8 SOILS, LANDFORMS AND PERMAFROST

8.1 Introduction

8.1.1 Scope

This section predicts and evaluates potential environmental effects from the project on soils, landforms and permafrost. These are considered important because landforms provide the physical framework of the landscape and soils provide the surficial mineral and organic materials that sustain plant growth. Permafrost is a main component of landforms in many areas. The nature of soils, landforms and permafrost control, to a great extent, the types of vegetation found in the project area. Vegetation provides habitat for wildlife, and northern communities use some plants for food, medicine and fuel.

Activities during project construction will affect soils, landforms and permafrost features more than other project activities will. Grading during construction might cause changes in landform stability, particularly in soils with high ice content. Uncommon landforms might be affected if intersected by the right-of-way or where used as supports for facilities and structures and sources of granular materials. Soils might be lost where pads are constructed for infrastructure and facility sites. The quality of the soil might be altered by excavation of the pipeline trench or by changes in drainage along the right-of-way during construction.

8.1.2 Summary of Findings

The soils, landforms and permafrost assessment investigated project effects on the following:

- ground stability
- uncommon landforms
- soil quality

These features were identified as valued components (VCs) for their environmental importance.

8.1.2.1 Ground Stability

Four key indicators (KIs) were used to assess effects on ground stability:

- drainage disruption from thaw settlement and pond formation
- drainage disruption or damming from frost bulb growth or heave of the ground surface
- erosion from wind and water flow
- mass movement or slope instability

Project effects were evaluated on the basis of postmitigation effectiveness. These effects on ground stability would remain after mitigation measures, but they would be low enough in magnitude and generally mitigated in the long term to be considered not significant.

8.1.2.2 Uncommon Landforms

Indicators used to assess effects on uncommon landforms were:

- pingos
- glaciofluvial deposits and aeolian deposits
- patterned ground

Pingos will not be affected because they will be avoided during facilities design. Adverse effects on glaciofluvial and aeolian deposits will occur and will extend into the long term or far future. Based on the size of affected areas, however, the residual effects will not be significant. Patterned ground effects will occur in the Tundra, Transition Forest and North Taiga Plains A ecological zones. Effects on uncommon landforms were assessed as not significant. The assessment was based on postmitigation effects.

8.1.2.3 Soil Quality

Indicators used to assess effects on soil quality included:

- changes in soil drainage
- soil loss
- changes in soil physical and chemical characteristics

Measurable adverse effects on soil quality indicators would occur after mitigation measures, but they would mostly be low magnitude. Low magnitude indicates that within the local study area (LSA) for each project component, less than 5% of the total coverage of the affected landform type might be affected. Low-magnitude effects on soil quality are not significant.

These low-magnitude effects include small areas of soil loss, changes in soil drainage and changes in soil physical and chemical characteristics. Soil loss occurs in localized areas primarily in the northern half of the project area where soils are left in place to preserve permafrost and maintain surface stability. Soil can be removed and replaced in thaw-stable terrain to reduce this impact.

Changes in soil drainage are less severe when thaw-settlement processes are not involved. Mitigation measures, such as re-establishment of drainage patterns at decommissioning, can be applied if the changes were related to damming or diversion of drainage. When thaw-settlement processes are likely to be involved, i.e., in the gathering system and along the pipeline corridor in the Transition

Forest and North Taiga Plains ecological zones, changes in drainage can be moderate magnitude. Moderate magnitude indicates that within the LSA for each project component, 5 to 10% of the total coverage of the affected landform type might be affected. Mitigation measures, such as filling the resultant ponds with granular material, will control thaw settlement and provide a surface for plant re-establishment in the long term. Effects on soil quality that are moderate magnitude and long-term duration are not significant.

Changes in soil physical and chemical characteristics are low magnitude and short- to long-term duration. Mitigation is frequently successful for effects on soil characteristics such as might occur from erosion and inadvertent leaks and spills. Other effects such as mixing and changes in chemical properties because of air emissions have minor effects on soil quality. Monitoring programs will be established to confirm the effectiveness of mitigation measures.

8.1.3 Traditional Knowledge

Volume 1, Section 3, Traditional Knowledge, outlines the status of the traditional knowledge studies that communities near the project are undertaking. As these studies are incomplete, the project proponents have reviewed existing published traditional knowledge for this EIS.

Little traditional knowledge related specifically to soils and landforms was identified in this review. Identified traditional knowledge focused on special features and long-term changes in the landscape.

The Thunder River Quarry, or Feetie Lushe, has been an important lithic quarry for centuries, used by the Slavey, Gwich'in and Inuvialuit peoples. It is located at the mouth of the Thunder River in the Gwich'in Settlement Area. The original names in Slavey and Gwich'in both refer to the quality of stone found here for making tools. There are many traditional stories about the site, which is the only known lithic source on this stretch of the Mackenzie River. There is evidence that the raw material, siliceous argillite, was traded over long distances in the western sub-Arctic (SHPSJWG 2000).

Rare geological landforms of ice-cored hills, known as pingos, are important to the communities of Tuktoyaktuk and Inuvik. Some of the largest pingos in the world occur near Tuktoyaktuk. The Pingo Canadian Landmark, located about 4 km southwest of Tuktoyaktuk, covers 16.4 km^2 (Community of Inuvik et al. 2000). Toker Point also has dome-shaped pingos (Community of Tuktoyaktuk et al. 2000).

Long-term changes in terrain have been observed by the Dene Tha' First Nation (1997). Several people have suggested that the terrain in the Dene Tha' traditional territory was much different several generations ago. The land was described as much more open, with expanses of prairie grasses, instead of the dense bush present today. One reason for this change could be unchecked forest fires. “Forest fires made the land bare. You had to move to get out of the way.” (Dene Tha’ First Nation 1997). Also, the Dene Tha’ used to set controlled fires in the springtime to rejuvenate the grasses around beaver ponds and lakes. “Muskrats and beavers then had new grasses to eat.” (Dene Tha’ First Nation 1997).

8.2 Assessment Approach

Volume 1, Section 2, Assessment Method, provides information on the assessment approach. The assessment approach for soils and landforms includes the following steps:

1. Identify project-related activities that might affect soils and landforms, i.e., key issues.
2. Identify VCs and KIs for measuring potential changes in VCs caused by project activities. In this assessment, ground stability, uncommon landforms and soil quality are the VCs.
3. Identify the potential effects, and illustrate the linkages between project activities and effects, using an effect pathway diagram.
4. Identify mitigation measures that will be used to reduce or prevent potential effects.
5. Evaluate the applicability of each pathway, after accounting for mitigation measures.
6. Predict changes in ground stability, uncommon landforms and soil quality for the applicable pathways.
7. Evaluate and classify the predicted effects, by comparing with regulatory guidelines or using site-specific benchmarks.
8. Identify the monitoring programs required to verify effect predictions and to comply with commitments described in Volume 7, Environmental Management.

8.2.1 Key Issues

Key issues in this assessment were developed from community meetings, technical workshops, professional judgment, existing traditional knowledge and existing environmental assessments.

These key issues are:

- permafrost thaw that causes ground subsidence, erosion, changes in drainage conditions and slope instability
- removal or burial of uncommon landforms

- change in soil quality caused by removal, burial, mixing, erosion, compaction and changes in soil drainage
- altered drainage, erosion or slope instability caused by induced ground freezing, i.e., frost bulbs or surface heave, and related effects
- ground subsidence caused by gas extraction, which can lead to:
  - flooding
  - loss of land
  - changes in active layer depth, vegetation patterns and channel migration
- ground subsidence and related effects, such as erosion or slope instability, on karst terrain, i.e., effects on soluble bedrock layers

8.2.2 Valued Components and Key Indicators

8.2.2.1 Valued Components Selection Process

The VCs were selected based on issues described previously. The issues were based on concerns raised during stakeholder or community consultation meetings, professional judgment on the vulnerability to disturbance and the Terms of Reference for this project.

These issues can be consolidated into three VCs:

- ground stability
- uncommon landforms
- soil quality

Table 8-1 summarizes the criteria for selecting soil and landform VCs.

Table 8-2 summarizes the VCs and associated KIs. The KIs were developed from candidate lists of issues and valued components.

Table 8-1: Selection Criteria for Valued Components

Valued Component	Selection Criterion			
	Stakeholder Concerns	Ecological Vulnerability	Importance to Local Communities	Precedence in Other Assessments
Ground stability	●	●	●	●
Uncommon landforms	●	●	●	●
Soil quality	–	●	●	●

NOTES:
● = selection criterion applies to the VC
– = selection criterion does not apply to the VC

Table 8-2: Valued Components and Key Indicators

Valued Component	Key Indicator
Ground stability	Drainage disruption potential from thaw settlement Drainage disruption or damming potential from frost bulb growth or surface heave Erosion from water or wind Mass movement and slope instability
Uncommon landforms	Pingos in the Tundra Ecological Zone Patterned ground, such as ice-wedge polygons in the Tundra and Transition Forest ecological zones Glaciofluvial and aeolian deposits
Soil quality	Soil loss Drainage class Chemical and physical properties e.g., structure, texture, depth of active layer, organic matter content, mineral content, chemical composition, soil reaction and nutrient regime

Ground Stability

Ground stability was selected as a valued component because of its importance in supporting other environmental components, such as vegetation. Mechanisms and processes that contribute to the stability of the ground surface include thermal considerations, drainage and movement of individual particles that make up the landforms, and soil layers. Key indicators of ground stability include:

- drainage changes caused by thermal changes, such as thaw settlement, or frost bulbs or surface heave
- erosion or mechanical alteration of the landforms caused by water flow or wind
- alteration of the ground surface by mass movement

A major factor contributing to ground stability is the presence of permafrost and maintenance of thermal equilibrium. Other factors include landform composition, slope, vegetation cover and groundwater conditions. Changes in existing ground conditions, or to thermal equilibrium, could affect other biophysical features such as soils, hydrology, vegetation, and fish and wildlife habitat. The key indicators of change for ground stability were identified because of their potential for direct or indirect effects on biophysical features.

Uncommon Landforms

Uncommon landforms in the study area fall under the following classes:

- landforms that might be common in the region but are not found, or are uncommon, elsewhere
- landforms that might be common in the rest of Canada but are uncommon in the region or study area
- landforms that have ecological value for supporting plant or animal species, aesthetic value or socio-economic value as sources of granular material

Pingos are ice-cored hills that develop in the Tundra Ecological Zone. There are more than 1,400 pingos north and east of Inuvik (Heginbottom 2000). Several pingos occur in the LSA and are important to the communities of Tuktoyaktuk and Inuvik (Community of Inuvik et al. 2000; Community of Tuktoyaktuk et al. 2000). Pingos have aesthetic value and are uncommon landforms based on definitions for this assessment.

Patterned ground is common in arctic and subarctic environments, including portions of the project area, but is uncommon elsewhere. Patterned ground considered in this assessment includes areas of ice wedge and high-centred and low-centred polygons. These areas are the result of specific hydrologic, climatic and geologic conditions. The formation of such landforms elsewhere is improbable. Patterned ground is likely to be lost if it is disturbed.

Glaciofluvial and aeolian deposits, including eskers, kames and outwash plains, are common in most of Canada but are often considered uncommon in some parts of the study area. In addition to their importance as sources of granular material for construction, these landforms might also be associated with rare or unusual plants, or denning habitat for animals. Excavation, removal or disturbance of these landforms is likely to have effects on soil, vegetation and wildlife.

Soil Quality

Soil is the natural, unconsolidated mineral or organic material on the immediate surface of the earth that has been influenced by genetic material, climate, macro- and micro-organisms, and relief. Over time, these factors produce a material different from which it was derived in many physical, chemical, biological and morphological properties, and which serves as a natural medium for the growth of land plants (Gregorich et al. 2001). The upper soil layers of a profile constitute the valuable rooting medium that provides nutrients and moisture for vegetation. Soil conditions are affected by climate, vegetation, time, drainage patterns, landforms and underlying geological conditions. Soil conditions provide information about the depositional environment of organic matter, ground temperature regimes and water table fluctuations.

For this assessment, soil quality is defined as the capacity of soil to function in a specific ecosystem in a way that (Powter 2002):

- sustains plant and animal productivity
- maintains or enhances water and air quality
- supports human health and habitation

Soil quality reflects several soil properties and is estimated from many measurements and observations. In the context of land disturbance, soil quality reflects the ability of the surface material, whether it is organic or mineral, to support the re-establishment of an ecosystem that represents the natural range of ecosystems in the LSA that existed before disturbance.

8.2.3 Key Questions and Effect Pathway Diagrams

The soils and landforms issues can be addressed by answering two key questions about the effects of the project on the environment:

- How will the project affect landforms?
- How will the project affect soil quality?

Table 8-3 shows the relationships between the key questions, issues and VCs. Effect pathway diagrams have been developed to illustrate the paths by which project activities could affect VCs. These diagrams are provided at the beginning of the key questions (see Section 8.3, Effects on Landforms, and Section 8.4, Effects on Soil Quality).

Table 8-3: Key Questions, Related Key Issues and Valued Components

Key Question	Related Key Issue	Potentially Affected Valued Component
How will the project affect landforms?	Permafrost thaw and related effects Soil freezing and related effects Effects of gas extraction Removal or burial of uncommon landforms	Ground stability, uncommon landforms
How will the project affect soil quality?	Change in soil drainage Loss of soil Change in physical and chemical properties	Soil quality

8.2.4 Effect Descriptions

Four attributes were used to estimate project effects:

- direction
- magnitude
- geographic extent
- duration

Quantitative estimates of effect attributes are used where the affected areas of the VC or KI have been calculated. Qualitative estimates are used where the estimates of these attributes are based on professional judgment. The combination of effect attributes is then used to determine if an effect is significant.

8.2.4.1 Direction

Direction describes the ultimate long-term trend of the effect, compared with baseline conditions. Table 8-4 defines the direction of effect attributes.

Table 8-4: Definition of Direction

Rank	General Definition
Adverse	Effect on VC or KI is worsening: • ground is less stable • uncommon landforms are lost • soil quality is reduced
Neutral	Effect on VC or KI is not changing: • ground stability is unchanged • uncommon landforms are unchanged • soil quality is unchanged
Positive	Effect on VC or KI is improving: • ground is more stable • uncommon landforms are more abundant • soil quality is increased

8.2.4.2 Magnitude

Magnitude describes the severity or intensity of the effect. Measurements of magnitude indicate gains or losses in features such as uncommon landforms, areas or volumes, or changes in natural conditions, and factors influencing the VCs or KIs. Where practical, magnitude ranks are based on quantitative assessments of the soils or landforms that are susceptible to impacts on VCs or KIs. Table 8-5 defines the magnitude effect attributes.

8.2.4.3 Geographic Extent

Geographic extent is the area in which an effect occurs. Most effects on soils and landforms are confined to the project footprint within the LSA (see Section 8.2.5, Study Areas and Boundaries). However, some of the project effects, such as air emissions, extend beyond the LSA into the regional study area (RSA). Therefore, regional effects on soil quality can occur. Table 8-6 defines the geographic extent of effect attributes.

Table 8-5: Definition of Magnitude

Rank	Definition
No effect	Stability factors or stability of ground are not affected Amount or volume of uncommon landforms are not affected Soil quality is not affected
Low effect	Project predicted to cause a <5% change in ground stability in LSA Project predicted to cause a <5% change in uncommon landforms in LSA Project predicted to cause a <5% change in a soil quality key indicator in LSA, or a change in soil quality might or might not be detectable and is unlikely to affect plant growth
Moderate effect	Project predicted to cause a change in soil stability of between 5–10% in LSA Project predicted to cause a change in uncommon landforms of between 5–10% in LSA Project predicted to cause a change in a soil quality key indicator of between 5–10% in LSA, or a change in soil quality will occur, but is unlikely to seriously restrict plant growth
High effect	Project predicted to cause a >10% change in soil stability in LSA Project predicted to cause a >10% change in uncommon landforms in LSA Project predicted to cause a >10% change in a soil quality key indicator in LSA, or a change in soil quality is likely to seriously restrict plant growth

Table 8-6: Definition of Geographic Extent

Rank	Definition
Local	Effect on VCs or KIs within LSA
Regional	Effect on VCs or KIs within RSA
Beyond regional	Effect on VCs or KIs extends beyond RSA

8.2.4.4 Duration

Duration refers to how long an effect persists and is based on how long a VC needs to recover from an impact. Recovery is defined as a return to conditions that would exist if the project had not occurred. Table 8-7 defines the duration effect attributes.

Table 8-7: Definition of Duration

Rank	Definition
Short term	Effect is limited to <3 years
Medium term	Effect occurs from 3 to 9 years
Long term	Effect lasts longer than 9 years, but does not extend more than 30 years after decommissioning and abandonment
Far future	Effect extends more than 30 years after decommissioning and abandonment

8.2.5 Study Areas and Boundaries

To assess the geographic extent of project effects, two study areas were defined:

- LSA
- RSA

Maps of the RSA and ecological zones are shown in:

- Figure 8-1, Ecological Zones – North Regional Overview Map
- Figure 8-2, Ecological Zones – Central Regional Overview Map
- Figure 8-3, Ecological Zones – South Regional Overview Map

The study areas were also partitioned into ecological zones to analyze effects. Niglintgak, Taglu, Parsons Lake and the gathering pipelines and associated facilities are in the Tundra Ecological Zone. The pipeline corridor and related infrastructure are partitioned among the Transition Forest, North Taiga Plains and South Taiga Plains ecological zones. The North Taiga Plains and South Taiga Plains ecological zones were subdivided into zones A and B to assess landforms. Climate, vegetation and permafrost characteristics vary over the pipeline route and the division into ecological zones allowed for site-specific assessments of project effects.

8.2.5.1 Local Study Area

Most effects on soils and landforms will be caused by direct disturbance to vegetation, surface cover or subsurface layers within a short distance of the disturbed area. LSAs are defined as being within 1 km of project facility site boundaries or developments. The LSAs include a 1-km buffer around the lease boundaries of the anchor fields, and a 1-km band centred on the gathering system and the pipeline corridor. Infrastructure-site LSAs include a 500-m buffer around the site footprint, and a 1-km band centred on the access road to the site.

In addition, each of the project component areas for which an effect analysis was done is referred to as the LSA for that component, i.e., the Niglintgak, Taglu, Parsons Lake, gathering pipelines and associated facilities, production area infrastructure, pipeline corridor and pipeline corridor infrastructure are each referred to as LSAs. The pipeline corridor is further broken down into LSAs for each ecological zone.

8.2.5.2 Regional Study Area

The RSA is a 60-km-wide corridor, centred on the pipeline route and production facilities, with expansions to include home range habitat for key wildlife VCs. It is used to evaluate potential changes in soils, landforms and permafrost in a larger regional context. This area would be affected by similar regional land planning and management policies in each of the land settlement areas. Like the LSA, the RSA is subdivided into the four ecological zones to classify soils and landforms in the project area. These four ecological zones are:

- Tundra Ecological Zone
- Transition Forest Ecological Zone
- North Tiaga Plains Ecological Zone
- South Tiaga Plains Ecological Zone

Figure 8.1 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

Figure 8.2 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

Figure 8.3 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

8.2.6 Analytical Approach

The soils, landforms and permafrost baseline data and the methods used in their preparation are presented separately (see Volume 3, Section 8, Soils, Landforms and Permafrost). Baseline data assembled for the LSAs included information on:

- genetic materials
- material textures
- surface expression
- topographic classifications
- drainage classifications
- existing processes and process modifiers
- associated soils and vegetation types

This allowed for a quantitative assessment of many of the potential project effects on soils and landforms, discussed in the following sections. For the VCs of ground stability and soil quality, the impact assessment assumes that the most important feature of soils and landforms is their ability to support vegetation communities and that similar landforms in an LSA support the same types of vegetation communities. For this reason, quantitative assessment of these VCs is similar to the vegetation assessment (see Section 9, Vegetation). The landforms in a particular LSA are determined to be sensitive or not sensitive to adverse changes in ground stability or soil quality after mitigation measures are taken. The magnitude of effect on the VC depends on the area of the sensitive landforms that will be disturbed by project activities, relative to the total area of those landforms in the LSA. The magnitude rating for ground stability and soil quality assumes that landforms rated as sensitive are incapable of supporting a stable vegetation community.

For the VC of uncommon landforms, the same approach was used for the key indicators of glaciofluvial and aeolian deposits and patterned ground. Quantitative data was not available for pingos however, so effects on these were assessed qualitatively.

8.2.6.1 Landforms

The landforms assessment was done in two steps. First, baseline information was reviewed for combinations of key parameters and associated threshold values that could lead to potential issues or effects. The threshold values were defined and developed from analytical and computer models, combined with criteria and information on the design, construction and operation of project facilities. Computer models were used to quantify threshold values for:

- thaw depths in permafrost areas
- thaw settlement and pond formation on right-of-way and ditch line

- frost heave at ground surface
- landslide and thaw-flow potential
- erosion potential from water flow and wind
- drainage disruption potential from frost bulb growth

After these threshold values were determined, each landform unit was assessed to determine the potential for:

- erosion caused by surface water flow
- erosion caused by wind, i.e., deflation
- slope instability, including mass movement and thaw-flow
- disrupted drainage or damming caused by frost bulbs or surface heave
- disrupted drainage caused by thaw settlement

The second step in the assessment was to overlay landform information with project disturbance areas, which included locations of pipelines, infrastructure and other project components. This allowed for identification and quantification of areas in the LSAs, intersected by project facilities, susceptible to potential effects.

Quantitative analysis determined the area of a particular landform that is susceptible to disturbance, relative to the total area of that landform in the LSA.

More details on specific analytical approaches and modelling results are presented with each key question and associated valued components in Section 8.3, Effects on Landforms and Section 8.4, Effects on Soil Quality.

8.2.6.2 Soil Quality

Effects on soil quality were determined by considering the effects on several key indicators separately.

Changes in Soil Drainage

Most potential changes in soil drainage were assessed qualitatively. The assessment was based on the potential for changes in soil drainage, after considering site-specific soil and landform characteristics and the construction and mitigation techniques at each location.

Where pond formation was predicted to be caused by thaw settlement, a quantitative analysis of changes in soil drainage was done. Areas and types of soils and landforms potentially affected by ponding were determined by overlaying the project disturbance layer on polygons where ponding was predicted. The proportion of each soil and landform type affected by ponding was calculated relative to total distribution of the affected landform type in the LSA.

Soil Loss

Soils were considered lost where a thick pad would be placed directly on the vegetated surface to protect the permafrost and control surface subsidence. This was expected to occur in thaw-unstable terrain, when preparing infrastructure sites and when levelling the right-of-way in unstable, ice-rich terrain. Soils could also be lost on slopes where ice-rich trench spoil might be replaced with select backfill.

Where the precise location of these sites was known, soil loss was quantitatively analyzed. Where the location of these sites has not been finalized, or will not be determined until final design, a qualitative analysis was done.

The actual size of each pad has not been determined. It is assumed that the pad will extend over the entire area allotted to each site, even though a buffer strip will be retained around each site. Expected soil loss has been overestimated as the pads will not cover the entire area.

Changes in Soil Physical and Chemical Characteristics

Project activities can change soil physical and chemical properties through:

- wind erosion
- water erosion
- mixing
- air emissions
- road dust deposition
- leaks and spills

Wind Erosion

Only sandy soils were regarded as susceptible to wind erosion. These soils were identified in the soils and landforms database and could be assessed quantitatively.

Water Erosion

As discussed previously in Section 8.2.6.1, Landforms, an assessment attribute for potential water erosion was assigned for each landform. The quantitative results from that section are included in the soil quality assessment.

Mixing

Mixing is assumed to occur through trench excavation and material replacement. For quantitative analysis, the area of mixing was calculated assuming a 2-m-wide trench for the gathering pipelines and the natural gas pipeline, and 1.5-m-wide trench for the natural gas liquid (NGL) pipeline from the Inuvik area facility to Norman Wells. Other instances of soil mixing were considered small in extent and are discussed qualitatively in the assessment.

Air Emissions

Emissions of NO_x, SO_2 and other substances are assessed in Section 2, Air Quality, which also presents deposition of acidifying substances as potential acid input (PAI). Acid deposition was not considered a factor that might affect soil quality because PAI from project emissions was predicted to be below the monitoring threshold (0.17 keq/ha/a) for sensitive soil (CASA and AENV 1999). Air emissions, however, will add to the soil nutrient pool and, in the nutrient-poor soils typical of cold climates, might have a fertilizer effect on plant growth.

Road Dust Deposition

The potential effect of road dust was evaluated qualitatively in this assessment.

Leaks and Spills

The potential effect of small leaks and spills was evaluated qualitatively in this assessment.

8.3 Effects on Landforms

8.3.1 Effect Pathways

The three primary cause-effect mechanisms on landforms are related to physical, thermal and drainage changes. The effect pathway diagram (see Figure 8-4) shows the key and intermediate pathways by which the project could affect landform valued components and key indicators.

Each pathway was evaluated to determine if it would be applicable, given the mitigation planned for the project. A pathway was considered inapplicable if mitigation would eliminate the potential for effects on landforms. Pathways from other disciplines were also considered inapplicable if they would have no effect on landforms. The pathways considered applicable for the landforms assessment are shown in Table 8-8.

Table 8-8: Applicable Pathways for Project Effects on Landforms

Primary Pathway	Intermediate Pathways	Applicability
Material removal, burial or mixing	No intermediate pathway	●
Change in surface or subsurface flow	Subsidence or heave	●
	Change in slope	●
	Change in material strength	●
	Change in thermal regime (change in air quality, vegetation or hydrology)	●
Increase in mass movement	Change in slope	●
	Change in material strength	●
	Change in thermal regime (change in air quality, vegetation or hydrology)	●
Change in erosion	Change in slope	●
	Change in material strength	●
	Change in thermal regime (change in air quality, vegetation or hydrology)	●
	Change in hydrology or vegetation	●
	Change in vegetation	●
NOTES: ● = applicable		

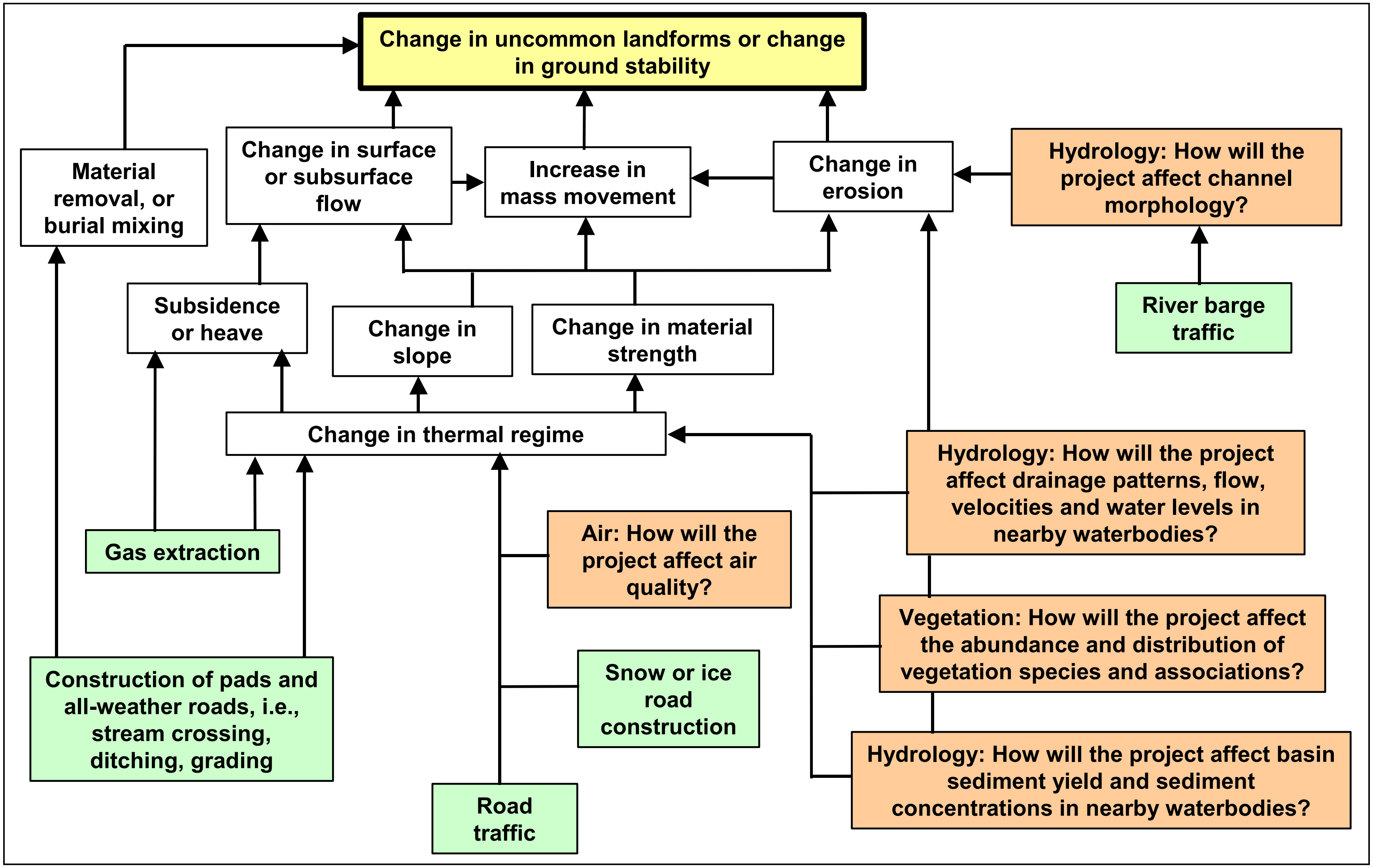

Figure 8-4: Effect Pathways – Landforms

Four key effect pathways that can lead to effects on landforms are:

- removal, burial or mixing of material – alteration or loss of uncommon landforms from project activities. Key mechanisms include physical changes such as grading, and borrow or trench excavation.
- change in surface or subsurface drainage – changes in surface or subsurface water flow that cause pond formation or other effects on soil moisture. Key mechanisms include physical changes such as grading, excavation and gas extraction, or thermal changes such as thaw subsidence, or frost bulbs or ground surface heave.
- increase in mass movement of landforms – changes that cause mass movement of landforms. Key mechanisms include physical changes such as grading, thermal changes such as thawing of slopes, or altered surface and subsurface drainage.
- increase in erosion – changes in ground conditions that cause water or wind erosion. Key mechanisms include physical changes such as grading, changes in thermal conditions such as thaw settlement, or changes in drainage conditions such as altered surface or subsurface flow patterns.

Interactions with other biophysical factors also initiate potential effects on ground stability or uncommon landforms. These include changes in air quality, hydrology and vegetation. Most project effects are initiated during construction, except for potential ground subsidence at Niglintgak and Taglu caused by gas extraction during operations.

The mechanisms of change are often related. For example, borrow material excavation can result in the removal of a landform, such as an esker, and also change the thermal or drainage conditions. Subsidence of the ground surface caused by gas extraction could lead to landform losses or changes, and altered thermal and drainage conditions. This could lead to further localized subsidence, ponds, erosion or slope instability.

