5. HYDROLOGY

Introduction

The findings of the environmental impact assessment for hydrology for the Mackenzie Gas Project (see EIS Volume 5, Section 5) were based on the following components (see Section 1, Introduction, of this document):

- anchor fields
- gathering pipelines and associated facilities
- NGL and gas pipeline corridor
- infrastructure
- NGTL NWML Dickins Lake Section

The two NGTL pipeline sections, Dickins Lake Section and Vardie River Section, are located in northwestern Alberta. The Dickins Lake assessment was included in the EIS. This EIS supplemental information includes:

- updated information for the Dickins Lake Section
- new information for the Vardie River Section
- an impact assessment for northwestern Alberta based on the updated and new information
- a combined project effects assessment that includes the Mackenzie Gas Project and NGTL's Dickins Lake and Vardie River sections

See under EIS Summary for a summary of the EIS findings for hydrology.

EIS Summary

Potential effects on hydrology (see EIS Volume 5, Section 5) are related primarily to:

- land disturbance during construction
- water withdrawal for constructing winter roads and using in camps
- land settlement along the pipelines
- flow obstruction that could result from frost bulb formation

Effects of the Mackenzie Gas Project on runoff amount, drainage pattern, and water level and velocity were expected to be low magnitude and localized, from construction through decommissioning. Where redirection of groundwater could lead to large icings and blocking streamflow, local effects of high magnitude could result.

Effects on sediment concentration ranged from low to moderate magnitude and local in extent. High-magnitude effects could occur at pipeline water crossings during construction. These effects would be localized and short term.

Effects on channel morphology were expected to be low magnitude, localized and long term.

No significant effects on hydrology were predicted in the EIS.

Study Areas

Study areas for the project were delineated near project elements to provide a conservative assessment of effects. For descriptions of the LSA and RSA, see EIS Volume 5, Section 5. For generic descriptions of the LSAs and RSAs, see Table 5-1.

Table 5-1: Study Areas and Boundaries

Study Area Type	Study Area	Geographic Extent
Local study area	Pipeline corridor	Watercourses situated within a 1-km-wide zone centred along the pipeline
	Pipeline corridor infrastructure	Disturbed land and drainage area of site at receiving waterbodies
Regional study area	All areas	LSAs and downstream to next major stream or waterbody
	Pipeline corridor	Watercourses situated within a 30-km-wide zone centred along the pipeline

The study area of northwestern Alberta extends from the Northwest Territories–Alberta boundary to the South Shekilie River (see Figure 5-1). For a description of the topography and geology of northwestern Alberta, see EIS Volume 3, Section 5. The predominant named surface water features that might be affected by the project, and which are all part of the Mackenzie River basin, are:

- Thinahtea River
- Petitot River
- Shekilie River
- South Shekilie River

Baseline

Methods

For a description of the approach used for the baseline hydrology study, see EIS Volume 3, Section 5.

A literature review and data search was done to identify data and information related to climate and hydrology in the northwestern Alberta study area.

