

b) Road Repair and Maintenance

In its Northern Region, the area with the most discontinuous permafrost, the Alaska Department of Transportation and Public Facilities (ADOTPF) maintains 1500 miles of paved roads and 2000 miles of gravel roads. The maintenance of these roads takes place through a system-wide review of road conditions in conjunction with the pavement management system that is used each summer to set repair and maintenance priorities for the following spring.

Statewide, a budget of \$300M exists for road design and construction projects. Approximately \$75M of this amount is for the Northern Region, where the risks due to discontinuous permafrost are most severe. The U.S. Government, through the Federal Highway Program, contributes \$20M for statewide maintenance. For maintenance projects, the Northern Region currently uses about \$2M from the state general fund and \$5M from the federal government for surface repair each year.

ADOTPF has a number of repair options. It can totally reconstruct a road, a so-called “4R” level, or perform remediation that may last for 7 years; or repair a road, a “3R” level of remediation, which may last for 3 to 5 years. The 4R repair corresponds, for example, to miles 1–7 on Chena Hot Springs Road east of Fairbanks; the 3R corresponds to 7–22 mile Chena Hot Springs Road. A 2” asphalt covering with leveling, costing about \$100,000 a mile, is another option.⁶

Annual cost of road repair is budgeted at \$15M in the Interior. Construction of the seven-mile stretch of Chena Hot Springs Road cost more than \$1M per mile, or about \$7M. The use of geomembranes and thermosyphons at low points in the road at risk for permafrost increased the total cost to \$12M. This new construction, which has been done with state-of-the-art methodology, is expected to last 10–15 years. Good roads are necessary for trucking, business, tourism and personal travel. Travel restrictions due to bad roads have been calculated to cost the trucking industry \$.5M per year.⁷

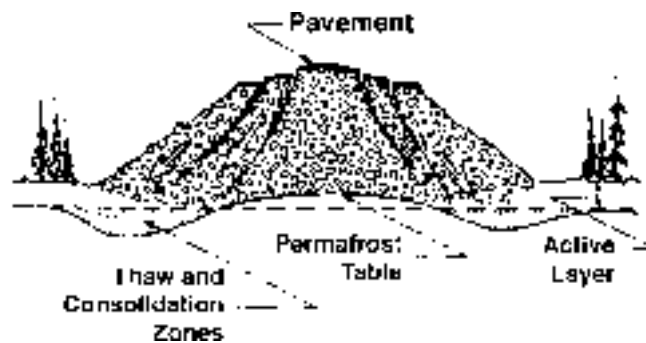


Figure 3. Cross-section of a surfaced road on top of permafrost ground. Note the fractures extending down from the road, which represent collapsing of the road foundation.⁸

Unfortunately, many of the engineering solutions for permafrost shown workable through University of Alaska research, such as snowsheds for road shoulders, thermosyphons, and the use of geotextiles or insulating hard fiber board, are employed in less than one percent of the road miles. Even if a good predictive scheme were established to indicate when and where a road would fail, it is possible that it wouldn't be used. The main determinant of the vigor of road repair is not information or research, but funding levels for the ADOTPF from the general budget of the State of Alaska. These funds go primarily to tested road building methods and far less to engineering research.

Engineering Construction Considerations

Effects of permafrost on housing foundations are no less dramatic than on roads and pipelines, as illustrated in Figure 4. Many houses that were built in earlier years in the Interior of Alaska, during a time when the nature and hazards of permafrost were not as well known, became dislocated and were either abandoned or totally rebuilt. Rebuilding meant drilling the foundation area to establish the extent of permafrost, and digging it out to remove it before building. If the permafrost was continuous or too deep to remove by digging, one could insulate the top of the ground with a thick gravel pad through which air could circulate and thereby keep the permafrost in its frozen state, and build the house on top of it. Alternatively, if the structure to be erected was a school or other large institutional building, devices such as thermosyphons could serve as supports for the building while maintaining the permafrost below ground in a permanently frozen state.



Figure 4. A permafrost-wracked house.⁹

The Trans Alaska Pipeline

The Trans Alaska Pipeline is the single most expensive and environmentally sensitive example of construction in a permafrost area, and it is very instructive to consider its history as an example of excellent planning and engineering under those conditions. The financial implications of not considering permafrost are substantial: the cost of a broken pipeline in thawed permafrost below ground would be a financial and environmental catastrophe. Since there may be other pipelines built in Alaska in the future, and since permafrost is also widespread in other countries with pipelines, such as China and Russia, it would be useful to consider briefly how permafrost came to be recognized as a threat during Trans Alaska Pipeline construction and why future atmospheric warming, due possibly to climate change, must be carefully planned for.

A vast oil field of several billion barrels was discovered on Alaska's North Slope at Prudhoe Bay in January of 1968.¹⁰ In October of the same year, a loose consortium of ARCO, Exxon and British Petroleum formed the Trans Alaska Pipeline System (TAPS) and sought a permit for a right-of-way for a route from Prudhoe Bay to Valdez and a permit to cross federal lands. In response, President Nixon formed the Federal North Slope Task Force, which tasked the U.S. Geological Survey to analyze the technical aspects of the route. The pipeline was to stretch 800 miles from the vast oilfields on the North Slope of Alaska at Prudhoe Bay to the ice-free deep waters of Valdez. This 48-inch-diameter pipeline would cross several major mountain ranges, innumerable rivers, geologic faults and about 400 miles of discontinuous and continuous permafrost-laden soil.



