Preliminary Engineering Assessment Notice

Revision 0

In support of AER Application No.: 32926881

Lamont Carbon Trunk Line Phase II

Location: SW 05-055-17 W4M to SW 06-056-16 W4M

For: Wolf Carbon Hub GP Inc.

Obsidian Engineering

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Calgary, Alberta

T2P 3N9

Obsidian Engineering File. 3848

Date: May 01, 2024

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Appendices

1 PROJECT CONTACTS

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2 PURPOSE

An Engineering Assessment document was initially compiled by Obsidian Engineering (Obsidian) to support the Wolf Carbon Hub GP Inc. (Wolf) response to the Alberta Energy Regulator's (AER's) Supplementary Information Request (SIR) No. 1 for Pipeline Application 32579964, which resulted in pipeline License No. 64048. That document has subsequently been updated and similarly provided herein to support Wolf's Application No. 32926881; to add a pipeline (new construction) to the existing Lamont Carbon Trunk Line (LCTL) License, No. 64048. For the purposes of this document, this new pipeline construction shall be referred to as LCTL Phase II. If approved, Phase I (licensed under License No. 64048) and Phase II (Application No. 32926881) shall be designed and constructed simultaneously and considered a single pipeline system for these purposes. All subsequent reference to the Lamont Carbon Trunk Line and the means by which its design and construction shall meet the requirements of CSA Z662-23 shall apply to both Phase I and Phase II.

All information and supporting documentation contained herein and attached is considered suitable in detailing how Wolf's proposed pipeline shall meet the requirements of CSA Z662-23. As the pipeline has not yet reached detailed design or construction, this Engineering Assessment has been considered preliminary and/or an Engineering Assessment Notice.

3 OVERVIEW

Wolf's affiliate, Wolf Carbon Solutions Inc., is the owner and operator of the Alberta Carbon Trunk Line (ACTL) and ACTL Edmonton Connector (Edmonton Connector) CO_2 pipeline systems. The Wolf pipeline licensed under AER License No. 64048, the Lamont Carbon Trunk Line, is an extension of this existing CO_2 infrastructure. It shall be designed to meet all the requirements of CSA Z662-23. Phase II of the Lamont Carbon Trunk Line, submitted under Application No. 32926881, extends the length from the initial application an additional (approximately) 20km, for a total of (approximately) 39km of NPS 12 pipeline to be licensed under the license No. 64048. The extended pipeline shall continue to facilitate the transportation of pure CO_2, initially from ACTL, to one or more CO_2 injection wells and their associated infrastructure (future application to be made separately). Although design of the LCTL is not at this time complete, the requirements of CSA Z662-23, and any additionally applicable codes or standards, shall be considered throughout the Project's design and construction phases and all design requirements and conditions applied accordingly.

4 PROJECT DETAILS AND CSA Z662-23 ADHERENCE

As detailed by CSA Z662-23 Section 4.1.12, this document shall outline at minimum the following (as applicable) for the LCTL Pipeline:

a) service fluid;
b) design conditions (e.g., pressure, temperature);
c) operating pressure and temperature range;
d) general and site-specific loading conditions;
e) material specifications and properties;
f) intended range of operating conditions;
g) loads and dynamic effects as specified in Clause 4.2;
h) manufacturing process and installation method;
i) technical data and test records;
j) potential modes of deterioration and means of detecting such modes;
k) control and protective devices;
l) environmental conditions and potential environmental consequences;
m) hazard type, frequency, and magnitude, including any hazards associated with the presence of foreign structures or environmental conditions;
n) consequences of failure; and
o) potential changes to any of the above.

Details on each of these Project design parameters can be found in the following sections.

4.1 Service Fluid

The LCTL pipeline shall carry dry, dense phase CO_2, entering the pipeline as at least 95% pure as required by the product specification, which can be found in ***Appendix A*** of this document.

Compositional analysis shall take place at the inlet to the LCTL pipeline. This analysis shall quantify and confirm the product stream entering the pipeline and shall ensure adherence to the product specification; alarms or shutdowns, as applicable, shall signal to Wolf operations (or automatically action a safety system response) should product composition deviate from specification. Moisture analysis shall take place as a part of this compositional analysis, and appropriate safety system responses shall be automated accordingly to prevent adverse effects to the pipeline system.

All requirements of CSA Z662-23 as they apply to general pipeline system design, and specifically those for CO_2 Service, such as but not limited to the applicable Location Factors (outlined in Table 4.2) or hydrostatic testing requirements (as outlined in Section 8 and specifically Table 8.1) shall be considered during the detailed design and construction phases of the Project.

A formal Class Location Study is not available at this time, however, will be completed during detailed design. It is anticipated that the pipeline shall be designed to Class 2 Location requirements as detailed in Section 4.3 and Table 4.1. Location Factors for non-sour service CO_2 are consistent within CSA Z662-23 Table 4.2 for Class Locations 3 and 4 as well, and designing to such requirements shall help to ensure that no issues are encountered in the future should additional industry or residential installations take place in the vicinity of the LCTL pipeline. This shall similarly apply to valve spacing in Class 2, 3, and 4 Locations as detailed by Table 4.7.

All additional requirements specific to CO_2 service not explicitly listed above shall similarly be addressed and accounted for in the LCTL design.

4.2 Design and Operating Conditions

The LCTL pipeline shall be designed to a Maximum Operating Pressure (MOP) of 20MPa and shall be hydrostatically tested accordingly, however shall be licensed to a Maximum Allowable Operating Pressure (MAOP) of 17,930 kPag, matching that of ACTL.

A full summary of design and operating parameters can be found tabled below:

	Pipeline	Assemblies
Design Standard or Code	CSA Z662-23	CSA Z662-23 & ASME B31.3-2022
Flange Rating	PN250 / CL 1500	PN250 / CL 1500
Design Temperature Range[1]	-5 / +50 °C	-45 / +50 °C
Minimum Operating Pressure[1]	7,500 kPag	7,500 kPag
Normal Operating Pressure[1]	14,500 kPag	14,500 kPag
Licensed MOP	17,930 kPag	17,930 kPag
Design Pressure	20,000 kPag	20,000 kPag
Hydrotest Pressure (min)	30,000 kPag	30,000 kPag
Inspection	100% X-ray Butt Welds 100% Visual All Welds	100% RT/MT Butt, Fillet, Socket Welds 100% Visual All Welds
Sour Service	No	No
Sour Design	No	No

1. The above Table is considered to address the (intended) operating pressure range as noted by CSA Z662-23 4.1.12(c) and (f) with respect to commentary within Engineering Assessments. All operating temperatures shall fall within the design ranges, and it is expected that the normal operating temperature at LCTL inlet shall be approximately 15°C.

These design and operating parameters shall be appropriately considered when completing the detailed design of the LCTL pipeline and applied accordingly to meet all requirements of CSA Z662-23. Section 4 (Design), as an example, shall consider these parameters for items such as hoop stress reviews and selection of pipeline materials and wall thicknesses, among others.

Design and operating parameters shall also be considered when selecting alarm and shutdown points for instrumentation and controls installed along the LCTL pipeline system; these controls are used to prevent upset or overpressure conditions. All requirements of Section 4.18 shall be considered in overpressure protection design.

4.3 General and Site-Specific Loading Conditions

The LCTL pipeline shall be installed in central Alberta, and generally East of Edmonton. It is expected, as based on recent project experience, that soil conditions in this area shall be largely sandy, silty clay till. These soil conditions are suitable for open cut and trenchless pipeline installation, and it is not expected that soil loading shall be detrimental to the pipeline.

General depth of pipeline installation is expected to be 1.2m on Right of Way (RoW) and 2m on lease. Where pipeline crossings take place (such as but not limited to beneath roads or third-party utilities), extra depth and appropriate separation as outlined in CSA Z662-23 Table 4.9 or greater if and as required by a specific crossing agreement shall be achieved. Maintaining minimum cover and clearance across the length of the pipeline will help to mitigate any impact from surface loadings above the pipeline.

Any potential settlement at crossings, such as rail and road, shall be mitigated with detailed design and through items such as geotechnical work, increased depth of installation, reduced trenchless installation ream size, and annulus grouting for trenchless crossings. Frac monitoring shall also be completed during trenchless installations; aerial patrols will take place as required, and post-construction revegetation assessments shall completed at water or other crossings, as applicable, to ensure there are no concerns with bank or riparian zone instabilities or revegetation programs.

Additional piping loads such as the weight of pipe and components, wind, snow, or otherwise, as detailed in Section 4.2.3, shall be considered during the detailed design phase, and all piping supports appropriately designed. Stress analysis shall also be performed to ensure there are no concerns from operating temperatures, pipeline restraint during installation, or any other loading and dynamic effects such as but not limited to those outlined by Section 4.2.4.

4.4 Material Specifications and Properties

All pipeline materials shall meet or exceed the requirements of CSA Z662-23 Section 5.

Further to CSA, Wolf has additionally completed an enhanced material study as a part of the ACTL and Edmonton Connector pipelines' design program to determine the appropriate pipe specification for use specifically in dense phase CO_2 pipeline systems. This study focused on ensuring positive control of longitudinal ductile fracture by employing increased mechanical properties such as steel toughness, crack arrestors, or both, and was based on empirical testing following the initiation of ductile fracture on test pipe in high-pressure dense phase CO_2 service.

The results of this study were analyzed to determine the appropriate wall thickness, grade, and toughness of steel selected for installation, and have since been used to develop a reliable database for thermodynamic analysis of decompression behaviour and longitudinal crack propagation speeds.

The LCTL pipeline will be constructed using the same NPS 12 pipe specification as was selected for ACTL and for the Edmonton Connector and shall be CSA Z245.1 Gr. 448 Cat II pipe of minimum 12.7mm wall thickness with increased proven notch toughness requirements; values resultant from the aforementioned study, verified in subsequent study-reviews (April 2024) for the design MOP (increased to 20MPa), and as tabled below.

Operating pipeline hoop stresses (in the mainline pipeline) are calculated to be below 55% at the licensed MOP of 17,930 kPag, and less than 60% should the pipeline's MOP ever be increased to match the maximum design pressure of 20 MPa. Pipeline wall thicknesses for all other installation cases are selected to ensure hoop stresses remain below those allowable for each case in Class 2 Location installations.