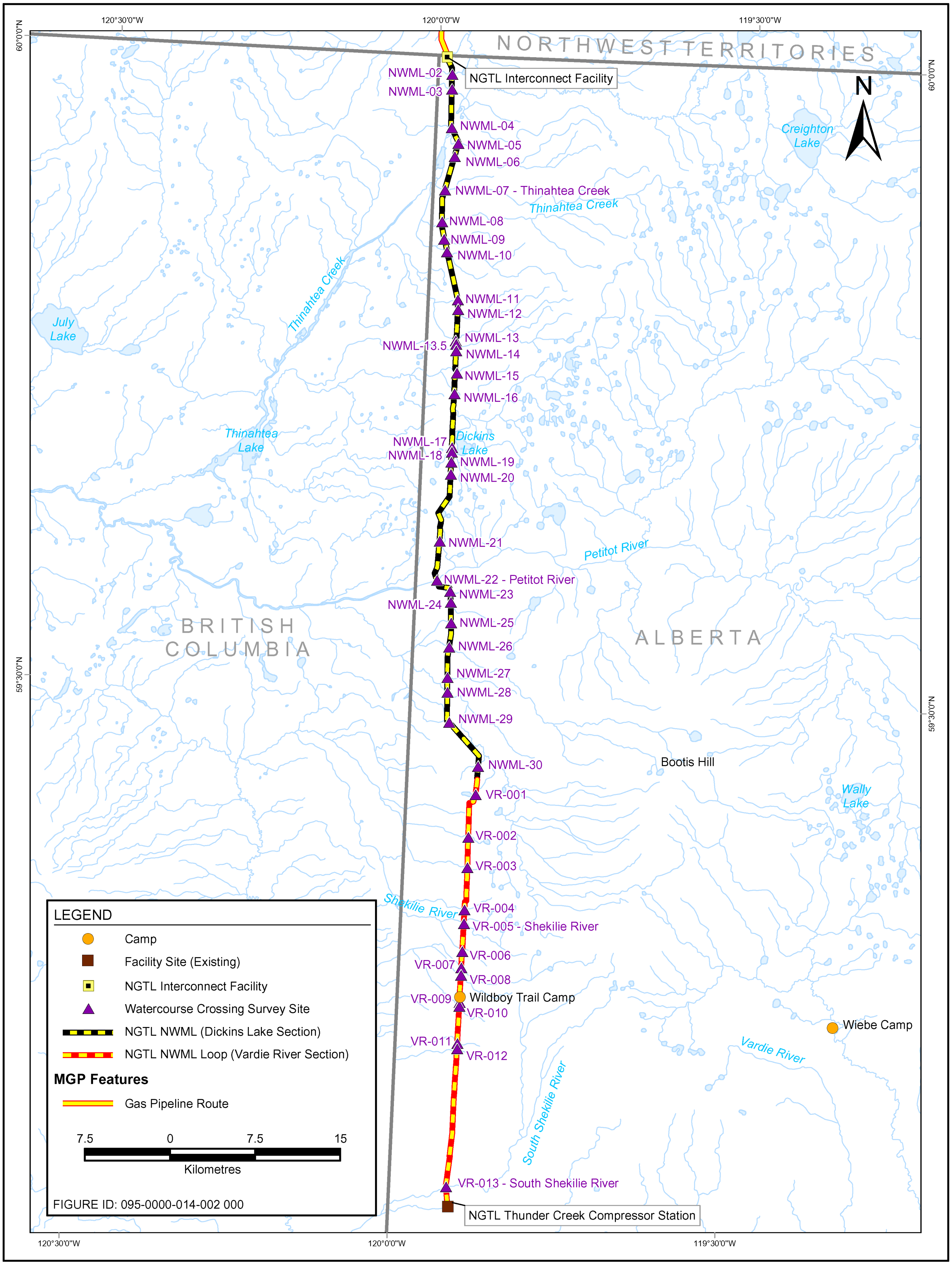

Figure 5-1: Watercourse Crossing Survey Sites

Field data collected during the 2002 and 2003 aquatic and stream surveys, and field methodology are summarized in EIS Volume 3, Section 5. Eight sites were visited in 2002 and 2003 for detailed surveys. Four sites were visited in 2004.

A stream classification system was developed to describe the drainage and flow characteristics of the watercourses that would be crossed by the proposed pipeline. The stream classes were based on published maps and data collected during field surveys of streams. For further details, see EIS Volume 3, Section 5.

Regional Baseline Conditions

The northwestern Alberta study area extends from the Northwest Territories – Alberta boundary south to the South Shekilie River, and is part of the southern hydrologic region.

The landscape along the Dickins Lake and Vardie River sections is undulating and characterized by boreal forests and large areas of wetland and muskeg. Sporadic discontinuous permafrost underlies the entire area.

The potential for encountering permafrost decreases from north to south along the proposed pipeline route. Discontinuous permafrost in the southern areas can affect drainage characteristics, such as the magnitude of summer peak flow and the extent of wetlands.

The area is poorly drained by watercourses with flat gradients. Ground thaw proceeds slowly in spring and summer as the surface vegetation and muskeg provide good insulation. Considerable volumes of water are held in the organic material at or near the surface, and are released slowly throughout the summer. Many streams are affected by beaver activity.

Climate Conditions

For climate conditions, see Section 2, Air Quality.

Based on information provided in Allen (1977), the average date for first ice at the Northwest Territories–Alberta boundary is November 1, and freeze-over occurs about November 15. The average date for first ice deterioration is May 5, and clearing of rivers occurs about May 15. Average maximum ice thickness is 1 m in rivers and 1.3 m in lakes.

Stream Flow and Water Levels

For the results of the regional hydrologic analysis for the southern hydrologic region, which includes northwestern Alberta, see EIS Volume 3, Section 5. The data indicates that, where all-year monitoring occurs, water yield, i.e., mean annual flow divided by drainage area, varies from 90 mm at the gauging station on Chinchaga River near High Level to 231 mm at the gauging station on Sahndaa Creek at Highway 1. The hydrologic regime of streams in the southern hydrologic region is dominated by snowmelt, with peak flow in late May and early June. Discharge typically decreases gradually over the summer.

Unit mean monthly discharge varies from 0.013 $m^3/s/km^2$ in July for a basin with a drainage area of 25 km^2, to 0.0002 $m^3/s/km^2$ in February for a basin with a drainage area of 5,000 km^2. These values were based on data at a number of regional stations. For empirical peak- and low-flow relationships, derived from the regional analysis and flow-duration analyses, see EIS Volume 3, Section 5.

Sediment Conditions

For a summary of basin sediment yield, potential extent of sediment transport within stream reaches and fine sediment deposition in lakes, see EIS Volume 3, Section 5. Based on the *Hydrological Atlas of Canada* (Environment Canada 1978), the mean annual sediment concentration in the southern hydrologic region can range from 50 to 200 mg/L.

Stream Classification and Geomorphology

For details on the stream classification system developed to describe drainage and flow characteristics of the watercourses, see EIS Volume 3, Section 5.

For definitions of the stream classes used, see Table 5-2. The thresholds between Vegetated Channels and Active Channels occur at a drainage area of about 15 km^2 and a slope of about 0.01 m/m. Active I Channels occur when drainage areas are greater than the threshold. Vegetated Channels occur when drainage areas and slopes are smaller than the thresholds. Active II channels occur when drainage areas are less than 15 km^2 and slopes are greater than 0.01 m/m.

