Performance Guideline for Corrugated Steel Pipe Culverts (300mm to 3,600mm Diameter)

1.0 Introduction

The purpose of this Guideline is to help practitioners in selecting the most appropriate corrugated steel pipe coating available given the desired service life of the application and the environmental parameters unique to the culvert site.

The following definitions and available CSP materials are listed below:

- DSL – Design Service Life. This parameter is typically set by the entity responsible for the culvert's ongoing operation (i.e. Government or Owner). DSL is often influenced by its relative importance, estimated project life, and overall cost of replacement. This Guideline sets DSL limits at 25, 50, 75 and 100 years.
- EMSL – Estimated Material Service Life. This parameter is influenced by factors unique to the project site. This Guideline takes into account the following factors:

  > Abrasion due to conveyance of bedload; and,

  > Site Chemistry – Resistivity, pH & other parameters.
- CSP Materials Available (as per CSA G401):
- Polymer Laminated Galvanized Steel
- Aluminized Type 2 Steel
- Galvalume (55Al-Zn)
- Galvanized Steel.

*Note Galvanized Steel Structural Plate is outside the scope of this Guideline.

To maximize cost effectiveness, it is recommended the practitioner first determine the DSL of the given culvert application then work toward selecting the culvert materials that will likely meet or exceed the EMSL (Estimated Material Service Life).

This Guideline is not a substitute for professional engineering advice and is made without guarantee or representation as to results. Although every reasonable effort has been made to assure its accuracy, neither the Corrugated Steel Pipe Institute (CSPI) nor any of its members or representatives warrants or assumes liability or responsibility for its use or suitability for any given application.

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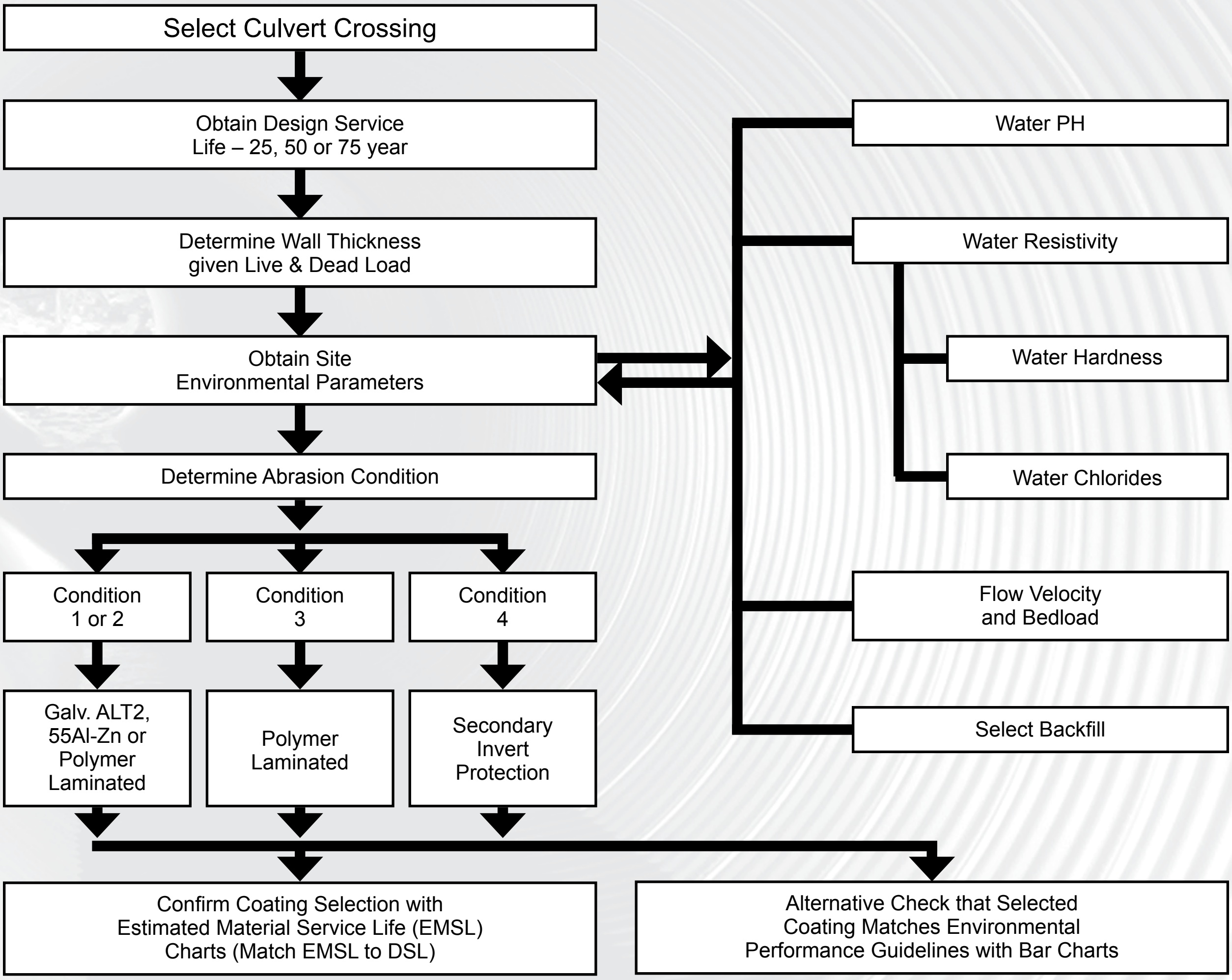
2.0 Guideline Flowchart

