LEDPA ANALYSIS OF ALTERNATIVES

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1.0 PURPOSE AND SCOPE

Resource Report (RR) 10 discusses the major project alternatives from the perspective of the National Environmental Policy Act (NEPA), i.e. the reasonable range of alternatives including the "No Action" alternative. The U.S. Army Corps of Engineers (USACE) must also perform a Clean Water Act (CWA) Section 404(b)(1) analysis which includes an alternatives analysis leading to a determination of the Least Environmentally Damaging Practicable Alternative (LEDPA). These two analyses (NEPA and LEDPA) may or may not include the same alternatives due to procedural differences based on the regulations associated with the different statutes. NEPA requires a reasonable range of alternatives whereas the CWA LEDPA determination includes all practicable alternatives, i.e. available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall purposes.

1.1 BACKGROUND

Alaska includes approximately 63 percent of the nation's wetland ecosystems (Hall et al. 1994). The State of Alaska encompasses an area of 403,247,700 acres and the total acreage of wetlands is estimated at 174,683,900 acres. This is 43.3 percent of Alaska's surface area. In the lower 48 states, on average, wetlands only occupy 5.2 percent of the surface area within the conterminous United States (Dahl 2011). Alaska's wetlands are also concentrated along the coasts and between the mountain ranges found in the state and along all of the major natural corridors for siting linear facilities (e.g., rivers, mountain passes, valleys) and for this reason, it will not be practicable for the Project to completely avoid impacts to aquatic resources, including jurisdictional wetlands.

1.2 LEDPA ANALYSIS

The information provided in this RR has been provided to help satisfy the Federal Energy Regulatory Commission's (FERC) requirements for a robust NEPA alternatives analysis that also accommodates much of what the USACE will require in a LEDPA analysis. Factors used to identify the LEDPA are outlined below and were considered for each Project component:

- Impacts to Waters of the U.S. (including Special Aquatic Sites)
- Practicability
  - Cost
  - Existing Technology
  - Logistics
- Safety, Security, Health, Environment, etc.

The Project's preferred alternative is the LEDPA based on cost, existing technology, and logistics in light of the overall purpose and need. These criteria including general environmental concerns were applied to the Project in a three-tiered approach:

1. The overall Project;
2. The major Project components; and
3. Individual stream, wetland, and water bodies.

1.3 PROJECT SCOPE

In order for the Project to transport natural gas from the North Slope of Alaska to markets via a liquefied natural gas (LNG) export facility, an approximate 807-mile pipeline is by far the most cost-effective, feasible, safe, and practicable method of product transport. As discussed in Sections 10.3.2.1 of Resource Report No. 10, the Project considered developing an LNG facility on the North Slope or shipping the untreated gas to Southcentral Alaska and treating and liquefying it there. Each of these alternatives were dropped from further consideration once they were determined not to be practicable and, in many cases, not feasible or did not reduce environmental impacts.

Each Project component (Gas Treatment Plant [GTP], Point Thomson Gas Transmission Line [PTTL], Mainline, and Liquefaction Facility) considered the previously discussed alternative methods, locations, and/or footprints in order to arrive at the proposed/preferred alternative. Tables depicting the alternatives are included with each component. Specific Resource Report No. 10 sections include:

- Liquefaction Facility alternatives - Section 10.3
    - System alternatives – Section 10.3.1
    - Site alternatives – Section 10.3.2
    - Layout alternatives – Section 10.3.3
    - Marine Terminal alternatives – Section 10.3.5
- Pipeline Alternatives – Section 10.4
    - System alternatives – Section 10.4.1
    - Route alternatives – Sections 10.4.3 and 10.4.4
    - Aboveground facility alternatives – Section 10.4.9
- GTP alternatives - Section 10.5
    - Site alternatives – Section 10.5.2 and 10.5.3
    - Layout alternatives – Section 10.5.4
    - Marine dock alternatives – Section 10.5.7

2.0 LIQUIFACTION FACILITY

Sub-components of the Liquefaction Facility include an onshore LNG Plant and offshore Marine Terminal, which includes a material offloading facility (MOF). A summary of estimated impacts to Waters of the U.S. for construction of the LNG Plant and Marine Terminal is provided in Sections 2.3 and 2.4 and Appendix E and H of Resource Report No. 2.

The Project has taken special care in the siting and orientation of the Liquefaction Facility to avoid and minimize impacts to waters of the U.S., including wetlands, to the maximum extent practicable (see Section 10.1.5 of Resource Report No. 10). There are logistical and safety constraints that require a certain amount of space between or around individual components of the facility. The spacing requirements drive the size of the footprint required for the facility. For example, the Project will adhere to all applicable regulatory and safety requirements including Occupational Safety and Health Administration (OSHA), Pipeline and Hazardous Materials Safety Administration (PHMSA), and FERC standards on equipment spacing and maintaining safety zones within the property boundaries. Building the facility using modules also drastically reduces the facility footprint because material isn't delivered, laid out, and then stick-built on site. Based on the facility throughput design, and planned construction execution shipping modules for most facility components (tanks must be stick built), this places all the equipment and the required safety zones within a 900+ acre site. Logistically, the preferred site is also located to maximize existing roads and infrastructure to the extent practicable to avoid building new infrastructure into a site.

2.1 DREDGING AT THE MOF

Dredging for the MOF is currently planned during construction only (see Section 1.5.2.2.1.16 of Resource Report No. 1). Approximately 800,000 cubic yards of material is expected to be dredged, which is the minimum necessary to ensure that the loaded barges can safely dock with free board of at least 2 feet. The minimum amount of dredging balanced with the minimum amount of dock footprint is planned to accommodate up to 3 delivery barges simultaneously so that shipping is maximized during the open water period.

The disposal site is located within the closing line of the baseline of the territorial seas; therefore, the discharge will be into inland waters and considered a Section 404 discharge regulated pursuant to the CWA (rather than ocean dumping regulated pursuant to the Marine Protection, Research, and Sanctuaries Act [MPRSA]). With the high tidal current regime in Cook Inlet, dispersal of sediments will occur naturally, similar to what is experienced for the current USACE navigation channel dredging and dredge disposal.

