A Look Back at the History of Risk Based Guidelines

Prepared for ESAA May 20, 2020

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Our vision

We strive to be the premier engineering solutions partner, committed to delivering complex projects from vision to reality for a sustainable lifespan.

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Outline

- A bit of history
- An evolution of guidelines in Canada
- Details on how risk we “quantify” risk
- Lists of pathways and receptor endpoints in various jurisdictions
- Examples of guideline calculations
- Myths busted

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Before Risk Based Guidelines

- *de minimus*
- ‘background’
- analytical detection limits

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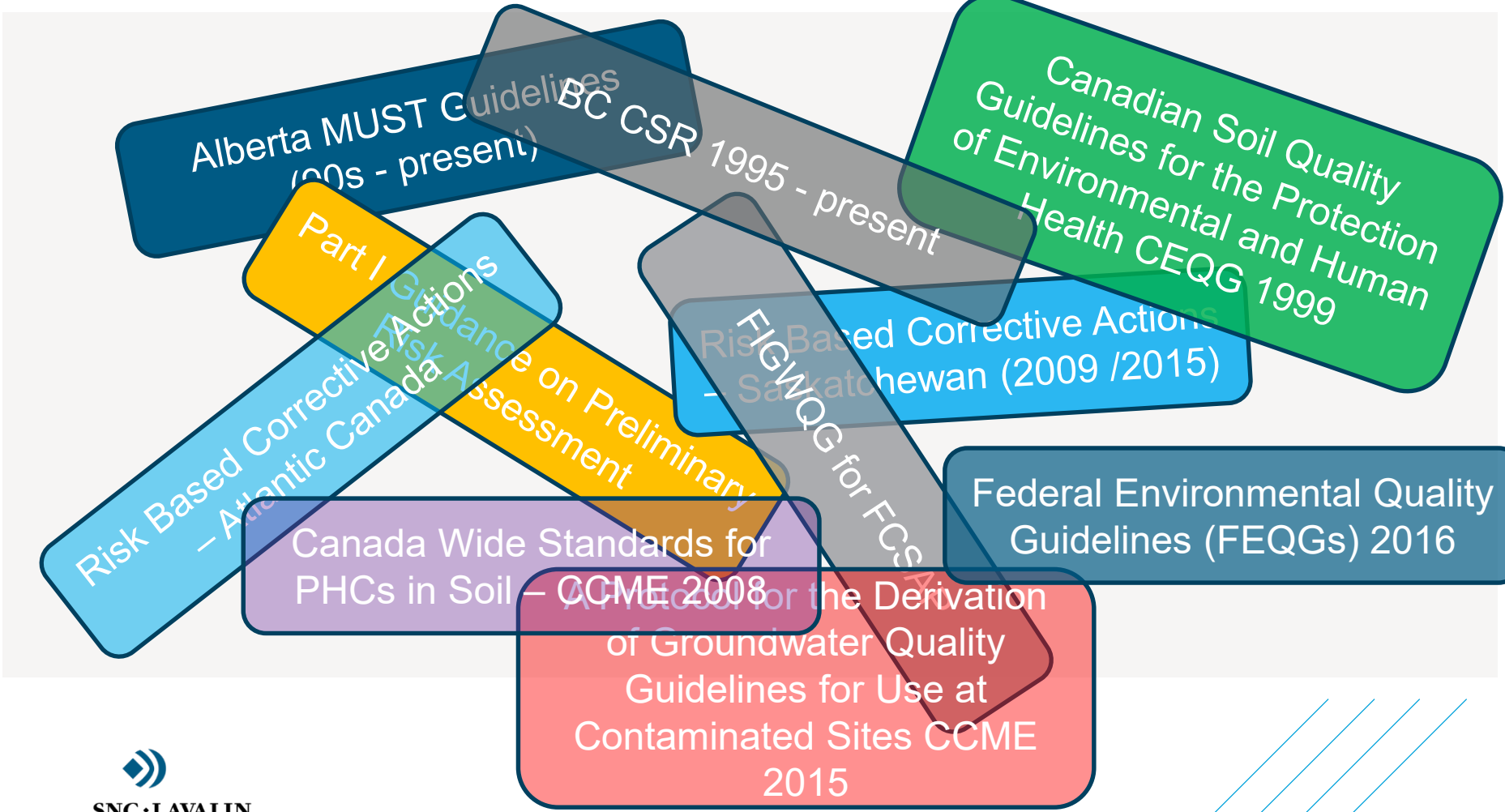
Alberta MUST Guidelines
(90s - present)
BC CSR 1995 - present
Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health CEQG 1999
Part I
Guidance on Preliminary Risk Assessment
Risk Based Corrective Actions – Atlantic Canada
Risk Based Corrective Actions – Saskatchewan (2009 /2015)
FIGWQG for FCSAP
Federal Environmental Quality Guidelines (FEQGs) 2016
Canada Wide Standards for PHCs in Soil – CCME 2008
Protocol for the Derivation of Groundwater Quality Guidelines for Use at Contaminated Sites CCME 2015

