INTRODUCTION

This section describes the biophysical baseline setting, potential effects and primary mitigation strategies associated with the watercourse crossings proposed for the gathering pipelines, travel lane and winter access roads in the ISR. It focuses on fish and fish habitat, but includes other related disciplines such as hydrology and water quality. Biophysical setting, effects and mitigation information for the Swimming Point barge landing site are provided in Section 7 of this application.

BIOPHYSICAL ENVIRONMENT SETTING

Soils, Landforms and Permafrost

The study area in the ISR falls within the Tundra ecological zone, which is covered by surficial sediments that reach a maximum thickness of 150 m near the Beaufort Sea shoreline. The area is characterized by continuous permafrost, although zones of discontinuous permafrost are found adjacent to the Mackenzie River. Surficial materials have commonly developed soils of the Cryosolic and Regosolic orders (see Table 8-1).

Table 8-1: Soil Orders in the ISR

Order	Great group	Typical Parent Material	Drainage	Slope (%)
Cryosolic	Turbic Cryosol	Colluvial, glaciolacustrine, morainal, fluvial	Moderately well to very poorly drained	0–5
	Static Cryosol	Glaciolacustrine, fluvial	Poorly to very poorly drained	0–1
	Organic Cryosol	Organic	N/A[a]	0–1
Regosolic	Orthic Regosol	Fluvial, glaciofluvial	Rapid to imperfectly drained	0–5
	Cumulic Regosol	Fluvial	Well drained	0–1
	Gleyed Regosol	Variable	Imperfectly to poorly drained	0–1

NOTE:
[a]Not applicable

At Niglintgak and Taglu, including the Niglintgak lateral, recent fluvial deposits of the Mackenzie River are common, and fluvial erosion and sedimentation are active geomorphic processes. Fluvial sediments are composed of silt and fine sand, although coarse sand and gravel are locally found within the Harry Channel. Moraine is found in upland areas, and is predominantly clay and silt-rich tills.

Lowland areas commonly develop low-centred polygons and more rarely pingos. Active geomorphic processes include thermokarst and retrogressive thaw-flow slides.

Surficial deposits in the Parsons Lake area and along most of the gathering pipeline system are composed primarily of hummocky moraine with subordinate units of glaciofluvial material. Tertiary bedrock is locally exposed in upland areas. Depressions in the moraine are filled with lakes, organic units and post-glacial lacustrine deposits and have commonly developed ice-wedged polygons. Slopes around some depressions are slumping, and retrogressive thaw slides are common.

Historically, the outer Mackenzie Delta has been described as being a continuous permafrost area (>90% permafrost soils). Recent reclassifications (Heginbottom 2000) describe the outer delta area and portions of Richards Island as being intermediate discontinuous permafrost areas with about 35 to 65% permafrost. In the Mackenzie Delta, permafrost thickness is generally less than 90 m thick, where present, and contains deep unfrozen zones (taliks), which in some cases extend to the base of the permafrost (through taliks). The depth of the active layer generally ranges from 30 to 100 cm but is largely a function of ground surface insulation and thermal conditions (vegetation cover, degree of ground disturbance and winter snow cover).

Low ice content is expected in well-drained, coarse-grained sediments above the local groundwater table, such as glaciofluvial sand and gravels. Massive ice might be contained in granular deposits at depths below about 7.0 m, in some localized areas. Ice-rich permafrost is more commonly associated with fine-textured moraine, lacustrine sediments, organic soils, and fluvial deltaic sand deposits. The ice content might be very high if the deposits are located in poorly drained areas. Ice veins, lenses and massive ground ice are common.

Hydrology

The ISR falls within the delta hydrologic region. The Mackenzie Delta is the largest delta in Canada, extending about 200 km from Point Separation in the south to the Beaufort Sea in the North. It is bounded on the west by the Richardson Mountains and on the east by the higher delta islands. The Mackenzie Delta consists of thousands of lakes and an intricate network of channels; over 25% of its area is covered by water.

Most runoff in the delta region is the result of snowmelt in the spring. Because precipitation in the region is low, water yield is low and tributary watercourses are small. Usually, the smaller catchments do not generate enough runoff or watercourse flow to maintain an active channel. In addition, the runoff period is short, allowing vegetation to establish itself within the flow path. Larger catchments are able to generate sufficient flow volume over a sufficient time period to maintain an active channel with discernable banks and substrate.

The hydrology of Mackenzie River delta channels is different from that of other local watercourses. The delta is a complicated network of distributary channels with hydrologic characteristics dominated by the proportion and temporal variation of flow that they convey. The network is highly dynamic, and aggradation and degradation within the channels play an important role in flow distribution. At the outer delta, coastal processes such as tides and storm surges affect the hydrologic regime of delta channels.

Most of the water in the Mackenzie Delta originates from the Mackenzie River, however, the Peel River west of the delta is also a contributor. Within the delta, most of the flow is carried by Middle Channel, which is about 80 to 95% of total delta inflow below Horseshoe Bend (DIAND 1999). About 10 km southwest of Tununuk Point, the flow of Middle Channel divides in three sections: west to Shallow Bay via Reindeer Channel, northwest to Mackenzie Bay via the Middle Channel, and northeast to Kugmallit Bay via the East Channel (DIAND 1999).

The Middle Channel flows north to large distributary channels around Ellice Island and west of Richards Island, before entering the Mackenzie Bay. In addition to the three main channels in the delta, there are numerous smaller channels. The proportion of the total discharge that each channel carries determines the sizes and shapes of the delta channels. The Middle Channel carries the highest percentage of delta inflow, while the East Channel typically carries between 25 to 35% of the total. The channel that extends northwest from Tununuk Point carries only about 1.0% of total delta inflow. Channels are fairly symmetrical in straight reaches and asymmetrical in bends.

Groundwater

The study area in the ISR is situated mainly in a zone of continuous permafrost, although zones of discontinuous permafrost are found adjacent to the Mackenzie River. In the areas of discontinuous and continuous permafrost, groundwater contributions to watercourse flow are seasonal, with no or negligible contributions made in winter.

Three groundwater zones are found in ISR permafrost regions. They are suprapermafrost, intrapermafrost, and subpermafrost.

- Suprapermafrost Groundwater – This occurs above the permafrost in the active layer. This zone is usually thin and freezes in winter. The active layer generally grows thinner with increased distance from waterbodies under which *through taliks* are found.

- Intrapermafrost Groundwater – This occurs in *closed taliks*, that is, unfrozen ground, surrounded on all sides by permafrost.

- Subpermafrost Groundwater – This occurs below the permafrost, and stays unfrozen because of heat flow from the earth, conducted upward by the geothermal gradient.

No evidence of perennial springs was found in the ISR study area, nor was any evidence found of groundwater inflow that would maintain winter watercourse flow. Open water and icings observed near the outlet from Noell Lake and along a nearby watercourse are attributed to lake storage rather than groundwater inflow.

An icing south of South Storm Hills was reported in late May 1992 (Thurber 1993). No icings were observed at this site during the winter survey in 2002, which indicates that the formation of icings at this location does not occur every winter.

Springs were reported on Holmes Creek and Yaya River (Thurber 1993). No springs were identified during the summer 2002 field program. A water sample collected from a seep near Yaya River during the 2002 survey had low specific conductivity and low total dissolved solids (TDS). The fresh quality of this water suggests that such seeps do not have long travel pathways and are likely seasonal and produced from thawing in the active layer.

Seasonal springs and seepages occur at retrogressive thaw-flow slides throughout the area. The water outflow at these locations is fed by ice melt-out from the active layer and melting of permafrost exposed at the slides. Flow is expected to cease shortly after winter freeze up. A small lake located close to Parsons Lake is reported to remain open in the winter. This lake might be fed by a talik through subpermafrost groundwater. Gas bubbling up through the lake water might be derived from an underlying natural gas reservoir.