3.0 PIPELINE

3.1 POINT THOMSON TRANSMISSION LINE

The PTTL from the Point Thomson development to the GTP was sited to provide safety setbacks from existing pipelines and minimize adverse environmental impacts (see Section 10.4.2.4 of Resource Report No. 10). The PTTL is proposed to be primarily aboveground on vertical support members (VSMs) because it will run perpendicular to the hydrologic gradient. This will avoid blocking or impeding minor drainages and surface flows which could occur with a belowground (i.e., buried) pipeline and reduce/eliminate the need for ancillary facilities such as compressor stations. The PTTL will parallel the Point Thomson Export Pipeline (liquids) (also above ground on VSMs) and Badami Sales Oil Pipeline (also on VSMs) for the first approximate 49 miles of the total approximate 62.5 miles. For the majority of the remainder of the route, the PTTL would parallel the Endicott Pipeline and other existing pipe racks within the PBU. The remainder of the distance traverses the shortest route possible since there are no other existing linear infrastructure facilities to collocate with.

As noted above, the PTTL's proposed method of installation is aboveground on VSMs similar to other pipelines on the North Slope. Major river crossings will be buried. A comparison of the above and belowground methods of installation are provided in Table 1.

Table 1: PTTL Components					
Asset	**Sub-Asset**	**Component**	**Estimated Impacts to Wates of the U.S.**	**Existing Technology**	**Logistics**
PTTL	PTTL Construction Method	Aboveground Route	103.61ac	VSMs and buried across 4 rivers	See Section 10.4.5.1 Aboveground versus Belowground Pipeline Design
		Belowground Route	6,115.71ac	Trench	

Construction will be accomplished in the winter via ice roads and ice pads to further reduce adverse impacts to aquatic resources and to reduce/avoid impacts to threatened and endangered species. The major river crossings will be buried to avoid impacts due to ice and high flows during spring break-up.

3.2 MAINLINE

Sub-components of the Mainline include aboveground facilities and pipeline associated infrastructure (See Table 3). A summary of estimated impacts to Waters of the U.S. for construction of the Mainline, aboveground facilities, and pipeline associated infrastructure is provided in Sections 2.3 and 2.4 and Appendix E and H of Resource Report No. 2.

The Project proposes to bury the Mainline for majority of the route (see Section 10.4.5.1 of Resource Report No. 10). This is primarily due to technological and logistical concerns with a natural gas pipeline that the Trans-Alaska Pipeline System (TAPS) pipeline does not have to deal with because moving oil generates heat through friction, namely liquid dropout in natural gas exposed to temperatures below -30 °F and technical challenges in cost-effectively getting steel milled at the required tensile strength and thickness necessary for exposure to brittle temperatures. Insulating an entire natural gas pipeline would also results in increased costs. In fact, there are currently no pipe manufacturers that have produced this diameter high-pressure pipe with specifications necessary for aboveground installation. Although other gas pipelines are built above-ground in Alaska, none are high pressure transmission systems with a chilled gas management system to maintain the frozen integrity of the permafrost that the pipeline will be buried within. Safety and security concerns also make buried pipelines the industry standard and the Project's proposed alternative.

For routing of the Mainline, the Project put each of the construction spreads and segments through an alternatives analysis of construction methods that considered:

- Soil conditions,
- Number, distance, and stability of soils in wetland/stream crossings,
- Presence of seismic stability (faults),
- Terrain traversed and stability of the Right-of-Way (ROW) for construction vehicles,
- Presence of National Register of Historic Places (NRHP)-eligible cultural resources,
- Duration of construction, mobilization of resources and manpower, and costs, and
- Other socioeconomic and environmental concerns.

Using these considerations, the Project identified several "pinch points" along the route where almost any economically viable, commercial utility line, especially a gas pipeline, must cross in order to make it across mountain ranges, major rivers, and/or seismic faults (see Section 10.4.2.2.1 of RR 10). These "pinch points" are the same ones used for the existing TAPS, highway, and other linear facility corridors present in Alaska. The Project determined that the LEDPA involved paralleling existing infrastructure such as the Dalton Highway and Parks Highway for most of the route. Paralleling the existing highways reduces impacts to pristine areas by using existing transportation corridors and previously disturbed areas, thereby avoiding the need to construct longer and additional roads in order to transport personnel, equipment, and materials to and from the construction right-of-way.

The design nature of the pipeline, a high pressure transmission system, precludes the placement of the pipeline in the road ROW or immediately adjacent to the existing roads. Most of the highways were routed and constructed in some of the optimum areas for placing a linear feature with little or no room adjacent to the road for anything else to be placed. Offsetting with a tree buffer also enhances the minimization of visual impacts by screening the ROW.

Where not collocated near to or adjacent to existing linear ROWs, the Mainline has been routed to avoid/minimize impacts to wetlands, to the extent practicable, by following ridges and crossing wetlands and waterbodies at near 90° to minimize the length of each crossing. Table 10.4.4-4 of RR 10 lists many of the mileposts associated with routing the pipeline to avoid jurisdictional wetlands.

3.2.1 Evaluation of Alternative Construction Methods for Crossing Wetlands in Alaska

The Project has made every effort to route away from wetlands to the maximum extent practicable (discussed in Section 10.4.2 of RR 10), but given the abundance of wetlands in Alaska and the siting of a North-South linear feature, impacts to wetlands are unavoidable. Permafrost is also abundant in Alaska, covering approximately 80 percent of the State. Of particular relevance to this Project is the fact that wetlands commonly overlay permafrost. This is particularly evident for thaw-sensitive permafrost and wetlands - the Mainline route crosses 372 miles of wetlands (i.e., 46 percent of the route) of which306 miles (82 percent) coincides with thaw-sensitive terrain. The abundance of both wetlands and thaw-sensitive permafrost, and overlap between the two, presents a unique challenge for pipeline construction and operation in Alaska – to construct safely and preserve pipeline integrity while reducing impacts to wetland ecosystems.