The dominant stream substrate is:

- silt at about 40% of the sites
- sand at about 10% of the sites
- gravel at about 5% of the sites
- cobble at about 20% of the sites
- boulder at about 25% of the sites

Local Baseline Conditions

Reconnaissance surveys of 43 watercourses in northwestern Alberta were carried out in 2002, 2003 and 2004. For a summary of the data collected as of 2003, see EIS Volume 3, Section 5. For a summary, updated with 2004 data, of watercourse types determined from the reconnaissance surveys, see Table 5-3.

Table 5-2: Stream Classes

Stream Class	Description
Large River Channel	Large named watercourses with perennial flow Drainage areas >1,000 km^2 and wetted width typically >25 m
Active Channel	Intermittent and perennial streams with drainage areas <1,000 km^2, including those that freeze partially or completely to the bottom in winter Discernible banks and substrate, including silt and organic material Two major subgroups: • Active I – Perennial or partially frozen to bottom in winter, including areas highly influenced by groundwater input or beaver activity that might create open water, and by perennial flow or large pools and water depths • Active II – Frozen to bottom or dry below ice during winter, i.e., smaller drainage basins with low flow and shallow depth
Vegetated Channel	Ephemeral streams including vegetated waterways, depressions and swales Watercourses that flow primarily during spring runoff and are dry in late summer and over winter No discernible banks or evidence of annual sediment transport Areas of dispersed overland flow, i.e., wetland drainage areas Shallow flow through shrubs and trees Very little to no groundwater contribution to flow

Table 5-3: Watercourse Types

Watercourse Type	Stream Class	Number of Sites	Percentage of Streams	Approximate Basin Size and Channel Slope
Lake	N/A	0	N/A	N/A
Stream	Large River	1	2	DA>1,000 km^2
	Active I	11	26	DA>15 km^2
	Active II	2	5	DA<15 km^2 and S>0.01 m/m
	Vegetated	29	67	DA<15 km^2 and S<0.01 m/m
Total		43	100	

NOTES:
N/A = not applicable
DA = drainage area
S = channel slope

Of the crossing sites assessed in northwestern Alberta, 29, or 67%, were found to cross Vegetated Channels with poorly defined flow paths or with drainage dispersed through shrubs or trees. Two streams were Active II Channels that are expected to freeze to the bottom in winter. Twelve Active I and Large River channels, including the Petitot River, might freeze only partially to the bottom in winter.

Streams classified as Active I Channels in EIS Volume 5, Section 7 included:

- NWML-04
- NWML-09
- NWML-13
- NWML-13.5
- NWML-15
- NWML-19
- NWML-23
- NWML-27

NWML-25 and NWML-30 were classified as Active II Channels. These 10 streams have been reclassified as Vegetated Channels based on drainage area and channel slope. The previous classifications were based on the presence of water resulting from beaver impoundments observed during field surveys. However, from a channel morphology perspective, these streams are more accurately referred to as Vegetated Channels. For a list of the streams in the Vardie River Section of the study area and their classification, see Table 5-4.

Table 5-4: Watercourse Crossing Descriptions in the Vardie River Section

Crossing ID	**Name**	**Drainage Area** (km^2)	**Hydrologic Region**	**Stream Class**	**Width**[1] (m)	**Channel Map Slope** (m/m)
VR-001	Unnamed stream	1.3	Southern	Vegetated	–	0.004
VR-002	Unnamed stream	3.2	Southern	Vegetated	–	<0.001
VR-003	Unnamed stream	1.5	Southern	Vegetated	–	0.004
VR-004	Unnamed stream	3.2	Southern	Vegetated	–	0.010
VR-005	Shekilie River	20.3	Southern	Active I	2–3.5	0.003
VR-006	Unnamed stream	5.5	Southern	Vegetated	–	0.006
VR-007	Unnamed stream	29.3	Southern	Active I	65	0.004
VR-008	Unnamed stream	5.8	Southern	Vegetated	–	0.006
VR-009	Unnamed stream	2.2	Southern	Active II	–	0.011
VR-010	Unnamed stream	4.1	Southern	Vegetated	–	0.007
VR-011	Unnamed stream	6.0	Southern	Vegetated	–	0.007
VR-012	Unnamed stream	4.4	Southern	Vegetated	–	0.006
VR-013	South Shekilie River	174.0	Southern	Active I	1.5–6	0.006

NOTES:
– = not available
1 Range of values reflects different widths measured in the study reach during detailed aquatic surveys

Effects on Runoff Amount, Drainage Pattern and Water Level and Velocity

Effect Pathways

The pathway diagram for northwestern Alberta (see Figure 5-2) is the same as that in EIS Volume 5, Section 5. It shows key and intermediate pathways, indicating how adding the Dickins Lake and Vardie River sections could affect runoff amount, drainage pattern, and water level and velocity. Only applicable pathways are discussed.

Nonapplicable pathways for the study area include effects of:

- land subsidence on water level and velocity in the anchor fields
- flow obstruction on water level and velocity in the anchor fields and gathering system
- water withdrawal and disposal on water level and velocity in the anchor fields and gathering system
- land disturbance on runoff amount in the anchor fields and gathering system
- frost heave and thaw settlement on drainage pattern in the anchor fields and gathering system

For a discussion of pathways, see EIS Volume 5, Section 5.

