KOERS
& ASSOCIATES
ENGINEERING LTD.
Consulting Engineers

PO BOX 790
194 MEMORIAL AVENUE
PARKSVILLE, BC V9P 2G8
Phone: (250) 248-3151
Fax: (250) 248-5362
www.koers-eng.com

September 20, 2023
2338-01

Comox Valley Regional District
770 Harmston Avenue
Courtenay, BC, V9N 0G8

Attention: **Kerly Acosta Hitchcock, P.Eng. C.E.M.**
Engineering Analyst in Water/Wastewater Services

RE: Graham Lake Water Local Service Area
AC Watermain Condition Assessment – Desktop Study

We are pleased to present our letter report summarizing our desktop condition assessment of the existing Asbestos Cement (AC) watermain piping in the Graham Lake Water Local Service Area (GLWLSA).

1 STUDY NEED

The Graham Lake water system was constructed in 1971/72 by a developer (Seaview Land Estates Ltd.) as part of the East Road residential subdivision from Owl Crescent to McFarlane Road.

As-built drawings dated July 10, 1972 by Ramsay Murray Consulting Engineer indicate the water system piping consists of:

Supply Main (Raw Water)

- ±750 m of 150 mm dia. consisting of:
  - i) ±10 m of PVC pipe within the lake,
  - ii) ±710 m of Class 150 Asbestos Cement (AC) pipe, and
  - iii) 30 m of steel pipe where the main crosses under Graham Lake Creek, approximately 100 m upstream of the pumphouse/water treatment building.

Distribution Main (Treated Water)

- ± 1,000 m of 150 mm dia. Class 150 AC pipe
- ± 230 m of 100 mm dia. Class 150 AC pipe

The mains are now 51 to 52 years old. If the operational service life of 60 years (estimated by the CVRD) is applied, the mains would have to be replaced in approximately eight years.

.../2

The CVRD would like to better understand the condition of the existing AC watermain piping and establish a more definitive estimate as to when replacement might be required. This information would be used to refine the CVRD's calculation of funds to be collected annually from the users to finance the replacement work (engineering design, regulatory approvals, tendering, construction, and commissioning).

The location of the GLWLSA (in relation to Graham Lake and the Denman Island Water Local Service Area (DIWLSA)) is shown in **Figure 1**. The CVRD took over operation of the Graham Lake water system earlier this year (2023) when the Graham Lake Improvement District was dissolved and replaced with the GLWLSA. The DIWLSA was created in 1972.

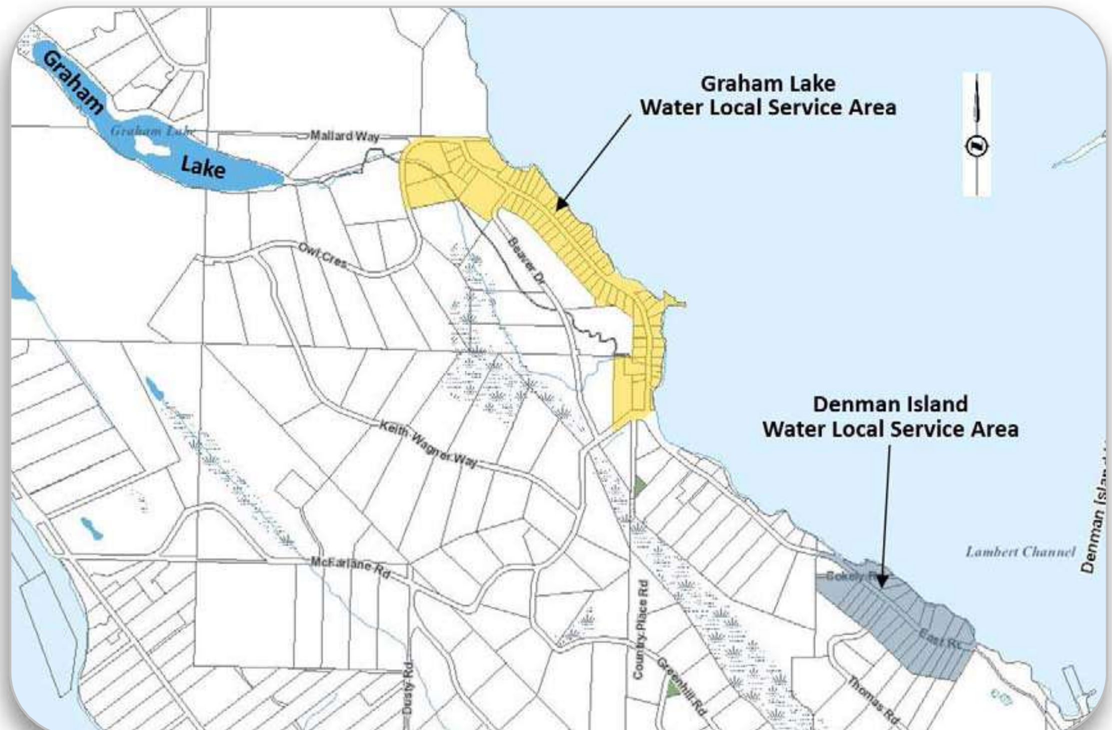


Figure 1 – Location of Graham Lake and the
Graham Lake and Denman Island Water Local Service Areas

There are many factors that contribute to the service life of AC mains, including but not limited to:

- Quality of Materials (watermain and service connection piping, hydrants, tees, valves, thrust restraints, etc.) and soils (pipe bedding, trench backfill)
- Quality of Installation
- Aggressiveness of the water inside the Pipe
- Aggressiveness of the soils the pipe is buried in
- Pipe Pressure Rating (Pressure Class) vs Operating Pressure

.../3

2 SCOPE OF WORK

The CVRD did not have sufficient funds to perform the type of destructive testing that is required to properly establish the condition of the existing AC pipe, and more accurately predict its remaining service life. In the absence of AC pipe destructive testing data, a desktop study was authorized by the CVRD to review relevant readily available information that might be able to help establish a rough estimate of the AC pipe's remaining service life. The authorized scope of work consisted of the following five tasks:

Task 1 – Review Watermain Historical Break and/or Leakage Information

- Historical watermain break and/or leakage information to be provided by the CVRD (includes location of repair, date of repair, method of repair).
- Review repair information and determine if the frequency of repairs is increasing.

Task 2 – Assess Watermain Pipe Internal Corrosive Potentials

- Review historical water quality data for raw water & treated water. Water quality information to be provided by the CVRD from historical records.
- Use AWWA published criteria and perform calculations to establish if the internal water chemistry is considered to be corrosive to AC pipe.

Task 3 – Assess Watermain Pipe External Corrosive Potential

- Help select 4 or 5 soil sampling locations along the existing watermains. Soil samples to be collected by the CVRD and submitted to a laboratory for testing.
- Review watermain trench soil test results.
- Use AWWA published criteria to establish if the external soil environment around the existing pipes is considered to be corrosive to AC pipe.

Task 4 – Remaining Service Estimate

- After reviewing published lifespans of AC pipe, and completing Tasks 1, 2 and 3, provide an opinion as to whether the testing results suggest a lower lifespan or a longer lifespan.
- Provide an estimate of the remaining service life of AC pipe.

Task 5 – Summarize Findings

- The findings will be presented in a brief letter report. The report may include recommendations for future condition assessment work, including destructive testing of the AC pipe.

.../4

Comox Valley Regional District
Kerly Hitchcock, P.Eng.

3 WATERMAIN REPAIR HISTORY

CVRD staff were able to find documentation for ten (10) repairs carried out with the most recent being this year and the last one being in 1994 (the past 29 years). The CVRD suspects that other undocumented repairs may have been made, since no documented repairs were found between 1995 to 2003 (nine years) and 2005 to 2016 (12 years).

The known repair history of the water system provided by the CVRD is presented in **Table 1** and the locations are shown in **Figure 2**. Photographs (provided by the CVRD) of repairs carried out in 2017 are presented after **Table 1**.