The flowchart to the right provides an overview of the typical steps in selecting a suitable CSP material given the parameters listed in Section 1.0.



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3.0 Guideline Steps

3.1 Select the Culvert

The practitioner should select the given culvert for review. For the purposes of this Guideline, the CSP should range between 300mm and 3,600mm diameter.

3.1.1 Determine the CSP Wall Thickness and Corrugation

From charts in the "Handbook of Steel Drainage & Highway Construction Products" available from CSPI, determine the minimum wall thickness and the corrugation profile to suit height of cover and live load vehicle.

3.2 Confirm the DSL

As noted in Section 1.0, typically the entity (i.e. Government or Owner) responsible for the ongoing operation of the culvert provides the DSL – typically 25, 50 or 75 years.

3.3 Obtain the Site Environmental Parameters:

Air, soil and water influence performance as follows:

- Air - With the exception of some extremely polluted environments, atmospheric contact has little effect on the performance of CSP.
- Soil – Backfills materials that contact CSP are generally pre-selected for their compactable, free draining and noncorrosive characteristics. These tend to isolate the pipe from native soils that may be corrosive due to their pH level and dissolved salt content. Refer to Section 5.1 for details.
- Water - At most installations it is the water in direct contact with the pipe that will most likely determine the long term performance of CSP material. As water samples are easily collected and measured, this Guideline will focus on water testing for environmental assessment.

3.3.1 Obtain the Water pH

pH is an indication of whether water is acidic indicated by a number less than 7 or basic being measured greater than 7 with 7 being neutral.

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3.3.2 Obtain the Water Resistivity (R)

Resistivity is an indication of waters inability to carry an electrical current and is a function of the concentration of Total Dissolved Solids (TDS) or salt ions dissolved in the water. As TDS increases, resistivity decreases and corrosivity generally increases.

Other tests of the water relative to resistivity include:

- Hardness is indicated by the amount of calcium carbonate ($CaCO_3$) ion dissolved in water and will determine the buffering capacity or ability of the water to neutralize acidity from rainwater and other sources. Natural soft water has a low concentration of $CaCO_3$ and despite high resistivity may be corrosive to galvanized steel. Hard water is rich in $CaCO_3$ which neutralizes acidity and forms a protective scale on the pipe's surface.

- Chlorides (Cl) are highly soluble ions commonly found in deicing salts, seawater and evaporation pools. These ions are the most likely contributor to low resistivity numbers and will promote the corrosion of unprotected steel.

