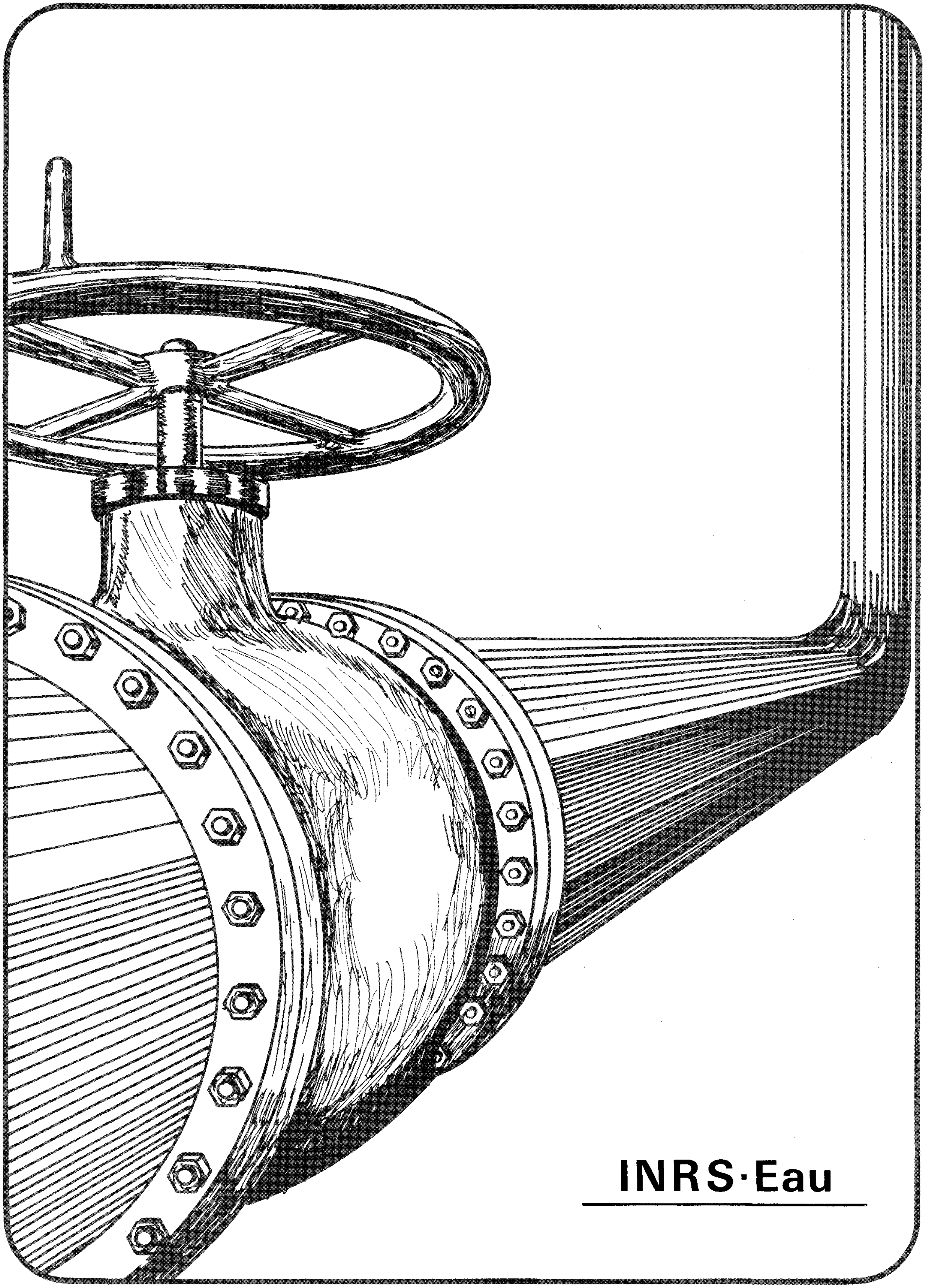

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HYDROGEOLOGICAL ASSESSMENT OF GROUNDWATER DATA FOR THE AREA ALONG THE PROPOSED PIPELINE ROUTE AND AN APPRAISAL OF THE ENVIRONMENTAL CONSEQUENCES

by

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RESUME

La région étudiée dans ce rapport consiste en une bande de terrain, large de 8 milles et s'étendant de Grande Ile, près de Kamouraska, à Rockburn, sur la frontière canado-américaine.

On a dressé un inventaire des municipalités, des villes et des villages situés dans cette superficie en se basant sur les données fournies par le département des Mines du Canada (1) et le département des Richesses Naturelles de la province de Québec (2).

L'annexe A reproduit la liste des localités situées le long du parcours proposé pour l'oléoduc. Les données disponibles actuellement sont insuffisantes pour estimer la quantité d'eau souterraine qui est utilisée par les habitants. Toutefois, on possède certaines données sur le nombre de personnes qui tirent leurs eaux de consommation de la nappe souterraine. A partir de ces données, on peut calculer la quantité approximative d'eau puisée de la nappe phréatique et qui sert aux usages domestiques.

Du point de vue qualité chimique, les données que nous possédons remontent en 1955-1960. Durant ces années, on a analysé la composition de l'eau provenant de vingt (20) puits différents. Ces résultats sont inclus à l'annexe C.

ABSTRACT

The general area considered in this report is a strip 8 miles wide that extends from Grande Ile to Rockburn at the United States border.

An inventory of municipalities, town and villages in the area has been compiled based on data taken from Canada Department of Mines and Technical Survey, Water Survey Report No 13, 1962 (1) and Records of the Quebec Department of Natural Resources (2).

Users of groundwater along the proposed pipeline route are indicated in tabular form. Data available at the present time is insufficient for estimation of groundwater usage but population figures (1970) are shown where available and approximate domestic usage is calculated.

Chemical analysis collected during a well inventory during 1955-1960 for 20 water supplies along the proposed route are included.

1. INTRODUCTION

1. INTRODUCTION

For the purpose of this study the proposed pipeline route was plotted on a reduced scale map of 1" = 20 miles, using major towns, highways and rivers as standard reference points (figures 1.1, 2.1 and 2.2).

The limited information available, particularly from Grand Isle to Quebec, made it necessary to generalize groundwater conditions in two major hydrogeological regions through which the proposed pipeline passes, namely the Appalachian Hydrogeological region and the St Lawrence Lowlands Hydrogeological region. A broad outline of the Hydrogeological conditions occuring in these regions is given.

All towns and villages within an eight mile wide strip of the pipeline were indexed sheet wise and the grid coordinates were plotted. This information is included in figure 1.1 and APPENDIX A.

