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- ENVIRONMENTAL ASSESSMENT

DEMPSTER LATERAL
PROPOSED PROCEDURES AND ESTIMATE OF MATERIAL REQUIREMENTS FOR EROSION CONTROL

2.10.4 Erosion Control Considerations

From the available data, it is considered that more than half of the terrain along the pipeline route within the Yukon Plateau is unfrozen. Permafrost occurrences are much less prevalent in the southern half of the region than in the northern half. In general, permafrost is present in areas that are underlain by fine-grained deposits at least 2 to 3 m thick, and covered by 1 m or more of insulating organic matter, as in some of the lacustrine and morainal deposits.

Other than in highly organic deposits and areas of thermokarst topography, there is little evidence of the existence of ice-rich surficial soils. All of the road cuts on the Klondike Highway and the Dawson Trail have been made in unfrozen soil, or bedrock, and all were relatively stable. Minor surface erosion and gullying were the only signs of degradation in most of the cuts. Many of the cut slopes in soil in this region were made at angles of 1.5 horizontal to 1 vertical.

No significant icings were reported by Van Everdingen during his reconnaissance of April, 1978. The only areas in this region where constraints on clearing and grading operations should be imposed are in those underlain by fine-grained, ice-rich soils. In these areas, disturbance of the surface vegetation mat should be kept to a minimum to control against thermal erosion.

With the exception of a few local slopes in the southern portion of the region, hydraulic erosion should not present a significant concern on the Yukon Plateau. However, to prevent hydraulic erosion and damage to the pipe, well defined flow channels crossing the pipeline should be adequately armoured. Stabilized backfill material and ditch plugs may also be required to avoid erosion of bedding and padding material where the pipe descends a long steep slope, such as that encountered at about Km 1170.

A few cuts are anticipated in local areas, such as west of Carmacks, along the Nordenskiold River section between about Km 1003 and Km 1087, and at

2.10.3 Drainage Features

Although relatively few well defined drainage channels cross the pipeline route on the Yukon Plateau, the region is considered to be generally well drained. On the average, well defined channels cross the route about every 9 km and only about 40% of these channels flow continuously. It was observed that culverts along the Klondike Highway, were generally spaced at intervals of about 300 m to 600 m. In some areas, the spacing was as close as 150 m. The wider culvert spacings were generally adopted in the more granular overburden soils. Areas of poor drainage are generally associated with flat lying local deposits of peat and other fine-grained organic soils. Most of these deposits are found between about Km 880 and Km 900 and along the Nordenskiold flood plain, just east of the pipeline.

The relatively low slope gradients throughout the region are expected to restrict flow velocities to a level where only a few velocity control structures will be required.

traversed. Bedrock is at or near the ground surface in much of this area. From Km 1155 to Km 1168, the terrain rises gently to an elevation of about 1050 m before descending to the Takhini River at a gradient of from 25 to 40%. Most of this area is underlain by bedrock covered with a variable thickness of glacial drift. The final 2 kms of the pipeline route crosses the flat lying glaciolacustrine plain bounding the Takhini River (Komex Consultants, Oct. 1978).

Bedrock is exposed at many locations along and adjacent to the route. The bedrock geology is quite complex, consisting primarily of Jurassic and Cretaceous formations. Intrusives (granodiorite, quartz diorite, granite), volcanics (andesite), metamorphics (quartzite, schist, slate) and sedimentary rocks (conglomerate, arkose, greywacke) all exist in this physiographic region.

2.10.2 Climate and Vegetation

The climate along the pipeline route on the Yukon Plateau is quite variable, although there is a trend to milder conditions in the southern part of the region. The mean annual air temperature ranges from about $-4^{o}C$ to $0^{o}C$. Thompson (1963) reports that the mean freezing index varies from about 3000 degree days in the north to about 2100 degree days in the south. The mean thawing index is relatively uniform throughout the region, being approximately 1800 degree days. The mean dates of the start of the freezing and thawing seasons are October 10 and April 20, respectively near Stewart Crossing and October 20 and April 20, respectively at Whitehorse. The annual average precipitation throughout the physiographic region is about 26 cm.

Vegetation in the region is generally moderate to dense. In the north, the ground is predominantly moss covered, with poplar and spruce trees and some shrubs. Toward Whitehorse, the ground cover changes to predominantly grasses. Alder, aspen, birch and spruce trees are commonly found toward the southern terminus of the route.

about Km 1003, but south of this point the terrain is very hummocky with many cross and longitudinal slopes up to about 30%. The ground elevation along this portion of the route is reasonably uniform at about 600 m.

South of Carmacks, the route continues in a southeasterly direction to about Km 1008 and rises to an elevation of about 750 m. In this portion of the region, the pipeline route follows a narrow upland between the meandering Nordenskiold River and its swampy flood plain to the east, and rugged hills to the west. The Klondike Highway parallels the pipeline just east of the river. Cross slope gradients are usually less than 10% in this area. However, to avoid burial in the flood plain where the terrace pinches out, the pipeline route must traverse cross slopes with gradients of up to 30%. Longitudinal slopes in this portion of the region generally have gradients of less than 10%. The terrain in which the pipeline is routed is largely glaciofluvial and alluvial in origin, the predominant land forms being terraces, plains and fans. Hills to the west of the route consist of volcanic rocks with a veneer of colluvium. Low swampy ground encountered to the east of the pipeline is occupied by alluvial and lacustrine deposits which are probably ice-rich, as indicated by the presence of thermokarst lakes.

From Km 1087 to the terminus of the pipeline at Km 1176.7, the route trends in a north-south direction. Along this portion, the route rises from an elevation of about 750 m at Km 1154, to about 1050 m at Km 1168. South of Km 1168, the route descends rapidly to an elevation of less than 750 m at Km 1176.7. The proposed pipeline approximately parallels the Dawson Trail from Km 1087 to about Km 1140. From Km 1087 to Km 1115, the terrain is relatively flat, with slope gradients generally less than 10%. South of this location to about Km 1130, the flat Klusha Creek flood plain is bordered by kame terraces up to 150 m high. Slope gradients between the flood plain and kame terraces range from 50 to 60%. Surficial material on the flood plain consists of sand and gravel. The route crosses hummocky moraine and glaciofluvial deposits from Km 1130 to Km 1140. Longitudinal and cross gradients are generally less than 10%. South of Km 1140 to Km 1155, a few steep cross slopes in talus and bedrock may have to be

2.10 Yukon Plateau (Km 860 to Km (1200)

2.10.1 Topography and General Geology

Along the proposed pipeline route, the Yukon Plateau physiographic region extends from about 5 km south of Stewart Crossing to the terminus of the route near the Takhini River at about 41 km upstream of its confluence with the Yukon River. Following the field reconnaissance, the southernmost part of the route was re-located. From Km 1087 south, the route is now proposed to roughly follow the Dawson Trail, rather than paralleling the Klondike Highway to the proposed junction of the Dempster Lateral with the Alaska Highway Pipeline. The Yukon Plateau is located entirely within the zone of discontinuous permafrost (Brown, 1967).

The Yukon Plateau is the largest physiographic region traversed by the pipeline. From Km 860, just south of Stewart Crossing, the route parallels the Klondike Highway, rising from an elevation of about 600 m at Km 860, to an elevation of about 750 m at Km 885.

The ground elevation then gradually descends to about 600 m at Minto (Km 953). The Pelly River is crossed at Km 923. Longitudinal and cross slope gradients are typically less than 10%. Morainal and glaciofluvial deposits predominate along this portion of the route, although a few peat-lands and deposits of eolian material are encountered near the northern limit of the region.

From Minto (Km 963) to just south of Carmacks (Km 1021), the route follows the Yukon River and the Klondike Highway in a southeasterly direction, crossing the Yukon River from east to west just upstream of the abandoned settlement of Yukon Crossing at about Km 988. The route along the east side of the Yukon River traverses a series of glaciofluvial and alluvial terraces and is relatively flat, with most of the slopes being less than 3% and all but a few local slopes having a gradient of less than 10%.

South of Yukon Crossing near Carmacks, the route crosses predominantly glaciofluvial deposits. Slope gradients are typically less than 10% to

2.9.4 Erosion Control Considerations

Almost half of the drill holes encountered unfrozen soil for at least the upper 4 to 5 m. For the most part, unfrozen soils consist of coarse-grained materials such as those found in glaciofluvial plains, although some unfrozen fine-grained soils were encountered. Permafrost was most frequently encountered in areas with a substantially thick (greater than 1 m) surficial cover of peat, or other organic veneer.

Icing of water courses does not appear to present a significant problem. Likewise, the effects of clearing and grading are not expected to present a significant concern in this region. However, special precautions should be taken to minimize damage to the surface vegetation mat in areas underlain by fine-grained permafrost soils.

Because of the predominantly coarse-grained soils and relatively flat ground in this region, the potential for hydraulic erosion is low to moderate. Likewise, the potential for thermal erosion is relatively low, providing that appropriate precautions are taken in right-of-way preparation and if cuts are located in predominantly unfrozen ground. Other than near Km 730, it is not anticipated that significant cuts in frozen ground will be necessary. Any cuts in permafrost are anticipated to be quite low and the use of diversion dikes and water breaks would be adequate to direct sheet flows around the cut slopes and across the pipeline. In areas where cuts are excavated through unfrozen soil, it is not expected that significant erosion will occur, other than minor ravelling and gullying. Cut slopes should be revegetated following construction.

To protect the mound in areas of significant sheet flow, control measures such as diversion dikes and water breaks may be required. Well defined flow channels crossing the pipeline should also be armoured to prevent hydraulic erosion. Photo 9 indicates damage to the highway due to the absence of suitable erosion control, such as let down structures or stilling basins.

reports that the mean date of the start of the freezing season is about October 5 and the mean date of the start of the thawing season is about April 20. Precipitation is assumed to be similar to that at Dawson, where an average of about 33 cm is recorded annually. Approximately 20 cm of this falls as rain.

Vegetation in this physiographic region is generally moderate to dense and consists primarily of spruce trees, with some poplars. A ground cover of moss and low shrubs is common to the whole region.

2.9.3 Drainage Features

Drainage along the Tintina Trench is generally good, although somewhat deranged. Relatively few well defined channelized water courses are crossed by the pipeline route, the average spacing between them being about 8.5 kms. Approximately half of these water courses flow continuously. For the most part, drainage is poorest in very flat areas occupied by peat-lands. Such areas are distributed throughout the region, although they are of limited areal extent.

As few well defined channels are crossed by the pipeline, drainage occurs predominantly as sheet flow, micro-drainage and groundwater flow towards swamps and ponds. Slopes are relatively flat through most of the region and high flow velocities are not anticipated.

The elevation in the trench along the pipeline route descends from about 750 m at Km 723 to about 500 m at the Klondike River at about Km 747. At about Km 730, the route turns south and away from the Dempster Highway and North Klondike River. In this area, most of the cross slopes and longitudinal slopes have gradients of less than 10%. However, a few cross slopes with gradients of up to 30% or more exist in this area. Between about Km 748 and 749, the route ascends the high south slope of a major glacial meltwater channel at a gradient of over 30% to an elevation of approximately 600 m. Several large, ancient slumps were observed on the high slope downstream of the pipeline route. South of Km 749, to the southern limit of the region at Km 860, the route approximately parallels the Klondike Highway. The terrain is relatively flat, with most of the longitudinal and cross slope gradients being less than 10%. The elevation of this portion of the region is for the most part about 600 m, except near McQuesten where the elevation is as low as 450 m. South of Km 805, the pipeline route approximately parallels the Stewart River, which is crossed at Km 828.

Surficial soils in the Tintina Trench physiographic region consist largely of an eolian veneer overlying a glaciofluvial flood plain. Pockets of thermokarst peatlands are present throughout the region and deposits of colluvial slopewash and alluvium are relatively common from Km 723 to Km 750. From south of Clear Creek at approximately Km 805, to the southern limit of the region, morainal and alluvial deposits are widespread.

No bedrock exposures were observed along the pipeline route in the Tintina Trench physiographic region. The area is underlain by deep deposits of Upper Eolene continental clastics and sedimentary rocks (Ricker, 1968).

2.9.2 Climate and Vegetation

The continental climate along the pipeline route in the Tintina Trench region is assumed to be similar to that at Dawson where the mean annual air temperature is about -5°C. The mean freezing and thawing indices are approximately 3800 and 1800 degree days, respectively. Thompson (1967)

Where the pipeline follows cross slopes having gradients of more than 10% and longitudinal slopes more than 30%, cuts may be necessary, thereby exposing the surficial soil to the possibility of thermal and hydraulic erosion. In areas where the cuts will be in bedrock, or unfrozen coarse granular soil, it is anticipated that the potential for thermal and hydraulic erosion will be low and few if any, special erosion or velocity control structures will be necessary. In areas where cuts will be made in ice-rich fine-grained soils, the potential for thermal and hydraulic erosion is very high and erosion and velocity control structures are required. Protective facilities that would be considered include diversion dikes, mound protection, frequent water breaks, channel linings, ditch plugs, ditch checks and let down structures.

In areas where cuts will not be required, but where sheet flow could cause disturbance by eroding the mound, or by ponding behind the mound, some of the above control measures would be required, such as diversion dikes, protective lining on the mound and water breaks. All well defined flow channels crossing the pipeline should be adequately armoured to prevent hydraulic erosion.

2.9 Tintina Trench (Km 723 to Km 869)

2.9.1 Topography and General Geology

The Tintina Trench physiographic region extends from the confluence of Benson Creek and the North Klondike River to about 5 km south of Stewart Crossing. The region is situated completely within the zone of discontinuous permafrost (Brown 1967). The region is bordered on the north by the Ogilvie Mountains and on the south by the Yukon Plateau.

The Tintina Trench represents a northwest-southeast trending transcurrent fault zone that is partially filled by Upper Eolian sediments. The actual fault zone is about 1000 km long and 15 to 20 km wide (Ricker, 1968).

2.8.4 Erosion Control Considerations

A reconnaissance of the proposed route and a review of the recently drilled test holes revealed that most of the surficial soils are ice-rich, except south of about Km 670, where granular alluvial soil deposits are encountered, which are often unfrozen. Of particular concern are the sections between about Km 625 and Km 670 on both the prime and alternate routes. In these sections, slope gradients of 10% or more are common in ice-rich, fine-grained soils. Numerous slumps and evidence of solifluction are evident along the alternate route and ice wedge polygons are common on both the prime and alternate routes. A large thermokarst depression on a 7% cross slope at about Km 637 on the alternate route is clear evidence of the presence of high amounts of excess ice in this area.

Van Everdingen (1978), has reported icings in many areas of this physiographic region. In the northern part of the region, groundwater-fed icings were observed in the Ogilvie River and its tributaries. In some locations, icings were evident on both sides of the Dempster Highway. Although no icing was found in the pass between the Ogilvie River and the Blackstone River, extensive icing was found along the Blackstone River north of Chapman Lake. Immediately north of Km 675 (North Fork Pass), extensive icings were present along the East Blackstone River. Some of the icings were fed by groundwater discharge from below the highway grade. In the southern portion of the region, widespread icings were reported in the channel of the North Klondike River. However, only two minor icing occurrences were noted at an appreciable distance above the valley floor.

In most of this region, as in all of the regions to the north, clearing of the right-of-way should be controlled to limit damage to the vegetative mat. Loss of the vegetative mat overlying ice-rich soils beyond the limits of the pipe trench could lead to severe thermal and possibly hydraulic erosion. In the southern portion of the region, where the surficial soils are granular and unfrozen, the potential for erosion due to construction activities is relatively low.

Besides the major well defined water courses such as the Ogilvie River and Engineers Creek, many well defined drainage channels exist along the route within the Ogilvie Mountains. Approximately half of these channels are considered to flow continuously.

is approximately 25 cm and the mean annual air temperature is approximately -5°C (Thompson, 1963). The mean freezing index ranges from about 4500 degree days in the extreme north to about 3600 degree days at the southern limit of the region. The mean thawing index ranges from about 1325 degree days to 1600 degree days, depending on the location. The mean dates of the start of the freezing and thawing seasons are October 1 and May 5, respectively.

Vegetation along the pipeline route in the Ogilvie Mountains is variable. From the northern limit of the region to about Km 600, a sparse to moderately dense growth of black spruce trees exists in most areas. Deciduous trees also are found on the flood plains. From Km 600 to about Km 690, the vegetation is primarily limited to mosses and shrubs and virtually no trees are present. South of Km 690, a moderate growth of spruce and some deciduous trees are present.

2.8.3 Drainage Features

The drainage in the Ogilvie Mountains ranges from poor to good. In the northern portion of the region to about Km 625, numerous steep side slopes are present. Sheet flows of relatively high velocities can be expected along these slopes and the presence of coarse-grained alluvial deposits at the surfaces of the valley bottoms through much of this area indicates that drainage is relatively good. From Km 625 to about Km 670, drainage is poor as most slopes are somewhat flatter (less than 10% gradient) and ice-rich fine-grained soil predominates. Culvert spacing along the highway in this portion of the region ranges from about 450 m to 600 m. However, to accommodate sheet flows, it is anticipated that a somewhat closer spacing between mound breaks will be required for the pipeline.

South of Km 670 to Km 723, the drainage is considerably better. Slope gradients of up to 30% in generally unfrozen, granular soils provide moderate to good drainage. Most of the drainage in this area flows across the pipeline route and the Dempster Highway toward the North Klondike River.

area, the valley is relatively broad and most longitudinal and cross slopes have gradients of less than 10%. The terrain is predominantly level and comprises a complex sequence of organic, colluvial, alluvial, lacustrine, eolian, glaciofluvial and morainal surficial deposits.

The alternate route between Km 607 and Km 666 parallels the Dempster Highway. The route follows a relatively narrow valley where extensive sidehill cutting will probably be necessary in ice-rich soils. From about Km 617, the alternate route parallels the Blackstone River to Chapman Lake. In this area, most of the cross slopes have a gradient of about 10% and numerous occurrences of slumping and ice wedge polygons were observed. South of Chapman Lake to Km 666, the alternate route parallels the east side of the East Blackstone River. Cross slopes of up to 10% are common in this area and numerous slumps and occurrences of ice wedge polygons were noted in the predominantly ice-rich eolian, alluvial and organic soils.

South of Km 666 to the southern limit of the physiographic region at Km 723, the route parallels the Dempster Highway along a widening valley, and gradually descends to an elevation of about 750 m at the confluence of Benson Creek and the North Klondike River. Longitudinal and cross slopes have gradients up to about 30%, although in most areas gradients are less than 10%. Surficial deposits are generally colluvial, alluvial or morainal. Granular alluvial materials, even when covered by a veneer of fine-grained soils are often unfrozen.

Bedrock is exposed in the Ogilvie Mountains at numerous locations. Although the bedrock generally consists of sedimentary rock with some metamorphics, the complexity of the various formations inhibits positive genetic identification. Principal rock types encountered are shale, siltstone, slate, limestone, dolomite, quartzite and phyllite.

2.8.2 Climate and Vegetation

Although temperatures are slightly higher, the climate in the Ogilvie Mountains is similar to that on the Eagle Plain. Annual precipitation

The Northern and Central Ranges occupy about half of the region. The Northern Ogilvies are a series of ranges rising to elevations of between 1200 m and 1800 m. The Central Ranges trend east-west and rise to an elevation of about 1500 m. The pipeline is routed along the north-south trending valley that separates the Northern and Central Ranges. The Southern Ogilvie Ranges form blocks of peaks that reach about 2100 m in elevation in the vicinity of the pipeline (Bostock, 1961).

The route followed by the pipeline trends approximately north-south and follows well defined river valleys through most of the physiographic region. From Km 547, the route parallels the Ogilvie River to Sapper Hill at about Km 574. In this area, the ground elevation is about 600 m. The narrow, flat river valley bottom is often bordered by steep talus covered bedrock slopes having gradients of at least 50% (Photo 8). Surficial materials are granular in the river flood plains, but tend to become ice-rich and fine-grained along the valley flanks. South of Km 574, the route parallels Engineers Creek and the Dempster Highway, ascending to an elevation of about 750 m. The route follows Engineers Creek along two narrow gorges at about Km 582 and Km 590. In both gorges, the pipeline route will be confined either in the creek bed, or on steep talus covered cross slopes which have gradients of approximately 70%. Surficial materials are similar to those encountered to the north, being ice-rich, fine-grained colluvium and alluvium overlying gravel.

South of Km 607, to about Km 666, two potential routes were inspected. The primary route departs from the Dempster Highway at Km 607 and rises through a mountain pass to an elevation of about 1200 m, before descending to an elevation of about 1050 m near Chapman Lake. In this portion of the pipeline route, numerous cross slopes with gradients of up to 30% and more are crossed. Most of the longitudinal grades are less than 10%. Surficial materials largely consist of ice-rich colluvium and alluvium that overlie gravel. Bedrock is at or near the surface at the higher elevations. On the primary route, south of Chapman Lake, the pipeline parallels the west side of the Blackstone River adjacent to the Dempster Highway, ascending to an elevation of about 1200 m at Km 666. In this probably be required at some locations. To combat thermal and hydraulic erosion caused by thawing and the incidence of channelized or sheet flow on cut slopes, measures for drainage and erosion control will be required. Controls would include facilities such as diversion dikes, ditch plugs and checks, mound protection, let down structures and stilling basins. To control sheet flow on natural slopes where cuts are not necessary, it is anticipated that water breaks will be required at close spacings. Depending on the orientation of the pipeline relative to the slope, other measures such as diversion dikes and mound protection may be required in these areas. All well defined flow channels crossing the pipeline should be adequately armoured to protect against hydraulic erosion.

Revegetation should be accomplished as rapidly as possible in areas disturbed by construction. Existing drainage channels should be preserved. Machine clearing is probably feasible during the winter, but "high blading" will be necessary to avoid destruction of the surface mat. Ideally, winter machine clearing should be delayed until the ground is solidly frozen and a snow cover is available to afford additional surface protection.

2.8 Ogilvie Mountains (Km 547 to Km 723)

2.8.1 Topography and General Geolgoy

The Ogilvie Mountains physiographic region extends from Churchward Hill on the Ogilvie River to Benson Creek at its confluence with the North Klondike River. In general, the region consists of three separate mountain ranges: the Northern, Central and Southern Ogilvie Ranges, all of which lie within the zone of continuous permafrost (Brown, 1967). The northern limit of the region borders the southern portion of the Eagle Plain (Porcupine Plateau), while the southern limit of the region borders the Tintina Trench.

2.7.4 Erosion Control Considerations

Although the Eagle Plain is in the zone of discontinuous permafrost, virtually all of the soils are frozen. This was confirmed by the recently completed drilling which showed that ice-rich silt and clay colluvium comprises the majority of the surficial materials. In the southern part of the region, near the Ogilvie River, gravel usually underlies frozen, fine-grained colluvial and alluvial materials.

Surface evidence of the presence of ice-rich fine-grained soils was noted in road cuts near the Eagle River crossing and along the highway near pipeline Km 503. In the vicinity of the Eagle River crossing, cuts have been excavated to a depth of about 3 m. At this location, both ice-rich silt and clay and ice-rich silty fine sand were melting and sloughing (Photo 5 & 6). Immediately adjacent to this location, a cut in shale has undergone considerable weathering, but was stable with a slope gradient of about 80%.

In the vicinity of Km 503, on a topographic high, the ice-rich surficial cover is generally less than 1 m thick. However, serious thermal erosion has occurred alongside the highway where tracked vehicles have damaged the vegetative cover. Just downslope of a borrow pit, apparent uncontrolled drainage has resulted in hydraulic erosion by carving gullies into the ice-rich silty overburden. Ponding and gullying at the outlets of culverts, caused by uncontrolled discharges of drainage is also evident in portions of the highway across the Eagle Plain (Photo 7).

Very little groundwater discharge or icing has been reported across the Eagle Plain.

It is anticipated that the thickness of ice-rich, fine-grained surficial soils is greatest in low lying areas and in proximity to major water courses. In many of these areas, particularly where the pipeline deviates from the highway alignment, slopes with gradients of up to 30% or more must be traversed. Therefore, cuts through ice-rich soils will

Vegetation on the Eagle Plain consists primarily of moss, grasses and low bushes, with a variable degree of tree cover. Tree growth consists mainly of black spruce, which is sparse in the northern end of the region and relatively dense toward the southern limit of the region, particularly at lower elevations. A limited number of deciduous trees are present near the banks of the Ogilvie River.

2.7.3 Drainage Features

The Eagle Plain is characterized by a dendritic drainage pattern. Most of the region is well drained, particularly on topographic highs, where much of the route is located. Well defined drainage courses are spaced at an average distance of about 2.5 km. Only about 20% of these are continuously flowing. Two significant rivers are crossed by the pipeline - the Eagle River and the Ogilvie River which are situated toward the north and south ends of the region, respectively.

Sheet flow occurs extensively along the Eagle Plain. Numerous cross slopes exist with gradients of 10 to 30% and backslopes of up to 200 m or longer. It is anticipated that mound breaks will be necessary to direct sheet flows across the pipeline. Along the lower portions of the highway, culverts are spaced about 300 m apart, whereas culvert spacings of about 800 m were observed on the higher sections of the highway.

The ground elevation on the Eagle Plain ranges from a low of under 450 m at the Eagle River at Km 925, to a high of about 750 m on a ridge near Km 500. Cross slope gradients typically range from 10 to 30%, with a few local areas having slope gradients as high as 40%. Longitudinal gradients along the pipeline route are normally less than 10%, although some slopes are steeper, particularly at stream crossings.

For the most part, the surficial material on the Eagle Plain consists of fine-grained colluvium of variable thickness. In general, little or no surficial cover exists along the ridge crests, whereas the overburden thickness increases in the slopes and low lying areas, according to the distance downslope from the crests. Near the major water courses such as the Eagle and Ogilvie Rivers, deep deposits of colluvium and alluvium are present.

Bedrock is at or near the surface of the ridges along most of the pipeline route. Long, broad, open anticlines and synclines can be seen in some areas and appear to constitute the predominant regional geologic structures. The bedrock underlying the northern portion of the proposed pipeline route is primarily Upper Devonian shale, conglomerate, siltstone and sandstone of the Imperial Formation. At about the mid point of the region, sandstone, conglomerate, limestone and chert of Carboniferous and Permian ages are crossed by the proposed route. The southern half of the route is underlain by Upper Cretaceous shale, sandstone and conglomerate.

2.7.2 Climate and Vegetation

Climatic data in this region are very sparse. However, annual precipitation is thought to be between 22 cm and 27 cm and the mean annual temperature is approximately -8^{o}C. According to Thompson (1963), the mean freezing index is about 4500 degree days and the mean thawing index is approximately 1325 degree days. The mean dates of the start of the freezing and thawing seasons are September 29 and May 12, respectively.

beside the highway. By choosing the alternative route, extensive side cutting of very steep colluvium covered bedrock slopes immediately adjacent to the highway would be avoided, and it is anticipated that icing impacts would be reduced substantially.

2.7 Eagle Plain (Porcupine Plateau) (Km 405 to Km 547)

2.7.1 Topography and General Geology

The Eagle Plain physiographic region is situated in the zone of discontinuous permafrost (Brown, 1967). The pipeline route follows the Plain from about 20 km north of the Eagle River, to Churchward Hill on the Ogilvie River. The Eagle Plain, which is bordered by the Richardson Mountains to the north and east and the Ogilvie Mountains to the south and west, is located on the southern portion of the Porcupine Plateau, and is part of a large area of the northern Yukon that has not been glaciated (Richardson & Sauer, 1975; Bostock, 1961). It comprises an elevated sedimentary basin which has been dissected by the down-cutting of numerous streams to form a vast area of long, broad, rounded ridges. Typically, the streams merge to form larger meandering streams and rivers that occupy wide flood plains. In most areas, mass wasting and fluvial processes have combined to carry weathered, decomposed bedrock downslope, creating alluvial deposits on the lower portions of the ridges (Richardson & Sauer, 1975).

For the most part, the Dempster Highway trends northeast-southwest and follows topographic highs across the Eagle Plain. In general, the proposed pipeline follows the same route. However, in some areas, the route has been shortened substantially by following a more or less "straight line" alignment, rather than by following a relatively circuitous alignment along the ridges. The route diverges most significantly from the ridges and highway alignment between about Km 460 and Km 520, where the pipeline is planned to cross several valleys.

2.6.4 Erosion Control Considerations

A reconnaissance of the proposed pipeline route across the Richardson Mountains and a review of the recently drilled test holes indicates that although the surficial materials along the route are predominantly ice-rich, they are generally shallow. Granular material, or bedrock was encountered within a depth of 2 m in all but one test hole. Although sheet and channelized flow velocities are high in this region, the presence of shallow bedrock and granular overburden limits the potential for hydraulic erosion.

Most of the cutting that appears necessary along the route would be in bedrock. Although a thin veneer of ice-rich material exists in some of the possible cut areas and may require protection, it is not expected that thermal erosion of the cuts will be a serious problem. Similarly, the potential for hydraulic erosion of the cuts is only moderate. High flow velocities should not have any serious effect on bedrock exposed in the cuts. However, structures for controlling flow velocities may be required at some of the steeper slopes, such as at the two main branches of the Rock River.

According to Van Everdingen (1978), significant groundwater-fed icing problems exist in the Richardson Mountains. Many of the streams and small flow channels exhibit icing phenomena both upstream and downstream of the Dempster Highway. In the narrowest section of the mountain pass along the highway, groundwater-fed icings tend to infringe upon the highway on both sides. Further study of the nature and extent of icings in the Richardson Mountains appears to be necessary before the potential impacts can be clearly defined.

To alleviate potential icing problems and to facilitate construction through the narrowest portion of the pass at about Km 322, an alternative route is suggested. From a geotechnical standpoint, re-routing the pipeline up and over a saddle just north of the highway at Km 322 appears to be more practical than attempting to squeeze the pipeline lower elevations on the Peel and Porcupine Plateaus. Minimum and maximum mean daily temperatures are probably a few degrees lower at the higher elevations. Although he apparently did not account for the higher elevations in his calculations, Thompson (1963) estimates the mean freezing and thawing indices in the region to be about 4750 and 1225 degree days respectively, which is the same as that estimated for the Peel Plateau. The mean dates of the start of the freezing and thawing seasons are September 27 and May 15, respectively.

Vegetation in the region is very sparse. Grass, mosses and low bushes comprise the majority of the vegetation, with scrub conifers appearing toward the southern limit of the physiographic region. The upper portions of many of the peaks and ridges are virtually devoid of vegetation.

2.6.3 Drainage Features

The Richardson Mountains are characterized by a large number of relatively high gradient drainage courses, including branches of the Rock River. Well defined drainage channels occur along the route at an average of about every 1200 m. Up to about 35% of these are continuously flowing.

Between the well defined drainage courses, sheet flow is common, originating on the steep mountain slopes. Although flow velocities tend to be high in nearly all areas, the presence of bedrock at or near the ground surface along much of the route allows a relatively wide spacing of water breaks. In some areas along the Dempster Highway, sheet flows have been successfully controlled by diverting the flows to the nearest well defined drainage course and thence across the highway in a culvert. Typical culvert spacing along the highway in the southern portion of the region is from 300 m to 500 m.

pipeline route rises to an elevation of about 900 m at the Yukon-Northwest Territories border, before descending to an elevation of about 600 m at the boundary of the Porcupine Plateau. Cross slope gradients along the proposed route in this region are typically between 10% and 30%. Locally, cross slopes with gradients exceeding 30% are encountered. For the most part, longitudinal slopes along the route have gradients of less than 10%.

The terrain along much of the route in the Richardson Mountains consists primarily of colluvium overlying a pediment surface. Surficial materials are thin, or absent on most of the steeper cross slopes and mountain ridges. However, portions of the route are thought to have up to about 12 m of overburden and talus. In most locations, the overburden depth is less than about 4 or 5 m. Within the northern 15 km of the route, the overburden material is variable, containing shallow pockets of silty clay glacial till interpsersed with the colluvium. The till deposits probably represent the western limit of Pleistocene glaciation, as the Porcupine Plateau to the west has not been glaciated (Bostock, 1961; Richardson & Sauer, 1975). Minor alluvial and glaciofluvial deposits also occur in a few locations along the pipeline route.

The Richardson Mountains consist of sedimentary rock which has been folded into a series of anticlines and synclines. Bedrock outcrops are numerous along the route and for the most part consist of Upper Devonian shale, sandstone and conglomerate of the Imperial Formation. Lower Cretaceous and Jurassic shale and sandstone also underlie the northern portion of the route. Ordovician and Silurian shale and sandstone of the Road River Formation are exposed just east of the pipeline on the southern half of the route within this physiographic region.

2.6.2 Climate and Vegetation

Climatic data for the Richardson Mountains are very sparse. However, because of the relatively high elevation of this Subarctic region, climatic conditions are assumed to be slightly more severe than those at flows from causing hydraulic damage to the mound over the buried pipe.

Both natural and cut slopes will require protection against potential erosion. The most substantial slopes, some of which may require cutting, are situated in the western half of the physiographic region. To control drainage and ensure stability on the more significant slopes, it is considered that drainage facilities and erosion control structures such as ditch checks, ditch plugs, let downs and stilling basins will be required. The cut segments will require erosion protection in zones where cutting exposes significant thicknesses of silt and clay. Protection would consist of sand and gravel buttresses, or insulation. Velocity control structures designed to limit water velocities to less than about 1.2 m/sec (4.0 fps) and diversion dikes, to keep the run-off away from the disturbed areas, will also be required.

2.6 Richardson Mountains (Km 315 to Km 405)

2.6.1 Topography and General Geology

The Richardson Mountains physiographic region extends from Km 315 to Km 405 on the proposed pipeline route. In the area of the pipeline, the mountain range is the boundary between the Peel Plateau to the east and the Porcupine Plateau to the west and serves as a divide for the Peel River and Porcupine River drainage systems. The pipeline crosses into the Yukon Territory from the Northwest Territories at about Km 343 of the proposed route. This point is also the approximate boundary between the continuous and discontinuous permafrost zones. Within the Richardson Mountains, the pipeline trends in an approximately northerly direction.

The Richardson Mountains are a relatively narrow range of fairly weathered and somewhat rounded peaks that rise to a height of 1500 m or more. The mountain range trends approximately north-south and the topography is controlled by steeply dipping bedrock. Through the mountains, the

2.5.4 Erosion Control Considerations

The reconnaissance of the proposed pipeline route and a review of recently drilled test holes revealed that the fine-grained colluvial overburden is predominantly ice-rich. Extensive ice lensing was common in all of the test holes and layers of ice up to about 1.5 m thick were encountered in some of the holes. One hole located near the western limit of the physiographic region encountered approximately 20 m of ice, with silt and clay. Surface evidence of ice-rich soil was noted at about Km 308, where thaw settlement and gullying have occurred in ice-rich clay along an old seismic line. Depressions were up to about 2 m deep on two slopes having gradients of 6% and 10%. The presence of flow slides in some of the deep gullies on the Plateau also indicates that ice-rich surficial soils are present. Further evidence of the presence of ice-rich surficial soils was observed at approximately Km 290 in a through cut for the Dempster Highway. Unlike the unprotected ice-rich cut at Km 255 on the Peel Plain, this through cut has been stabilized by covering the slopes with a layer of coarse granular material and shot rock (Photo 4). This cut is performing satisfactorily and is not sloughing.

Although ice-rich fine-grained soils are very extensive on the Peel Plateau, icings associated with surface and subsurface flows do not appear to present a concern. Van Everdingen (1978), has reported that no icings were observed along the Dempster Highway during a reconnaissance in April 1978.

