that the same route can be used each year, if usage in prior years did not degrade the permafrost. In ice-rich soils, snow removal and relocation during construction may have a profound effect on the degradation of permafrost or, conversely, may increase the possibility of frost heave in areas of chilled pipeline burial. These possibilities need to be considered in O&M snow removal as well. In any case, preservation of permafrost is necessary for stability in the future; it is a unique aspect of sustainability in the north.

Deicing chemicals and snow storage have been studied for O&M in urban regions, but we looked at them afresh for rural regions. Also important are the effects of construction noise and dust on non-endangered species, especially game species. While endangered species are protected by permitting stipulations, game animals, both for subsistence and for recreational viewing, are generally not so protected.

1.3 Summary of Objectives

- Translate common sustainable construction methods in use for vertical construction into similar approaches for horizontal construction, for use as a checklist of topics for horizontal construction in remote and cold regions.
- Identify appropriate sustainable horizontal construction methods for use in remote regions and in severe climates.
- Develop guidelines and means for the formal transfer of methodologies to those who conduct construction operations in such environments. Examine practicality of sustainable techniques for use in remote and harsh environments by rural residents.

CHAPTER 2.0 PRELIMINARY WORK: LITERATURE SEARCH, TAXONOMY, AND ORGANIZATION

2.1 Summary of Literature Search

This section summarizes the literature search and basic findings. A complete annotated bibliography is found in Appendix A. Information on all sources cited can be found in Appendix A and in Appendix F.

As noted in Chapter 1.0, much of the emphasis on sustainable construction to date has been on the planning and design phases of the construction project life cycle, with significant developments in material design and specification and the development of systems to make completed projects more environmentally efficient. Such developments have tended to apply to vertical, more so than horizontal, construction. However, a review of the literature reveals the availability of a substantial body of information related directly to the field construction process. Furthermore, it is clear that many of the environmentally sustainable methods used by contractors in building construction can apply equally to the construction of roadways, airfields, and other horizontal facilities.

The United States government, through its Environmental Protection Agency, enforces federal mandates that must be followed by all industries, including construction, in complying with a large number of environmental laws and regulations. A manual, “Managing Your Environmental Responsibilities: A Planning Guide for Construction and Development” (U.S. Environmental Protection Agency 2005) is available. A guide that interprets this manual has been published for contractors (U.S. Environmental Protection Agency n.d.).

To assist its members and other contractors in interpreting and meeting federal and other environmental requirements, the Associated General Contractors (AGC) of America provides guidance on developing company- or project-specific environmental management systems (Associated General Contractors 2004a and 2004b).

Two books about sustainable, or green, construction (Glavinich 2008; Kibert 2008) provide helpful guidance throughout the project development life cycle; each book contains sections specific to field construction operations. Likewise, the Institute for Sustainable Infrastructure (2014) provides a system for evaluating various aspects of a project's development, including field construction, through its Envision™ system.

The U.S. Green Building Council (2014) sponsors the well-known LEED (Leadership in Energy and Environmental Design) rating system. The system is confined to buildings and is mostly about design, but some of the concepts apply to building construction operations. In an attempt to apply the LEED building-oriented concepts to road building, a system called Greenroads™ (Muench et al. 2011) was developed. This rating system covers both design and construction of roadways. Construction activities include site recycling planning, fossil fuel reduction, equipment emissions reduction, paving emissions reduction, and water tracking.

The most relevant and complete document related to our study appears to be the Field Guide for Sustainable Construction (Pulaski 2004). Ten chapters, each covering such topics as site/environment, waste prevention, recycling, and energy, include sections organized roughly by construction specification (site work, foundations, substructure, and the like). Each chapter has specific suggestions for environmentally effective contractor actions, plus case studies and references. In addition, a paper by Pearce et al. (2010, p. 116) reports a benchmark study of best sustainability practices in construction; the study used interviews and observations to "better understand what types of sustainability-related innovations are most easily and effectively adopted over time by project teams in capital projects."

With regard to specific construction-related environmental impacts and means for dealing with them, the matter of construction waste and demolition debris is of major concern in many places in the world (Couto and Couto 2007; Liao et al. 2011; State of Washington Department of Ecology 2014; Tamraz et al. 2011; Zhang and Wu 2011). Air pollution, especially dust caused by equipment operation on roadways and construction sites, has been dealt with by several authors (Anderson 2014; Barnes and Connor 2014; James 2014, Skorseth and Selim 2000; Withycombe and Dulla 2006). This problem is of special concern in rural Alaska.

Water pollution of many kinds is a major concern on most construction sites. In the United States, there are stringent requirements for storm water pollution prevention, and contractors have become very familiar with contractual requirements for a SWPPP (storm water pollution prevention plan) and have learned to comply or face substantial penalties (U.S. Environmental Protection Agency 2005). A presentation by Nowack (2014) contains helpful guidelines for the prevention of many types of water and other pollution.

Along with other construction site environmental issues discussed in the literature, concern is expressed about energy efficiency on construction sites, including the generation and delivery of electric power and the efficient use of power for tools, lighting, and signage (Sharrard et al. 2007).

2.2 Taxonomy

We have drawn from the literature just cited, from other literature sources, and on our own personal experience (a combined 90 years in construction and over 80 years in Alaska for the 2 authors) and the experience of our colleagues to compile an array of potential negative environmental effects. As a starting point, we included any and all information, without regard to type of construction or whether construction projects are in remote or more urban, cold climate or more temperate areas. Ultimately, as stated earlier in the report, the focus will be on possible impacts in remote cold regions and on methods for dealing with those impacts. To lower the chance of neglecting some of those impacts and techniques, our research method is to include as many as possible and refine the list as the study proceeds.

One of the project's biggest challenges has been how to organize findings into a reasonable and useful outline or taxonomy. Many writers (Huang and Hsu 2011, for example) start by listing the various kinds of environmental impacts—water pollution, solid waste production and disposal, and the like—as major categories and then discuss the operations that produce such impacts and some means for dealing with them. We decided, instead, to begin the outline from the contractor's viewpoint by listing, as major categories, the construction operations or activities that have the potential to produce environmental impacts. We then identify those impacts and suggest possible methods for avoiding, reducing, and/or mitigating their effects. Thus, in Figure 2.1, we show a generalized construction project activity taxonomy, broken down into the major categories of project support, the project itself, and operations and maintenance.

Within each major category, we list type of work activity (Worker Housing, Life Support, Office and Shops, Support Equipment Operation, etc.), and then we identify possible negative environmental impacts associated with that work activity and attach measures that the contractor can use to avoid, reduce, and/or mitigate those impacts. Two examples are shown.

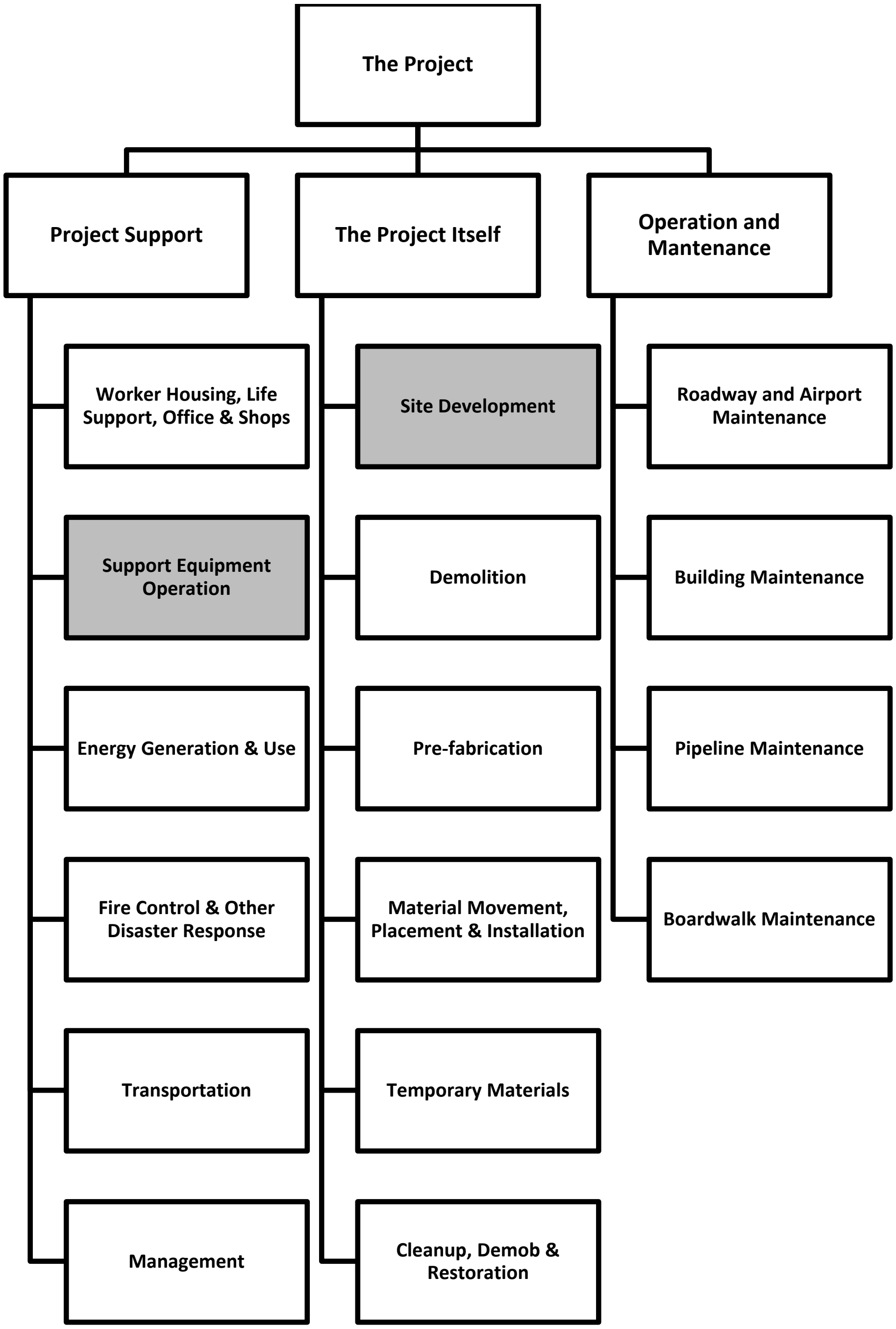


Figure 2.1 Construction project taxonomy (highlighted work activities are shown in detail in Figure 2.2 and Figure 2.3

Figure 2.2 is a diagram of Support Equipment Operation work activity. Figure 2.3 shows a similar breakdown for Site Development work activity. Note that for Support Equipment Operations, possible negative impacts include air and noise pollution, excessive vibration, improper fuel storage, handling and use, and pollution that can result from cleaning and storage of vehicles and equipment. For each impact, measures are shown that might be used to combat it. For example, to respond to air pollution, the contractor might provide respiratory protection for workers, minimize equipment run time, use alternative fuel vehicles, and conduct regular inspection and maintenance activities.

For Site Development (Figure 2.3), degradation of permafrost (permanently frozen ground), improper and excessive clearing, insufficient project site layout, improper handling and storage of removed soil, survey damage, improper storage tank location and operation, improper storm water management, historical and archeological sites issues, and endangered and subsistence species issues are included as potential negative impacts. To combat the effects of improper and excessive clearing, for example, the contractor might grind and chip trees to provide mulch, resell trees and other plants, avoid damage to existing improvements, and limit the cleared area to an absolute minimum.

At this point in the process, we have not considered whether an impact might have to be dealt with in a remote cold area, nor have we considered whether a method of contending with the impact might be practical for such a region. Those aspects are dealt with in a preliminary way in Chapter 3.0.

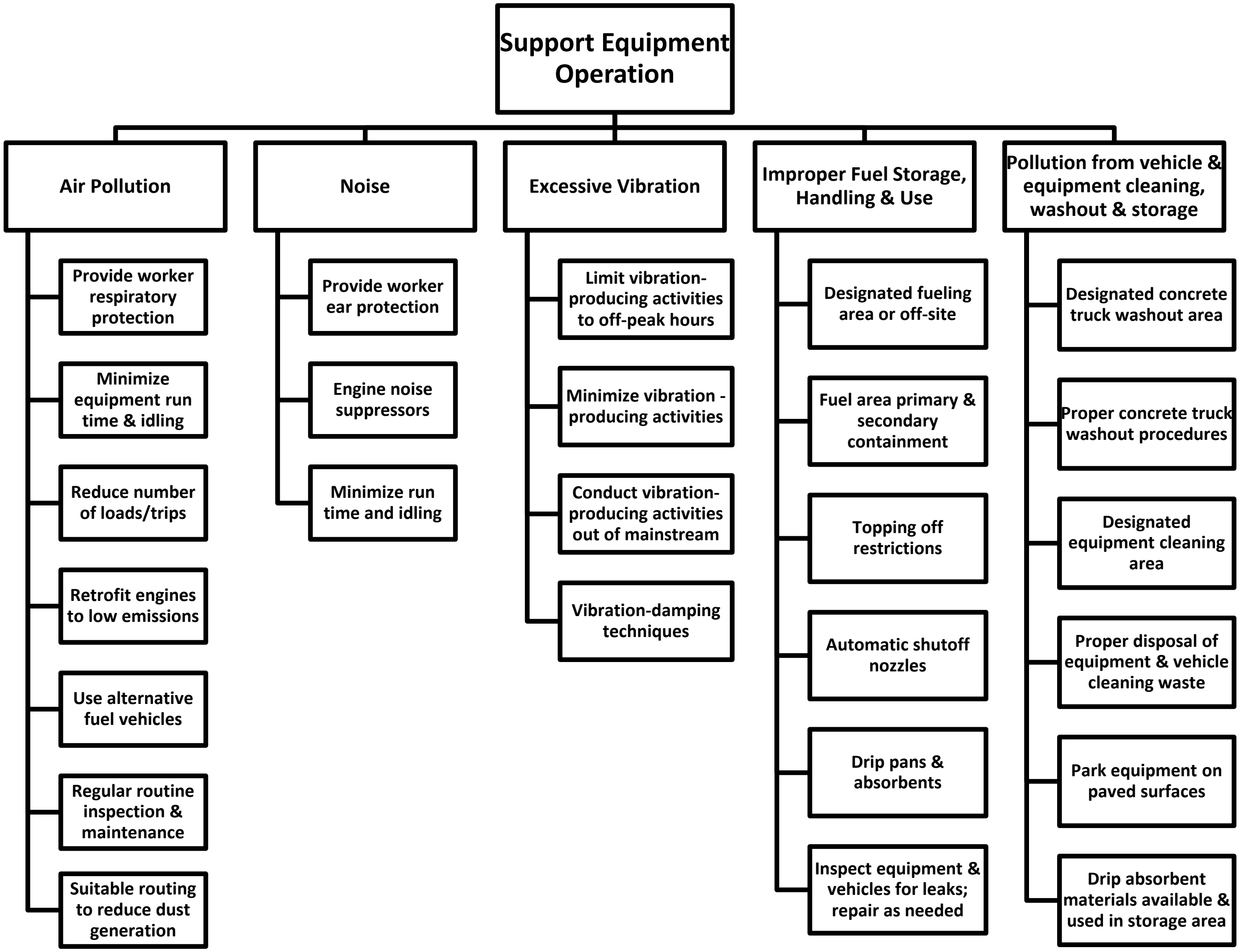


Figure 2.2 Diagram of Support Equipment Operation work activity.