From the index of towns and villages, groundwater users and the chemical analysis of the water where available were com-

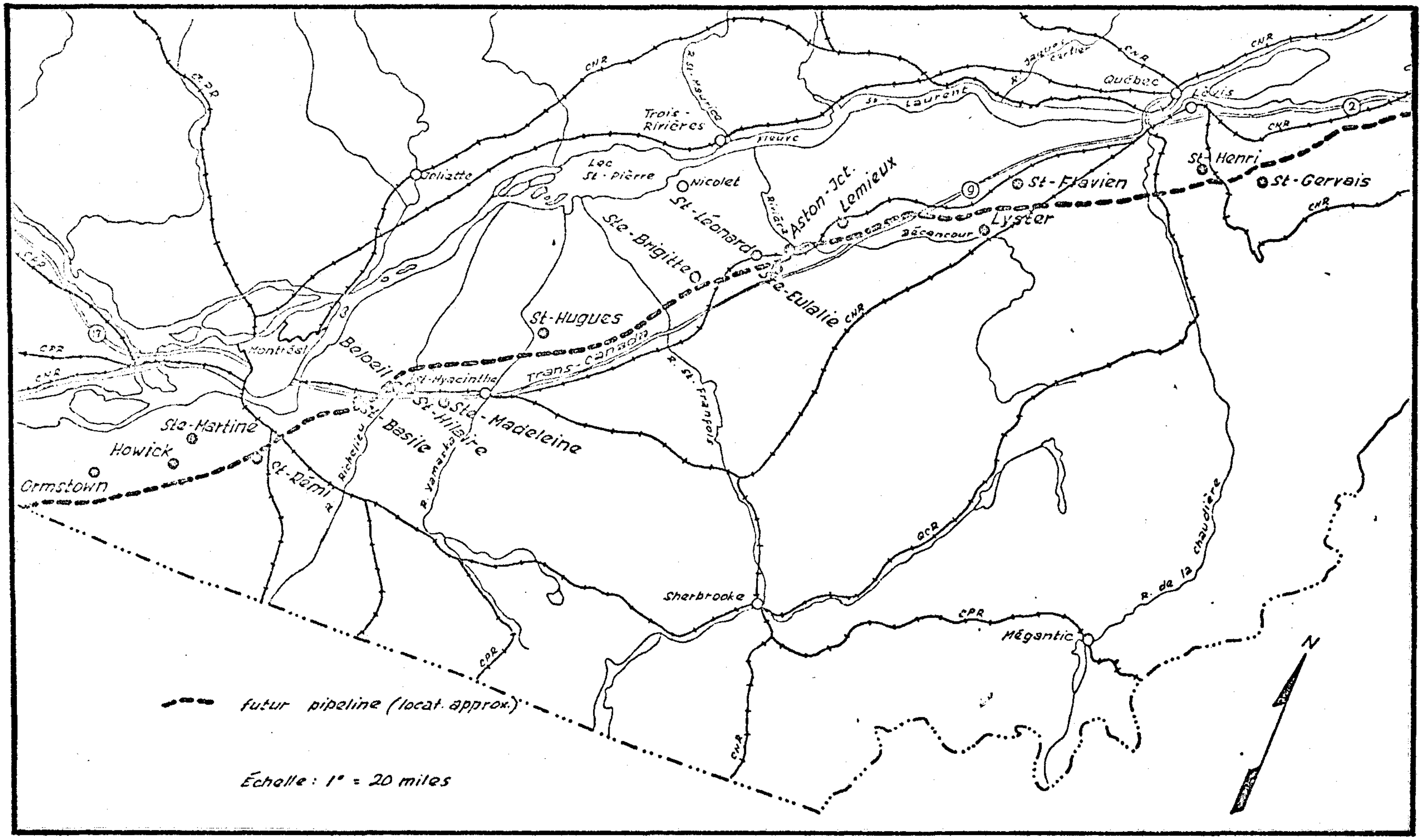

FIGURE 1.1: Towns and Villages Using Groundwater Along Proposed Pipeline Route Quebec-U.S. Border

piled as APPENDIX B and C respectively. The approximate water usage computed on the bases of the population figures for 1970 and a consumption rate of 80 gallons per head per day (3) is also included (appendix B).

No information on major aquifers is available from Grand Isle to Quebec, but some information on the type of aquifers and their properties from Quebec to the U.S. border is tabulated in APPENDIX D.

A general description of the bedrock aquifers encountered along the pipeline route in the Quebec-U.S. border sector is incorporated in this report.

No generalization could be made of the chemical characteristics of the groundwater, as the chemical analysis available pertain to waters occuring at different depths representing different components of the flow system.

2. GENERAL HYDROGEOLOGY

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The proposed pipeline passes through two major hydrogeological regions:

1) the Appalichian Hydrogeological region,
2) the St Lawrence Lowlands Hydrogeological region.

The regions are broadly divided on the bases of geology, chemical properties, precipitation, topography and general hydrologic characteristics. The boundaries do not represent sudden changes but are zones of change.

2.1 Appalachian Hydrogeological region

Little published information concerning the groundwater along the pipeline route within the Appalachian Hydrogeological region is available.

Lee (5) reports two types of sand and gravel deposits in the Rivière du Loup area approximately 20 miles east of the tank farm that should be good aquifers. The first type are outwash deposits comprising silty sands. The second type is represented by high and low terrace sands. The high terrace sands are clean and occur between 50 and 350 feet above sea-level, the low terrace sands comprise silty sand that occur below and elevation of 50 feet. The aquifer thickness is about 20 feet.

The groundwater flow is controlled by topography and follows the surface drainage system. On a regional scale the groundwater flows from the highlands to the lowlands towards the Gulf of St Lawrence.

2.2 St Lawrence Lowlands Hydrogeological Region

More data is available for this region, even though sufficient detailed studies have not been made, as yet, to permit a detailed quantitative assessment of the groundwater potential of the region. Reports of the Quebec Dept. of Natural Resources provide some basic data from which a preliminary qualitative assessment of the groundwater resources can be made (4).

Groundwater in the St Lawrence Lowlands Hydrogeological region is obtained primarily from aquifers made up of unconsolidated materials but is also often obtained from the bedrock aquifers. Significant variations in stratification and in area of the lithology of the geological materials occur throughout the lowlands area: consequently aquifer characteristics vary from place to place.

2.2.1 Bedrock Hydrogeology

The oldest rocks in the area are sandstones of the Potsdam Formation of the Cambrian Age. The groundwater is mineralized to varying degrees, depending upon the solubility of the minerals contained in the rocks and the rate and flow of groundwater through the rocks.

Middle Ordovician strata of the Chazy and Trenton Group from another aquifer are characterized by thick to thin beds of limestone, where horizontal and vertical jointing is moderately well developed.

The hydraulic conductivity is not the same over the whole region and there is considerable variation in the aquifer potential.

The Upper Ordovician rocks of the Utica, Lorraine and Richmond Groups are made up of shales with minor interbeds of limestone and sandstone form another distinct aquifer.

Vertical and horizontal fractures are not well developed but are present to an extent that allow some movement of groundwater through the rocks. The aquifer potential is poor with yields of a few gallons per minute. Bedrock geology is shown in FIGURE 2.1.