Table 1 – Documented Water System Repairs

Date	Address (East Rd)	Description
2023		
May 5	# 4181	1" service connection leak supplying 4215 & 4251 East Rd. Repaired with compression fittings.
2019		
July 30	# 3796	Pictures on file of curb stop and appears to be new service line. Suspected repair of customer side.
March 18	# 4046	Low pressure complaint, possible service connection leak. Unknown if resolved or what side.
2017		
Nov 29	# 4356	Unexpectedly, watermain side of curb stop had 3/4" thin walled PVC which snapped when curb stop attempted to shut off. Temporary compression fitting installed until proper service connection installed.
Oct 13	# 3616	Repaired 7 ft section of damaged service line (watermain side) and curb stop.
Aug 28	# 3941	Pictures on file of curb stop leak on customer side.
2004		
n/a	# 3567	AC main crushed by concrete truck near pumphouse gate. Repaired with blue brute.
1994		
Sep 5	# 3556	Repaired service line. Installed new shut off valve
Sep 5	# 3547	Reinstalled service line.
Sep 5	# 3541	Repaired service line. Installed new shut off valve

.../5

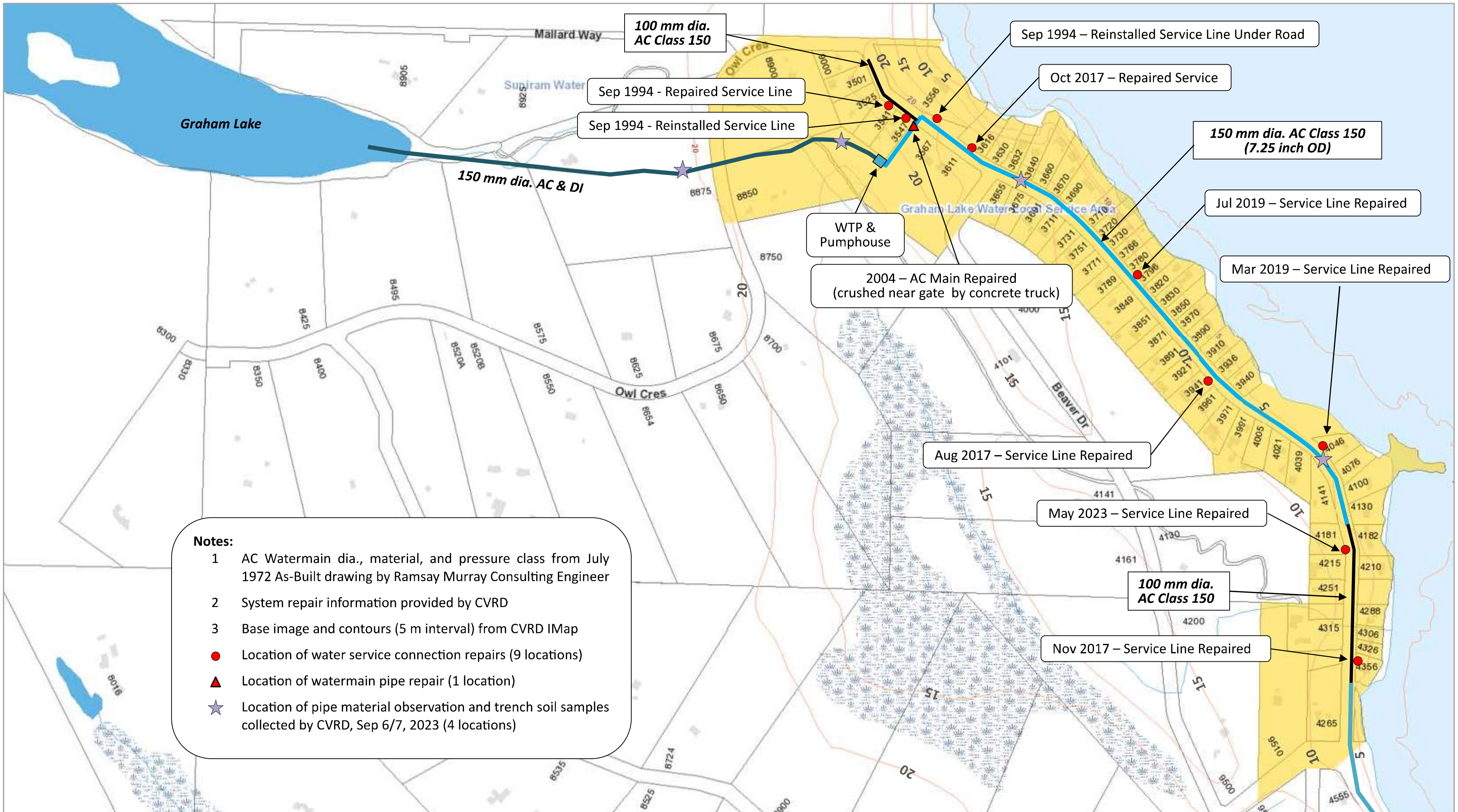


Figure 2 – Locations of Water System Repairs & Trench Soil Samples

Comox Valley Regional District
Kerly Hitchcock, P.Eng.

It is noted that:

i) All, except for one, of the repairs were on service connection piping and most were indicated to be on private property (customer side), i.e., not owned or responsibility of the GLWLSA.

ii) Only one repair was on the distribution piping when a cement truck drove over the pipe on a non-paved surface (near the pumphouse gate) in 2004.

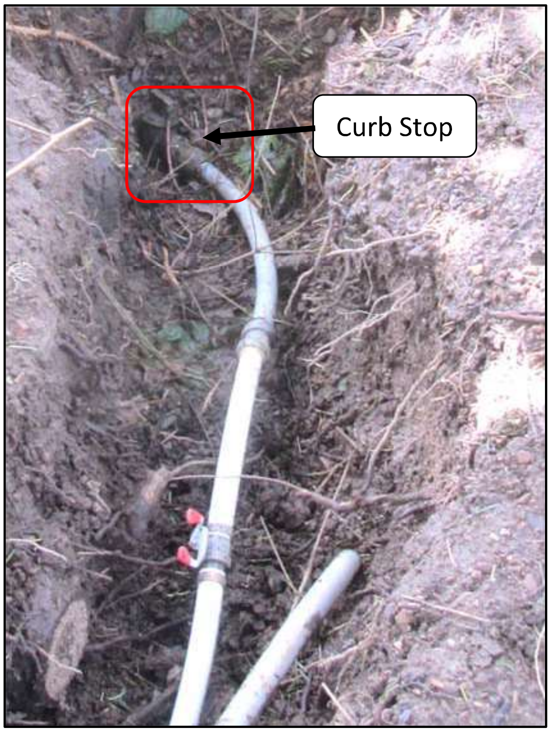
iii) **No repairs** were reported on the water supply main.

iv) **No repairs** were reported on service connections where they connect to the main. This location is known to be a common point of leakage when the service connection piping is connected to the AC pipe without the use of a saddle. This is referred to as a direct tap connection. The record drawings do not include a service connection detail, but the air valve connect detail shows a pipe saddle.

v) Past system operators (prior to CVRD) noted that the location of leak becomes evident during dry summers by green vegetation growing near it.

August 28, 2017
3941 East Road – Leak at curb stop, customer side.

../6



October 13, 2017
3616 East Road – Watermain side.
Repaired 7 ft section of damaged service line and curb stop.

November 29, 2017
4356 East Road - Watermain side
Unusual PVC service connection.
PVC (thin walled) snapped when attempting to shut off curb stop. Installed compression fitting.

4 WATER SUPPLY & DISTRIBUTION MAINS

On September 6/7, 2023, the water supply and the distribution mains were exposed by the CVRD using a smaller track excavation and hand shovel in four locations; two on the supply main and two on the distribution main, in order to observe the physical condition of the outside of the pipe and to collect soil samples for laboratory analyses. The locations of the four sites are shown in **Figure 2** and photographs are presented on the following pages.

.../7

4.1 Exposed Supply Main: Diameter, Material, Exterior Condition & Static Pressure

8875 Owl Crescent (front yard)

The supply main was exposed at 8875 Owl Crescent where the As-built drawings indicate the pipe to be AC. The pipe was observed by CVRD staff to be DI with an outside diameter of 6.95 inches. The pipe exterior appeared to be in very good condition with no obvious signs of deterioration of the black coating even though the pipe appeared to have been buried with common backfill i.e., no pipe bedding sand or fine gravel as can be seen in the photographs below.

The static pressure in the main at this location is estimated to be around ±140 kPa (20 psi).

