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121869-G-G-001
Revision Number B

Arianne Phosphate Inc.
Lac a Paul Phosphate Project

Conceptual Study
July 2013

15-Jul-2013

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Revision Status

Revision	Date	Description	Author		Checked By		Approver	
			FirstName LastName	Position Title	FirstName LastName	Position Title	FirstName LastName	Position Title
B	16-Jul-13	Issued for Client Review	[signature]	Process Engineer	[signature]	Lead Process Engineer	[signature]	Project Manager
A	15-Jul-13	Issued for Internal Review	KK	Process Engineer	RT	Lead Process Engineer	APS	Project Manager

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1 Introduction

In June 2013, Arianne Phosphate awarded Ausenco the scoping study for a phosphate slurry pipeline system from their mine site near Lac a Paul, which is located approximately 200 km north of the town of Saguenay in the Saguenay–Lac-Saint-Jean region of Quebec, Canada to the port of Grande-Anse.

1.1 Scope of Work

The scope of this work includes:

- Pipeline route and profile selection using Google Earth software.
- Preliminary hydraulic analysis.
- Preliminary pump specification including pump, head, flow rate, and horsepower.
- Preliminary pipe specification including pipe material, grade, diameter, and wall thickness.
- Capital cost estimate; estimated accuracy is +/-50%.

Operating cost estimate based on similar systems estimated accuracy of +/-50%.

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2 Route Description

The selected route generally follows existing roads between the mine site and port.

Table 2-1: Route Information

Description	Phosphate Pipeline
Start Point km Post (mine site)	0
Distance of Intermediate Pump Station from the Mine(km)	90.6
End Point km for Route 1 (port site)(km)	226.6
Start Point Elevation (m)	448.1
End Point Elevation (m)	121.6

Figure 2-1: Route from Mine Site to Terminal

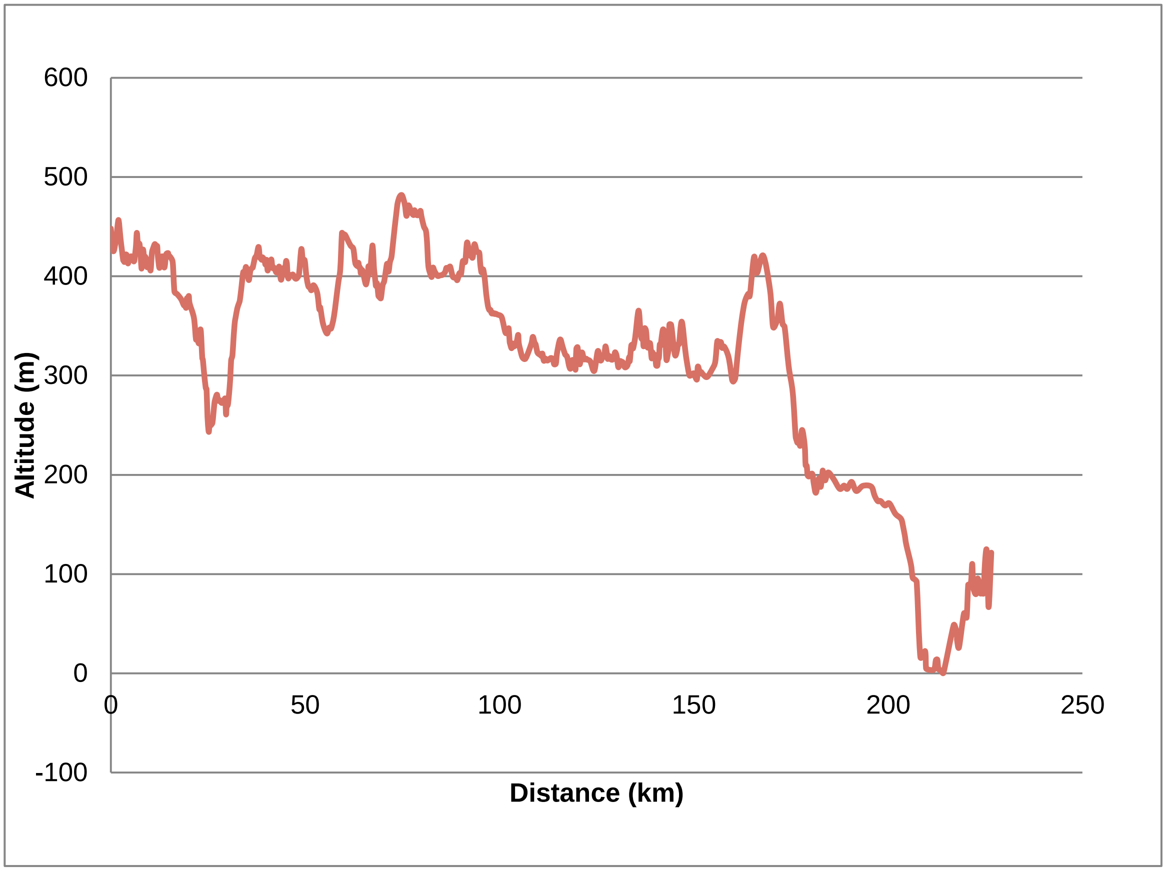

Figure 2-2: Pipeline Route Elevation Profile

3 System Design Criteria: Slurry Pipeline

The design basis for the slurry pipeline was prepared using route data and throughput provided by Arianne Phosphate and was complemented with Ausenco's in-house information from similar commercial operations.

Key elements of the design basis for this project have been summarized in the sections below.

3.1 Battery Limits

Ausenco's scope of work starts at the inlet of the agitated slurry storage tanks at the mine site and ends at the outlet of the agitated slurry receiving tanks at the port. Ausenco will design pumping and piping facilities between the initial storage and the terminal receiving tanks.

3.2 Slurry System Design Criteria

3.2.1 Summary of Slurry Characteristics

Ausenco assembled the following phosphate design characteristics, summarized in Table 3-1, based on in-house historical data. The data can be confirmed in the next phase with laboratory test work on a representative phosphate sample.

Table 3-1: Slurry Characteristics

Parameter	Value		Source
Solids Specific Gravity (SG)	2.84		In-house data
Slurry Temperature, ºC	5		In-house data
Viscosity, cP	7.44		In-house data
Particle Size Distribution (cumulative % passing Tyler Mesh)	48 mesh (297µm)	98--100%	In-house data
	65 mesh (210 µm)	90--98%	
	100 mesh (149 µm)	70--90%	
	150 mesh (105 µm)	58--70%	
	200 mesh (74 µm)	40--58%	
	325 mesh (44 µm)	20--40%	
Corrosion Rate	7 mils*/year for first 20 km after Pump Station, 5 mils/year for the rest of the pipeline		In-house data
Concentration by Weight of Solids (wt %)	60%		

*One mil equals one thousandth of an inch.

3.2.2 System Throughput

Table 3-2 presents the solids throughput and slurry flow rate at the design transport concentration for the slurry pipeline design.

Table 3-2: Slurry System Throughput

Parameter	3 Mt/y	6 Mt/y
Throughput, Mt/y	3	6
Availability	90%	90%
Slurry Concentration, C_w	60%	60%
Flow Rate, (m^3/h) (tph)	388 380.5	775 761

3.2.3 Operating Velocity

The minimum safe operating velocity for a concentrate pipeline is intended to maintain pseudo-homogeneous flow behavior in order to avoid unstable pipeline operation resulting from deposition of particles. The minimum velocity is based on the evaluation of deposition velocity and transition velocity. The transition velocity represents the point of change from laminar to turbulent flow in the pipeline; turbulent eddies serve to maintain suspension of the particles.

Ausenco uses an in-house model to calculate both the transition and deposition velocities. The greater of these two values, with adequate margin, is selected as the minimum safe operating velocity for each pipe size. This minimum velocity is different for the two throughputs.

3.2.4 Pipeline Life

The slurry pipeline is designed for a 30 year life, which represents the economic life for evaluation and design of system components.

3.2.5 Pump Selection

Pumps used for slurry transportation generally fall into two categories:

- Centrifugal
- Positive displacement

Centrifugal pumps are ideally suited for low-discharge pressure design conditions, up to the range of 725 – 870 psi (50 – 60 bars). Many long-distance slurry pipelines utilize positive-displacement pumps due to the higher discharge pressure requirements, up to 3626 psi (250 bars).

