WATER QUALITY OBJECTIVE SERIES

Water Quality Objectives for Burrard Inlet

British Columbia Ministry of Environment & Climate Change Strategy and Tsleil-Waututh Nation

February 2024

Tsleil-Waututh Nation
səlilwətaɬ

BRITISH COLUMBIA

No. WQO-02

The **Water Quality Objective Series** is a collection of British Columbia (B.C.) Ministry of Environment and Climate Change Strategy water quality objectives reports. Water quality objectives are developed for waterbodies to promote the protection and stewardship of provincially significant water resources. Once approved, water quality objectives constitute formal Ministry policy and must be considered in any decision affecting water quality made within the Ministry of Environment and Climate Change Strategy. For additional information visit: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-objectives.

ISBN: 978-0-7726-7886-7

Citation:
British Columbia Ministry of Environment and Climate Change Strategy (ENV) and Tsleil-Waututh Nation (TWN). 2024. Water Quality Objectives for Burrard Inlet. Water Quality Objective Series, WQO-02. Prov. B.C., Victoria B.C.

Cover Photo:
Underwater monitoring equipment is installed from the Tsleil-Waututh Nation boat in Burrard Inlet. Photo credit: Tsleil-Waututh Nation.

Acknowledgements

The water quality objectives presented here are based on work to update the Burrard Inlet Water Quality Objectives, led by the Tsleil-Waututh Nation (TWN), in collaboration with the B.C. Ministry of Environment and Climate Change Strategy (ENV) the B.C. Ministry of Water, Land and Resource Stewardship (WLRS) and the B.C. Ministry of Health (HLTH). Progress on this work has been supported by:

- The project Coordination Team including: Anuradha Rao and Kate Menzies (TWN); Diane Sutherland (ENV); Patrick Lilley (Kerr Wood Leidal, consultant to TWN).
- The Burrard Inlet Water Quality Technical Working Group and Roundtable (including representatives of First Nations, local, provincial, and federal government agencies, Health Authorities, industry, academia, and non-government organizations).
- Staff, specialists, and consultants (past and present) including:
    - Adrienne Hembree, Andrew George, Bridget Doyle, Carleen Thomas, Ernie George, Gabriel George, Graham Nicholas, Jessica Steele, John Konovsky, Kate Menzies, Melany Sanchez, Stormy MacKay, Sarah Dal Santo, Lindsey Ogston (TWN), Allison Hunt and Anne Sheridan (Inlailawatash)
    - Kristy Gabelhouse (ENV), Angeline Tillmanns, Heather Thompson, Nicole Obee and Kevin Rieberger (WLRS).
    - Daniel Brown, Jack Lau, Jessica LeNoble, Karin Björklund, Larissa Low, Luke Warkentin (Kerr Wood Leidal)
    - Kelsey Delisle, Marie Noël, Stephanie Braig (Ocean Wise Conservation Association)
    - Past contributors including: Deborah Epps, Cindy Meays, Colleen Loguisto, Sheldon Reddekopp and Sophia Goertsen (ENV), Dan Stein and Geneen Russo (HLTH).

We gratefully acknowledge financial support from: the Government of Canada; New Relationship Trust; the Province of British Columbia – Indigenous Funding Envelope; Sitka Foundation; Vancity Credit Union; and financial and in-kind contributions from Roundtable member organizations including: the City of Vancouver; Neptune Terminals; Parkland; and the Vancouver Fraser Port Authority.

The Water Quality Objectives (WQOs) for Burrard Inlet represent a collaborative effort led by Tsleil-Waututh Nation (TWN) with the Province of British Columbia (the Province), represented by the Ministry of Environment and Climate Change Strategy (ENV) and the Ministry of Water, Land, and Resource Stewardship (WLRS). The WQOs have been co-developed by TWN, ENV, and WLRS representing benchmarks to inform the management of water quality in Burrard Inlet and protect the water values for the benefit of all.

The development of the Burrard Inlet WQOs is an iterative process to efficiently support the acquisition of information and optimize the use of limited resources in consideration of the scope of work. The policy document will be updated as work is advanced. Changes to this document will not be made without the approval of both parties.

While efforts will be made to continue monitoring the water quality of Burrard Inlet, approval of the Burrard Inlet WQOs does not imply any obligation to conduct monitoring by either the Province of B.C. or TWN.

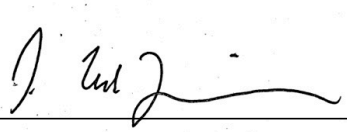
Once approved, the Burrard Inlet WQOs constitute ENV policy and must be considered in any decision affecting water quality made within ENV. The policy may also be used by other agencies to inform resource management or land use decisions.

Signed on behalf of TWN:

Date: 2/15/2024

Gabriel George, Director
Treaty, Lands and Resources
Tsleil-Waututh Nation

Signed on behalf of the Province of British Columbia:



Date: 03/04/2024

Ted Zimmerman, Executive Director
Watershed Stewardship and Security Branch, WLRS

EXECUTIVE SUMMARY

Burrard Inlet water quality objectives (WQOs), originally developed in 1990, are being updated to promote the protection of water quality and the associated water values. The development of the Burrard Inlet WQOs has been undertaken in partnership between the Province of British Columbia (the Province), represented by the Ministry of Environment and Climate Change Strategy (ENV) and the Ministry of Water, Land and Resource Stewardship (WLRS), and Tsleil-Waututh Nation (TWN), and demonstrates the Province's commitment to implementing the *Draft Principles that Guide the Province of British Columbia's Relationship with Indigenous Peoples*. Updating the Burrard Inlet WQOs is the first of six priority actions proposed by TWN in their Burrard Inlet Action Plan. TWN has provided leadership in initiating inter-agency collaboration and conducting the technical assessments required for the project. Updating the WQOs lays the foundation for further efforts to protect the water quality and values of Burrard Inlet.

The Burrard Inlet WQOs update is an iterative process with initial focus on the marine waters. The WQOs for freshwater tributaries to Burrard Inlet are in the process of being updated. B.C. water quality guidelines (WQGs) for freshwater should be applied in the interim. The marine waters are to be protected for human consumption of shellfish, human consumption of finfish, aquatic life, wildlife, cultural practices, recreational uses, and institutional uses.

This report presents updated and existing WQOs for the marine waters of Burrard Inlet, including the Central, Inner and Outer Harbours, False Creek, Indian Arm, and Port Moody Arm. The updated WQOs are based on extensive technical assessments led by TWN, undertaken by Qualified Professionals, and formally approved by both TWN and the Province. New WQOs will be added to this document as the supporting technical reports are completed for each water quality parameter.

The absence of a specific water quality parameter in the WQOs does not imply its irrelevance to Burrard Inlet; reducing contamination of any kind in Burrard Inlet stands as an overarching objective.

The WQOs are summarized in the following tables, and are established for contaminants of emerging concern, metals, microbiological parameters, microplastics, oil and grease, persistent organic pollutants, pesticides, pharmaceuticals and personal care products, physical parameters, polybrominated diphenyl ethers, and polycyclic aromatic hydrocarbons. Readers should refer to the supporting technical reports available online for more complete information on each parameter.

Contaminants of Emerging Concern (new)

Medium	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
All	All CECs: decreasing trend in concentrations					
Water	**Alkylphenols and their Ethoxylates** Nonylphenol and its Ethoxylates: 0.7 µg/L (total toxic equivalent of nonylphenolic compounds)					
	Bisphenols Bisphenol A (BPA): 0.9 µg/L					
	Phthalates Di-methyl phthalate (DMP): 2000 µg/L Di-ethyl phthalate (DEP): 600 µg/L Di-(n)-butyl phthalate (DnBP): 30 µg/L Benzyl butyl phthalate (BBP): 0.1 µg/L Di-(2-ethylhexyl) phthalate (DEHP): 0.37 µg/L Di-n-butyl phthalate (DnOP): Do not detect* and/or decrease in current levels					
	6PPD and 6PPD-Quinone 6PPD and 6PPD-Quinone: Do not detect* and/or decrease in current levels					
	Organotins Tributyltin (TBT): 0.001 µg/L					
	Brominated Flame Retardants Hexabromocyclododecane (HBCD): 0.56 µg/L Tetrabromobisphenol A (TBBPA): 3.1 µg/L Hexabromobenzene (HBB): Do not detect* and/or decrease in current levels					
	Perfluoroalkyl and Polyfluoroalkyl Substances Perfluorooctanoic acid (PFOA): Do not detect* and/or decrease in current levels Perfluorooctanesulfonic acid (PFOS): 3.4 µg/L					
Sediment	**Alkylphenols and their Ethoxylates** Nonylphenol and its Ethoxylates: 1.0 µg/g dry weight (total toxic equivalent of nonylphenolic compounds; adjust objective to site-specific levels of total organic carbon [TOC])					
	Bisphenols BPA: 0.025 µg/g dry weight (adjust objective to site-specific levels of TOC)					
	Phthalates DMP: 0.53 µg/g dry weight (adjust objective to site-specific levels of TOC) DEP: 0.61 µg/g dry weight (adjust objective to site-specific levels of TOC) DnBP: 2.2 µg/g dry weight (adjust objective to site-specific levels of TOC) BBP: 0.049 µg/g dry weight (adjust objective to site-specific levels of TOC) DEHP: 0.47 µg/g dry weight (adjust objective to site-specific levels of TOC) DnOP: 0.58 µg/g dry weight (adjust objective to site-specific levels of TOC)					
	6PPD and 6PPD-Quinone 6PPD and 6PPD-Quinone: Do not detect* and/or decrease in current levels					
	Organotins Do not detect* and/or decrease in current levels					
	Brominated Flame Retardants HBCD: 1.6 µg/g dry weight TBBPA: 0.6 µg/g dry weight HBB: Do not detect* and/or decrease in current levels					
	Perfluoroalkyl and Polyfluoroalkyl Substances PFOA: Do not detect* and/or decrease in current levels PFOS: Do not detect* and/or decrease in current levels					

Contaminants of Emerging Concern (new) ***continued***

Medium	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Tissue	**Alkylphenols and their Ethoxylates** Nonylphenol and its Ethoxylates: 0.018 µg/g wet weight					
	Bisphenols BPA: Do not detect* and/or decrease in current levels					
	Phthalates DMP: Do not detect* and/or decrease in current levels DEP: Do not detect* and/or decrease in current levels DnBP: Do not detect* and/or decrease in current levels BBP: Do not detect* and/or decrease in current levels DEHP: Do not detect* and/or decrease in current levels DnOP: Do not detect* and/or decrease in current levels					
	6PPD and 6PPD-Quinone 6PPD and 6PPD-Quinone: Do not detect* and/or decrease in current levels					
	Organotins TBT: 0.0088 µg/g wet weight Organotins: 0.0088 µg/g wet weight					
	Brominated Flame Retardants HBCD: Do not detect* and/or decrease in current levels TBBPA: Do not detect* and/or decrease in current levels HBB: 0.070 µg/g wet weight					
	Perfluoroalkyl and Polyfluoroalkyl Substances PFOA: 0.0007 µg/g wet weight PFOS: 0.0021 µg/g wet weight					

*Any objective of 'do not detect' implies non-detection when using best available detection limits.

Metals

Parameter	Medium	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Arsenic (total)	Water	2.4 µg/L (avg)					
	Sediment	7.24 µg/g dw (max)					
	Tissue	0.0018 µg/g ww (max)					
Cadmium (total)	Water	0.12 µg/L (avg)					
	Sediment	0.7 µg/g dw (max)					
	Tissue	0.03 µg/g ww					
Copper (total)	Water	1.3 µg/L (avg)					
	Sediment	18.7 µg/g dw (max)					
	Tissue	15 µg/g ww (max)					
Lead (total)	Water	2 µg/L (avg)					
	Sediment	30.2 µg/g dw (max)					
	Tissue	0.16 µg/g ww (max) (short-term by 2025)					
		0.087 µg/g ww (max) (long-term by 2040)					
Mercury (total)	Water	0.016 µg/L (avg)					
	Sediment	0.13 µg/g dw (max)					
	Tissue	0.033 µg/g ww (max)					
Nickel (total)	Water	0.8 µg/L (avg)					
	Sediment	30 µg/g dw (max)					
	Tissue	0.42 µg/g ww (max)					
Zinc (total)	Water	10 µg/L (avg)					
		55 µg/L (max)					
	Sediment	124 µg/g dw (max)					
	Tissue	17 µg/g ww (max)					

Microbiological

Parameter	Medium	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Short-term: 2021 - 2025							
Fecal coliforms (MPN/100 mL)	Water (shellfish harvest)						≤14 (median); ≤10% of results >43
E. coli (CFU or MPN/100mL)	Water	≤1,000 (geo mean)	≤200 (geo mean); ≤400 (max)				
Enterococci (MPN/100 mL)	Water (shellfish harvest)						≤4 MPN (median); ≤11 MPN (90th %ile)
Enterococci (CFU or MPN/100 mL)	Water	≤175 (geo mean)	≤35 (geo mean); ≤70 (max)				
Medium-term: 2025 - 2050							
Fecal coliforms (MPN/100 mL)	Water		≤14 (median); ≤10% of results >43		≤14 (median); ≤10% of results >43		
E. coli (CFU or MPN/100mL)	Water	≤200 (geo mean); ≤400 (max)					
Enterococci (MPN/100 mL)	Water (shellfish harvest)		≤4 (median); ≤11 (90th %ile)		≤4 (median); ≤11 (90th %ile)		
Enterococci (CFU or MPN/100 mL)	Water	≤35 (geo mean); ≤70 (max)					
Long-term: 2050 onwards							
Fecal coliforms (MPN/100 mL)	Water	≤14 (median); ≤10% of results >43					
E. coli (CFU or MPN/100mL)	Water	≤200 (geo mean); ≤400 (max)					
Enterococci (MPN/100 mL)	Water (shellfish harvest)	≤4 (median); ≤11 (90th %ile)					
Enterococci (CFU or MPN/100 mL)	Water	≤35 (geo mean); ≤70 (max)					

Microplastics

Parameter	Medium	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Microplastics	water	No increase over current levels - short-term WQO to 2025 Decrease in current levels - long-term WQO to 2050					
	sediment						
	tissue						

Oil and Grease

Parameter	Medium	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Oil and Grease							
Oil and grease	Water	Should not be present					

Persistent Organic Pollutants

Parameter	Medium	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Total PCBs	Water	6.2×10^{-4} ng/L (max)					
2,3,7,8-TCDD		5.1×10^{-6} ng/L (max)					
Total PCBs	Sediment	3.7×10^{-6} µg/g (dw) (max)					
Total PCDDs and PCDFs		8.5×10^{-7} µg/g (dw) (max)					
Total PCBs	Tissue	3.47×10^{-4} µg/g (ww) (max)					
Total PCDDs, PCDFs, and Dioxin-like PCBs		8.0×10^{-8} µg/g (ww) (max)					
PCBs, PCDDs, and PCDFs	All	Decreasing trend in concentrations					

Pesticides (new)