Effect Attributes

Effects on hydrologic conditions are described in terms of four characteristics:

- direction
- magnitude
- geographic extent
- duration

For the effect attributes for the KIs of runoff amount, drainage pattern, and water level and velocity, see Table 5-5.

Analysis and Significance

Construction, operations and decommissioning could disrupt water flow and sediment concentration in waterbodies. Activities that could cause these disruptions include:

- land disturbance
- disturbance to stream beds and banks
- flow obstructions
- changes in thermal regime because of frost heave and thaw settlement

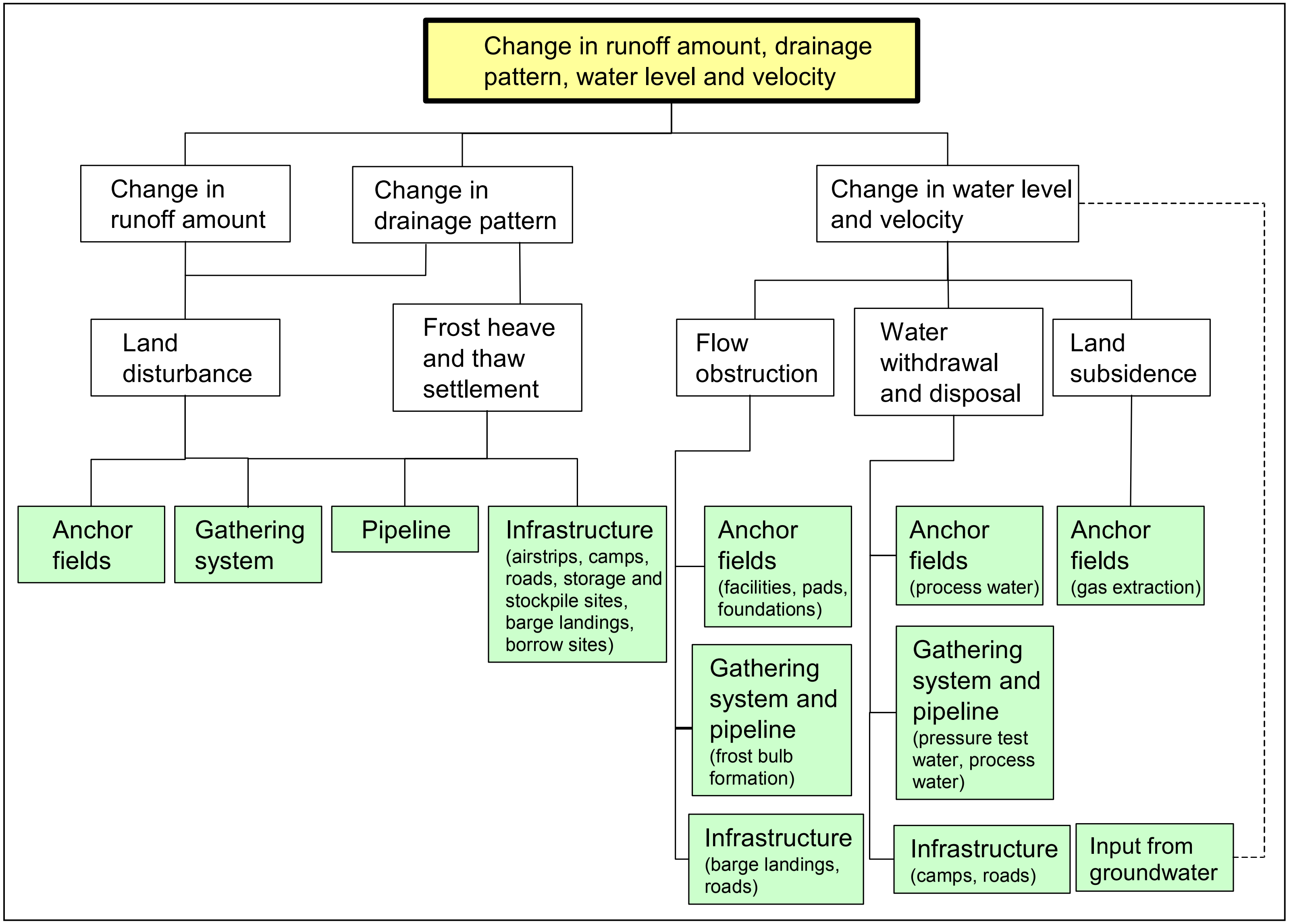

Figure 5-2: Effect Pathways – Runoff Amount, Drainage Pattern, and Water Level and Velocity