The number of miles of wetlands that will be crossed, the season of construction and the construction methodology (Modes) are shown in Table 2.

Table 2: Construction ROW Modes and Seasons for Wetlands to be crossed

Mode	Construction ROW Mode	Length (miles)	Winter Construction (miles)	Summer Construction (miles)
01	Ice Work Pad North Slope	**53.4**	53.4	0.0
02	Winter Frost Packed	**40.1**	40.1	0.0
03	Matted Summer Wetlands	**0.5**	0.0	0.5
04	Granular Work Pad	**207.1**	84.8	122.3
5A	Graded	**66.9**	27.3	39.6
16	Water Crossings - Winter	**1.7**	1.7	0.1
17	Water Crossings - Summer	**2.1**	0.1	2.0
Total		**371.8**	**207.4**	**164.5**
			56%	44%

In order to minimize impact on wetlands from construction of the pipeline, ROW modes were selected on a preferential basis (see Section 1.5.2.3.1.1.2 and Appendix M of Resource Report No. 1). The first preference is to apply Ice Work Pad (Mode 1) or Winter Frost Packed (Mode 2), which provide the least environmental impact during construction. For the small sections of inundated wetlands that can't be crossed using Mode 1 (south of the Brooks Range) or Mode 2 (water sources not adequate for frost packing), Matted Summer Wetlands (Mode 3) is applied. Graded Cross Slopes (Mode 5A) is applied for remaining wetlands where the underlying ground conditions are stable. Finally, for other remaining wetlands, where the underlying ground is thaw-sensitive permafrost, granular work pad (Mode 4) is required to ensure safe construction and long-term pipeline integrity. The resulting balance of winter and summer construction sees 207 miles, or 56 percent, of the wetlands being crossed during winter, while the remainder will take place during summer.

In light of the 207.1 miles of granular (mostly gravel) fill required to safely construct in thaw-sensitive permafrost and safeguard pipeline integrity, and the associated impacts to wetlands, the Project has provided a more detailed comparison of alternative construction methods for Pipeline construction in wetlands that overlay thaw-sensitive permafrost to justify the use of the Granular Work Pad ROW mode. The analysis is prefaced with an overview of the challenges presented by infrastructure construction and operations in thaw-sensitive permafrost, with reference to historical experience and examples of working in permafrost in Alaska.

3.2.1.1 Historical Background

Historical use of cross country trails in Alaska during the 20th Century led to a better understanding of the problems caused when traversing permafrost terrain. Techniques for traversing permafrost terrain were developed during construction of the AlCan (Alaska-Canadian) Highway during World War II. Over time Alaska Department of Transportation & Public Facilities (ADOT&PF) Northern Region in Fairbanks has developed a substantial body of knowledge and experience about proven practices for construction in permafrost terrain.

TAPS adopted design principles based on lessons learned from prior experience of ADOT&PF and others with construction in thaw-sensitive terrain by using mostly granular embankment fills over thaw-sensitive terrain and cutting only in thaw stable soils and bedrock when building the pipeline in the 1970's. Because TAPS was not a chilled system (have to allow the oil to heat through friction to move the viscous oil through the pipeline), it was always planned to be placed aboveground to avoid the long-term maintenance predicted from removing both vegetation and opening a trench in permafrost areas. TAPS built a permanent granular work pad for almost the entire length of the pipeline to provide a safe working platform for construction and to allow for future operations access and maintenance. Since the TAPS work pad is permanent, the pad thickness was designed thicker in more thaw-sensitive terrain to prevent subsidence or causing melting of the permafrost. The Alaska LNG planned granular work pad thickness is less than what was used by TAPS because it is not planned to be maintained and used for permanent access (other than for permanent access roads to aboveground facilities such as compressor stations) and is expected to gradually settle into the active layer overlaying the permafrost thereby reducing the probability of conversion from wetlands to uplands over the long-term. Where required for permanent access, granular pad thickness will be adjusted accordingly.

3.2.1.2 Permafrost characteristics

Wetlands are areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands in Alaska generally include tundra, permafrost areas, marshes, bogs, and other similar areas.

Permafrost is ground that remains frozen year after year. Made up of soil and rocks as well as frozen water, permafrost forms when the depth of winter freezing exceeds the depth of summer thawing. Permafrost is thickest on the arctic coastal plain where it extends as much as 2,000 feet below the surface and is found virtually everywhere. From the Brooks Range southward its thickness gradually decreases and it becomes more and more discontinuous, broken by taliks (pockets of unfrozen ground). Near Anchorage, permafrost is found only in isolated patches, and in Southeast Alaska it is found only high in the mountains.

Many of the grasses, flowers, and berries of the arctic tundra owe their existence to the presence of permafrost. With only a few inches of precipitation a year, arctic Alaska could well be a barren desert, but permafrost forms a frozen floor beneath seasonally thawed ground, and rainfall and snowmelt cannot percolate or drain off. Instead, water collects at the surface, providing moisture to nourish plants, forming innumerable shallow lakes and ponds. This also explains the high coincidence of surface wetlands over sub-surface permafrost along the Mainline route. Tundra plants, in turn, insulate the permafrost beneath from thawing.

USFWS
Permafrost area with spruce trees

The ground surface in permafrost terrain may be tundra (mostly north of the Brooks Range) or stunted boreal forests (mostly south of the Brooks Range). For either vegetation type, beneath the organic surface mat is normally an ice-rich silty layer known as the 'active layer' because it thaws in the summer months and freezes solid in the winter months. When the active layer thaws, the ground surface becomes soft due to the saturated silty soils in the active layer beneath the vegetation.