Parameter	Medium	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
All pesticides	All	Decreasing trend in concentrations					
Legacy Pesticides							
Aldicarb	Water	Not available					
	Sediment	Not available					
	Tissue	0.0351 µg/g ww; decreasing trend in concentrations					
Aldrin	Water	0.0000077 µg/L; decreasing trend in concentrations					
	Sediment	Do not detect* and/or decrease in current levels					
	Tissue	Do not detect* and/or decrease in current levels					
Chlordane	Water	0.000093 µg/L; decreasing trend in concentrations					
	Sediment	0.00226 µg/g dw; decreasing trend in concentrations					
	Tissue	0.0026 µg/g ww; decreasing trend in concentrations					
2,4,6-Trichlorophenol	Tissue	0.161 (µg/g ww; decreasing trend in concentrations					
2,4-Dichlorophenol	Tissue	3.47 µg/g ww; decreasing trend in concentrations					
2,3,4,6-Tetrachlorophenol	Tissue	0.35 µg/g ww; decreasing trend in concentrations					
Monochlorophenol	Water	0.1 µg/L; decreasing trend in concentrations					
Total Dichlorophenols	Water	0.3 µg/L; decreasing trend in concentrations					
Total Tetrachlorophenols	Water	1 µg/L; decreasing trend in concentrations					
Total Trichlorophenols	Water	2 µg/L; decreasing trend in concentrations					
DDE	Water	0.000018 µg/L; decreasing trend in concentrations					
	Sediment	0.00207 µg/g dw; decreasing trend in concentrations					
	Tissue	0.01 µg/g ww; decreasing trend in concentrations					
DDT	Water	0.000025 µg/L; decreasing trend in concentrations					
	Sediment	0.00119 µg/g dw; decreasing trend in concentrations					
	Tissue	0.01 µg/g ww; decreasing trend in concentrations					
DDD	Water	Not available					
	Sediment	0.00122 µg/g dw; decreasing trend in concentrations					
	Tissue	0.014 µg/g ww; decreasing trend in concentrations					
Diazinon	Water	0.03 µg/L; decreasing trend in concentrations					
	Sediment	Do not detect* and/or decrease in current levels					
	Tissue	Do not detect* and/or decrease in current levels					
Dieldrin	Water	0.0000012 µg/L; decreasing trend in concentrations					
	Sediment	0.00071 µg/g dw; decreasing trend in concentrations					
	Tissue	0.00020 µg/g ww; decreasing trend in concentrations					
Endosulfan	Water	0.0016 µg active ingredient/L; decreasing trend in concentrations					
	Sediment	Not available					
	Tissue	0.21 µg/g ww; decreasing trend in concentrations					
Endrin	Water	0.0023 µg/L; decreasing trend in concentrations					
	Sediment	0.00267 µg/g dw; decreasing trend in concentrations					
	Tissue	0.011 µg/g ww; decreasing trend in concentrations					
Heptachlor	Water	0.0000059 µg/L; decreasing trend in concentrations					
	Sediment	Do not detect* and/or decrease in current levels					
	Tissue	Do not detect* and/or decrease in current levels					

Pesticides (new) ***continued***

Parameter	Medium	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Hexachlorobenzene	Water	0.000079 µg/L; decreasing trend in concentrations					
	Sediment	0.0038 µg/g dw; decreasing trend in concentrations					
	Tissue	0.002 µg/g ww; decreasing trend in concentrations					
Methoxychlor	Water	0.02 µg/L; decreasing trend in concentrations					
	Sediment	Not available					
	Tissue	0.17 µg/g ww; decreasing trend in concentrations					
Mirex	Water	Not available					
	Sediment	Not available					
	Tissue	0.007 µg/g ww; decreasing trend in concentrations					
Oxy-chlordane	Water	Not available					
	Sediment	Not available					
	Tissue	Do not detect* and/or decrease in current levels					
Toxaphene	Water	Not available					
	Sediment	0.0001 µg/g dw; decreasing trend in concentrations					
	Tissue	Do not detect* and/or decrease in current levels					
Current Use Pesticides (CUPs)							
Atrazine	Water	1.8 µg/L; decreasing trend in concentrations					
	Sediment	Do not detect* and/or decrease in current levels					
	Tissue	Do not detect* and/or decrease in current levels					
Carbaryl	Water	0.29 µg/L					
	Sediment	Not available					
	Tissue	Do not detect* and/or decrease in current levels					
Chlorpyrifos	Water	0.002 µg/L; decreasing trend in concentrations					
	Sediment	Do not detect* and/or decrease in current levels					
	Tissue	Do not detect* and/or decrease in current levels					
Lindane (*gamma*-hexachlorocyclohexane (γ-HCH))	Water	0.010 µg/L; decreasing trend in concentrations					
	Sediment	0.00032 µg/g dw; decreasing trend in concentrations					
	Tissue	0.00289 µg/g ww; decreasing trend in concentrations					
Imidacloprid	Water	0.65 µg/L; decreasing trend in concentrations					
	Sediment	Not available					
	Tissue	2.11 µg/g ww; decreasing trend in concentrations					
Malathion	Water	0.1 µg/L; decreasing trend in concentrations					
	Sediment	Not available					
	Tissue	Do not detect* and/or decrease in current levels					
Permethrin	Water	0.001 µg/L; decreasing trend in concentrations					
	Sediment	Not available					
	Tissue	1.74 µg/g ww; decreasing trend in concentrations					

Pharmaceuticals and Personal Care Products

Parameter	Medium	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
PPCPs	sediment	No increase over current levels - short-term WQO to 2025 Decrease in current levels - long-term WQO to 2050					
	water						
	tissue						

Physical Parameters (new)

Parameter	Medium	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Temperature	Water	No further increase in temperature; the natural temperature cycle[1] characteristic of the site should not be altered in amplitude or frequency by human activities					
Salinity	Water	No change in concentration (NaCl or equivalent) from the expected natural level[1] at that time and depth					
Dissolved Oxygen[2]	Water	8 mg/L 30-day mean[3]					
		5 mg/L instantaneous minimum					
pH	Water	7.7 to 8.8[4]					
Total Suspended Solids	Water	No increase from the expected natural levels in the ambient background, defined by best available data[5] as 10 mg/L					
Turbidity	Water	No increase from the expected natural levels in the ambient background, defined by best available data[5] as < 1 NTU[6]					

[1] Data are unavailable to conclusively define "natural" levels; until additional information becomes available, monitoring results can be compared to current conditions as described in Bjorkland et al 2023. The WQOs are intended to limit the ongoing effects of climate change.

[2] In cases where natural DO concentrations do not meet the criteria, no statistically significant reduction below natural levels should be permitted.

[3] A mean should be calculated from 5-in-30 sampling (i.e., five samples taken over 30 days).

[4] To be refined when data are available for additional sub-basins.

[5] See Appendix B for details on how background concentrations were determined. Although other datasets may exist, the datasets used for determining the background (i.e., data available in ENV's Environmental Monitoring System database) were found to be the 'best available data' within the constraints of the project. As more data becomes available, the background concentration may be revisited.

[6] For comparison to the background, a mean should be calculated from 5-in-30 sampling (i.e., five weekly samples taken over 30 days).

Polybrominated Diphenyl Ethers

Parameter	Medium	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
PBDEs (total)	Sediment	1 ng/g dw					
Tri-BDE (total)	Water	46 ng/L (avg)					
	Tissue	120 ng/g ww					
Tetra-BDE (total)	Water	24 ng/L (avg)					
	Tissue	44 ng/g ww					
Tetra-BDE-47	Tissue	4 ng/g ww					
Penta-BDE (total)	Water	0.2 ng/L (avg)					
	Tissue	1 ng/g ww					
Hexa-BDE (total)	Water	120 ng/L (avg)					
	Tissue	4 ng/g ww					
Hepta-BDE (total)	Water	17 ng/L (avg)					
	Tissue	64 ng/g ww					
Octa-BDE (total)	Water	17 ng/L (avg)					
	Tissue	63 ng/g ww					
Nona-BDE (total)	Tissue	78 ng/g ww					
Deca-BDE (total)	Tissue	9 ng/g ww					

Polycyclic Aromatic Hydrocarbons

Parameter	Medium	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Acenaphthene	Water	6 µg/L (avg)					
	Sediment	6.71 ng/g dw					
Anthracene	Sediment	46.9 ng/g dw					
Benzo(a)-pyrene	Water	0.01 µg/L (avg)					
	Sediment	88 ng/g dw					
	Tissue	0.0025 µg/g ww					
Benzofluoranthene	Sediment	2.3 µg/g dw					
Chrysene	Water	0.1 µg/L (avg)					
	Sediment	108 ng/g dw					
Fluoranthene	Sediment	113 ng/g dw					
Fluorene	Water	12 µg/L (avg)					
	Sediment	21.2 ng/g dw					
Naphthalene	Water	1 µg/L (avg)					
	Sediment	34.6 ng/g dw					
2-methylnaphthalene	Sediment	20 ng/g dw					
Phenanthrene	Sediment	86.7 ng/g dw					
Pyrene	Sediment	153 ng/g dw					

Other Parameters (to be updated in the future)

Parameter	Medium	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Chlorinated ethanes							
1,2-Dichloroethane	Water			0.2 mg/L (avg); 2 mg/L (max)			
Chlorine							
Cl-produced oxidants	Water				3 µg/L (avg)		
Chromium (total)	Water	50 µg/L (max)				50 µg/L (max)	
	Sediment	60 µg/g dw (max)				60 µg/g dw (max)	
Cyanide							
CN WAD	Water					1 µg/L (max)	
Nutrients							
Total ammonia nitrogen	Water	1 mg/L (avg); 2.5 mg/L (max)					
Phenols							
Phenols	Water				1 µg/L (max)		
Sulphide							
Undissociated H_2S	Water			2 µg/L (max)		2 µg/L (max)	

CONTENTS

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

BBP	Benzyl butyl phthalate
BDE	Brominated diphenyl ethers
BPA	Bisphenol A
CCME	Canadian Council of Ministers of the Environment
CEC	Contaminants of Emerging Concern
CFIA	Canadian Food Inspection Agency
CFU	Colony forming unit
CUP	Current use pesticide
DEHP	Di-(2-ethylhexyl) phthalate
DEP	Di-ethyl phthalate
DMP	Di-methyl phthalate
DnBP	Di-(n)-butyl phthalate
DnOP	Di-n-butyl phthalate
dw	Dry weight
ENV	British Columbia Ministry of Environment and Climate Change Strategy
HBB	Hexabromobenzene
HBCD	Hexabromocyclodecane
MP	Microplastics
MPN	Most probable number
PAH	Polycyclic aromatic hydrocarbons
PBDE	Polybrominated diphenyl ethers
PCB	Polychlorinated biphenyls
PCDD	Polychlorinated dibenzo-p-dioxins
PCDF	Polychlorinated dinzofurans
PEL	Probable effect level
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
PPCP	Pharmaceuticals and personal care products
TBBPA	Tetrabromobisphenol A
TBT	Tributyltin
TEL	Threshold effect level
TOC	Total organic carbon
TWN	Tsleil-Waututh Nation
WLRS	British Columbia Ministry of Water, Land and Resource Stewardship
WQG	Water quality guideline(s)
WQO	Water quality objective(s)
WSQG	Working sediment quality guideline
WWQG	Working water quality guideline
ww	Wet weight

1. INTRODUCTION

> *Tsleil-Waututh means "People of the Inlet", referring directly to the Burrard Inlet up to the Indian River and including Indian Arm. We were born with a sacred obligation to protect the waters. Our first grandfather was transformed from a wolf into a human being. When it was time for him to have a mate, the Creator gave him a vision that he was to dive off one of the tallest cliffs in Indian Arm, grab two handfuls of sediment from the floor of the Inlet and bring them back to the beach. Our first grandmother was transformed from that sediment – our first grandmother comes from the Inlet. Our ties to this Inlet run deep. It's important that we hold that responsibility, that as a Nation we gather people around who see our vision, and that our work resonates with their own spirit.*
>
> - *Carleen Thomas, Tsleil-Waututh Nation*

In British Columbia (B.C.), water quality objectives (WQOs) are developed for specific waterbodies of regional, provincial, inter-provincial, and international significance to promote the protection and stewardship of our shared water resources. WQOs define conditions that represent levels of low risk to water values. WQOs are set with the goal of protecting water values by maintaining existing water quality, improving existing water quality, or protecting water quality for a specific use. They formalize expectations with respect to water quality for a given waterbody and are used to inform land and resource management decisions. Once approved, WQOs constitute formal Provincial policy and are considered in decisions affecting water quality.

WQOs consider the characteristics of the waterbody, including: the ambient water quality; the aquatic life, wildlife, and related habitat; the hydrology; the sediments; the potential contaminant loadings from point and non-point source waste discharges; and the cultural and social values associated with a waterbody.

WQOs for the water body known as Burrard Inlet - səlilwət in the hən̓q̓əmin̓əm language - were initially developed in 1990 (Nijman and Swain 1990) to protect:

- aquatic life, wildlife, and primary-contact recreation in Burrard Inlet, Lynn Creek and School House Brook;
- aquatic life and wildlife in False Creek; and
- aquatic life, wildlife, primary-contact recreation, and drinking water supplies in the Capilano River.

The significance of Burrard Inlet, and knowledge via Indigenous and western science indicating that the health of the Inlet has deteriorated over time, indicated a need to update the WQOs for Burrard Inlet. Updating the provincial WQOs for Burrard Inlet is a priority for the Province, Metro Vancouver, and Tsleil-Waututh Nation (TWN). It is the first of six priority actions proposed by TWN in their Burrard Inlet Action Plan (TWN 2017).

This update combines Tsleil-Waututh Indigenous science and knowledge, improved western science regarding the biological thresholds and pathways of contaminants in aquatic organisms, a more complete understanding of contaminants of concern, more recent monitoring data and documentation of discharges into the Inlet, agreement by multiple sectors on sensitive water uses and values, and future goals for the health of the Inlet. Updating the WQOs lays the foundation for further efforts to protect the water quality and values in Burrard Inlet.

This report focuses on the marine environment and presents updated and existing WQOs for Burrard Inlet, including the Central, Inner, and Outer Harbours, False Creek, Indian Arm and Port Moody Arm. The updated WQOs are based on extensive technical assessments led by TWN. Readers should refer to Rao

et al. (2019) for a detailed description of the approach taken and an overview of the water quality of Burrard Inlet. The updated WQOs have been co-developed by TWN and the Province and approved by both jurisdictions, although this does not imply any obligation with respect to future monitoring activities. New WQOs will be added as the supporting technical reports are completed for each parameter. The WQOs from 1990 (Nijman and Swain 1990) for certain parameters remain until updated through this process. The WQOs for freshwater tributaries to Burrard Inlet are in the process of being updated. B.C. water quality guidelines (WQGs) for freshwater should be applied in the interim. The absence of a specific water quality parameter in the WQOs does not imply its irrelevance to Burrard Inlet; reducing contamination of any kind in Burrard Inlet stands as an overarching objective.

2. TSLEIL-WAUTUTH NATION

Tsleil-Waututh (səlilwətaɬ) means "People of the Inlet". Since time out of mind, Tsleil-Waututh people have used, occupied, governed, and stewarded their territory. Tsleil-Waututh hold a sacred, legal obligation and responsibility to protect, defend, and steward the lands and waters of their territory, in accordance with Tsleil-Waututh law, for past, present, and future generations. This stewardship responsibility requires restoring conditions that provide the environmental, cultural, spiritual, and economic foundation for Tsleil-Waututh people to thrive.