3.3 Process Design Criteria

The following design criteria were used to develop the hydraulic model for the concentrate slurry pipeline. These criteria are the same for the design of all pipelines at the conceptual study level and will be refined in future phases of work.

For slurry flows, pressure loss calculations will be determined from Ausenco's proprietary slurry hydraulic computer model, Ausenco-WASP 1.1.

A design factor of 6% for flow is used for the hydraulic design to account for variations in slurry characteristics and general operations variability. This is equivalent to a design factor of approximately 12% on pressure loss.

A 5% design factor on pipeline length is included to account for deviations/optimizations in the final pipeline route.

The minimum clearance between the hydraulic gradient line and the pipeline profile is 50 m.

The minimum clearance between the static pressure line and the pipeline profile is 100 m.

The minimum clearance between the hydraulic gradient line and the maximum allowable operating pressure and head (MAOP/MAOH) line is 50 m.

3.4 Pipeline Mechanical Design Criteria

The pipeline will be designed in accordance with the mechanical design criteria specified below:

Code for Slurry	ASME B31.4:2012
Mainline Pipe	Carbon Steel, API-5L, Grade B
Pipe Design Factor	0.80 of Specified Minimum Yield Stress (SMYS)
Transient Pressure Factor	1.10 times maximum allowable operating pressure

4 Hydraulic Design

4.1 Slurry Pipeline

4.1.1 Pipeline Design Philosophy

The hydraulic design of the slurry pipeline is based on a conservative sizing of equipment and facilities because of the additional safety factors required to design a system without specific slurry data. Future engineering optimization may improve the facility design.

4.1.2 Pipe Diameter Selection

Selection of a pipeline diameter is based on commercial operations for slurries with similar solids specific gravity and particle size distribution. Various pipe diameters were reviewed to avoid particle deposition and optimize friction losses (pump duty).

For a 3 Mt/y throughput, a standard pipeline with a 12.75-inch outside diameter (OD) has an operating velocity less than the minimum safe operating velocity. For a 10.75-inch OD pipeline the pressure requirements are very high. Therefore, a non-standard 12-inch OD pipeline was selected.

For a 6 Mt/y throughput a 16-inch OD pipeline was selected.

3 Mt/y throughputs can also be obtained using 16-inch OD pipe by designing for water/slurry batching.

4.1.3 Minimum Velocity

The minimum safe operating velocity is 1.5 m/s for the 12-inch OD, and 1.6 m/s for 16-inch OD pipe.

4.1.4 Hydraulic Design

The hydraulic gradient is a graphical illustration of the head in meters at any point in the pipeline. The hydraulic gradient must stay above the pipeline profile in order to eliminate slack flow. If the gradient line is too close to the profile, slack flow can occur (the pipeline runs partially full, creating high operating velocity at the bottom of the pipe), which can result in premature pipeline failure due to erosion.

The hydraulic design was developed for the pipeline system as summarized in the following sections.

The ground profile, hydraulic gradient, and maximum allowable operating pressure for 6 Mt/y throughput are presented in Figure 4-1.

The ground profile, hydraulic gradient, and maximum allowable operating pressure for 3 Mt/y throughput are presented in Figure 4-2.

As shown in Figure 4-3, the minimum throughput obtained using the 16-inch OD pipe with a minimum velocity of 1.6m/s is 4.72 Mt/y. Water/slurry batching is required at lower throughputs.

When a pipeline is required to transport a lower tonnage than its design quantity, it is operated in batch mode in order to maintain the minimum velocity for the slurry. Thus, to obtain the desired throughput in a 16-inch OD pipeline, water/slurry batching is required.

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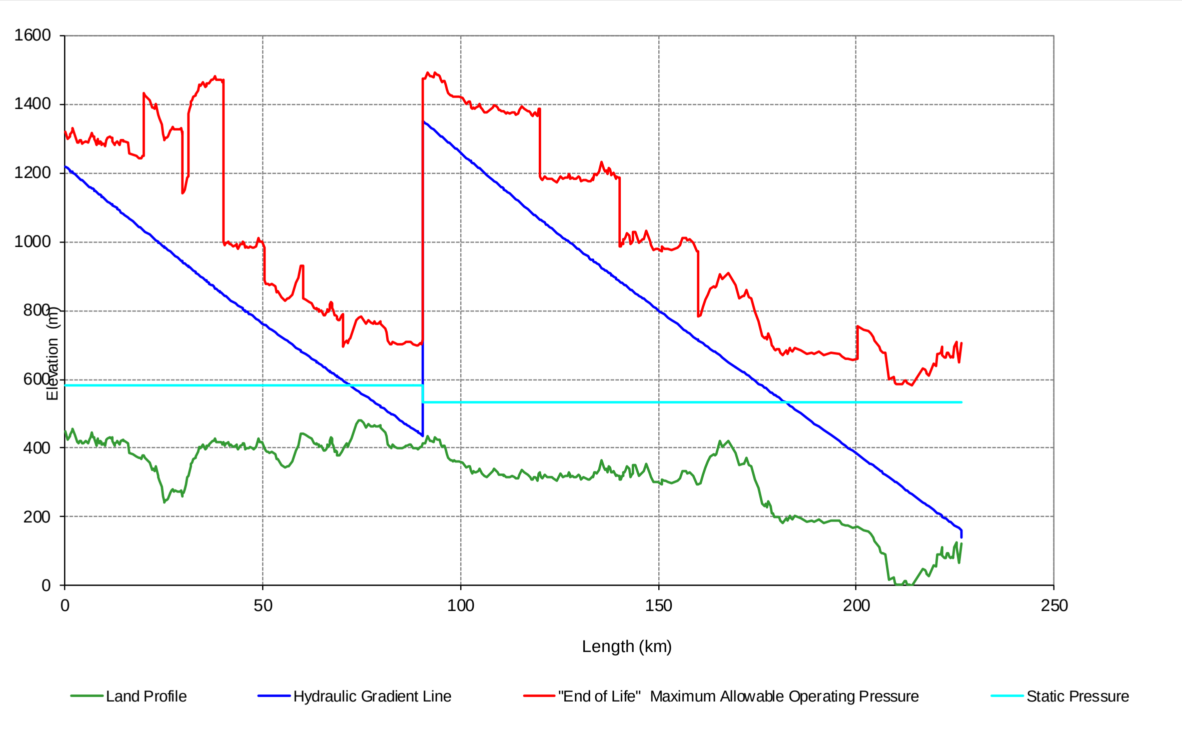
Lac a paul project 6Mt/y



Slurry Characteristics

Solids S.G.	2.84	
Temp (°C)	5	
B'	1.65	
Von Karman	0.9	
Durand	150	
Slurry viscosity	**7.44**	cP
Slurry SG	1.64	

Particle Size Distribution

48	99.19
65	97.09
100	85.76
150	66.34
200	52.03
325	36.78

Pipeline Life	30	yr
Corrosion Rate	5	mpy
Corrosion Rate (after PS)	7	mpy
Length Pipe	226.56	km
Steel Tonnage	23,201	mt
API5L X	70	

Pipeline Characteristics

OD (inch)	16.000
Avg wall thickness (inch)	0.000
HDPE Liner (inch)	0.000
ID (inch)	16.000
Roughness (inch)	0.002000
Availability (%)	90.0

Pipeline Throughput		
Flowrate	775	m³/h
Cw%	60.0%	
Throughput	761.0	tph
Annual Throughput	6.00	MTA

Pumping Requirements	*PS 1*	*PS2*	
PS location	0.0	100.6	km
TDH	770.7	895.2	m
Discharge Pressure	1793	2082.9	psig
	12354	14351	kPa
	123.543	143.511	Bar
Pump Efficiency	90%	90%	
Motor HP	4200	3669	HP
Motor kW	3132	2736	kW