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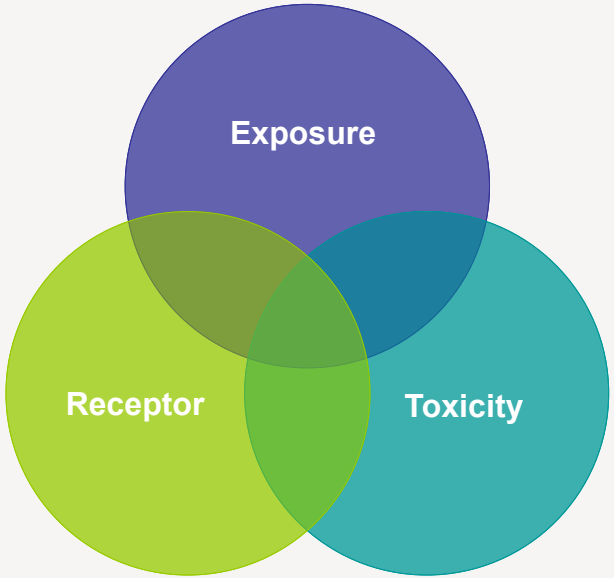
Risk Assessment

- Used in the Management of Corrective Actions for Spill Response and Reclamation of Impacted Sites
- Risk Assessment used to develop guidelines
- Risk Assessment may rely on different “tools” depending on the pathways that are creating potential risk



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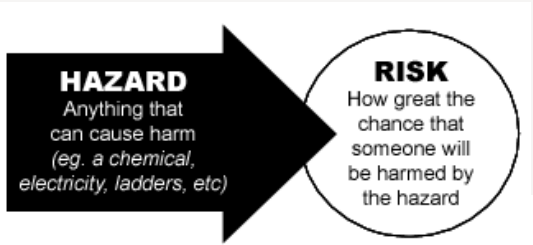
What is Risk?

Hazard: chemical in environmental medium

Without receptor/exposure there is no risk

Risk: potential for harm to individual exposed to hazard (i.e., receptor)



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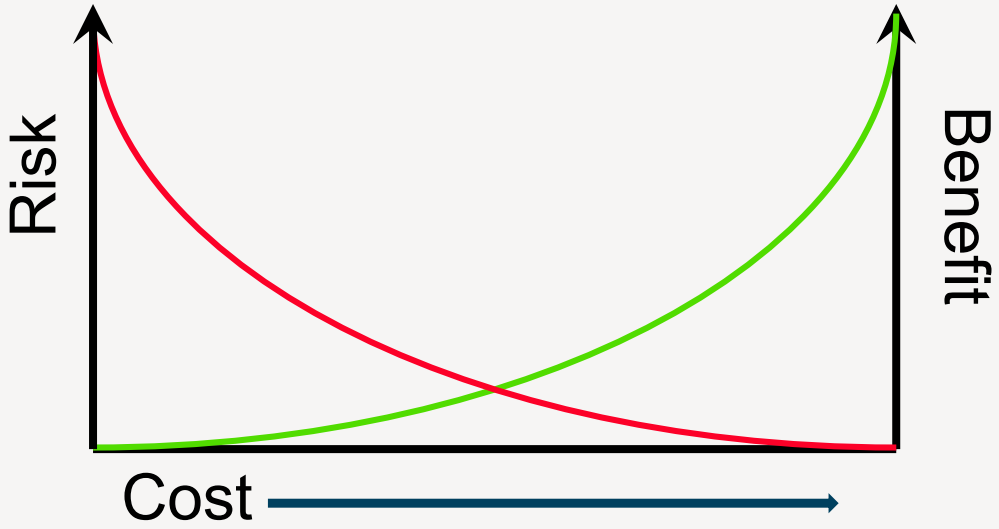
Relative Risk

