# Appendix G

# North Slope Construction Methods

POINT THOMSON PROJECT EIS

# Appendix G – North Slope Construction Methods

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# Introduction

Alaska's North Slope has been explored by many oil and gas producers, each of which has unique requirements for personnel and environmental safety that typically govern the producer's construction methods. These corporate methods are usually intended to meet or exceed the local, state, or federal regulations that govern the standard industry construction model for exploration on the North Slope. This appendix describes in general terms the standard practices for ice, gravel, pipeline, and dock construction, and the types of equipment used to complete construction (see Chapter 6 for a list of typical North Slope construction equipment).

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# Chapter 1. Ice Construction

According to the American Petroleum Institute (API), temporary ice infrastructure allows "the construction of oil field pipelines during the winter months, thus largely eliminating the need for permanent gravel roads adjacent to pipelines. Ice-road building techniques are also used to create ice runways and ice pads to support exploratory drilling. Ice roads and pads melt in the spring and leave no significant damage to the tundra" (API 2009).

Prior to construction, the locations for ice pads and the routes of ice roads are surveyed and staked. These locations and routes are planned to avoid tussock areas, deep holes in streams, steep river banks, cultural resources, and the previous year's ice pad locations and road routes, and to minimize the distance between water sources and the final placement of the water. Permitted and unpermitted potential water sources are identified, and the water use permitting process begins midsummer. For currently unpermitted water sources, the permit applicant is required to document that the source recharges annually. Permitted water sources may be shared, with several North Slope operators holding permits for the same water source with a single total withdrawal limit. It is the operators' responsibility to divide the permitted withdrawal amounts between themselves, and each operator reports its own withdrawals for the source (HDR 2011bb).

Two typical ice infrastructure elements are ice roads and ice pads, which share similar construction methodology. Ice construction begins once the temperature and snow cover, or snow slab, on the tundra meet Alaska Department of Natural Resources (DNR) criteria for tundra travel:

> *DNR will implement tundra opening for general cross country travel in wet sedge tundra when a minimum 15 cm (6 inches) of snow cover is available and ground hardness reaches a minimum of 75 drops of the slide hammer to penetrate one foot of ground. At this combination of ground and snow conditions, no significant change in the depth of active layer, soil moisture, or vegetation composition and structure is anticipated.*
>
> *DNR has determined that once a minimum threshold of 23 cm (9 inches) of snow cover and a ground hardness of 25 drops of the slide hammer for one foot of soil penetration has been attained, general tundra opening in tussock tundra can proceed without a significant change in active layer depth, soil moisture, or vegetation community composition and structure.*
> (DNR 2004)

Figure 1: Rolligon all-terrain vehicle on the North Slope use low-pressure, adjustable tires to compact snow without damaging tundra (National Energy Technology Laboratories n.d.)

The tundra travel permit applicant can install temperature readers, or thermistors, along its proposed ice road routes to monitor the ground temperature, and can notify DNR once readings are consistently reporting -5°F. DNR will perform onsite penetrations of the tundra to verify the readings before granting a permit (HDR 2011bb).

Once DNR has permitted tundra travel for the area in question, approved all-terrain vehicles compact the snow along the route or pad area to provide a level base (see Figure 1 at right). There is no scraping or snow removal because the snow insulates the permafrost layer and limits the impact of traffic and development activities on the tundra itself. If the existing snow is not sufficient to provide a level base, then the base layer is supplemented by ice aggregate, or ice chipped from permitted water sources in 6-inch or smaller chips (ExxonMobil 2010a), transported via large dump trucks and mixed with water to set the ice. Once the base is complete, large dump trucks haul ice aggregate or snow from cleared areas. The chips are laid on the roadbed water is spread over the chip base; as each layer freezes solid, the next layer is applied until the road or pad is the desired thickness.

## 1.1 ICE ROADS

Ice roads are used primarily for seasonal access to remote sites such as during exploration, pipeline construction or annual resupply. These roads are built entirely of frozen water, either in snow or ice form, and can cross either tundra or sea ice. Historically, tundra travel permits are issued and ice road construction begins on or about December 15 of each year. Completion times vary depending on the kind of ice road; tundra ice roads require a fabricated ice base and are ready near February 15 (see Figure 2), while sea ice roads, built on existing sea ice, can be ready for use around February 1. The ice road season lasts between two and two-and-a-half months, and ends with the spring thaw on or near April 15.