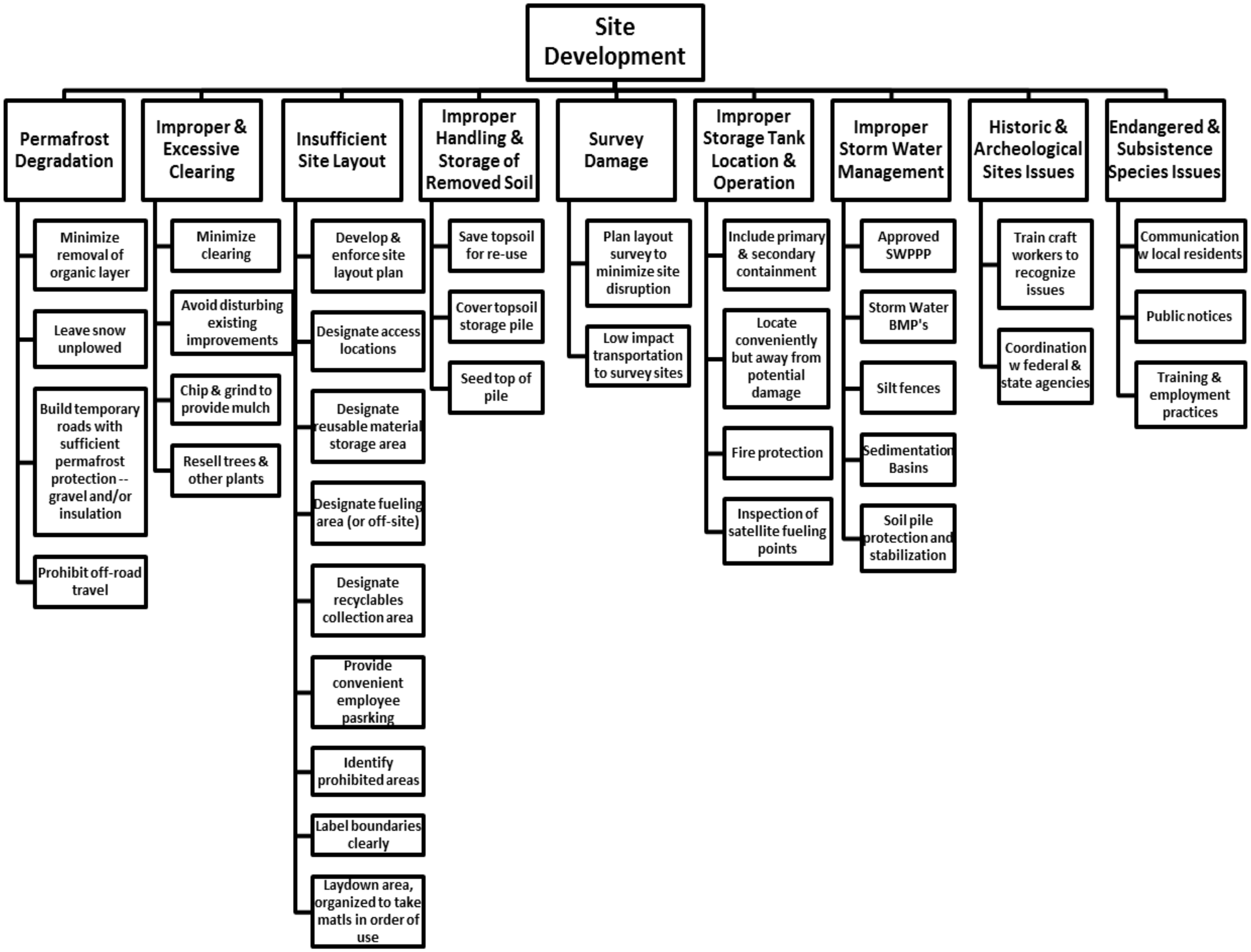


Figure 2.3 Diagram of Site Development work activity.

CHAPTER 3.0 MEETINGS AND INTERVIEWS WITH ALASKA COLD REGION EXPERTS, WITH PRELIMINARY GUIDELINES

3.1 Practical Approaches for Remote Cold Regions

Based on the authors' experience in Alaska and an extensive literature search, a preliminary taxonomy with the lists and items described in Chapter 2.0 was developed. From among the myriad methods for dealing with negative environmental impacts of field construction operations, practical methods that could avoid, reduce, and/or mitigate such impacts on projects in remote cold regions like rural Alaska needed to be identified. In Anchorage and Fairbanks, we interviewed 22 people whom we considered experts in Alaska construction practices or who were referred to us as experts. These people were employed by owners, contractors, agencies, and environmental consultants. The interviews were summarized and organized by topic (e.g., solid waste or air pollution), and the comments were fit into our taxonomy, which was modified as needed. What follows is an example of our summary for the topic of "Clearing." (The name of the interviewee is redacted.)

Clearing

Interviewee A

- Minimize cleared area, especially in permafrost area.
- Might use organics from cleared area to protect disturbed areas.

Interviewee B

- Unless this is done when ground is frozen, this is a permit issue. This is a "ground disturbing activity" and must be done by hand with no wheeled vehicles unless frozen. A seasonality consideration.
- Might leave cut trees and brush in place – minimize erosion; quicker regrowth.
- Chipping and using for mulch is a re-use example.
- Over a certain size (4 inch maybe 6 inch, not practical to chip) – their spec requires decking. Can then be made available locally.

Interviewee C

- No permit required if existing root mass not disturbed.
- Try to use existing pad rather than more clearing.

Interviewee D

- Better done in winter; and/or phased construction.
- If clearing chipped debris, in some cases might bury it in deep fill. Then cover it. In some cases, the result is sufficiently structurally stable.

Interviewee E

- Ref: Tok project by State Forestry
    - Cleared dead trees from wildfire.
    - Made available to locals for firewood.
    - Good PR.

Interviewee F

- Avoid too much work in woods.
- Mow and mulch.
    - Use as a cover material.
    - Permafrost protector.
- Example: Eielson AFB project.
- All unsalable timber was chipped and used as insulation.
- 3 feet thick; enzymes cause temperature rise. >32°F when air is very cold.

Interviewee G

- Often dictated by specs.
- Salvage trees greater than 6–8 inches; yard them up and make available locally.
- Hydro-ax the smaller stuff.
- Do not disturb until ready to start work.
- This is another seasonality issue – work on frozen ground if possible.

Interviewee H

- Minimize footprint

Interviewee I

- Use debris as mulch.
- Make firewood available to community.

- Select the appropriate time of year for the project. By conducting work in winter, for example, the ground surface and vegetation can be more easily protected in its frozen condition.
- The appropriate type of equipment must be used so that impacts are minimized. Smaller equipment that can be better maneuvered or equipment that uses low impact wheels or tracks can significantly reduce impacts.
- Hand tools, rather than heavy equipment, should be used as much as possible when working in sensitive areas. Sensitive areas include wetlands, stream banks, alpine or arctic tundra, areas underlain by permafrost, or other areas of high ecological value that are slow to recover or difficult to rehabilitate.
- Use of tundra mats, Dura-Mat™, or snow/ice roads to protect the ground surface can reduce the expense of building temporary or permanent gravel access roads while allowing for quicker restoration of underlying vegetation.
- Use snow machines, tuckers, and other low-impact vehicles only after the ground surface is sufficiently frozen and covered with enough deep snow.
- Preplanning of equipment access points, traffic flow in the work area, and incorporation of site-specific features into work plans can minimize the footprint of a project.
- Use of trails, winter roads, or other existing access routes can significantly reduce impacts.
- Careful selection of staging areas, areas for dewatering basins, and work areas can minimize vegetation impacts.
- Use of previously disturbed areas, such as material sites, during a spill response, for example, reduces the amount of restoration required.
- Strict adherence to off-ROW or other permitted travel restrictions greatly reduces impacts. This includes marking boundaries and clearing limits and clearing only within approved boundaries.
- If clearing of sensitive areas cannot be avoided, it is often helpful to remove mature shrubs from the work area and stockpile them for later use. This can also be done when removing the organic layer (topsoil) when clearing a work site.
- Maintaining existing vegetative screens at highway crossings reduces the visibility of work sites from public access roads. Protection of buffer zones along water bodies eliminates the need for subsequent restoration.
- Minimize disturbance of the plant root mass as much as possible when clearing a work area. Avoid/minimize disturbance to the organic layer of the soil.
- Avoid disturbance of trees and older growth plants as much as possible. When trees must be cleared, clearing should be done so that trees and brush fall

within the cleared area. Trees greater than 4 inches in diameter should be yarded such that they are available for salvage.

Thus, from the interviews, the taxonomy was created with practical advice and information, all of which helped create the draft guidelines. Next, the draft guidelines were presented to groups that might find them useful and provide feedback. These groups are listed in Chapter 5.0, where our outreach efforts are discussed.

CHAPTER 4.0 REVISED GUIDELINES

The full guidelines are given in Appendix C. Here, the overall organization of the *Guidelines* and two examples—Construction Camp Guidelines and Transportation Guidelines—are provided.

4.1 Overall Organization:

- Management, Planning and Coordination
- Logistics and Support
- Site Impacts – The Ground
- Operational Impacts

The contents of the *Guidelines* were distributed into the main categories:

- Management, Planning and Coordination
  - Planning and Management
  - Local Community Issues

- Logistics and Support
  - Construction Camp
  - Power Production and Use
  - Transportation

- Site Impacts – The Ground
  - Clearing
  - Historic Sites
  - Material Sources and Storage
  - Permafrost
  - Vegetation
  - Water Flow/ Runoff/ Erosion
  - Wildlife

- Operational Impacts
  - Air Pollution
  - Equipment
  - Fuels and Other Petroleum
  - Hazardous Waste
  - Solid Waste

4.2 Example: Construction Camp Guidelines

1. Location
    - Minimize land use
    - Locate camp close to project to minimize total site area.
    - Hire locally to reduce camp size
    - Plan road system; do not build excessive roads and trails
    - Rent houses in the village if available (and maybe fix them up)
    - Avoid use of sensitive areas, subsistence areas, high-value recreation/scenic areas
    - If ground conditions can be ascertained, place camp near the center of a permafrost polygon rather than at its edges where melting is more likely to occur
    - Pick a site that does not drain to a river
    - Locate camp in a low spot if possible

2. Repurposing/reuse
    - Make temporary buildings more permanent
    - Leave temporary pad in place for local use
    - Leave clothes washers, dryers, and similar equipment for local use

3. Provide ground protection in permafrost areas with such methods as insulated mats and boardwalks

4. Water and wastewater management
    - For water supply, use local supply if available; otherwise consider drilling a well or using rainwater or melted snow with treatment
    - Consider packaged water and wastewater treatment systems
        - Locate portable toilets in nearby convenient locations
        - Save water
    - Use low-water-use fixtures
    - Do not let toilets run
    - Consider waterless toilets

5. Waste from food service
    - Compost food waste
    - Use minimal waste-producing dishes; ceramic instead of paper

6. Burn waste, as appropriate, in a Burn-Easy (or other) agricultural incinerator

7. Provide products to address spills from equipment leakage, fueling, etc.

8. Use sturdy lighting, such as heavy-duty sealed fluorescent fixtures

Comments:

Hiring first from the local community, then relatives from nearby villages who can live with locals, and, finally, workers from outside the area is a successful approach.
Renting existing local buildings reduces camp size.
Locating the camp in a low spot so that water drainage can be directed to a settling pond in the middle can avoid the use of silt barriers.
Temporary buildings made more permanent can be repurposed for local use.
The contractor is responsible for a trailer, or other assets, left at the site that nobody wants.
A well means less water to haul.
A "temporary" well can be left for local use.
Packaged water and wastewater treatment systems are practical in many cases and can be transported from job to job.

4.3 Example: Transportation Guidelines

1. Prefabricate as much as possible to save on shipping costs and resources.

2. Have prefabricated components inspected at the fabrication site rather than at the jobsite, if possible.

3. Reduce the size of equipment that must be transported to the site in order to lower transport costs and resource requirements.

4. Explore potential low-impact methods for delivery and backhaul.
   Barge
   Airplane
   Motorized vehicles on river ice
   Cat train over snow

Comments:

Prefabrication results in less on-site waste, but requires precise drawings.
Inspection at the fabrication site saves time and transportation costs and resources.

CHAPTER 5.0 MEETINGS AND DISTRIBUTION OF GUIDELINES

5.1 CESTiCC Conference

At the International Symposium on Systematic Approaches to Environmental Sustainability in Transportation, held in Fairbanks, Alaska, USA, from August 2–5, 2015, we presented a paper, "Methods for Achieving Environmentally Sustainable Field Construction Practices in Remote Cold Regions and a Plan for Transferring Such Knowledge."

5.2 CESTiCC Webinar

We presented the preliminary *Guidelines* and an overview of methods at a CESTiCC webinar on September 23, 2015. The webinar was attended by engineering and transportation professionals.

5.3 Industry Meetings

5.3.1 Associated General Contractors, Fairbanks, Alaska

After the *Guidelines* were developed, two industry meetings were held: the first with the AGC in Fairbanks on October 6, 2015, and the second with the Alaska DOT&PF in Anchorage on October 27, 2015. The AGC meeting, which took place in the AGC building on Bonita Street, was attended by 15 people.

5.3.2 Alaska DOT&PF

The meeting with the Alaska DOT&PF had two phases: an introduction at the quarterly design managers' meeting in the morning and a work session with interested people in the afternoon. The morning session was attended by about 50 transportation professionals. The afternoon session had attendees from various departmental sections, including Design, Research, and Environmental.

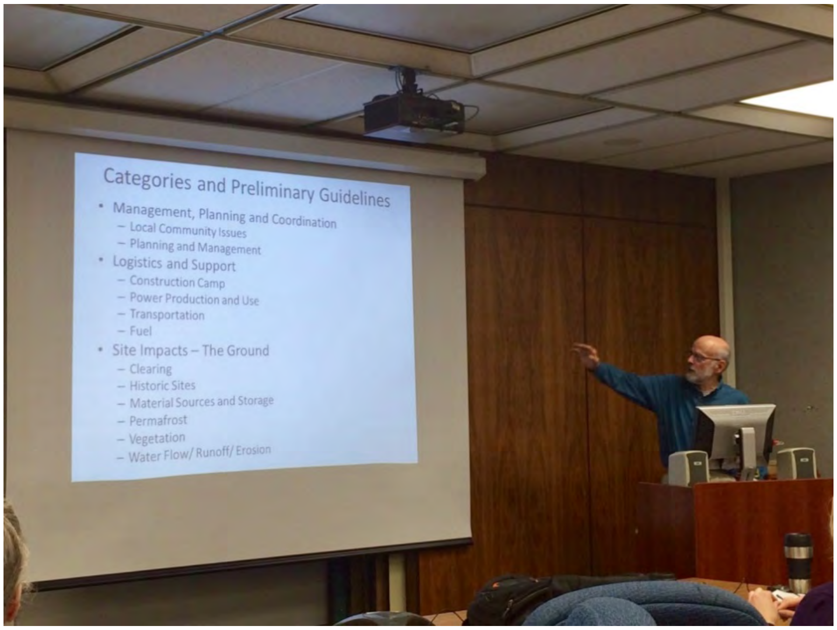


Figure 5.1 Dr. Perkins explains taxonomy at an Alaska DOT&PF quarterly design managers' meeting.

At both venues, the *Guidelines* were presented after explanation about how they came about, and comments were requested. During the afternoon session, there was enough time to review the main rubrics and most of the suggestions. After the meetings with the AGC in Fairbanks and the Alaska DOT&PF in Anchorage, we revised the *Guidelines*, which are included in the report as Appendix C.

5.4 Community and Technical College Lecture

On December 3, 2015, we presented a summary of the project and *Guidelines* as part of a lecture to a class in Construction Project Management at the UAF Community and Technical College.

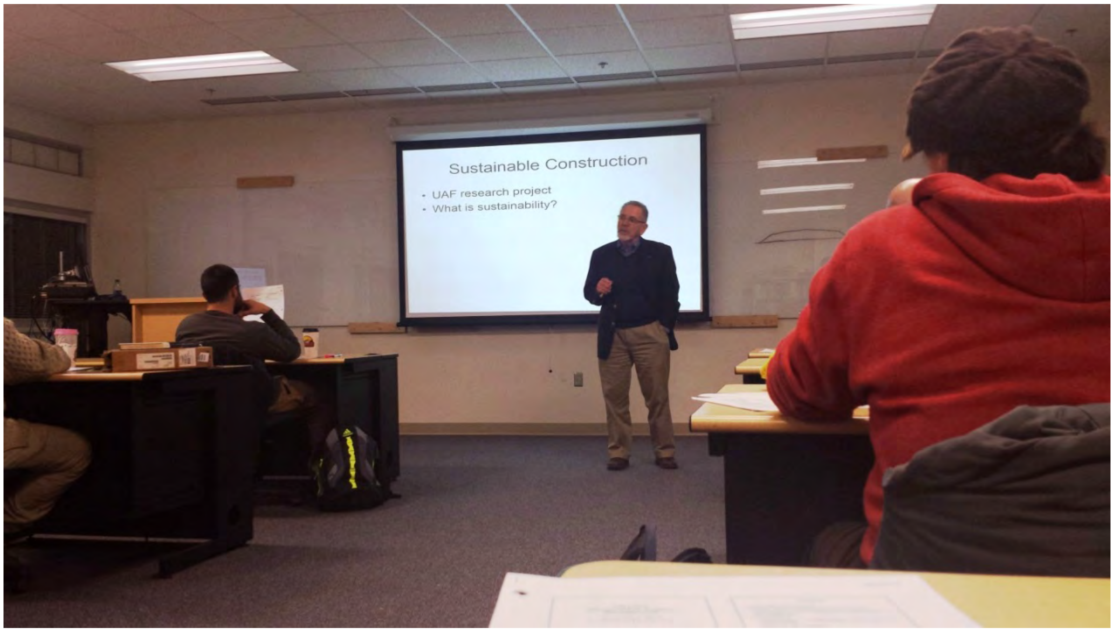


Figure 5.2 Dr. Bennett addresses the Construction Project Management class at the UAF Community and Technical College.