2.2.2 Unconsolidated Deposits-Hydrogeology

The bedrock aquifers are covered in most

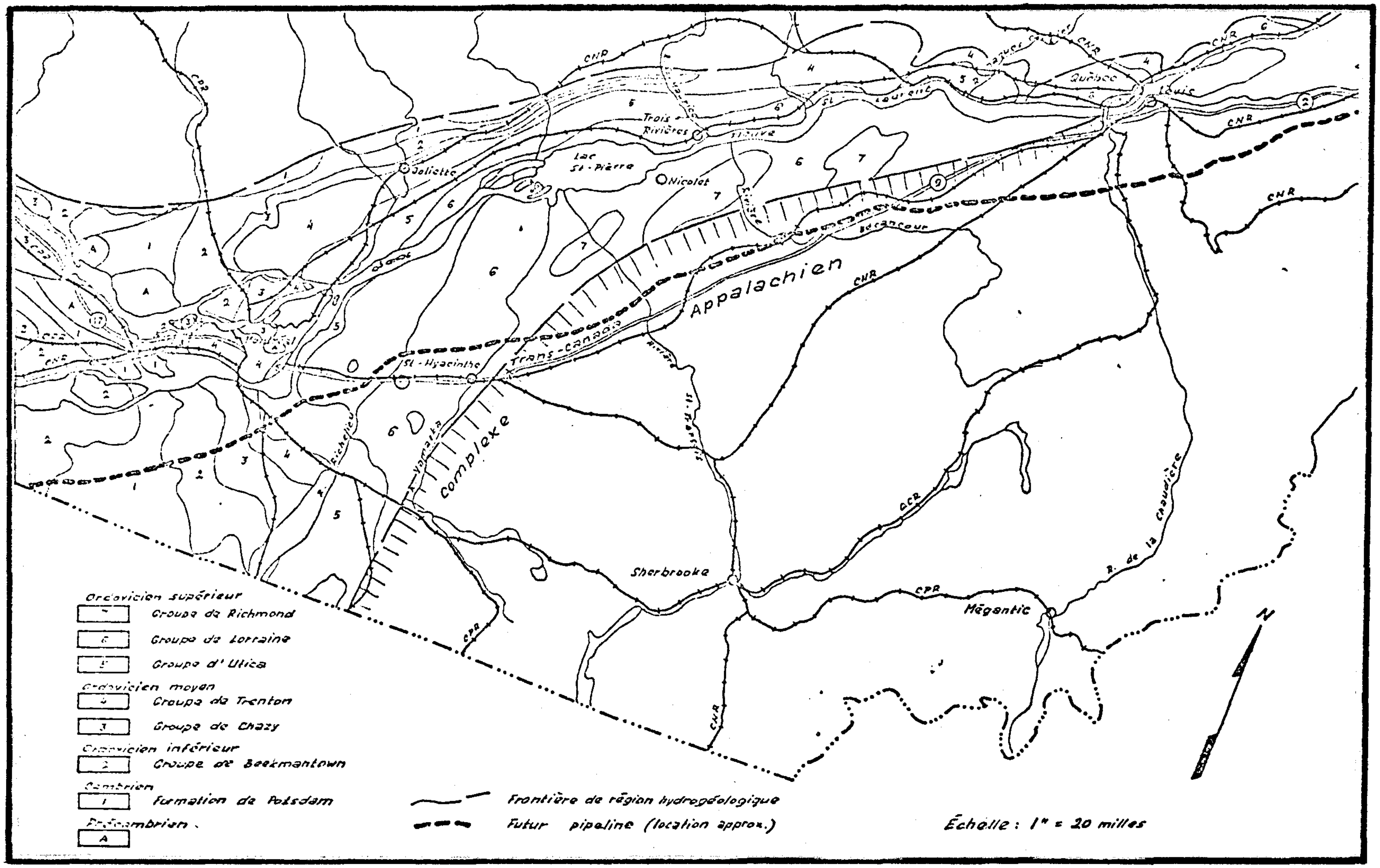

FIGURE 2.1: Bedrock Geology Along Proposed Pipeline Route Quebec-U.S. Border

places by unconsolidated sediments of glacial and related origin along with relatively small areas of recent sediments associated with recent streams and rivers.

The unconsolidated materials have been deposited as a result of (1) glaciation, (2) Marine invasion during the recessional phase of glaciation, (3) alluvial deposition during the withdrawal of the seas from the area.

With the recession of the glacier the area was covered by marine silts, clays and minor sands deposited in the Champlain sea which make up the thickest and most extensive sequence of surficial deposits. Drainage of the Champlain Sea was replaced in progressive stages first by estuarine, then by fresh-water lacustine and fluvial sediments of the present fresh water drainage system.

The deposits of terrace and alluvial sands constitute some of the best aquifers which serve as public water supplies for many of the towns and villages in the area. Second in importance are the springs that issue at the contact of the terrace sands with the underlying clay that are used as sources of water by some communities.

The third source are deposits of glacial outwash composed of sand and gravel which are generally of local occurrence. The distribution of coarse granular materials in the surficial deposits that make up the better aquifers are shown in FIGURE 2.2.

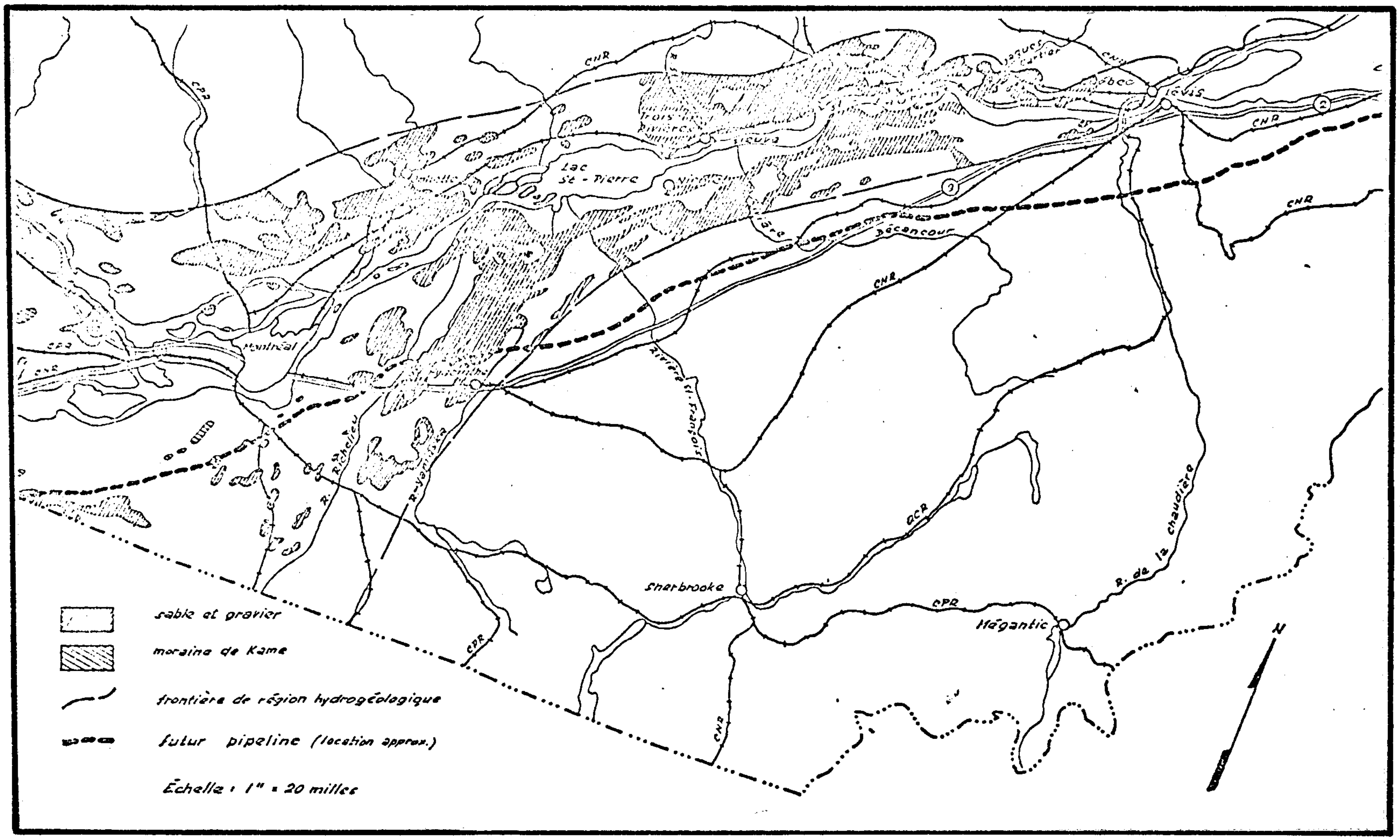

FIGURE 2.2: Distribution of Ground as National Along Proposed Pipeline Route Quebec-U.S. Border

3. FLOW SYSTEM

3. FLOW SYSTEM

No quantitative assessment of the groundwater flow system has been made in the area. The general regional flow pattern would be from the physiographic hights to the lowlands. The local groundwater flow system where most of the groundwater supplies are obtained is influenced by local surface drainage patterns, further in the lowland area aquifer characteristics vary significantly with changes in the lithology of aquifer materials both in stratification and in area distribution. Water level measurement information is limited, therefore no flow pattern in the major aquifers could be established.