There are two primary kinds of ice road: "standard" ice roads, and "rig-ready" ice roads. Standard, bidirectional ice roads are generally 50 feet wide (minimum 35 feet on tundra), with minimal slope from crest to base. The roads are designed to carry module loads of up to 300,000 pounds. Rig-ready ice roads are designed to support the weight and significant width of modules and drill rig components weighing up to 1,300 tons. The rig-ready ice road is generally 75 feet wide (ExxonMobil 2010a). Because the ice sheet underlying a rig-ready sea ice road may already be thick enough to support the modules or rig components, the rig-ready sea ice road may be ready for transport on or near February 15. A rig-ready tundra ice road, however, may require an additional 3 weeks before it reaches the standard 12-inch to 18-inch thickness (API 2009) required to support the heavier, wider loads.

Figure 2: A typical tundra ice road on the North Slope (National Energy Technology Laboratories n.d.)

The availability of water between the initiation point and the terminus of the ice road determines its route (Campbell 2009), as do the slope and other terrain features such as lakes, streams, and vegetation. If a sensitive area, such as a previously unidentified tussock area, is identified along a surveyed ice road route during construction, the route is adjusted to avoid that area (HDR 2011bb). A standard tundra ice road capable of use by large trucks can require one million gallons of fresh water per mile; a rig-ready ice road requires approximately 1.25 million gallons of fresh water per mile (ExxonMobil 2010a) to construct. Similar sea ice roads require 800 thousand gallons and 1.24 million gallons, respectively.

Sea ice roads require less fresh water than tundra ice roads because they use sea water for the majority of construction. Trucks with augers drill through the existing sea ice to the water level to flood the road area. The salt water is allowed to freeze, and an additional hole is drilled to flood the roadbed with another lift of ice. This process is repeated until the water is within 1 foot of the seafloor, at which depth the water becomes silty and unusable for the ice road. The saltwater ice is capped with 6 inches of ice from freshwater over the completed road; this cap of freshwater enables any melt during the day to refreeze at night faster than it might if the roadbed were all saltwater (HDR 2011a). Sea water cannot be used to construct tundra ice roads because of the increase in groundwater salinity once the sea water ice melts into the tundra (HDR 2010a).

Tundra ice roads crossing rivers or streams must be grounded, or cross the waterbody at a point where the river or stream is frozen from the surface to the riverbed. Sea ice roads must be grounded, or thickened to support the heaviest anticipated load (ExxonMobil 2010a).

Once the ice roads are thick enough to support their intended loads, a road-grader blade scars the road to create traction grooves (ExxonMobil 2010a); the roads are not sanded, salted, or graveled to increase traction. Because of the size of the loads transported on ice roads and their lack of artificial traction, road grades may not exceed 3 percent and should not include abrupt or “S” curves that pose a traffic hazard. Snow is removed as necessary from both tundra and sea ice roads over the course of the season to maintain traction, define the location of the road, and facilitate melting in the spring (ExxonMobil 2010a). The ice roads are inspected daily to maintain width, thickness, and surface, and any spills, chemical releases, or litter along the ice roads are removed before the ice melts (API 2009). At the end of the ice road season, crews trace the route to remove reflectors and any litter, and additional surveys for litter are performed during breakup (HDR 2011bb), when the ice roads are allowed to melt naturally.

## 1.2 ICE PADS

Standard ice pads are intended to last a single winter season, usually for exploration in remote areas (API 2009). They are constructed in the same manner as ice roads, with a base layer of compacted snow and ice laid in a surveyed, permitted area after tundra travel has been approved. The base layer is supplemented with 6-inch layers of water and ice chips until they reach the required thickness, at a minimum 18 inches thick (ExxonMobil 2010a). They are monitored for thickness and stability, routinely cleared of snow, and melt completely in the spring. It is possible, however, to extend the life of an ice pad beyond a single winter by using insulation.

### 1.2.1 Multiseason Ice Pads

Multiseason ice pads are designed for use over multiple winter and summer seasons, with the goal of avoiding permanent fill for temporary activities. These pads begin with snow compaction and a base layer of ice, similar to standard ice pads. Once the layers of ice are of a height required for the operation to be conducted on the pad, generally three to four feet at a minimum (Peak Oilfield Service Company 2010), a vapor barrier is placed over the ice to prevent melting from rain and evaporation. Four-inch-thick foam insulation mats are placed over the vapor barrier and covered by white tarp to reflect sunlight and heat. The pads are covered by rig mats made of wood, steel, or composite materials (Alutiiq Oilfield Solutions, LLC 2010) if they are intended for summer use.