The below table outlines the pipeline material specifications:

Case	NPS 12	
	WT (mm)	Material
Mainline	12.7	Gr 448 CAT II M5C Min. Toughness: • 70J pipe body • 70J weld zone • 40J fusion line
Road, Watercourse, and Utility Crossings	12.7	
Railway Crossings	14.8	
Fabricated Bends	14.8	
Riser Bends	14.27	Gr 359 CAT II M45C[1]
Assemblies	14.27	

1. Gr. 359 materials have been selected for the above grade assemblies due to typical material availability. These materials shall be low temperature as required for above grade installations in Alberta climates.

All above grade materials (pipe, fittings, and valves) shall be specified per Wolf EXZ20 or EX piping specifications; each of which are designed for systems with a pressure rating of PN 250 (CL 1500). This pressure rating exceeds the intended design and licensed MOP of the LCTL pipeline. Any requested deviation from these specifications will be documented and undergo an appropriate engineering review with respect to CSA Z662-23 or any additionally applicable codes as required prior to approval. These specifications have been included within ***Appendix B*** and ***Appendix C*** of this document for reference.

Material Test Reports (MTR) are unavailable at this time but shall be obtained with material purchase and when available. These MTRs shall be reviewed upon receipt to ensure material properties and compliance, and kept with all Project records.

4.5 Manufacturing Process and Installation Method

Specific manufacturing processes will be completed as required to meet the increased notch toughness requirements for the Gr. 448 steel line pipe as detailed in the *"Material Specifications and Properties"* Section above.

These requirements have been successfully achieved by pipe mills on previous projects, and it is anticipated that this shall again be achievable for the LCTL pipeline. Impact testing will be completed using standard Charpy practices undertaken by the pipe manufacturer, with specimen test temperatures that meet the proposed minimum pipe design temperature requirements of the LCTL. Wolf will engage independent third-party inspection resources with appropriate experience and credentials to witness testing and confirm results are in line with engineering requirements prior to pipe installation. As noted above, Material Test Records will be audited and assessed for specification compliance.

The pipeline shall in general be installed by open cut and trenchless methods. All requirements of CSA Z662-23 Sections 6 and 8 shall be met during the pipeline installation and testing, and all requirements of Section 7 shall be adhered to with respect to Joining. Wolf has developed a proprietary Weld Procedure Specification (WPS) meeting the requirements of CSA Z662-23, including those updated from the 2019 version of the Z662 Standard (such as, but not limited to, Clause 7.7.3.4 for pipe-to-pipe tension test specimens for pipe with SMYS greater than 386 MPa) which shall be used for construction in the event that similarly appropriate WPS are not readily available from the selected mainline Contractor. All WPS shall be reviewed by Engineering prior to being approved for use in the construction of the LCTL.

4.6 Technical Data and Test Records

Test records are unavailable at this time, however, shall be generated and maintained as applicable throughout detailed design, installation, testing, and commissioning, and shall be kept on record for the life of the pipeline system as required by CSA Z662-23.

The following is a representative list of construction or test records which shall be kept for the life of the pipeline system to ensure CSA standards are met; additional records beyond this may be kept as well:

- CSA hoop stress calculations – to show that the pipe and crossing pipe is designed to minimum wall thickness per maximum designed operating conditions.
- Pipe and material MTRs – to show material strength, composition, and rating, and provide traceability against QA documentation.
- Hydrotest reports – to show that the pipeline was tested to minimum test pressures, and that there are no signs of leakage during testing.
- Weld procedures – will be reviewed by a qualified inspector to ensure appropriate application, compatibility with CSA regulations, material hardness requirements, etc.
- Material receipt – for example, flanges and gaskets to be in good working condition with no evidence of face scoring or prior use with all ratings to be consistent with design pressure.
- Cathodic protection – to show that a cathodic protection system has been designed and is in place.
- Visual inspection records – to show that external coating was inspected to be intact with only minor anomalies acceptable. Record of weld inspection will show there are no uneven or undersized welds.

4.7 Potential Modes of Deterioration and Means of Detection

The primary threat to deterioration of the LCTL pipeline is considered corrosion; internal and/or external.

External corrosion shall be prevented with external coatings applied to the pipe (anticipated to be FBE) and pipe girth welds (anticipated to be liquid epoxy), and via an impressed current Cathodic Protection (CP) system. This CP system shall be monitored by Remote Monitoring Units (RMUs) and test leads installed at pertinent locations such as crossings or fences to validate system potential and functionality. Third-party CP specialists shall be consulted for the design and installation of the CP system, and the requirements of Clause 11.25.3 shall be considered in this system design.

In general, the risk of internal corrosion is considered to be extremely low for the LCTL pipeline. The CO_2 product specification requires water content be maintained below a maximum of 10 lbs/MMscfd, and dedicated moisture analyzers at the pipeline inlet shall provide constant feedback to Wolf's control center via the Project's SCADA system; the pipeline's safety systems shall be automated to respond should product composition deviate from specification.

With inherently low product water content, constant moisture analysis and automated response in the event of specification deviation, it is not expected that the LCTL pipeline shall be subject to internal corrosion as a result of impurities or moisture contamination/carbonic acid formation as can occur when water interacts with CO_2. Periodic inline inspections shall be conducted to validate this expectation and to confirm pipe wall integrity. Inline inspection shall be completed on a regular basis and shall be used to verify that no corrosion, dents, cracks, or otherwise exist in the piping. These deficiencies, among others, are detailed in Section 10 of CSA Z662-23 and all requirements of this Section shall be adhered to in the Operation and Maintenance of the LCTL pipeline.

Wolf shall in general implement their existing, and continuously updated, Integrity Management Program, meeting the requirements of CSA Z662-23 Section 3 at minimum.

4.8 Control and Protective Devices

Pipeline pressures shall be monitored 24 hours a day with industry standard pressure transmitters specified for the maximum allowable operating pressures. All transmitters shall be calibrated on a regularly scheduled basis to ensure accurate indication of operating parameters throughout their operation. Signals from these devices shall be relayed to the pipeline control system via the LCTL SCADA network. Instruments shall be selected with consideration of CSA Z662-23 Section 4.19.

Maintaining a minimum pressure in the pipeline (of at least 7,500 kPag) shall be implemented for phase control and operation of the LCTL pipeline system. Automatically actuated valves shall be installed at pipeline inlet, outlet, and at any intermediate valve sites to help maintain minimum pressure, to prevent any overpressure scenarios from occurring, and to isolate the LCTL in the event of an emergency. Overpressure protection shall consider all requirements of CSA Z662-23 Section 4.18. These automated valves shall automatically close on high-high, low-low, and rapid rate of change pressure signals. High and low alarms shall be sounded ahead of these closure actions to warn operators of escalating or descending pressures. It is expected that the initial high-high setting shall be 17,930 kPag and the initial low-low setting shall be 8,250 kPag. Any high and low alarm set points shall be determined in consultation with the Wolf operations team during Project design and/or commissioning.

Automated valves are intended to be specified with electrohydraulic functionality and capable of spring-closed actuation without an electric signal. Valves shall also be capable of remote close as commanded by Wolf operations (also via the SCADA system). A mini-Uninterrupted Power Supply (UPS) shall be installed at each valve site to allow for temporary control and information relay in the event of a loss of utility power.

Hydraulic analyses have been completed to review and confirm the anticipated pressure drop across the length of the LCTL pipeline, and based on preliminary results, it is not expected that any low-pressure conditions should arise during normal operation.

4.9 Environmental Conditions and Potential Environmental Consequences

Environmental conditions, such as loading due to wind and snow or low temperature installations shall be appropriately considered and any requirements for these items, as outlined or stated in Section 4 of CSA Z662-23, shall be implemented in the LCTL pipeline design.

Upset conditions such as fire or 10-year storms shall be considered as appropriate given the installation location of the LCTL pipeline and its associated infrastructure (such as riser sites).

4.10 Hazards Type, Frequency, And Magnitude

Hazards beyond those typically associated with the design, construction and operation of a dense phase CO_2 pipeline are not anticipated at this time. Wolf have recognized and acknowledged general project hazards or risks which can be associated with ground disturbance in industrial areas, those associated with pipeline crossings, or hazards related to surface topography; each of which will be addressed per the applicable sections of CSA Z662-23 and as they have been outlined in the previous sections of this report.

4.11 Consequences of Failure

Wolf has undertaken a detailed analysis to assess the effects of CO_2 dispersion from the LCTL pipeline. The primary hazard associated with a CO_2 pipeline release is the displacement of oxygen. CO_2 gas is colourless, odourless, and heavier than air at standard conditions, and prolonged exposure can be hazardous to human health or fatal in high local concentrations.

ERCBSLAB modeling software was utilized to simulate a CO_2 release at selected local meteorological conditions for several different release scenarios from the LCTL. ERCBSLAB is a steady state one-dimensional model that solves equations of momentum, conservation of mass, species, and energy, and the equation of state. It accommodates analyses of ground level and elevated jets, liquid pool evaporation, and instantaneous volume sources.

The final report of findings following these dispersion modelling simulations for LCTL Phase II, as were utilized to determine the LCTL's Emergency Planning Zone (EPZ) boundaries, can be found in ***Appendix D***.

Operators working on the LCTL pipeline shall be appropriately trained and adhere to suitable Safe Work Practices (SWPs) as developed by Wolf and meeting the intent of CSA Z662-23 Section 10.2.11.

The Pipeline shall be continuously monitored to ensure no failure, catastrophic or minor, goes unnoticed and any upset conditions are rapidly addressed. Pipeline leak detection will be achieved through mass balance calculations performed utilizing metering systems at the upstream and downstream ends of the pipeline and via pressure monitoring devices installed at each riser site. Leak detection shall be designed to provide detection capabilities in accordance with Section 10.3.4 for CO_2 service and as detailed by Section 4.20.

4.12 Potential Changes to Any of the Above.

This section is not considered applicable as neither detailed design nor construction has been initiated. Any future changes in design which are required as a result of a change in operating conditions, external factors, or otherwise arising during design, will be reviewed against the applicable sections of CSA Z662-23, documented and changes made accordingly.

5 CONCLUSION

It has been the purpose of this document to highlight, in the fashion of an Engineering Assessment as outlined by CSA Z662-23 Section 4.1.12 and in supporting Wolf's pipeline Application 32926881, that the Wolf LCTL pipeline shall be designed, constructed, and operated in a manner meeting all requirements of CSA Z662-23.

Several Sections of Z662-23 have been referenced within the body of this document; however, it should be noted that this listing is not considered exhaustive, but representative for the required considerations for LCTL pipeline system design. All requirements of CSA Z662-23 shall be adhered to, and appropriately trained and experienced engineering and quality personnel shall be responsible for the design of this system. Periodic design reviews shall be completed with input from senior Engineering staff as well as Wolf engineers and operators, and all design documents shall receive the appropriate stamp and permit prior to being issued for construction.