3.3.3 Determine Abrasion Condition

The anticipated flow velocity & expected bedload gradation should be assessed for the site, and the abrasion condition classified as follows:

Figure 2

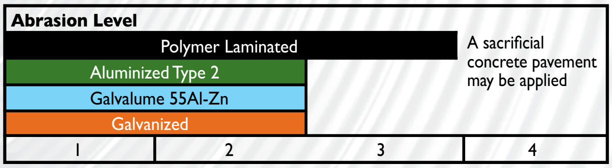
Abrasion Condition

Abrasion Level	Bedload Description	Anticipated Flow Velocity (m/s)	
		Minimum	Maximum
1	No bedload regardless of velocity. (Eg. Storm Sewer or Stormwater Detention Facility)	NA	NA
2	Minor bedloads of sand and gravel	0	1.5
3	Bedloads of sand and gravel	1.5	4.5
4	Heavy bedloads of gravel and rock	4.5	Above

Based on the Abrasion Condition chart (Figure 2), the chart to the right (Figure 3) can be used to make an initial selection of the CSP material.

Figure 3

Abrasion Condition vs. CSP Material



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3.4 Use Design Charts – Match DSL to EMSL

Given the site's Water Resistivity (R) and pH data obtained Sections, 3.3.1 and 3.3.2, respectively, and the DSL confirmed in Section 3.2, refer to the following "Guidelines for Suitability of Metal Culverts" Charts for the appropriate DSL. CSP materials are represented by the following coloured boundary lines:

- Galvanized Steel – Orange
- Aluminized Steel Type 2 – Green
- Galvalume 55Al-Zn – Blue
- Polymer Laminated – Black

Plot the site's R and pH data point on the Chart. The CSP materials are considered suitable when the data point falls to the right of AND above their respective coloured boundary lines.

Figure 4.1

100 year DSL Chart

Estimated Material Service Life (EMSL) 100 years. Based on minimum 100 years to First Perforation of Polymer Laminated, Aluminized, Galvalume and Galvanized Steel.

*Horizontal lines reflect Environmental Range per Figure 8

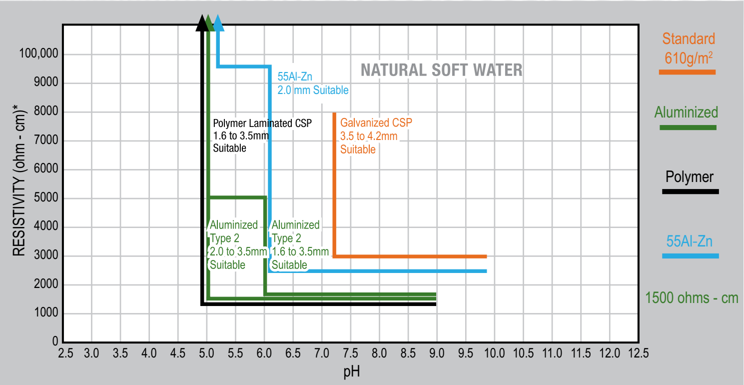
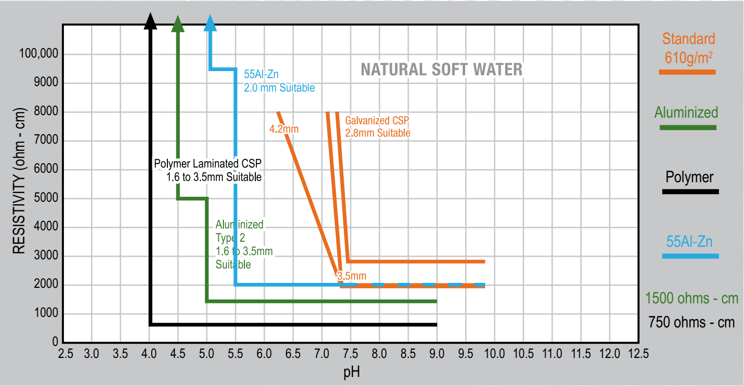


Figure 4.2

75 year DSL Chart

Estimated Material Service Life (EMSL) 75 years. Based on minimum 75 years to First Perforation of Polymer Laminated, Aluminized, Galvalume and Galvanized Steel.

*Horizontal lines reflect Environmental Range per Figure 8



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3.4 Use Design Charts – Match DSL to EMSL cont'd

Figure 4.3

50 year DSL Chart

Estimated Material Service Life (EMSL) 50 years. Based on minimum 50 years to First Perforation of Polymer Laminated, Aluminized, Galvalume and Galvanized Steel.