5.5 Outreach

Besides presenting at the venues just discussed, we transmitted the *Guidelines* and web information to Dave Waldo of the Alaska DOT&PF, who manages the local technical assistance program (LTAP) for municipalities, and to Byron Bluehorse, who manages the tribal technical assistance program (TTAP) for Alaska Native villages and communities. The *Guidelines* are now on the CESTiCC website, where they can be located by search engines.

APPENDICES

A. Annotated Bibliography

B. Interviewees

C. *Guidelines*

D. UAF Course Material

E. Website

F. Methods Paper from CESTiCC Conference

APPENDIX A – ANNOTATED BIBLIOGRAPHY

<u>Annotated Works Cited</u>

Note: Annotations are primarily to identify sustainable field construction issues and practices.

Ahn, C., F. Pena-Mora, S. H. Lee, and C. A. Arboleda. (2013) "Consideration of the environmental cost in construction contracting for public works: A + C and A + B + C bidding methods." *ASCE Journal of Management in Engineering*, Vol. 29, No. 1, 86-94.

> Greenhouse gasses; energy consumption; diesel exhaust; reducing number of loads, etc.; bidding preference to a green contractor

Anderson, M. K., J. K. Bidgood, and E. J. Heady. (2010) "Hidden legal risks of green building." *The Florida Bar Journal*, Vol. 84, No. 3, 35-41.

> Owner risks -- loss of a tenant or sale, loss of government incentives and tax credits, increased design and construction costs, rescinded donations on endowed projects, penalties on public projects with green mandates, increased energy and water costs over the life of the building, diminished asset value and consequential damages arising from a breach of contract.
> Architect risks -- guaranteeing LEED Certification; design changes during construction
> Contractor risks -- design changes, LEED related guarantees, and potential liability for consequential damages; confusion between performance specifications and design specifications; potential delays

Anderson, W. D. (2014) "Dust control practices currently being used in the oil patch in North Dakota." Road Dust Institute Best Management Practices Conference, Minneapolis, MN. http://roaddustinstitute.org/archive/2014Conference/A2_Anderson.pdf

> Rhinosnot – a soil stabilizer; Oil field produced salt water; Durabond – a lignin based product; Coherex – a petroleum, emulsion with resins; WISP – a synthetic organic oil; Durablend – a calcium chloride and polymer blend; Calcium Chloride; Crude oil; Magnesium Chloride

Associated General Contractors of America. (2004) *Constructing an Environmental Management System: Guidelines and Templates for Contractors Section I: Guidelines*. http://www.agc.org/galleries/default-file/AGC_EMS_Section_I_Guide.pdf

Summary of Applicable Federal Legal and Other Requirements—

- Water -- Storm Water Runoff; Oil Spill Prevention and Response; Dredge and Fill Activities
- Waste – Hazardous Solid Waste; Nonhazardous Solid Waste; Lead-based Paint Waste; Universal Wastes; Underground Storage Tanks; Hazardous Substances; Polychlorinated Biphenyl (PCB) Wastes
- Air – Diesel Retrofit; Asbestos; Air Pollution Permits;
- Endangered Species -- Threatened or Endangered Species
- Spill and Release Reporting – Oil Spill Reporting; Hazardous Substance Release Reporting
- Other Considerations – NEPA; Historic Properties; Green Building; Brownfields

Associated General Contractors of America. (2004) *Constructing an Environmental Management System: Guidelines and Templates for Contractors, Section II: Sample EMS Manual and Sample EMS Records.* http://www.agc.org/galleries/default-file/AGC_EMS_Section_II_Templates.pdf

Samples from portion of EMS Manual – Solid Wastes (Construction materials and supplies waste; construction and demolition debris; hazardous and nonhazardous waste); Discharges to Water (Storm water); Spillage (Petroleum-based fuels and auto/equip fluids); Habitat destruction (site disturbance; wetlands). Each includes objectives, target dates, action plans and company process (= construction activities)

Then "Aspects and Significance Determination Form," with Inputs [Energy, Water, Materials, Supplies/Consumables, Chemicals (each with several items) and Outputs (Air Emissions, Nuisance, Solid Wastes, Discharges to Water, Spillage, Habitat Destruction (again, each with several items)]

Also includes subcontractor questionnaire, with questions about intended activities involving air emissions, water discharges, materials, waste generation, energy, and other)

Barnes, D., and B. Connor. (2014a) "Dust 101." Power Point presentation at 17th Annual National Tribal Transportation Conference, Anchorage, September 23-25.

Methods to management fugitive dust include limiting fugitive dust by limiting speed, and various types of palliatives – water, water absorbing products (deliquescent/hydroscopic) calcium chloride, magnesium chloride, brine), synthetic fluids (with or without "binders"), organic nonpetroleum products (vegetable oils, animal fats, lignosulfonate, tall oil emulsions), synthetic polymer products (polyvinyl acetate, vinyl acrylic), organic petroleum products (asphalt emulsions, dust oils), electrochemical products (enzymes, ionic products, sulfonated oils) and clay additives.

Barnes, D., and B. Connor (2014b) *Managing Dust on Unpaved Roads and Airports*. Fairbanks: Alaska University Transportation Center INE/AUTC 14.14. Alaska Department of Transportation Report No. 4000096.

Materials, profile and drainage are key to good design. Speed important in dust management. (See previous citation for palliatives.) Best palliatives for Alaska: Water, Calcium Chloride, Synthetic Fluids, and Polymers. Water often used for dust control on construction sites; its effect is short lived. Portable palliative applicators for use in rural areas; easily transportable. Life cycle cost discussion; benefits of dust control; road user costs; environmental costs – plants, animals, water quality.

Blake, D. M. (2013) "The construction of Halley VI station in Antarctica." *Proceedings of 2013 ASCE Conference on Planning for Sustainable Cold Regions*, 59-66.

Site access challenges; short construction season; minimize use of hydrocarbon fuels; water from snow melt; insulation and low energy equipment reduce energy demand; modular construction.

Bloecher, P. (2014) "Road dust, air quality, and health." Power Point presentation at 17th Annual National Tribal Transportation Conference, Anchorage, September 23-25.

Introduction to Alaska Native Health Consortium; health impacts of dust; road dust is #1 air quality concern in rural Alaska.

Burrow, M., H. Evdorides, M. Wehbi, and M. Savva. (2013) "The benefits of sustainable road management: a case study." *Proceeding s of the Institution of Civil Engineers, Transport 166*, Issue TR4, 222-232.

Good review of the "three pillars" – economy, environment and society; case study from Cyprus.

Cass, D., and A. Mukherjee. (2011) "Calculation of greenhouse gas emissions for highway construction operations by using a hybrid life-cycle assessment approach: case study for pavement operations." *ASCE Journal of Construction Engineering and Management*, Vol. 137, No. 11, 1015-1025.

Greenhouse gases; CO2; quantifying the life cycle emissions of various pavement designs. The goal is to support strategies that reduce long-term environmental impacts. Considers environmental impacts from the following activities: Equipment manufacturing, material extraction/ manufacturing, fuel production, stationary construction equipment use, to-site transportation, and on-site transportation. "System boundary" includes material acquisition/manufacturing phase (raw materials. Extraction and production, transportation, final product) and construction phase (on-site transportation, manufacture off construction equipment, construction equipment usage – fuel and emissions). Case study from Michigan concrete pavement rehabilitation project.

Cho, Alleen. (2010) "Researchers unveil green rating system for roads." *Engineering News-Record*, Vol. 264, No. 3.

News article announcing new Greenroads rating system for roads, similar to LEED for buildings. Sets forth minimum requirements to qualify as a green roadway, including noise mitigation, storm-water management and waste management. Includes voluntary actions like minimizing light pollution, using recycled materials, incorporating quiet pavement and accommodating non-motorized transportation.

Clemente, C. (2007) "Local actions to improve the sustainable construction in Italy." *Sustainable Construction, Materials and Practices Portugal SB07*, Amsterdam: IOS Press BV, 98-104.

Guides for the design process. Site analysis, soil use, internal environment quality, materials, coherent use of climatic and energy resources, rational use of water resources. Cites national directives plus several city examples.

Connor, B., and D. Barnes. (2014) "Managing dust in Alaska." Power Point presentation at 17th Annual National Tribal Transportation Conference, Anchorage, September 23-25.

Good summary of several points in the *Managing Dust on Unpaved Roads and Airports* manual. Palliative application must be uniform. Good equipment is not expensive. Equipment requires proper adjustment.

Couto, J. P., and A. M. Couto. (2007) "Construction sites environment management: establishing measures to mitigate the noise and waste impact." *Sustainable Construction, Materials and Practices Portugal SB07*, Amsterdam: IOS Press BV, 56-62.

Portugal; emphasis on urban projects; construction site "inconveniences" – Waste production ("production of residue"), mud on streets, dust production, contamination of land and water and damaging of the public drainage system, damaging of tress, visual impact, noise, increasing traffic volume and reduction of parking spaces, damaging of public space. Some excellent suggestions for mitigation of noise impacts and waste production. **See attachment (1).**

Fortunato, B. R., M. R. Hallowell, M. Behm, and K. Dewlaney. (2012) "Identification of safety risks for high-performance sustainable construction projects." *ASCE Journal of Construction Engineering and Management*, Vol. 138, No. 4, 499-508.

Worker safety and health risks and opportunities "associated with the building elements and construction processes." An interesting study relating increased exposure of contractor employees to safety risks when project is trying to achieve LEED certification -- increased fall hazards, struck-by-equipment hazards, trench work, standing water, overexertion, exposure to chlorine, abrasions, airborne gypsum, silica, and musculoskeletal injuries; also decreased exposure to generator exhaust, VOCs and acetone.

Gastrock, B., and L. Barber-Wiltse. (2013) "Campbell Lake winter construction projects." *Proceedings of 2013 ASCE Conference on Planning for Sustainable Cold Regions*, 13-23.

Winter construction preferred: summer has more lake activity by residents; driving across frozen lake provides easier access; summer work would use standard techniques that encounter high water table and unfrozen ground; can stockpile excavated material on frozen surface (using geotextile separation from the ice); shoreline damage is minimized. Excavate until encountering groundwater, then wait overnight for more freeze; then excavate some more …

Glavinich, T.E. (2008) *Contractor's Guide to Green Building Construction: Management, Project Delivery, Documentation, and Risk Reduction*. Hoboken, NJ: John Wiley & Sons, Inc.

A grand overview of the planning-design-construction-commissioning process, plus discussion of LEED. Contract types, project delivery methods, subcontracting, etc. Ideas relevant to our project – Green <u>procurement</u> –raw and manufactured material transport; building product removal and disposition; salvaged product, refurbished product, and recovered material transport; landfill/incinerate waste; energy efficiency; water conservation. <u>Constructing</u> a green project – safety, ergonomics, use of local workforce, standard material dimensions, prefabrication, site layout and use (reduced site disturbance, set site boundaries, restrict vehicle and equipment movement, establish laydown areas, prevent site erosion and sediment runoff, manage storm water and wastewater), construction waste management, material storage and protection, healthy work environment, creating an environmentally friendly jobsite, construction equipment selection and operation.

Greenroads™ Errata. (2013) Seattle, WA: University of Washington.

Revisions to the Muench, S.T., Anderson, J. L., Hatfield, J.P., Koester, J. R., and Söderlund, M., et al. (2011) document, based on committee and public comment.

Guggemos, A. A., and A. Horvath. (2006) "Decision-support tool for assessing the environmental effects of constructing commercial buildings." *ASCE Journal of Architectural Engineering*, Vol. 12, No. 4, 187-195.

Construction Environmental Decision Support Tool (CEDST) was created to identify and quantify the construction process inventories and impacts to be used as the construction phase input to an overall environmental LCA of a commercial building. Temporary and consumable materials, equipment (transport, site, and shop), waste generation. Tracks movements of all equipment, generation of all waste. Case study of structural frame for Bren School, UC Santa Barbara.

Halliday, S. (2008) *Sustainable Construction*. Oxford: Butterworth-Heinemann.

"Construction" is construed very broadly. Emphasis on the environmental stem of the big three: environment, social, economic. Items from the construction processes chapter include the following "key site issues:" Wildlife, contamination, waste, emissions, water, noise, archeology. **See attachment (2)** for details under each of these issues)

Hinze, J., R. Godfrey, and J. Sullivan. (2013) "Integration of construction worker safety and health in assessment of sustainable construction." *ASCE Journal of Construction Engineering and Management*, Vol. 139, No. 6, 594-600.

Helpful definitions of sustainability. Argues that, based on these definitions, construction worker health and safety are no less important than animal and plant health and safety in the construction process, if sustainability is to be attained.

Hosseini, S.A.A, A Nikakhtar, K.Y. Wong, and A. Zavichi. (2011) "Implementing lean construction theory to construction processes' waste management." *Proceedings of the 2011 International ASCE Conference on Sustainable Design and Construction*, 414-420.

Emphasis on reducing waste, from lean construction theory and practice. Waste is related to:

Construction site (Due to wait periods, due to design errors, equipment wear and tear, resting time, excess materials on site)
External factors (Excess materials, safety costs, clarification needs)
Construction process (Due to nature of operations – Defects, rework, overproduction; Non value-added work -- Transport/handling time, waiting, unnecessary inventories, improper choice of methods)

Huang, R.-Y., and W.-T. Hsu. (2011) "Framework development for state-level appraisal indicators of sustainable construction." *Civil Engineering and Environmental Systems*, Vol. 28, No. 2, 143-164.

An indexing system for assessing the performance of a nation in terms of sustainable construction. Delphi-type method. Developed framework of sustainable construction indicator system, including all three pillars – environment, society, and economy, including descriptions of each indicator category. **See attachment (3).**

Institute for Sustainable Infrastructure. (2014) *Envision™ Sustainable Infrastructure Rating System.* http://www.sustainableinfrastructure.org/rating/index.cfm

Founded by ACEC, AWPA and ASCE, this institute provides, *interalia*, the Envision Rating System ("a rating system for sustainable infrastructure"), for any type of development. General categories include quality of life, leadership, resource allocation, natural world, and climate and risk. **See attachment (4)** Self-Assessment Checklist.

James, D. (2014) “Advances in state of knowledge of environmental impacts of dust palliatives.” Road Dust Institute Best Management Practices Conference, Minneapolis, MN. http://roaddustinstitute.org/archive/2014Conference/A2_DJames_final.pdf

Power Point presentation on knowledge advances since 2002. Advises 1) follow best practices in Gravel Roads manual (proper gradation, compact and grade correctly, do not over apply suppressant). 2) reconfigure culverts, shoulders, ditches where possible to drain away from sensitive areas or into retention basins.

Jesus, L. N., M. G. Almeida, and A. C. Almeida. (2007) “Methodology for the application of sustainable construction.” *Sustainable Construction, Materials and Practices Portugal SB07,* Amsterdam: IOS Press BV, 82-89.

Methodology to evaluate cost-effectiveness of sustainable buildings. Five project phases – pre-design, design, construction, operation and demolition, each with five categories – planning; energy management; water management; materials, resources and waste; and indoor environmental quality.

Kibert, C. J. (2008) *Sustainable Construction*, 2nd ed. Hoboken, NJ, John Wiley & Sons, Inc.