Table 5-5: Definitions of Effect Attributes for Hydrology

Attribute	Definition		
	Runoff Amounts, Drainage Patterns, and Water Levels and Velocity	Sediment Concentration	Change in Channel Morphology
Direction			
Adverse	Change in mean annual runoff, drainage pattern or mean water level and velocity	Increase in mean annual sediment concentration	Change in natural channel morphology
Neutral	No change in mean annual runoff, drainage pattern or mean water level and velocity	No increase in mean annual sediment concentration	No change in natural channel morphology
Magnitude			
No effect	No change in mean annual runoff No change in drainage pattern No change in mean water level and velocity	No change in mean annual sediment concentration	No change in natural channel morphology
Low	<2% change in mean annual runoff, or not measurable, e.g., <0.001 m^3/s change in mean annual flow, or distributed, i.e., nonpoint, flow to the Mackenzie River No detectable change in drainage pattern beyond 50 m from disturbance footprint and runoff is directed to natural receiving waterbody Change in mean water level and velocity that is not detectable over the long term using standard gauging techniques, i.e., <2% of natural range	<10 mg/L increase in mean annual concentration or <50 mg/L short term increase For Mackenzie River and Liard River: <50 mg/L in excess of background concentrations	Rate of change in morphology not distinguishable from natural regional morphological processes
Moderate	2–5% change in mean annual runoff Change in drainage pattern is detectable between 50–200 m from disturbance footprint, but runoff is directed toward natural receiving waterbody Change in mean water level and velocity that is 2–5% of natural range	10–25 mg/L increase in mean annual concentration or 50–100 mg/L short term increase For Mackenzie River and Liard River: 50–5,000 mg/L in excess of background concentrations	Change in morphology occurs at a rate that could be distinguishable from natural regional morphological processes, but is likely similar to historical changes

Table 5-5: Definitions of Effect Attributes for Hydrology (cont'd)

Attribute	Definition		
	Runoff Amounts, Drainage Patterns, and Water Levels and Velocity	Sediment Concentration	Change in Channel Morphology
Magnitude (cont'd)			
High	>5% change in mean annual runoff Change in drainage pattern is detectable at any distance from disturbance area and runoff is not directed toward natural receiving waterbody. Change in mean water level and velocity that is >5% of natural range	>25 mg/L increase in mean annual concentration or >100 mg/L short term increase For Mackenzie River and Liard River: >5,000 mg/L in excess of background concentrations	Change in morphology occurs at a rate less than historical changes
Geographic Extent			
Local	Effect on VC or KI within LSA		
Regional	Effect on VC or KI within RSA		
Beyond regional	Effect on VC or KI extends beyond RSA		
Duration			
Short term	Effect on VC or KI is limited to less than one year		
Medium term	Effect on VC or KI occurs from one to four years		
Long term	Effect on VC or KI lasts longer than four years, but does not extend more than 30 years after decommissioning and abandonment		
Far future	VC or KI is unlikely to recover from effect within 30 years after decommissioning and abandonment		

These activities can affect:

- runoff amount
- natural drainage pattern
- water level
- velocity

For a summary of effects on runoff amount, drainage pattern and water level and velocity through construction, operations, and decommissioning and abandonment, see Table 5-6.

Table 5-6: Effects on Runoff Amount, Drainage Pattern, and Water Level and Velocity

Key Indicator	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	**Magnitude**	**Geographic Extent**	**Duration**	
Runoff amount	Construction	Adverse	Low	Local	Medium term	No
	Operations		Low	Local	Long term	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No
Drainage pattern	Construction	Adverse	Low	Local	Medium term	No
	Operations		Low	Local	Long term	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No
Water level and velocity associated with flow obstruction because of frost bulb formation	Construction	Neutral	No effect	N/A	N/A	No
	Operations	Adverse	No effect to low Possibly moderate to high where icings occur	Local	Long term	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No

NOTE:
N/A = not applicable

In general, effects in the Dickins Lake and Vardie River sections are expected to be similar to those predicted along the Mackenzie Valley pipeline corridor (see EIS Volume 5, Section 5). Development of project components could affect:

- runoff amount
- drainage pattern
- water level
- velocity

Effects on these KIs are expected to be low magnitude from construction through decommissioning and abandonment. In all cases effects on runoff amount, drainage pattern, and water level and velocity will be restricted to the LSA. Effects on runoff amount and drainage pattern are considered not significant.

Runoff Amount

Construction

Effects on runoff amount because of pipeline construction are expected to be low magnitude.

The land disturbed during construction will be less permeable than natural surfaces. This will result in higher volumes of runoff from these areas than would occur under natural conditions. Changes in drainage pattern could result from land disturbance, frost heave and thaw settlement associated with construction and operations.

The disturbance area associated with the expansion of the Wildboy Trail camp is about 10 ha, compared with the drainage area of about 8.1 km^2 for the watercourse that receives runoff from the site. The disturbance area is about 1% of the basin area. Therefore, the effects from the camp on runoff amount are expected to be low magnitude.

The footprint occupied by the heater at the NGTL Thunder Creek compressor station and block valves is considered negligible and was not assessed.

Operations

The effects on runoff amount from land disturbance will generally be less during operations than during construction.

Decommissioning and Abandonment

Following reclamation, it is expected that changes in runoff amount will return to near predisturbance levels. The infrastructure facilities will be decommissioned causing nondetectable changes in runoff compared with baseline conditions, after revegetation has been completed.

Drainage Pattern

Construction

Runoff will be routed toward a natural receiving body at facility sites. Effects on drainage patterns are expected to be low magnitude and no changes in total groundwater input to waterbodies are expected.

Operations

Effects on drainage patterns from land disturbance will generally be less during operations than during construction.