Any additional design information required to support the review and approval of Wolf's LCTL pipeline can be provided upon request.

6 APPROVALS

Name: Jesse McLean, P.Eng.

Signature:

Date: May 01, 2024

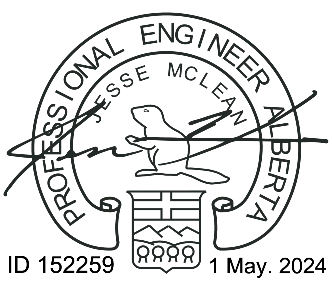
Name: Marcus Guedo, P.Eng.

Signature:

Marcus Guedo

Date: May 01, 2024

Stamp:



Permit:

PERMIT TO PRACTICE
OBSIDIAN ENGINEERING CORP
Signature #89164
Date 2024-May-01
PERMIT NUMBER: P13834
The Association of Professional
Engineers and Geoscientists of Alberta

Appendix A

LCTL CO_2 Product Specification

LCTL Pipeline Product Specification

	Receipt Point
Minimum CO2, (mol)	95%
Maximum Hydrocarbons , (mol)	2.0%
Maximum Hydrocarbon Dewpoint	- 20° F
Maximum Glycols, Amines Ammonia	3 lbs/MMscf
Maximum H_2O Content	10 lbs/MMscf
Maximum H_2S Content	10 ppm by Volume
Maximum S content	16 ppm by volume
Maximum N_2 Content (mol)	1.0%
Maximum MeOH Content (mol)	0.1%
Maximum H_2 Content (mol)	1.0%
Maximum CO Content (mol)	1.0%
Maximum CH_4 Content (mol)	1.0%
Maximum total inert content (mol)	4.0%
Maximum O_2 (mol)	0.1%
Maximum SO_2 (vol)	100 ppm
Maximum NO_x (vol)	100 ppm
Maximum Hg (vol)	100 ppb
Other substances	Commerically free from sand, dust, gums, oils, impurities, and other objectionable substances
Maximum Temperature	104° F
Maximum Pressure	2600 psig
Minimum Pressure	1300 psig

Appendix B

Pipe Specification – EXZ20

	SPECIFICATION: EXZ (CSA Z662, PN250, LOW TEMP, SWEET)		DESIGN CODE	CSA Z662	**EXZ20**
	MATERIAL	CARBON STEEL	HYDROTEST	30,000 kPag (4351 psig) / 1 H (S9)	
	PRESSURE CLASS	PN250 (ASME 1500)	NDE ALL	100% VISUAL	
	PRESSURE	20,000 kPag (2900 psig)	BW, FILLET, SW	100% RT / MT	
	TEMPERATURE	-45°C / 50°C (-49°F / 1224°F) (S12)	SW GAP	15% RT	
SWEET SERVICE, LOW TEMPERATURE	C.A.	N/R	HARD. CONTROL	WT > 31.8 mm (S4)	
DENSE PHASE CARBON DIOXIDE PER LCTL SPECIFICATIONS RISER AND ASSEMBLY PIPING			HARDNESS TEST	N/R	Rev 1
			DESIGN/SERVICE	F=0.8, L=0.8, J=1.0, T=1.0	Dec 2023

PIPE

TYPE	NPS	MIN SCH	ENDS	DESIGN / MATERIAL CODE	DESCRIPTION	NOTE
THR PIPE	0.5 - 1.5	SCH 160	THR	ASME B36.10M / ASTM A333 Gr. 6	SMLS	S1
WLD PIPE	0.5 - 1.5	SCH 160	SW	ASME B36.10M / ASTM A333 Gr. 6	SMLS	
	2 - 6	SCH 80	BE	CSA Z245.1 Gr. 359 CAT II M45C / API 5L PSL2 X52N M50F	SMLS or ERW	S5, S11
	8 - 12	SCH 60	BE	CSA Z245.1 Gr. 359 CAT II M45C / API 5L PSL2 X52N M50F	SMLS or ERW	S5, S11
	14 - 24	SCH 80	BE	CSA Z245.1 Gr. 359 CAT II M45C / API 5L PSL2 X52N M50F	SMLS or ERW	S5, S11

FLANGES / FITTINGS

TYPE	NPS	MIN SCH / RTG	CONN.	DESIGN / MATERIAL CODE	DESCRIPTION	NOTE
FLANGES	0.5 - 1.5	ANSI 1500	THR / SW	CSA Z245.12 / ASME B16.5 / CSA Gr.248 CAT II M45C / ASTM A350 LF2 CL1	RF	S1, S10
	2 - 24	ANSI 1500	BW, WN	CSA Z245.12 Gr.359 CAT II M45C	RF, Bore to match pipe	S10
BLIND FLANGES	ALL	ANSI 1500	-	CSA Z245.12 / ASME B16.5 / CSA Gr.248 CAT II M45C / ASTM A350 LF2 CL1	RF	S10
ORIFICE FLANGES	-	-	-			
SPECTACLE BLINDS, BLANKS, SPACERS	ALL	ANSI 1500	-	ASME B16.48 / ASTM A516-70N, IMPACT TESTED TO -45°C	For RF flanges	
FITTINGS	0.5 - 1.5	CLASS 3000	THR	ASME B16.11 / ASTM A350 LF2 CL1		S1
	0.5 - 1.5	CLASS 3000	SW	ASME B16.11 / ASTM A350 LF2 CL1		
	2 - 24	SCH TO MATCH PIPE	BW	CSA Z245.11 Gr.359 CAT II M45C		
UNIONS	NOT USED	-	-	NOT USED		S1
NIPPLES	0.5 - 1.5	SCH 160	THR	ASTM A333 Gr. 6	Min 100mm long, SMLS	S1
	0.5 - 1.5	SCH 80	SW	ASTM A333 Gr. 6	Min 100mm long, SMLS	
SWAGES	0.5 - 1.5	SCH 160	THR	MSS SP-95 / ASTM A420 WPL6-S		S1
	0.5 - 1.5	SCH 80	SW	MSS SP-95 / ASTM A420 WPL6-S		
THREADOLETS	NOT USED	-	-	NOT USED		S1
SOCKOLETS	0.5 - 1.5	CLASS 3000	SW	MSS SP-97 / ASTM A350 LF2 CL1		
WELDOLETS	ALL	Note S2	BW	MSS SP-97 / ASTM A350 LF2 CL1		S2

BOLTING

TYPE	NPS	MIN SCH / RTG	ENDS	DESIGN / MATERIAL CODE	DESCRIPTION	NOTE
GASKET	ALL	3.2mm / ANSI 1500	-	ASME B16.20 / 316 SS	RF, CGI style, 316 SS winding, flexible graphite filler, CS centering ring, 316SS inner ring	S6
STUDS	-	-	-	ASME B16.5 / ASTM A193-B7M	Dimensions per ASME B16.5	
NUTS	-	-	-	ASME B16.5 / ASTM A194-2H		

TUBING

TYPE	OD	MIN WT	ENDS	DESIGN / MATERIAL CODE	DESCRIPTION	NOTE
TUBING	1/4" - 3/8"	0.035"		ASTM A269 / 316 SS	SMLS, Fully Annealed	
	1/2"	0.049"		ASTM A269 / 316 SS	SMLS, Fully Annealed	
	5/8" - 3/4"	0.065"		ASTM A269 / 316 SS	SMLS, Fully Annealed	
TUBING FITTINGS	ALL	-		ASTM A182 / 316 SS	Swagelok or equivalent	

VALVES

TYPE	NPS	CLASS / RTG	TRIM	ENDS	DESIGN / MATERIAL CODE	DESCRIPTION	NOTE
BALL	0.5 - 1.5	6000 CWP	SS	THR X SW	ASME B16.34 / ASTM A350 LF2 CL1	FLT, Lever Op., RP	S3
	0.5 - 1.5	6000 CWP	SS	THR X SW	ASME B16.34 / ASTM A350 LF2 CL1	FLT, Lever Op., FP	S3
	0.5 - 1.5	6000 CWP	SS	SW	ASME B16.34 / ASTM A350 LF2 CL1	FLT, Lever Op., RP	S3
	0.5 - 1.5	6000 CWP	SS	SW	ASME B16.34 / ASTM A350 LF2 CL1	FLT, Lever Op., FP	S3
	2 - 20	CLASS 1500	ENP	FLG, RF	ASME B16.34 / API 6D / CSA Z245.15 / ASTM A352 LCC, METAL SEATED, DBB	TM, Gear Op., RP	S3, S10
	2 - 20	CLASS 1500	ENP	FLG, RF	ASME B16.34 / API 6D / CSA Z245.15 / ASTM A352 LCC, METAL SEATED, DIB-1	TM, Gear Op., RP	S3, S10
	2 - 20	CLASS 1500	ENP	FLG, RF	ASME B16.34 / API 6D / CSA Z245.15 / ASTM A352 LCC, METAL SEATED, DIB-2	TM, Gear Op., RP	S3, S10
	2 - 20	CLASS 1500	ENP	FLG, RF	ASME B16.34 / API 6D / CSA Z245.15 / ASTM A352 LCC, METAL SEATED, DBB	TM, Gear Op., FP	S3, S10
	2 - 20	CLASS 1500	ENP	FLG, RF	ASME B16.34 / API 6D / CSA Z245.15 / ASTM A352 LCC, METAL SEATED, DIB-1	TM, Gear Op., FP	S3, S10
	2 - 20	CLASS 1500	ENP	FLG, RF	ASME B16.34 / API 6D / CSA Z245.15 / ASTM A352 LCC, METAL SEATED, DIB-2	TM, Gear Op., FP	S3, S10
	2 - 20	CLASS 1500	ENP	BW	ASME B16.34 / API 6D / CSA Z245.15 / ASTM A352 LCC, METAL SEATED, DBB	TM, Gear Op., FP	S3, S10, S7
	2 - 20	CLASS 1500	ENP	BW	ASME B16.34 / API 6D / CSA Z245.15 / ASTM A352 LCC, METAL SEATED, DIB-1	TM, Gear Op., FP	S3, S10, S7
	2 - 20	CLASS 1500	ENP	BW	ASME B16.34 / API 6D / CSA Z245.15 / ASTM A352 LCC, METAL SEATED, DIB-2	TM, Gear Op., FP	S3, S10, S7
	2 - 20	CLASS 1500	ENP	BW x FLG,RF	ASME B16.34 / API 6D / CSA Z245.15 / ASTM A352 LCC, METAL SEATED, DBB	TM, Gear Op., FP	S3, S10, S7
	2 - 20	CLASS 1500	ENP	BW x FLG,RF	ASME B16.34 / API 6D / CSA Z245.15 / ASTM A352 LCC, METAL SEATED, DIB-1	TM, Gear Op., FP	S3, S10, S7
	2 - 20	CLASS 1500	ENP	BW x FLG,RF	ASME B16.34 / API 6D / CSA Z245.15 / ASTM A352 LCC, METAL SEATED, DIB-2	TM, Gear Op., FP	S3, S10, S7
GATE	0.5 - 1.5	CLASS 1500	12	THR X SW	ASME B16.34 / API 602 / ASTM A350 LF2 CL1	BB, OS&Y	
	0.5 - 1.5	CLASS 1500	12	SW	ASME B16.34 / API 602 / ASTM A350 LF2 CL1	BB, OS&Y	
	2 - 20	CLASS 1500	12	FLG, RF	ASME B16.34 / API 600 / API 6D / CSA Z245.15 / ASTM A352 LCC	BB, OS&Y, VTS Gear Op.	S10
GLOBE	0.5 - 1.5	CLASS 1500	12	SW	ASME B16.34 / API 602 / ASTM A350 LF2 CL1	BB, OS&Y	
	2 - 12	CLASS 1500	12	FLG, RF	ASME B16.34 / API 623 / ASTM A352 LCC	BB, OS&Y, VTS Gear Op.	S10
CHECK	0.5 - 1.5	CLASS 1500	12	SW	ASME B16.34 / API 602 / ASTM A350 LF2 CL1	BC, Swing, Ball or Piston	
	2 - 20	CLASS 1500	12	FLG, RF	ASME B16.34 / API 594 / CSA Z245.15 / ASTM A352 LCC	BC, Swing	S10
	2 - 20	CLASS 1500	12	FLG, RF	ASME B16.34 / API 6D / CSA Z245.15 / ASTM A352 LCC, PIGGABLE	BC, Swing	S10
NEEDLE	0.5 - 0.75	6000 CWP	SS	THR	ASTM A182 / 316 SS	SS Body	S8