Goal 1: to find the solution (risk management) that presents the best combination (compromise?) of risk reduction/control and societal benefit

Goal 2: to find a balance between the ‘precautionary principle’ and evidence-based risk management decision-making



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We Choose to Accept Risk in everything we do…

So what's acceptable?

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How do we quantify risk?

- Incremental Risk – Incidence of Cancer
- Non-carcinogens (Threshold Compounds)

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How do we calculate risk?

Zinc Supplement

$$\frac{50\ mg/day}{65\ kg \cdot bw} = 0.77\ \frac{mg}{kg \cdot bw}/day$$

Health Canada *TRV* = *0.57 mg/kg·bw/day* (Adults)

$$HQ = \frac{0.77}{0.57} = 1.35$$

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Risks by Choice vs Not?

- Incremental Risk – of getting cancer
  ILCR = 1 in 100,000 – 10^{-5}
- Non-carcinogens (Threshold Compounds)
  HQ = 0.2 up to 1

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Risks that we can't control…..

Proportionate Causes of Death in Canadians 2019

- Cancer is the leading cause of death in Canada - 29.6%
- Heart Disease - 19.2%

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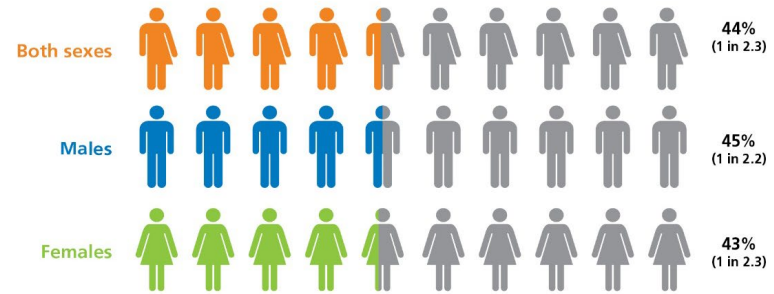
Probability of Developing Cancer

FIGURE 1.1 Lifetime probability of developing cancer, Canada (excluding Quebec), 2015



Analysis by: Centre for Surveillance and Applied Research, Public Health Agency of Canada
Data sources: Canadian Cancer Registry and National Cancer Incidence Reporting System databases at Statistics Canada

Canadian Cancer Statistics 2019

43,000/100,000 or 0.43478
So we are working on….0.43479

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Age standardized incidence rates