CIB’s seven principles of sustainable construction (reduce resource consumption, reuse resources, use recyclable resources, protect nature, eliminate toxics, apply life-cycle costing, focus on quality) apply across the project life cycle, from planning to disposal. Some topics: Sustainable sites and landscaping, energy and atmosphere, the building hydrologic system, selecting materials, indoor environmental quality, construction operations, building commissioning, economic analysis of green buildings. Obvious emphasis on buildings.

In chapter on construction operations— Construction waste management, erosion and sedimentation control, limiting the footprint of construction operations, construction indoor air quality. **See attachment (5).**

Landsberg, K. (2014) “Dust control and air quality in tribal communities – collaboration in Alaska.” Power Point presentation at 17th Annual National Tribal Transportation Conference, Anchorage, September 23-25.

Approach to dust management – Good base road; palliative or stabilizer, behavior change. Emphasizes behavior change – slow down, eliminate unnecessary trips. Regulation of air quality. Rural Alaska Dust Workgroup.

Lemay, L., and T. Peng. (2014) “Concrete’s contribution to LEED v4.” *Concrete Sustainability Report*, National Ready Mixed Concrete Association, CSR11.

Mostly about the claimed advantages of concrete as a material and how it can contribute to LEED points. Topics related to on-site construction practices include construction and demolition waste management planning and construction waste management itself, such as diverting construction, demolition and land clearing waste from landfill and incinerator disposal (example: returned concrete that is diverted from landfills by making landscaping blocks or recycling into new concrete).

Liao, Q., M. Luo, and S. Jia. (2011) “Study on the problems and countermeasures of disposal of construction caste in Chongqing.” *Proceedings of the 2011 International ASCE Conference on Sustainable Design and Construction*, 384-390.

6% of construction waste in Chongquin makes its way to landfills. Some used for construction backfill, some mixed with solid waste disposal, and “even some are dumped anywhere.” Recycle rate of construction waste in Chongquin is about 5%, far below the world average. Countermeasures: Better quality control, thus reducing wastage from rework; Use as large a percentage of material as possible (sheet of plywood, for example); Recycle building materials; concrete block, brick, etc.; crush, sift, sort.

Liu, A. M. M., W. S. W. Lau, and R. Fellows. (2012) “The contributions of environmental management systems towards project outcome: case studies in Hong Kong.” *Architectural Engineering and Design Management*, Vol. 8, 160-169.

Major effects of the construction industry upon the environment originate from energy consumption, carbon emission, construction waste, noise pollution, health and safety, land use, existing site dereliction, habitat destruction and use of natural resources, use of water resources/water discharges. Air pollution especially important in Hong Kong. Also, large recent increase in construction and demolition material to landfills. Environmental management system sustainable construction performance measures include construction cost, cost predictability, time predictability, construction and demolition materials, construction and demolition waste, electricity consumption, water consumption, accident rate and defects. Case studies from Hong Kong.

Liu, J. Y., S. P. Low, and J. Yang. (2013) “Conceptual framework for assessing the impact of green practices on collaborative work in china’s construction industry.” *ASCE Journal of Professional Issues in Engineering Education and Practice*, Vol. 139, No. 3, 248-255.

First paragraph of introduction has some good general words. Needed: more cohesive collaborations among different stakeholders. Identifies significant green practices (throughout project life cycle) and major stakeholders of each. Field construction practices include contract types (including incentives) and material resources (construction waste management plan and building reuse plan).

Lu, Y., and Q. Cui. (2011) “Sustainability rating system for construction corporations: a best practice review.” *Proceedings of the 2011 International ASCE Conference on Sustainable Design and Construction*, 151-160.

Established a SRSCC based on four previous similar systems. Included social and economic dimensions (We have to decide whether we are going there.) Some of the environmental indicators are: Resource conservation and resource efficiency; Air emissions measurement, reporting, volumes, reduction targets, realization; Water management: Volumes, reduction targets; Water recycled and reuse; Solid waste: Amounts, reduction targets; Hazardous waste: Transported, Imported, Exported, treated; Spill: Numbers and volumes; Energy consumption: Direct and Indirect; Transport and logistics for product; On-site combustion.

Marty, J. W. (2000) "The construction challenges." *Civil Engineering*, Vol. 70, No.12, 46-49.

Rebuilding South Pole Station. (Note: written in 2000; scheduled for completion 2005) Some construction techniques, such as arc welding and painting, must be modified for these extreme temperatures. Scientific studies mandated to continue during construction. All materials and supplies delivered by ski-equipped Hercules LC-130. Productivity factor calculated as 2.16 (unclear whether this means an additional 216% or just 216% of normal hours). Factors contributing to this factor – altitude, temperatures, clothing, isolation, living conditions, remoteness. Nothing in article specific to environmental effects of construction operations.

Muench, S.T., J. L. Anderson, J. P. Hatfield, J. R. Koester, and M. Söderlund et al. (2011) *Greenroads ™ Manual v1.5*. Seattle, WA: University of Washington.

Big bold attempt to apply LEED ideas (which apply to buildings) to road building. Rating system. Some activities are mandatory; some are optional. Overall categories are project requirements (mandatory), environment and water, access and equity, construction activities, materials and resources, pavement technologies, custom credits. Construction activities include site recycling plan, fossil fuel reduction, equipment emissions reduction, paving emissions reduction, water tracking. **See attachment (6)** Greenroads Rating System.

National Ready Mixed Concrete Association. (2011) *Sustainable Concrete Plant Guidelines*, Version 1.1. RMC Research and Education Foundation.

Example of industry-produced standards. Categories include prerequisites, material acquisition, production, delivery and construction, product use, material reuse and recycling, and additional strategies. **See attachment (7)** for details within these categories.

Nowack, R. (2014) "Pollution prevention good housekeeping for municipal operations." Power Point presentation at 17th Annual National Tribal Transportation Conference, Anchorage, September 23-25.

Although oriented toward "municipal operations," this presentation contains many good management practices for sustainable construction. **See attachment (8)**.

Nowack, R., and F. Nelson. (2014) "Green infrastructure and highways." Power Point presentation at 17th Annual National Tribal Transportation Conference, Anchorage, September 23-25.

Design concepts for storm water management using "green infrastructure." Limiting the water cycle. Highway drainage system. Functions of such a system: Capture and retain a given storm event and capture pollutants of concern. Maintenance is a big part. Discussion of porous pavements, in which water travels though pavement to minimize runoff.

Pearce, A. R., S. Shenoy, C. M. Fiori, and Z. Winters. (2010) "The state of sustainability best practices in construction: a benchmark study." *Journal of Green Building*, Vol. 5, No. 3, 116-130.

Interviews and observations to "better understand what types of sustainability-related innovations are most easily and effectively adopted over time by project teams on capital projects." Categories of practices: temporary construction materials, sustainable site management practices, indoor environmental quality management practices, solid waste management practices, energy-related practices, and alternative transportation/equipment practices. **See attachment (9)** for details.

Pulaski, M. H., ed. (2004) *Field Guide for Sustainable Construction*. University Park, PA: Partnership for Achieving Construction Excellence.

A massive (312 pages!) and essential document for our study. Ten chapters (Procurement, site/environment, material selection, waste prevention, recycling, energy, building and material reuse, construction technologies, health and safety, and indoor environmental quality. For each of these, there are sections on

Summary Page	
0. Planning	8. Roofing
1. General Conditions	9. Interior Construction
2. Demolition and Abatement	10. Conveying Systems
3. Site Work	11. Mechanical
4. Foundations	12. Electrical
5. Substructure	13. Information Technology
6. Superstructure	14. Equipment
7. Exterior closure	15. Finishes

Section 4.3 Waste avoidance – Site work, for example, includes, *interalia*, Utilize excess concrete for sparking stops, jersey barriers, etc.; Utilize excess asphalt paving to fix surrounding roads, drives, parking lots, etc.; Sell marketable trees; Grind, chip or shred other vegetation for mulching or composting. Etc etc. I have an electronic copy but am not including it as an attachment. Case studies and references for each subsection.

Pulaski, M. H., M. J. Horman, and D. R. Riley. (2006). "Constructability practices to manage sustainable building knowledge." *ASCE Journal of Architectural Engineering*, Vol. 12, No. 2, 83–92.

The four practices: (1) the use of an integrated organizational team to champion the effort; (2) physical and computer building models (mock-ups); (3) on-board reviews; and (4) lessons learned workshops. The focus was on capturing and managing building sustainability knowledge. The study developed sustainability and constructability principles for design and construction, using Pentagon remodel as a case study. **See attachment (10)** for examples.

Santos, I., L. Soares, and J. Teixeira. (2007) "Guidelines for a good practices manual on sustainable construction." *Sustainable Construction, Materials and Practices Portugal SB07*, Amsterdam: IOS Press BV, 1006-1012.

Environmental impacts: waste production, energy consumption, CO2 emissions and natural resources consumption. Sustainable construction good practices categorized into action vectors: planning; energy and gas emissions; water and wastewater; materials, waste and quality; indoor air; and social aspects (comfort, relation with users, and environmental promotion). Paper is clearly oriented toward design aspects.

Sharrard, A. L., H. S. Matthews, and M. Roth. (2007) "Environmental implications of construction site energy use and electricity generation." *ASCE Journal of Construction Engineering and Management*, Vol. 133, No. 11, 846-854.

Focus is on environmental and energy implications of the construction process, specifically on-site energy consumption. Fuel use is higher than reported by government. Discusses non-road diesel engines, on-road gasoline and diesel engines, on-site generators, hybrid engines. Regulations should help (EPA's non-road rule, e.g.). Other than "meeting regulations," noting on responsible practices.

Skorseth, K., and A. A. Selim. (2000) *Gravel Roads Maintenance and Design Manual*. South Dakota Local Transportation Assistance Program and US Federal Highway Administration.

This is the "bible" on gravel road design, construction and maintenance. Sections on routine maintenance and rehabilitation, drainage, surface gravel, dust control/stabilization and innovations, plus five appendices. Specific to our project: erosion control, proper shaping, dust control/stabilization, gravel handling, ditches.

State of Washington Department of Ecology. (2014) *Making Green Building Practices Mainstream: Construction and Demolition Debris.* http://www.ecy.wa.gov/beyondwaste/bwprogGBCandD.html

State of Washington "beyond waste" website. Date on construction and demolition debris 2003-2012. Ideas to reduce C & D material generated: 1) Coordinating with local health jurisdictions to inspect C&D material recovery facilities to ensure they are operated in a manner that protects human health and the environment and in compliance with solid waste regulations; 2) Verifying that all known transporters covered under WAC 173-345 are appropriately registered and permitted to address sham recycling; and 3) Developing new uses and markets for recycled materials, such as paint and carpet.

Stringer, C. "Bridge erection off the ice." *Proceedings of 2013 ASCE Conference on Planning for Sustainable Cold Regions,* 1-12.

Ice used as a platform to support heavy construction loads. Often the most economical method. Site assessment, bearing capacity, inspection, and maintenance of ice bridges.

Tamraz, S. N., I. M. Srour, and G. R. Chehab. (2011) "Construction demolition waste management in Lebanon." *Proceedings of the 2011 International ASCE Conference on Sustainable Design and Construction*, 375-383.

Construction demolition waste (CDW) – some reused for backfilling, port expansion and sea reclamation; some, such as steel, being salvaged for reuse or recycling. Majority is being illegally dumped in empty quarries or valleys.

Construction and demolition waste refers to a wide variety of materials resulting from different activities and sources: Soil, rocks, and vegetation resulting from excavation, land leveling, civil works and site clearance; Roadwork and associated materials (such as asphalt, sand, gravel, and metals) resulting from road maintenance works; Worksite waste materials (such as wood, plastic, paper, glass, metal and wires) resulting from constructing, repairing and renovation works; and Demolition waste or debris (e.g., bricks, concrete, soil, gravel, gypsum, and porcelain) resulting from total or partial demolition of buildings. In Beirut alone, one million tons of CDW has been generated in 2 years.

Recommendation, interalia: Limit disposal of CDW to engineered landfills, Devise an affordable fee for dumping, Encourage reuse of generated rubble (backfill, sea reclamation). Note this paper is mostly about demolition waste, not general construction waste.

Tan, Y., L. Shen, and H. Yao. (2011) “Sustainable construction practice and contractors’ competitiveness: a preliminary study.” *Habitat International,* Vol. 35, 225-230.

There is little research to show that adopting sustainable construction practices improves competitiveness. This paper develops a framework for implementing sustainable construction practice to improve contractors’ competitiveness. .Reducing waste generation, waste flows and control; six principles (Kibert): 1) minimize resource consumption 2) maximize resource reuse 3) use renewable or recyclable resources 4) protect the natural environment 5) create healthy, non-toxic environment and 6) pursue quality in creating the built environment.

The Salt Institute. (2013) *Salt Storage Handbook: Practical Recommendations for Storing and Handling Deicing Salt*. Alexandria, VA.

A manual obviously written, in part, to sell more salt. But – some good suggestions: Drainage – not into freshwater reservoir, well or groundwater supply; build curbs if necessary. Clean up spillage immediately. Always store on a pad; if outside, cover the pile and provide tie-downs.

Thompson, J. W., and K. Sorvig. (2007) *Sustainable Landscape Construction: A Guide to Green Building Outdoors, 2nd ed*. Washington, DC: Island Press.

Obviously not written specifically for construction, this big manual (340+ pages) has some relevant suggestions. Topics from the index: protect streams, lakes and wetlands; avoid survey damage; physically protect site during construction – designate protected areas (fenced as appropriate), limit on-site stockpiling and parking areas, choose staging areas carefully; preserve healthy topsoil – avoid soil compaction, do not “improve” healthy native soils; save every possible existing tree; construction machinery – use lightest machinery possible; stockpile existing topsoil; erosion control – living plants, mats and blankets, mulches and composts; energy use – generation, equipment, transportation.

“Tremco’s renovated headquarters demonstrates sustainable construction.” (2011) *Coatings Tech*, Vol. 8, No. 9. 13.

A typical news article in a trade magazine. Nothing was disposed of in landfills during construction. Everything removed was recycled, reused, or burned for energy. Building design features: “sustainable” roofing systems, energy efficient exterior wall façade, high performance windows, wind turbine, and water capture and reuse system.

U.S. Environmental Protection Agency. (n.d.) *Federal Environmental Requirements for Construction: What do you need to consider?* EPA305-F-03-007. http://www.cem.va.gov/pdf/fedreqs.pdf

Written for contractors, this guide tells about federal regulations that may apply to a project, how to comply and penalties for non-compliance. Topics: Storm water runoff, dredged and fill material in waters of the US including wetlands, solid and hazardous wastes (cleaners, used oil, etc.; lead-based paint; fluorescent lamps, construction/demolition wastes; storage tanks; generation, storage and transport of same), spill reporting, hazardous substances (Superfund liability), PCB wastes, air quality, asbestos, NEPA, threatened or endangered species, historic properties. Note: states may have more stringent requirements.

U.S. Environmental Protection Agency. (2005) *Managing Your Environmental Responsibilities: A Planning Guide for Construction and Development*, EPA/305-B-04-003. http://www.epa.gov/compliance/resources/publications/assistance/sectors/constructmyer/myerguide.pdf

A huge (255 pages) on-line "guidance manual that provides the construction industry comprehensive environmental information." General areas include Storm water, Dredge and Fill/Wetlands, Oil Spill Prevention, Hazardous and Non-Hazardous Solid Waste, Hazardous Substances, Polychlorinated Biphenyl (PCB), Air Quality, Asbestos, Endangered Species Act (ESA). Includes very detailed self-audit checklists for each of these areas to assist in completing the paperwork (not attached hereto).

U.S. Green Building Council. (2014) *LEED v4 Rating Systems: Building Design and Construction.* Scorecard for New Construction and Major Renovations. http://www.usgbc.org/credits/new-construction/v4

Website for LEED rating of new construction and major renovation. All about buildings and primarily about design, but some topics apply to our study. Great emphasis on preparing a plan (and meeting EPA paperwork requirements, for example) rather than executing the plan. Example: "Create and implement an erosion and sedimentation control plan for all construction activities associated with the project." **See attachment (11)** one page scorecard LEED for New Construction and Major Renovations (v4).

Withycombe, E., and R. Dulla. (2006) *Alaska Dust Control Alternatives*. Sacramento, CA: Sierra Research, Inc., Report No. SR2006-03-03.

