APPENDIX D:
Transmission Line Design Criteria

1.1 Climatic Data and Loading Conditions

The proposed transmission line alignment travels through a variety of climatic and terrain features. In general, the alignment was considered to traverse two main areas: Whitehorse to Carcross, and Carcross to White Pass. In general, the Whitehorse to Carcross segment traverses mild terrain with rolling hills, moderate winds and moderate snow and ice levels. In contrast, the Carcross to White Pass segment traverses very mountainous terrain with high winds, ice and snow levels. The following anticipated 138 kV transmission line design criteria were referenced while selecting preliminary structure configurations to be assumed for this technical feasibility study.

Table A.1-1 – Climatic Design Data

	Whitehorse – Carcross	Carcross – White Pass
Mean Annual Temperature[1]	-5°C	0°C
10% Winter Design Temperature[1]	-43°C	-30°C
Extreme Minimum Temperature[1]	-52°C	-40°C
Extreme Maximum Temperature[1]	+34°C	+30°C
Maximum Wind Speed[2]	85 km/h	125 km/h
Maximum Radial Ice[3]	10 mm	38.1 mm
Maximum Ground Snow Accumulation[4]	1.5 m	6.0 m

1 – Design temperatures are taken from the Northern Canada Power Commission (NCPC) "Whitehorse – Skagway Transmission line Feasibility Study", September 1983.

2 – Maximum Wind Speed is the 50 year return period 10 minute average wind speed at 10 m above ground for the region under consideration. Wind speeds were either taken from CAN/CSA C22.3 No. 60826-10 or provided by local experience.

3 – Maximum Radial Ice is the 50 year return period equivalent radial ice thickness at 10 m above ground over flat, open terrain from freezing precipitation. Ice thicknesses were either taken from CAN/CSA C22.3 No. 60826-10 or provided by local experience. Note that additional abnormal icing conditions should be considered, particularly for the last few kilometres approaching White Pass where in-cloud icing may be a concern.

4 – Maximum Ground Snow Accumulation was taken from the Northern Canada Power Commission (NCPC) "Whitehorse – Skagway Transmission line Feasibility Study", September 1983. For Whitehorse to Carcross, the snow depth is the maximum resident-reported depth of 1.5 m for Carcross. For Carcross to White Pass, the snow depth is a compromise between the 1983 Environment Canada 1.08 m accumulation for the Fraser area, and the up to 9 m reported by local residents in Fraser.

The climatic loads will be applied to conductors and structures through a variety of load cases and combinations. These are generally based on the CAN/CSA C22.3 No. 1-10 deterministic approach or the CAN/CSA C22.3 No. 60826-10 reliability-based approach. The effect of broken wires on dead-end structures shall be considered at the detailed design stage.

Table A.1-2 – Whitehorse - Carcross – Load Cases and Combinations – Structure Loads

Load Combination	Wind Speed (km/h)[2]	Wind Pressure (Pa)	Radial Ice Thickness (mm)[3]	Wire Temperature (°C)
CSA C22.3 No. 1-10 – CSA Medium B	80	300	12.5	-20
CSA C22.3 No. 60826-10 – Wind Only[1]	85	356	0	-5
CSA C22.3 No. 60826-10 – Ice Only[1]	0	0	10.0	-20
CSA C22.3 No. 60826-10 – Ice & Wind 1[1]	34	60	10.0	-20
CSA C22.3 No. 60826-10 – Ice & Wind 2[1]	51	135	5.0	-20

1 – CSA C22.3 No. 60826-10 loading uses terrain, height, gust and span factors per CAN/CSA No. 60826-10.
2 – Wind speed for CSA C22.3 No. 60826-10 load cases is the 50 year return period 10 minute average wind speed at 10 m above ground.
3 – Radial Ice Thickness for CSA C22.3 No. 60826-10 load cases is the 50 year return period equivalent radial ice thickness at 10 m above ground over flat, open terrain from freezing precipitation.