Horizontal lines reflect Environmental Range per Figure 8

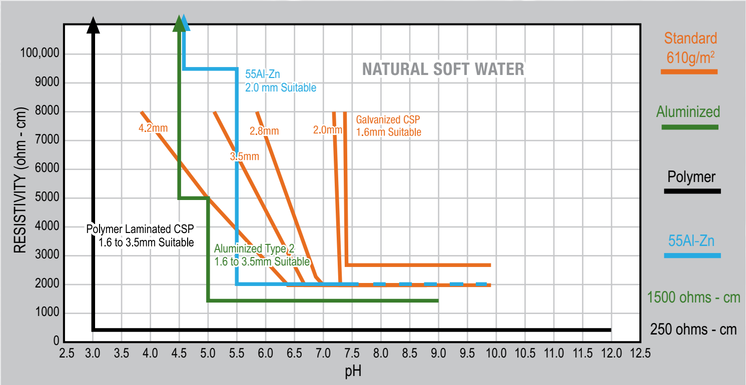
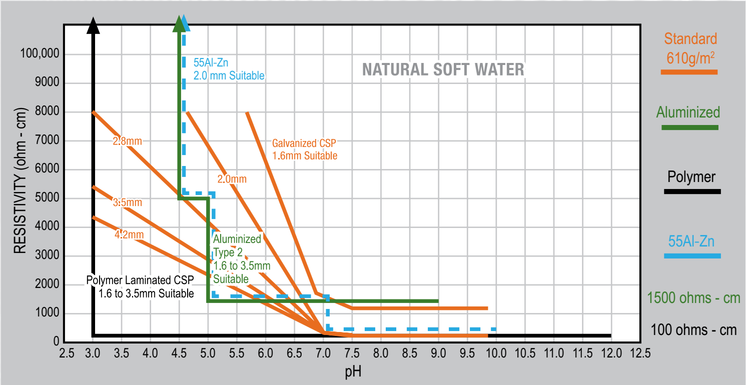


Figure 4.4

25 year DSL Chart

Estimated Material Service Life (EMSL) 25 years. Based on minimum 25 years to First Perforation of Polymer Laminated, Aluminized, Galvalume and Galvanized Steel.



Many studies have been performed in North America to better understand and quantify the durability performance of CSP. These are discussed in "The Handbook of Steel Drainage and Highway Construction Products" and at www.cspi.ca.

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4.0 Alternative Culvert Material Review Methods

CSP material selection can be further checked using the bar charts in Section 4.1 in conjunction with Section 4.2 – Surface Water Field Test

4.1 Bar Charts

If the measured critical characteristics of water fall outside shaded area, the CSP material may not be appropriate for the environment.

Figure 7

pH vs. Culvert Material

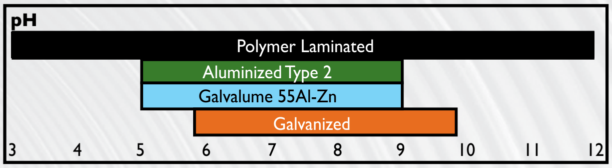


Figure 8

Resistivity vs. Culvert Material

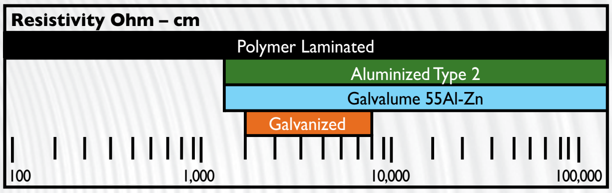


Figure 9

Hardness vs. Culvert Material

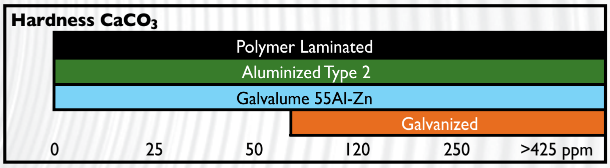
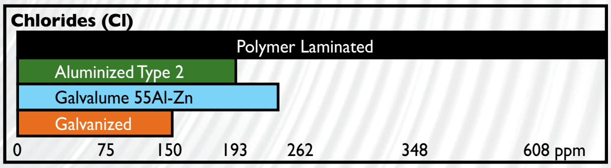


Figure 10

Chlorides vs. Culvert Material



4.2 Surface Water Field Test

The following tests using commercially available test strips will help the practitioner identify existing water chemistry and through a process of elimination select culvert materials that are best suited to the existing environmental conditions to meet the project DSL.