The quantity of the groundwater supply varies. Till, or boulder clay, does not yield water freely. However, gravelly and sandy deposits furnish abundant volumes of water. As a result, the availability of groundwater varies markedly from one area to another and with subsurface depth.

Sand and gravel aquifers, produce moderate to high yields, most notably along the St.Lawrence River. In this area, the sand and gravel deposits are elongated and are separated by fine grained tills. Where fractured, and in hydrologic contact with surface waters, crystalline aquifers can produce groundwater in excess of 200 gallons per minute, but normal yield is 10 gallons per minute. Sandstone units are slightly more productive, having a normal yield of 15 to 20 gallons per minute and up to 475 gallons per minute where recharge and permeability are high. Still greater normal yields, 25 to 30 gallons per minute are derived from carbonate units.

4. DESCRIPTION OF BEDROCK AQUIFERS

4. DESCRIPTION OF BEDROCK AQUIFERS

The following is a qualitative assessment of major bedrock aquifer systems through which the proposed pipeline passes;

1. Appalachian Complex. Heterogenous composition mainly schists. Low permeability with flows from 1-10 g.p.m. Occasional yields of up to 200 g.p.m. in structurally favorable areas.

2. St Germain Complex. Strongly faulted and folded Lorraine, Trenton and Utica rocks. Yields from 5-10 g.p.m., the water is generally hard.

3. Queenstone Group. Red and grey schists with minor amounts of gypsum. Poor permeability, in general flows do not exceed 10-20 g.p.m., the water is mineralized due to gypsum.

4. Lorraine Group. Essentially calcareous shale, good yields of up to 50 g.p.m., water is basic and hard.

5. Nicolet River Formation. Fairly widespread, composed of shales and fine grained sandstones. Few wells tap this formation, flows from 20-50 g.p.m. encountered.

6. Cretaceous. Mainly gabbros and alkaline rocks, no information on aquifer potential.

7. Utica Group. Includes shales in contact with Upper Trenton Thickness from 300-400 feet. Average yields from 5-10 g.p.m.

8. Trenton Group. Essentially limestones from 200-1100 feet thick. Depending on depth and extent of fissures, yields may be from 500-1000 g.p.m.

9. Chazy Group. Predominately dolomitic schistose limestone, thickness about 300 feet. Permeability variable but low with yields less than 10 g.p.m.

10. Beauharnois and March Group. Comprises dolomitic sandstones, contains alteration zones where good yields of up to 750 g.p.m. may be obtained.

5. ANTICIPATED IMPACT ON QUALITY AND YIELD OF AQUIFERS

5. ANTICIPATED IMPACT ON QUALITY AND YIELD OF AQUIFERS

Potential impacts of pipeline construction and operation are discussed below. In addition, impacts foreseeable as a result of potential accidental releases of crude oil are addressed in this section.

5.1 Actual Quality of Groundwater

Quality of the groundwater is dependent on the aquifer type. High quality water with low mineral content is usually obtainable from crystalline aquifers. Carbonates yield supplies with high mineral, dissolved solids, and hardness levels.

Chemical quality of the groundwater varies with the rock unit from which it is drawn but normally is high enough for domestic use with little or no treatment. Water derived from the bedrock aquifers is usually more highly mineralized than that from the unconsolidated sand and gravel lenses.

5.2 Impact of Tank Form and Pipeline Construction.

It is impracticable to quantitatively determine the extent the pipeline will cut through aquifers at the present stage. It can be expected, however that the pipeline will pass through some of the watertable aquifers in the St Lawrence Lowlands Hydrogeological region.

Trench dewatering during the construction phase could possibly result in the lowering of water levels, specially where the water table is at or near the ground surface.

Construction on this scale would have various impacts on the immediate environment in the tank form and along the pipeline easement.

Removal of stabilizing vegetation and grading of the topsoil presents an erosion potential. Erosion and transportation of finely divided materials can increase the turbidity of nearby surface waters and result in areas of anomalous deposition. The water quality would be degraded specially if heavy runoff occurred in areas of highly erodible soils. Also, trenching of the river substrates and removal of bank vegetation would temporarily increase turbidity levels in the surface water.

Areas of clay and silt deposition have an impact on groundwater systems if the flow through recharge or discharge zones is clogged. If surface drainage patterns are altered, flow rates in neighboring streams could change, as well as recharge to groundwater aquifers. Limited effects on the groundwater systems will result from construction activities. If excessive amounts of fine particles are put into suspension, to be deposited elsewhere, it is possible that the surface of a recharge area may be clogged. The result of such clogging will be an increase in surface runoff and a decrease in groundwater volume. If significant deposition occurs in a discharge area, an impermeable silt and clay layer will be formed, blocking water flow. In this case, stream flow will be reduced. Both of these cases are improbable, yet possible, impacts.

5.3 Impact Due to Oil Leaks

Accidental releases of crude oil, the primary hazard to the environment during operation of the pipeline, will lower the quality of groundwaters. In the event of an accidental release of product on a dry soil, the oil will penetrate to a depth that will depend not only on the quantity of spilled oil and the topography but also on the porosity of the soil. Deeply oiled soils, if dry, are difficult to wet. In case of rain, the water will enter oiled land from the sides and from below by the rising water table. Should this occur, an important long-term impact would result.

The St.Lawrence River Valley has been identified as a tectonically active area. While the degree of earthquake risk in the area is still being debated, the possibility of a seismic event cannot be discounted. While pipeline design could ordinarily make failure during a quake a small risk, the thixotropic nature of the Pleistocene clays precludes this. Pipeline rupture would result in rapid dispersion of crude oil directly into the environment. In this event, release and mitigating measures prove inadequate, water quality would be degraded. Surface waters would be damaged first, and if the volume of the release is large, groundwater aquifers could be contaminated. Should a fire break out during operation, air quality would be unavoidably lowered.

The potential contamination to the groundwater system due to oil leaks in the operational phase would need more study. The detrimental impact to the groundwater system and the extent of contamination would depend on various factors such as the physical properties of the aquifer materials, rates of flow and the nature of the local flow system.

5.4 Impact on Water Use

From information available, there are 27 communities using groundwater systems along the proposed pipeline route, not including numerous individual users. The importance of this resource, which is often the only water source to some communities, will increase with industrial expansion and population growth (6). The overall chemical quality of the groundwater is good, most of the groundwater is used without pretreatment other than, in some cases, chlorination and filtration. Limited information does not permit any quantitative assessment of groundwater flow systems in the area; in order to study the groundwater regime in more detail, it would be necessary to update the existing information and identify users and long-term requirements more accurately.

In the two major hydrogeological regions through which the proposed pipeline passes, numerous municipal water supplies are drawn from sand and gravel aquifers. Generally, pollutants disperse widely in aquifers of these types. Accidental releases of crude oil en tering the groundwater system will have an impact over a large area. Contaminated surface waters have a capacity to restore themselves rapidly through biochemical degradation and dilution of pollutants, but groundwater aquifers, when contaminated, will cleanse themselves very slowly, if at all.