The pressure rating for this 150 mm dia. Ductile Iron pipe is not known. The 1981 American Water Works Association (AWWA) document C150/A21.50-81 notes a rated working pressure of 2,400 kPa (350 psi) plus a pressure surge allowance of 700 kPa (100 psi) for 75 mm dia. to 450 mm dia. DI pipe.

The small dia. pipe suspected to be the 19 mm dia. connection for the then future hypochlorinator to be constructed at the lake as noted on the July 10, 1972 As-built drawing.

.../8

Comox Valley Regional District
Kerly Hitchcock, P.Eng.

Graham Lake Creek Crossing (rear yard of 8850 Owl Crescent/3525 East Road)

The supply main was exposed at the creek crossing in the area where the As-built drawing showed a 30 m long section of steel pipe. The pipe was found to be 150 mm dia. Ductile Iron with an Outside Diameter of 6.95 inches. The pipe exterior appeared to be in very good condition with no obvious signs of deterioration of the black coating even though the pipe appeared to have been buried with common backfill around the pipe, i.e., no pipe bedding sand or fine gravel as can be seen in the photographs below.

The static pressure in the main at this location is estimated to be around ±200 kPa (28 psi).

The pressure rating for this 150 mm dia. Ductile Iron pipe is not known. The 1981 American Water Works Association (AWWA) document C150/A21.50-81 notes a rated working pressure of 2,400 kPa (350 psi) plus a pressure surge allowance of 700 kPa (100 psi) for 75 mm dia. to 450 mm dia. DI pipe.

The small dia. pipe suspected to be the 19 mm dia. connection for the then future hypochlorinator to be constructed at the lake as noted on the July 10, 1972 As-built drawing.

.../9

Comox Valley Regional District
Kerly Hitchcock, P.Eng.

4.2 Exposed Distribution Main: Diameter, Material, Exterior Condition & Static Pressure

3640 East Rd

The distribution main was found to be 150 mm dia. Asbestos Cement (AC) with an Outside Diameter of 7.25 inches. The pipe exterior appeared to be in very good condition with no obvious signs of damage, saturation, sponginess or loss of material. The pipe appears to be surrounded with a layer of bedding sand or other fine grained material. The As-built drawings noted the pipe bedding to be sand or fine gravel.

The static pressure in the main at this location is estimated to be around ±380 kPa (55 psi) based on a system pressure of 345 kPa (50 psi) at the pumphouse.

The pressure rating for 150 mm dia. Class 150 AC pipe is 1,035 kPa (150 psi).

.../10

Comox Valley Regional District
Kerly Hitchcock, P.Eng.

4046 East Rd

The distribution main was found to be 150 mm dia. Asbestos Cement (AC. The pipe exterior appeared to be in very good condition with no obvious signs of damage, saturation, sponginess or loss of material. The pipe appears to be surrounded with a layer of bedding sand or other fine grained material. The As-built drawings noted the pipe bedding to be sand or fine gravel.

The static pressure in the main at this location is estimated to be around ±500 kPa (73 psi) based on a system pressure of 345 kPa (50 psi) at the pumphouse.

The pressure rating for 150 mm dia. Class 150 AC pipe is 1,035 kPa (150 psi).

.../11

5 CORROSIVE POTENTIAL

Asbestos Cement (AC) pipe is known to corrode/deteriorate/experience loss of pipe strength as a result of cement mortar leaching. AC piping is susceptible to deterioration both internally and externally. Two deterioration processes typically occur:

Lime Leaching
Free lime formed during the hydration process of the manufacturing of the pipe maintains the strength of the cement matrix. However, free lime can be leached from the cement by aggressive water in contact (internally and externally) with the pipe. Soft water, with very low ion content is aggressive to free lime and results in the leaching of free lime from the pipe.

Free lime (because of its alkali nature) can react with acids in the water both inside and outside the pipe. Strong acidic environments may exist in wetland soils due to decomposition of plants or may occur in contaminated soils (e.g., due to leaks of petroleum products).

Lime leaching can result in a loss of bonding agents and possibly hydrated products, and thereby can reduce pipe strength and increase the potential for pipes to leak and fail.

Sulphate Attack
Sulphate contained in the water inside the pipe and groundwater outside the pipe can also react with AC pipe material to form the mineral ettringite (calcium sulphoaluminate). The formation of the mineral causes swelling which can lead to the expansion and destruction of the cementitious portion of the AC pipe.

5.1 INTERNAL CORROSIVE POTENTIAL

There are two indexes that are frequently used to assess the aggressiveness of the water conveyed in the AC pipes:

- Aggressive Index (1)
- Langelier Index (1)

(1) American National Standards Institute/American Water Works Association, *The Selection of Asbestos Cement Pressure Pipe, 4 in. Through 16 in. (100 mm Through 400 mm), for Water Distribution Systems,* Section 4.8 Type of Pipe (ANSI/AWWA C401-03).

.../12

Calculation Results

The Aggressive Index and the Langelier Index were calculated for both Raw Water and Treated Water (sampled from the system piping) utilizing laboratory water quality testing reports provided by the CVRD.

The Raw Water calculations for the Aggressive Index and the Langelier Index are presented in **Table 2** and the calculated values are graphically shown in **Figure 3** and **Figure 4**. The Treated Water calculations are represented in **Table 3** and the calculated values are graphically shown in **Figure 5** and **Figure 6**.

Based on the water quality data provided, the Aggressive Index and the Langelier Index both indicate a tendency of the Raw Water and the Treated Water to be aggressive to AC pipe.

The indices, in and of themselves, do not predict with certainty the deterioration of AC pipes. Other analyses can be used, including, but not limited to:

i) An increase in pH value and calcium content after water has passed through AC pipes is an indication of leaching of free lime from the cement matrix. A review of the raw and treated water pH data does not indicate a significant change in pH as shown in **Table 4**.

ii) The presence of asbestos fibers in conveyed water can be used to indicate pipe conditions, as deteriorated AC pipe can release asbestos fibers in the conveyed water.

iii) A laboratory analyses and testing of a section of AC pipe. This is the best means by which to establish the condition of the existing AC pipe, and more accurately predict its remaining service life. This type of testing is very expensive and typically includes:

    - Dimensional measurement
    - Visual examination by stereomicroscopy
    - Surface hardness and scratch tests
    - Phenolphthalein indicator "staining" to evaluate gross leaching of the cement mortar
    - Chemical analysis of the AC pipe wall to evaluate degree and extent of cement mortar leaching
    - Crush strength test
    - Hydrostatic strength test

.../13

KOERS & ASSOCIATES ENGINEERING LTD.

Table 2

RAW Water Aggressive & Langelier Indices 2013 - 2023

Graham Lake Water Local Service Area

Aggressive Index = pH + Log (Alkalinity x Hardness)
Langelier Index = pH - pH_s
pHs = A+B-C-D

Corrosive Characteristics	Langelier Index	Aggressive Index
Highly aggressive	< –2.0	< 10.0
Moderately aggressive	–2.0 to 0.0	10.00 to 12.0
Nonaggressive	>0.0	>12.0

Date	Water Type	Sample Location	Water Quality Parameter					Calculated Indexes						
								Aggressive	Langelier					
			pH	TDS [2] mg/L	Alkalinity mg/L	Hardness mg/L	Temp [3] °C	Index (AI)	A [4] (temp based)	B (TDS based)	C (Log Alk)	D (Log Hard)	pH_s	Index (LI)
2005														
2006														
2007														
2008														
2009														
2010														
2011														
Mar 5, 2012	Raw	Pumphouse					5		2.48					
Oct 4, 2013	Raw	? Pumphouse ?	7.1	52	19	20	7	9.7	2.43	9.74	1.28	1.30	9.58	-2.48
Nov 6, 2014	Raw	? Pumphouse ?	7	50	20	19	5	9.6	2.48	9.74	1.30	1.28	9.63	-2.63
Dec 11, 2015	Raw	Pumphouse	7.52	56	17.2	17.5	4	10.0	2.50	9.74	1.24	1.24	9.76	-2.24
2016														
April 6, 2017	Raw	Pumphouse	7.35	38	15.6	16.9	8	9.8	2.40	9.73	1.19	1.23	9.71	-2.36
Jul 5, 2017	Raw	Pumphouse	7.42	40	22.5	16.8	19	10.0	2.13	9.73	1.35	1.23	9.28	-1.86
Nov 21, 2017	Raw	Pumphouse	7.48	38	20.6	18.7	4	10.1	2.50	9.73	1.31	1.27	9.64	-2.16
Sep 14, 2018	Raw	3567 East Rd	7.45	32	21.6	17.7	12	10.0	2.30	9.72	1.33	1.25	9.44	-1.99
Jan 16, 2019	Raw	Step #10, Sample Pt 2	6.88	56	14.5	16.7	4	9.3	2.50	9.74	1.16	1.22	9.86	-2.98
Jan 16, 2019	Raw	Step #10, Sample Pt 5	6.75	58	13	15.7	4	9.1	2.50	9.74	1.11	1.20	9.93	-3.18
Jan 16, 2019	Raw	Step #10, Sample Pt 6	4.89	68	1	15.7	4	6.1	2.50	9.75	0.00	1.20	11.05	-6.16
2020														
2021														
2022														
Aug 17, 2023	Raw	Pumphouse	7.14	49.3	20.35	15	21.7	9.6	2.07	9.73	1.31	1.18	9.32	-2.18
Aug 28, 2023	Raw	From Lake	7.4	47.7	21.7	15	17.1	9.9	2.17	9.73	1.34	1.18	9.39	-1.99

