CSAP
Society of Contaminated Sites Approved Professionals of British Columbia

PCOC SELECTION AND GUIDANCE, VERSION 1
For CSAP Members – June 2018

Document Title: **POTENTIAL CONTAMINANTS OF CONCERN AT COMMERCIAL AND INDUSTRIAL LAND USES**

CSAP is pleased to provide to our members "Potential Contaminants of Concern at Commercial and Industrial Land Uses," prepared under contract to CSAP by PGL Environmental Consultants (PGL). This document is intended to help our members in the selection of potential contaminants of concern (PCOCs) at industrial and commercial sites in BC. PGL recently completed this effort and, after a few rounds of internal review at CSAP, we are ready to issue the document to our members as a "working document," with the recognition that it has not undergone a formal review by ENV, and is subject to modifications. To that end, constructive feedback is most welcome and will be considered in any subsequent edition. Should you have any suggestions, questions or comments, please do not hesitate to contact CSAP.

Potential Contaminants of Concern at Select Commercial and Industrial Land Uses

PREPARED FOR:
CSAP Society
613 – 744 West Hastings
Vancouver, BC V6C 1AS

PREPARED BY:
PGL Environmental Consultants
#1200 – 1185 West Georgia Street
Vancouver, BC V6E 4E6

PGL File: 4136-49.01

June 2018

PGL ENVIRONMENTAL CONSULTANTS

solve and simplify

Table of Contents

PGL ENVIRONMENTAL CONSULTANTS

List of Acronyms

ACQ	alkaline copper quat
BTEX	benzene, toluene, ethylbenzene, xylene
CCA	chromated copper arsenate
CFC	chlorinated fluorocarbons
CSAP	Contaminated Sites Approved Professionals Society
CSR	Contaminated Sites Regulation
DCA	1,2-dichloroethane
EDB	1,2-dibromoethane
ENV	BC Ministry of Environment and Climate Change Strategy
EPA	(United States) Environmental Protection Agency
HEPH	heavy extractable petroleum hydrocarbons
LEPH	light extractable petroleum hydrocarbons
MEK	methyl ethyl ketone
MIBK	methyl isobutyl ketone
MTBE	methyl tert-butyl ether
PAH	Polycyclic Aromatic Hydrocarbons
PCB	polychlorinated biphenyls
PCOC	Potential Contaminant of Concern
PCP	pentachlorophenol
PFBS	Perfluorobutane sulfonate
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
PGL	PGL Environmental Consultants
PSI	Preliminary Site Investigation
SAD	strong acid dissociable
TCMTB	thiocyanomethylbenzothiazole
TBT	Tributyl tin
TEL	tetraethyl lead
VOC	volatile organic compounds
VPH	volatile petroleum hydrocarbons
WAD	weak acid dissociable

I. AUTHORS

The Contaminated Sites Approved Professionals (CSAP) Society of British Columbia retained PGL Environmental Consultants (PGL) to prepare this document. This document was prepared by Zayed Mohamed, Duncan Macdonald, and Will Gaherty at PGL Environmental with input from the CSAP Technical Review committee, particularly Guy Patrick, and Ajay Tumber.

Thank you to all the CSAP members that took the time to provide input and feedback.

II. DISCLAIMER

The lists of potential contaminants of concern in this document are not exhaustive, nor are they intended to be prescriptive. These lists are based on literature review, input from CSAP membership, and our own experience and are intended as a guide only. This document includes the opinions and suggestions of the authors and does not necessarily reflect the opinions and recommendations of CSAP or the BC Ministry of Environment and Climate Change Strategy. Our opinions are subject to change as new information is obtained. This document could be expanded or corrected in the future as we receive further feedback from CSAP membership or new research becomes available. This document should be applied in practice solely at the readers discretion and responsibility in combination with a site-specific Stage 1 Preliminary Site Investigation.

III. REQUEST FOR COMMENTS

We welcome all comments and feedback. We are particularly interested in experiences with new and emerging potential contaminants. Feedback on the inclusion or exclusion of various potential contaminants of concern, as well as suggestions for the addition of other land uses is also welcome.

Please send comments to Zayed Mohamed at zmohamed@pggroup.com or to the CSAP Society at communications@csapsociety.bc.ca.

PGL
ENVIRONMENTAL CONSULTANTS

1.0 INTRODUCTION

The Contaminated Sites Approved Professionals (CSAP) Society of British Columbia retained PGL Environmental Consultants (PGL) to prepare this document summarizing potential contaminants of concern (PCOCs) associated with common commercial and industrial land uses. Specific land uses were chosen from Schedule 2 of the Contaminated Sites Regulation (CSR). PCOCs were chosen from regulated parameters listed in Schedules 3.1 through 3.4 of the Stage 10/11 (Omnibus) Amendments to the CSR. Other parameters might be considered PCOCs in other jurisdictions.

Not all Schedule 2 land uses are included in this document. We have summarized the most common land uses listed in the BC Ministry of Environment & Climate Change Strategy (ENV) Site Registry (as of April 2017), and land uses commonly encountered in our experience conducting Stage 1 Preliminary Site Investigations (PSIs).

The PCOC lists in this document are not exhaustive, nor are they intended to be prescriptive. These lists are based on literature review, input from CSAP membership, and our own experience, and are intended as a guide only. This document includes the opinions and suggestions of the authors and does not necessarily reflect the opinions and recommendations of CSAP or the ENV. Our opinions are subject to change as new information is obtained. This document could be expanded or corrected in the future as we receive further feedback from CSAP membership or new research becomes available.

Professionals should apply judgement and data from site-specific Stage 1 PSIs when deciding which PCOCs should be investigated. When deciding which PCOCs to include, investigators may wish to consider the following:

- PCOCs for a given land use will differ depending on the specific activities performed, and the specific inputs or effluents for those activities. For example, PCOCs for wood treatment will depend on the type of treatment being applied – in this example, investigating polycyclic aromatic hydrocarbons (PAHs) sourced from creosote might be unnecessary at a facility that only applied chlorinated phenols. Similarly, PCOCs at an automotive repair operation that paints cars would be different than one that does not;
- PCOCs might depend on when activities were conducted. Classic examples of this are contaminants that were phased out through regulation, such as leaded fuel and polychlorinated biphenyls (PCBs), which were phased out in the 1970s. Assigning PCOCs based on dates is not always clear cut. For example, PCBs might not be a PCOC for electrical equipment manufacturing after 1979, but would continue to be a PCOC for electric equipment refurbishing;
- Large and complex site uses such as sawmills, pulp and paper mills, and petroleum production sites may have auxiliary activities that are Schedule 2 uses on their own (such as machine shops or fuel storage and distribution, for example);
- PCOCs can degrade into other contaminants. For example, the dry cleaning solvent tetrachloroethylene can degrade into trichloroethylene, dichloroethylene, and vinyl chloride; and
- Investigators may wish to differentiate between primary and secondary contaminants. This idea is relevant where the presence of some PCOCs is not expected without other primary PCOCs. For example, gasoline contamination, where some fuel components and additives are unlikely to exceed standards unless primary petroleum hydrocarbons (e.g. volatile petroleum hydrocarbons [VPH], light extractable petroleum hydrocarbons [LEPH], and benzene, toluene, ethylbenzene and xylenes [BTEX] compounds) are also present. Similar categorizations can be made in other scenarios such as PCBs in hydraulic oil, metals in waste oil or antifreeze, dioxins/furans in PCBs or chlorophenols, etc.

2.0 PCOC TABLES FOR SCHEDULE 2 LAND USE

PCOCs are summarized below by Schedule 2 land use. PCOCs are listed by substance class (e.g., metals, hydrocarbons etc.). The parameters included in each substance class are listed in Section 4.0. Not all parameters in each group are necessarily PCOCs for every land use. For example, the mix of metals that are PCOCs for foundries might be different from PCOCs for auto repair, dyes, or herbicides. Where some parameters in a group are of particular concern (but not necessarily the only concern), we highlight them in the comments column. Where the list of PCOCs within a group is very large (e.g., herbicides), we provide examples of common contaminants with the understanding that site-specific information would be needed to narrow down the list. We have attempted to order the substance classes by level of concern.

2.1 A – Chemical Industries and Activities

A8 – Paint, Lacquer or Varnish Manufacturing, Formulation, Recycling or Wholesale Bulk Storage

PCOCs are the ingredients and intermediate chemicals used to formulate the coatings, mostly solvents, fillers, pigments, and preservation agents.

PCOC Substance Class	Activity/Source	Comments
Metals	Fillers and pigments	Particularly aluminium, antimony, cadmium, chromium, cobalt, lead, titanium, and zinc
Petroleum hydrocarbons	Solvents	Mostly aliphatics, LEPH, VPH
BTEX	Solvents	Particularly toluene and xylene
Glycol ethers	Solvents	Particularly 2-butoxyethanol
Ketones	Solvents	
Esters	Solvents	Particularly ethyl acetate and, to a lesser degree, methyl acetate and vinyl acetate
Nonylphenol and nonylphenol ethoxylates	Intermediate manufacturing chemicals	
Organometallics	Preservation agent	E.g., tributyl tin, mercury
Chlorinated phenols	Preservation agent	Mostly in antifouling paints
PCBs	Paint ingredient	Used before 1979, mostly in specialty coatings for industrial or military uses

2.2 B – Electrical equipment and activities

B2 – Communications Stations Using or Storing Equipment That Contains PCBs

PCOC Substance Class	Activity/Source	Comments
PCBs	Electrical capacitors, transformers, electromagnets	
Petroleum hydrocarbons	Carrier oils	Mostly aliphatics, LEPH, and VPH

B3 – Electrical Equipment Manufacturing, Refurbishing, or Wholesale Bulk Storage

Manufacture and refurbishing of industrial electrical equipment such as transformers, capacitors, switches, industrial lighting, and electric motors. Manufacture or refurbishing of appliances is covered under a different site use (E1).