The importance of this impact becomes apparent when the large number of municipal water supplies drawn from the groundwater system is considered, any accidental releases or changes in the recharge capacities would diminish the quality and quantities of these supplies. When water supply sources are affected, the water quality reductions would influence the human environment and local populations could suffer some inconveniences due to odor and taste problems resulting from the oil spillage. In this event, additional treatment may be necessary.

6. CONCLUSIONS

6. CONCLUSIONS

1. From information available there are 27 communities using groundwater systems, this does not include numerous individual users.

2. With industrial expansion and population growth, the importance of groundwater is increasing, ofter groundwater is the only source available to some communities.

3. The overall chemical quality of the groundwater is good, most of the groundwater is used without pretreatment other than in some cases chlorination.

4. Limited information does not permit any quantitative assessment of groundwater flow system in the area.

5. In order to study the groundwater regime in more detail, it would be necessary to update the existing information and identify users and long term requirements more accurately.

6. The nature of aquifers with their hydrological properties are tabulated in APPENDIX D. Additional field

works is required to supplement existing data in order to delineate the more important hydrologically homogenous aquifers along the proposed pipeline route.

7. REFERENCES

7. REFERENCES

(1) Canada Department of Mines and Technical Survey Water Survey, Report No. 13, 1962. Ottawa, Ontario. 1962.

(2) Quebec Department of Natural Resources Données hydrologiques sur les eaux souterraines, Québec, Canada. 1972.

(3) Cluis, D.; Couillard, D.; Mascolo, D. et Meybeck, M. "Caractéristiques physico-chimiques des effluents urbains", présenté à la conférence conjointe AQTE-FACE, Montréal, 30 avril - 3 mai, rapport technique no. 4, INRS-Eau, 1972.

(4) Prévot, J.M. Hydrogeological Map of the St Lawrence Lowlands Quebec Dept. of Natural Resources. 1972.

(5) Brown, I.C. Groundwater in Canada G.S.C. Economic Geology Report No. 24 1967.

(6) Thomas J.F.J. Industrial Water Resources of Canada. Dept. of Mines and Technical Services. Water Survey Report No. 13.

APPENDIX A

INDEX OF TOWNS AND VILLAGES ALONG PROPOSED PIPELINE ROUTE.

INDEX OF TOWNS AND VILLAGES AND POPULATION			
	COORDINATES		POPULATION (1970)
	N-S	E-W	
GRANDE-ILE	34.85	73.85	---
ST-GERMAIN	40.00	70.70	487
KAMOURASKA	35.40	68.20	532
ST-PASCAL	39.00	64.00	1214
ST-DENIS	30.50	61.35	610
ST-PHILIPPE-DE-NERI	33.00	57.00	1176
RIVIERE-OUELLE	23.00	53.60	1590
ST-PACÔME	28.50	50.70	571
LA POCATIERE	21.40	46.30	1310
STE-LOUISE	24.00	36.50	949
ST-ROCH-DES-AULNAIES	11.00	40.00	1005
ST-ROCH VILLAGE	13.50	40.70	---
ST-JEAN-PORT-JOLI	04.00	29.50	3325
ST-HUBERT	07.70	25.70	1429
BONSECOURS	20.5	96.3	1165
L'ISLET VILLE	17.7	97.3	1280
ST-EUGENE	15.0	98.3	1534
CAP-ST-IGNACE	10.0	89.1	2756
CAP-ST-IGNACE STATION	9.5	90.4	---

INDEX OF TOWNS AND VILLAGES AND POPULATION (CONTINUED)			
	COORDINATES		POPULATION (1970)
	N-S	E-W	
MONTMAGNY	03.0	81.0	11800
ST-PIERRE-DE-MONTMAGNY	96.8	76.2	1280
BERTHIER	98.2	68.0	982
ST-FRANCOIS-DE-MONTMA-GNY	94.0	69.5	1850
ST-VALLIER STATION	91.7	63.2	----
ARTHURVILLE	87.0	66.0	----
ST-RAPHAEL	83.7	66.0	---
LA DURANTAYE	88.3	58.3	---
ST-CHARLES	81.5	51.3	---
ST-GERVAIS	75.0	55.4	---
D'ARTAGNON	71.5	43.6	---
ST-HENRI-DE-LEVIS	72.8	41.8	1010
BREAKEYVILLE	71.2	29.7	----
ST-LAMBERT-DE-LEVIS	61.5	30.5	1610
ST-GILLES	53.3	18.5	---
ST-AGAPIT	59.2	13.5	----
ST-OCTAVE-DE-DOSQUET	48.8	05.8	---
ST-FLAVIEN	54.0	01.0	---

INDEX OF TOWNS AND VILLAGES AND POPULATION (CONTINUED)			
	COORDINATES		POPULATION (1970)
	N-S	E-W	
ST-JANVIER-DE-JOLY	51.0	95.0	---
LYSTER	38.4	98.3	848
VAL-ALAIN	43.5	88.5	---
VILLEROY	41.1	79.0	---
LOURDES	34.0	83.0	762
BLANDFORD	26.0	30.9	---
LEMIEUX	30.9	22.5	486
MADELINGTON-FALLS	21.8	20.6	---
DAVELUYVILLE	20.5	20.7	935
ASTON-JONCTION	16.5	14.0	342
STE-EULALIE	09.9	12.5	986
ST-LEONARD-D'ASTON	09.0	03.0	1009
STE-PERPETUE STATION	01.4	01.8	---
NOTRE-DAME-DU-BON-CONSEIL	97.7	06.0	1000
STE-BRIGITTE-DES-SAULTS	99.9	94.4	825
ST-JOACHIM-DE-COURVAL	93.9	89.8	404
ST-MAJORIC	89.0	87.5	---

INDEX OF TOWNS AND VILLAGES AND POPULATION (CONTINUED)			
	COORDINATES		POPULATION (1970)
	N-S	E-W	
DRUMMONDVILLE	84.0	94.0	30852
ST-GERMAIN	83.3	80.4	1078
ST-EDMOND-DE-GRANTHAM	79.0	89.0	511
STE-EUGENE-DE-GRANTHAM	74.7	78.9	1008
ST-HUGUES	73.0	66.5	500
ST-SIMON DE BAGOT	66.5	65.5	---
ST-BARNABE-SUD	65.9	61.6	---
ST-THOMAS-D'AQUIN	56.8	56.2	---
LA PRESENTATION	58.5	51.8	---
SALVAIL	59.7	50.0	---
STE-MADELEINE	50.5	48.8	---
ST-HILAIRE	47.0	41.0	---
BELOEIL	48.0	40.0	---
McMASTERVILLE	45.0	39.0	---
OTTERBURN-PARK	44.0	39.0	---
ST-BASILE-LE-GRAND	42.6	33.7	---
ST-BRUNO	42.0	30.0	---

INDEX OF TOWNS AND VILLAGES AND POPULATION (CONTINUED AND END)			
	COORDINATES		POPULATION (1970)
	N-S	E-W	
CARIGNAN	34.0	32.0	---
ST-HUBERT	38.0	23.0	---
BROSSARD	35.0	21.0	---
LAPRAIRIE	30.0	18.0	---
ST-PHILIPPE-DE-LAPRAI-RIE	23.0	20.0	---
CANDIAC	27.0	15.0	---
DELSON	25.5	14.0	---
ST-CONSTANT	24.0	12.0	---
ST-MATHIEU	18.6	15.8	---
ST-ISIDORE JONCTION	22.0	06.3	---
ST-REMI	12.0	09.0	---
ST-ISIDORE	17.0	04.0	---
ST-URBAIN-DE-CHATEAU-GUAY	08.0	99.0	---
STE-MARTINE	11.5	94.4	---
HOWICK	03.7	90.6	---
CAIRNSIDE	97.0	86.6	---
ORMSTOWN	97.0	79.0	---
ROCKBURN	85.7	78.0	---

APPENDIX B

GROUNDWATER USERS ALONG PROPOSED PIPELINE ROUTE.