Unlike the physiographic regions to the north where the topography is fairly flat and thermal erosion processes constitute the primary concern for soil degradation, the Peel Plateau is susceptible to both hydraulic and thermal erosion. The presence of numerous longitudinal and cross slopes with gradients up to 15% and more indicates that erosion control structures will be necessary to control hydraulic erosion of the ice-rich fine-grained soils. Special structures, such as diversion dikes, may be required to direct the drainage toward existing drainage courses or water breaks. Closely spaced water breaks would prevent concentrated occurrences of Jurassic, Carboniferous, Permian and Devonian sedimentary rocks can also be expected toward the extreme western limit of the region.

2.5.2 Climate and Vegetation

Climatic data for the Peel Plateau are very sparse. However, from a topographic and geographic standpoint, the climate is assumed to be very similar to that of the Peel Plain, with the exception that temperatures are probably slightly cooler for a longer period of time near the Richardson Mountains. This is supported by Thompson (1963), who estimates that the mean freezing index is about 4750 degree days, while the mean thawing index is approximately 1225 degree days. The mean dates of the start of the freezing and thawing seasons are September 26 and May 16, respectively.

Tree growth on the Peel Plateau is rather sparse, consisting mainly of stunted coniferous trees. Vegetation in the region consists predominantly of mosses and low bushes.

2.5.3 Drainage Features

In general, the drainage on the Peel Plateau is rather well developed. Well defined cross drainage channels occur frequently. Culverts along the Dempster Highway are spaced at intervals ranging from about 150 to 300 m. As the pipeline closely parallels the Dempster Highway along nearly all of the route in this region, the spacing of culverts under the highway should be considered in estimating the spacing of breaks to conduct channelized flows across the pipe mound. From the field reconnaissance, the majority of the continuously flowing drainage courses were observed to be located near the western limit of the physiographic region, at the foot of the Richardson Mountains.

Sheet flow is also an important consideration on the Peel Plateau. As cross slopes up to about 15% and more and backslopes up to 2 kms long exist along much of the pipeline route, numerous water breaks will be necessary to direct the sheet flow across the pipeline.

If deep cuts are necessary, immediate protection and covering of the exposed slopes would be required.

2.5 Peel Plateau (Km 277 to Km 315)

2.5.1 Topography and General Geology

The Peel Plateau extends from about 2 km to 40 km west of the Peel River. This is the smallest physiographic region that is crossed by the pipeline. It is bordered on the east by the Peel Plain and on the west by the Richardson Mountains. Although the region as a whole lies within both the discontinuous and continuous permafrost zones, the portion of the region crossed by the pipeline lies completely within the zone of continuous permafrost (Brown, 1967).

The Peel Plateau is for the most part a rolling pediment on the east flank of the Richardson Mountains. Along the plateau, the pipeline route rises from an elevation of approximately 70 m at Km 277, just west of the Peel River, to an elevation of about 600 m at Km 315. Slope gradients in most areas are no greater than about 15%, with many slopes having a gradient in the range of 3 to 10%. Only a few slopes, particularly near the Richardson Mountains, are steeper than 15%. The Plateau is incised by deep erosional gullies, which trend easterly toward the Peel River. However, none of the gullies intersect the pipeline route. Only a few lakes and ponds are present on the Peel Plateau.

The bedrock surface is for the most part covered by silt, sand and clay of varying depths. Some angular, coarse material is also present. In areas where the colluvium is very thin, the surface topography reflects the underlying bedrock topography. However, with increasing depth of colluvium, the topography of the bedrock surface becomes masked.

The bedrock that underlies the Peel Plateau physiographic region, is predominantly Lower Cretaceous shale and sandstone. However, limited

2.4.4 Erosion Control Considerations

To a large extent, the Peel Plain is underlain by ice-rich fine-grained organic soils. Although both the glacial moraine soils and the organic soils of the peatlands and fenlands are ice-rich, it is expected that the organic soils possess a somewhat higher percentage of excess ice.

Extensive icing has been reported near the pipeline route at two locations on the highway between Fort McPerson and Arctic Red River, as well as on Frog Creek (Van Everdingen, 1978). As on the Anderson Plain, icing problems can be expected on the Peel Plain in localized areas.

In this region, the low topographic relief significantly reduces the potential for hydraulic erosion. However, the potential for thermal erosion is high. Therefore, disturbance of the ground, other than that required for clearing and the proposed snowpad should be kept to a minimum. To avoid ponding on the uphill side of the pipeline and to allow water to flow past the pipeline in swampy areas, properly spaced water breaks will be needed. At the Peel River Crossing and at Frog Creek, velocity control and flow diversion structures will be needed.

Although the necessity for cutting is likely to be minimal due to the generally flat ground on the Peel Plain, an existing cut in glacial till was examined adjacent to Km 255 on the proposed pipeline route. The cut, which is located at Mile 343 of the Dempster Highway between Arctic Red River and Fort McPherson, is estimated to be about 1 km long, 80 m wide, and 11 m deep. Side slopes are at gradients of 30 to 50%. The cut is understood to have been excavated in 1973. The slopes are actively eroding and have regressed a considerable distance. Extensive siltation along the road side was also evident (Photo 2 & 3). Although revegetation of the cut slopes has been attempted, most of the revegetated sections have continued to erode and little organic cover remains.

In view of the problems encountered with the highway cut, deep cuts into slopes in this region should be avoided, unless absolutely necessary.

and fenlands tend to be flatter than the morainal deposits. Deposits of sorted, fine-grained sediments occasionally cover the moraines. Within the river valley of the Peel River, fine-grained deposits of silt and silty sand with some gravel occur in river channels, flood plains, alluvial fans and low terraces. The thickness of surficial soils is probably quite variable, although drilling data indicate that the depth to bedrock is as shallow as about 3.5 m over much of the area between the Mackenzie River and Km 250.

The only bedrock exposures observed on the Peel Plain along the pipeline route are situated in the Peel River Valley. For the most part, the bedrock underlying the Peel Plain is Upper Devonian sandstone, siltstone, shale and conglomerate. Lower Cretaceious shale and sandstone may also exist west of the Peel River, near the boundary with the Peel Plateau.

2.4.2 Climate and Vegetation

The Peel Plain physiographic region is situated in the Subarctic. The mean annual temperature is about -9°C and the minimum and maximum mean daily temperatures are approximately -28°C and +13°C, respectively. Annual precipitation is approximately 23 to 25 cm, of which up to 15 cm falls as rain from May through September. According to Thompson (1963), the mean freezing and thawing indices for the region are about 4450 degree days and 1225 degree days, respectively. The mean dates of the start of the freezing and thawing seasons are September 25 and May 17, respectively.

Vegetation in the Peel Plain is limited and is virtually identical to that found on the Anderson Plain.

2.4.3 Drainage Features

Numerous thermokarst lakes and ponds occupy the Peel Plain. However, few continuously flowing drainage channels are crossed by the proposed pipeline route. Drainage on the flat, swampy plain is therefore quite poor and limited mainly to sheet flow and intermittently flowing micro-channels.

Although nearly all of the longitudinal and cross slopes along the pipeline route in this region have gradients of less than 10%, it is possible that a few shallow cuts will be required. It is expected that most of these cuts will be less than about 1.5 m deep and will self-stabilize without significant slumping. However, to protect the pipeline in areas where cuts are necessary, or where cross slopes approach a 10% gradient, some diversion dikes, ditch checks and slope stabilization measures will probably be required. Erosion and velocity control structures will also be needed at several locations, including the Rengleng River and at the stream crossings at Kms 141 and 169.

2.4 Peel Plain (Km 229 to Km 277)

2.4.1 Topography and General Geology

The Peel Plain physiographic region lies within the zone of continuous permafrost (Brown, 1967) and extends from the left bank of the Mackenzie River to 2 km west of the Peel River on the proposed pipeline route. It is bordered by the Mackenzie Delta and the Anderson Plain to the north and east, respectively and by the Peel Plateau to the west.

The Peel Plain is generally flat and featureless, with numerous thermokarst lakes and ponds. Throughout the entire physiographic region, the ground elevation remains relatively constant, with the highest point of land being just under 60 m. The banks of the Peel and Mackenzie Rivers represent the lowest points in the region, where elevations are just under 30 m. With the exception of a limited number of local slopes, such as those at the Peel River and Frog Creek all slopes in the region have a gradient of less than about 10%. Over half of the region is virtually flat, with gradients of less than about 3%.

Large areas of the Peel Plain are covered by organic complexes in the form of peatlands and fenlands, and by unsorted glacial drift in the form of rolling moraines and morainal plains. In general, the peatlands

2.3.4 Erosion Control Considerations

Although the Anderson Plain physiographic region is located in the zone of continuous permafrost, the ice content in surficial soils is not very high. Inspection of borrow pits and drill holes along the route indicates that silty clay till, which comprises the majority of the soils, is not generally ice-rich. At a borrow pit located at about Km 194, 10 m high cuts into till and shale are standing at about 1½ horizontal to 1 vertical, with no indication of significant sloughing. Slopes in the bedrock portions of the cuts are standing at about ½ horizontal to 1 vertical. Ice is evident, primarily in small localized pockets. However, little erosion due to melting of ice was observed. Ice concentrations along this portion of the route are anticipated to occur in organic soils within fenlands and peatlands. Moreover, some of the fine-grained soils on the glaciolacustrine plain near the north end of Campbell Lake are likely to be ice-rich.

According to a recent report on icing potential (Van Everdingen, 1978), icing conditions may be found on the Anderson Plain. Reconnaissance indicates that icings exist under natural conditions on the Rengleng River and on two streams that are to be crossed by the pipeline. The report concludes that "*icing and frost heave problems may also be encountered along the route between Fort McPherson and Inuvik, wherever poorly defined surface and subsurface drainage channels are crossed*".

It is understood that the thermal workpad designed for the Mackenzie Delta portion of the pipeline route will be used on the Anderson Plain to as far as Km 140. All transverse flow in this area would therefore, be intercepted and controlled in a manner similar to that discussed in Section 2.2. South of Km 140, it is understood that winter construction practices will be followed, thus allowing a temporary snowpad to be utilized during construction. In order to accommodate the numerous intermittently flowing drainage courses in this region and the large areas of flat swampy ground, equilizers and breaks in the pipe mound will be required to accommodate flows.

many small lakes and ponds are present. Although the overall gradient in this area is westerly, most of the drainage is controlled by local topography. Typical local gradients range between about 3 and 5%. South of Km 170, few lakes and ponds exist and the overall drainage is from east to west.

With the exception of the Rengleng River and two minor streams, most of the drainage courses consist of intermittently flowing micro drainage channels, or minor water courses flowing at less than about 28 l/sec (1 cfs). Where drainage intensity is high, the minor water courses are as little as 15 m apart, whereas in low density areas, water courses are up to about 500 m apart. Along the Dempster Highway, which parallels the pipeline along much of the route, culverts are spaced at intervals ranging from 30 m to 600 m. The culverts range from 0.75 to 1.2 m in diameter and for the most part appear to be providing adequate drainage across the highway. Because of the very low longitudinal gradients along some portions of the highway, some ponding of water has occurred, indicating that micro relief is a significant factor in locating culverts and other drainage facilities.

Vegetation growth in water courses with flow velocities less than about 1.2 m/sec (f fps) is noticeable in this region (Photo 1).

Very little bedrock is exposed on the Anderson Plain along the route of the pipeline. South of about Km 120, bedrock consists primarily of shale of the Upper Devonian Imperial Formation. The shale is commonly interbedded with thin layers of sandstone, siltstone and conglomerate. North of Km 140, Upper Cretaceous shale and sandstone predominate, with minor formations of Middle Devonian shale and limestone.

2.3.2 Climate and Vegetation

Although the Anderson Plain physiographic region is situated in the Subarctic, climatic conditions, notably minimum and maximum mean daily temperatures and amount and distribution of precipitation, are quite similar to conditions in adjacent continental regions. The mean thawing index for the Anderson Plain is about 1150 degree days, and the mean freezing index is about 4450 degree days (Thompson, 1963). The mean dates of the start of the freezing and thawing seasons are September 25 and May 18, respectively.

For the most part, vegetation is limited to ground cover consisting of mosses, alder and low bushes. Some tree growth, primarily scrub spruce, also exists in this physiographic region.

2.3.3 Drainage Features

The intensity and type of drainage that can be expected along the pipeline route in the Anderson Plain physiographic region varies from north to south. At the northern end of the region from Km 120 to about Km 140, the pipeline traverses the toe of an extensive east facing slope. Extensive sheet flow and intermittent channelized flow towards lakes and ponds will tend to be intercepted by the pipeline. To avoid ponding on the uphill side of the pipeline, cross drainage facilities will be required.

South of Km 120, to the southern limit of the physiographic region, the general surface flow is from east to west. However, drainage is poor, because overall gradients are relatively low. Between Km 140 and Km 170,

2.3 Anderson Plain (Km 120 to Km 229)

2.3.1 Topography and General Geology

The Anderson Plain physiographic region lies within the zone of continuous permafrost (Brown, 1967). Within this region, the proposed pipeline route extends from approximately Km 120 to the Mackenzie River near Point Separation. It is bordered by the Mackenzie Delta to the north and west and by the Peel Plain to the south. The Mackenzie River serves as the boundary between the Anderson and Peel Plains.

In general, the Anderson Plain is characterized by broadly dissected, gently rolling hills. The northern half of the region is more hummocky and undulating than the southern half. Between Km 120 and Km 170, the ground elevation varies from a low of about 30 m to a high of over 150 m. Slope gradients are typically less than 10%, with the majority of gradients between 2% and 5%. A few abrupt topographic changes occur locally. Overall, the area slopes gradually to the west. Many lakes are present in the region, especially in the northern portion.

South of Km 170, the pipeline crosses a flat, generally featureless upland, which gradually descends in elevation to less than 30 m near the Mackenzie River. The land surface in this area has a general westerly slope. The overall gradient is less than 2% and many swampy areas occur locally.

Morainal plains occupy most of the Anderson Plain along the pipeline route. Drumlinoid and hummocky moraines also exist in a few areas. Peatlands and fenlands occur to some extent throughout this physiographic region, although they are most prevalent in the southern half of the region. Locally, particularly near the north end of Campbell Lake, glaciolacustrine plains are present.

Surficial deposits in the region tend to be in the order of 5 m thick. Inspection of borrow pits and drill holes along the route indicate that the moraines consist of silty clay till. Peat and organic silt are present on the fenlands and peatlands.

Soil erosion as a consequence of crossing steep longitudinal, or cross slopes is not a serious concern in this physiographic region. The only relatively steep slope within the region is located a few kms north of the East Channel of the Mackenzie River, at about Km 30 of the pipeline route. At this location, the proposed route passes over a longitudinal slope with a gradient of about 30%. Sloughing and mass wasting are evident on this slope. Although the pipeline route is normal to the strike of the slope at this location and a longitudinal slope cut would probably not be required, the stability of the insulated workpad and possible sloughing of the pipe trench both require attention. Erosion control and drainage diversion measures will be required to direct any surface flow away from the workpad. Over the remaining portion of the route in this physiographic region, it is anticipated that very little grading will be necessary. If required, cuts will probably be less than about 1.5 m in height and will generally stabilize without a significant amount of slumping. However, cut grading should not be planned in this area, unless it is unavoidable.

Since summer construction is being planned for this region, deterioration of the open trench is of concern. During the summer, water may enter the trench from the active layer and surface run-off. Excessive infiltration could create a muddy condition in the trench walls and bottom. The degree of trench deterioration will be affected by how long the trench is allowed to remain open prior to placement of bedding, padding and backfill. Should this period be a matter of days rather than hours, significant lengths of the trench may deteriorate. To reduce the possibility of undesirable conditions from developing, it is preferred that the trench be excavated after freeze-up, when surface water is not available for seepage. Where this is not possible, the period between excavation and backfill should be as short as possible.

The southern half of the physiographic region, from Km 60 to Km 120, contains considerably fewer bodies of water. In the North Storm Hills area (Km 60 to Km 75), closely spaced minor flow channels are present. South of the North Storm Hills, from Km 75 to the southern limit of the physiographic region, the drainage is poor and is mostly in the form of intermittently flowing micro channels (less than 28 l/sec (1 cfs) flow) and sheet flow. Generally, gradients are low and local drainage flows towards thermokarst lakes.

2.2.4 Erosion Control Considerations

The Mackenzie Delta is for the most part underlain by fine-grained, ice-rich soils. Numerous ice ploygons and pingos are present, generally occurring on flat ground in areas where the drainage is poor. As a consequence, the portion of the pipeline route in this physiographic region is quite sensitive to thermal and/or hydraulic erosion on sloping ground. Fortunately, a large portion of the route in this area follows essentially level ground, where the potential for hydraulic erosion will be low. However, destruction of the protective mat of vegetation that covers the ground surface in this region, such as by indiscriminate clearing and grading, could result in serious thermal erosion.

It is understood that a thermally designed granular workpad will be used within the Mackenzie Delta portion of the pipeline route. The principal advantage of an insulated workpad is that subgrade thaw will be eliminated, thus reducing the requirements for erosion control and revegetation in the thermally degradable areas. A thermal workpad is most useful where protective vegetation is particularly difficult to re-establish.

All transverse flow in the vicinity of the pipeline should be intercepted and directed to existing drainage courses. The flow can then cross the insulated workpad via water breaks. Before building the thermal workpad, the ground surface should be prepared through a combination of minor levelling of the vegetation and filling in of low spots with compacted snow, or sand.

2.2.2 Climate and Vegetation

On the basis of both climate and vegetation, the Mackenzie Delta physiographic region is situated in both the Arctic and Subarctic regions. The transition between the two regions occurs at approximately Km 90 of the proposed pipeline route (Mackay, 1963). Generally speaking, north of Km 90 (the Arctic), the mean temperature for the warmest month is less than 10°C. Vegetation consists mainly of low scrub type bushes. South of about Km 90 (the Subarctic), the mean temperature for the warmest month is above 10°C and the land supports some scrub tree growth.

Within the Arctic and Subarctic regions, the mean daily temperature is below freezing from about the end of September to approximately the middle of May. The lowest mean daily temperature is about -28°C and occurs in January or February, whereas the highest mean daily temperature is approximately +13°C and occurs in July (Mackay, 1963). According to studies by Thompson (1963), the mean annual freezing index in the region is about 4750 degree days (with respect to 0°C) and the mean annual thawing index is about 1100 degree days. The mean date of the start of the freezing season (the date following the maximum seasonal accumulation of thawing degree days) is about September 23 and the corresponding mean date of the start of the thawing season is about May 20.

The annual total precipitation in the Mackenzie Delta physiographic region is about 25 cm. Almost one-third of this falls in July and August, while precipitation is relatively evenly distributed throughout the remainder of the year.

2.2.3 Drainage Features

The northern half of the Mackenzie Delta physiographic region is occupied by numerous stream and river channels and lakes. North of about Km 10 on the proposed pipeline route, the flat land surface is very swampy and susceptible to flooding. Equilizers will be required in this area to avoid flood damage to the pipeline. From about Km 10 to Km 60, the land is generally not as swampy, but drainage is still regarded as poor.

2.2 Mackenzie Delta (Km 0 to Km 120)

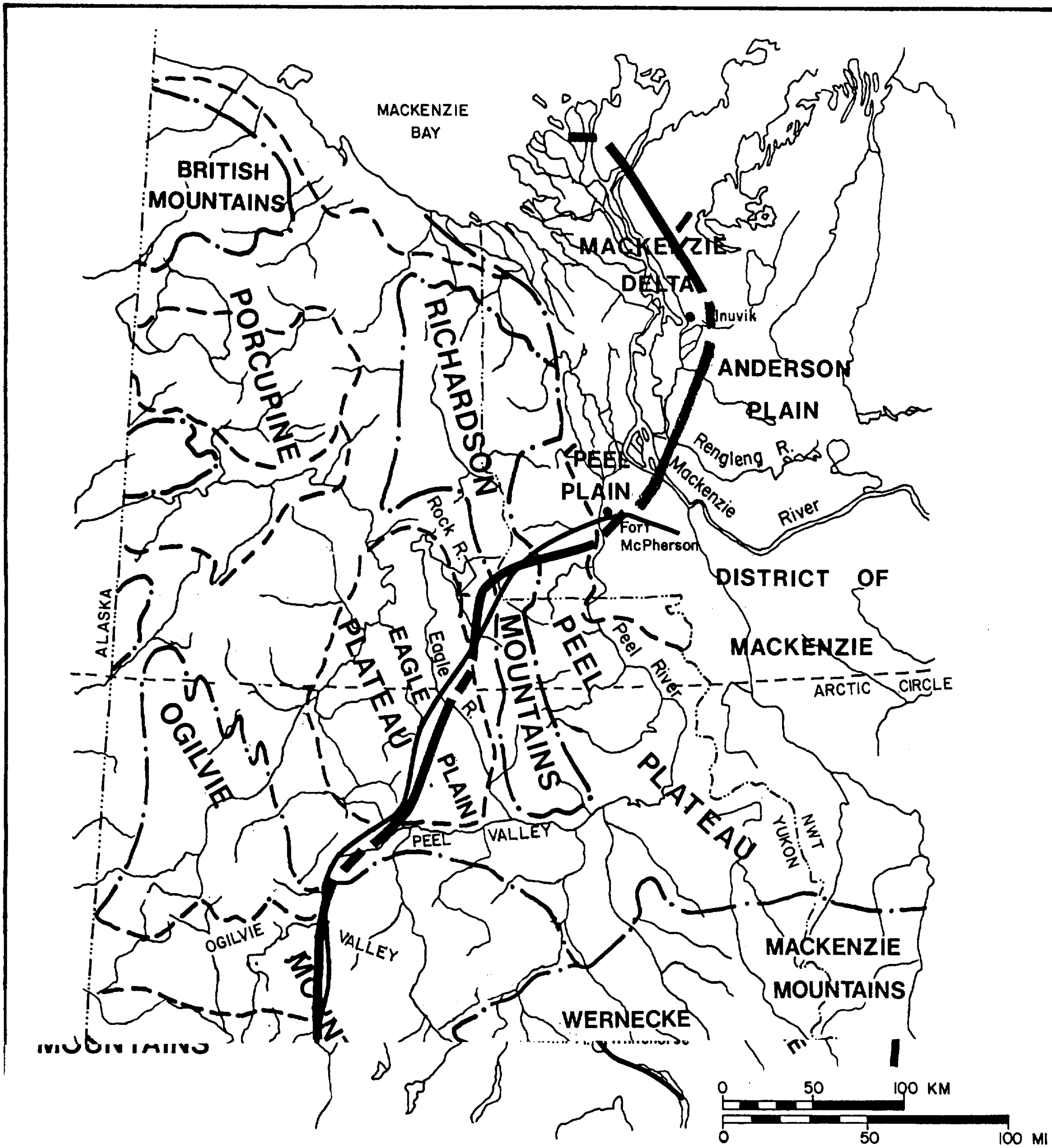
2.2.1 Topography and General Geology

The northernmost portion of the proposed pipeline route, to about 4 km south of Noell Lake, traverses the Mackenzie Delta physiographic region. The region is situated entirely within the zone of continuous permafrost (Brown, 1967).

Topographically, the Mackenzie Delta physiographic region can be divided into two sub-regions. From the northern terminus to about Km 10, on Richards Island, the land is flat with numerous channels and thermokarst lakes. South of Km 10 to Km 60, the land surface becomes somewhat rolling, with eskers and ridges up to about 50 m high. In this area, the slope gradients are generally less than about 5%. The major exception to this is a slope with a gradient of about 30% near Km 30.

From Km 60 to Km 75, the pipeline route crosses the North Storm Hills where the ground elevation rises to a maximum of about 250 m. The topography is rolling in this area, with only a few longitudinal slopes having a gradient greater than about 10%. From Km 75 to Km 120, the pipeline route descends to an elevation of about 120 m. Within this region, the ground surface is hummocky, with numerous morainal deposits, kames and meltwater channels. Slope gradients are typically less than 10% and the land surface is dotted with many lakes. For the most part, only minor grading will be necessary south of Km 60. Some cutting can be avoided by minor re-routing of the pipeline in localized areas.

Bedrock is not exposed along the pipeline route through the Mackenzie Delta physiographic region. The area north of the East Channel of the Mackenzie River is underlain by deep deposits of Tertiary and Quaternary sediments, consisting primarily of clay, silt and sand. South of the East Channel, the area is underlain by Upper Cretaceous shale and sandstone.



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2. GEOTECHNICAL CONDITIONS RELATING TO EROSION CONTROL

2.1 General

The potential for erosion and requirements for its control are influenced by a variety of factors, including physiography, climate, geology, permafrost distribution and presence of ice segregations, soil types and drainage characteristics. This section constitutes an overview of these factors and highlights areas of potential concern for drainage and erosion. Terrain characteristics are summarized and general requirements for the preservation of drainage across the pipeline and protection of the terrain from excessive erosion are stated.

The contents of this section are based on the following sources of information:

a) Field reconnaissances in June and August, 1978.
b) Terrain typing provided by Foothills.
c) Test hole logs provided by Foothills from drilling programs conducted in 1977 and 1978.
d) Interpretation of aerial photographs.
e) Review of appropriate background literature.

Discussion is presented for each of the following physiographic regions crossed by the pipeline (Drawing 1):

a)	Mackenzie Delta	(Km 0 to Km 120)
b)	Anderson Plain	(Km 120 to Km 229)
c)	Peel Plain	(Km 229 to Km 277)
d)	Peel Plateau	(Km 277 to Km 315)
e)	Richardson Mountains	(Km 315 to Km 405)
f)	Eagle Plain	(Km 405 to Km 547)
g)	Ogilvie Mountains	(Km 547 to Km 723)
h)	Tintina Trench	(Km 723 to Km 860)
i)	Yukon Plateau	(Km 860 to Km 1200)

In rugged areas with conspicuous topographic features, an analysis was carried out to estimate the approximate length and inclination of side slopes, true slopes and longitudinal slopes, where such slopes were considered to have an effect on drainage, erosion and grading requirements. Areas of grading were identified and the approximate lengths and heights of cuts, especially in ice-rich soils, were estimated from air photos.

Cross drainage requirements were estimated for defined channels, including continuous flow and intermittent flow courses. Drainage requirements to control sheet flow were estimated from the approximate length and width of back slopes. The selection of the appropriate erosion and drainage control measures is affected by the construction geometry, type of workpad (gravel or snow), location of workpad with respect to the pipeline (uphill or downhill), proximity of the highway, and the season of construction. The effect of these conditions was considered where such information was available.

From the analysis of the above data, drainage and erosion control structures were specified to accommodate the different typical conditions most likely to be encountered during construction. Material requirements were calculated for the various typical designs. An allowance of 10 to 20% of the calculated quantities was made for contingencies.

1.5 Method of Study

In developing an approach to erosion control and design procedures, reference has been made to the experience and practices of the Alaska Highway Department, the Department of Public Works and the Trans-Alaska Pipeline System. The approach followed is consistent with previous applications by Foothills for the Maple Leaf Pipeline and the Alaska Highway Pipeline.

To arrive at a realistic estimate of material quantities needed for erosion and drainage control for the construction of the pipeline, it was necessary to establish the erosion potential of soils occurring within the right-of-way. Field reconnaissance trips were undertaken, soil types were classified on the basis of erodibility, and designs of control structures and procedures for implementing erosion control, were developed to establish guidelines for estimating material quantities.

Field reconnaissance trips were made during the months of June and August of 1978, with the objective to record information on soil and rock, vegetative cover, drainage courses and groundwater conditions; and to observe occurrences of natural erosion along the pipeline route. Areas of potential problems were located and identified for design consideration. Field observations were made to delineate areas where topographic configurations and drainage patterns indicated possible grading, cut and fill construction and drainage re-routing. The performance of ice-rich cuts and locations where hydraulic and thermal erosion were evident along the Dempster Highway were examined and considered in the proposed designs.

A soil erosion code system was developed to identify the erosion susceptibility of the various soil types. The available soil data obtained from borehole logs, terrain typing and field reconnaissance observations were classified in the form of erosion codes and were posted along the pipeline route to indicate soil changes from station to station.

in drainage patterns, removal of the vegetation cover and excavations in permafrost soil. Thawing of fine-grained soil with high moisture contents may result in ground subsidence, slope instability and siltation of streams.

Thawing, fine-grained permafrost soils are subject to mass flow, even on relatively gentle slopes. By comparison, sand and gravel deposits when thawed, often remain stable. The thermal regime of an area is extremely sensitive to alteration of drainage, ponding of water and channelization of runoff.

1.4.4 Wind Erosion

Wind usually erodes only dry clay and dry, cohesionless fine sand and silt. However, wind erosion potential is minor and highly localized in terms of surface disturbance related to construction of the proposed pipeline.

1.4.5 Gravity Erosion

The downward movement of earth materials in the form of landslides, creep and solifluction represents gravity related natural geological phenomena. Man made structures, including cut slopes, embankments and disposal piles, are subjected to the same natural forces and erosion processes. The action of gravity is combatted by flattening a slope, or providing stabilization measures.

Aspects of slope stability are considered to be part of site specific designs and do not fall within the scope of this report.

by human activity. Accelerated erosion is the increased rate of erosion that arises when man alters the natural system by various land use practices. Erosion associated with pipeline construction activiites belongs to the latter category of accelerated erosion.

The erosion rate is affected by numerous variables, of which soil type, climate, vegetation and drainage basin characteristics (such as length and steepness of slopes, drainage density and relief) are considered to be the most important. Other factors imposed by construction activities such as clearing, excavation of ditches, side and through cuts, diversion and concentration of flow, embankment construction and disposal of waste material, are the major causes of accelerated erosion. Erosion can occur when an area is disturbed and can be of several types: hydraulic erosion, thermal erosion, erosion due to gravity, and wind erosion. Each type of erosion is briefly described below.

1.4.2 Hydraulic Erosion

The two principal agents for hydraulic erosion are rainfall and flowing water. The detachment and transport of soil particles results from surface runoff occurring as channelized flow or sheet flow. The susceptibility of a disturbed site to hydraulic erosion depends primarily on the soil properties, slope, and corresponding flow velocity. Silts and fine sand that are low in cohesion are most susceptible to erosion, whereas gravels are least susceptible due to the large particle sizes. Although clays are finer in grain size, they are often less suceptible to erosion due to their structure and cohesion.

Hydraulic erosion can also be caused by groundwater seepage. This erosion process is commonly referred to as "piping or boiling".

1.4.3 Thermal Erosion

Thermal erosion is generally associated with the rapid thawing of ice-rich, fine-grained soils. Thawing and erosion may result from alterations

1.3 Assumptions and Constraints

In preparing the design requirements and estimate of material quantities, several assumptions and constraints were adopted. These include:

a) The pipe would be 86 cm (34 in.) in diameter and the trench would be a minimum of 130 cm (51 in.) wide.

b) The pipeline would be buried, with a minimum cover of 90 cm (3.0 ft.).

c) The frost bulb would extend only 30 cm (1.0 ft.) above the crown of the pipe, at the time when the active layer is fully developed.

d) The chilling point cut-off would be located between Km 684 and Km 705. South of this point, the pipeline would transport gas above $0^{o}C$.

e) From 0 to 140 km, construction would be undertaken in non winter periods, utilizing an insulated gravel pad.

f) From 140 to 746 km, the construction would be carried out during the winter, utilizing a snow pad constructed on frozen ground.

g) Summer construction without a pad is proposed from km 746 to 1200.0.

h) Side slopes greater than 10% would require cut and fill designs.

i) Longitudinal slopes greater than 30% would require flattening.

1.4 Erosion Mechanisms

1.4.1 General

Erosion involves the physical and chemical weathering of rock and the transport and deposition of unconsolidated materials by the action of water and wind, by gravity and by thermal processes. A distinction is made between "geological" and "accelerated" erosion. Geological erosion is the rate at which the land would normally be eroded without disturbance

1. INTRODUCTION

1.1 General

The purpose of this report is to evaluate and identify from presently available information the potential erosion and drainage problems that may emerge during the construction of the Dempster Lateral Pipeline and propose suitable methods to control drainage and erosion. The report is primarily intended to aid in estimating the cost of materials by providing approximate quantities of the various types of construction materials that would be required in drainage and erosion control facilities. While the report embodies a broad spectrum of soil erosion and drainage conditions, emphasis is placed on the following aspects:

a) areas where drainage and erosion control measures would be required.

b) design concepts and procedures for preventive measures.

c) estimate of quantities of various materials required for drainage and erosion control.

1.2 Scope of Work

The study involved an evaluation of the erosion potential of soils occurring within the right-of-way by studying the terrain units, borehole logs, topography and surface drainage features. Soils were classified according to a "soil erosion code" system to provide a basis for determining the erosion susceptibility of various soil types. Potential problem areas were identified from a field reconnaissance and interpretation of aerial photographs. Procedures for drainage and erosion control and structural solutions were developed for typical conditions to obtain a realistic basis for estimating the material requirements.

INTRODUCTION

List of Photos

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DEMPSTER LATERAL - PROPOSED PROCEDURES AND ESTIMATE OF MATERIAL REQUIREMENTS FOR EROSION CONTROL

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komex
consultants ltd.
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Frederic B. Claridge
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Douglas R. Piteau

March 20, 1979

Foothills Pipe Lines (Yukon) Ltd.
1600 Bow Valley Square II
205 - 5th Avenue S.W.
Calgary, Alberta
T2P 2W4

ATTENTION: DR. F. C. YIP

Dear Dr. Yip:

We are pleased to submit fourteen (14) copies of our report entitled, "Dempster Lateral, Proposed Procedures and Estimate of Material Requirements for Erosion Control".

The purpose of this report is to aid in estimating the cost of materials by providing approximate quantities of the various types of construction materials that would be required in drainage and erosion control facilities. Procedures for drainage and erosion control and structural solutions for typical conditions are also included in this report.

Should you have any questions regarding the contents, we shall be pleased to address them.

Yours very truly

KOMEX CONSULTANTS LTD.

A. Mirza, P. Eng.

AM/ct
ENCL.14

#965, 808 4th Avenue S.W., Calgary, Alberta, Canada. T2P 0K4/Telephone (403) 265-8266, 265-8267/Telex 03-822879

several local slopes near the terminus of the pipeline. It is further expected that most of the cuts will be into rock or talus. The remainder of the cuts are likely to be made in predominantly granular soils. It is anticipated that few, if any, special erosion or velocity control measures would be required on unfrozen, cut slopes in these materials. If cutting through frozen ground is found to be necessary, the use of diversion dikes and water breaks will generally be sufficient to re-direct flows away from the cut slopes and across the pipeline. Where cuts expose fine-grained soils, the slopes should be revegetated.

PHOTO 1 - VEGETATION GROWTH IN WATER COURSE WITH FLOW VELOCITY LESS THAN ABOUT 1.2 m/sec

PHOTO 2 - ICE-RICH CUT IN CLAYEY SOIL AT MILE 343 OF THE DEMPSTER HIGHWAY AND ADJACENT TO KM 255 OF THE PROPOSED PIPELINE ROUTE

PHOTO 3 - EROSION IN ICE-RICH CUT AT MILE 343 OF THE DEMPSTER HIGHWAY

PHOTO 4 - ICE-RICH HIGHWAY CUT NEAR KM 255 OF THE PROPOSED PIPELINE ROUTE, PROTECTED WITH RIP-RAP

PHOTO 7 - PONDING AT CULVERT OUTLET - EAGLE PLAIN

PHOTO 8 - VIEW OF ENGINEER CREEK

PHOTO 5 - HIGHWAY CUT NEAR EAGLE RIVER CROSSING

PHOTO 6 - DITCH SLOPE SLUMPING AND REGRESSING NEAR EAGLE RIVER

PHOTO 9 - DAMAGE TO HIGHWAY DUE TO UNCONTROLLED OUTLET FLOW AND ABSENCE OF LET DOWN AND STILLING BASIN

3. SOIL EROSION CODE SYSTEM

The diversity in physical characteristics of soils encountered along the pipeline route necessitates a system of classification based on those characteristics that are fundamental to erosion. A soil classification system has been devised to identify various soil types in terms of their susceptibility to erosion processes. This classification system is referred to as the Soil Erosion Code (SEC). It allows delineation of erodible soil types along the pipeline right-of-way and serves as a guide for selecting suitable designs for controlling erosion.