NOTES

GENERAL

G1. This specification applies to pipeline risers, assemblies, and block valve sites. This specification shall not be used for pump station piping, capture facilities or for mainline pipeline sections.

G2. Segments that will be installed below grade shall have a suitable coating applied. Coating shall be liquid epoxy (Protal 7200/7250, HBE-95, SPC SP-2888 RG) or approved equivalent.

S1. Threaded piping only allowed for instrument piping downstream of a flanged or welded root valve.

S2. Branch connections shall be as per branch table. For buttwelded olets: vendors shall be required to complete and provide area replacement calculations to CSA Z662.

S3. Valve vendor shall confirm suitability of non-metallic components used for seats or seals with dense phase CO2 to prevent degradation or decompression issues. No elastomeric materials shall be used. Non-metallic materials shall have resistance to full temperature range. Sealant injection is not recommended without evidence of past successful experience. The valve vendor may propose alternatives to fully metal seats; evidence of previous experience will be required.

S4. Post weld heat treatment (stress relief) shall be required when the effective weld throat exceeds the lower of 31.8mm per CSA Z662 7.9.15 or the value specified on the welding procedure specification.

S5. API 5L pipe shall meet the impact test requirements indicated in CSA Z662 Table 5.3 Note 6. Use of 609.6mm (NPS 24) pipe shall be limited to pig barrel major piping.

S6. Isolation kits shall be Pikotek VCS (or approved equivalent), 316L SS core, Teflon seal, G10 sleeves and washers.

S7. Valves shall have welding ends in accordance with CSA Z245.15. Counter bore and taper transitions (1m length) shall be considered for mainline valves. Valves may be top-entry valves to allow for maintenance activities.

S8. Limited to basic needle valves for instrument connections. For instrument valves requiring multiple ports, bleeds or double-blocking elements refer to instrument details.

S9. Hydrostatic test time for fully exposed piping and pre-tested assemblies. Any sections not considered fully exposed must undergo a 4hr (min) strength test and 4hr (min) leak test per CSA Z662.

S10. All flanged connections shall be in accordance with ASME PCC-1 and include a suitable bolt lubricant.

S11. Pipe runs of the same wall thickness and grade, without components or material changes, shall be limited to 30m or less. Where longer pipe runs are required the user shall consider the need for crack arrestors or piping with CVN ratings higher than what is specified in CSA Z245.1. Flanges, valves and fittings (except for olets) shall be considered components.

S12. Engineering and administrative controls shall be used to avoid temperature excursions below the MDMT where the hoop stress is above 50MPa. Additional considerations required for blowdowns, vents or other upset cases.

KEY

BB = Bolted Bonnet BC = Bolted Cap BE = Beveled Ends BW = Butt Weld CA = Corrosion Allowance CWP = Cold Working Pressure ENP = Electroless Nickel Plating FLT = Floating FS = Forged Steel NDE = Non-Destructive Examination NPS = Nominal Pipe Size OS&Y = Outside Stem & Yoke PE = Plain Ends PWHT = Post-Weld Heat Treatment RF = Raised Face RTJ = Ring Type Joint SMLS = Seamless Pipe SS = Stainless Steel SW = Socket Weld TBG = Tubing TM = Trunnion Mounted THR = Threaded VTS = Vendor to Specify WLD = Welded WN = Weld Neck WT = Wall Thickness

Appendix C

Pipe Specification – EX

WOLF CARBON SOLUTIONS INC.	SPECIFICATION: EX (ASME B31.3, PN250, LOW TEMP, SWEET)		DESIGN CODE	ASME B31.3	EX
	MATERIAL	CARBON STEEL	HYDROTEST	30,000 kPag (4351 psig) 1 H (S7)	
	PRESSURE CLASS	ASME 1500	NDE ALL	100% VISUAL	
	PRESSURE	20,000 kPag (2900 psig)	BW, FILLET, SW	100% RT / MT	
	TEMPERATURE	-45°C / 50°C (-49°F / 122°F) (S8)	SW GAP	15% RT	
SWEET SERVICE, LOW TEMPERATURE	C.A.	0.0mm	HARD. CONTROL	WT > 25 mm (S4)	
DENSE PHASE CARBON DIOXIDE PER LCTL SPECIFICATIONS STATION PIPING			HARDNESS TEST	N/R	Rev 1
			DESIGN/SERVICE	Normal Fluid Service	Dec 2023

PIPE

TYPE	NPS	MIN SCH	ENDS	DESIGN / MATERIAL CODE	DESCRIPTION	NOTE
THR PIPE	0.5 - 1.5	SCH 160	THR	ASME B36.10M / ASTM A333 Gr. 6	SMLS	S1
WLD PIPE	0.5 - 1.5	SCH 80	SW	ASME B36.10M / ASTM A333 Gr. 6	SMLS	
	2 - 3	SCH 80	BE	ASME B36.10M / ASTM A333 Gr. 6	SMLS	
	4 - 12	SCH 120	BE	ASME B36.10M / ASTM A333 Gr. 6	SMLS	
	14 - 24	SCH 140	BE	ASME B36.10M / ASTM A333 Gr. 6	SMLS	

FLANGES / FITTINGS

TYPE	NPS	MIN SCH / RTG	CONN.	DESIGN / MATERIAL CODE	DESCRIPTION	NOTE
FLANGES	0.5 - 1.5	ANSI 1500	THR	ASME B16.5 / ASTM A350 LF2 CL1	RF	S1
	0.5 - 1.5	ANSI 1500	SW	ASME B16.5 / ASTM A350 LF2 CL1	RF, Bore to match pipe	
	2 - 24	ANSI 1500	BW, WN	ASME B16.5 / ASTM A350 LF2 CL1	RF, Bore to match pipe	
BLIND FLANGES	ALL	ANSI 1500	-	ASME B16.5 / ASTM A350 LF2 CL1	RF	
ORIFICE FLANGES	-	-	-			
SPECTACLE BLINDS, BLANKS, SPACERS	ALL	ANSI 1500	-	ASME B16.48 / ASTM A516-70N, IMPACT TESTED TO -45°C	For RF flanges	
FITTINGS	0.5 - 1.5	CLASS 3000	THR	ASME B16.11 / ASTM A350 LF2 CL1		S1
	0.5 - 1.5	CLASS 3000	SW	ASME B16.11 / ASTM A350 LF2 CL1		
	2 - 12	SCH TO MATCH PIPE	BW	ASME B16.9 / ASTM A420 WPL6-S		
UNIONS	NOT USED	-	-	NOT USED		S1
NIPPLES	0.5 - 1.5	SCH 160	THR	ASTM A333 Gr. 6	Min 100mm long, SMLS	S1
	0.5 - 1.5	SCH 80	SW	ASTM A333 Gr. 6	Min 100mm long, SMLS	
SWAGES	0.5 - 1.5	SCH 160	THR	MSS SP-95 / ASTM A420 WPL6-S		S1
	0.5 - 1.5	SCH 80	SW	MSS SP-95 / ASTM A420 WPL6-S		
THREADOLETS	NOT USED	-	-	NOT USED		S1
SOCKOLETS	0.5 - 1.5	CLASS 3000	SW	MSS SP-97 / ASTM A350 LF2 CL1		
WELDOLETS	ALL	SCH TO MATCH PIPE	BW	MSS SP-97 / ASTM A350 LF2 CL1		S2

BOLTING

TYPE	NPS	MIN SCH / RTG	ENDS	DESIGN / MATERIAL CODE	DESCRIPTION	NOTE
GASKET	ALL	3.2mm / ANSI 1500	-	ASME B16.20 / 316 SS	RF, CGI style, 316 SS winding, flexible graphite filler, CS centering ring, 316SS inner ring	S5
STUDS	-	-	-	ASME B16.5 / ASTM A193-B7M	Dimensions per ASME B16.5	
NUTS	-	-	-	ASME B16.5 / ASTM A194-2H		

TUBING

TYPE	OD	MIN WT	ENDS	DESIGN / MATERIAL CODE	DESCRIPTION	NOTE
TUBING	1/4" - 3/8"	0.035"		ASTM A269 / 316 SS	SMLS, Fully Annealed	
	1/2"	0.049"		ASTM A269 / 316 SS	SMLS, Fully Annealed	
	5/8" - 3/4"	0.065"		ASTM A269 / 316 SS	SMLS, Fully Annealed	
TUBING FITTINGS	ALL	-		ASTM A182 / 316 SS	Swagelok or equivalent	