8.3.1.1 Ground Stability

Potential effects on ground stability include altered drainage, mass movement and erosion. The primary mechanisms for these effects are physical and thermal changes in landforms. Drainage effects include potential for thaw settlement and pond formation in permafrost areas, and altered surface and subsurface drainage from frost bulb formation and ground surface heave in unfrozen areas. Mass movement includes the potential for slides and thaw-flow. Erosion includes potential water and wind erosion.

Thaw Subsidence and Pond Formation

Thaw subsidence and pond formation can result from project activities and changes in thermal equilibrium. Figure 8-5 illustrates the progression of thaw settlement and pond formation.

The main factor that contributes to subsidence and pond development is an increase in thaw depth in ice-rich soils. As thawing progresses, the surface settles and water migrates to it. The amount of thaw settlement depends on ground texture and moisture content, i.e., ice content.

Ponds can occur in subsided areas if the volume of water flowing into the depression exceeds the volume of water leaving through drainage or evaporation. Incoming water comprises precipitation water and groundwater, including melted ice.

Frost Bulbs or Surface Heave and Drainage Disruption

The two general mechanisms by which frost effects can disrupt drainage are:

- heave of the ground surface and disruption of surface drainage, potentially leading to erosion or slope instability
- freezing of the ground around buried pipelines, i.e., frost bulb formation, and disruption (damming) of subsurface water flow

Both mechanisms are most likely to occur on cross slopes. Figure 8-6 illustrates the conditions that lead to potential drainage disruption caused by frost bulb growth or surface heave mechanisms.

Based on project design specifications, pipe temperature north of Fort Good Hope should be below freezing. This area is in continuous permafrost and potential for frost bulb formation is low. South of Little Chicago pipe temperature varies with location and time of year, but is close to zero over most of the route. On this basis, it was concluded that in discontinuous permafrost conditions there are locations where pipe temperature will be below freezing and would be prone to drainage disruption effects from frost bulb growth or ground surface heave.

Damming of surface or subsurface water flow can be caused by formation of a frost bulb around buried pipeline. A frost bulb refers to an area of frozen ground, which was previously unfrozen, around the operating pipeline. The presence of a frost bulb can change soil drainage because ponds can form upslope of the pipe, slope instability can result or drainage pathways can be redirected.

Figure 8.5 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

Figure 8.6 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

Where frost bulbs form in unfrozen ground, the potential for disrupted drainage depends mainly on material texture, existing drainage conditions and ground slope. Poorly drained flat areas are either fine-textured materials that would not be affected by a change in ground surface, or saturated coarse-textured materials where a frost bulb would not likely affect groundwater flow. Well-drained flat areas are usually coarse-textured soils that are not sensitive to frost bulb growth or surface heave. Frost bulbs will likely not affect well-drained steep slopes. Poorly drained steep slopes are typically fine-textured materials that shed water by surface drainage. In these locations, the amount of ground surface heave would have to be high to alter drainage conditions. These areas are not considered susceptible to disrupted drainage from frost bulb or heave effects.

The frost bulbs will begin to thaw after the flow of chilled gas is shut off at the end of operations. The bulbs will gradually reduce in size and the surface and groundwater flow characteristics will approach conditions that existed before project construction and operations. Some residual effects related to frost heave of the pipeline and groundwater surface might remain in some areas.

Conditions most susceptible to altered drainage from frost effects include gentle to moderately steep cross slopes combined with moderate to poor drainage conditions. Such conditions have medium-textured soils, and existing drainage conditions could be affected by a change in ground surface level or development of a frost bulb.

Mass Movement

Mass movement is classified as flows or slides. Flows have a fluid character, whereas slides have a rigid character, with downslope movement mostly as intact blocks. Grading, excavation or removal of surface vegetation can trigger mass movement. More details on the characteristics and physical processes in slides and flows are presented in Volume 3, Section 8, Soils, Landforms and Permafrost.

Slides

Slope instability can be caused by physical, thermal or drainage changes, and is often the result of a combination of the mechanisms. Slope instability can be retrogressive, or can expand and maintain ongoing and periodic movement patterns once initiated (see Figure 8-7).

Figure 8.7 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

Using methods developed by Hanna and McRoberts (1988), McRoberts and Morgenstern (1974), and Morgenstern and Nixon (1971), in conjunction with estimated thaw depths, the various landform units were evaluated for potential slope instability. Key observations from this evaluation include:

- potential for sliding increases along the pipeline right-of-way with the width of the thawed area, reaching a maximum at about 25 m
- for clay-textured materials south of Fort Good Hope, it is expected that the critical thaw depth for instability will occur before the maximum predicted thaw depth and that critical thaw depth will be reached within the first several years (likely five to 10) of operations

Flows

Soil flows are common in the Tundra, Transition Forest and North Taiga Plains A ecological zones. The mechanism differs from slide movement discussed previously. Flows occur where the toe of the slope does not have material to resist movement, and in ice-rich soils. Such conditions are usual for a flatter slope with a steep face in the lower slope, as would occur at the edge of lakes, rivers or depressions.

Field observations and experience suggest that soil flows occur near river and creek valleys, lakes and depressions when slope angles are less than 20%.

Water Erosion

The four main factors that influence surface erosion are:

- precipitation
- soil texture
- vegetation
- ground surface topography

Figure 8-8 illustrates the types of erosion that can occur.

For this assessment, the only applicable pathway for erosion is where project activities intersect with landforms that have slopes and material texture susceptible to erosion. Erosion along rivers caused by barge traffic is not considered an applicable pathway, based on the assessment in Section 5, Hydrology.

Wind Erosion

When vegetation is removed from aeolian deposits, wind erosion can occur.

Figure 8.8 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

8.3.1.2 Uncommon Landforms

The main potential effects on uncommon landforms include excavation, mixing or burial caused by project activities such as excavation of glaciofluvial landforms for borrow material and burial of patterned ground for pad construction.

8.3.2 Overview of Project Design and Mitigation

The primary mitigation strategy refers to a suite of options that could be used to address the identified issues in most situations. Site-specific mitigation may be required in certain circumstances. Following construction, the need for additional mitigation will be determined by monitoring.

Most potential effects from the project will be mitigated through management practices applied during design, construction, operations and decommissioning.

Effect pathways are discussed in more detail in Section 8.3.1, Effect Pathways. Mitigation strategies are presented in Table 8-9.

Table 8-9: Mitigation Strategies for Ground Stability and Uncommon Landforms

Effect Pathway	Primary Mitigation Strategy
Altered drainage, erosion or slope instability caused by pipeline right-of-way and access road clearing and grading	Conduct most pipeline construction activities during winter. Reduce grading and surface disturbance especially on steep slopes and thaw-unstable ground. Design for thaw settlement.
Altered drainage, erosion and slope instability caused by pipeline ditching and backfilling	Use thaw-stable backfill. Reclaim, stabilize and armour slopes and banks as necessary. Place an insulting cover on cut surfaces in thaw-unstable ground where required.
Altered drainage and erosion caused by thaw settlement along the pipeline ditch	Place additional fill material in areas of thaw settlement.
Loss of uncommon landforms along the pipeline right-of-way	Avoid uncommon landforms, where practical.
Altered drainage and ground instability caused by access road construction	Install borrow material on access roads, as appropriate. Use geotextile to limit loss of borrow material. Construct winter roads, where required.
Altered drainage and ground instability caused by facilities construction	Provide sufficient insulation for pads to protect permafrost. Install drainage diversions around facility sites such as compressor stations, where required.

Most effects will be initiated during construction, resulting in changes that will persist through the remainder of the project. Decommissioning and abandonment will remove many project components that generate effects. Some effects are longer lasting, and those related to project components abandoned in place are expected to persist after decommissioning and abandonment, e.g., frost bulb thaw.

8.3.3 Niglintgak

Niglintgak will have six to 12 production wells drilled from the proposed north, central and south well pads, associated above-ground flow lines, a remote drilling sump, one disposal well and supporting infrastructure (see Volume 2, Project Description).

Two options are being considered for the Niglintgak gas conditioning facility:

- on a barge in a side channel of Kumak Channel adjacent to Kumak Island
- on land on the east bank of Kumak Channel

8.3.3.1 Baseline Conditions

Volume 3, Section 8, Soils, Landforms and Permafrost presents baseline information on the landforms in Niglintgak. Table 8-10 provides an overview of the major landform types in the Niglintgak LSA, relative to the facility and pipeline rights-of-way.

Table 8-10: Summary of Landforms in the Niglintgak LSA

Landform Type	Area in LSA		Barge-based Gas Conditioning Facility				Land-based Gas Conditioning Facility			
			Area Covered by Facilities		Area Crossed by Flow Lines		Area Covered by Facilities		Area Crossed by Flow lines	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Colluvial	16	0.2	0	0	0.1	0.6	0	0	0.1	0.6
Fluvial deltaic	3,044	44.3	7.1	0.2	11.1	0.4	7.1	0.2	9.7	0.3
Glaciofluvial	224	3.3	0	0	3.3	1.5	7.2	3.2	1.3	0.6
Lacustrine	132	1.9	0	0	2.8	2.1	0	0	2.8	2.1
Morainal	390	5.7	0	0	1.7	0.4	0	0	1.0	0.3
Other, i.e., water	3,070	44.6	2.6	0.1	7.9	0.3	2.6	0.1	7.6	0.3
Total	6,876	100.0	9.7	0.1	26.9	0.4	16.9	0.3	22.5	0.3

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

Most of the Niglintgak LSA consists of low-relief, recent fluvial deposits of the Mackenzie River Delta. River channels, thaw settlement ponds and waterbodies are common. Upland areas contain morainal and glaciofluvial deposits. Lacustrine deposits occupy low-lying shorelines. The gas conditioning facility for the land-based option will be located on glaciofluvial deposits.

Fluvial deposits at Niglintgak comprise silt, sand and some gravel, with a thin organic veneer. Silt actively deposits in low-lying areas during flooding. Related features include poorly defined, low-centred polygons and ice wedges. Water erosion, sedimentation and channel widening are ongoing.

The active layer depth varies considerably. Permafrost occurs in most areas but there are taliks beneath and adjacent to waterbodies. Segregated ice bodies are expected in patterned ground areas. A few pingos occur in the Niglintgak LSA, but not within the disturbance area for the anchor fields.

8.3.3.2 Niglintgak Effects

The assessment of potential effects on ground stability was based on areas identified as having potential for subsidence and pond formation, and for erosion along flow line and lateral rights-of-way. The assessment of effects on uncommon landforms was based on occurrences of ice-wedge polygons in the areas where facilities and pipelines will be located.

Table 8-11 summarizes the effect attributes for the barge-based and land-based gas conditioning facility at Niglintgak.

Table 8-11: Effects on Landforms – Niglintgak: Barge-Based or Land-Based Gas Conditioning Facility

Valued Component	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Ground stability	Construction	Adverse	Low	Local	Long term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Uncommon landforms	Construction	Adverse	Low	Local	Long term to Far future
	Operations	Adverse	Low	Local	Far future
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
NOTE: N/A = not applicable					

The development at Niglintgak will cause subsidence at the ground surface by removal of gas and fluids from the reservoir at depth. The subsidence area will be:

- oval-shaped, with the long axis centred beneath Middle Channel south of the proposed drilling pads. The length of the long axis will be about 7 km and the width will be about 3 km.
- deepest beneath Middle Channel, about 0.45 m after 25 years, and taper to nil toward the edges. For this assessment, incremental subsidence was assumed to

take place almost uniformly during 25 years of expected gas extraction, i.e., about 18 mm/a.

The expected subsidence could cause channel banks and floodplains to flood more frequently and cause some land areas to be covered permanently by water.

Ground Stability

Table 8-12 summarizes potentially affected areas related to ground stability. The areas represented are from the flow line rights-of-way and a short part of the Niglintgak lateral in the Niglintgak LSA. The two key indicators used to assess potential effects at Niglintgak were potential for erosion and potential for pond formation from thaw settlement.

Table 8-12: Areas of Potential Ground Stability Effects – Niglintgak

Genetic Material	Area in LSA	Barge-based Gas Conditioning Facility				Land-based Gas Conditioning Facility			
		Area with Potential for Pond Formation		Area with Potential for Water Erosion		Area with Potential for Pond Formation		Area with Potential for Water Erosion	
	(ha)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Colluvial	16	0	0	0	0	0	0	0	0
Fluvial deltaic	3,044	10.0	0.3	0	0	8.6	0.3	0	0
Glaciofluvial	224	0	0	0	0	0	0	0	0
Lacustrine	132	2.8	2.2	0	0	2.8	2.1	0	0
Morainal	390	0	0	1.2	0.3	0	0	1.2	0.3
Other, i.e., water	3,070	0	0	0	0	0	0	0	0
Total	6,876	12.8	0.2	1.2	<0.1	11.4	0.2	1.2	<0.1

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

Construction

Elevated well pads and flow lines will be constructed from temporary snow pads during the winter. Drilling operations will include winter camps supported on snow pads adjacent to the elevated drilling platforms. Summer activities will be carried out on the drilling platforms. The elevated platforms and the barge-based gas conditioning facility will reduce the potential for ground surface thaw and related effects. For this method of construction, the areas of actual disturbance will likely be reduced from the estimated areas of potential disturbance.

Construction of above-ground facilities during the winter, from snow pads, will cause a neutral to adverse direction of effect. The magnitude will be low, based on the small areas of disturbance identified in the Niglintgak LSA, accounting for up to 2% of particular landforms. The duration of effects should be limited to the short term. The effects of construction will be limited to a small part of the LSA.

Operations

The well pads and flow lines will be operated from structures above the ground, with maintenance scheduled for winter months from temporary snow pads. Operations will not cause additional areas of disturbance to those initiated during construction for the land-based or barge-based options.

Drilling will last for about three years, and drill cuttings will be transported for disposal over a winter road to a remote sump about 30 km away. The materials will be frozen, buried and covered. The size of the sump will be about 2 ha.

Effects on potential areas of ground stability from subsidence caused by gas and liquid extraction are expected to be small. The subsidence is primarily located beneath Middle Channel and will occur slowly relative to potential changes in indicators of ground stability, i.e., erosion, slope instability or thaw subsidence.

Operations activities will result in an adverse direction of low magnitude. Potential effects will be confined to the Niglintgak LSA and will occur into the far future, mainly because of activities related to sump disposal and subsidence.

Decommissioning and Abandonment

Elevated platforms, flow lines and wellheads will be removed. The support piles, casing and conductor pipes will be cut off below ground surface, and the upper parts removed. The gas conditioning facility will be removed. In the case of the land-based option, the granular material will be reclaimed in place. Subsidence from reserves extraction will not be reversed. The activities will have no effect on landform stability.

Uncommon Landforms

Table 8-13 summarizes affected uncommon landforms. Parts of the proposed facilities are located in areas of patterned ground, comprising ice-wedge polygons and glaciofluvial deposits. Pingos occur in the Niglintgak LSA but will not be affected by the proposed development.

Table 8-13: Areas of Potential Uncommon Landforms Effects – Niglintgak

Uncommon Landform	Area in LSA	Land-based Area Affected		Barge-based Area Affected	
	(ha)	(ha)	(%)	(ha)	(%)
Glaciofluvial	224	8.4	3.8	0	0
Patterned ground	1,610	20.1	1.2	20.1	1.2

Decommissioning the barge-based gas conditioning facility will include refloating the barge by removing the ballast water and dredging out the surrounding sediments that will have accumulated.

Construction

Potentially affected areas during construction represent only about 1% of observed patterned ground in the Niglintgak LSA. About 4% of glaciofluvial deposits in the LSA occur where facilities and pipelines will be located. The magnitude of the effect on these deposits will be low. Duration of the effects on patterned ground will extend through operations and decommissioning and abandonment. Effects generated during construction will be limited to the immediate area of development.

Operations

Subsidence during operations could affect uncommon landforms in the Niglintgak LSA. The potential effect will be low magnitude.

Decommissioning and Abandonment

Effects of decommissioning and abandonment on uncommon landforms are the same as those described previously for effects of decommissioning and abandonment on ground stability at Niglintgak.

8.3.4 Taglu

Taglu includes the gas conditioning facility, 10 to 15 production wells on a single well pad, associated short above-ground flow lines and one to two disposal wells and supporting infrastructure including an airstrip (see Volume 2, Project Description).

8.3.4.1 Baseline Conditions

Detailed information on the landforms in Taglu is in Volume 3, Section 8, Soils, Landforms and Permafrost. Table 8-14 provides an overview of the major landform units in the Taglu LSA, relative to the proposed facilities.

Most of the LSA is low-relief, recent fluvial deposits of the Mackenzie River. River channels, thaw settlement ponds and waterbodies are common. Upland areas contain lacustrine, morainal and lesser amounts of glaciofluvial deposits. Lacustrine deposits occupy low-lying shorelines of thaw settlement lakes and ponds and connecting lowlands. Glaciofluvial deposits do not occur in the proposed facility areas.

Table 8-14: Summary of Landforms in the Taglu LSA

Landform Type	Area in LSA		Area Covered by Facilities		Area Covered by Lateral	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Colluvial	3	<0.1	0	0	0	0
Fluvial deltaic	5,311	60.5	18.2	0.3	5.8	0.1
Glaciofluvial	78	0.9	0	0	0	0
Fluvial	5	0.1	0	0	0	0
Lacustrine	186	2.1	0	0	0	0
Morainal	456	5.2	0	0	0	0
Other, i.e., water	2,736	31.2	0.1	<0.1	0	0
Total	8,775	100.0	18.3	0.2	5.8	0.1

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

Delta deposits at Taglu comprise silt, sand and some gravel, with a thin organic veneer. Silt actively deposits in low-lying areas during flooding. Related features include poorly defined low-centred polygons and ice wedges. Water erosion, sedimentation and channel widening are ongoing.

The active layer depth varies considerably. Permafrost occurs in most areas but taliks occur beneath and adjacent to waterbodies. Segregated ice bodies are expected in patterned ground areas. A few pingos occur in the LSA but not within the disturbance area for facility field development.

8.3.4.2 Taglu Effects

The well pad will support the drilling equipment and will consist of either gravel fill or a steel deck. The pad will provide sufficient area to support the drilling rig, and any additional equipment and materials required. Elevated flow lines will transport the natural gas and NGLs from the wells to the gas conditioning facility.

Table 8-15 summarizes the effect attributes for Taglu facilities.

Proposed drilling and gas production operations at Taglu might result in subsidence at the ground surface caused by removing the gas from the reservoir. The greatest amount of subsidence will be in the order of 0.3 to 0.5 m north of the production facilities after 25 to 30 years. The subsidence dish will be located primarily beneath land areas. Subsidence could cause the banks and floodplains adjacent to channels and waterbodies to flood more frequently, and also cause some areas to be covered permanently by water.

Table 8-15: Effects on Landforms – Taglu

Valued Component	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Ground stability	Construction	Adverse	Low	Local	Long term
	Operations	Adverse	Low	Local	Far future
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Uncommon landforms	Construction	Adverse	Low	Local	Far future
	Operations	Adverse	Low	Local	Far future
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A

NOTE:
N/A = not applicable

Ground Stability

The drilling areas will include a single well pad. The pile foundations will be set in drilled holes and frozen in place. Actively refrigerated conductors will maintain integrity of the foundation. Effects on ground stability include potential for subsidence and pond formation caused by installing the section of buried lateral, and subsidence from extracting reserves during operations. Table 8-16 summarizes the areas of potential effects on ground stability along the sections of buried laterals.

Table 8-16: Areas of Potential Ground Stability Effects – Taglu

Genetic Material	Area in LSA	Area with Potential for Pond Formation	
	(ha)	(ha)	(%)
Colluvial	3	0	0
Fluvial deltaic	5,311	5.8	0.1
Glaciofluvial	78	0	0
Fluvial	5	0	0
Lacustrine	186	0	0
Morainal	456	0	0
Other, i.e., water	2,736	0	0
Total	8,775	5.8	0.1

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

The Taglu facilities are not expected to cause ground instability, because pads will support structures and elevated flow lines. Sections of the gathering pipeline lateral traverse the Taglu LSA and could cause pond formation at some locations.

Construction

A portion of the buried laterals was located in the Taglu LSA. The buried laterals will be constructed from temporary snow pads during the winter. Construction will require excavation and will cause potential adverse effects on ground stability. The magnitude is low because of the small areas where pond formation could occur, i.e., less than 1% of the landform is within the Taglu LSA. Duration of effects should be long term.

Operations

Effects on ground stability from subsidence caused by gas extraction are expected to be small and will take place slowly compared with potential changes from erosion or thaw subsidence. Effects should be confined to the Taglu LSA but will not be reversed following decommissioning and abandonment. Activities related to the lateral’s operations phase will mostly occur during the winter months. Effects will be short- to medium-term duration and confined to small areas of the LSA.

Decommissioning and Abandonment

Drilling platforms, flow lines and wellheads will be removed. Support piles, casing and conductor pipes will be cut off below ground surface, and the upper parts removed. The gas conditioning facility will be removed and the pads could be reclaimed. Reclamation activities should not cause any new effects on ground stability. Effects of ground subsidence at Taglu will not be reversed following decommissioning and abandonment.

Uncommon Landforms

Parts of the proposed facilities are located in areas of patterned ground that consist of ice-wedge polygons (see Table 8-17). Pingos and glaciofluvial deposits occur in the Taglu LSA but will not be affected by the field development.

Table 8-17: Areas of Potential Uncommon Landforms Effects – Taglu

Uncommon Landform	Area in LSA	Area Affected	
	(ha)	(ha)	(%)
Glaciofluvial	78	0	0
Patterned ground	3,941	22.6	0.5

Construction

Affected areas of patterned ground represent less than 1% of the ice-wedge polygon areas in the Taglu LSA. Therefore, the magnitude of effect is low. Pingos and glaciofluvial deposits occur in the LSA but are not affected by facilities.

Effects on uncommon landforms extend into the far future because pads will not be removed during decommissioning and abandonment.

Operations

Operations include activities associated with fluids disposal and maintenance. The facilities and flow lines will be operated from elevated structures above thick pads. A lined in-ground containment pond will provide temporary storage for the first well cuttings. The containment pond contents will be injected and the site reclaimed after the first drilling program.

Subsidence from gas extraction will potentially cause the loss of uncommon landforms but the area is expected to be small compared with total landforms area in the Taglu LSA. Effects will extend into the far future.

Decommissioning and Abandonment

During decommissioning, above-ground facilities will be removed. It is possible that the pads will be left in place or removed. Support piles, casing and conductor pipes will be cut off below pad surface and the upper parts removed. No new disturbance to uncommon landforms is expected. The activities will cause neutral effects on uncommon landforms because most of the activity will occur on existing gravel pads.

8.3.5 Parsons Lake

Parsons Lake includes the gas conditioning facility, north and south pads, above-ground flow lines and two disposal wells (see Volume 2, Project Description). The site will be developed in two phases. The north pad will be developed first, including a single well pad with nine to 19 production wells, two disposal wells, the gas conditioning facility and supporting infrastructure including an airstrip. The south pad will follow development of the north pad about seven to ten years later. The south pad will include a single well pad with three to seven wells. An above-ground flow line will transport product from the south pad to the north pad for processing.

8.3.5.1 Baseline Conditions

Detailed information on the landforms in Parsons Lake is in Volume 3, Section 8, Soils, Landforms and Permafrost. Table 8-18 provides an overview of the major landform units in the Parsons Lake LSA, relative to proposed facilities.

Table 8-18: Summary of Landforms in the Parsons Lake LSA

Landform Type	Area in LSA		Area Covered by Facilities		Area Covered by Lateral	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Colluvial	325	0.8	0	0	0	0
Glaciofluvial	7,350	17.9	19.6	0.3	0.3	<0.1
Fluvial	1,226	3.0	0	0	0	0
Lacustrine	6,878	16.7	0	0	0.3	<0.1
Morainal	5,851	14.2	2.8	0.1	0.5	<0.1
Tertiary	2,229	5.4	0	0	0	0
Other, i.e., water	17,240	42.0	0.8	<0.1	0	0
Total	41,099	100.0	23.2	0.1	1.1	<0.1

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

Surface deposits at Parsons Lake are primarily glaciofluvial, lacustrine and hummocky glacial morainal deposits. Tertiary landforms include Tertiary bedrock plus a thin veneer of surficial deposits. Topography is characterized by thaw subsidence in fine-grained deposits. Low areas are mostly filled with postglacial lakes and organic deposits.

The active layer depth varies considerably. Permafrost is present in most areas but taliks likely occur beneath and adjacent to waterbodies. A few pingos occur in the LSA but not within the proposed facility sites. Patterned ground was observed in the LSA. Thaw slides occur in the area but are uncommon.

8.3.5.2 Parsons Lake Effects

The pads will have sufficient area to support drilling equipment, third party services and any additional equipment and materials required. The Parsons Lake assessment was based on potential loss of uncommon landforms, specifically glaciofluvial deposits. Subsidence caused by gas extraction is not expected at Parsons Lake.

Table 8-19 summarizes effect attributes for the facilities in the Parsons Lake LSA.

Ground Stability

Drilling and facilities pad will include steel piles and borrow material. Piles will extend into the pads to support drilling facilities, structures and flow lines. A short part of the Parsons Lake lateral is in the Parsons Lake LSA. Effects on ground stability include potential for ground subsidence and pond formation from installing the section of buried lateral (see Table 8-20).

Table 8-19: Effects on Landforms – Parsons Lake

Valued Component	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Ground stability	Construction	Adverse	Low	Local	Long term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Uncommon landforms	Construction	Adverse	Low	Local	Long term to far future
	Operations	Adverse	Low	Local	Far future
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A

NOTE:
N/A = not applicable

Table 8-20: Areas of Potential Ground Stability Effects – Parsons Lake

Landform Type	Area in LSA	Area With Potential for Pond Formation	
	(ha)	(ha)	(%)
Colluvial	325	0	0
Glaciofluvial	7,350	0	0
Fluvial	1,226	0	0
Lacustrine	6,878	0.3	<0.1
Morainal	5,851	0	0
Tertiary	2,229	0	0
Other, i.e., water	17,240	0	0
Total	41,099	0.3	<0.1

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

The Parsons Lake facilities are not expected to cause ground instability because pads and piles will be used to support structures and elevated flow lines.

Construction

A short portion of the laterals was located in the Parsons Lake LSA. Construction of the lateral will require excavation in areas susceptible to thaw subsidence. The magnitude is low because less than 1% of landforms are potentially affected. Duration of effects should be limited to operations.

Operations

Activities during the lateral's operations phase will mostly occur during the winter months and affect small areas of the Parsons Lake LSA. Effects will be short to long term and confined to the LSA.

Decommissioning and Abandonment

Reclamation activities should have no effect on ground stability in the Parsons Lake LSA.

Uncommon Landforms

Table 8-21 shows potential loss in uncommon landforms in the Parsons Lake LSA, including glaciofluvial deposits and patterned ground (ice-wedge polygons). Pingos occur in the LSA but will not be affected by the proposed facilities. Aeolian deposits were not observed in the study areas.

Table 8-21: Areas of Potential Uncommon Landforms Effects – Parsons Lake

Uncommon Landform	Area in LSA	Area Affected	
	(ha)	(ha)	(%)
Glaciofluvial	7,350	19.9	0.3
Patterned ground	6,694	0.3	<0.1

Construction

Part of the Parsons Lake lateral will cross ice-wedge polygons, but the potentially affected areas represent less than 0.1% of the Parsons Lake LSA. Facility pads will cover about 20 ha of glaciofluvial deposits, but this represents less than 1% of this landform in the LSA. The magnitude is low for both landforms. The duration of the effects will extend into the far future. Effects generated during construction will be confined to the LSA.

Operations

The facilities at the south pad at Parsons Lake will be installed about seven to 10 years after start of construction at the north pad. Effects during operations will be the same as during construction.

Decommissioning and Abandonment

Activities during decommissioning and abandonment are not expected to affect uncommon landforms.

8.3.6 Gathering Pipelines and Associated Facilities

The gathering pipelines connect the three production fields to the Inuvik area facility near Inuvik (see Volume 2, Project Description). For this assessment, the gathering pipelines and associated facilities include the Niglintgak lateral, Taglu lateral, Parsons Lake lateral, Storm Hills lateral, Inuvik area facility, Storm Hills pigging facility, two intermediate block valves and pads for the trenchless installation at East Channel of the Mackenzie River.

8.3.6.1 Baseline Conditions

Detailed information on landforms in the gathering pipelines and associated facilities is in Volume 3, Section 8, Soils, Landforms and Permafrost. Table 8-22 provides an overview of the major landform units in the gathering pipelines and associated facilities LSA, relative to the proposed facilities.

Table 8-22: Summary of Landforms in the Gathering Pipelines and Associated Facilities LSA

Landform Type	Area in LSA		Area Covered			
			Pipelines		Facilities[1]	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Colluvial	199	1.2	10	5.0	0	0
Fluvial deltaic	1,920	11.2	67	3.5	0	0
Glaciofluvial	2,260	13.2	101	4.5	0	0
Fluvial	586	3.4	22	3.8	0	0
Lacustrine	1,810	10.6	72	4.0	0	0
Morainal	3,394	19.8	155	4.6	0	0
Tertiary	4,444	25.9	190	4.3	5	0.1
Other, i.e., water	2,517	14.7	30	1.2	0	0
Total	17,130	100.0	647	3.8	5	1.9

NOTE:
1 Includes Storm Hills and block valves; does not include Inuvik area facility
Percentage is based on total area of facilities or pipelines divided by total area in LSA

The gathering pipelines and associated facilities LSA is dominated by Tertiary landforms, i.e., thin moraine, and glaciofluvial or lacustrine deposits over shallow bedrock. Other landforms include glacial morainal, glaciofluvial, lacustrine and deltaic deposits. Topography is characterized by thaw subsidence in fine-grained deposits. Low areas are mostly filled with postglacial lakes and organic deposits.

The active layer depth varies considerably. Permafrost occurs in most areas but taliks occur beneath and adjacent to waterbodies. Pingos occur in the LSA but were not observed along the gathering pipeline rights-of-way or at facility sites.

8.3.6.2 Gathering Pipelines and Associated Facilities Effects

Table 8-23 summarizes the effect attributes for the gathering pipelines and associated facilities LSA.

Table 8-23: Effects on Landforms – Gathering Pipelines and Associated Facilities

Valued Component	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Ground stability	Construction	Adverse	Low	Local	Long term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Uncommon landforms	Construction	Adverse	Low	Local	Long term to far future
	Operations	Adverse	Low	Local	Far future
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A

NOTE:
N/A = not applicable

The gathering pipeline rights-of-way and facilities are located in areas where many landforms are susceptible to processes that affect ground stability. Uncommon landforms are also crossed, including patterned ground and glaciofluvial deposits.

Ground Stability

The gathering pipelines will be subject to potential effects on ground stability related to erosion, slope instability and permafrost thaw and freezing effects along the rights-of-way (see Table 8-24).

Construction

Construction of the gathering pipelines could cause erosion and thaw settlement leading to pond formation, which could affect ground stability of the lands in the gathering pipelines and associated facilities LSA. Some areas with potential for slope drainage disruption and slope instability are also encountered. The effects from thaw, subsidence and pond formation would likely occur during operations. Erosion would likely occur within the first year after exposure of the ground surface, in areas where vegetation is disturbed, mostly along the ditch line.