Under the Soil Erosion Code system, soils with similar erodibility characteristics are grouped under a single code, each code consisting of two letters. The first letter indicates the thermal condition of the soil: "U" designates an unfrozen soil and "F" represents a frozen soil. The second letter of the SEC indicates the erodibility classification of the soil. The combination of both letters is used to identify thermal and erosion characteristics of all the soils encountered along the proposed pipeline route.

The Soil Erosion Code system follows the simple rule of designating a natural soil by its principal constituent fraction, i.e. the component having the highest percentage by weight. The materials identified from borehole logs, terrain classifications and surficial geology maps have been classified in three major categories: peat (P), soils (G, S, M, L, C) and bedrock (B).

a) Soils

Soils are divided into three principal groups based on grain size: "coarse-grained", "fine-grained", and "mixed-grained" soils. The coarse-grained soils represent gravel (when the predominant grain size is between 0.1 mm and 2.0 mm). Under the Soil Erosion Code, free-draining, relatively clean sand and gravel which is not readily erodible is classified as a "G" type soil, if it contains less than 7% silt or clay content. Where more than 7% silt or clay is present, the soil is classified as mixed-grained, which can be either predominantly coarse-grained, or fine-grained. Predominantly coarse-grained soil, such as silty or clayey sand and gravel, with a silt-clay content less than 50%, is identified as "S" in the Soil Erosion Code. When the amount of fines is greater than 50%, corresponding to a sandy or gravelly silt or clay, it is classified as 'M' in the SEC. Since the erosion potential of mixed soils can vary with the amount of fines and the geologic origin of the deposits, further subdivision of this group would be advisable during the design stage. At present, such a subdivision is not practical due to the limited number of grain-size analyses available.

In the fine-grained category, silts, including organic, inorganic and clayey silt are identified in the SEC as "L", while clay or silty clay is classified as "C".

Ice Content In Frozen Soils

For the purpose of erosion control, the ice content in a soil sample is identified as low, high or massive. If a sample contains little or no visible ice and maintains its natural structure when thawed (i.e. does not become a slurry), it is considered to have low ice content.

The ice content is considered to be high when a sample contains visible ice in excess of 20% by volume, or when a sample tends to behave as a slurry upon thawing. Massive ice inclusions are considered to be present where ice constitutes more than 50% of the soil sample, or where there are ice layers thicker than 2.5 cms.

b) Peat

Peat and organic matter having a fibrous texture is represented with an erosion code of P.

c) Bedrock

Unweathered bedrock, or frozen bedrock that does not crumble under hand pressure when thawed, is considered non-erodible and classified as "B". However, if the bedrock is weathered, it is identified as S, M, L or C, depending upon the degree of weathering.

The relationship between the SEC, terrain type and soil type is shown on Table I. Where borehole information and laboratory tests are available, the SEC can be determined by using the Unified Soil Cassification System (Table I). In the absence of borehole and laboratory data, terrain type data can be correlated to obtain the most likely SEC for use in preliminary designs.

The SEC combinations considered in this study are shown in Table II, along with descriptions of each SEC, occurrences along the route and erosion potential. Descriptions of soil characteristics, occurrences and erosion potential are based on the following data sources:

a) 1976 and 1977 test hole logs prepared by Klohn Leonoff Consultants Ltd.

b) 1978 terrain typing by R. M. Hardy and Associates Ltd.

c) 1978 reconnaissance of pipeline route by Komex Consultants Ltd.

d) 1972 and 1976 test hole logs and laboratory tests along the Dempster Highway route from the Department of Public Works.

The accuracy of soil classifications are based on presently available data and are considered adequate for estimating material requirements for erosion control. However, additional soil investigation and SEC refinements will be required prior to doing final designs.

LOCATION					Terrain Type	SEC	ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			Remarks
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.			less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	
861.5	874.3	12.8	41	10	Gm, Gp (Ap)	US (UP)			X											.7	.2		
880.4	881.8	1.4	G41A	10	$\frac{Mv \cdot Cv}{iR}$	UM				X					1.4		.5		3-10%				
884.4	888.7	4.3	G41A	10	Mh . $\frac{pOv}{Lp}$	US & UP .7 .3				X					1.8		.3		3-10%				
903.8	912.2	8.4	G41C	11	Mm $\frac{pOv}{Ap}$. $\frac{pOv}{Lp}$ $\frac{Mv}{iR}$, Mm·$\frac{pOv}{M}$ $\frac{Mv \cdot Cv}{iR}$	UM & UP .7 .3				X					1.9		.4		3-10%				
912.2	922.0	9.8	G41D	11	$\frac{Mv \cdot Cv}{iR}$ Mm & Ap·Cp & Cm & Gp	UM & US .8 .2									3.8		X		3-10%				
930.0	936.8	5.9	43	11	Mm· $\frac{Mv}{mR}$, Lb	UM (FL)			X	X					3.6		.3		3-10%				
949.8	952.1	2.3	44	11	Mp, $\frac{MvCv.Mm}{vR}$ vR·Cm	UM (UB)			X	X										.3	.2		
961.3	977.3	16.0	45	11	At, Gt (Cm)	US (UM)				X										.4	.2		
976.8	984.4	12.4	46	11	Gt (Ap)	US				X										.3	.1		stream
981.1	998.7	17.6	47	11	Gt, At, Ap & Gp	US														.8	.1-.3		
998.7	1016.3	17.6	48	11	Ap, Gh, Gt Gm															.2 11.3	.1 .1		
1016.3	1035.2	18.9	G48A	11	Gh, Gt, At, Gm, Af, Ap, Ap-k, Gp (vR.$\frac{Cv}{vR}$+ Cm)	US US (UM & US)									5.3		.1 - .2		3-10%				
1034.1	1046.6	12.5	G48B	12	At, Gt, Gp (vR . $\frac{Cv}{vR}$)	US (UM & UB)									.5 4.8		 .2	.3 	10-30% 3-10%				

LOCATION							ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			
om (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.	Terrain Type	SEC	less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	Remarks
832.0	846.3	14.3	39	10	Mm & Mp/IR & Mp Ev/Gp & Mp/IR & Mm Cm	UM									6.5		.7		3-10%				
846.3	848.5	2.2	39	10	Gt	US																	
51.2	858.4	7.2	40	10	Mv/IR, (Ap,At)	UM									1.4		.5		3-10%				
					Mp Mv/ssR	US									.6		.3		3-10%				
58.4	861.7	3.3	40	10	Af, At Ap·Ap_2 (CM)	US (UM)														.2	.1		

LOCATION							ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.	Terrain Type	SEC	less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	Remarks
724.3	725.9	1.6	G33A	9	$\frac{Cv}{At}$.Af	FM		X		X			X										
725.9	728.3	2.4	G33A	9	Ap_2 Ap_1 At Af	US						X X			1.3		.5		3-10%				
728.3	730.0	1.7	G33A	9	$\frac{Cv}{At}$	FM		X					X		1.7		.5		3-10%				
730.0	731.4	1.4	G33A	9	Af,At	US						X											
731.4	741.2	9.8	G33A	9	$\frac{Cv}{At}$,Cm.Af,$\frac{Cv}{Gp}$ $\frac{Ev}{Gp}$,$\frac{Cv}{Gp}$-C	FM (US)		X				X	X				.5		3-10%	.8		.2	Stream Crossing
741.2	743.9	2.5	G33B	9	$\frac{Ev}{Gp}$,$\frac{Cv}{Gp}$	UM						X								.8		.2	
743.7	744.4	3.7	G33B	9	Mp&$\frac{pOv}{Mp}$&$\frac{pOv}{At}$ Ap_2.$\frac{pOv}{Ap}$	FP (FM&US)		X															
747.4	748.4	1.0	G33B	9-10	Ap	US																	
748.4	749.4	1.0	G33B	10	$\frac{pOv}{At}$, $\frac{pOv}{Cm}$	FP		X												1.0		.2	
749.4	751.8	2.4	G33B	10	$\frac{Cv}{Gp}$ -C $\frac{Ev}{Gp}$	UM																	
768.9	784.3	15.4	35	10	$\frac{Ev}{Gp}$ & $\frac{Ev}{Gp}$.pO-k (fO.pO)^1	UM (UP)														.2		.2	
817.0	823.3	6.3	38	10	At Ap_2	US																	
823.3	828.7	5.4	38	10	Ap_2 Ap_2 fO	US UP																	
828.7	832.4	3.7	38	10	Cm $\frac{Ev}{Gp}$	UM														.2		.2	

LOCATION					Terrain Type	SEC	ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			Remarks
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.			less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	
701.7	704.8	3.1	32/31	9	AfAp	US	X			X		X											
704.8	713.8	9.0	33/32	9	Af,At Af (mqR)	US (UB)			X	X		X			2.8		1.0		3-10%				
713.8	723.0	9.2	33/32	9	$\frac{Cv.Mv}{mqR}$ · $\frac{Mv}{mqR}$ $\frac{Cv}{mqR}$	UM			X	X		X			4.8		1.0		3-10%				

LOCATION					Terrain Type	SEC	ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			Remarks
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.			less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	
641.0	651.7	10.7	G27I	8-9	Mm & $\frac{Cv}{M}$	FM (FS&FP)		X	X			X											
					Af&Ap&$\frac{pOv}{M}$			X	X				X		3.5		.5		3-10%				
651.7	658.8	7.1	G27I	9	Af.Cv ($\frac{Ev}{M}$)	FS & FM		X	X			X											
658.8	661.0	2.2	29(28)	9	$\frac{Ev}{M}$, pOv, Af.Ct-S $\frac{Ev}{G\text{-}p}$	UM (UP)	X								2.2		.2						
661.0	664.0	3.0	29(28)	9	Gp (Ap)	US	X								3.0		.5		3-10%				
664.0	670.6	6.6	29(28)	9	Ma, Af, $\frac{Ev}{Mn}$ Ap, $\frac{Ev}{Mp}$, $\frac{pOv}{Lp}$ Mh	UM (US) (UP)	X													1.6	.5		
															1.2		.5		3-10%				
671.9	677.0	5.1	30/29	9	Ct, Mn (Ap)	UM (US)	X		X			X											
													X		2.0		1.0		3-10%				
677.0	677.3	.3	31/30	9	Mn	UM	X		X				X							.3	1.0		
677.3	678.0	.7	31/30	9	ssR	UB	X					X								.7	1.0		
678.0	679.9	1.9	31/30	9	$\frac{Mv}{R}$	UM	X		X			X								1.9	1.0		
679.9	687.3	7.4	31/30	9	At, Gp, Ap Cr	US (UG)	X		X			X											
684.2	686.2	2.0	32/31	9	Af & mqR 3 7	FB & US .7 .3	X		X			X			2.0			.8	3-10%				
686.2	690.0	3.8	32/31	9	Ap & Af	US	X					X			1.0		.2		3-10%				
690.0	692.9	2.9	32/31	9	$\frac{Cv}{mR}$&$\frac{Cv}{Af}$&mqR	FM & FB .8 .2	X		X			X	X		2.9		.2		3-10%				
692.9	694.2	1.3	32/31	9	Af	US	X		X			X											
694.2	701.7	7.5	32/31	9	$\frac{Cv}{Af}$ ($\frac{Af}{mR}$)	FM (FB & US)	X		X	X		X											

LOCATION							ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.	Terrain Type	SEC	less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	Remarks
605.7	606.6	.9	G27E	8	Cb(P)	FM		X				X											
606.6	607.1	.5	G27E	8	ScR $\frac{Cv}{sR}$	FM .5 FB .5	X					X								.5		.4	
607.1	607.6	.5	G27E	8	Ap	FS	X					X											
607.6	609.1	1.5	G27E	8	Cb(P)	FM		X				X								1.0	.4		
609.1	609.9	.8	G27E	8	ScR. $\frac{Cv}{sR}$	FB & FM	X						X							.8		.4	
609.9	614.7	5.8	G27E	8	Cb(P) & $\frac{Cv}{sR}$	FM		X				X X	X							1.0	1.0		
614.7	615.4	.7	G27E	8	ScR	FB	X					X								.7	1.0		
615.4	617.1	1.7	G27G	8	ScR	FB	X					X								.6 1.1	.5	.2	
617.1	624.4	7.3	G27G	8	Cb(P) - R	FM		X				X	X							4.6	1.0		
624.4	624.8	.4	G27G	8	Ap	FS	X					X			5.2		.5		3-10%				
624.8	632.6	7.8	G27G	8	Cb(P) - R	FM		X				X			2.6		1.0		3-10%				
631.4	632.0	.6	G27H	8	Cb(P) - R smR	FM & FB	X					X			.6		.5		3-10%				
632.0	634.6	2.6	G27H	8	Cb(P) - R Mm	FM		X					X		2.6		.5		3-10%				
634.6	635.8	1.2	G27H	8	smR. $\frac{Cv}{sR}$	FB & FM	X					X			1.2		.5		3-10%				
635.8	639.0	3.2	G27H	8	Cb(P) - R Mm	FM		X					X		3.2		.5		3-10%				
639.0	639.8	.8	G27H	8	Ap,At $\frac{pOv}{M}$. k	FS & FP	X					X											
639.8	641.0	1.2	G27H	8	Mm	FM		X				X											

LOCATION					Terrain Type	SEC	ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			Remarks
From (km)	To (km)	Dis-tance (km)	Align-ment Sheet No.	Spread No.			less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Great-er than 30%	
574.6	577.0	2.4	G27B	8	Ap_1 Ap_2 At (Cb(P)	FS (FM)	X		X			X			1.2		.5		3-10%				
577.0	580.5	3.5	G27B	8	Cb(P) Cm (At)	FM (FS)		X	X				X		3.5		.5		3-10%				
580.5	582.5	2.0	G27B	8	Af At Ap_1 Ap_2	FS	X		X			X			.6 1.4		.5	 .8	3-10% 3-10%				
582.5	583.7	1.2	G27B	8	ScR	FB	X					X			1.2			.8	3-10%				
586.0	586.3	.3	G27C	8	ScR	FB	X					X			.3			.8	3-10%				
586.3	589.0	2.7	G27C	8	Cb(P)	FM		X				X			1.5		1.0		3-10%				
589.0	591.9	2.9	G27C	8	At (Cb(P))	FS FM	X					X											
591.9	593.6	1.7	G27C	8	ScR	FB	X					X			1.7			1.0	3-10%				
593.6	596.0	2.4	G27C	8	Ap, (Cb(P)), At	FM .6 FS .4	X					X											
596.0	597.7	1.7	G27C	8	Ap_2	FS	X					X								.3	.1		
597.7	599.2	1.5	G27C	8	Cb(P)	FM		X				X											
596.6	598.4	1.8	G27D	8	Cb(P)	FM		X						X									
598.4	599.2	.8	G27D	8	At, Ap, (Cb(P)) 5 5	FM .5 FS .5	X					X											
599.2	600.0	.8	G27D	8	ScR. $\frac{Cv}{sR}$	FB & FM .5 .5	X		X			X			.8		1.0		3-10%				
600.0	602.0	2.0	G27D	8	Cb(P)	FM		X	X				X		2.0		1.0		3-10%				
602.0	603.1	1.1	G27D	8	At & Cb(P) 3 7	FS .3 FM .7	X		X			X											
603.1	603.9	.8	G27D	8	ScR	FB	X		X			X			.8		1.0		3-10%				
603.9	605.7	1.8	G27D	8	Cb(P), At, Ap_2 5 5	FM FS 5 5	X		X			X											

LOCATION							ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			
From (km)	To (km)	Dis-tance (km)	Align-ment Sheet No.	Spread No.	Terrain Type	SEC	less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	Remarks
543.3	549.0	5.7	26(25)	7	At, Ap	FS	X					X											
549.0	549.6	.6	26(25)	7	Cb(P)	FM		X					X							.6		.1	
549.6	554.7	5.1	26(25)	7	At, Af	FS	X					X											
554.3	555.3	1.0	(27)26	7	At	FS	X					X											
555.3	556.1	.8	(27)26	7-8	ScR	FB	X					X								.8		.8	
556.1	563.2	7.1	(27)26	8	Ap_1 Ap_2 At' At (Cb(P))	FS (FM)	X					X											
563.2	563.9	.7	(27)26	8	$\frac{Cv}{sR}$	FM		X					X							.2		.2	
563.9	564.2	.3	(27)26	8	At	FS	X					X								.3		.3	
564.2	566.5	2.3	G27A	8	Ap_1 Ap_2	FS	X					X			1.2 .9		.5	 1.0	3-10% 3-10%	.2		.1	
566.5	566.9	.4	G27A	8	ScR	FB	X					X			.4			1.0	3-10%				
566.9	568.0	1.1	G27A	8	At	FS	X					X			1.1			1.0	3-10%				
568.0	569.0	1.0	G27A	8	Ap_2	FS	X					X			1.0			1.0	3-10%				
569.0	570.0	1.0	G27A	8	At	FS	X					X			1.0		.4		3-10%				
570.0	571.3	1.3	G27A	8	ScR. $\frac{Cv}{sR}$	FB & FM		X	X				X							1.3		1.0	
571.3	572.4	1.1	G27A	8	Ap_2 & $\frac{Av}{At}$	FS	X					X											
571.5	572.4	.9	G27B	8	$\frac{Cv}{sR}$, Cb(P)	FM		X				X	X		1.5			1.0	10-30%				
573.4	574.0	.6	G27B	8	ScR	FB	X					X			.6			1.0	10-30%				
574.0	574.6	.6	G27B	8	ScR. $\frac{Cv}{sR}$ $\frac{Cv}{sR}$ - R	FM FB	X					X	X		.2			1.0	10-30%				

LOCATION							ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.	Terrain Type	SEC	less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	Remarks
505.6	508.1	2.5	G22C	7	ss,smR. $\frac{Cv}{sR}$	FB & FC .5 .5		X					X		2.5			.2	10-30%				
508.6	510.1	1.5	G22D	7	ss,smR. $\frac{Cv}{sR}$	FB & FC .5 .5						 X	X 		1.0 .5		 .4	.2 	10-30% 3-10%				
510.1	510.3	.2	G22D	7	Cm	FM							X		.2		.1		3-10%				Stream Crossing
510.3	513.1	2.8	G22D	7	ss,smR. $\frac{Cv}{sR}$	FB & FC .5 .5							X		2.8		.4		3-10%				
513.1	516.4	3.3	G22D	7	ss,smR	FB				X		X			3.3			.1	3-10%				
516.4	517.2	.8	G22D	7	ss,smR. $\frac{Cv}{sR}$	FB & FC .5 .5				X			X		.8		.3		3-10%				
518.3	525.6	6.2	24	7	ss,smR (ss,smR. $\frac{Cv}{sR}$)	FB (FM)				X		X			3.0 3.2		 .1	.1 	3-10% 3-10%				
525.6	529.9	4.3	24	7	ss,smR. $\frac{Cv}{sR}$	FB & FM .5 .5				X		X	X		4.3		.1		3-10%				
526.4	527.1	.7	25	7	Cm. $\frac{Cv}{sR}$	FC	X			X					.7		.3		3-10%				
527.1	529.9	2.8	25	7	Ap_1&Ap_2&At	US	X					X								.4	.3		River Crossing
529.9	533.1	3.2	25	7	Cb(P)	FM		X															
533.1	535.6	2.5	25	7	Af	FS	X																
535.6	539.6	4.0	25	7	Cm. $\frac{fOv}{Cm}$ & $\frac{fOv}{Cb(P)}$	FM & FP																	
539.6	541.1	1.5	25	7	$\frac{Cv}{sm,smR}$	FM									1.5		.1		3-10%				
541.4	543.3	1.9	26(25)	7	Cb(P)	FM		X					X		.4			.2	3-10%				

LOCATION					Terrain Type	SEC	ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			Remarks
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.			less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	
436.5	439.3	2.8	21(20)	6	$\frac{\text{Cv}}{\text{sm,ssR}}$	FC		X		X		X											
439.3	443.6	4.3	22(21)	6	$\frac{\text{Cv}}{\text{sm,ssR}}$	FC		X	X	X					1.3		.1		3-10%				
443.6	454.9	11.3	22(21)	6	sm,ssR.$\frac{\text{Cv}}{\text{sR}}$ (Cm)	FC & FB									2.0			.5	0-3%	7.1	.1-.3		
454.2	464.5	10.3	G22A	6- 7	ss,smR.$\frac{\text{Cv}}{\text{sR}}$ ss,smR	FC & FB .3 .7	X			X		X			10.3		.2		3-10%				
464.5	464.8	.3	G22A	7	Cm,Ap;pO-k	FS (FP)		X				X			.3		.1		10-30%				Stream Crossing
464.8	468.8	4.0	G22A	7	ss,smR.$\frac{\text{Cv}}{\text{sR}}$ ss,smR	FC & FB .3 .7	X					X			.9 3.1		 3-1.0	.1	10-30% 3-10%				
468.8	469.0	.2	G22A	7	Cm,Ap,pO-k	FS FP .7 .3		X				X								.2	.1		Stream Crossing
469.0	472.8	3.8	G22A	7	ss,smR.$\frac{\text{Cv}}{\text{sR}}$ ss,smR	FB & FC .7 .3	X					X			2.5		.2		3-10%				
471.9	491.9	20.0	G22B	7	ss,smR.$\frac{\text{Cv}}{\text{sR}}$ ss,smR (Cm)	FB & FL .6 .4	X X X	X	X	X		X			1.8 14.7		 .2-.5	.3	3-10% 3-10%	1.9		.1	
491.0	496.0	5.0	G22C	7	ss,smR.$\frac{\text{Cv}}{\text{sR}}$ ss,smR	FC & FB .3 .7	X			X		X			5.0		.3		3-10%				
496.0	496.5	.5	G22C	7	Cm	FC		X					X		.5			.2	10-30%	Stream Crossing			
496.5	501.0	3.5	G22C	7	ss,smR.$\frac{\text{Cv}}{\text{sR}}$	FC & FB .5 .5		X				X			.8 1.1 1.6		 .2	.2 .1	10-30% >30% 3-10%	Stream Crossing			
501.0	505.6	4.6	G22C	7	ss,smR (ss,smR.$\frac{\text{Cv}}{\text{sR}}$)	FB (FC)	X			X		X			4.6		.1-.2		3-10%				

LOCATION					Terrain Type	SEC	ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			Remarks
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.			less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	
405.0	406.7	1.7	G20F	6	Cv/sm,ssR ss,smR	FC (FB)		X		X		X											
406.7	408.6	1.9	G20F	6	ss,smR Cv/sm,ssR	FB (FC)	X			X		X			1.9		.3		0-3%				
408.6	411.3	2.7	G20F	6	Cv/sm,ssR ss,smR	FC (FB)		X				X			1.3		.7		0-3%				
411.3	414.2	2.9	G20F	6	Cv/sm,ssR ss,smR	FC (FB)		X					X		2.9		.7		0-3%				
413.4	415.1	1.7	G20G	6	Cv/sm,ssR	FM		X		X					1.7		2.0		3-10%				
415.1	419.5	4.4	G20G	6	ss,smR	FB	X			X													
419.5	421.4	1.9	G20G	6	Cv/ss,smR	FM		X		X													
421.4	423.3	1.9	G20G	6	Cv/At (Cm. Cv/sm,ssR)	FS (FM)		X		X										.3 River/Stream Crossing .7		.1 .3	
423.3	425.1	1.8	G20G	6	Cm,Ap (At)	FS		X		X													
425.1	427.2	2.1	G20G	6	Cv/sm,ssR	FM		X		X													
426.5	427.7	1.2	21(20)	6	Cv/sm,ssR	FC		X		X		X											
427.7	430.8	3.1	21(20)	6	sm,ssR	FB	X		X	X		X											
430.8	435.1	4.3	21(20)	6	Cv/sm,ssR	FC		X		X		X											
435.1	436.5	1.4	21(20)	6	sm,ssR	FB	X		X			X								1.4	.2		

LOCATION							ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.	Terrain Type	SEC	less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	Remarks
364.0	365.9	1.9	G20C	5	ss, smR	FB (FP)		X		X		X			1.9		.7		0-3%				
365.9	372.4	6.5	G20C	5	Cb(P)	FM		X		X			X		6.5		.7		0-3%				
372.4	373.9	1.5	G20C	5	Cv·Av / sm, ssR	FM		X		X			X							.4		.2	stream crossing
373.9	374.5	.6	G20C	5	Ap	FS	X			X			X							.2		.2	stream crossing
374.5	379.5	5.0	G20C	5	Cv·Av / sm, ssR Cv / sm, ssR	FC		X		X		X	X		1.3		.7		0-3%				
379.5	380.8	1.3	G20D	5	Cv / sm, ssR	FC		X		X		X											
380.5	381.1	.3	G20D	5	At	FS	X			X		X											
381.1	384.8	3.7	G20D	6	Cv / sm,ssR	FC				X		X											
384.8	385.1	.3	G20D	6	At	FS				X		X											
385.1	387.5	2.4	G20D	6	Cv / sm,ssR	FM				X		X											
387.5	390.6	3.1	G20E	6	Cv / sm, ssR	FC				X		X											
390.6	390.8	.2	G20E	6	At	FS				X		X											
390.8	395.0	4.2	G20E	6	Cv / sm, ssR ss,smR·Cv / sR (At)	FC FB (FS)				X		X											
395.0	400.6	5.6	G20E	6	ss, smR (Cv / ss, smR)	FB (FC)			X	X		X			2.6		1.0		0-3%				
400.6	405.0	4.4	G20F	6	ss, smR (Cv / sm, ssR)	FB (FC)	X		X	X		X											

LOCATION					Terrain Type	SEC	ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			Remarks
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.			less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	
315.9	316.9	1.0	18	5	ss, smR	FB	X		X														
316.9	322.9	6.0	18	5	Cb(P)	FC		X	X	X					6.0		1.0-2.0		0-3%				
322.9	324.3	1.4	18	5	ss, smR	FB	X								1.6			1-6	0-3%				
321.7	324.9	3.2	19(18)	5	ss, smR Cv/ssR	FB (FC)		X	X			X						.3		3.2			
324.9	329.4	4.5	19(18)	5	Mv·Cv/ss, smR ss, smR	FC FB		X	X	X			X X		1.0 3.2		/ .3 to .7		0-3% 3-10%	.3		.1	
329.4	330.4	1.0	19(18)	5	Ap_1, Ap_2	FS			X			X			.4		1.0		3-10%				
330.4	332.2	1.8	19(18)	5	Av/ss, smR	FM		X	X				X							1.8	.3		
332.2	337.7	5.5	19(18)	5	Cb(P) -G ss, smR	FB FC		X	X	X		X	X										
333.3	339.4	6.1	20(19)	5	smR - s	FB	X		X			X								.6	.1		
339.4	344.7	5.3	20(19)	5	Cb(P) -G smR - s	FB FS		X	X			X	X		5.3		2.0		0-3%				
344.7	354.8	10.1	G20A	5	Cb(P) -G ss, smR	FC FB		X	X			X	X		9.9		1.0-3.0		0-3%	.2	.2		
352.6	360.4	7.8	G20B	5	Cb(P) -G Cv/ss, smR	FM FC		X	X			X	X		4.8		1.0-3.0		3-10%	.1		.1	
360.4	361.7	1.3	G20B	5	Ap			X	X			X	X										
361.7	362.5	.8	G20C	5	Ap	FS	X			X		X											stream crossing
362.5	364.0	1.5	G20C	5	Cv·Av/ss, smR	FM		X		X			X		1.5		.2		0-3%				

LOCATION							ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.	Terrain Type	SEC	less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	Remarks
276.0	276.6	.6	G16A	4	Cm·ss, smR - G	FM														.6		.6	river crossing
276.6	282.2	5.6	G16A	4	$\frac{Mv}{smR}$ -R	FC														.5	.3		
282.2	285.6	2.6	G16A	4	$\frac{Mv \cdot Cv}{smR}$ -R	FC, FM														.6	.2		
285.6	286.9	1.3	G16A	4	Cb(P)-G	FS																	
286.9	289.3	2.4	G16A	4	$\frac{Mv \cdot Cv}{smR}$ -R	FC, FM				X										1.7	.1		
289.3	292.6	3.3	G16A	4	ss, smR	FB				X													
292.6	297.9	5.3	G16A	4	ss, smR Cb(P) -G	FB, FS				X													
297.1	298.8	1.7	17	4	ss, smR	FB		X		X		X											
298.8	304.1	5.3	17	4	Cb(P) -G	FC		X	X				X		4.0		2.0		0-3%				
304.1	305.4	1.3	17	4	$\frac{Cv}{ss,\ smR}$	FC		X	X			X											
305.4	308.5	3.1	17	4	Cb(P) -G Mp	FC		X	X			X											
308.5	311.4	2.9	18	4	ss, smR Cb(P) -G	FC, FB		X	X						1.0		.2		0-3%				
311.4	311.8	.4	18	4	Ap	FL		X	X											.3	.1		
311.8	314.5	2.7	18	4	Cb(P) - G	FC		X	X	X													
314.5	315.9	1.4	18	4	Cb(P) -G $\frac{Cv}{ss,\ smR}$ -C	FC		X	X						1.4		1.0		3-10%				

LOCATION							ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.	Terrain Type	SEC	less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	Remarks
275.4	275.6	.2	16	4	Ap_1 & Ap_2	FM		X				X			.1								
275.6	275.9	.3	16	4	water							X											
275.9	276.1	.2	16	4	Ap_2	FM		X				X			.1								
276.1	277.7	1.6	16	4	Ap - k	FM		X				X											

LOCATION					Terrain Type	SEC	ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			Remarks
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.			less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	less than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	
252.7	259.2	6.5	G14	4	Mp·pO·fO 8 1 1 Mn·fO,fO.pO 8 2	FP FC		X				X											
259.2	260.1	.9	G14	4	Mh·Mv/smR	FC (FP)		X				X											
260.1	260.7	.6	G14	4	fO·pO	FP		X				X											
260.7	261.2	.5	G14	4	Mm	FC		X				X											
261.2	262.0	.8	G14	4	fO·pO	FP		X				X											
262.6	264.8	2.2	16	4	Mp & pOv·fOv/Mp	FC & FP		X				X											
264.8	264.9	.1	16	4	Cm	FL		X					X		.1		X		.1				
264.9	265.6	.7	16	4	Mp - R	FC		X				X											
265.6	267.5	1.9	16	4	Mp·pO 5 1 fO·pO	FC FP		X			X												
267.5	268.9	1.4	16	4	Mp & fO	FC FP		X				X											
268.9	270.1	1.2	16	4	Mp - R	FC		X				X											
270.1	270.9	.8	16	4	Ap - k	FM		X				X											
270.9	272.4	1.5	16	4	Mp - R	FC		X				X											
272.4	273.7	1.3	16	4	fO·pO	FP		X				X											
273.7	274.4	.7	16	4	Mp	FC		X				X											
274.4	274.6	.2	16	4	Ap - k	FM		X				X											
274.6	274.9	.3	16	4	Mv/smR	FC		X					X		.3		X	.1	10-30%				
274.9	275.4	.5	16	4	Ap - k	FM		X				X											

LOCATION					Terrain Type	SEC	ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			Remarks
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.			less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	
229.0	229.9		G13E	3	Ap - k	FM		X				X											
229.9	230.2	.3	G13E	3	$\frac{pOv}{smR}$ $\frac{pOv}{Mp}$	FP		X				X											
231.6	233.2	1.6	G13F	3-4	$\frac{pOv}{smk}$ · $\frac{pOv}{Mp}$	FP		X				X											
233.2	233.6	.4	G13F	4	$\frac{Mv}{smR}$· pO	FC FP		X				X											
233.6	243.7	10.1	G13F	4	$\frac{pO\cdot fO}{Mp}$ $\frac{pOv\cdot fOv}{Mp}$ $\frac{fOv}{Mp}$ fO·pO	FP		X				X											
243.7	243.9	.2	G13F	4	Mp	FC		X				X											
243.9	244.2	.3	G13F	4	$\frac{pOv\cdot fOv}{Mp}$ fO·pO	FP		X				X											
244.2	244.9	.7	G13F	4	Mp	FC		X				X											
244.9	245.0	.1	G13F	4	fO·pO	FP		X				X											
245.0	245.4	.4	G13F	4	$\frac{pOv\cdot fOv}{Mp}$ ·$\frac{Mv}{smR}$	FP FC		X				X											
245.4	245.5	.1	G13F	4	Cm	FM		X					X							.1		.1	
245.5	245.6	.1	G13F	4	Ap	FM		X					X							.1		.1	
245.6	247.7	2.1	G13F	4	Mn·fO·pO	FP FC		X				X											
247.7	248.1	.4	G13F	4	Mp	FC		X					X							.1		.4	
248.1	248.5	.4	G13F	4	Mn·fO·pO 6 3 1	FC FP		X				X											
248.5	251.7	3.2	G14	4	Mn·fO·pO 6 3 1 fO	FP FC		X				X											
251.7	252.7	1.0	G14	4	Mn	FC		X				X											

LOCATION							ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.	Terrain Type	SEC	less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	Remarks
220.3	224.1	3.8	G13E	3	Mp-R	FC		X				X											
224.1	227.5	3.4	G13E	3	Md	FC		X				X											
227.5	227.6	.1	G13E	3	Ap_1	FM		X					X							.1	.1		river crossing
227.6	228.9	1.3	G13E	3	water																		river crossing
228.9	229.0	.1	G13E	3	Ap_1	FM		X					X							.1	.1		river crossing

LOCATION							ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.	Terrain Type	SEC	less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	less than 30%	Remarks
180.9 continued	181.1	.2	G13C	3	pOv·fOv/Mp	FP FC		X	X			X											
					Ap	FM		X	X			X											
197.4	198.6	1.2	G13D	3	Mp	FC	X		X			X											
198.6	199.4	.8	G13D	3	pOv·fOv/Mp	FP		X	X			X											
199.4	201.2	1.8	G13D	3	Mp	FC	X		X			X											
201.2	201.7	.5	G13D	3	pOv·fOv/Mp	FP		X	X			X											
201.7	202.6	.9	G13D	3	Mp	FC	X		X			X											
202.6	203.8	1.2	G13D	3	pOv/Mp	FP		X	X			X											
203.8	208.5	4.7	G13D	3	Mp	FC	X		X			X											
208.5	208.6	.1	G13D	3	Cm	FM		X	X				X							.1		.1	
208.6	208.9	.3	G13D	3	Ap	FM		X	X			X											
208.9	209.0	.1	G13D	3	Cm	FM		X	X				X							.1		.1	
209.0	209.5	.5	G13D	3	Mp	FC	X		X			X											
209.5	211.1	1.6	G13D	3	fOv·pOv/Mp	FP		X	X			X											
211.1	214.4	3.3	G13D	3	Mp-R	FC	X		X			X											
214.4	214.5	.1	G13D	3	fO	FP		X	X			X											
214.5	218.5	4.0	G13D	3	Mp-R	FC	X			X		X											
216.5	217.8	1.3	G13E	3	pO·fO/Mp	FP & FC		X				X											
217.8	220.3	2.5	G13E	3	Mp	FC		X				X											