Another thick report on Alaskan dust. Focus on two communities: Kotzebue and Noatak. Recommendations: reduce number of vehicles, reduce vehicle speed, proper road structural maintenance, increase moisture content, bind particles together, cover unpaved road surface soils with gravel, seal unpaved road surface soils with pavement or other durable materials. Costs and benefits analyses.

Yates, J. K. (2014) "Design and construction for sustainable industrial construction." *ASCE Journal of Construction Engineering and Management*, Vol. 140, No. 4, 160-166.

Survey of representative corporate- and project-level sustainability information for the purpose of providing members of the engineering and construction industry with (1) information on the types of sustainability practices that are being implemented and on why they are being implemented on industrial construction projects and (2) to provide information to assist in the decision-making processes regarding the implementation and evaluation of sustainable practices on industrial construction projects.Very helpful Checklist for Sustainability Evaluation of Industrial Construction Projects. S**ee attachment (12).**

Yeang, K., and A. Spector, eds. (2009) *Green Design from Theory to Practice*. London: Black Dog Publishing.

Collection of essays from 2009 Jerusalem Seminar in Architecture. Example of various topics on design aspects – materials, renewable energy, water efficiency.

Zhang, W., and Q. Wu. (2011)”Development model for construction waste management in China.” *Proceedings of the 2011 International ASCE Conference on Sustainable Design and Construction,* 421-430.

One problem is “poor transportation management system.” In Beijing, only 10% of construction waste was transported to the designated location. Minimize site waste. Mechanized methods tend to be less wasteful than hand methods. Use qualified haulers.

APPENDIX B – INTERVIEWEES

Name	Affiliation
Bill Hoople	HC Contractors
Clark Milne	DOWL HKM
Paul Perreault	UAF
Galen Johnson	UAF Community & Tech College
Byron Bluehorse/Darrell Williams	UAF Interior-Aleutians/Ninilchik Traditional Council
Aaron Cook	CCHRC
Doug Smith	Haskell Corp
John Hargesheiner/Peter Beardsley	Nortech
Bill Smythe	ADEC retired
Bob Tsigonis	Lifewater Engineering
Bert Bell/Heather Patterson	Ghemm Company
Frank Ganley	DOTPF Northern Region
Larry Peterson/Eddie Packee	Travis-Peterson Fairbanks
Al Vezey	Lakloey Inc.
Doug Buteyn	ADEC
Don May/Jeremiah Dobberpuhl	Osborne Construction
Sam Lamont	DOTPF retired
Chuck Southerland/Ken Wilson	Alyeska Pipeline
Marcus Trivette	Brice Construction
Bruce Bridwell	Tiaga Ventures
Donna Mears	Central Environmental, Inc.
Mike Travis	Travis-Peterson Anchorage

APPENDIX C – GUIDELINES

Guidelines for Sustainable Construction in Alaska

Tips, suggestions, and ideas for increasing the net benefit of Alaskan construction projects

Sponsored by CESTiCC and UAF

Dr. F. Lawrence Bennett, P.E.

Dr. Robert A Perkins, P.E.

Sustainability implies projects that help meet the needs of the present without compromising the ability of future generations to meet their own needs. Projects are scrutinized in three dimensions: their impact on the economy, the environment, and society. Sustainability requires a balance among those three aspects, implying the need, often, for tradeoffs and compromise between them. Moving towards field construction, we can assume the project's effects on the economy and society are acceptable, but the construction process offers opportunities to improve the effects on the environment. Here we offer a collection of tips, suggestions, and ideas that we call *Guidelines* that are focused on northern regions, especially remote projects. The process of gathering these suggestions began with a search of published material, most from warmer regions. Later interviews with Alaskan experts, listed in Appendix A, led to the selection of guidelines presented here.

The Guidelines are arranged by logical categories to help locate information; however, some overlap is inevitable.

Categories:

Management, Planning and Coordination
- Planning and Management
- Local Community Issues

Logistics and Support
- Construction Camp
- Power Production and Use
- Transportation

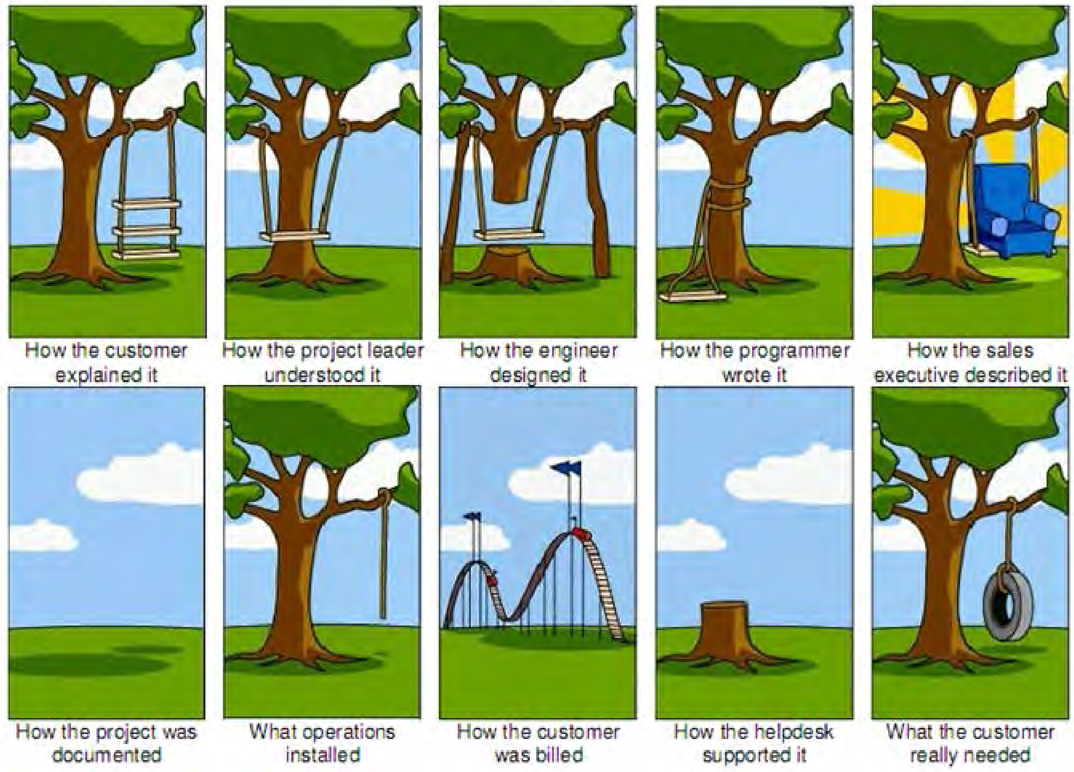
Site Impacts – The Ground
- Clearing
- Material Sources and Storage
- Permafrost
- Vegetation and Historic Sites
- Water Flow/ Runoff/ Erosion
- Wildlife

Operational Impacts
- Air Pollution
- Equipment
- Fuels and Other Petroleum
- Hazardous Waste
- Solid Waste

Appendix A: Interviewees and helpers

Appendix B: CESTiCC

Management, Planning and Coordination



Guidelines:

- Planning and Management
- Local Community Issues

Planning and Management Guidelines

1. Coordinate with other projects and entities
2. Pre-plan thoroughly, including
   Waste management
   Economic planning to minimize numbers of personnel and equipment
3. Consider the effects of seasonality on construction operations
4. Manage the permitting process well
   Get acquainted with the agency
   Know their requirements
   Get their checklists
5. Prefabricate modularized components to reduce on-site activity
6. Consider sustainability qualifications of subs, especially in QBS
7. Consider sustainability improvements for value engineering submittals.
8. Hold frequent sustainability meetings, similar to safety meetings.
9. When planning electronic communication, don't assume sufficient bandwidth; plan to transmit smaller drawings, with no color or highlighting
10. Use electronic submittal exchange methods
11. Utilize electronic meetings to the greatest extent possible

Comments:

Cooperation and coordination with others might include co-use of equipment, materials sites, labor crews, thus reducing transportation impacts and site footprint.

Thorough pre-planning is especially important in remote area projects.

Many operations are best performed in winter – frozen ground, lake/stream ice for transportation, excavation, piling.

Obtaining permits as early as practical can allow proper scheduling of season-dependent activities (an issue for all parties).

Proper planning and use of electronic communications, including meetings and document transfer, will save wasted paper and transportation costs and resources.

Local Community Guidelines

1. Engage in local hire as much as possible
2. Use local equipment when possible
3. Use already existing laydown areas when available
4. Consider use of power generated by local utility rather than stand-alone generators transported to the site
5. Leave equipment at village after project (gift or sell)
6. Make clearing debris available for local use as firewood
7. Make demolition debris and leftover materials available for local use
8. Hold a pre-construction meeting at the location, in cooperation with local leadership

Comments:

Transportation impacts can be reduced by local hire, use of local equipment and local utility (rather than stand-alone generators), leaving equipment after project (gift or sell), and making demolition debris and leftover materials available for local use (reduce backhaul)

Site footprint can be reduced through local hire (housing), and the use of existing laydown areas.

There may be a net reduction in air pollution through use of local utility-generated power.

Training is essential if equipment is left behind.

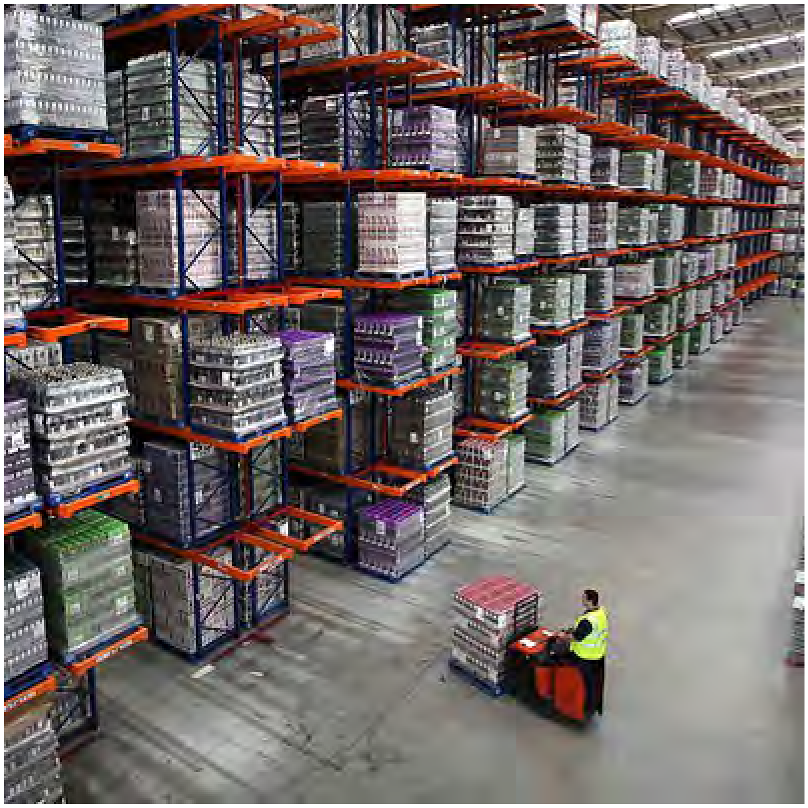
Broken, nearly unusable used equipment may not be an appreciated gift.

Demolition debris and leftover materials must be sorted and labeled.

A fairness protocol may be needed when making demolition debris and leftover material available.

There may be some federal rules about giving away excess materials, etc.

Logistics and Support



Guidelines:

- Construction Camp
- Power Production and Use
- Transportation

Construction Camp Guidelines

1. Location

   Minimize land use
   - Locate camp close to project to minimize total site area.
   - Hire locally to reduce camp size
   - Plan road system; don't build excessive roads and trails
   - Rent houses in the village if available (and maybe fix them up)

   Avoid use of sensitive areas, subsistence areas, high value recreation and scenic areas

   If ground conditions can be ascertained, place camp near the center of permafrost polygon rather than at edges where melting is more likely to occur

   Pick a site that doesn't drain to a river

   Locate camp in a low spot if possible

2. Repurposing/reuse

   Make temporary buildings more permanent

   Leave temporary pad in place for local use

   Leave clothes washers, dryers and similar equipment for local use

3. Provide ground protection in permafrost areas with such methods as insulated mats and boardwalks

4. Water and wastewater management
   - For water supply use local supply if available; otherwise consider drilling a well or using rainwater or melted snow with treatment.
   - Consider packaged water and wastewater treatment systems
   - Locate portable toilets in nearby convenient locations
   - Save water
     - Low water-use fixtures
     - Don't let toilets run
     - Consider waterless toilets

5. Waste from food service –
   - Compost food waste
   - Use minimal waste-producing dishes – ceramic instead of paper

6. Burn waste, as appropriate, in a BurnEasy (or other) agricultural incinerator

7. Provide products to address spills from equipment leakage, fueling, etc

8. Use sturdy lighting, such as heavy duty sealed fluorescent fixtures

Comments:

Hiring first from local community, then relatives from nearby villages who can live with locals, and, finally, workers from outside area is a successful approach.

Renting existing local buildings reduces camp size.

Locating the camp in a low spot so that water drainage can be directed to a settling pond in the middle can avoid the use of silt barriers.

Temporary buildings made more permanent can be repurposed for local use.

The contractor will be responsible for a trailer, or other assets, left at the site that nobody wants.

A well means less water haul.

“Temporary” well can be left for local use.

Packaged water and wastewater treatment systems are practical in many cases and can be transported from job to job.

Power Production and Use Guidelines

Production

1. Research what is available locally before starting project; contact local AVEC utility in advance re: power needs, when, how to plug into.
2. Consider solar or wind power; sell equipment locally upon project completion.
3. Be cautious that locally produced power may be "dirty."
4. Be attentive to changing fuel costs; LNG may become competitive, e.g.

Use

1. Save energy by accelerating the schedule
2. Work in the warm season to save lighting and heating costs and resources.
3. Reduce idling; have a policy
4. For engine warming, consider indirect heating (e.g. Frost Biter) instead of long idling.
5. Use timers on equipment
6. Use waste heat for heating or generating more power

Comments:

Many feel solar and wind power are not feasible for remote construction applications.

Solar may have some limited uses; e.g. bear fences

Wind, solar and locally produced power probably produce less air pollution than project-generated diesel. Also there is less chance of fuel spills.

A local power source may not have enough capacity to run large equipment such as a crusher.

Conserving energy is a big economic incentive.

A balance is needed between working in the warm season to save energy resources and costs and working in the cold for the advantage and practicality of some operations.

Indirect heating (e.g. Frost Biter) may be less expensive, cost- and resource-wise, than long idling.

Transportation Guidelines

1. Prefabricate as much as possible to save on shipping costs and resources
2. Have prefabricated components inspected at the fabrication site rather than at the jobsite if possible
3. Reduce the size of equipment that must be transported to the site in order to lower transport costs and resource requirements.

4. Explore potential low-impact methods for delivery and backhaul

   Barge
   Airplane
   Drive on river ice
   Cat train over snow

Comments:

Prefabrication results in less on-site waste but requires really good drawings.

Inspection at the fabrication site saves time and transportation costs and resources.

Site Impacts – The Ground

Guidelines:

- Clearing
- Material Sources and Storage
- Permafrost
- Vegetation and Historic Sites
- Water Flow/ Runoff/ Erosion
- Wildlife

Clearing Guidelines

1. Do not disturb the ground until just before the start of work
2. Minimize the cleared area
3. Consider using existing pad, roads, material sites, etc., as much as possible
4. Plan the use of clearing debris
   Leave in place (minimize erosion; faster regrowth), or
   Chip smaller debris and use for mulch
5. Deck larger (> 4” – 6”) trees for use as firewood
6. Use organic material to protect cleared areas
7. Minimize disturbance of root mass and organic layer
8. Remove mature shrubs, stockpile, protect, and reuse
9. Plan the timing of clearing operations
10. Work on frozen ground if possible
11. Unless ground is frozen, perform clearing by hand with no wheeled vehicles

Comments:

Chipped debris might be allowed as non-structural (or maybe even structural) fill.

Chipped debris has been used as insulation over permafrost.

For “ground disturbing activity,” a permit may be required.

The use of hand tools and smaller equipment usually has fewer impacts.

Some additional clearing may be needed for moose safety.