VALVES

TYPE	NPS	CLASS / RTG	TRIM	ENDS	DESIGN / MATERIAL CODE	DESCRIPTION	NOTE
BALL	0.5 - 1.5	6000 CWP	SS	THR X SW	ASME B16.34 / ASTM A350 LF2 CL1	FLT, Lever Op., RP	S3
	0.5 - 1.5	6000 CWP	SS	THR X SW	ASME B16.34 / ASTM A350 LF2 CL1	FLT, Lever Op., FP	S3
	0.5 - 1.5	6000 CWP	SS	SW	ASME B16.34 / ASTM A350 LF2 CL1	FLT, Lever Op., RP	S3
	0.5 - 1.5	6000 CWP	SS	SW	ASME B16.34 / ASTM A350 LF2 CL1	FLT, Lever Op., FP	S3
	2 - 20	CLASS 1500	ENP	FLG, RF	ASME B16.34 / API 6D / ASTM A352 LCC, METAL SEATED, DBB	TM, Gear Op., RP	S3
	2 - 20	CLASS 1500	ENP	FLG, RF	ASME B16.34 / API 6D / ASTM A352 LCC, METAL SEATED, DIB-1	TM, Gear Op., RP	S3
	2 - 20	CLASS 1500	ENP	FLG, RF	ASME B16.34 / API 6D / ASTM A352 LCC, METAL SEATED, DIB-2	TM, Gear Op., RP	S3
	2 - 20	CLASS 1500	ENP	FLG, RF	ASME B16.34 / API 6D / ASTM A352 LCC, METAL SEATED, DBB	TM, Gear Op., FP	S3
	2 - 20	CLASS 1500	ENP	FLG, RF	ASME B16.34 / API 6D / ASTM A352 LCC, METAL SEATED, DIB-1	TM, Gear Op., FP	S3
	2 - 20	CLASS 1500	ENP	FLG, RF	ASME B16.34 / API 6D / ASTM A352 LCC, METAL SEATED, DIB-2	TM, Gear Op., FP	S3
	2 - 20	CLASS 1500	ENP	BW	ASME B16.34 / API 6D / ASTM A352 LCC, METAL SEATED, DBB	TM, Gear Op., FP	S3
	2 - 20	CLASS 1500	ENP	BW	ASME B16.34 / API 6D / ASTM A352 LCC, METAL SEATED, DIB-1	TM, Gear Op., FP	S3
	2 - 20	CLASS 1500	ENP	BW	ASME B16.34 / API 6D / ASTM A352 LCC, METAL SEATED, DIB-2	TM, Gear Op., FP	S3
	2 - 20	CLASS 1500	ENP	BW x FLG,RF	ASME B16.34 / API 6D / ASTM A352 LCC, METAL SEATED, DBB	TM, Gear Op., FP	S3
	2 - 20	CLASS 1500	ENP	BW x FLG,RF	ASME B16.34 / API 6D / ASTM A352 LCC, METAL SEATED, DIB-1	TM, Gear Op., FP	S3
	2 - 20	CLASS 1500	ENP	BW x FLG,RF	ASME B16.34 / API 6D / ASTM A352 LCC, METAL SEATED, DIB-2	TM, Gear Op., FP	S3
GATE	0.5 - 1.5	CLASS 1500	12	THR X SW	ASME B16.34 / API 602 / ASTM A350 LF2 CL1	BB, OS&Y	
	0.5 - 1.5	CLASS 1500	12	SW	ASME B16.34 / API 602 / ASTM A350 LF2 CL1	BB, OS&Y	
GLOBE	0.5 - 1.5	CLASS 1500	12	SW	ASME B16.34 / API 602 / ASTM A350 LF2 CL1	BB, OS&Y	
	2 - 12	CLASS 1500	12	FLG, RF	ASME B16.34 / API 623 / ASTM A352 LCC	BB, OS&Y, VTS Gear Op.	S8
CHECK	0.5 - 1.5	CLASS 1500	12	SW	ASME B16.34 / API 602 / ASTM A350 LF2 CL1	BC, Swing, Ball or Piston	
	2 - 20	CLASS 1500	12	FLG, RF	ASME B16.34 / API 594 / ASTM A352 LCC	BC, Swing	S8
NEEDLE	0.5 - 0.75	6000 CWP	SS	THR	ASTM A182 / 316 SS	SS Body	S6

NOTES

GENERAL

G1. This specification applies to CO2 station piping (pump, metering, pressure control) under the Safety Codes Act or Oil and Gas Conservation Act. It is not intended for pipeline assemblies or risers.

G2. All flanged connections shall be in accordance with ASME PCC-1 and include a suitable bolt lubricant.

S1. Threaded piping only allowed for instrument piping downstream of a welded root valve.

S2. Branch connections shall be as per branch table.

S3. Valve vendor shall confirm suitability of non-metallic components used for seats or seals with dense phase CO2 to prevent degradation or decompression issues. Non-metallic materials shall have resistance to full temperature range. Sealant injection is not recommended without evidence of past successful experience. The valve vendor may propose alternatives to fully metal seats; evidence of previous experience will be required.

S4. Post weld heat treatment (stress relief) shall be required when the effective weld throat exceeds the lower of 25mm per ASME B31.3 Table 331.1.3 or the value specified on the welding procedure specification.

S5. Isolation kits shall be Pikotek VCS (or approved equivalent), 316L SS core, Teflon seal, G10 sleeves and washers.

S6. Limited to basic needle valves for instrument connections. For instrument valves requiring multiple ports, bleeds or double-blocking elements refer to instrument details.

S7. Hydrostatic test time may be reduced to the minimum required per ASME B31.3 if approved by Owner.

S8. Engineering and administrative controls shall be used to avoid temperature excursions below the MDMT unless verified to comply with the allowances per ASME B31.3 323.2.2 (g). Additional considerations required for blowdowns, vents or other upset cases.

KEY

BB = Bolted Bonnet BC = Bolted Cap BE = Beveled Ends BW = Butt Weld CA = Corrosion Allowance CWP = Cold Working Pressure ENP = Electroless Nickel Plating FLT = Floating FS = Forged Steel NDE = Non-Destructive Examination NPS = Nominal Pipe Size OS&Y = Outside Stem & Yoke PE = Plain Ends PWHT = Post-Weld Heat Treatment RF = Raised Face RTJ = Ring Type Joint SMLS = Seamless Pipe SS = Stainless Steel SW = Socket Weld TBG = Tubing TM = Trunnion Mounted THR = Threaded VTS = Vendor to Specify WLD = Welded WN = Weld Neck WT = Wall Thickness

Appendix D

LCTL Phase II CO_2 Pipeline Release Simulations Results Report

Integrated Modelling Inc.
1820, 715 – 5 Avenue S.W. **contact@intmod.com**
Calgary, AB T2P 3C8 **403.269.1606**
www.intmod.com

File Number: IMP# 2737

March 13, 2024

Wolf Carbon Hub GP Inc.
1500, 520 - 3rd Ave SW
Calgary, AB T2P 0R3

Attention: Cody Schroeter

Dear Sir:

Project Name	Lamont Carbon Trunk Line Phase II Release Simulations
Region	Alberta, Canada
CO_2 Pipeline Release Simulations Results Report	

This CO_2 Pipeline Release Simulations Report assesses effects of CO_2 dispersion from the Lamont Carbon Trunk Line Phase II CO_2 pipeline.

Please contact me at 403-269-1606 or by email if you have any questions about this report.

Sincerely,

INTEGRATED MODELLING INC.

<Original Retained On File>

Marc Polivka, P.Eng.
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/jb
Enclosures

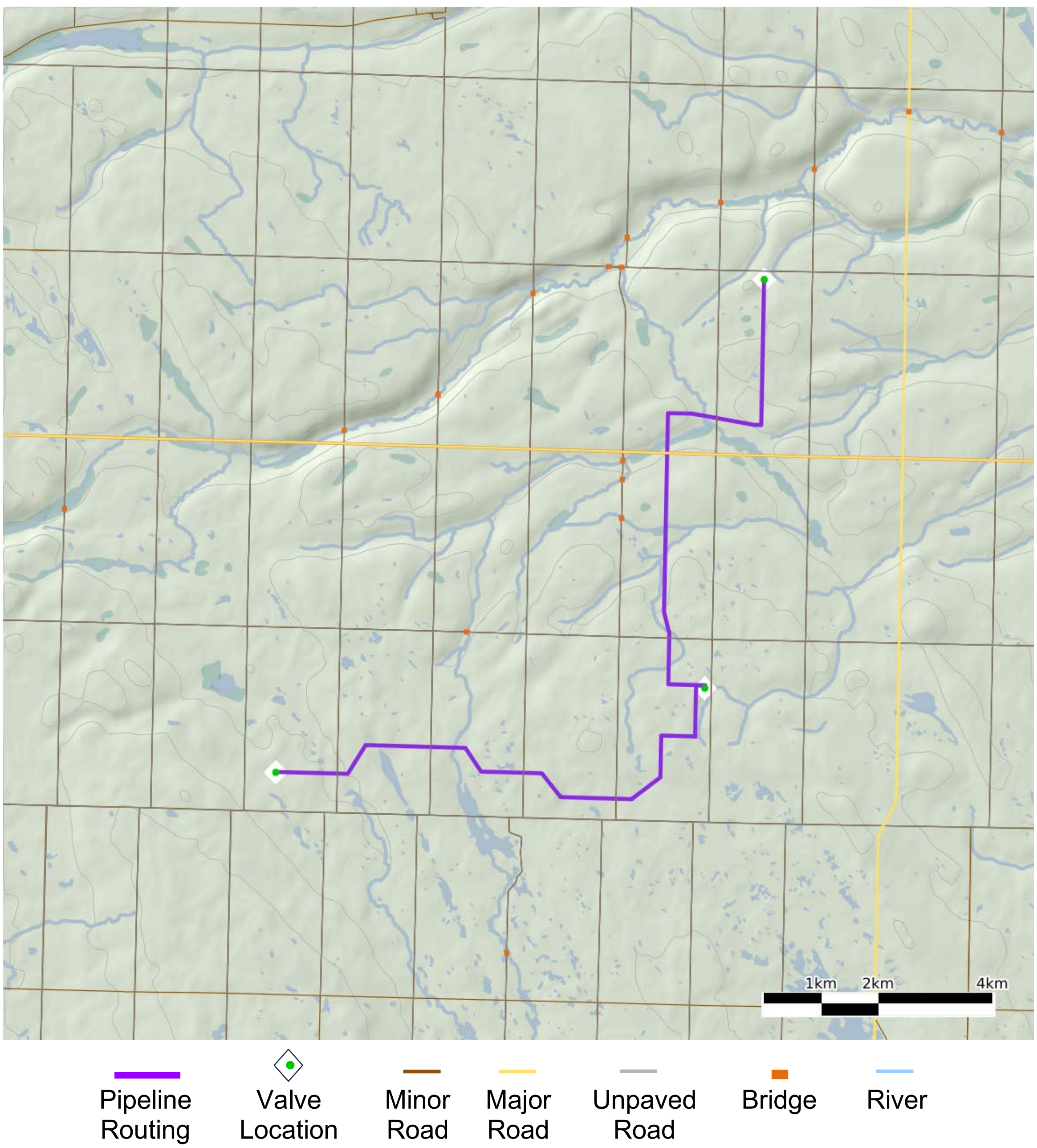
PROJECT NAME: Lamont Carbon Trunk Line Phase II Release Simulations
REGION: Alberta, Canada
CO_2 PIPELINE RELEASE SIMULATIONS RESULTS REPORT

