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Welcome to this Module – an overview of cold regions utilities. This module will provide a general introduction to cold regions utilities design and construction, along with some issues associated with project planning and development. More technical details are available in a new UAA course, CE A684 Arctic Utilities Design, offered each spring semester as a Distance Ed course.
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This module serves as an introduction. You can read through the slides at your own pace. The emphasis is on rural Alaska, but the same principles and procedures apply to resource development facilities or other locations which fall under the definition of cold regions.
Each of the cold region countries have unique approaches to design and constructing utilities, but our focus will be on Alaska. Although the majority of slides and pictures will be from rural Alaska, much can be applied to other non-rural communities, or construction camps. This module is somewhat general, but serves to set the stage for many types of utility projects. Details of utility design can be found in the American Society of Civil Engineers monograph, “Cold Regions Utility Design”.

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- Introduce basic principles of cold regions engineering on water and wastewater infrastructure
- Influence of cold climate on utility design
- Primary study - Alaska
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These are some of the fundamental objectives in the design and construction of cold regions utilities. They’re similar to the more temperate locations. The third item above is particularly significant in rural Alaska, where the lack of infrastructure continues to have a direct impact on individual and public health.
The development of water and wastewater systems in the state, particularly in small rural communities, has developed at different rates, and using different technologies. This module will give some background in the types of cold regions utilities which have found successful application.
The majority of Alaska’s 600,000 people live in the larger population centers, like Anchorage, Juneau, Fairbanks, and the surrounding subdivisions. There are about 300 communities, with about 100,000 people that live in isolated locations scattered across the state. This graphic summarizes the condition of the approximately 300 communities in the state. It shows the populations size, represented by the diameter of the circle, and the percent without fully running water and sewer in the houses. For the most part, the larger communities have had piped utilities for many years. With the exception of the farther north communities, conventional utility design has been used.
Federal and state programs have been building utilities in Alaska since 1960, with over $1.5 billion expended to date. An estimated additional $1.0 billion is needed to complete service. The communities vary in size from several dozen to 600 to 1000 people, with an average of about 500 people. They developed differently over time – some of them historic, some of them recent. They exist in a variety of geographic conditions. Some are very linear, located along coastal or river systems, others are “clustered.” Many developed without consideration for water and sewer service.
The main objective of providing water and removal of wastewater is health, with a number of secondary considerations, like convenience, comfort, economic growth and development. There is a minimum quantity of water that is needed for the full health benefit of treated water to be realized. In addition, removal of human waste from contact and from the living environment is also very critical. The graph on the left is from the Cold Regions Utilities Monograph, and is representative of similar studies by the Public Health Service, World Health Organization (WHO), and Pan American Health Organization (PAHO).
The design engineer's role typically is focused on the first 4 items. The other 4 related to social-political factors, which make individual and community involvement in project planning very important if a project is to be successful.
Both ground water and surface resources have been developed in cold regions. On a number basis, 80% of the water systems in Alaska use groundwater sources, whereas on a population basis the majority of people use surface water. Lakes, ponds and rivers may be the only source of water in areas of deep permafrost, and may be preferred due to poor groundwater quality. Numerous shallow ponds and lakes cover vast areas. Water quality may vary from pond to pond in the same region. Some of the factors to consider for intake structures include protection from ice damage, flooding, and bank stability. Because of the high cost of permanent structures, many intakes are temporary (see photo left). Larger demands usually require a permanent structure (photo right).
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In areas where only seasonal frost occurs, the pipeline is buried below the frost line. In frozen ground, depths of 3-4 feet are common. The pipeline on the right has a glycol heat line to add heat to prevent the line from freezing.
Over the years, different alternatives and levels of service have developed. This originally was planned as a phased approach, in which increments of improvement were built as funds from the federal and state government became available, as the community government progressed, and as the individual's ability to pay for service improved. The social philosophy in the US included the model that federal/state funds would provide capital construction funding, while the local governments would be responsible for operation, maintenance and continuing payments for upgrades and improvements.