Line Velocity		
Minimum	1.77	m/s
Maximum	1.92	m/s

Hydraulic Gradient		
Minimum	7.94	m/km
Maximum	9.69	m/km

Profile Clearance		
Minimum	20.0	m
Maximum	935.4	m

	MAOP Clearance	Static Clearance	
Minimum	67.9	50.2	m
Maximum	623.8	959.2	m

Intermediate Pump Station		
Suction Head	0.0	m
Tank Height	20.0	m

Terminal		
Choke	0.0	m
Tank Height	20.0	m

Hydraulic SF	1.00
Flowrate SF	1.06
Length Factor	1.05

Figure 4-1: Hydraulic for 16-inch OD pipeline with 6 Mt/y throughput

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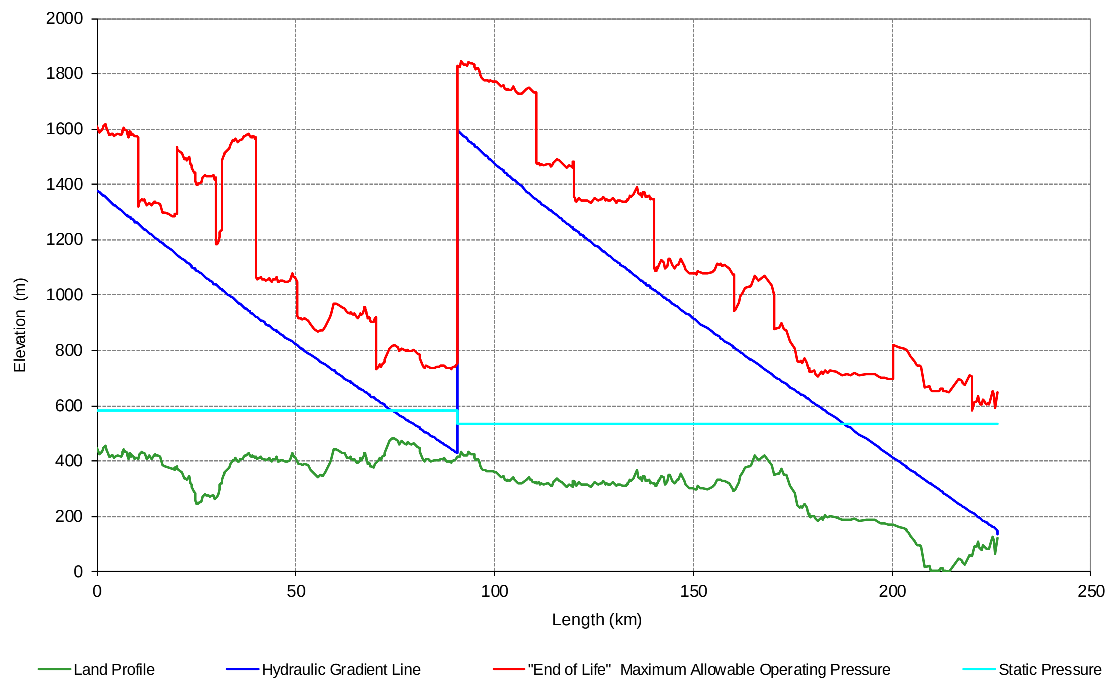
Lac a paul project (3 Mt/y)



Slurry Characteristics

Solids S.G.	2.84
Temp (°C)	5
B'	1.65
Von Karman	0.9
Durand	150

Slurry viscosity	**7.44**	cP
Slurry SG	1.64	

Particle Size Distribution

48	99.19
65	97.09
100	85.76
150	66.34
200	52.03
325	36.78

Pipeline Life	30	yr
Corrosion Rate	5	mpy
Corrosion Rate (after PS)	7	mpy
Length Pipe	226.56	km
Steel Tonnage	15,879	mt
API5L X	70	

Pipeline Characteristics

OD (inch)	12.000
Avg wall thickness (inch)	0.000
HDPE Liner (inch)	0.000
ID (inch)	12.000
Roughness (inch)	0.002000
Availability (%)	90.0

Pipeline Throughput

Flowrate	388	m³/h
Cw%	60.0%	
Throughput	380.5	tph
Annual Throughput	3.00	MTA

Pumping Requirements	*PS 1*	*PS2*	
PS location	0.0	100.6	km
TDH	930.7	1111.7	m
Discharge Pressure	2165	2586.5	psig
	14920	17821	kPa
	149.201	178.212	Bar
Pump Efficiency	90%	90%	
Motor HP	2536	2095	HP
Motor kW	1891	1562	kW

Line Velocity		
Minimum	1.60	m/s
Maximum	1.80	m/s

Hydraulic Gradient		
Minimum	9.45	m/km
Maximum	12.56	m/km

Profile Clearance		
Minimum	14.0	m
Maximum	1180.5	m

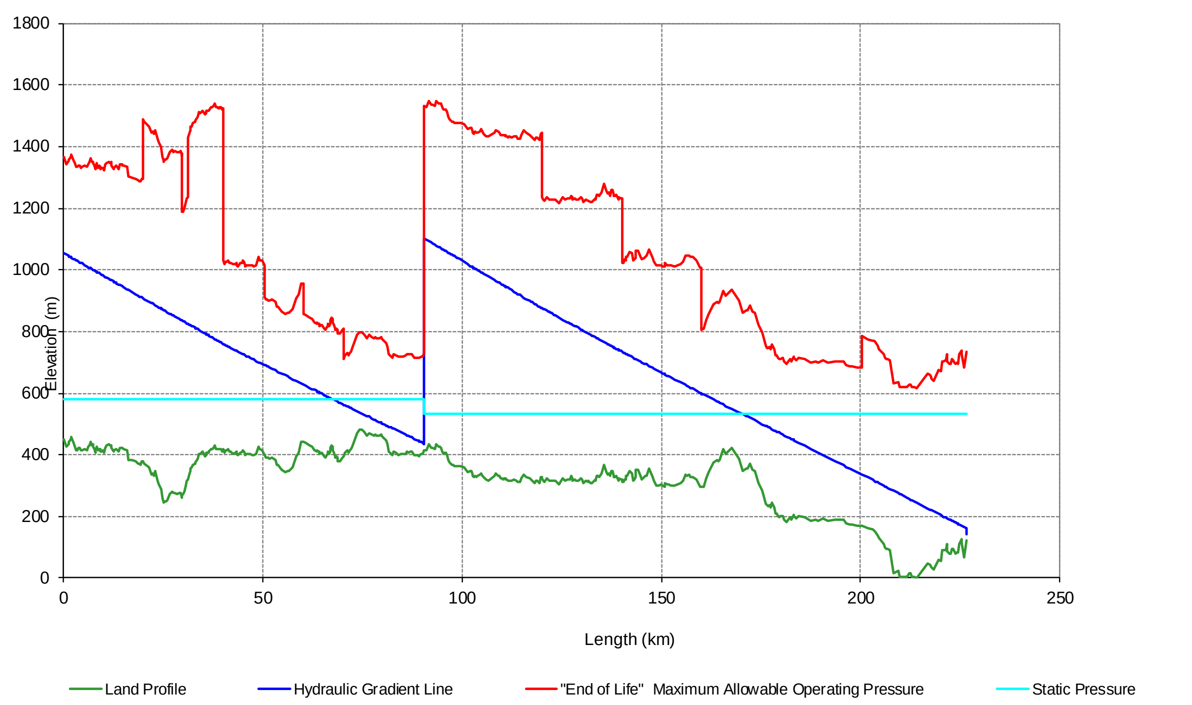
MAOP Clearance		Static Clearance	
Minimum	63.6	47.8	m
Maximum	650.7	1312.2	m

Intermediate Pump Station		
Suction Head	0.0	m
Tank Height	14.0	m

Terminal		
Choke	0.0	m
Tank Height	14.0	m

Hydraulic SF	1.00
Flowrate SF	1.06
Length Factor	1.05

Figure 4-2: Hydraulic gradient for 12-inch OD pipeline with 3 Mt/y throughput



Slurry Characteristics

Solids S.G.	2.84	
Temp (°C)	5	
B'	1.65	
Von Karman	0.9	
Durand	150	
Slurry viscosity	**5.13**	cP
Slurry SG	1.55	