REGION II

LOCATION					Terrain Type	SEC	ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			Remarks
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.			less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	
178.0	178.2	.2	G13C	3	fO	FP		X	X			X											
178.2	178.7	.5	G13C	3	Mv / smR	FC	X		X			X											
178.7	178.8	.1	G13C	3	fO	FP		X	X			X											
178.8	179.2	.4	G13C	3	Gm	FM	X		X			X											
179.2	179.4	.2	G13C	3	Ap	FM		X	X			X											
179.4	180.0	.6	G13C	3	Gm	FM	X		X			X											
180.0	180.5	.5	G13C	3	Mp	FC		X	X			X											
180.5	180.7	.2	G13C	3	Ap	FM		X	X			X											
180.7	180.9	.2	G13C	3	Mv / smR	FC	X		X			X											
180.9	181.1	.2	G13C	3	Gm	FM	X		X			X											
					pO·fO	FP		X	X			X											
					Mp	FC		X	X			X											
					Mp·fO, fO·pO fO & fOv·pOv / Mp	FP		X	X			X											
					fOv·pOv	FP		X	X			X											
					Mp	FC		X	X			X											
					Ap	FM		X	X			X											
					Mp	FC		X	X			X											
					fOv·pOv / Mp	FP		X	X			X											
					Mp	FC		X	X			X											
					fOv·pOv / Mp	FP		X	X			X											
					Mp	FC		X	X			X											
					Ap	FM		X	X			X											
					Mp	FC		X	X			X											

LOCATION							ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.	Terrain Type	SEC	less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	Remarks
157.3	157.9	.6	G13B	2	Mp	FC		X				X											
157.9	158.1	.2	G13B	2	fO	FP		X				X											
158.1	161.1	3.0	G13B	2 - 3	Mp	FC		X				X											
161.1	162.1	1.0	G13B	3	pO·fO	FP		X				X											
162.1	163.5	1.4	G13B	3	Mm	FC		X				X											
163.5	163.7	.2	G13B	3	fO	FP		X				X											
163.7	165.1	1.4	G13B	3	Mv/sR	FC	X					X											
165.1	168.5	3.4	G13B	3	pOv·fOv/Mp &fO	FP		X				X											
168.5	168.7	.2	G13B	3	Cm	FM		X					X									.2	stream crossing
168.7	169.1	.4	G13B	3	Ap	FM		X	X			X											
169.1	169.3	.2	G13B	3	Cm	FM		X	X				X									.2	stream crossing
169.3	170.9	1.6	G13B	3	pOv·fOv/Mp	FP		X	X			X											
170.9	173.7	2.8	G13B	3	Mm & Mp	FC		X	X			X											
173.7	173.8	.1	G13B	3	fO	FP		X	X			X											
173.8	174.9	1.1	G13B	3	Mp	FC		X	X			X											
174.9	175.3	.4	G13B	3	Lb	FC		X	X			X											
175.3	177.0	1.7	G13B	3	Mv/smR	FC	X		X			X											
177.0	177.3	.3	G13B	3	fO	FP		X	X			X											

REGION I

LOCATION					Terrain Type	SEC	ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			Remarks
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.			less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	
22.4	24.0	1.6	4	1	Cm, Gp	FL					X									.2	.1		
81.3	91.9	10.6	9	1- 2	$\frac{Mv}{ssR}$ - G (Ap) (pO) (At)	FC (FS & FP)					X				1.5		.2		3-10%				

APPENDIX 2

LOCATION					Terrain Type	SEC.	Highway		Workpad				CHANNELIZED FLOW			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
													APPROXIMATE WIDTH OF CHANNEL COURSES			Length of Side Slope	Grade of Backslope			Length of Backslope				
													Continuous Flow		Intermittent Flow									
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.		3 to 10%	10 to 30%	>30%					
1171.1	1174.6	3.5	50	12	Gh	US								(1) 100m		.2 3.3	X		X	.1 .3	>30% 3-10%	River Crossing E		
1174.6	1175.5	.9	50	12	Lp	UL										.9	X			.3	3-10%	E		
1175.5	1176.7	1.2	50	12	Gh	US										1.2	X			.3	3-10%	E		
(Alternate) 1172.0	1174.0	2.0				US,UM																		

LOCATION					Terrain Type	SEC.	Highway		Workpad				CHANNELIZED FLOW			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
													APPROXIMATE WIDTH OF CHANNEL COURSES											
													Continuous Flow		Intermittent Flow	Length of Side Slope	Grade of Backslope			Length of Backslope				
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.		3 to 10%	10 to 30%	>30%					
1111.1	1130.8	19.7	G48G	12	Mv.Cv/sR & (ssR.Cv/sR)	UM (UB)							2		2	19.7		X		.1 - .4	3-10%	C		
(Alternate) 1130.0	1140.0	10.0				US																		
1140.0	1145.0	5.0															X							
1130.8	1149.5	18.7	48H	12	Mv.Cv/sR & Mv Mm/sR. ssR.MvCv/sR & Mv/sR	UM (UM&UB)							1		6	15.2		X		.1 - .3	3-10%	C		
														(1) 5-10m		3.5	X			.3	3-10%	D		
(Alternate) 1145.0	1147.0	2.0				UM																		
1147.0	1155.0	8.0				(UB)																		
1149.5	1152.6	3.1	49	12	Mv/sR.Mm-C	UM							1			1.4	X			.4	3-10%	D		
																1.7		X		.3	3-10%	C		
1152.6	1157.5	4.9	49	12	Gh,Gm	US							1		1	2.0 2.9	X	X		.3 .4	3-10% 3-10%	E E		
1157.5	1165.4	7.9	49	12	ssR.MvCv/sR (Af)	UM & UB (US)								(1) 5-10m		7.9	X			.4	3-10%	D		
													1											
(Alternate) 155.0	1172.0	17.0				US,UG							1											
164.1	1165.4	1.3	50	12	Mv.Cv/sR	UM	X									1.3	X			.3	3-10%	D		
1165.4	1169.4	4.0	50	12	Lp	UL	X									4.0	X			.3	3-10%	D		
1169.4	1170.3	.9	50	12	Mv.Cv/sR	UM	X									.9	X			.3	3-10%	D		
1170.3	1171.1	.8	50	12	Lp	UL	X									.8	X			.3	3-10%	D		

LOCATION					Terrain Type	SEC.	Highway		Workpad				CHANNELIZED FLOW			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
													APPROXIMATE WIDTH OF CHANNEL COURSES			Length of Side Slope	Grade of Backslope			Length of Backslope				
													Continuous Flow		Intermittent Flow									
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.		3 to 10%	10 to 30%	>30%					
1016.3	1035.2	18.9	G48A	11	Gh,Gt,At,Gm, Af,Ap,Ap-k, Gp ($vR.\frac{Cv}{vR}$&Cm)	US (UM&US)								(1) 5-10m		5.3 13.6	 X	X 		.1 - .2 .3	3-10% 3-10%	E F		
1034.1	1046.6	12.5	G48B	11- 12	At,Gt,Gp ($vR.\frac{Cv}{vR}$)	US (UM&UB)							1			.5 4.8 7.2	 X	 X 	X 	.3 .2 .4	10-30% 3-10% 3-10%	E E F		
1046.6	1049.7	3.1	G48C	12	Gt,At &Af ($vR.\frac{Cv}{vR}$)	US (UB&UM)										3.1	X			.2	3-10%	F		
1049.7	1051.6	1.9	G48C	12	$vR.\frac{Cv}{vR}$	UB										1.9	X			.2	3-10%	F		
1051.6	1062.0	10.4	G48C	12	Gt,At,Gp,Ap (pO)	US (FP)	X									10.4	X			.2	3-10%	F		
1061.3	1075.5	14.2	G48D	12	Gp,Ap,(Cm), Gt ($\frac{Cv.Mv}{vR}$)	US (UM)		X						(1) 5-10m	1	4.6 5.2	 X	X 		.3 .3	3-10% 3-10%	E F		
1075.5	1077.8	2.3	G48D	12	$\frac{Cv.Mv}{vR}$	UM	X									2.3		X		.3	3-10%	F		
1077.8	1080.4	2.6	G48D	12	At,Ap.Gh	US									2	2.6		X		.3	3-10%	F		
1082.2	1100.4	18.2	G48E	12	Gh,Gt,At,Ap	US		X						(1) 10-15m	1	3.8 14.4	 X	X 		.3 .4	3-10% 3-10%	E F		
(Alternate) 1087.0	1115.0	28	48E2	12	Gp,$\frac{MvCv}{vR}$,Gh	US UB		X																
1099.8	1103.6	3.8	G48F	12	Mm	UM	X								2	3.8	X			.4	3-10%	D		
1103.6	1108.6	5.0	G48F	12	$ssR.\frac{Mv}{sR}$	UM.UB	X	X								1.8 3.2	 X	X 		.3 .4	3-10% 3-10%	C D		
1108.6	1110.8	2.2	G48F	12	$\frac{Mv.Cv}{sR}$	UM							1			2.2		X		.3	3-10%	C		
(Alternate) 1115.0	1130.0	15.0				[illegible]																		

LOCATION					Terrain Type	SEC.	High-way		Work-pad				CHANNELIZED FLOW — APPROXIMATE WIDTH OF CHANNEL COURSES			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
													Continuous Flow		Intermittent Flow	Length of Side Slope	Grade of Backslope			Length of Backslope				
From (km)	To (km)	Dis-tance (km)	Align-ment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.		3 to 10%	10 to 30%	>30%					
922.0	928.2	6.2	G41D	11	Gt,(Cm),At, Ap.Lp,Ap_1, Ap_2	US & (UM)								(1) 180m		6.6	X			.5	3-10%	F		
928.2	933.8	5.6	G41D	11	(Gt), Cm, Mm.$\frac{Mv}{mR}$	FM (US)									2	5.6	X			.5	3-10%	C		
930.9	936.8	5.9	43	11	Mm.$\frac{Mv}{mR}$,Lb	UM (FL)	X	X							2	2.3 3.6	X	 X		.4 .3	3-10% 3-10%	D E		
936.8	938.1	1.3	43	11	$\frac{Av}{Lp}$	US	X									1.3	X			.4	3-10%	E		
938.1	949.8	11.7	43	11	Mm.$\frac{Mv}{mR}$ &Mm &$\frac{Mv.Cv}{vR}$. Mm (Mp.pO)	UM (FP)									2	11.7	X			.4	3-10%	E		
949.8	952.1	2.3	44	11	Mp,$\frac{MvCv}{vR}$ .Mm & vR.Cm	UM (UB)	X X	X X								2.0 .3	X	 X		.4 .2	3-10% 10-30%	D E		
952.1	961.3	9.2	44	11	At,Ap_1	US	X									.6	X			.4	3-10%	D		
961.3	977.3	16.0	45	11	At,Gt (Cm)	US (UM)		X X								.4 8.9	 X	X		.2 .4	10-30% 3-10%	E E		
976.8	984.4	12.4	46	11	Gt (Ap)	US		X					1			.3 12.1	 X	X		.1 .4	10-30% 3-10%	Stream Crossing E		
981.1	998.7	17.6	47	11	Gt,At,Ap & Gp	US							 2	1		.8 16.0	 X	X		.1 - .3 .4	10-30%	E E		
998.7	1016.3	17.6	48	11	Ap,Gh,Gt & Gm									(1) 5 - 10m	2	.2 6.1 11.3	 X	 X	X	.1 .1	>30% .3 10-30%	E F E		

LOCATION					Terrain Type	SEC.	High-way		Work-pad				CHANNELIZED FLOW — APPROXIMATE WIDTH OF CHANNEL COURSES			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
From (km)	To (km)	Dis-tance (km)	Align-ment Sheet No.	Spread			u/h	d/h	T	S	G	N	Continuous Flow: less than 4.5 m.	Continuous Flow: stream crossings	Intermittent Flow: less than 4.5 m.	Length of Side Slope	Grade of Backslope: 3 to 10%	Grade of Backslope: 10 to 30%	Grade of Backslope: >30%	Length of Backslope				
861.5	874.3	12.8	41	10	Gm,Gp (Ap)	US (UP)		X								12.1	X			1.0	3-10%	F		
																.7		X		.2	10-30%	E		
874.3	876.4	2.1	41	10	pOv/Gp	FP										2.1	X			1.0	3-10%	B		
876.4	877.4	1.0	41	10	Gp	US										1.0	X			1.0	3-10%	F		
877.4	878.1	.7	G41A	10	Gp & Mv.Cv/lR	US UM		X								.5	X			1.0	3-10%	F		
878.1	880.4	2.3	G41A	10	pOv/Gp (Af)	UP (US)		X								2.3	X			1.0	3-10%	F		
880.4	881.8	1.4	G41A	10	Mv.Cv/lR	UM		X								1.4		X		.5	3-10%	E		
881.8	884.4	2.6	G41A	10	Gp,Gh	US		X								2.6	X				3-10%	F		
884.4	888.7	4.3	G41A	10	Mh. pOv/Lp (Cm. Cv/lR)	US & UP .7 .3 (UM)		X								1.8		X		.3	3-10%	F		
								X								2.5	X			.5	3-10%	F		
889.1	903.0	13.9	G41B	10-11	pOv/Lp Mh.Ev pOv/Lp Mh. pOv/Lp	UM & UP									2	13.9	X			.1	3-10%	D		
903.8	912.2	8.4	G41C	11	Mm&pOv/Ap . pOv/Lp Mv/lR . Mm Mv/lR . Mm. pOv/m Mv.Cv/lR	UM & UP .7 .3		X							2	1.9		X		.4	3-10%	E		
																6.5	X			.1	3-10%	D		
912.2	922.0	9.8	G41D	11	Mv.Cv/lR &Mm & Ap.Lp&Gm&Gp	UM & US .8 .2								(1) 10-20m		3.8		X		.3	3-10%	E		
																6.0	X			.7	3-10%	E		

LOCATION					Terrain Type	SEC.	Highway		Workpad				CHANNELIZED FLOW			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
													APPROXIMATE WIDTH OF CHANNEL COURSES			Length of Side Slope	Grade of Backslope			Length of Backslope				
													Continuous Flow		Intermittent Flow									
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.		3 to 10%	10 to 30%	>30%					
784.3	798.8	14.5	36	10	$\frac{Ev}{Gp}$, Gm (pO-k)($\frac{fOv}{Gp}$) ($\frac{pOv}{Gp}$)	UM (UG &FP)										6.4	X			.3	3-10%	E		
798.8	803.8	5.0	37	10	$\frac{Ev}{Gp}$	UM										5.0	X			.3	3-10%	E		
803.8	804.8	1.0	37	10	Ap &$\frac{pOv}{At}$	US (UP)								(1) 10-20m		1.0	X			.5	3-10%	Stream Crossing		
804.8	817.9	13.1	37	10	Gt,At,$\frac{pOv}{At}$ Af, Ap	US (UP)		X								8.4	X			.3	3-10%	E		
817.0	823.3	6.3	38	10	At Ap_2	US		X																
823.3	828.7	5.4	38	10	Ap_2 Ap_2 fO	US UP										2.7	X			.3	3-10%	E		
828.7	832.4	3.7	38	10	Cm $\frac{Ev}{Gp}$	UM										.2 3.5	 X		X 	.2 .5	>30% 3-10%	D D		
832.0	846.3	14.3	39	10	Mm & $\frac{Mp}{1R}$ & Mp $\frac{Ev}{Gp}$ $\frac{Mp}{1R}$ & Mm Cm	UM								(1) >5m	1	6.5 7.8	 X	X 		.7 .4	3-10% 3-10%	C E		
846.3	848.5	2.2	39	10	Gt	US										2.2	X			.4	3-10%	E		
849.0	851.2	2.2	40	10	GT	UG				X						2.2	X			.4	3-10%	F		
851.2	858.4	7.2	40	10	$\frac{Mv}{1R}$, (Ap,At) Mp - $\frac{Mv}{ssR}$	UM FM US								(1) >5m (1) 5-10m		1.4 2.2 .6 3.0	 X X	X X 		.5 1.0 .3 .5	3-10% 3-10% 3-10% 3-10%	E A E F		
858.4	861.7	3.3	40	10	Af,At Ap,Ap[illegible] (Cm)	US (UM)								(1) 20-30m		3.1	X			.3	Stream Crossing 3-10%	F		

LOCATION From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread	Terrain Type	SEC.	High-way u/h	High-way d/h	Work-pad T	Work-pad S	Work-pad G	Work-pad N	CHANNELIZED FLOW – APPROXIMATE WIDTH OF CHANNEL COURSES – Continuous Flow: less than 4.5 m.	Continuous Flow: stream crossings	Intermittent Flow: less than 4.5 m.	SHEET FLOW – Length of Side Slope	Grade of Backslope 3 to 10%	Grade of Backslope 10 to 30%	Grade of Backslope >30%	Length of Backslope	Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
724.3	725.9	1.6	G33A	9	Cv/At.Af	FM		X			X					1.6	X			1.0	3-10%	B		
725.9	728.3	2.4	G33A	9	Ap_2 Ap_1 At Af	US				X				(1) 30-40m		1.1	X			1.0	3-10%	F		
										X					1	1.3		X		.5	3-10%	E		
728.3	730.0	1.7	G33A	9	Cv/At	FM					X					1.7		X		.5	3-10%	A		
730.0	731.4	1.4	G33A	9	Af,At	US				X			1			1.4	X			.5	3-10%	E		
731.4	741.2	9.8	G33A	9	Cv/At,Cm.Af,Cv/Gp Ev/Gp,Cv/Gp - C	FM (US)				X	X			(1) 5-10m		4.3		X		.5	3-10%	A		
																4.7	X			.5	3-10%	B		
																.8			X	.2	>30%	Stream Crossing		
741.2	743.7	2.5	G33B	9	Ev/Gp, Cv/Gp	UM										1.7	X			.5	3-10%	D		
																.8			X	.2	>30%	E		
743.7	747.4	3.7	G33B	9	Mp&pOv/Mp&pOv/At Ap_2.pOv/Ap	FP (FM&US)									2	3.7	X			.5	3-10%	B		
747.4	748.4	1.0	G33B	9- 10	Ap	US								(1)>50m		1.0	X			.5	3-10%	River Crossing		
748.4	749.4	1.0	G33B	10	pOv/At , pOv/Cm	FP										1.0	X			1.0	3-10%	B		
749.4	751.8	2.4	G33B	10	Cv/Gp -C Ev/Gp	UM										1.0			X	.2	>30%	D		
																1.4	X			1.0	0-3%	F		
750.7	768.9	18.2	34/33	10	Ev/Gp,Cv/Gp - C Cm (pOfO) (pO-k) (pO.fO)	UM (UP)																D		
768.9	784.3	15.4	35	10	Ev/Gp & Ev/Gp.pO-k 9 1 (fOpO)	UM (UP)									3	.2		X		.2	10-30%	D		
																2.2	X			1.0	3-10%	F		

LOCATION					Terrain Type	SEC.	Highway		Workpad				CHANNELIZED FLOW			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
													APPROXIMATE WIDTH OF CHANNEL COURSES			Length of Side Slope	Grade of Backslope			Length of Backslope				
													Continuous Flow		Intermittent Flow									
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.		3 to 10%	10 to 30%	>30%					
679.9	687.3	7.4	31(30)	9	At,Gp,Ap Cr	US (UG)	X			X				(1) >5m (1) 5-10m		7.4	X			1.0	3-10%	E		
684.2	686.2	2.0	32/31	9	Af & mqR 3 7	UB & US .7 .3	X			X						2.0			X	.8	3-10%	F		
686.2	690.0	3.8	32/31	9	Ap & Af	US				X				(2) 20-30m		2.8 1.0	X	 X		.8 .2	3-10% 3-10%	F E		
690.0	692.9	2.9	32/31	9	Cv/MR & Cv/Af & mqR	UM UB .8 .2	X			X						2.9		X		.2	3-10%	E		
692.9	694.2	1.3	32/31	9	Af	US	X			X					1	1.3	X			1.0	3-10%	E		
694.2	701.7	7.5	32/31	9	Cv/Af (Af)/(mR)	UM (UB&US)	X	X		X					1	7.5	X			1.0	3-10%	E		
701.7	704.8	3.1	32/31	9	Af,Ap	US		X		X					2	3.1	X			1.0	3-10%	E		
704.8	713.8	9.0	33/32	9	Af,At,Af (mqR)	US (UB)	X	X		X					2	6.2 2.8	X	 X		1.0 1.0	3-10% 3-10%	E E		
713.8	723.0	9.2	33/32	9	Cv.Mv/mqR . Mv/mqR Cv/mqR	UM	X	X		X				(1) 20-30m	1	4.8 4.4	 X	X		1.0 1.0	3-10% 3-10%	E E		

LOCATION					Terrain Type	SEC.	Highway		Workpad				CHANNELIZED FLOW — APPROXIMATE WIDTH OF CHANNEL COURSES			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
													Continuous Flow		Intermittent Flow	Length of Side Slope	Grade of Backslope			Length of Backslope				
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.		3 to 10%	10 to 30%	>30%					
634.6	635.8	1.2	G27H	8	smR.$\frac{Cv}{sR}$	FB & FM				X					1	1.2		X		.5	3-10%	B		
635.8	639.0	3.2	G27H	8	Cb(P)-R Mm	FM					X				3	3.2		X		.5	3-10%	A		
639.0	639.8	.8	G27H	8	Ap,At $\frac{pOv}{M}$. R	FS & FP				X				(1) 20-30m		.8	X			.3	3-10%	C Stream Crossing		
639.8	641.0	1.2	G27H	8	Mm	FM				X						1.2	X			.3	3-10%	B		
641.0	651.7	10.7	G27I	8 - 9	Mm & $\frac{Cv}{M}$ (Af&Ap&$\frac{pOv}{M}$)	FM (FS&FP)	X			X				(4) >5m	1	7.2	X			.5	3-10%	A		
							X				X			(1) 5-10m		3.5		X		.5	3-10%	A Stream Crossing		
651.7	658.8	7.1	G27I	9	Af.Cv ($\frac{Ev}{M}$)	FS & FM	X			X				(2) > 5m	7	7.1	X			.8	0	C		
658.8	661.0	2.2	29(28)	9	$\frac{Ev}{M}$, pOv, (Af:Ct-S) $\frac{Ev}{G-p}$	UM (FP)	X			X						2.2		X		.2	3-10%	E		
661.0	664.0	3.0	29(28)	9	Gp (Ap)	US	X			X				(1) >5m (1) 5-10m		3.0		X		.5	3-10%	E		
664.0	670.6	6.6	29(28)	9	Ma,Af,$\frac{Ev}{Mm}$	UM (US) (UP)				X				(2) >5m	1	3.8	X			.5		D		
					Ap,$\frac{Ev}{Mp}$,$\frac{pOv}{Lp}$ Mh					X X						1.2 1.6		X X		.5 .5	3-10% 10-30%	D D		
671.9	677.0	5.1	30(29)	9	Ct,Mm (Ap)	UM US	X			X				(1) 5-10m (1) 5-10m	1	3.1 2.0	X	 X		1.0 1.0	3-10% 3-10%	D E		
677.0	677.3	.3	31(30)	9	Mm	UM	X				X					.3		X		1.0	10-30%	D		
677.3	678.0	.7	31(30)	9	ssR	UB				X						.7		X		1.0	10-30%	F		
678.0	679.9	1.9	31(30)	9	$\frac{Mv}{R}$	UM	X									1.9		X		1.0	10-30%	D		

LOCATION					Terrain Type	SEC.	Highway		Workpad				CHANNELIZED FLOW – APPROXIMATE WIDTH OF CHANNEL COURSES			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
													Continuous Flow		Intermittent Flow	Length of Side Slope	Grade of Backslope			Length of Backslope				
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.		3 to 10%	10 to 30%	>30%					
600.0	602.0	2.0	G27D	8	Cb(P)	FM	X				X				3	2.0		X		1.0	3-10%	A		
602.0	603.1	1.1	G27D	8	At & Cb(P) 3 7	FS & FM .3 .7	X			X						1.1	X			.8	3-10%	C		
603.1	603.9	.8	G27D	8	ScR	FB	X			X						.8		X		1.0	3-10%	E		
603.9	605.7	1.8	G27D	8	Cb(P),At,Ap_2 5 5	FM FS .5 .5	X			X						1.8	X			.8	3-10%	C		
605.7	606.6	.9	G27E	8	Cb(P)	FM				X						.9	X			.8	3-10%	B		
606.6	607.1	.5	G27E	8	ScR $\frac{Cv}{sR}$	FM & FB .5 .5				X						.5			X	.4	>30%	B		
607.1	607.6	.5	G27E	8	Ap	FS				X						.5	X			.8	3-10%	D		
607.6	609.1	1.5	G27E	8	Cb(P)	FM				X	X					.5 1.0	X	X		.8 .4	3-10% 10-30%	B A		
609.1	609.9	.8	G27E	8	ScR, $\frac{Cv}{sR}$	FB & FM				X	X					.8			X	.4	>30%	B		
609.9	614.7	4.8	G27E	8	Cb(P) & $\frac{Cv}{sR}$	FM				X						4.8 1.0	X	X		1.0 1.0	3-10% 10-30%	B A		
614.7	615.4	.7	G27E	8	ScR	FB				X						.7		X		1.0	10-30%	E		
615.4	617.1	1.7	G27G	8	ScR	FB				X						.6 1.1		X	X	.5 .2	10-30% >30%	E E		
617.1	624.4	7.3	G27G	8	Cb(P) - R	FM				X	X			(1) >5m (1) 10-20m	4	4.6 2.7	X	X		1.0 .3	10-30% 3-10%	A B		
624.4	624.8	.4	G27G	8	Ap	FS				X				(1) 20-30m		.4	X			.3	3-10%	C		
624.8	632.6	7.8	G27G	8	Cb(P) - R	FM				X				(1) >5m (1) >5m (1) 5-10m	3	5.2 2.6		X X		.5 1.0	3-10% 3-10%	A A		
631.4	632.0	.6	G27H	8	Cb(P) - R smR	FM & FB				X						.6		X		.5	3-10%	A		
632.0	634.6	2.6	G27H	8	Cb(P) - R Mm	FM					X					2.6		X		.5	3-10%	A		

LOCATION					Terrain Type	SEC.	Highway		Workpad				CHANNELIZED FLOW: APPROXIMATE WIDTH OF CHANNEL COURSES			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	Continuous Flow: less than 4.5 m.	Continuous Flow: stream crossings	Intermittent Flow: less than 4.5 m.	Length of Side Slope	Grade of Backslope: 3 to 10%	Grade of Backslope: 10 to 30%	Grade of Backslope: >30%	Length of Backslope				
574.0	574.6	.6	G27B	8	ScR.Cv/ScR Cv/sR - R	FM & FB				X	X					.2 .4	 X		X 	1.0 .5	10-30% 3-10%	B B		
574.6	577.0	2.4	G27B	8	Ap_2,Ap_1,Af (Cb(P))	FS (FM)				X						1.2 1.2	X 	 X		.5 .5	3-10% 3-10%	D D		
577.0	580.5	3.5	G27B	8	Cb(P) Cm (At)	FM (FS)					X		1		2	3.5		X		.5	3-10%	A		
580.5	582.5	2.0	G27B	8	Af,At,Ap_2 Ap_1	FS				X						.6 1.4		X 	 X	.5 .8	3-10% 3-10%	D D		
582.5	583.7	1.2	G27B	8	ScR	FB				X						1.2			X	.8	3-10%	E		
586.0	586.3	.3	G27C	8	ScR	FB				X						.3			X	.8	3-10%	E		
586.3	589.0	2.7	G27C	8	Cb(P)	FM				X			1	(1) 5-10m	1	1.2 1.5	X 	 X		.3 1.0	3-10% 3-10%	Stream Crossing A		
589.0	591.9	2.9	G27C	8	At (Cb(P))	FS (FM)				X					1	2.9	X			.5	3-10%	D		
591.9	593.6	1.7	G27C	8	ScR	FB				X						1.7			X	1.0	3-10%	E		
593.6	596.0	2.4	G27C	8	Ap,Cb(P),At	FM FS .6 .4				X					1	2.4	X			.5	3-10%	C		
596.0	597.7	1.7	G27C	8	Ap_2	US				X						1.4 .3	X 	 X		.5 .1	3-10% 10-30%	E E		
597.7	599.2	1.5	G27C	8	Cb(P)	FM				X						1.5	X			1.0	3-10%	A		
596.6	598.4	1.8	G27D	8	Cb(P)	FM					X					1.8	X			1.0	3-10%	B		
598.4	599.2	.8	G27D	8	At,Ap,Cb(P) 5 5	FM & FS .5 .5				X						.8	X			1.0	3-10%	C		
599.2	600.0	.8	G27D	8	ScR.Cv/sR	FB & FM .5 .5	X									.8		X		1.0	3-10%	C		

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LOCATION					Terrain Type	SEC.	High-way		Work-pad				CHANNELIZED FLOW — APPROXIMATE WIDTH OF CHANNEL COURSES			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
													Continuous Flow		Intermittent Flow	Length of Side Slope	Grade of Backslope			Length of Backslope				
From (km)	To (km)	Dis-tance (km)	Align-ment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.		3 to 10%	10 to 30%	>30%					
543.3	549.0	5.7	26(25)	7	At,Ap	FS				X						5.7	X			.5 - 1.0	3-10%	D		
549.0	549.6	.6	26(25)	7	Cb(P)	FM					X					.6			X	.1	>30%	A		
549.6	554.7	5.1	26(25)	7	At,Af	FS				X					1	5.1	X			1.0	3-10%	D		
554.3	555.3	1.0	(27)26	8	Af	FS				X						1.0	X			.3	3-10%	D		
555.3	556.1	.8	(27)26	7 - 8	ScR	FB				X						.8			X	.8	>30%	E		
556.1	563.2	7.1	(27)26	8	Ap_2,Ap_1, At Af Cb(P)	FS (FM)				X				(1) 5-10m	1	7.1	X			.5 - 1.0	3-10%	D		
563.2	563.9	.7	(27)26	8	$\frac{Cv}{sR}$	FM					X					.5 .2	X		 X	1.0 .1	3-10% >30%	A A		
563.9	564.2	.3	(27)26	8	At	FS				X						.3			X	.1	>30%	C		
564.2	566.5	2.3	G27A	8	Ap_1 Ap_2	US				X			2			1.2 .2 .9		X	 X X	.5 .1 1.0	3-10% >30% 3-10%	E E E		
566.5	566.9	.4	G27A	8	ScR	FB				X			1			.4			X	1.0	3-10%	F		
566.9	568.0	1.1	G27A	8	At	FS				X			2			1.1			X	1.0	3-10%	C		
568.0	569.0	1.0	G27A	8	Ap_2	FS				X						1.0			X	1.0	3-10%	C		
569.0	570.0	1.0	G27A	8	At	FS				X						1.0		X		.4	3-10%	C		
570.0	571.3	1.3	G27A	8	ScR.$\frac{Cv}{sR}$	FB & FM .5 .5	X				X					1.3			X	1.0	>30%	A		
571.3	572.4	1.1	G27A	8	Ap_2 & $\frac{Av}{At}$	FS				X						1.1	X			.5	3-10%	D		
571.5	572.4	.9	G27B	8	$\frac{Cv}{sR}$, Cb(P)	FM				X	X		1			1.5 .4	 X		X	1.0	10-30% 3-10%	A A		
573.4	574.0	.6	G27B	8	ScR	FB				X						.6			X	1.0	10-30%	E		

LOCATION					Terrain Type	SEC.	High-way		Work-pad				CHANNELIZED FLOW			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
													APPROXIMATE WIDTH OF CHANNEL COURSES											
													Continuous Flow		Intermittent Flow	Length of Side Slope	Grade of Backslope			Length of Backslope				
From (km)	To (km)	Dis-tance (km)	Align-ment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.		3 to 10%	10 to 30%	>30%					
539.6	541.1	1.5	25	7	Cv sm,smR	FM					X					1.5		X		.1	3-10%	A		
541.4	543.3	1.9	26(25)	7	Cb(P)	FM					X		1			.4 1.5	 X		X 	.2 .5	3-10% 3-10%	A B		

LOCATION					Terrain Type	SEC.	High-way		Work-pad				CHANNELIZED FLOW — APPROXIMATE WIDTH OF CHANNEL COURSES			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	Continuous Flow: less than 4.5 m.	Continuous Flow: stream crossings	Intermittent Flow: less than 4.5 m.	Length of Side Slope	Grade of Backslope: 3 to 10%	Grade of Backslope: 10 to 30%	Grade of Backslope: >30%	Length of Backslope				
496.5	501.0	4.5	G22C	7	ss,smR.$\frac{Cv}{sR}$	FM &FB .5 .5				X				(3) >5m	1	.8 1.1 1.6		 X	X X	.2 .1 .2	10-30% >30% 3-10%	A,E Stream Crossing B		
501.0	505.6	4.6	G22C	7	ss,smR (ss,smR.$\frac{Cv}{sR}$)	FB (FC)		X		X					1	4.6		X		.1 - .2	3-10%	E		
505.6	508.1	2.5	G22C	7	ss,smR.$\frac{Cv}{sR}$	FB &FM .5 .5					X				3	2.5			X	.2	10-30%	E,A		
508.6	510.1	1.5	G22D	7	ss,smR.$\frac{Cv}{sR}$	FB &FM .5 .5				 X	X				1	1.0 .5		 X	X	.2 .4	10-30% 3-10%	A,E C		
510.1	510.3	.2	G22D	7	Cm	FM					X			(1) >5m		.2		X		.1	3-10%	Stream Crossing		
510.3	513.1	2.8	G22D	7	ss,smR.$\frac{Cv}{sR}$	FB &FM .5 .5					X					2.8		X		.4	3-10%	B,E		
513.1	516.4	3.3	G22D	7	ss,smR	FB		X		X						3.3			X	.1	3-10%	E		
516.4	517.2	.8	G22D	7	ss,smR.$\frac{Cv}{sR}$	FB &FM .5 .5		X			X					.8		X		.3	3-10%	B,E		
518.3	525.6	6.3	24	7	ss,smR (ss,smR.$\frac{Cv}{sR}$)	FB (FM)		X		X						3.0 3.3		 X	X	.1 .1	3-10% 3-10%	E E		
525.6	529.9	4.3	24	7	ss,smR.$\frac{Cv}{sR}$	FB FM .5 .5		X		X	X					4.3		X		.1	3-10%	A,E		
526.4	527.1	.7	25	7	Cm.$\frac{Cv}{sR}$	FM		X			X					.7		X		.3	3-10%	A		
527.1	529.9	2.8	25	7	Ap_1&Ap_2&At Cb(P)	US				X						.4 .7	 X	X		.3 1.0	10-30% 3-10%	River Crossing E		
529.9	533.1	3.2	25	7		FM				X						3.2	X			1.0	3-10%	B		
533.1	535.6	2.5	25	7	Af	FS				X												D		
535.6	539.6	4.0	25	7	Cm.$\frac{fOv}{Cm}$ & $\frac{fOv}{Cb(P)}$	FM & FP .5 .5				X						4.0	X			.4	3-10%	D		