Notes:

1 S. Hdyrant is believed to be the hydrant at 4356 East Road. It is equipped with an automatic flush-out.

2 TDS = Total Dissolved Solids.

3 No temperature data available. Temperature extrapolated from seasonal water temperature curve from mid Vancouver Island watercourse.

4 Based on the extrapolated water temperature (see Not 3).

Table 2

RAW Water Aggressive & Langelier Indices 2013 - 2023

Graham Lake Water Local Service Area

Aggressive Index = pH + Log (Alkalinity x Hardness)

Langelier Index = pH - pH_s

pHs = A+B-C-D

Corrosive Characteristics	Langelier Index	Aggressive Index
Highly aggressive	< –2.0	< 10.0
Moderately aggressive	–2.0 to 0.0	10.00 to 12.0
Nonaggressive	>0.0	>12.0

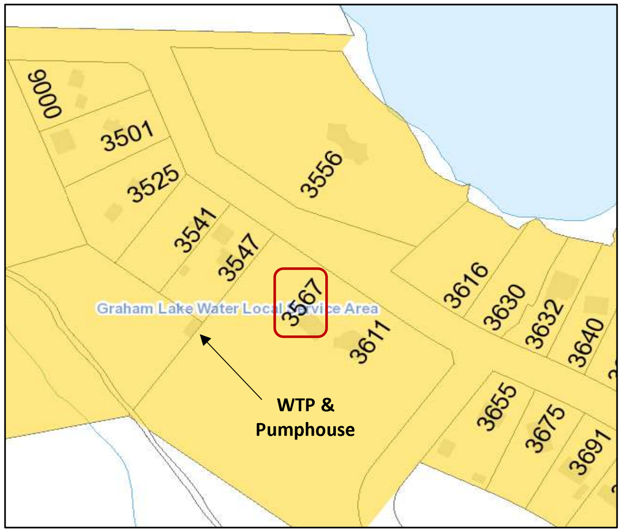


Table 1

Water Temperature, °C	A
0	2.60
4	2.50
8	2.40
12	2.30
16	2.20
20	2.10
25	2.00
30	1.90
40	1.70
50	1.55
60	1.40
70	1.25
80	1.15

Table 2

TDS, mg/L	B
0	9.70
100	9.77
200	9.83
400	9.86
600	9.89
1000	9.90

Table 3

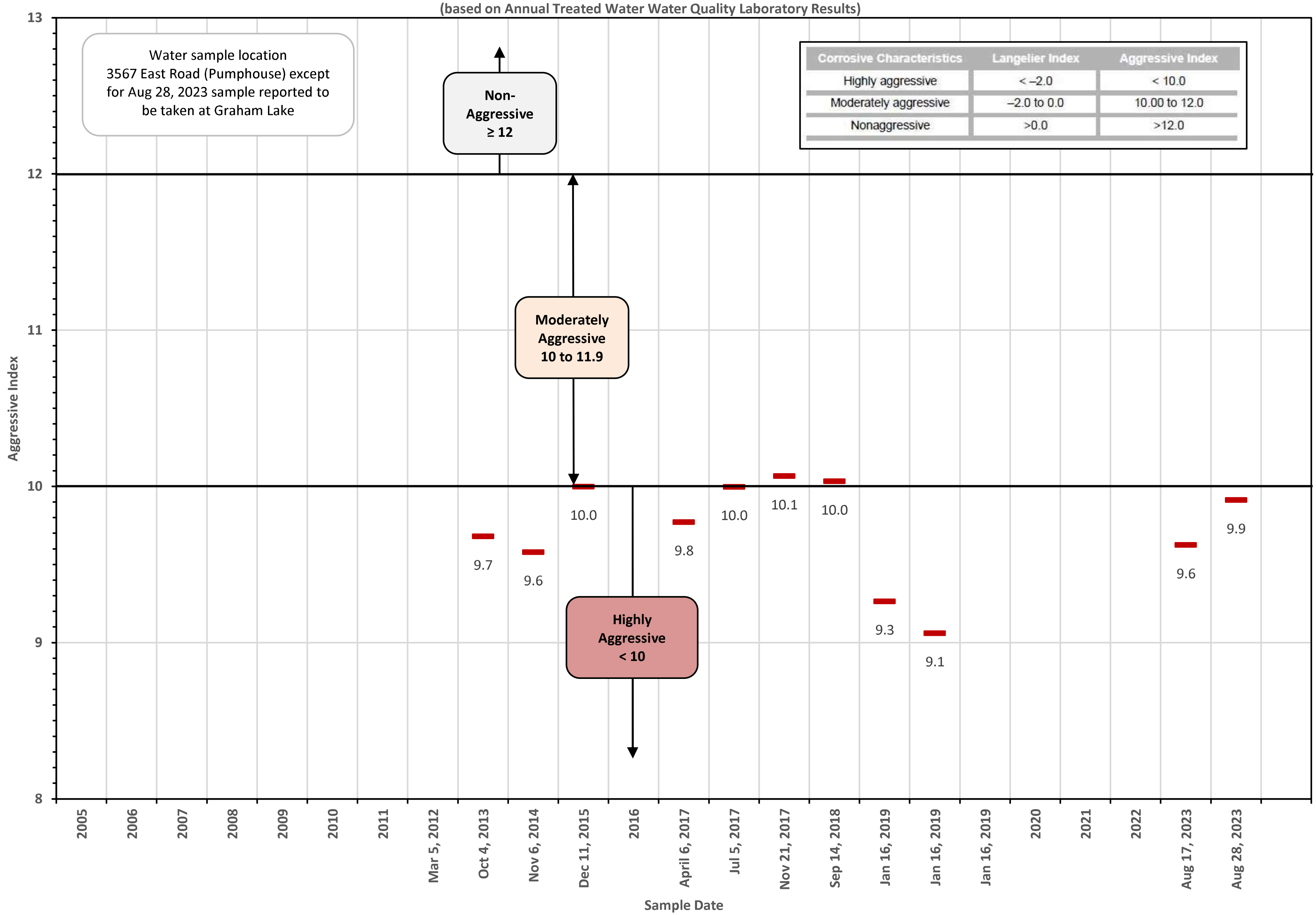
Calcium Hardness or Total Alkalinity in mg/L $CaCO_3$	C* or D**
10	1.00
20	1.30
30	1.48
40	1.60
50	1.70
60	1.78
70	1.84
80	1.90
100	2.00
200	2.30
300	2.48
400	2.60
500	2.70
600	2.78
700	2.84
800	2.90
900	2.95
1000	3.00

* Factor C is the logarithm (base 10) of the calcium hardness expressed in mg/L

** Factor D is the logarithm (base 10) of the total alkalinity expressed in mg/L

KOERS & ASSOCIATES ENGINEERING LTD.
Consulting Engineers

Graham Lake Water System
RAW Water
Aggressive Index, 2013 - 2023
(based on Annual Treated Water Water Quality Laboratory Results)



Corrosive Characteristics	Langelier Index	Aggressive Index
Highly aggressive	< –2.0	< 10.0
Moderately aggressive	–2.0 to 0.0	10.00 to 12.0
Nonaggressive	>0.0	>12.0