PCOC Substance Class	Activity/Source	Comments
Metals	Machining, blasting grit, solder	Particularly zinc from galvanized steel
PCBs	Liquid dielectrics in transformers	Most common pre-1980, but could be found later at refurbishing operations. PCB-containing equipment remains in use in some electrical transmission and distribution facilities.
Petroleum hydrocarbons	Transformer oil, solvents, and oil filled cables	LEPH and HEPH (heavy extractable petroleum hydrocarbons) in transformer oil, VPH in solvents
Chlorinated aliphatics	Solvents, and liquid dielectrics in transformers	Particularly tetrachloroethylene, trichloroethylene, 1,1,1-trichloroethane, and 1,2-dichloromethane. Tetrachloroethylene was used as a dielectric in transformers – mostly post-1980.
Trichlorobenzene, 1,2,4-	Additive to liquid dielectrics in transformers	Trichlorobenzene, 1,2,4-, and breakdown products
Ions	Caustics like sodium hydroxide	Sodium
BTEX	Solvents	Non-flammable chlorinated solvents were preferred

B4 – Electrical Transmission or Distribution Substations

Electrical substations contain transformers and other electrical equipment that may contain, or have previously contained, oils, PCBs, or tetrachloroethylene. Vegetation is a threat to equipment and underground grounding wires, and is often aggressively controlled with herbicides.

PCOC Substance Class	Activity/Source	Comments
Petroleum hydrocarbons	Transformer oil	LEPH and HEPH
PCBs	Liquid dielectrics in transformers and capacitors	Most common pre-1980. PCB-containing equipment will remain in use in some electrical transmission and distribution facilities until 2025
Chlorinated aliphatics		Tetrachloroethylene and breakdown products – mostly used post-1980
1,2,4-trichlorobenzene		1,2,4-trichlorobenzene and breakdown products
Metals	Handling and storage of cable and electrical components, galvanized metal structures, herbicides	Particularly arsenic (from herbicides), copper, lead, and zinc
Herbicides	Vegetation control	E.g., atrazine, bromacil, 2,4-dichlorophenoxy acetic acid (2,4-D), diuron, glyphosate, linuron, simazine, tebuthiuron, among others. Note that organic herbicides are not PCOCs if they have been applied according to the manufacturers' instructions. We suggest that tests for herbicide parameters be conducted where herbicides are stored in bulk, or if there is no evidence one way or the other that herbicides have been improperly applied. Investigators may wish to consider screening with a composite sample for presence absence.

B5 – Electronic Equipment Manufacturing

Electronics manufacturing includes activities such as circuit board printing and assembly of electronic components. PCOCs are metals and cleaning solvents. Generally, non-flammable chlorinated solvents are preferred over hydrocarbons.

PCOC Substance Class	Activity/Source	Comments
Chlorinated aliphatics	Circuitry, solvents	Particularly tetrachloroethylene, trichloroethylene, 1,1,1-trichloroethane, and 1,2-dichloromethane
Ketones, esters, and other solvents	Solvents	E.g., acetone, acrylonitrile, ethyl acetate, and methanol
Metals	Circuitry, solder	Particularly cadmium, copper, lead, nickel, silver, tin, and zinc
Ions	Electroplating baths, etching solutions	Particularly, chloride, fluoride, sodium, and sulfate

2.3 C – Metal smelting, Processing or Finishing Industries and Activities

C1, C5 – Foundries or Metal Smelting (Ferrous and Nonferrous)

Foundries smelt and cast metal in shapes. Chemicals (fluxes) can be added to molten metals to change properties and remove impurities. Heated metal can be treated by quenching in various chemical baths. PCOCs are mostly metal impurities from the smelting process (slag, pickling waste), waste from castings, and trimmings. Solvents for metal cleaning, and waste from treatment baths are also potential contaminants.

PCOC Substance Class	Activity/Source	Comments
Metals	Slag, pickling waste, used foundry sand, blasting grit, and dust	Metals mix depends on the metals/alloys being smelted or cast
Petroleum hydrocarbons	Solvents, lubricants, cutting oil, and oil used as binders in sand castings	Particularly VPH, LEPH, HEPH
BTEX	Solvents	
Chlorinated aliphatics	Solvents	Particularly carbon tetrachloride, tetrachloroethylene, trichloroethylene, 1,1,1-trichloroethane
Cyanide[1]	Cyanide salts (e.g., sodium cyanide) in hardening baths	

[1] Different analysis is required to demonstrate compliance depending on the standard. Strong Acid Dissociable (SAD) for drinking water and Weak Acid dissociable (WAD) for aquatic life

PCOC Substance Class	Activity/Source	Comments
Ions	Salt bath waste and fluxes	Particularly chloride, fluoride, sodium, and sulfate
Dioxins/furans	Process wastes and melting plastics on scrap metal	Secondary to metals (i.e. unlikely to be present if metals concentrations are not elevated)
Non-Chlorinated Phenols	Phenol-formaldehyde resins (binder for sand castings)	Particularly phenol, methylphenols, and dimethylphenols. Secondary to metals
Nitrogen Compounds	Urea-formaldehyde resins (binder for sand castings)	Particularly ammonia, nitrate, and nitrite. Secondary to metals

C2, C3 – Metal plating or finishing including galvanizing

Operations adding metal coatings or polish, usually to other metal equipment. PCOCs are metals from the coating media, process wastes, and solvents for metal cleaning. The mix of potential metal contaminants depends on the process. Precious metal plating has different metal PCOCs than chrome plating, which has different PCOCs than hot dip zinc galvanizing.

PCOC Substance Class	Activity/Source	Comments
Metals	Coatings, pickling waste, blasting grit, flux salts, and contaminated rinse water	Particularly cadmium, chromium (both Cr_{III} and Cr_{VI}), copper, iron[1], lead, manganese[1], nickel, silver, and zinc
Chlorinated aliphatics	Solvents	Particularly tetrachloroethylene, trichloroethylene,1,1,1-trichloroethane, and breakdown products
Petroleum hydrocarbons	Solvents, coolants, and lubricants	Particularly VPH, LEPH, HEPH
Ions and Nitrogen Compounds	Caustics, fluxes, and electroplating solutions	Particularly ammonia, chloride, fluoride, nitrate, nitrite, sodium, and sulfate
1,1,2-trichloro-1,2,2 trifluoroethane (CFC-113)	Solvents	Used pre-1990. CFC-113 has a relatively high standard and would need to be used/processed in large volumes to be a risk
Cyanide[2]	Stabilizers	Used in copper, zinc, cadmium, silver and gold plating solutions
Perfluorinated compounds	Coatings, wetting agent/fume suppressant, cleaners	Perfluorobutane sulfonate (PFBS), Perfluorooctane sulfonate (PFOS), Perfluorooctanoic acid (PFOA)

[2] Different analysis is required to demonstrate compliance depending on the standard. SAD for drinking water and WAD for aquatic life

C4 – Metal Salvage Operations

Includes the collection and processing of scrap metal. Properties listed as metal salvage operations often process products beyond scrap metal, e.g. appliances, tanks, cars, transformers, and batteries. Metals components are extracted, sorted, cut or shredded to size, and packaged for transport. Packaged scrap metal is usually smelted offsite (C5).

PCOC Substance Class	Activity/Source	Comments
Metals	Metal cutting, compacting, shredding, and storage	
PCOCs from other "salvage uses" e.g., E1, G2, G6		

C6 – Welding or Machine Shops (Repair or Fabrication)

Machine shops involve various metal cutting and cleaning processes. Various fluids are used for cooling, lubrication, and cleaning. Some machine shops are associated with other metal processing activities such as metal plating and finishing (C1, C2) or larger industrial activities such as oil and gas operations, and sawmills.

PCOC Substance Class	Activity/Source	Comments
Metals	Metal cutting/grinding, sandblast grit, welding slag, and cutting fluids	Particular metals depend on what metals are being worked
Petroleum hydrocarbons	Lubricants, cutting fluids, and solvents	Particularly VPH, LEPH, HEPH
BTEX	Solvents	
Chlorinated aliphatics	Solvents	Particularly tetrachloroethylene, trichloroethylene, 1,1,1-trichloroethane, and breakdown products

2.4 E – Miscellaneous Industries, Operations or Activities

E1 – Appliance, Equipment or Engine Repair, Reconditioning, Cleaning or Salvage

This land use covers a broad range of equipment types and activities. Activities might include paint or other coating removal and/or application, cleaning/degreasing, welding/soldering, metal cutting, lubrication, and fluid changes. Equipment and appliances might include refrigerators, air conditioners, boilers, hydraulic systems, electric motors, and internal combustion engines, and more.

PCOC Substance Class	Activity/Source	Comments
Petroleum hydrocarbons	Lubricants, solvents, hydraulic systems, and fuel	Hydrocarbons associated with lubricants and solvents are primarily aliphatic (i.e. VPH, LEPH, HEPH). Fuel hydrocarbons depend of the type – see Section 3.2.
BTEX	Solvents, fuel	
Polycyclic aromatic hydrocarbons	Waste oil, fuel	
Metals	Blasting grit, welding, cutting wastes, and waste oil	Particular metals depend on the metals being worked and the metal content of paints and coatings being removed
Chlorinated aliphatics	Parts washing, cleaners/degreasers, and non-destructive testing	Particularly carbon tetrachloride, tetrachloroethylene, trichloroethylene, and breakdown products
Chlorobenzenes	Solvents	Particularly chlorobenzene and 1,2-dichlorobenzene
Ketones	Degreasers, solvents used in paint	Particularly acetone, methyl ethyl ketone (MEK), and methyl isobutyl ketone (MIBK). These solvents are usually associated with the manufacture or large-scale application of paints and coatings. In our experience, they are rarely found at typical automotive repair operations, but may be used by more specialized industries.
Glycols	Coolants, antifreeze	
PCBs	Hydraulic fluids, present in some electrical equipment (B3)	PCBs are likely secondary to hydrocarbons in hydraulic fluids (LEPH, HEPH), but may be primary in transformer dielectrics

PCOC Substance Class	Activity/Source	Comments
Chlorinated Fluorocarbons (CFC)	Coolants, solvents	Particularly 1,1,2-trichloro-1,2,2-trifluoroethane, (CFC-113) (pre-1990), a common solvent and refrigerant. CFC-113 has a relatively high standard and would need to be used/processed in large volume to be a risk. Likely not a risk in soil or groundwater at automotive repair shops. Impacts from other CFCs are expected to be rare since most are gases at or below room temperature.