LOCATION From (km)	LOCATION To (km)	LOCATION Distance (km)	LOCATION Alignment Sheet No.	LOCATION Spread	Terrain Type	SEC.	Highway u/h	Highway d/h	Work-pad T	Work-pad S	Work-pad G	Work-pad N	CHANNELIZED FLOW – Approximate Width of Channel Courses – Continuous Flow: less than 4.5 m.	Continuous Flow: stream crossings	Intermittent Flow: less than 4.5 m.	SHEET FLOW – Length of Side Slope	Grade of Backslope 3 to 10%	Grade of Backslope 10 to 30%	Grade of Backslope >30%	Length of Backslope	Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
436.5	439.3	2.8	21(20)	6	Cv / sm,ssR	FM		X		X					1	2.8	X			.3	0-3%	B		
439.3	443.6	4.3	22(21)	6	Cv / sm,ssR	FM	X	X							3	1.3		X		.1	3-10%	B		
																3.0	X			.1	0-3%	C		
443.6	454.9	11.3	22(21)	6	sm,ssR.Cv/sR ss,ssR.Cv/sR (Cm)	FM & FB .5 .5	X	X		X	X		1		4	2.0			X	.5	0-3%	B		
																7.1		X		.1 - .3	3-10%	C		
																2.2	X			.1 - .3	3-10%	D		
454.2	464.5	10.3	G22A	6 -7	ss,smR.Cv/sR ss,smR	FM&FB .3 .7		X		X					6	10.3		X		.2	3-10%	C		
464.5	464.8	.3	G22A	7	Cm.Ap.pO-k	FS&FM (FP)				X				(1) 5-10m		.3		X		.1	10-30%	Stream Crossing		
464.8	468.8	4.0	G22A	7	ss,smR.Cv/sR ss,smR	FM&FB .3 .7				X						.9			X	.1	10-30%	B		
																3.1		X		.3 - 1.0	3-10%	C		
68.8	469.0	.2	G22A	7	Cm.Ap.pO-k	FM FS FP .7 .3				X				(1) 20-30m		.2		X		.1	10-30%	Stream Crossing		
69.0	472.8	3.8	G22A	7	ss,smR.Cv/sR ss,smR	FB & FC .7 .3				X						2.5		X		.2	3-10%	B	All Rock	
																1.3	X			.2	0-3%	E	All Rock	
71.9	491.9	20.0	G22B	7	ss,smR.Cv/sR ss,smR (Cm)	FB & FM .6 .4	X	X		X			2		8	1.8			X	.3	3-10%	B		
																1.9			X	.1	>30%	E	Rock	
																1.6	X			.1	3-10%	E	Rock	
																14.7		X		.2 - .5	3-10%	C		
91.0	496.0	5.0	G22C	7	ss,smR.Cv/sR ss,smR	FM & FB .3 .7		X		X					8	5.0		X		.3	3-10%	A,E		
96.0	496.5	.5	G22C	7	Cm	FM					X			(1) 5-10m		.5			X	.2	10-30%	Stream Crossing		

LOCATION					Terrain Type	SEC.	Highway		Workpad				CHANNELIZED FLOW — APPROXIMATE WIDTH OF CHANNEL COURSES: Continuous Flow		Intermittent Flow	SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.	Length of Side Slope	Grade of Backslope 3 to 10%	Grade of Backslope 10 to 30%	Grade of Backslope >30%	Length of Backslope				
405.0	406.7	1.7	G20F	6	Cv/sm,ssR, ss,smR	FM (FB)		X		X					2	1.7	X			.2	0-3%	B		
406.7	408.6	1.9	G20F	6	ss,smR Cv/sm,ssR	FB (FM)		X		X						1.9		X		.3	0-3%	E		
408.6	411.3	2.7	G20F	6	Cv/sm,ssR ss,smR	FM (FB)				X					1	1.4	X			1.0	3-10%	B		
																1.3		X		.7	0-3%	D		
411.3	414.2	2.9	G20F	6	Cv/sm,ssR (ss,smR)	FM (FB)					X				3	2.9		X		.7	0-3%	C		
413.4	415.1	1.7	G20G	6	Cv/sm,ssR	FM		X		X						1.7		X		2.0	3-10%	A		
415.1	419.5	4.4	G20G	6	ss,smR	FB		X		X						4.4	X			.1 - 1.0	0-3%	E		
419.5	421.4	1.9	G20G	6	Cv/ss,smR	FM		X		X						1.9	X			1.0	0-3%	B		
421.4	423.3	1.9	G20G	6	Cv/At (Cm. Cv/sm,ssR)	FM		X		X				(1) 5-10m		1.6	X			1.0	0-3%	B		
																.3			X	.1	> 30%	Stream Crossing		
423.3	425.1	1.8	G20G	6	Cm, Ap (At)	FS		X						(1) 200m		.7			X	.3	> 30%	River Crossing		
425.1	427.2	2.1	G20G	6	Cv/sm,ssR	FM		X								2.1	X			.4	3-10%	B		
426.5	427.7	1.2	21(20)	6	Cv/sm,ssR	FM		X		X						1.2	X			.1	3-10%	B		
427.7	430.8	3.1	21(20)	6	sm,ssR	FB	X	X		X						1.0 2.1	 X	X 		.1 .1	0-3% 0-3%	E E		
430.8	435.1	4.3	21(20)	6	Cv/sm,ssR	FM		X		X					1	4.3	X			.1	0-3%	B		
435.1	436.5	1.4	21(20)	6	sm,ssR	FB	X			X						1.4		X		.2	10-30%	E		

LOCATION: From (km)	LOCATION: To (km)	LOCATION: Distance (km)	LOCATION: Alignment Sheet No.	LOCATION: Spread	Terrain Type	SEC.	Highway: u/h	Highway: d/h	Workpad: T	Workpad: S	Workpad: G	Workpad: N	CHANNELIZED FLOW — APPROXIMATE WIDTH OF CHANNEL COURSES — Continuous Flow: less than 4.5 m.	CHANNELIZED FLOW — Continuous Flow: stream crossings	CHANNELIZED FLOW — Intermittent Flow: less than 4.5 m.	SHEET FLOW: Length of Side Slope	SHEET FLOW: Grade of Backslope 3 to 10%	SHEET FLOW: Grade of Backslope 10 to 30%	SHEET FLOW: Grade of Backslope >30%	SHEET FLOW: Length of Backslope	Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
400.6	405.0	4.4	G20F	6	ss,smR ($\frac{Cv}{sm,ssR}$)	FB (FM)	X	X		X					1	4.4	X			.2	0-3%	E		

LOCATION					Terrain Type	SEC.	Highway		Workpad				CHANNELIZED FLOW — APPROXIMATE WIDTH OF CHANNEL COURSES			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	Continuous Flow: less than 4.5 m.	Continuous Flow: stream crossings	Intermittent Flow: less than 4.5 m.	Length of Side Slope	Grade of Backslope: 3 to 10%	Grade of Backslope: 10 to 30%	Grade of Backslope: >30%	Length of Backslope				
364.0	365.9	1.9	G20C	5	ss,smR	FB (FP)		X		X						1.9		X		.7	0-3%	E		
365.9	372.4	6.5	G20C	5	Cb(P)	FM		X			X		1		6	6.5		X		.7	0-3%	A		
372.4	373.9	1.5	G20C	5	Cv.Av/sm,ssR	FM		X		X						1.1 .4	X		 X	.7 .2	0-3% >30%	B Stream Crossing		
373.9	374.5	.6	G20C	5	Ap	US		X		X				(1) 120m		.2			X	.2	>30%	Stream Crossing Stream Crossing		
374.5	379.5	5.0	G20C	5	Cv.Av/sm,ssR & Cv/sm,ssR	FM		X	X	X					7	 1.3 2.6	 X	 X		 .7 .7	 0-3% 0-3%	E A B		
379.5	380.8	1.3	G20D	5	Cv/sm,ssR	FM		X		X						1.3	X			1.0		C		
380.8	381.1	.3	G20D	5	At	FS		X		X			1									Stream Crossing		
381.1	384.8	3.7	G20D	6	Cv/sm,ssR	FC		X		X					3	3.7	X			1.0		C		
384.8	385.1	.3	G20D	6	At	FS		X		X				(1) 5-10m								Stream Crossing		
385.1	387.5	2.4	G20D	6	Cv/sm,ssR	FM		X		X					4	2.4	X			1.0		C		
387.5	390.6	3.1	G20E	6	Cv/sm,ssR	FM		X		X					2	3.1	X			1.0	0-3%	B		
390.6	390.8	.2	G20E	6	At	FS		X		X				(1)30-40m								Stream Crossing		
390.8	395.0	4.2	G20E	6	Cv/sm,ssR ss,smR . Cv/sR (At)	FM FB (FS)		X		X				(1) 5-10m	3	.5	X			.5	3-10%	C		
395.0	400.6	5.6	G20E	6	ss,smR (Cv/ss,smR)	FB (FC)	X	X		X			2		3	2.6 3.0	 X	X		1.0 .2	0-3% 0-3%	D D		

REGION V RICHARDSON MOUNTAINS

LOCATION					Terrain Type	SEC.	Highway		Workpad				CHANNELIZED FLOW			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
													APPROXIMATE WIDTH OF CHANNEL COURSES			Length of Side Slope	Grade of Backslope			Length of Backslope				
													Continuous Flow		Intermittent Flow									
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.		3 to 10%	10 to 30%	>30%					
315.9	316.9	1.0	18	4 - 5	ss,smR	FB	X			X						1.0	X			.5	0-3%	F		
316.9	322.9	6.0	18	5	Cb(P)	FC	X	X			X			(2) 5-10m (1) 10-20m	4	6.0		X		1.0 - 2.0	0-3%	A Stream Crossing		
322.9	324.3	1.4	18	5	ss,smR	FB				X						1.4			X	2.0	0-3%	F		
321.7	324.9	3.2	19(18)	5	ss,smR Cv ssR	FB (FC)	X			X				(1) 5-10m	1	3.2			X	.3	0-3%	E		
324.9	329.4	4.5	19(18)	5	Mv.Cv ss,smR & ss,smR	FC, FB	X	X			X X			(1) 5-10m	2	1.0 .3 3.2		X X	X	1.0 .1 .3-.7	0-3% >30% 3-10%	B E B		
329.4	330.4	1.0	19(18)	5	Ap, Ap_2	US	X			X				(1) 300m	1	.4		X		1.0	3-10%	Stream Crossing E		
330.4	332.2	1.8	19(18)	5	Av ss,smR	FM	X				X		1		1	1.8		X		1.0	10-30%	A		
332.2	337.7	5.5	19(18)	5	Cb(P)-G ss,smR	FB (.3) FC (.7)	X	X		X	X		2	(1) 5-10m (1) 10-20m	1	1.9 3.6	X	X		1.0 1.0	10-30% 3-10%	A B		
333.3	339.4	6.1	20(19)	5	smR-s	FB	X			X					1	5.5 .6	X	X		.2 .1	0-3% 10-30%	F F		
339.4	344.7	5.3	20(19)	5	Cb(P)-G smR-s	FB FS	X			X	X				4	5.3		X		2.0	0-3%	D		
344.7	354.8	10.1	G20A	5	Cb(P)-G ss,smR	FM FB	X			X	X		2	(1) 5-10m	3	9.9 .2		X	X	1.0 - 3.0 .2	0-3% >30%	A A		
352.6	360.4	7.8	G20B	5	Cb(P)-G Cv ss,smR	FM FC	X			X	X		1		2	1.0 4.7 .1	X	X	X	.2 1.0 - 3.0 .1	3-10% >30%	C B Stream Crossing		
360.4	361.7	1.3	G20B	5	Ap	FS	X			X	X		1									Stream Crossing		
361.7	362.5	.8	G20C	5	Ap	FS		X		X				(1) 20-30m								Stream Crossing		
362.5	364.0	1.5	G20C	5	Cv.Av ss,smR	FM		X			X					1.5		X		.2	0-3%	B		

LOCATION: From (km)	LOCATION: To (km)	LOCATION: Distance (km)	LOCATION: Alignment Sheet No.	LOCATION: Spread	Terrain Type	SEC.	Highway: u/h	Highway: d/h	Workpad: T	Workpad: S	Workpad: G	Workpad: N	CHANNELIZED FLOW (Approximate Width of Channel Courses): Continuous Flow: less than 4.5 m.	CHANNELIZED FLOW: Continuous Flow: stream crossings	CHANNELIZED FLOW: Intermittent Flow: less than 4.5 m.	SHEET FLOW: Length of Side Slope	SHEET FLOW: Grade of Backslope: 3 to 10%	SHEET FLOW: Grade of Backslope: 10 to 30%	SHEET FLOW: Grade of Backslope: >30%	SHEET FLOW: Length of Backslope	Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
276.0	276.6	.6	G16A	4	Cm.ss, smR-G	FM										.6			X	.6	>30%	River Crossing		
276.6	282.2	5.6	G16A	4	Mv/smR - R	FC									2	.5		X		.3	10-30%	A		
282.2	285.6	3.4	G16A	4	Mv.Cv/smR -R	FC & FM									6	.9 2.5	 X	X 		.2 .1	10-30% 3-10%	A B		
285.6	286.9	1.3	G16A	4	Cb(P)-G	FC										1.3	X			.1	3-10%	B		
286.9	289.3	2.4	G16A	4	Mv.Cv/smR - R	FC & FM		X X					1			.7 1.7	X 	 X		.1 .1	3-10% 10-30%	B A		
289.3	292.6	3.3	G16A	4	ss smR	FB		X							4	3.3	X			.1	3-10%	E		
292.6	297.9	5.3	G16A	4	ss, smR Cb(P)-G	FB FC	X	X							3	5.3	X			.1	3-10%	D		
297.1	298.8	1.7	17	4	ss, smR	FB		X		X					2	1.7	X			.1	3-10%	F		
298.8	304.1	5.3	17	4	Cb(P)-G	FC	X				X		1		7	4.0 .6	 X	X 		2.0 .2	0-3% 3-10%	A B		
304.1	305.4	1.3	17	4	Cv/ss, smR	FC	X			X						1.3	X			.2	3-10%	B		
305.4	308.5	3.1	17	4	Cb(P)-G Mp	FC	X			X			1		3	3.1	X			.2	3-10%	B		
308.5	311.4	2.9	18	4	ss, smR Cb(P)-G	FC (.7) FB (.3)	X			X	X				5	1.0 1.9	 X	X 		.2 .5	0-3% 0-3%	A,E C		
311.4	311.8	.4	18	4	Ap	FS	X			X						.3		X		.1	10-30%	C		
311.8	314.5	2.7	18	4	Cb(P)-G	FC	X	X		X			1		2	2.7	X			.2	3-10%	B		
314.5	315.9	1.4	18	4	Cb(P)-G Cv/ss,smR - C	FC	X				X		1			1.4		X		1.0	3-10%	A		

LOCATION From (km)	LOCATION To (km)	LOCATION Distance (km)	LOCATION Alignment Sheet No.	LOCATION Spread	Terrain Type	SEC.	Highway u/h	Highway d/h	Workpad T	Workpad S	Workpad G	Workpad N	CHANNELIZED FLOW – Approximate Width of Channel Courses – Continuous Flow: less than 4.5 m.	Continuous Flow: stream crossings	Intermittent Flow: less than 4.5 m.	SHEET FLOW Length of Side Slope	Grade of Backslope 3 to 10%	Grade of Backslope 10 to 30%	Grade of Backslope >30%	Length of Backslope	Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
274.9	275.4	.5	16	4	Ap-R	FM	X			X												River Crossing		
275.4	275.6	.2	16	4	Ap_1 & Ap_2	FS	X			X						.1	X			.1	3-10%	River Crossing		
275.6	275.9	.3	16	4	Water					X				(1) 240m								River Crossing		
275.9	276.1	.2	16	4	Ap_2	FS	X			X						.1	X			.1	3-10%	River Crossing		
276.1	277.7	1.6	16	4	Ap-k	FM	X			X				(1) 10-20m								River Crossing		

LOCATION					Terrain Type	SEC.	Highway		Workpad				CHANNELIZED FLOW — APPROXIMATE WIDTH OF CHANNEL COURSES			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
													Continuous Flow		Intermittent Flow	Length of Side Slope	Grade of Backslope			Length of Backslope				
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.		3 to 10%	10 to 30%	>30%					
251.7	252.7	1.0	G14	4	Mm	FC				X						1.0	X			.1	3-10%	B		
252.7	259.2	6.5	G14	4	Mp.p0.f0 8 1 1 Mm.f0 8 2 f0.p0	FP & FC				X						6.5	X			.1	3-10%	B		
259.2	260.1	.9	G14	4	Mh.Mv/smR	FC (FP)				X						.9	X			.1	3-10%	B		
260.1	260.7	.6	G14	4	f0.p0	FP				X						.6	X			.1	3-10%	B		
260.7	261.2	.5	G14	4	Mm	FC				X						.5	X			.1	3-10%	B		
261.2	262.0	.8	G14	4	f0.p0	FP				X						.8	X			.1	3-10%	B		
262.6	264.8	2.2	16	4	Mp & p0v.f0v/Mp	FC & FP .8 .2				X					1							B		
264.8	264.9	.1	16	4	Cm	FM					X		1			.1		X		.1	10-30%	Stream Crossing		
264.9	265.6	.7	16	4	Mp-R	FC				X												B		
265.6	267.5	1.9	16	4	Mp.p0 9 1 & f0.p0	FC & FP .6 .4				X												C		
267.5	268.9	1.4	16	4	Mp & f0	FC & FP .8 .2				X					1							B		
268.9	270.1	1.2	16	4	Mp-R	FC				X												C		
270.1	270.9	.8	16	4	Ap-k	FM				X				(1) 5-10m								Stream Crossing		
270.9	272.4	1.5	16	4	Mp-R	FC				X												C		
272.4	273.7	1.3	16	4	f0.p0	FP				X												C		
273.7	274.4	.7	16	4	Mp	FC		X		X												C		
274.4	274.6	.2	16	4	Ap-k	FM		X		X					1							B		
274.6	274.9	.3	16	4	Mv/smR	FC	X				X					.3		X		.1	10-30%	A		

LOCATION					Terrain Type	SEC.	Highway		Workpad				CHANNELIZED FLOW — APPROXIMATE WIDTH OF CHANNEL COURSES			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
													Continuous Flow		Intermittent Flow	Length of Side Slope	Grade of Backslope			Length of Backslope				
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.		3 to 10%	10 to 30%	>30%					
229.0	229.9	.9	G13E	3	Ap-k	FM				X												B		
229.9	230.2	.3	G13E	3	p0v/smR & p0v/Mp	FP				X												B		
231.6	233.2	1.6	G13F	3 - 4	p0v/smk p0v/Mp	(FP)				X												B		
233.2	233.6	.4	G13F	4	Mv/smR · p0	FC FP				X												C		
233.6	243.7	10.1	G13F	4	p0.f0/Mp p0v.f0v/Mp f0v/Mp f0.p0	FP				X					2							B		
243.7	243.9	.2	G13F	4	Mp	FC				X												C		
243.9	244.2	.3	G13F	4	p0v.f0v/Mp f0.p0	FP				X					1							B		
244.2	244.9	.7	G13F	4	Mp	FC				X												C		
244.9	245.0	.1	G13F	4	f0.p0	FP				X					1	.1	X			.1	3-10%	A		
245.0	245.4	.4	G13F	4	p0v.f0v/Mp · Mv/smR	FP FC				X												C		
245.4	245.5	.1	G13F	4	Cm	FM					X					.1			X	.1	>30%	Stream Crossing		
245.5	245.6	.1	G13F	4	Ap	FS					X			(1) 10-20m		.1			X	.1	>30%	Stream Crossing		
245.6	247.7	2.1	G13F	4	Mm.f0.p0	FP FC				X						.8	X			.1	3-10%	Stream Crossing		
247.7	248.1	.4	G13F	4	Mp	FC					X		1			.4		X		.1	10-30%	Stream Crossing		
248.1	248.5	.4	G13F	4	Mm.f0.p0 6 3 1	FC FP				X						.4	X			.1	3-10%	A		
248.5	251.7	3.2	G14	4	Mm.f0.p0 6 3 1 f0	FP & FC				X			1		1	3.2	X			.1	3-10%	C		

LOCATION From (km)	LOCATION To (km)	LOCATION Distance (km)	LOCATION Alignment Sheet No.	LOCATION Spread	Terrain Type	SEC.	Highway u/h	Highway d/h	Workpad T	Workpad S	Workpad G	Workpad N	CHANNELIZED FLOW – APPROXIMATE WIDTH OF CHANNEL COURSES – Continuous Flow less than 4.5 m.	Continuous Flow stream crossings	Intermittent Flow less than 4.5 m.	SHEET FLOW Length of Side Slope	Grade of Backslope 3 to 10%	Grade of Backslope 10 to 30%	Grade of Backslope >30%	Length of Backslope	Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
202.6	203.8	1.2	G13D	3	pOv/Mp	FP	X			X												C	1.2	
203.8	208.5	4.7	G13D	3	Mp	FC	X			X												C	4.7	
208.5	208.6	.1	G13D	3	Cm	FM	X				X					.1			X	.1	>30%	Stream	Crossing	
208.6	208.9	.3	G13D	3	Ap	FS	X			X				(1) 10-20								Stream	Crossing .3	
208.9	209.0	.1	G13D	3	Cm	FM	X				X					.1			X	.1	>30%	Stream	Crossing	
209.0	209.5	.5	G13D	3	Mp	FC	X			X												C	.5	
209.5	211.1	1.6	G13D	3	fOv.pOv/Mp	FP	X			X												C	.1.6	
211.1	214.4	3.3	G13D	3	Mp-R	FC	X			X												C	3.3	
214.4	214.5	.1	G13D	3	fO	FP	X			X					1							C	.1	
214.5	218.5	4.0	G13D	3	Mp-R	FC		X		X												C	4.0	
216.5	217.8	1.3	G13E	3	pO.fO Mp	FP FC				X												C	1.3	
217.8	220.3	2.5	G13E	3	Mp	FC				X												C	2.5	
220.3	224.1	3.8	G13E	3	Mp-R	FC				X												C	3.8	
224.1	227.5	3.4	G13E	3	Md	FC				X												C	3.4	
227.5	227.6	.1	G13E	3	Ap_1	FS					X					.1		X		.1	10-30%	River	Crossing	
227.6	228.9	1.3	G13E	3	Water									(1) 1300m								River	Crossing 1.3	
228.9	229.0	.1	G13E	3	Ap_1	FS					X					.1		X		.1	10-30%	River	Crossing	

LOCATION					Terrain Type	SEC.	High-way		Work-pad				CHANNELIZED FLOW			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
													APPROXIMATE WIDTH OF CHANNEL COURSES											
													Continuous Flow		Intermittent Flow	Length of Side Slope	Grade of Backslope			Length of Backslope				
From (km)	To (km)	Dis-tance (km)	Align-ment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.		3 to 10%	10 to 30%	>30%					
181.5	181.9	.4	G13C	3	Mp	FC	X			X												C	.4	
181.9	183.8	1.9	G13C	3	Mp.f0, f0.p0 9 3 f0, f0v.p0v/Mp	FP (FC)	X			X					1							C	1.9	
183.8	191.6	7.8	G13C	3	f0v.p0v/Mp	FP	X			X												C	7.8	
191.6	191.9	.3	G13C	3	Mp	FC	X			X												C	.3	
191.9	192.1	.2	G13C	3	Ap	FS	X			X					1							D	.2	
192.1	192.5	.4	G13C	3	Mp	FC	X			X												C	.4	
192.5	192.6	.1	G13C	3	f0v.p0v/Mp	FP	X			X												C	.1	
192.6	192.8	.2	G13C	3	Mp	FC	X			X												C	.2	
192.8	193.4	.6	G13C	3	f0v.p0v/Mp	FP	X			X												C	.6	
193.4	195.0	1.6	G13C	3	Mp	FC	X			X												C	1.6	
195.0	195.1	.1	G13C	3	Ap	FS	X			X			1									D	Stream Crossing .1	
195.1	195.7	.6	G13C	3	Mp	FC	X			X												C	.6	
195.7	197.1	1.4	G13C	3	p0v.f0v/Mp	FP	X			X												C	1.4	
197.1	197.3	.2	G13C	3	Ap	FS	X			X			1									D	Stream Crossing .2	
197.4	198.6	1.2	G13D	3	Mp	FC	X			X												C	1.2	
198.6	199.4	.8	G13D	3	p0v.f0v/Mp	FP	X			X												C	.8	
199.4	201.2	1.8	G13D	3	Mp	FC	X			X												C	1.8	
201.2	201.7	.5	G13D	3	p0v.f0v/Mp	FP	X			X												C	.5	
201.7	202.6	.9	G13D	3	Mp	FC	X			X												C	.9	

LOCATION From (km)	LOCATION To (km)	LOCATION Dis-tance (km)	LOCATION Align-ment Sheet No.	LOCATION Spread	Terrain Type	SEC.	High-way u/h	High-way d/h	Work-pad T	Work-pad S	Work-pad G	Work-pad N	CHANNELIZED FLOW – APPROXIMATE WIDTH OF CHANNEL COURSES – Continuous Flow less than 4.5 m.	Continuous Flow stream crossings	Intermittent Flow less than 4.5 m.	SHEET FLOW Length of Side Slope	Grade of Backslope 3 to 10%	Grade of Backslope 10 to 30%	Grade of Backslope >30%	Length of Backslope	Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
168.5	168.7	.2	G13B	3	Cm	FM					X					.2			X	.2	>30%	Stream Crossing		
168.7	169.1	.4	G13B	3	Ap	FS	X			X				(1) 5-10								Stream Crossing	.4	
169.1	169.3	.2	G13B	3	Cm	FM	X				X					.2			X	.2	>30%	Stream Crossing		
169.3	170.9	1.6	G13B	3	pOv.fOv / Mp	FP	X			X												C	1.6	
170.9	173.7	2.8	G13B	3	Mm & Mp	FC	X			X						.6	X			.2	0-3%	B	2.2	
173.7	173.8	.1	G13B	3	fO	FP	X			X												C	.1	
173.8	174.9	1.1	G13B	3	Mp	FC	X			X												B	1.1	
174.9	175.3	.4	G13B	3	Lb	FC	X			X												B	.4	
175.3	177.0	1.7	G13B	3	Mv / smR	FC	X			X												B	1.7	
177.0	177.3	.3	G13B	3	fO	FP	X			X												C	.3	
178.0	178.2	.2	G13C	3	fO	FP	X			X					1							B	.2	
178.2	178.7	.5	G13C	3	Mv / smR	FC	X			X												B	.5	
178.7	178.8	.1	G13C	3	fO	FP	X			X					1							B	.1	
178.8	179.2	.4	G13C	3	Gm	FS	X			X						.4	X			.1	3-10%	D		
179.2	179.4	.2	G13C	3	Ap	FS	X			X			1			.2	X			.1	3-10%	Stream Crossing		
179.4	180.0	.6	G13C	3	Gm	FS	X			X						.6	X			.1	3-10%	D		
180.0	180.5	.5	G13C	3	Mp	FC	X			X												C	.5	
180.5	180.7	.2	G13C	3	Ap	FS	X			X			2									D	Stream Crossing .2	
180.7	180.9	.2	G13C	3	Mv / smR	FC	X			X												C	.2	
180.9	181.1	.2	G13C	3	Gm	FS	X			X						.2	X			.1	3-10%	D		
181.1	181.5	.4	G13C	3	pO.fO	FP	X			X												C	.4	

LOCATION					Terrain Type	SEC.	Highway		Workpad				CHANNELIZED FLOW — APPROXIMATE WIDTH OF CHANNEL COURSES			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
													Continuous Flow		Intermittent Flow	Length of Side Slope	Grade of Backslope			Length of Backslope				
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.		3 to 10%	10 to 30%	>30%					
119.5	122.9	3.4	11	2	Md, Cv/ssR	FM			X						1	2.7	X			.2	3-10%	B	.7	
122.9	123.4	.5	11	2	Mv/ssR . p0	FC.FP .8 .2			X							.5	X			.2	3-10%	B		
123.4	128.6	5.2	12	2	Mv/ssR . p0	FC&FP .8 .2			X						2	5.2	X			.2	3-10%	B		
128.6	129.7	1.1	12	2	p0.Lp 8 2	FP.FC .8 .2			X					(1) 5-10m		1.1	X			.2	3-10%	C		
129.7	138.4	8.7	12	2	Mp - R	FC			X													B	8.7	
138.4	141.0	2.6	12	2	(Lp), Ap	FS (FC)			X					(1) 5-10m								D	2.6	
141.0	142.9	1.9	GBA	2	p0.Lp 8 2 (MpR) (Ap)	FP & FC .8 .2 (FC&FS)				X												C (D)	1.9	
142.9	145.5	2.6	GBA	2	Mp - R (Mp)	FC				X					2							B	2.6	
145.5	146.0	.5	GBA	2	Ap	FS				X				(1) 5-10m								D	.5	
146.0	157.3	11.3	GBA	2	Mp - R Mp (f0)	FC				X												B	11.3	
157.3	157.9	.6	G13B	2	Mp	FC				X												C	.6	
157.9	158.1	.2	G13B	2	f0	FP				X					1							B C	.2	
158.1	161.1	3.0	G13B	2--3	Mp	FC				X						1.0	X			.2	0-3%	B	2.0	
161.1	162.1	1.0	G13B	3	p0.f0	FP				X												C	1.0	
162.1	163.5	1.4	G13B	3	Mm	FC				X						1.4	X			.1	3-10%	B		
163.5	163.7	.2	G13B	3	f0	FP				X												C	.2	
163.7	165.1	1.4	G13B	3	Mv/sR	FC				X						.4	X			.1	3-10%	B	1.0	
165.1	168.5	3.4	G13B	3	p0v.f0v/Mp & f0	FP				X												C	3.4	

PARSONS LAKE LATERAL

LOCATION					Terrain Type	SEC.	Highway		Workpad				CHANNELIZED FLOW: APPROXIMATE WIDTH OF CHANNEL COURSES			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
													Continuous Flow		Intermittent Flow	Length of Side Slope	Grade of Backslope			Length of Backslope				
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.		3 to 10%	10 to 30%	30%					
13.9	16.4	2.5	9b	1	Mm, $\frac{Lv}{M}$, Ap Gt	FM, FC&FS .5 &.5			X							2.5	X			.3	3-10%	C		
16.4	20.2	3.8	9b	1	Mm (Lb)	FC			X							3.8	X			.3	3-10%	B		

PARSONS LATERAL

LOCATION From (km)	LOCATION To (km)	LOCATION Distance (km)	LOCATION Alignment Sheet No.	LOCATION Spread	Terrain Type	SEC.	Highway u/h	Highway d/h	Workpad T	Workpad S	Workpad G	Workpad N	CHANNELIZED FLOW Approximate Width of Channel Courses: Continuous Flow less than 4.5 m.	Continuous Flow stream crossings	Intermittent Flow less than 4.5 m.	SHEET FLOW Length of Side Slope	Grade of Backslope 3 to 10%	Grade of Backslope 10 to 30%	Grade of Backslope 30%	Length of Backslope	Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
0.0	13.9	13.9	9a	1	$\frac{Mv}{ssR}$ - G (Lb)	FC			X						2	13.9	X			.2	3-10%	B		

LOCATION From (km)	LOCATION To (km)	LOCATION Dis-tance (km)	LOCATION Align-ment Sheet No.	LOCATION Spread	Terrain Type	SEC.	High-way u/h	High-way d/h	Work-pad T	Work-pad S	Work-pad G	Work-pad N	CHANNELIZED FLOW: APPROXIMATE WIDTH OF CHANNEL COURSES, Continuous Flow, less than 4.5 m.	CHANNELIZED FLOW: Continuous Flow, stream crossings	CHANNELIZED FLOW: Intermittent Flow, less than 4.5 m.	SHEET FLOW Length of Side Slope	SHEET FLOW Grade of Backslope 3 to 10%	SHEET FLOW Grade of Backslope 10 to 30%	SHEET FLOW Grade of Backslope >30%	SHEET FLOW Length of Backslope	Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
115.8	117.0	1.2	11	2	Cm.Mm	FM.FC			X													B	1.2	
117.0	119.5	2.5	11	2	Mp, pO.fO.Lb 5 3 2	FC (FP)			X							2.5	X			.2	3-10%	B		

LOCATION					Terrain Type	SEC.	Highway		Workpad				CHANNELIZED FLOW: APPROXIMATE WIDTH OF CHANNEL COURSES			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
													Continuous Flow		Intermittent Flow	Length of Side Slope	Grade of Backslope			Length of Backslope				
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	less than 4.5 m.	stream crossings	less than 4.5 m.		3 to 10%	10 to 30%	>30%					
46.4	48.7	2.3	6	1	Ad.Mh-k	FM			X						2	2.3	X			.1	3-10%	B		
48.7	51.5	2.8	6	1	Gh.Mh	FS&FM			X				1			2.8	X			.1	3-10%	C		
51.5	54.4	2.9	6	1	Ad.Mm.pO Gh.Mh	FM&FC (FP&FS)			X							2.9	X			.1	3-10%	B		
54.4	56.8	2.4	6	1	Ad.Mh-k	FM			X						1	2.4	X			.1	3-10%	B		
56.8	58.2	1.4	6	1	Mv/ssR - G	FC			X							1.4	X			.1	3-10%	B		
56.4	59.1	2.7	7	1	Gh	FS			X						1	2.7	X			.2	3-10%	D		
59.1	65.0	5.9	7	1	Cm.ssR, Mv/ssR -G (pO)	FC (FM&FP)			X				1		3	.8 5.1	 X	X		.7 .2	10-30% 3-10%	A B		
64.5	78.9	14.4	8	1	Mv/ssR - G	FC			X					(1) 5-10m	6	14.4	X			.3	3-10%	B		
78.1	80.3	2.2	9	1	Mv/ssR - G (Lb)	FC (FP)			X							2.2	X			.2	3-10%	B		
80.3	81.3	1.0	9	1-2	pO (Lb)	FP (FC)			X					(1) 5-10m		1.0	X			.2	3-10%	C		
81.3	91.9	10.6	9	2	Mv/ssR - G (Ap) (pO)(At)	FC (FS&FP)			X				1	(1) 5-10m	3	1.5 9.1	 X	X		.2 .2	3-10% 3-10%	A B		
91.6	100.3	8.7	10	2	Mm, (Lb, pO)	FC (FP)			X					(2) 5-10m	2	8.7	X			.2	3-10%	B		
100.3	104.1	3.8	10	2	Lb,Mm (Gt)	FC (FS)			X X					(1)10-20m (1) 5-10m		3.8	X			.2	3-10%	B		
104.1	108.9	4.8	10	2	(Ad.pO) Mm	FC (FM&FP)			X				1		1	4.8	X			.2	3-10%	B		
108.9	110.0	1.1	10	2	Mh	FM			X						3	1.1	X			.2	3-10%	B		
108.5	110.3	1.8	11	2	Mh	FM			X							1.8	X			.2	3-10%	B		
110.3	115.8	5.5	11	2	(Lb.pO) Mm (Cm.pO)	FC (FM&FP)			X						3	5.5	X			.2	3-10%	B		

LOCATION					Terrain Type	SEC.	Highway		Workpad				CHANNELIZED FLOW — APPROXIMATE WIDTH OF CHANNEL COURSES			SHEET FLOW					Grade of Pipeline	Approx. Density of Cross Drainage	Breakers Spacing	Remarks
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread			u/h	d/h	T	S	G	N	Continuous Flow: less than 4.5 m.	Continuous Flow: stream crossings	Intermittent Flow: less than 4.5 m.	Length of Side Slope	Grade of Backslope: 3 to 10%	Grade of Backslope: 10 to 30%	Grade of Backslope: >30%	Length of Backslope				
-17	-7	10	1	1	Ad(pO)	FM (FP)								(1) 900m	1							D	10	
-8.4	-5.9	2.5	2	1	Ad	FM			X													B	2.5	
-5.9	-4.6	1.3	2	1	Ad & PO 8 2	FM & FP .8 .2			X													B	1.3	
-4.6	+2.8	7.4	2	1	Ad (pO)	FM (FP)			X					(1) 120 (1) 100 (2) 30 (1) 50								B	7.4	
1.8	4.3	2.5	3	1	Ad	FM			X					(1) 50m								B	2.5	
4.3	17.6	13.3	3	1	$\frac{Mv}{Ad}$ -k & $\frac{Mv}{Ad}$.Lb (Ap)	FC (FS)			X					(1) 140 (2) 20 - 30		5.6	X			.1	3-10%	B	7.7	
17.0	22.4	5.4	4	1	$\frac{Mv}{Ad}$ -k Lb (Ap)	FC (FS&FM)			X				1			5.4	X			.1	3-10%	B		
22.4	24.0	1.6	4	1	Cm, Gp	FL			X							1.4 .2	X	X		.1 .1	3-10% 10-30%	D C		
24.0	28.3	4.3	4	1	$\frac{Mv}{Ad}$ .Lb, Lb (Ap), $\frac{Mv}{Ad}$ .k	FC (FS)			X				1		2	4.3	X			.1	3-10%	B		
28.3	30.0	1.7	4	1	Ap_2	FS			X						1							D	1.7	
30.0	37.8	7.8	5	1	Ap_2 Ap_1 - pO 7 3	FS (FP)			X													D	7.8	
37.8	38.3	.5	5	1	Ad.Mm-k	FM & FC			X					(1) 1200m		.1 ..4	X	X		.1 .1	10-30% 3-10%	River crossings B	.4	
38.3	43.8	5.5	6	1	Lb, Ad.Mm-k	FC FM			X						1	5.5	X			.1	3-10%	B		
43.8	46.0	2.2	6	1	pO, Ad.Mm Lb	FM (FP&FC)			X							2.2	X			.1	3-10%	B		
46.0	46.4	.4	6	1	Ap	FS			X					(1) 10- 20m		.3 ..1	X	X		.1 .1	3-10% 10-30%	C Stream		

APPENDIX 1

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6.10 Channel Liners

Unprotected cuts in fine-grained soils	= 73 km
Longitudinal ditches in other areas besides side and through cuts	= 10 km
Total	= 83 km

Permanent Liners

a) sand and gravel (64% of total) = 53.12 km

b) cobbles and rock (15% of total) = 12.50 km

c) rip-rap (5% of total) = 4.10 km

d) gabions (2% of total) = 1.70 km

e) plastic filter (14% of total) = 11.60 km

Quantities

Sand and gravel	= 0.3 m^3/m of ditch
Cobbles and rock	= 0.2 m^3/m
Rip-rap	= 0.3 m^3/m
Gabions (cobbles & rock)	= 0.2 m^3/m

Temporary Liners

As temporary liners are primarily related to soil stabilization, mulching and revegetation requirements, an estimate of material requirements is beyond the scope of this study.