Melting of permafrost can pose problems for activities such as use of heavy construction equipment. If overlying vegetation is removed or disturbed, its insulating qualities are lost and the permafrost begins to melt. Waterlogged ground becomes soft and collapses, and does not possess the structural strength to support heavy construction equipment or to allow for rubber tired transport of pipe and materials. These conditions are effectively unworkable for any type of heavy construction, let-alone the heavy equipment required for installation of a large-diameter pipeline. This is true on both flat and sloped terrain surfaces. Traveling over the thawed active layer results in compression and tracking or rutting of the organic layer, exposing the permafrost to more melting, and exacerbating already unstable ground conditions. The rutting leads to accelerated thermal degradation (thawing) of the permafrost beneath the tracks. The surface depression or rutting also channels or ponds surface water leading to long-term hydraulic erosion in sloping terrain and ponding in flat terrain. Resulting erosion from permafrost thawing on sloping terrain, leads to ongoing ground instability and jeopardizes pipeline stability and integrity in the long-term.

Such tracking or rutting is visible for decades from the air even for one-time trail uses. Examples of this type of damage to the permafrost terrain is famously visible in the Hickel Highway, a Caterpillar bulldozer Train (Cat Train) trail used in the 1960's to move heavy equipment from Fairbanks to the North Slope. There are numerous trails in permafrost terrain throughout Alaska that were caused by equipment or vehicles traveling cross country, disturbing the vegetative surface mat leading to thawing of underlying permafrost. Examples of both of these occurrences are illustrated with images below.

Left, 1959 D8 Caterpillar Bulldozer; Right, tracks left by a summer Cat-Train near Prudhoe Bay
ADNR (Div. ML&W) – History of the Alaska DNR, Tundra Travel Management - 1969-2003 – Appendix D

Off-Road Vehicle trail in permafrost during summer of 1977, after two seasons' traffic
C. W. Slaughter and others. 1990 - Use of off-road vehicles in permafrost affected terrain of Alaska - Environmental Management Vol. 14, No. 1

A common solution for building roads or work pads in thaw-sensitive permafrost terrain in Alaska is to place granular fill on the vegetative mat without cutting or breaking through the surface of the vegetated mat to preserve the physical integrity of the vegetative insulation layer.

Cut and fill techniques are sometimes employed in permafrost terrain, though more commonly in thaw stable material and in discontinuous permafrost regions, as per ROW Mode 5A for the Alaska LNG Project.

In light of the considerations for building infrastructure in thaw-sensitive permafrost, the following analysis presents a comparative analysis of alternative methods for constructing the Mainline in wetlands that overlay thaw-sensitive permafrost - using granular fill or no fill i.e. conventional grading.

3.2.1.3 Construction methods for Pipeline construction in wetlands that overlay thaw-sensitive permafrost

Application of Mode 4 (Granular Work Pad over Thaw-Sensitive Permafrost) would require placement of a level granular fill working surface in the construction ROW at a depth sufficient to enable a safe working platform for large diameter pipeline installation. The granular work pad would be left in place following construction to avoid damage to the vegetative mat and slow resultant thawing of the active layer. If the no-fill alternative were adopted, this would require application of Mode 5A (Graded Cross Slopes). Because of damage to the vegetative insulation layer permafrost would thaw, leading to unsafe, unworkable conditions in summer. As a result, application of Mode 5A in thaw-sensitive permafrost would require all winter/no summer construction. Winter construction would enable safe construction due to frozen ground conditions, but cut and fill techniques would still disturb the vegetative layer resulting in thawing of the underlying permafrost in the following shoulder/summer season, leading to long term ponding and hydraulic erosion that would compromise long-term pipeline integrity. Table 3 provides a side-by-side comparison of these two alternative construction methods.

Table 3: Alternative construction methods for pipeline construction in wetlands that overlay thaw-sensitive permafrost.

	Use of Granular Work Pad			Conventional Grading – No-Imported Fill		
Aspect	**During Construction**	**Short Term Impact**	**Long Term Impact**	**During Construction**	**Short Term Impact**	**Long Term Impact**
Logistics	Granular material must be sourced and transported to ROW.	NA	Increase in regulated footprint results in increased mitigation and monitoring.	Transport of heavy equipment and bedding material to ROW.	NA	Same as long-term impact for granular.
Safety and constructability	Granular work pad allows year round safe ROW access and construction, particularly for sloping terrain which is extensive across the Mainline route, and to accommodate heavy equipment required for large diameter pipeline construction. Granular work pad allows multiple equipment passes without incremental damage to vegetation.	Granular work pad provides level work surface.	Granular work pad is intended to settle and allowed to revegetate over time.	Permafrost melts in shoulder / summer seasons; second winter permafrost is rough and difficult for trafficability. Impassable ROW prevents passage of construction traffic, emergency vehicles etc.	Cuts made into the frozen side hills would thaw, slump and widen the footprint.	Entire footprint would have settled into a stable condition, but below the original grade.
Construction Duration	Granular work pad allows a balance of winter and summer construction.	Construction impacts to adjacent landowners/communities spread across winter/summer seasons. Shorter overall construction duration.	NA	No ground stabilization would preclude summer construction i.e.; all winter construction. Construction duration would be approximately twice as long as the base case mix of winter and summer construction.	Increased construction duration increases stakeholder impacts, increases resource use and emissions from increased mobilization and demobilization of equipment and work crews.	NA
Impact to drainage	Cross drainage maintained using culverts and low water crossings.	Cross drainage maintained; culverts removed, and ECMs installed.	Cross drainage returns to a stable, natural condition.	Graded ROW channels run-off. Exposed cut accelerates thawing of ice rich soils and cross drainage could result in erosion of the ROW.	Surface water captured by ROW, results in sediment flow and hydraulic erosion. Thermal degradation and surface erosion continues.	Surface runoff would have changed with the cut/sunken ROW interfering with natural cross-drainage. Potential for erosion of bedding material, pipeline instability and compromised pipeline integrity.