Water Quality

Water quality data is available for two lakes and two delta channels near Niglintgak and Taglu, and for six lakes and one river near Parsons Lake. Data is also available for the East Channel of the Mackenzie River, and five lakes and three rivers along the Niglintgak, Taglu and Storm Hills laterals. Field measured water quality data is available for an additional 45 locations. Water quality data is described qualitatively and compared to drinking water guidelines and chronic exposure guidelines for the protection of aquatic life (CCME 1999). Drinking water guidelines are generally either maximum acceptable concentrations for the protection of human health or aesthetic objectives to control drinking water taste, colour and odour.

Table 8-2 summarizes the 2002 and 2003 field-measured water quality parameters for the ISR. Waterbodies were well-oxygenated during summer, and the annual range of pH values was similar throughout, that is, ranging from 6.5 to 9.0. With the exception of Yaya Lake and Parsons Lake, most lakes were less than 5.0 m deep. Lakes were not found to be thermally stratified during investigations in summer 2002 and 2003.

Water was usually moderately coloured (ranging from 4.0 to 55 true coloured units (TCU)), often with values above the aesthetic objectives for drinking water guidelines (CCME 1999). Total suspended solids (TSS) levels were high (i.e., above 25 mg/L) in delta channels and typically low (i.e., less than 10 mg/L) in lakes near Niglintgak and Taglu. TSS levels were low in waterbodies around Parsons Lake and along the laterals, with the exception of an unnamed watercourse, which had high levels.

Major ion concentrations varied among sites, as indicated by TDS and conductance levels. Levels were mostly low (i.e., TDS less than 100 mg/L and conductance less than 165 µS/cm) in streams and rivers, and moderately low (i.e., TDS from 101 to 200 mg/L and conductance from 166 to 330 µS/cm) in the delta channels. These levels were more variable among lakes, with field measured conductance levels ranging from low to very high (i.e., greater than 830 µS/cm).

Table 8-2: Average ISR Seasonal Water Quality – 2002 and 2003

Season	Statistic	Dissolved Oxygen (mg/L)[a]	pH	Conductance (µS/cm)	Temperature (°C)[a]	Turbidity (NTU)[b]
Winter	Mean	9.2	7.0	305	0.0	3
	Minimum	7.4	6.5	252	-	2
	Maximum	11.0	7.5	357	-	3
Spring	Median	-	7.1	50	4.0	2
	Minimum	-	7.0	40	2.0	2
	Maximum	-	7.4	90	6.0	5
Summer	Median	10.0	7.8	138	10.1	7
	Minimum	7.8	6.5	30	2.0	1
	Maximum	11.8	**8.9**[c]	1,389	18.1	827
Fall	Mean	-	7.6	115	6.6	4
	Minimum	-	7.3	80	5.6	3
	Maximum	-	7.8	150	7.5	4

NOTES:
[a]A hyphen indicates data not available.
[b]NTU – nephelometric turbidity unit
[c]Concentrations in boldface are higher than the water quality guidelines and the relevant drinking water guideline or are beyond the recommended pH range.

Lakes near Niglintgak and Taglu had field conductance levels ranging from moderately low to very high (see Table 8-3). Outer delta lakes in Niglintgak and

Taglu are low-closure lakes which are annually flooded by the Mackenzie River. These lakes are also occasionally subject to marine influences.

Conductance and TDS levels were mostly low to moderately low in lakes around Parsons Lake and along the Taglu and Storm Hills laterals. In most cases, alkalinity levels indicated that waterbodies in the study area are not sensitive to acid deposition.

Total Kjeldahl nitrogen levels were high (i.e., greater than 0.5 mg/L) in all waterbodies in 2003 with the exception of Big Lake, Zed Creek and Jimmy Lake, and an unnamed lake (RPR-006). Phosphorus levels were typically lower in streams and high in delta channels. The trophic status of lakes ranged from nutrient-poor to nutrient-rich. However, most phosphorus was found to be in the particulate form and likely not available for biological uptake. Chlorophyll *a* data for Yaya Lake, Jimmy Lake and two unnamed lakes indicates oligotrophic conditions.

For total metals, concentrations of total aluminum and iron were above both aquatic life and drinking water guidelines (CCME 1999) in delta channels, reflecting the high suspended sediment load in the Mackenzie River. Total chromium, copper, lead and zinc levels were above the aquatic life guidelines in delta channels. Maximum levels of total iron were above both the aquatic life and drinking water guidelines in streams, and maximum levels of total cadmium chromium, copper, iron, lead, selenium and zinc were above the aquatic life guidelines in lakes. Concentrations of total manganese were above the drinking water guideline in delta channels and some lakes.

Sediment quality data is available for two lakes and two delta channels near Niglintgak and Taglu, and for six lakes and one river near Parsons Lake. Data is also available for the East Channel of the Mackenzie River, and five lakes and two rivers along the Niglintgak, Taglu and Storm Hill laterals. Available data was compared to the sediment quality guidelines for the protection of aquatic life (CCME 1999).

Bottom sediment in watercourses usually contained higher proportions of sand than silt or clay, and Mackenzie Delta channels contained higher proportions of silt than sand or clay. Sediment in lakes in the ISR varied, but was usually dominated by silt and clay.

Total organic carbon concentrations were usually low (i.e., less than 5.0%) in streams and delta channels and moderate (i.e., 5 to 20%) in lakes. Lakes typically had high levels of total recoverable hydrocarbons (i.e., more than 500 µg/g), whereas streams and delta channels had low to moderate levels (i.e., low: less than 200 µg/g; moderate: 200 to 500 µg/g).

Table 8-3: ISR Water Quality – 2002 and 2003

Water Quality Parameter	Units	Watercourses (Summer)[a,b]				Lakes (Summer)[a,b]				Delta Channels (Summer)[a,b]			
		Median	Min.	Max.	n[c]	Median	Min.	Max.	n[c]	Median	Min.	Max.	n[c]
Field Measured													
pH	N/A[d]	7.7	7.4	7.8	4	7.7	6.5	8.2	14	7.8	7.8	**8.8**[e]	3
Conductance	µS/cm	75	57	135	4	131	56	576	14	251	240	257	3
Temperature	°C	9	6.8	10.1	4	7.4	5.1	18.1	14	14.2	14.1	17.8	3
Dissolved oxygen	mg/L	10.4	10.3	10.9	4	10.2	8.9	11.3	14	9.2	8.3	9.3	3
Conventional Parameters													
Colour	TCU[e]	15	15	**50**[e]	4	**20**[e]	5	**125**[e]	14	**30**[e]	**20**[e]	**30**[e]	3
Conductance	µS/cm	78	55	135	4	162	61	559	14	272	269	297	3
Dissolved organic carbon	mg/L	7	5	10	4	11	5	30	14	6	5	7	3
Hardness	mg/L	30	23	52	4	65	28	166	14	123	123	137	3
pH	N/A[d]	7.3	7.1	7.5	4	7.8	6.9	8.1	14	7.9	7.8	7.9	3
Total alkalinity	mg/L	23	20	47	4	56	10	120	14	89	89	93	3
Total dissolved solids	mg/L	40	29	66	4	80	27	330	14	149	148	190	3
Total organic carbon	mg/L	7	5	11	4	11	5	32	14	6	6	9	3
Total suspended solids	mg/L	<3	<3	3	4	3	<3	112	14	136	82	218	3
Major Ions													
Bicarbonate	mg/L	28	24	58	4	68	12	147	14	109	109	113	3
Calcium	mg/L	8	6	14	4	17	7	43	14	34	34	38	3

Table 8-3: ISR Water Quality – 2002 and 2003 (cont'd)