E2 – Ash Deposit from Boilers, Incinerators, Or Other Thermal Facilities

Ash is generated from combustion of coal, municipal waste, wood-waste/hog fuel, and other materials. Coal ash is produced in coal-fired power plants. It includes bottom ash and fly ash. Bottom ash is removed from the bottom of boilers. Fly ash is collected from chimneys by particle filtration. Coal ash can be landfilled, discharged in wastewater, or recycled (cement, plaster, etc.). Metals in coal ash vary depending on the source rock. Incinerator ash from waste incineration plants consists of sintered combustion products, mineral components, metal scrap, and other unburnt materials.

Woodwaste ash typically has a high pH and contains variable levels of dioxins. Other fuels used by wood-fired boilers can include chlorine-containing sludges from pulp and paper processes, tires, plastic debris and organic compounds from recycling wood wastes, cardboard, and heavy fuel oils which themselves may contain chlorinated compounds that can form dioxins when burned. Wood ash containing dioxins has been applied to soil as a fertilizer.

PCOC Substance Class	Activity/Source	Comments
Metals	Ash	Depends on fuel or waste inputs
Polycyclic aromatic hydrocarbons	Ash	Likely secondary to metals
Dioxins/furans	Ash	If incinerator fuel included a chlorine source such as waste from a pulp mill, chlorophenol treated wood, or marine wood waste. Dioxin/furan concentrations are generally higher in fly ash as opposed to bottom ash.

E4 – Coal Gasification (Manufactured Gas Production)

Coal gasification plants produced coal gas for heating and light. A by-product of the gasification process was coal tar. Wastewater was often contaminated with tar, ammonia and/or drip oils, as well as waste tars and tar-water emulsions.

PCOC Substance Class	Activity/Source	Comments
Polycyclic aromatic hydrocarbons	Coal tar	
BTEX	Coal tar	
Petroleum hydrocarbons	Fuels, coal tar	See section 3.2
Metals	Process wastes (Coal tar, coke), waste water treatment sludge, purifier wastes. Leaded solder for gas mains, lead piping, coal ashes.	Primarily metals associated with coal combustion
Non-Chlorinated Phenols	Coal tar	Phenol and methylphenols (cresols)
Cyanide[3]	Purifier and scrubber wastes, coal tar	“Blue billy", is a ferroferricyanide waste compound (blue from Prussian blue dye)
Ions and Nitrogen Compounds	Purifier and scrubber wastes, waste water treatment sludge	Ammonia, nitrate, nitrite, and sulfate

E6 – Rifle or Pistol Firing Ranges

Sources of contamination are primarily the metals present in bullets and bullet jackets. Trap shooting ranges are often impacted by PAHs, which are present in the clay targets.

PCOC Substance Class	Activity/Source	Comments
Metals	Bullets, bullet jackets, and shell casings	Primarily antimony, arsenic, cadmium, copper, lead, tin, and zinc
Polycyclic aromatic hydrocarbons	Present in clay targets	

[3] Different analysis is required to demonstrate compliance depending on the standard. SAD for drinking water and WAD for aquatic life

Nitrogen Compounds	Propellants	Nitrates, nitrites. Likely secondary at small arms firing ranges. Might be present at ranges with unexploded ordinance.
Herbicides	Vegetation control	E.g., atrazine, 2,4-dichlorophenoxy acetic acid (2,4-D), diuron, glyphosate, picloram, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) among others. Note that organic herbicides are not necessarily PCOCs if they have been applied according to the manufacturers' instructions. We suggest that tests for herbicide parameters be conducted where herbicides are stored in bulk, or if there is no evidence one way or the other that herbicides have been improperly applied. Investigators may wish to consider screening with a composite sample for presence absence.

E7 – Road Salt Storage Facilities

Road Salts, mostly sodium chloride, are used in Canada as de-icing and anti-icing chemicals for winter road maintenance. Calcium chloride is the leading chemical used for dust suppression in Canada. To prevent the clumping of chloride salts during storage and de-icing operations, sodium ferrocyanide and ferric ferrocyanide can be added.

PCOC Substance Class	Activity/Source	Comments
Ions	Salt	Specifically, chloride and sodium
Cyanide[4]	Anticaking compounds	Secondary to sodium or chloride contamination (i.e. unlikely to be present if salt ion concentrations are not elevated)

E9 – Dry-Cleaning Facilities or Operations and Dry-Cleaning Chemical Storage

Dry cleaners use solvents (typically tetrachloroethylene) to clean clothing and other items. Contaminants can be released to the environment through leaking storage tanks or drums, improper waste disposal, or spills. Perhaps the most common mode of contamination is leaking sumps or sewers, which collect contact water contaminated by solvents.

[4] Different analysis is required to demonstrate compliance depending on the standard. SAD for drinking water and WAD for aquatic life

PCOC Substance Class	Activity/Source	Comments
Chlorinated aliphatics	Cleaning solvents, contact water	Particularly tetrachloroethylene and breakdown products. Carbon tetrachloride and trichloroethane may have been used historically, primarily as spot cleaners.
Petroleum hydrocarbons	Cleaning solvents, contact water	Primarily LEPH and VPH in Stoddard solvent – used before 1970, but mostly before 1960; or in some modern formulations

2.5 F – Petroleum and Natural Gas Drilling, Production, Processing, Retailing, Distribution and Storage Other Than the Storage of Residential Heating Fuel in Tanks

F1 and F2 – Petroleum or Natural Gas Drilling and Production

- F1 – petroleum or natural gas drilling;
- F2 – petroleum or natural gas production.

Petroleum drilling operations install wells and remove petroleum and gas from the ground. Extraction is often accomplished with the aid of injected fluids. Injected fluids can contain a wide variety of chemicals that act as surfactants, friction reducers, gellants, and corrosion inhibitors among many other uses. Producing wells usually generate 'produced water', which is a mixture of formation water, injected water/chemicals, and hydrocarbons. Workover fluids are injected into oil and gas wells during major maintenance or intervention, either for pressure control, or to maintain or increase the flow of product. Vegetation around wells is often controlled with pesticides.

Production facilities generally process produced water from extraction wells and export a usable petroleum product. Petroleum liquids and gas are separated from water and other impurities through a variety of physical and chemical processes. In addition to petroleum hydrocarbons, potential contaminants include chemical additives, and waste impurities.

Upstream petroleum sites can be complex and may have auxiliary uses like vehicle fuelling, machine shops, or landfills.

PCOC Substance Class	Activity/Source	Comments
Petroleum hydrocarbons	Fuel, crude oil, condensate, solvents, lubrication oil, and produced water	HEPH, LEPH, VPH
BTEX	Fuel (diesel), crude oil, condensate, solvents, and produced water	
Polycyclic aromatic hydrocarbons	Fuel (diesel), condensate, crude oil, and produced water	
Metals	Produced water	Depends on mineral composition of the deposit and known impurities
Chlorinated Aliphatics	Solvents	E.g. chloroform, dichloroethane, 1,2-, dichloromethane, 1,1,2-trichloroethane
Non-chlorinated solvents	Workover fluids, solvents	Particularly methanol
Glycols, Glycol ethers	Antifreeze, workover fluids	
Ions	Produced water, ponds, workover fluids, and drill fluid additives	Particularly sodium, chloride, and sulfate
Nitrogen Compounds	Produced water, ponds, drill fluid additives, and amine breakdown products	Ammonia, nitrate, and nitrite
Amines and other sweetening agents (i.e chemicals added to remove hydrogen sulfide, 'sour' gas)	Sweetening additives	Particularly sulfolane, diethanolamine, and diisopropanolamine
Sulphur compounds	Sulphur storage areas, amine sumps	
Nonylphenol and nonylphenol ethoxylates	Surfactants	

PCOC Substance Class	Activity/Source	Comments
Herbicides/sterilants	Vegetation control	E.g., atrazine, bromacil, 2,4-dichlorophenoxy acetic acid (2,4-D), diuron, glyphosate, linuron, simazine, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), tebuthiuron among others. Note that organic herbicides are not necessarily PCOCs if they have been applied according to the manufacturers' instructions. We suggest that tests for herbicide parameters be conducted where herbicides are stored in bulk, or if there is no evidence one way or the other that herbicides have been improperly applied. Investigators may wish to consider screening with a composite sample for presence absence.

F5, F7, and F8 – Petroleum product distribution and/or storage

- F5 – petroleum product other than compressed gas, and dispensing facilities including service stations and card locks;
- F7 – petroleum product, other than compressed gas, or produced water storage in above ground or underground tanks;
- F8 – petroleum product, other than compressed gas, wholesale bulk storage, or distribution.

PCOCs are the components of petroleum mixtures and various fuel additives. Petroleum products stored at upstream operations may have various sweetening agents added.

PCOC Substance Class	Activity/Source	Comments
Petroleum hydrocarbons	Fuels, oil	LEPH, VPH – gasoline and diesel HEPH – heavier distillates and fuel oil (e.g., bunker fuel)
BTEX		Specifically, benzene, ethylbenzene, toluene, and xylene
Polycyclic aromatic hydrocarbons		
Fuel additives	Primarily gasoline	Pre-1986: tetraethyl lead, 1,2-dibromoethane, 1,2-dichloroethane 1988 to 2001: MTBE
Amines and other sweetening agents	Oil and gas refining (upstream)	Particularly sulfolane, diethanolamine, and diisopropanolamine. Applies at petroleum storage at upstream oil and gas operation only (F7).