Material Sources and Storage Guidelines

1. Limit the size of laydown areas
2. Protect storage areas from contamination
3. Protect materials and supplies from freezing
4. Pay extra attention to ordering the right materials
5. Locate gravel sources sufficiently far from streams to prevent water runoff from entering waterways
6. Use local materials where possible
7. Order the least possible quantity of a product, particularly for products with a limited shelf life
8. Consider just-in-time delivery if practical

Comments:

Protecting materials and supplies from freezing avoids high replacement costs and resource use.

Ordering the least possible quantity reduces backhaul costs and resource use.

Just-in-time delivery reduces required laydown area.

Permafrost Guidelines

1. Carry out pre-planning, obtain permits, etc. as early as practical, to allow conducting sensitive operations on the frozen active layer
2. Schedule work so as to open minimal areas at a time
3. Schedule work so as to conduct operations after ground freezing in fall/winter
4. Limit travel to frozen tundra
5. Leave organic layer in place where possible
6. Install gravel pads for protection
7. Place separation fabric between permafrost and pad
8. Consider using wood chips to protect open permafrost (such as ice-rich cut slopes)
9. Harvest the organic mat for use in protecting open permafrost
10. Put nothing heated on the ground
11. Minimize clearing to allow shade to protect permafrost
12. Build temporary roads with the same care that permanent roads are built on permafrost – insulation, rock embankments, etc
13. Consider using HDPE overlay mats (approx 3-4" thick) for laydown area, temporary roads, camp site, etc.
14. Consider use of geo foam for frozen ground protection
15. Elevate temporary structures above ground
16. Control water drainage
17. Consider use of boardwalks
18. Don't disturb riverbanks, since they are especially vulnerable

Comments:
The key is seasonality. Recognizing seasonality is a matter for all parties, including permit agencies.
Piling installation is a good example of an operation conducted when the active layer is frozen.
Avoiding disturbing riverbanks will minimize permafrost melt and stream pollution.

Vegetation and Historic Sites Guidelines

1. Place interlockable , 6” thick, plastic mats over vegetation that has been “mowed” level; do not remove any shrub stubs, etc.
2. Preserve existing natural vegetation and root mass – leave in place if possible, or reuse
3. Plow up and stockpile organic matter, including shrubs. Re-spread after project completion.
4. Leave no debris resulting from clearing or brushing operations in water bodies (including periods when the water body is dry).
5. To minimize spread of invasive species:
    - Use native species, certified weed-free seed and weed-free fill if possible
    - Minimize/eliminate the use of straw or hay bales
    - Minimize the size of disturbed areas
    - Maintain buffers of undisturbed native vegetation along streams and rivers
6. Stop ground-disturbing work immediately upon the discovery of a suspected archeological site.

Comments:

Interlockable plastic mats can be driven on and worked upon.

Stockpiling and respreading organic material allows native species to reestablish quickly.

Water Flow/ Runoff/ Erosion Guidelines

1. Sequence work properly, so that ground work is completed as fast as possible from initial disturbance to final stabilization
2. Schedule as much work as possible in the winter
3. Finish/seed side slopes before paving and before the end of growing season
4. Catch storm water for project use, using sediment ponds; use for compaction, dust control, etc.
5. Look for alternative methods for silt fences and sediment traps, maybe using local materials
    - Use the organics that have been cleared as a silt barrier. e.g., hydro-axe to protect the surface and then reuse it later on site as a silt barrier
    - Roll up the organic mat to make a silt fence
    - Consider using fiber-filled tubes
        - Possibly do the filling at the site by harvesting grasses at the rural location
        - Reuse tubes
        - Use weed free materials for filler
6. Consider using snow berms for diversion
7. Leave a “vegetative buffer” (15’ ± uncleared) around the perimeter and sensitive areas
8. Consider blankets of various types for slope stabilization
9. Keep vegetation on portions of the site as long as possible
10. Store hazardous materials a specified distance away from water sources
11. Be aware that hazardous waste may be more important than sediment with respect to water pollution
12. Consider the effects of run-on as well as run-off; i.e., control the source; divert water around where possible
13. Prevent the release of turbid water when dewatering excavations, by using either
    - Settling ponds before discharge, or
    - Dewatering wells around the site.
14. Protect stockpiles with visqueen; consider seeding stockpiles that will be in place for an extended time
15. Maintain a clean and orderly workspace to prevent or reduce wastewater contamination from contacting petroleum or other products
16. Control equipment shop and facility melt water
    - Use drip pans under stored vehicles. Check drip pans and remove residual oil prior to use.
    - Discharge melt water to work pad or domestic sewage system.
17. Provide for proper collection of concrete truck washout water
18. Minimize mud tracking by trucks and other equipment

Comments:

Doing work in the winter has a much smaller impact; no need for silt fencing, etc.

Finishing side slopes before paving can help control runoff/erosion and is a matter of scheduling.

An advantage to straw wattles v. silt fences is that wattles don’t have to be removed at project end. Note that “wattle” may be a trademark or a patented term.

In real cold areas, snow berms may last into summer.

Vegetative buffer may be a desirable alternative to a silt fence, especially in wetland areas.

Blankets for slope stabilization are more costly than seeding and mulching but are more reliable.

The use of dewatering wells around an excavation allows removal of non-turbid water rather than the water that was disturbed by the excavation process.

Wildlife Protection Guidelines

1. Be aware of, and provide training for, regulations and specification requirements related to
   - Work in fish streams
   - Stream diversion
   - Culverts
   - Migratory bird nesting
   - Wildlife harassment
   - Wildlife migration and connectivity
   - Blasting scheduling to protect vulnerable species
2. Protect the aquatic habitat by avoiding and minimizing
   - Discharge of silt or contaminants
   - Disturbances to streambeds and stream banks
   - Placement of debris in streams and lakes
   - Use of equipment in or near streams and lakes
   - Use of chemically treated wood in fish-bearing streams
3. Screen water intake structures in fish streams to prevent entrainment or entrapment of fish eggs, larvae, fry, or adult fish
4. Prevent stranding of fish in streams due to construction operations
5. If installing temporary culverts, be sure they are properly sized and located
6. Use low water stream crossings
7. For equipment crossing streams, cross from bank-to-bank, perpendicular to the stream flow, and only at points with gently sloping banks
8. To protect wildlife habitat :
   - Plan activities – clearing, camp layout, etc-- to impact the smallest feasible footprint on the land
   - Avoid sensitive periods (bear, wolf, fox denning; caribou calving; sheep lambing, etc)
9. Don’t feed bears or other wildlife
10. Minimize attractants
    - Food waste – Tight covered containers; frequent pick=up
    - Human waste – Pump often (Porta johns)
    - Food storage – Tight covered containers
    - Trash – Tight covered containers; frequent pick-up
    - Keep break areas clean
11. Have policies regarding hunting, fishing and trapping, including making sure regulations are followed

Operational Impacts

Guidelines:

- Air Pollution
- Equipment
- Fuels and Other Petroleum
- Hazardous Waste
- Solid Waste

Air Pollution Guidelines

1. Equipment operation
   Don't leave engines running more than necessary
   Maintain equipment to assure it runs more efficiently
   Use newer equipment and vehicles
   Consider using Tier 4 urea injection engines
2. Dust control
   Use an anti-tracking device like a cattle guard
   Consider temporary paving to reduce dust
   Provide wheel wash and recycle wash water
   Minimize number of trips
   Take water from environmentally responsible sources; *don't harm the fish in the process of doing dust control.*
   Have a general rule about dust control, such as – "If you see visible dust, 'Call out the water truck.'"
   Use water with or without palliative (calcium chloride, e.g.,) for temporary roads
   Track water use
   Be cautious about storing palliatives over winter
   Drive more slowly
   Haul on rainy days if possible
   Incorporate excavated soil into the project rather than hauling it away
   Attach sprayer to crusher belt
3. Indoor air quality
   Specify non-toxic cleaning agents only
   Use non-polluting adhesives
   Enforce a no smoking policy inside buildings
   Use Visqueen barricades to isolate sheetrock and tile cutting, vented to outside
4. For worker health, supply clean heat for temporary heat
   Not Master heaters or air heaters from outside
   Use a temporary boiler or permanent boiler installed early
5. Burning
   Minimize burning of brush, scrap materials; don't burn plastic
   When burning, burn well – hot enough, with lots of air
   Burn only what is burnable; sort out what is not
6. Cover, wet or seed topsoil and other soil piles
7. Operate facilities and equipment in a manner that avoids or minimizes ice fog, particularly near airfields, communities, and roads

Comments:

Tier 4 urea injection engines work well in the cold and emit less pollution.

Newer equipment and vehicles are much more fuel efficient (and therefore less polluting) and are more productive

Throwing a pump intake hose into an *androgynous fish stream may harm the fish.*

Palliatives must be applied judiciously (in proper sequence v. water)

Note that some palliatives will freeze if stored over winter and are difficult to remix and reuse.

Incorporating excavated soil into the project rather than hauling it away results in less dust, less equipment wear and less fuel use; note this is primarily a design and planning issue.

Attaching a sprayer to the crusher belt reduces dust and puts more minus 200 into the crushed product.

Master heaters and outdoor air heaters are inefficient and, in the case of Master heaters, supply bad quality air.

This last issue is a short learning curve –workers notice and appreciate an immediate benefit from better quality heated air.

Boilers provide better air quality and are more efficient.

Equipment Guidelines

1. Rent locally if possible: Fix it up; train operators; leave spare parts
2. Avoid the need for heavy equipment
3. Provide catch basins and secondary containment for fuel spills
4. Perform fuel storage and fueling off site
5. Use Herc-able equipment if hauling to site is necessary
6. Move materials as seldom as possible
7. Maintain & tune up equipment; repair leaks
8. Avoid damaging permafrost with heavy equipment

Comments:

Avoiding the need for heavy equipment is partly a design issue; smaller assemblies require smaller equipment to install.

Moving materials as seldom as possible is related to site planning, layout, and storage sequencing.

Fuels and Other Petroleum Guidelines

1. Assure that used oil containers or tanks are:
    In good condition (no severe rusting, apparent structural defects, or deterioration);
    Not leaking (no visible leaks); and
    Closed at all times, except when oil is being added or removed.
2. Consider smart ash burners for oily waste
3. Be prepared with
    Spill prevention plan
    Spill response kits and plan
    Booms (around water)
    Policies and procedures in place
    Training
4. Understand regulations related to spill cleanup
5. Consider using double walled self contained tanks inside secondary containment.
6. Clean up spills in secondary containment to prevent contamination of water and degradation of liners by the spilled product.
7. Keep petroleum out of water
8. Use environmentally friendly hydraulic oil if available
9. Purchase fuel locally if available
10. Consider using propane instead of diesel for equipment and power generation
11. Be careful when using fuel bladders
12. Protect fuel lines over the winter (whether operating in winter or not)
13. Check hoses, fittings and valves before and after a transfer
14. Use proper grounding procedures for all transfers
15. Use portable containment to promote spill prevention and for keeping job sites clean so that no spill or potential spill goes unnoticed.
16. Use portable containment berms under stationary and portable equipment (e.g., generators, compressors, heaters, welding units, hydraulic power units and cranes) when in use
17. Use portable containment berms of suitable size and appropriate material under any equipment or vehicle dripping or leaking engine oil or fluids until the equipment can be safely removed from the site and repairs made
18. Store fuel, lubricants, used oil and chemicals (e.g., paints, solvents and thinners) in secondary containment.
19. Maintain hydraulic hoses and fittings to avoid breakage
20. Check equipment daily to ensure there is no dripping or leaking
21. Keep work sites clean and neat so that spills or risk of potential spills do not go unnoticed

22. Monitor fueling at all times do not leave the fueling area or get back into the vehicle during fueling.
23. Burn used oil to avoid backhaul

Comments:

Environmentally friendly hydraulic oil is new and available.

Propane is currently more expensive then diesel, but, if a spill occurs, the consequences of diesel are much worse.

Liquid natural gas (LNG) may supplant diesel.

- Some trucking companies believe they can recover greater first cost (buying new or converting) of LNG engines with 3 ± year payback.
- Environmentally, LNG is virtually inert.

Fuel bladders are easy but fragile.

An example of portable containment: A folding drip pan that holds one 18-inch by 18-inch sorbent pad. Use for small drips where the total volume is expected to be less than one-half pint.

Used oil can be burned in heaters, but they require lots of maintenance.

Hazardous Waste Guidelines

1. For naturally occurring asbestos, monitor and move operations to different site if detected
2. Assure that shipping containers that delivered hazardous materials (epoxy part B, e.g.) do not get used by local residents. Crush them, poke holes in them, etc.
3. Maintain proper storage of waste until it is practical to ship it out
4. Store waste containers in secondary containment
5. Containers should be:
   - In good condition. If waste begins to leak, contents must be transferred to a new container or over packed in a larger container.
   - Compatible with the waste they hold. Different waste streams must be accumulated in separate containers. Do not mix waste.
   - Covered and tightly sealed except when waste is being added or removed.
   - Properly labeled
   - Not filled completely full or exceed UN/DOT container weight requirements
   - Stored out of direct sun (volatile wastes)
   - Kept from freezing (liquids); heated storage may be necessary.
   - Stored in a manner that allows adequate aisle space (for inspection)
6. Maintain a 50-foot buffer zone from the facility boundary for container storage of ignitable or reactive wastes

Solid Waste Guidelines

1. Save on waste with good pre-planning of quantities; don't buy too much; pre-cut to length
2. When ordering, specify minimal packaging (though enough to provide sufficient protection)
3. Utilize prefabrication and modular construction as much as possible
4. Reuse/repurpose in the rural community to the fullest extent possible
    - Scrap lumber
    - Fasteners, tools, maybe even used nails,
    - Other demolition "debris" – windows, doors, electrical, insulation
    - Cleared trees
    - Extra materials of many kinds
5. Involve the community in planning the transfer of ownership (waste, equipment, etc)
6. Be aware of potential liability issues associated with giving away regulated waste
7. Chip wood waste as well as brush/small trees for mulch
8. Burning waste

    Use efficient burn boxes, such as *SmartAsh cyclonic burners*

    Do not burn kitchen waste, paint cans, aerosol cans, medical waste, or wet garbage in Smart Ash burners

    Comply with air quality regulations with respect to burning
9. Sort different types of waste

    Leave only benign waste for village use; sort out treated lumber, OSB, etc., and don't let them burn these.

    Use separate, well-labeled waste bins for different waste products

    Educate workers on sorting and recycling
10. Cover the waste in the landfill; minimize needed cover by compacting waste.
11. Consider contributing an upgrade of the village landfill
12. Shred wood and light metal waste to save volume in landfill
13. Time backhauls (often empty) to haul out solid waste
14. Collect old equipment and vehicles in a warehouse or other environmentally acceptable area until there is a large enough quantity to justify low rate backhaul, such as by barge.
15. Use personal water bottles (clip-on-the-belt type are best) rather than paper cups, to reduce paper litter

Comments:

Inefficient burn boxes may produce residue that cannot be placed in a Class 3 landfill.

Burning may produce undesirable air pollution.

Smart Ash-type cyclonic burners produce little or no smoke; they are good for oils, oily rags, combustible waste, etc.

Covering waste in the landfill helps the community's environmental efforts.

It may be necessary for the contractor to develop its own permitted landfill.

APPENDIX D – UAF COURSE MATERIAL

Suggested Outline for a Short Segment on Sustainable Construction
in a Construction Management Course

1. Start with an open discussion around the question, "What practices can contractors (working in cold remote areas?) implement in the field to be more environmentally responsible?"

2. Concepts of sustainability: Definitions, the three pillars

3. A brief history and background, focused on the emphases on design and buildings

   LEED

   Reference: U.S. Green Building Council. (2014) *LEED v4 Rating Systems: Building Design and Construction.* Scorecard for New Construction and Major Renovations. http://www.usgbc.org/credits/new-construction/v4

   Greenroads

   References: Muench, S.T., Anderson, J. L., Hatfield, J.P., Koester, J. R., & Söderlund, M. et al. (2011). *Greenroads ™ Manual v1.5*. Seattle, WA: University of Washington. (and updates)

   https://www.greenroads.org/

   Some work on field construction

   Reference: Pulaski, M. H., ed. (2004) *Field Guide for Sustainable Construction*. University Park, PA: Partnership for Achieving Construction Excellence.