Updating the WQOs is a key priority in the TWN Burrard Inlet Action Plan (TWN 2017). TWN considers the level of contamination in Burrard Inlet to have long surpassed acceptable levels; the cumulative impacts of contamination from urban and industrial development on water quality have impacted TWN's Aboriginal rights and interests by reducing or eliminating opportunities to fish, harvest shellfish and practice culture. Improving the water quality in Burrard Inlet through the adoption of the WQOs will help advance TWN's goal of being able to sustainably harvest healthy, wild marine resources, and to practice spiritual, cultural, ceremonial, and recreational activities in clean water free of risk from contamination and harmful pathogens.

TWN continues to play a leading role in initiating collaboration on the exploration of environmental issues, developing technical assessments, and coordinating strategic solutions to improve the ecological integrity and health of Burrard Inlet for the benefit of all.

3. SITE DESCRIPTION

Burrard Inlet is located off the Strait of Georgia near Vancouver and extends to Port Moody and the head of Indian Arm (Figure 1). The Inlet can be divided into six sub-basins: False Creek, Outer Harbour, Inner Harbour, Central Harbour, Port Moody Arm, and Indian Arm (Figure 2). Each sub-basin has its own distinct oceanographic and usage characteristics, allowing for the meaningful subdivision of analyses as well as the analysis of the Inlet as a whole. The characteristics of the individual sub-basins, including oceanography, are described in Rao et al. (2019). The Inlet's outer boundary, closest to its mouth, is defined as the line connecting Point Atkinson (West Vancouver) and Point Grey (Vancouver).

Burrard Inlet is 113 km^2 in size, extending 46 km from its outer boundary to the head of Indian Arm (with Port Moody Arm adding 7 km) and includes 190 km of shoreline. Its catchment area is 1,288 km^2 (Rao et al. 2019). Burrard Inlet supports Canada's largest and busiest port and is a major transportation hub.

Approximately 1.2 million people live in the eight municipalities and local First Nations communities bordering Burrard Inlet (2021 Statistics Canada census). Coast Salish First Nations have occupied the area and depended on the health of Burrard Inlet for their sustenance since time out of mind. Intensive settlement and industrial development over the last 150 years has impacted the health of Burrard Inlet, including its water quality. Urban development is expected to increase as the population in the region continues to grow (Rao et al. 2019), increasing the pressure on the receiving waters of Burrard Inlet.

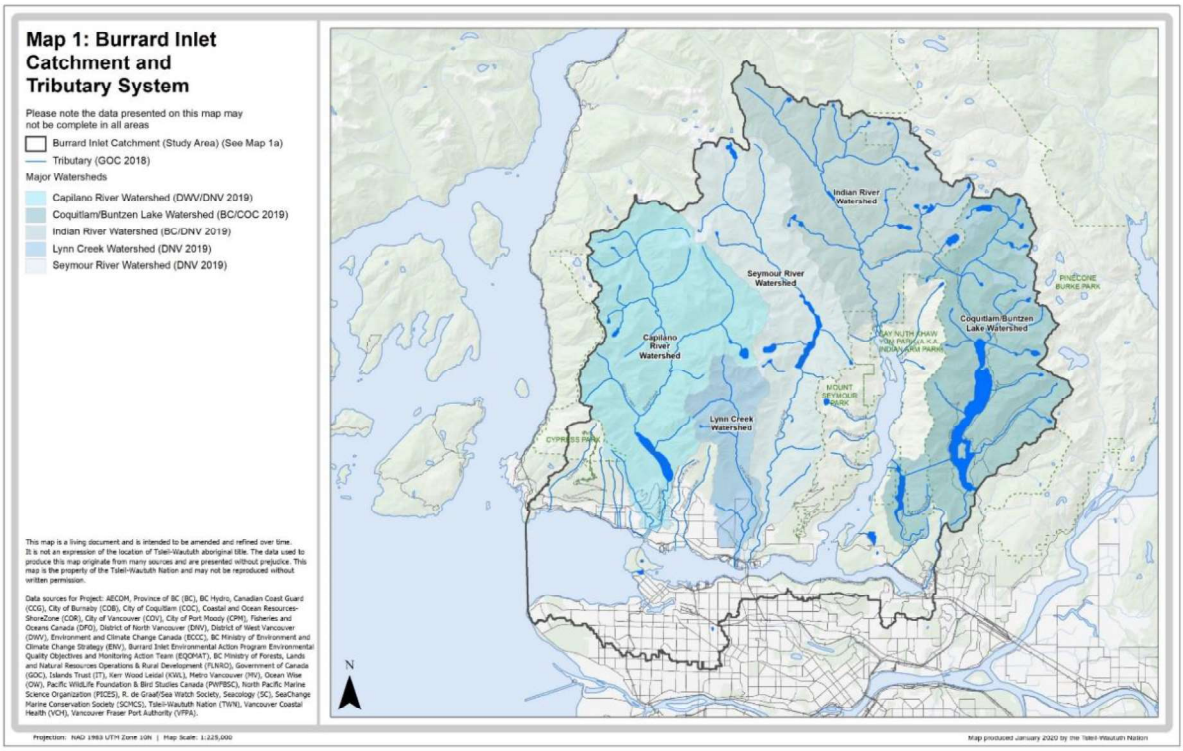


Figure 1. Burrard Inlet Catchment and Tributary System (from Rao et al. 2019).

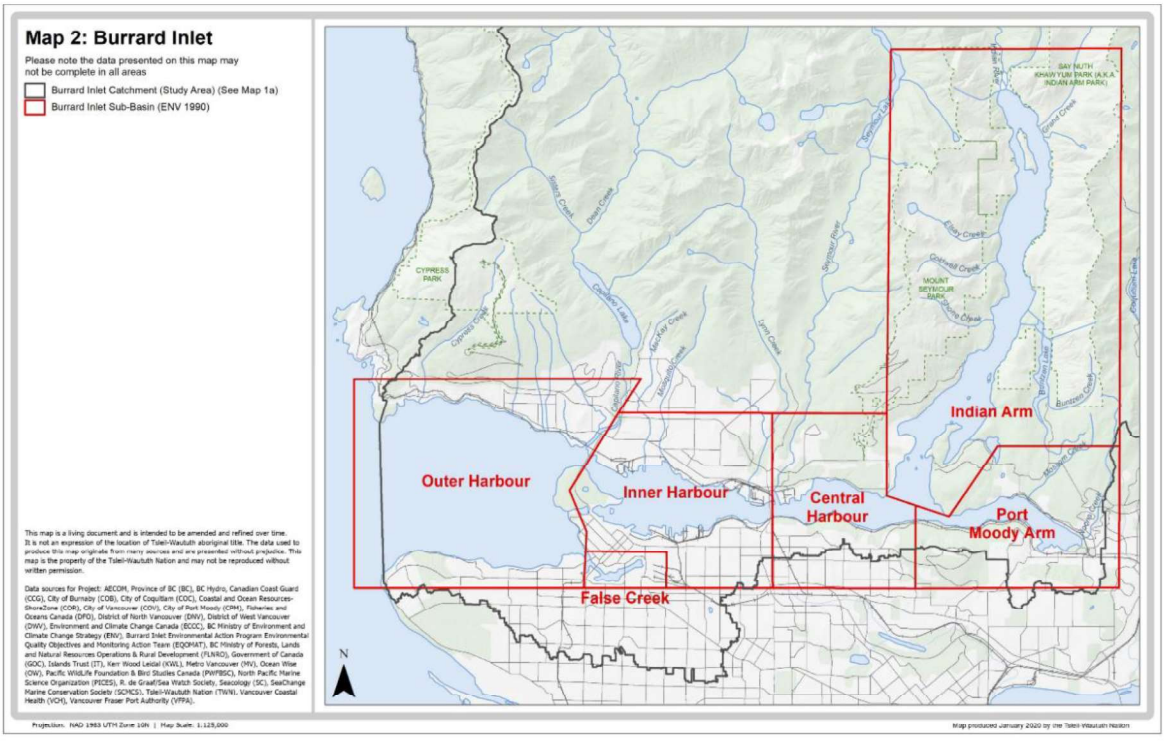


Figure 2. Burrard Inlet Sub-basins (from Rao et al. 2019).

4. WATER VALUES

The overall vision of the Burrard Inlet WQOs (as developed by the Burrard Inlet Water Quality Roundtable) is *to increase the benefits of Burrard Inlet to all in the region by reducing stressors and improving water quality while balancing ecological, social, economic, health, and First Nation cultural values*. TWN's Burrard Inlet Action Plan (TWN 2017) provides the basis for the water values identified for Burrard Inlet. Within the Action Plan, TWN envisions a productive, resilient, and diverse Burrard Inlet ecosystem where:

- healthy, wild foods can be harvested safely and sustainably.
- water and sediment are safe and clean for cultural, spiritual, ceremonial, and recreational activities; and
- high levels of biodiversity and healthy populations of key species are viable and continue to persist in the long term.

The water values to be protected in Burrard Inlet include:

- human consumption of shellfish;
- human consumption of finfish;
- aquatic life (including reproduction);
- wildlife (including reproduction);
- cultural practices and recreational uses; and
- institutional water uses.

These values (Table 1), and the short-term (by 2025) and long-term (by 2050) goals associated with each, were developed with consideration of each sub-basin's characteristics. For example, the water quality of False Creek and the Inner Harbour has been heavily impacted, limiting the extent to which they can be realistically improved in the short term. Conversely, the water quality in certain areas of Indian Arm can potentially support values such as shellfish consumption in the short term.

The long-term goals reflect TWN's aspiration to improve overall water quality and restore values and traditional uses throughout Burrard Inlet. The short-term goals reflect what may be attainable in a shorter time frame. Where appropriate, short-term and long-term WQOs will be set for water quality parameters based on the short-term and long-term goals for the most sensitive value for that parameter. In this way, all water values will be protected.

Although drinking water is a value that is often included among WQOs, it is not included here because drinking water sources in Burrard Inlet's tributaries are managed through Metro Vancouver's Drinking Water Management Plan and Drinking Water Conservation Plan.

It is important to note that WQOs are set for the ambient environment. Although in some instances they are set in consideration of the requirements to enable certain activities (e.g., swimming, shellfish consumption), they are not in themselves a statutory decision or statement about which activities are possible in which areas.

Table 1. Water values and goals for Burrard Inlet by sub-basin. The timeframe for short-term goals (S) is 2025, and 2050 for long-term goals (L).

Value	Outer Harbour		False Creek		Inner Harbour		Central Harbour		Port Moody Arm		Indian Arm	
	S	L	S	L	S	L	S	L	S	L	S	L
Human consumption of shellfish[1]		x		x		x		x		x	x	x
Human consumption of finfish	x	x	x	x		x	x	x	x	x	x	x
Aquatic life	x	x	x	x	x	x	x	x	x	x	x	x
Wildlife	x	x	x	x	x	x	x	x	x	x	x	x
Cultural/Recreation[2]	x	x	x[4]	x	x	x	x	x	x	x	x	x
Institutional uses[3]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

[1] The goal of shellfish consumption could potentially be reached via medium-term goals of enabling harvest from marginally affected areas according to recommended Canadian Shellfish Sanitation Program procedures.
[2] Cultural practices and recreational uses refer to primary contact activities such as bathing and swimming. Secondary contact activities could include canoeing, fishing, and boating.
[3] Institutional uses include industrial, commercial, and municipal intakes and discharges, as well as on-water uses such as shipping.
[4] The short-term goal is for secondary contact activities.

5. WATER QUALITY OBJECTIVES FOR BURRARD INLET

The update of the Burrard Inlet WQOs includes an extensive set of parameters of concern which are listed in Appendix 1 along with the status of the associated technical assessment report and appropriate references. This section summarizes the WQOs for specific parameters which have been updated. Additional summaries will be included as the technical reports are completed and approved.

The Burrard Inlet WQOs consider the updated parameters of concern identified in Rao et al. (2019). WQOs for parameters that are no longer of concern (e.g., barium) are not included while parameters with updated WQOs (e.g., cadmium) or new WQOs (e.g., microplastics) are included. WQOs for new parameters of concern (see Appendix 1) will be added as they are developed. The WQOs for freshwater tributaries to Burrard Inlet are in the process of being updated. B.C. WQGs for freshwater should be applied in the interim.

For some parameters, short-term, medium-term, and long-term WQOs are specified. The short-term WQOs are intended to prevent any further degradation of conditions while the medium- and long-term WQOs provide a goal for improvements. The WQOs always apply to all Burrard Inlet sub-basins, unless specified otherwise, with an overarching objective of decreasing trends in all contaminants in all media (water, sediment and tissue) over time.

5.1 Metals

5.1.1 Arsenic

Arsenic (As) levels in Burrard Inlet were reviewed, assessed, and fully discussed in Sanchez et al. (2022a). Screening benchmarks were defined to assess current conditions with respect to water, sediment, and tissue As concentrations and derive appropriate WQOs to protect water values.

Arsenic concentrations in water were well below the screening benchmark value of 12.5 µg/L and the 1990 WQO value of 10 µg/L in all basins. An updated WQO of 2.4 µg/L is based on 10 years of existing monitoring data from Metro Vancouver's Burrard Inlet Ambient Monitoring Program. The toxicity and

bioavailability of As depends on its chemical form and oxidation state. Trivalent species such as arsenite are more acutely toxic to aquatic organisms than pentavalent species like arsenate, and inorganic arsenic species are more toxic than organic species. Therefore, this WQO may be revised in the future pending further studies on As speciation in Burrard Inlet.

Sediment As concentrations exceeded the threshold effect level (TEL) of 7.24 µg/g dry weight (dw) in all basins; however, the most recent data showed results below this at sites in the Inner Harbour, Central Harbour, and Indian Arm. The probable effect level (PEL) of 42 µg/g dw was not exceeded.

Two screening benchmarks for concentrations of As in tissue were selected to capture a range of potential fishers, with the most sensitive receptor being an adult from a subsistence fishing population. A toddler from a subsistence fishing population was not considered for the tissue objective since As is a carcinogen, and the method used to derive the screening benchmark is based on lifetime (60 years) exposure to a carcinogen. The screening benchmarks also assume 10% of the total As to be inorganic As resulting in screening benchmarks of 0.0018 µg/g wet weight (ww) for an adult subsistence fisher and 0.0510 µg/g ww for an adult recreational fisher. Note that the screening benchmark for an adult subsistence fisher differs slightly from that reported in Sanchez et al. (2022a) due to updated toxicological information from Health Canada (2021). The available data showed liver, muscle, and whole-body English sole As concentrations, and blue mussel tissue As concentrations to be consistently higher than these benchmarks.

The As WQOs are listed in Table 2.

Table 2. Water quality objectives for arsenic in Burrard Inlet.

	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Water	2.4 µg/L mean[1]					
Sediment	7.24 µg/g dry weight single-sample maximum[2]					
Tissue	0.0018 µg/g wet weight single-sample maximum (all tissue types)[3]					

[1] Minimum of 5 samples in 30 days collected during the wet season. No more than 20% of samples > 2.4 µg/L.
[2] Based on at least 1 composite sample consisting of at least 3 replicates.
[3] Applies to all tissue types. Based on at least 1 composite sample consisting of at least 5 fish or 25 bivalves. Assumes that 10% of total arsenic is present as inorganic arsenic.