Multiseason ice pads must be rehabilitated each year by removing mats and insulation to fill and level any ice lost to melting over the summer, and the vapor barrier, insulation, and tarp are replaced. The insulation board currently used on the North Slope is a Styrofoam™ base, either with or without plywood backing, and after more than one season the foam can degrade, requiring crews to collect and dispose of crumbled foam pieces that can be spread by wind (Peak Oilfield Service Company 2010). Once a multi-season ice pad has served its purpose, the rig mats, tarp, insulation, and vapor barrier are removed, any spills or releases are cleaned, and the ice base is allowed to melt over the course of the summer.

## 1.3 ICE AIRSTRIP

Ice airstrips, used on the North Slope mainly to bring personnel or enable emergency access to a remote site, are constructed similarly to tundra ice roads and pads. Their dimensions are governed by the needs of the largest aircraft that may use the strip, and any additional requirements implemented by the Federal Aviation Administration (FAA), which regulates both public and private airstrips.

Airstrips must be level to accommodate aircraft landing, and thick enough to support the load of the fully-loaded aircraft. An ice airstrip should be located on level tundra, or built to a level grade by adjusting the thickness of the ice in unlevel areas. A sea ice airstrip does not have the same terrain considerations that a tundra ice airstrip has, but it must be grounded or, if it cannot be grounded, thickened to support the weight of the largest anticipated aircraft. According to the U.S. Air Force in *Engineering Technical Letter 07-12* regarding air ice strip design for McMurdo Sound in Antarctica, an airstrip of 40 inches thick would support a Lockheed C-130 at maximum weight, though producers on the North Slope have built ice air strips in thicknesses of up to 60 inches (HDR 2010b). Once the airstrip is constructed, it is equipped with runway navigation, lighting, a generator, and weather shack to house personnel and the Supplemental Aviation Weather Reporting Station (SAWRS)(ExxonMobil 2010a). This support equipment is installed each season.

# Chapter 2. Gravel Construction

Permanent infrastructure on the North Slope is usually made from gravel, which insulates the permafrost layer year round against the heat generated by vehicles, equipment, and facilities in the same way that ice insulates that layer in the winter. While gravel pits used during initial North Slope development were largely surface pits within shallow flood plains, the increasing scarcity of both gravel and water in various areas of the North Slope has resulted in an industry shift to deep gravel mines that can be filled and used for water storage or fish habitat once mining is complete (McClean 1993).

Geological surveys identify material sites, which are staked during the summer. Because mines are excavated on soft tundra, they are excavated during the winter to prevent damage to the equipment on the extremely soft ground and minimize damage to the surrounding area. When the ground has frozen, any snow is scraped and trimmers (see Figure 3 at right) remove the active layer of tundra, which ranges from 8 to 80 inches depending on drainage (Board on Environmental Studies and Toxicology 2003). Then organic matter is piled, loaded, and hauled to a storage area, usually located on an ice pad (ExxonMobil 2010a).

Figure 3: A Series II Profiler Roto Trimmers similar to those used to remove organic overburden (Joe Bland Construction, L.P. 2006)

After the inorganic overburden is exposed, air track drills create holes that are loaded with approximately 100 pounds of ammonium nitrate/fuel oil solution (AN/FO), a detonator, and primer. This explosive is connected to boosters and surface relays. Once approximately 325 of these holes have been drilled and filled, the area is detonated ("shot"), yielding approximately 65 cubic yards per hole (total 21,000 cubic yards per shot) in what is known as "blast and shoot" gravel mining. Dozers consolidate the overburden and dump trucks transport it to a storage ice pad (ExxonMobil 2010a).

The gravel is mined in the same "blast and shoot" method. Because the gravel is at its most stable when frozen, enough gravel is mined to support the year's construction needs, and stored on a pad of either gravel or ice, depending on the amount of gravel required.

The fill site, whether road, pad, or airstrip, is surveyed and staked. Snow is removed from the site, with a 4-inch snow barrier left atop the tundra. Gravel is transported in belly dump units to the site and spread with a fill dozer in 1-foot layers, or lifts. Each lift is compacted by multiple passes with a slow-moving vibratory compactor, and traffic is routed over the area to assist in compaction. Subsequent lifts are installed and compacted in the same way, until the road or pad achieves its design elevation (ExxonMobil 2010b).