Water Quality Parameter	Units	Streams (Summer)[a,b]				Lakes (Summer)[a,b]				Delta Channels (Summer)[a,b]			
		Median	Min.	Max.	n[c]	Median	Min.	Max.	n[c]	Median	Min.	Max.	n[c]
Major Ions (cont'd)													
Carbonate	mg/L	<5	<5	<5	4	<5	<5	<5	14	<5	<5	<5	3
Chloride	mg/L	3	<1	9	4	8	2	106	14	5	5	6	3
Magnesium	mg/L	3	2	4	4	5	2	16	14	9	9	10	3
Potassium	mg/L	1	1	1	4	1	0.1	3	14	1	1	1	3
Sodium	mg/L	3	2	5	4	6	2	46	14	6	6	7	3
Sulphate	mg/L	6	3	13	4	5	2	35	14	41	40	45	3
Sulphide	mg/L	<0.003	<0.003	0.005	4	0.009	<0.003	0.028	14	0.004	<0.003	0.028	3
Nutrients and Chlorophyll *a*													
Nitrate + nitrite	mg/L	<0.1	<0.1	<0.1	4	<0.1	<0.1	0.4	14	<0.1	<0.1	<0.1	3
Nitrogen – ammonia	mg/L	<0.05	<0.05	<0.05	4	<0.05	<0.05	<0.05	14	<0.05	<0.05	<0.05	3
Nitrogen – Kjeldahl	mg/L	0.7	0.5	0.8	4	0.85	<0.2	1.5	14	1.2	0.8	1.3	3
Phosphorus – total	mg/L	0.014	0.006	0.02	4	0.014	0.008	0.072	14	0.105	0.043	0.118	3
Phosphorus – dissolved	mg/L	0.005	0.002	0.01	4	0.004	<0.001	0.013	14	0.004	0.003	0.005	3
Chlorophyll *a*	µg/L	–	–	–	–	2.5	1	3	3	–	–	–	–
Organic Compounds													
Total phenolics	mg/L	–	–	–	–	<0.001	<0.001	<0.001	3	–	–	–	–
Total recoverable hydrocarbons	mg/L	–	–	–	–	<0.5	<0.5	<0.5	3	–	–	–	–
Total Metals													
Aluminum	mg/L	0.07	0.04	0.1	4	0.06	<0.02	**4.19**[e,g]	14	**5.42**[e,g]	**4.71**[e,g]	**5.87**[e,g]	3

Table 8-3: ISR Water Quality – 2002 and 2003 (cont'd)

Water Quality Parameter	Units	Streams (Summer)[a,b]				Lakes (Summer)[a,b]				Delta Channels (Summer)[a, b]			
		Median	Min.	Max.	n[c]	Median	Min.	Max.	n[c]	Median	Min.	Max.	n[c]
Total Metals (cont'd)													
Antimony	mg/L	0.0006	<0.0004	0.0014	4	0.0008	0.0005	0.0015	14	0.0011	0.0008	0.0011	3
Arsenic	mg/L	<0.0004	<0.0004	0.001	4	0.0005	<0.0004	0.0027	14	0.0021	0.0021	0.0022	3
Barium	mg/L	0.041	0.039	0.058	4	0.067	0.021	0.241	14	0.141	0.136	0.158	3
Beryllium	mg/L	<0.001	<0.001	<0.001	4	<0.001	<0.001	<0.001	14	<0.001	<0.001	<0.001	3
Boron	mg/L	<0.02	<0.02	<0.02	4	<0.02	<0.02	0.02	14	<0.02	<0.02	<0.02	3
Cadmium	mg/L	<0.0002[i]	<0.0002[i]	<0.0002[i]	4	<0.0002[i]	<0.0002[i]	**0.0011**[g]	14	<0.0002[h]	<0.0002[h]	<0.0002[h]	3
Chromium	mg/L	<0.0008	<0.0008	<0.0008	4	<0.0008	<0.0008	**0.0078**[g]	14	**0.0062**[g]	**0.0058**[g]	**0.0077**[g]	3
Cobalt	mg/L	0.0002	<0.0002	0.0007	4	0.0002	<0.0002	0.0019	14	0.0019	0.0019	0.0028	3
Copper	mg/L	<0.001	<0.001	0.002	4	0.001	<0.001	**0.007**[g]	14	**0.007**[g]	**0.006**[g]	**0.007**[g]	3
Iron	mg/L	0.27	0.19	**0.48**[g,h]	4	0.18	0.06	**5.25**[e,g]	14	**4.94**[e,g]	**4.3**[e,g]	**5.75**[e,g]	3
Lead	mg/L	0.0002	0.0001	0.0003	4	0.0006	<0.0001	**0.0046**[g]	14	**0.0028**[g]	**0.0024**[g]	**0.0053**[g]	3
Lithium	mg/L	<0.006	<0.006	<0.006	4	<0.006	<0.006	0.008	14	0.008	0.007	0.01	3
Manganese	mg/L	0.017	0.016	0.036	4	0.013	0.005	**0.067**[e]	14	**0.075**[e]	**0.064**[e]	**0.092**[e]	3
Mercury[i]	mg/L	<0.0000006	<0.0000006	0.0000033	4	0.0000014	<0.0000006	0.0000051	14	0.0000068	0.0000062	1.89E-05	3
Molybdenu m	mg/L	0.0004	0.0002	0.0005	4	0.0006	0.0002	0.002	14	0.0016	0.0015	0.0018	3
Nickel	mg/L	0.0011	0.0005	0.0022	4	0.0011	0.0004	0.0071	14	0.0076	0.0068	0.009	3
Selenium	mg/L	<0.0004	<0.0004	0.0004	4	<0.0004	<0.0004	**0.0025**[g]	14	0.0007	<0.0004	0.0008	3
Silver[i]	mg/L	0.000013	0.000009	0.000015	4	0.000017	<0.000005	0.000033	14	0.000051	0.000035	0.00006	3
Strontium	mg/L	0.03	0.02	0.05	4	0.06	0.02	0.21	14	0.22	0.21	0.22	3

Table 8-3: ISR Water Quality – 2002 and 2003 (cont'd)

Water Quality Parameter	Units	Streams (Summer)[a,b]				Lakes (Summer)[a,b]				Delta Channels (Summer)[a,b]			
		Median	Min.	Max.	n[c]	Median	Min.	Max.	n[c]	Median	Min.	Max.	n[c]
Total Metals (cont'd)													
Thallium	mg/L	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	0.0001	14	0.0001	<0.0001	0.0001	3
Titanium	mg/L	<0.005	<0.005	<0.005	4	<0.005	<0.005	0.033	14	0.044	0.039	0.05	3
Uranium	mg/L	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	0.0008	14	0.0009	0.0009	0.001	3
Vanadium	mg/L	<0.0002	<0.0002	0.0004	4	0.0003	<0.0002	0.0134	14	0.0175	0.0161	0.0206	3
Zinc	mg/L	<0.004	<0.004	0.004	4	0.007	<0.004	**0.038**[g]	14	**0.046**[g]	**0.037**[g]	**0.058**[g]	3
Dissolved Metals													
Aluminum	mg/L	0.01	<0.01	0.04	4	<0.01	<0.01	0.08	14	0.05	0.03	0.09	3
Antimony	mg/L	0.0004	<0.0004	0.0004	4	0.0005	<0.0004	0.0015	14	0.0005	<0.0004	0.0006	3
Arsenic	mg/L	<0.0004	<0.0004	0.0009	4	<0.0004	<0.0004	0.0007	14	0.0005	0.0005	0.0007	3
Barium	mg/L	0.044	0.04	0.057	4	0.061	0.02	0.238	14	0.059	0.058	0.06	3
Beryllium	mg/L	<0.001	<0.001	<0.001	4	<0.001	<0.001	<0.001	14	<0.001	<0.001	<0.001	3
Boron	mg/L	0.01	0.01	0.01	4	0.01	0.002	0.018	14	0.01	0.01	0.02	3
Cadmium	mg/L	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	0.0002	14	<0.0001	<0.0001	<0.0001	3
Chromium	mg/L	0.0005	<0.0004	0.0063	4	<0.0004	<0.0004	0.0008	14	0.0005	<0.0004	0.0008	3
Cobalt	mg/L	<0.0001	<0.0001	0.0001	4	0.0001	<0.0001	0.0002	14	0.0001	<0.0001	0.0001	3
Copper	mg/L	0.001	<0.0006	0.0023	4	0.0011	<0.0006	0.0023	14	0.0024	0.0022	0.0025	3
Iron	mg/L	0.13	0.07	0.32	4	0.04	0.01	2.77	14	0.08	0.04	0.09	3
Lead	mg/L	0.0003	0.0002	0.0003	4	0.0003	0.0001	0.0004	14	0.0004	0.0002	0.0004	3
Lithium	mg/L	0.002	0.002	0.004	4	0.003	<0.0001	0.006	14	0.005	0.004	0.005	3
Manganese	mg/L	0.01	0.005	0.012	4	0.002	<0.001	0.238	14	0.002	0.002	0.004	3