The pipeline gas temperature might be subzero. As a result, the ground around the pipeline might freeze and the ground surface could rise in areas subject to frost heave. As the permafrost is sporadic in this region, intermittent lengths of the right-of-way might be susceptible to frost heave. For a discussion of frost heave effects, see EIS Volume 5, Section 5. Changes in basin drainage patterns resulting from frost heave are expected to be low magnitude.

The effect at facilities of frost heave on drainage pattern is expected to be low magnitude.

Decommissioning and Abandonment

Activities during decommissioning and abandonment will include decommissioning of the pipeline. As a result, the frozen area around the pipeline will return to ambient conditions, i.e., areas subject to frost heave will subside. Changes in drainage pattern that occurred as a result of operations will return to near predisturbance levels.

Water Level and Velocity

Construction

Water supply and disposal will be required for the camp at Wildboy Trail. If water is required for pressure testing of the pipeline during construction, the following regulatory requirements regarding water withdrawal and disposal will be met:

- *Code of Practice for the Temporary Diversion of Water for Hydrostatic Testing of Pipelines*
- *Code of Practice for the Release of Hydrostatic Test Water from Hydrostatic Testing of Petroleum Liquids and Gas Pipelines*

Effects on water level and velocity are expected to be low magnitude.

Beaver impoundments are common in many streams in the study area. The locations of the beaver impoundments can change depending on the frequency of extreme flows and biological factors. The construction methods selected at stream crossings affected by beaver impoundments will reduce effects on water level and velocity. Effects are expected to be low magnitude.

Operations

At watercourse crossings, subzero gas temperatures in the pipeline might create a frost bulb beneath the stream channel. Frost bulb growth might extend into the channel, particularly over the winter, and could obstruct stream flow. Similarly, frost bulb growth beneath the channel could obstruct groundwater input and stream base flow. Potential effects on water level and velocity depend on the stream type and mitigation measures used to reduce frost bulb growth.

Changes in local water levels and velocities might occur in limited cases where Active I streams are subject to icing formation because of groundwater blockage. Effects are expected to be low magnitude. Effects on water level and velocity from land disturbance will generally be less during operations than during construction.

Decommissioning and Abandonment

Activities during decommissioning and abandonment will include decommissioning of the pipeline. As a result, the frozen area around the pipeline will return to ambient conditions, i.e., frost bulbs will disappear. Changes in water level and velocity that had occurred as a result of operations will return to near predisturbance levels.

Prediction Confidence

Because of the precautionary approach used to predict the effects of the project on runoff amount, drainage pattern, and water level and velocity, there is a high degree of confidence in the assessment of significance of effects. The level of confidence is consistent with that in EIS Volume 5, Section 5.

Effects on Sediment Concentration

Effect Pathways

The pathway diagram for northwestern Alberta (see Figure 5-3) is the same as that in EIS Volume 5, Section 5. It shows the key and intermediate pathways, indicating how adding the Dickins Lake and Vardie River sections could affect sediment concentration. Only applicable pathways are discussed.