In subarctic areas, the moisture content of the gravel typically ranges between 10 and 25 percent, and the gravel can be mined, compacted, and used for transport in the same season. The moisture content on the North Slope, however, ranges between 25 and 35 percent, and the gravel must be "seasoned" before it can be used. Natural seasoning, in which the gravel is spread over its intended final location on a pad or road and allowed to dry and settle, can take up to two seasons for a 5-foot depth. To speed the process, producers often farm the gravel, or lay it in its intended location and turn the upper layers once or twice in a single season to expose the buried areas and facilitate drying (HDR 2010b), and water is placed on the gravel for both compaction and dust suppression (HDR 2011b). Once the gravel is seasoned, the combination of large and fine particles is compacted and usable for transport or building.

Over the summer, the mine's newly-exposed area of gravel melts slightly, and the gravel mine begins to fill. If the mine is intended for future mining, it will be dewatered, or pumped empty, over a number of weeks in the fall before the water freezes. Because the water is untreated natural seepage, it can be pumped into a natural drainage under an Environmental Protection Agency (EPA) general permit. If mine use is finished, the mine can be allowed to fill with water and later used as a freshwater source for camp operations or ice road building (HDR 2010a).

## 2.1 ROADS

Because gravel roads are constructed during the winter, an ice road must first be installed to protect the permafrost and tundra from the equipment used for gravel installation (see Section 1.1). Once the ice road is in place, construction of the gravel road begins as described above. Similar to ice roads, gravel road depth and width are determined by the size of the largest vehicle intended to travel the road. On average, gravel roads used for transport of rig components are nominally 5 feet thick and 32 feet wide at the crown, with a 2:1 slope to the base, and support bidirectional traffic unless being used for module or rig component transport (HDR 2010b).

Gravel road routes are designed to avoid, to the greatest extent possible, large bodies of water, and use culverts and standard bridge building techniques when crossing streams. The design vehicle for the road determines the load capacity and width of the bridge. The North Slope hydrology, however, consists of defined streams and areas of undefined, or sheet, flow. To accommodate the natural sheet flow, gravel roads incorporate 24-inch-diameter (minimum) culverts approximately every 500 feet, and more frequently in particularly wet areas (HDR 2010b). While corrugated pipe is commonly used for culverts, on the North Slope such pipe can be damaged by ice during spring thawing, and North Slope culverts are generally constructed from the same kind of steel pipe used in pipelines (G.N. McDonald & Associates 1994).

### 2.1.1 Light-duty Roads

In some instances, an all-year road is only required for personnel and light consumables transport, and a light-duty gravel road can be installed, rather than a rig-ready gravel road. A light-duty gravel road, surveyed and staked, would require a 6-inch to 12-inch layer of gravel on the tundra to provide a level plane for the insulation. That gravel would not require farming, since farming is intended to promote compaction that the insulation negates. The road would then require two layers of insulation, offset to prevent buckling or gaps. The insulation itself is rigid, usually 1-inch thick, and available in several pounds-per-square-inch (psi) ranges, though 60 psi is usually viable. When using insulation, North Slope construction companies estimate 1 inch of insulation to provide the same insulation as 1 foot of gravel (HDR 2010b). Another 2 feet of gravel would be placed atop the insulation for a conservative total of approximately 3 feet of gravel.

Light-duty gravel roads have similar impacts on the hydrology of the area as rig-ready gravel roads, and likewise would require culverts to allow water passage. The insulation would be ramped over the culvert, and would require extra gravel for insulation and support. Placing a 24-inch culvert every 500 feet in a 36-inch-deep road creates undulations in the road, and traffic speed and vehicle use are adjusted accordingly.

## 2.2 PADS

Gravel pads are surveyed, staked, and filled in the same method as gravel roads. They do not require culverts, but do have embankments at the edge of the pad to minimize snow drifting, which is a constant problem on the North Slope (HDR 2010b).

The gravel pad insulates the permafrost because in the winter the gravel itself freezes, and the inner core of the pad remains frozen throughout the year. To prevent greater-than-necessary thawing over the summer, buildings on the pads are raised above the ground elevation on piles, or pipe in the tundra. The piles can be driven vertically with a vibratory hammer through the gravel pad into the tundra below, or drilled and then cemented or foam supported in place. These piles allow for a cushion of cool ambient air between the facility and the gravel (Board on Environmental Studies and Toxicology 2003).