Table 8-3: ISR Water Quality – 2002 and 2003 (cont'd)

Water Quality Parameter	Units	Streams (Summer)[a,b]				Lakes (Summer)[a,b]				Delta Channels (Summer)[a,b]			
		Median	Min.	Max.	n[c]	Median	Min.	Max.	n[c]	Median	Min.	Max.	n[c]
Dissolved Metals (cont'd)													
Mercury	mg/L	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	0.0001	14	<0.0001	<0.0001	<0.0001	3
Molybdenum	mg/L	0.0004	0.0001	0.0004	4	0.0006	0.0002	0.0017	14	0.0014	0.0011	0.0014	3
Nickel	mg/L	0.0009	0.0005	0.0016	4	0.0008	0.0003	0.002	14	0.0012	0.0007	0.0017	3
Selenium	mg/L	<0.0004	<0.0004	<0.0004	4	<0.0004	<0.0004	0.0007	14	0.0005	<0.0004	0.0006	3
Silver	mg/L	<0.0002	<0.0002	0.0002	4	<0.0002	<0.0002	0.0003	14	<0.0002	<0.0002	<0.0002	3
Strontium	mg/L	0.04	0.03	0.07	4	0.06	0.02	0.21	14	0.19	0.19	0.2	3
Thallium	mg/L	<0.00005	<0.00005	<0.00005	4	<0.00005	<0.00005	0.00023	14	<0.00005	<0.00005	0.00007	3
Titanium	mg/L	<0.0003	<0.0003	<0.0003	4	<0.0003	<0.0003	0.0016	14	0.0015	<0.0003	0.0024	3
Uranium	mg/L	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	0.0007	14	0.0008	0.0007	0.0009	3
Vanadium	mg/L	0.0002	<0.0001	0.0026	4	<0.0001	<0.0001	0.0006	14	0.0006	0.0004	0.0007	3
Zinc	mg/L	0.003	<0.002	0.003	4	0.004	<0.002	0.02	14	0.003	<0.002	0.003	3

NOTES:
[a]A hyphen indicates data is not available.
[b]Boldface values are higher than water quality guidelines.
[c]n – number of samples
[d]N/A – not applicable
[e]Concentration higher than the relevant drinking water guideline or beyond the recommended pH range.
[f]TCU – true colour unit
[g]Concentration higher than the relevant chronic aquatic life guideline.
[h]Analytical detection limit is higher than the chronic aquatic life guideline.
[i]Ultra-low metal analysis was conducted on total mercury and silver. The same level of precision is not available for dissolved mercury and silver.

Arsenic levels were commonly present at levels above the interim sediment quality guideline in streams and rivers, lakes and delta channels. Arsenic concentrations were also occasionally higher than the probable effects level in lakes. Other metals present above guidelines in some lakes and delta channels included cadmium, chromium, copper and zinc.

Naphthalene, C1-substituted naphthalene and phenanthrene were often at levels above the interim sediment quality guidelines in lakes and delta channels. C1-substituted naphthalene levels were also occasionally above the probable effects level in lakes and delta channels.

Fish and Fish Habitat

The Mackenzie River and its tributaries throughout the ISR support diadromous and resident fish species, including marine and brackish water species that could be present in channels in the lower portions of the delta. None of these species are listed as being endangered, threatened, or of special concern. Fish species potentially present in watercourses in the ISR are listed in Table 8-4.

Of the species potentially present in the Mackenzie River and its tributaries within the ISR, 19 species spawn in the fall or winter. Fall spawners include all the salmonid species except Arctic grayling. For the eggs to survive through winter conditions, fall spawning generally occurs in the larger watercourses with perennial flow. The remaining species spawn in the spring or summer. Spring spawning species typically spawn in the small tributaries and can spawn in the intermittent or ephemeral drainages, that is, vegetated or Active II channels.

Delta channels have similar and uniform habitat characteristics, consisting of moderate or deep turbid flats and silty substrates. In-channel cover for fish is provided by depth, turbidity, aquatic vegetation and overhanging vegetation along the channel margins.

Numerous lakes are present within the delta and adjacent to the proposed corridors for the gathering pipelines. Typically, delta lakes are small and shallow. Broad whitefish, lake whitefish, inconnu, least cisco, northern pike, longnose sucker and ninespine stickleback have been captured in these lakes. The presence of burbot, spoonhead sculpin, lake chub and rainbow smelt has also been reported. The low lying lakes that are regularly inundated by flood waters from the Mackenzie River are used as rearing, adult and holding habitat by fish that enter the lakes during periods of flooding. With the exception of large lakes such as Parsons Lake, Jimmy Lake and Noell Lake, most lakes are likely to freeze to, or close to, the bottom in winter and are therefore unlikely to support fish year round.

Table 8-4: Fish Species Potentially Present in the ISR

Family	Common Name	Scientific Name	Spawning Period
Carps and Minnows Cyprinidae	Flathead chub	*Platygobio gracilis* (Richardson)	Spring and mid-summer
	Lake chub	*Couesius plumbeus* (Agassiz)	Spring and mid-summer
Cods – Gadidae	Burbot	*Lota lota* (Linnaeus)	Winter
	Saffron cod[b]	*Eleginus gracilis* (Tilesius)	Winter (marine)
	Polar cod[b]	*Arctogadus glacialus* (Peters)	Winter (marine)
	Arctic cod[b]	*Boreogadus saida* (Lepechin)	Winter (marine)
Flounders – Pleuronectidae	Arctic flounder[b]	*Liopsetta glacialis* (Pallas)	Winter (marine)
	Starry flounder[b]	*Platichthys stellatus* (Pallas)	Winter (marine)
Herring – Clupeidae	Pacific herring[b]	*Clupea harengus* (Linnaeus)	Late winter and early spring (marine)
Lampreys – Petromyzontidae	Arctic lamprey[c]	*Lampetra japonica* (Martens)	Spring and early summer
Perches – Percidae	Walleye[a]	*Sander vitreum* (Mitchill)	Spring and early summer
Pikes – Esocidae	Northern pike[a]	*Esox lucius* Linnaeus	Spring
Sculpins – Cottidae	Fourhorn sculpin[b]	*Myoxocephalus quadricornis* (Linnaeus)	Mid-winter (marine)
	Slimy sculpin	*Cottus cognatus* Richardson	Spring
	Spoonhead sculpin	*Cottus ricei* (Nelson)	Late summer and early fall
Smelts – Osmeridae	Pond smelt[a]	*Hypomesus olidus* (Pallas)	Summer
	Rainbow smelt[a,c]	*Osmerus mordax* (Mitchill)	Spring
Sticklebacks – Gasterosteidae	Ninespine stickleback[c]	*Pungitius pungitius* (Linnaeus)	Spring and early summer
Suckers – Catostomidae	Longnose sucker	*Catostomus catostomus* (Forster)	Spring
Trout – Salmonidae	Arctic cisco[a,d]	*Coregonus autumnalis* (Pallas)	Fall
	Arctic grayling[a]	*Thymallus Arcticus* (Pallas)	Spring
	Broad whitefish[a,c]	*Coregonus nasus* (Pallas)	Fall and early winter
	Chum salmon[a,d]	*Oncorhynchus keta* (Walbaum)	Fall and early winter
	Dolly varden[a,c]	*Salvelinus malma* (Walbaum)	Fall
	Inconnu[a,c]	*Stenodus leucichthys* (Güldenstadt)	Fall
	Cisco[a]	*Coregonus artedii* (Lesueur)	Fall and early winter