Table A.1-3 – Carcross - White Pass – Load Cases and Combinations – Structure Loads

Load Combination	Wind Speed (km/h)[2]	Wind Pressure (Pa)	Radial Ice Thickness (mm)[3]	Wire Temperature (°C)
CSA C22.3 No. 1-10 – CSA Heavy	92	400	12.5	-20
CSA C22.3 No. 60826-10 – Wind Only[1]	125	768	0	-15
CSA C22.3 No. 60826-10 – Ice Only[1]	0	0	38.1	-20
CSA C22.3 No. 60826-10 – Ice & Wind 1[1]	50	130	38.1	-20
CSA C22.3 No. 60826-10 – Ice & Wind 2[1]	75	292	19.1	-20

1 – CSA C22.3 No. 60826-10 loading uses terrain, height, gust and span factors per CAN/CSA No. 60826-10.
2 – Wind speed for CSA C22.3 No. 60826-10 load cases is the 50 year return period 10 minute average wind speed at 10 m above ground.
3 – Radial Ice Thickness for CSA C22.3 No. 60826-10 load cases is the 50 year return period equivalent radial ice thickness at 10 m above ground over flat, open terrain from freezing precipitation.

Table A.1-4 – Whitehorse - Carcross – Load Cases and Combinations – Conductor Loads & Maximum Tension

Load Combination	Wire Creep/Stretch	Wire Temperature (°C)	Maximum Conductor Tension (% RTS)
Table 2 Weather Load Combinations	Final Loaded	Per Table A.1-2	60
Mean Annual	Final Unloaded	-5	22
10% Winter Design 1	Initial Unloaded	-43	28
10% Winter Design 2	Final Unloaded	-43	25

Maximum conductor tensions assume that the conductors will be installed with armour rods and vibration dampers.

Table A.1-5 – Carcross - White Pass – Load Cases and Combinations – Conductor Loads & Maximum Tension

Load Combination	Wire Creep/Stretch	Wire Temperature (^oC)	Maximum Conductor Tension (% RTS)
Table 3 Weather Load Combinations	Final Loaded	Per Table A.1-3	60
Mean Annual	Final Unloaded	-15	22
10% Winter Design 1	Initial Unloaded	-30	28
10% Winter Design 2	Final Unloaded	-30	25

Maximum conductor tensions assume that the conductors will be installed with armour rods and vibration dampers.

1.2 Material Properties

Depending on the type of structure and load combination under consideration, the material strength to be used in calculations will vary. At this feasibility stage, Western Red Cedar was assumed for wood poles, while 350WT steel was assumed for tubular steel structures. Steel braces and cross arms were assumed to be 300WT.

For steel structures and components, the strength used in both the CSA C22.3 No.1-10 and CSA C22.3 No. 60826-10 load combinations will be the nominal 350 or 300 MPa, as applicable. For wood poles, however, the mean fibre bending strength will be used for the deterministic CSA Medium B and CSA Heavy combinations, while the 10% exclusion strength (modified further by a wood deterioration factor) will be used for the CSA C22.3 No. 60826-10 load combinations.

Table A.2-1 – Material Strengths for Design

Load Combination	WRC Wood Pole Strength (MPa)	Steel Structure/Component Strength (MPa)
CSA C22.3 No. 1-10 – CSA Medium B / Heavy	38.6	350/300
CSA C22.3 No. 60826-10 – Wind Only	21.5	350/300
CSA C22.3 No. 60826-10 – Ice Only	21.5	350/300
CSA C22.3 No. 60826-10 – Ice & Wind 1	21.5	350/300
CSA C22.3 No. 60826-10 – Ice & Wind 2	21.5	350/300

1.3 Safety and Resistance Factors

The load combinations and material strengths above will be combined with load and resistance factors for structure design. In general, load factors are applied to CSA C22.3 No.1-10 CSA Medium B and CSA Heavy load combinations (with resistance factors equal to 1.0), and resistance factors are applied to material strengths for CSA C22.3 No.60826-10 load combinations (with load factors equal to 1.0). The anticipated load and resistance factors are summarized in tables below.