5.1.2 Cadmium

Cadmium (Cd) levels in Burrard Inlet were reviewed, assessed, and fully discussed in LeNoble et al. (2019). The current B.C. working water quality guideline (WWQG) for Cd to protect marine aquatic life (30-d mean concentration of 0.12 µg/L) was used in the assessment as it provides a better reflection of the current level of knowledge than the 1990 WQO (see Nijman and Swain 1990). A review of available monitoring data shows that concentrations are consistently below 0.12 µg/L in all basins except the Outer Harbour and False Creek. In the Outer Harbour, mean Cd concentrations were generally <0.12 µg/L with individual measurements occasionally exceeding this level prior to 2014. Mean and maximum Cd concentrations in False Creek were occasionally above 0.12 µg/L, but there are no data available after 2009.

Sediment data are limited but Cd concentrations are generally below the B.C. lower working sediment quality guideline (WSQG) of 0.7 µg/g dw (ENV 2021). The lower WSQG is a concentration that will protect aquatic life from the adverse effects of a toxic substance in most situations and is rarely associated with adverse biological effects and is therefore adopted as the sediment WQO for Burrard Inlet.

Cadmium concentrations may be naturally elevated in shellfish in the Pacific Northwest (Bendell 2009), therefore a tissue-based Cd WQO for included to protect human health. The limited data available suggest that the average Canadian consumer is not at risk; however, Cd levels in fish and shellfish may be of higher concern for Indigenous persons who regularly consume wild marine foods. The WQO is set at the screening value level of 0.03 µg/g ww to protect toddlers of a subsistence fishing population. Screening values for adults of a subsistence fishing population and a recreational fishing population are less stringent at 0.07 µg/g ww and 0.1 µg/g ww, respectively. Details on the derivation of screening values is provided in Thompson and Stein (2021) and Rao (2021). It should be noted that the screening values are based on assumed consumption rates, and fish and shellfish tissue may be safe for consumption at lower rates. Additional data are required to properly assess Cd concentrations in fish and shellfish tissue in Burrard Inlet.

The Cd WQOs are listed in Table 3.

Table 3. Water quality objectives for cadmium in Burrard Inlet.

	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Water	0.12 µg/L mean[1]					
Sediment	0.7 µg/g dry weight single-sample maximum[2]					
Tissue	0.03 µg/g wet weight single-sample maximum (all tissue types)[3]					

[1] Minimum of 5 samples in 30 days collected during the wet season. No more than 20% of samples > 1.2 µg/L.
[2] Based on at least 1 composite sample consisting of at least 3 replicates.
[3] Applies to all tissue types. Based on at least 1 composite sample consisting of at least 5 fish or 25 bivalves.

5.1.3 Copper

Copper (Cu) levels in Burrard Inlet were reviewed, assessed, and discussed in Rao et al. (2021a). Screening benchmarks of 0.3 µg/L and 1.3 µg/L, representing protection of 99% and 95% of aquatic species, respectively, were used to assess Cu data in the water column. Benchmarks for sediments were 18.7 µg/g dw (TEL) and 108 µg/g dw (PEL). Tissue benchmarks to assess risk to human health were 15 µg/g ww for toddler subsistence fishers, 30 µg/g ww for adult subsistence fishers, and 59 µg/g ww for adult recreational fishers.

The more recent water quality monitoring results show Cu concentrations are generally below 1.3 µg/L throughout Burrard Inlet while older measurements were much higher resulting from differences between the monitoring programs producing the data. The 1.3 µg/L level is consistent with the *Draft Recommended Environmental Quality Guidelines for the Protection of Southern Resident Killer Whales and their Prey* (ECCC 2021).

Total Cu concentrations in sediment exceeded the threshold effect level (18.7 µg/g dw) at all sites. Some samples from the location Outer Harbour North and all samples from Port Moody Arm and Indian Arm South also exceeded the higher probable effect level benchmark of 108 µg/g dw. The highest average concentrations were found in the Port Moody Arm, and the lowest concentrations in Indian Arm North.

Tissue Cu concentrations in English Sole and mussels were below the 15 µg/g ww benchmark at all sites.

The WQOs for Cu in the marine waters of Burrard Inlet are listed in Table 4 and apply to all sub-basins. The water and sediment objectives are set to protect marine aquatic life. The tissue objective is set to protect consumption of shellfish and finfish by humans.

Table 4. Water quality objectives for total copper in Burrard Inlet.

	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Water	1.3 µg/L mean[1]					
Sediment	18.7 µg/g dry weight single-sample maximum[2]					
Tissue	15 µg/g wet weight single-sample maximum (all tissue types)[3]					

[1] Minimum of 5 samples in 30 days collected during the wet season. No more than 20% of samples > 1.3 µg/L.
[2] Based on at least 1 composite sample consisting of at least 3 replicates.
[3] Applies to all tissue types. Based on at least 1 composite sample consisting of at least 5 fish or 25 bivalves.

5.1.4 Lead

Lead (Pb) levels in Burrard Inlet were reviewed, assessed, and discussed in Rao et al. (2021b). The B.C. WQGs for the protection of marine aquatic life (average of ≤2 µg/L and a maximum of 140 µg/L) were used as benchmarks to analyze existing water quality data. The B.C lower and upper WSQGs (30.2 µg/g and 112 µg/g, respectively) were used to assess sediment conditions. Human health screening values for toddler subsistence fishers (0.070 µg/g ww), adult subsistence fishers (0.16 µg/g ww), and adult recreational fishers (0.276 µg/g ww) (Thompson and Stein 2021) were used to assess the quality of fish and shellfish tissue. Note that some screening benchmarks differ slightly from those reported in Rao et al. (2021b) due to updated toxicological information from Health Canada (2021).

Past monitoring results showed Pb concentrations in water frequently above 2 µg/L in the water column throughout Burrard Inlet. More recent results (2007 – 2016) were consistently below the 2 µg/L benchmark at all sites.

Sediment Pb concentrations exceeded the lower benchmark of 30.2 µg/g at the locations Port Moody Arm and Indian Arm South, with the highest measurement of 67 µg/g taken at Indian Arm in 2011.

Fish tissue and shellfish data are limited. Fish muscle tissue appear to have met the screening values, but it should be noted that data are very limited and further monitoring should be conducted to confirm these results.

The WQOs for Pb in Burrard Inlet are listed in Table 5 and apply to all sub-basins. The water and sediment objectives are set to protect marine aquatic life. The tissue objective is set to protect consumption of shellfish and finfish by humans and applies to all tissue types.

Table 5. Water quality objectives for total lead in Burrard Inlet.

	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Water	2 µg/L mean[1]					
Sediment	30.2 µg/g dry weight single-sample maximum[2]					
Tissue	Short-term (by 2025): 0.16 µg/g wet weight single-sample maximum (all tissue types)[3]					
	Long-term (by 2040): 0.087 µg/g wet weight single-sample maximum (all tissue types)[3]					

[1] Minimum of 5 samples in 30 days collected during the wet season. No more than 20% of samples > 2 µg/L.
[2] Based on at least 1 composite sample consisting of at least 3 replicates.
[3] Applies to all tissue types. Based on at least 1 composite sample consisting of at least 5 fish or 25 bivalves.

5.1.5 Mercury

Mercury (Hg) levels in Burrard Inlet were reviewed, assessed, and discussed in Rao and LeNoble (2022). The Canadian Council of Ministers of the Environment (CCME) WQG of 0.016 µg/L for inorganic Hg (CCME 2003) was used as the screening benchmark for total Hg in water. This provides a more conservative benchmark given the inorganic fraction will always be less than or equal to the total fraction. Additionally, B.C.'s Hg WQG is based on methylmercury and this information is lacking for Burrard Inlet. The B.C. WSQGs of 0.13 µg/g dw (threshold effect level) and 0.70 µg/g dw (probable effect level) were used to assess sediment quality. Finally, human health screening values were calculated for various consumers ranging from 0.035 µg/g ww (subsistence fisher – toddler) to 0.324 µg/g ww (recreational fisher – adult). Note that some screening benchmarks differ slightly from those reported in Rao and LeNoble (2022) due to updated toxicological information from Health Canada (2021).

The screening benchmark for Hg in water was generally met in the most recent monitoring results analyzed, with exceedances occurring in 2012 at locations Outer Harbour, Inner Harbour, Port Moody Arm, and Indian Arm South.

Sediment Hg levels exceeded the threshold effect level benchmark (0.13 µg/g dw) in at least one sample at all stations except for Indian Arm North. This benchmark was also exceeded in every sample collected from both Port Moody Arm and Indian Arm South. The probable effect level benchmark of 0.7 µg/g dw was met in all samples collected.

The most recent tissue Hg data analyzed (2012) show that English sole whole-body and muscle samples met screening benchmarks, but liver tissue levels exceeded the toddler and wildlife benchmarks in some cases. Blue mussel tissue results (2015 and 2016) were all below all benchmarks. It should be noted that data are extremely limited, and more information would be required to properly assess conditions.

The Hg WQOs for Burrard Inlet are listed in Table 6. The WQOs for water and sediment are intended to protect aquatic life and wildlife, while the tissue WQOs are to protect wildlife and human consumers of finfish and shellfish.

Table 6. Water quality objectives for total mercury in Burrard Inlet.

	Outer Harbour	False Creek	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Water	0.016 µg/L mean[1]					
Sediment	0.13 µg/g dry weight single-sample maximum[2]					
Tissue	0.033 µg/g wet weight single-sample maximum[3]					

[1] Minimum of 5 samples in 30 days collected during the wet season.
[2] Based on at least 1 composite sample consisting of at least 3 replicates.
[3] Applies to all tissue types. Based on at least 1 composite sample consisting of at least 5 fish or 25 bivalves.

5.1.6 Nickel

Nickel (Ni) levels in Burrard Inlet were reviewed, assessed, and discussed in Rao et al. (2021c). The B.C. WWQG was used as the benchmark for assessing water quality for the protection of aquatic life (8.3 µg/L). The B.C. WSQGs were used as the benchmarks for assessing the risks of Ni in sediments to aquatic life: a lower WSQG of 30 µg/g dw and an upper WSQG of 50 µg/g dw. Tissue screening values for the protection of human health were calculated for toddler subsistence fishers (0.42 µg/g ww); adult subsistence fishers (0.83 µg/g ww), and adult recreational fishers (1.65 µg/g ww) (Thompson and Stein 2021).

The most recent monitoring results (2007 – 2016) show Ni concentrations in water are generally well below the aquatic life benchmark. Occasional single sample exceedances were observed at False Creek, Inner Harbour, Central Harbour, and Port Moody Arm.

Sediment Ni concentrations measured between 2008 and 2015 were variable between sites. Concentrations at Central Harbour and Indian Arm North were well below the lower WSQG value of 30 µg/g. At the Outer Harbour sites, concentrations were approaching the upper WSQG value of 50 µg/g and occasionally exceeded that benchmark. Concentrations in the Inner Harbour and Port Moody Arm fluctuated around the lower WSQG level with a few exceedances.

Nickel concentrations in English Sole were below the toddler subsistence fisher screening value at all sites. Mussel concentrations exceeded this benchmark in the Outer Harbour and Central Harbour; however, data are very limited and further monitoring is required for proper assessment.

The WQOs for Ni in the marine waters of Burrard Inlet are listed in Table 7 and apply to all sub-basins. The water and sediment objectives are set to protect marine aquatic life. The water objective is based on current conditions (see Rao et al. 2021c). The sediment objective is based on the lower WSQG. The tissue objective is set to protect consumption of shellfish and finfish by humans and is set at the screening value level for toddler subsistence fishers.

Table 7. Water quality objectives for total nickel in Burrard Inlet.

	Outer Harbour	False Creek	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Water	0.8 µg/L mean[1]					
Sediment	30 µg/g dry weight single-sample maximum[2]					
Tissue	0.42 µg/g wet weight single-sample maximum[3]					

[1] Minimum of 5 samples in 30 days collected during the wet season.
[2] Based on at least 1 composite sample consisting of at least 3 replicates.
[3] Applies to all tissue types. Based on at least 1 composite sample consisting of at least 5 fish or 25 bivalves.

5.1.7 Zinc

Zinc (Zn) levels in Burrard Inlet were reviewed, assessed, and discussed in Rao et al. (2021d). The current B.C. WQGs for Zn (10 µg/L average and 55 µg/L maximum) were used to assess current conditions in the water column. The B.C. lower and upper WSQGs (124 µg/g and 271 µg/g, respectively) were used to assess sediment conditions. Tissue screening values were calculated to assess risks to human health as described in Thompson and Stein (2021). Toddlers from a subsistence fishing population were identified as the most sensitive receptors (17 µg/g ww).

The most recent monitoring results showed average total Zn concentrations in water were generally below the chronic guideline level with individual samples occasionally above 10 µg/L. Older data show frequent exceedances of the acute WQG with concentrations up to 270 µg/L.

Monitoring results show Zn sediment concentrations were generally below the lower WSQG level, although exceedances are noted (e.g., Port Moody Arm).

Except for Metro Vancouver English Sole liver tissue samples, Zn levels in tissue were well below the screening benchmarks for adults from both recreational and subsistence fishing populations, and rarely exceeded the screening benchmark for toddlers from a subsistence fishing population.

The WQOs for Zn in the marine waters of Burrard Inlet are listed in Table 8 and apply to all sub-basins. The water and sediment objectives are set to protect marine aquatic life. The tissue objective is set to protect consumption of shellfish and finfish by humans.

Table 8. Water quality objectives for total zinc in Burrard Inlet.

	Outer Harbour	False Creek	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Water	10 µg/L mean[1]					
	55 µg/L – maximum					
Sediment	124 µg/g dry weight single-sample maximum[2]					
Tissue	17 µg/g wet weight single-sample maximum[3]					

[1] Minimum of 5 samples in 30 days collected during the wet season.
[2] Based on at least 1 composite consisting of at least 3 replicates.
[3] Applies to all tissue types. Sample Based on at least 1 composite sample consisting of at least 5 fish or 25 bivalves.

5.2 Microbiological Indicators

Microbiological indicators are used to indicate the potential presence of pathogens and risks to human health. Waterborne pathogens are a common source of a wide variety of diseases which can infect humans either through skin contact or ingestion. Current analytical methods do not allow for fast or economical monitoring of all potential human pathogens. For this reason, indicator species or groups of species are commonly used as a surrogate for microbiological water quality to assess risks to human health. Microbiological indicator levels in Burrard Inlet were reviewed, assessed, and fully discussed in LeNoble et al. (2021).

The updated WQOs for microbiological indicators reflect current B.C. and Health Canada guidelines for recreational water quality (ENV 2019, Health Canada 2012), and Canadian Shellfish Sanitation Program requirements for shellfish harvest areas (CFIA 2020). They apply year-round to protect shellfish harvesting, other cultural practices, and recreational use in consideration of current impacts and uses, anticipated availability of management options, and Tsleil-Waututh Nation's Burrard Inlet recovery goals.