Estimated total length of cuts in fine-grained frozen soils	= 64.0 km
Length of cuts in ice-rich fine-grained soil	= 30.6 km
Ice-rich cuts in predominantly silty soil	= 19.1 km
Ice-rich cuts in predominantly clayey soil	= 11.5 km

Estimate of Materials

Total length of ice-rich cuts in clayey soil	= 11.5 km
Sand and buttress protection	= 7.5 km
Insulation Protection	= 4.0 km
Average height of cut	= 3.4 m

a) Quantities for sand and gravel buttress	= 5.6 m^3/m of cut
b) Quantities sand and gravel for insulated cuts	= 0.5 m^3/m of cut
Artificial insulation	= 7.5 m^2/m of cut

6.9 Rock Aprons and Stilling Basins

No. of let down structures	= 116
10% of cross drainage structures	= 2000
Total No. of rock aprons and stilling basins	= 2116

Rock aprons = 80% of total = 1690
Stilling Basins = 426

Volume for fan shape apron	= 0.4 m^3 per apron
Volume for stilling basins (50% cobbles & rock and 50% rip-rap)	= 0.7 m^3 per basin

Sacked sand and gravel	= 9.0 m^3/plug
Plastic liner or (Bentonite)	= 5.0 m^2/plug

6.7 Ditch Checks

Cuts in frozen and unfrozen fine-grained soils (excluding buttress protection areas)	= 73 km
1 ditch check per 30 m of cut = 73000/30 (Although some of the cuts may not require ditch checks, other disturbed areas and drainage ditches may require checks. It is assumed that these areas are covered in the estimate if checks are allowed for all of the cuts)	= 2433
a) Sand, gravel and cobble type (70% of total)	= 1704
b) Wood, log and filter type (20% of total)	= 486
c) Straw bale type (10% of total)	= 243

Straw bales .3x.3 m size	= 12.00 per d.c.
Filter cloth for b & c types	= 2.00 m^2 per d.c.
Sand and gravel for a type	= 0.28 m^3 per d.c.
Coarse gravel, cobbles or rip-rap for type a	= 0.38 m^3 per d.c.

6.8 Ice-Rich Cut Protection

It is assumed that north of the Richardson Mountains, about 50% of the cuts would require insulation protection due to non-availability of sand and gravel. South of the Richardson Mountains, it is assumed that sand and gravel is available and insulation is not necessary.

Diversion Dikes

30% of unprotected cuts in fine-grained soil	=	22.0 km
Dike length on longitudinal slopes greater than 10% and more than 60 m long in fine-grained soil	=	21.0 km
Length of Herring Bone dikes on longitudinal slopes at river crossings where soils are M, L and C type	=	24.3 km
Additional 10% for disturbed areas	=	7.0 km
Total length	=	74.3 km

10% of the requirements may be fulfilled by using suitable cut spoil.

Total quantity of sacked sand and gravel = 1.11 m^3/m of dike.

Mound Protection

Length of sand and gravel liner for mound protection	=	58.0 km
Quantity of sand and gravel	=	0.171 m^3/m of mound.

6.6 Ditch Plugs

50% of the total number of all longitudinal slopes greater than 10% in C, L and M soils	=	33
No. of continuous flow water breaks on side and longitudinal slopes	=	35
Minimum 2 plugs per longitudinal slope	=	(33x2)
Total No. of ditch plugs = (33x2) + 35	=	101

6.3.3 Stream Crossings

The material required for stream crossings (with the exception of rivers) with channel width between 4.5 and 50 m, and anticipated flow greater than 1120 l/sec is calculated below. All other channels wider than 50 m are considered beyond the scope of this report. A minimum of 1.3 m cover is assumed on top of the pipe. Calculations are based on assuming sand and gravel backfill, protected with a cover of 0.6 m of rip-rap or gravel and cobbles.

Number of stream crossings (Km -17 to 140)	=	17
Number of stream crossings (Km 140 to 1176.7)	=	67
Total number of stream crossings		84

Average length of stream crossing	= 20.0 m
Sand and gravel	= 46.4 m^3 per crossing
Rip-rap or gravel and cobbles	= 20.0 m^3 per crossing

6.4 Let Down Structures

No. of water courses across cuts that are in fine-grained soil = 116

Average width = 1.52 m
Average height = 3.35 m

Rip-rap = 0.8 m^3 per structure
Sand and gravel = 0.8 m^3 per structure

6.5 Diversion Dikes and Mound Protection

In frozen fine-grained soils with side slopes greater than 5% and in unfrozen fine-grained soil with side slopes greater than 10%, either diversion dikes, or mound protection may be required.

When mound protection or diversion dikes are used, the spacing for categories A, B, C and D can be increased according to site conditions.

Estimate of Quantities

Total No. of water breaks on the basis of above criteria = 18,200
For material estimate purposes, following break down is assumed:

Type a = 70% of the total breaks
Type b = 20% of the total breaks
Type c = 10% of the total breaks

Type a Breaks (1.5 m wide and 3:1 slope)

70% of total breaks = 12,740
Sand and gravel = 1.0 m^3 per break

Type b Breaks (2.3 m wide and 3:1 slope)

20% of total breaks = 3,640
Sand and gravel = 1.22 m^3 per break

Type c Breaks (3.8 m wide and 3:1 slope)

10% of total breaks = 1,820
Sand and gravel = 1.56 m^3 per break

Rip-Rap or Cobbles

Protection by the use of rip-rap or cobbles is assumed necessary where flow velocity may exceed the allowable limit for sand and gravel.

5% of the total breaks that may have to contain flow velocity greater than 1.8 m/sec = 910

Quantity of cobbles or rip-rap per water course = 1.6 m^3

Type c Breaks (3.8 width and 6:1 slopes)

20% of total defined water courses = 9

Armour (gravel and cobbles or rip-rap)	=	51.0 m^3 per break
Sand and gravel	=	25.5 m^3 per break
Insulation	=	167.5 m^2 per break

6.3.2 Water Breaks on Pipe Mound (Km 140 to 1176.7)

The following categories of water break spacings have been used in the material estimate:

A - 15 m spacing: where the SEC is FM, FC, or FL, drainage density is very high, side slope is greater than 5% and back-slope is of significant dimensions.

B - 30 m spacing: where conditions are similar to category A, except drainage density is moderate.

C - 60 m spacing:
i) where soil is FM, FC, or FL and ponding is likely on relatively flat ground.
ii) where soil is UM, UC, or UL, drainage density is high and back slopes are steep.

D - 90 m spacing: where soil is FS, UM, UC, or UL and ground slopes are from 3 to 10%.

E -150 m spacing: where soil is US or FG.

F -300 m spacing-
450 m spacing: where soil us UG or B.

thickness of 0.6 m and width of 15 m is assumed for the workpad embankment. Since channel width less than 4.5 m is difficult to measure precisely from the air photo, the total number of water courses are divided into different categories on the following basis:

Type a = 50% of total number
Type b = 30% of total number
Type c = 20% of total number

Total number of defined water courses with channel width less than 4.5 m = 47.

<u>Type a Breaks (1.5 m wide and 6:1 slope)</u>

50% of total defined water courses	= 24
Intermediate breaks, 1 every 5 km	= 28
Total No. of Type a breaks	= 52

Armour (gravel & cobbles or rip-rap)	= 41.1 m^3 per break
Sand and gravel	= 20.6 m^3 per break
Insulation	=135.0 m^2 per break

<u>Type b Breaks (2.4 m width and 6:1 slope)</u>

30% of total defined water courses = 14

Armour (gravel and cobbles or rip-rap)	= 45.4 m^3 per break
Sand and gravel	= 22.7 m^3 per break
Insulation	= 149.0 m^2 per break

5. Sacked Cement - Stabilized Soil

Where sand and gravel is not available, unfrozen soil and Type 1 cement can be mixed and placed in burlap bags. A quantity of 1.2 cu. ft. per sack is suggested for convenient handling.

6.3 Estimate of Quantities

The drainage courses are divided into the following three categories for estimating purposes:

Type a = Estimated width of water course less than 1.5 m; anticipated flow less than 56 l/sec, and water break width of 1.5 m.

Type b = Estimated width of water course between 1.5 m and 3.0 m, anticipated flow less than 280 l/sec and average water break width of 2.4 m.

Type c = Estimated width of water course between 3.0 m and 4.5 m; anticipated flow less than 1120 l/sec and average water break width of 3.8 m.

The side slopes of breaks are assumed to be 6:1 in the thermal pad and 3:1 in the remainder of the pipeline. Channel width larger than 4.5 m, but smaller than 50 m, are considered as stream crossings and are treated separately from the water breaks.

6.3.1 Water Breaks on Thermal Pad (Km -17 to 140)

Estimate of Materials

A break in the workpad is assumed to be provided at each defined water course, as well as at intermediate locations as site conditions demand. For estimate purposes, an allowance of one every 5 Km of type "a" water break has been made to account for provision of intermediate breaks. A

An allowance of 20% of the material quantities derived from the following calculations should be added to the estimate to account for contingencies.

6.2 Materials Description

The approximate sizes of different materials that may be required for erosion and drainage control structures are given below:

1. Rock Rip-Rap

Lighter by Weight		Limit of Stone Weight in Kgms	
Class I	Class II	Class I	Class II
100%	100%	16-40	80-205
50	50	8-13	40-60
15	15	3-7	13-35

2. Gabions

   Wire mesh baskets filled with 5 to 12 inch stones.

3. Cobbles and Shot Rock

   Four to eight inches in size.

4. Sand and Gravel

   a) Clean sand and gravel containing less than 7% fines.
   b) Coarse gravel - 1½ inches to 4 inches.
   c) Sacked sand and gravel - sand and gravel, sand and gravel mixed with other acceptable soils.

6. ESTIMATE OF MATERIAL REQUIREMENTS

6.1 General

The basic data for the estimate of material quantities as shown in Appendix "A" were obtained from an examination of air photos, terrain typing and borehole logs. The pipeline alignment shown on preliminary terrain type sheets was used to estimate the drainage and excavation requirements. Although minor route changes have been made by Foothills Pipe Lines since the estimate was made, the effect on the estimated quantities is not considered to be significant.

An estimate of construction materials required for drainage and erosion control structures is presented in this Section. Requirements for select backfill materials at minor stream crossings having a width of from 4.5 m to 50 m are included in the estimate. Erosion control requirements for streams having a width more than about 50 m require special designs and are not included in the material estimate. In calculating the width of a stream, where applicable the active flood plain and one-half of the height of the banks are included.

Quantities of select trench backfill material for major river crossings, flood plain burial and on steep, longitudinal slopes are not included in the estimate. Nevertheless, it is recommended that select backfill should be used to replace native fine-grained soils where longitudinal slopes are greater than 10%. Stabilized backfill should be used where longitudinal slopes are greater than 40% and flattening is not planned.

Other items that have not been estimated include fertilizers, mulches and stabilizers, as well as temporary sediment retention basins (siltation basins), the requirement for which can only be determined on a site specific basis. For estimating purposes, it is assumed that 3 retention basins would be necessary along the route. These would be situated in areas of extensive grading, such as at the locations of compressor stations.

only minimal maintenance efforts are anticipated to be necessary.

The main effort of maintenance should be directed at the protection of cross-drainage breaks and culverts and stabilization of cut and fill slopes. Maintenance of water breaks will be required to counter the effects of thaw-settlement, frost heave and overstressing of drainage structures during storms and spring run-off. Additional diversion structures and equilizers may be required where unexpected ponding develops. Changes in natural drainage patterns may result in concentrations of flow and an increase in velocities, causing erosion in formerly stable areas.

Clogged siltation traps will have to be periodically cleaned out. Accumulation of sloughed material in a buffer zone at the toes of 1:4 ice-rich cuts is an important part of the slope stabilization process. However, sloughed material should not be allowed to restrict the flow of run-off, or cause excessive siltation.

Although structural solutions would provide immediate control against siltation, the most effective erosion control procedure is through the revegetation of disturbed areas.

Seeded areas will require occasional fertilization over the years until the native plant species regenerate. Access to topsoil stock piles and selected borrow pits should be retained for maintenance purposes.

Prolonged freezing weather where there is little snow to insulate the ground is the ideal setting for the formation of icings, which can be troublesome to drainage control. Naturally occurring icings will tend to be aggravated by the construction of the pipeline, workpad and right-of-way grading. On roadways, icings in culverts and ditches may lead to over topping of the workpad or pipe mound by an ice sheet. Methods of combatting such icings generally involve movement of the icing condition to a less sensitive location. Fire-pots, steaming and fencing procedures are commonly used by highway departments to control or remove icings.

Where native organic material cannot be used, revegetation should be accomplished by using procedures that will include:

a) Fertilizer application
b) Temporary and permanent seeding (subject to timing constraints)
c) Mulches for sloping ground
d) Watering and sprigging

Application of mulches would limit erosive processes, while promoting revegetation efforts in exposed areas. Mulches can be utilized for the control of erosion from wind, rain, seepage and snow melt on cut slopes, fill slopes and within other disturbed areas. Mulches should be applied in conjunction with, or immediately following seed application. Mulches are commonly used on sloping ground, although they may also be beneficial in flat areas.

Detailed procedures for establishing revegetation through the use of seeding, fertilizing and mulching are beyond the scope of this report.

5.6 Maintenance

It is not practical to identify in advance of pipeline construction all of the hydrological and geotechnical factors contributing to erosion processes. Therefore, maintenance efforts will be required, both to treat locations where unexpected erosion occurs and to sustain erosion control structures and facilities in their original operating condition. Advance engineering assessment is essential in determining the type of maintenance procedures to be carried out. Periodic inspection and advance identification of potential trouble spots should be made to permit the selection of timely and appropriate maintenance measures.

Siltation, sloughing in of ditches, continuously degrading cuts and icing conditions constitute evidence that existing systems are inadequate and additional controls are required. However, properly designed and constructed structures will accommodate most potential siltation and erosion and fan shape to cover all areas downstream from the outlet.

Other energy dissipators, such as stilling basins, can be used at appropriate locations where the allowable velocity is exceeded and the thermal conditions allow the construction of such structures.

5.4.6 Siltation Basins

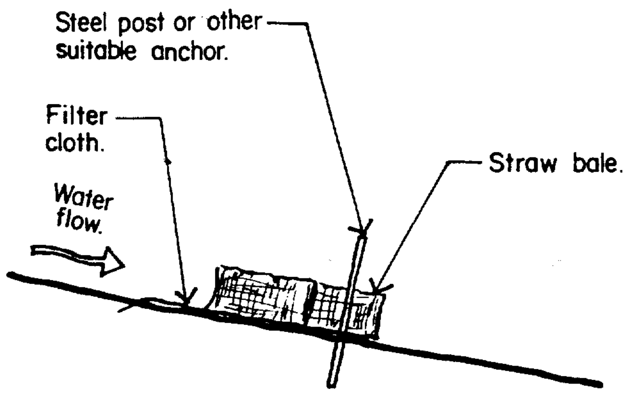
Siltation basins are built for temporary retention of sediments. Their purpose is to prevent sediment loaded water from the construction zone entering sensitive areas such as fish streams. Siltation basins are basically small dams and therefore are not suitable in areas of predominantly fine-grained permafrost soils. Unless specially designed for site specific conditions, their heights should not exceed about 2.5 m and should contain provision for an overflow spillway.

In addition to having an application in siltation control along the pipeline right-of-way, siltation basins may also be used in the protection of sensitive portions of large construction areas, such as at compressor stations.

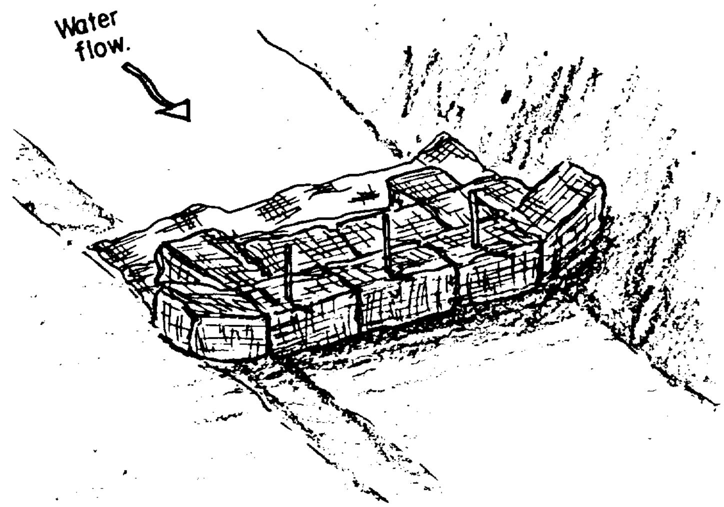
5.5 Revegetation and Mulching

The primary objective of revegetation is to rapidly establish a grass cover that is effective in controlling soil erosion. The second objective is to alter the albedo of the disturbed ground surface and thereby reduce the radiation component of heat penetration into normally frozen soil. Vegetation cover is also an effective deterrent to hydraulic erosion, as it protects the surface from the impact of rainfall and reduces the available run-off and flow velocities.

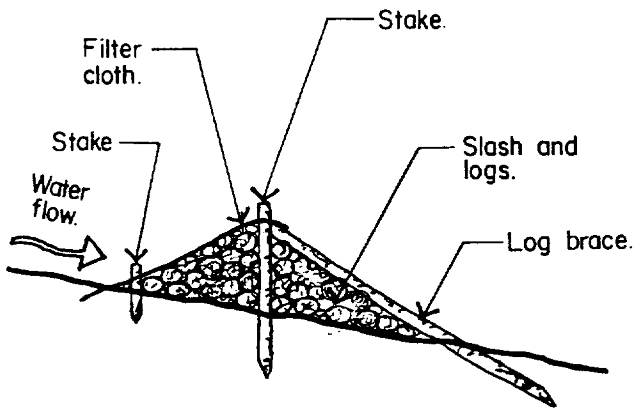
Where it is considered practical, the material from the surface organic layer should be removed and stored separately from other excavated material. The organic mat removed and segregated during excavation should be utilized to revegetate the disturbed areas.



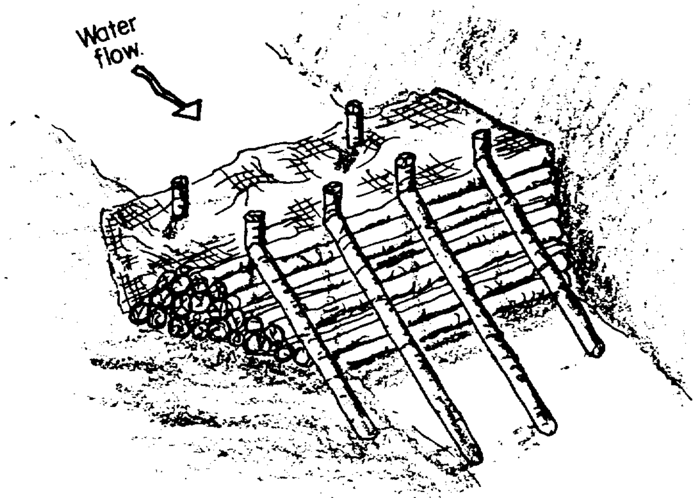
STRAW BALE



TEMPORARY DITCH CHECK



SLASH-LOG-FILTER CLOTH



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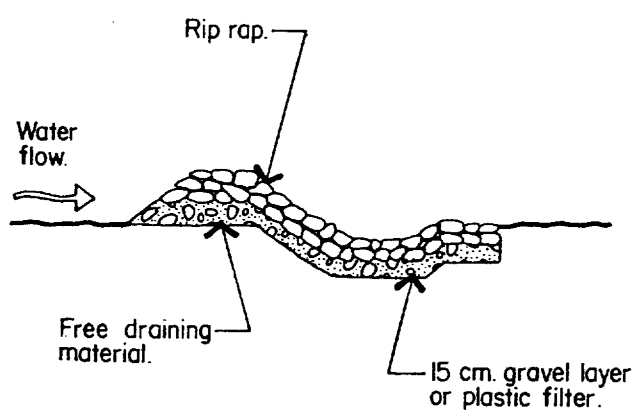
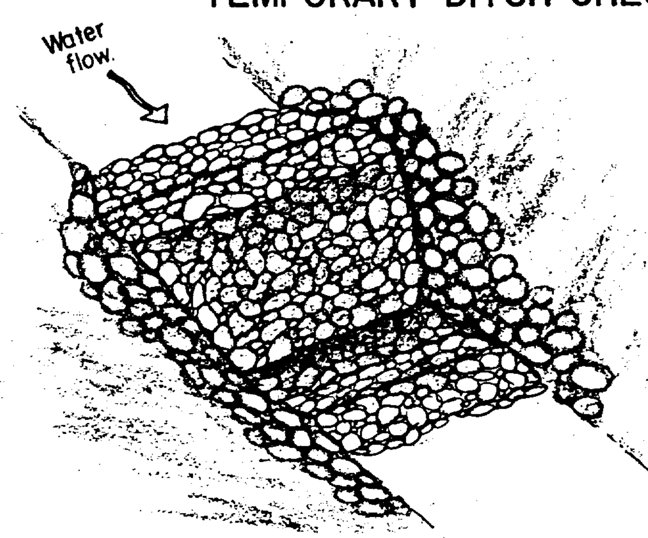


FREE DRAINING MATERIAL-RIPRAP



PERMANENT DITCH CHECK

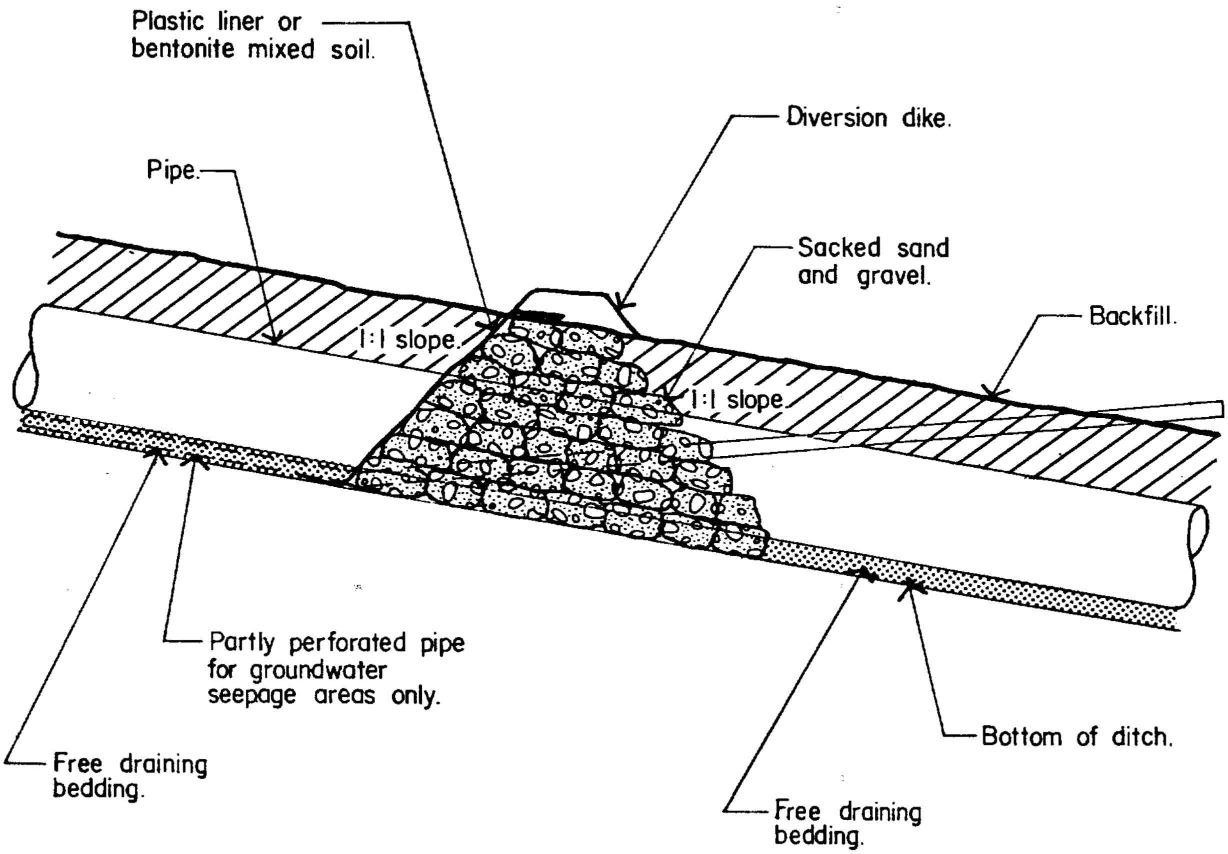
KOMEX

FOOTHILLS PIPE LINES (YUKON) LTD.

DEMPSTER LATERAL

REVISION NO. & DATE	DATE	DRAWING
	Feb. 5/1979	13

DITCH CHECKS



KOMEX	FOOTHILLS PIPE LINES (YUKON) LTD.		DITCH PLUG
	DEMPSTER LATERAL		
REVISION NO. & DATE	DATE	DRAWING	
	Feb. 5 / 1979	12	

is shown in Drawing 12. A dry mixture of 15 to 20% bentonite with soil can be substituted for the plastic liner.

In areas where groundwater seepage is encountered, perforated drain pipes can be installed to bring flows to the ground surface, as shown on Drawing 12. As an alternative to sacked sand, a vertical cut-off consisting of a bentonite and clay mixture 1.5 m thick, or a vertical cut-off consisting of 100% bentonite will provide a suitable barrier to seepage.

The sacked sand design is preferred where settlement or frost heave is expected and where longitudinal slopes exceed about 20%.

5.4.4 Ditch Checks

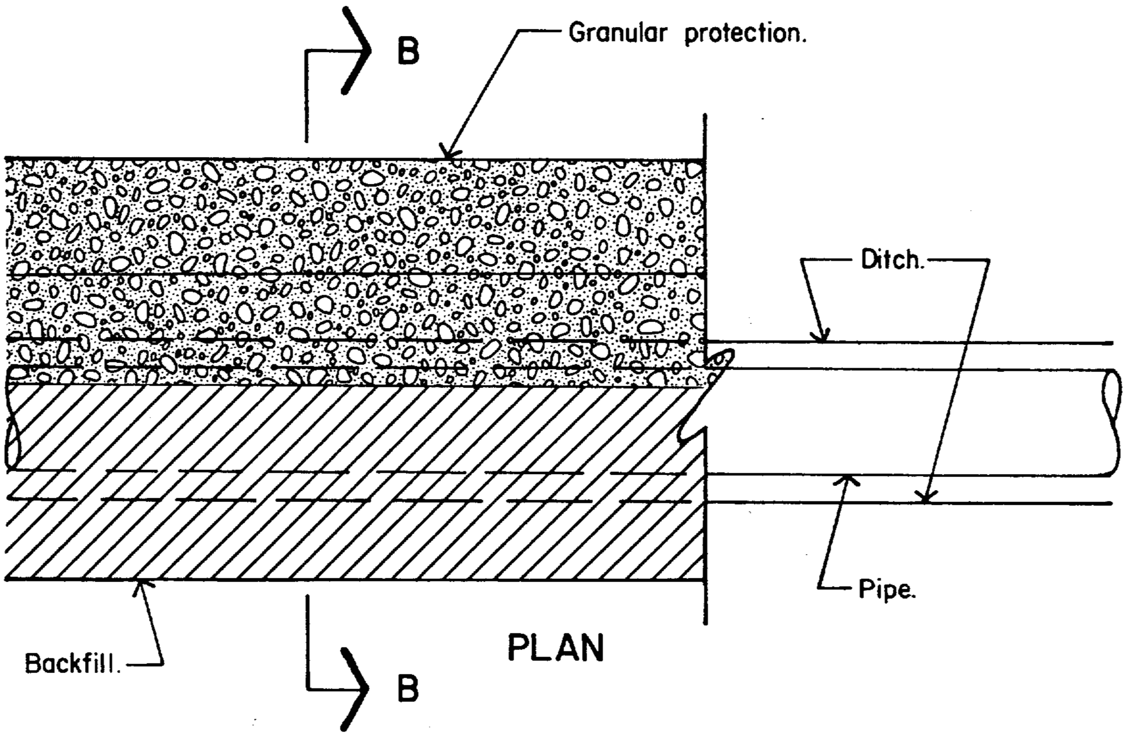
Ditch checks can serve a dual purpose. They can be used to reduce flow velocity, as well as to control the sediment load. Ditch checks are commonly installed to control erosion along drainage ditches, especially at the toes of cuts in fine-grained soils.

Ditch checks can be either temporary or permanent. Temporary structures are built with either straw bales, or wood logs and filter cloth. Permanent structures should be constructed with free draining coarse gravel and rip-rap (Drawing 13).

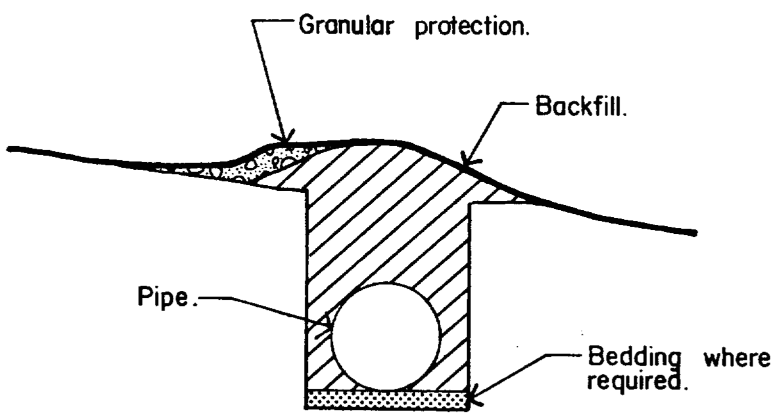
Temporary ditch checks should not be more than 0.6 m high. However, permanent structures built with coarse granular material can be constructed up to about 1.2 m. Specific dimensions and spacings between checks should be based on flow data.

5.4.5 Rock Aprons and Energy Dissipators

A rock apron is commonly used to dissipate energy and spread the flow of water where outlet velocities are excessive. A rock apron should be used instead of a stilling basin in fish streams and in areas where ponding caused by other energy dissipating structures would result in thaw settlement. Where there is no defined channel, the apron should be placed in a



PLAN



SECTION B-B

KOMEX	FOOTHILLS PIPE LINES (YUKON) LTD.		BACKFILL MOUND PROTECTION
	DEMPSTER LATERAL		
REVISION NO. & DATE	DATE Feb. 5/1979	DRAWING 11	

5.4.2 Backfill Mound Protection

Granular protection for the ditch crown will be required where the pipeline traverses a side slope and is expected to intercept extensive sheet flow. On side slopes where the ditch is excavated through bedrock or granular material, and in areas where a gravel or thermal pad is used, backfill protection is not considered to be necessary, provided that sufficient breaks are installed for cross drainage. Hence, mound protection will be required only on those slopes consisting of fine-grained material and where snowpad or non-padded construction is planned.

In fine-grained permafrost soil, where the back slopes are greater than 6%, the backfill crown should be protected against erosion. This protection can be provided by spreading non erodible granular material, or by using diversion dikes upslope of the pipeline. An example of the use of granular protection is shown in Drawing 11. Granular protection should consist of a layer of sand and gravel of 15 cm thickness and should extend at least 0.6 to 1.2 m upslope from the toe of the crown. If the velocity is expected to be higher than 1.8 m/sec, the protective granular layer should be armoured with cobbles or rip-rap.

5.4.3 Ditch Plugs

Ditch plugs would primarily be required to prevent erosion of backfill material in the pipe trench. Ditch plugs should be installed where the longitudinal slope is greater than 10% and high groundwater seepage or sheet flow is anticipated and where surface drainage crossing the pipe trench has the potential for seepage and wash out. Where seepage is likely to enter the trench from water breaks in sufficient quantity to cause internal erosion or pipe buoyancy, a ditch plug should be installed on the downslope side of the break.

Ditch plugs can consist of sacked sand, sealed with a plastic impervious liner to prevent flow along the ditch. A diversion dike should be extended over top of the plug to divert flow away from the ditch. A typical design

2) Permanent Liners

The following materials are recommended for use as permanent liners.

a) Coarse Gravel

A layer of coarse gravel (2.0 to 7.5 cm), having a thickness of about 15.2 to 30.5 cm should be placed where velocities are less than 1.8 m/sec.

b) Cobbles and Rock

Well graded cobbles and rock of about 7.5 to 20 cm in size may be used as a permanent liner where velocities do not exceed 2.4 m/sec.

c) Sacked Sand and Gravel and Cement-Soil

Sacked sand and gravel can be used as protection where velocities are less than 2.4 m/sec. As an alternative, a dry mixture of 4 bags of cement per cu. yard of soil can be placed in sacks to provide protection where flow velocities are less than 3.0 m/sec.

d) Rip-Rap

Rip-rap of different classes can be used where velocities are between 2.4 and 4.5 m/sec. A sand and gravel filter layer having a minimum thickness of 15 cm should be placed on the soil beneath the rip-rap, filler material may be necessary to fill the large voids in the rip-rap

e) Gabions

Gabions filled with cobbles or shot rock, ranging in size from 10 to 20 cm, may be used where velocities are expected to be between 3.0 and 4.5 m/sec.

5.4 Hydraulic Erosion

5.4.1 Channel Liners

To protect ditches and natural and induced drainage courses from erosion, temporary or permanent liners can be used where flow velocities exceed the allowable limits. Permanent liners should be used where velocities exceed about 1.2 m/sec in erodible soils. Where the flow velocities are less than 1.2 m/sec, the channels can generally be revegetated. Temporary liners consisting of chemical stabilizers can be used to protect the channels until vegetative growth is established.