4. The Guidelines Project

   Purpose

   Method

   Findings

   Results

   References: Final Report
   Website with Guidelines

5. Review some of the guidelines

6. Introduce the case study

7. In-class (or take-home) completion of the case study exercise

8. In-class review and discussion of case study responses

Notes:

1. This segment might lend itself to a flip classroom approach, in which the recorded lecture would cover items 2, 3, 4, and 5, and the in-class portion could start with 1, and then do the case study in 6, 7 and 8. That would require some writing in class, but the participants could work in groups to select the ten guidelines and then parcel out the writing. With good management, the in-class portion could be completed in an hour.
2. To add to the content, invite a contractor (Brice, Ghemm, etc.) to speak about an actual project where environmental sustainability was important.
3. Another enhancement could be subject matter guest experts – Alyeska on wildlife and vegetation, ADEC on solid waste, AKDOT&PF on runoff/stormwater/erosion, Taiga Ventures on camps, Campwater/Lifewater on water/wastewater, etc.

APPENDIX E – WEBSITE

The *Guidelines* are now on the CESTiCC website, where they can be located by search engines.

APPENDIX F – METHODS PAPER FROM CESTICC CONFERENCE

Sustainable Construction in Remote Cold Regions: Methods and Knowledge Transfer

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ABSTRACT

This project aims to identify sustainable construction techniques appropriate for remote and cold regions, noting extension to operations and maintenance as applicable. This paper explains the methods used to review the vast body of literature regarding green construction in warm regions, and the use of a hierarchal taxonomy to categorize the information found in order to reduce it to a form useful for eventual presentation to engineering and construction managers.

INTRODUCTION

Remoteness and cold climate make construction in rural Alaska challenging and expensive. Sustainable construction practices serve to reduce the negative environmental consequences of construction projects and often reduce their life-cycle cost. While such practices are commonly considered in warm climate construction, especially for vertical construction, little knowledge has been accumulated about sustainable construction in cold regions. Besides the constructed work, remote projects often require their own infrastructure, such as camps and supply depots. In addition, most construction in remote cold regions is horizontal construction, requiring continuing maintenance and operations (M&O) efforts, likewise with its own infrastructure. Since most M&O for these kinds of projects uses the same types of equipment and infrastructure, we include this work under the rubric of “construction.” Although we focus on the field construction, typically by a contractor as opposed to the owner’s own forces, there is often little to distinguish those with respect to the operations. Likewise, we cannot exclude design, insofar as the specifications may require certain features during the construction, and/or include permit stipulations. Finally, in a design-build or CMAR project delivery, the contractor may include sustainable features as an enhancement in the design competition. Here we present our process for winnowing down the vast amount of “green construction” items in the literature to those possibly relevant to remote cold regions, and then our plan to review these with remote cold regions experts and revise and add new items based on their expertise.

BACKGROUND

Many definitions of sustainability have been suggested. All revolve around the importance of creating and maintaining conditions under which human and natural needs can be met both in the present and in the future. Thus, “a sustainable society is one that can persist over generations, one that is far-seeing enough, flexible enough, and wise enough not to undermine either its physical or its social systems of support" (Meadows et al, 1992). An enduring classic definition of sustainability was suggested by the World Commission on Environment and Development as follows: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (quoted in Burrow et al, 2013).

As noted by Burrow (2013), it is common to represent sustainability in three dimensions, including the economy, the environment and society. From this point of view, sustainability is achieved only when there is a balance among those three aspects, implying the need, often, for tradeoffs and compromise among the three. In the context of the study reported in this paper, a sustainable construction project would be one for which there is a balance among present and future needs for economic viability, a flourishing society, and a healthy natural world. For this project, and in the spirit of the theme of this symposium, we confine our consideration to environmental sustainability while recognizing the importance of the other two aspects of the overall sustainability challenge.

It follows from the above discussion of environmental sustainability that, within the context of the construction process, sustainability involves "creating construction items using best-practice clean and resource-efficient techniques from the extraction of the raw materials to the demolition and disposal of its components." (Yates, 2014) The project described in this paper examines one relatively small but significant aspect of sustainable construction – environmentally responsible methods for conducting field construction and maintenance operations in remote cold regions.

Sustainable, or "green," construction has been an essential part of the building construction process for many decades. The contemporary interest in such practices arose in the 1970's when rapid increases in world oil prices instigated improvements in building energy efficiency. Furthermore, the environmental movement that began in the 1960's and 70's spurred the development of environmentally friendly and energy efficient buildings and other structures (EPA 2014).

A review of the literature of sustainable construction (see, for example Clemente 2007, U.S. Green Building Council 2014, Santos et al 2007, Institute for Sustainable Infrastructure 2014) reveals two important realities about the work accomplished to date. First, "sustainable construction" embraces all phases of the project life cycle, from early planning to operations, maintenance and even decommissioning, but the greatest emphasis has been on the design and material specification aspects of the project development process. Second, the emphasis to date has been on buildings and other such structures ("vertical" construction), with much less consideration of such practices in heavy construction ("horizontal" construction), such as roadways, pipelines, boardwalks, and airfields. For example, a typical Internet entry explaining sustainable, or "green," construction (GSC 2014) states, in part, "Green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by: 1. efficiently using energy, water and other resources, 2. protecting occupant health and improving employee productivity, 3. reducing waste, pollution and environmental degradation." Note the emphasis on <u>buildings</u> and <u>design</u>.

There is a need, especially in remote cold regions such as rural Alaska, for a compilation of guidelines to assist construction contractors in conducting their operations in environmentally responsible ways. Since a large proportion of construction efforts in such areas develop horizontal projects, it is for this kind of work that such guidelines will be most helpful. The purpose of this study, then, is to identify and codify practical environmentally sustainable construction practices for use by contractors operating in remote cold regions and to convey the findings in useful form to those who can use them.

This paper is a status report on an on-going investigation. It describes the work accomplished to date and sets forth planned tasks to be carried out by project completion in late 2015.

PROJECT OBJECTIVES AND WORK PLAN

As set forth in the proposal for the project (Perkins 2014), the primary objectives are as follows:

1. Translate common sustainable construction methods in use for vertical construction into similar approaches for horizontal construction for use as a checklist of topics for horizontal construction in remote and cold regions.
2. Identify appropriate sustainable horizontal construction methods for use in remote regions and in severe climates
3. Develop guidelines and means for the formal transfer of such methodologies to those who conduct construction operations in such environments. Examine practicality of such techniques for use in remote and harsh environments by rural residents.

The project plan includes the following tasks:

1. Compile inventory of sustainable construction methods currently used in vertical construction, from existing compendiums, sustainability organizations, and worldwide literature and meetings with Alaskan experts.
2. Compile inventory of sustainable construction methods currently used in horizontal construction, from existing compendiums, sustainability organizations, worldwide literature and meetings with Alaskan experts.
3. Identify current construction practices in rural Alaska that have, or could have, a sustainability component, noting particular challenges due to a) cold climate aspects and b) rural aspects. Draft a preliminary report.
4. Organize and conduct a gathering of construction industry leaders, in either a short course or seminar setting, to review findings to date and seek guidance as to potential changes in practices that could lead to greater sustainability.
5. Revise preliminary report and develop guidelines for selected practices.
6. Design an outreach course for use with rural Alaskan construction personnel that sets forth suggested practical sustainable construction methodologies - a manual, teaching materials or multi-media presentation.
7. Revise existing UAF construction course(s) to incorporate sustainability practices for rural Alaska, and/or develop a new course that emphasizes horizontal construction.

To date, the investigation has proceeded through task 3. This paper serves as the preliminary report called out in Task 3. The following section summarizes the literature search that identified various construction-caused environmental impacts and potential ways to deal with such impacts.

REVIEW OF SUSTAINABLE CONSTRUCTION IMPACTS AND PRACTICES

As noted above, much of the emphasis on sustainable "construction" to date has been on the design phase of the construction project life cycle, with significant developments in material design and specification and the development of systems to make completed projects more environmentally efficient. Also, such developments have tended to apply more to vertical, rather than horizontal, construction. However, a review of the literature reveals that there is a substantial body of information related directly to the field construction process itself. Furthermore, it is clear that many of the environmentally sustainable methods used by contractors in building construction can apply equally to the construction of roadways, airfields, and other horizontal facilities.

The United States government, through its Environmental Protection Agency, enforces federal mandates that must be followed by all industries, including construction, in complying with a large number of environmental laws and regulations. A manual, *Managing Your Environmental Responsibilities: A Planning Guide for Construction and Development* (U.S. Environmental Protection Agency 2005) is available. A guide that interprets this manual has been published for contractors (U.S. Environmental Protection Agency n.d.).

To assist its members and other contractors in interpreting and meeting federal and other environmental requirements, the Associated General Contractors of America provides guidance on developing company- or project-specific environmental management systems (Associated General Contractors 2004a and 2004b).

Two books about sustainable, or green, construction (Glavinich 2008; Kibert 2008) provide helpful guidance throughout the project development life cycle; each contains sections specific to field construction operations. Likewise, the Institute for Sustainable Infrastructure (2014) provides a system for evaluating various aspects of a project's development, including field construction, through its Envision™ system.

The U.S. Green Building Council (2014) sponsors the well-known LEED (Leadership in Energy and Environmental Design) rating system. The system is confined to buildings and is mostly about design, but some of the concepts apply to building construction operations. In an attempt to apply LEED's building-oriented concepts to road building, a system called Greenroads™ (Muench et al 2011) was developed. This rating system covers both design and construction of roadways; construction activities include site recycling planning, fossil fuel reduction, equipment emissions reduction, paving emissions reduction, and water tracking.

The most relevant and complete document related to our study appears to be the *Field Guide for Sustainable Construction* (Pulaski (2004). Ten chapters, each covering such topics as site/environment, waste prevention, recycling and energy, include sections organized roughly by construction specification (sitework, foundations, substructure, and the like). Each has specific suggestions for environmentally effective contractor actions, plus case studies and references. In addition, a paper by Pearce et al (2010) reports a benchmark study of best sustainability practices in construction; the study utilized interviews and observations to "better understand what types of sustainability-related innovations are most easily and effectively adopted over time by project teams on capital projects."

With regard to specific construction-related environmental impacts and means for dealing with them, the matter of construction waste and demolition debris is of major concern in many places in the world (Couto et al 2007, Liao et al 2011, State of Washington Department of Ecology 2014, Tamraz et al 2011, Zhang et al 2011). Air pollution, especially dust caused by equipment operation on roadways and the construction site, has been dealt with by several authors (Anderson 2014, Barnes et al 2014, James 2014, Skorseth et al 2000, Withycombe et al 2006); this problem is of special concern in rural Alaska.

Water pollution of many kinds is a major concern on most construction sites. In the United States, there are stringent requirements for storm water pollution prevention, and contractors have become very familiar with contractual requirements for a SWPPP (Storm Water Pollution Prevention Plan) and have learned to comply or face substantial penalties (U.S. Environmental Protection Agency 2005). A presentation Nowack (2014) contains helpful guidelines for the prevention of many types of water and other pollution.

Among other construction site environmental issues in the literature, there is concern about energy efficiency on construction sites, including the generation and delivery of electric power and the efficient use of power for tools, lighting, and signage (Sharrard et al 2007).

A TAXONOMY

We next draw from the literature cited above, other literature sources, our own personal experience (a combined 90 years in construction and over 80 years in Alaska for the two authors) and that of our colleagues to compile as large an array of potential negative environmental effects as we could find. As a starting point, we include any and all, without regard to the type of construction or whether it is remote or more urban, cold climate or more temperate. Ultimately, as suggested earlier in the paper, we intend to focus on impacts that can occur in remote cold regions and methods for dealing with those impacts. So as to lower the chance of neglecting some of those, our research method is to start with as many as possible and refine as the study proceeds.

One of the project's biggest challenges so far has been how to organize those findings into a reasonable and useful outline or taxonomy. Many writers (Huang 2011, for example) start by listing the various kinds of environmental impacts – water pollution, solid waste production and disposal, and the like – as major categories and then discuss the operations that produce such impacts and then some potential means for dealing with those impacts. We decided, instead, to begin the outline from the contractor's viewpoint by listing, as major categories, the construction operations or activities that can potentially produce environmental impacts, then identify those impacts and, finally, suggest possible methods for avoiding, reducing and/or mitigating those effects. Thus, in Figure 1, we show a generalized construction project activity taxonomy, broken down into the major categories of project support, the project itself, and operations and maintenance.

Within each Major Category, we list type of work activity (Worker Housing, Life Support, Office & Shops; Support Equipment Operation; and the like), and then we identify those potential negative environmental impacts associated with that work activity and attach possible measures the contractor can use to avoid, reduce and/or mitigate those impacts. Two examples are shown. In Figure 2, we show a diagram for the Support Equipment Operation work activity, while in Figure 3, we show a similar breakdown for the Site Development work activity. Note that, for Support Equipment Operations, the potential negative impacts include air and noise pollution, excessive vibration, improper fuel storage, handling and use, and pollution that can result from cleaning and storage of vehicles and equipment. For each, we show some measures that might be used to combat such impacts. For example, to respond to air pollution, the contractor might provide respiratory protection for workers, minimize equipment run time, use alternative fuel vehicles, and conduct regular inspection and maintenance activities, among others.

For Site Development, Figure 3 includes degradation of permafrost (permanently frozen ground), improper and excessive clearing, insufficient project site layout, improper handling and storage of removed soil, survey damage, improper storage tank location and operation, improper storm water management, historical and archeological sites issues, and endangered and subsistence species issues as potential negative impacts. To combat the effects of improper and excessive clearing, for example, the contractor might grind and chip trees to provide mulch, resell trees and other plants, avoid damage to existing improvements, and limit the cleared area to an absolute minimum.

At this point in the process, we have not considered whether an impact might have to be dealt with in a remote cold area, nor have we considered whether a method of contending with the impact might be practical for such a region. We deal in a preliminary way with that aspect of the study in the next section.

PRACTICAL APPROACHES FOR REMOTE COLD REGIONS

From among the myriad of possible methods for dealing with the negative environmental impacts of field construction operations, we are currently (January 2015) in the process of identifying practical methods that could potentially avoid, reduce and/or mitigate such impacts on projects in remote cold regions such as rural Alaska. As an example, we show in Figure 4 some highlighted measures that appear to be practical for environmental impacts resulting from the Support Equipment Operation work activity. Note that these measures include, among others, providing respiratory protection for workers and minimizing equipment run time and idling to combat air pollution, designating a fueling area with primary and secondary containment and providing drip pans, absorbents and automatic shutoff nozzles to mitigate damage due to improper fuel storage and handling, and reducing pollution caused by vehicle and equipment washing and storage by using a designated concrete truck washout area and having drip absorbent materials available in equipment and vehicle parking areas. Note that a measure such as using alternative fuel vehicles is thought not to be practical because such fuels are typically not available in remote cold regions.

The completion of this identification of practical approaches, and the advice of construction experts in assisting the refinement of that list, will be essential steps in the successful conclusion of this project.

FUTURE PROJECT TASKS

Since this is a status report for a project whose completion is scheduled for several months in the future, it is appropriate to describe briefly the project's remaining work effort. We list those tasks below, in roughly the order we anticipate completing them.

We will fully develop a large spreadsheet (not shown in this paper) that categorizes potential environmental impacts and associated possible mitigation measures for all of the work activities shown in Figure 1. This information will be converted into diagrams similar to those in Figures 2 and 3 for each work activity, for ease of use in the tasks that follow.

On each if these detailed diagram, we will indicate our judgment as to which mitigation measures might be practical for remote cold regions, similar to Figure 4.

We will then meet with construction experts – contractors, designers, owners, facility maintenance personnel – with knowledge of and experience in construction and facility maintenance operations in remote cold regions. At these meetings, we will explain the purpose of our project and ask for their advice on the categories in our taxonomy, which items should be deleted or modified, and what might be added. We will then have them help us to refine and add to those mitigation measures they consider necessary and practical for remote cold regions. Lastly, we will ask for suggestions about how our eventual findings might best be transferred to those operating in such regions.

After digesting and organizing the results of our meetings with construction experts, we will publish a set of guidelines. The intent is to make such a publication practical and easy to use. It is expected that the guidelines will be published for distribution in hard copy and also made available electronically via the Internet.