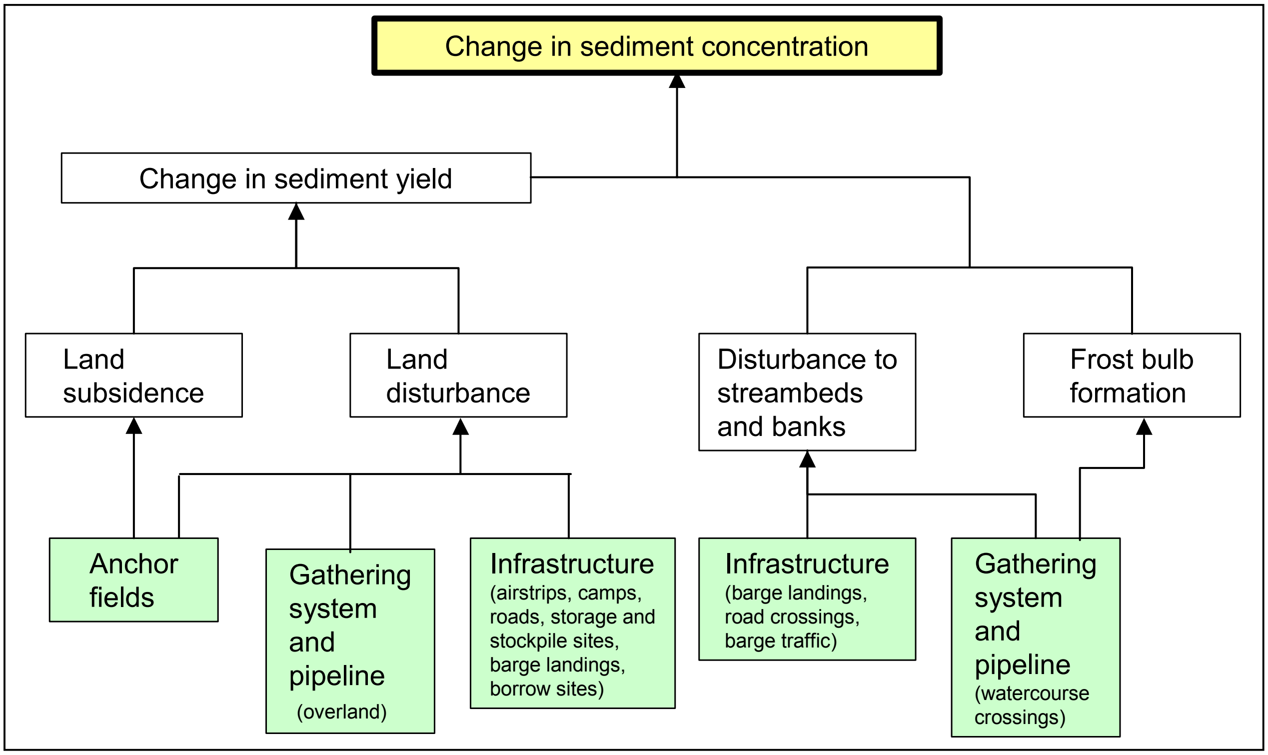

Figure 5-3: Effect Pathways – Sediment Concentration

Nonapplicable pathways for the study area include effects of:

- land subsidence on sediment yield in the anchor fields
- land disturbance on sediment yield in the gathering system
- frost bulb formation on sediment concentration in the gathering system
- disturbance to stream beds and banks on sediment concentration in the gathering system
- disturbance to stream beds and banks on sediment concentration in infrastructure (barge landings, road crossings and barge traffic)

For a discussion of pathways, see EIS Volume 5, Section 5.

Effect Attributes

For effect attribute definitions for sediment concentration, see Table 5-5, shown previously.

Analysis and Significance

For a summary of effects on sediment yield and concentration through construction, operations and decommissioning and abandonment, see Table 5-7. Effects on sediment concentration from land disturbance are expected to be low magnitude. Effects on sediment concentration at watercourse crossings are expected to be no effect to high magnitude during construction, depending on the crossing construction method, but will have no effect during operations and decommissioning and abandonment.

Table 5-7: Effects on Sediment Concentration

Key Indicator	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Sediment concentration – land disturbance in right-of-way and facilities in main infrastructure sites	Construction	Adverse	Low	Local	Medium term	No
	Operations	Adverse	Low	Local	Long term	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No
Sediment concentration – during watercourse crossing construction	Construction	Adverse	No effect to high	Local	Short term	No
	Operations	Neutral	No effect	N/A	N/A	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No
Sediment concentration – from frost bulbs and related flow obstruction	Construction	Neutral	No effect	N/A	N/A	No
	Operations	Adverse	Low	Local	Long term	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No
NOTE: N/A = not applicable						

In general, effects in northwestern Alberta are expected to be similar to those predicted along the Mackenzie Valley pipeline corridor (see EIS Volume 5, Section 5). Pipeline and facility development could affect sediment yield from basins and sediment concentration in nearby waterbodies because of land disturbance, and bed and bank disturbance. Effects on sediment concentration in streams and waterbodies because of land disturbance are expected to be low magnitude. However, moderate to high-magnitude effects on sediment concentration could occur in the short term during watercourse crossing construction. Effects are expected to be low magnitude during operations and decommissioning and abandonment. In all cases, effects on basin sediment yield and sediment concentration are restricted to the LSA. Effects on sediment concentration are considered not significant.

Land Disturbance

Construction

Clearing the pipeline right-of-way could affect basin sediment yield. For the screening procedure developed to assess the locations where moderate and high sediment concentration might result, see EIS Volume 5, Section 5, which also tabulates changes in sediment yield for sample watershed sizes.

Increased sediment concentration from expansion of the Wildboy Trail camp is estimated to be about 20 mg/L, which indicates a moderate-magnitude effect. The receiving waterbody is between 800 and 1000 m downslope of the camp. The effect on the downstream waterbody is expected to be low magnitude.

Operations

Effects on sediment yield and concentration because of land disturbance will generally be less during operations than during construction as reclamation proceeds.

Decommissioning and Abandonment

Effects on sediment yield associated with pipeline decommissioning and abandonment activities will be nondetectable because the right-of-way and facility sites will be reclaimed and revegetated.

Disturbance to Stream Beds and Banks

Sediment concentration could be affected by bed and bank disturbance associated with watercourse crossing construction. Crossing construction methods (see EIS Volume 7), have been selected to reduce the potential for sediment entrainment and transport. For a discussion of methods proposed for pipeline watercourse crossing installation and the potential for increases in instream sediment concentration, see EIS Volume 5, Section 5.

Results presented in EIS Volume 5, Section 5, suggest that there will be negligible deposition of coarse silt at a distance of 45 times bankfull width downstream of a crossing location. The sediment that remains in suspension, as indicated by elevated concentrations, consists of finer material that will only settle out at greater distances downstream.

Effects on sediment concentration at watercourse crossings are expected to be no effect to high magnitude and short duration during construction, depending on the crossing construction method, but will have no effect during operations, and no effect during decommissioning and abandonment.

Frost Bulb Formation

Operation of the gas pipeline might create frost bulbs at some stream crossings because of subzero gas temperatures in the pipeline. As discussed previously, formation of the frost bulbs could create obstructions that might change local flow pattern and velocity in watercourses. These changes could result in local erosion and sediment generation. These effects are expected to result in low-magnitude changes in sediment concentration.

Prediction Confidence

Because of the precautionary approach used to predict the effects on sediment concentration, there is a high degree of confidence in the assessment of significance of effects. The level of confidence is consistent with that in EIS Volume 5, Section 5.