	Use of Granular Work Pad			Conventional Grading – No-Imported Fill		
Aspect	**During Construction**	**Short Term Impact**	**Long Term Impact**	**During Construction**	**Short Term Impact**	**Long Term Impact**
Impact to wetlands; flat terrain	Permanent fill on working side of ROW; but wetlands on either side are not disturbed.	Permanent fill starts to settle; wetlands on either side remain undisturbed.	Permanent fill reaches stable condition; some local ponding next to fill may occur depending on final height of granular berm.	Physical vegetative mat is compromised. Thawing of permafrost in shoulder/summer season.	Water ponding on ROW; original vegetation may not recover.	Water ponding on ROW; original vegetation would not have recovered.
Impact to wetlands; rolling or cross sloped terrain	Permanent fill on working side of ROW; but wetlands on either side are not disturbed.	Permanent fill starts to settle; wetlands on either side remain undisturbed.	Permanent fill reaches stable condition; some local ponding next to fill on the upslope may occur depending on final height of granular berm.	Physical vegetative mat is compromised. Thawing of permafrost in shoulder/summer season.	Hydraulic erosion leading to sediment runoff in adjacent wetlands. Requires extensive erosion control.	Water flow would prevent vegetation from recovering. Requires extensive erosion control.
Impact to thaw-sensitive permafrost	None	Gradual thaw beneath work pad. Chilled pipeline re-freezes bulb around pipeline to resist further thawing.	Thawing under ROW but away from frozen pipeline goes seasonably deeper until stable condition is reached.	Active layer disturbed and thermal protection removed. Permafrost begins to degrade and settle during summer months.	Accelerated thaw beneath work pad (increasing depth of active layer). Chilled pipeline re-freezes bulb around pipeline to resist further thawing.	Accelerated thawing under ROW but away from frozen pipeline goes seasonably deeper until stable condition is reached.
Impact to pipeline integrity	None	None	None	Impassable ROW in summer months preventing access for planned inspections and maintenance, and emergency access.	Thermal degradation on ROW adjacent to pipeline may cause pipeline to move laterally into thawed ROW, and sunken ROW would become a channel for surface water, compromising pipeline integrity.	Sunken ROW may become a waterbody leading to risk of pipeline buoyancy and compromised pipeline integrity. Pipeline backfill would require regular maintenance.
Restoration	Granular work pad allows timely access for remedial restoration work that otherwise may have to be performed in winter.	More timely remedial action due to year round accessibility reduces worsening of erosion and permafrost thawing.	Reduced need for ongoing restoration.	Without granular fill, restoration equipment would cause further damage to vegetation and underlying permafrost.	Delayed response timeframes, due to winter access limitations, increases magnitude of impacts before remedial action takes effect.	Increased need for ongoing restoration.

Benefits of a Granular Fill Work Pad

A granular fill work pad provides several critically important benefits as explained below.

Provides a Safe Working Surface

Much of the terrain along the route is hilly and because the existing linear corridors the Project is collocated with occupy most of the level ground, the route traverses the hills on the side, resulting in cross slopes. Ice work pads, frost packing or using Low Ground Pressure (LGP) equipment does not allow for the leveling of cross slope conditions to allow a safe working surface. Especially in winter, a nearly level cross slope is required because the grousers of the tracked equipment would be parallel to the slope and sitting on the frozen ground, the tracked equipment would slide downhill. Either a granular work pad or side slope cuts (grading) as the only two ROW modes that provide a safe level working surface on cross slopes. Both modes have the advantage that sand or gravel can be spread on the surface to provide traction for equipment on hills in the winter when compacted snow becomes too slippery.

Given that graded ROW can only be used where soils are competent and capable of supporting construction equipment, only granular work pad ROW mode is possible on hilly terrain in thaw-sensitive permafrost, where thick organics are present or in other poor soil conditions.

Another advantage of granular fill work pad is that it provides firm support for the sidebooms that lower the pipe into the ditch or when they have to hold two pipe ends for making tie-ins that are in close proximity to the ditch. Fully loaded during lowering in, the sideboom may have over 300,000 pounds of combined weight and load. The working side of the ditch must be capable of safely supporting such heavily loaded equipment. In the summer, organics or fine grained soils, saturated or not, do not provide the compressive and cohesive strength to adequately support equipment, even away from the edge of the ditch. Close to the ditch, failure of the soils under moving, heavy equipment is a real danger. If the soils are not competent enough to be graded, then a granular work pad must be used.

Provides Better Control of Surface Erosion

Without either a granular work pad or an ice work pad, the surface vegetation and active layer beneath would be compressed by construction traffic to the point where the entire working width of the ROW would be below natural ground level. This would allow the water from all the cross drainages, sheet flow and saturated soils to accumulate in the ROW. Because much of the route is on hills and often on cross slopes, a depressed ROW surface would redirect the water intercepted along the ROW until it reached streams or gullies at the bottom of each hill. At the same time, all the cross drainages on the downhill side of the ROW would be starved of their natural flow.

Such capture of cross drainage flow is particularly damaging to thaw-sensitive permafrost where flowing water accelerates the melting of ice rich soils. Any water that collects in a compressed, lowered ROW would accelerate melting of the upper level of the permafrost, causing thaw settlement and further water accumulation.

Although the granular work pad will often be placed across drainages or areas of sheet flow, such drainage patterns can be maintained to a large degree by the use of drainage structures such as bridges, culverts, and low water crossings. In areas of sheet flow, the location of culverts or low water crossings will be frequent.

For winter construction, most drainages or small steams will be frozen solid and the channels can be filled with logs and snow for passage of equipment. Before breakup, these materials are removed and the natural channel re-established for break up. If the granular work pad is needed in the summer, culverts or bridges can be installed in these types of channels. In the fall, culverts that were in place for the summer are pulled and natural drainage gradients are re-established in the channels. This avoids icing or plugging of the culverts during the winter and keeps the drainage open for break up. If necessary, the culverts can be reinstalled for another summer of use and access.