We will conduct a meeting or series of meetings with contractors, owners and others to report our findings, distribute the guidelines and explain each of the recommended mitigation measures.

Finally, we will develop an outline of a suggested syllabus for a module on sustainable construction practices, based on our findings, which could be made a part of a standard university course on construction engineering and management. Such a module might occupy, say, a two or three hour lecture/discussion.

CONCLUSION

The body of literature regarding green construction is vast indeed. Two tasks in distilling information useful for sustainable construction in cold and remote regions are, first, to screen out the information that pertains mainly to buildings in warmer climates, and, second, to order the information such that it can be analyzed and presented to practical construction engineers and managers. The first and second tasks may be done simultaneously by developing an orderly hierarchal taxonomy, which we have developed and presented here.

ACKNOWLEDGMENTS

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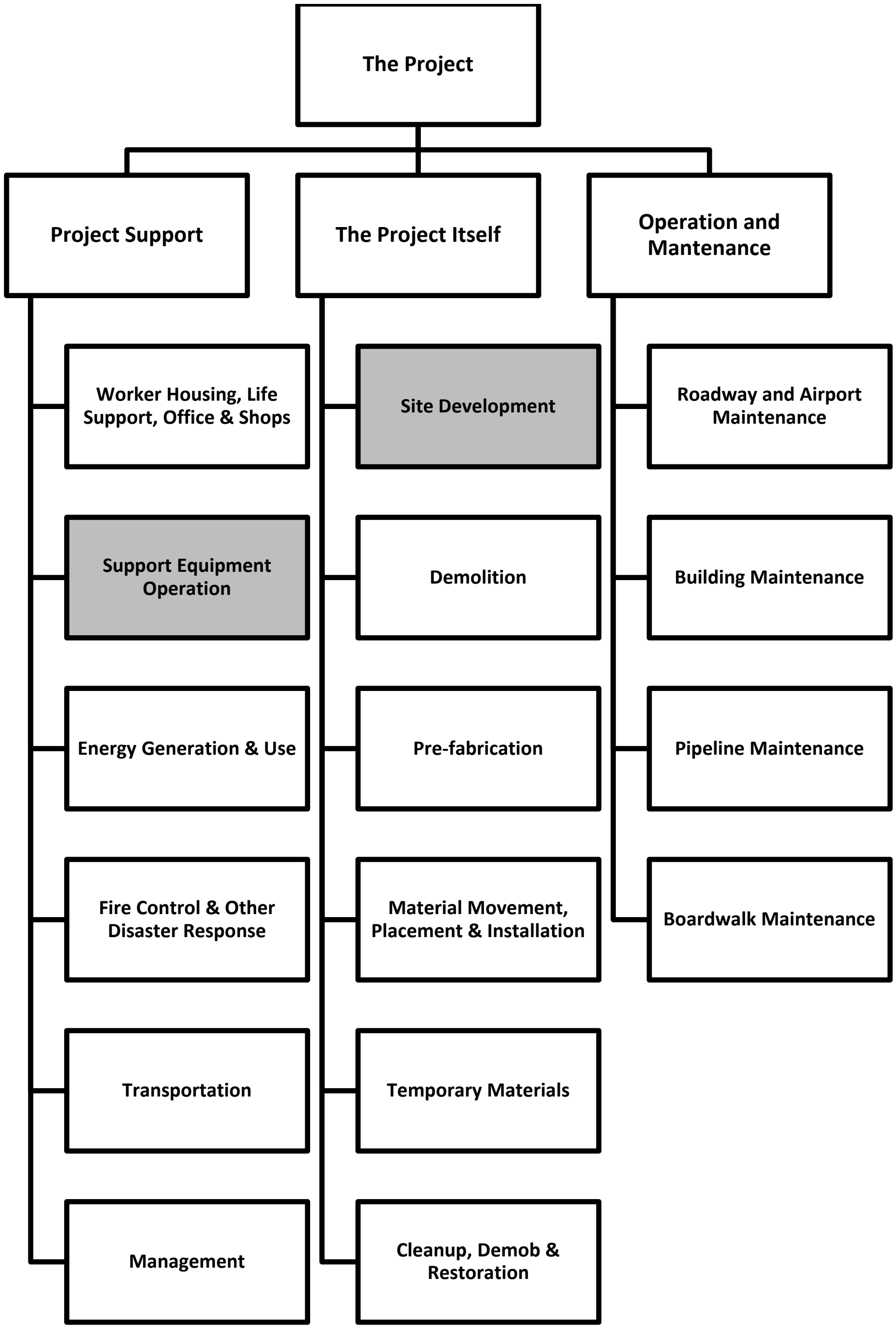

FIG 1. A Construction Project Taxonomy (Highlighted work activities are shown in detail in Figures 2 & 3.)

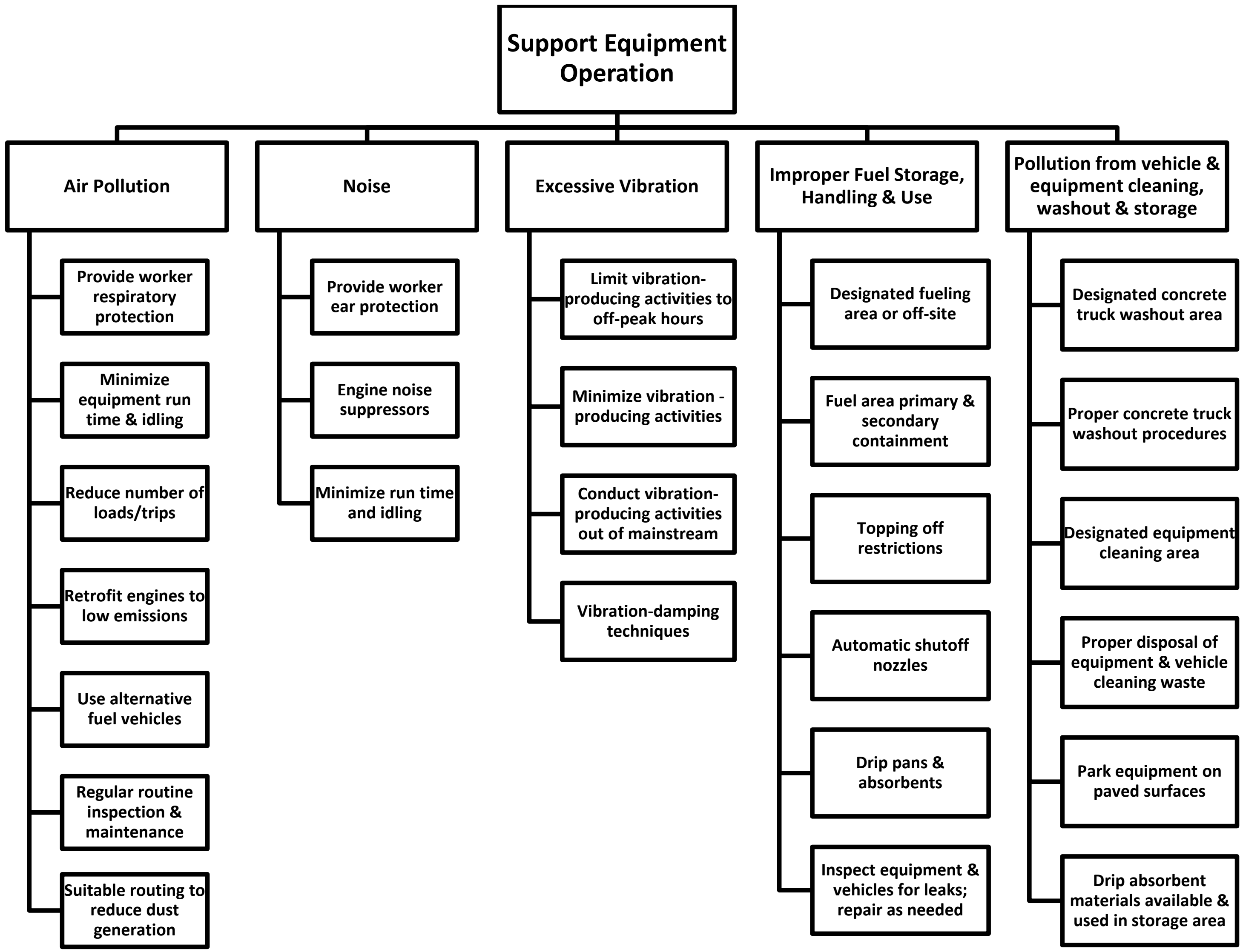

FIG 2. Taxonomy of Support Equipment Operation Impacts and Mitigation Methods

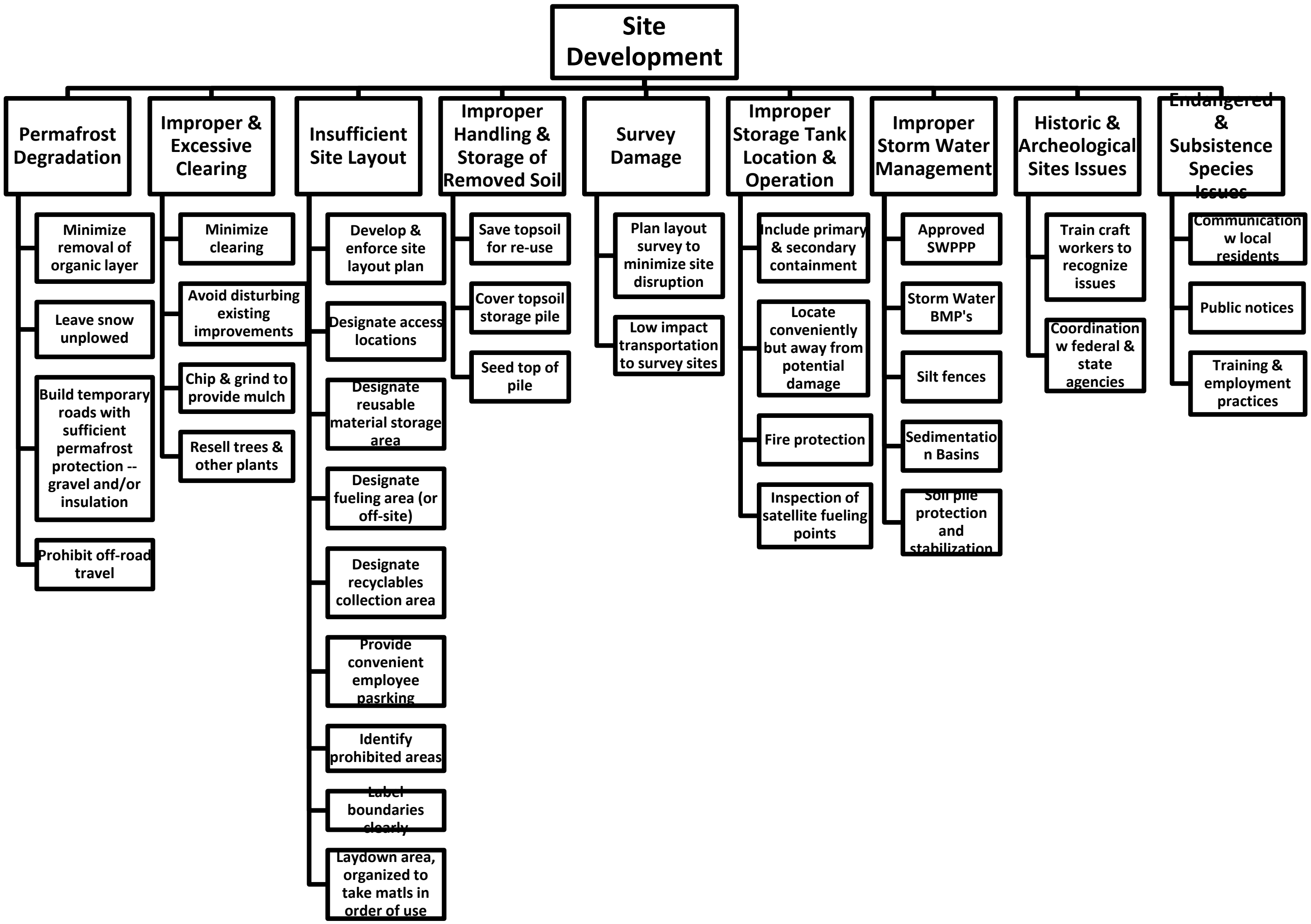

FIG 3. Taxonomy of Site Development Impacts and Mitigation Methods

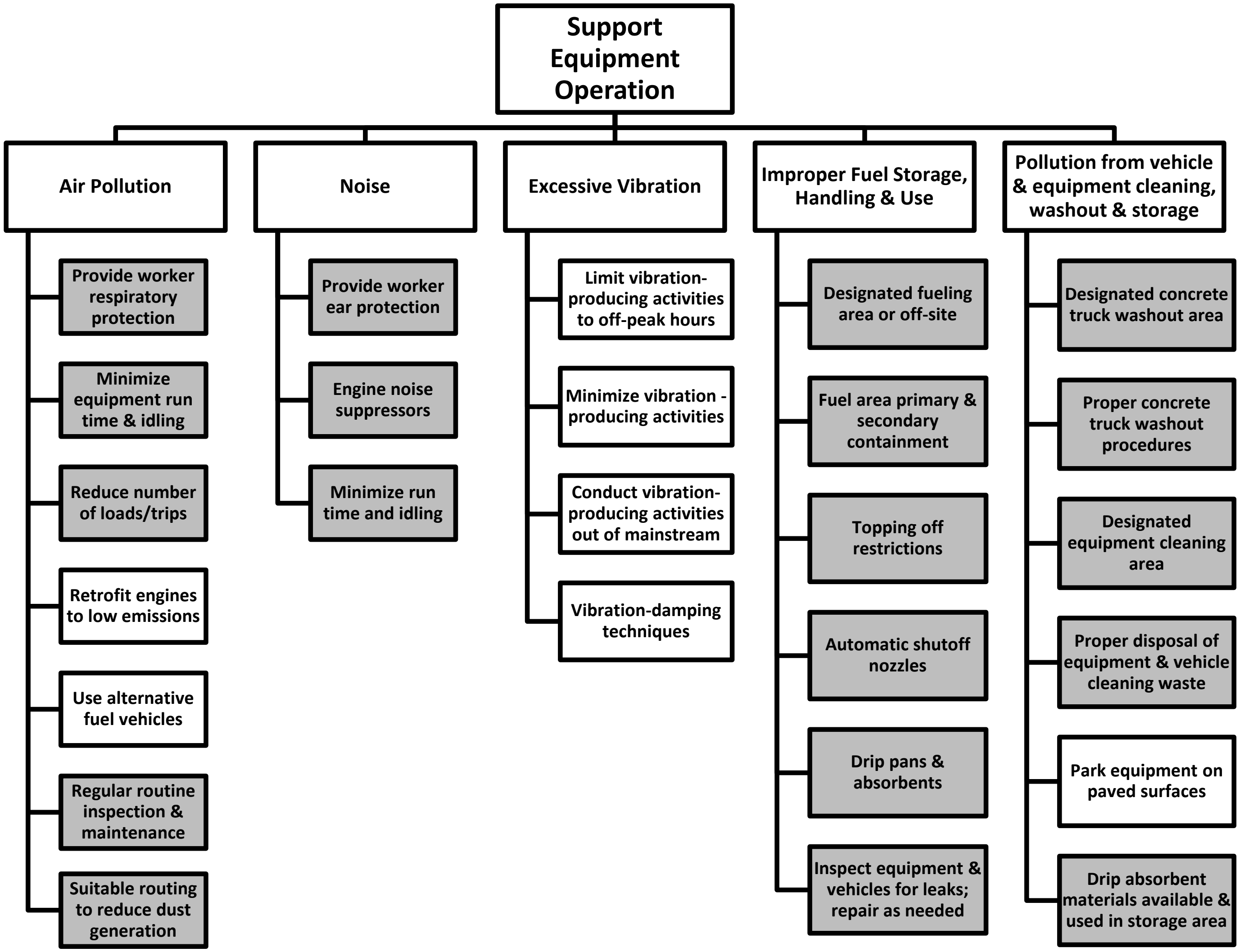

FIG 4. Taxonomy of Support Equipment Operation Impacts and Mitigation Methods, Highlighting Potential Remote Cold Regions Mitigation Measure