Less than 2% of the LSA is susceptible to ground stability effects. Therefore, the magnitude of potential effects is low. Effects would be confined to the LSA.

Table 8-24: Areas of Potential Ground Stability Effects – Gathering Pipelines and Associated Facilities

Landform Type	Area in LSA	Area with Potential for Pond Formation		Area with Potential for Water Erosion		Area with Potential Effects from Frost Bulbs or Surface Heave		Area with Potential for Slope Instability	
	(ha)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Colluvial	199	10	5.0	1	0.5	0	0	1	0.5
Fluvial deltaic	1,920	60	3.1	0	0	0	0	0	0
Glaciofluvial	2,260	6	0.3	21	0.9	0	0	0	0
Fluvial	586	10	1.7	1	0.2	0	0	0	0
Lacustrine	1,810	67	3.7	0	0	0	0	0	0
Morainal	3,394	79	2.3	23	0.7	0	0	0	0
Tertiary	4,444	0	0	4	0.1	7	0.2	0	0
Other, i.e., water	2,517	0	0	0	0	0	0	0	0
Total	17,130	232	1.4	51	0.3	7	<0.1	1	<0.1
NOTE: Percentage is based on total of area of facilities or pipelines divided by total area in LSA									

Operations

The gathering pipelines will be operated at temperatures below zero to reduce potential effects of potential thawing of the ground surface. Traffic and maintenance vehicles will not normally be required along the pipeline routes during operations. Operational effects on ground stability are expected to be lower magnitude than those initiated during construction.

Decommissioning and Abandonment

The buried laterals will likely be abandoned in place, which is less intrusive than removing the pipelines. As ground thermal regimes recover, and annual thaw depths return to the baseline active layer depth, the pipe will become encased in frozen soils.

Decommissioning and abandonment is expected to have no effect on ground stability.

Uncommon Landforms

Table 8-25 summarizes affected uncommon landforms. Parts of the proposed facilities are located in areas with glaciofluvial deposits and patterned ground.

Table 8-25: Areas of Potential Uncommon Landforms Effects – Gathering Pipelines and Associated Facilities

Uncommon Landform	Area in LSA	Affected Area	
	(ha)	(ha)	(%)
Glaciofluvial	2,260	101	4.5
Patterned ground	3,422	150	4.4

About 50 ha of surface area will be covered by pads for facilities in the gathering pipelines and associated facilities LSA. The facility pad areas will be used during operations and might be removed during abandonment. For this assessment it is considered that the pads would be left in place.

Construction

The gathering pipeline rights-of-way and facility sites cross glaciofluvial deposits and patterned ground that includes ice-wedge polygons, and high and low-centred polygons. For both types of uncommon landforms, the area intersected is less than 5% of the amount of these landforms in the gathering pipelines and associated facilities LSA. Effects will be low magnitude, local in extent and will last into the far future.

Operations

Activities during operations will have limited effects on uncommon landforms. The areas of impact will be much smaller than those affected during initial construction. Therefore, the effects on uncommon landforms during operations will be low magnitude. The other effect attributes for landforms are similar to those during construction.

Decommissioning and Abandonment

Decommissioning and abandonment activities along the gathering pipelines are not expected to cause any new disturbances leading to ground instability or loss of uncommon landforms.

8.3.7 Pipeline Corridor

For the purposes of the impact assessment, the pipeline corridor includes the natural gas pipeline, the NGL pipeline and pipeline facilities, including block valves, compressor stations and a heater station. The 1,220-km natural gas pipeline will transport sweet natural gas from the Inuvik area facility to the NOVA Gas Transmission Ltd. (NGTL) interconnect facility. The natural gas pipeline and NGL pipeline will share a common right-of-way for about 475 km from the Inuvik area facility to a point near the Norman Wells compressor station. The assessment has been completed on the basis of ecological zones and subsets of ecological zones to be consistent with baseline reporting in Volume 3, Biophysical Baseline, and to consider different landforms, climate and permafrost conditions along the pipeline route.

8.3.7.1 Baseline Conditions

Transition Forest Ecological Zone

The Transition Forest Ecological Zone extends from the Tundra Ecological Zone near Inuvik to Caribou Lake. Moraine is the most common landform in the Transition Forest Ecological Zone (see Table 8-26).

Table 8-26: Summary of Landforms in the Transition Forest Ecological Zone LSA

Landform Type	Area in LSA		Area in the Pipeline Right-of-way	
	(ha)	(%)	(ha)	(%)
Colluvial	64	0.8	2.4	3.8
Organic	1,056	13.6	59.7	5.6
Glaciofluvial	24	0.3	1.6	6.6
Fluvial	71	0.9	1.2	1.7
Glaciolacustrine	157	2.0	10.4	6.6
Morainal	3,315	42.7	173.3	5.2
Tertiary	2,136	27.5	111.1	5.2
Other, i.e., water	949	12.2	23.8	2.5
Total	7,771	100.0	383.5	4.9

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

Moraine is typically flat to gently undulating, with low rolling hills that might reflect the form and slope of the underlying shale and siltstone, or its depositional history. Continuous permafrost is present in most of the landforms in the Transition Forest Ecological Zone. Unfrozen ground occurs in limited areas of glaciofluvial landforms not covered with grass or moss vegetation.

The active layer depth ranges from 0.75 m to 3 m for mineral soil, and from 0.3 to 0.6 m for organic soil. Patterned ground, stone polygons, frost boils and peat deposits might occur in certain landforms in this ecological zone. More details on each of the landforms in this ecological zone are in Volume 3, Section 8, Soils, Landforms and Permafrost.

North Taiga Plains A Ecological Zone

The North Taiga Plains A Ecological Zone extends from the Transition Forest Ecological Zone boundary to Fort Good Hope. The Little Chicago compressor station will occupy 11 ha of a colluvial landform in the North Taiga Plains A Ecological Zone.

The most common landforms in the North Taiga Plains A Ecological Zone are Tertiary and morainal (see Table 8-27). Morainal topography varies from level to steep slopes, and drainage varies from well-drained to very poorly drained. Continuous permafrost occurs in most of the morainal landforms in this ecological zone. However, some south-facing slopes might be unfrozen.

Table 8-27: Summary of Landforms in the North Taiga Plains A Ecological Zone LSA

Landform Type	Area in LSA		Area in the Pipeline Right-of-Way		Area Covered by the Little Chicago Compressor Station	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Colluvial	1,563	5.9	67.2	4.3	11.0	<0.1
Organic	3,975	15.0	212.1	5.3	0	0
Glaciofluvial	1,939	7.3	104.9	5.4	0	0
Fluvial	502	2.0	28.7	5.7	0	0
Glaciolacustrine	2,903	11.0	161.9	5.6	0	0
Morainal	7,274	27.5	388.4	5.3	0	0
Tertiary	6,933	26.2	346.5	5.0	0	0
Aeolian	147	0.6	8.2	5.6	0	0
Rock	8	NI	0	0	0	0
Other, i.e., water	1,196	4.5	2.5	0.2	0	0
Total	26,443	100.0	1,320.4	5.0	11.0	<0.1

NOTES:
NI = not included
Percentage is based on total area of facilities or pipelines divided by total area in LSA

Active layer depth ranges from 0.8 m to 3.3 m for mineral soil, and from 0.3 m to 0.8 m for organic soil. Patterned ground, stone polygons, frost boils and peat deposits are common in this ecological zone.

North Taiga Plains B Ecological Zone

The North Taiga Plains B Ecological Zone extends from Fort Good Hope to Tulita. The Norman Wells compressor station occupies about 9.6 ha of the organic and fluvial landforms in the North Taiga Plains B Ecological Zone.

Tertiary, morainal, glaciolacustrine and organic are the most common landforms in the North Taiga Plains B Ecological Zone. Morainal plains might have abundant patches of organic materials, including peatlands and fen-filled depressions. Tops of hummocks are well drained. Local depressions might be poorly drained and contain fens. Discontinuous permafrost occurs in the morainal landforms (see Table 8-28).

Table 8-28: Summary of Landforms in the North Taiga Plains B Ecological Zone LSA

Landform Type	Area in LSA		Area in the Pipeline Right-of-Way		Area Covered by the Norman Wells Compressor Station	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Colluvial	1,184	5.5	59.3	5.0	0	0
Organic	3,708	17.4	170.4	4.6	3.3	0.08
Glaciofluvial	267	1.2	7.2	2.7	0	0
Fluvial	1,493	7.0	45.1	3.0	6.3	0.4
Glaciolacustrine	2,802	13.1	167.4	6.0	0	0
Morainal	4,823	22.6	247.2	5.1	0	0
Tertiary	5,309	24.9	252.2	4.7	0	0
Aeolian	300	1.4	25.7	8.5	0	0
Rock	38	0.2	0	0	0	0
Other, i.e., water	1,439	6.7	13.5	0.9	0	0
Total	21,367	100	988.0	4.6	9.6	<0.1

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

Active layer depth ranges from 1 m to 3.4 m for mineral soil, and from 0.4 m to 0.7 m for organic soil. Permafrost might be absent from well- to moderately well-drained areas and from the glaciofluvial landforms, except where underlain by morainal or glaciolacustrine landforms with a high possibility of permafrost. Patterned ground, stone polygons, frost boils and peat deposits might be present in this ecological zone but do not occur in the right-of-way. Affected landforms comprise mostly Tertiary, morainal, glaciolacustrine and organic deposits.

South Taiga Plains A Ecological Zone

The South Taiga Plains A Ecological Zone extends from Tulita to Willowlake River. The Blackwater River compressor station will result in about 7.8 ha of site disturbance of the organic and glaciofluvial landforms in the South Taiga Plains A Ecological Zone.

Glaciolacustrine, glaciofluvial and organic deposits are the most common landform types in the South Taiga Plains A Ecological Zone. Glaciolacustrine landforms comprise interbedded silt, clayey silt and some fine sand. Where frozen, they could have high ice content. Silt-rich sediments might contain pore ice and segregated ice, as tabular lenses 1 m or more thick, in irregular veins (see Table 8-29).

Table 8-29: Summary of Landforms in the South Taiga Plains A Ecological Zone

Landform Type	Area in LSA		Area in the Pipeline Right-of-Way		Area Covered by Blackwater River Compressor Station	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Colluvial	1,725	6.6	63.8	3.7	0	0
Organic	7,997	30.5	331.6	4.1	<0.1	<0.1
Glaciofluvial	3,851	14.7	175.6	4.6	7.7	0.2
Fluvial	1,037	4.0	45.2	4.4	0	0
Glaciolacustrine	9,141	34.8	385.4	4.2	0	0
Morainal	706	2.6	29.6	4.2	0	0
Tertiary	285	1.1	0.3	0.1	0	0
Aeolian	544	2.1	18.5	3.4	0	0
Rock	7	0	0	0	0	0
Other, i.e., water	954	3.6	1.7	0.2	0	0
Total	26,249	100	1,051.7	4.0	7.8	<0.1

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

The active layer depth ranges from 1.1 m to 3.3 m for mineral soil, and from 0.4 m to 0.9 m for organic soil. Permafrost might be present in areas with moss cover and absent from south-facing slopes.

South Taiga Plains B Ecological Zone

The South Taiga Plains B Ecological Zone extends from Willowlake River to south of the Alberta boundary. The Trail River compressor station is in the South Taiga Plains B Ecological Zone and occupies about 8.9 ha of an aeolian landform. Moraine and organic are the most common landform types in this ecological zone (see Table 8-30).

Organic deposits include mostly decomposed peat from sedge and mosses. Thaw depths in undisturbed areas in the field ranged between 0.5 and 0.8 m.

Discontinuous permafrost occurs in this ecological zone. Permafrost is expected in about 15% of the morainal and 30% of the glaciolacustrine landforms. However, permafrost is more widely spread in organic deposits, i.e., about 70%. The active layer depth ranges from 1 m to 1.7 m for mineral soil, and from 0.5 m to 0.8 m for organic soil.

8.3.7.2 Transition Forest Ecological Zone Effects

The effects on landforms in the Transition Forest Ecological Zone will be adverse, low to moderate magnitude and local in extent (see Table 8-31). Most effects will occur during construction.

Table 8-30: Summary of Landforms in the South Taiga Plains B Ecological Zone

Genetic Material	Area in LSA		Area in the Pipeline Right-of-Way		Area Covered by the Trail River Compressor Station	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Colluvial	108	0.3	3.2	3.0	0	0
Organic	20,217	50.6	822.2	4.1	0	0
Glaciofluvial	1,892	4.7	76.8	4.0	0	0
Fluvial	655	1.6	19.5	3.0	0	0
Glaciolacustrine	2,690	6.7	122.8	4.6	0	0
Morainal	6,530	16.4	276.4	4.2	0	0
Tertiary	389	1.0	13.5	3.5	0	0
Aeolian	1,506	3.8	70.8	4.7	8.9	0.6
Rock	0	0	0	0	0	0
Other, i.e., water	5,928	14.9	189.8	3.2	0	0
Total	39,919	100.0	1,595.0	4.0	8.9	<0.1

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

Table 8-31: Effects on Landforms – Transition Forest Ecological Zone

Valued Component	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Ground stability	Construction	Adverse	Moderate	Local	Long term
	Operations	Adverse	Moderate	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Uncommon landforms	Construction	Adverse	Low to moderate	Local	Long term to far future
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Adverse	No effect	N/A	N/A

NOTE:
N/A = not applicable

Ground Stability

Table 8-32 shows areas along the pipeline corridor that are susceptible to subsidence, pond formation, water erosion and frost effects.

Table 8-32: Potential Ground Stability Effects – Transition Forest Ecological Zone

Landform Type	Area in LSA		Area with Potential for Subsidence and Pond Formation		Area with Potential for Water Erosion		Area with Potential for Effects from Frost Bulbs or Surface Heave	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Colluvial	64	0.8	0	0	2.4	3.7	0	0
Organic	1,056	13.6	0	0	0	0	0	0
Glaciofluvial	24	0.3	0	0	0	0	1.6	6.7
Fluvial	71	0.9	0	0	0.7	2.4	0	0
Glaciolacustrine	156	2.0	10.4	6.6	0	0	0	0
Morainal	3,315	42.7	1.2	<0.1	0	0	0	0
Tertiary	2,135	27.5	0	0	0	0	0	0
Other, i.e., water	949	12.2	0	0	0	0	0	0
Total	7,771	100.0	11.6	0.1	3.1	<0.1	1.6	<0.1

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

Construction

Pipeline construction will occur over several years, predominantly during the winter. Activities include clearing, surface levelling, grading, pad building, trenching and backfilling. The main project activities that will affect ground stability are excavation and earthworks during pipeline construction. Initial construction will disturb surface layers, existing thermal regime and drainage conditions. Where permafrost is present, disturbance will promote a rise in ground temperature and alter surface and subsurface drainage patterns, which will encourage thawing of the permafrost. Therefore, effects of construction will have:

- adverse direction, because the ground surface will be altered and become less stable
- moderate magnitude, because areas of the right-of-way are prone to thaw settlement
- local geographic extent, because construction activities are limited to the right-of-way
- long-term duration, because the effects of construction might extend until recovery of the vegetation cover

Operations

During operations, the flow of gas will have an effect on permafrost, which will affect slope stability, erosion and frost effects in this ecological zone. The pipeline will generally be operated below freezing, which could cause ground freezing and frost bulb propagation around the pipes. This could lead to altered drainage and erosion in some locations. Because effects could occur throughout operations and into decommissioning and abandonment, the magnitude of the effects will be long term.

Decommissioning and Abandonment

It is expected that the buried pipeline will be abandoned in place, whereas above-ground facilities will be removed. A neutral effect is expected from decommissioning and abandonment as ground temperatures are expected to stabilize after termination of pipeline operations.

Uncommon Landforms

Uncommon landforms in the Transition Forest Ecological Zone include patterned ground and glaciofluvial landforms. The pipeline right-of-way will affect about 4.7% of the patterned ground and about 6.7% of the glaciofluvial landforms in the Transition Forest Ecological Zone LSA (see Table 8-33).

Table 8-33: Areas of Potential Uncommon Landforms Effects – Transition Forest Ecological Zone

Uncommon Landform	Area in LSA	Area in Right-of-Way	
	(ha)	(ha)	(%)
Patterned ground	225	10.5	4.7
Glaciofluvial	24	1.6	6.7

Construction

Construction impacts on glaciofluvial landforms along the pipeline route will be long term. Impacts on patterned ground will likely extend to the far future. Effects are considered adverse and areas affected comprise about 12 ha, or 4.7%, of the uncommon landforms in the Transition Forest Ecological Zone LSA. This results in a rating of low magnitude for these key indicators.

Operations

Operations activities might affect uncommon landforms in the Transition Forest Ecological Zone LSA, but much less than during construction. Therefore, the effect attributes for pipeline operations will be adverse, low magnitude and local.

Decommissioning and Abandonment

Decommissioning and abandonment activities are not expected to affect uncommon landforms.

8.3.7.3 North Taiga Plains A Ecological Zone Effects

The North Taiga Plains A Ecological Zone assessment of potential effects relative to ground stability was based on identified areas prone to subsidence and pond formation, erosion and potential for slope instability. The assessment of effects on uncommon landforms was based on occurrences of:

- patterned ground including ice-wedge polygons, stone polygons, frost boils and stone stripes
- glaciofluvial landforms
- aeolian landforms

Most of the effects on ground stability and uncommon landforms will occur during construction. Effects will be low to moderate magnitude and local in extent (see Table 8-34).

Table 8-34: Effects on Landforms – North Taiga Plains A Ecological Zone

Valued Component	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Ground stability	Construction	Adverse	Moderate	Local	Long term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Uncommon landforms	Construction	Adverse	Low to moderate	Local	Long term to far future
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
NOTE: N/A = not applicable					

Ground Stability

Table 8-35 shows the potential for subsidence and pond formation, water erosion and slope instability.

The effect on ground stability will be moderate because 5% of the glaciolacustrine units in the North Taiga Plains A Ecological Zone LSA are susceptible to pond formation.

Table 8-35: Areas of Potential Ground Stability Effects – North Taiga Plains A Ecological Zone

Landform Type	Area in LSA	Area with Potential for Subsidence and Pond Formation		Area with Potential for Water Erosion		Area with Potential for Slope Instability	
	(ha)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Colluvial	1,563	60.1	3.8	5.4	0.3	0	0
Organic	3,975	4.6	0.1	0	0	0	0
Glaciofluvial	1,939	0	0	7.5	0.4	1.6	<0.1
Fluvial	502	0	0	0.6	0.1	0	0
Glaciolacustrine	2,903	146.2	5.0	2.0	<0.1	0	0
Morainal	7,274	0	0	15.2	0.2	0	0
Tertiary	6,933	0	0	22.6	0.3	0	0
Aeolian	147	0	0	4.3	2.9	0	0
Rock	8	0	0	0	0	0	0
Other, i.e., water	1,196	0	0	0	0	0	0
Total	26,443	210.9	0.8	57.6	0.2	1.6	<0.1

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

Construction

The activities described for the Transition Forest Ecological Zone during pipeline construction apply for pipeline construction in this ecological zone. In addition, the Little Chicago compressor station's construction activities will include:

- clearing of trees and shrubs
- grading and filling to level the site
- sloping the surface to direct surface runoff away from the site

Initial construction will disturb surface layers, existing thermal regime and drainage conditions. Where permafrost is present, disturbances will promote thawing of the permafrost.

Effects on ground stability will be adverse and moderate magnitude. Effects will be local to the right-of-way and could occur until a stable vegetation community has been re-established, which might occur within 30 years following decommissioning and abandonment, i.e., long term.

Operations

Few activities are expected during pipeline operations. However, the flow of gas, as previously discussed, could affect permafrost.

The pipeline will generally be operated below freezing which could generate frost bulbs around the pipes in areas without permafrost. Potential effects are frost bulb generation and ground heaving in some locations and altered drainage, slope instability and erosion conditions. As well, some areas are prone to ongoing thaw settlement and pond formation, erosion and slope instability. Magnitude of effects will likely decrease postconstruction. The effects would extend over the long term after the end of operations.

Decommissioning and Abandonment

Decommissioning and abandonment activities are not expected to have an effect on ground stability. Frost bulb and ground heave effects would diminish over time and stabilize over the long term.

Uncommon Landforms

Patterned ground, glaciofluvial and aeolian landforms occur in the North Taiga Plains A Ecological Zone (see Table 8-36). The area these landforms occupy in the right-of-way is less than 5% of total uncommon landforms in the North Taiga Plains A Ecological Zone LSA and more than 5% of glaciofluvial and aeolian landforms. There are no uncommon landforms at the Little Chicago compressor station site.

Table 8-36: Areas of Uncommon Landforms Effects – North Taiga Plains A Ecological Zone

Uncommon Landform	Area in LSA	Area in Right-of-Way	
	(ha)	(ha)	(%)
Patterned ground	96	4.1	4.3
Glaciofluvial	1,939	104.9	5.4
Aeolian	147	8.2	5.6

Construction

Effect on uncommon landforms during construction of the pipeline in the North Taiga Plains A Ecological Zone will be low to moderate because less than 5% of the patterned ground and greater than 5% of the glaciofluvial deposits and aeolian landforms might be affected during construction. Duration of loss for uncommon landforms is long term for glaciofluvial and aeolian landforms because the loss could recover to a stable condition, but extends to far future for patterned ground because recovery would extend into the far future.

Operations

Pipeline operations and maintenance activities might have a small impact on uncommon landforms in this ecological zone. The impact will be similar to the Transition Forest Ecological Zone.

Decommissioning and Abandonment

Decommissioning and abandonment is not expected to affect uncommon landforms.

8.3.7.4 North Taiga Plains B Ecological Zone Effects

Table 8-37 summarizes the effects on ground stability and uncommon landforms during construction, operations, and decommissioning and abandonment of the pipeline right-of-way. The Norman Wells compressor station's effect on ground stability and uncommon landforms will be negligible.

Table 8-37: Effects on Landforms – North Taiga Plains B Ecological Zone

Valued Component	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Ground stability	Construction	Adverse	Moderate	Local	Long term
	Operations	Adverse	Moderate	Local	Long term
	Decommissioning and abandonment	Adverse	Moderate	Local	Long term
Uncommon landforms	Construction	Adverse	Low to moderate	Local	Long term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
NOTE: N/A = not applicable					

Ground Stability

Table 8-38 shows the potential for subsidence and pond formation, water erosion and frost effects. Potential ground stability effects related to erosion and frost effects will be moderate for aeolian deposits.

Construction

Construction activities in the North Taiga Plains B Ecological Zone will be similar to those carried out in the Transition Forest and North Taiga Plains A ecological zones. Construction of the Norman Wells compressor station will disturb surface layers, existing thermal regime and drainage conditions. Design and mitigation measures should reduce the effect on ground stability. Effects will be moderate because of the susceptibility of the aeolian landforms to erosion for more than 8% of the North Taiga Plains B Ecological Zone LSA.

Table 8-38: Areas of Potential Ground Stability Effects – North Taiga Plains B Ecological Zone

Landform Type	Area in LSA	Area with Potential for Subsidence and Pond Formation		Area with Potential for Water Erosion		Area with Potential for Effects from Frost Bulbs or Surface Heave	
	(ha)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Colluvial	1,184	54.7	4.6	2.9	0.4	1.4	0.1
Organic	3,708	0	0	0	0	0	0
Glaciofluvial	267	0	0	2.6	0.9	0	0
Fluvial	1,493	0	0	0	0	0	0
Glaciolacustrine	2,802	135.9	4.8	11.0	0.4	11.0	0.4
Morainal	4,823	0.5	<0.1	2.3	<0.1	22.7	0.5
Tertiary	5,309	0	0	35.6	0.7	0	0
Aeolian	300	0	0	25.7	8.5	25.7	8.5
Rock	38	0	0	0	0	0	0
Other, i.e., water	1,439	0	0	0	0	0	0
Total	21,367	191.1	0.9	80.1	0.4	60.8	0.3

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

Operations

Pipeline operations activities in the North Taiga Plains B Ecological Zone will be similar to the North Taiga Plains A Ecological Zone. The flow of gas during pipeline operations affects permafrost. As the pipeline will be operated above and below freezing temperature, frost bulbs or ground surface heave might occur in this ecological zone. There is potential for frost bulb growth or ground surface heave leading to drainage disruption in about 8.6% of the aeolian landforms in the North Taiga Plains B Ecological Zone LSA. Magnitude of effects will be moderate.

Decommissioning and Abandonment

Thaw of frost bulbs might result in small adverse effects to drainage, erosion or slope stability during decommissioning and abandonment. Effects are expected to stabilize within 30 years following decommissioning and abandonment. Based on the areas identified with frost effects potential, the moderate magnitude is expected to stabilize over the long term.

Uncommon Landforms

Patterned ground is absent in this ecological zone. However, the aeolian landforms affected by the project comprise about 8.6% of the pipeline right-of-way, whereas the compressor station location has no uncommon landforms. Table 8-39 presents the areas each of these landforms occupy, and the percentage of uncommon landforms they form in the right-of-way.

Table 8-39: Areas of Potential Uncommon Landforms Effects – North Taiga Plains B Ecological Zone

Uncommon Landforms	Area in LSA	Area in Right-of-Way	
	(ha)	(ha)	(%)
Glaciofluvial	267	7.2	2.7
Aeolian	300	25.7	8.6

Construction

A low to moderate magnitude is assigned to uncommon landforms during construction in the North Taiga Plains B Ecological Zone because about 8.6% of the aeolian landforms are in the LSA. Duration of loss of uncommon landforms is long term because these landforms will recover to a stable condition after decommissioning and abandonment.

Operations

Activities during pipeline operations might have a small adverse effect on uncommon landforms, similar to the Transition Forest and North Taiga Plains A ecological zones.

Decommissioning and Abandonment

Decommissioning and abandonment activities are not expected to affect uncommon landforms.

8.3.7.5 South Taiga Plains A Ecological Zone Effects

Assessment of potential effects on ground stability was based on areas prone to subsidence and pond formation, erosion, slope instability and frost effects. Uncommon landforms were evaluated on the basis of aeolian and glaciofluvial deposits.

Table 8-40 summarizes the effects on ground stability and uncommon landforms during construction, operations, and decommissioning and abandonment.

Ground Stability

Table 8-41 shows the areas of potential for thaw settlement and pond formation, erosion, frost effects and slope instability.

Table 8-40: Effect on Landforms – South Taiga Plains A Ecological Zone

Valued Component	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Ground stability	Construction	Adverse	Low	Local	Long term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Adverse	Low	Local	Long term
Uncommon landforms	Construction	Adverse	Low	Local	Long term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A

NOTE:
N/A = not applicable

Table 8-41: Areas of Potential Ground Stability Effects – South Taiga Plains A Ecological Zone

Landform Type	Area in LSA	Area With Potential for Subsidence and Pond Formation		Area with Potential for Water Erosion		Area with Potential for Effects from Frost Bulbs or Surface Heave		Area with Potential for Slope Instability	
	(ha)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Colluvial	1,725	20.8	1.2	52.6	3.0	44.4	2.6	0.8	<0.1
Organic	7,997	8.4	0.1	0.5	<0.1	0	0	0	0
Glaciofluvial	3,851	0	0	44.1	1.1	7.9	0.2	0	0
Fluvial	1,037	0	0	18.8	1.8	18.8	1.8	0	0
Glaciolacustrine	9,141	269.3	3.0	144.6	1.6	174.3	1.9	10	0.1
Morainal	706	15.1	2.1	6.3	0.9	29.7	4.2	0	0
Tertiary	285	0	0	0.0	0	0	0	0	0
Aeolian	544	0	0	3.5	0.6	15.5	2.8	0	0
Rock	7	0	0	0	0	0	0	0	0
Other, i.e., water	954	0	0	0	0	0	0	0	0
Total	26,249	500.8	1.9	260.4	1.0	290.6	1.1	10.8	<0.1

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

Construction

Construction activities discussed for the Transition Forest Ecological Zone are expected along the pipeline right-of-way and at the Blackwater River compressor station in the South Taiga Plains A Ecological Zone. Magnitude of effects will be low for the South Taiga Plains A Ecological Zone.

Operations

Thaw settlement initiated during construction will be ongoing, but at progressively slower rates, during operations. Frost bulb growth and ground surface heave could occur during operations. Expected effects from these mechanisms are rated as low.

Decommissioning and Abandonment

Thaw of frost bulbs might result in small adverse effects to drainage, erosion or slope stability during decommissioning and abandonment. Effects are expected to stabilize within 30 years following decommissioning and abandonment. Based on the areas identified with frost effects potential, the moderate magnitude is expected to stabilize over the long term.

Uncommon Landforms

Patterned ground is absent in this ecological zone. Glaciofluvial and aeolian landforms occupy less than 5% of the LSA (see Table 8-42).

Table 8-42: Areas of Potential Uncommon Landforms Effects – South Taiga Plains A Ecological Zone

Uncommon Landforms	Area in LSA	Area in Right-of-Way		Area Covered by Compressor Station		Total Area in Right-of-Way and Compressor Station	
	(ha)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Glaciofluvial	3,851	175.6	4.6	7.7	0.2	183.3	4.8
Aeolian	544	18.5	3.4	0	0	18.5	3.4

Construction

A low magnitude is assigned to effects on uncommon landforms during construction in the South Taiga Plains A Ecological Zone. About 4.8% of the glaciofluvial and 3.4% of the aeolian landforms in the South Taiga Plains A Ecological Zone LSA might be affected during construction. Duration of loss of uncommon landforms is long term because landforms are expected to recover to a stable condition within 30 years following decommissioning and abandonment.

Operations

As discussed for the previous ecological zones, pipeline operations might have some effect on uncommon landforms. Any effect on uncommon landforms will have an adverse direction. The magnitude and geographic extent will be low and local. Duration of the effect of operations will be far future because of uncommon landforms.

Decommissioning and Abandonment

Decommissioning and abandonment is not expected to cause effects on uncommon landforms.

8.3.7.6 South Taiga Plains B Ecological Zone Effects

Assessment of potential effects relative to ground stability was based on areas prone to subsidence and pond formation, erosion and frost effects. Glaciofluvial and aeolian deposits occur in this ecological zone.

Table 8-43 summarizes the effects on ground stability and uncommon landforms during construction, operations and decommissioning and abandonment.

Table 8-43: Effects on Landforms – South Taiga Plains B Ecological Zone

Valued Component	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Ground stability	Construction	Adverse	Low	Local	Long term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Adverse	Low	Local	Long term
Uncommon landforms	Construction	Adverse	Moderate	Local	Long term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
NOTE: N/A = not applicable					

Ground Stability

Table 8-44 shows the potential for thaw settlement and pond formation, erosion and frost effects.

Construction

In this zone, less permafrost results in more stable ground. However, there are still areas prone to pond formation and erosion. Areas prone to effects on ground stability comprise less than 5% of landform area in the South Taiga Plains B Ecological Zone LSA. Therefore, magnitude of effects is assessed as low.