H:\1014 Comox Valley RD\2338 Graham Lake Water System\02 Design\Corrosive Index Calcs\Graham Lake Water Sys. Corrosive Indices Calcs.xlsx

FIGURE 3

KOERS & ASSOCIATES ENGINEERING LTD. Consulting Engineers

Graham Lake Water System
RAW Water
Langelier Index, 2013 - 2023
(based on Annual Treated Water Water Quality Laboratory Results)

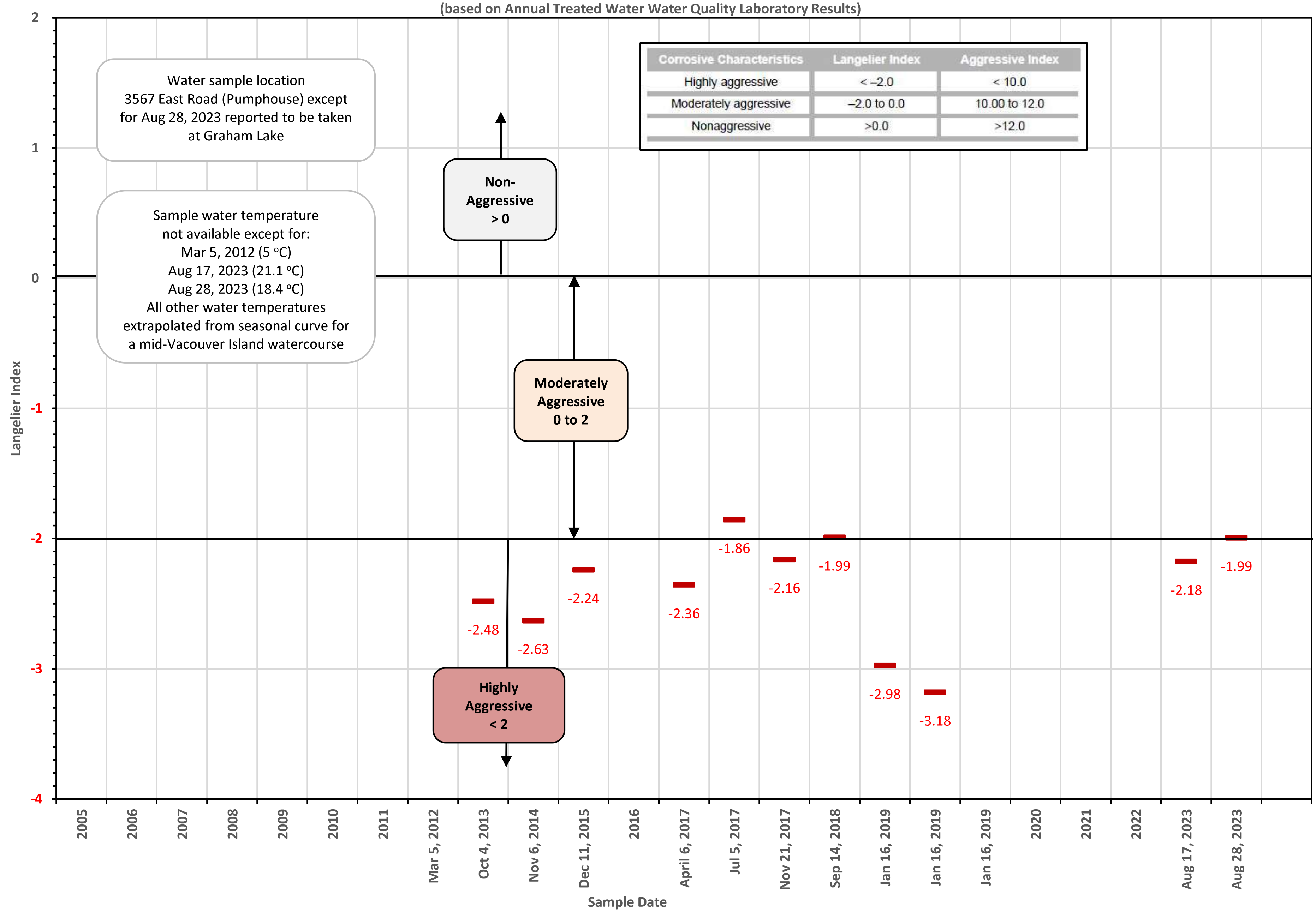


FIGURE 4

KOERS & ASSOCIATES ENGINEERING LTD.

Table 3

TREATED Water Aggressive & Langelier Indices 1993 - 2023

Graham Lake Water Local Service Area

Aggressive Index = pH + Log (Alkalinity x Hardness)

Langelier Index = pH - pH_s

pHs = A+B-C-D

Corrosive Characteristics	Langelier Index	Aggressive Index
Highly aggressive	< –2.0	< 10.0
Moderately aggressive	–2.0 to 0.0	10.00 to 12.0
Nonaggressive	>0.0	>12.0

Date	Water Type	Sample Location	Water Quality Parameter					Calculated Indexes						
								Aggressive	Langelier					
			pH	TDS [2] mg/L	Alkalinity mg/L	Hardness mg/L	Temp [3] °C	Index (AI)	A (temp base)	B (TDS based)	C (Log Alk)	D (Log Hard)	pH_s	Index (LI)
Oct 26, 1993	Treated	?	7	?	19.9	16.4	7	9.5	2.43		1.30	1.21		
1994														
1995														
Feb 7, 1996	Treated	?	6.7	?	16.4	?	3		2.53		1.21			
1997														
1998														
Mar 2, 1999	Treated	?	7.05	?	17.9	17.6	5	9.5	2.48		1.25	1.25		
2000														
2001														
2002														
2003														
2004														
Jan 26, 2005	Treated	4356 East Road, Open Hydrant	6.9	87	19	19	4	9.5	2.50	9.76	1.28	1.28	9.70	-2.80
Feb 16, 2006	Treated	4356 East Road	7.1	87	19	16	3	9.6	2.53	9.76	1.28	1.20	9.80	-2.70
Feb 14, 2007	Treated	S. Hydrant [1]	7.3	160	21	17	3	9.9	2.53	9.81	1.32	1.23	9.78	-2.48
Feb 26, 2008	Treated	S. Hydrant [1]	6.96	112	18	18	4	9.5	2.50	9.78	1.26	1.26	9.77	-2.81
March 4, 2009	Treated	4356 East Road	7.12	140	21	21	5	9.8	2.48	9.79	1.32	1.32	9.62	-2.50
March 2, 2010	Treated	4356 East Road	7.2	138	21	24	5	9.9	2.48	9.79	1.32	1.38	9.57	-2.37
March 23, 2011	Treated	4356 East Road	7.3	98	20	18	5	9.9	2.48	9.77	1.30	1.26	9.69	-2.39
2012														
2013														
2014														
2015														
2016														
2017														
March 14, 2018	Treated	3567 East Road	7.23	60	14	16	5	9.6	2.48	9.74	1.14	1.19	9.88	-2.65
2019														
2020														
2021														
2022														
Aug 17, 2023	Treated	Pumphouse	7.13	59.1	21.8	15.6	21.1	9.7	2.08	9.74	1.34	1.19	9.29	-2.16
Aug 28, 2023	Treated	4356 East Rd	7.23	61.9	22.9	18	18.4	9.8	2.14	9.74	1.36	1.26	9.27	-2.04

Notes:

1 S. Hdyrant is believed to be the hydrant at 4356 East Road. It is equipped with an automatic flush-out.

2 TDS = Total Dissolved Solids.

3 No temperature data available. Temperature extrapolated from seasonal water temperature curve from mid Vancouver Island watercourse.

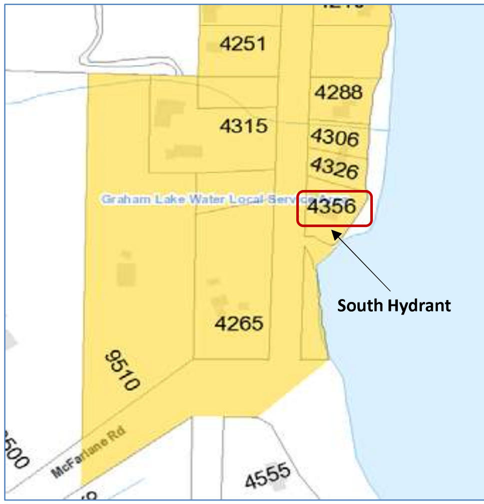
4 Based on the extrapolated water temperature (see Not 3).