Table A.3-1 – CAN/CSA C22.3 No. 1-10 – CSA Medium B and CSA Heavy Load Factors

Load Type	Grade 1[2]		Grade 2[2]	
	Steel (COV ≤ 10%)	Wood (COV ≥ 20%)	Steel (COV ≤ 10%)	Wood (COV ≥ 20%)
Vertical	1.30	2.00	1.15	1.50
Transverse	1.20	1.90	1.10	1.30
Longitudinal with terminations or tension changes	1.20	1.90	1.10	1.30
Longitudinal without terminations or tension changes	1.10	1.20	1.00	1.00

1 – Load factors are in accordance with CAN/CSA C22.3 No. 1-10 Table 31, and are to be used in conjunction with a nonlinear analysis of the structure, including a stability (buckling) check.
2 – Depending on the line usage and proximities, either Grade 1 or Grade 2 construction was assumed in accordance with CAN/CSA C22.3 No. 1-10 Tables 28 and 29 (Grade 1 for third-party communication under-build scenarios, railway crossings and navigable waterways, and Grade 2 for all others).

For the CAN/CSA C22.3 No. 60826-10 load combinations, resistance factors will be chosen to reflect the desired reliability and sequence of failure of various components within the transmission line. In general, factors similar to the following are in accordance with the philosophy and recommendations of CAN/CSA C22.3 No. 60826-10.

Table A.3-2 – CAN/CSA C22.3 No. 60826-10 Resistance Factors

Transmission Line Component	Resistance Factor (ϕ)
Tangent Structure	0.90
Angle Structure	0.80
Dead End Structure	0.75
Foundation Materials (steel, wood, concrete)	0.65
Deadweight Anchors, Drilled Rock Anchors	0.60
Skin Friction or Punching Shear Anchors	0.45
Suspension & Dead End Insulators & Hardware	0.50

1.4 Conductor Clearances and Separations

A number of minimum clearances will need to be considered in the 138 kV transmission line design. Generally, these are taken from CAN/CSA C22.3 No. 1-10. For vertical clearance checks, the 138 kV conductors can be assumed to have a temperature of 100ºC, while the communication wires can be assumed to have a temperature of 50ºC. For horizontal clearance checks, the Wind Only load combination from Tables A.1-2 or A.1-3 (as applicable) will likely be the governing load case. The clearances requirements and governing load cases shall be reviewed and updated as a part of the detailed design.

Table A.4-1 – Minimum Vertical Ground Clearance Requirements

Line Crossing Over	138 kV Minimum Vertical Clearance (m)	Communication Minimum Vertical Clearance (m)
Roads and Highways	5.5	4.42
Pedestrians Only[1]	4.0 + Snow Depth[2]	2.5 + Snow Depth[2]
Railways	8.4	7.3
Navigable Waterways[3]	16.7	15.0

1 – Includes snowmobiles and personal-use all-terrain vehicles.

2 – When checking vertical clearances, the design snow depth shall be added to the minimum vertical clearance for the Pedestrians Only case (assumes roads, highways, or railways must be cleared of snow in order to be passable).

3 – Assumes surface area of navigable waterway is greater than 800 ha, and reference vehicle height is 14.0 m.

The minimum horizontal clearance to ground accessible to pedestrians only can be taken as 3.4 m for 138 kV conductors, and 2.5 m for communication fibre. The minimum conductor to supporting structure clearance was can be taken as 1.27 m in any direction. The minimum horizontal phase-to-phase separation of the 138 kV conductors can be taken as 4.0 m.

For the communication under-build case, the minimum in-span vertical clearance between the 138 kV transmission lines and the communication fibre can be taken as 1.06 m between the point of maximum sag of the energized conductor and the line of sight between the points of attachment of the communication line. The minimum vertical separation between the points of attachment of the energized conductor and communication line can be taken as 1.9 m.

The minimum horizontal clearance to edge of right of way can be taken as 2.7 m for 138 kV conductors under the typical CSA Swing case (230 Pa, 40ºC), or 0.3 m for 138 kV conductors under the maximum horizontal swing cases (for power frequency (60Hz) withstand distance). These clearances will be used to determine the minimum right of way width for the circuit alignment.

An additional tolerance should be added to the above basic clearances to provide for the inherent inaccuracies in survey data, design and construction. The anticipated value of this tolerance is provided in the table below.

Table A.4-2 – Clearance Tolerance Breakdown

Component	Vertical Tolerance (m)	Horizontal Tolerance (m)
Survey	0.50	0.15
Structure & Hardware Design	0.15	0.08
Sag & Tension Modeling and Design	0.15	0.08
Construction Tolerance	0.30	0.15
Stringing and Sagging	0.15	0.08
Deflection	-	0.50
Total Tolerance to be Added to Basic Clearance	1.25	1.04