WQOs are included for fecal coliforms, *Escherichia coli* (*E. coli)*, and enterococci. The addition of *E. coli* as an indicator recognizes that *E. coli* was selected as the preferred indicator by Metro Vancouver and health authorities for recreational water quality monitoring. Enterococci are included as the indicator recommended by both ENV and Health Canada for marine waters. An objective for fecal coliform has also been retained as a "legacy objective" and because of its continued use in some jurisdictions and monitoring programs, including the Canadian Shellfish Sanitation Program.

Microbiological indicator concentrations in all sub-basins, except for Indian Arm, frequently exceed levels to allow shellfish harvesting; shellfish harvesting in Burrard Inlet has been closed since 1972 due to contamination. Most results meet the primary recreational contact guidelines in all sub-basins except False Creek where the guidelines are exceeded throughout the area. For this reason, a phased approach was developed with short-term WQOs (Table 9) to be protective of secondary contact only for False Creek. In Indian Arm, the short-term objective aims to protect the food, social, and ceremonial shellfish harvest already occurring in a portion of this sub-basin and to possibly expand areas in Indian Arm available for harvest. This WQO also recognizes that Indian Arm could potentially be used to depurate bivalve shellfish harvested in other sub-basins prior to consumption. The WQO for False Creek recognizes that the current condition of False Creek does not meet conditions suitable for primary contact and that the current management objective of the City of Vancouver and Vancouver Coastal Health is to protect non-immersive (i.e., secondary contact) uses.

Table 9. Short-term (2021 – 2025) water quality objectives for microbiological indicators in Burrard Inlet.

<table>
<tr><th rowspan="2">Parameter</th><th rowspan="2">Value</th><th colspan="6">Sub-basin</th></tr>
<tr><th>False Creek</th><th>Outer Harbour</th><th>Inner Harbour</th><th>Central Harbour</th><th>Port Moody Arm</th><th>Indian Arm</th></tr>
<tr><td>Fecal coliform (MPN/100 mL)</td><td>Shellfish consumption</td><td colspan="5">Not applicable</td><td>≤14 (median); ≤10% of results >43</td></tr>
<tr><td>E. coli (CFU or MPN/100 mL)</td><td>Recreation and cultural practices</td><td>≤1,000 (geometric mean)[1,2]</td><td colspan="5">≤200 (geometric mean)[1,3]
≤400 (maximum)[3,4]</td></tr>
<tr><td>Enterococci (MPN/100 mL)</td><td>Shellfish consumption</td><td colspan="5">Not applicable</td><td>≤4 (median); ≤11 (90th percentile)</td></tr>
<tr><td>Enterococci (CFU or MPN/100 mL)</td><td>Recreation and cultural practices</td><td>≤175 (geometric mean)[1,2]</td><td colspan="5">≤35 (geometric mean)[1,3]
≤70 (maximum)[3,4]</td></tr>
<tr><td colspan="8">[1]Using at least 5 weekly samples collected in a 30-day period.
[2]To protect secondary contact activities only (Health Canada 2012).
[3]To protect both primary and secondary contact activities (ENV 2019).
[4]Single sample maximum allowable concentration.</td></tr>
</table>

The medium-term WQOs (Table 10) represent water quality suitable for shellfish harvesting in four of the six sub-basins—the Outer Harbour, Central Harbour, Port Moody Arm, and Indian Arm—and for primary contact activities in False Creek and the Inner Harbour. The selection of WQOs was informed by the range of microbiological indicator levels measured, the observed exceedances of shellfish harvesting benchmarks since 2007, and the frequency of microbiological indicator levels that are an order of magnitude or more above the shellfish harvesting benchmarks.

Table 10. Medium-term (2025 – 2050) water quality objectives for microbiological indicators in Burrard Inlet.

Parameter	Value	Sub-basin					
		False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Fecal coliform (MPN/100 mL)	Shellfish consumption	Not applicable	≤14 (median); ≤10% of results >43	Not applicable	≤14 (median); ≤10% of results >43		
E. coli (CFU or MPN/100 mL)	Recreation and cultural practices	≤200 (geometric mean)[1,2] ≤400 (maximum)[2,3]					
Enterococci (MPN/100 mL)	Shellfish consumption	Not applicable	≤4 (median); ≤11 (90th percentile)	Not applicable	≤4 (median); ≤11 (90th percentile)		
Enterococci (CFU or MPN/100 mL)	Recreation and cultural practices	≤35 (geometric mean)[1,2] ≤70 (maximum)[2,3]					

[1]Using at least 5 weekly samples collected in a 30-day period.
[2]To protect both primary and secondary contact activities (ENV 2019).
[3]Single sample maximum allowable concentration.

The long-term WQOs (Table 11) are based on a long-term recovery goal to reopen shellfish harvesting in all sub-basins of Burrard Inlet. Any future approvals of shellfish harvesting areas will be dependent on the success of measures taken to reduce microbiological pollution, among other criteria. The data assessment showed that benchmark exceedances occur more frequently in the winter when the region receives the most rainfall (LeNoble et al. 2021). This suggests that timelines for the elimination of combined sewer overflows (CSOs) and wet weather planning will be key components for achieving desired water quality improvements. The timeline for meeting the long-term WQOs was set to align with Metro Vancouver's commitment to eliminate CSOs by 2050.

Attainment of these WQOs alone may not be sufficient to protect human health. Decisions on swimming and shellfish harvest area approvals are made by the relevant health authorities and the Canadian Shellfish Sanitation Program, respectively, considering microbiological indicator monitoring results, other potential pollutants, information on pollution sources, and other factors.

Pathogenic risk assessments may require additional monitoring beyond the microbiological indicators outlined in these WQOs; however, the WQOs consider the best available science and data for health outcomes and provide a relevant measure of microbiological water quality for the marine environment and designated values in Burrard Inlet.

Table 11. Long-term (2050 – onwards) water quality objectives for microbiological indicators in Burrard Inlet.

Parameter	Value	Sub-basin					
		False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Fecal coliform (MPN/100 mL)	Shellfish consumption	≤14 (median); ≤10% of results >43					
E. coli (CFU or MPN/100 mL)	Recreation and cultural practices	≤200 (geometric mean)[1,2] ≤400 (maximum)[2,3]					
Enterococci (MPN/100 mL)	Shellfish consumption	≤4 (median); ≤11 (90th percentile)					
Enterococci (CFU or MPN/100 mL)	Recreation and cultural practices	≤35 (geometric mean)[1,2] ≤70 (maximum)[2,3]					

[1]Using at least 5 weekly samples collected in a 30-day period.
[2]To protect both primary and secondary contact activities (ENV 2019).
[3]Single sample maximum allowable concentration.

5.3 Microplastics

Microplastics (MPs) are plastic waste particles smaller than 5 mm and made of organic polymers derived from petroleum products, including polyvinylchloride, low density polyethylene, nylon, polystyrene, polyethylene, and polypropylene. MP levels in Burrard Inlet were reviewed, assessed, and fully discussed in Braig et al. (2019a).

Due to their small size, MP particles can be ingested by various marine organisms potentially causing both physical and chemical adverse effects. There are three mechanisms by which MPs can present significant risks to marine biota:

- physical interactions, such as ingestion of plastics;
- indirect toxicity through release of toxic additives or bound chemicals; and
- as a vector for pathogenetic microorganisms and parasites.

Sources of MP pollution into Burrard Inlet include personal care products, marine coatings, plastic pellets, vehicle tires, road markings, fibres from synthetic textiles and plastic shoreline waste. Treatment at the Annacis Island wastewater treatment plant was found to remove approximately 92% of MP particles prior to discharge, with fibres being the dominant form of MP in the discharged effluent. In marine sediments, higher concentrations of MPs were associated with urban development, with fibres and fragments being the most dominant types. In Burrard Inlet mussels, fibres and fragments were also observed to be the most common MP types. MPs in Burrard Inlet were also found to provide sorption sites for lead, cadmium, copper, and zinc (Braig et al. 2019a).

Water quality benchmarks for the protection of marine life are not available for MPs, and the toxicological information currently available and the data specific to Burrard Inlet are limited. Therefore, the WQOs for MPs, listed in Table 12, are general in nature and should be considered interim until additional information is available. Monitoring of MPs in sediment, water, and biota is recommended for Burrard Inlet, with year-round sampling to account for potential seasonal variability in MP abundance associated with variations in wastewater treatment plant discharges and plastic use. Until marine-relevant toxicity data are

available, management priorities should be source control and monitoring, with the goal of reducing concentrations of MPs in water, sediment, and biota over time.

Table 12. Water quality objectives for microplastics in Burrard Inlet.

	Short Term (to 2025)	Long Term (to 2050)
Water	No increase from current levels.	Decrease from current levels.
Sediment		
Tissue		

5.4 Persistent Organic Pollutants

5.4.1 PCBs, PCDDs, and PCDFs

The persistent organic pollutants polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs or dioxins), and polychlorinated dibenzofurans (PCDFs or furans) were reviewed, assessed, and fully discussed in Sanchez et al. (2022b).

PCBs, PCDDs and PCDFs are three structurally related classes of persistent organic pollutants that are almost exclusively derived from anthropogenic activities, bioaccumulate in the marine food web, and are toxic to wildlife and humans. PCBs have been identified as the contaminant of greatest concern for Southern Resident Killer Whales. PCDDs and PCDFs are endocrine disruptors, and the most toxic congener, 2,3,7,8-tetrachlorodibenzo-para-dioxin (2,3,7,8-TCDD), is carcinogenic.

Although banned for decades, PCBs, PCDDs, and PCDFs continue to persist in the environment. Current sources include leaching from improper waste disposal and aging equipment, long-range atmospheric transport, combined sewer overflows, and urban runoff. Due to their hydrophobicity, they tend to settle into sediments and can accumulate in fish and mammals. Humans are exposed through diet, with a disproportional risk to Indigenous peoples, relative to other populations, due to subsistence fishing (Sanchez et al. 2022b).

PCB, PCDD and PCDF levels exceeded sediment and tissue benchmarks throughout Burrard Inlet. Note that some screening benchmarks differ slightly from those reported in Sanchez et al. (2022b) due to updated toxicological information from Health Canada (2021). Interim WQOs for PCBs, PCDDs, and PCDFs in water are in place until more information becomes available; these WQOs will be useful for characterizing waste discharges and assessing contaminated sites. Sediment and tissue WQOs are intended to protect aquatic life, including apex predators. The tissue objectives are also considered protective of Indigenous consumers of seafood.

The WQOs for PCBs, PCDDs and PCDFs are listed in Table 13. The WQOs for the water are interim values pending improvements in laboratory method detection limits. In addition to the numerical WQOs listed, an overall narrative WQO of decreasing concentrations of PCBs, PCDDs, and PCDFs over time is included.

Table 13. Polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs) water quality objectives (WQO) for the marine waters of Burrard Inlet.

Sub-basin	Outer Harbour	False Creek	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Water						
Total PCBs (interim WQO)	6.2×10^{-4} ng/L single sample maximum[1]					
2,3,7,8-TCDD[2] (interim WQO)	5.1×10^{-6} ng/L single sample maximum[3]					
Sediment						
Total PCBs in Sediment	3.7×10^{-6} µg/g dry weight single-sample maximum[4,5]					
Total PCDDs and PCDFs in Sediment	8.5×10^{-7} µg/g dry weight single sample maximum[4,5]					
Tissue						
Total PCBs in Tissue	3.47×10^{-4} µg/g wet weight single-sample maximum[4,6]					
Total PCDDs, PCDFs, and Dioxin-like PCBs in Tissue	8.0×10^{-8} µg/g wet weight single-sample maximum[6,7]					
All						
All PCBs, PCDDs and PCDFs in all media	Decreasing trend in concentrations					

[1]See Sanchez et al. (2022b) for details.
[2]2,3,7,8-tetrachlorodibenzo-*p*-dioxin, the most toxic of the PCDDs and PCDFs.
[3]Adopted from US EPA (2002).
[4]Adopted from ENV (2021).
[5]Based on at least 1 composite sample consisting of at least 3 replicates.
[6]Applies to all tissue types. Based on at least 1 composite sample consisting of at least 5 fish or 25 bivalves. [7]PCDDs, PCDFs, and dioxin-like PCBs are assessed by converting their concentrations to units of 2,3,7,8-TCDD toxic equivalence using toxic equivalency factors applied to human health (see Sanchez et al. 2022b).

5.5 Pharmaceuticals and Personal Care Products

Pharmaceuticals and personal care products (PPCPs) in Burrard Inlet were reviewed, assessed, and fully discussed in Braig et al. (2019b). PPCPs were grouped into the following classes:

- Analgesics
- Antimicrobials
- Antihypertensives
- Antihistamines
- Selective Serotonin Reuptake Inhibitors (SSRIs)
- Stimulants/recreational drugs/personal care products
- Hormones

Sources of PPCPs are entirely anthropogenic and usually released into the marine environment via sewage from municipal sources, illegal sewage release from marine vessels, and combined sewer overflows. Aquaculture and agriculture waste and run-off and leachate from landfills are also sources, but not relevant to Burrard Inlet. The main source of PPCPs in Burrard Inlet is municipal sewage discharges.

When PPCPs reach the receiving marine environment, photodegradation, biodegradation and other abiotic transformation processes, such as hydrolysis, occur and may reduce their concentrations. PPCPs can also be transported within the marine environment depending on their physico-chemical properties and environmental factors (e.g., pH, temperature, and the amount of sunlight exposure).

Since PPCPs are active molecules with target receptors in most vertebrates, their presence in the environment is highly concerning. To date, PPCP concentrations measured in Burrard Inlet waters are below the acute and chronic toxicity thresholds found in the literature. These thresholds are derived from acute exposure experiments, however, and likely do not reflect environmentally relevant low dose chronic exposures or the potential for toxicity from complex mixtures of PPCPs through additive, synergistic and antagonistic interactions. Measured PPCPs concentrations in Burrard Inlet waters and sediments are listed in Tables 14 and 15, respectively. Information on PPCPs in Burrard Inlet biota was not available at the time of writing.

Water quality benchmarks for the protection of marine life were not found for the PPCPs detected in Burrard Inlet and the toxicological information currently available is insufficient to establish specific numerical marine WQOs. Until marine-relevant toxicity data are available, management priorities should be source control and monitoring, with the goal of reducing concentrations of PPCPs in water, sediment, and biota over time. Therefore, general WQOs for PPCPs have been set and are listed in Table 16.

Sampling for PPCPs in Burrard Inlet has been limited. Monitoring recommendations are provided in Braig et al. (2019b) to guide future monitoring efforts and inform the development of numerical PPCP WQOs for Burrard Inlet. Monitoring for PPCPs in Burrard Inlet should continue to support the assessment of spatial and temporal trends in both background and impacted sites, and to develop appropriate numerical WQOs for PPCPs.

Table 14. Minimum and maximum PPCP concentrations measured in Burrard Inlet seawater (see Braig et al. 2019b).