At the lowest level of service, treated drinking water is provided at a central location such as a watering point, where individuals could come to haul water for consumption. A place was provided where wastewater (honey buckets) could be disposed of. Water use was minimal (5 gallons per capita per day or less), as the effort and energy required to haul water is high. Water reuse in the home, cross contamination, and contamination from open containers, many times spread disease. It did provide an improvement over hauling water from the slew or untreated source.
In those locations where the soil and site conditions limit conventional collection systems, honeybuckets are prevalent. A 5-gallon bucket, with a plastic bag, and a toilet seat. Pinesol or lysol is added periodically to reduce odors.
An initial approach to community disposal was to provide wood bunkers where people could dispose of their buckets. Of course, they filled up over time, and had to be relocated. High water table, and poor soils lead to both pollution and public health concerns, not to mention aesthetic considerations.
An alternative that was developed in the early 1980’s was the honeybucket bins – plastic, covered containers located throughout the community. Waste was dumped into the HDPE bins. A ATV or snow machine would back up, and lift the bins. Contact with the waste was minimized.
The next service level developed was central washeterias. These industrial type buildings housed laundry facilities, toilets, showers, and saunas that were available for public use. During the summer months, a distributed watering point (as shown in the lower left hand photo), provided treated water closer to the home. Water use was greater (10-20 gallons per capita per day), and was an incremental improvement.
In the late 1960s, trucked vehicle haul of water was practiced in some locations. The high cost of delivery, equipment upkeep, and the need to maintain roads, caused many to go into disuse. During the late 1980s and early 1990s, renewed emphasis on eliminating contact with water and wastewater lead to small vehicle haul systems, several examples are shown above. Water use was still meager, due to the cost of service. Building of gravel roads and boardwalks was considered part of the project.
Larger vehicle haul continues to be used at larger communities, or where roads are available and maintained. The picture on the right shows an in-house holding tank at Galena, with small on-demand pressure pump below the tank. The household had hot and cold running water under pressure in the house. This method of service is common in the Canadian north.
The highest service level is piped utilities. Where larger quantities of water are required, pipes are the most economical method of delivery, but also the most costly to construct, operate, and maintain. Large volumes of water also require methods of wastewater collection, treatment and disposal. The next few slides will cover piped utilities materials, methods of water delivery, and associated appurtenances.
The most common material used for both water and wastewater is the arctic pipe. It has been in use for many years, using many different materials. It is a three part, manufactured material. The inner pipe is used for fluid transport. Up until the mid 1980’s, copper, ductile or PVC or other material was used as the inner pipe. After a series of tests done at UAA by the Public Health Service, both water and sewer were switched to high density polyethylene (HDPE), due to it’s ability to withstand repeated freeze/thaw cycles without damage. Urethane foam is used for insulation, and the outer layer of either corrugated metal pipe (galvanized steel or aluminum), spray on coating, or HDPE used. The purpose of the outer coating is to protect the pipe, add structural strength, prevent moisture migration into the foam, and maintain straight pipe runs. It is manufactured to specification, for various materials, material properties, dimensions, configurations. It’s usually manufactured in 20-ft lengths, but 40-feet lengths are available. Connection of joints is critical to maintain pipeline integrity, as well as prevent moisture migration, and reduce heat loss.
There are 4-5 different suppliers, some in Alaska, Canada, and the lower 48. It can be bundled for shipment to the project site by air or barge. Because it is custom built, lead times are required.
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Utilidors can be designed for different configurations, with boardstock insulation installed. They’re designed for above ground installation, as it is difficult to make water tight. Water and sewer along with heat and heat trace lines can be installed.
The utilidors can be “nested,” and shipped to the project site, where they can be field assembled.
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In some projects, many different types of materials and carriers are used, depending on the needs and purposes of the particular location. This slide shows a vacuum sewer system, along with circulating water lines in arctic pipe and aluminum utilidors in Savoonga on St. Lawrence Island.
Many different modifications have been used, such as the integral glycol heat trace line shown in the upper photo. Arctic pipe can also be used as a carrier pipe (sometimes called a utiliduct).