Particle Size Distribution

48	99.19
65	97.09
100	85.76
150	66.34
200	52.03
325	36.78

Pipeline Life	30	yr
Corrosion Rate	5	mpy
Corrosion Rate (after PS)	7	mpy
Length Pipe	226.56	km
Steel Tonnage	23,201	mt
API5L X	70	

Pipeline Characteristics

OD (inch)	16.000
Avg wall thickness (inch)	0.000
HDPE Liner (inch)	0.000
ID (inch)	16.000
Roughness (inch)	0.002000
Availability (%)	90.0

Pipeline Throughput		
Flowrate	701	m³/h
Cw%	55.0%	
Throughput	599.1	tph
Annual Throughput	4.72	MTA

Pumping Requirements	*PS 1*	*PS2*	
PS location	0.0	100.6	km
TDH	606.5	666.2	m
Discharge Pressure	1340	1472.0	psig
	9233	10142	kPa
	92.329	101.420	Bar
Pump Efficiency	90%	90%	
Motor HP	2839	2655	HP
Motor kW	2117	1980	kW

Line Velocity		
Minimum	1.60	m/s
Maximum	1.74	m/s

Hydraulic Gradient		
Minimum	6.28	m/km
Maximum	7.65	m/km

Profile Clearance		
Minimum	20.0	m
Maximum	686.1	m

	MAOP Clearance	Static Clearance	
Minimum	149.3	81.1	m
Maximum	765.5	1015.3	m

Intermediate Pump Station		
Suction Head	0.0	m
Tank Height	20.0	m

Terminal		
Choke	0.0	m
Tank Height	20.0	m

Hydraulic SF	1.00
Flowrate SF	1.06
Length Factor	1.05

Figure 4-3: Hydraulic for 16-inch OD pipeline at minimum throughput

5 Pipeline System Description

5.1 Slurry Pipeline

Pipeline materials and construction are selected to optimize initial cost, operating cost, operating life, and hydraulic performance of the pipeline. The pipeline is designed to have adequate steel wall thickness to withstand the steady state slurry hydraulic gradient and the static head when the line is shutdown on slurry. The wall thickness determination is preliminary and will be finalized in a further design phase. The recommended external pipeline corrosion coating is a 3-layer fusion bond epoxy. The pipeline will be buried for security with a minimum 1.0 m depth of cover. The final depth of cover for this project will be decided in future phases.

The recommended mainline pipe for the slurry pipeline system is API 5L Grade X70, carbon steel.

For a 3 Mt/y throughput a 12-inch OD pipeline with a 0.375-inch average wall thickness is proposed.

For a 6 Mt/y throughput a 16-inch OD pipeline with a 0.408-inch average wall thickness is proposed.

5.2 Pumps Selection

Data on the selected pumps is listed in Tables 5-1 and 5-2.

Table 5-1: Pump Data for 6 Mt/y throughput

Item	Description
Pipeline	16 inch X 227 km
Flow Rate (m^3/h)	775
Mine Site/PS1	
Mainline Pump Type	Positive displacement
Number of Pumps	3 (2 operating + 1 standby)
Pump Station Discharge Pressure, (bar)	124
Pump Operating Power, (kW)	3132
Intermediate Pump Station/PS2	
Mainline Pump Type	Positive displacement
Number of Pumps	3 (2 operating + 1 standby)
Pump Station Discharge Pressure, (bar)	144
Pump Operating Power, (kW)	2736

Table 5-2: Pump Data for 3 Mt/y throughput

Slurry	Mine Site
Pipeline	12" x 227 km
Flow Rate, (m^3/h)	388
Mine Site/PS1	
Mainline Pump Type	Positive displacement
Number of Pump	2 (1 operating + 1 standby)
Pump Station Discharge Pressure, psi (bar)	149
Pump Operating Power, (kW)	1891
Intermediate Pump Station/PS2	
Mainline Pump Type	Positive displacement
Number of Pump	2 (1 operating + 1 standby)
Pump Station Discharge Pressure, psi (bar)	178
Pump Operating Power, (kW)	1562

5.3 Storage Tanks

Studies completed by Ausenco for other projects indicate that agitated storage tanks of equal diameter and height are the most economic when considering capital and operating costs.

Table 5-3 and 5-4 present the recommended tank quantity and size.

Table 5-3: Agitated Slurry Storage Tanks for 6 Mt/y throughput

Location	Number of Tanks	Diameter (M)	Height (m)	Working Volume (m^3)
Mine Site	2	17	17	3085 X 2
Intermediate Pump Station	1	17	17	3085 X 1
Terminal	2	17	17	3085 X 2

Table 5-4: Agitated Slurry Storage Tanks for 3 Mt/y throughput

Location	Number of Tanks	Diameter (M)	Height (m)	Working Volume (m^3)
Mine Site	2	14	14	1723 X 2
Intermediate Pump Station	1	14	14	1723 X 1
Terminal	2	14	14	1723 X 2

5.4 Test Loop

Long-distance slurry pipelines are generally provided with a test loop to confirm the hydraulic characteristics of the slurry in advance of committing slurry to the pipeline.

The test loop has the same diameter as the slurry pipeline and is of sufficient length to obtain reliable pressure drop readings. The loop will be installed at the mine site pump station after the first stage of the horizontal centrifugal slurry pump train. The pipeline will be equipped with block valves so that flow from the tanks to the pipeline can be diverted through the loop, or can bypass the loop. Downstream of the loop, flow can be sent to the pipeline (into the suction of the second stage of the horizontal centrifugal slurry pump train) or diverted back to the storage tanks.

During commissioning, slurry will be re-circulated back to the storage tanks. During normal operation, the test loop can be used in series with the main line (no recirculation to tanks). The instrumentation will give advance warning of increasing pressure drop, which could indicate too coarse a grind or an unexpected increase in slurry concentration.

5.5 Flush and Gland Seal Water

Flush and gland seal water required for the pipeline is presumed to be provided by the client from the beneficiation plant.

5.6 Terminal Station

Major components of the terminal facility will be the slurry storage tanks.

5.7 Pipeline Slope Restrictions

The maximum pipeline slope will be restricted to 12 percent to minimize the risk of blockage during pipeline shutdown.

5.8 Pipeline Crossings

Road crossings will be trenched or bored. Railroad crossings would normally be bored and include an external steel casing. The Saguenay river crossing is about 1.3-km wide at the selected crossing location and 12- to 15-feet deep. There is mud and silt of unknown depth on the river bottom. A 20-foot deep shipping channel is maintained by dredging. The crossing would be constructed either by trenching or by directional drilling depending on geology. A geotechnical investigation is recommended in the next phase of the project. A review of available data and a discussion of crossing methods are attached in the appendix.

5.9 Cathodic Protection

A cathodic protection system is provided to protect any areas of the pipe that may have gaps in the external coating, which were not detected during installation. Insulating joints will be provided to electrically isolate the pipeline from the pump station and terminal facilities. Bonding bridges will be installed across the station for cathodic protection continuity. Cathodic protection test leads will be spaced at a maximum distance of 1 km along the pipeline. Consideration will be given to the influence of any high-tension power lines in the pipeline corridor.

A temporary system, using sacrificial anodes, may be required to protect the pipeline at any crossings.

5.10 Leak Detection

Two methods normally are used in pipelines to detect leaks:

- Pressure wave detection
- Mass balance

Pipeline Advisor™, an Ausenco software product, is recommended for leak detection on slurry pipelines.

5.10.1 Detection by Pressure Wave

Pressure wave detection uses two or more pressure signals to both detect and locate leaks. This works on the principle that any leak in a pipeline will generate a pressure wave that travels upstream and downstream from the leak source. Such waves are detectable using standard instrumentation. Using the time difference between the wave detections, it is possible to detect leak location. Leaks in the range of 3-5 percent of design flow have been detected, and leak locations can be estimated within 1 km. With this method, a leak can be detected within minutes.

5.10.2 Detection by Mass Balance

Mass balance uses flow meters and is based on the principle of conservation of mass. Running averages are used to account for short-term flow fluctuations.

5.11 SCADA System

The pipeline will be operated from the wash plant pump station.