GROUNDWATER USERS ALONG PROPOSED PIPELINE ROUTE			
COMMUNITY	SOURCE OF SUPPLY	POPULATION	APPROXIMATE CONSOMMATION G.P./D.
GRANDE-ILE	---	---	---
ST-GERMAIN-DE-KAMOURASKA	springs	487	38960
KAMOURASKA	---	532	42560
ST-PASCAL	springs	1214	97120
ST-DENIS	---	610	48800
ST-PHILIPPE-DE-NERI	springs	1176	94080
RIVIERE-OUELLE	wells	1590	127200
ST-PACOME	spring-wells	571	45680
STE-ANNE-DE-LA-POCATIERE	---	1310	104800
STE-LOUISE	springs	949	75920
ST-ROCH-DES-AULNAIES	---	1005	80400
ST-JEAN-PORT-JOLY	tubed wells	3325	266000
ST-AUBERT	---	1429	114320
BONSECOURS	---	1165	93200
L'ISLETVILLE	---	1280	102400
ST-EUGENE	---	1534	122700
CAP-ST-IGNACE	springs	2756	220480
CAP-ST-IGNACE STN.	---	---	---

GROUNDWATER USERS ALONG PROPOSED PIPELINE ROUTE (CONTINUED)			
COMMUNITY	SOURCE OF SUPPLY	POPULATION	APPROXIMATE CONSOMMATION G.P./D.
MONTMAGNY	---	11800	944000
ST-PIERRE-DE-MONTMAGNY	---	1280	102400
BERTHIER	springs, deep wells	982	78560
ST-FRANCOIS-DE-SALES-DE-LA-RIVIERE-DU-SUD	---	1850	148000
ST-VALLIER STN.	---	---	---
ARTHURVILLE	---	---	---
ST-RAPHAEL	---	---	---
LA DURANTAYE	---	---	---
ST-CHARLES	---	---	---
ST-GERVAIS	springs	---	---
D'ARTAGNAN	---	---	---
ST-HENRI-DE-LEVIS	wells	1010	80800
BREAKEYVILLE	---	---	---
ST-LAMBERT-DE-LEVIS	---	1610	128800
ST-GILLES	---	---	---
ST-AGAPIT	---	---	---
ST-OCTAVE-DE-DOSQUET	---	---	---

GROUNDWATER USERS ALONG PROPOSED PIPELINE ROUTE (CONTINUED)

COMMUNITY	SOURCE OF SUPPLY	POPULATION	APPROXIMATE CONSOMMATION G.P./D.
ST-FLAVIEN	artesian wells	---	---
ST-JANVIER-DE-JOLY	---	---	---
LYSTER	deep wells	848	67840
VAL-ALAIN	---	---	---
VILLEROY	---	---	---
LOURDES	---	762	60960
BLANDFORD	---	---	---
LEMIEUX	artesian wells	486	38880
MADDINGTON-FALLS	---	---	---
DAVELYUVILLE	---	935	74800
ASTON-JONCTION	artesian wells	342	27360
STE-EULALIE	artesian wells	986	78880
ST-LEONARD-D'ASTON	artesian wells subsurface drainage	1009	80720
STE-PERPETUE STN	---	1000	80000
NOTRE-DAME-DU-BON-CONSEIL	---	---	---
STE-BRIGITTE-DES-SAULTS	artesian wells	825	66000
ST-JOACHIM-DE-COUR-VAL	---	404	32320

GROUNDWATER USERS ALONG PROPOSED PIPELINE ROUTE (CONTINUED)

COMMUNITY	SOURCE OF SUPPLY	POPULATION	APPROXIMATE CONSOMMATION G.P./D.
ST-MAJORIC	---	---	---
DRUMMONDVILLE	---	30852	2468160
ST-GERMAIN-DE-GRANTHAM	---	1078	86240
ST-EDMOND-DE-GRANTHAM	---	511	40880
ST-EUGENE-DE-GRANTHAM	---	1008	80640
ST-HUGUES	wells	500	40000
ST-SIMON-DE-BAGOT	---	---	---
ST-BARNABEE-SUD	---	---	---
ST-THOMAS-D'AQUIN	---	---	---
LA PRESENTATION	---	---	---
SALVAIL	---	---	---
STE-MADELEINE	springs & wells	---	---
ST-HILAIRE	springs & wells	---	---
BELOEIL	surface-artesian wells	---	---
McMASTERVILLE	---	---	---
OTTERBURN-PARK	---	---	---
ST-BASILE-LE-GRAND	springs & wells	---	---
ST-BRUNO	---	---	---

GROUNDWATER USERS ALONG PROPOSED PIPELINE ROUTE (CONTINUED AND END)			
COMMUNITY	SOURCE OF SUPPLY	POPULATION	APPROXIMATE CONSOMMATION G.P./D.
CARIGNAN	---	---	---
ST-HUBERT	---	---	---
BROSSARD	---	---	---
LAPRAIRIE	---	---	---
ST-PHILIPPE-DE-LAPRAIRIE	---	---	---
CANDIAC	---	---	---
DELSON	---	---	---
ST-CONSTANT	---	---	---
ST-MATHIEU	---	---	---
ST-ISIDORE-JNCT	---	---	---
ST-REMI	artesian wells	---	---
ST-ISIDORE-LAPRAIRIE	---	---	---
ST-URBAIN-DE-CHATEAUGUAY	---	---	---
STE-MARTINE	wells	---	---
HOWICK	wells	---	---
CAIRMSIDE	---	---	---
ORMSTOWN	wells	---	---
ROCKBURN	---	---	---

APPENDIC C

CHEMICAL QUALITY OF GROUNDWATER

ALONG PROPOSED PIPELINE ROUTE.

CHEMICAL QUALITY OF GROUNDWATER			
PARAMETER	ST PASCAL	ST PHILIPPE	ST PACOME
pH (units)	7.8	7.3	7.5
Color (units)	5	10	0
Turbidity (units)	0.4	0.8	0.4
Dissolved solids (residue)	170	100	117
Specific conductance (micro-mhos at 25°C)	270.9	145	183.9
Calcium (PPM)	19.3	21.1	18.6
Magnesium (PPM)	4.5	1.9	4.8
Iron (PPM)	---	---	---
Manganese (PPM)	0.0	0.02	0.0
Aluminium (PPM)	0.08	0.0	0.0
Copper (PPM)	0.0	0.0	0.0
Zinc (PPM)	0.5	0.0	0.0
Sodium (PPM)	30.5	4.7	10.4
Potassium (PPM)	2.4	0.9	2.3
Ammonia (PPM)	0.0	0.05	0.05
Carbonate (PPM)	0.0	0.0	0.0
Bicarbonate (PPM)	135	66.6	84.8
Sulfate (PPM)	20.1	12.4	16.8
Chloride (PPM)	4.8	1.9	2.2
Fluoride (PPM)	0.0	0.1	0.0
Nitrate (PPM of N)	1.8	3.0	4.0
Silica (PPM of SiO_2)	7.6	4.0	7.1
Total Hardness (PPM of $CaCO_3$)	66.7	54.6	66.1