## 2.3 AIRSTRIP

Like gravel roads and pads, gravel airstrips are surveyed, staked, and filled in 1-foot increments. They must be seasoned or farmed and designed to a width and thickness that will accommodate the largest aircraft intended for use on the airstrip, both in terms of the aircraft’s minimum operational requirements and the FAA’s minimum safety standards.

Airstrips must be flat and thick enough to support the fully-loaded aircraft, and should be located on reasonably-level tundra, or built to a reasonably-level grade by adjusting the thickness of the gravel in uneven areas. Once the airstrip is constructed, the construction crews drill holes for the piling that will support navigational aids, approach lights, and buildings such as a weather shack that houses the SAWRS and provides personnel shelter. After the holes are drilled, the piles will be placed, surveyed for alignment and elevation, and filled with sand cement, which is then allowed to freeze and set the piling.

Piling for the buildings and navigational aids will be set from the gravel area; the approach-light pilings, lights, and associated power cable are usually on the edge of the strip per FAA requirements, and are built from an ice road. In the spring, once the gravel has been conditioned and compacted, crews dig trenches for facility power cables and install runway and threshold lights.

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# Chapter 3. Docks

Historically, equipment and goods have been transported to the North Slope by seagoing barges. Standard practice includes use of light coastal barges or large sealift barges. Coastal barges are generally 200 feet long by 60 feet wide with a 20-foot profile (bottom hull to deck), and carry an average 300 tons per load. They can, using tug boats, enter shallow water and beach on the coast for offloading by ramp (HDR 2010a).

Sealift barges average 400 feet long by 100 feet wide by 25 feet deep, and have a 4-foot draft when empty. Standard calculations estimate an additional 1-inch draft per 100 tons of cargo, and when fully loaded with 12,600 tons of material the sealift barges have a 16-foot draft, though the shallower drafts of the North Slope docks can limit cargo capacity to 5,000 tons (Cassidy, John. H and R.D. Sorbo 1989). While these barges do not require a dock in the traditional sense of an extension of elevated platforms into the offshore area, they do require more infrastructure than coastal barges to facilitate offloading.

## 3.1 SEAFLOOR MODIFICATIONS

Because of the size of sealift barges and the shallow nature of the North Slope coastal waters, docking sealift barges can require some modification to the seafloor, such as dredging or screeding.

Dredging is the removal of material from the seafloor to create a deeper draft than naturally exists. Screeding is the process of shifting material on the seafloor to level it and allow even barge settling. Dredging and screeding are usually summer activities. A backhoe with a 25-foot to 30-foot reach is positioned on a deck barge that is secured by temporary vertical steel piles known as spuds (ExxonMobil 2009; Occupational Safety and Health Administration 2009). Dredged material is placed on a second barge and transported to the shore, where it is usually trucked to a disposal site or shore reinforcement area.

Figure 4: A deck barge can be used for equipment transport or can function as a floating work surface for subsea construction (Jerico Products, Incorporated 2010).

If dredging or screeding occurs during winter, the same process is followed but use of the deck barge is not needed.

## 3.2 ONSHORE BARGE ABUTMENT

An on-shore barge abutment is a shallow-angled ramp in the shoreline that, supplemented by a bulkhead, enables the barge to move very close to the shore and to offload its cargo on a relatively even plane.

As with other construction activities, coastal modifications are typically conducted during the winter to take advantage of the frozen state of the sea ice. After the abutment area has been surveyed and staked, backhoes remove block ice and ground material from the shoreline down to the level of the seabed that will provide access to the sealift barge. Then the bulkhead area is surveyed and staked. A template to control location is maneuvered into place with a crane and temporarily pinned with piles to prevent movement while sheet piles are driven. Because the soil in the abutment area is permafrost, it must be thawed before the sheet pile and anchor piles can be driven into the ground. A drill creates pilot holes into which a steam probe is inserted; powered by a boiler unit, the steam from the probe thaws the soil sufficiently so that the sheet pile, once lifted and placed in the template, can be driven into the ground. The sheet and anchor pile are driven to a depth determined by the specific abutment design using a vibratory hammer, and the template is removed.

The sheet and anchor pile are reinforced using gravel fill, which is laid in level lifts across the entire cell area. The gravel is compacted using a vibratory roller and the sheet pile cut and welded after compaction is complete.