A supervisory control and data acquisition (SCADA) system provides input to the pipeline programmable logic controller (PLC) and provides the operator the information and functions needed to operate the pipeline. Facilities will allow remote (i.e. from the control room) and manual (by a local operator) control of all pipeline equipment. A leak detection system will be included in the SCADA system.

During future phases of work, operating procedures will be developed to convert to program sequences, permitting automated operation of the pipeline system, as well as all other operating functions.

5.12 Telecommunications

A fiber-optic telecommunications system using Ethernet technology is provided to support the pipeline control requirements at the pump stations and the terminal. While the fiber-optic system is primarily installed as the most economic and reliable method to control remote stations, it will also be capable of transporting voice, data, video, or other information if required by the project. Based on experience on other projects, a 12-fiber cable is recommended. Four fibers would be dedicated for the pipeline control system and eight would be available for other possible communication needs including:

- Linking wash plant and terminal site DCS systems.
- Linking wash plant and terminal site PABX systems.

- Providing communication link to commercial/ public system.
- Providing internal networks for email, data exchange, file servers, etc.

The above system has adequate capacity to support the SCADA systems for all future pipelines.

Based on Ausenco's experience, an Ethernet technology is recommended as the most cost-effective approach for telecommunications. Under this approach, Ethernet switches would be located at each of the stations.

A radio system with coverage along the pipeline is also recommended. A radio system provides a communication link between the control room operator and operations/maintenance personnel working between the mine site and terminal stations and can be used as partial voice back-up to the primary fiber optic communications system to support manual operation of the pipeline.

5.13 Cold Weather Design

The following options are available:

1. The pipeline can be buried below frost line (3 m or more of cover over top of pipe). This eliminates all concerns about freeze-up of the pipeline but it is very expensive to trench to this depth especially in rock.
2. If the pipeline is to be buried at a shallower depth, a thermal analysis must be undertaken to model various operating scenarios and then determine whether insulation is required.

Ausenco recommends pursuing a pipeline design with the following key features in order to minimize capital costs:

- 12-inch OD, API 5L X70 carbon steel pipeline with 2 pump stations for 3 Mt/y throughput; or 16-inch OD, API 5L X70 carbon steel pipeline with 2 pump stations for 6 Mt/y throughput.
- Buried, uninsulated pipeline.
- 1 to 1.5 m cover over top of pipe.
- Insulate slurry storage tanks and exposed piping. Slurry is normally at an elevated temperature leaving the grinding plant and this temperature needs to be maintained in winter.
- Install all equipment in heated buildings to minimize heat loss.
- Provide back-up power at all locations so that the pipeline can be restarted in case of loss of power.
- Flush water volume needs to be available at a suitable temperature to flush the entire pipeline.
- Store a sufficient volume of concentrated propylene glycol to fill the pipeline at about 10 percent dilution for longer duration shutdown in winter.
- Have contingency plan and equipment in place to respond quickly to repair a pipe rupture.

5.14 Recommendations for Future Work

Ausenco recommends carrying out the following data gathering in order to provide a firm basis for the design and capital cost estimate:

1. Collect a “representative” slurry sample and conduct the slurry tests to develop the slurry rheological characteristics (viscosity, yield, particle size distribution, solids specific gravity, shutdown and restart characteristics, etc.) for the pipeline system design.
2. Drive the route to define areas of rock, types of terrain, river crossings, etc., and to optimize the route on the ground.
3. Collect geotechnical data along the pipeline corridor and at the Saguenay River crossing, soil thermal data (using temperature arrays) and climate data – this is a 12-month undertaking.
4. Conduct a pipeline thermal analysis considering all operating scenarios including normal operation, shutdown, water flush and restart to determine depth of cover and any insulation requirements, based on agreed shutdown duration.
5. Collect data on local working conditions and construction costs.
6. Prepare pipeline CAPEX based on actual rock/terrain data and design burial depth.

6 Capital Cost Estimate

6.1 Basis

6.1.1 Material Costs

The following material cost basis was used:

- Positive-displacement pumps: Vendor quotation
- Mainline pipe: Vendor quotation
- Slurry storage tanks: Based on recent estimate for tank plus agitator

Other costs are from in-house data.

6.1.2 Pipeline Construction

Construction costs were developed using the Ausenco pipeline cost database and judgment to adjust for local conditions. Pipeline construction includes:

- Stringing
- Bending
- Pipe laying and installation of flanges
- Welding
- Non-destructive testing (NDT)
- Field-coated joints
- Lowering in
- Padding and backfill
- Hydrostatic testing

6.1.3 Exclusions

The following items are excluded from the capital cost estimate:

- Start up
- Construction camps
- Permits and royalty fees
- Owner's costs, including staff, PPE, finance costs and taxes, transport and accommodation, laydown area at the mine site for free issue materials, etc.

- Owner's contingency
- Resettlement, relocation, or related community compensation costs
- Project insurances (public liability, third-party motor vehicle, marine transit, contractors all risk, project professional indemnity insurance)
- Operational insurance
  (business interruption insurance, machinery breakdown, loss of profit, etc.)
- Land acquisition costs
- Environmental studies
- Mine closure and rehabilitation costs
- Modifications or upgrading to the national or state roads
- Main power supply line and high-voltage switchyard
- Supply of potable water to site boundaries
- Special incentives (schedule, safety, or others)

6.2 Recommendation for Next Project Phase

In the next phase of the project, pipeline and station construction costs are recommended to be thoroughly investigated. The following items are required:

- Working conditions and local costs
- Route and site conditions
- Capabilities of local contractors

6.3 Cost Summary

The capital cost estimate was developed to an accuracy of +/-50 percent for the defined scope of work, and assumes that the project will be executed as an engineering, procurement, and construction management (EPCM) contract through to the completion of commissioning. Pipeline and station construction contracts will be competitively bid. The pipeline is assumed to be uninsulated and buried with 1 m of cover.

The capital cost estimate for 6 Mt/y throughput is presented in Table 6-1. The capital cost estimate for 3 Mt/y throughput is presented in Table 6-2.

Table 6-1: Capital Cost Estimate for 6 Mt/y, 16-inch OD pipeline

Pipeline	**$206,241,200**
Pipeline Construction	$178,400,000
Pipeline Materials	$27,841,200
PS1	**$30,000,000**
Pumps	$9,000,000
Tanks	$3,000,000
Other station work	$18,000,000
PS2	**$28,500,000**
Pumps	$9,000,000
Tanks	$1,500,000
Other station work	$18,000,000
Terminal Station	**$4,680,000**
Tanks	$3,000,000
Other station work	$1,680,000
River Crossing	**$10,000,000**
Sub Systems	**$3,220,000**
SCADA	$800,000
Telecom	$2,420,000
Subtotal System	**$282,641,200**
Spare Parts	$2,784,000
Eng., Proc. & Constr. Mgmt.	$28,264,000
Commissioning	$300,000
SUBTOTAL-BASE ESTIMATE	**$313,989,200**
Contingency 25%	$78,497,000
Total Cost	**$392,486,000**

Table 6-2: Capital cost Estimate for 3 Mt/y, 12- OD pipeline

Pipeline	**$152,854,800**
Pipeline Construction	$133,800,000
Pipeline Materials	$19,054,800
PS1	**$24,000,000**
Pumps	$6,000,000
Tanks	$3,000,000
Other station work	$15,000,000
PS2	**$22,500,000**
Pumps	$6,000,000
Tanks	$1,500,000
Other station work	$15,000,000
Terminal Station	**$4,680,000**
Tanks	$3,000,000
Other station work	$1,680,000
Sub Systems	**$3,150,000**
SCADA	$800,000
Telecom	$2,350,000
River Crossing	**$10,000,000**
Subtotal System	**$217,184,800**
Spare Parts	$2,184,000
Eng., Proc. & Constr. Mgmt.	$21,718,000
Commissioning	$300,000
SUBTOTAL-BASE ESTIMATE	**$241,386,800**
Contingency 25%	$60,347,000
Total Cost	**$301,734,000**

7 Operating Cost Estimate

7.1 Basis

One mechanic and one electrician per shift will be appointed for the maintenance of the pump and terminal station. These mechanics will have a full complement of skills (welding, pipe-fitting, etc.). A total of four shifts will be required to provide coverage 24 hours per day, 365 days per year. A dedicated Lead Operator and Operator Assistant will be present as well.