CHEMICAL QUALITY OF GROUNDWATER (CONTINUED)	
PARAMETER	STE LOUISE
pH (units)	7.5
Color (units)	3
Turbidity (units)	0
Dissolved solids (residue)	144
Specific conductance (micro-mhos at 25^{o}C)	230.4
Calcium (PPM)	33.3
Magnesium (PPM)	3.3
Iron (PPM)	---
Manganese (PPM)	0.01
Aluminium (PPM)	trace
Copper (PPM)	trace
Zinc (PPM)	0.05
Sodium (PPM)	9.2
Potassium (PPM)	1.3
Ammonia (PPM)	0.0
Carbonate (PPM)	0.0
Bicarbonate (PPM)	108
Sulfate (PPM)	25.8
Chloride (PPM)	1.7
Fluoride (PPM)	0.0
Nitrate (PPM of N)	0.6
Silica (PPM of SiO_2)	5.7
Total Hardness (PPM of $CaCO_3$)	88.9

CHEMICAL QUALITY OF GROUNDWATER (CONTINUED)		
PARAMETER	CAP ST IGNACE	ST GERVAIS
pH (units)	7.3	7.5
Color (units)	5	0
Turbidity (units)	0	0.4
Dissolved solids (residue)	10.4	143
Specific conductance (micro-mhos at 25°CO	56.63	212.4
Calcium (PPM)	5.0	30.5
Magnesium (PPM)	1.1	3.7
Iron (PPM)	0.02	trace
Manganese (PPM)	0.0	0.01
Aluminium (PPM)	0.05	0.08
Copper (PPM)	0.08	0.07
Zinc (PPM)	---	0.14
Sodium (PPM)	1.7	3.0
Potassium (PPM)	0.4	3.8
Ammonia (PPM)	0.0	0.05
Carbonate (PPM)	0.0	0.0
Bicarbonate (PPM)	23.6	89.8
Sulfate (PPM)	4.1	8.0
Chloride (PPM)	0.2	5.0
Fluoride (PPM)	0.0	0.0
Nitrate (PPM of N)	1.2	17.0
Silica (PPM of SiO_2)	7.2	7.8
Total Hardness (PPM of $CaCO_3$)	19.4	73.7

CHEMICAL QUALITY OF GROUNDWATER (CONTINUED)		
PARAMETER	ST HENRI DE LEVIS	ST FLAVIEN
pH (units)	8.5	8.4
Color (units)	10	30
Turbidity (units)	0	20
Dissolved solids (residue)	449	312
Specific conductance (micro-mhos at 25°CO	719.4	481.3
Calcium (PPM)	62.5	59.0
Magnesium (PPM)	17.1	7.5
Iron (PPM)	0.11	2.7
Manganese (PPM)	0.04	0.03
Aluminium (PPM)	0.15	0.0
Copper (PPM)	0.35	0.0
Zinc (PPM)	0.05	0.0
Sodium (PPM)	79.0	22.7
Potassium (PPM)	4.7	12.4
Ammonia (PPM)	---	0.0
Carbonate (PPM)	0	3.0
Bicarbonate (PPM)	389	171
Sulfate (PPM)	65.8	53.7
Chloride (PPM)	3.4	22.6
Fluoride (PPM)	0.0	0.0
Nitrate (PPM of N)	1.6	40.0
Silica (PPM of SiO_2)	14	11
Total Hardness (PPM of $CaCO_3$)	338	178

CHEMICAL QUALITY OF GROUNDWATER (CONTINUED)	
PARAMETER	LYSTER
pH (units)	8.7
Color (units)	10
Turbidity (units)	0.4
Dissloved solids (residue)	320
Specific conductance (micro-mhos at 25^{o})	525.4
Calcium (PPM)	4.9
Magnesium (PPM)	1.2
Iron (PPM)	0.03
Manganese (PPM)	0.01
Aluminium (PPM)	0.07
Copper (PPM)	0.02
Zinc (PPM)	0.0
Sodium (PPM)	112
Potassium (PPM)	2.0
Ammonia (PPM)	0.0
Carbonate (PPM)	7.2
Bicarbonate (PPM)	210
Sulfate (PPM)	33.1
Chloride (PPM)	39.9
Fluoride (PPM)	0.35
Nitrate (PPM of N)	0.5
Silica (PPM of SiO_2)	11
Total Hardness (PPM of $CaCO_3$)	17.2

CHEMICAL QUALITY OF GROUNDWATER (CONTINUED)		
PARAMETER	DAVELUYVILLE	ST LEONARD D'ASTON
pH (units)	7.7	8.3
Color (units)	0	10
Turbidity (units)	7	1
Dissolved solids (residue)	422	300
Specific conductance (micro-mhos at 25°C)	631.5	509
Calcium (PPM)	83.2	17.6
Magnesium (PPM)	14.8	6.2
Iron (PPM)	1.9	0.19
Manganese (PPM)	0.01	0.01
Aluminium (PPM)	0.02	0.15
Copper (PPM)	trace	0.0
Zinc (PPM)	0.05	0.0
Sodium (PPM)	23.3	87.6
Potassium (PPM)	4.5	2.1
Ammonia (PPM)	0.05	0.05
Carbonate (PPM)	0.0	0.0
Bicarbonate (PPM)	234	261
Sulfate (PPM)	33.1	7.6
Chloride (PPM)	68.1	30.8
Fluoride (PPM)	0.0	0.6
Nitrate (PPM of N)	0.3	2.4
Silica (PPM of SiO_2)	15	12
Total Hardness (PPM of $CaCO_3$)	268	69.4

CHEMICAL QUALITY OF GROUNDWATER (CONTINUED)			
PARAMETER	ST HILAIRE	BELOEIL	ST BASILE LE GRAND
pH (units)	8.1	8.1	8.0
Color (units)	5	30	10
Turbidity (units)	0	0	2
Dissolved solids (residue)	214	626	---
Specific conductance (micro-mhos at $25^{o}C$)	340.3	1080	311.1
Calcium (PPM)	45.9	14.9	21.7
Magnesium (PPM)	7.1	12.0	12.9
Iron (PPM)	trace	0.22	0.22
Manganese (PPM)	0.0	0.01	0.00
Aluminium (PPM)	0.11	0.40	0.02
Copper (PPM)	0.03	0.0	0.0
Zinc (PPM)	0.07	0.1	0.05
Sodium (PPM)	11.2	195	21.4
Potassium (PPM)	2.3	8.4	2.0
Ammonia (PPM)	0.0	0.1	0.0
Carbonate (PPM)	0.0	0.0	0.0
Bicarbonate (PPM)	130	324	92.8
Sulfate (PPM)	51.7	40.2	71.4
Chloride (PPM)	7.9	156	3.6
Fluoride (PPM)	0.2	0.4	0.0
Nitrate (PPM of N)	8.6	4.0	4.0
Silica (PPM of SiO_2)	106	20	12
Total Hardness (PPM of $CaCO_3$)	144	86.5	107.3