Where soil conditions permit, buried utilities are preferred. Use of geo-textile materials, and board stock above the pipe to minimize depth of freeze, and below the pipe to reduce thawing of frozen ground are common. In many cases, due to the high moisture content of the soil, winter construction may be required.
In some locations, massive ice, thaw unstable soils, and logistics of construction, do not allow buried utilities.
Drilled or driven piles for above ground installations have been used for many years.
Piles can be expensive to install, and may require winter construction to get the equipment on to the frozen ground. For water lines, grade is not as critical as sewer mains. Mud sills are a low cost alternative. One of the issues of pipes on the ground include the periodic movement due to freeze/thaw cycles. Spring breakup flooding require duckbill anchors to maintain alignment.
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Unless properly designed, piles may settle or jack (as shown in the photo in the upper right). Helical piers or anchors have been used in the last 5 years to provide a stable ground support. UAA has an on-going research program into the use of helical piles in permafrost. The UAA class in Frozen Ground Engineering provides a module on helical pile design.
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One of the major planning issues related to the fact that above ground utilities can create problems with human and vehicle movement. It can separate a community, create barriers, and reduce the aesthetic quality. During winter, snow accumulation and barriers to snow machine transport occur.
Arctic Water System Types

- Single main recirculating (pitorifice)
- Dual pipe (high/low pressure)
- Extended Main
- Deep bury - bleed back, heat tape, glycol
- Other
  - slow main w/ individual circ
  - utilidor w/ heat, sewer, cable TV
  - pipe w/in pipe (TuPipe)
  - summer only use

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Five different types of water systems have been developed over the years, each with particular advantages and disadvantages. All require the net addition of energy to prevent freezing.
The most common type of system in Alaska is the single main recirculating system or pitorifice system. It consists of a loop of arctic pipe or utilidor in which heated water is circulated in a loop. Heated water in the service line is induced by a “pitorifice” (see subsequent slides).
Pitorifices were developed in the 1950's after research at Washington State University by the PHS Arctic Health Research lab. Piped and circulating water systems installed in Fairbanks in the late 1950's, and in the communities of Unalakleet, Holy Cross, Grayling, and many more locations. There are over 50 such systems now in use. Both an upstream and downstream pitorifice are used. The constant flow of water induces flow into the service line.
Both single main direct bury arctic pipe, and above ground utilidors are used for circulating system. This slide shows a main-line service connection box for service to a house. Minimum flow velocities in the main line of about 2 feet per second (0.60 meters per second) are required, and line lengths are limited to 100 feet, before circulation pumps are required. The right photo shows a small in-house circulation pump for a longer house service line.
The selection of system type, design and analysis is a combination of hydraulic, thermal, and economic considerations, as well as other non-engineering issues.
Some fairly sophisticated piping and controls are required for water distribution, beyond the treatment, pumping and pressure systems common on water systems. This photo shows one loop of a multiple loop circulating water system. Notice the meters, alarms, and methods of heat addition.
There are a number of unique features in water distribution systems as shown above.
Water service lines usually require a supply and return line. Heat tape is typically provided at the connection to the house for freeze prevention, and a longer heat tape for line thawing.
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The connection to the house is critical. Access for turning service off, while maintain circulation is required, as is the transition from a fixed, buried utility, to a structure that may periodically move under freeze/thaw soils conditions.
Fire protection and suppression is another critical issue in cold climates. Low humidity dries out building products, and the continuous use of heat such as wood burning stoves, oil burning heaters, etc. increase the risk of fire. Providing high volumes of water through an arctic distribution system is difficult due to the system configuration, the method of operation, and the limited sizes of pipes to keep operation expenses low.
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It is probable that all utilities may eventually freeze. System redundancy, increased reliability, multiple pumps and components, and freeze “friendly” materials are all important, as is means of thawing. The above shows thaw ports for ready access under winter conditions.
Wastewater disposal relies on natural processes for completion of the treatment process. Wetland treatment as been used for many years in the form of tundra ponds and seasonal disposal to the tundra.