For this study, it was assumed that the pipeline will operate at its design annual throughput to generate an operating cost estimate.

- Labor – experience from cost data of previous and similar projects.
- Contracted Services – maintenance of the pipeline right of way (ROW), piping spools, etc.
- Power – estimated according to the operating horsepower for a continuous slurry operation. $0.10/kWh was used for the power cost based on in-house data.
- Contingency – a 10 percent contingency was added to the preliminary operating cost estimate.
- Supplies/ miscellaneous maintenance material for all other equipment.

7.3 Operating Cost

The operating cost estimate was developed to an accuracy of +/-50 percent for the defined scope of work. The Operating cost estimate for 6 Mt/y throughput is presented in Table 7-1. The Operating cost estimate for 3 Mt/y throughput is presented in Table 7-2.

Table 7-1: Operating Cost Estimate for 6 Mt/y, 16-inch OD pipeline

LABOR (Note 1)	Personnel Staff required per shift	On-duty shifts per day	Manpower Total	Costs Annual Salary (1)	Annual Cost (US$)
Pipeline Supervisor	1.0	1.0	1.0	$120,000	$120,000
Operators	2.0	4.0	8.0	$77,000	$616,000
Engineer Support	1.0	1.0	1.0	$74,000	$74,000
Helpers	1.0	1.0	4.0	$50,000	$200,000
Maintenance-Helpers	4.0	1.0	4.0	$50,000	$200,000
Maintenance--Mechanical (7 d/w x 24 hrs.)	4.0	1.0	4.0	$82,000	$328,000
Maintenance--Electrical (7 d/w x 24 hrs.)	2.0	1.0	2.0	$82,000	$164,000
Maintenance-ROW	2.0	1.0	2.0	$82,000	$164,000
Admin Support	1.0	1.0	1.0	$50,000	$50,000
				Subtotal Labor Cost	***$1,916,000***

ELECTRIC POWER	Operating kW	Annual kWh	Power Cost $ / kWh	Annual Cost (US$)
Slurry Pipeline System				
Slurry Tank Agitators at Mine site (2)	600	4,730,400	$0.10	$473,040
PS1 Slurry Mainline Pumps (2 Operating, 1 Spare)	3,132	24,692,688	$0.10	$2,469,269
Slurry Tank Agitators at PS2 (1)	300	2,365,200	$0.10	$236,520
PS2 Slurry Mainline Pumps (2 Operating, 1 Spare)	2,736	21,570,624	$0.10	$2,157,062
Slurry Tank Agitators at Terminal (2)	600	4,730,400	$0.10	$473,040
Miscellaneous Loads (Charge Pumps, Gland Seal Pumps etc.)	737	5,808,931	$0.10	$580,893
Subtotal Electric Power -	*8,105*	63,898,243	$0.10	$6,389,824
Total Annual Electric Power Cost				*$6,390,000*

OTHERS	
Supplies/Miscellaneous maintenance material (spares, safety equipment) allowance	$350,000
Slurry Mainline Pumps maintenance material (4% of positive displacement pump cost)	$360,000
Contract Services	$250,000
Emergency Plans	$250,000
Overhead and Administration	$100,000
Others (travel, training, security)	$100,000
Subtotal Operating Cost	***$9,616,000***
Contingency, 10%	***$962,000***
Total Annual Operating Cost	***$10,578,000***

(1) Annual salaries figures include cost of benefits, etc.

(2) Staff on call 24 hours a day, 7 days a week.

Table 7-2: Operating Cost Estimate for 3 Mt/y, 12-inch OD pipeline

	Personnel			Costs	
LABOR (Note 1)	**Staff required per shift**	**On-duty shifts per day**	**Manpower Total**	**Annual Salary (1)**	**Annual Cost (US$)**
Pipeline Supervisor	1.0	1.0	1.0	$120,000	$120,000
Operators	2.0	4.0	8.0	$77,000	$616,000
Engineer Support	1.0	1.0	1.0	$74,000	$74,000
Helpers	1.0	1.0	4.0	$50,000	$200,000
Maintenance--Helpers	4.0	1.0	4.0	$50,000	$200,000
Maintenance--Mechanical (7 d/w x 24 hrs.)	4.0	1.0	4.0	$82,000	$328,000
Maintenance--Electrical (7 d/w x 24 hrs.)	2.0	1.0	2.0	$82,000	$164,000
Maintenance--ROW	2.0	1.0	2.0	$82,000	$164,000
Admin Support	1.0	1.0	1.0	$50,000	$50,000
				Subtotal Labor Cost	***$1,916,000***

ELECTRIC POWER	**Operating kW**	**Annual kWh**	**Power Cost $ / kWh**	**Annual Cost (US$)**
Slurry Pipeline System				
Slurry Tank Agitators at Mine site (2)	600	4,730,400	$0.10	$473,040
PS1 Slurry Mainline Pumps (2 Operating, 1 Spare)	1,891	14,908,644	$0.10	$1,490,864
Slurry Tank Agitators at PS2 (1)	300	2,365,200	$0.10	$236,520
PS2 Slurry Mainline Pumps (2 Operating, 1 Spare)	1,562	12,314,808	$0.10	$1,231,481
Slurry Tank Agitators at Terminal (2)	600	4,730,400	$0.10	$473,040
Miscellaneous Loads (Charge Pumps, Gland Seal Pumps etc.)	495	3,904,945	$0.10	$390,495
Subtotal Electric Power	*5,448*	42,954,397	$0.10	$4,295,440
Total Annual Electric Power Cost				*$4,295,000*

OTHERS	
Supplies/Miscellaneous maintenance material (spares, safety equipment) allowance	$300,000
Slurry Mainline Pumps maintenance material (4% of positive displacement pump cost)	$240,000
Contract Services	$250,000
Emergency Plans	$250,000
Overhead and Administration	$100,000
Others (travel, training, security)	$100,000
Subtotal Operating Cost	***$7,351,000***
Contingency, 10%	***$735,000***
Total Annual Operating Cost	***$8,086,000***

(1) Annual salaries figures include total cost of benefits, etc.

(2) Staff on call 24 hours a day, 7 days a week.

Appendix 1 – Saguenay River Crossing Methods

Description

The Lac a Paul Phosphate Slurry Pipeline route crosses the Saguenay River near Saguenay, Quebec. The small village of Canton-Tremblay is located on the north bank of the crossing, and the village of Chicoutimi-Est is located on the south bank of the crossing. The water in the Saguenay comes from Lac Saint-Jean and is controlled by three dams near the city of Alma located 50 kilometers west of the city of Saguenay. The river deposits into the Gulf of Saint Lawrence.

At the crossing location the river is about 1.3 km wide and 12- to 15-feet deep. A 20 foot deep shipping channel is maintained by dredging.

The pipeline crossing will be 12- or 16-inch OD steel pipe and will be approximately 1300 meters long.

The crossing location is shown in Figures 1 and 2.