2.6 G – Transportation industries, Operations and Related Activities

G2 – Automotive, Truck, Bus, Subway or Other Motor Vehicle Repair, Salvage or Wrecking

The type and scale of vehicle repair operations can vary widely. Contaminants from repair operations are usually associated with new and used vehicle fluids (fuel, oil, antifreeze, etc.). Contamination might be also sourced from parts cleaning solvent. Used vehicle fluids (oil/antifreeze) often carry secondary contamination (e.g. metals from engine wear, or improper disposal of solvents). Salvage and wrecking PCOCs are similar to those of repair uses.

PCOC Substance Class	Activity/Source	Comments
Petroleum hydrocarbons	Fuels, lubricants, solvents, and hydraulic systems	HEPH, LEPH, VPH
BTEX	Fuels, solvents	Particularly benzene, ethylbenzene, toluene and xylene
Polycyclic aromatic hydrocarbons	Fuel and waste oil	
Fuel additives	Primarily gasoline	Pre-1986: tetraethyl lead, 1,2-dibromoethane, 1,2-dichloroethane 1988 to 2001 - methyl tert-butyl ether (MTBE)
Metals	Engine wear, vehicle dismantling, oil additives, and body fillers	For auto repair, metals are mostly sourced from waste oil (see Section 3.3), solvents, antifreeze, and batteries. Salvage and wrecking uses would include metals found in vehicle components. E.g. mercury in thermostats and switches.
Chlorinated aliphatics	Parts washing, cleaners, degreasers	Specifically, carbon tetrachloride, tetrachloroethylene, trichloroethylene and breakdown products
Ketones	Solvents used in paint, degreasers	Acetone, MEK, and MIBK
Glycols	Radiator fluid/ antifreeze	

G4 – Dry Docks, Ship Building or Boat Repair and Maintenance, Including Paint Removal from Hulls

PCOCs for boat building are similar to those for machine shops and welding. Boat building or repair operations might also have PCOCs associated with new and used engine fluids, similar to vehicle repair. Uniquely, boat building and repair operations may have contaminants associated with application and removal of antifouling paint.

PCOC Substance Class	Activity/Source	Comments
Petroleum hydrocarbons	Fuels, lubricants, solvents, and hydraulic systems	HEPH, LEPH, and VPH
BTEX	Fuels, solvents	
Polycyclic aromatic hydrocarbons	Fuel, creosote (preserved boat/barge hull timber), and waste oil	
Metals	Blasting grit, antifouling paint, engine wear, and oil additives	Particularly copper, lead, antimony, tin, arsenic, and mercury
Chlorinated aliphatics	Parts washing, metal cleaners, and degreasers	Specifically, carbon tetrachloride, tetrachloroethylene, trichloroethylene, and breakdown products
Ketones	Degreasers, solvents used in paint	Acetone, MEK, and MIBK
Organometallics	Antifouling paint	Mostly tributyl tin and organo mercury primarily from 1970 to 2003
Organic Biocides (pesticides/fungicides/ herbicides)	Antifouling paint	E.g., diuron, chlorothalonil, folpet, maneb, thiocyanomethylbenzothiazole (TCMTB), thiram, (cuprous) thiocyanate, and zineb. Mostly in use after 1989 after regulations limiting TBT (Tributyl tin) use.

G6 – Rail Car or Locomotive Maintenance, Cleaning, Salvage or Related Uses, Including Railyards

Contaminants associated with rail car or locomotive maintenance are similar to other vehicle repair uses. Contamination from operating railyards might be sourced from locomotive maintenance (oil changes, painting and paint stripping, hydraulic system repair, coolant disposal, metal machining, battery disposal, and engine parts cleaning), track maintenance (rail tie preservatives, switch lubricants, and track ballast), tank car cleaning, or spillage from hazardous cargo during transport.

PCOC Substance Class	Activity/Source	Comments
Petroleum hydrocarbons	Fuels, engine lubricants, solvents, hydraulic systems, and lubricants sprayed on switches	See Section 3.2

PCOC Substance Class	Activity/Source	Comments
Polycyclic aromatic hydrocarbons	Creosote preservation of rail ties, component of fuel and waste oil	
BTEX	Fuels and solvents	
Metals	Engine wear, oil additives, track and overhead electric wire abrasion, track ballast, cinder from coal fired boilers, and herbicides	
Chlorinated aliphatics	Parts washing, metal cleaners, and degreasers	Specifically, carbon tetrachloride, tetrachloroethylene, trichloroethylene, and breakdown products
Ketones	Degreasers, solvents used in paint.	Acetone, MEK, and MIBK
Glycols	Coolants	
Herbicides	Clearing vegetation around track areas	E.g., atrazine, bromacil, 2,4-dichlorophenoxy acetic acid (2,4-D), diuron, glyphosate, linuron, simazine, tebuthiuron, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) among others. Note that organic herbicides are not necessarily PCOCs if they have been applied according to the manufacturers' instructions. We suggest that tests for herbicide parameters be conducted where herbicides are stored in bulk, or if there is no evidence either way that herbicides have been improperly applied.
PCBs	Transformers in locomotives and self-propelled railcars	

G7 – Truck, Rail or Marine Bulk Freight Handling

PCOCs are those associated with automotive, rail, or marine infrastructure, plus any PCOCs specifically associated with the bulk freight being handled.

2.7 H – Waste Disposal and Recycling Operations and Activities

H1 – Antifreeze Bulk Storage or Recycling

Ethylene glycol and propylene glycol antifreeze are used to lower the freezing point of water. Ethylene glycol is used in the automotive sector. Propylene glycol is generally used in building heating systems. Waste coolant picks up wear metals from the engine and pipes.

PCOC Substance Class	Activity/Source	Comments
Glycols	Antifreeze	
Metals	Contaminant of waste radiator fluid	Specifically, arsenic, cadmium, chromium, copper, lead, nickel, tin and zinc. Likely secondary to glycol contamination (i.e. unlikely to be present if glycol concentrations are not elevated).

H13 – Industrial Woodwaste (Log Yard Waste, Hog fuel) Disposal

Industrial wood waste might be disposed of through landfilling, composting, or burning. Log yard waste is primarily wood trimmings and bark. Dredge spoils may be disposed if there is an associated water sort. Hog fuel is unrefined wood residue that has been processed through a grinding or milling machine.

PCOC Substance Class	Activity/Source	Comments
Non-chlorinated Phenols	Buried wood waste	Phenol, methylphenols, hydroxyphenols. Nitrophenols may form in secondary reactions in surface water.
Ions	Buried wood waste from marine water lots	Specifically, sodium and chloride
Dioxins/furans	Burner ash	If burning marine or chlorophenol treated wood
If treated wood is buried or burned then PCOCs include treatment parameters. See I4, I7		

H22 – Street or Yard Snow Removal Dumping

Snow falling onto municipal roads and highways may become mixed with contaminants such as dissolved salts, heavy metals, and oil.

PCOC Substance Class	Activity/Source	Comments
Ions	Salt	Specifically, sodium and chloride
Metals	Contamination from vehicle exhaust and garbage entrained in snow	Secondary to chloride contamination (i.e. unlikely to be present if salt ion concentrations are not elevated)

H23 – Waste Oil Reprocessing, Recycling or Bulk Storage

Reprocessing and re-refining involve operations which will separate and remove contaminants in used oil so that this oil becomes suitable for reuse. Reprocessing involves relatively simple physical or chemical treatments such as settling, dehydration, flash evaporation, filtration, coagulation, and centrifugation to remove contaminants.

PCOC Substance Class	Activity/Source	Comments
Petroleum hydrocarbons	Waste oil	LEPH, HEPH
Polycyclic aromatic hydrocarbons	Waste oil	
Metals	Waste oil	See Section 3.3
Secondary PCOC for waste oil could include all other PCOCs associated with the used oil's source land use. Used oil can be contaminated with other hazardous materials e.g., solvents, and PCBs.		

2.8 I – Wood, Pulp and Paper Products and Related Industries and Activities

I1, I5, I6 – Particle Board, Veneer, Plywood, or Wafer Board Manufacturing

- I1 – particle board manufacturing;
- I5 – veneer or plywood manufacturing;
- I6 – wafer board manufacturing.

Particle board, veneer, plywood, and wafer board are manufactured from wood chips, flakes, sawdust, or thin wood layers with a synthetic resin. Common resins are phenol-formaldehyde and urea formaldehyde.

PCOC Substance Class	Activity/Source	Comments
Non-chlorinated phenols	Phenol formaldehyde resins	Phenol, methylphenols
Ions and Nitrogen Compounds	Urea-formaldehyde resins, caustics, process chemicals like ammonia, ammonia chloride, and ammonium sulfate	Specifically, ammonia, chloride, nitrate, nitrite, and sulfate. In addition to direct use in process chemicals, nitrogen compounds may form in the subsurface during the degradation of urea.
Formaldehyde and acetaldehyde	Formaldehyde resins	Acetaldehyde may be found in commercial grade formaldehyde and has more stringent groundwater standards than formaldehyde.

I2 and I3 – Pulp and Paper Mill Operations

In the chemical pulping process, wood fibres are liberated from the wood matrix by dissolving in a cooking liquor at high temperature. Kraft pulping uses sulphur to extract fibres. Kraft pulp is usually dark, and bleached with chlorine compounds. Mechanical pulping involves physically shredding trees into pulp. Mechanical pulp is commonly used for newspapers and is often bleached with hydrogen peroxide or other chlorine-free alternatives.

Wastewater is high in biochemical oxygen demand, total suspended solids, chemical oxygen demand, nitrogen, and phosphorus. Chlorinated organic compounds are generated, which include dioxins, furans, and other absorbable organic halides.

Solid waste includes wood waste (mainly bark), sodium salts from recovery boiler, pulp screening rejects and dregs and grit from causticizing. Ashes are generated during burning of wood wastes and sludges.