TEST STRIPS REQUIRED (available from www.HACH.com)

1. SOFCHEK Total Hardness, Product # 27452-50
2. pH 4-9, Product # 27456-50
3. Chloride, Low Range 30-600 Product # 27449-40

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Method

1. Collect a water sample from the test site in a small, clean glass container.

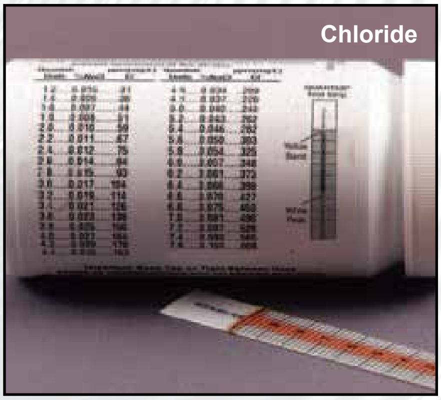
2. Remove a Total Hardness Strip from the package, dip the strip in the water sample for 1 second, wait for 15 seconds and then match the color with those on the package. If ppm reading is 50 or less, eliminate Galvanized from the selection process. If ppm reading is 120 or greater continue with all coating options.

3. Remove a pH strip from the package, dip the strip in the water sample for 1 second, wait for 15 seconds and then match the color with those on the package. If the reading is 5 or less eliminate Galvanized. If the reading is 4 or less eliminate Aluminized Type 2 & Galvalume. Continue with all remaining coating options.

4. Partially empty the glass leaving water 1 to 2 cm deep. Remove a Chloride Titrator Strip from the package. Stand the strip in the water ensuring that the yellow string remains dry. Let stand until yellow string turns black. Remove the strip and note the upper level of the white peak. If the level is less than 4.2 consider all remaining coating options. If the level is greater than 4.2 eliminate Galvanized and Aluminized Type 2 & Galvalume from the selection process. If the level is greater than 7.6 the EMSL for Polymer Laminated CSP may be less than 75 years.

Notes:

For readings beyond the range of test strips additional and alternate testing may be required to determine suitability of materials and estimated material service life. Tests reflect the conditions on the day of sample only. Wet weather and high flows will dilute the concentration of dissolved



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salts while hot dry weather will increase concentration. Future site development may change environmental conditions. Coating selection should reflect past performance of materials at the site and anticipated conditions into the future, for the entire DSL of the project.

These tests identify the most common elements found in Canadian waters that influence the performance of steel culverts. Other elements may exist locally. Past experience and local knowledge should always be considered in material selection.

These tests were developed by the CSPI as a tool to assist in the decision making process. It is the responsibility of the design professional to ensure that all factors are considered and to make the final CSP Material selection.

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5.0 Commentary

The following commentary provides recommendations on engineered backfill properties, identifies other factors affecting performance and illustrates the variability of soil / water chemistry across Canada.

5.1 Engineered Backfill

The engineered backfill in direct contact with the CSP should conform to the limits:

1. pH >5 < 10
2. Resistivity > 3,000 ohm cm
3. Organic Content 1% Maximum

Some native soil backfills and the potential inflow of dissolved salts from outside of the backfill envelope must be considered to determine the long-term regime of the engineered backfill. Salts may be diverted from contacting the structure with pavements, geo-textiles, and membranes in the backfill or with a polymer coating on the steel. Low organics content is also required for structural purposes.

5.2 Other Factors Affecting Durability

The performance of a culvert may be affected by a number of physical factors including static and live loads, repetitive loading cycles, freeze / thaw cycles, hydraulic and frost pressures, shifting ground, gravity and fire. CSP has an excellent record in resisting these forces however all should be considered in a design risk analysis and in some cases preventative methods should be considered. Polymer laminated CSP should not be used in northern tidal waters.

5.3 Soil Chemistry in Canada

Regions in South Eastern Canada experience acid rain with a low pH. Regions indicated in orange have thin soils or peat with insufficient $CaCO_3$ to neutralize the acidity of the rain. Regions indicated in yellow and green have deeper soils and progressively higher levels of $CaCO_3$ that provides both buffering to acids and protective scaling on pipe surfaces.