Compound	Class	Minimum Concentration (µg/L)	Maximum Concentration (µg/L)
Acetaminophen	Analgesic	0.143	0.182
Naproxen	Analgesic	0.00698	0.00929
Clarithromycin	Antimicrobial	0.0034	0.00574
Ciprofloxacin	Antimicrobial	<0.00565	0.00624
Erythromycin-H2O	Antimicrobial	0.000524	0.000608
Desmethyldiltiazem	Antihypertensive (metabolite)	0.000161	0.000214
Diltiazem	Antihypertensive	0.00059	0.000622
Diphenhydramine	Antihistamine	0.000657	0.000698
Benzoylecgonine	Recreational drug (metabolite)	0.00325	0.00331
Cocaine	Recreational drug	0.000785	0.000988
N,N-Diethyl-meta-toluamide (DEET)	Personal care product	0.00218	0.00381
Caffeine	Stimulant	0.0989	0.179
1,7-dimethylxanthine	Stimulant	<0.0565	0.0705

Table 15. Minimum and maximum PPCP concentrations measured in Burrard Inlet sediments (see Braig et al. 2019b).

Compound	Class	Minimum Concentration (µg/L)	Maximum Concentration (µg/L)
Clarythromycin	Antimicrobial	1.36	1.58
Erythomycin-H20	Antimicrobial	0.263	0.554
Miconazole	Antimicrobial	1.39	1.73
Norverapamil	Antihypertensive	0.134	0.269
Verapamil	Antihypertensive	0.136	0.201
Diphenhydramine	Antihistamine	0.942	1.76
N,N-Diethyl-meta-toluamide (DEET)	Personal Care Product	0.622	1.18
Triclocarban	Personal Care Product	9.06	15.6
Cocaine	Recreational Drug	<0.123	0.27
Amphetamine	Stimulant	2.86	2.99
Sertraline	SSRI	0.354	0.453

Table 16. Water quality objectives for PPCPs in Burrard Inlet.

	Short Term (to 2025)	Long Term (to 2050)
Water	No increase from current levels.	Decrease from current levels.
Sediment		
Tissue		

5.6 Polybrominated Diphenyl Ethers

Levels of polybrominated diphenyl ethers (PBDEs) in Burrard Inlet were reviewed, assessed, and fully discussed in Braig et al. (2021a), including a description of the benchmarks used to assess current conditions. PBDEs are a class of anthropogenic organobromine compounds used as flame retardant additives in various materials such as plastics and rubber. They are persistent, bioaccumulative, and toxic to both humans and aquatic life. PBDEs can undergo long-range global atmospheric transport and biomagnify in the food chain, affecting aquatic life and apex predators. Wastewater treatment plant effluent and combined sewer overflows are also potential sources of PBDEs to Burrard Inlet.

Burrard Inlet data showed that BDE-47 (tetra-BDE), BDE-99 (penta-BDE), BDE-100 (penta-BDE), and BDE-209 (deca-BDE) were the dominant congeners in sediment samples. Total PBDE concentrations were above the BC Working Sediment Quality Guideline of 1 ng/g dw in most samples with the highest concentrations found in the Inner Harbour, Outer Harbour, and Port Moody Arm.

In fish tissue, BDE-47, BDE-99, and BDE-100 were the congeners found in the highest concentrations. Concentrations of total tetra- and penta-BDEs were above the homologue-specific benchmark values in most samples. In both fish and mussel tissue samples, tetra-BDEs were found at the highest concentrations. PBDE levels in English Sole were highest at the Outer Harbour and Inner Harbour sites, with some elevated concentrations in the Port Moody area. For mussel tissue, PBDE levels were highest in the Outer Harbour, Central Harbour, and Inner Harbour sites, but at least one order of magnitude lower than in fish tissue samples. Mussel tissue samples were below the benchmarks for all homologue groups.

The PBDE WQOs for the marine waters of Burrard Inlet are listed in Table 17. Additional benchmarks are included to support the assessment of risks to other values, beyond the value most sensitive to each

homologue. Objectives for the water column are for the protection of marine aquatic life. The sediment objective represents the concentration that will protect higher trophic level aquatic life (e.g., killer whales) from the adverse effects of PBDEs. The fish tissue objectives specify the concentrations in whole-body fish tissue (wet weight) which is not expected to cause adverse effects to the fish. The wildlife diet objectives specify the PBDE concentrations in whole food (wet weight) which is not expected to cause adverse effects to wildlife consumers. The human health screening values represent the potential risk to human health and apply to all tissue types (e.g., fish muscle, bivalves, crustaceans). The screening values shown in the table are for the most sensitive receptors, namely toddlers from a subsistence fishing population. Screening values for adult consumers are provided in Braig et al. (2021a, Appendix A). In addition to these numerical objectives, a general objective for a decreasing trend in PBDE concentrations in all media is included.

Table 17. Polybrominated diphenyl ether (PBDE) water quality objectives (values in bold print) for the marine waters of Burrard Inlet.

Homologue	Congener	Water[1] (ng/L)	Sediment[2] (ng/g dry weight)	Fish Tissue[3] (ng/g wet weight)	Wildlife Diet[4] (ng/g wet weight food source)	Human Health Screening Value (ng/g wet weight)[5]
Tri-BDE	Total	**46**		**120**		
Tetra-BDE	Total	**24**		88	**44**	
Tetra-BDE	BDE-47					**4**
Penta-BDE	Total	**0.2**		**1**	3 (mammal) 13 (birds)	70
Penta-BDE	BDE-100	**0.2**		**1**		
Hexa-BDE	Total	**120**		420	**4**	
	BDE-153					7
Hepta-BDE	Total	**17**			**64**	
Octa-BDE	Total	**17**			**63**	105
Nona-BDE	Total				**78**	
Deca-BDE	Total				**9**	
Total PBDEs			**1**			

[1] Based on a minimum of 5 surface samples in 30 days collected during the wet season.
[2] Based on a minimum of 1 composite sample composed of at least 3 replicates.
[3] The concentration not expected to cause adverse effects to the fish, based on a whole-body composite sample consisting of at least 5 individual fish.
[4] The concentration in whole food not expected to cause adverse effects to wildlife consumers, based on a whole-body composite sample consisting of at least 5 individual fish or 25 bivalves.
[5]The concentration not expected to cause adverse effects to human consumers, based on a composite sample consisting of at least 5 individual fish or 25 bivalves.

5.7 Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbon (PAH) levels in Burrard Inlet were reviewed, assessed, and fully discussed in Braig et al. (2021b), including a description of the benchmarks used to assess current conditions. PAHs are a large and diverse group of substances consisting of hydrogen, carbon, and two or more aromatic rings. They are grouped into low molecular weight PAHs (≤3 aromatic rings) and high molecular weight PAHs (≥4 aromatic rings). Low molecular weight PAHs are more water soluble than high molecular weight PAHs and are generally more bioavailable. This variation in structure results in diverse physical and chemical properties, which in turn determine the fate and effects of PAHs in marine systems.

PAHs are formed in petroleum and coal deposits, and from the incomplete combustion of organic matter, such as forest fires, vehicle exhaust, and industrial emissions. Most PAHs are classified as persistent organic pollutants and can cause carcinogenic and non-carcinogenic effects in biological systems. Limited studies on the health effects in humans suggest that fish and shellfish consumption may pose health risks including endocrine disruption, cancer, and decreased birth rates.

Recent monitoring results indicate PAH levels in Burrard Inlet are a concern with respect to aquatic life and human health. In 2001, limited water column measurements showed occasional exceedances of the benzo(a)pyrene and chrysene benchmarks in Port Moody Arm and False Creek. More recent monitoring results to 2015 were below detection limits.

Sediment PAH concentrations exceeded benchmark levels in all sub-basins for all PAHs except total benzofluoranthenes. Concentrations at monitoring sites in the Inner Harbour, Outer Harbour, and Port Moody Arm frequently exceeded the benchmarks for priority PAH compounds. The north Indian Arm site had the lowest PAH concentrations, possibly because it is geographically removed from many PAH sources.

Tissue PAH concentrations were below the screening values; however, data are very limited and further information is required for proper assessment.

PAH objectives for Burrard Inlet are listed in Table 18. The water and sediment objectives are set to protect marine aquatic life. The tissue objectives are set to protect consumption of shellfish and finfish by individuals from a subsistence fishing population. Note that some screening benchmarks differ slightly from those reported in Braig et al. (2021b) due to updated toxicological information from Health Canada (2021). The benzo(a)pyrene WQO provides a benchmark to evaluate exposures to mixtures of carcinogenic PAHs by totaling their measured concentrations adjusted according to their toxic equivalency factors (Health Canada 2021) as listed in Table 19. For example:

> In a fish or shellfish tissue sample with the following PAH concentrations:
>
> - Benzo(a)pyrene concentration – 1 µg/g
> - Benzo(k)fluoranthene – 4 µg/g
> - Chrysene – 5 µg/g
> - Phenanthrene – 6 µg/g
>
> the benzo(a)pyrene toxic equivalency concentration would be:
>
> 1 + (4 x 0.1) + (5 x 0.01) + (6 x 0.001) = 1.456 µg/g
>
> which exceeds the benzo(a)pyrene WQO in tissue (see Thompson and Stein (2021) for details).

In addition to these numeric WQOs, an overall objective of a decreasing trend in PAH concentrations in all media is included.

Table 18. Polycyclic aromatic hydrocarbon (PAH) water quality objectives for the marine waters of Burrard Inlet.

PAH	Water Quality Objectives (all sub-basins)
Water (µg/L, average)[1]	
Acenaphthene	6
Benzo(a)pyrene	0.01
Chrysene	0.1
Fluorene	12
Naphthalene	1
Sediment (µg/g dry weight, maximum for a single composite sample)[2]	
Acenaphthene	0.00671
Anthracene	0.0469
Benzo(a)pyrene	0.088
Total Benzofluoranthenes[3]	2.3
Chrysene	0.108
Fluoranthene	0.113
Fluorene	0.0212
Naphthalene	0.0346
2-methylnaphthalene	0.02
Phenanthrene	0.0867
Pyrene	0.153
Tissue (µg/g wet weight, maximum for a single composite sample) [4]	
Benzo(a)pyrene[5]	0.0025

[1] Based on a minimum of 5 surface samples in 30 days collected during the wet season.
[2] Based on a minimum of 1 composite sample composed of at least 3 replicates.
[3] This objective applies to the sum of all benzofluoranthenes. Concentrations are expressed in terms of sediment containing 1% organic carbon. Adjustments to guidelines are required with different organic carbon content.
[4] Based on a composite sample consisting of at least 5 individual fish or 25 bivalves. [5] The benzo(a)pyrene WQO provides a benchmark to evaluate exposures to mixtures of carcinogenic PAHs by totaling their measured concentrations adjusted according to their potency equivalence factors (Health Canada 2021). See text and Table 19 for details.

Table 19. Benzo(a)pyrene toxic equivalency factors for carcinogenic polycyclic aromatic hydrocarbons (PAHs) (Health Canada 2021).

Carcinogenic PAH	Toxic Equivalence Factor
Anthracene	0.1
Benzo(a)pyrene	1
Benzo(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(g,h,i)perylene	0.01
Benzo(k)fluoranthene	0.1
Chrysene	0.01
Dibenzo(a,h)anthracene	1
Fluoranthene	0.001
Indeno(1,2,3-cd)pyrene	0.1
Phenanthrene	0.001

5.8 Physical Parameters

Physical water quality parameters in Burrard Inlet were reviewed, assessed, and fully discussed in Bjorklund et al. (2024). The physical parameters assessed include temperature, salinity, dissolved oxygen (DO), pH, total suspended solids, and turbidity.

The most sensitive value to changes in physical parameters is aquatic life. Changes in temperature impact almost every physical property of seawater, and shifts can have detrimental effects on the growth and survival of aquatic species. Changes to salinity may impact the structure of communities and distribution of species. A decrease in dissolved oxygen can have both sublethal and lethal effects in a variety of organisms. Changes in pH can directly impact some organisms and have secondary effects on many others. Increased suspended solids concentrations and turbidity can reduce the primary production of phytoplankton, resulting in impacts to other organisms and their habitats.

While global climate change is the major anthropogenic factor influencing physical parameters in marine waters, local anthropogenic activities related to land use and development can also have an effect. Natural processes that affect levels of physical parameters in Burrard Inlet include water column stratification (salinity and temperature driven), freshwater inputs, winds, and tides and currents.

Sensor-based data were collected during cruises performed by TWN in 2018 – 2020, with technical and data management support from Ocean Networks Canada. Existing B.C. Water Quality Guidelines and Washington State Water Quality Standards for Surface Waters for marine and/or estuarine aquatic life were used as screening benchmarks.

Water temperatures in Burrard Inlet are characterized by uniform temperatures throughout the water column in winter, and a stratified water column in all sub-basins in spring, summer, and fall, with the highest surface temperatures in Port Moody Arm and Indian Arm. The Outer Harbour is most influenced by the Fraser River, with more variable summer surface temperatures than other sub-basins. Historical data collected by DFO (DFO, 2009) shows that deep water temperatures in Indian Arm increased by 1.5 °C when comparing 1950s – 1970s to post-1980s levels. Compared to the Water Quality Standards for Surface Waters of the State of Washington, observed maximum water temperatures in Burrard Inlet reach “extraordinary” (≤ 13°C) or “excellent” (13-16°C) quality in all sub-basins in fall, winter, and spring. During summer, maximum surface temperatures in Indian Arm, Port Moody, and Outer Harbour fall into the most impaired temperature category and are classified as “fair” (≥ 19°C), while surface temperatures in Central Harbour and Inner Harbour are of “good” quality (16-19°C).

Salinity is measured as a ratio of measured conductivity to a standard potassium chloride solution conductivity and is therefore dimensionless (no units). The salinity in Burrard Inlet typically ranges between 15 and 30, whereas the average global ocean salinity is 35. Salinity in Burrard Inlet is generally low and highly variable due to seasonal variations in precipitation and freshwater inputs. Surface salinities increase toward the seaward entrance due to exchange with water from the Strait of Georgia. The seasonal trends in the Outer Harbour are affected by the Fraser River, with lowest salinity observed during freshet. Salinity in the other sub-basins is more affected by local streams, with lower salinity in the fall, winter, and spring, and higher salinity in the summer due to reduced rainfall. The highest and most stable salinity is measured in the bottom layer in all sub-basins. Salinity monitoring in Burrard Inlet has not been designed to detect short-term changes and the existing data cannot be assessed using the short-term working WQGs. Historical salinity data collected by DFO in Indian Arm (DFO, 2009) showed no overall trend or anomalies over the 1951 – 2000 timespan, suggesting that the long-term working WQG of ≤ 10% change from background was met.

Burrard Inlet has a relatively high DO content. Surface concentrations peak in the spring in all sub-basins, averaging 8.8 mg/L, and decline over the year, with the lowest concentrations usually found in the fall (average of 5.7 mg/L). By depth, the lowest DO levels are found in the mid- and bottom-depth layers of Indian Arm and Outer Harbour. In these deepest basins, the DO was below the 5 mg/L minimum instantaneous benchmark for the protection of aquatic life. In deeper layers during spring and summer and in all layers during fall and winter, the average DO concentrations fell below the long-term DO benchmark of 8 mg/L in all sub-basins, with some exceptions. Low oxygen at depth has been observed in other inlets on the B.C. coast, particularly those with low-runoff inputs or where circulation was not sufficient to replace oxygen (ENV, 1997).