Limits damage to the Active Layer

A granular work pad isolates tracked and wheeled equipment from contact with the vegetation and active layer on thaw-sensitive permafrost, and limits damage to the active layer in contrast to other ROW modes (except for ice pads). Without this physical protection, the active layer vegetation and subsoil would be mixed and widespread remediation would be required during the summer to minimize erosion and melting of the permafrost.

Compressed or damaged vegetation, roots and soils of the active layer in this type of terrain take a long time to recover. Alaska has a very short growing season and very cold soil temperatures compared to the Lower 48 states. Regrowth or re-establishment of the vegetation to the point that the original ground level is re-established may never happen. In addition to slow growth, the tundra vegetation in Alaska is adapted to various micro-topographical features and is very sensitive to water levels. The active layer would likely not recover with the same species of plants as it originally had. A compressed and lowered ROW would not provide the same conditions for plants due to higher water levels and entirely different species of plants would have to establish themselves.

Allows Multiple Passes of Equipment without Compressing the Soils

For this project, on each typical five-mile segment, there will be 330 double joints of pipe to string. With two joints per trailer, that is 165 round trip loads of pipe. If this is in thaw-sensitive permafrost, there will be 20,000 to 25,000 cubic yards of bedding and padding to import. That might be 600 to 1,000 round trip loads. At a daily linear progress of installing the pipeline at about one mile, it would take the pipe laying spread five days to go through the five-mile segment. That is five round trips for every bus, pickup truck, flatbed, fuel truck, mechanics truck, and other vehicles necessary to support the spread during construction. That might be 200 pieces of equipment over five days or 1,000 round trips. Not included in that total are the tracked equipment which usually only make one or two passes over a given area as they progress along the ROW (and don’t usually back-track). Conservatively estimating the logistical considerations, there are likely to be 2,000 round trips over the same area where the access road enters the ROW. That means the ROW mode, whatever it is, will see 4,000 passes of equipment, much of which is heavily laden.

A granular fill work pad protects the underlying active layer and permafrost with minimal incremental damage to the vegetation. A properly maintained ice work pad and a graded ROW will also hold up to repeated passes of equipment but they have their own limitations in regards to where they can be used.

A frost packed ROW will not hold up quite as well to repeated passes of equipment and that is why granular work pads are used preferentially in non-permafrost areas, thaw-stable permafrost areas or very select areas of thaw-sensitive permafrost with a deep active layer.

Allows Access for Further Restoration Work

Restoration will start soon after the completion of pipeline installation and backfill, and without a granular work pad, the ability to access many portions of the ROW would be difficult given wet soils and cross slopes. Without gravel, restoration equipment would cause further damage to the vegetation and active layer, but having a granular work pad allows access for remedial restoration work that otherwise may have to be done in the winter. It is much better to be able to access areas that need remedial work as soon as possible before erosion or thermal degradation of the permafrost gets worse than to have to wait days or weeks for specialty LGP equipment or worse, wait for winter. Furthermore, there are some hills where a granular fill work pad may be the only way to access the ROW.

Disadvantages of Using a Granular Fill Work Pad

There are disadvantages to using a granular fill work pad for a ROW mode. The following discusses the disadvantages.

Cost

A granular fill work pad is one of the most expensive ROW modes to construct. The fill material is costly to mine. It is often in permafrost and must be shot or scraped in thin layers, or it can be in bedrock requiring it to be shot and possibly requiring crushing operations to develop the material. The development of materials sites for the granular fill comes with its own set of issues regarding access roads, overburden removal and storage, additional footprint to manage and monitor, and restoration. All of this adds cost.

Matting is cost prohibitive because there are no manufacturers in Alaska and shipping/transporting the quantity of matts required for extensive stretches being worked on in multiple segments of 5-20 miles each would not be practicable.

Schedule

This type of ROW mode adds length to the front end of the construction schedule as it requires a long duration activity that often has to be completed in the summer season preceding pipe lay activities to develop, mine, and stockpile material to use for the granular pad. This adds indirect costs to support the longer duration work schedule. Such costs include administration, work camps, additional months of manpower, construction management, inspection, and support staff.

Covers Vegetation and Loss of Natural Habitat

One of the most notable disadvantages of a granular work pad is the fact that it covers the natural vegetation and that immediate footprint under the work pad will be lost forever.

The only ROW modes that preserve the natural vegetation are ice work pad and frost packing. Unfortunately, the use of these two modes is limited as explained above. Matting can help preserve some of the vegetation, however as pointed out previously, it cannot offer complete protection. Nor can matting be used on side slopes or hills. Grading temporarily removes the vegetation even though it may brought back with topsoil resulting in a temporal impact.

Results on Long Term Settlement over Thaw-Sensitive Permafrost

Over a number of years, the surface of the granular work pad over thaw-sensitive permafrost will continue to be well above the natural vegetation. But over decades, the higher thermal conductivity of the work pad relative to the natural active layer, combined with the increased solar radiation absorption (gravel isn't white in color) will mean that the uppermost layer of the permafrost will very gradually melt lowering the granular work pad as the ground surface slowly settles. This process takes decades. There are many such examples of TAPS work pad over thaw-sensitive work pad that still function today, over 40 years after construction, even though that work pad has settled over time.

Alternative Stabilization Materials to Granular Fill

Wood Chips / Shredded Wood

Use of wood chips is possible in some circumstances – perhaps as an access road in winter or for LGP vehicle access. However, for a ROW on permafrost soils or saturated hillsides, wood chips are not a viable option.

Very importantly, in Alaska, there are hundreds of miles of ROW with few or no trees underlain by thaw-sensitive permafrost. North of Atigun Pass (MP 180) there are no trees and very few shrubs. Most of those are to small to generate much chip material. South of Atigun Pass there are few if any commercial timber operations near the ROW that could provide wood chips. In most places where the wood chips might be produced, the haul distances are vast. To haul wood chips from the nearest available stand of trees south of the Brooks Range to the Sagwon Hills south of the Arctic Coastal Pain would be over 100 miles one way. Hauling wood-chips for long distances would increase safety risk and socio-economic impacts from additional heavy-vehicle traffic, and additional emissions during construction.