Effects on Channel Morphology

Effect Pathways

Channel morphology is the adjustment of channel shape in response to water flow and sediment conveyance. For a discussion of the effects, see EIS Volume 5, Section 5. Changes in runoff amount could change channel hydraulics, i.e., flow, depth, velocity and river ice, which directly affect the sediment transport capacity of a channel.

The pathway diagram for northwestern Alberta (see Figure 5-4) is the same as that in EIS Volume 5, Section 5. It shows the pathways by which the project could affect channel morphology. Only applicable pathways are discussed.

Nonapplicable pathways for the study area shown in Figure 5-4 include effects of land subsidence on morphology of streams, rivers and delta channels at Niglintgak and Taglu. This pathway, where it is applicable, is discussed in detail in EIS Volume 5, Section 5.

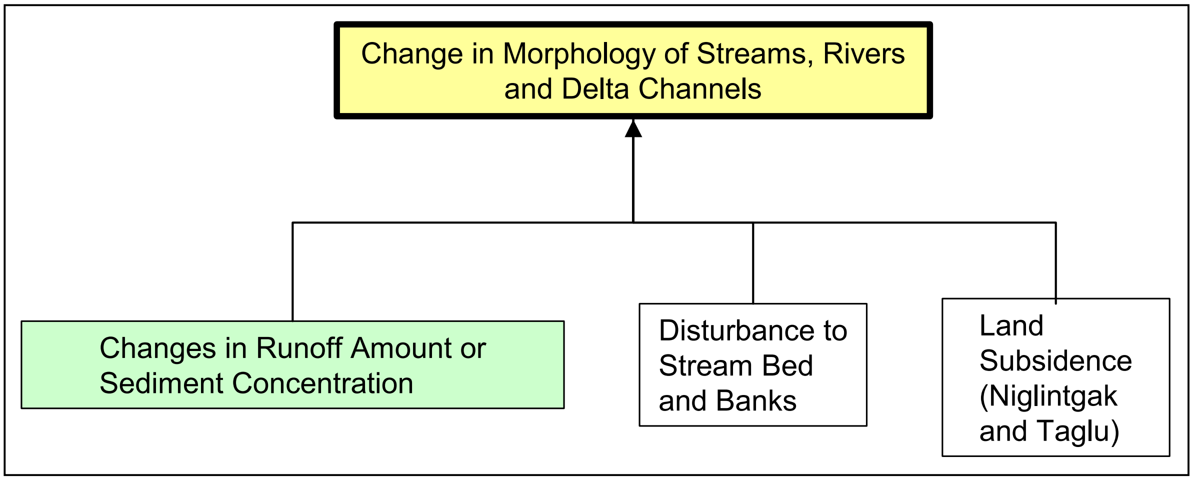

Figure 5-4: Effect Pathways – Channel Morphology

Effect Attributes

For effect attribute definitions for channel morphology, see Table 5-5, shown previously.

Analysis and Significance

Effects on channel morphology are expected to be low magnitude (see Table 5-8). Construction, operations and decommissioning and abandonment of infrastructure are not expected to affect channel morphology.

In general, effects in northwestern Alberta are expected to be similar to those predicted along the Mackenzie Valley pipeline corridor (see EIS Volume 5, Section 5). Effects on channel morphology are expected to be low magnitude and confined to the LSA during construction and operations. No effects are expected as a result of decommissioning and abandonment activities. Effects on morphology are considered not significant.

Table 5-8: Effects on Channel Morphology

Key Indicator	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Channel morphology	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

NOTE:
N/A = not applicable

Construction

Disturbance associated with pipeline installation could result in weakened stream banks and looser stream bed material. At high flows during operations, erosion could increase in disturbed areas and result in increases in sediment supply and concentration. However, suitable design approaches and construction practices will be implemented to reduce erosion (see EIS Volume 7). Locating pipeline watercourse crossings at stable sites increases the likelihood that banks can be successfully restored and that existing stream morphology can continue to evolve naturally. In general, effects of the pipeline on channel morphology are expected to be low magnitude. Site-specific effects on channel morphology are also expected to be low magnitude. Infrastructure is not expected to affect channel morphology during construction.

Operations

Effects on channel morphology during operations will be low magnitude. Infrastructure is not expected to affect channel morphology during operations.

Decommissioning and Abandonment

Pipeline crossing locations will likely stabilize by the end of operations because of reclamation and vegetation growth. No bank instabilities are expected and no effects on flow or sediment concentration resulting from decommissioning activities will occur. As a result, no noticeable effect on channel morphology is expected. Infrastructure is not expected to affect channel morphology during decommissioning and abandonment.

Prediction Confidence

Because of the precautionary approach used to predict effects on channel morphology, there is a high degree of confidence in the assessment of significance of effects. The level of confidence is consistent with that in EIS Volume 5, Section 5.

Combined Project Effects

The EIS concluded that the Mackenzie Gas Project in combination with NGTL's Dickins Lake Section would produce no significant effects on:

- surface water flow, level and velocity
- sediment concentration
- channel morphology

This assessment for northwestern Alberta concludes that the Mackenzie Gas Project combined with NGTL's Dickins Lake and Vardie River sections will also produce no significant effects.