Operations

Pipeline and compressor station operations activities and effects in the South Taiga Plains B Ecological Zone are expected to be similar to those for the

South Taiga Plains A Ecological Zone. Frost effects are possible in this ecological zone during operations, but the areas are less than 5% of the total amount in the South Taiga Plains B Ecological Zone LSA for any given landform.

Table 8-44: Areas of Potential Ground Stability Effects – South Taiga Plains B Ecological Zone

Landform Type	Area in LSA	Area With Potential for Subsidence and Pond Formation		Area with Potential for Water Erosion		Area with Potential for Effects from Frost Bulbs or Surface Heave	
	(ha)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Colluvial	108	0	0	1.4	1.3	3.2	3.0
Organic	20,217	0	0	0	0	0	0
Glaciofluvial	1,892	0	0	51.9	2.7	29.7	1.6
Fluvial	655	0	0	0	0	0	0
Glaciolacustrine	2,690	2.9	0.1	16.9	0.6	76.8	2.8
Morainal	6,530	0	0	33.2	0.5	156.4	2.4
Tertiary	389	0	0	13.1	3.4	0	0
Aeolian	1,506	0	0	54.2	3.6	8	0.5
Other, i.e., water	5,928	0	0	0	0	0	0
Total	39,919	2.9	<0.1	170.7	0.4	274.1	0.7

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

Decommissioning and Abandonment

Thaw of frost bulbs might result in small adverse effects on drainage, erosion or slope stability during decommissioning. The effects are expected to stabilize within 30 years following decommissioning and abandonment. Based on areas identified with frost effects potential, the moderate-magnitude effect is expected to stabilize over the long term.

Uncommon Landforms

Patterned ground is absent in this ecological zone. Glaciofluvial and aeolian landforms cover 147.6 ha of the right-of-way. The Trail River compressor station occupies 8.9 ha of the aeolian landform (see Table 8-45).

Construction

A low to moderate magnitude is assigned to uncommon landforms during construction in the South Taiga Plains B Ecological Zone because 5.3% of the aeolian landforms in the LSA are affected by the pipeline right-of-way and compressor station construction activities. The remaining effect attributes of construction are similar to those in the other ecological zones.

Table 8-45: Areas of Potential Uncommon Landforms Effects – South Taiga Plains B Ecological Zone

Uncommon Landforms	Area in LSA	Area in Right-of-Way		Area Covered by Compressor Station		Total Area Affected in Right-of-Way and Compressor Station	
	(ha)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Glaciofluvial	1,892	76.8	4.0	0	0	76.8	4.0
Aeolian	1,506	70.8	4.7	8.9	0.6	79.7	5.3

Operations

Effects of pipeline operations on uncommon landforms will be low magnitude because only small amounts of these landforms will be affected.

Decommissioning and Abandonment

Decommissioning and abandonment activities are not expected to affect uncommon landforms.

8.3.8 Northwestern Alberta

The proposed pipeline crosses the boundary into northwestern Alberta where it ties into the NGTL interconnect facility. The NGTL pipeline extends from this tie-in point to about 65 km south of the Alberta and Northwest Territories boundary.

8.3.8.1 Baseline Conditions

In northwestern Alberta the pipeline will cross the South Taiga Plains B Ecological Zone. This zone has been described previously (see Section 8.3.7.6, South Taiga Plains B Ecological Zone Effects).

8.3.8.2 Northwestern Alberta Effects

The effects of construction on ground stability and uncommon landforms for this zone were described previously (see Section 8.3.7.6, South Taiga Plains B Ecological Zone Effects).

8.3.9 Infrastructure

The project infrastructure for construction and operations includes:

- barge landing sites
- pipe and material stockpile sites
- fuel storage sites
- camps
- potable water supplies

- access roads
- airstrips and helipads
- communication centres

During construction, the project will require large amounts of materials, supplies and personnel. Extensive transportation of goods by barge, rail, aircraft and truck will be necessary. During operations, transportation of smaller amounts of materials and supplies will be necessary.

8.3.9.1 Baseline Conditions

Production Area Infrastructure

Infrastructure sites required in the project production area comprise three main groups, based on similar issues and effects:

- winter roads, all-weather roads, barge landings, airstrips and helipads
- borrow sites to supply project fill requirements
- camps, stockpile sites and fuel storage sites

This assessment includes infrastructure outside the Niglintgak, Taglu and Parsons Lake LSAs. Infrastructure in the anchor field LSAs was addressed in previous sections. Exact locations of roads and other infrastructure sites have not been finalized.

About 350 km of winter road will be prepared to provide access to borrow sites (65 km), water sources (130 km), and stockpile and fuel storage sites (155 km). These roads will be routed over lakes and along rivers, where practical, to reduce potential environmental effects.

All-weather roads will total about 23 km, of which the road to the Inuvik area facility accounts for 19 km. The granular base of the all-weather roads will cover about 37 ha.

Pads required for infrastructure sites will cover about 40 ha (not including the anchor fields). The infrastructure pads required for Taglu and Parsons Lake, e.g., barge landing and airstrip, were included in the assessment of the production facilities.

This qualitative assessment assumes that the soils and ground conditions encountered at production area infrastructure sites will be similar to those described for Niglintgak, Taglu, Parsons Lake and the gathering pipelines and associated facilities.

Borrow sites are expected to be located in weakly developed sand or gravel soils, either of glaciofluvial or morainal origin. Sixteen potential borrow sites have been identified, of which seven are likely to be developed. For this assessment it was assumed that each borrow site would be about 10 ha in size.

Development of infrastructure might cause ground stability effects and losses of uncommon landforms. This assessment considers that the range of landforms and ground conditions expected at infrastructure sites would be similar to those described for Niglintgak, Taglu and Parsons Lake and along the gathering pipelines.

Pipeline Corridor Infrastructure

The same types of infrastructure sites are required along the pipeline corridor as described previously for the production area.

Wide-ranging variability in ground conditions and landform types in the LSA are considerations for infrastructure along the pipeline corridor. Baseline conditions are expected to be similar to those in the adjacent pipeline corridor LSA.

Borrow sites along the pipeline corridor are located in areas dominated by medium coarse-textured, rapidly drained glaciofluvial deposits. Other landform types identified as potential borrow sites along the pipeline corridor include coarse-textured, rapidly drained aeolian dune complexes, fluvial fans, colluvium and bedrock ridges.

8.3.9.2 Production Area Infrastructure Effects

Potential effects on ground stability and uncommon landforms caused by constructing pads for infrastructure sites includes loss of landforms beneath the pads, and possible changes in drainage, erosion and slope stability. Effects are likely to be adverse, because of loss of landforms, low magnitude and local to the LSA for these facilities (see Table 8-46). Duration of effects will be long term for ground stability and far future for landforms.

Ground Stability

Construction

Site-specific landform characteristics are not available for the production area infrastructure sites. Therefore, effects are assessed qualitatively for ground stability.

The construction of winter roads and the effects of winter roads on ground stability indicators, such as potential for disrupted drainage, erosion and slope instability, will be similar to a pipeline right-of-way outside the ditch line.

Changes in drainage and erosion could also occur adjacent to pads placed for transportation infrastructure such as barge landing sites, airstrips and helipads.

Placement of pads has the potential to interrupt surface drainage and cause pond formation adjacent to pads, which might cause thaw subsidence.

Table 8-46: Effects on Landforms – Production Area Infrastructure

Valued Component	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Ground stability	Construction	Adverse	Low	Local	Long term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Uncommon landforms	Construction	Adverse	Low	Local	Far future
	Operations	Adverse	Low	Local	Far future
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
NOTE: N/A = not applicable					

Infrastructure components, such as camps, barge landings and storage sites will be located on higher ground, in well-drained areas, where the potential for changes in soil drainage because of thaw settlement is low. The potential effects will likely be reduced through the use of drainage control. Borrow sites will also be located on higher ground where ground stability will not likely be affected.

During construction for production area infrastructure, the effects on ground stability will be adverse, low magnitude, local in extent and long term, i.e., during operations.

Operations

Changes in ground stability indicators following construction, i.e., pond formation and erosion, will require mitigation through operations to reduce the potential effects of winter roads and pad construction. Therefore, the effects of changes on ground stability during operations for production area infrastructure will be adverse, low magnitude, local in extent and long term.

Decommissioning and Abandonment

Pads and roadbeds are likely to remain in place after decommissioning and abandonment. Drainage will be restored along roadbeds and at facility pads. Surfaces will be recontoured, scarified and seeded. No additional changes in ground stability are expected during decommissioning and abandonment.

Uncommon Landforms

Construction

An estimated 77 ha of landforms will be lost where pads are placed for infrastructure and all-weather roads. The winter roads will affect another estimated 230 ha of landforms. Based on the assessment of the gathering pipeline rights-of-way, about 3% to 5% of LSAs for road alignments and pad areas could comprise uncommon landforms such as patterned ground or glaciofluvial deposits. Pingos and aeolian deposits would be avoided.

It is expected that about 70 ha of granular deposits will be removed as borrow material for pad construction and roadways. The amount of granular resources used on the project, relative to the size of the production area LSAs, will likely cause losses of less than 5% of available local quantities of glaciofluvial deposits.

The effects on uncommon landforms will be adverse and low, based on the estimated areas of impact. The geographic extent will be local and the effects are expected to extend into the far future, as the landforms will not recover to a stable condition.

Operations

Losses to uncommon landforms would not be compounded during operations, providing road alignments are maintained and the areas of borrow sites do not exceed estimated values. Ongoing operations will require occasional uses of small amounts of borrow material. The effects attributes during operations are expected to be similar to those for construction, but the affected area will be reduced from that required for construction.

Decommissioning and Abandonment

No further losses to uncommon landforms are expected during decommissioning and abandonment. It is possible that some of the borrow material in the pads could be used as construction material for other developments, or as denning habitat for wildlife after decommissioning and abandonment.

8.3.9.3 Pipeline Corridor Infrastructure Effects

Potential effects on ground stability and uncommon landforms caused by constructing thick pads for infrastructure sites include loss of landforms beneath the pads, beneath all-weather roads and at borrow sites, and potential for changes in drainage, erosion and slope stability.

A total of 100 potential borrow sites have been identified, of which 60 are likely to be developed. For this assessment it was assumed that each borrow site would be 10 ha in size.

It is expected that about 490 km of winter roads will be needed: 275 km to access borrow sites, 175 km to access water sources and 40 km to access infrastructure. About 52 km of all-weather roads will be needed to provide access to facility sites all year. The footprint of the all-weather road base will cover about 82 ha.

Pads required for infrastructure sites will cover about 85 ha. Where infrastructure pads are located on stable terrain, surface soil will be removed and stockpiled before placement of borrow material.

Construction effects on ground stability, caused by extracting borrow material and constructing pads at infrastructure sites and roads, will be adverse, low magnitude and local in extent (see Table 8-47). These effects are not likely to extend beyond decommissioning and abandonment.

Table 8-47: Predicted Effects – Pipeline Corridor Infrastructure

Valued Component	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Ground stability	Construction	Adverse	Low	Local	Long term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Uncommon landforms	Construction	Adverse	Low	Local	Far future
	Operations	Adverse	Low	Local	Far future
	Decommissioning and abandonment	Neutral	No effects	N/A	N/A
NOTE: N/A = not applicable					

Construction effects on uncommon landforms are likely to be adverse, low magnitude and local in extent, and last into the far future. In some cases, effects might last more than several decades after decommissioning and abandonment.

During operations, smaller amounts of borrow material will be required for maintaining roads, barge landing sites and other sites. The effects will be similar to those during construction but the magnitude will be much lower.

Pads and roadbeds are likely to remain in place after decommissioning and abandonment. Drainage will be restored along roadbeds and at facility pads. Surfaces will be recontoured, scarified and seeded.

Ground Stability

Construction

Site-specific landform characteristics are not available for the pipeline infrastructure sites. Effect, impact and assessment results are similar to those presented previously for production area infrastructure. Site-specific characteristics cannot be evaluated. Potential changes in drainage, erosion and slope stability were considered in the assessment for ground stability indicators.

Operations

Changes in ground stability indicators following construction, primarily pond formation and erosion, will require mitigation through operations to reduce the potential effects of winter roads and pad construction. Therefore, the effects of changes on ground stability during operations for pipeline corridor infrastructure will be adverse, low magnitude, local in extent and long term.

Decommissioning and Abandonment

During decommissioning and abandonment, borrow material will likely not be removed. No additional changes in ground stability are expected.

Uncommon Landforms

Construction

An estimated 167 ha of landforms will be lost where pads are placed for infrastructure. The all-weather roads will affect about 52 ha. Based on the assessment of the pipeline right-of-way, road alignments and pad areas could cover uncommon landforms such as patterned ground or glaciofluvial deposits. Aeolian deposits could also be affected because they tend to be elevated areas with good drainage.

It is expected that about 600 ha of granular deposits will be removed as borrow material for pad construction and roadways. The amount of resources used in the project, relative to available quantities in the LSAs, will likely cause losses to uncommon landforms of less than 5% of available local quantities.

The effects on uncommon landforms will be adverse and low magnitude, based on the areas of expected impact. The geographic extent will be local and the effects will mostly be unrecoverable, extending into the far future.

Operations

Ongoing operations will require borrow material in smaller quantities than required for initial construction. The effect attributes during operations are expected to be similar to those for construction, but the affected areas will be reduced.

Decommissioning and Abandonment

Decommissioning and abandonment activities for the pipeline corridor infrastructure are not expected to affect any more uncommon landforms.

8.3.10 Significance of Effects

In the previous section, the characteristics of the residual effects of the project were described in terms of direction, magnitude, geographic extent and duration. These characteristics are used to determine the significance of the effects on ground stability and uncommon landforms.

Volume 1, Section 2, Assessment Method, provides a discussion about the rationale for determining significance. An adverse residual effect is considered significant if the effect is either:

- moderate or high magnitude and extends into the far future, i.e., more than 30 years after project decommissioning and abandonment
- high magnitude and occurs outside the LSA at any time

In this section, the significance of the effects for each project component and the combined project is presented. Tables provide the results of the effects assessment and indicate if an effect is significant.

Predicted effects on ground stability are low or moderate magnitude and duration does not exceed long term. Most predicted effects on uncommon landforms are low to moderate magnitude and long-term duration. Along the pipeline corridor, the loss of patterned ground in the Transition Forest and North Taiga A Ecological Zones will result in a predicted residual effect for this indicator that is low magnitude and far future in duration. Therefore, the predicted effects on landforms will be not significant.

8.3.10.1 Niglintgak

Effects on ground stability at Niglintgak are expected to include drainage disruption from thaw subsidence and erosion. Slope stability is not expected to be an issue in the Niglintgak LSA. Effects on uncommon landforms include losses of patterned ground and glaciofluvial deposits traversed by the flow line rights-of-way and beneath facility areas. The effects of both the barge-based and land-based options for the gas conditioning facility will be not significant because the area affected is small (see Table 8-48).

Table 8-48: Significance of Effects of Niglintgak on Landforms

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Ground stability	Construction	Adverse	Low	Local	Short term	No
	Operations	Adverse	Low	Local	Long term	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No
Uncommon landforms	Construction	Adverse	Low	Local	Far future	No
	Operations	Adverse	Low	Local	Far future	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No
NOTE: N/A = not applicable						

8.3.10.2 Taglu

Ground stability effects at Taglu relate primarily to parts of the pipeline lateral rights-of-way that traverse the Taglu LSA. Effects on uncommon landforms are based primarily on expected impacts to patterned ground, and will be low magnitude. The effects will be not significant (see Table 8-49) as at Niglintgak.

Table 8-49: Significance of Effect of Taglu on Landforms

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Ground stability	Construction	Adverse	Low	Local	Long term	No
	Operations	Adverse	Low	Local	Long term	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No
Uncommon landforms	Construction	Adverse	Low	Local	Far future	No
	Operations	Adverse	Low	Local	Far future	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No
NOTE: N/A = not applicable						

8.3.10.3 Parsons Lake

Effects on ground stability at Parsons Lake are related primarily to pond formation along parts of the Parsons Lake lateral in the Parsons Lake LSA. The effects on uncommon landforms include potential loss in ice-wedge polygons and glaciofluvial deposits in the LSA. The magnitude of effects will be low because the affected areas are small compared with LSA available quantities (see Table 8-50). The effects are not significant and are the same as at Niglintgak and Taglu.

Table 8-50: Significance of Effects of Parsons Lake on Landforms

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Ground stability	Construction	Adverse	Low	Local	Long term	No
	Operations	Adverse	Low	Local	Long term	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No
Uncommon landforms	Construction	Adverse	Low	Local	Far future	No
	Operations	Adverse	Low	Local	Far future	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No
NOTE: N/A = not applicable						

8.3.10.4 Gathering Pipelines and Associated Facilities

The magnitude of effects along the gathering pipelines on ground stability and uncommon landforms will be low. The affected areas relate primarily to potential erosion, pond formation or drainage disruption, and slope stability. Losses of uncommon landforms include patterned ground and glaciofluvial deposits. The losses of uncommon landforms are small compared with locally available amounts (see Table 8-51).

Table 8-51: Significance of Effects of the Gathering Pipelines and Associated Facilities on Landforms

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Ground stability	Construction	Adverse	Low	Local	Long term	No
	Operations	Adverse	Low	Local	Long term	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No
Uncommon landforms	Construction	Adverse	Low	Local	Long term to far future	No
	Operations	Adverse	Low	Local	Far future	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No
NOTE: N/A = not applicable						

8.3.10.5 Pipeline Corridor

The magnitude of the effects of the pipeline corridor on ground stability will be low to moderate with local geographic extent. The effect of the pipeline corridor on landforms is predicted to be not significant (see Table 8-52).

Table 8-52: Significance of Effects of the Pipeline Corridor on Landforms

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Ground stability	Construction	Adverse	Low to moderate	Local	Long term	No
	Operations	Adverse	Low to moderate	Local	Long term	No
	Decommissioning and abandonment	Adverse	Low to moderate	Local	Long term	No
Uncommon landforms[1]	Construction	Adverse	Low to moderate	Local	Long term to far future	No
	Operations	Adverse	Low	Local	Long term to far future	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No

NOTES:
N/A = not applicable
1 The ratings were based on low magnitude combined with long-term or far-future effects and on moderate magnitude combined with long-term duration

8.3.10.6 Infrastructure

The magnitude of effects of infrastructure will not exceed low magnitude, and will be local. Effects on ground stability will be long term, and effects on uncommon landforms will extend into the far future. The effect of infrastructure on landforms is predicted to be not significant (see Table 8-53).

Table 8-53: Significance of Effects of Infrastructure on Landforms

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Ground stability	Construction	Adverse	Low	Local	Long term	No
	Operations	Adverse	Low	Local	Long term	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No
Uncommon landforms	Construction	Adverse	Low	Local	Far future	No
	Operations	Adverse	Low	Local	Far future	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No

NOTE:
N/A = not applicable

8.3.10.7 Combined and Regional Effects

Areas of potential ground instability for the individual LSAs range from 1 ha at Parsons Lake to more than 1,000 ha along the pipeline corridor in the South Taiga Plains A Ecological Zone. These areas represent a range of less than 0.1% to 4%

of the total area in the LSAs (see Table 8-54). For uncommon landforms, the areas affected range from 0 to about 7% of the patterned ground in the LSAs (see Table 8-55).

The data on areas of glaciofluvial and aeolian deposits in the RSAs, and areas of patterned ground in the Tundra Ecological Zone is sufficient to allow for a quantitative assessment of regional effects (see Table 8-56). About 0.5 to 2.5% of the total area of glaciofluvial and aeolian deposits in the RSAs will be affected by project activities. The area of patterned ground affected in the Tundra Ecological Zone is less than 0.1% of the total area of patterned ground in this RSA. Because of the low percentage of area affected, the effects on uncommon landforms are considered to be local in geographic extent.

Table 8-54: Summary of Combined Affected Areas for Ground Stability

Project Component or Ecological Zone	Total Area of LSA	Drainage Disruption, Thaw Subsidence and Pond Formation		Drainage Disruption from Effects from Frost Bulbs or Surface Heave		Water Erosion		Slope Instability	
	(ha)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Niglintgak	6,876	13	0.2	0	0	1	<0.1	0	0
Taglu	8,775	6	0.1	0	0	0	0	0	0
Parsons Lake	41,099	1	<0.1	0	0	0	0	0	0
Gathering pipelines and associated facilities	17,130	232	1.4	7	<0.1	51	0.3	1	<0.1
Transition Forest Ecological Zone	7,771	12	0.2	2	<0.1	3	<0.1	0	0
North Taiga Plains A Ecological Zone	26,444	211	0.8	0	0	58	0.2	2	<0.1
North Taiga Plains B Ecological Zone	21,367	191	0.9	61	0.3	80	0.4	0	0
South Taiga Plains A Ecological Zone	26,249	500	1.9	291	1.1	260	1.0	11	<0.1
South Taiga Plains B Ecological Zone	39,920	3	<0.1	274	0.7	171	0.4	0	0
Total	195,631	1,176	0.6	588	0.3	624	0.3	14	<0.1

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

Table 8-55: Summary of Combined Affected Areas for Uncommon Landforms – Local Study Areas

Project Component or Ecological Zone	Glaciofluvial and Aeolian			Patterned Ground		
	In LSA (ha)	Affected (ha)	Affected (%)	In LSA (ha)	Affected (ha)	Affected (%)
Niglintgak	224	9	4.0	1,610	20	1.2
Taglu	78	0	0	3,941	24	0.6
Parsons Lake	7,350	20	0.3	6,694	1	<0.1
Gathering pipelines and associated facilities	2,260	101	4.5	3,422	150	4.4
Transition Forest Ecological Zone	24	2	6.7	225	11	4.9
North Taiga Plains A Ecological Zone	2,086	113	5.4	96	4	4.2
North Taiga Plains B Ecological Zone	568	33	5.8	0	0	0
South Taiga Plains A Ecological Zone	4,396	202	4.6	0	0	0
South Taiga Plains B Ecological Zone	3,398	157	4.6	0	0	0
Total	22,919	781	3.4	15,988	210	1.3

Table 8-56: Summary of Combined Affected Areas for Uncommon Landforms – Regional Study Area

Project Component or Ecological Zone	Glaciofluvial and Aeolian			Patterned Ground		
	In RSA (ha X 100)	Affected[1] (ha)	Affected (%)	In RSA (ha X 100)	Affected[2] (ha)	Affected (%)
Tundra Ecological Zone	100	210	2.1	25,184	195	<0.1
Transition Forest Ecological Zone	82	42	0.5	N/A	11	N/A
North Taiga Plains A Ecological Zone	490	283	0.6	N/A	4	N/A
North Taiga Plains B Ecological Zone	140	353	2.5	N/A	0	N/A
South Taiga Plains A Ecological Zone	150	335	2.2	N/A	0	N/A
South Taiga Plains B Ecological Zone	205	258	1.3	N/A	0	N/A
Total	1,167	1,481	1.3	25,184	210	<0.1

NOTES:
N/A = data not available for the RSA
1 Includes borrow sites and areas covered by facilities at Niglintgak land-based option, Taglu and Parsons Lake and compressor station sites
2 Includes facilities at Niglintgak, Taglu and Parsons Lake and compressor station sites
Percentage is based on total area of facilities or pipelines divided by total area in LSA

8.3.10.8 Prediction Confidence

Available information and understanding of landforms were used to provide an assessment of significance of the effects of the project on ground stability and uncommon landforms. Predictions of future conditions, in the impact assessment have an associated level of uncertainty.

Prediction confidence for significance related to ground stability and uncommon landforms is high, mainly because the precautionary principle has been applied in developing the effects assessment (see Volume 1, Section 2, Assessment Method).

Where available data and uncertainty about the locations of some project facilities existed, conservative parameters and conditions were used to assess the significance of expected effects. Similarly, simplified models used in the assessment relied on conservative assumptions and were applied to ranges of parameters to determine the accuracy of the assessment.

Confidence in the effectiveness of mitigation, especially related to the effects on permafrost, is high, based on using proven techniques in other locations under similar conditions.

8.4 Effects on Soil Quality

8.4.1 Effect Pathways

The effect pathway diagram in Figure 8-9 shows the key pathways and intermediate pathways by which the project could affect soil quality key indicators.

Each pathway was evaluated to determine if it would be applicable, given the mitigation planned for the project. A pathway was considered inapplicable if mitigation would eliminate the potential for effects on soil quality. A pathway from another discipline was also considered inapplicable if it would have no affect on soil quality. The pathways considered to be applicable for the soil quality assessment are shown in Table 8-57.

Table 8-57: Applicable Pathways for Project Effects on Soil Quality

Pathway		Applicable
Change in soil chemical properties	Leaks and spills	N/A
	Air emissions, dust	●
	Mixing	●
Change in soil physical properties	Mixing	●
	Soil erosion	●
Change in soil drainage	Surface subsidence or heave, or frost bulbs, i.e., from project effects on landforms	●
	Soil burial	●
Loss of soil	Soil burial	●
	Soil removal	●

NOTES:
● = applicable
N/A = not applicable

Each pathway, whether it is applicable or not, is discussed in the following sections. In the assessment discussed in the sections that follow, only applicable pathways are assessed.

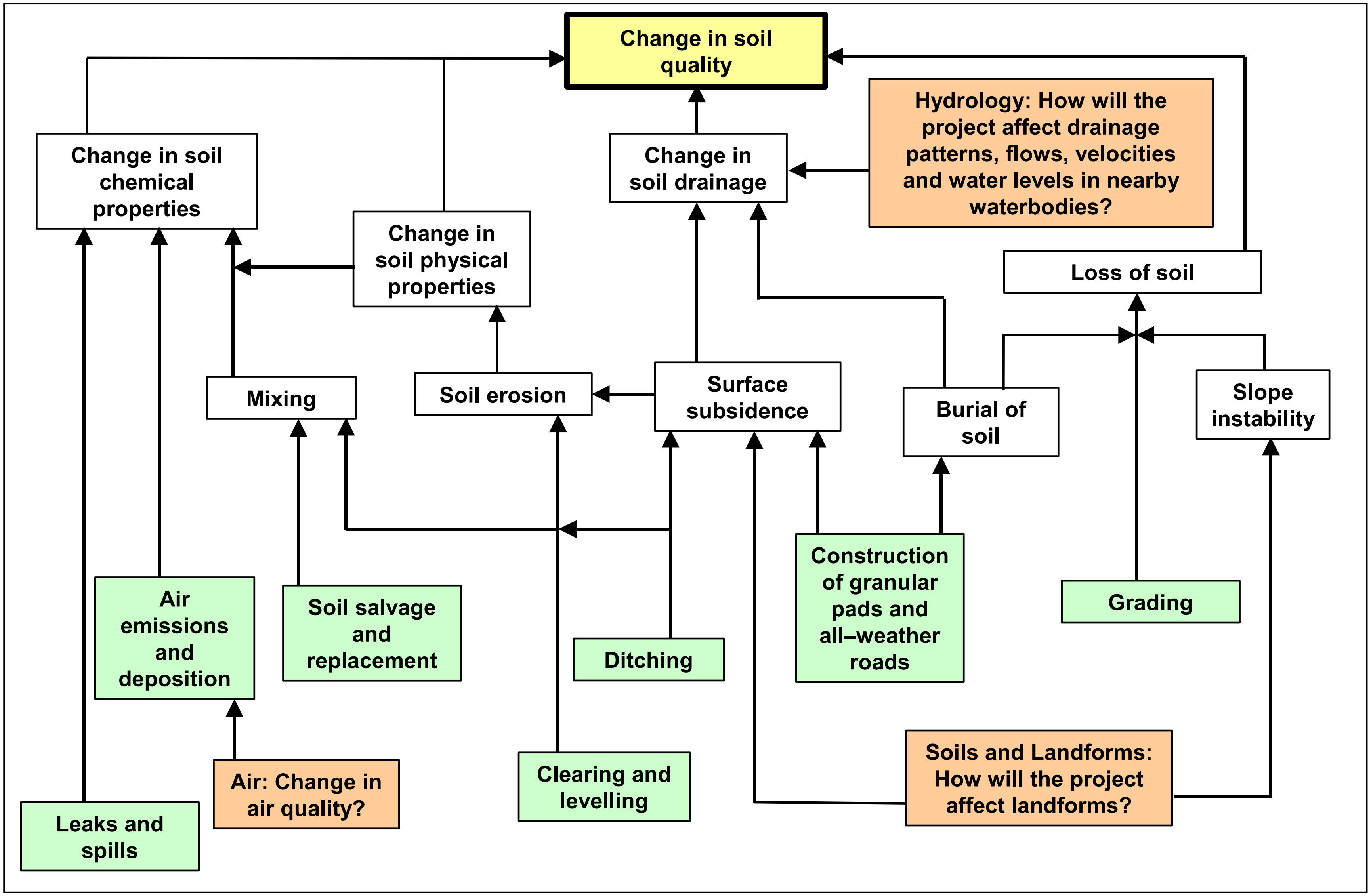

Figure 8-9: Effect Pathways – Soil Quality

The key pathways that can lead to a change in soil quality are:

Change in soil drainage – A change in drainage conditions, usually to wetter conditions, is mainly caused by thaw subsidence along trench lines. There could also be situations where drainage is improved. Ditching and the associated clearing and levelling activities required to prepare land surfaces for ditching could cause subsidence. Development of a frost bulb around the buried pipe during operations might also change soil drainage. Construction of pads could also lead to change in drainage by thaw subsidence around the perimeter of pads, and through alteration of normal drainage patterns. Change in drainage is linked to assessments of other key questions concerning landforms, as indicated in Figure 8-6, shown previously (see Section 8.3, Effects on Landforms and Section 5, Hydrology).

Soil loss – The main pathway for soil loss involves burial of native soils. Other possible mechanisms are mass movement of landforms caused by unstable slopes, and transfer of soil material from one location to another. Constructing all-weather roads and pads for infrastructure sites and facilities are the main project activities that will cause burial of soils. Loss initiated by grading is another pathway whereby soils on slopes are removed and transferred or buried. Another pathway begins with pipeline effects on slope stability, as assessed through the soil and landform key question: *How will the project affect landforms?* (see Section 8.3, Effects on Landforms). Unstable slope conditions can lead to land slips and slides, with soils moved downslope and buried or mixed with underlying materials, or submerged in waterbodies.

8.4.1.1 Soil Drainage

Changes in soil drainage could affect soil quality over extensive distances along the pipeline, at production facilities, infrastructure sites and borrow sites. The consequences could be positive and adverse. Increased moisture in a dry soil is likely to increase the capability of a soil to support plants and soil biota, with increased plant cover and numbers of species. However, soil that is initially in a moist to wet condition could become saturated or completely flooded, adversely affecting soil quality. In situations where surface water is diverted or channelled, soil could become drier, reducing plant cover and increasing erosion risk, especially in sloped terrain.

Most soils in the production area are on fine-textured, ice-rich genetic material, with a shallow permafrost table. Disruption of the surface thermal equilibrium caused by removing vegetation or soil could change drainage conditions. If exposed, the ice-rich soil will thaw because the insulating surface vegetation has been removed and because the dark surface will absorb more heat. This will increase the amount of water flowing over the top of the permafrost table and the active layer will deepen.