Even trying to use wood chips very close to the source presents the problem that the tree species that might provide the most wood chips (white spruce, cottonwood, aspen, and birch) are found in non-permafrost soils or soils with a relatively deep active layer overlaying more competent thaw-stable soils. Such places are often suitable for graded ROW where a granular fill work pad is not needed. So even though there may be some length of ROW that may have trees that can be made into wood chips, these areas generally do not need a work pad and can have graded ROW.

A very serious problem with wood chips is that they would not provide the structural support for the equipment working in close proximity to the ditch during lowering in, and can be slippery when wet or when the sun warms them in the winter, offering no traction to wheeled equipment. Furthermore, the wood chip thickness would have to be much greater than granular fill to offer the same structural protection to the active layer over permafrost. This means that not only would it take more loads of wood chips to cover a given length of ROW but also, as discussed above, the distance each load is hauled would be much greater. Finally, wood chips in thick fills are known to produce heat when decomposing which can thaw permafrost underneath as happened on the Norman Wells Project.

Timber for Corduroy Roads

Most areas where timber for a corduroy exists are where a corduroy is not needed. This means that new footprint will have to be cleared with the corresponding impact, or hauling distances would be extraordinarily long for hauling timber for corduroy. Hauling timber for corduroy roads would result in similar impacts from increased heavy vehicle traffic described above for hauling of wood-chips long distances.

There are hundreds of miles of ROW with no trees and often not even shrubs. Furthermore, the stands of trees (white spruce and birch) between the Alaska Range (MP 530) and the Brooks Range (MP 180) are not at all continuous. The ROW is in such trees stands usually only at river crossings or on south facing slopes. North facing slopes, hilltops and many side slopes have tundra. A significant portion of the route is in black spruce forests but black spruce is often very short, with small diameters and would not provide timbers of adequate strength, diameter and length to support the kind of equipment required for this project.

Additionally, the ROW is extremely isolated in some areas. There are multiple ROW segments of 10, 15, 20 miles or greater that have no access other than end-only access down the ROW and a few of these are even one way in and the same way back out. There are very few, if any, segments where enough large timber exists within the ROW that is also in proximity to long wetland crossings.

For the reasons provided above, the use of trees and timbers to build a continuous ROW is not feasible. However, the use of trees may be beneficial in some isolated segments. Timbers can and will be used to reinforce frost packing in areas where groundwater prevents adequate freezing depth.

LGP Equipment on Natural Ground

There will be a need on the Project to use LGP equipment of various types for surveying; waterbody, bog and wetland crossings; erosion control structure installation; used during initial stages of ice pad construction; and during some restoration work. LGP equipment will also be needed to provide summer access and work capability over the ungraded natural vegetation for segments where the winter ROW mode was either ice pad or frost packed.

However, LGP equipment is not planned to be used for pipe laying including ditching, stringing, pipe lay, lowering in, and bedding/padding/backfill in any ROW mode, summer or winter. The weight and diameter of the pipe on this project dictates that the equipment to string it, lay it, excavate the ditch, lower it in and backfill it have the capacity to do so. The 42-inch line pipe weighs 300 pounds per foot and an 80-foot joint weighs 24,000 pounds or 12 tons. While certain specialty equipment exists that can haul up to 40,000 pounds on a tractor-trailer configuration - consisting of twelve LGP tires resulting in ground pressure of 3.1 psi - such equipment does not have any significant capabilities to perform other pipe laying activities.

A key difference between Alaska and the Lower 48 in terms of the use of LGP equipment, is that the vegetation needing protection in Alaska is underlain by permafrost. Excavating permafrost and seasonally frozen soils requires large chain trenchers, bucket wheel trenchers, drilling and blasting, or very large excavators with frost buckets. Trenchers weighing 325,000 pounds and excavators weighing 100,000 to 175,000 pounds will be used on the project. Even after blasting the ditch in frozen material, excavators will often have much of their weight forward on their tracks as they attempt to break out material. This greatly increases their ground pressure.

Along the Project route, saturated soils, wetlands and active layer are found extensively on hillsides with longitudinal and cross slopes frequently making timber mats unworkable. Specialty equipment for wetland and marsh work in the Lower 48, whether it is tracked marsh buggies or special wheeled LGP tractor/trailers, are not designed to work on hills and cross slopes. Thus to create a level ROW, granular fill is the only option when it is not permissible to cut and grade permafrost soils.

A further difference between Alaska and the Lower 48, is the vulnerability of the active layer vegetation and soils. In the Lower 48, whether using mats or swamp buggies, the wetland vegetation is compressed and possibly damaged, however with long growing seasons and with the root systems left intact, such vegetation in the Lower 48 can recover. In Alaska, if the active layer vegetation is damaged, compressed or torn, the underlying permafrost can start melting, which can cause erosion, settlement, flooding and other damage that must be physically remediated.

Lighter Color Work Pad Material

Other than possibly mitigating post construction settlement of a granular fill work pad, lighter colored material would have no benefit during construction. Its use after construction would not reduce the use or thickness of a granular work pad. Lighter colored material cannot be used during construction as it would get mixed and covered by construction activities. Furthermore, use of lighter colored material during construction would have no effect on the thickness of the work pad which is determined by the desired structural capacity of the fill over specific types of underlying soils.

Lighter color material placed as a topping on a granular work pad during restoration might inhibit absorption of solar radiation into the work pad. This in turn might reduce the temperature gradient between the work pad and the permafrost which may extend the period of time it takes for the active layer to deepen and the work pad to settle. The work pad takes years, likely decades, to settle due to long term warming of the upper permafrost layer. Postponing this by using lighter colored material would likely add only a few years to the process.