Table 8-4: Fish Species Potentially Present in the ISR (cont'd)

Family	Common Name	Scientific Name	Spawning Period
Trout – Salmonidae cont'd	Lake trout[a]	*Salvelinus namightcush* (Walbaum)	Fall
	Lake whitefish[a,c]	*Coregonus clupeaformis* (Mitchill)	Fall
	Least cisco[a,c]	*Coregonus sardinella* (Valenciennes)	Fall
	Round whitefish[a]	*Prosopium cylindraceum* (Pallas)	Fall and early winter
Trout-Perches – Percopsidae	Trout-perch	*Percopsis omiscomightcus* (Walbaum)	Spring and early summer

NOTES:
[a]Harvested commercially, recreationally, or for food
[b]Marine or brackish water species
[c]Diadromous and fresh water resident
[d]Diadromous

BIOPHYSICAL EFFECTS AND MITIGATION

This subject identifies potential effects of the proposed project on watercourse environments in the ISR. The effects of project development on the biophysical environment have been broken down by biophysical discipline for the different site activities associated with watercourse environments. For each biophysical discipline, a description of the potential effects is provided. While the effect descriptions include consideration of effects during construction and operations activities, the majority of effects are predicted to occur during installation.

In addition to addressing potential effects, this topic identifies some of the primary mitigation strategies that have been used to help guide the development of specific mitigation measures for each phase of the watercourse crossing construction process. These include physical works mitigation measures for pipeline watercourse crossings (see Section 3). They also include general activity-related measures that are provided for the gathering pipelines in Section 4, the travel lane in Section 5, winter access roads in Section 6 and the Swimming Point barge landing in Section 7.

A series of 10 decision trees have been developed to demonstrate the decision-making process that will be used to select and implement an appropriate combination of activity-related and physical works mitigation for pipeline watercourse crossings (see Section 3). Each decision tree focuses on a specific effect pathway for fish and fish habitat. Collectively, they are intended to describe a comprehensive mitigation strategy for reducing harmful effects on fish and fish habitat.

Six of the decision trees will be used to address effect pathways that might be present during the installation of pipeline watercourse crossings. They are:

- sediment release from banks and riparian zones
- sediment release from slopes
- sediment release from the pipeline ditch
- mechanical effects on fish and fish eggs
- mechanical effects on fish habitat
- mechanical effects on water flow

The remaining mitigation decision trees will be used to address effect pathways that might be present after installation, during operation of the gathering pipeline. They are:

- sediment release from banks and riparian zones
- sediment release from slopes
- frost bulb growth potential effects
- channel morphology and scour

The mitigation decision trees relate to reducing or eliminating potential effects on fish and fish habitat and are not directed at potential effect pathways for other ecological, geographic, social or pipeline integrity components.

Soils, Landforms and Permafrost

This description addresses the potential effects on soils, landforms and permafrost in the ISR and summarizes some of the primary mitigation strategies for mitigating these effects. The proposed project components within the ISR fall into the Tundra ecological zone.

Summary of Effects

Potential effects of the project on soils, landforms and permafrost in the ISR might include:

- effects on ground stability
  - drainage disruption potential from thaw settlement
  - drainage disruption or damming potential from frost bulb growth or surface heave
  - mass movement and slope instability
  - erosion from water or wind
- alteration of less common landforms from project activities
- effects on soil quality
  - changes in soil drainage
  - soil loss
  - changes in soil physical and chemical characteristics; that is, structure, texture, depth of active layer, organic matter content, mineral content, chemical composition, soil reaction and nutrient regime

Effects on Ground Stability

Drainage Disruption Potential from Thaw Settlement

Thaw subsidence and pond formation can result from changes in thermal equilibrium. Construction activities at watercourse crossings will disturb surface layers, the existing thermal regime and drainage conditions. These disturbances might promote some thawing of the permafrost. As thawing progresses, the surface can settle and water might migrate into depressions, resulting in pond formation. The amount of thaw settlement depends on ground texture and ice content.

Effects can be reduced by ensuring proper drainage is established, where necessary, to help control pond development. In addition, locations more prone to potential pond formation will be monitored to ensure any effects are identified early. Where problematic, ponds might be backfilled with borrow material to help reduce effects.

Drainage Disruption or Damming Potential from Frost Bulb Growth or Surface Heave

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

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

Both mechanisms are most likely to occur on cross slopes. Since most of the ISR is in a continuous permafrost area, the potential for frost bulb formation or surface heave is low.

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

Where frost bulbs or surface heaves occur in unfrozen ground, the potential for disrupted drainage depends mainly on soil 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 do not cause frost heaving. 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 bulbs or heave effects.

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

The frost bulbs will begin to thaw after the flow of cold 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.

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.

Slope instability, or slides, can be caused by physical, thermal or drainage changes, and is often the result of a combination of these mechanisms. Slope instability can be retrogressive, or can expand and maintain ongoing and periodic movement patterns once initiated.

Soil flows are common in the Tundra ecological zone. Flows can 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 can 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%.

To help limit the potential effects from mass movement, grading and surface disturbance will be reduced as much as practical on slopes that might be prone to flows or slides. Thaw stable fill might also be used, where necessary, to prevent these effects. Areas that might be susceptible to flows or slides will be monitored during project operations to ensure any effects are identified early and can be dealt with appropriately.

Erosion from Water or Wind

The four main factors that influence surface erosion are:

- precipitation
- soil texture
- vegetation
- ground surface topography

Water erosion is likely to take place where project activities intersect with landforms that have slopes and material texture susceptible to erosion. Wind erosion is not expected to occur in the ISR.

Within the ISR, there are locations with slopes and soil textures that might be susceptible to erosion following construction. Where these areas are identified, slopes will be stabilized to reduce the potential for erosion. In addition, the gathering pipelines will be monitored during operations to ensure any erosion-related effects are identified early and can be dealt with appropriately. It is likely that water erosion will require some mitigation during operations.

Alteration of Less Common Landforms

Less common landforms in the ISR include pingos, patterned ground and glaciofluvial landforms. The gathering pipeline rights-of-way cross glaciofluvial deposits and patterned ground that includes ice-wedge polygons, and high and low-centred polygons. No pingos will be affected by the project. Operations activities might affect less common landforms in the ISR, but much less than during construction, as very little new disturbance will take place.

Winter access roads could also affect less common landforms such as patterned ground or glaciofluvial deposits.

Construction effects on less common landforms are likely to be localized. Pipeline operations and maintenance activities might have a limited effect on less common landforms, but much less than during construction. Overall, these effects are expected to be limited. Decommissioning and abandonment activities are not expected to affect less common landforms.

Effects on Soil Quality

Changes in Soil Drainage

Changes in soil drainage could affect soil quality over extensive distances along the gathering pipelines, at infrastructure sites and at borrow sites. Increased moisture in a dry soil is likely to increase the capability of a soil to support plants and soil biota, resulting in increased plant cover. 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.

The development of poorly-drained areas might result 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 rights-of-way and pipeline crossing preparation activities including clearing, levelling, grading and ditching. Infrastructure components such as winter access roads also have the potential to cause changes in soil drainage.

Environmental effects causing diversion or damming of surface water could cause changes in soil drainage along the gathering pipeline rights-of-way. Changes in surface drainage patterns could increase soil moisture content and might lead to some ponding in certain locations. 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.

Some lands along the gathering pipeline rights-of-way in the ISR might be susceptible to thaw settlement following construction. If thaw-settlement processes have occurred, ponds might increase in size during operations. Drainage will be re-established when the area is experiencing problematic thaw settlement.

The flow of gas during pipeline operations might result in frost bulbs forming around the pipe in unfrozen ground, which could cause changes in soil drainage in some locations. Drainage is expected to stabilize within 30 years following decommissioning and abandonment. The effects of changes in soil drainage during operations are likely to be limited.