Once the abutment is complete, a sealift barge, guided by a tug, can move into the abutment area and fill its ballast tanks until it settles to the seafloor, becoming a stable platform from which to offload modules and equipment.

## 3.3 DOLPHINS

Figure 5: A vibratory hammer sets a piling for a bridge in a process very similar to driving pipe for mooring dolphins (WSDOT 2008).

Sealift barges have the ability to form barge bridges, in which one barge moves into an abutment area, ballasts itself on the seafloor, and is followed by another barge. The second barge moves in until its front is secured against the back end of the first barge, and the second barge settles to the seafloor. These two barges unload their cargo, the second using the first as a ramp to the shore. A third barge can repeat the maneuver, using the first two barges as a bridge to the shore; this third barge, once offloaded, can move quickly to sea because it is in deeper water than the first two, and another barge can take the third barge's place in the bridge (HDR 2010a).

Dolphin piles on the North Slope are generally placed in shallow waters in the winter when sea ice is frozen through to the seafloor. The ice is removed with a backhoe and stockpiled on the sea ice while the vertical and angled piles are driven into the sea floor using an impact hammer. The piles are cut to grade, and a cap is welded to tie the piles together. This cap can, in some instances, feature a rubber fender and a bollard to secure the barge (ExxonMobil 2010b).

## 3.4 BOAT DOCKS AND LAUNCHES

While most North Slope marine traffic supports large materials transport, some activities (such as emergency response) require smaller vessels such as skiffs and inflatable rafts. These craft can sometimes be launched from the shoreline, but may require boat docks, which generally consist of a gangway, an approach trestle and a float system; or launches, which include a gravel ramp with concrete planks for a running surface. In some cases, a boat launch may include both dock and launch characteristics to maximize useability. The boat launch design is determined by the vessels that will launch from it, but the launch is usually built in the winter. The ice over the footprint is cut according to survey stakes, and gravel fill is placed and compacted using vibratory rollers. The piles for the trestle and float system are driven, and the trestle is installed. The concrete planks are placed, and a riprap or concrete revetment is placed on the side slopes of the ramp to provide slope protection (ExxonMobil 2009).

# Chapter 4. Hydrocarbon Pipelines

Hydrocarbon production lines are divided into two major categories: infield lines and export pipelines. Infield lines transport gas, produced water, seawater, and diesel fuel within a field and typically consist of gathering lines that connect the drill sites within a single field to that field's processing facility, and flowlines that transport processed hydrocarbons within the field. For example, a flowline may return injection gas from a compressor plant to a reinjection well. Export pipelines transport a field's processed hydrocarbons to a common carrier line, such as the Trans Alaska Pipeline, or point of sale. New, cross-tundra pipelines on the North Slope are installed during the winter to limit damage to the surrounding tundra.

Oil and gas industry standard practice worldwide is to bury pipelines, which minimizes visual impacts and provides a measure of security for the pipeline. The nature of the polar environment and permafrost layer, however, has posed significant challenges to buried pipelines. Hydrocarbons extracted from North Slope range in temperature from 145°F to 180°F, and are cooled to between 85°F and 120°F. The permafrost layer in which that line might be buried must maintain a temperature of 32°F or lower or it will destabilize and create pressure on the pipeline (Board on Environmental Studies and Toxicology 2003).

Because of the challenges associate with buried pipelines, oil producers on the North Slope have designed a network of elevated pipelines that keep the lines well above the tundra. Vertical pipes topped by horizontal I-beams, called vertical and horizontal support members (VSMs and HSMs, respectively) keep the line above the ground. Many North Slope operators n the North Slope design these elevated pipelines either with bridge-like caribou crossings or large (up to 7 feet) elevations to enable the free movement of wildlife around the pipeline. The pipe rests in saddles on the HSMs, and the pipe's freedom of movement, combined by periodic Z-shaped or offset routing in the pipeline, allow for temperature-induced expansion and contraction, and a measure of flexibility in the event of an earthquake.

## 4.1 CONSTRUCTION

As with other permanent infrastructure construction on the North Slope, pipeline construction typically begins with ice road construction. Because aboveground pipelines do not interrupt hydrology in the same way that roads can, pipeline routes are often more direct than roads, and do not necessarily parallel existing gravel roads. Pipeline construction is also phased, with multiple work crews constructing different sections of a pipeline simultaneously in different areas. These multiple simultaneous operations, or SIMOPs, create travel hazards, and often require a single road dedicated to pipeline construction, and another for standard traffic to and from a facility or work site (HDR 2010a).