The soil moisture content in areas with a shallow active layer, which is common in the production area, varies depending on location in the landscape and time of year. Melting snow and thawing soils in early spring cause water perched at or near the surface, over impermeable frozen ground, in areas of level terrain. As warming progresses, the near-surface ice in the active layer melts and saturates the layer immediately above the permafrost table. This water moves laterally over the permafrost table in response to slope gradients and collects in ponds or depressions. In fall and winter, this water freezes as lenses and veins. Over time, the amount of ice or water tends to increase in localized areas.

The development of poorly drained areas results in wetter soils in the summer and possibly higher ice contents at shallow depths. Soils located at the crest or upper slope positions in the landscape could benefit from a deeper active layer, which would also provide a deeper rooting zone.

Changes in soil drainage are expected to result from right-of-way and facility preparation activities including clearing, levelling, grading and ditching. Infrastructure components such as pads and all-weather roads, borrow material excavations and winter roads also have the potential to cause changes in soil drainage. Subsidence caused by gas extraction and vehicle traffic can also affect soil drainage.

Clearing

Clearing refers to the removal of standing surface vegetation, which will occur before construction of most project components. Ditching is normally associated with subsequent project activities such as levelling, grading, trenching or pad placement. Parts of the proposed footprint might be cleared, but will not be subject to further disturbance. These areas will be limited to small buffer zones of cleared land surrounding certain development sites.

Clearing has the potential to cause changes in soil drainage because once vegetation is removed, the surface is exposed to greater solar radiation. This change in thermal conditions could be sufficient to cause permafrost degradation and a deeper active layer at thaw-sensitive sites (Hernandez 1973; Adam and Hernandez 1977). Settlement of the ground surface could occur when permafrost thaws in soils with excess ice. Thaw settlement often results in wetter soil conditions because the water table is located closer to the surface. This effect will most likely occur in flat or depressional sites where soil water does not drain freely.

Clearing on moderately to strongly sloping sites also has the potential to induce permafrost thaw and development of a deeper active layer, but the likely impact to soil drainage is a change to drier conditions. Once water infiltrates vertically through the soil profile, it reaches the impermeable permafrost table and then moves laterally along the top of this layer. If active layer depth has increased because of clearing, most of the available water in the soil profile will be deeper than it was before clearing. The result will be a drier moisture regime, and depending on the degree of change, vegetation communities could be affected.

Soils with the highest susceptibility to thaw settlement are fine-textured mineral Cryosols and Organic Cryosols with a shallow permafrost table. Regional location will also influence the magnitude of the effects of clearing on soil drainage. Cryosols in forested areas will be affected to a greater degree than Cryosols located in the tundra because larger volumes of surface vegetation will be removed in forested areas, causing a greater change to thermal conditions.

Levelling

A smooth travel and work surface will be established during construction along the pipeline right-of-way and access roads. In the Tundra Ecological Zone, a winter road will generally be constructed on the right-of-way travel lane and along watercourses. South of the Tundra Ecological Zone, a smooth travel surface will be prepared by surface levelling, whereby the tops of tussocks will be removed, where necessary, and used to fill in low areas. Surface levelling will cause localized disturbance to soil and will have the potential to cause subsidence in thaw-sensitive permafrost areas. The removal of insulating surface organic materials and the exposure of dark-coloured material could change the thermal conditions of the soil sufficiently to initiate permafrost thaw. The thawing of ice-rich soils will result in increased soil moisture content, a deeper active layer and ponding of water in depressions. Long-term ponding might lead to surface subsidence.

Soils in which poor drainage or ponding are likely to occur because of surface levelling are organic-rich and fine-textured Cryosols in low-lying landscape positions such as depressions and at the base of slopes. Poor drainage or ponding could also occur in areas where permafrost tables are shallow. Large areas in the production area meet these criteria, as there are many soils with shallow permafrost that have developed in fine-textured genetic material and are located in landscapes with little relief. Changes in surface drainage associated with permafrost degradation are discussed in Section 8.3.1.1, Ground Stability.

Soils in upper landscape positions, or on sloping topography, are well drained and not subject to ponding. Permafrost thaw related to surface levelling in these areas is likely to cause warmer, drier soils that have deeper active layers and root zones.

Regional location will also influence the effects of levelling on soil drainage. Cryosols in forested areas of taiga will be affected more than Cryosols in tundra. Larger volumes of surface vegetation will be removed in forested areas, which will cause larger changes in thermal conditions compared with tundra. In addition, the permafrost in areas of discontinuous permafrost is warmer and might thaw more easily if warmed by heat transfer into the ground as a consequence of levelling.

Ditching

Backfilled pipeline trenches could have an affect on soil drainage throughout the life of the project. The mechanisms through which change in soil drainage could occur are thaw settlement, damming and placement of select fill.

Thaw settlement is more likely to occur in areas where the permafrost table lies within trench depth before construction. Materials with excess ice, such as fine-textured moist soils, are particularly susceptible to thaw settlement. Organic materials are also at risk of thaw settlement as they usually contain excess ice and have shallow permafrost.

Thaw settlement can lead to wetter soil conditions or changed surface water drainage patterns. Areas susceptible to thaw settlement will generally receive sufficient select fill in the trench before backfilling the excavated material to compensate for the expected thaw settlement. Therefore, the composition of the material at the surface will be comparable to material composition before construction. Even so, it is likely that in some areas, particularly in depressions and low-lying areas, thaw settlement will occur. Where such thaw settlement could change drainage patterns (see following) select fill would be placed in the depressions to control drainage.

Thaw settlement along the trench line can change drainage patterns by developing a pathway where surface water collects and flows. This can cause poor to very poor drainage along the trench, which can lead to erosion as soil particles are removed by water flow in the trench. Changes in drainage patterns caused by ditching are most likely to occur where the pipeline is placed across a slope and the trench captures upslope drainage, or in nearly level terrain where drainage patterns are not well-established.

Thaw settlement along the trench line will occur following construction, and effects on surface drainage will continue throughout operations and decommissioning and abandonment. Depending on local permafrost conditions and revegetation success, ground thaw settlement could continue throughout operations, or decline as disturbed areas stabilize.

The frost bulbs will begin to thaw after the flow of chilled gas is shut off at the end of operations. The bulbs will gradually reduce in size and the surface and groundwater flow characteristics will approach conditions that existed before project construction and operations. Some residual effects related to frost heave of the pipeline and groundwater surface might remain in some areas.

Ditching could also change soil drainage when the material in the backfilled trench forms a barrier to subsurface water flow. Damming of subsurface water flow is most likely to arise in areas where blanket slope drainage is present. This drainage type occurs on long, gentle slopes in ice-rich, fine-textured sediments.

Blanket slope drainage is characterized by the flow of water in a sheet-like manner at the surface of the gently sloping permafrost table. A fairly high volume of water moves downslope, especially during the summer months, draining relatively large upslope surfaces. If this flow is impeded, ponding can occur upslope of the pipeline trench and subsequent thaw settlement or erosion might develop. Blanket slope drainage is commonly found in morainal landform units and in moraine or colluvium overlying bedrock.

Placement of select fill during trench backfilling, or as a remedial measure during operations, might affect soil drainage because the textural characteristics of the fill will be different than the original material. Select fill might change soil drainage characteristics. The rate at which water might pass through and infiltrate the new material will be faster than in soil that formerly occupied the trench. Soil drainage might change to a drier state in areas where select fill is placed.

Frost Bulb Formation

Damming of surface or subsurface water flow can be caused by the formation of a frost bulb around buried pipeline. Frost bulb refers to an area of frozen ground, which was previously unfrozen, around the operating pipeline. The presence of a frost bulb can change soil drainage because ponds can form upslope of the pipe, slope instability can result or drainage pathways can be redirected. Details about frost bulb formation and the terrain conditions where frost bulbs are likely to occur are provided in Section 8.3, Effects on Landforms. As the frost bulb thaws, drainage is expected to stabilize within 30 years following decommissioning and abandonment.

Grading

Grading is done during construction in areas of sloping terrain to produce stable surfaces for facility or pipeline development. Grading could affect soil drainage through changes in landforms, permafrost thaw and placement of select fill.

Where grading is done, there is potential to change the shape of landforms and surface drainage patterns. Changes in surface drainage patterns could cause poor drainage in areas that were formerly well drained.

Where grading is done in permafrost areas, thaw could be induced by the removal of insulating surface material. As permafrost melts at upslope locations, water will transfer to lower landscape positions, changing soil drainage characteristics. Soils in toe slope positions and in depressions could become wetter, and ponding could result. Conversely, soils in higher landscape positions might change to drier moisture regimes with deepening of the active layer and water table.

Ice-rich areas that require grading might be contoured and stabilized with select fill rather than with existing material from that location. Select fill might change soil drainage characteristics. The rate at which water might pass through and infiltrate the new material will be faster than in the original slope material. Soil drainage might change to a drier state in areas where select fill is placed.

Pads and All-weather Roads

Thick pads are placed on top of ice-rich sediments to preserve permafrost and maintain a stable surface for facility or road construction. These pads will be maintained during operations and might not be removed during decommissioning and abandonment. The presence of these pads and roadbeds could alter soil drainage through diversion or damming of surface water. The permafrost table below these pads might rise and increase the damming effect.

Poorly drained soils or ponds might develop upslope from roads or pads where surface drainage is impeded by the pad, or because of runoff from the pad. Soils that are saturated or flooded for several years can become unstable because of thaw subsidence and erosion. Conversely, soils downslope of a road or pad might become drier. In either situation, soil quality will be affected and will likely cause a shift in vegetation composition in response to the change in soil moisture content.

Pads and all-weather roads will be established during construction and will continue to affect drainage during operations. Additional mitigation measures will be applied, as required, to reduce effects of ponding or drainage diversion on the soils adjacent to pads and roadbeds.

Winter Roads

Winter roads might be built along the right-of-way travel lane and at shooflies, and to access water sources, borrow sites, stockpile areas and other infrastructure, as required during construction. Road surfaces will be continuously maintained and upgraded, where necessary, to reduce disturbance to the soil surface.

Localized ponding might result from temporary damming of meltwater in the spring by the thick ice or snow pad. These effects are expected to temporarily cover small surfaces, with minor long-term effects on soil quality.

Subsidence Resulting from Gas Extraction

Project development and operations might cause land subsidence at both Niglintgak and Taglu. The extraction of natural gas and NGLs will reduce reservoir volumes and pressures, leading to compression of the reservoir and potential subsidence of overlying land.

The land areas of the outer Mackenzie Delta are only slightly above sea level. A small decrease in land elevation could cause inundation of low-lying areas. Potential issues that affect several environmental components include possible:

- increased extent and duration of land inundation
- changes in stream hydrology, sediment characteristics and channel morphology
- changes in water quality from increased saltwater intrusion

In particular, inundation of low-lying fluvial landforms might cause siltation and saturation of high-ice-content Cryosols, which would affect soil quality and the ability of plants to survive.

Vehicle Traffic and Road Dust Deposition

Long-term use of all-weather roads might cause dust accumulation on vegetation and soils. A darker surface, created by settled dust adjacent to roadways or pads, or mud scattered on the surface of winter roads, might lead to surface warming and induce thawing in Cryosols with shallow permafrost (Auerbach et al. 1997; Walker and Everett 1987). Soil drainage might be affected by thaw settlement, resulting in poorly drained conditions.

The magnitude of the effects would be linked to traffic volume and is expected to be greatest during construction, and reduced during operations, and decommissioning and abandonment. Effect magnitude is also related to location, as active layer thaw is deepest next to the road and decreases farther away from the road. Walker and Everett (1987) found that active layer thaw was greatest within 10 m of a road. Dust accumulation is not the only cause of active layer thaw adjacent to roads. Other factors include vegetation loss and increased insulation against freezing provided by snow accumulation adjacent to the road.

8.4.1.2 Soil Loss

Soil is lost when fill is placed on the soil surface, without removal of the soil, to construct pads and all-weather roads. This fill will be present throughout operations and might not be removed at decommissioning and abandonment. Ice-rich soil and subsoil will be replaced with select backfill in the trench. Soil loss is important because soils are a valuable resource, especially in cold-climate areas where soil development rates are slow. Soils are low in plant-available nutrients in most of the project area, but they support natural vegetation communities adapted to a wide range of conditions. If lost or clearly altered, the soils will not be restored within the life of the project.

Soil quality will change where soil is completely removed or covered with select fill. The new surface material will be more likely to support early successional stage grasses and sedges, rather than mature native plant communities.

Ditching

In some locations along the right-of-way, such as steep slopes in material with high ice content, the excavated material will be completely removed from the trench during construction and will be replaced with select fill. The select fill will likely be of lower quality than the soil that was present before construction because of its possibly coarser texture and lack of organic matter.

Surface soils can also be lost because of water or wind erosion. This process might be considered a redistribution of soil material, with an impact on soil physical and chemical properties, as discussed in Section 8.4.1.3, Soil Physical and Chemical Characteristics.

Grading

Where grading in ice-rich soils cannot be avoided, sufficient thaw-stable fill or insulating materials will be placed over the surface of the exposed cut so that the slope will remain stable following construction. If the reconstructed surface is not compatible with soil replacement and revegetation, the soil will be lost by disposal, along with the ice-rich, excavated, subsurface material.

Pads and All-weather Roads

In terrain where permafrost is not present, soil will be removed before the placement of select fill at infrastructure sites and on the right-of-way. This will include a mixture of the surface organic material and variable amounts of mineral material that is loosened during grubbing, i.e., the removal of tree stumps and major roots. In permafrost terrain, pads and right-of-way fill will be placed directly on the undisturbed soil surface and will not be removed during decommissioning and abandonment, resulting in loss of soil.

8.4.1.3 Soil Physical and Chemical Characteristics

Soils in the project area are weakly developed and low in plant-available nutrients. Where the soil is completely removed and genetic material or fill is used as the rooting medium (see Section 8.4.1.2, Soil Loss), the soils will still support rudimentary vegetation such as early successional stage grasses and sedges. Where the soil surface is only partially removed, is physically disturbed or receives foreign substances, the ability to support vegetation will be greater and recovery of the former plant community will be more rapid. The colder climate in the production area accounts for slower soil development and for slower recovery following disturbance, compared with areas farther south along the pipeline corridor.

Changes in soil chemical and physical properties are addressed by assessing individual soil chemical and physical attributes.

Changes in soil chemical and physical properties during construction could occur because of levelling of the pipeline right-of-way, excavation and backfilling of the trench, extraction of borrow material, and leaks and spills. Types of changes that could occur are:

- surface soil thickness and composition changed by wind or water erosion
- soil organic matter and nutrient content dilution, along with soil structure alteration, caused by mechanical mixing
- topsoil and subsoil admixing during removal and replacement operations

Soil changes that could occur during operations and decommissioning and abandonment are likely to be associated with extraction of borrow material, air emissions, leaks and spills, road dust and final site reclamation. Possible changes include:

- changed properties caused by deposition of air emissions
- soil reaction and changed properties caused by road dust deposition
- soil chemistry changed caused by substance release
- topsoil and subsoil admixing during removal and replacement operations

Clearing and Levelling

Levelling the right-of-way surface might cause localized removal and mixing of soil, possibly changing soil chemical and physical characteristics and increasing the erosion potential.

Doing work when the ground is frozen reduces the effect of soil compaction. Compaction associated with rutting could occur in late winter, near the end of the construction season, when longer days and a higher sun angle might soften the work surface by late afternoon.

Ditching

The trench line will be excavated in winter using backhoes and wheeled ditchers. The soil over the trench line will not be removed and replaced but will be mixed with subsoil during ditching and backfilling. Given the shallow depths of the soils, compared with the 2-m depth of the trench, the soil chemical and physical properties of the backfill material will more closely resemble the subsoil than the original topsoil. The thickness of the A and B soil horizons ranges from 10 to 30 cm in the Tundra Ecological Zone to 40 cm in the southern areas, with some occurrences of 60 to 80 cm in well-drained, nonpermafrost soils.

The surface materials of backfilled trenches will usually have a higher mineral content than the original undisturbed soil, except for organic bogs and peat plateaus south of Fort Simpson. Mixing of subsurface with surface soil materials will dilute the organic matter and nutrient content, and the soil texture and structure could differ from the original material. These changes in soil properties could affect soil quality.

Ditching will also expose surfaces and increase soil susceptibility to erosion during construction and possibly throughout operations. Soils replaced along the trench line are susceptible to erosion, as they have been loosened and exposed to the erosive forces of wind and water. Erosion is most likely to occur before the surface is revegetated or recovers naturally.

Borrow Material Excavations

Select fill will be extracted from borrow sites and used to construct all-weather access roads and pads, and used as fill for the pipeline trench. Removal, storage and replacement of loose surface material in these areas will alter chemical and physical characteristics to a limited degree.

Leaks and Spills

Small leaks and spills of fuel, engine fluids or chemical products used during construction, at camps or other sites, might change soil chemical characteristics and reduce soil quality. Measures to prevent leaks and spills, and to address storage and cleanup are addressed in Volume 7, Environmental Management.

The incidence of leaks and spills and their potential effects on soil quality will be reduced during operations because activities will be mainly limited to installing remedial drainage and erosion control measures along the right-of-way.

Air Emissions

Compressor stations will be the main source of air emissions. Emissions might include unburned hydrocarbons, oxides of nitrogen, sulphur dioxide, carbon monoxide, suspended particulates and water vapour. Because of the low levels of emissions, measurable changes in soil chemistry adjacent to the compressors are not expected. The low-level nitrogen and sulphur emissions would be added to the soil nutrient pool and could enhance plant growth. The primary effect of vehicle road dust deposition on soil quality is expected to occur through changes in soil drainage, discussed previously in Section 8.4.1.1, Soil Drainage.

8.4.2 Overview of Project Design and Mitigation

This section provides an overview of project design features and mitigation relevant to potential effects on soil quality. The project design features, and mitigation measures are detailed in Volume 2, Project Description and Volume 7, Environmental Management. Management practices during design, construction, operations, and decommissioning and abandonment will reduce most potential effects of the project. The effect pathways are discussed in more detail in Section 8.4.1, Effect Pathways. Most effects will be initiated during construction and will cause changes that will persist through the remainder of the project. Decommissioning and abandonment activities will remove many project components that generate effects. Some long-lasting effects, and those related to project components abandoned in place, are expected to persist into postdecommissioning. Mitigation measures that will be used to reduce project effects are listed in Table 8-58.

Table 8-58: Mitigation Strategies for Soil Quality During Construction

Effect Pathway	Primary Mitigation Strategy
Changes in soil drainage, physical and chemical properties caused by clearing and grading of pipeline and access road rights-of-way	Conduct most pipeline construction activities during the winter. Use winter roads. Reduce surface grading in thaw-unstable terrain, where practical. Place an insulating cover on cut surfaces in thaw-unstable terrain. Incorporate drainage culverts in all-weather roads, as required.
Loss of soil on slopes caused by pipeline and access road construction	Reduce surface grading where practical. Remove loose surface material on thaw-stable ground and replace after completing activity. Reclaim, stabilize and armour slopes and banks as necessary.
Loss of soil at borrow sites during development	In summer, remove loose surface material on thaw-stable ground and replace during reclamation. Store loose surface material away from subsoil in thaw-stable ground, where practical.
Changes in soil drainage along ditch after backfilling and settlement	Use thaw-stable backfill in the trench as required. Place additional fill materials in areas experiencing thaw settlement along the pipeline corridor.
Changes in soil physical and chemical properties caused by inadvertent leaks and spills	Implement management practices, contingency plans and emergency response plans to prevent and address leaks and spills.

8.4.3 Niglintgak

See Section 8.3.3, Niglintgak, for a description of the Niglintgak development.

8.4.3.1 Baseline Conditions

See Section 8.3.3.1, Baseline Conditions, for a description of the baseline conditions found at Niglintgak.

The dominant soil great groups and subgroups found at Niglintgak reflect the climatic regime and processes present in the area.

Soils found at Niglintgak are described relative to the landforms with which they are associated. Cryosols dominate, comprising mostly mineral soils, such as Regosolic Cryosols, Orthic Cryosols, Gleysolic Cryosols and Brunisolic Cryosols. Turbic Cryosols show evidence of cryoturbation and occur mostly on fine-grained Orthic or Brunisolic Cryosols on upper slope and crest positions. Static Cryosols do not show evidence of soil horizon churning and are mostly found on very recent surfaces, such as floodplains. Organic Cryosols are not common at Niglintgak. Depths of the surface organic layer range from 5 to 60 cm, with the deepest accumulations found in the centre of ice-wedge polygons.

A more detailed description of the landform and soil baseline conditions at Niglintgak is in Volume 3, Section 8, Soils, Landforms and Permafrost.

8.4.3.2 Niglintgak Effects

Table 8-59 summarizes project effects related to soil quality, after mitigation, caused by activities required to construct, operate and decommission Niglintgak.

Table 8-59: Effects on Soil Quality – Niglintgak

Pathway	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Changes in soil drainage	Construction	Neutral	Low	Local	Long term
	Operations	Adverse	Low	Local	Far future
	Decommissioning and abandonment	N/A	No effect	N/A	N/A
Soil loss	Construction	Adverse	Low	Local	Far future
	Operations	N/A	No effect	N/A	N/A
	Decommissioning and abandonment	N/A	No effect	N/A	N/A
Changes in soil chemical and physical characteristics	Construction	Adverse	Low	Local	Short term
	Operations	Adverse	Low	Local	Short term
	Decommissioning and abandonment	Adverse	Low	Local	Short term
NOTE: N/A = not applicable					

The main effects on soil quality at Niglintgak will occur during construction when the most surface disturbance will occur. Soil quality will primarily be affected through changes in soil drainage and soil loss if the land-based Niglintgak gas conditioning facility option is selected. In this scenario, effects of soil loss will also continue after decommissioning and abandonment. Therefore, construction-related effects on soil quality will be neutral to adverse, low magnitude, local in extent and short term to far future in duration.

Effects on soil quality during operations are related to changes in soil drainage caused by thaw settlement or subsidence resulting from gas extraction and changes in soil properties. The remote sump, previously discussed in Section 8.3.3.2, Niglintgak Effects, is most likely to affect surface drainage. Surface soil will be removed before sump excavation and replaced when the sump is reclaimed, after drilling of production wells is completed. Soil chemical and physical properties might change during operations because of mixing, small leaks or spills, and air emissions. Effects on soil quality during operations will likely be adverse, low magnitude, local in extent and short term to far future in duration (see Table 8-59, shown previously).

Effects on soil quality during decommissioning are minor, related to any surface disturbance required to decommission the project. Effects will likely be adverse, low magnitude, local in extent and short term.

Changes in Soil Drainage

Construction

Changes in soil drainage are expected to be minimal at Niglintgak because several project components will be built on raised platforms, rather than on pads. Raised facilities are necessary because the Niglintgak field is close to sea level and will likely be subject to flooding. Effects on soil drainage are expected to be most noticeable immediately following construction and are closely related to effects of permafrost degradation and permafrost-related subsidence.

The land-based option for the gas conditioning facility will cause potential changes in soil drainage because of the placement of a 7.2-ha facility pad. Diversion or damming of surface drainage could cause changes in soil drainage in areas adjacent to the pad. If changes in soil drainage occur, they will be most evident in the area surrounding the facility footprint. However, changes in soil drainage are expected to be minor for construction of the land-based gas conditioning facility because it is located on sandy-textured glaciofluvial deposits, which are not prone to thaw settlement.

The potential for thaw settlement was determined based on landform characteristics described in Section 8.2.6.1, Landforms. The fluvial floodplains, where the well pads and sections of the lateral lines are located, have fine texture, poor drainage and ice-wedge polygons that contribute to high thaw-settlement susceptibility (see Table 8-60). Well pads will consist of steel decking on piles. Therefore, surface disturbance at these sites will be limited to support structures for the raised well pads. Changes in soil drainage will likely be minimal.

Table 8-60: Extent of Potential Changes in Soil Drainage caused by Thaw Settlement at Niglintgak

Landform Type	Drainage Class	Footprint Area Subject to Changes in Soil Drainage (ha)	Area of Landform Type in the Niglintgak LSA (ha)	Proportion of Landform Type Affected by Changes in Soil Drainage (%)
Fluvial floodplains with ice-wedge polygons, occasional flooding	Poor to very poor	3.9	1,173	0.3
Fluvial floodplains, seasonal flooding	Imperfect to very poor	4.0	758	0.5
Fluvial floodplains, occasional flooding	Poor to very poor	0.6	261	0.2
Total		8.5	2,192	0.4

Ice pads might also change soil drainage characteristics. The raised, steel well pads in Niglintgak will be constructed with equipment on ice pads during winter. Ice pads will melt at a slower rate than snow or ice on the surrounding terrain. Spring runoff near ice pads could be impeded and a wetter soil condition or ponding might occur. This effect will likely be temporary and constrained to a small area. The remote sump could also change soil drainage through diversion or damming of surface water.

Changes in soil drainage following construction will likely occur throughout operations to decommissioning and abandonment. Mitigation measures will be applied, where surface or site stability is at risk, to reduce the potential impacts associated with wet soils or areas of ponding. The effects of changes in soil drainage on soil quality during construction will be neutral, low magnitude, local in extent and long term.

Operations

Niglintgak is close to sea level and inundation might occur if gas extraction leads to subsidence. The effects of long-term subsidence described in Section 8.4.1.1, Soil Drainage, could change soil drainage during operations. These effects are irreversible and will be present throughout operations and after decommissioning and abandonment. Therefore, the effects of changes in soil drainage on soil quality during operations for Niglintgak will be adverse, low magnitude, local in extent and far future in duration.

Decommissioning and Abandonment

As discussed for construction, the land-based option for the gas conditioning facility will require placement of a pad. This material might not be removed at decommissioning and abandonment, but the surface will be recontoured and drainage patterns will be re-established. No additional changes in soil drainage are expected during decommissioning and abandonment. Therefore, no effects on soil quality are predicted for Niglintgak because of changes in soil drainage during decommissioning and abandonment.

Soil Loss

Construction

Loss of soil cover at Niglintgak will be limited to the construction phase and will occur only if the land-based gas conditioning facility is selected. The land-based option involves placing the facility on a glaciofluvial outwash plain and occupying an area of 7.2 ha. A pad would be placed over a sandy-textured soil (see Table 8-61). There is no predicted soil loss during construction of the flow lines or the production pads, as they will be elevated.

Table 8-61: Characteristics of Soil Loss at Niglintgak

Project Facility	Area of Loss (ha)	Landform Type	Terrain Texture	Drainage Class	Soil Type	Area of Landform in LSA (ha)	Loss of Landform Type in LSA (%)
Barge-based gas conditioning facility	0.0	Facility on barge, grounded in stream channel	N/A	N/A	N/A	N/A	N/A
Land-based gas conditioning facility	7.2	Glaciofluvial outwash plain	Sand	Well to poor	Static Cryosols, Turbic Cryosols	224	3.2
NOTE: N/A = not applicable							

The effects of soil loss will extend beyond decommissioning and abandonment. However, plants will establish on the pad and the processes of soil development will begin. Given the cold climate and the coarse texture of the substrate, soil development will proceed slowly, and over hundreds of years a soil resembling that found on well-drained upland glaciofluvial deposits is expected to develop. Because the substrate is coarser than the native soil, the quality of the developing soil will be lower than the original soil, with lower inherent nutrient content and lower water-holding capacity.

The effects of soil loss will likely be low, occurring over less than 4% of the affected landform. Effects will be adverse, low magnitude, local in extent and far future in duration.

There will be no additional soil losses during operations and decommissioning and abandonment.

Changes in Soil Physical and Chemical Characteristics

Possible impacts on soil physical and chemical characteristics are summarized in the following sections.

Construction

Construction effects include the following considerations:

- wind erosion effects will likely be low magnitude as there are no soils rated as moderately to highly erodible by wind
- soil mixing effects are expected to be low magnitude related mainly to drilling holes for vertical support members of above-ground flow lines and pads
- should they occur, substance releases through leaks and spills are predicted to be low as a prevention plan sets the goal of no occurrences; any large incidents will be managed through an emergency response plan

The combined effects at Niglintgak of wind and water erosion, mixing and leaks and spills will be none to low. The effects will be adverse, low magnitude, local in extent and short term. Table 8-59, shown previously, summarizes the effects.

Operations

Operations effects include the following considerations:

- minor areas of soil mixing could occur because of maintenance and operating activities.
- a prevention plan sets the goal of no releases through leaks and spills. Any large incidents will be managed through an emergency response plan.

The combined effects on soil physical and chemical properties will likely be none to low, occurring over less than 1% of the area. The effects will be adverse, low magnitude, local in extent and short term (see Table 8-59, shown previously).

Decommissioning and Abandonment

During decommissioning and abandonment, minor disturbance of soil surfaces is expected from machinery used to remove production and pipeline components. The combined effects on soil physical and chemical properties will likely be none to low. The effects will be adverse, low magnitude, local in extent and short term.

8.4.4 Taglu

See Section 8.3.4, Taglu, for a description of the Taglu development.

8.4.4.1 Baseline Conditions

Taglu is located in an area dominated by low-relief, recent fluvial deposits of the Mackenzie River and channels. These fine- to coarse-textured landforms, which account for 61% of the 8,777 ha Taglu LSA, are characterized by level to very gentle slopes with poor to very poor drainage and polygonal ground. Other associated processes include occasional or seasonal flooding, and storm surge activity near the Beaufort Sea. Less extensive areas of higher elevation are made up of 5% fine- to moderately fine-textured morainal, 2% fine- to medium-textured lacustrine and 1% coarse-textured glaciofluvial deposits, with less than 1% medium-textured fluvial and variable-textured colluvial deposits. Thaw-settlement lakes, ponds and stream channels make up 31% of the LSA. Permafrost is continuous, except under large ponds, lakes and channels, where the active layer is so deep that permafrost is considered discontinuous.

Taglu soils are described relative to the landforms where they usually occur. Cryosolic soils dominate, consisting primarily of mineral soils including Regosolic Cryosols, Gleysolic Cryosols and Orthic or Brunisolic Cryosols. Turbic Cryosols, which display evidence of cryoturbation, occur mostly on fine-textured Orthic or Brunisolic Cryosols on upper slope and crest positions. Static Cryosols do not show evidence of cryoturbation within the control depth of 1 m. These soils are found on more recent surfaces, such as delta floodplain deposits. Organic Cryosols are not common at Taglu. Depths of the surface organic layer range from 5 to 60 cm, with the deepest accumulation found in the centre of ice-wedge polygons.

8.4.4.2 Taglu Effects

Project components that affect soil quality are primarily related to surface disturbance. Development will mainly occur on the pad with the gas conditioning facility, flow lines, the well pad and less than 1 km of all-weather road, occupying about 18.4 ha. Table 8-62 summarizes project effects related to soil quality, following mitigation, caused by construction, operations, and decommissioning and abandonment activities at Taglu.

The main effects on soil quality during construction in Taglu are related to soil loss and changes in soil drainage caused by constructing the pad and all-weather road. Construction-related effects will likely be adverse, low magnitude, local in extent and short term to far future in duration.