PCOC Substance Class	Activity/Source	Comments
Petroleum hydrocarbons	Fuels, lubricants, and hydraulic and heat transfer systems	PCOCs associated with lubricants and hydraulic fluids are primarily LEPH and HEPH. For fuels see Section 3.2
Ions	Caustics, bleaching agents, and waste liquor	Specifically, chloride, sodium, sulfate, and sulfide
Metals	Burner ash	Particularly boron, cadmium, chromium, lead, mercury, silver, and zinc
Polycyclic aromatic hydrocarbons	Burner ash	

PCOC Substance Class	Activity/Source	Comments
Non-chlorinated Phenols	Chip pile, buried wood waste, and liquor effluent	Phenol, methylphenols, hydroxyphenols. Nitrophenols may form in secondary reactions in surface water.
Chlorinated phenols	Produced during some bleaching processes	See Section 4.0
Dioxins/furans	Burner ash and bleaching processes.	Produced by burning marine wood or chlorinated process wastes
9,10-anthraquinone,	Used in digesters for delignification	

I4, I7 – Wood Treatment (Antisapstain or Preservation)

Canada's wood preservation industry initially developed using creosote to service the needs of the railroads. Pentachlorophenol (PCP) became popular, particularly for utility poles, in the 1970s, and chromated copper arsenate (CCA) came into use in the 1980s. Since the early 2000s, CCA has been largely replaced with alkaline copper quat (ACQ), and copper azole. Borates, in the form of disodium octaborate tetrahydrate, were used for dip-diffusion treatment of lumber in the 1960s and 1970s for export to the UK. Later antisapstains include didecyl dimethyl ammonium chloride and 3-iodo-2-propynyl-butyl carbamate, disodium octaborate tetrahydrate, and ammoniacal copper zinc arsenate.

The preservative treatment of wood in Canada can comprise a sequence of processes including drying, incising, pre-staining, pressure treatment, and accelerated fixation (for CCA). Antisapstains are typically applied in dip tanks or spray booths.

PCOC Substance Class	Activity/Source	Comments
Petroleum hydrocarbons	Carrier oils, lubricants, and hydraulic systems	HEPH, LEPH, VPH
BTEX	Creosote, carrier oils	
Polycyclic aromatic hydrocarbons	Creosote, copper-8	Quinoline from copper-8 antisapstain (8-quinolinolate)
Metals	Preservatives (chromated arsenicals, borates, copper-based preservatives, and phenylmercury acetate)	Particularly arsenic, boron, chromium, copper, and mercury
Chlorinated Phenols	Preservatives	Particularly pentachlorophenol (PCP) and tetrachlorophenol
Non-chlorinated Phenols	Creosote	Specifically, methylphenols (cresols)

TCMTB and other Fungicides	Preservatives	E.g., TCMTB, propiconazole, and triadimefon
Nitrogen compounds	Preservative ACQ breakdown products	Ammonia, nitrate, and nitrite
Dioxins/furans	Impurities in PCP preservatives	Secondary to PCP (i.e. unlikely to be present if PCP concentrations are not elevated)

I9 – Sawmills

Sawmill operations include log grading, debarking, and sawing. Lumber is then finished with trimming, drying, and planing. Sawmill operations typically include log yards, a planer mill, vehicle/equipment fuelling and maintenance facilities, a scrap yard/boneyard, and wood waste storage/landfilling. They may include kilns, a thermal oil system to heat kilns, a wood waste incinerator, and wood treatment.

PCOC Substance Class	Activity/Source	Comments
Petroleum hydrocarbons	Fuels, lubricants, and hydraulic and heat transfer systems	PCOCs associated with lubricants and hydraulic fluids are primarily LEPH and HEPH. For fuels see Section 3.2
BTEX	Fuels	
Polycyclic aromatic hydrocarbons	Fuel and waste oil, creosote	
Metals	Machine shops, bone yards, and burners	
Non-chlorinated Phenols	Buried wood waste	Phenol, methylphenols, hydroxyphenols. Nitrophenols may form in secondary reactions in surface water.
Dioxins/furans	Burners	If burning marine or treated wood
PCOCs associated with wood treatment (see I7/I4)		

3.0 DISCUSSION

3.1 Fill

Deciding the PCOCs for fill of unknown quality can be challenging because, in most cases, the origin of fill is unknown. During the Stage 1 PSI, an attempt should be made to determine the source of the fill. If the fill source is known and the source property has a Schedule 2 use, then PCOCs in fill should be those of that use. However, in most cases, the source of historical fill is unknown. In this case, PCOCs could be almost anything, but analyzing for every parameter is costly. We suggest analyzing for the most commonly found parameters, then supplement as needed based on careful observations during field work.

The most common contaminants in fill are **metals and PAH**. Fill from unknown sources could be tested for these parameters when no other information is available. Other PCOCs could be added based on field observations. Common scenarios are below:

Field Observation	PCOCs
No obvious anthropogenic impacts	Metals and PAH. Analyzing for metals only might be acceptable in fill soils with little to no organic content.
Building debris (brick, glass, lumber, metal)	Metals – building components (siding, drainage pipes, gutters, treated wood etc.). PAH – treated wood, tar, asphalt, and fuel exhaust. Fill with large amounts of building debris may contain asbestos, chlorophenols from treated wood, and sulfur compounds from gypsum board.
Odour, staining, or high field vapour measurements	BTEX, HEPH, LEPH, PAH, VOC, VPH – spilled fuels and solvents, creosote. Analysis of PCBs might be appropriate where oily stained soils of unknown origin are encountered.
Asphalt, concrete	Metals, PAH.
Foundry sand/slag, cinder	Metals, PAH, non-chlorinated phenols.
Wood waste (hog fuel, wood chips)	Non-chlorinated phenols for hog fuel, and PAH, PCP, and metals for (potentially treated) woodchips or dimensional lumber.
Dredged material	Metals and PAH (common contaminants in waterways), sodium, chloride.

3.2 Fuel

Stage 10/11 Amendments added soil and groundwater standards for parameters that were once routinely analysed in vapour, but not in soil and groundwater. New parameters were also added. We conducted a literature review, and reviewed our databases to generate preliminary recommendations on the analysis of these new parameters when investigating hydrocarbon fuel impacts. We recognise that as an industry we lack experience with the new parameters, and industry methods may change with time as new information becomes available.

Fuel composition information was mostly obtained from the Total Petroleum Hydrocarbon Working Group Series Volume 2 and Volume 3. Volume 2 of the series includes a list of various fuel additives. An important conclusion of that document is that, of all the blending agents and additives listed, only lead, barium, MTBE, 1,2-dibromoethane (EDB), and 1,2-dichloroethane (DCA) are likely to be detected in the environment. During our review of the literature around this topic we could not find any examples of fuel-impacted sites contaminated by fuel additives other than those listed above.

Specific fuel PCOCs are given more detail in the table below. We focus on parameters that are commonly analysed, parameters that were previously regulated in soil-vapour only, newly regulated parameters that are part of a hydrocarbon mix, and the fuel additives listed above. Fuel mix and additives vary depending on the date the fuel was produced and the fuel type.

In most cases the new parameters have relatively less stringent standards and are expected to be secondary to parameters that were regulated in soil and groundwater prior to the Stage 10/11 updates to the CSR in November 2017. The notable exceptions are **EDB and DCA** (historical lead scavengers in gasoline) in groundwater. Studies by the Environmental Protection Agency (EPA) in the United States show that exceedances of the parameters can occur when other parameters, like BTEX, are below standards. EDB is of particular concern since the standard is low (i.e., stringent). They are both relatively soluble and persistent in the environment. The EPA now recommends testing for these parameters where leaded gasoline was stored.

Complicating investigations are the effects of weathering and differences in parameter transport dynamics, both of which can change the relative concentrations of contaminants in soil or groundwater after the initial release.

- During weathering some parameters are degraded first, generally lower molecular weight hydrocarbons, which results in heavier and more persistent parameters becoming primary contaminants; and
- More soluble parameters (e.g. MTBE and benzene) are generally transported by groundwater more quickly than less soluble parameters. This can cause them to ‘lead’ their plumes separating them from the bulk of contamination.

Fuel PCOCs in soil and groundwater:

Parameter	Associated Fuel Type	Comments
barium	Diesel smoke suppressant	Barium-containing fuel additives have been added to high sulfur diesel fuels to reduce engine smoke. Most literature attributes barium contamination from fuel to deposition of particulate from vehicle exhaust, not liquid spills. Barium contamination is expected to be secondary to other hydrocarbon parameters.
BTEX	All types	Parameters commonly analyzed in association with most fuels. Likely secondary to LEPH in higher alkane fuels like diesel or fuel oil.
butadiene, 1,3-	Gasoline	1,3-butadiene is mostly associated with automotive exhaust. There is very little literature data for concentrations of this parameter in soil and groundwater, but where there is data, 1,3-butadiene is typically below detection limits in soil and groundwater (although most detection limits are above the lowest CSR standards). More information is needed.
butylbenzenes (n-, sec-, tert-)	Gasoline and diesel	Lower percentage in the mix than other parameters that have more stringent standards (like BTEX). Therefore, given that the butylbenzene standards are much less stringent, these parameters will likely be secondary to BTEX parameters. Based on the (limited) information in our database, these parameters may exceed standards where other contaminant levels are high.
cyclohexene	Gasoline	Lower percentage in the mix than other parameters that have more stringent standards (like BTEX). Cyclohexene is likely secondary to BTEX parameters. Groundwater or soil analysis might be warranted where other contaminant levels are high, but more experience is needed.

dibromoethane, 1,2-, and dichloroethane, 1,2-	Leaded gasoline lead scavengers	There is limited data on these parameters as relatively few jurisdictions require their analysis. However, where analysis has been conducted in the United States, contamination has been found relatively frequently (particularly 1,2-dibromoethane). The fate and transport dynamics of these parameters are such that they can persist independent of the original gasoline source. More experience with these parameters is needed. In the meantime, we suggest that they be routinely analyzed where leaded gasoline is a suspected contaminant.
dicyclopentadiene	Gasoline	Lower percentage in the mix than other parameters that have more stringent standards (like BTEX). Dicyclopentadiene is likely secondary to BTEX or other hydrocarbon parameters. Groundwater or soil analysis might be warranted where other contaminant levels are high, but more experience is needed.
HEPH	Diesel, Kerosene, and Fuel Oils	Parameter commonly analyzed in association with high alkane fuels.
isopropylbenzene	Gasoline, diesel, Jet fuel	Lower percentage in the mix than other parameters that have more stringent standards (like BTEX). Isopropylbenzene is likely secondary to BTEX parameters. Groundwater or soil analysis might be warranted where other contaminant levels are high.
LEPH	All fuel types	Commonly analyzed in association with all fuel types.
methanol	Gasoline octane enhancer, Methanol fuel	Methanol can sometimes be blended with gasoline to increase performance, but its use is uncommon in North America where ethanol blends are preferred. Methanol fuels are sometimes used in specialized engines but are not common.
MTBE	Gasoline octane enhancer	Commonly analyzed parameter. MTBE is an octane enhancer mostly used in gasoline produced in Canada between 1986 and 2000. MTBE has a high water solubility, and may lead plumes and exceed standards in groundwater when other parameters are not present.