Figure 6: A sideboom tractor lifts a welding shack during pipeline assembly (Bradner 2007).

Pipeline construction can begin while the ice road is still being built, provided there is sufficient room for the multiple crews to operate safely on the completed ice road portions. In the first phase of pipeline construction, surveyors mark the VSM positions, the spacing of which are determined by engineering and pipeline diameter but is typically 55 feet apart. Following the VSM marking, an air drill auger drills the

VSM to a depth determined by the soil profile at that point along the route. The holes are covered with plywood for personnel safety until the VSMs are placed.

The VSM setting crew follows the survey and drilling crews, and uses hydraulic cranes, side boom tractors, or hydraulic forklifts to place the VSMs along the road next to the holes. VSMs generally consist of line pipe approved for structural uses. The HSMs are bolted to the pile cap on the VSMs, and the assembly, or pipe rack, is set in the drilled holes and leveled. Angle iron jigs, welded to the VSM, stabilizes it in the hole until the hole is filled with sand slurry from mixer trucks and allowed to freeze. Once the sand slurry has set, the HSMs are equipped with saddle assemblies, which cradle the pipe, along the upper flange of the I-beam (ExxonMobil 2010b).

After the support members are in place along the pipeline route, the line pipe is laid out along the road, welded into long sections, and placed on wooden skids. While on the skids, the welds are tested using X-ray or other nondestructive examination (NDE) methods, and the pipe is coated and insulated per specification. The insulated sections are then lifted into the pipe saddles on the HSMs by a series of side boom tractors, cranes, and loaders. The elevated sections are then welded into a single continuous pipeline, and cleaning and gauging tools known as “pigs” are pushed through the pipeline with compressed air to remove any construction debris (ExxonMobil 2010b).

## 4.2 HYDROSTATIC TESTING

Before the pipeline can be used to transport hydrocarbons, the operator must verify that all welds and flanges are secure and that the pipeline is impermeable. To do this, the summer after pipeline construction, a series of hoses, tanks, and high-pressure pumps connect a water source to the pipeline. The pumps fill the pipeline with water to more than its intended operating pressure, and hold that pressure for at least 4 hours, if the lines are completely visible, and 8 hours if the lines are not completely visible (49 CFR 195.300). Any water leaking from the pipeline will identify a breach in the pipeline, which will be resolved and retested before the line can enter hydrocarbon service.

After a successful hydrostatic test, the pumps are replaced with a pig launcher and a pig pushes the water through the pipe’s terminus, where the water is filtered of any anticorrosive additives and injected into a disposal well or treated and discharged to the tundra according to a discharge permit. Air compressors and dehydration equipment dry the line, and it is filled with nitrogen or another inerting agent to prevent internal corrosion until the line begins active service (ExxonMobil 2010b).

# Chapter 5. Utilities

Water and wastewater lines, power lines, and telecommunications/fiber optic cables are the three primary utilities on the North Slope.

Water lines are used mainly to bring water from the freshwater source to camps and offices, and are generally small-diameter, insulated high-density polyethylene (HDPE) pipelines. An ice road is build along the water line route, and the insulated pipe is fusion-bond welded. The welding machine completes one 1,000-foot section, then another, and welds the two, moving along the line until the water line is one continuous pipe. The line is then lifted and anchored onto 1-foot timber supports called "sleepers" (ExxonMobil 2010b). Wastewater can be treated and released to the tundra, but is frequently treated and injected into a disposal well by pipelines similar to the waterlines described above.

Whenever possible, power lines and telecommunications/fiber optic cables are trenched in gravel roads, or suspended from HSMs in armored cables (for power lines) or cable trays (for other types of cable) along infield pipelines. In instances where cables are suspended from pipelines, the clearance from the bottom of the suspended cable to the ground is a minimum of 7 feet, to maintain wildlife clearance (HDR 2010b).

# Chapter 6. Equipment

The equipment list in Table 1 lists equipment commonly used for various construction activities on the North Slope.

Most equipment below can only be operated on some type of infrastructure, such as a gravel or ice road. Some vehicles, however, are fitted with low ground pressure tires that enable them to travel across uncompacted snow and in summer across the tundra with little to no impact to the vegetation. These vehicles are used for summer pipeline inspection, to compact snow for ice roads, and to deliver pioneer and exploration camps in advance of the ice road season.