Table 8-62: Effects on Soil Quality – Taglu

Pathway	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Changes in soil drainage	Construction	Adverse	Low	Local	Far future
	Operations	Adverse	Low	Local	Far future
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Soil loss	Construction	Adverse	Low	Local	Far future
	Operations	Neutral	No effect	N/A	N/A
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Changes in soil chemical and physical characteristics	Construction	Adverse	Low	Local	Short term
	Operations	Adverse	Low	Local	Short term
	Decommissioning and abandonment	Adverse	Low	Local	Short term
NOTE: N/A = not applicable					

Changes in soil drainage caused by pad placement are likely to continue into operations until the site has stabilized. Additional changes in soil drainage might become evident during operations because of the effects of subsidence resulting from gas extraction. If subsidence occurs, changes in soil drainage will last longer than the life of the project and could be permanent. Soil chemical and physical properties might change during operations because of minor mixing and from small leaks or spills. Should they occur, leaks and spills would be contained to pads. Operations effects on soil quality will likely be adverse, low magnitude, local in extent and short term to far future in duration.

Effects on soil quality during decommissioning and abandonment are minor, related to any surface disturbance required to remove facilities and materials. Effects will likely be adverse, low magnitude, local in extent and short term.

Changes in Soil Drainage

Construction

Diversion and damming in areas adjacent to the pad and all-weather road could cause changes in soil drainage. Changes in surface drainage patterns could increase soil moisture content and might lead to ponding and thaw subsidence. The pad at Taglu will occupy about 18.4 ha in an area of poorly drained fluvial deltaic deposits. Sections of the lateral lines are also located on these deposits. These deposits are sensitive to changes in drainage as ice-wedge polygons might be present, indicating high ice content (see Table 8-63). In addition, the baseline drainage conditions of the site are imperfect to very poor and inundation occurs seasonally to occasionally. Changes in soil drainage, if they occur, will be concentrated in the area surrounding the pad and all-weather road.

Table 8-63: Extent of Potential Changes in Soil Drainage caused by Thaw Settlement at Taglu

Landform Type	Drainage Class	Footprint Area Subject to Changes in Soil Drainage (ha)	Total Area of Landform Type in the Taglu LSA (ha)	Proportion of Landform Type Affected by Changes in Soil Drainage (%)
Fluvial floodplains with ice-wedge polygons, occasional flooding	Poor to very poor	22.6	2,421	0.9
Fluvial floodplains, seasonal flooding	Imperfect to very poor	1.5	1,166	0.1
Total		24.1	3,587	0.7

Effects on soil drainage are expected to be most noticeable immediately following construction and are closely related to effects of permafrost degradation and permafrost-related subsidence. Changes in soil drainage initiated by construction activities will likely be present throughout the life of the project and beyond. Duration into the far future is expected because the main facility site is on terrain that is potentially ice-rich. Permafrost thaw and the associated changes in drainage that might occur at this site will be permanent. Therefore, effects will be adverse, low magnitude, local in extent and far future in duration.

Operations

If thaw-settlement processes have occurred, ponds might increase in size during operations because permafrost will continue to thaw until the site has stabilized.

Taglu is close to sea level and inundation might occur if development leads to subsidence resulting from gas extraction. The effects of long-term subsidence could change soil drainage during operations (see Section 8.4.1.1, Soil Drainage). These effects are irreversible and will be present throughout operations and after decommissioning and abandonment. Therefore, the effects of changes in soil drainage on soil quality will be adverse, low magnitude, local in extent and far future in duration.

Decommissioning and Abandonment

As discussed for construction, the site of the facility and well sites will require construction of a pad. This material might not be removed at decommissioning and abandonment, but the surface will be recontoured and drainage patterns will be re-established. No additional changes in soil drainage are expected during decommissioning. Therefore, changes in soil drainage during decommissioning and abandonment are predicted to have no effect on soil quality at Taglu.

Soil Loss

Construction

Loss of soil cover at Taglu will be limited to construction, with about 18.4 ha covered by the pads, airstrip and an all-weather road. The covered soils range in texture from sand to silt, and are developed on fluvial floodplain deposits subject to flooding on a seasonal to occasional basis (see Table 8-64).

Table 8-64: Characteristics of Soil Loss at Taglu

Project Facility	Area of Loss (ha)	Landform Type	Terrain Texture	Drainage Class	Soil Type	Area of Landform in LSA (ha)	Loss of Landform Type in LSA (%)
Taglu well pads	5.2	Fluvial floodplains with ice-wedge polygons, occasional flooding	Sand and silt	Poor to very poor	Static Cryosols	2,421	0.2
Gas conditioning facility	13.1	Fluvial floodplains, seasonal flooding	Silt	Imperfect to very poor	Regosols, Static Cryosols	1,166	1.1
	0.1	Water	N/A	N/A	N/A	N/A	N/A
NOTES: N/A = not applicable							

The effects of this soil loss will extend far beyond decommissioning and abandonment. However, vegetation will begin to establish on the pad within several years after construction and the processes of soil development will begin. Given the cold climate and the coarse texture of the substrate, soil development will proceed slowly, and over hundreds of years a soil resembling that found on upland, well-drained glaciofluvial deposits in the area is expected to develop.

The effects of soil loss will likely be low, occurring over less than 2% of the affected landforms. Effects will be adverse, low magnitude, local in extent and far future in duration.

There will be no further soil losses during operations and decommissioning.

Changes in Soil Physical and Chemical Characteristics

The potential effects on soil physical and chemical characteristics in the Taglu LSA are similar to those discussed for the Niglintgak LSA. During decommissioning and abandonment, minor disturbance of soil surfaces by machinery used to remove production and pipeline components is expected. The combined effects on soil physical and chemical properties will likely be none to low. Effects will be adverse, low magnitude, local in extent and short term (see Table 8-62, shown previously).

8.4.5 Parsons Lake

See Section 8.3.5, Parsons Lake, for a description of the Parsons Lake development.

8.4.5.1 Baseline Conditions

See Section 8.3.5.1, Baseline Conditions for a description of the conditions at Parsons Lake.

Soils of Parsons Lake are described relative to the landforms where they most commonly occur. Soils on the crests and slopes of hummocky, kettled and dissected hills have formed on till or gravelly glaciofluvial sand. These soils are poorly developed and have low organic matter content. On fine-textured moraine, moderately well- to imperfectly drained Orthic and Brunisolic Turbic Cryosols are most common. Shallow depth to permafrost in these landform types impedes drainage. Similar soil subgroups formed on glaciofluvial genetic material are well-drained with little to no ice controlling drainage at shallow depths. In depressions, channels and low-relief areas, poorly to very poorly drained Gleysolic Turbic Cryosols, Terric Mesic or Fibric Organic Cryosols and Regosolic Cryosols dominate. These soils are formed on either lacustrine or morainal genetic material and occasionally on glaciofluvial deposits where the water content is high enough to create a drainage impediment. Active layers are shallow, ranging from 20 to 60 cm, with surface organic layers ranging from 15 to 70 cm thick.

8.4.5.2 Parsons Lake Effects

The north pad will cover about 20.4 ha, including the production wells, the gas conditioning facility, a small float plane dock and a short road, an airstrip, and two short roads that connect dock and airstrip to the main pad. The south pad will cover a smaller area than the north pad, i.e., about 3.3 ha, as it will be used primarily for production wells and not for additional facilities. Flow lines will be above ground, which will limit surface disturbance to the support structures used for the pipeline. In addition, the flow lines will be built after construction in the lateral line right-of-way, and no additional disturbance will occur.

The main effects on soil quality during construction at Parsons Lake are related to soil loss that will occur when constructing the pads because of the nature of the glaciofluvial deposits. Changes in soil drainage will be low. Construction effects will likely be adverse, low magnitude, local in extent and short term to far future in duration (see Table 8-65).

Table 8-65: Effects on Soil Quality – Parsons Lake

Pathway	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Changes in soil drainage	Construction	Adverse	Low	Local	Long term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Soil loss	Construction	Adverse	Low	Local	Far future
	Operations	Neutral	No effect	N/A	N/A
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Changes in soil chemical and physical characteristics	Construction	Adverse	Low	Local	Short term
	Operations	Adverse	Low	Local	Short term
	Decommissioning and abandonment	Adverse	Low	Local	Short term
NOTE: N/A = not applicable					

Effects on soil quality are expected to diminish during operations. Minor changes in soil drainage might continue into operations, until the site has stabilized. Soil chemical and physical properties might change during operations because of mixing, minor leaks or spills, and air emissions. Operations effects on soil quality will likely be adverse, low magnitude, local in extent and short term to long term.

Effects on soil quality for decommissioning and abandonment will be related to any surface disturbance required to decommission the project and will be minor. Effects will likely be adverse, low magnitude, local in extent and short term.

Changes in Soil Drainage

Construction

Diversion or damming of surface drainage adjacent to pads and all-weather roads could cause changes in soil drainage. Changes in surface drainage patterns could increase soil moisture content and might lead to ponding and thaw subsidence. Pads will be used at Parsons Lake to construct the north and south pads and the airstrip. These pads will occupy an area of sandy to gravelly textured, hummocky glaciofluvial deposits. The coarse texture and moderate slopes of these deposits creates rapidly drained soils. These site conditions have low potential for changes in soil drainage caused by thaw settlement. A small area, i.e., 0.5 ha, of the south pad is located on thin lacustrine deposits, with ice-wedge polygons that are susceptible to changes in drainage caused by thaw settlement (see Table 8-66).

Table 8-66: Extent of Potential Changes in Soil Drainage Caused by Thaw Settlement at Parsons Lake

Landform Type	Drainage Class	Footprint Area Subject to Changes in Soil Drainage (ha)	Total Area of Landform Type in the Parsons Lake LSA (ha)	Proportion of Landform Type Affected by Changes in Soil Drainage (%)
Lacustrine deposits of variable thickness over moraine or glaciofluvial with ice-wedge polygons	Well to very poor	0.8	1,413	Less than 0.1

Effects on soil drainage are expected to occur immediately following construction and will likely be present throughout operations until decommissioning and abandonment. Long-term duration is expected because changes in drainage are more likely to be attributed to diversion or damming rather than thaw settlement. Diversion or damming can be reduced at decommissioning by re-establishing drainage patterns. Therefore, effects will be adverse, low magnitude, local in extent and long term.

Operations

If thaw-settlement processes have occurred, ponds might increase in size during operations because permafrost will continue to thaw until the site has stabilized. Effects of subsidence resulting from gas extraction are not expected in the Parsons Lake area. Therefore, the effects of changes in soil drainage on soil quality will be adverse, low magnitude, local in extent and long term.

Decommissioning and Abandonment

As discussed for construction, the well pads and airstrip will require construction of a pad. This material might not be removed at decommissioning and abandonment, but the surface will be recontoured and drainage patterns will be re-established. No additional changes in soil drainage are expected during decommissioning. Therefore, no effects on soil quality caused by changes in soil drainage are predicted for Parsons Lake.

Soil Loss

Construction

Loss of soil cover at Parsons Lake will be limited to construction. Construction will cause the loss of soil cover over an area of about 23.7 ha, including the north and south pads. The affected soils are coarse, ranging from sand to gravel in texture (see Table 8-67). No soil loss is expected in constructing the elevated flow line.

Table 8-67: Characteristics of Soil Loss at Parsons Lake

Project Facility	Area of Loss (ha)	Landform Type	Terrain Texture	Drainage Class	Soil Type	Area of Landform in LSA (ha)	Loss of Landform Type in LSA (%)
Parsons Lake north pad, airstrip, roads	19.7	Hummocky glaciofluvial outwash	Sand, gravel	Variable, rapid to poor	Static Cryosols, Turbic Cryosols, Eutric Brunisols	6,651	<0.1
	0.7	N/A, i.e., abandoned well pad	Sand, gravel	N/A	N/A	N/A	N/A
Parsons Lake south pad	2.8	Low-relief moraine	Till	Imperfect to very poor	Turbic Cryosols, Organic Cryosols	511	0.5
	0.5	Lacustrine deposits of variable thickness over moraine or glaciofluvial with ice-wedge polygons	Fine-grained	Well to very poor	Organic Cryosols, Turbic Cryosols	1,431	<0.1

NOTE:
N/A = not applicable

The effects of this soil loss will extend beyond decommissioning and abandonment. However, vegetation will begin to establish on the pads within several years after construction and the processes of soil development will start.

The effects of soil loss will likely be low, occurring over less than 1% of the affected landforms. They will be adverse, low magnitude, local in extent and far future in duration.

There will be no further soil losses during operations and decommissioning.

Changes in Soil Physical and Chemical Characteristics

The potential effects on soil physical and chemical characteristics in the Parsons Lake LSA are the same as those discussed for the Niglintgak and Taglu LSAs. During decommissioning, minor disturbance of soil surfaces by machinery used to remove production and pipeline components is expected. The combined effects on soil physical and chemical properties will likely be none to low. The effects will be adverse, low magnitude, local in extent and short term (see Table 8-65, shown previously).

8.4.6 Gathering Pipelines and Associated Facilities

The gathering pipelines connect the three production fields to the Inuvik area facility near Inuvik (Volume 2, Project Description). The gathering pipelines and associated facilities include:

- Niglintgak lateral
- Taglu lateral
- Parsons Lake lateral
- Storm Hills lateral
- Storm Hills pigging facility
- Inuvik area facility
- two intermediate block valves
- pads for the trenchless installation at Mackenzie River's East Channel

8.4.6.1 Baseline Conditions

The baseline conditions along the proposed gathering pipelines are similar to the conditions at Parsons Lake, south of Swimming Point, and to Taglu, north of Swimming Point.

The gathering pipelines and associated facilities at Storm Hills and at the Inuvik area facility will be on mostly fine- to moderately fine-textured morainal deposits. Morainal units encompass 45% of the 17,132-ha gathering pipelines and associated facilities LSA. Morainal deposits of variable thickness over Tertiary bedrock will likely be the most common landform type encountered, accounting for 20%. Thaw-settlement depressions with ice-wedge polygons are numerous, and steep slopes susceptible to gully erosion will also be encountered. Pipelines will cross glaciofluvial or lacustrine sediments to a lesser extent. Glaciofluvial deposits, which encompass 12% of the LSA, are mainly hummocky, coarse-textured outwash, whereas lacustrine deposits, at 11% of the LSA, typically overlie, within 4 m, fine- to moderately fine-textured moraine or coarse-textured glaciofluvial with ice-wedge polygons. Inclusions of fine- to coarse-textured fluvial deltaic sediments, variable-textured colluvium and medium- to coarse-textured fluvial channel deposits constitute 18% of the total area. Thaw-settlement lakes, ponds and stream channels occupy 11%. Permafrost is in most areas, with the thickness and distribution expected to be irregular because of the size, depth and temperature regime near and under waterbodies.

Soils of the gathering pipelines and associated facilities are described relative to the landforms they are most commonly associated with. As at Niglintgak, Taglu and Parsons Lake, soils of the gathering pipelines are dominantly Cryosolic, comprising mainly mineral soils. Regosolic Turbic Cryosols, Orthic Turbic Cryosols, Brunisolic Turbic Cryosols and Gleysolic Turbic Cryosols are common in the dominant morainal units. Soils not affected by permafrost, such as Orthic Regosols, might be encountered on steep to very steep Tertiary bedrock overlain by very rapidly to well-drained morainal deposits. In hummocky coarse-textured glaciofluvial outwash, Orthic Brunisols might be encountered on very rapidly to rapidly drained crest slope positions. Depth to permafrost and topographic variation control the drainage types in these cases. Gleysolic Turbic Cryosols and Terric Fibric or Mesic Organic Cryosols are associated with moderately well- to very poorly drained moraine or glaciofluvial overlain by fine- to medium-textured, i.e., thin, lacustrine deposits. Although common in low-relief morainal and lacustrine deposits, these soils have also formed in poorly drained depressions and channels on colluvial and fluvial deposits and on fluvial deltaic sediments. Permafrost is within 1 m of the surface, with thin or discontinuous surface organic layers ranging from 5 to 70 cm thick.

8.4.6.2 Gathering Pipelines and Associated Facilities Effects

The gathering pipelines will have a 30- to 40-m-wide right-of-way that will cover about 176 km. The Storm Hills pigging facility will have a pad that will cover about 4.8 ha, and the Inuvik area facility will have a pad that will cover about 47.5 ha. Landform and soil information is not currently available for the Inuvik area facility site. Table 8-68 summarizes project effects on soil quality likely to result, following mitigation, from construction, operations and decommissioning of the gathering pipelines and associated facilities.

Table 8-68: Effects on Soil Quality – Gathering Pipelines and Associated Facilities

Pathway	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Changes in soil drainage	Construction	Adverse	Moderate	Local	Long term
	Operations	Neutral	No effect	N/A	N/A
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Soil loss	Construction	Adverse	Low	Local	Far future
	Operations	Neutral	No effect	N/A	N/A
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Changes in soil chemical and physical characteristics	Construction	Adverse	Low	Local	Long term
	Operations	Adverse	Low	Local	Short term
	Decommissioning and abandonment	Adverse	Low	Local	Short term

NOTE:
N/A = not applicable

One of the main effects on soil quality during construction in the gathering system will be soil loss from placement of pads at the Storm Hills pigging facility and the Inuvik area facility. Soil drainage changes are also an issue in the gathering system because terrain susceptible to thaw settlement covers large segments of the proposed pipeline routes. Water erosion and mixing along the proposed pipeline routes might affect soil physical and chemical properties. Construction-related effects will likely be adverse, low to moderate magnitude, local in extent and long term to far future in duration.

Where thaw-settlement processes are active, minor changes in soil drainage will continue into operations until the site has stabilized. Soil chemical and physical properties might be changed during operations because of minor mixing, small scale leaks or spills and air emissions. Operations effects on soil quality are predicted to be adverse, low magnitude, local in extent and short term.

Effects on soil quality during decommissioning are minor, related to any surface disturbance required to remove facilities and materials. Effects will likely be adverse, low magnitude, local in extent and short term.

Changes in Soil Drainage

Construction

Diversion or damming of surface drainage, described in Section 8.4.1.1, Soil Drainage, could cause changes in soil drainage along the lateral rights-of-way and adjacent to facility pads. A change in surface drainage patterns could increase soil moisture content and might lead to ponding. Effects on soil drainage are expected to be most noticeable in the years immediately following construction and are closely related to effects of permafrost degradation and subsidence.

Pads will be used at the Storm Hills pigging facility and the Inuvik area facility and are expected to cover a total of 52.3 ha of soil. Ponding is not predicted to occur in the Storm Hills pigging facility site because the site is located on rapidly to well-drained morainal deposits of variable thickness over Tertiary material. These site conditions decrease the potential for changes in soil drainage resulting from ponding.

Landform conditions are not currently available for the Inuvik area facility site.

Construction of the laterals will require trenching and possibly limited grading, both of which have the potential to affect soil drainage. Borrow material might also be used to stabilize thaw-sensitive terrain near the laterals. The soil surface along the right-of-way travel lane and access roads will be protected by construction and maintenance of a winter road. Segments of the proposed laterals are susceptible to pond formation because of thaw settlement. These areas have been grouped by landform type and results are shown in Table 8-69.

Table 8-69: Extent of Potential Changes in Soil Drainage caused by Thaw Settlement along the Gathering Pipelines and Associated Facilities

Landform Type	Processes and Modifiers	Drainage Class	Footprint Area Subject to Changes in Soil Drainage (ha)	Area of Landform Type in the Gathering System LSA (ha)	Proportion of Landform Type Affected by Changes in Soil Drainage (%)
Fluvial and fluvial deltaic	Fluvial channel	Poor to very poor	0.5	33	1.5
	Fluvial channel deposits of variable thickness over moraine, glaciofluvial, lacustrine or Tertiary formation	Imperfect to very poor	0.9	42	2.1
	Fluvial channel deposits of variable thickness over moraine, glaciofluvial, lacustrine or Tertiary formation with ice-wedge polygons and beaded streams	Imperfect to very poor	4.9	218	2.2
	Fluvial floodplains with ice-wedge polygons	Poor to very poor	11.3	252	4.5
	Fluvial floodplains with ice-wedge polygons, occasional flooding	Poor to very poor	25.7	584	4.4
	Fluvial floodplains with ice-wedge polygons, seasonal flooding	Poor to very poor	10.0	285	3.5
	Fluvial floodplains, seasonal flooding	Imperfect to very poor	5.5	312	1.8
	Fluvial plains	Moderately well to very poor	7.2	251	2.9
Lacustrine	Lacustrine deposits in channels or depressions with ice-wedge polygons	Poor to very poor	8.4	261	3.2
	Lacustrine deposits of variable thickness over moraine or glaciofluvial with ice-wedge polygons	Well to very poor	24.1	660	3.7
	Lacustrine plains	Moderately well to very poor	9.7	312	3.1
	Lacustrine plains with ice-wedge polygons	Poor to very poor	25.4	493	5.2
Morainal	Hummocky moraine	Moderately well to poor	15.5	1,280	1.2
	Low-relief moraine	Moderately well to imperfect	12.6	358	3.5
	Low-relief moraine	Imperfect to very poor	1.1	239	0.5

Table 8-69: Extent of Potential Changes in Soil Drainage caused by Thaw Settlement along the Gathering Pipelines and Associated Facilities (cont'd)

Landform Type	Processes and Modifiers	Drainage Class	Footprint Area Subject to Changes in Soil Drainage (ha)	Area of Landform Type in the Gathering System LSA (ha)	Proportion of Landform Type Affected by Changes in Soil Drainage (%)
Morainal (cont'd)	Low-relief morainal deposits of variable thickness over deltaic sediments	Moderately well to imperfect	44.7	782	5.7
	Moraine with ice-wedge polygons or beaded streams	Poor to very poor	5.4	212	2.5
Colluvial	Colluvial fan	Poor to very poor	8.9	111	8.0
	Colluvial deposits of variable thickness over moraine, glaciofluvial or lacustrine	Imperfect to very poor	0.8	73	1.1
	Colluvial deposits of variable thickness over Tertiary formation	Moderately well to very poor	10.7	540	2.0
Total			233	7,298	3.2

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

There is potential for ponding to occur, because of thaw settlement, on more than 5% of the following landforms: lacustrine plains with ice-wedge polygons, low-relief morainal deposits over deltaic sediments and colluvial fans. Soils with fine textures of silt to clay and with ice-wedge polygons are associated with high ice content and are therefore susceptible to thaw settlement when disturbed. These characteristics are commonly present in colluvial, lacustrine and morainal landform types. Landform types prone to ponding usually also have imperfect to poor drainage, indicating that the water table is likely within 1 m of the surface at baseline.

Changes in soil drainage caused by thaw settlement are predicted to affect about 233 ha or 1.4% of the gathering system LSA.

The gathering pipelines contain areas of blanket slope drainage type (see the discussion under Ditching in Section 8.4.1.1, Soil Drainage, for a description of blanket slope drainage). Changes in soil drainage could occur where the pipeline is built on cross slopes with blanket slope drainage. Locations where this might occur are not currently known, but sites with potential blanket slope drainage cover 20.5 ha of the right-of-way or 0.1% of the gathering pipelines and associated facilities LSA.

Effects on soil drainage are expected to be most noticeable immediately following construction and are closely related to effects of permafrost degradation and permafrost-related thaw settlement. Select fill will be placed in resulting depressions to control thaw settlement and provide a surface that can be revegetated. Because soil drainage is likely to be changed where the select fill is placed (described previously in Section 8.4.1.1, Soil Drainage), the vegetation that develops might differ from that which existed previously. Rate of natural recovery, however, is expected to be high where moist conditions persist. Where the backfilled surface becomes dry, as a new moisture equilibrium establishes, natural recovery will be slowed because of the coarse texture of the backfill. The duration of effects is expected to be long term because vegetation recovery might be slower on portions of the backfilled ditch. Therefore, effects will be adverse, moderate magnitude, local in extent and long term. The flow of gas during pipeline operations might cause changes in soil drainage because of the formation of a frost bulb around the pipe as discussed in Section 8.3.7, Pipeline Corridor.

Operations

If thaw-settlement processes have occurred, ponds might increase in size during operations. Should this occur, additional fill would be added to control pond development. No additional changes in soil drainage are expected during operations.

Decommissioning and Abandonment

Borrow material might not be removed at decommissioning, but the surface of pads will be recontoured and drainage patterns will be re-established. No additional changes in soil drainage are expected during decommissioning and abandonment. Therefore, there will be no effects on soil quality during this phase.

Soil Loss

Construction

Loss of soil cover in the gathering pipelines will be limited to the construction phase. About 4.8 ha of soil cover will be lost at the Storm Hills pigging facility and about 47.5 ha at the Inuvik area facility. Soil at the Storm Hills pigging facility is composed of well- to imperfectly drained till (see Table 8-70). Characteristics of soil at the Inuvik area facility are currently unknown. Soil might also be lost on the right-of-way, in areas that are graded or where trench spoil is replaced with select backfill, e.g., on slopes. However, these slopes and the area of soil loss will not be determined until final design. The total area of soil lost because of grading is expected to be small, accounting for considerably less than 5% of the gathering pipelines and associated facilities LSA.

Table 8-70: Characteristics of Soil Loss Along the Gathering Pipelines and Associated Facilities

Project Facility	**Area of Loss** (ha)	**Landform Type**	**Terrain Texture**	**Drainage Type**	**Soil Type**	**Area of Landform in LSA** (ha)	**Loss of Landform Type in Ecological Zone LSA** (%)
Storm Hills pigging facility	4.8	Morainal deposits of variable thickness over Tertiary Formation	Till	Well to imperfect	Turbic Cryosols	3,332	0.1
Inuvik area facility	47.5	No data	No data	No data	No data	No data	No data

The effects of this soil loss will extend into the far future. However, plants will begin to establish on the pad within several years after decommissioning and abandonment and the processes of soil development will begin. A soil resembling that found on glaciofluvial deposits in the area is expected to develop on the pads.

The effects of soil loss are predicted to be less than 1% of the affected landforms in the LSA and are considered to be adverse, low magnitude, local in extent and far future in duration.

There will be no further soil losses during operations and decommissioning.

Changes in Soil Physical and Chemical Characteristics

Construction

Landforms susceptible to water erosion are identified as part of the ground stability valued component in Section 8.3.6.2, Gathering Pipelines and Associated Facilities Effects. The total length of pipeline right-of-way that could be affected by water erosion is 14.4 km. This represents about 8.4% of the total length of the laterals. In terms of areal extent, about 0.01% of the gathering pipelines and associated facilities LSA could be affected by water erosion, and up to 0.25% of any individual landform and soil type in the LSA could be affected.

There are no soils rated as being moderately to highly erodible by wind. Therefore, any effects caused by wind erosion are predicted to be minor.

Soil mixing, calculated for a 1.5-m trench width for the laterals, will occur along about 176 km of the gathering pipelines. About 0.15% of the LSA area could be affected. The extent of disturbance of individual landform and soil types in the LSA will be up to 0.3% of their areas. About 52% of the pipeline will pass through morainal landform types, with 11% passing through glaciofluvial types, 9% through lacustrine types, 9% through fluvial deltaic types, 5% through colluvial types, 3% through fluvial types, and less than 5% through water and existing disturbances.

Surface soil disturbances consisting of mixing, rutting and compaction could occur if winter roads are used during relatively warm weather when thaw could occur, i.e., during road development and the beginning of spring thaw. These situations can be avoided through awareness of weather conditions, and effects are therefore likely to be minor.

Table 8-68, shown previously, lists the predicted effects on soil quality during construction. The combined effects of wind and water erosion and mixing will potentially affect less than 1% of the gathering pipelines and associated facilities LSA. The effects are considered to be adverse, low magnitude, local in extent and long term. Duration is predicted to be long term because mitigation by soil reclamation and revegetation could require several years in some site-specific situations.

Operations

Provisions will be in place to control leaks and spills (see Volume 7, Environmental Management). Any large-scale occurrences will be managed through an emergency response plan.

Table 8-68, shown previously, presents the predicted effects on soil quality during operations. The combined effects are predicted to occur over much less than 1% of the area, and are considered to be adverse, low magnitude, local in extent and short term.

Decommissioning and Abandonment

The potential effects on soil physical and chemical characteristics during decommissioning and abandonment will be limited to minor disturbance of soil surfaces by machinery used to remove above-ground structures. The combined effects on soil physical and chemical characteristics are predicted to be none to low. The effects are considered to be adverse, low magnitude, local in extent and short term.

8.4.7 Pipeline Corridor

For purposes of the impact assessment, the pipeline corridor includes the natural gas pipeline, the NGL pipeline and pipeline facilities including block valves, compressor stations and a heater station (see Volume 2, Project Description). The 1,286-km natural gas pipeline will transport sweet natural gas from the Inuvik area facility to the NGTL system. The gas pipeline and the NGL pipeline will share a common right-of-way for about 480 km from the Inuvik area facility to a point near Norman Wells.

8.4.7.1 Baseline Conditions

The pipeline route crosses a wide range of environment and landform types. Soils formed on these landforms are strongly influenced by genetic material, position in the landscape, and regional and micro-site climatic conditions.

Soils found along the corridor can be subdivided in two general types: mineral and organic. Mineral soils are weakly developed and have low organic matter content. Mineral Cryosols are Orthic or Brunisolic, and large parts of the unfrozen mineral soils are part of the Regosolic or Brunisolic Great Groups. Most soils are considered to be poor in nutrients with the exception of soils located in mesic landforms such as fluvial terraces or floodplains.

Soils, for this assessment, are defined in terms of texture, drainage, slope, position in the landscape, presence or absence of permafrost and genetic material. Following is an overview of dominant landforms and associated soils for each ecological zone along the pipeline corridor.

Transition Forest Ecological Zone

The Transition Forest Ecological Zone is in an area dominated by fine- to moderately fine-textured, low-relief morainal deposits that are moderately well- to very poorly drained. These landforms constitute 70% of the 7,771-ha Transition Forest Ecological Zone LSA. Permafrost is continuous throughout, with active layer depths ranging from 0.2 to 1.2 m. Less extensive low-lying areas include about 14% of poorly to very poorly drained recent organic deposits, consisting of bog, fen, bog and fen complexes, and undifferentiated organic units. Lacustrine, fluvial, colluvial, glaciolacustrine and glaciofluvial deposits represent minor inclusions in the LSA totalling 4%. Discontinuous permafrost can be expected in most coarse-textured glaciofluvial deposits. At 1%, waterbodies constitute only a minor area of the total LSA.

Soils of the Transition Forest Ecological Zone are described relative to the landforms they are most commonly associated with. Soils in the Transition Forest Ecological Zone are mainly of two types. The most dominant are poorly developed Turbic Cryosols on fine- to moderately fine-textured, moderately well- to poorly drained morainal deposits. The least dominant are Fibric or Mesic Organic Cryosols developed on poorly to very poorly drained fens and bogs.

On fine- to moderately fine-textured moraine, imperfectly to very poorly drained Regosolic Cryosols, Brunisolic Cryosols, Gleysolic Cryosols, and Terric Fibric or Mesic Organic Cryosols are most common. Shallow active layer depths in these landforms often inhibit drainage. Similar soil subgroups in coarser-textured glaciofluvial genetic materials have deeper active layers and lower ice contents with improved drainage. Terric Fibric or Mesic, and Fibric or Mesic Organic Cryosols dominate on poorly to very poorly drained depressions, channels and areas of low relief associated with morainal, organic, lacustrine, fluvial and glaciolacustrine deposits. Nonpermafrost-affected mineral soils such as Orthic and Cumulic Regosols are more commonly associated with medium- to coarse-textured, rapidly to imperfectly drained fluvial channel deposits over moraine.