1) Temporary Liners

The following types of temporary channel liners can be used as protection for drainage ditches and channels.

a) Plastic sheets

Where flow velocities are less than about 1.8 m/sec, plastic filter sheets can be used, as a temporary liner, or as an alternative where coarse gravel is not available. The plastic sheets can be held down with pins or cobbles to prevent displacement.

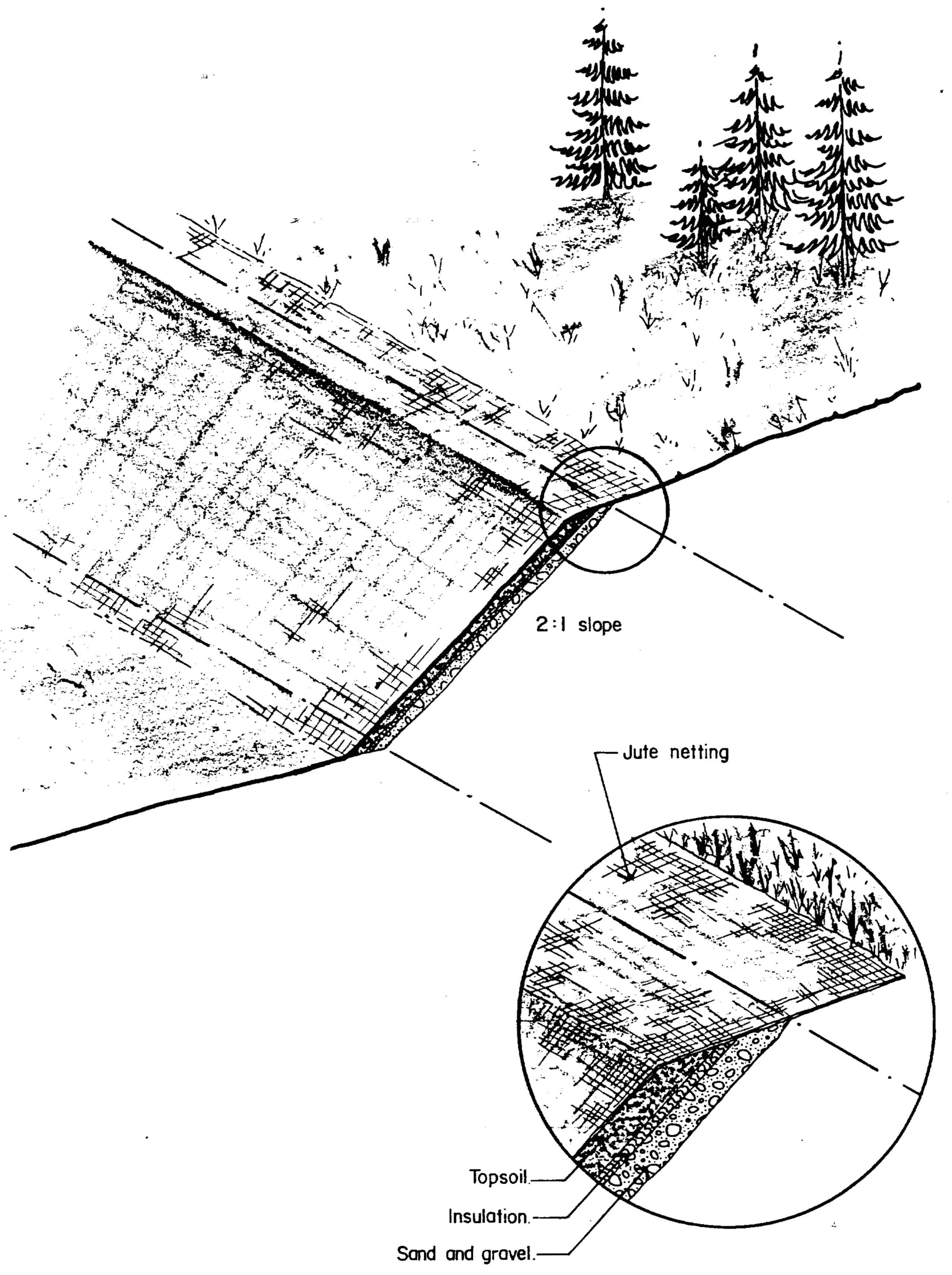
b) Fiberglass Rovings

Fiberglass rovings can be spread by using an applicator. To hold the fiberglass rovings in place, a soil stabilizer should be applied at the recommended rate.

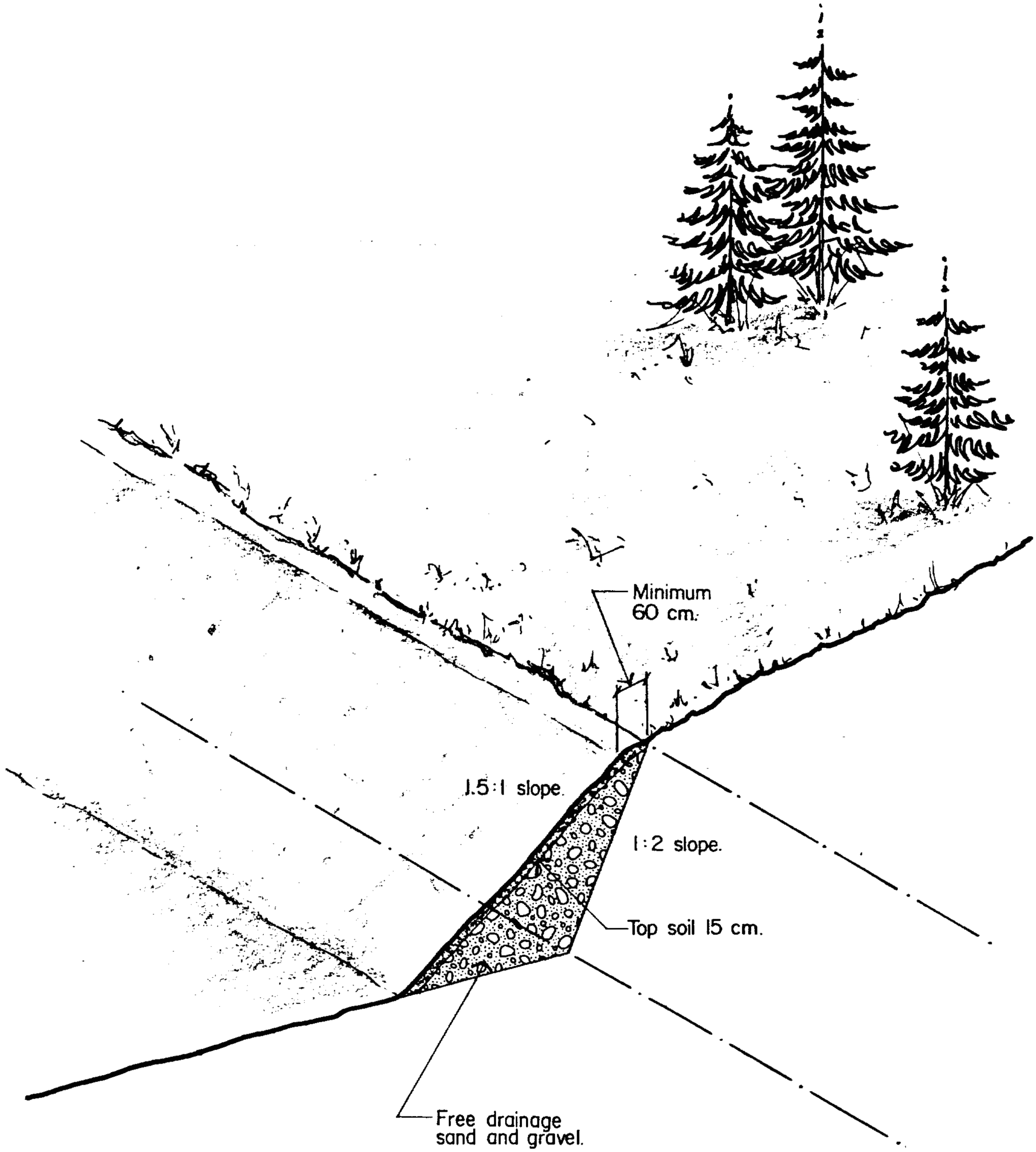
c) Soil Stabilizing Chemicals

Polyvinyl Acetate (PVA), diluted with water, can be applied to stabilize drainage ditches having a flow velocity of less than 1.2 m/sec.

Stabilizing chemicals, particularly fiberglass rovings, should be used with discretion as they are not bio-degradable and may present hazards to fish and wildlife.



KOMEX	FOOTHILLS PIPE LINES (YUKON) LTD.		INSULATION PROTECTION
	DEMPSTER LATERAL		ICE-RICH CUT
REVISION NO. & DATE	DATE Feb. 5/1979	DRAWING 10	



KOMEX	FOOTHILLS PIPE LINES (YUKON) LTD.		BUTTRESS SUPPORT
	DEMPSTER LATERAL		ICE-RICH CUT
REVISION NO. & DATE	DATE Feb. 5/1979	DRAWING 9	

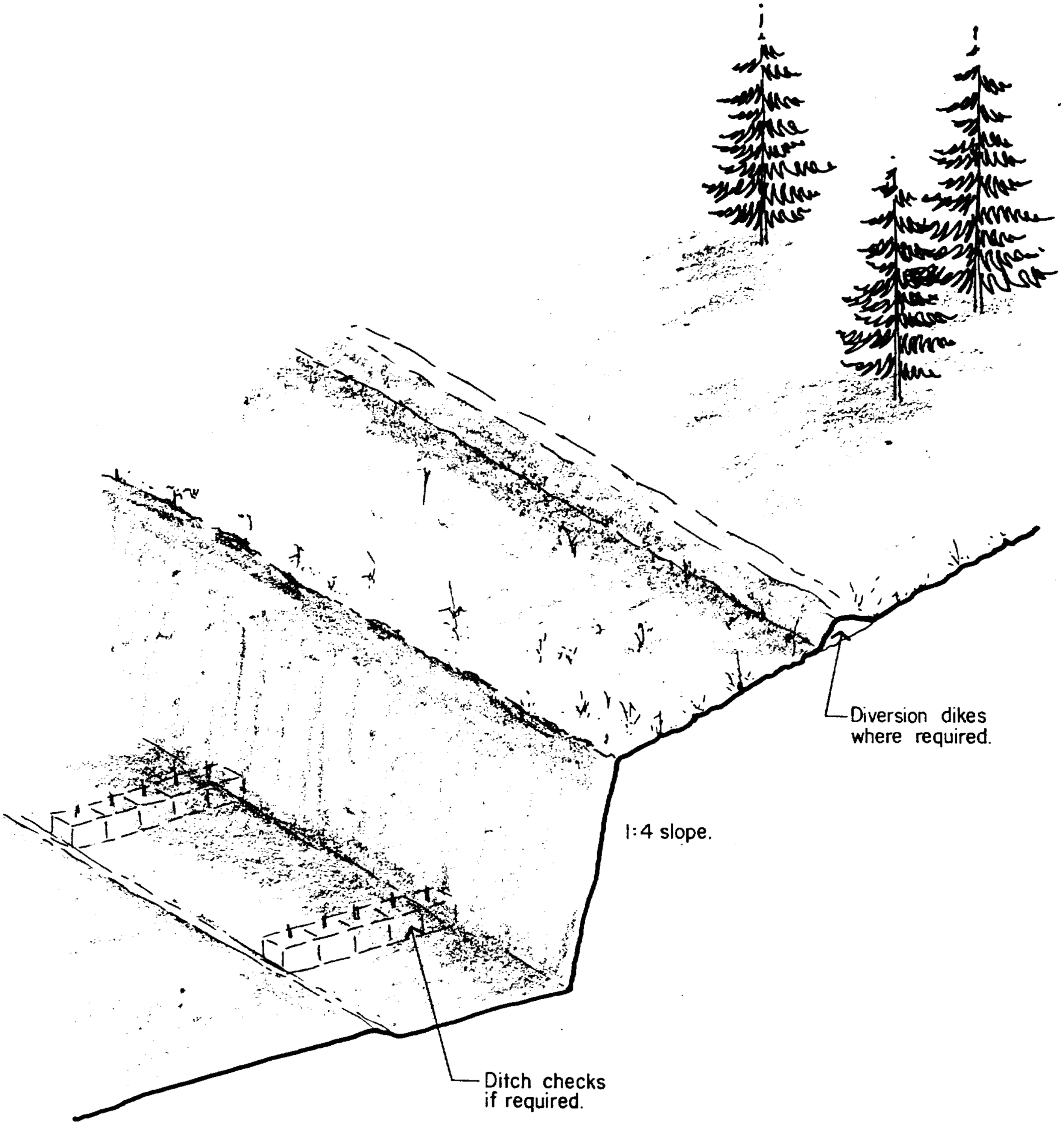
anticipated to be through predominantly clayey soils, for which the following design approaches are recommended (Purahl and Morgenstern and Roggensack, 1974).

To avoid unnecessary excavation of ice-rich materials and to conserve material resources, cut slopes in frozen clayey soil with high moisture contents should be made at a minimum of 1:2. A sand and gravel buttress should be placed on a stable base in front of the cut face as shown on Drawing 9. The buttress placed in front of the cut should be at least 0.6 m wide and should have a finished slope not steeper than 1½:1. The buttress slope should be covered with about 15 cm of topsoil prior to seeding.

Where buttress protection is not practical due to limited availability of sand and gravel, cuts in fine-grained permafrost soils should be excavated at a slope of 2:1 (Drawing 10). A minimum of 15 cm of sand and gravel should be spread over the entire area of the exposed cut. A 5 to 15 cm thick layer of insulation should then be placed over the sand blanket. The insulation in turn should be covered with 15 cm of topsoil and seeded, fertilized and mulched by placing jute netting over the slope.

5.3.2 Protection of Disturbed Areas

Where the natural vegetation mat has been removed or destroyed in disturbed areas other than cuts, the surface should be seeded, fertilized and revegetated. In areas of snow pad construction, the pad should not be built directly on exposed, or graded fine-grained permafrost soil. If the snow pad has to be built on graded fine-grained permafrost, it should be removed before the spring thaw. The exposed working area should then be covered with a layer of sand and gravel 15 to 30 cm thick. The sand and gravel blanket should in turn be covered with topsoil, which should be seeded to protect the underlying soil from thawing. Alternatively, if sufficient material is available, an insulated gravel pad should be constructed instead of a snow pad.



KOMEX	FOOTHILLS PIPE LINES (YUKON) LTD.		NEAR VERTICAL SLOPE
	DEMPSTER LATERAL		ICE-RICH CUT
REVISION NO. & DATE	DATE Feb. 5/1979	DRAWING 8	

cuts are proposed, containment structures should be installed and the behavior of the slopes should be monitored in the summer so that remedial measures can be undertaken the following winter. Where 1:4 slopes are selected, the following design constraints should be considered (Drawing 8):

a) The maximum height of the cuts should not be more than 6.0 m.

b) The slope should be observed periodically and the recession monitored.

c) If the slope fails to stabilize naturally, insulation, or a free-draining buttress should be installed as soon as possible.

d) Provision should be made to divert run-off from cut faces by constructing diversion dikes adjacent to the top of the cut. Provision should also be made for ditch checks, sediment basins and channel liners to prevent silt laden run-off from entering water courses.

e) Where necessary, after the slope has stabilized, the natural regrowth of vegetation should be supplemented with seeding.

Near vertical cuts are economical and more advantageous than conventional cuts, as they eliminate the need of massive revegetation programs, as well as reduce the need for disposal and excavation of large volumes of ice-rich materials.

2) Cuts in Ice-Rich Clayey Soils

Cuts in ice-rich, fine-grained soils should not be made without providing suitable insulating protection. In the case of vertical cuts, the vegetative mat will generally be restored sufficiently to insulate the cut in 2 to 5 years (Lotspeich, 1971). By comparison, sloped cuts may recede a considerable distance due to the lack of vegetative cover. Along the proposed Dempster Lateral route, many of the ice-rich cuts are vertical slopes of 1:4 and at conventional slopes of 1½:1 or 2:1 have performed successfully in most cases, where proper protective measures were taken at an appropriate time. From the existing practices and knowledge it appears that:

a) Near vertical slopes (i.e. 1:4) can be successful in all ice-rich, fine-grained soils where the height of cut is between 1 and 2 m. To prevent the organic mat from ripping, larger vegetation behind the cut-face should be removed. Provision of a buffer zone to accommodate sloughing soils from the cut slopes, ditch checks and periodic maintenance will be necessary for all near vertical cuts (Lotspeich, Aug. 1971).

b) Near vertical slopes in ice-rich silt and colluvium deposits may perform successfully if the height of the cuts is less than 6.0 m.

c) The experience of the Trans-Alaska Pipeline in the Copper River Basin indicates that steep or near vertical slopes in predominantly clayey soils with excessive segregated ice may not be successful, if the height of the cut is more than about 1.5 m. Cuts in clayey soils require insulation, sand and gravel buttressing, rip-rap protection, or a combination of these types of protection.

d) Conventional cuts have been generally successful in ice-rich sand, gravel and other soils with ice contents less than 15%.

e) Revegetation is required for all cuts, except for 1:4 cuts, which require periodic surveillance and maintenance.

1) Cuts in Ice-Rich Silts

Cuts in ice-rich silts should be made near vertical and allowed to self stabilize. As the cut slope recedes, the sloughed material at the toe provides stability and the vegetative mat behind the cut face slumps over the exposed soil, thereby insulating and stabilizing the soil. Where 1:4

5.3 Thermal Erosion

Thermal erosion may occur if fine-grained, frozen soils (FL, FC and FM) with high moisture contents are exposed to thawing. The amount of grading in ice-rich, fine-grained soils should be minimized. In the northern portion of the pipeline route, where the land is basically covered with tundra, grading should be severely restricted as the soil is extremely hard to rehabilitate or revegetate. The amount of grading in ice-rich soils may be reduced by minor re-routing where feasible and by utilizing overlay snow or gravel pads on side slopes of up to about 10%. It is estimated that the depth of cutting required would not exceed approximately 1.0 m for a 10% side slope, and 1.5 m for a 15% side slope.

A rough estimate from the topographic maps indicates that there are about 64 km of pipeline alignment where cuts in frozen soil can be expected. This extimate is based on the assumption that side slopes greater than 10% would require excavation. About 30.6 km of cuts would be made through fine-grained soils having a potential to be ice-rich. The majority of the cuts are not likely to be deeper than about 1.5 m.

Some soils, although frozen, are stable and have little potential for thermal erosion. Fine-grained soils with ice contents in excess of 20% are most susceptible to erosion and are discussed below under the heading of "Cuts in Ice-Rich Soils". For the design of cuts in ice-rich fine-grained soils, the essential factors to be determined include the geologic origin of the deposits, soil type, amount and type of ice and the geometric and topographic set up of the back slope. Cut slopes in stratified soils, or in glaciolacustrine deposits with segregated ground ice, are the most likely to undergo flow slide activity and hence require special design considerations (Komex Consultants, Jan. 1977).

5.3.1 Cuts in Ice-Rich Soils

The experience of the Alaska Highway Department, Trans-Alaska Pipeline and Department of Public Works indicates that cuts excavated at near

5.2 Clearing and Site Preparation

The impact of pipeline construction will begin with the clearing and site preparation operations, particularly when these activities are accompanied by grading and excavation. Once an area has been cleared and the surface soil disturbed, accelerated erosion may occur. This is especially so in permafrost soils with high ice contents, where loss or damage to the organic cover can result in deeper thawing, slumping or mass flow. Where accelerated erosion has resulted from improper clearing or site preparation, restoration work is commonly quite difficult and expensive.

Machine clearing should be used only where the ground surface can support clearing equipment without damage to the organic surface, or where cutting or grading is proposed. In fine-grained frozen soils, if the active layer is thawed, clearing should be carried out by hand. The most attractive procedure would be to conduct clearing operations during winter months when the surface soils are frozen and preferably covered by snow. This would allow the movement of heavy equipment without damaging the ground surface. The snowpad should be constructed so that the organic layer is not disturbed during construction and remains intact after the pad has melted.

Stripping or scalping of the surface organic layer under the insulated workpad should not be permitted. After clearing and grading, the disposal of fine-grained, frozen material which is unsuitable for engineering purposes would require special stabilization measures due to its susceptibility to erosion. Stabilization measures may consist of placement in layers, compaction (if possible) and disposal behind containment dikes. Disposal piles should not exceed allowable heights and slopes and should be revegetated.

5. EROSION CONTROL PROCEDURES

5.1 General

The natural drainage pattern, soils and geology of the area and the proposed construction activities are the major factors in determining measures for preventing erosion. The season and mode of construction, as well as the type and location of workpad, would have a significant effect on drainage. Many problems involving erosion during and after construction can be avoided by implementation of proper and timely control measures. Potential landslide areas, stream crossings and cut and fill sections require special measures to prevent siltation of streams and lakes. Run-off water should be essentially free of sediments before it is allowed to enter a lake or stream. Preventive measures should be selected on the basis of both the effectiveness of the control device and the potential consequences of any erosion.

Severe erosion of exposed slopes is usually caused by concentrated flows. Diversion dikes, ditches and control structures should be constructed at appropriate locations early in the construction of the project. Benches, mulching or covering the soil with various protective materials may be required to reduce slope erosion. Facilities for cross drainage between natural drainage courses should also be installed because rain storm, snow melt and intermittent freezing can result in thaw settlement and damage to the pipe mound.

The control structures provided may be temporary or permanent, depending upon the possibility of restoring disturbed areas by revegetation. The erosion control measures outlined in this section are generally applicable to most of the conditions that can be anticipated, however, final design parameters and site specific designs will have to be developed later on.

areas, alternative locations for construction can be selected. Most of the treatment methods and remedial works are generally carried out at a time when little or no aufeis is evident. It is therefore essential that comprehensive records be made during winter seasons prior to construction so that problem areas can be well identified and the depth and extent of seasonal ice build-up known.

To evaluate potential icing problems that may result due to the operation of chilled gas lines, studies carried out by the Canadian Arctic Gas Pipeline group should be reviewed and if required, a mathematical model should be used to study the effect of the frost bulb growth on the groundwater flow system.

4.6 Icings

Although studies of the occurrence of icings and discussion of possible remedial treatments are beyond the scope of this report, a brief review of potential icing impacts as they relate to erosion is appropriate. Groundwater discharge is primarily responsible for the formation of aufeis, or icing deposits. Icings fed by the active layer often cease to grow during mid winter, but icings formed by perennial springs, or water from unfrozen zones within permafrost will continue to grow, as long as temperatures remain below freezing. Stream icings are generally formed when the water is frozen to the bottom of the stream and freezing continues into the underlying soil.

A field reconnaissance report by the Hydrology Research Division of Environment Canada (Van Everdingen, 1978) indicates that severe icing conditions exist in portions of the Ogilvie Ranges and the Richardson Mountains. Conditions that can lead to icing problems may be present at a number of locations along the proposed pipeline right-of-way. The accumulation of ice on access roads or the pipeline right-of-way can cause damage to facilities and create hazards for equipment and personnel working in the area. Aside from natural icings, the formation of a frost-barrier in water bearing materials due to the operation of a chilled pipeline may result in quick conditions, ponding and growth of aufeis during the winter. Where a stream is blocked by induced icing at the time of spring run-off, there is danger that meltwater will cause flooding and the creation of new channels.

Significant savings in construction and maintenance costs will result from an early recognition of potential icing and other groundwater discharge problems. It is therefore recommended that the location, extent and sources of icings be investigated and the hydrogeological causes of natural icings be evaluated to allow appropriate remedial measures to be developed in advance. If the location, extent and nature of icing problems are known in advance, measures can be taken to prevent damage from erosion and to divert flows that may cause icings. In aufeis prone

4.4 Longitudinal Drainage

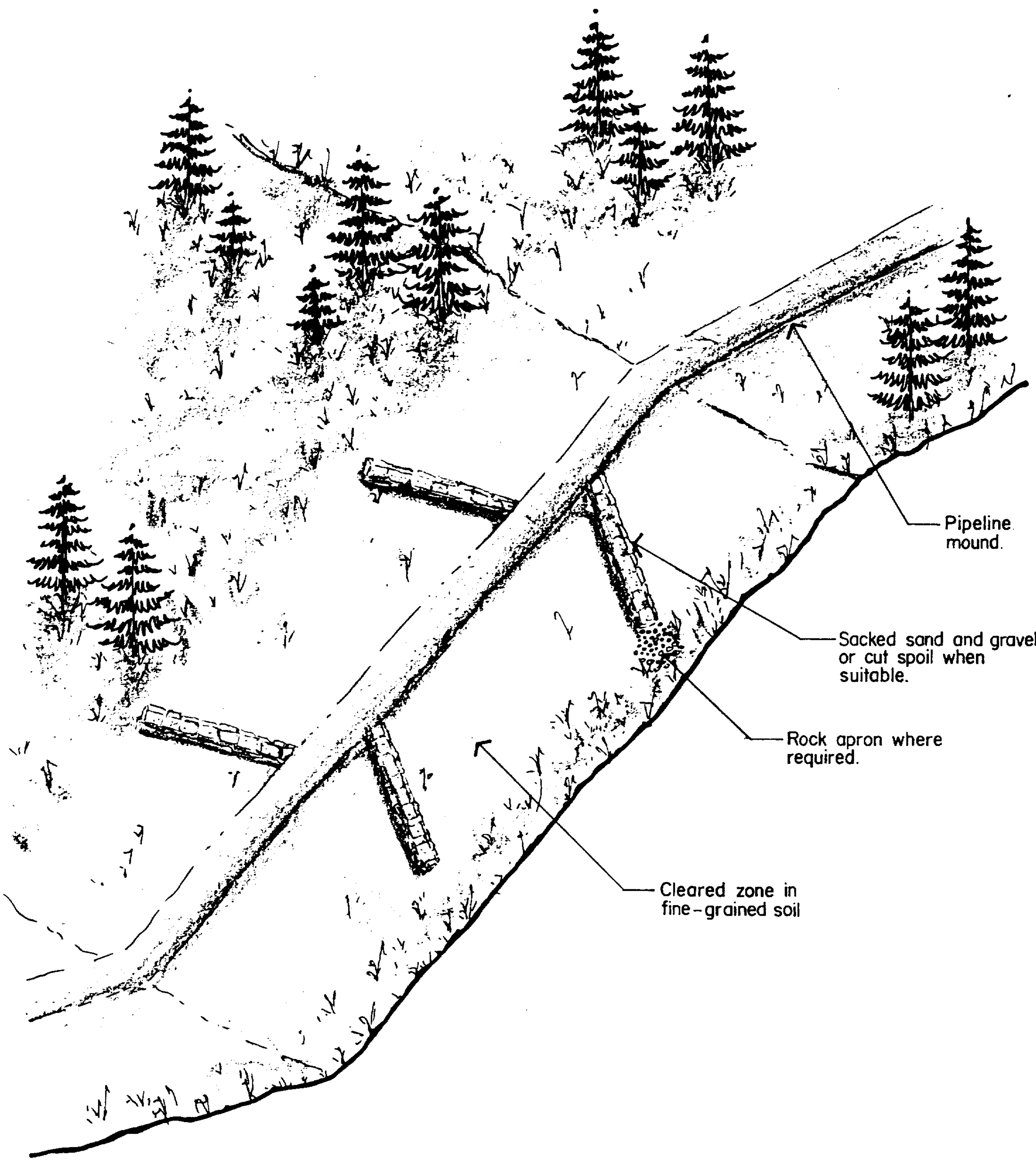
In permafrost soils, longitudinal drainage parallel to the ditch mound or workpad should be minimized by providing for cross drainage at more frequent intervals than would be necessary for directing identified channelized and sheet flows across the pipeline. Ditches should not be constructed in fine-grained frozen soils and ponding should be prevented by providing for cross drainage at appropriate locations. If it becomes necessary to construct longitudinal ditches, the need for a protective liner should be determined from calculations based on discharge quantities and velocities.

4.5 Thaw Settlement and Overfill

Where the pipeline is buried in fine-grained frozen soils and the gas temperature is above 0°C, and where loose frozen material is used as backfill, drainage along a depression resulting from thaw settlement may produce undesirable thermal and hydraulic erosion. Overfill, consisting preferably of non erodible soil, should be placed in areas where the anticipated thaw settlement would be sufficient to result in ponding and erosion.

The topographic configuration, depth of thaw penetration and the consequences of ponding should be considered in determining the dimensions of overfills. On sloping ground, sand and gravel should be used as overfill. However, in relatively flat areas, silty sand can be used, but it should be mulched or revegetated.

Application of overfill should be completed as part of the right-of-way restoration program as soon as construction has been completed.



KOMEX	FOOTHILLS PIPE LINES (YUKON) LTD.	
	DEMPSTER LATERAL	
REVISION NO. & DATE	DATE Feb. 5/1979	DRAWING 7

DIVERSION DIKES
HERRINGBONE TYPE
LONGITUDINAL SLOPE

Diversion dikes may be required above cut slopes in fine-grained permafrost soil if the height of cut is greater than about 1.5 m and anticipated sheet flows exceed about 1 l/sec per lineal meter of cut. In unfrozen, erodible soils, diversion dikes should be considered if the height of the cut exceeds about 3.0 m.

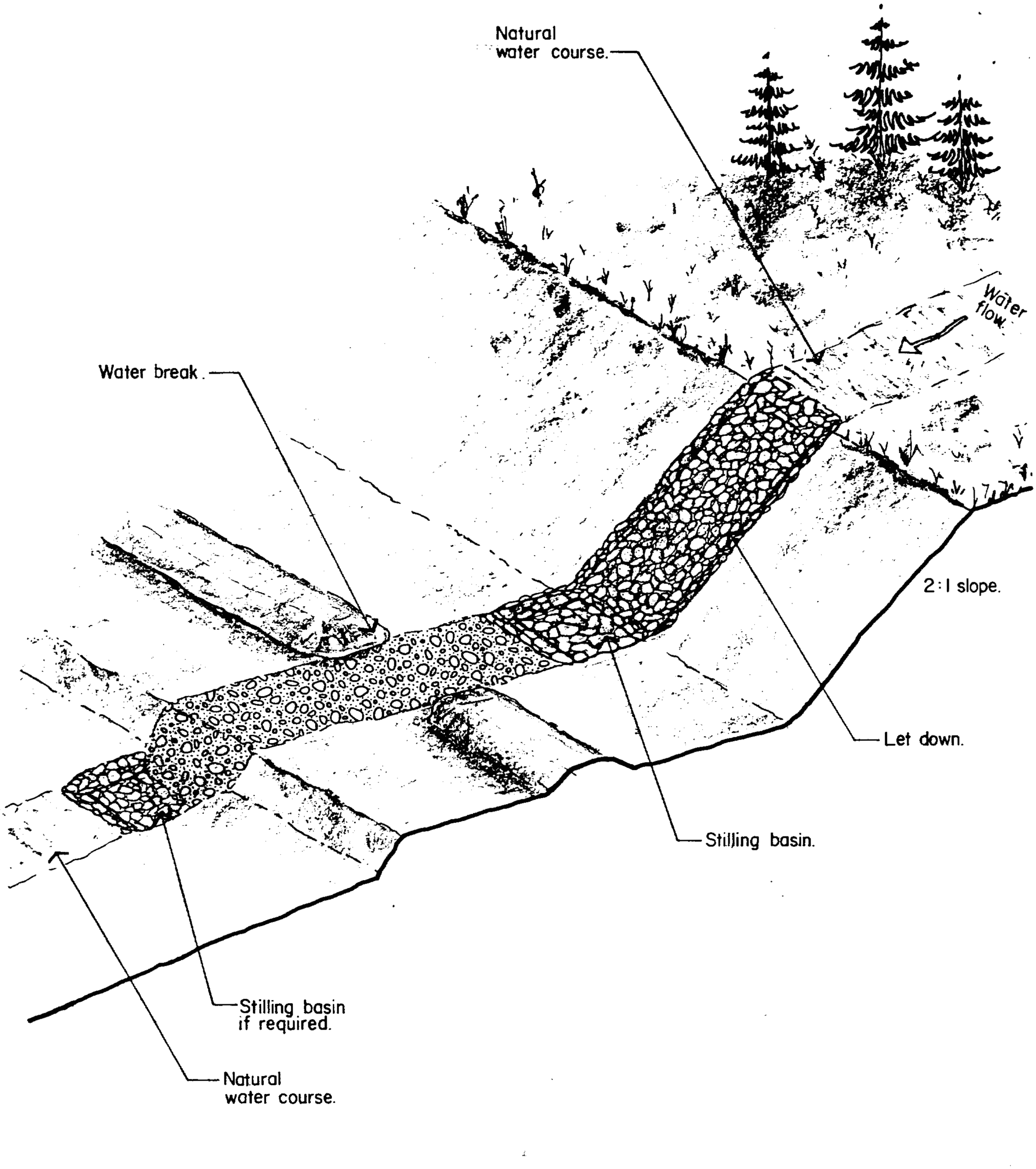
In areas of permafrost, the construction of diversion dikes would require a suitable placement method to ensure that the natural organic mat will not be seriously disturbed. If it is necessary to construct diking in the summer in areas of fine-grained permafrost soil, the dikes may be built of sacked sand placed by hand. In non-permafrost areas, suitable cut spoil can be used for dike construction. Ponding should not be allowed behind the diversion dikes.

The flow velocity behind the dike should not exceed the allowable limit for the respective soil types. Where the longitudinal slope of the natural ground along the dike is sufficient to result in excessive velocity, a channel liner, or other suitable velocity control structure should be installed to avoid serious erosion.

A Herring Bone pattern of diversion dikes can also be used to disperse flows. This type of diversion is most effective where the pipeline traverses longitudinal slopes in fine-grained soils (Drawing 7).

4.3.7 Drainage in Snow Pad Areas

At the end of the winter construction season, snow pad use should be halted before soft spots can develop due to local melting and result in damage to the underlying vegetation. At the completion of pipeline activities and before abandoning the snow pad, it is essential that snow be removed from all natural drainage courses. Water breaks should be cut into the snow pad to avoid ponding.



KOMEX	FOOTHILLS PIPE LINES (YUKON) LTD.		LET DOWN STRUCTURE
	DEMPSTER LATERAL		
REVISION NO. & DATE	DATE Feb. 5/1979	DRAWING 6	

In areas of summer construction, the pipe ditch excavation should be interrupted at an adequate distance from the stream crossing to leave a protective plug of unexcavated material at each bank. The plugs should be left in place until the stream bed excavation is complete and the pipe laying operation is about to commence (Drawing 5).

Temporary access over stream beds should be made by using coarse-grained fill or snow ramps, rather than excavating through the stream banks. Ramps should be removed upon termination of seasonal use.