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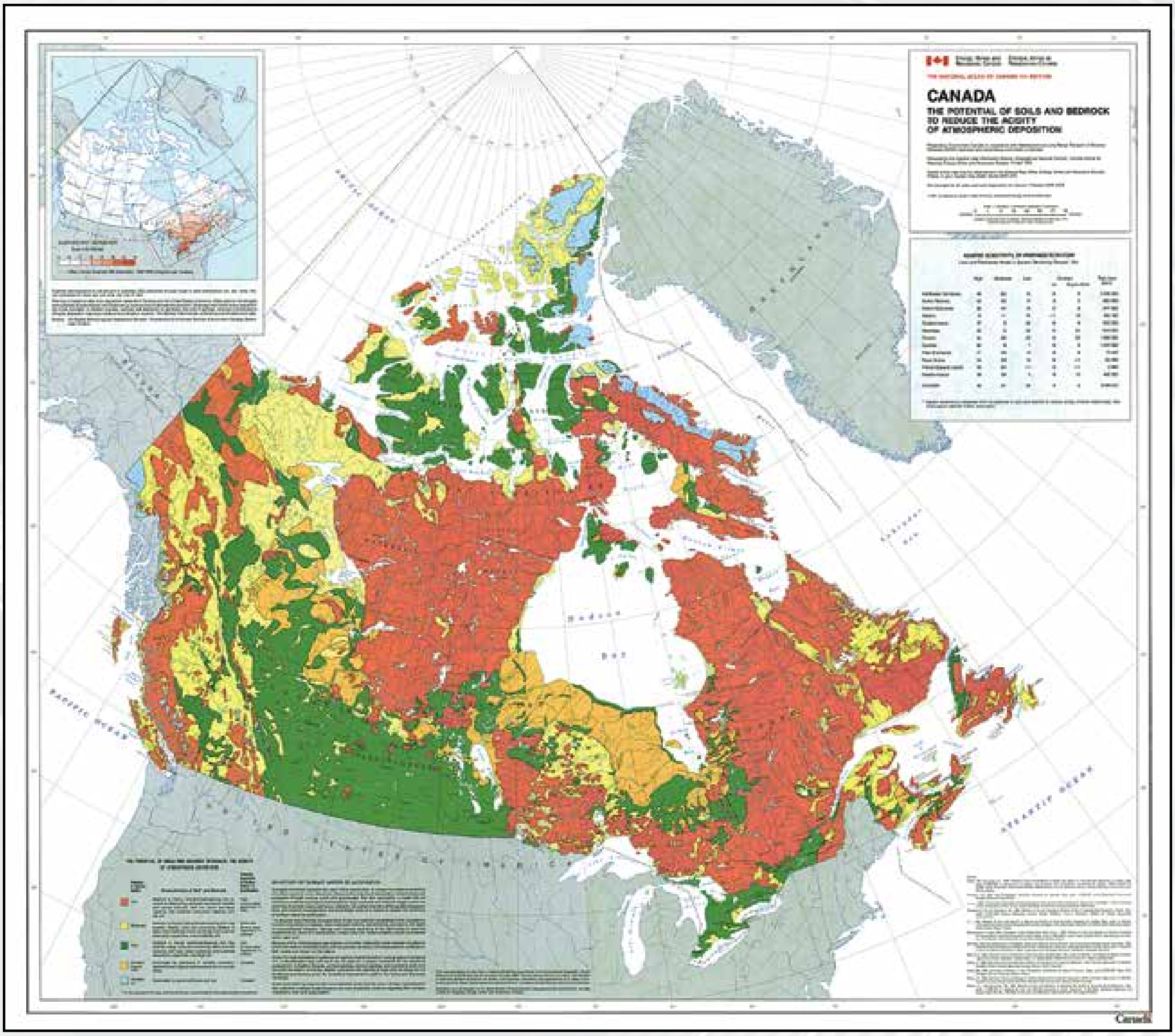

Reference: National Atlas of Canada, 5th Edition, 1985 – 1995.

The above map illustrates the variability in soil chemistry across Canada. Regional characteristics should be considered when selecting a suitable CSP pipe material.

http://www.cspi.ca/sites/default/files/download/cspiSoil_AcidRainMap_100.pdf