INTRODUCTION

Wolf Carbon Hub GP Inc. (Wolf) has requested CO_2 Pipeline Release Simulations to evaluate effects of vaporised CO_2 dispersion from a theoretical failure of Wolf's proposed Lamont Carbon Trunk Line Phase II (LCTL II) pipeline project. The proposed pipeline required for the project is 12" in outer diameter and approximately 19.6 km in length running east and north.

The planned pipeline routing is shown below.

Figure 1 – Planned LCTL II CO_2 Pipeline Routing



Results show the maximum ERCBSLAB predicted distances shown in Table 1.

Table 1 – Summary of Maximum Plume Distances to Selected CO_2 Concentrations

Pipeline Distance [m]	**Maximum Distance to CO_2 Concentration Threshold [m]**				
	7%	**6%**	**5%**	**4%**	**3%**
9981	953	980	1006	1033	1060
9646	952	979	1005	1031	1057

HAZARDS CONSIDERED

The major hazard associated with a CO_2 pipeline release would be the displacement of oxygen. Carbon dioxide gas is colourless, odourless, and more dense than air at standard conditions. CO_2 may exist in liquid form until evaporation has taken place.

CO_2 can have a range of effects on the human body and can be fatal if it increases above 10%[1].

Table 2 – Effects of Increased CO_2 Concentrations on People[2]

CO_2 concentration in air [%]	**Timeframe**	**Effect on People**
1	-	Indefinite tolerance[2]
2	Several hours	Headache, dyspnea upon mild exertion
3	**15 minutes**	**NIOSH Short Term Exposure Limit**[3]
3	1 hour	Mild headache, sweating, and dyspnea at rest
4	30 minutes	NIOSH Immediately Dangerous to Life and Health[3]
4-5	A few minutes	Headache, dizziness, increased blood pressure, uncomfortable dyspnea
5	**60 minutes**	**AER selected EPZ endpoint**
6	1-2 minutes	Hearing and visual disturbances
6	< 16 minutes	Headache, dyspnea
6	Several hours	Tremors
7-10	**A few minutes**	**Unconsciousness, near unconsciousness**
7-10	1.5 to 60 minutes	Headache, increased heart rate, shortness of breath, dizziness, sweating, rapid breathing
>10-15	1 to several minutes	Dizziness, drowsiness, severe muscle twitching, unconsciousness
17-30	Within 1 minute	Loss of controlled and purposeful activity, unconsciousness, convulsions, coma, death

Selected concentrations for analysis are indicated in bold.

Secondary or additional hazards that may result from a pipeline failure have not been considered.

[1] Compressed Gas Association, (1990), "Handbook of Compressed Gases"
[2] US EPA, (2000), Table B-1 "Acute Health Effects of High Concentrations of Carbon Dioxide"
[3] The National Institute for Occupational Safety and Health Publications & Products, (May 1994), "Carbon Dioxide", https://www.cdc.gov/niosh/idlh/124389.html

ASSESSED SOURCE PARAMETERS

Based on client provided data and initial assumptions, the following model input parameters were used:

- Release height at ground level, oriented horizontally downwind
- Maximum Operating Pressure of 17.9 MPa (2600 psi)
- Low Pressure Emergency Shut Down Trigger Pressure of 8000 kPa (1160 psi)
- Emergency Shut Down Time of 20 s
- Emergency Shut Down Valve Pressure Rate of Change Trigger of 6.9 kPa/s
- Ambient air is at 5°C

The 19.6 km pipeline is split by a block valve into two segments, detailed below:

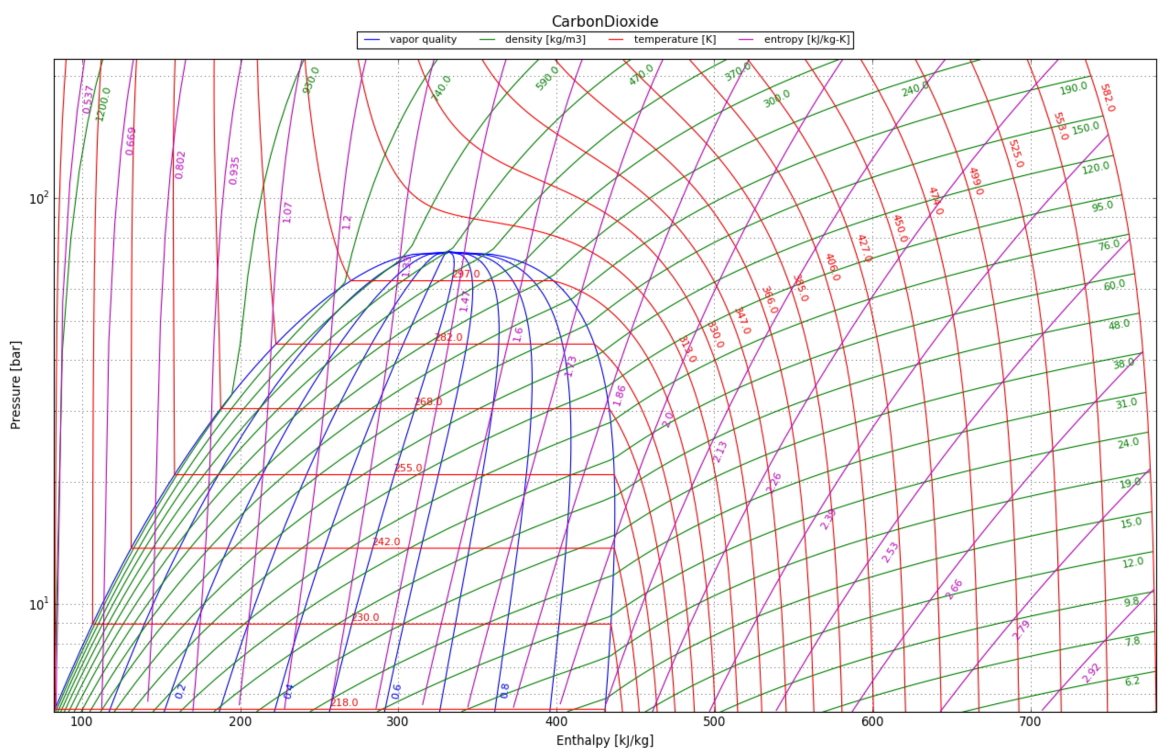
Table 3 – Pipeline Sections

Distance [m]	Pipeline Diameter [mm]	Segment Volume [m^3]
9981	324	699
9646	324	675

Individual pipeline segments have been analysed with assessed source parameters to determine maximum predicted distances to selected CO_2 concentration thresholds.

Properties of CO_2 at exit conditions have been assessed assuming initial conditions per assessed source parameters with final conditions at atmospheric conditions, assuming an isentropic transformation, per Figure 2.

Figure 2 – CO_2 Pressure-Enthalpy Diagram



Additional raw gas release properties from ERCBH2S are summarised in Tables 4 and 5:

Table 4 – Raw Gas Release Properties

Release Gas Property	Value
Vapour Heat Capacity [J/kg·K]	891
Boiling Point Temperature [K]	182
Initial Liquid Fraction	0.495
Heat of Vapourisation [kJ/kg]	396
Liquid Specific Heat Capacity [J/kg·K]	1652
Liquid Density [kg/m^3]	1350
Saturation Pressure Constant B [K]	1803
Saturation Pressure Constant C [K]	-57

Table 5 – Input Raw Gas Properties

Gas Component	Gas Composition [mol]
H_2	0.0100
He	0.0000
N_2	0.0100
CO_2	0.9600
H_2S	0.00001
CH_4	0.0100
C_2H_6+	0.00999

The concentration of flammable compounds within the input raw gas composition does not meet one half of the lower flammability limit threshold for any gas component indicating that gas flammability is not a hazard.

ERCBSLAB MODELLING

Integrated Modelling has used the most recent version of ERCBSLAB to perform steady state modelling of CO_2 simulations at selected meteorological conditions for the referenced release scenarios. ERCBSLAB is a steady state one-dimensional model that solves equations of momentum, conservation of mass, species, and energy, and the equation of state. It accommodates the following release scenarios: ground level and elevated jets, liquid pool evaporation, and instantaneous volume sources.

Specific concerns with a CO_2 release are for workers and the public within the vicinity of the planned pipeline. For the planned pipeline routing that has been selected, additional analysis of site specific terrain and meteorological data may be considered to account for low lying areas susceptible to increased dense gas risks. Risks associated with liquid CO_2 are out of scope of this report. A rupture hole size ratio of 2.0, representative of a guillotine rupture has been used.

Meteorology

The ERCBSLAB model evaluates for combinations of wind speed and stability class. The meteorology of stability class F and wind speed 2 m/s has been used to determine the EPZ.