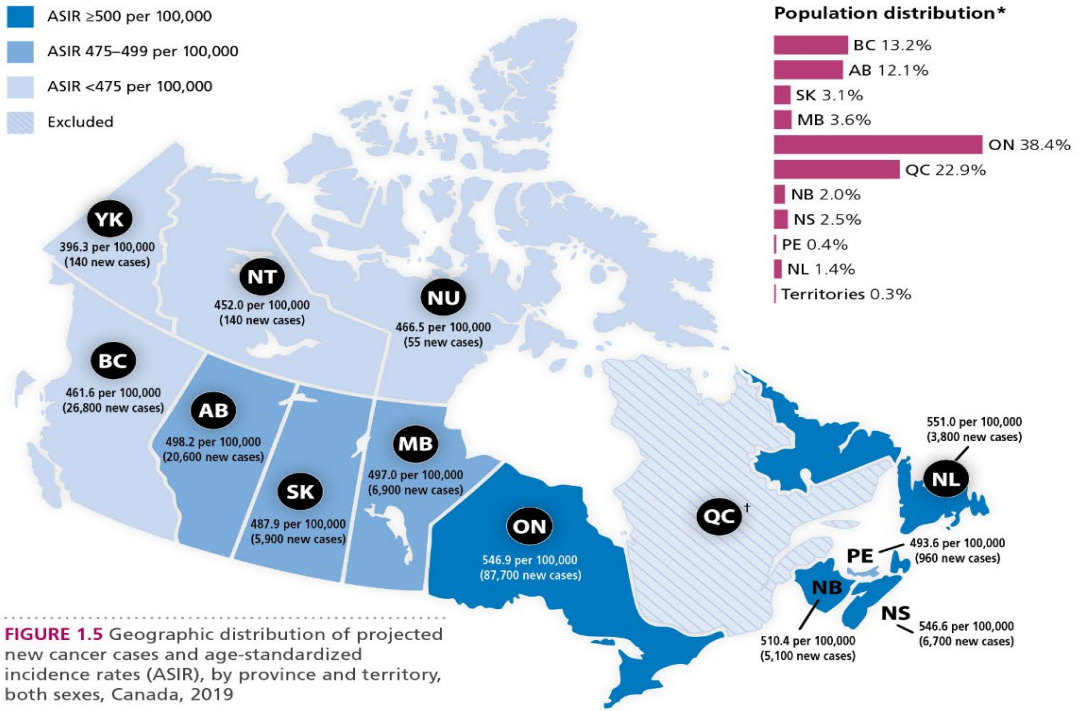

FIGURE 1.5 Geographic distribution of projected new cancer cases and age-standardized incidence rates (ASIR), by province and territory, both sexes, Canada, 2019

* Based on projected estimates of population size in 2019.

† Quebec was not included because a different projection method was used for Quebec than the other regions, meaning the estimates are not comparable. See *Appendix II: Data source and methods* for additional details.

Note: Rates are age-standardized to the 2011 Canadian population.

Analysis by: Centre for Surveillance and Applied Research, Public Health Agency of Canada

Data sources: Canadian Cancer Registry and National Cancer Incidence Reporting System databases at Statistics Canada

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Key findings

- 1 in 2.3 Canadians will get diagnosed with Cancer; 1 in 4 Canadians will die from Cancer
- 82,100 Canadians are expected to die from cancer in 2019
  - (comparison: 12,200 hospitalizations from influenza and 3,500 death ~5%)
- The mortality rates for **all cancers combined peaked in 1988** and have been decreasing ever since.

The number of cancer deaths continues to increase each year due to the growing and aging population.

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In Perspective

- The biggest risk for cancer is **age**
  - **96% of cancer deaths occur >50**
- Canada now has a greater proportion of seniors (>65 years of age)
- CoVID–19 in perspective:
  - *Saskatchewan 0.05% of the population (5×10^{-4})*
  - *Alberta 0.15% of the population (1.5×10^{-3})*

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Risk Assessment is a Methodology