nonane, n-	All fuel types	N-nonane is part of the hydrocarbon mix, but generally at concentrations less than BTEX in gasoline and diesel. N-nonane contamination will likely be secondary to BTEX parameters in most cases, but more experience with this parameter is needed. N-nonane is a significant component of some higher alkane fuels like kerosene and jet fuel, and may be a primary contaminant for these fuels.
Polycyclic aromatic hydrocarbons (PAH) – alkyl-naphthalenes (naphthalene, 1-methylnaphthalene, 2-methylnaphthalene)	All fuel types	Naphthalene is commonly analyzed and is associated with all fuel types. 1-methylnaphthalene and 2-methylnaphthalene were added in the Stage 10/11 amendments to schedules in the CSR, and have not been consistently analyzed in the past. Naphthalene is routinely analyzed when assessing gasoline and diesel spills. Methylnaphthalenes are more commonly present in higher alkane fuels, and have similar concentrations in the mix as naphthalene. However, methylnaphthalenes have less stringent standards and are likely secondary to naphthalene in most cases.
PAH (excluding naphthalenes)	Diesel, kerosene, fuel oil	Parameters commonly analyzed in association with high alkane fuels. Secondary to LEPH in most cases.
propylbenzene, 1-	Gasoline, diesel, jet fuel	Lower percentage in the mix than other parameters that have more stringent standards (like BTEX). Propylbenzene is likely secondary to BTEX and other hydrocarbon parameters. Groundwater or soil analysis might be warranted where other contaminant levels are high, but more experience is needed.

styrene	Gasoline and diesel	Lower percentage in the mix than other parameters that have more stringent standards (like BTEX). Styrene is likely secondary to BTEX and other hydrocarbon parameters. Styrene is commonly included with BTEX analysis in some lab packages. In our experience, styrene exceedances are rare.
tetraethyl lead (TEL)	Gasoline octane enhancer	TEL was added to some gasolines produced from the 1920s to 1995. Most literature attributes lead contamination from fuel to vehicle exhaust, not liquid spills. Outside of petroleum liquid TEL is expected to degrade quickly; therefore, we might expect TEL to be secondary to other fuel parameters. However, TEL standards are stringent, so more experience is needed to conclude that TEL is a secondary parameter in all circumstances. In our experience, total lead exceedances due to leaded gasoline spills are rare, and are usually secondary to hydrocarbon contamination.
trimethylbenzene, 1,3,5-	All fuel types	1,3,5-trimethylbenzene seems to appear at similar or lower concentrations than BTEX. Therefore, given that the standards are less stringent, it will likely be a secondary parameter. Routine analysis is likely not required, but 1,3,5-trimethylbenzene may exceed standards when other contamination is present. Trimethylbenzenes are less biodegradable than BTEX, and weathered fuels may have higher trimethylbenzene concentrations.
VPH	All fuel types	Commonly analyzed in association with all fuel types, likely secondary in higher alkane fuels (diesel, jet fuel, and fuel oil).

3.3 Waste Oil

Waste oil tanks are often improperly used to dispose of other substances, gasoline/diesel, solvents, and antifreeze for example. As a result, PCOCs associated with waste oil tanks should include all PCOCs at a site that might be added to a waste oil tank (see the table for Schedule 2 use G2 above).

Metals are often contaminants in waste oil and are sourced from engine/machine wear and additives. Metals commonly associated with waste oil are: arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, molybdenum, nickel, tin and zinc.

PAHs in waste oil are often elevated compared to unused oil. PAH parameters, particularly those with low standards, may be primary contaminants in waste oil.

4.0 SUBSTANCE CLASS

The table below provides a parameter level breakdown of the substance classes used in the Schedule 2 land use tables in Section 2.0. Not all parameters in a substance class will be PCOCs for a specific Schedule 2 land use. For example, the mix of metals for wood preserving operations, will be different than for foundries.

The lists below contain the parameters that we think are most relevant in the context of the Schedule 2 uses listed above and do not necessarily contain all parameters that might fit into that class.

BTEX	
benzene ethylbenzene toluene xylenes, total	Common aromatic components of hydrocarbon fuels and solvents
Chlorinated Fluorocarbons (CFC)	
trichlorofluoromethane (CFC-11) trichloro-1,1,2-trifluoroethane, 1,2,2- (CFC-113)	Historically used as refrigerants, aerosol propellants, and solvents. Discontinued after ~1990.
Chlorinated Aliphatics	
carbon tetrachloride chloroethane chloroform chloromethane dichloroethane, 1,1- dichloroethane, 1,2- dichloroethylene, 1,1 - dichloroethylene, 1,2-cis- dichloroethylene, 1,2-trans- dichloromethane Tetrachloroethylene tetrachloroethane, 1,1,1,2- tetrachloroethane, 1,1,2,2- trichloroethane, 1,1,1- trichloroethane, 1,1,2- Trichloroethylene vinyl chloride	Primarily used as solvents. Perhaps most notable is tetrachloroethylene which is commonly used for dry cleaning. Other parameters are breakdown products of tetrachloroethylene and are used as solvents on their own. Trichloroethylene is the next most commonly used solvent after tetrachloroethylene. Longer chained chlorinated hydrocarbons are also regulated (chloropropane, chlorohexane, etc.) but are usually used as chemical intermediates in the manufacture of other chemicals, and are not routinely analyzed.

Chlorinated Benzenes	
chlorobenzene dichlorobenzene, 1,3- dichlorobenzene, 1,2- dichlorobenzene, 1,4- hexachlorobenzene pentachlorobenzene, 1,2,3,4,5- tetrachlorobenzene, 1,2,3,4- tetrachlorobenzene, 1,2,3,5- tetrachlorobenzene, 1,2,4,5- trichlorobenzene, 1,2,3- trichlorobenzene, 1,2,4- trichlorobenzene, 1,3,5-	Chlorinated benzenes are mostly used in the synthesis of other products, perhaps most notably the production of herbicides and dyes. Some chlorinated benzenes, particularly chlorobenzene and 1,2-dichlorobenzenes, are used as degreasers, but chlorinated aliphatic solvents (tetrachloroethylene and trichloroethylene) are more common.
Chlorinated Phenols	
chlorophenol, 2- chlorophenol, 3- chlorophenol, 4- dichlorophenol, 2,3- dichlorophenol, 2,4- dichlorophenol, 2,5- dichlorophenol, 2,6- dichlorophenol, 3,4- dichlorophenol, 3,5- pentachlorophenol [PCP] tetrachlorophenol, 2,3,4,5- tetrachlorophenol, 2,3,4,6- tetrachlorophenol, 2,3,5,6- trichlorophenol, 2,4,6- trichlorophenol, 2,3,4- trichlorophenol, 2,3,5- trichlorophenol, 2,3,6- trichlorophenol, 2,4,5- trichlorophenol, 3,4,5-	Chlorinated phenols are mostly associated with wood preservation. Pentachlorophenol and its breakdown products are the most common.
Esters	
ethyl acetate ethyl acrylate methyl acetate methyl methacrylate vinyl acetate	Used as solvents in paints and other coatings, and in industrial and laboratory processes.
Glycols	
ethylene glycol propylene glycol	Commonly used as coolant and antifreeze in automotive applications. Ethylene glycol is used in aircraft de-icing fluids.

Glycol Ethers	
butoxyethanol, 2- diethylene glycol monobutyl ether diethylene glycol monoethyl ether ethoxyethanol acetate, 2- ethoxyethanol, 2- methoxyethanol, 2- Methoxyethanol acetate, 2- propylene glycol monomethyl ether	Solvents with diverse applications. Commonly used in paints and coatings, cleaning compounds, and detergents. Sometimes used as general solvents in industrial processes (particularly 2-butoxyethanol).
Ions	
chloride (Cl-) fluoride (F-) sodium (Na+) sulfate (SO_4^{-2})	Sodium and chloride are contaminants associated with salt use, usually form road de-icing facilities. Fluxes used in metallurgic applications can be sources (e.g., ammonium chloride, calcium fluoride, and zinc chloride).
Ketones	
acetone acetophenone cyclohexanone isophorone 2-hexanone (MBK) methyl ethyl ketone (MEK) methyl isobutyl ketone (MIBK)	Ketone solvents are most commonly used with paints and coatings.

Metals	
aluminum antimony arsenic barium beryllium boron cadmium chromium, hexavalent chromium, trivalent cobalt copper iron lead lithium manganese mercury molybdenum nickel selenium silver strontium thallium tin titanium tungsten vanadium zinc	Metals are common contaminants at a wide variety of contaminated sites. Sources range from metallurgical operations, to wood preservation, pesticides, and used lubricating oil.
Nitrogen Compounds	
ammonia, total (as N) nitrate (as N) nitrite (as N)	Nitrogen compounds are usually associated with fertilizers and agricultural operations, but are also found associated with waste disposal and sewage sites. Industrial operations that use nitrogen containing chemicals (e.g. urea, ammonium chloride, or nitrate explosives) can be impacted by nitrogen compounds.
Organometallics	
dibutyltin methyl mercury tetraethyl lead tributyltin tricyclohexyltin triethyltin triphenyltin	Tetraethyl lead is best known as a component of leaded gasoline. Organotins, are biocides and are best known as contaminants associated with marine anti-foulant paints and coatings.