Figure 1: Aerial Photo showing Saguenay River Crossing

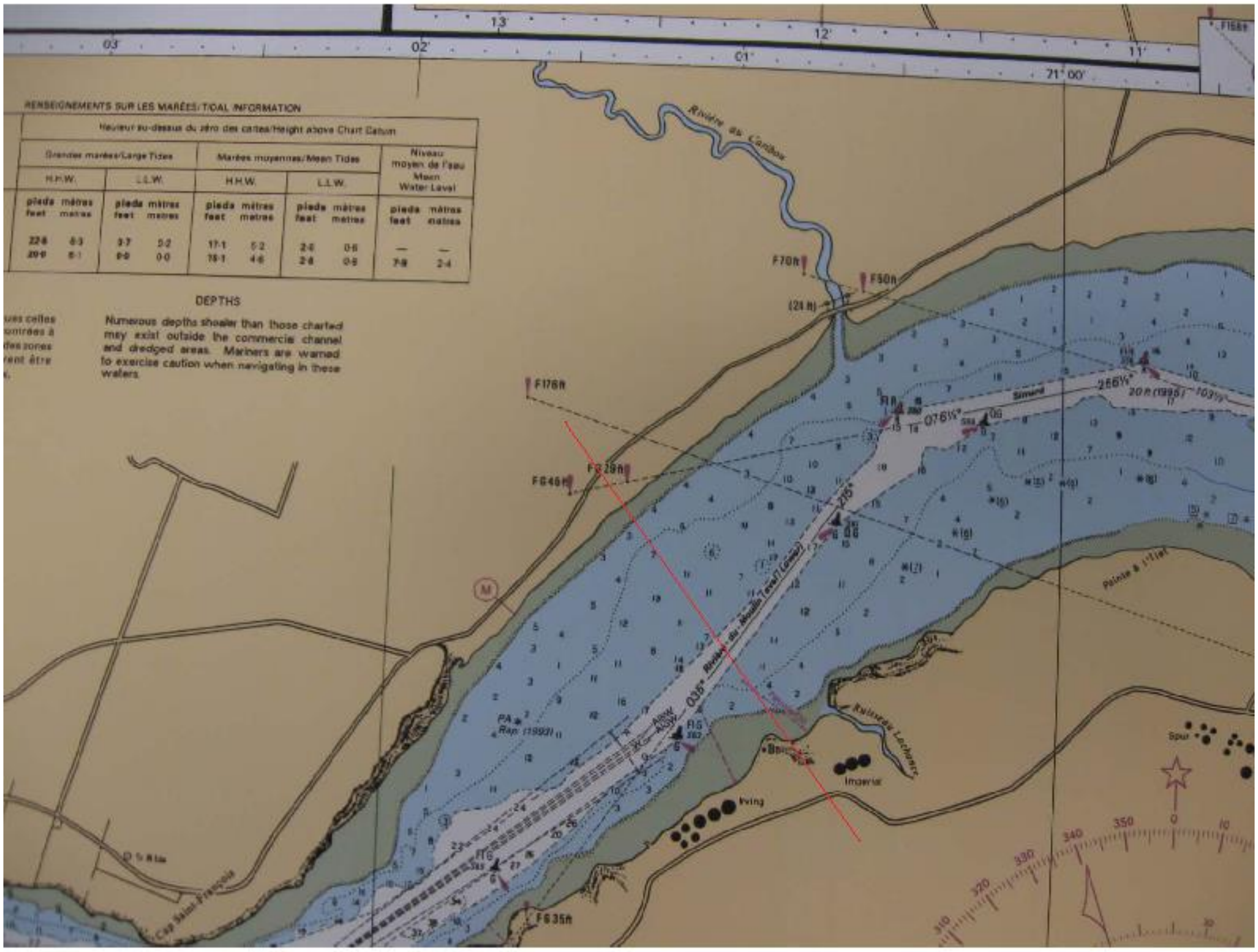


Figure 2: Saguenay River Crossing shown on the Nautical Chart

Geology

Soil characteristics are not currently known; however photos copied from Google Earth indicate rock bluffs and rocky valleys. Refer to Figures 3, 4 and 5.

Figure 6 shows surface geology. The river crossing location is principally blue, which is calcareous mud (number 4) and silt (number 5). The pink zone is where bedrock is predominant. The mud and silt is likely to be several meters thick.

Figure 3: North bank of Saguenay River approximately 2.7 kilometers downstream

Figure 4: North bank of Saguenay River approximately one kilometer downstream

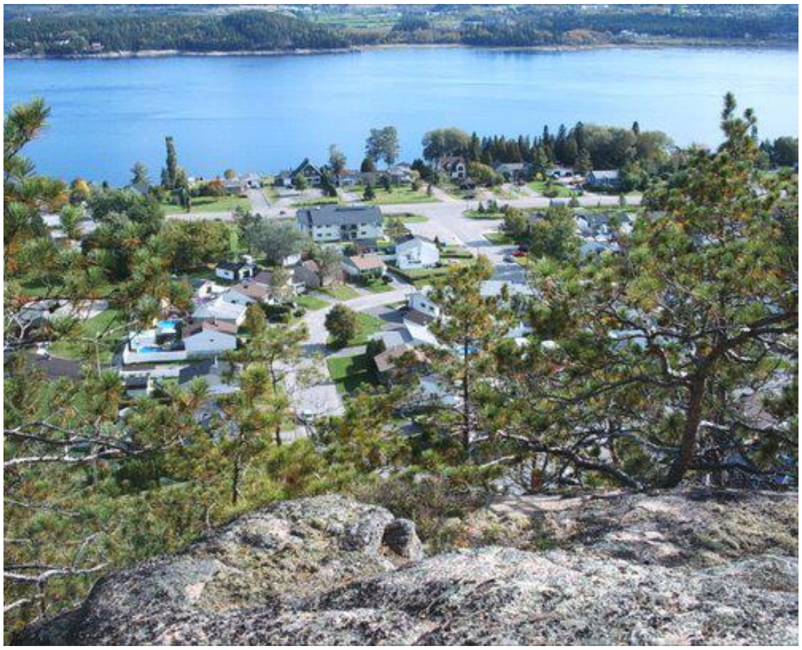


Figure 5: Bluff overlooking Canton Tremblay approximately 500 meters north of the crossing

Figure 6: Surface Geology

Horizontal Directional Drilling (HDD)

The preferred method of crossing most rivers is via HDD. With HDD there is very little disruption to river traffic and the environment. The pipeline can normally be easily placed beneath the scour depth. The limitations of HDD are the profile of the crossing and certain soil types. A slurry pipeline is generally designed with slopes limited to 12 percent, so the crossing geometry needs to accommodate this limitation. Figure 7 shows a photo of a typical directional drill rig. Figure 8 shows a pictorial explanation of the process.

Figure 7: Photo of typical directional drilling rig

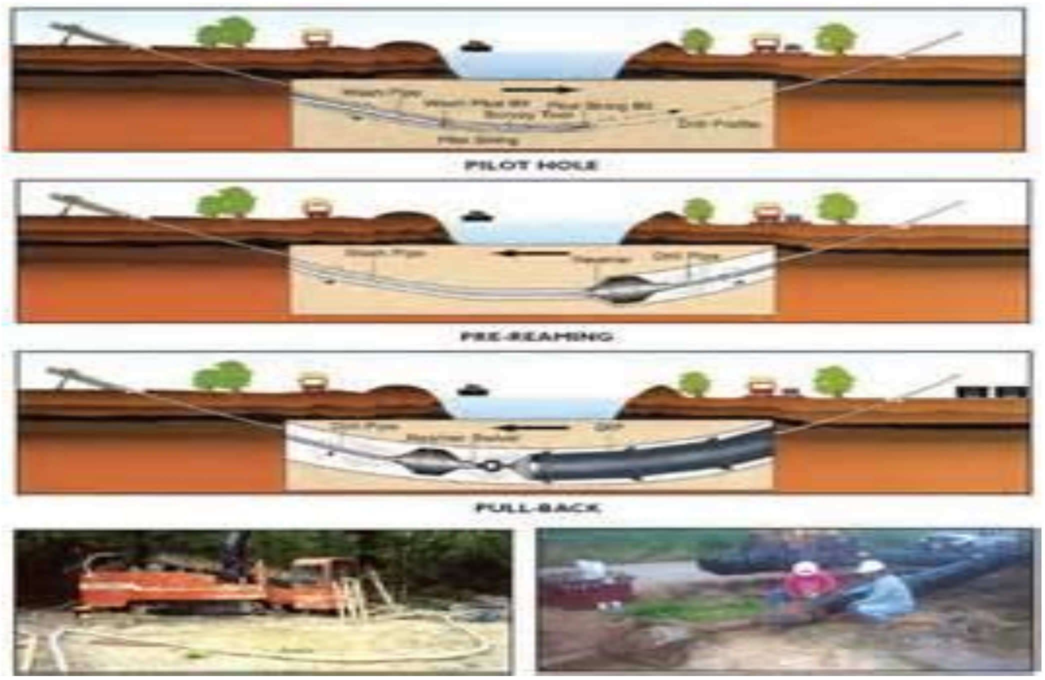


Figure 8: Pictorial explanation of HDD process

HDD in solid rock, though expensive, is relatively risk free, as once the hole is made under the river it will not collapse. Rocky soils, (i.e. cobble stones, river rock), with rocks exceeding 1.5 inches in diameter, are the most risky as the rocks are too large to be floated back through the inside of the drill pipe and thus remain in the hole. There is also a greater risk of the hole collapsing as heavy rocks on the top side of the hole may fall into the hole. In this system the pipe is welded up into a long section on the shore and pulled into the bored hole under the river. When pulling the pipe into a hole full of rocks the rocks are often pushed forward ahead of the pipe until the pile of rocks is too large to push, thus sticking the pipe, and stopping the installation.