Figure 5. A section of the Trans Alaska Pipeline supported by vertical support members with thermosyphons in the ground. Note the fins on top of the support member whose function is to release heat transported up from the permafrost soil.

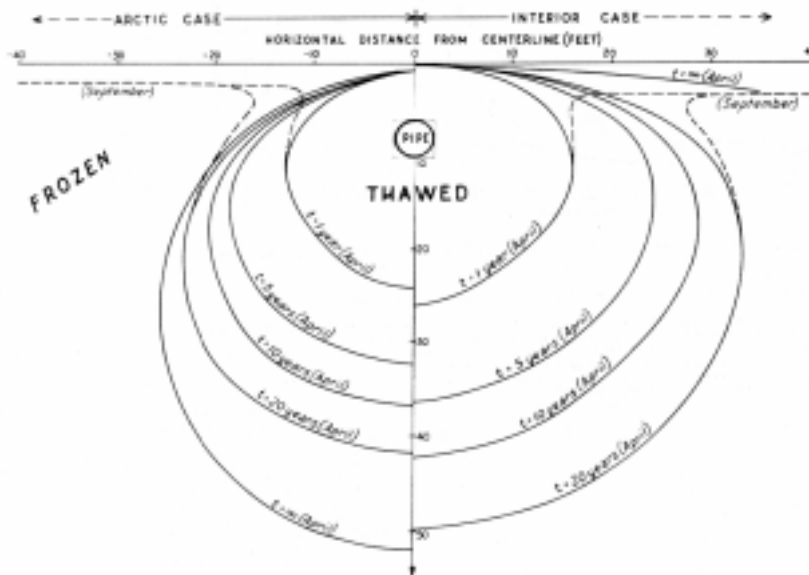


Figure 6. A cross-section of thawed permafrost showing thawing distances at 1, 5, 10, and 20 years due to a very large hot buried pipeline.

Initially TAPS planned to pump cold oil 800 miles through a buried pipeline. But engineering problems convinced TAPS to revise their plan and consider instead pumping oil hot at 158–176°F. As a result of this new scenario, a six-month technical review by the U.S.G.S. led to Geologic Survey Circular #632, *Some Estimates of Thermal Effects of a Heated Pipeline in Permafrost* by Dr. Art Lauchenbruch (1970).¹¹ This paper and the graphic results of the thermal computer-based models of “thaw bulbs of permafrost” (Figure 6) convinced the oil companies that some 400 miles of pipeline had to be raised above ground on supports, so-called thermosyphons, which could maintain the permafrost in a frozen state. Prior to 1970, there had been no quantitative and comprehensive calculations about the impact of a heated pipeline on permafrost.

Upon completion in 1977, the total cost of the pipeline was \$9B and the operating consortium had been reformed into the Alyeska Pipeline Service Company. A rough estimate puts the cost of elevating the 400 miles of pipe at around \$800M, a calculation based upon the costs for thermosyphons, setting them in place, engineering, geophysical studies and transportation costs.

Inquiry and comments in 1998 by knowledgeable design engineers say that the Alyeska pipeline has over 110,000 thermosyphons supporting about 400 miles of the line. These supports have design criteria to operate between certain temperatures in winter and summer, and are oversized by a considerable factor. These thermosyphons also stand in permafrost soils at specific temperatures and are subject to jacking and frost heaving as the permafrost thaws. Total costs for replacement of individual thermosyphons is \$10,000 for the unit itself and associated costs. Such costs may vary with location along the line, but replacement of 10 miles of support members could cost \$20M and 400 miles would be \$800M in 1998 dollars.¹²

These dollar amounts represent a huge expenditure in pipeline construction for permafrost conditions. Since this pipeline is already elevated in permafrost areas of Alaska, additional warming due to global climate change would have minimal effect. But present-day changes in the temperature of permafrost, possibly due to climate change, and normal aging of the refrigerant fluids in the thermosyphons will require ongoing maintenance and replacement of these systems with their associated costs.

The success of the Trans Alaska Pipeline has been demonstrated over the past 22 years of oil transportation, with only one shutdown, to the knowledge of this author, due to a permafrost burial problem. Hence, since July of 1977, when oil began to flow, the consequence of any climate change–induced permafrost thawing to pipeline operation has been negligible.

d) Ice Roads in the Interior and the North Slope

A final transportation topic to be considered is ice roads that permit winter travel. Much of Alaska is wetland and rivers and for that reason little summer overland travel is possible, with the rare exception of hovercraft. Ice-road and river travel is crucial to communication between Native villages and to subsistence activities. In fact, Alaska becomes a very open and widely traveled region in winter. Warming would reduce the extent of these activities and the value of the non-wage economies that they represent.

Also, warming on the North Slope may reduce the available winter months during which travel and transport of heavy equipment is possible over oil lease areas. The span of winter months during which geophysical prospecting and seismic surveys can be carried out on snow-covered tundra and leave a minimal footprint, may be shortened by climate change. If gradual warming does take place, winter roads made on lease areas may not be thick enough to support much traffic and geophysical seismic surveys would have to be performed by helicopter, hovercraft or other means, leading to greater expense. Oil lease surveys have a dollar cost associated with them but subsistence activities and Native travel cannot be tallied on a balance sheet. Nevertheless, for both of these categories a value for winter travel could be placed at between \$1M and \$3M.