Polycyclic Aromatic Hydrocarbons (PAH)	
acenaphthene anthracene benz(a)anthracene benzo(a)pyrene benzo(b+j)fluoranthene benzo(ghi)perylene benzo(k)fluoranthene chrysene dibenz(a,h)anthracene fluoranthene fluorene indeno(1,2,3-cd)pyrene methylnaphthalene, 1- methylnaphthalene, 2- naphthalene phenanthrene pyrene quinoline	PAH are common contaminants associated with incomplete combustion, particularly petroleum and coal burning. PAH are primary contaminants at creosote, coal tar, and used motor oil sites. PAH are likely secondary contaminants at fuel and new lubricating oil sites.
Petroleum Hydrocarbons	
EPHw10-19 HEPH LEPH VHw6-10 VPH	Common contaminants associated with hydrocarbon fuels, solvents, and lubricating oil.
Perfluoronated Compounds	
PFBS PFOS PFOA	Perfluoronated compounds are used to impart oil and water repellency, temperature resistance, and friction reduction to a large range of products. They have applications in a range of manufacturing industries and chemical formulations. As contaminants they are commonly associated with firefighting foams, and coatings to enhance water repellency.

Phenols, Non-Chlorinated	
catechol dimethylphenol, 2,4- dimethylphenol, 2,6- dimethylphenol, 3,4- hydroquinone methylphenol, 2- methylphenol, 3- methylphenol, 4- phenol resorcinol	Non-chlorinated phenols are commonly associated with effluents from pulp mills, and decomposition of buried wood waste. Phenol and methylphenols are components of coal tar and related products like creosote, but are likely to be secondary to PAH.

5.0 REFERENCES

A.J. Chandler & Associates Ltd., 2006. Review of Dioxins and Furans from Incineration.

Alberta Environment, 2001. Phase 1 Environmental Site Assessment Guideline for Upstream Oil and Gas Sites. Alberta Environment, Edmonton, Alberta. Report # ESD/LM/01-1. ISBN: 0-7785-1421-8 (Printed Edition), 0-7785-1422-6 (On-line Version), Publication No: T/573.

Alberta Environmental Protection, 1996. Environmental Protection and Enhancement Act Waste Control Regulation, Industrial Waste Identification and Management Options.

Amer, S.I., AQUACHEM INC., 1998. “Treating Metal Finishing Wastewater” Environmental Technology, March/April 1998.

A.R.G. Price and J.W. Readman, Late lessons from early warnings: science precaution, innovation. Booster biocide antifoulants: is history repeating itself?

ATSDR, 1992. Agency for Toxic Substances and Disease Registry. Toxicological Profile for 2-Butanone.

ATSDR, 1994. Agency for Toxic Substances and Disease Registry. Toxicological Profile for Acetone.

ATSDR, 1999. Agency for Toxic Substances and Disease Registry. Toxicological Profile for Total Petroleum Hydrocarbons (TPH).

B. Boughton and A. Horvath, 2004. Environmental Assessment of Used Oil Management Methods. Environmental Science & Technology, 38.2. 2004.

BC Hydro, 2012. Pest Management Plan for Management of Vegetation at BC Hydro Facilities #105-0980-12/17.

BC Oil & Gas Commission, 2016. Certificate of Restoration Application Manual, Version 1.2. June 2016.

British Columbia Water Stewardship Division 2007, Well Protection Toolkit. Available online at < http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/wells/well_protection/acrobat.html>

C. Hoskinson. Recommendation for States, Tribes and EPA Regions to Investigate and Clean Up Lead Scavengers When Present at Leaking Underground Storage Tank (LUST) Sites. United States Environmental Protection Agency. May 2010.

California Environmental Protection Agency, 1995. Department of Toxic Substances Control, Office of Pollution Prevention & Technology Development. Parts Cleaning Alternatives in Machine Shops.

California State University, Sacramento, 1986. Operation of Wastewater Treatment Plants, First Edition, Volume IV, Treatment of Wastewater from Electroplating, Metal Finishing and Printed Circuit Board Manufacturing.

Canadian Association of Petroleum Producers (CAPP), 2002. Assessment of Monitored Natural Attenuation at Upstream Oil & Gas Facilities in Alberta – final report.

Canadian Council of Ministers of the Environment, 1999. Canadian soil quality guidelines for the protection of environmental and human health: Cadmium (1999). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 1999. Canadian soil quality guidelines for the protection of environmental and human health: Chromium (total 1997) (VI 1999). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 1999. Canadian soil quality guidelines for the protection of environmental and human health: Copper (1999). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 1999. Canadian soil quality guidelines for the protection of environmental and human health: Cyanide (free) (1997). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 1999. Canadian soil quality guidelines for the protection of environmental and human health: Ethylene glycol (1999). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 1999. Canadian soil quality guidelines for the protection of environmental and human health: Lead (1999). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 1999. Canadian soil quality guidelines for the protection of environmental and human health: Pentachlorophenol (1997). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 1999 Canadian soil quality guidelines for the protection of environmental and human health: Phenol (1997). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 1999. Canadian soil quality guidelines for the protection of environmental and human health: Polychlorinated biphenyls (total) (1999). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 2001. Canadian soil quality guidelines for the protection of environmental and human health: Arsenic (inorganic) (1997). Updated In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 2002. Canadian soil quality guidelines for the protection of environmental and human health: Nonylphenol and its ethoxylates. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 1999. Canadian soil quality guidelines for the protection of environmental and human health: Tetrachloroethylene (1997). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 1999. Canadian soil quality guidelines for the protection of environmental and human health: Zinc (1999). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 2002. Canadian soil quality guidelines for the protection of environmental and human health: Dioxins and Furans. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 2004. Canadian soil quality guidelines for the protection of environmental and human health: Benzene (2004). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 2004. Canadian soil quality guidelines for the protection of environmental and human health: Ethylbenzene (2004). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 2004. Canadian soil quality guidelines for the protection of environmental and human health: Toluene (2004). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 2004. Canadian soil quality guidelines for the protection of environmental and human health: Xylenes (2004). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 2006. Canadian soil quality guidelines for the protection of environmental and human health; Sulfolane (2006). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 2006. Canadian soil quality guidelines for the protection of environmental and human health: Trichloroethylene (2006). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 2010. Canadian soil quality guidelines for the protection of environmental and human health: Carcinogenic and Other PAHs. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 2013. Canadian soil quality guidelines for the protection of environmental and human health: Barium. In: Canadian environmental quality guidelines, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment, 2015. Canadian soil quality guidelines for the protection of environmental and human health: Nickel (2015). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment (CCME), 2016. Guidance Manual for Environmental Site Characterization in Support of Environmental and Human Health Risk Assessment, Volume 1 Guidance Manual.

Canadian Environmental Protection Act, 1991. Environment and Health Canada. Priority Substances List Assessment Report No. 2: Effluents from Pulp Mills Using Bleaching.

Canadian Pacific Railway, 2015. CP Rail 2015 Integrated Vegetation Management Plan. Pest Management Plan Reference Number – CP01122014.

CH2M HILL for the Alaska Department of Environmental Conservation, 2006. Evaluation of Snow Disposal into Near Shore Marine Environments.

CSAP Soil Vapour Advice and Practice Guidelines Development Panel, 2009. Soil Vapour Advice and Practice Guidelines Development Panel - Stage 1.

Department of Environment, Government of Western Australia, 2004. Contaminated Sites Management Series, Potentially Contaminating Activities, Industries and Land uses.

Dr. R.S. Mansell, Dr. L. Ou, Dr. R.D. Rhue, and Dr. Y. Ouyang, 1995. The Fate and Behavior of Lead Alkyls in The Subsurface Environment. November 1995.

Eastern Research Group, 1997. Solvent Cleaning; Volume III: Chapter 6. September 1997.

EEA, 2013. European Environment Agency. Late lessons from early warnings: science, precaution, innovation.

Envirochem Services Inc., 2008. Emissions from Wood-Fired Combustion Equipment.

Environment Canada, Health Canada, 1992. Priority Substances List Assessment Report No. 5, methyl tertiary-butyl ether. 1992.

Environment Canada, Health Canada. 2000. Priority Substances List Assessment Report; 1,3-Butadiene. May 2000.

Environment and Climate Change Canada, 2017. Federal Environmental Quality Guidelines: Perfluorooctane Sulfonate (PFOS). February 2017.

Environment Yukon, Environmental Programs Branch, 2015. General Information on Waste Oil. November 2015.

Environmental and Safety Services, 1999. Environment Australia; Department of the Environment and Heritage. Incineration and Dioxins: Review of Formation Processes.

Environmental Defense Fund, 1995. White Paper No. 5, Environmental Comparison of Bleached Kraft Pulp Manufacturing Technologies.

EPA, 1975. US Environmental Protection Agency. Nitrogen in the Subsurface Environment. June 1975.

EPA, 1989. US Environmental Protection Agency. Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category, Volume I, General Development Document.

EPA, 1990. US Environmental Protection Agency. Guides to Pollution Prevention: The Commercial Printing Industry.

EPA, 1990. US Environmental Protection Agency. Guides to Pollution Prevention: The Fabricated Metal Products Industry.

EPA, 1990. US Environmental Protection Agency. Guides to Pollution Prevention: The Paint Manufacturing Industry.

EPA, 1990. US Environmental Protection Agency. A Review of Sources Of Ground-Water Contamination From Light Industry: Technical Assistance Document.

EPA, 1991. US Environmental Protection Agency. Guides to Pollution Prevention, The Automotive Repair Industry.

EPA, 1991. US Environmental Protection Agency. Guides to Pollution Prevention, The Marine Maintenance and Repair Industry.

EPA, 1992. US Environmental Protection Agency. Contaminants and Remedial Options at Wood Preserving Sites.

EPA, 1992. US Environmental Protection Agency. Guides to Pollution Prevention, Metal Casting and Heat Treating Industry.