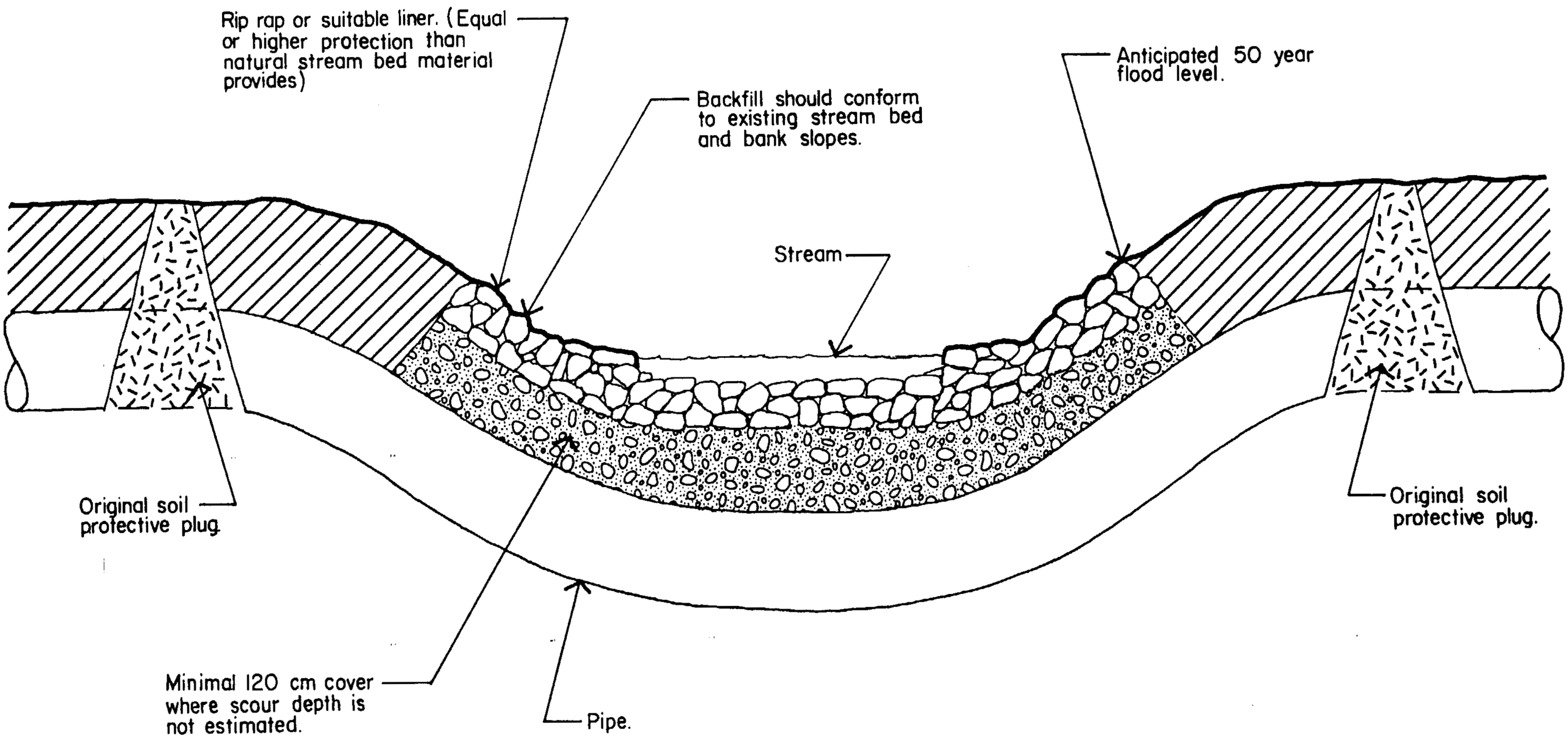
4.3.5 Drainage Across Cut Slopes and Fill Slopes

A let down structure is a lined channel that facilitates the flow of water down a steep slope, while protecting the soil from serious erosion. Let down structures would be required in some cut and fill areas where channelized or induced flow is intercepted by construction. The size of channel liner should be selected on the basis of flow velocity. The bottom of the structure should have the same width as that of the corresponding water break in the pipe trench. A velocity control structure, such as a stilling basin, or rock apron, would normally be required at the downstream end of a let down structure, before the flow is returned to the natural water course (Drawing 6).

The size of protective materials and the let down channel should be selected on the basis of slope inclination and design flow data.

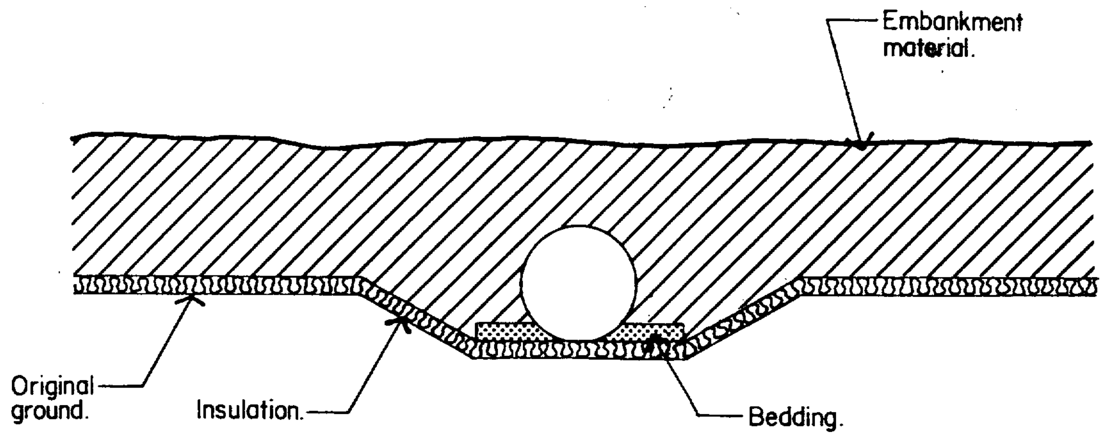
4.3.6 Diversion Dikes

Diversion dikes would be required to divert sheet flow or micro drainage away from cut slopes, the ditch mound and other disturbed areas. The purpose of dikes is to direct drainage into an adjacent water course or to a drainage facility constructed across the pipeline. The need for diversion dikes would depend on the height of cut slopes and the type of soil exposed in disturbed areas.



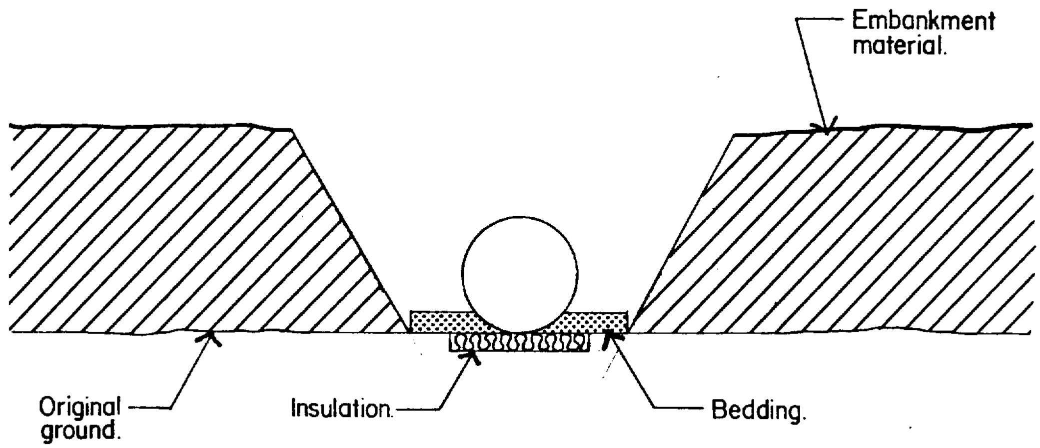
KOMEX	FOOTHILLS PIPE LINES (YUKON) LTD.		TYPICAL STREAM CROSSING
	DEMPSTER LATERAL		
REVISION NO & DATE	DATE Feb. 5/1979	DRAWING 5	

TYPICAL STREAM CROSSING



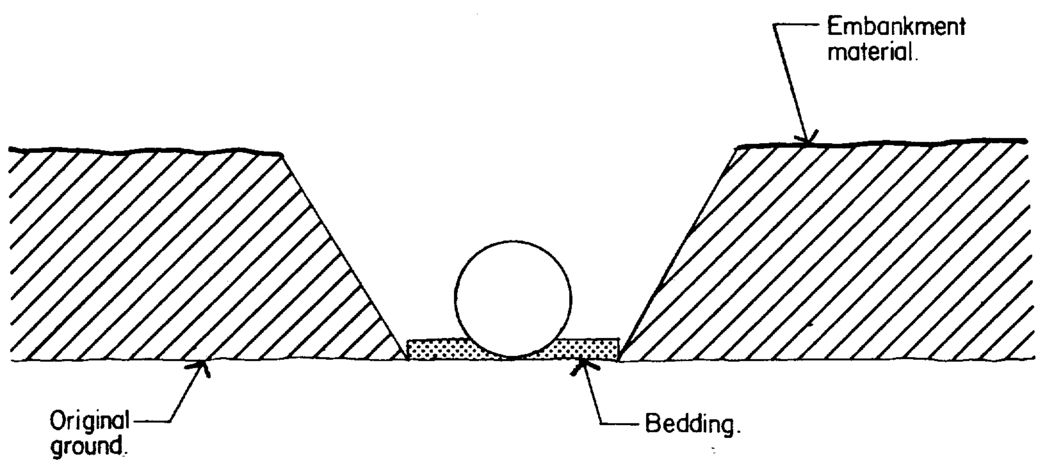
INSULATED EMBANKMENT

PERMAFROST AREA



NON-INSULATED EMBANKMENT

PERMAFROST AREA



NON-PERMAFROST AREA

KOMEX	FOOTHILLS PIPE LINES (YUKON) LTD.		CULVERTS
	DEMPSTER LATERAL		
REVISION NO. & DATE	DATE Feb. 5/1979	DRAWING 4	

4.3.3 Culverts

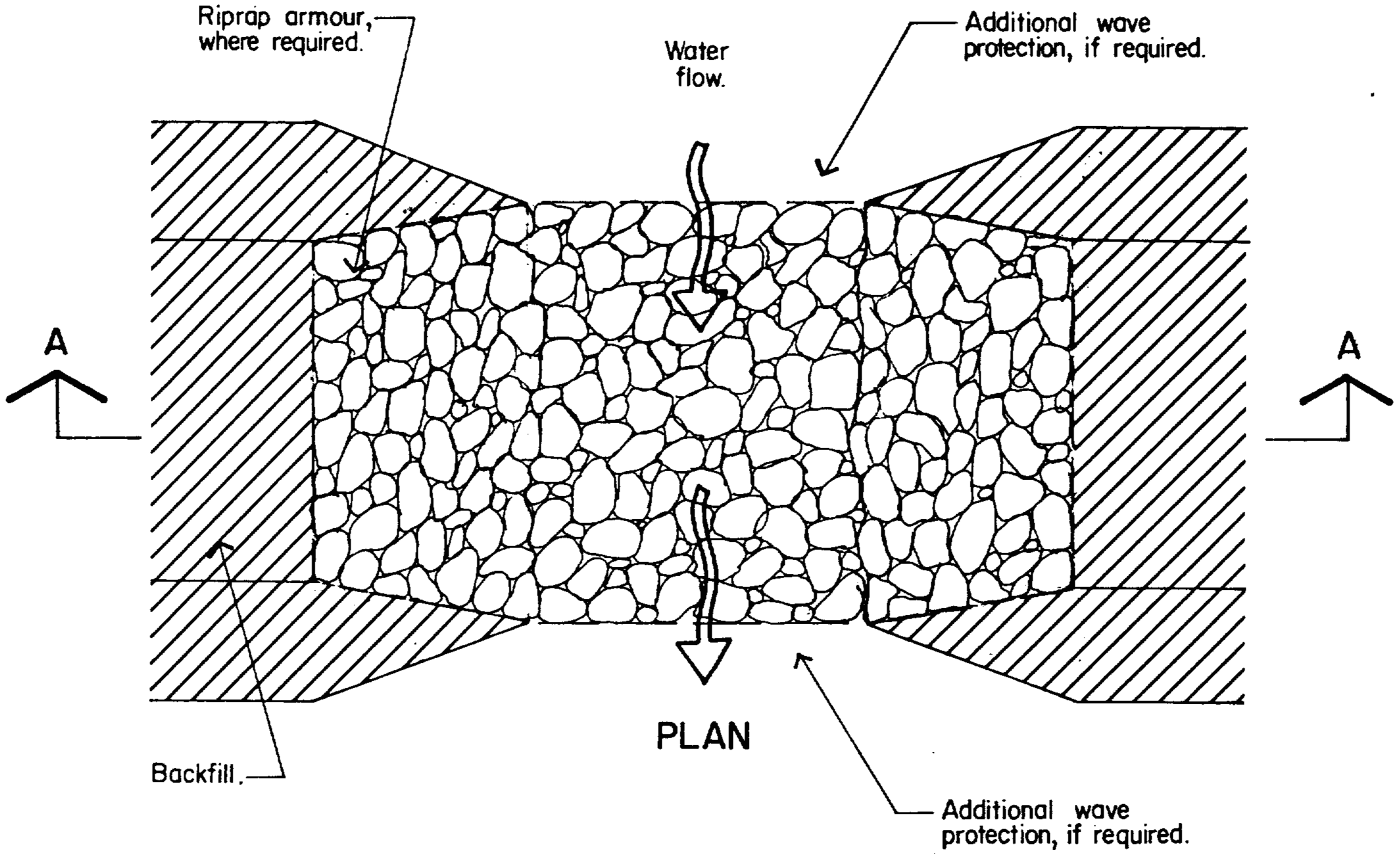
Culverts should be used to facilitate surface drainage across access roads and embankments having a thickness greater than about 75 cm. A culvert generally increases water velocity and may cause erosion at the culvert outfall, particularly when the culvert is undersized with respect to the stream geometry and the soils are fine-grained. Fish passage can be restricted if the culvert is too small and the flow velocity is above about 1.2 m/sec. Ideally, the grade of a culvert should be the same as the grade of the stream. The estimated design flow and culvert grade should be used to tabulate the design outlet velocity for the culvert. If the outlet velocity exceeds the value allowable for the natural soil or stream bed material, a stilling basin, or various types of armouring, including rip-rap should be used.

All culverts should be cambered at least 0.5% of total length. The highest point of the camber should not be above the pipe inlet. In non-permafrost areas, the bedding thickness for the culverts should be about 20% of the culvert height. In permafrost areas, 5 to 10 cm of insulation should be placed below the culvert bedding (Drawing 4). Maximum culvert slope and minimum required gravel embankment must be considered to ensure that the insulated culvert does not become a part of the permafrost.

Since the location of access roads and other embankments is not known at this time, material requirements for culverts are not included in the material estimate presented in this report.

4.3.4 Stream Crossings

Stream crossings would require backfill material of sufficient size to prevent scour and siltation. The material placed should provide protection equivalent to, or higher than the natural stream bed material. The surface of backfill and stabilization materials should conform to the existing stream bed and bank slope profiles.



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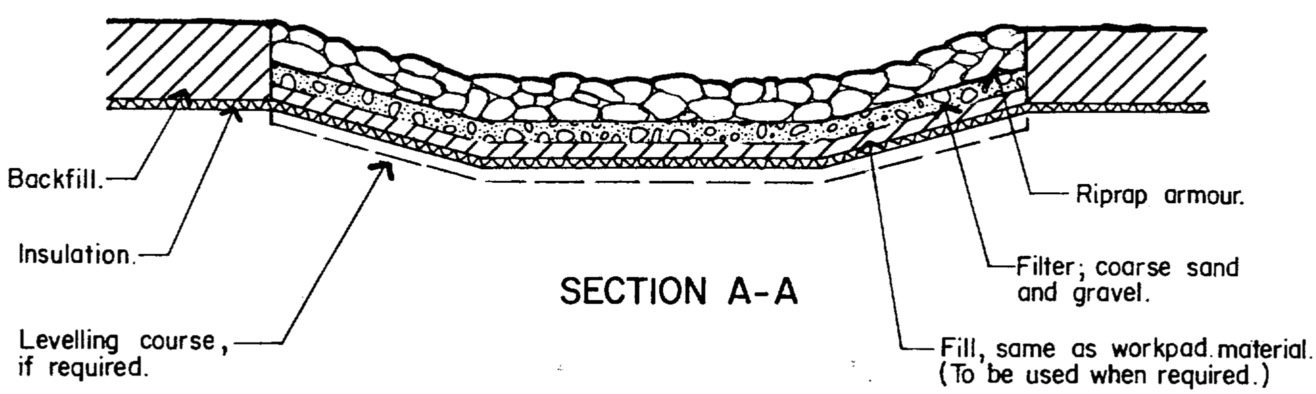


SECTION A-A

KOMEX	FOOTHILLS PIPE LINES (YUKON) LTD.		INSULATED WORKPAD BREAK
	DEMPSTER LATERAL		
REVISION NO. & DATE	DATE Feb. 5/1979	DRAWING 3	

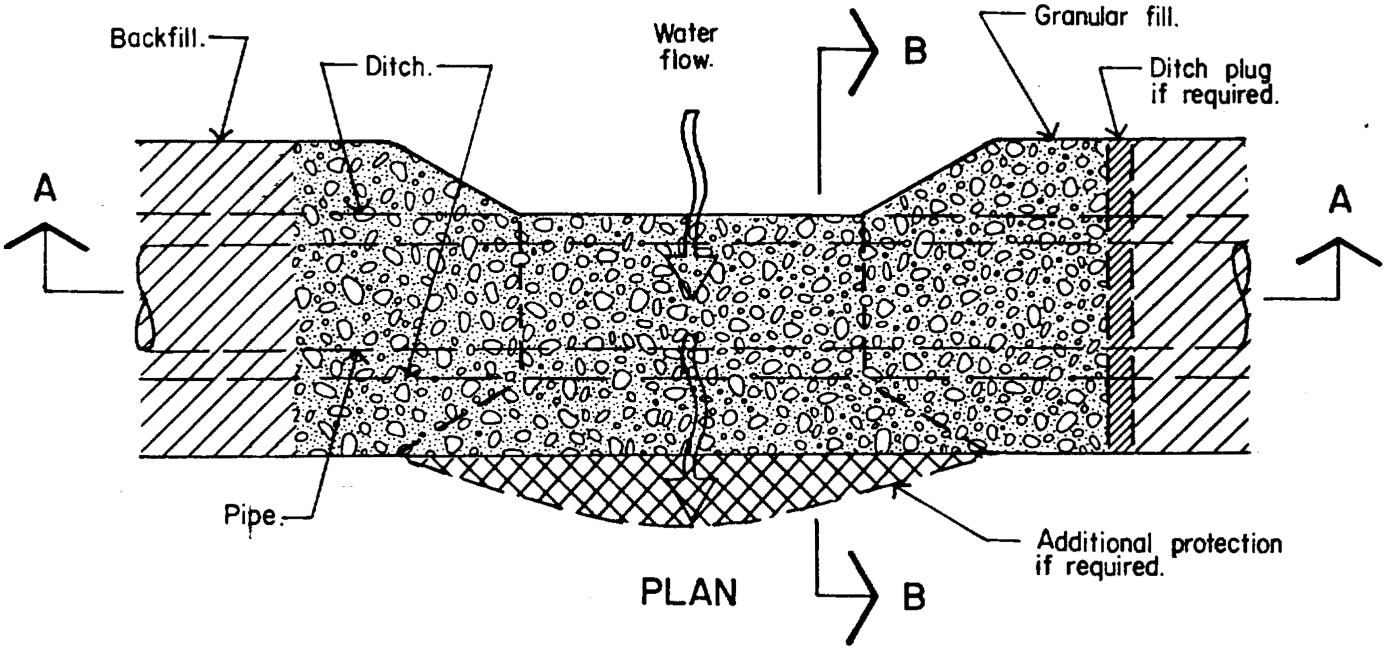
materials to withstand heavy construction traffic. Workpad breaks should be constructed to match the existing stream geometry as closely as possible. The design of a typical insulated workpad break is shown on Drawing 3.

Unlike the breaks required for the backfill mound, breaks in the insulated workpad are assumed to be necessary only in easily distinguishable drainage courses and in depressions where ponding would otherwise occur. A much larger spacing between breaks is thus permissible in the thermal pad than would apply for an unprotected backfill mound. Between pad breaks, minor drainage will tend to be intercepted and diverted to adjacent drainage courses and breaks. This is acceptable, providing that the upslope side of the pad consists of non erodible fill, or is protected with armour. In this study, it is assumed that pad fill would be essentially non erodible.

The insulation thickness would depend upon the soil properties, insulation properties and climatic conditions, however, a thickness of 5.0 cm was assumed for estimating purposes. An armour layer 15 to 30 cm thick should be placed over free draining, well graded filter material having a minimum thickness of 15 cm. To protect the water breaks from wave action due to heavy traffic, the armour layer should extend beyond the workpad limit. On the Trans Alaska Pipeline, it was found that phemeral streams and streams with less than 57 l/sec (2cfs) flow, the use of well graded material ranging from a coarse sand to six inch cobbles was more satisfactory than rip-rap (Ecology and Evironments Inc., 1977).

The excavation for workpad breaks should preferably be done "in the dry". This may require diversion of flowing water courses either by pumping over the workpad, or by diversion into adjacent channels. Most construction drainage problems would be avoided if construction is done during the winter, or after freeze-up.

Workpad construction material can be used as fill between the insulation and filter material provided that the material conforms to placing requirements in effect for protecting the insulation from being damaged.



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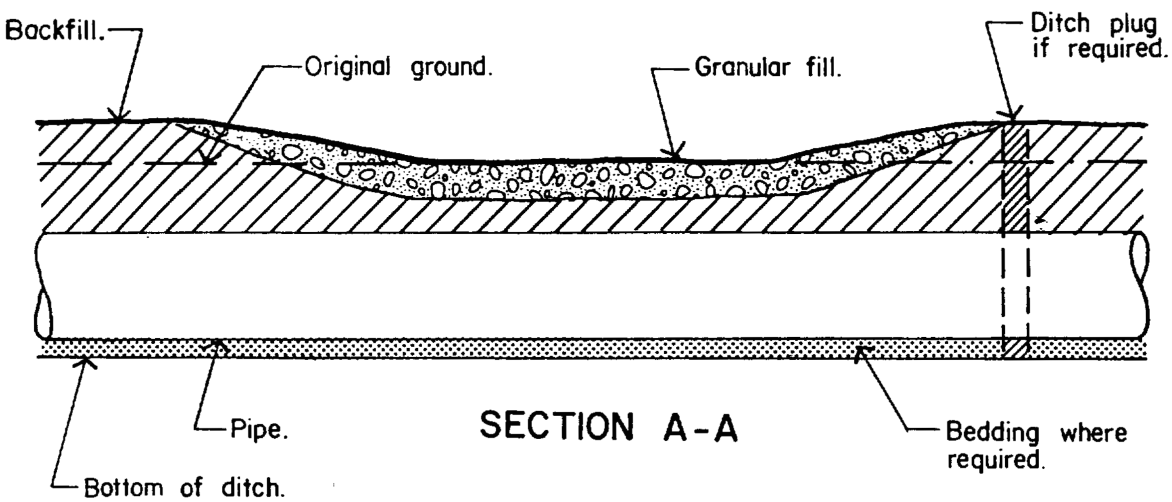
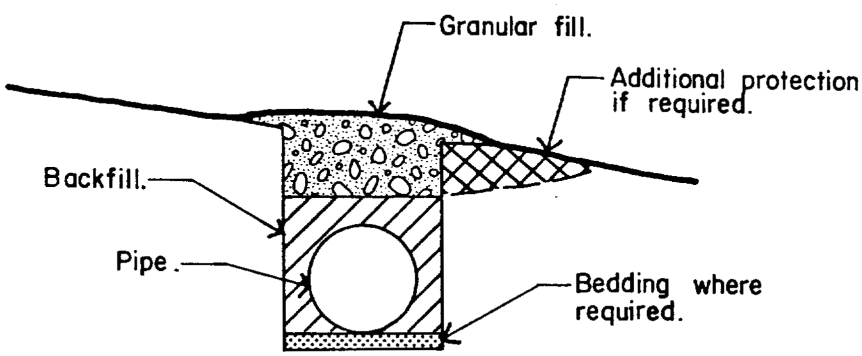


SECTION A-A



SECTION B-B

KOMEX	FOOTHILLS PIPE LINES (YUKON) LTD. DEMPSTER LATERAL		TYPICAL WATER BREAK
REVISION NO. & DATE	DATE Feb. 5/1979	DRAWING 2	

granular soil, ditches placed parallel to the pipeline would allow a much wider spacing between breaks by diverting micro drainage into adjacent water courses and breaks. However, the combined flows should not be allowed to exceed about 300 l/sec.

A typical design of a water break is shown on Drawing 2. Breaks should be placed at all defined water courses and in swampy and flat areas at locations to suit local drainage conditions and topographic configurations. In addition, breaks should be placed at locations intermediate between well defined water courses, so that localized flows will not be unduly concentrated and cause erosion. Where the pipeline is located on the down-slope side of the Dempster Highway, breaks should be designed to allow for discharges anticipated through the highway culverts.

Breaks should be constructed of coarse-grained materials in order to minimize the effects of thaw settlement and frost heaving. Well graded gravel should be used for crossings having velocities of 1.8 m/sec or less. For fish streams, protective materials should consist of clean, well graded gravel having less than 5% fines. Coarse, well graded cobbles or rip-rap should be used as armour for crossings with velocities of between 1.8 and 3.0 m/sec.

If the longitudinal grade of the pipeline in relation to the grade of the water course is such that surface water can enter the pipe trench, a ditch plug should be installed on the downslope side of the water break. Other-wise, flows into the trench could lead to internal erosion and contribute to buoyancy uplift.

4.3.2 Breaks in Insulated Workpad

An insulated workpad is proposed for the northern section of the pipeline across the Mackenzie Delta and the northernmost 20 km of the Anderson Plain. The design of breaks in the workpad would follow the same criteria described previously for the pipe mound breaks. However, the water breaks would be insulated and a layer of armour placed over filter and fill

4.3 Cross Drainage

Drainage facilities will be needed along the pipeline route to ensure that surface drainage crosses the right-of-way in a controlled fashion. The design of cross-drainage structures should accommodate variations in flow without causing excessive changes in channel size, accelerated erosion, or undue siltation. Drainage across the pipeline right-of-way can occur in the form of channelized flow or sheet flow. The following cross-drainage conditions along the pipeline right-of-way are anticipated:

a) Channelized or sheet flow across the pipeline trench
   i) in relatively flat or swampy ground
   ii) in sloping ground

b) Channelized or sheet flow across cut slopes and fill slopes.

c) Channelized or sheet flow across workpads and access roads.

4.3.1 Breaks in Backfill Mound

Breaks in the trench backfill mound will be required to facilitate cross-drainage. The design of stable drainage breaks should be based on a maximum allowable velocity for each soil type. The maximum allowable velocity is that velocity which a particular soil will withstand without eroding. Excluding some special cases, the majority of the breaks would be designed to accommodate flows of between about 56 and 560 l/sec. For estimating purposes, it is assumed that the width of the breaks may vary from 1.5 to 4.5 m and side slopes from 3:1 to 6:1, depending upon the magnitude of maximum flow estimated for a 50 year return.

The spacing between water breaks has been estimated for different areas along the right-of-way on the basis of drainage intensity, ground topography and the soil erosion code. The length and steepness of the slopes in fine-grained permafrost soils (FM, FC and FL) are the most important factors in determining the spacing between breaks. Since longitudinal ditches are to be avoided in these areas, the breaks would have to be located at a relatively close spacing. In areas of bedrock and coarse according to the steepness of slopes and topographic configurations. The sizes of granular materials required as erosion protection have been determined according to the following flow velocity relationship:

Maximum Flow Velocity	Less Than 1.8 m/sec	1.8 - 2.4 m/sec	2.4 - 4.5 m/sec	3.0 - 4.5 m/sec
Material Required	Coarse gravel	Cobbles or rock	Rip-rap	Gabions

To determine the locations of velocity control structures, the following allowable maximum velocities for different soil types have been used:

Soil Type	Maximum Allowable Velocity
L, M and C	0.6 meters/sec
G and P	0.6 to 1.8 meters/sec (depending upon amount and size of gravel, and fibrous or nonfibrous nature of organic matter in P soils)
B	4.6 meters/sec

Further details relating to spacing of structures and design dimensions are discussed in Section 7. Special requirements for fish stream crossings, which are also applicable to the design of drainage structures are beyond the scope of this report.

during the construction of the pipeline. If necessary, intermittent summer streams may be re-routed, but the re-routed streams should be returned to the original courses, or to other adjacent natural drainage ways.

The estimate of drainage control requirements given in this report has been determined from the interpretation of air photos and topographic maps. The pipeline route crosses about 420 well defined drainage courses visible on maps and photos. The courses range in size from intermittent streams having an average annual flow of less than about 28 l/sec (1 cfs) to major rivers. Requirements for erosion protection at some of the major river crossings are discussed in a separate report (Komex Consultants, 1979), and are not included in this study.

For estimating purposes, the water courses along the route have been divided into four categories on the basis of estimated widths and an order of magnitude of flows that are anticipated. These categories apply to intermittent and continuously flowing drainage courses as follows:

a) courses less than 1.5 m (5 ft.) wide; flows generally less than 56 l/sec (2 cfs).

b) courses between 1.5 m (5 ft.) and 3.0 m (10 ft.) wide; flows generally less than 280 l/sec (10 cfs).

c) courses between 3.0 m (10 ft.) and 4.5 m (15 ft.) wide; flows generally less than 1120 l/sec (40 cfs).

d) continuous drainage courses wider than 4.5 m (15 ft.); flows may exceed 1120 l/sec (40 cfs).

Details of each water course, including the type of water course, length and gradient of backslope and the type of soil in which the drainage course is contained are given in Appendix A.

To estimate the requirements for the various types of materials to construct the drainage structures, approximate flow velocities have been estimated

4. DRAINAGE CONTROL

4.1 General

Measures taken for drainage and erosion control should be closely tailored to the particular construction methods adopted. The design concepts presented in this report take into account most of the foreseeable construction including cuts and fills and the use of thermal pads and snow-pads.

Hydrologic data based on studies of the different watersheds and basins and computations of channel discharges and velocities for predicted design flows are not available at this time. Therefore, it has been necessary to base the selection of drainage control methods and structures on generalized design parameters which are considered to be representative of the typical conditions identified. During the design stage, detailed design parameters that are applicable to site specific conditions, should be developed. This will allow the determination of design details and precise dimensions of structures to accommodate the estimated design flows and the anticipated construction on a kilometer by kilometer basis along the pipeline route.

4.2 Design Bases

The permanent drainage system should be designed to accommodate the design run-off expected for a particular region and watershed over a prolonged period. It is recommended that the permanent drainage structures be designed to carry the maximum flows calculated to have a 50 year recurrence interval. Thus, there would be a 0.02 probability that the design discharge would occur in a given year. Temporary drainage controls should be designed for flows having a recurrence interval of about 5 years.

Natural drainage courses should not be permanently re-routed unless the integrity of the pipeline system would otherwise be jeopardized. Temporary re-routing and temporary drainage structures will, however, be required

TABLE 2 - SOIL EROSION CODE

SEC	SOIL DESCRIPTION	OCCURRENCE ALONG THE ROUTE	GENERAL CHARACTERISTICS	EROSION POTENTIAL
FG or UG	Clean sand and gravel with little or no fines (less than 7% silt and clay content).	Occurs in floodplains glacial outwash deposits and Kames & moraines.	Free-draining. Medium to high density, occurs in frozen & unfrozen state, massive ice inclusions are uncommon.	Erosion potential generally extremely low to nil.
FS or US	Silty sand & gravel, mixture of clay, silt, sand & gravel or cobbles & boulders. Fine-grained material less than 50%.	Derived by colluvial processes and weathering of bedrock, as well as occurs commonly in alluvial & glacial deposits along the route.	Found in frozen & unfrozen state. Massive ice inclusions may be encountered, especially in colluvium deposits.	Erosion potential low to medium depending upon thermal conditions, topography & hydrology.
FM or UM	Sandy or gravelly silt or clay. Fine-grained material greater than 50%.	Occurs in the form of glacial, colluvial and alluvial deposits.	Either frozen or unfrozen. High ice-content or massive ice segregation common.	Medium to high erosion potential.
FL or UL	Silt - organic & inorganic silt and clayey silt.	Formed by alluvial, colluvial & glacio-fluvial processes.	Occurs in frozen & unfrozen state, high ice content, common in frozen silt.	High erosion potential
FC or UC	Clay or silty clay.	Occurs in the form of glacial till and lacustrine deposits.	Varies in moisture content, in place density and color.	Medium to high erosion potential.
FP	Peat and organic matters.	Comprises upper 15 to 46 cm of soil profile along most of the pipeline route. Also found in thicker layers.	High moisture, low density.	Erosion potential low to medium, depending upon silt content.
FB or UB	Bedrock, unweathered.	Occurs commonly along the route.		Non-erodible.

* F indicates frozen soil and rock and U denotes unfrozen materials.

TABLE 1

SEC - USC AND TERRAIN TYPE CORRELATION CHART

SEC	SOIL TYPES	TERRAIN TYPE	UNIFIED SOIL CLASSIFICATION
C	clay & silty clay	Lp, Ad, Lb, Mp, Mh, Mv	CH, CL, ML-CL, MH-CH
L	silt	Af, Gp, Ad, Cm	ML, MH, OL, CH-ML, MH-CL
M	sandy or gravelly silt or clay	Af, Md, Mh, Mr, Mv, Ad, Ct, Cs, Cf, Cm	SC, SM, ML-SM, CL-SM
S	silty or clayey sand & gravel	GP, Gt, AP, AF, At, Ad, Cm Ct, Cs, Cf	GM, GC, SM, SC
G	sand & gravel ($<$7% silt)	GP, Gt, AP, Af, At, Eb, Ed, Mv	GW, GP, SW, SP
P	peat and organic matter	pO, pCk, pOv	Pt, Oh, Ol
B	unweathered bedrock	R	—

LOCATION							ESTIMATED ICE CONTENT (by volume)		HIGHWAY		WORKPAD				SIDE SLOPES					LONGITUDINAL SLOPES			
From (km)	To (km)	Distance (km)	Alignment Sheet No.	Spread No.	Terrain Type	SEC	less than 20%	more than 20%	u/h	d/h	T	S	G	N	Length (km)	3% to 10%	10% to 30%	Greater than 30%	Grade of Pipe	Length (km)	10% to 30%	Greater than 30%	Remarks
1061.3	1075.5	14.2	G48D	12	Gp, Ap, (Cm) ($\frac{Cv\cdot Mv}{vR}$)	US (UM)				X					4.6		.3		3-10%				
1075.5	1077.8	2.3	G48D	12	$\frac{Cv\cdot Mv}{vR}$	UM			X						2.3		.3		3-10%				
1077.8	1080.4	2.6	G48D	12	Af, Ap, Gh	US									2.6		.3		3-10%				
1082.2	1100.4	18.2	G48E	12	Gh, Gt, At, Ap	US				X					3.8		.3		3-10%				
1103.6	1108.6	5.0	G48F	12	ssR· $\frac{Mv}{sR}$	UM·UB			X	X					1.8		.3		3-10%				
1108.6	1110.8	2.2	G48F	12	$\frac{Mv\cdot Cv}{sR}$	UM									2.2		.3		3-10%				
1111.1	1130.8	19.7	G48G	12	$\frac{Mv\cdot Cv}{sR}$ (ssR· $\frac{Cv}{sR}$)	UM (UB)									19.7		1-.4		3-10%				
1130.8	1149.5	18.7	48H	12	$\frac{Mv\cdot Cv}{sR}$ $\frac{Mv}{sR}$ · Mm ssR·$\frac{MvCv}{sR}$ $\frac{Mv}{sR}$	UM (UP & UB)									15.2		.1-3		3-10%				
1149.5	1152.6	3.1	49	12	$\frac{Mv}{sR}$, Mm-C	UM									1.7		.3		3-10%				
1152.6	1157.5	4.9	49	12	Gh, Gm	US									2.0		.3		3-10%				
1171.1	1174.6	3.5	50	12	Gh	US														.2		.1	
Alternate Route 1155	1172	17	49	12		US UG															-	X	