The gathering pipelines traverse areas of blanket slope drainage. Changes in soil drainage could occur where a pipeline is built on cross slopes with blanket slope drainage. Locations with potential for blanket slope drainage will be monitored following construction for changes in soil drainage that might result in adverse effects.

In unstable soils, where borrow materials might be used as backfill to replace the soil in the ditch, soil drainage conditions might be changed because the composition of the ditch material has been changed.

Winter access roads will be constructed across diverse terrain. During spring runoff, temporary changes in soil drainage might occur as a result.

Soil Loss

Other possible causes of soil loss are mass movement of landforms caused by unstable slopes, and transfer of soil material from one location to another. Loss initiated by grading is another pathway whereby soils on slopes are removed and transferred. Another pathway begins with gathering pipeline effects on slope stability. Unstable slope conditions can lead to land slips and slides, with soils moving downslope and burying or mixing with underlying materials, or submerging in waterbodies.

Due to the very localized occurrence of soil loss, the overall effects are expected to be limited.

Changes in Soil Physical and Chemical Characteristics

Small-scale leaks and spills could potentially effect soil chemistry, however, the implementation of spill contingency and management plans will likely prevent any measurable effects from occurring.

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 expected to result in a minor change in soil quality.

A combination of soil mixing, compaction and rutting could occur during construction, typically on the workside and travel lane portions of the right-of-way, and use of winter access roads. These processes could occur if winter access roads are prepared before complete freeze-up, or if they continue to be used once thaw begins. Ensuring that vehicles only travel on the pipeline travel lane and winter access roads that are adequately frozen will prevent these effects.

Minor disturbance of soil surfaces by machinery used to remove infrastructure components is expected during decommissioning and abandonment. The combined effects of these activities on soil quality are expected to result in a small change in soil quality.

Changes in soil physical and chemical characteristics are likely to be limited and localized. 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.

Hydrology

This description addresses the potential effects on hydrology in the ISR and summarizes the primary mitigation strategies to reduce these effects.

Summary of Effects

Potential effects of the project on hydrology in the ISR might include:

- changes in local surface water drainage characteristics
- increased sediment concentrations in surface water
- changes in channel morphology, including changes in channel geometry, shape and conveyance capacity

Changes in Local Surface Water Drainage Characteristics

Construction and operation of the project at watercourse crossings could lead to changes in runoff amounts and drainage patterns from land disturbance and potential changes in the ground’s thermal regime because of frost heave and thaw settlement. Changes in water levels and velocities could also occur because of flow obstruction, water withdrawal and disposal, and land subsidence.

Areas of land disturbance and compacted surfaces associated with the gathering pipelines will be less permeable than natural surfaces. This could result in higher volumes and flow rates of water runoff from these areas than would occur under natural conditions.

The project provides for site drainage so that runoff is routed in an appropriate manner into the surrounding watershed. Changes in the runoff rate associated with the project will be confined to the immediate area of project developments and are expected to be low.

The land disturbance associated with the pipelines could interrupt existing overland drainage patterns. A disrupted drainage route could lead to a change in drainage pattern in, and in the immediate vicinity of the watercourse crossings. Notching the pipeline ditch crown will reduce the redirection and routing of surface water flow along the gathering pipeline rights-of-way. This is intended to maintain natural drainage patterns.

Subzero operating temperatures of the gas in the gathering pipelines can cause a frost bulb to form around the circumference of the pipe in areas of unfrozen soil. The diameter of the frost bulb will grow over time until equilibrium between freezing and melting is reached. The frost bulb below the pipe will remain all year during operations, whereas the portion above the pipe generally will be subject to a seasonal freeze-thaw cycle. The size of the frost bulb and the resulting magnitude of effects on groundwater and watercourse flow are site-specific and influenced by:

- surface water flow
- groundwater flow
- substrate particle size
- pipe temperature
- soil temperature
- burial depth of the pipe
- pipeline design (e.g. insulation)

The frost bulb could create a frost heave which could raise the ground surface that could interrupt overland drainage paths, create ponding areas and result in changes in the local drainage pattern. However, most of the ground in the ISR is continuous permafrost, therefore little effect from frost heave is expected.

A frost bulb in the bed of a watercourse could result in partial damming of flow, depending on the depth of flow in the channel. If a frost bulb develops into a flow obstruction, it could affect water levels and velocities in the stream. Deeper burial or insulation of the pipeline at selected crossings will be sufficient to reduce the effect of a frost bulb and prevent flow obstruction in most cases.

Increased Sediment Concentrations

Construction and operation of the project at watercourse crossings could alter the flow of overland runoff or instream flow. These alterations could affect the sediment regime of watersheds and watercourses through land disturbance, bed and bank disturbance, land subsidence and frost bulb formation.

Land disturbance at approach slopes to the pipeline watercourse crossings associated with construction and operations of the pipelines might result in higher sediment runoff compared with natural conditions. The eroded material from a disturbed surface will only result in increased basin sediment yield or suspended solids concentrations if the eroded material enters the watercourse system. Implementation of appropriate sediment control measures will prevent a large amount of this sediment from entering a waterbody.

The disturbance of watercourse beds and banks during construction of winter pipeline watercourse crossings has the potential to increase erosion, entrainment and sedimentation, and affect sediment concentration. Sediment concentrations could be affected by bed and bank disturbance associated with watercourse crossing construction.

Frost bulb formation at pipeline watercourse crossings might also result in changes in sediment concentration because of flow obstruction, as discussed earlier. Potential redirection of local flow patterns could result in erosion and increased sediment concentrations.

Deep burial or insulation of the gathering pipelines at selected crossings will be sufficient to reduce the effect of frost bulb formation and prevent flow obstruction in most cases.

Changes in Channel Morphology

Changes in channel morphology refer to the adjustment of channel shape in response to water flow and sediment conveyance. Morphologic change occurs continuously under natural conditions. Changes in channel morphology could result if there are long-term, sizeable and sustained project-induced changes in channel hydraulics, that is, flow, depth and velocity, river ice, or sediment supply.

Changes in runoff amount could change channel hydraulics, which directly affect the sediment transport capacity of a channel. Existing channel regimes have evolved and adjusted over time in response to runoff and sediment production that vary over their respective long-term ranges. Therefore, if the project results in small changes in runoff amount, sediment production, or both, that are not distinguishable from the natural regional variability, no changes in channel morphology beyond those expected naturally would occur.

Disturbance associated with pipeline installation at watercourse crossings could result in weakened banks and an unconsolidated substrate. During operations, erosion because of water flow could increase in disturbed areas and result in increases in sediment supply and concentrations. However, the development of erosion-prone areas will be limited by implementing suitable design approaches and construction practices.

In general, the effect of the project on channel morphology is expected to be limited and localized. Locating pipeline and winter access watercourse crossings at stable sites increases the likelihood that banks can be successfully stablilized and that the existing channel morphology can continue to evolve naturally.

Groundwater

This description addresses the potential effects on groundwater in the ISR and summarizes the primary mitigation strategies to reduce these effects.

Summary of Effects

Potential effects of the project on groundwater in the ISR might include:

- obstruction of groundwater flow
- change in recharge and discharge of groundwater
- change in groundwater quality

Obstruction of Groundwater Flow

The pipelines could affect shallow groundwater by blocking and deflecting groundwater flow paths. A blockage usually results in upslope ponding and a change in the shallow groundwater flow direction. Deflection of shallow groundwater flow and water ponding could occur in areas where the pipeline crosses a sidehill slope of permeable borrow material, such as alluvial fans, kames and eskers. Icings could form where deflection occurs in the active layer.

Ditching and grading on approach slopes to watercourse crossings through the active layer, pipe placement and replacement of cover will generally be done during frozen conditions, which will reduce effects on shallow groundwater in the active layer.

The potential for effects related to blockage is considered low because groundwater flow is primarily restricted to the relatively thin active layer.