North Taiga Plains Ecological Zone

The North Taiga Plains Ecological Zone is in an area dominated by morainal landforms. Morainal units, which account for about 49% of the 47,808-ha North Taiga Plains Ecological Zone LSA, are largely till veneers or blankets over bedrock and hummocky low-relief moraine. Material textures range from fine to moderately fine, and well- to imperfectly drained on crests and upper slope positions. Poor to very poor drainage is most common in depressions, subsidence sinkholes, channels and thaw-settlement areas at the base of slopes. Recent organic deposits are less extensive, occupying 16% of the total LSA. Fens overlying morainal deposits, glaciolacustrine sediments, and colluvial, alluvial and lacustrine deposits or bedrock are the most widespread organic units. Fine- to moderately fine-textured glaciolacustrine deposits constitute 11% of the LSA, consisting largely of undulating plains that are moderately well to poorly drained. Minor inclusions of colluvial, alluvial and glaciofluvial deposits and lacustrine sediments account for 17%. Exposed bedrock is rare, as are waterbodies. Permafrost is present in most areas, with solifluction and karst processes frequently occurring in thin morainal veneers or blankets over bedrock. Where permafrost is present, active layer depths range from 0.3 to 3.3 m. Coarse-textured glaciofluvial deposits such as eskers and kames are not perennially frozen.

Soils of the North Taiga Plains Ecological Zone are described relative to the landforms they are most commonly associated with. Cryosols are the most common soil order in the extensive discontinuous permafrost zone. They become less prevalent to the south as active layer depth increases and permafrost thickness decreases. Their development occurs mainly in organic and poorly drained, fine-textured mineral materials. The active layer of these soils is frequently saturated with water, especially near the permafrost table. Organic Cryosols are widespread and associated with well-developed bogs, peat palsas, plateaus and fens. Nonpermafrost-affected Brunisolic soils are frequently associated with coarse-textured genetic material. However, in the North Taiga Plains Ecological Zone, these soils are found on a variety of surficial deposits because of the climatic regime and processes in the area. Orthic Eutric Brunisols are the most common Brunisolic subgroup in the North Taiga Plains Ecological Zone and are often found on south-facing slopes, coarse-textured genetic materials, veneers or blankets overlying bedrock, and on moderately fine-textured glaciolacustrine, colluvial and morainal deposits.

South Taiga Plains Ecological Zone

The South Taiga Plains Ecological Zone is in an area dominated by organic deposits. Low-relief, poorly to very poorly drained organic deposits account for 40% of the 66,171-ha South Taiga Plains Ecological Zone LSA. Shallow undifferentiated organic deposits overlying morainal, glaciolacustrine, glaciofluvial, aeolian and fluvial deposits or bedrock are the most widespread. Organic fens and bogs are also common. Less extensive are fine- to moderately fine-textured glaciolacustrine sediments, comprising 20% of the LSA. The greatest proportion of these deposits consists of undulating glaciolacustrine plains. Drainage classes associated with these sediments are wide ranging because of topographic variability, processes and active layer depths in discontinuous permafrost. Crests and upper slope positions are generally well- to imperfectly drained, whereas poor to very poor drainage is more common in thaw-settlement depressions and at the base of slopes. Colluvial, fluvial, glaciofluvial, lacustrine and aeolian deposits constitute 17% of the total area. Exposed bedrock and waterbodies constitute a small portion of the LSA. Continuous permafrost in landform units is rare, occurring more frequently in imperfectly to poorly drained, fine-textured genetic materials and organic deposits north of Willowlake River. Discontinuous permafrost is common with the exception of coarse-textured glaciofluvial deposits. Where permafrost is present, active layer depths range from 0.4 to 2.7 m. Associated processes such as gully erosion and mass movement are common to steep slopes in a range of landform types and material textures. In coarse-textured aeolian deposits, deflation could occur following ground disturbance.

Organic soils consisting of Fibrisols, Mesisols, and Fibric or Mesic Organic Cryosols are dominant in the South Taiga Plains Ecological Zone. Organic Cryosols with low pH are commonly found in peat palsas and plateaus throughout the region. Typic or Terric Fibrisols and Mesisols, associated with level to very gently sloping bogs and fens, are more frequent south of Fort Simpson. Less dominant are nonpermafrost-affected mineral soils such as Orthic Brunisols. Well-to moderately well-drained soils associated with fine- to moderately fine-textured glaciolacustrine and morainal deposits are dominantly Orthic Eutric Brunisols, with some Orthic Dystric subgroups. Eluviated subgroups of Brunisolic soils have developed on moderate to very steep slopes in glaciolacustrine, morainal and glaciofluvial deposits. Poorly drained soils formed on these materials in depressions are typically gleyed subgroups of Eutric Brunisols, and peaty phase Orthic or Rego Gleysols. Brunisolic subgroups of Cryosolic soils often occur north of Willowlake River on fine- to moderately fine-textured glaciolacustrine and morainal deposits. South of Trail River and the Mackenzie River, Orthic Eutric Brunisols have formed on very rapidly to well-drained aeolian and glaciofluvial deposits less than 2 m thick, which might be prone to deflation if the vegetation cover is removed. Luvisols were observed in a few instances, mostly in areas of higher elevation on medium- to moderately coarse-textured genetic materials.

Northwestern Alberta

The NGTL Northwest Mainline is in the South Taiga Plains Ecological Zone. Soil types and conditions along this section are expected to be similar to those described above.

8.4.7.2 Transition Forest Ecological Zone Effects

Changes in soil drainage, physical and chemical characteristics, and soil loss each have the potential to affect soil quality in the pipeline corridor in the Transition Forest Ecological Zone. The pipeline corridor through the Transition Forest Ecological Zone contains the NGL and natural gas pipelines in a 50-m right-of-way and extends for 77.6 km. No compressor stations occur in this zone and one intermediate block valve is required. Table 8-71 summarizes project effects on soil quality likely to result, following mitigation, from pipeline construction, operations, and decommissioning and abandonment activities in the Transition Forest Ecological Zone.

Table 8-71: Effects on Soil Quality – Transition Forest Ecological Zone

Pathway	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Changes in soil drainage	Construction	Adverse	Moderate	Local	Long term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Soil loss	Construction	Adverse	Low	Local	Far future
	Operations	Neutral	No effect	N/A	N/A
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Changes in soil chemical and physical characteristics	Construction	Adverse	Low	Local	Long term
	Operations	Adverse	Low	Local	Short term
	Decommissioning and abandonment	Adverse	Low	Local	Short term
NOTE: N/A = not applicable					

Construction effects on soil quality following mitigation are likely to be adverse, low to moderate magnitude, local in extent and long term to far future in duration. Effects are related primarily to changes in drainage caused by thaw settlement, or changes in soil chemical and physical properties associated with mixing and water erosion. Soil loss might occur where ice-rich slopes are graded or where ice-rich trench spoil is replaced with select backfill. Such areas of soil loss are expected to be limited in extent. Locations in the Transition Forest Ecological Zone where this might occur cannot be determined until construction and therefore, cannot be quantified.

If thaw-settlement processes are active, the effects will continue as described in Section 8.4.6.2, Gathering Pipelines and Associated Facilities Effects. Operations effects on soil quality are predicted to be adverse, low magnitude, local in extent and short term to long term.

Effects on soil quality at decommissioning and abandonment are minor and related to any surface disturbance required to decommission the project. Effects are predicted to be adverse, low magnitude, local in extent and short term.

Changes in Soil Drainage

Construction

Diversion or damming of surface water could cause changes in soil drainage along the pipeline corridor right-of-way and adjacent to the intermediate block valve site (see Section 8.4.1.1, Soil Drainage). Changes in surface drainage patterns could increase soil moisture content and might lead to ponding. Effects on soil drainage will be most noticeable in the years immediately following construction and are closely related to the effects of permafrost degradation and subsidence.

Construction of the NGL and natural gas pipelines will require clearing, trenching and possibly limited grading, which have the potential to affect soil drainage. Sections of the right-of-way susceptible to pond formation caused by thaw settlement have been grouped by landform type (see Table 8-72).

Both glaciolacustrine and lacustrine plains are prone to thaw settlement, and ponding will potentially occur in more than 5% of these landform types. The soils in these landforms are susceptible to thaw settlement as described under Changes in Soil Drainage in Section 8.4.6.2, Gathering Pipelines and Associated Facilities Effects. It is expected that about 12.3 ha or 0.2% of the Transition Forest Ecological Zone LSA will experience changes in soil drainage because of thaw settlement.

The Transition Forest Ecological Zone contains areas that have blanket slope drainage. See Ditching in Section 8.4.1.1, Soil Drainage, for a description of blanket slope drainage. Locations where this might occur along the pipeline corridor have not been identified, but sites with potential for blanket slope drainage cover 226.1 ha of the right-of-way, or 2.9% of the Transition Forest Ecological Zone LSA.

Table 8-72: Extent of Potential Changes in Soil Drainage from Thaw Settlement in the Transition Forest Ecological Zone

Landform Type	Processes and Modifiers	Drainage Class	Footprint Area Subject to Changes in Soil Drainage (ha)	Area of Landform Type in the Transition Forest Ecological Zone LSA (ha)	Proportion of Landform Type Affected by Changes in Soil Drainage (%)
Fluvial	Fluvial deposits of variable thickness over moraine	Moderately well to very poor	1.9	67.5	2.8
Glaciolacustrine	Glaciolacustrine plains	Very poor	2.6	43.1	5.9
Lacustrine	Lacustrine plains	Poor to very poor	7.8	92.9	8.4
Total			12.3	203.5	5.9
NOTE: Percentage is based on total area of facilities or pipelines divided by total area in LSA					

One intermediate block valve will be constructed in the Transition Forest Ecological Zone at Fish Trap Lake and will require a pad of about 0.2 ha. This pad has the potential to change soil drainage through diversion or damming of surface water flow, but the small area required reduces the potential impact on soil drainage.

In unstable soils, where borrow material is used as backfill to replace the soil in the trench, soil drainage conditions might be changed because the composition of the trench material has been altered (see Section 8.4.1.1, Soil Drainage). Locations in the Transition Forest Ecological Zone where this might occur cannot be determined until construction and therefore cannot be quantified.

Effects on soil drainage are expected to be most noticeable immediately following construction and are closely related to effects of permafrost degradation and permafrost-related subsidence. Ponds will be filled with borrow material to control thaw settlement, as discussed previously in Section 8.4.1.1, Soil Drainage. Changes in soil drainage that are initiated by construction activities will likely be present throughout the life of the project and beyond. Therefore, effects are considered to be adverse, moderate magnitude, local in extent and long term.

Operations

If thaw-settlement processes have occurred, ponds might increase in size during operations. Should this occur, additional fill would be added to control pond development. The flow of gas during pipeline operations might result in frost bulbs forming around the pipe, which could cause changes in soil drainage in some locations (see Section 8.3.1.1, Ground Stability). The effects of changes in soil drainage on soil quality are considered to be adverse, low magnitude, local in extent and long term.

Decommissioning and Abandonment

As discussed for the construction scenario, the intermediate block valve site will require construction of a pad. Borrow material might also be used to stabilize thaw-sensitive terrain during pipeline construction. Borrow material might not be removed at decommissioning and abandonment, but the surface of the block valve pad will be recontoured and drainage patterns will be re-established. No additional changes in soil drainage are expected during decommissioning and drainage is expected to be restored within 30 years following decommissioning and abandonment. Therefore, no effects on soil quality because of changes in soil drainage are predicted.

Soil Loss

Construction

Loss of soil cover in the Transition Forest Ecological Zone LSA is expected to occur only during construction. Soil loss will be limited to the right-of-way where areas of thaw-unstable soils are graded and trench spoil is replaced with select backfill, and to the intermediate block valve site at Fish Trap Lake. Locations where thaw-unstable soil might be encountered or where trench spoil might be replaced will not be identified until final design and therefore, cannot be quantified at this time.

An estimated 0.2 ha of fine-grained soil will be lost with the placement of the pad for the intermediate block valve. The extent of the area is small and will account for less than 1% of the affected landform (see Table 8-73). The quality of soil that will develop on the granular fill is expected to be lower as a coarse-textured substrate will replace a finer-textured soil.

Table 8-73: Characteristics of Soil Loss at the Intermediate Block Valve Site – Transition Forest Ecological Zone

Project Facility	Area of Loss (ha)	Landform Type	Terrain Texture	Drainage Class	Soil Type	Area of Landform Type in Ecological Zone LSA (ha)	Loss of Landform Type in Ecological Zone LSA (%)
Fish Trap Lake Intermediate Block Valve	0.2	Hummocky moraine	Till	Moderately well	Turbic Cryosol	640	Less than 0.1

The effects of soil loss are predicted to be low, occurring over 1% or less of the affected landforms, and are considered to be adverse, low magnitude, local in extent and far future in duration.

There will be no further soil losses during operations and decommissioning and abandonment.

Changes in Soil Physical and Chemical Characteristics

Construction

Of the 77.6 km right-of-way, 621 m or 0.8% is rated as water-erodible. The erodible area represents less than 0.1% of the area of the Transition Forest Ecological Zone LSA.

High wind-erodible soils do not occur in this ecological zone and wind erosion effects are therefore predicted to be none to low.

Soil mixing, calculated for a 2.5 m minimum combined width for the natural gas and NGL pipelines, will occur along the entire length of the pipeline. This represents 0.4% of the LSA area. The percentage of disturbance of individual landform and soil types in the LSA ranges from 0.1% to 0.7%. About 74% of the right-of-way occurs in moraine, 7% in water and anthropogenic areas, 6% in fens and less than 3% in other landform types.

Table 8-71, shown previously, identifies the predicted effects of construction activities on soil quality. Less than 1% of the corridor segment passing through the Transition Forest Ecological Zone could be affected by the combination of wind erosion, water erosion, and topsoil and subsoil mixing. The effects are considered to be adverse, low magnitude, local in extent and long term. Effects will mostly be remedied within the first couple of years after the soil disturbance. However, because of site-specific conditions, some areas might require several years to return to full vegetative cover. Therefore, duration is predicted to be long term.

Operations

Table 8-71, shown previously, indicates the predicted effects on soil quality during operations. Small-scale leaks and spills would be the main activity leading to an effect on soil chemistry. The combined effects are predicted to be adverse, low magnitude, local in extent and short term.

Decommissioning and Abandonment

The potential effects on soil physical and chemical characteristics during decommissioning and abandonment will be limited to minor disturbances of soil surfaces by machinery used to remove above-ground structures. The combined effects on soil physical and chemical properties are predicted to be none to low. The effects are considered to be adverse, low magnitude, local in extent and short term.

8.4.7.3 North Taiga Plains Ecological Zone Effects

Changes in soil drainage, physical and chemical characteristics, and soil loss each have the potential to affect soil quality in the pipeline corridor in the North Taiga Plains Ecological Zone. Table 8-74 summarizes project effects on soil quality likely to result from pipeline construction, operations and decommissioning and abandonment activities in the North Taiga Plains Ecological Zone. The pipeline corridor through the North Taiga Plains Ecological Zone contains the NGL and natural gas pipelines in a 50-m right-of-way that extends from the Inuvik area facility to Norman Wells. The right-of-way decreases to 40 m wide south of Norman Wells where it only contains the natural gas pipeline.

Table 8-74: Effects on Soil Quality – North Taiga Plains Ecological Zone

Pathway	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Changes in soil drainage	Construction	Adverse	Moderate	Local	Long term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Soil loss	Construction	Adverse	Low	Local	Far future
	Operations	Neutral	No effect	N/A	N/A
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Changes in soil chemical and physical characteristics	Construction	Adverse	Low	Local	Long term
	Operations	Adverse	Low	Local	Short term
	Decommissioning and abandonment	Adverse	Low	Local	Short term

NOTE:
N/A = not applicable

Two compressor stations are located in the North Taiga Plains Ecological Zone. Intermediate block valves will be located on the natural gas pipeline at Thunder River, Loon River, Chick Lake and Great Bear River, each covering a 0.2-ha area in the right-of-way. Surface soil will not be removed before placement of pads for these facilities.

Construction effects on soil quality following mitigation are likely to be adverse, low to moderate magnitude, local in extent and long term to far future in duration. The primary cause of these effects is described in Section 8.4.7.2, Transition Forest Ecological Zone Effects.

If thaw-settlement processes are active, the effects will continue as described in Section 8.4.6.2, Gathering Pipelines and Associated Facilities Effects. Operations effects on soil quality are predicted to be adverse, low magnitude, local in extent and short term to long term.

Effects on soil quality during decommissioning and abandonment are minor and related to any surface disturbance required to decommission the project. Effects are predicted to be adverse, low magnitude, local in extent and short term.

Changes in Soil Drainage

Construction

Diversion or damming of surface drainage could cause changes in soil drainage along the pipeline corridor right-of-way and adjacent to the four intermediate block valve sites and the two compressor stations. Changes in surface drainage patterns could increase soil moisture content and might lead to ponding. Effects on soil drainage will be most noticeable in the years immediately following construction and are closely related to permafrost degradation and subsidence.

Pipeline construction activities could affect soil drainage (see Section 8.4.1.1, Soil Drainage). Sections of the right-of-way susceptible to pond formation caused by thaw settlement have been grouped by landform type (see Table 8-75).

Ponding will potentially occur in more than 5% of the glaciolacustrine, lacustrine and colluvial landform types in the North Taiga Plains Ecological Zone. The soils in these landforms are susceptible to thaw settlement as described under Changes in Soil Drainage in Section 8.4.6.2, Gathering Pipelines and Associated Facilities Effects. The total area predicted to experience changes in soil drainage because of thaw settlement covers about 404.4 ha or 0.8% of the North Taiga Plains Ecological Zone LSA.

The North Taiga Plains Ecological Zone contains areas that have blanket slope drainage. See Ditching in Section 8.4.1.1, Soil Drainage, for a description of blanket slope drainage. Changes in soil drainage could occur where the pipeline is built on cross slopes with blanket slope drainage. Locations where this might occur along the pipeline corridor are not currently available, but potential sites with blanket slope drainage cover 602.9 ha of the right-of-way, or 1.3% of the North Taiga Plains Ecological Zone LSA.

The four intermediate block valves will each require a pad of about 0.2 ha. These pads could change soil drainage through diversion or damming of surface water flow but the small area of these sites reduces the potential impact on soil drainage. The Loon River intermediate block valve is located on terrain susceptible to thaw settlement and the associated changes in soil drainage.

Table 8-75: Extent of Potential Changes in Soil Drainage caused by Thaw Settlement in the North Taiga Plains Ecological Zone

Landform Type	Processes and Modifiers	Drainage Class	Footprint Area Subject to Changes in Soil Drainage (ha)	Area of Landform Type in the North Taiga Plains Ecological Zone LSA (ha)	Proportion of Landform Type Affected by Changes in Soil Drainage (%)
Fluvial	Fluvial deposits over moraine or glaciolacustrine	Moderately well to poor	0.5	45.4	1.1
	Fluvial deposits of variable thickness over moraine, glaciolacustrine or glaciofluvial	Poor to very poor	1.0	27.2	3.7
Glaciolacustrine	Glaciolacustrine deposits in depressions	Poor to very poor	1.6	29.0	5.5
	Glaciolacustrine plain	Moderately well to poor	209.9	3,681.4	5.7
	Glaciolacustrine plain	Poor to very poor	0.7	19.0	3.8
	Kettled glaciolacustrine plain	Imperfect to poor	35.1	647.7	5.4
	Steep slopes in glaciolacustrine deposits	Moderately well to poor	7.8	111.0	7.0
Lacustrine	Lacustrine plains	Imperfect to very poor	22.4	435.0	5.1
	Lacustrine blanket over moraine	Poor to very poor	4.5	54.5	8.3
Colluvial	Colluvial deposits of variable thickness over moraine, glaciofluvial or glaciolacustrine	Rapid to moderately well	0.2	7.0	2.7
	Colluvial deposits of variable thickness over moraine, glaciofluvial or glaciolacustrine	Moderately well to poor	106.6	2,186.0	4.9
	Colluvial deposits of variable thickness over moraine, glaciofluvial or glaciolacustrine	Poor to very poor	8.1	84.9	9.6
Organic	Shallow undifferentiated organic deposits over moraine, glaciolacustrine, fluvial or colluvial	Poor to very poor	5.9	323.5	1.8
Total			404.4	7,651.6	5.3

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

Compressor stations can change soil drainage in a similar manner to block valve sites. The compressor station at Little Chicago will cover 11 ha and the station at Norman Wells will cover 9.6 ha. Both compressor stations will require pads. The Norman Wells station is located on stable terrain where thaw settlement is not predicted. However, the Little Chicago compressor station is susceptible to thaw settlement and the associated transition to a wetter environment.

In unstable soils, where borrow material is used as backfill to replace the soil in the trench, soil drainage conditions might be changed because the composition of the trench material has been altered, as described previously in Section 8.4.1.1, Soil Drainage.

Effects on soil drainage are expected to be most noticeable immediately following construction and are closely related to effects of permafrost degradation and permafrost-related subsidence. Ponds will be filled with borrow material to control thaw settlement, as discussed previously in Section 8.4.1.1, Soil Drainage. Changes in soil drainage that are initiated by construction activities will likely be present throughout the life of the project and beyond. A duration of long term is assigned because segments of the pipeline in the North Taiga Plains Ecological Zone are on terrain where thaw settlement might occur. Therefore, effects are considered to be adverse, moderate magnitude, local in extent and far future in duration.

Operations

If thaw-settlement processes have occurred, ponds might increase in size during operations. Should this occur, additional fill would be added to control pond development. The flow of gas during pipeline operations might cause changes in soil drainage in some locations because of the formation of a frost bulb around the pipe as explained in Section 8.3.1.1, Ground Stability. Drainage is expected to stabilize within 30 years following decommissioning and abandonment. The effects of changes in soil drainage on soil quality during operations in the North Taiga Plains Ecological Zone are considered to be adverse, low magnitude, local in extent and long term.

Decommissioning and Abandonment

Borrow material might not be removed at decommissioning, but pad surfaces will be recontoured and drainage patterns will be re-established. No additional changes in soil drainage are expected. Therefore, no effects on soil quality are predicted for the North Taiga Plains Ecological Zone because of changes in soil drainage during decommissioning and abandonment.

Soil Loss

Construction

Loss of soil cover in the North Taiga Plains Ecological Zone of the pipeline corridor is expected to be limited to the construction phase. Soil will be lost at the two compressor stations over an area of about 20.6 ha, and at the four intermediate block valve sites over an area of about 0.8 ha. Soil will also be lost in areas of thaw-unstable soil that are graded and areas where trench spoil is replaced with select backfill. Where the ground is thaw stable, as opposed to thaw unstable, soil will be removed and replaced before placement of a pad or grading the right-of-way, and used to reclaim the site. Because it is not known whether the terrain at these sites will be thaw stable, it was assumed for this assessment that soil would not be removed and replaced.

Soil loss at the compressor stations comprises 11 ha of fine-grained mineral soil at Little Chicago, and 3.3 ha of organic soil plus 6.3 ha of sand and silt-textured mineral soil at Norman Wells. Soil loss at intermediate block valve sites has developed mainly on till, and to a lesser extent, organic deposits (see Table 8-76). Expressed on the basis of landform type, soil loss at the compressor stations and block valve sites is less than 3% and in most cases less than 1% of the affected landform type in the LSA. The amount of soil loss because of grading or replacement with granular backfill cannot be determined at this time. However, the magnitude of loss would be low, representing considerably less than 5% of the LSA.

The effects of this soil loss will extend beyond decommissioning and abandonment. Where soil is removed and replaced, soil moisture conditions are expected to be somewhat limiting because the substrate is coarse-textured and relatively well-drained. Therefore, it is expected that a soil will develop that approaches the quality of soil present before construction.

The effects of soil loss are predicted to be low, occurring over 5% or less of the affected landforms, and are considered to be adverse, low magnitude, local in extent and far future in duration.

There will be no further soil losses during operations and decommissioning.

Changes in Soil Physical and Chemical Characteristics

Construction

The pipeline corridor passes through about 478 km of the North Taiga Plains Ecological Zone. The length of right-of-way that could be affected by water erosion is estimated to be about 30 km, or about 6.3% of the total length of the pipeline corridor in the LSA. In terms of areal extent, 9.3 ha, or less than 0.01% of the pipeline corridor in the North Taiga Plains Ecological Zone LSA could be affected by water erosion, and up to 1.1% of any individual landform and soil type in the LSA could be affected.

A small area of sandy, aeolian soils is rated as being moderately to highly erodible by wind. These soils occur over a distance of 7 km and are about 14 ha in area. This area represents about 2.5% of the aeolian landform and soil type in the LSA.

Table 8-76: Characteristics of Soil Loss – North Taiga Plains Ecological Zone

Project Facility	**Area of Loss** (ha)	**Landform Type**	**Terrain Texture**	**Drainage Class**	**Soil Type**	**Area of Landform in Ecological Zone LSA** (ha)	**Loss of Landform Type in Ecological Zone LSA** (%)
Little Chicago compressor station	11	Colluvial deposits of variable thickness over morainal, glaciolacustrine, glaciofluvial or fluvial deposits	Fine grained	Moderately well to poor	Turbic Cryosol	1,314	0.8
Norman Wells compressor station	3.3	Shallow fens over morainal, glaciolacustrine, lacustrine, colluvial, fluvial deposits or bedrock	Organic	Imperfect to very poor	Organic Cryosol, Terric Fibrisol	3,541	0.1
	6.3	Fluvial long slope	Sand, till	Moderately well	Turbic Cryosol, Static Cryosol	224	2.8
Thunder River intermediate block valve	0.2	Hummocky moraine	Till	Moderately well to very poor	Brunisolic Eutric Turbic Cryosol	3,295	<0.1
Loon River intermediate block valve	0.2	Shallow undifferentiated organic deposits over morainal, glaciolacustrine, fluvial or colluvial deposits	Organic	Well to very poor	Organic Cryosol, Turbic Cryosol	966	<0.1
Chick Lake intermediate block valve	0.2	Long slopes in morainal deposits	Till	Moderately well to poor	Turbic Cryosol	3,987	<0.1
Great Bear River intermediate block valve	0.2	Morainal deposits of variable thickness over bedrock	Till	Moderately well to poor	Turbic Cryosol, Eutric Brunisol	9,391	<0.1
Total area of loss	21.4	N/A	N/A	N/A	N/A	22,718	<0.1

NOTES:
N/A = not applicable
Percentage is based on total area of facilities or pipelines divided by total area in LSA

Mixed soil will be put back in the pipeline trench along the entire right-of-way, after excavation and pipe placement. The area of mixed soil will be about 155 ha, or about 0.3% of the LSA area. The extent of disturbance of individual landform and soil types in the LSA will be up to 0.6% of their total areas. About 53% of the pipeline will pass through morainal landform types, with 13% passing through glaciolacustrine landform types, 16% through fens and bogs, 7% through glaciofluvial types, 6% through colluvial landform types and less than 5% through other landform types.

Table 8-74, shown previously, indicates the predicted effects on soil quality during construction. The combined effects of wind and water erosion and mixing will potentially affect less than 1% of the pipeline corridor in the North Taiga Plains Ecological Zone LSA. The effects are considered to be adverse, low magnitude, local in extent and long term. Duration is predicted to be long term because mitigation by soil reclamation and revegetation could require several years in some site-specific situations.

Operations

Should they occur, small-scale leaks and spills could affect soil chemistry. The combined effects are predicted to be adverse, low magnitude, local in extent and short term.

Decommissioning and Abandonment

The potential effects on soil physical and chemical characteristics during decommissioning and abandonment will be limited to minor disturbance of soil surfaces by machinery used to remove above-ground structures. The combined effects on soil physical and chemical properties are predicted to be none to low. The effects are considered to be adverse, low magnitude, local in extent and short term.

8.4.7.4 South Taiga Plains Ecological Zone Effects

Changes in soil drainage, physical and chemical characteristics, and soil loss each have the potential to affect soil quality in the pipeline corridor in the South Taiga Plains Ecological Zone. The pipeline corridor has a 40-m right-of-way, contains the natural gas pipeline and passes through about 663 km of the South Taiga Plains Ecological Zone to the NGTL interconnect facility. Two compressor stations, a heater station at Trail River, five intermediate block valves and the NGTL interconnect facility are located in the South Taiga Plains Ecological Zone. Soil will not be removed at these project facilities before placement of a pad.

Construction effects on soil quality following mitigation are likely to be adverse, low to moderate magnitude, local in extent and long term to far future in duration (see Table 8-77). The primary cause of these effects is described in Section 8.4.7.2, Transition Forest Ecological Zone Effects.

Table 8-77: Effects on Soil Quality – South Taiga Plains Ecological Zone

Pathway	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Changes in soil drainage	Construction	Adverse	Moderate	Local	Long term
	Operations	N/A	Low	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Soil loss	Construction	Adverse	Low	Local	Far future
	Operations	Neutral	No effect	N/A	N/A
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Changes in soil chemical and physical characteristics	Construction	Adverse	Low	Local	Long term
	Operations	Adverse	Low	Local	Short term
	Decommissioning and abandonment	Adverse	Low	Local	Short term
NOTE: N/A = not applicable					

If thaw-settlement processes are active, the effects will continue as described in Section 8.4.6.2, Gathering Pipelines and Associated Facilities Effects. Operations effects on soil quality are predicted to be adverse, low magnitude, local in extent and short term.

Effects on soil quality during decommissioning are minor and related to any surface disturbance required to decommission the project. Effects are predicted to be adverse, low magnitude, local in extent and short term.

Changes in Soil Drainage

Construction

Diversion or damming of surface drainage could cause changes in soil drainage along the pipeline corridor right-of-way and adjacent to block valve sites and compressor stations. Sections of the proposed right-of-way susceptible to pond formation caused by thaw settlement have been grouped by landform type (see Table 8-78).

Ponding will potentially occur in more than 5% of two of the landform types in the glaciolacustrine deposits. The soils in these landforms are susceptible to thaw settlement as described under Changes in Soil Drainage in Section 8.4.6.2, Gathering Pipelines and Associated Facilities Effects.

About 349 ha or 0.5% of the South Taiga Plains Ecological Zone LSA are expected to experience changes in soil drainage because of thaw settlement.