KOERS & ASSOCIATES ENGINEERING LTD.

Table 3
TREATED Water Aggressive & Langelier Indices 1993 - 2023
Graham Lake Water Local Service Area

Aggressive Index = pH + Log (Alkalinity x Hardness)
Langelier Index = pH - pH_s
pHs = A+B-C-D

Corrosive Characteristics	Langelier Index	Aggressive Index
Highly aggressive	< –2.0	< 10.0
Moderately aggressive	–2.0 to 0.0	10.00 to 12.0
Nonaggressive	>0.0	>12.0



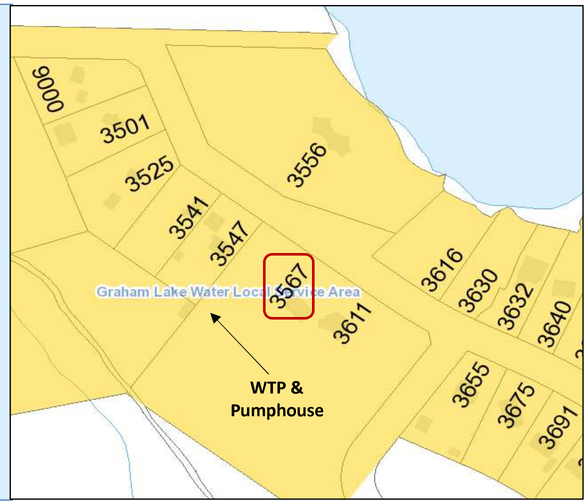


Table 1

Water Temperature, °C	A
0	2.60
4	2.50
8	2.40
12	2.30
16	2.20
20	2.10
25	2.00
30	1.90
40	1.70
50	1.55
60	1.40
70	1.25
80	1.15

Table 2

TDS, mg/L	B
0	9.70
100	9.77
200	9.83
400	9.86
600	9.89
1000	9.90

Table 3

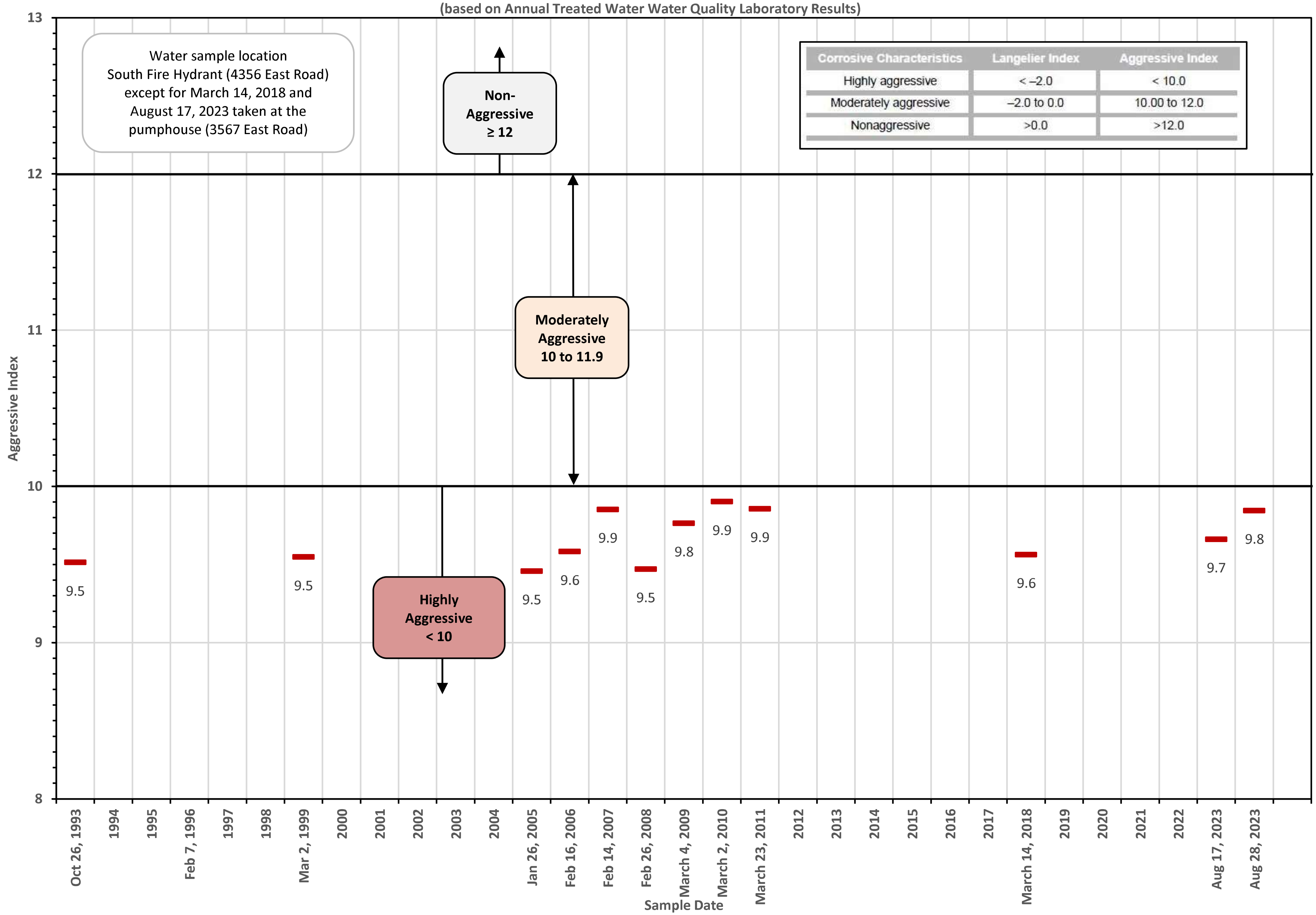
Calcium Hardness or Total Alkalinity in mg/L $CaCO_3$	C* or D**
10	1.00
20	1.30
30	1.48
40	1.60
50	1.70
60	1.78
70	1.84
80	1.90
100	2.00
200	2.30
300	2.48
400	2.60
500	2.70
600	2.78
700	2.84
800	2.90
900	2.95
1000	3.00

* Factor C is the logarithm (base 10) of the calcium hardness expressed in mg/L
** Factor D is the logarithm (base 10) of the total alkalinity expressed in mg/L

KOERS & ASSOCIATES ENGINEERING LTD.
Consulting Engineers

Graham Lake Water System
Treated Water
Aggressive Index, 1993 - 2023

(based on Annual Treated Water Water Quality Laboratory Results)