EPA, 1992. US Environmental Protection Agency. Guides to Pollution Prevention, The Mechanical Equipment Repair Industry.

EPA, 1993. US Environmental Protection Agency. Wellhead Protection: A Guide for Small Communities February 1993.

EPA, 1993. US Environmental Protection Agency. Guides to Pollution Prevention: Wood Preserving Industry.

EPA, 1994. US Environmental Protection Agency. Locating and Estimating Air Emissions from Sources of Chlorobenzenes (Revised). March 1994.

EPA, 1994. US Environmental Protection Agency. Locating and Estimating Air Emissions from Sources of Methyl Ethyl Ketone. March 1994.

EPA, 1995. US Environmental Protection Agency. EPA Office of Compliance Sector Notebook Project, Profile of the Iron and Steel Industry.

EPA, 1995. US Environmental Protection Agency. EPA Office of Compliance Sector Notebook Project, Profile of the Lumber and Wood Products Industry.

EPA, 1999. US Environmental Protection Agency. Technical Approaches to Characterizing and Cleaning Up Automotive Repair Sites Under the Brownfields Initiative. February 1999.

EPA, 2009. US Environmental Protection Agency. PFOs Chromium Electroplanter Study: U.S. Environmental Protection Agency-Region 5.

EPA, 2010. US Environmental Protection Agency. Nonylphenol (NP) and Nonylphenol Ethoxylates (NPEs) Action Plan, [RIN 2070-ZA09].

EPA, 2014. US Environmental Protection Agency. Risk Assessment of Spent Foundry Sands in Soil-Related Applications. Evaluating Silica-based Spent Foundry Sand from Iron, Steel, and Aluminium Foundries. October 2014.

EPA, 2015. US Environmental Protection Agency. PCBs in Building Materials—Questions & Answers.

EPA, 2017. US Environmental Protection Agency. National Primary Drinking Water Regulations. Available online at https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations#Organic. March 21, 2017.

EPA, 2017. US Environmental Protection Agency. Technical Fact Sheet – 1,4-Dioxane.

G. Zając, J. Szyszlak-Bargłowicz, T. Słowik, A. Kuranc, A. Kamińska, 2015. Designation of Chosen Heavy Metals in Used Engine Oils Using the XRF Method. Pol. J. Environ. Stud. Vol.24.5. 2015.

Getting Up to Speed: Ground Water Contamination adapted from US EPA Seminar Publication. Wellhead Protection: A Guide for Small Communities. Chapter 3. EPA/625/R-93/002 (1993).

Global Asset Protection Services LLC. Transformer and Capacitor Dielectric Fluids. GAPS Guidelines, 5.4.5. 2015.

Goodwin Proctor, 2006. Historic Fill at Brownfields Properties: Opportunities and Challenges for Developers. Environmental & Energy Advisory: An update of law, policy and strategy. August 2006.

H. Devold, 2013. Oil and gas production handbook: An introduction to oil and gas production, transport, refining and petrochemical industry. 2013.

I.A. Ololade, 2014. An Assessment of Heavy-Metal Contamination in Soils within Auto-Mechanic Workshops Using Enrichment and Contamination Factors with Geoaccumulation Indexes. Journal of Environmental Protection, 5. 2014.

ICF Consulting, 2004. The U.S. Solvent Cleaning Industry and the Transition to Non Ozone Depleting Substances.

Interstate Technology and Regulatory Council (ITRC), 2003. Technical/Regulatory Guidelines: Characterization and Remediation of Soils at Closed Small Arms Firing Ranges.

ITRC, 2017. Interstate Technology Regulatory Council. History and Use of Per- and Polyfluoroalkyl Substances (PFAS).

ITRC, 2018. Interstate Technology Regulatory Council. Site Characterization Considerations, Sampling Precautions, and Laboratory Analytical Methods for Per- and Polyfluoroalkyl Substances (PFAS).

J. Evans, 2010. Where does all that metal come from? Technical Bulletin, 47. 2010.

J. Michalowicz and W. Duda, 2007. Phenols – Sources and Toxicity. Polish J. of Environ. Stud. Vol.16.3. 2007.

J.B. Gustafson, J. Griffith Tell, and D. Orem, 1997. Selection of Representative TPH Fractions Based on Fate and Transport Considerations. July 1997.

J.H. Montgomery and L.M. Welkom, 1991. Groundwater Chemicals Desk Reference. Lewis Publishers Inc.

J-Y. Chin and S.A. Batterman, 2011. VOC composition of current motor vehicle fuels and vapors, and collinearity analyses for receptor modeling. February 2011.

Kent Engineering Ltd., 1997. Technical Pollution Prevention Guide for Foundries in the Lower Fraser Basin of British Columbia.

L. Olivella, M. Figueras, J. Fraile, M. Vilanova, A. Ginebreda, and D. Barceló, 2002. Fate of MTBE and DCPD Compounds Relative to BTEX in Gasoline-Contaminated Aquifers. The Scientific World Journal, 2. April 2002.

L. Turczynowicz and N. Robinson, 2008. Review of current international approaches to total petroleum hydrocarbon assessment. CRC for Contamination Assessment and Remediation of the Environment, Technical Report no. 8. Coffey Environments. June 2008.

Linn et. al, 2010. State Coalition for Remediation of Drycleaners (SCRD). Conducting Contamination Assessment Work at Dry Cleaning Sites.

M. Bosnic, J. Buljan, and R. P. Daniels, UNIDO, 2000. United Nations Industrial Development Organization, Regional Programme for Pollution Control in the Tanning Industry in South-East Asia. Pollutants in Tannery Effluents, Limits for Discharge Into Water Bodies and Sewers.

M. Mwinyihija, 2010. Chapter 2 Main Pollutants and Environmental Impacts of the Tanning Industry. Ecotoxicological Diagnosis in the Tanning Industry.

M.A. Zali, W. Kamaruzaman Wan Ahmada, A. Retnama, and N. Catrina, 2015. Concentration of heavy metals in virgin, used, recovered and waste oil: a spectroscopic study. Procedia Environmental Sciences, 30. 2015.

Methanol Institute. Methanol Use in Gasoline: Blending, Storage and Handling of Gasoline Containing Methanol. Methanol Blending Technical Product Bulletin.

Ministry of Environment, 1998. Water Quality, Roadsalt and Winter Maintenance for British Columbia Municipalities, Best Management Practices to Protect Water Quality. Retrieved from http://www.env.gov.bc.ca/wat/wq/bmps/roadsalt.html#tab2

Ministry of Environment, 2005. Technical Guidance on Contaminated Sites 9, Chlorophenol Aquatic Life Water Quality Standards. October 2005.

Ministry of Environment, 2009. Facts on Contaminated Sites, Requirements for the Environmental Cleanup of Illegal Drug Manufacturing Sites.

Ministry of Environment, 2010. Technical Guidance on Contaminated Sites 4, Vapour Investigation and Remediation. September 2010.

Ministry of Environment, 2011. Wood Waste Landfills Guideline for the Code of Practice for Industrial Non-Hazardous Waste Landfills Incidental to the Wood Processing Industry. September 2011.

Ministry of Environment, 2013. Guidance on Schedule 2 Purposes and Activities. August 2013.

Morrison, R. D., Murphy, B. L. (2006). Environmental Forensics: Contaminant Specific Guide.

National Park Service, Water Resources Divisions, Water Operations Branch, 1997. Environmental Contaminants Encyclopedia: Oil, Used Motor Oil Entry. July 1997.\

NIIR Project Consultancy Services, 2007. Modern Technology of Paints, Varnishes & Lacquers (2nd Edition).

Oregon Department of Environmental Quality. Typical Contaminants from Land Uses / Sources.

Pichtel, J., 2016. “Oil and Gas Production Wastewater: Soil Contamination and Pollution Prevention” Applied and Environmental Soil Science, Volume 2016, Article ID 2707989.

Schlesinger, M., and M. Paunovic, 2011. Modern Electroplating. John Whiley & Sons.

State Coalition for Remediation of Drycleaners (SCRD), 2009. Chemicals Used in Dry Cleaning Operations. SCRD Chemicals Database.

T.L. Potter and K.E. Simmons, 1998. Composition of Petroleum Mixtures. May 1998.

Tonkin & Taylor Ltd. And SPHERE, 2008. Assessment of Dioxin Contamination at Sawmill Sites. October 2008.

U.S. Public Health Service, Agency for Toxic Substances and Disease Registry, 1992. TOXICOLOGICAL PROFILE FOR NITROPHENOLS: 2-NITROPHENOL, 4-NITROPHENOL. July 1992.

Vermont Agency of Natural Resources, Department of Environmental Conservation, 1994. Vermont Used Oil Analysis and Waste Oil Furnace Emissions Study. September 1994; Revised March 1996.

Wang et al., 2010. “Characterization of Persistent Organic Pollutants in Ash Collected from Different Facilities of a Municipal Solid Waste Incinerator” Aerosol and Air Quality Research, 10, 391–402.

W.R. Swanson and P. Lamie, 2010. Urban Fill Characterization And Risk-Based Management Decisions – A Practical Guide. Proceedings of the Annual International Conference of Soils, Sediments, Water and Energy; Vol.12. January 2010.

XL Group Insurance, 2014. Urban Fill: Navigating the transactional and redevelopment uncertainty of clean vs. contaminated fill. 2014.

Y. Du, Y. Jin, S. Lu, Z. Peng, X. Li, J. Yan, 2013. Study of PCDD/Ss distribution in fly ash, ash deposits, and bottom ash from a medical waste incinerator in China. Journal of the Air & Waste Management Association. Vol.63.2. 2013.

6.0 LIMITATIONS

PGL Environmental and the CSAP Society accept no responsibility for any damages that may be suffered by third parties as a result of decisions or actions based on this report.

The findings and conclusions were developed in a manner consistent with the level of care and skill normally exercised by environmental professionals currently practicing under similar conditions in the BC. Changing, information, assessment techniques, and regulations mean that our conclusions can quickly become dated, so this report is for use now. Professionals should use up-to-date information and their own discretion when selecting PCOCs.