Construction activities located upgradient of a spring discharge could intercept groundwater flow and divert a portion of this flow into the ditch. Appropriate measures where groundwater flow exists are expected to be sufficient to:

- enable groundwater flow to continue
- prevent any substantial change in groundwater flow patterns that could otherwise result in the interruption or substantial reduction of spring flow

Effects related to redirection of groundwater flow upgradient of discharge areas could persist into the far future. Effects could occur during construction and, in areas where the pipelines are removed, during decommissioning and abandonment.

Should a frost bulb form around the pipe, it could form a barrier to downgradient movement of groundwater. In some cases, this obstruction could be sufficient to force groundwater to the surface. Icing buildups are an indication of flow obstruction. Where moderate groundwater flow passes through a confined area of high permeability underneath a watercourse bed, a pipeline, with or without a frost bulb, might be a sufficient barrier to subsurface water movement and could result in the same effects. Deep burial or insulation of the gathering pipeline at selected crossings where fall spawning or overwintering fish habitat is present, will be sufficient to reduce the effect of frost bulb formation, thus preventing icings or substantial groundwater blockage.

Watercourse crossings where mitigation is not applied and some cross-slope areas could experience effects due to frost bulb formation. Monitoring for frost bulb development in other areas will enable an appropriate engineering response to manage effects as necessary.

Change in Recharge and Discharge of Groundwater

Recharge and discharge areas are locations where water enters or leaves the groundwater system. Changes in surface water flow patterns and quantities can be caused by land disturbance, surface water withdrawals and other activities. These changes can alter the recharge of surface water into the groundwater system and result in changes in groundwater quantity and flow patterns.

Effects through the recharge and discharge pattern pathway in the study area could occur in areas of groundwater discharge. Ditching and other subsurface activities at watercourse crossing locations near groundwater discharge areas might divert or block groundwater flow or require dewatering during construction.

Specific potential groundwater discharge effects resulting from project activities include the locations downslope and close to perennial springs, construction could temporarily divert spring flow. Ditch dewatering might be required and upslope ponding is possible. Some means of establishing spring outflow might be necessary in some places.

Effects through the recharge and discharge pathway could also occur due to the development of slides. Ditching and other activities upslope and close to a retrogressive thaw–flow slide or high bank of a lake, pond or watercourse have the potential to create a zone of weakness, which could trigger further slide retrogression and concentrate shallow groundwater flow.

The pipeline route selection process tried to avoid these areas where practical and no particular areas of concern are expected along the pipeline routes in the ISR. Monitoring pipeline integrity during operations, including aerial inspections, would identify the development of any slides and enable the correct response.

Change in Groundwater Quality

Small spills that can occur during normal construction, operations and decommissioning activities have the potential to affect groundwater quality in wetland areas, where the water table is near or above the ground surface.

Management practices will reduce the potential for spills and leaks and any spillage will be cleaned up in accordance with Imperial's emergency response and spill contingency plan as described in Section 11. Therefore, effects will be very localized and very limited.

Water Quality

This description addresses the potential effects on water quality in the ISR and summarizes the primary mitigation strategies to reduce these effects.

Summary of Effects

Potential effects of the project on water quality in the ISR might include:

- leaks and spills
- suspended sediment inputs

Leaks and Spills

Small spills of some substances, including fuel, oil and grease, can reach waterbodies if intercepted by surface runoff or if incidents occur during the construction of watercourse crossings. Implementation of best management practices and application of the ERP will reduce the potential of these substances to reach nearby waterbodies. Therefore, adverse effects from spills or leaks are not expected.

In the highly unlikely event of a large spill, appropriate provisions in the ERP will be implemented (see Section 11).

Suspended Sediment Inputs

Suspended sediment inputs to waterbodies could result from frost bulb formation, disturbance of bed and bank sediments by instream activities or construction on the banks and approach slopes. This discussion is concerned with water quality changes caused by increases in concentrations of sediment-associated parameters and release of chemicals from suspended sediments that have been added to waterbodies, rather than with the effect of sediment addition.

During construction activities, land disturbance on the watercourse approach slopes could result in increased sediment levels in runoff. These increases in sediment levels might result in increased concentrations of sediment-associated water quality parameters, such as nutrients and metals, when measured as total concentrations. However, changes in water quality will be limited by the following:

- Mitigation measures applied during project-related activities that could generate sediment will reduce sediment inputs from construction and operations.

- Sediment releases are expected to occur over short periods, during and immediately following rain events and during spring breakup.

- Project-related activities will not cause release of sediments from areas that could have elevated levels of chemicals associated with human activities. Implementation of mitigation measures for leaks and spills will ensure that runoff and suspended sediment does not contain chemicals from human sources.

- Under the conditions expected during sediment releases, water quality parameters associated with particulate material would remain attached to suspended sediments and would ultimately settle out in depositional areas downstream of the point of input.

Should a frost bulb form around the pipe, it might result in frost heave which could cause seasonal sediment releases. If frost heave raises a watercourse substratum, erosion of the raised area could introduce sediments to watercourse water.

Alternatively, if groundwater or surface water flow in a small watercourse is blocked, ponding and sediment deposition could occur upstream of the crossing. Spring runoff could then mobilize the deposited sediments. Reduction or interruption of watercourse flow, as well as the introduction of excessive sedimentation can affect fish overwintering habitat and spawning and nursery habitat, as described in greater detail in the section entitled Fish and Fish Habitat. Enhanced runoff from ice formed upstream of the crossing might cause erosion and subsequent sediment input to watercourse water.

Watercourse crossings during pipeline construction could release suspended sediments into watercourse water.

Fish and Fish Habitat

This description addresses the potential effects on fish and fish habitat in the ISR and summarizes the primary mitigation strategies to reduce these effects.

Summary of Effects

Potential effects on fish and fish habitat in the ISR as a direct result from activities such as ditch excavation, bank construction activities, site preparation, placement of structures, fill or other materials in the near-shore areas of lakes or streams, or operation of heavy equipment in water include:

- effects from exposure to suspended sediments that are disturbed or discharged by project-related activities, then transported in water to be deposited elsewhere
- effects of channel blockage from frost bulb formation on fish movements at gathering pipeline watercourse crossing sites
- effects of blockage of fish passage at access road crossings
- effects on fish health of changes in water quality resulting from wastewater discharge to local waterbodies

- effects on fish health of changes in water quality resulting from small-scale accidental spills associated with pipeline and facilities construction and normal operations

- effects of in-water or near-shore on land detonations of explosives on fish or incubating eggs

Direct Effects on Fish and Fish Habitat

With the exception of HDD crossings, pipeline watercourse crossing construction in the ISR requires the excavation of a ditch that disturbs the bed and banks of the watercourses, placement of the pipe in the ditch and backfilling. These disturbances will cause localized changes in habitat at the crossing sites.

Direct effects on fish habitat result from:

- changes in watercourse morphology
- changes in the watercourse bed from disturbance during ditch excavation
- changes in composition and size of bed materials
- changes in bank configuration
- removal of bank vegetation

The gathering pipelines in the ISR will cross many watercourses, ranging from vegetated channels to large rivers. Crossings of vegetated and Active II channels are not expected to directly affect fish habitat because these will be either dry or frozen to the bed during crossing construction.

However, if fish habitat is present in the immediate crossing area at the time of installation, direct effects on fish habitat cannot be avoided when open cut or isolation techniques are used.

An isolated technique will avoid disrupting or disturbing habitat downstream of the crossing location because the water flow will be diverted around the excavation area during installation. However, direct effects on habitat features (i.e. the bed and banks) at the immediate crossing area cannot be avoided. If an open cut is used, ditching, pipe installation and backfilling will disturb habitat features present at the crossing site. If this occurs under frozen conditions, there will be no effect on fish and fish habitat during the installation period. Clean up of the disturbance prior to runoff will minimize the potential for an effect on fish and fish habitat.