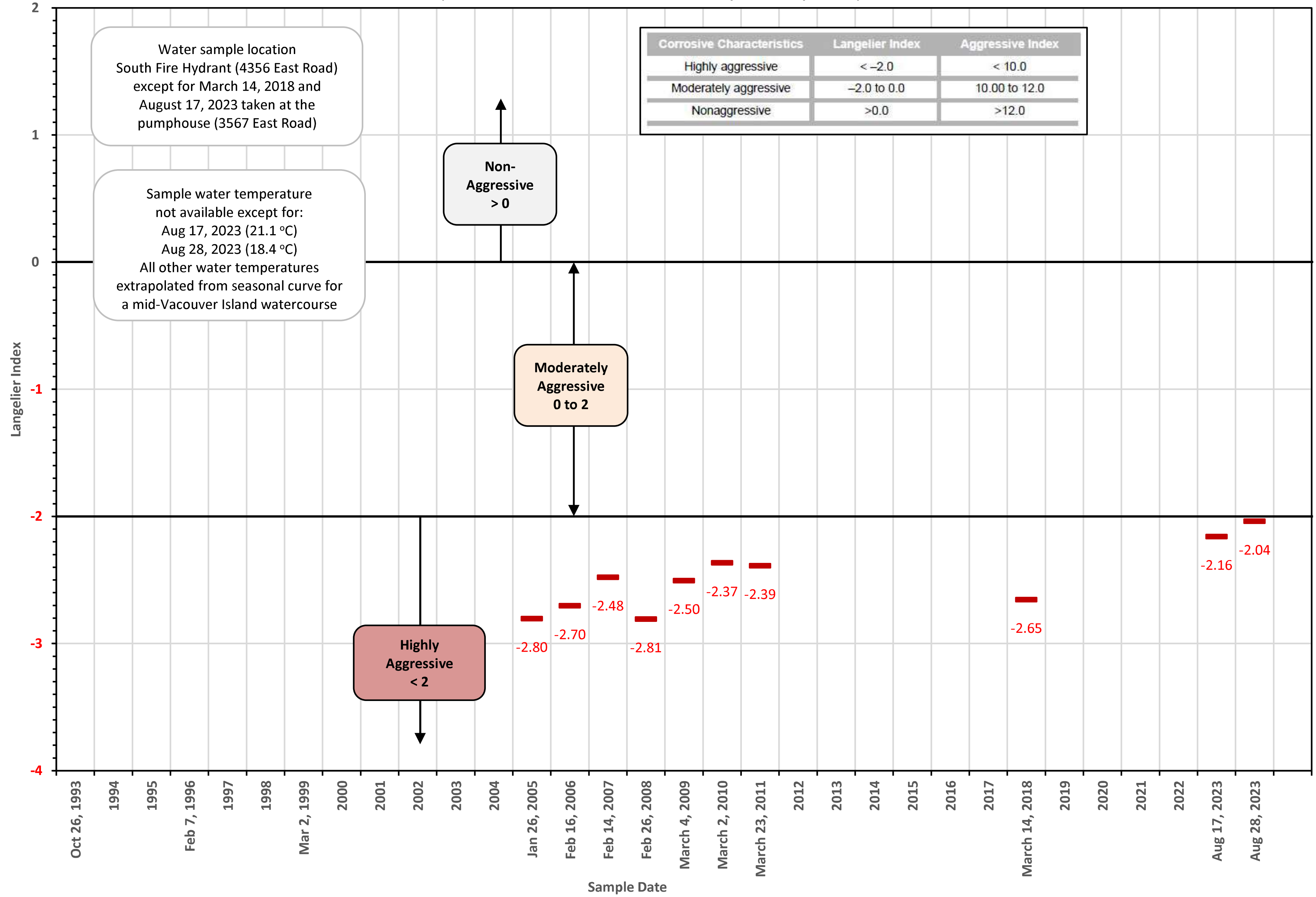


H:\1014 Comox Valley RD\2338 Graham Lake Water System\02 Design\Corrosive Index Calcs\Graham Lake Water Sys. Corrosive Indices Calcs.xlsx

FIGURE 5

KOERS & ASSOCIATES ENGINEERING LTD.
Consulting Engineers

Graham Lake Water System
Treated Water
Langelier Index, 2005 - 2023
(based on Annual Treated Water Water Quality Laboratory Results)



H:\1014 Comox Valley RD\2338 Graham Lake Water System\02 Design\Corrosive Index Calcs\Graham Lake Water Sys. Corrosive Indices Calcs.xlsx

FIGURE 6

KOERS & ASSOCIATES ENGINEERING LTD.

Table 4
Graham Lake Water System
Water Quality Lab Reports, 2005 - 2023
pH Reading: Raw Water, Treated Water, & Trench Soils

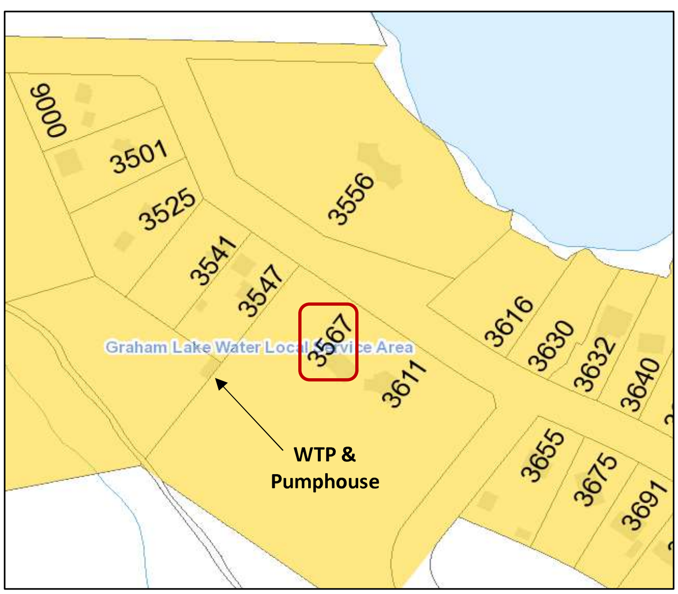
Date Sep 20, 23
File: 2338

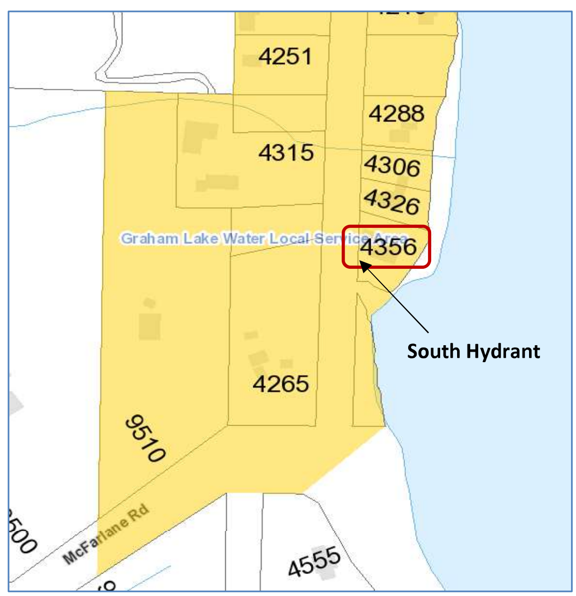
Year	Date	Water Type	Sample Location	pH	
				RAW Water	Treated Water
2005	Jan 26, 2005	Treated	4356 East Road, Open Hydrant		6.9
2006	Feb 16, 2006	Treated	4356 East Road		7.1
2007	Feb 14, 2007	Treated	S. Hydrant (1)		7.3
2008	Feb 26, 2008	Treated	S. Hydrant (1)		6.96
2009	March 4, 2009	Treated	4356 East Road		7.12
2010	March 2, 2010	Treated	4356 East Road		7.2
2011	March 23, 2011	Treated	4356 East Road		7.3
2012	2012				
2013	Oct 4, 2013	RAW	? Pumphouse ?	7.1	
2014	Nov 6, 2014	RAW	? Pumphouse ?	7	
2015	Dec 11, 2015	RAW	Pumphouse	7.52	
2016	2016				
2017	April 6, 2017	RAW	Pumphouse	7.35	
2016	Jul 5, 2017	RAW	Pumphouse	7.42	
2017	Nov 21, 2017	RAW	Pumphouse	7.48	
2018	March 14, 2018	Treated	3567 East Road		7.23
2018	Sep 14, 2018	RAW	3567 East Rd	7.45	
2019	Jan 16, 2019	RAW	Step #10, Sample Pt 2	6.88	
	Jan 16, 2019	RAW	Step #10, Sample Pt 5	6.75	
	Jan 16, 2019	RAW	Step #10, Sample Pt 6	4.89	
2020	2020				
2021	2021				
2022	2022				
2023	Aug 17, 2023	RAW & Treated	Pumphouse	7.13	7.14
	Aug 28, 2023	RAW & Treated	Lake & 4356 East Rd	7.4	7.23
	Sept 6, 2023	Pipe Trench Soil	Supply & Distribution Main		

pH (trench soil)			
Supply Main DI, C900 150 mm dia.		Distribution Main AC, Class 150 150 mm dia.	
8875 Owl Cres	3525 East Rd	3640 East Rd	4046 East Rd
5.75	5.70	7.07	6.03

Notes:

1 S. Hdyrant is believed to be the hydrant at 4356 East Road. It is equipped with an automatic flush-out.





Comox Valley Regional District
Kerly Hitchcock, P.Eng.

5.2 EXTERNAL CORROSIVE POTENTIAL

Soil samples collected at the four excavation sites (see **Figure 2**) were analyzed for soluble pH and soluble Sulphate (SO4). The results are presented in **Table 5**.