Suspended solids and turbidity in Burrard Inlet are affected by the silty waters of the Fraser River, especially near the Inlet entrance and in the Outer Harbour. Suspended solids were not measured during cruises for physical parameters, but surface concentrations of suspended material from the Fraser River plume in Burrard Inlet have been estimated at ≤10 mg/L using satellite imagery. Turbidity data collected during TWN cruises showed levels are generally below 8 NTU, with site and seasonal averages ranging from 0.18 NTU to 3.94 NTU. Turbidity met the short term WQG, with exceptions in Indian Arm in the fall and winter, and the Outer Harbour in the winter. Turbidity data from Indian Arm, Port Moody Arm, and the Outer Harbour show larger variations than the ±2 NTU long-term benchmark on some occasions.

pH was not measured during the TWN cruises, but was measured by DFO in the Outer Harbour in 2018 through 2020. Results were within the lower bound of the B.C.-based benchmark, but were above the upper limit of 8.7 on occasion at all monitored locations.

The WQOs for dissolved oxygen, pH, salinity, temperature, total suspended solids, and turbidity across all sub-basins are listed in Table 20.

Table 20. Physical parameter water quality objectives for the marine waters of Burrard Inlet.

Parameter	Medium	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Temperature	Water	No further increase in temperature; the natural temperature cycle[1] characteristic of the site should not be altered in amplitude or frequency by human activities					
Salinity	Water	No change in concentration (NaCl or equivalent) from the expected natural level[1] at that time and depth					
Dissolved Oxygen[2]	Water	8 mg/L 30-day mean[3]					
		5 mg/L instantaneous minimum					
pH	Water	7.7 to 8.8[4]					
Total Suspended Solids	Water	No increase from the expected natural levels in the ambient background, defined by best available data[5] as 10 mg/L					
Turbidity	Water	No increase from the expected natural levels in the ambient background, defined by best available data[5] as < 1 NTU[6]					

[1] Data are unavailable to conclusively define "natural" levels; until additional information becomes available, monitoring results can be compared to current conditions as described in Bjorkland et al 2023. The WQOs are intended to limit the ongoing effects of climate change.

[2] In cases where natural DO concentrations do not meet the criteria, no statistically significant reduction below natural levels should be permitted.

[3] A mean should be calculated from 5-in-30 sampling (i.e., five samples taken over 30 days).

[4] To be refined when data are available for additional sub-basins.

[5] See Appendix B for details on how background concentrations were determined. Although other datasets may exist, the datasets used for determining the background (i.e., data available in ENV's Environmental Monitoring System database) were found to be the 'best available data' within the constraints of the project. As more data becomes available, the background concentration may be revisited.

[6] For comparison to the background, a mean should be calculated from 5-in-30 sampling (i.e., five weekly samples taken over 30 days).

5.9 Contaminants of Emerging Concern

Contaminants of Emerging Concern (CECs) in Burrard Inlet were reviewed, assessed, and fully discussed in Bjorkland and LeNoble (2024). CECs are not one group of chemicals with similar characteristics, but a unifying concept for chemicals for which environmental transport and fate, toxicity to aquatic biota, and human exposure may not yet be fully understood, or which are not yet subjected to adequate regulatory criteria or norms for the protection of human health or the environment (Sauvé & Desrosiers, 2014). CECs can refer to many kinds of chemicals – including those used in household, industrial and other products. Those covered in this report include:

- Alkylphenols and their ethoxylates;
- Bisphenols;
- Phthalates;
- 6PPD and 6PPD-quinone;
- Organotins;
- Brominated flame retardants; and
- Perfluoroalkyl and polyfluoroalkyl substances.

These CECs are of anthropogenic origin and, once in marine waters, can be persistent, bioaccumulative, and toxic to biota at low concentrations. The most sensitive values requiring protection from CEC pollution are aquatic life and human consumption of finfish and shellfish, as well as wildlife due to bioaccumulation risks.

Sampling for CECs in Burrard Inlet has been limited to date. Available data from Burrard Inlet were used to screen CECs against benchmarks from relevant B.C. guidelines, and guidelines from other jurisdictions in the absence of B.C. guidelines. The majority of measured CECs were below laboratory detection limits but, in many cases, detection limits were higher than the screening benchmark level. Among the available data, nonylphenol and its ethoxylates were detected in marine water samples; nonylphenol and its ethoxylates, bisphenol A, organotins, tributyltin, perfluorooctanesulfonic acid (PFOS) and hexabromobenzene (HBB) were detected in sediment samples; and nonylphenol and its ethoxylates were detected in tissue samples. The only compound that exceeded a screening benchmark was nonylphenol and its ethoxylates, which exceeded the tissue benchmark in blue mussels in 87% of 15 composite samples analyzed between 2015 and 2019.

The WQOs for CECs are listed in Table 21.

Table 21. Contaminants of emerging concern (CEC) water quality objectives for the marine waters of Burrard Inlet.

Sub-basin	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
All media	**All CECs** Decreasing trend in concentrations					

Sub-basin	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Water	**Alkylphenols and their Ethoxylates** Nonylphenol and its Ethoxylates: 0.7 µg/L (total toxic equivalent of nonylphenolic compounds)					
	Bisphenols Bisphenol A (BPA): 0.9 µg/L					
	Phthalates Di-methyl phthalate (DMP): 2000 µg/L Di-ethyl phthalate (DEP): 600 µg/L Di-(n)-butyl phthalate (DnBP): 30 µg/L Benzyl butyl phthalate (BBP): 0.1 µg/L Di-(2-ethylhexyl) phthalate (DEHP): 0.37 µg/L Di-n-butyl phthalate (DnOP): Do not detect* and/or decrease in current levels					
	6PPD and 6PPD-Quinone 6PPD and 6PPD-Quinone: Do not detect* and/or decrease in current levels					
	Organotins Tributyltin (TBT): 0.001 µg/L					
	Brominated Flame Retardants Hexabromocyclododecane (HBCD): 0.56 µg/L Tetrabromobisphenol A (TBBPA): 3.1 µg/L Hexabromobenzene (HBB): Do not detect* and/or decrease in current levels					
	Perfluoroalkyl and Polyfluoroalkyl Substances Perfluorooctanoic acid (PFOA): Do not detect* and/or decrease in current levels Perfluorooctanesulfonic acid (PFOS): 3.4 µg/L					
Sediment	**Alkylphenols and their Ethoxylates** Nonylphenol and its Ethoxylates: 1.0 µg/g dry weight (total toxic equivalent of nonylphenolic compounds; adjust objective to site-specific levels of total organic carbon [TOC])					
	Bisphenols BPA: 0.025 µg/g dry weight (adjust objective to site-specific levels of TOC)					
	Phthalates DMP: 0.53 µg/g dry weight (adjust objective to site-specific levels of TOC) DEP: 0.61 µg/g dry weight (adjust objective to site-specific levels of TOC) DnBP: 2.2 µg/g dry weight (adjust objective to site-specific levels of TOC) BBP: 0.049 µg/g dry weight (adjust objective to site-specific levels of TOC) DEHP: 0.47 µg/g dry weight (adjust objective to site-specific levels of TOC) DnOP: 0.58 µg/g dry weight (adjust objective to site-specific levels of TOC)					
	6PPD and 6PPD-Quinone 6PPD and 6PPD-Quinone: Do not detect* and/or decrease in current levels					
	Organotins Do not detect* and/or decrease in current levels					
	Brominated Flame Retardants HBCD: 1.6 µg/g dry weight TBBPA: 0.6 µg/g dry weight HBB: Do not detect* and/or decrease in current levels					
	Perfluoroalkyl and Polyfluoroalkyl Substances PFOA: Do not detect* and/or decrease in current levels PFOS: Do not detect* and/or decrease in current levels					

Sub-basin	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Tissue	**Alkylphenols and their Ethoxylates** Nonylphenol and its Ethoxylates: 0.018 µg/g wet weight					
	Bisphenols BPA: Do not detect* and/or decrease in current levels					
	Phthalates DMP: Do not detect* and/or decrease in current levels DEP: Do not detect* and/or decrease in current levels DnBP: Do not detect* and/or decrease in current levels BBP: Do not detect* and/or decrease in current levels DEHP: Do not detect* and/or decrease in current levels DnOP: Do not detect* and/or decrease in current levels					
	6PPD and 6PPD-Quinone 6PPD and 6PPD-Quinone: Do not detect* and/or decrease in current levels					
	Organotins TBT: 0.0088 µg/g wet weight Organotins: 0.0088 µg/g wet weight					
	Brominated Flame Retardants HBCD: Do not detect* and/or decrease in current levels TBBPA: Do not detect* and/or decrease in current levels HBB: 0.070 µg/g wet weight					
	Perfluoroalkyl and Polyfluoroalkyl Substances PFOA: 0.0007 µg/g wet weight PFOS: 0.0021 µg/g wet weight					
*Any objective of 'do not detect' implies non-detection when using best available detection limits.						

5.10 Pesticides

Pesticides in Burrard Inlet were reviewed, assessed, and fully discussed in Braig et al. (2024). There are many different types of pesticides, originally developed to target specific classes of biota. They are applied to forests, rangelands, wetlands, cultivated crops, cities, and towns. They often drift or translocate into non-target aquatic systems and may unintentionally impact non-target species.

Both legacy and current use pesticides (CUPs) were considered. Legacy pesticides are compounds that were once used but are now banned due to adverse effects to humans and the environment. Many are highly persistent and can bioaccumulate and biomagnify within biological systems. In general, CUPs are more target-specific and less persistent, but some are more acutely toxic.

The benchmarks for pesticide levels in sediment and water are based on the B.C. Working Water Quality Guidelines, the B.C. Working Sediment Quality Guidelines, the US EPA Freshwater Sediment Screening Benchmarks, and the Water Quality Standards for Surface Waters of the State of Washington. Benchmarks that screen for the protection of human health are derived from ENV and HLTH (2021). Pesticide concentrations were screened against the most conservative tissue benchmark, i.e., for either a toddler from a subsistence fisher population (for non-carcinogens) or an adult subsistence fisher (for carcinogens).

Of the 18 pesticides analyzed in Burrard Inlet marine water samples, three were detected and none exceeded applicable benchmarks. Of the 59 analyzed in Burrard Inlet sediments, 23 were detected and

six exceeded applicable benchmarks. Of the 33 analyzed in fish and mussel tissue, 19 were detected and three exceeded applicable benchmarks.

The objectives for water, sediment and tissue are listed in Table 22.

Table 22. Pesticide water quality objectives for the marine waters of Burrard Inlet (dw = dry weight; ww = wet weight).

Parameter	Medium[2]	WQO	Value to protect	Reference	Comments
All pesticides	All	Decreasing trend in concentrations			
Legacy Pesticides					
Aldicarb	Tissue	0.0351 µg/g ww	Human consumption of finfish and shellfish	ENV and HLTH 2021	Sum concentrations of aldicarb, aldicarb sulfone, and aldicarb sulfoxide
Aldrin	Water	0.0000077 µg/L	Human consumption of shellfish	US EPA 2015, 2020	Based on carcinogenicity of 10^{-6} risk
	Sediment	Do not detect, when using best available detection limits	Aquatic life	ENV 2020 (Long and Morgan 1990)	EPA chronic marine EqP threshold; 0.0001 significantly toxic to *R. abronius* based on CoA[3]
	Tissue	Do not detect, when using best available detection limits	Human consumption of finfish and shellfish	ENV and HLTH 2021	Carcinogen; Aldrin, dieldrin, heptachlor assessed together: add measured concentrations in tissue and compare to screening value
Chlordane	Water	0.000093 µg/L	Human consumption of finfish	Washington State 2019	Carcinogen; Based on an additional lifetime cancer risk of one-in-100,000 (1 x 10^{-5} risk level)
	Sediment	0.00226 µg/g dw	Aquatic life	ENV 2020b (CCME 1998)	Canadian interim sediment quality guideline

Parameter	Medium[2]	WQO	Value to protect	Reference	Comments
Chlordane	Tissue	0.0026 µg/g ww	Human consumption of finfish and shellfish	ENV and HLTH 2021	Carcinogen; Combine with other chlordane/nonachlor isomers, except oxy-chlordane which has a different mechanism of toxicity
2,4,6-Trichlorophenol	Tissue	0.161 µg/g ww	Human consumption of finfish and shellfish	ENV and HLTH 2021	Carcinogen
2,4-Dichlorophenol	Tissue	3.47 µg/g ww	Human consumption of finfish and shellfish	ENV and HLTH 2021	
2,3,4,6-Tetrachlorophenol	Tissue	0.35 µg/g ww	Human consumption of finfish and shellfish	ENV and HLTH 2021	
Monochlorophenol	Water	0.1 µg/L	Primary contact	ENV 1997	
Total Dichlorophenols	Water	0.3 µg/L	Primary contact	ENV 1997	
Total Tetrachlorophenols	Water	1 µg/L	Primary contact	ENV 1997	
Total Trichlorophenols	Water	2 µg/L	Primary contact	ENV 1997	
DDE	Water	0.000018 µg/L	Human consumption of shellfish	US EPA 2015, 2020	Carcinogen; Based on carcinogenicity of 10^{-6} risk
	Sediment	0.00207 µg/g dw	Aquatic life	ENV 2020b (CCME 1998)	Canadian interim sediment quality guideline
	Tissue	0.01 µg/g ww	Human consumption of finfish and shellfish	ENV and HLTH 2021	Carcinogen
DDT	Water	0.000025 µg/L	Human consumption of finfish	Washington State 2019	Carcinogen; Based on an additional lifetime cancer risk of one-in-100,000 (1 x 10^{-5} risk level)

Parameter	Medium[2]	WQO	Value to protect	Reference	Comments
	Sediment	0.00119 µg/g dw	Aquatic life	ENV 2020b (CCME 1998)	Canadian interim sediment quality guideline
	Tissue	0.01 µg/g ww	Human consumption of finfish and shellfish	ENV and HLTH 2021	Carcinogen
DDD	Sediment	0.00122 µg/g dw	Aquatic life	ENV 2020b (CCME 1998)	Canadian interim sediment quality guideline
	Tissue	0.014 µg/g ww	Human consumption of finfish and shellfish	ENV and HLTH 2021	Carcinogen
Diazinon	Water	0.03 µg/L	Aquatic life	Province of BC 2013	Assumes minimum 1:10 dilution; Standards for all organic substances are for total substance concentrations
	Sediment	Do not detect, when using best available detection limits	Aquatic life	US EPA 2006	Value derived from the EqP method with Region III BTAG[4] freshwater values and log K_{ow} values between 2 and 6
	Tissue	Do not detect, when using best available detection limits	Human consumption of finfish and shellfish	ENV and HLTH 2021	Include diazinon-oxon
Dieldrin	Water	0.0000012 µg/L	Human consumption of shellfish	US EPA 2015, 2020	Carcinogen; Based on carcinogenicity of 10^{-6} risk
	Sediment	0.00071 µg/g dw	Aquatic life	ENV 2020b (CCME 1998)	Canadian interim sediment quality guideline
	Tissue	0.00020 µg/g ww	Human consumption of finfish and shellfish	ENV and HLTH 2021	Carcinogen; Aldrin, dieldrin, heptachlor assess together: add measured concentrations in tissue and compare to screening value