Table 6 – Pasquill (P-G) Stability Classes

Stability Class	Definition	Description
A	Very Unstable	Strong to moderate solar radiation coupled with low to moderate wind speeds. This condition usually occurs during calm, warm and sunny days where near-surface winds rise vertically due to ground heating which increases turbulence. Unstable conditions are restricted to daylight hours.
B	Unstable	
C	Slightly Unstable	
D	Neutral	During overcast conditions or moderate to high wind speeds. Neutral stability can occur during any time of the day or night.
E	Slightly Stable	During calm, cool, clear nights with a stable temperature gradient resulting in reduced turbulence. Stable conditions occur during any time of the night.
F	Stable	

Table 7 – Meteorological Conditions Associated to P-G Stability Classes[4]

Surface Wind Speed		Daytime Incoming Solar Radiation			Night-time Cloud Cover	
m/s	km/hr	Strong	Moderate	Slight	Thinly overcast or ≥ 4/8 low cloud	≤ 3/8 cloud
< 2	< 7.2	A	A – B	B	F	F
2 – 3	7.2 – 10.8	A – B	B	C	E	F
3 – 5	10.8 – 18.0	B	B – C	C	D	E
5 – 6	18.0 – 21.6	C	C – D	D	D	D
> 6	> 21.6	C	D	D	D	D

Note: Stability Class D should be used regardless of wind speed for overcast conditions during day or night.

[4] Johnson, et al. (September 1999), “Workbook for Gaussian Modeling Analysis of Air Concentration Measurements”, Report EH99-03. Environmental Protection Agency, Department of Pesticide Regulation, Environmental Monitoring and Pest Management Branch, Environmental Hazards Assessment Program.

ERCBSLAB Modelling Output

Tables 8 and 10 show ERCBSLAB output for pipeline transient maximum H_2S concentrations in the column labeled ‘co(x)’. Following extensive developmental work with the AER on a similar project and the resulting analysis direction, these H_2S concentrations have been scaled to CO_2 concentrations via the CO_2 to H_2S ratio and ppm to percent conversion.

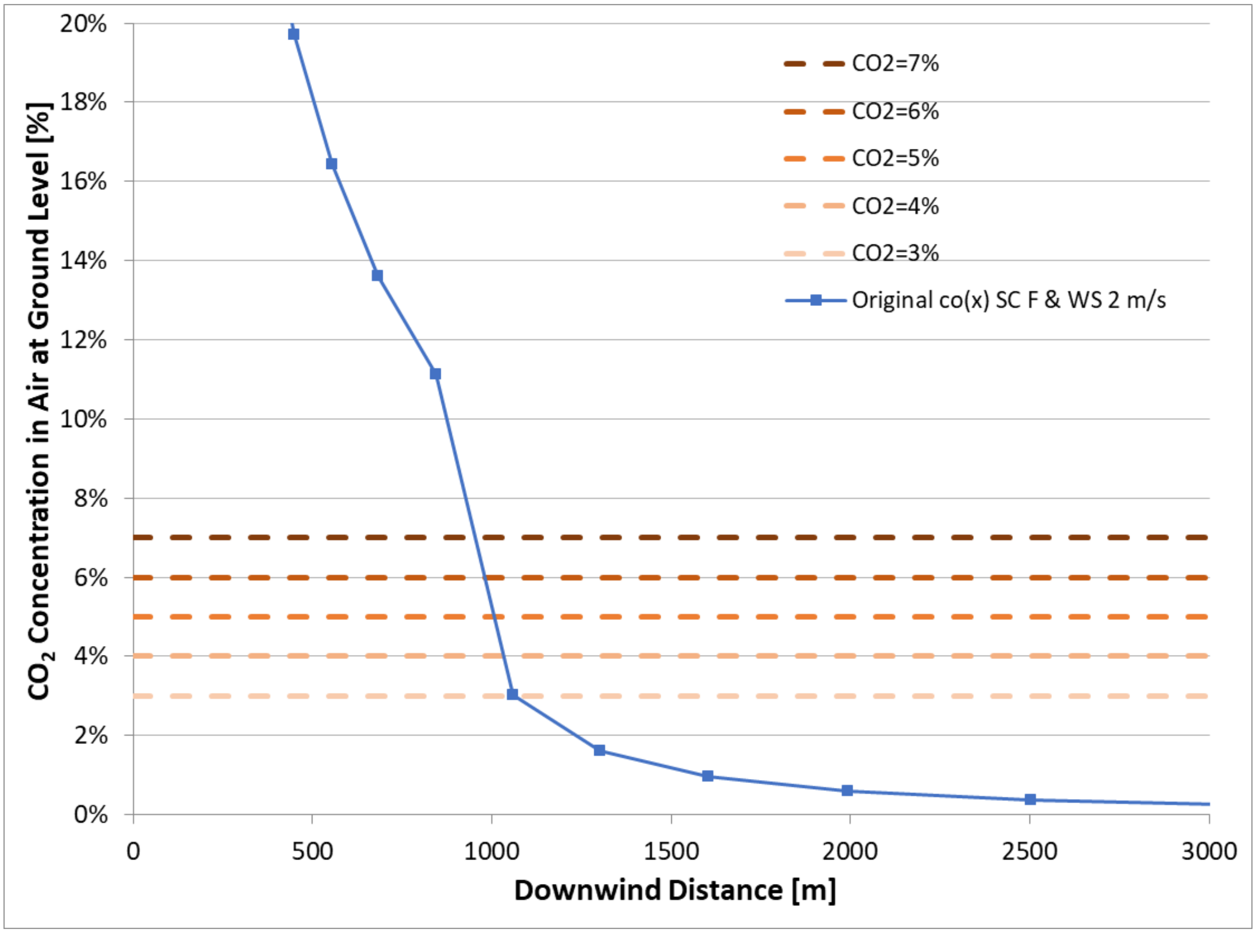
For the 9981 m pipeline distance, results show:

Table 8 – ERCBSLAB Downwind distance, H_2S, and Converted CO_2 Concentrations – 9981 m Pipeline Rupture Hole Size Ratio 2.0

X [m]	co(x) [ppm H_2S]	Converted CO_2 Concentration [%]
…	…	…
364.079	24.534	23.551
449.032	20.523	19.701
553.857	17.106	16.420
683.202	14.177	13.608
842.802	11.605	11.140
1059.331	3.142	3.016
1302.049	1.682	1.615
1602.585	1.001	0.961
1991.790	0.617	0.593
2504.603	0.385	0.370

Predicted maximum distances to CO_2 concentration thresholds have been linearly interpolated as a discontinuity is present between concentrations of interest (3%, 4%, 5%, 6%, and 7% CO_2).

Figure 3 – Predicted Maximum CO_2 Concentration Profile Over Distance – 9981 m Pipeline Stability Class F and Wind Speed 2 m/s



Data points, indicated by boxes, are connected linearly in Figure 3. Table 9 shows maximum predicted distances to selected CO_2 concentrations.

Table 9 – Summary of Maximum Plume Distances to Selected CO_2 Concentrations – Stability Class F and Wind Speed 2 m/s

Pipeline Distance [m]	Maximum Distance to CO_2 Concentration Threshold [m]				
	7%	6%	5%	4%	3%
9981	953	980	1006	1033	1060

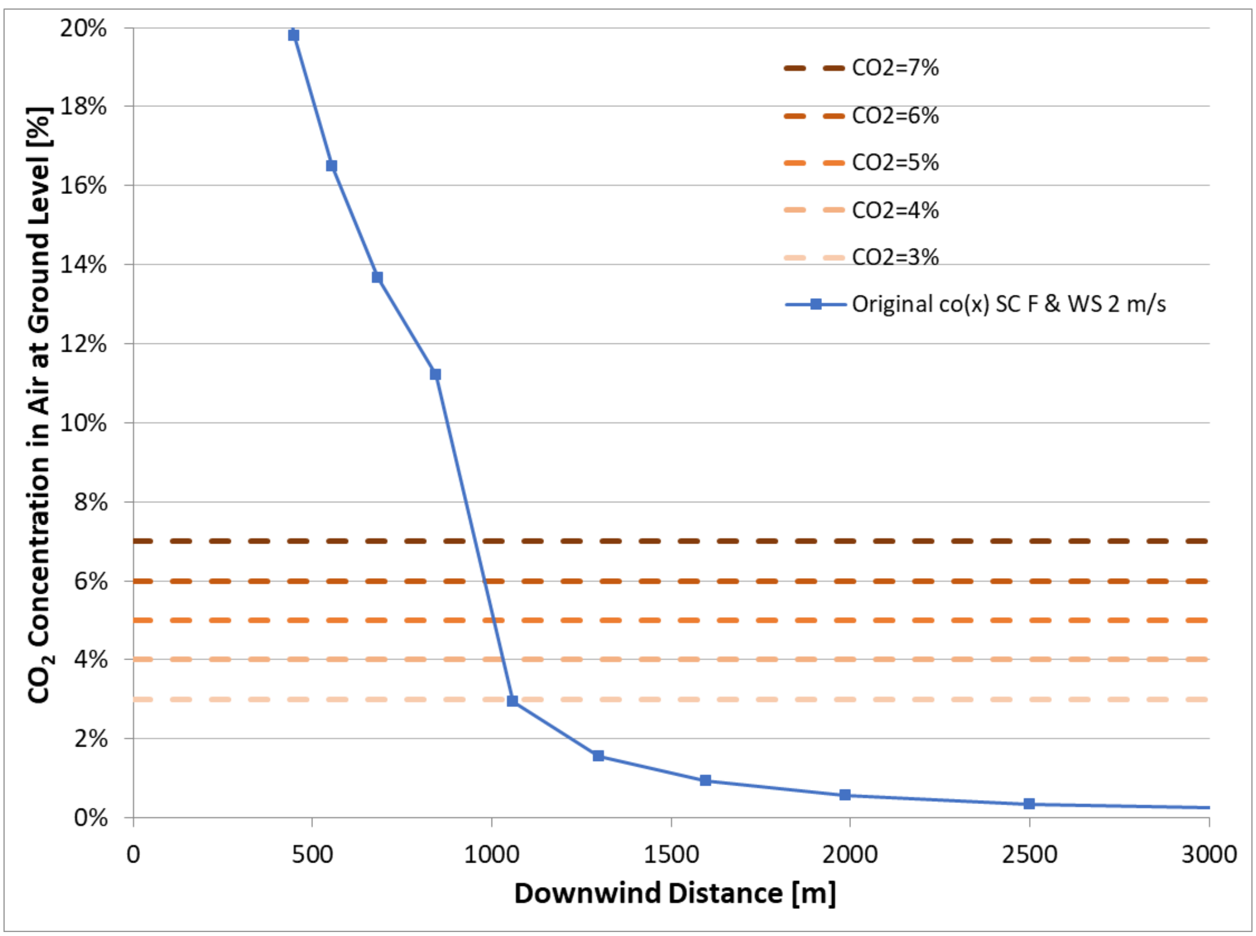
For the 9646 m pipeline length from block valve to end of pipeline, results show:

Table 10 – ERCBSLAB Downwind distance, H_2S, and Converted CO_2 Concentrations – 9646 m Pipeline Rupture Hole Size Ratio 2.0

X [m]	co(x) [ppm H_2S]	Converted CO_2 Concentration [%]
…	…	…
364.079	24.652	23.664
449.032	20.623	19.797
553.857	17.192	16.503
683.202	14.252	13.680
842.802	11.670	11.202
1058.583	3.057	2.935
1299.782	1.624	1.559
1599.028	0.962	0.923
1987.396	0.592	0.568
2499.841	0.369	0.354

Predicted maximum distances to CO_2 concentration thresholds have been linearly interpolated as a discontinuity is present between concentrations of interest (3%, 4%, 5%, 6%, and 7% CO_2).