Table 5 – Pipe Trench Soil Lab Results

Parameter (1) (Soluble)		Supply Main (2)		Distribution Main (3)	
		8875 Owl Cres	Creek Crossing	3640 East Rd	4046 East Rd
pH		5.75	5.70	7.07	6.03
Sulphate (SO4)	mg/L	<20	<20	<20	<20

Notes:

1 Samples collected by CVRD staff on Sep 6/7, 2023 at the locations shown in **Figure 2**.
2 The supply main was reported to be Ductile Iron at the two locations where it was exposed.
3 The distribution main was Asbestos Cement at the two locations at the two locations where it was exposed.

The AWWA document C401-03 notes:

- Soil with a water soluble neutral sulphate content below 1,000 mg/L can be classified as non-aggressive to AC pipes.

It is reported that AC pipe is vulnerable to sulphate attack depending on:

- the free lime content,
- the type of cement used,
- and the permeability and density of the matrix.

AC pipe with low free lime content is reported to have more resistance to moderate amounts of sulphates in the soil. Although it is not known what the free lime content is in the GLWLSA AC pipe, the photographs of the AC pipe at both locations appear to show the exterior pipe wall to be in very good condition.

.../14

6 AWWA SERVICE LIFE ESTIMATES

The American Water Works Association's (AWWA) 2012 report entitled Buried No Longer: Confronting America's Water Infrastructure Challenge estimated the average life expectancy of various sizes and material types of watermain pipes across the US. The country was divided into four regions based on the similarities, such as population dynamics and the historical patterns of pipe installation driven by those dynamics. The four regions are shown in **Figure 7**.

Figure 7 – AWWA Watermain Pipe Life Expectancy Study Regions
(copy of Figure 1 from AWWA's 2012 report entitled
Buried No Longer: Confronting America's Water Infrastructure Challenge)

An estimated average service life for each of the four regions taking into consideration:

- The size of the water system (large, medium & small, very small)
- pipe material
- ground conditions and installation practices.

The results are presented in **Table 6**.

.../15

Comox Valley Regional District
Kerly Hitchcock, P.Eng.

Table 6 – AWWA Average Estimated Service Lives by Pipe Materials
(average years of service)

Derived Current Service Lives (Years)	CI	CICL (LSL)	CICL (SSL)	DI (LSL)	DI (SSL)	AC (LSL)	AC (SSL)	PVC	Steel	Conc & PCCP
Northeast Large	130	120	100	110	50	80	80	100	100	100
Midwest Large	125	120	85	110	50	100	85	55	80	105
South Large	110	100	100	105	55	100	80	55	70	105
West Large	115	100	75	110	60	105	75	70	95	75
Northeast Medium & Small	115	120	100	110	55	100	85	100	100	100
Midwest Medium & Small	125	120	85	110	50	70	70	55	80	105
South Medium & Small	105	100	100	105	55	100	80	55	70	105
West Medium & Small	105	100	75	110	60	105	75	70	95	75
Northeast Very Small	115	120	100	120	60	100	85	100	100	100
Midwest Very Small	135	120	85	110	60	80	75	55	80	105
South Very Small	130	110	100	105	55	100	80	55	70	105
West Very Small	130	100	75	110	60	105	65	70	95	75

LSL indicates a relatively long service life for the material resulting from some combination of benign ground conditions and evolved laying practices etc.
SSL indicates a relatively short service life for the material resulting from some combination of harsh ground conditions and early laying practices, etc.

Notes:

1. Above table is a copy of Figure 5 from AWWA's 2012 report entitled Buried No Longer: Confronting America's Water Infrastructure Challenge.

2. The four water system size categories are differentiated as follows:

   Very Small: Serving fewer than 3,300 people
   Small: Servicing 3,300 to 9,999 people
   Medium: Servicing 10,000 to 49,999 people
   Large: Servicing more than 50,000 people

The Graham Lake Water Local Service Area is closest to the West region and would be classified as a Very Small system. Applying these two parameters to **Table 5**, the average estimated service life for the AC pipe ranges from:

- 105 years for a relatively Long Service Life (LSL), to
- 65 years for a relatively Short Service Life (SSL)

as indicated by the red lined boxes.

.../16

7 FINDINGS

Service Connections & Main Repairs

Since 1994, there have been a reported 10 repairs on the distribution system. Nine repairs were on service connections and only one was on the watermain pipe and was likely not related to pipe deterioration. No repairs have been reported on the water supply main.

Supply Main Material, Pressure Rating and Static Pressures

At the two locations where the supply main was exposed, the pipe was found to be 150 mm dia. Ductile Iron (DI). It is not known if the remainder of the supply main is 150 mm dia. Asbestos Cement (AC), as noted on the 1972 As-built drawing, or if DI was used instead.

The lowest elevation along the supply main is at the Graham Lake Creek crossing, resulting in a maximum static pressure of only ±200 kPa (28 psi). The pressure rating of this DI pipe (installed in 1971/72) is not known. The 1981 American Water Works Association (AWWA) document C150/A21.50-81 notes a rated working pressure of 2,400 kPa (350 psi) plus a pressure surge allowance of 700 kPa (100 psi) for 75 mm dia. to 450 mm dia. DI pipe.

Distribution Main Material, Pressure Rating, and Static Pressures

At the two locations where the distribution main was exposed, the pipe was found to be 150 mm dia. AC pipe, as per the 1972 As-built drawings.

The As-built drawings note that AC piping is Class 150, which has a pressure rating of 1,035 kPa (150 psi). The lowest elevation along the distribution main is reported to be near 4100 East Road. Based on a system pressure of 345 kPa (50 psi) at the pumphouse, the static pressure in the main at this location is estimated to be around ±500 kPa (73 psi); well below the pipe pressure rating.

Internal Corrosion Potential

AC pipe is susceptible to corrosion (loss of strength) due to cement mortar leaching and sulphate attack. The Aggressive and Langelier Indices were used to assess aggressiveness of the raw water samples taken from the supply main and the treated water samples taken from the distribution main. Both Indices indicate the water is highly aggressive to AC pipe.

External Corrosion Potential & Visual Observations

The soluble sulphate concentrations in the four soil samples that were tested indicate the trench soils are not aggressive to the AC pipe. The photographs of the pipe appear to show the exterior pipe wall to be in very good condition with no obvious signs of damage, saturation, sponginess or loss of material. The AC pipe appears to be bedded with sand or another fine grained material.

AC Pipe Regional Service Life Estimates

Based on an AWWA study published in 2012, the average estimated service life for the AC pipe in the Graham Lake water system ranges from 65 years to 105 years. For the DI pipe on the supply main, the average service life ranges from 60 years to 110 years.

.../17

8 CONCLUSIONS

Factors suggesting the lifespan may be reduced include:

i) The laboratory analyses of the raw water samples taken from the supply main and treated water samples taken from the distribution main indicate the water to be in the highly aggressive range of the Aggressive and Langelier Indices.

Factors suggesting the lifespan may not be reduced include:

i) the visual observation of the AC pipe exterior,

ii) the soluble sulphate concentrations in the four soil samples that were tested indicate the trench soils are not aggressive to the AC pipe,

iii) operating pressures being well within/below the pipe pressure rating,

iv) no pipe repairs have been reported on the supply main,

v) All except for one of ten (10) repairs on the distribution system were on service connection piping and most were indicated to be on private property (customer side), i.e., not owned or responsibility of the GLWLSA.

vi) Only one repair was on the distribution piping when a cement truck drove over the pipe (on a non-paved surface). This was likely not due to deterioration of the AC pipe.

Based on the data reviewed, we suggest the AC pipe lifespan is likely not at the lower end of what is expected and could be in the range of 70 to 90 years from the original 1971/72 installation date, excluding the destructive impacts that a large earthquake would have on the AC pipe.

We recommend the CVRD budget for the removal of a section(s) of the AC piping and submission to a laboratory for destructive testing to assist in the refinement of the potential remaining service life of the AC piping. If a repair is carried out on the AC main, a section should be removed at that location for destructive testing.

.../18

Comox Valley Regional District
Kerly Hitchcock, P.Eng.

9 CLOSURE

We trust this report is sufficient for your needs at this time. Please call if you have any questions or if we can be of further assistance in assessing the condition and service life of the AC mains.

Yours truly,

KOERS & ASSOCIATES ENGINEERING LTD.

Sep 21, 2023
Chris Holmes, P.Eng.
Project Engineer

Sep. 21 2023
Matt Palmer, P.Eng.
Project Manager

Permit to Practice No. 1001658