Parameter	Medium[2]	WQO	Value to protect	Reference	Comments
Endosulfan	Water	0.0016 µg active ingredient/L	Aquatic life	ENV 2020 (CCME 2010)	Long term exposure; Value calculated from low-effect data using lowest endpoint approach
	Tissue	0.21 µg/g ww	Human consumption of finfish and shellfish	ENV and HLTH 2021	Combine all endosulfan isomers and compare to this screening value
Endrin	Water	0.0023 µg/L	Aquatic life	Washington State 2019	Chronic value; more conservative than Washington or US EPA value for finfish / shellfish consumption
	Sediment	0.00267 µg/g dw	Aquatic life	ENV 2020 (CCME 1998)	
	Tissue	0.011 µg/g ww	Human consumption of finfish and shellfish	ENV and HLTH 2021	Endrin is either endrin aldehyde or endrin ketone; If both are being reported add them together, but otherwise just compare to endrin screening value
Heptachlor	Water	0.0000059 µg/L	Human consumption of shellfish	US EPA 2015, 2020	Based on carcinogenicity of 10^{-6} risk
	Sediment	Do not detect, when using best available detection limits	Aquatic life	ENV 2020 (CCME 1998)	Canadian interim sediment quality guideline
	Tissue	Do not detect, when using best available detection limits	Human consumption of finfish and shellfish	ENV and HLTH 2021	Carcinogen; Aldrin, dieldrin, heptachlor assessed together: add measured concentrations in tissue and compare to screening value

Parameter	Medium[2]	WQO	Value to protect	Reference	Comments
Hexachlorobenzene	Water	0.000079 µg/L	Human consumption of shellfish	US EPA 2015, 2020	Carcinogen; Based on carcinogenicity of 10^{-6} risk
	Sediment	0.0038 µg/g dw	Aquatic life	Washington State, 2013	
	Tissue	0.002 µg/g ww	Human consumption of finfish and shellfish	ENV and HLTH 2021	Screening value for all potential receptors
Methoxychlor	Water	0.02 µg/L	Human consumption of finfish and shellfish	US EPA 2015, 2020	Protective of the general adult population from noncarcinogenic effects due to chronic exposure from consuming fish and shellfish from inland and nearshore waters
	Tissue	0.017 µg/g ww	Human consumption of finfish and shellfish	ENV and HLTH 2021	Screening value for all potential receptors
Mirex	Tissue	0.007 µg/g ww	Human consumption of finfish and shellfish	ENV and HLTH 2021	Screening value for all potential receptors
Oxy-chlordane	Tissue	Do not detect, when using best available detection limits	Human consumption of finfish and shellfish	ENV and HLTH 2021	Oxy-chlordane is a metabolite of chlordane, and generally seems much more toxic than chlordane itself, and also persistent in fat tissue and bioaccumulative. It should be evaluated separately from chlordane
Toxaphene	Sediment	0.0001 µg/g dw	Aquatic life	ENV 2020 (CCME 1999c, 2002)	Canadian interim sediment quality guideline

Parameter	Medium[2]	WQO	Value to protect	Reference	Comments
	Tissue	Do not detect, when using best available detection limits	Human consumption of finfish and shellfish	ENV and HLTH 2021	
Current Use Pesticides					
Atrazine	Water	1.8 µg/L	Aquatic life	CCME 1999	Highest trophic level protected = fish; guideline is for freshwater, but can be applied to marine (D. Spry (ECCC), per. communication)
	Sediment	Do not detect, when using best available detection limits	Aquatic life	US EPA 2006	Highest trophic level protected = fish; guideline is for freshwater sediment, but can be applied to marine (D. Spry (ECCC), per. communication)
	Tissue	Do not detect, when using best available detection limits	Human consumption of finfish and shellfish	ENV and HLTH 2021	
Carbaryl	Water	0.29 µg/L	Aquatic life	CCME 2009	May be refined when data available
	Tissue	Do not detect, when using best available detection limits	Human consumption of finfish and shellfish	ENV and HLTH 2021	
Chlorpyrifos	Water	0.002 µg/L	Aquatic life	ENV 2020b (CCME 2008)	
	Sediment	Do not detect, when using best available detection limits	Aquatic life	New York State Department of Environmental Conservation (NYSDEC)	Interim sediment quality guideline

Parameter	Medium[2]	WQO	Value to protect	Reference	Comments
	Tissue	Do not detect, when using best available detection limits	Human consumption of finfish and shellfish	ENV and HLTH 2021	
Lindane (*gamma*-hexachlorocyclohexane (γ-HCH))	Water	0.010 µg/L	Human consumption of finfish and shellfish	US EPA 2015, 2020	
	Sediment	0.00032 µg/g dw	Aquatic life	ENV 2020 (CCME 1998)	Canadian interim sediment quality guideline
	Tissue	0.00289 µg/g ww	Human consumption of finfish and shellfish	ENV and HLTH 2021	Carcinogen; This is the screening value for gamma HCH (lindane), since it is used as an agricultural insecticide; In the interim, recommendation from HLTH was to combine all HCH and compare to this screening value
Imidacloprid	Water	0.65 µg/L	Aquatic life	ENV 2020b (CCME 2007)	
	Tissue	2.11 µg/g ww	Human consumption of finfish and shellfish	ENV and HLTH 2021	Toddler subsistence fisher
Malathion	Water	0.1 µg/L	Aquatic life	USEPA 1986	

Parameter	Medium[2]	WQO	Value to protect	Reference	Comments
	Tissue	Do not detect, when using best available detection limits	Human consumption of finfish and shellfish	ENV and HLTH 2021	
Permethrin	Water	0.001 µg/L	Aquatic life	CCME 2006	Derived by multiplying the 96-h LC_{50} value of 0.02 µg a.i./L for *Mysidopsis bahia* by an acute application factor of 0.05 for nonpersistent substances; Highest trophic level protected = fish
	Tissue	1.74 µg/g ww	Human consumption of finfish and shellfish	ENV and HLTH 2021	Add all permethrin isomers and compare to WQO

[1] Any water sample to be analyzed for organic substances should not be filtered. Most other Contaminated Sites Regulations levels are at least an order of magnitude higher than WQGs, particularly for other pesticides, so may need to convert this value to an order of magnitude lower, particularly if actual levels in Burrard Inlet are much lower.

[2] For sediment guidelines that are expressed as µg/g, is based on the sediment as a whole and does not require adjustment for organic carbon content. Adjustments to guidelines are only required when they are expressed in terms of the sediment containing 1% organic carbon. For sediments with organic carbon other than 1%, an adjustment in guidelines should be made by multiplying the guideline by the % organic carbon content of the sediment.

[3] CoA = Co-Occurrence analysis.

[4] Region III BTAG = Mid-Atlantic region, Biological Technical Assistance Group (BTAG).

6. MONITORING RECOMMENDATIONS

The WQOs presented in this document establish benchmarks to assess water quality and determine if the identified water values are being protected. They apply throughout Burrard Inlet in both areas of concern and less impacted (ambient) areas and should be used in all water quality monitoring programs conducted in the Inlet. Sampling and monitoring recommendations for Burrard Inlet are outlined in Rieberger et al. (In Prep).

Burrard Inlet and its watershed are large and complicated with many influencing factors affecting the Inlet's health. Given the extensive list of parameters of concern (see Appendix 1), it is unlikely that any single monitoring program will be able to assess all parameters at any given time. Cooperation and collaboration amongst interested groups are therefore key to assessing the health of Burrard Inlet with respect to the WQOs. TWN has convened the organizations currently conducting major water quality monitoring programs in Burrard Inlet to identify opportunities to coordinate efforts and collectively design a comprehensive water quality monitoring program for Burrard Inlet. Any water quality monitoring program for Burrard Inlet should be informed by the results of this initiative.

Monitoring efforts should be coordinated, and produce data that can be compared to the WQOs and assess the level of WQO attainment (i.e., are the WQOs being met?) to contribute to a better understanding of current conditions and trends. WQOs can be used as benchmarks in a variety of monitoring programs (e.g., baseline monitoring, WQO attainment monitoring, aquatic effects monitoring), so the purpose of monitoring efforts should be documented and clearly described. As much as possible, the selection of monitoring sites should be consistent to build on the body of knowledge. Data collection and analysis methodologies should be valid, appropriate, and clearly documented. All monitoring data should be openly available to First Nations, regulatory agencies, local governments, and the public in a timely manner. Coordinated monitoring will enable the refinement of the Burrard Inlet WQOs over time, as needed, to ensure meaningful benchmarks that will help protect the identified water values.

The technical chapters referenced in this document provide information on established monitoring locations. Any group or agency planning to monitor water quality in Burrard Inlet is advised to contact ENV or TWN to discuss coordination with existing initiatives.

7. MANAGEMENT OPTIONS

The supporting technical chapters for the Burrard Inlet WQOs recommend management options specific to each parameter. Several of these options are common across parameters, including the following:

- Improve regulations, or more effectively implement existing regulations, related to contaminant reduction.
- Reduce the frequency, duration, and magnitude of combined and sanitary sewer overflows through infrastructure improvements, and gradually phase out completely.
- Adopt source controls and green stormwater infrastructure, to reduce both point- and non-point source pollution.
- Improve wastewater management.
- Implement Integrated Stormwater Management Plans.
- Implement municipal, regional, and provincial development standards that protect watershed health.
- Ensure timely reporting of monitoring results, including data collected as required under waste discharge authorizations.

- Improve education, awareness, regulation, and access to disposal facilities to ensure proper disposal of hazardous materials.
- Limit or ban the use of harmful substances in consumer products, including single-use plastics and chemicals that can harm aquatic life.
- Remediate contaminated sites in the Burrard Inlet watershed.
- Carry out directed research or monitoring to address identified knowledge gaps.
- Establish an integrated working group to develop a coordinated approach to monitoring the water quality of Burrard Inlet.

Note that this is not intended to be an exhaustive list of management options, and these options are not mutually exclusive. Readers should refer to the technical chapters for more details on parameter specific options.

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APPENDICES

Appendix 1. Parameters of concern for Burrard Inlet and status of technical assessment reports.

Parameter	Status	Reference
Contaminants of emerging concern (alkylphenols and their ethoxylates, bisphenols, phthalates, 6PPD and 6PPD-quinone, organotins, brominated flame retardants, perfluoroalkyl and polyfluoroalkyl substances)	Complete	Björklund, K., and LeNoble, J. 2024. Water Quality Assessment and Proposed Objectives for Burrard Inlet: Contaminants of Emerging Concern Technical Report. Prepared for Tsleil-Waututh Nation and the Province of B.C.
Metals		
• Arsenic	Complete	Sanchez, M., LeNoble, J, Björklund, K. and Rao, A.S. 2022. Water Quality Assessment and Proposed Objectives for Burrard Inlet: Arsenic Technical Report. Prepared for Tsleil-Waututh Nation and the Province of B.C.
• Cadmium	Complete	LeNoble, J., Lilley, P. and A. Rao. 2019. Water Quality Assessment and Updated Objectives for Burrard Inlet: Cadmium Technical Report. Prepared for Tsleil-Waututh Nation and the Province of B.C. Rao, A.S. 2021. Addendum to cadmium technical report: updated tissue objective. Prepared for Tsleil-Waututh Nation and the Province of B.C.
• Copper	Complete	Rao, A.S., K. Björklund, J. LeNoble, and P. Lilley. 2021. Water Quality Assessment and Proposed Objectives for Burrard Inlet: Copper Technical Report. Prepared for Tsleil-Waututh Nation and the Province of B.C.
• Lead	Complete	Rao, A., J.L. LeNoble, and P. Lilley. 2021. Water quality assessment and proposed interim objectives for Burrard Inlet: Lead Technical Report. Prepared for Tsleil-Waututh Nation and the Province of B.C.
• Mercury	Complete	Rao, A.S. and LeNoble, J. 2022. Water Quality Assessment and Proposed Objectives for Burrard Inlet: Mercury Technical Report. Prepared for Tsleil-Waututh Nation and the Province of B.C.
• Nickel	Complete	Rao, A., J.L. LeNoble, and P. Lilley. 2021. Water quality assessment and proposed interim objectives for Burrard Inlet: Nickel Technical Report. Prepared for Tsleil-Waututh Nation and the Province of B.C.
• Zinc	Complete	Rao, A.S., J.L. LeNoble, H.C. Thompson, and P. Lilley. 2021. Water Quality Assessment and Proposed Objectives for Burrard Inlet: Zinc Technical Report. Prepared for Tsleil-Waututh Nation and the Province of B.C.
Microbiological Indicators	Complete	LeNoble, J.L., P. Lilley, and A. Rao. 2021. Water Quality Assessment and Proposed Objectives for Burrard Inlet: Microbiological Indicators Technical Report. Prepared for Tsleil-Waututh Nation and the Province of B.C.
Microplastics	Complete	Braig, S., K. Delisle, and M. Noël. 2019a. Water Quality Assessment and Updated Objectives for Burrard Inlet: Microplastics Technical Report.
PBDEs	Complete	Braig, S., Delisle, K., LeNoble, J., Björklund, K., Noël, M., Rao, A.S. and H.C. Thompson. 2021. Water quality assessment and proposed objectives for Burrard Inlet: polybrominated diphenyl ethers (PBDEs) technical report. Tsleil-Waututh Nation and Province of BC.
Pesticides (current use and legacy)	Complete	Braig, S., LeNoble, J., and Delisle, K. 2024. Water Quality Assessment and Proposed Objectives for Burrard Inlet: Pesticides Technical Report. Prepared for Tsleil-Waututh Nation and the Province of B.C.

Pharmaceuticals and Personal Care Products	Complete	Braig, S., K. Delisle, and M. Noël. 2019b. Water Quality Assessment and Updated Objectives for Burrard Inlet: Pharmaceuticals & Personal Care Products Technical Report.
Physical Parameters • Dissolved Oxygen • pH • Salinity • Suspended Solids • Temperature • Turbidity	Complete	Björklund, K., Braig, S, Rao, A.S. and Gabelhouse, K. 2024. Water Quality Assessment and Proposed Objectives for Burrard Inlet: Physical Parameters Technical Report. Prepared for Tsleil-Waututh Nation and the Province of B.C.
Polycyclic Aromatic Hydrocarbons	Complete	Braig, S., Delisle, K, Noël, M., LeNoble, J., Thompson, H.C. and A.S. Rao. 2021. Water Quality Assessment and Proposed Objectives for Burrard Inlet: Polycyclic Aromatic Hydrocarbons (PAHs) Technical Report. Prepared for Tsleil-Waututh Nation and the Province of B.C.
Polychlorinated Biphenyls, Dioxins and Furans	Complete	Sanchez, M., LeNoble, J. and Rao, A.S. 2022. Water Quality Assessment and Proposed Objectives for Burrard Inlet: Polychlorinated Biphenyls (PCBs), Dioxins (PCDDs) and Furans (PCDFs) Technical Report. Prepared for Tsleil-Waututh Nation and the Province of B.C.
Freshwater tributaries	In progress	
Remaining Marine Parameters	In progress	
Underwater Noise	In progress	