A detailed soil investigation is required to confirm HDD crossing is feasible.

Open-cut Wet Trench

The Saguenay River is wide and relatively shallow at the crossing location. The water flow is controlled by three upstream dams. The river appears to be dredged to 20 feet to maintain a channel for shipping. All of these factors combined indicate a shallow scour depth. The pipeline must be buried beneath the scour and dredge depths. Maximum scour depth must be determined and pipeline burial depth selected.

Once the depth of trench required is selected, the means of digging the trench are by either mechanical excavation or by dredging. A backhoe mounted on a barge could be utilized to dig the trench in shallow water. The trench spoil could be placed on a barge and hauled to a dump site. Refer to Figure 9.

If the water is too deep for a backhoe, a clam shell or dragline bucket could be used. Refer to Figures 10 and 11. At times, it is prudent to use both, particularly when the water depths vary significantly. Refer to Figure 12.

Figure 9: Backhoe excavations in water placing spoils on barge

Figure 10: Clam shell excavation in water

Figure 11: Dragline excavations in water

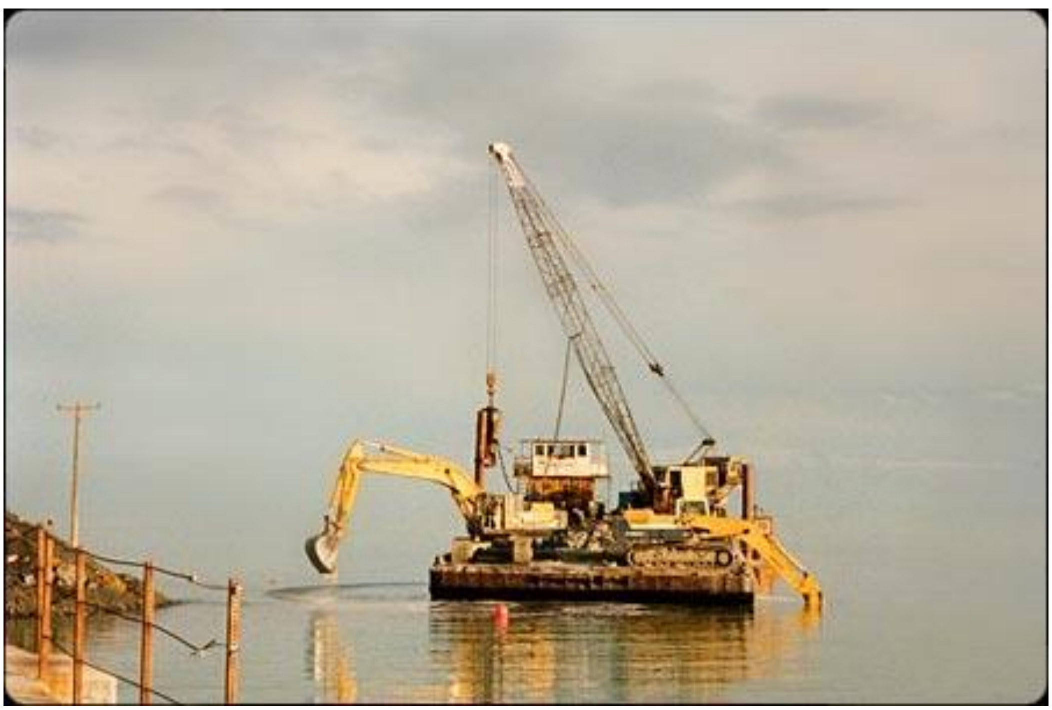


Figure 12: Combination backhoe and dragline on barge excavating trench in water

A faster method is utilizing a pump suction dredge. A “stinger” with a cutting head is lowered to the river floor. The cuttings are carried by water sucked into a tube and subsequently pumped through a hose to be deposited on either a barge, or a location on land. Figures 13 through 16 illustrate various dredging techniques.

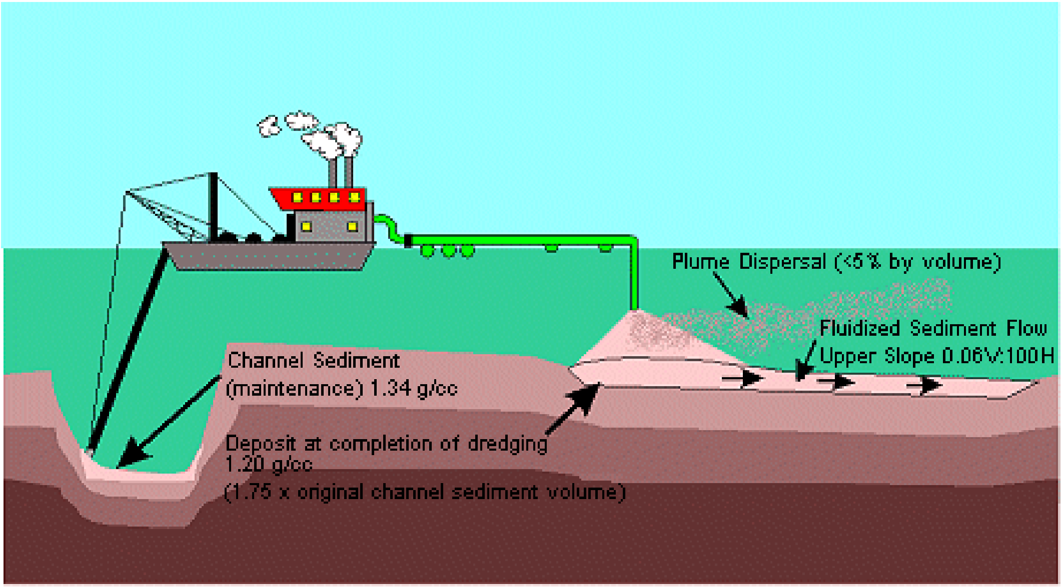


Figure 13: Pictorial view of the process of a dredge excavating a trench in water

Figure 14: Photo of a dredge illustrating the excavation of a trench in the water

Figure 15: Photo of typical dredge cutter head

Figure 16: Photo of spoils discharge pipe from dredge

Pipe Installation in Wet Trench

In the event a trench is dug across the river, the pipe would be welded up in a long section on shore. It would be concrete coated for both physical protection and buoyancy control. Floats would be attached to the concrete coated section to give it less negative buoyancy. A large winch, well anchored, would then pull the entire section into and across the river. The floats would then be removed and the pipe lowered into the trench. It is doubtful the trench would need to be backfilled, as the natural sediments would fill the trench over time. However, if the trench needs to be backfilled, clean crushed rock or soil would be dumped from barges as a backfill material.

Proper signage would be required on both sides of the river indicating a pipeline is buried in the river bottom.

The open cut method of trenching would have some impact on river traffic while the trench was being dug in the channel. If a suction pump dredge is utilized the pipe carrying the trench spoil would be floating on top of the river, therefore closing up to one half of the river to traffic. When the pipe is pulled across the river, all river traffic would be stopped during the pipe pulling operation. This portion of the operation should not take more than 24 hours.

Open Cut Dry Trench

A typical dry trench river crossing is shown in Figure 17. In this method a cofferdam isolates over one half of the river. Several large water pumps are used to keep the area dry. The ditch is excavated with backhoes and the pipe installed very similar to how the work is performed on dry land, only slower. After the pipeline has been installed under one half of the river, the water is diverted by a new cofferdam on the other side of the river. After the second half is installed and tied into the first one half, the cofferdam is removed.

This method is probably not feasible if a 20-foot river channel needs to be maintained during pipeline installation.

Figure 17: Typical dry open cut trench crossing