Disruption of habitat by crossing construction is typically short in duration and the affected habitats are reclaimed naturally after construction, therefore the effects on fish or fish habitat are expected to be limited to individual or small groups of fish. The direct effects on fish habitat are confined to the physical construction of the pipelines, so no effects are expected during normal operations or decommissioning and abandonment unless the pipe is removed.

Temporary watercourse crossing structures are required for vehicles and equipment to cross watercourses during construction. These structures include snow or ice crossings, and portable bridges. Direct effects on fish habitat will be limited to disturbances of the banks at the approaches to the watercourses. Fish passage might also be affected by ice crossings at some locations. Watercourse banks at these crossing sites will be stabilized before spring breakup.

Effects from Exposure to Suspended Sediments

Construction of gathering pipeline watercourse crossings might increase the amount of sediment entrained in nearby waterbodies.

Deposited sediments can modify bed conditions, thus affecting the availability and suitability of various types of fish habitat, but in particular habitat for the development of fish eggs.

Effects of Watercourse Crossing Construction on Sediment Deposition

Deposition of sediment entrained during the construction period of the watercourse crossing can adversely affect fish habitat downstream of the crossing location. The distance sediment is transported downstream is related to flow and sediment particle size. Large sediment particles settle quickly, whereas small particles are transported farther downstream. Fine particles can remain suspended indefinitely in flowing water and might not settle until they reach a lake or an area with no turbulence. The deposited sediment can clog the interstitial spaces of gravel and cobble substrates that are used as spawning, egg incubation and rearing habitat. Sediment entrained during crossing construction can also settle in pools, decreasing their depth and suitability as overwintering habitat.

Effects of sediment are rarely permanent. Full recovery can occur as early as six weeks after construction, but more typically within one or two years after construction. Sediment deposited during winter construction will likely be scoured clean by the hydraulic forces of the spring freshet.

Effects of sediment deposited during construction will be limited to large river crossings and Active I channels should the crossing be open cut. Flow during winter construction will be low, and peak TSS concentrations will decrease rapidly as particles settle quickly under less turbulent low flow conditions.

Effects of Surface Runoff on Sediment Deposition

Land disturbance caused by construction and operation of the pipelines on previously unaltered approach slopes can result in higher sediment runoff compared with natural conditions. However, sediment yield or suspended sediment entrainment and deposition will only increase if the material enters the waterbody. The changes in basin sediment yield will depend on the sediment source, and on the transport of sediment to the receiving waterbody, that is on surface runoff characteristics and capacity, distance to watercourse, drainage density, drainage slope and basin size. Mitigation measures will reduce the amount of sediment that could enter a waterbody.

Effects of Erosion on Sediment Deposition

Erosion is one way in which sediments can be entrained in runoff and deposited in a waterbody. Potential causes of erosion are:

- bank disturbance during winter access road and pipeline crossing construction
- scouring at barge landing sites

Erosion from disturbed or unstable banks or disturbed substrates at pipeline watercourse crossings can increase sediment loads and affect habitats downstream of the crossing. Crossings of large rivers as well as Active I and Active II channels with steep approach slopes are most susceptible to incidental erosion. Sediment inputs from erosion along the rights-of-way and banks of the watercourses will decline during operations, once disturbed areas revegetate. Because most watercourses will be frozen during construction, most sediment input will occur during the spring freshet when suspended sediment concentrations are already naturally high and many watercourses are already subject to scour. Watercourses with stabilized banks will clear up shortly after breakup and are unlikely to contribute further sediment loading thereafter.

Where warranted, site-specific erosion and sediment control plans for construction and operations will be developed to reduce erosion due to bank disturbance and limit input of sediment into watercourses. Mitigation measures to maintain bank stability and revegetation of approach slopes will limit inputs of sediment from bank erosion. Regular monitoring of erosion-prone slopes and repairing eroded areas as required will limit erosion and limit sediment from reaching the waterbody. Because mitigation measures can control erosion and limit sediment from reaching waterbodies, the effects of sedimentation from erosion at watercourse crossings are expected to be limited.

Effects of Channel Blockage from Frost Bulb Formation

Should a frost bulb form around the pipe it might result in a blockage of flow in winter in watercourses that normally have flowing water beneath the ice. This can cause a reduction of fish habitat downstream of the crossing and at the crossing itself. Reduction or interruption of watercourse flow could affect overwintering and spawning habitat. A frost bulb could also partially or completely block the watercourse under certain conditions, impeding or completely blocking fish movement upstream.

Active I channels with a talik thaw zone will have the highest risk of flow blockage by frost bulbs in winter because of the shallower depth of flow and narrower watercourse width.

Insulating the pipe or burying it deeper at water crossings will ensure that a thaw zone persists beneath the stream bed in Active I channels that are susceptible to large frost bulb growth. These mitigation strategies in the talik thaw zone will prevent frost bulbs from penetrating the channel bottom.

Although Active II channels freeze to the bottom in winter, they can serve as migratory corridors for fish during the open-water period. Preliminary thermal simulations predict that pipe temperatures will not delay thawing of the channel in the spring and that the frost bulb above the pipe will continue to thaw throughout the summer (Nixon 2003). Therefore, blockage or interference with spring or summer fish movements is not expected.

Active II channels might freeze earlier in the fall should a frost bulb form and partially block water flow. However, as Active II channels are unlikely to provide overwintering or spawning habitat because of their intermittent flow, earlier freezing or partial groundwater blockage is not expected to affect fish movement. Fish in Active II channels would migrate out of the system to overwintering habitats at the onset of lower flow and colder temperatures.

The effect of frost bulb formation on fish movement will be localized and limited to a small number of watercourses.

Blockage of Fish Passage

Fish passage can be blocked at ice crossings that are generally perpendicular to the watercourse being crossed. These crossings will be breached or v-notched prior to spring breakup. This should prevent any effects on fish due to blockage of fish passage.

Effects of Water Withdrawals

Water withdrawals might be necessary for the planned HDD crossings. Water withdrawal can affect watercourse flow and water levels in lakes and watercourses. Lower lake levels might change:

- shoreline habitat, such as littoral zones and areas with macrophytes growth
- overwintering capacity of fish-bearing lakes
- effect on food for fish
- outlet creek discharge

Similarly, reduced watercourse flow might affect spawning, rearing, feeding, migration and overwintering habitats of fish-bearing streams and rivers, and it can affect watercourse productivity and the availability of food for fish, such as benthic invertebrates. The sources of water for the planned water withdrawals will have specified withdrawal amounts to ensure that drawdown of water does not adversely affect fish habitat.

Effects on Fish Health from Spills

Small-scale spills of some substances, such as fuel, oil, grease from accidental leaks along the banks and approach slopes to a water course or within a watercourse, if intercepted by surface runoff, have the potential to reach surface waters.

Small spills can affect fish health including normal survival, growth, development or reproduction. Following the implementation of best management practices and application of the emergency response and spill contingency plans, the potential of spills reaching nearby waterbodies will be greatly reduced, such that no adverse effects are expected (see the Emergency Response and Spill Containment Frameworks in Section 11).

Effects of Detonations In or Near Water

Use of explosives is not currently anticipated at watercourse crossings in the ISR. However, if detonation of explosives is required in or near water, fish and other aquatic organisms can be affected. Detonation of the explosives produces a compressive shock wave followed by a rapid decay to lower than ambient pressures (Wright and Hopky 1998). This rapid change in pressure can cause the swim bladder and other organs, such as the kidney, liver and spleen to rupture or haemorrhage.

Effects of in-water detonation of explosives will be limited to fish occupying overwintering habitat at the immediate crossing location in Active I channels or large rivers. No effects on fish are expected if there is no overwintering habitat at present at the crossing. The exposure time is limited to the period of detonation.

If blasting is required, the operations will be done in compliance with the applicable laws and regulations and with the provisions in the DFO *Guidelines for the Use of Explosives In or near Canadian Fisheries Waters* (Wright and Hopky 1998), except as otherwise authorized.