Table 8-78: Extent of Potential Changes in Soil Drainage from Thaw Settlement – South Taiga Plains Ecological Zone

Landform Type	**Processes and Modifiers**	**Drainage Class**	**Footprint Area Subject to Changes in Soil Drainage** (ha)	**Area of Landform Type in the South Taiga Plains Ecological Zone LSA** (ha)	**Proportion of Landform Type Affected by Changes in Soil Drainage** (%)
Glaciolacustrine	Glaciolacustrine plains	Moderately well to imperfect	11.6	222	5.3
	Glaciolacustrine plains	Poor to very poor	143	3,116	4.6
	Glaciolacustrine shoreline deposits	Moderately well to very poor	6.3	150	4.2
	Long slopes in glaciolacustrine deposits	Moderately well to poor	65	1,786	3.7
	Steep slopes in glaciolacustrine deposits	Moderately well to poor	4.8	174	2.8
	Steep slopes in glaciolacustrine deposits	Very poor	0.4	15.6	2.7
	Thin glaciolacustrine deposits over moraine	Moderately well to poor	84	1,549	5.4
Colluvial	Colluvial fan	Moderately well to poor	14.8	361	4.1
	Thin colluvial deposits over glaciolacustrine or glaciofluvial	Moderately well to imperfect	8.3	253	3.3
Organic	Shallow undifferentiated organic deposits over moraine, glaciolacustrine or lacustrine	Imperfect to very poor	11.3	298	3.8
Total			349.5	7,924.6	4.4

NOTE:
Percentage is based on total area of facilities or pipelines divided by total area in LSA

The South Taiga Plains Ecological Zone contains areas that have blanket slope drainage. The locations where this might occur are not currently known, but potential sites cover 195.2 ha of the right-of-way, or 0.3% of the South Taiga Plains Ecological Zone LSA.

Pads could change soil drainage through diversion or damming of surface water flow but the small area of these sites reduces the potential impact on soil drainage. The Little Smith Creek and Willow Lake River intermediate block valves are located on terrain susceptible to thaw settlement and the associated changes in soil drainage. About 0.1 ha of the Blackwater River compressor station is also susceptible to thaw settlement and the associated transition to a wetter environment.

Changes in soil drainage that are initiated by construction activities will likely be present throughout the life of the project and beyond. Effects are considered to be adverse, moderate magnitude, local in extent and long term.

Operations

If thaw-settlement processes have occurred, ponds might increase in size during operations. Should this occur, additional fill would be added to control pond development. The flow of gas during pipeline operations might cause changes in soil drainage in some locations if a frost bulb forms around the pipe, as explained in Section 8.3.1.1, Ground Stability. Drainage is expected to be restored in 30 years following decommissioning and abandonment. The effects of changes in soil drainage on soil quality are considered to be adverse, low magnitude, local in extent and long term.

Decommissioning and Abandonment

Borrow material might not be removed at decommissioning, but pad surfaces will be recontoured and drainage patterns will be re-established. No additional changes in soil drainage are expected during decommissioning and abandonment.

Soil Loss

Construction

Soil cover will potentially be lost over 28.6 ha, including 19.5 ha at the two compressor stations, 4.3 ha at the heater station, a total of 1 ha at five intermediate block valve sites and 3.8 ha at the NGTL interconnect facility. It is expected that loss of soil because of grading thaw-unstable ground or replacing ice-rich trench spoil with select backfill would be reduced in the southern part of this ecological zone as permafrost becomes more sporadic, compared with the more northerly ecological zones.

Soil that could be lost at the compressor station and heater station sites is primarily coarse-textured, i.e., sand and gravel. About 0.3 ha of organic soil could also be lost. No soil or landform data is available for 2.8 ha of the Blackwater compressor station or for the NGTL interconnect facility. Soil at the intermediate block valve sites ranges in texture from fine- to medium-grained (see Table 8-79).

Table 8-79: Characteristics of Soil Loss – South Taiga Plains Ecological Zone

Project Facility	**Area of Loss** (ha)	**Landform Type**	**Terrain Texture**	**Drainage Class**	**Soil Type**	**Area of Landform in Ecological Zone LSA** (ha)	**Loss of Landform Type in Ecological Zone LSA** (%)
Blackwater compressor station	7.7	Glaciofluvial outwash Plains or terrace	Sand, gravel	Very rapid to moderately well	Orthic Regosol, Eutric Brunisol	1,936	0.4
	0.1	Shallow undifferentiated organic deposits over moraine, glaciolacustrine or lacustrine	Organic	Poor to very poor	Typic Mesisol, Rego Gleysol	2,798	<0.1
	2.8	No data	No data	No data	No data	No data	No data
Trail River compressor station	8.9	Aeolian deposits of variable thickness over glaciolacustrine	Sand	Well to imperfect	Eutric Brunisol	649	1.4
Trout River heater station	4.1	Low-relief moraine	Gravel, till	Rapid to imperfect	Eutric Brunisol	2,213	0.2
	0.2	Mixed bogs and fens	Organic	Moderately well to very poor	Typic Fibrisol, Terric Fibrisol	25	0.9
Little Smith Creek intermediate block valve	0.2	Thin colluvial deposits over moraine, glaciolacustrine or glaciofluvial	Clay, silt	Moderately well to imperfect	Turbic Cryosol	412	<0.1
Hodgson Creek intermediate block valve	0.2	Existing disturbance	N/A	N/A	N/A	N/A	<0.1
Willow Lake River intermediate block valve	0.2	Glaciolacustrine plains	Sand	Moderately well to poor	Eutric Brunisol	830	<0.1

Table 8-79: Characteristics of Soil Loss – South Taiga Plains Ecological Zone (cont'd)

Project Facility	**Area of Loss** (ha)	**Landform Type**	**Terrain Texture**	**Drainage Class**	**Soil Type**	**Area of Landform in Ecological Zone LSA** (ha)	**Loss of Landform Type in Ecological Zone LSA** (%)
Manners Creek intermediate block valve	0.2	Aeolian dune complexes	Sand	Rapid to moderately well	Eutric Brunisol	1,153	<0.1
Deep Lake intermediate block valve	0.1	Bogs	Organic	Poor to very poor	Typic Fibrisol, Terric Fibrisol, Terric Mesisol	3,979	<0.1
	0.1	Low-relief moraine	Till	Moderately well to poor	Eutric Brunisol	3,475	<0.1
NGTL interconnect facility	3.8	Unknown	No data	No data	No data	No data	No data
Total	28.6					12,087	0.2

NOTES:
N/A = not applicable
Percentage is based on total area of facilities or pipelines divided by total area in LSA

The effects of this soil loss will extend beyond decommissioning but, as described previously, soils will eventually begin to develop on the pads. Where soil is removed and replaced, a soil is expected to develop that approaches the quality of soil present before construction.

The effects of soil loss are predicted to be low, occurring over 1.4% or less of the affected landforms and are considered to be adverse, low magnitude, local in extent and far future in duration.

There will be no further soil losses during operations and decommissioning.

Decommissioning and Abandonment

Because the material used to construct pads might be coarser than the material it covered, the quality of the soil that will develop might be lower, and the plant community supported more characteristic of drier conditions, than the soil that is covered.

Changes in Soil Physical and Chemical Characteristics

Construction

The pipeline corridor passes through about 663 km of the South Taiga Plains Ecological Zone to the NGTL interconnect facility. An area of sandy, aeolian and glaciofluvial soils, it is rated as being moderately to highly erodible by wind. These soils occur over a distance of 25 km and are about 51 ha in area. This area represents about 2.5% of sandy Eutric Brunisols and Regosols occurring on aeolian and glaciofluvial landforms in the LSA.

The length of right-of-way that could be affected by water erosion is estimated to be about 116 km, or about 17.6% of the total length of the corridor in the LSA. In terms of areal extent, about 23 ha or 0.04% of the pipeline corridor in the South Taiga Plains Ecological Zone could be affected by water erosion, and up to 1.5% of any individual landform and soil type in the LSA could be affected.

Mixed soil will be put back in the pipeline trench along the entire right-of-way, after excavation and pipe placement along the entire right-of-way. The area of mixed soil, based on a 2-m wide disturbance along the trench line, will be about 133 ha, or about 0.2% of the LSA area. The extent of disturbance of individual landform and soil types in the LSA will be up to 0.4% of their areas. About 45% of the pipeline will pass through organic landform types, i.e., bog and fen, with 19% passing through glaciolacustrine landform types, 11% through glaciofluvial landform types, 10% through morainal landform types and less than 5% through other types of landforms.

Table 8-77, shown previously, lists the predicted effects of construction activities on soil quality along with the key indicators. The combined effects of wind and water erosion and mixing will potentially affect less than 1% of the LSA. The effects are considered to be adverse, low magnitude, local in extent and long term. Duration is predicted to be long term because mitigation by soil reclamation and revegetation could require several years in some site-specific situations.

Operations

Should they occur, small-scale leaks and spills would be the main activity leading to an effect on soil chemistry. The combined effects are predicted to be adverse, low magnitude, local in extent and short term.

Decommissioning and Abandonment

The potential effects on soil physical and chemical characteristics during decommissioning and abandonment will be limited to minor disturbance of soil surfaces by machinery used to remove above-ground structures. The combined effects on soil physical and chemical properties are predicted to be none to low. The effects are considered adverse, low magnitude, local in extent and short term.

8.4.8 Northwestern Alberta

Project components in northwestern Alberta were described previously in Section 8.3.8, Northwestern Alberta.

8.4.8.1 Baseline Conditions

Baseline conditions in northwestern Alberta were described previously (see Section 8.3.7.6, South Taiga Plains B Ecological Zone Effects).

8.4.8.2 Northwestern Alberta Effects

The effects of construction on soil quality for this zone were described previously (see Section 8.4.7.4, South Taiga Plains Ecological Zone Effects), and summarized in Table 8-78, shown previously.

8.4.9 Infrastructure

See Section 8.3.9, Infrastructure for a description of the project infrastructure.

8.4.9.1 Production Area Infrastructure Baseline Conditions

The production area mainly covers low-relief floodplain deposits originating from the Mackenzie River and channels. Rolling, hummocky and kettled morainal and glaciofluvial deposits are more common near Parsons Lake. Soils associated with these deposits include Regosolic Cryosols, Gleysolic Cryosols and Orthic or Brunisolic Cryosols. In hummocky, coarse-textured glaciofluvial outwash, Orthic Brunisols might be encountered in very rapidly to rapidly drained crest slope positions. Ice-wedge polygon formation and thaw subsidence are typical processes.

Borrow sites are principally located in hummocky, coarse-textured glaciofluvial outwash deposits. Weakly developed Orthic or Brunisolic Cryosols and Orthic Brunisols are associated with this landform type. Associated processes include thaw subsidence.

8.4.9.2 Production Area Infrastructure Effects

Soil quality might be affected by construction of winter roads, pads for all-weather roads, camps, fuel storage, stockpile sites, barge landings, airstrips, communication centres and borrow sites. The exact locations of these infrastructure sites have not been finalized. Therefore, the assessment that follows is qualitative.

This qualitative assessment assumes that the soils and ground conditions encountered at production area infrastructure sites will be similar to those described for the Niglintgak, Taglu, Parsons Lake and the gathering pipelines and associated facilities. Borrow sites are expected to be located in weakly developed sand or gravel soils, of either glaciofluvial or morainal origin.

Construction effects on soil quality following mitigation are likely to be adverse, low magnitude, local in extent and long term to far future (see Table 8-80).

Effects are related primarily to changes in drainage caused by thaw settlement and soil loss. Soil loss will occur in thaw-unstable terrain when soil is not removed and replaced at camp and borrow site locations. Mixing and admixing during operations might affect soil chemical and physical properties.

Table 8-80: Effects on Soil Quality – Production Area Infrastructure

Pathway	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Changes in soil drainage	Construction	Adverse	Low	Local	Far future
	Operations	Adverse	Low	Local	Far future
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Soil loss	Construction	Adverse	Low	Local	Far future
	Operations	Neutral	No effect	N/A	N/A
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Changes in soil chemical and physical characteristics	Construction	Adverse	Low	Local	Short term
	Operations	Adverse	Low	Local	Short term
	Decommissioning and abandonment	Adverse	Low	Local	Short term

NOTE:
N/A = not applicable

Where thaw-settlement processes are active, minor changes in soil drainage will continue into operations until the site has stabilized. Dust deposition and small-scale leaks and spills during operations might affect soil chemical and physical properties. Operations effects on soil quality are predicted to be adverse, low magnitude, local in extent and short term to far future in duration.

Any surface disturbance required to decommission the project will have a minor effect on soil quality. Effects are predicted to be adverse, low magnitude, local in extent and short term.

Changes in Soil Drainage

Construction

Changes in soil drainage could occur in areas adjacent to the pads used during construction of infrastructure sites. Pads have the potential to interrupt surface drainage and cause ponding adjacent to pads and roads, which might in turn lead to thaw subsidence. Dust accumulation from traffic along all-weather roads also has the potential to change soil drainage as described in Section 8.4.1.1, Soil Drainage.

Several winter roads will be constructed throughout the production area, covering long distances and diverse terrain. Temporary damming during spring runoff can cause changes in soil drainage.

Damming activities at borrow sites can potentially affect soil drainage. Surface drainage might be dammed where soil and subsoil stockpiles block overland flow. Borrow site development can also contribute to thaw settlement and subsequent ponding and create wet soil conditions. Excavation at borrow sites in areas of ice-rich deposits will cause melting and permafrost thaw. Ponding caused by thaw settlement might also occur in the terrain surrounding borrow sites. However, the potential for thaw settlement is low because borrow sites are typically located in coarse-textured material. Surface subsidence following excavation might also lead to the capture of surface drainage and ponding in the excavation.

Infrastructure components, such as camps and storage sites, will typically be located on higher ground in well-drained areas where the potential for changes in soil drainage because of thaw settlement is low.

Changes in soil drainage that are initiated by construction activities will likely be present throughout the life of the project and beyond. Far future duration is assigned because terrain that is potentially ice-rich is common in the production area. The area affected by changes in soil drainage is not expected to exceed 5% of the coverage of any landform type in the production area LSA. Therefore, effects are considered to be adverse, low magnitude, local in extent and far future in duration.

Operations

If thaw-settlement processes have occurred, ponds might increase in size during operations. Should this occur, additional fill would be added to control pond development. The effects of changes in soil drainage on soil quality will be adverse, low magnitude, local in extent and far future.

Decommissioning and Abandonment

No additional changes in soil drainage are expected during decommissioning and abandonment so no effects on soil quality are predicted because of changes in soil drainage.

Soil Loss

An estimated 77 ha of soil cover will be lost where pads are placed. Soils will eventually develop on these pads. The effects of soil loss will be adverse, low magnitude, local in extent and far future in duration. No effects on soil loss are predicted during operations or decommissioning and abandonment.

Changes in Soil Physical and Chemical Characteristics

Construction

A combination of soil mixing, compaction and rutting could occur during construction and use of winter roads. Some compaction could occur where little snow or ice is available for the road surface. These processes could occur if winter roads are built before complete freezeup, or if they continue to be used when thaw begins. It is expected that 350 km of winter roads will be needed. Assuming a 20-m width of disturbance, the road footprint for these winter roads is about 700 ha. However, only a portion of this will occur on land.

Soil admixing could occur during removal and replacement of surface soil operations at borrow sites.

Some road dust could originate from construction and use of all-weather roads. Dust deposition could have a cumulative effect on soils over time. Further discussion is provided in the following operations section because most of the deposition will occur during the operations phase.

The predicted effects on soil chemical and physical properties of construction activities will be adverse, low magnitude, local in extent and short term.

Operations

Some road dust could originate from all-weather roads and possibly affect soil chemistry causing an increase in pH and base cation (Ca, Mg) content (Walker and Everett 1987). Where soils are already neutral to alkaline, vegetation would not be affected because species would be adapted to high pH and base cation contents. Impacts are more likely for acidic soils. Acidic peatlands, namely bogs and poor fens, might be the most susceptible to effects of road dust because vegetation could be affected both directly and indirectly through change in soil chemistry. The extent of effects could be a few metres to some tens of metres along the roadways. Thus, the extent is expected to be quite low.

Substance releases via small-scale leaks and spills could occur at the various infrastructure sites.

The predicted effects of operations activities on soil quality, considered in combination, will be adverse, low magnitude, local in extent and short term.

Decommissioning and Abandonment

Minor disturbance of soil surfaces by machinery used to remove infrastructure components is expected. The combined effects on soil quality will be adverse, low magnitude, local in extent and short term.

8.4.9.3 Pipeline Corridor Infrastructure Baseline Conditions

Baseline conditions for pipeline corridor infrastructure are expected to be similar to those encountered in the adjacent pipeline corridor LSA.

Borrow sites along the corridor are located in areas dominated by coarse-textured, rapidly drained glaciofluvial deposits. Surface expression of these deposits is mostly hummocky, but might range from undulating plains to steep slopes or terraces. Nonpermafrost-affected Brunisols are the most commonly occurring soils, with the largest proportion consisting of Orthic Eutric or Eluviated Eutric subgroups. Rare occurrences of Orthic Dystric or Eluviated Dystric Brunisolic subgroups are also expected. Related processes include potential deflation in aeolian deposits and glaciofluvial veneers. Landform types identified as potential borrow sites along the pipeline corridor include coarse-textured, rapidly drained aeolian dune complexes, fluvial fans, colluvium and bedrock ridges. Discontinuous permafrost and thaw subsidence could be associated with some of these landform types.

8.4.9.4 Pipeline Corridor Infrastructure Effects

The exact locations of the infrastructure sites along the pipeline corridor have not been finalized. Therefore, a qualitative assessment of these infrastructure sites was completed. This assessment assumes that the range of soils and ground conditions will be similar to those described for the pipeline corridor LSA.

Construction effects on soil quality following mitigation will be adverse, low magnitude, local in extent and short term to long term (see Table 8-81). Effects on soil quality during construction of the pipeline corridor are similar to those described for the production area (see Section 8.4.9.2, Production Area Infrastructure Effects).

Similarly, the effects of thaw settlement, dust deposition, and small-scale leaks and spills will also be the same as for the production area (see Section 8.4.9.2, Production Area Infrastructure Effects). Operations effects on soil quality will be adverse, low magnitude, local in extent and short term to long term.

Effects on soil quality for decommissioning and abandonment will be minor and related to any surface disturbance required to decommission the project. Effects will be adverse, low magnitude, local in extent and short term.

Changes in Soil Drainage

Construction

As with the production area, changes in soil drainage could occur in areas adjacent to pads and dust accumulation from traffic can also change soil drainage.

Table 8-81: Effects on Soil Quality – Pipeline Corridor Infrastructure

Pathway	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Changes in soil drainage	Construction	Adverse	Low	Local	Long term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Soil loss	Construction	Adverse	Low	Local	Far future
	Operations	Neutral	No effect	N/A	N/A
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Changes in soil chemical and physical characteristics	Construction	Adverse	Low	Local	Short term
	Operations	Adverse	Low	Local	Short term
	Decommissioning and abandonment	Adverse	Low	Local	Short term
NOTE: N/A = not applicable					

Winter roads and all-weather roads will be constructed for pipeline corridor infrastructure across diverse terrain. Temporary damming during spring runoff can cause changes in soil drainage.

Borrow site development can potentially affect soil drainage through damming or by contributing to thaw settlement and subsequent ponding.

Infrastructure will typically be located on higher ground in well-drained areas where the potential for changes in soil drainage because of thaw settlement is low.

Construction effects will be adverse, low magnitude, local and long term.

Operations

If thaw-settlement processes have occurred, ponds might increase in size during operations. Should this occur, additional fill would be added to control pond development. The effects of changes in soil drainage on soil quality during operations for pipeline corridor infrastructure will be adverse, low magnitude, local in extent and long term.

Decommissioning and Abandonment

No additional changes in soil drainage are expected during decommissioning. Therefore, no effects on soil quality because of changes in soil drainage during decommissioning and abandonment are predicted for pipeline corridor infrastructure.

Soil Loss

Construction

A loss of soil cover will occur where pads are constructed on thaw-unstable terrain, whereas soil will be removed and replaced at those sites that are on thaw-stable terrain. Because site-specific assessments have not been completed, it is assumed that pads will be constructed on thaw-unstable terrain and therefore, soil loss will occur. At most, pads at the infrastructure sites and all-weather roads will cover 252 ha of soil.

Soil will also not be removed along all-weather roads before placement of the fill. The footprint of the pad for these roads covers about 82 ha.

Effects of construction on soil loss will be adverse, low magnitude, local in extent and far future in duration.

Operations and Decommissioning

No additional soil loss is expected during operations and decommissioning and abandonment. Surfaces will be recontoured, scarified and where soil has been previously removed, it will be replaced and the sites seeded. This will greatly reduce the time required for soil to return to pre-existing characteristics. Because the material used to construct the pads might be coarser than the material it covered, the quality of the soil that will develop might be lower, and the plant community supported might be more xeric than the one that is covered.

Changes in Soil Physical and Chemical Characteristics

Construction

Wind erosion of soils could occur during construction of facilities on sandy soils. The sandy soils are mostly thaw stable, and it is expected these soils will be removed and stockpiled before facility construction. The stockpiled, sandy soils will be susceptible to wind erosion.

Water erosion could occur at some sites associated with roads and pads, but the area is expected to be small.

A combination of soil mixing, compaction and rutting could occur during construction and use of winter roads. These processes could occur if winter roads are prepared before complete freeze-up, or if they continue to be used once thaw begins. It is expected that about 490 km of borrow site and other winter access roads will be required. The road area over this distance is about 490 ha.

Soil admixing could occur during surface soil removal and replacement activities. Soils are most likely to be removed and replaced at borrow sites, comprising about 600 ha, taking into account the number and estimated size of the borrow sites.

Table 8-81, shown previously, identifies the combined effects on soil chemical and physical properties of construction activities. The effects will be adverse, low magnitude, local in extent and short term.

Operations

Some road dust could originate from all-weather roads, including about 51 km of all-weather roads at facilities along the right-of-way. The extent of this effect is expected to be small.

Inadvertent substance releases from small-scale leaks and spills would be the main activity during operations leading to an effect on soil chemistry.

The combined effects of operations activities on soil physical and chemical characteristics will be adverse, low magnitude, local in extent and short term.

Decommissioning and Abandonment

Minor disturbance of soil surfaces by machinery used to remove infrastructure components is expected during decommissioning and abandonment. The combined effects on soil quality will be adverse, low magnitude, local in extent and short term.

8.4.10 Significance of Effects

In previous sections, the characteristics of the residual effects of the project were described in terms of direction, magnitude, geographic extent and duration. These characteristics are used to determine significance of effects on soil quality.

Volume 1, Section 2, Assessment Method, discusses the rationale for determining significance. An adverse residual effect is considered significant if the effect is either:

- moderate or high magnitude and extends into the far future, i.e., more than 30 years after project decommissioning and abandonment
- high magnitude and occurs outside the LSA at any time

This section discusses the significance of effects for each project component and for the combined project. Tables show the results of the effects assessment and indicate if an effect is significant.

8.4.10.1 Niglintgak

Soil quality at the Niglintgak will be affected primarily through changes in soil drainage and soil loss if the land-based gas conditioning facility option is selected. Soil chemical and physical properties might be changed because of minor mixing, air emissions and inadvertent leaks and spills. However, changes in soil quality are also reduced because several project components will be built on raised platforms rather than on pads. Effects on soil quality of both the barge- and land-based gas conditioning facility option would have effects on soil quality but these would not exceed low magnitude (see Table 8-82).

Table 8-82: Significance of Effects of Niglintgak on Soil Quality

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Soil quality	Construction	Adverse	Low	Local	Short term to far future	No
	Operations	Adverse	Low	Local	Short term to far future	No
	Decommissioning and abandonment	Adverse	Low	Local	Short term	No

The effects of the project at Niglintgak on soil quality will be not significant.

8.4.10.2 Taglu

The main effects on soil quality at Taglu are related to soil loss and changes in soil drainage caused by constructing the pad and all-weather road. Soil chemical and physical properties might change because of mixing or inadvertent leaks and spills. Effects on soil quality are not expected to exceed low magnitude when compared with the distribution of the affected landform type in the Taglu LSA and are the same as at Niglintgak (see Table 8-83). The effects of Niglintgak on soil quality will not be significant.

Table 8-83: Significance of Effects of Taglu on Soil Quality

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Soil quality	Construction	Adverse	Low	Local	Short term to far future	No
	Operations	Adverse	Low	Local	Short term to far future	No
	Decommissioning and abandonment	Adverse	Low	Local	Short term	No

8.4.10.3 Parsons Lake

The main effects on soil quality at Parsons Lake are related to soil loss from constructing pads and the airstrip. Effects on soil quality related to changes in soil drainage are low at Parsons Lake because most facilities are located on thaw-stable terrain where thaw settlement is usually not an issue. Soil chemical and physical properties might be changed, adversely affecting soil quality, because of mixing, air emissions, or leaks and spills. Effects on soil quality will not be significant because of their low magnitude in affected areas compared with the distribution of the affected landform type in the Parsons Lake LSA (see Table 8-84) and are the same as at Niglintgak.

Table 8-84: Significance of Effects of Parsons Lake on Soil Quality

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Soil quality	Construction	Adverse	Low	Local	Short term to far future	No
	Operations	Adverse	Low	Local	Short term to long term	No
	Decommissioning and abandonment	Adverse	Low	Local	Short term	No

8.4.10.4 Gathering Pipelines and Associated Facilities

The primary impact to soil quality in the gathering pipelines and associated facilities is related to changes in soil drainage that could occur because terrain susceptible to thaw settlement is present over substantial segments of the gathering pipeline route and soil quality will be affected by the placement of pads for the Storm Hills and Inuvik area facilities. The duration of these effects is considered long term.

Effects on soil quality will be not significant because the magnitude in affected areas is low to moderate when compared with the distribution of the affected landform type in the gathering pipelines and associated facilities LSA, and because the duration is long term (see Table 8-85).

Table 8-85: Significance of Effects of the Gathering Pipelines and Associated Facilities on Soil Quality

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Soil quality	Construction	Adverse	Low to moderate	Local	Long term to far future	No
	Operations	Adverse	Low	Local	Short term	No
	Decommissioning and abandonment	Adverse	Low	Local	Short term	No

8.4.10.5 Pipeline Corridor

Soil quality effects in the pipeline corridor are related to changes in soil drainage that could occur because terrain susceptible to thaw settlement is present over substantial segments of the pipeline route. Low-magnitude effects on soil quality will also occur during each project phase. Soil loss during construction because of placement of the pads for the block valves infrastructure and compressor stations will affect soil quality. Water erosion, mixing and minor leaks or spills also have the potential to affect soil quality by changing soil physical and chemical properties. Mitigation applied to these areas is expected to be successful in re-establishing vegetation in the long term.

Effects of the pipeline corridor on soil quality will not be significant because the magnitude in affected areas is low to moderate when compared with the distribution of the affected landform type in the pipeline corridor. The duration of the effect will not exceed long term (see Table 8-86).

Table 8-86: Significance of Effects of the Pipeline Corridor on Soil Quality

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Soil quality[1]	Construction	Adverse	Low to moderate	Local	Long term to far future	No
	Operations	Adverse	Low	Local	Short to long term	No
	Decommissioning and abandonment	Adverse	Low	Local	Short term	No

NOTE:
1 The ratings were based on low magnitude combined with far-future effects and on low to moderate magnitude combined with long-term duration

8.4.10.6 Infrastructure

The main effects of infrastructure on soil quality will be related to soil loss and changes in soil drainage caused by constructing the infrastructure components. Changes in soil chemical and physical properties might affect soil quality through mixing, erosion, dust deposition and inadvertent leaks and spills. Effects on soil quality will not be significant because of the low magnitude in affected areas when compared with the distribution of the affected landform types in the production area and pipeline corridor LSAs (see Table 8-87).

Table 8-87: Significance of Effects of Infrastructure on Soil Quality

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Soil quality	Construction	Adverse	Low	Local	Short term to far future	No
	Operations	Adverse	Low	Local	Short term to far future	No
	Decommissioning and abandonment	Adverse	Low	Local	Short term to far future	No

8.4.10.7 Combined and Regional Effects

Most project effects on soil quality will be related to surface disturbance or burial of soil. Therefore, effects on soil quality will usually be localized with respect to the area of surface disturbance. Effects will be regional when they are outside the LSA. Therefore, effects related to infrastructure in the production area and pipeline corridor will be classified as regional, but will be concentrated around the area of disturbance.

The primary impact to soil quality along the gathering system and pipeline corridor is related to changes in soil drainage that could occur because terrain susceptible to thaw settlement is present over substantial segments of the route. Mitigation applied to these areas is expected to be successful in controlling thaw settlement and in re-establishing vegetation in the long term. Effects will be contained in the gathering system and pipeline corridor. Effects of the combined project on soil quality are predicted to be not significant.

8.4.10.8 Prediction Confidence

Available information and understanding of soil quality were used to provide an assessment of the significance of the effects of the project on soil quality. Predictions of future conditions in the impact assessment have an associated level of uncertainty.

Prediction confidence for significance related to soil quality is high, mainly because the precautionary principle has been applied in developing the effects assessment (see Volume 1, Section 2, Assessment Method).

Where available data and uncertainty about locations of some project facilities existed, conservative parameters and conditions were used to assess the significance of expected effects. Similarly, simplified models used in the assessment relied on conservative assumptions and were applied to ranges of parameters to determine accuracy of the assessment.

8.5 Monitoring

Volume 7, Section 6, Environmental Compliance and Effects Monitoring Plan, provides an overview of the intent and purpose of the environmental monitoring program to be implemented for the project.

Two types of programs will be developed:

- compliance monitoring
- effects monitoring

8.5.1 Compliance Monitoring

Compliance monitoring will ensure that environmental mitigation, as outlined in the environmental protection plan, is implemented. It will also ensure that work proceeds in compliance with regulations and the project proponents' environmental policies.

Compliance monitoring will be a component of each project phase. It includes monitoring, during construction and reclamation, specific to the protection of soils and landforms, such as:

- ground stability, including:
  - thaw depth and ground temperature
  - groundwater level
  - slopes and grades
  - ground subsidence or heave
- uncommon landforms, including landform types
- soil quality, including:
  - removal and replacement of soil in thaw-stable ground
  - application of seed and fertilizer
  - occurrence of soil erosion
  - plant cover development
  - soil chemistry near compressor stations and facility sites where emissions might affect soil chemistry

8.5.2 Effects Monitoring

Effects monitoring will confirm the accuracy of the prediction of effects, and determine the effectiveness of mitigation and enhancement measures. The Environmental Compliance and Effects Monitoring Plan provides a framework for adapting project practices in response to the results of effects monitoring programs.

The effects monitoring program for soils and landforms will be designed to assess the key indicators used to assess project effects. Table 8-88 shows a summary of the effects monitoring program being proposed, including key indicators, monitoring parameters and sampling locations.

Effects monitoring programs will be established in consultation with communities and regulators.

Table 8-88: Monitoring of Effects on Landforms and Soils

Effect	Monitoring Parameters	Sampling Locations
Ground Stability		
• Disruption of drainage from thaw settlement and frost effects	• Thaw settlement and frost heave • Pond formation and drainage	• Overland right-of-way • Granular pads and roads • Slopes
• Erosion of landforms and soils caused by wind or water	• Erosion	• Overland right-of-way • Granular pads and roads • Slopes
• Slope stability, mass movement and landslides caused by thaw	• Slope movement areas • Groundwater levels	• Slopes
Uncommon Landforms		
• Glaciofluvial and aeolian deposits	• Tracking of quantities of borrow used from a specific location	• LSAs • Overland rights-of-way • Granular pads and roads
Soil Quality		
• Soil drainage • Soil loss	• Soil erosion • Plant cover	• Overland right-of-way • Slopes • Granular pads and roads

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