Which is the best option? That all depends on which of the above selection criteria proves most important. Many times, the treatment method and selection criteria are presented in a matrix, with points assigned to permit order ranking.
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Not surprising that the majority of treatment types in the state are lagoons and tundra ponds. A separate module part on lagoons will cover design and construction. The text has an excellent discussion of them.
There are many ways to characterize lagoons. The typical way is based on operation, that is facultative, aerobic or anaerobic. Another way is by method of construction – naturally occurring tundra ponds or constructed. Lagoons have been constructed on the tundra using winter construction techniques and geo-textile materials by placing frozen, high moisture content silts on geo-fabric, wrapping the fabric into “tubes” or “burritos”, and continuing the process until sufficient berm height is obtained – usually 12-14 feet. Settlement of 40-50% sometimes occurs. The photo above is at Kotlik.
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Naturally occurring tundra ponds have been used for wastewater treatment for many years. The above photo shows Bethel and another community. There are a number of factors that go into selected a pond for use as wastewater disposal, most of which were included in a field guidance directive from ADEC several years ago.
Septic tanks and drainfields (st/df) have been used in the north, given unfrozen soil conditions and in granular material. Community drainfields have been installed on St. Lawrence Island (Gambel), Yukon-Kuskowim Delta (Lower Kalskag), and up north in Ft. Yukon and at Kobuk. Many washeterias have also used st/df systems. A key factor is trying to minimizing heat loss by addition of insulation, deep bury, arctic pipe lines, and in some cases heat tapes. In areas without gravel (eg. Sand), gravelless systems have been used, as shown above.
More examples of insulation (Ft. Yukon had 6-8-inches), and the use of Infiltrators (gravelless seepage beds). Due to cold ground temperatures, a reduced operating life is expected (10-12 years is typical). Mid-winter failure can mean overflowing sewage until late into the following summer, or longer, depending on funding availability.
After treatment, a method of disposal is needed. Inland areas normally use land disposal to the tundra. Few studies have been done on cold region land disposal, as compared to the lower 48 which has had extensive evaluations. The photo on the left is to wetlands from a lagoon. The upper photo is a constructed wetlands at Shageluk. The lower right is a seasonal discharge from the Kiana lagoon. Discharge is normally in the late summer, which vegetative growth is most active. The overflow from Kiana was in excess of 500 gpm, with no noticeable impact on the tundra. This is an area which should receive more research and study.
Rivers and streams are not preferred for wastewater disposal due to concerns over subsistence and fisheries. Public perception is such that land disposal is preferred, even if pumping costs are significant. Ocean disposal following primary treatment has been an acceptable alternative. An evaluation of impacts to the receiving water through a dilution/dispersion study is normally required. The construction aspect of ocean outfall use is very important due to the rugged conditions during installation and during the life of the facility. This is a photo of the outfall installation in St. Paul.
Here are several construction photos. Notice the lower photo showing the weighted collars due to the large wave conditions. A separate module reviews ocean outfall hydrodynamics.
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Outfall construction requires many considerations, including coordination on shore and off. Photo on the left is from southeast Alaska (Angoon), and the one on the right is winter construction over the ocean ice in Elim. Chain saws were used to cut thru the ice, and a backhoe used. The pipeline was welded, and concrete anchors installed.
There have been many improvements and innovations over the years. Many have had a positive influence on cold climate utility development. In spite of these improvements, capital costs and operation and maintenance costs continue to rise. The textbook provides some information for comparative purposes.
There will continue to be issues associated with cold climate utility deliver, not the least of which is the need to understand that fully service will continue to require a high energy input. The public continues to demand greater regulatory control over water and wastewater in the lower 48, which has been applied in cold regions. This has added to the expense of construction, operation and maintenance.
In summary, the above points are worthy of note. The need for economic engineering design, and the very high capital investment, is one of the motivating factors in developing a course specific to Arctic Utilities design.
More details on design of cold regions utilities can be found in the ASCE Monograph of Cold Regions Utilities, published by ASCE, or in the UAA class on Arctic Utilities Design, offered during spring semester.