CHEMICAL QUALITY OF GROUNDWATER (CONTINUED)		
PARAMETER	ST HUGUES	STE MADELEINE
pH (units)	8.2	8.1
Color (units)	40	0
Turbidity (units)	0	0
Dissolved solids (residue)	769	204
Specific conductance (micro-mhos at 25^{o}C)	1259	294.9
Calcium (PPM)	12.4	47.0
Magnesium (PPM)	14.4	1.8
Iron (PPM)	0.05	0.01
Manganese (PPM)	0.0	0.0
Aluminium (PPM)	0.0	0.03
Copper (PPM)	---	0.0
Zinc (PPM)	0.10	0.2
Sodium (PPM)	267	8.5
Potassium (PPM)	11.5	1.9
Ammonia (PPM)	0.0	0.05
Carbonate (PPM)	0.0	0.0
Bicarbonate (PPM)	682	87.8
Sulfate (PPM)	1.5	64.3
Chloride (PPM)	92.1	1.4
Fluoride (PPM)	0.0	0.8
Nitrate (PPM of N)	6.0	0.4
Silica (PPM of SiO_2)	17	112
Total Hardness (PPM of $CaCO_3$)	89.6	125

CHEMICAL QUALITY OF GROUNDWATER (CONTINUED AND END)

PARAMETER	ST REMI	STE MARTINE	HOWICK	ORMSTOWN
pH (units)	6.4	7.8	8.3	8.0
Color (units)	0	5	5	5
Turbidity (units)	0	0	6	12
Dissolved solids (residue)	47.2	144	669	940
Specific conductance (micro-mhos at 25^{o}C)	45.4	240.8	1144	1412
Calcium (PPM)	5.5	35.3	52.2	134
Magnesium (PPM)	0.3	6.0	28.7	39.2
Iron (PPM)	---	trace	0.52	1.6
Manganese (PPM)	0.2	0.0	0.07	0.0
Aluminium (PPM)	0.15	0.07	0.17	---
Copper (PPM)	0.13	trace	0.0	---
Zinc (PPM)	---	0.0	0.05	---
Sodium (PPM)	1.0	6.1	143	100
Potassium (PPM)	0.8	0.8	7.4	8.0
Ammonia (PPM)	0.0	0.0	0.0	0.1
Carbonate (PPM)	0.0	0.0	0.0	0.0
Bicarbonate (PPM)	7.7	144	331	258
Sulfate (PPM)	5.2	9.2	123	248
Chloride (PPM)	0.7	1.0	130	171
Fluoride (PPM)	0.0	0.0	0.10	0.0
Nitrate (PPM of N)	8.0	0.4	1.5	0.6
Silica (PPM of SiO_2)	6.3	13	14	211
Total Hardness (PPM of $CaCO_3$)	15.0	113	248	845

APPENDIX D

AQUIFER PROPERTIES OF GROUNDWATER ALONG

PROPOSED PIPELINE QUEBEC-U.S. BORDER.

AQUIFER PROPERTIES						
COMMUNITY	ROCK FORMATION	DRILLING TERMINATED IN: UM: Unconsolidated materials R: Rock	WATER HEAD (FEET)	FLOWING RATE G.P.M.	SPECIFIC FLOW RATE (G.P.M./Feet)	AQUIFER DEPTH (Feet)
St-Henri-de-Lévis	Appalachian complex	---	---	---	---	---
Breakeyville	"	R	27	6.6	0.2	55
St-Lambert-de-Lévis	"	UM	18	80	---	---
St-Gilles	"	R	6	2.5	---	45
St-Agapit	"	UM	0	---	1.4	---
St-Flavien	"	---	---	---	---	---
St-Janvier-de-Joly	"	---	---	---	---	---
Lyster	"	---	---	---	---	---
Val-Alain	"	R	8	2.9	---	49
Villeroy	"	R	5	5	0.16	35
Blandford	Appalachian complex	---	---	---	---	---
Lemieux	St-Germain complex	---	---	---	---	---
Maddington Falls	Appalachian complex	---	---	---	---	---

AQUIFER PROPERTIES (CONTINUED)						
COMMUNITY	ROCK FORMATION	DRILLING TERMINATED IN: UM: Unconsolidated materials R: Rock	WATER HEAD (FEET)	FLOWING RATE G.P.M.	SPECIFIC FLOW RATE (G.P.M./Feet)	AQUIFER DEPTH (Feet)
Daveluyville	Appalachian complex	---	---	---	---	---
Aston-Jct	"	---	---	---	---	---
Ste-Eulalie	"	---	---	---	---	---
St-Léonard d'Aston	"	UM	---	---	---	---
Notre-Dame-du-Bon-Conseil	"	---	---	---	---	---
Ste-Brigitte-des-Saults	"	R	3	10	5	50
St-Joachim-de-Courval	St-Germain complex	---	---	---	---	---
St-Majoric	"	---	---	---	---	---
Drummondville	Appalachian complex	---	---	---	---	---
St-Germain-de-Grantham	St-Germain complex	---	---	---	---	---
St-Edmond-de-Grantham	"	---	---	---	---	---
St-Eugène-de-Grantham	"	---	---	---	---	---

AQUIFER PROPERTIES (CONTINUED)						
COMMUNITY	ROCK FORMATION	DRILLING TERMINATED IN: UM: Unconsolidated materials R: Rock	WATER HEAD (FEET)	FLOWING RATE G.P.M.	SPECIFIC FLOW RATE (G.P.M./Feet)	AQUIFER DEPTH (Feet)
St-Hugues	St-Germain complex	---	---	---	---	---
St-Simon-de-Bagot	"	---	---	---	---	---
St-Barnabé-Sud	Queenstone Group	UM	6	20	---	100
St-Thomas-d'Aquin	"	---	---	---	---	---
La Présentation	"	---	---	---	---	---
Salvail	"	---	---	---	---	---
Ste-Madeleine	Lorraine Group	R	12	29	---	188
Beloeil	Nicolet River Formation	---	---	---	---	---
St-Hilaire	"	---	---	---	---	---
McMasterville	Cretaceous	---	---	---	---	---

AQUIFER PROPERTIES (CONTINUED)						
COMMUNITY	ROCK FORMATION	DRILLING TERMINATED IN: UM: Unconsolidated materials R: Rock	WATER HEAD (FEET)	FLOWING RATE G.P.M.	SPECIFIC FLOW RATE (G.P.M./Feet)	AQUIFER DEPTH (Feet)
Otternburn Park	Nicolet River Formation	---	---	---	---	---
St-Basil-Le-Grand	"	---	---	---	---	---
St-Bruno	"	---	---	---	---	---
St-Hubert	"	---	---	---	---	---
Brossard	Utica Group	---	---	---	---	---
Laprairie	Nicolet River Formation	---	---	---	---	---
St-Philippe-de-Laprairie	Utica Group	---	---	---	---	---
Candiac	"	---	---	---	---	---
Delson	"	---	---	---	---	---
St-Constant	Trenton Group	---	---	---	---	---
St-Mathieu	Chazy Group	---	---	---	---	---
St-Isidore JCT	"	---	---	---	---	---

AQUIFER PROPERTIES (CONTINUED AND END)						
COMMUNITY	ROCK FORMATION	DRILLING TERMINATED IN: UM: Unconsolidated materials R: Rock	WATER HEAD (FEET)	FLOWING RATE G.P.M.	SPECIFIC FLOW RATE (G.P.M./Feet)	AQUIFER DEPTH (Feet)
St-Rémi	Beauharnois Group	R	---	150	---	400
St-Isidore Laprairie	Chazy Group	---	---	---	---	---
St-Urbain de Châteauguay	March Group	---	---	---	---	---
Howick	"	R	---	---	---	---
Cairnside	"	---	---	---	---	---
Ormstown	"	R	---	750	---	124