Leaving Granular Fill in Place

The Project considered removing the granular fill after construction was completed and during restoration activities. However, removing the gravel/granular fill was determined <u>not</u> to be practicable due to cost and logistics. It would cost at least as much to pick up the granular material as it would to place it (effectively doubling the Project pipeline installation cost in these areas). Lessons learned from construction of TAPS demonstrated that picking up gravel from temporary access roads constructed on thaw unstable permafrost resulted in significant thermokarst where the tundra had been disturbed. Lastly, ADNR and BLM do not allow material that has left the permitted mine site to be returned to that site due to the possibility of both contamination and introduction of invasive species. Most of the mine sites used by the Project would be located on property managed or partially owned by the state of Alaska or BLM. This would necessitate the development of more disposal sites, increasing the Project footprint to accommodate disposal of the material, or, if sold to private users, the storage of the material until it could be used.

4.0 GAS TREATMENT PLANT (GTP)

The sub-components of the GTP include the GTP site and GTP associated infrastructure (See Table 7). A summary of estimated impacts to Waters of the U.S. for construction of the GTP and associated infrastructure (e.g., water reservoir/material sites, west dock modifications) is provided in Sections 2.3 and 2.4 and Appendix E and H of Resource Report No. 2.

The proposed alternative for the GTP site was selected primarily for logistical reasons (near the supply gas facility and being able to utilize existing infrastructure) and location inside the industrialized Prudhoe Bay Unit (PBU) development area between Deadhorse and West Dock (see Section 10.5.3 of Resource Report No. 10). The preferred location balances environmental impacts by:

- Optimizing transportation of the GTP modules from West Dock to the site (i.e., length of road upgrades), and
- Utilizing proximity to existing oil and gas facilities (i.e., new transfer line lengths) to bring the natural gas to the GTP.

The size of the pad is mainly driven by safety (safety setbacks from processing equipment) and logistics such as staging areas for personnel and equipment during construction for placement/connection of the modules (these staging areas will be incorporated into the layout of the permanent pad as safety zones, parking areas, and onsite storage), and cannot be reduced further without compromising one or more of the factors described above. The location and configuration were determined by maximizing space and orienting the pad to avoid open water areas and historical sites to the maximum extent practicable while meeting OSHA and other federal and state requirements. Not using modules to build the facility will result in a much larger pad footprint to accommodate the delivery, storage, and stick-build of the materials that comprise the modules which manufactured elsewhere and delivered to the site (See Section 10.5.6.1 of RR 10 for additional information regarding Onsite Fabrication).

4.1 MATERIAL SITES AND WATER RESERVOIR

There does not appear to be enough gravel available from any currently available commercial gravel sources in the vicinity of the GTP, nor is there a water source with enough drawdown capacity to support operations that is in close proximity to the GTP site. Therefore, the Project will require its own gravel mine to support construction and water reservoir to support operations for the GTP Facility. Section 10.5.4.3 of RR 10 discusses the alternatives that were considered.

4.2 WEST DOCK MODIFICATIONS

Construction of a new dock at Dock Head (DH) 4 at West Dock is the Proposed Alternative under LEDPA because it negates the need for dredging (see Section 10.5.7 of RR 10), unlike the other alternatives.

5.0 WETLAND/WATERBODY CROSSINGS

The Liquefaction Facility was sited and oriented to avoid all streams and all but the minimum area of wetlands necessary to construct and operate the facility (less than 10 percent of the construction footprint is in wetlands). The Project has further minimized impacts as much as is practicable by minimizing the need for a permanent access road along the approximate 807-mile Mainline pipeline, thereby reducing overall impacts to wetlands. Additionally, the Project is proposing only temporary impacts to streams and does not anticipate any permanent adverse impacts to rivers or streams. The Project continues to assess stream crossing locations and conceivably could make minor changes in the field during construction in order to avoid high-value fish habitat or optimize the angle of crossing for stabilization purposes. The Project plans to restore streams to near pre-project conditions (unless changes are required for stabilization) while looking for opportunities to provide ecological lift.

The Project also reviewed a number of alternatives related to construction practices and methods, including winter versus summer season of construction, and for the following aspects of construction activities (see Section 10.6 of RR 10) related to the following Project components:

- Marine Terminal (see Section 10.3.5.1 of RR 10);
- Onshore and Offshore Pipeline Construction Alternatives (see Section 10.6.1 and 10.6.2 of RR 10);
- Dredge Method and Dredge Material Placement Alternatives (see Section 10.6.4 of RR 10); and
- Pipeline Pressure Testing (see Section 10.6.3 of RR 10).

The Project is consulting with ADF&G and other resource agencies to select crossing methods/locations that minimize impacts.

Crossing frozen streams, lakes and wetlands using ice roads and pads or frost packing greatly reduces the overall environmental impacts to these aquatic resources. The use of ice roads and ice/snow pads or frost-packing minimizes impacts by eliminating the need for permanent discharges of dredged or fill material for work pads and access roads. The temporary nature of the impacts associated with these winter construction practices reduce the need for major restoration/rehabilitation efforts. Additionally, the Project has identified and will implement a number of Best Management Practices (BMPs) specifically designed to reduce overall impacts, including the use of rig mats when crossing some waters of the U.S.

6.0 ACRONYMS AND TERMS

Term	Definition
ADOT&PF	Alaska Department of Transportation & Public Facilities
CWA	Clean Water Act
FERC	Federal Energy Regulatory Commission
GTP	Gas Treatment Plant
LEDPA	Least Environmentally Damaging Practicable Alternative
LGP	low ground pressure
LNG	liquefied natural gas
MOF	material offloading facility
MPRSA	Marine Protection, Research, and Sanctuaries Act
NEPA	National Environmental Policy Act
OSHA	Occupational Safety and Health Administration
PHMSA	Pipeline and Hazardous Materials Safety Administration
PTTL	Point Thomson Gas Transmission Line
ROW	right-of-way
TAPS	Trans-Alaska Pipeline System
TBD	to be determined
USACE	U.S. Army Corps of Engineers
VSM	vertical support member

7.0 REFERENCES

Dahl, T.E. 2011. Status and Trends of Wetlands in the Conterminous United States 2004 to 2009, USFWS.