Table 1: Standard North Slope Construction Equipment and Uses

| | Ice Construction | | | Gravel Construction | | | | Docks | | | | Pipelines | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Road | Pad | Airstrip | Mining | Road | Pad | Airstrip | Seafloor Modification | Onshore Barge Abutment | Dolphin | Boat Launch | Construction | Hydrotesting | Utilities |
| *Vehicles* | | | | | | | | | | | | | | |
| Fuel truck | X | X | X | | X | X | X | | | | | X | | |
| Mechanic truck | X | X | X | | X | X | X | | | | | X | | |
| Personnel bus | X | X | X | | X | X | X | | | | | X | | |
| Pickup truck | X | X | X | | X | X | X | | X | X | X | X | X | X |
| Powder truck | | | | X | | | | | | | | | | |
| Powder van | | | | X | | | | | | | | | | |
| Service truck | X | X | X | | X | X | X | | | | | X | | |
| Slurry truck | | | | | X* | | | | | | | X | | |
| Snow blower | X | X | X | | | | | | | | | | | |
| Snowmobile (survey vehicle) | X | X | X | | | | | | | | | X | | |
| Tanker | X | X | X | | | | | | | | | | X | |
| Tire truck | X | X | X | | | | | | | | | X | | |
| Tool van | | | | | X | X | X | | | | | | | |
| Tractor trailer | X | X | X | | | | | | | | | | | |
| Vac truck | X | X | X | | | | | | | | | X | | |
| Water truck | X | X | X | | X | X | X | | | | | X | | |
| Welding truck | | | | | | | | | X | X | X | X | | X |
| *Equipment* | | | | | | | | | | | | | | |
| Backhoe | | | | | | | X* | X | X | X | | X | | |
| Barge | | | | | | | | X | | | | | | |
| Boom truck | | | | | | | X* | | | | | X | | |
| Buffing truck | | | | | | | | | | | | X | | |
| Chipper | X | X | X | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Road | Pad | Airstrip | Mining | Road | Pad | Airstrip | Seafloor Modification | Onshore Barge Abutment | Dolphin | Boat Launch | Construction | Hydrotesting | Utilities |
| Compactor | | | | | X | X | X | | X | | X | | | |
| Compressor | | | | | | | | | | | | X | X | X |
| Crane (e.g., 120+ ton) | | | | | X* | X* | | | X | X | | X | X | X |
| Deck barge | | | | | | | | X | | | | | | |
| Ditch witch | | | | | | | X | | | | | | | |
| Dozer (e.g., D7G) | X | X | X | X | | | | | | | | X | | |
| Drill | | | | | | X* | | | X | | | X | | |
| End dump | | | | | | | | X | | | | X | | |
| Generator | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Grader (e.g., CAT 16G) | X | X | X | X | X | X | X | | X | | | | | |
| Hauler | X | X | X | X | | | | | X | | X | | | |
| Heater, portable | X | X | X | X | X | X | X | X | X | X | X | X | | |
| Hydrotest pump | | | | | | | | | | | | | X | |
| Impact hammer | | | | | | | | | | X | | | | |
| Loader (e.g., Caterpillar 966) | X | X | X | X | | X* | X* | X | | | | X | X | X |
| Manlift | | | | | X* | | | | | | | X | | |
| Preheat truck | | | | | | | | | | | | X | | |
| Rolligon™ | X | X | X | | | | | | | | | | | |
| Shovel loader | | | | X | | | | | | | | | | |
| Sideboom | | | | | | | | | | | | X | | |
| Steaming unit | | | | | X* | | | | X | | | | | |

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| | Ice Construction | | | Gravel Construction | | | | Docks | | | | Pipelines | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Road | Pad | Airstrip | Mining | Road | Pad | Airstrip | Seafloor Modification | Onshore Barge Abutment | Dolphin | Boat Launch | Construction | Hydrotesting | Utilities |
| Tack rig | | | | | | | | | | | | X | | |
| Tractor trailer | | | | | | | | | | | | X | X | |
| Transfer pump | | | | | | | | | | | | | X | |
| Trimmer | | | | X | | | | | | | | | | |
| Vibratory hammer | | | | | X* | | | | X | | | | | |
| Welding machine | | | | | X* | | | | X | X | | X | X | |

*For bridge building or piling

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