Figure 4 – Predicted Maximum CO_2 Concentration Profile Over Distance – 9646 m Pipeline Stability Class F and Wind Speed 2 m/s



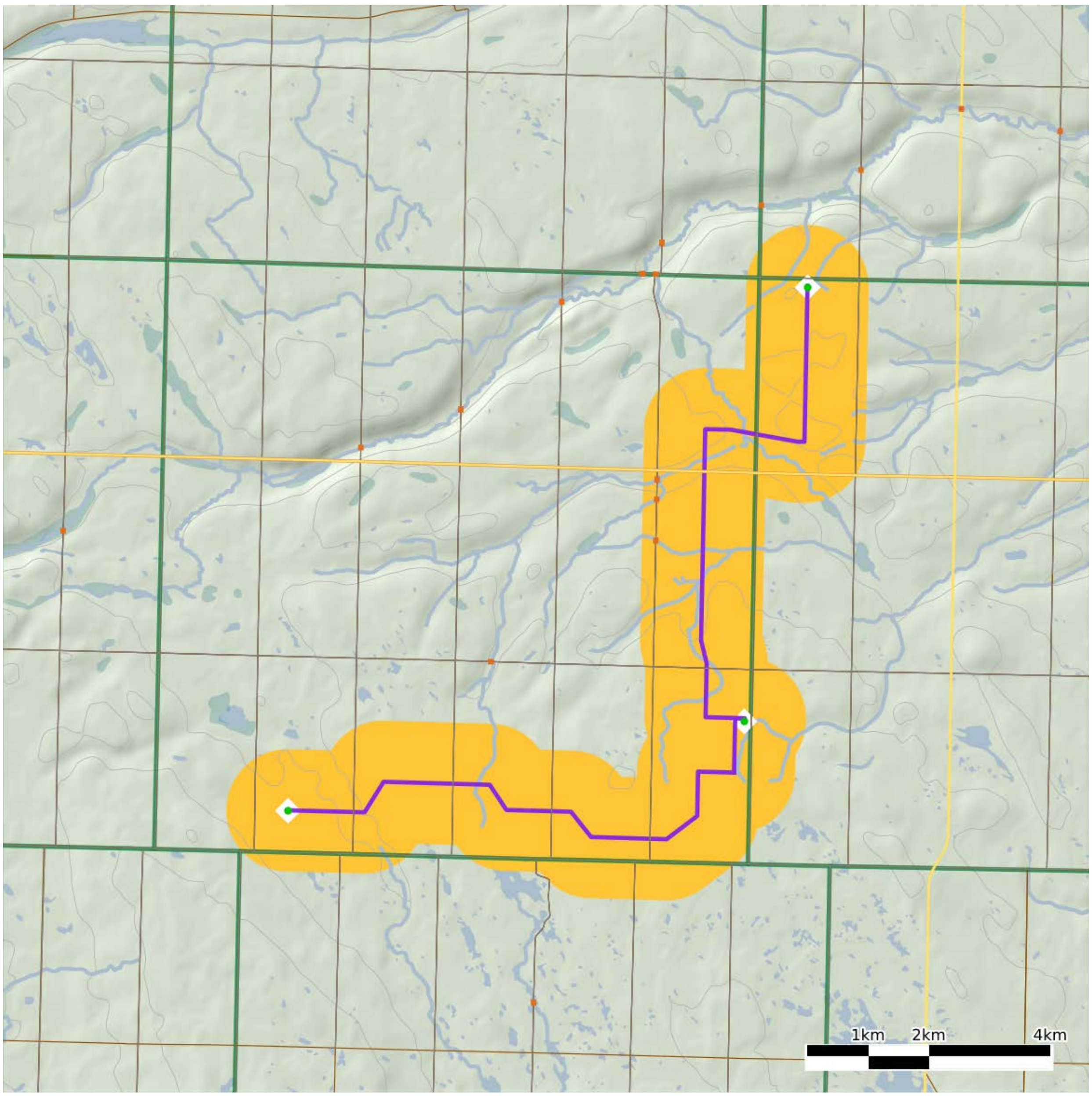
Data points, indicated by boxes, are connected linearly in Figure 4. Table 11 shows maximum predicted distances to selected CO_2 concentrations.

Table 11 – Summary of Maximum Plume Distances to Selected CO_2 Concentrations – Stability Class F and Wind Speed 2 m/s

Pipeline Distance [m]	Maximum Distance to CO_2 Concentration Threshold [m]				
	7%	6%	5%	4%	3%
9646	952	979	1005	1031	1057

The EPZ distances based on maximum distances to 5% CO_2 for the LCTL II pipeline routing is shown below.

Figure 5 – EPZs For Planned LCTL II Pipeline Routing



CONCLUSIONS AND RECOMMENDATIONS

ERCBSLAB CO_2 release simulation results show the following maximum distances to concentration thresholds as given in Table 12:

Table 12 – Maximum Downwind Distances to CO_2 Concentrations Based on ERCBSLAB Simulations

Pipeline Distance Between Valves [m]	Maximum Distance to CO_2 Concentration Threshold [m]				
	7%	6%	5%	4%	3%
9981	953	980	1006	1033	1060
9646	952	979	1005	1031	1057

The EPZ may need to be extended within low-lying areas having higher-gradient topography and where specific elevation characteristics present potential for reduced vaporisation and dispersion.

LIST OF CONTRIBUTORS

Contributors
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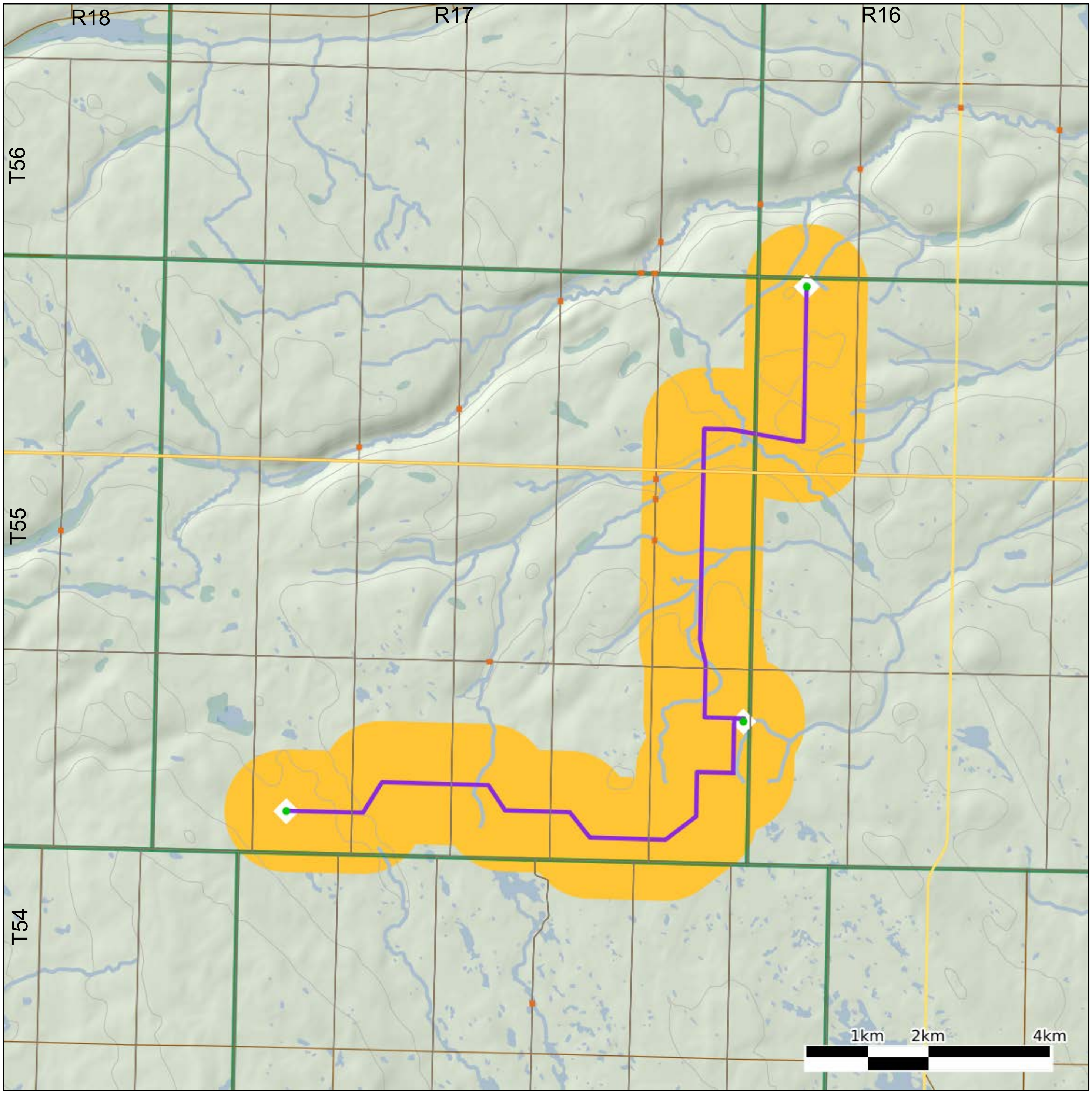

Wolf LCTL Phase II Pipeline

LEGEND

Pipeline Routing	Valve Location	Minor Road	Major Road
Unpaved Road	Bridge	River	Township Line

1.006 km radius

March 13, 2024 Rev. 0

Pipeline Distance [m]	Distance to CO_2 Concentration Threshold [m]				
	7%	6%	5%	4%	3%
9981	953	980	1006	1033	1060
9646	952	979	1005	1031	1057

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