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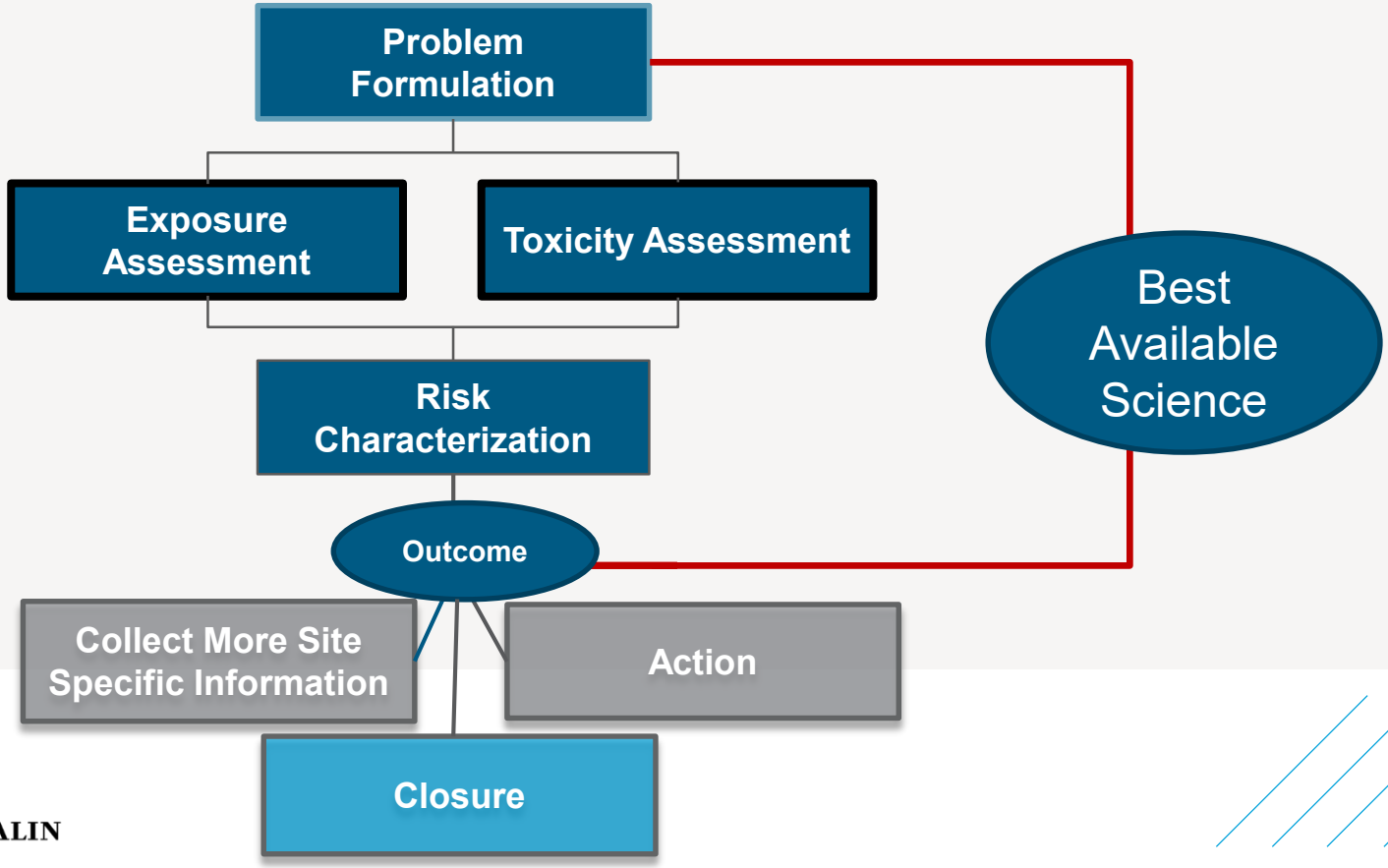
Risk Assessment is a Methodology



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Risk Characterization

For non-carcinogens, exposure estimates are compared to TRVs (TDI, RfD) to estimate a Hazard Quotient (HQ):

$$HQ = \frac{\text{Estimated Exposure (µg/kg bw/d)}}{\text{TDI/RfD(µg/kg bw/d)}}$$

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Risk Characterization

For non-carcinogens:

- Health Canada Negligible Risk Level is: Hazard Quotient <0.2
  - If EDI is available and taken into account in estimation of exposures
  - Then: HQ or 1 may be acceptable
  - HQ of 0.5 to 0.8 considered acceptable for some petroleum hydrocarbons
- Some jurisdictions allow for a HQ <1

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When Do We Use It?

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When Do We Use It?

- Physical remediation not possible / limited / costly / undesirable
- Limited exposure potential (e.g., deep, localized)
- Identify priorities for risk management / site liabilities

Pros of Risk Assessment:

- Sustainable remediation
  - Areas that require physical remediation (hot spots)
  - Areas that can be managed through administrative / risk controls
  - Areas that do not require remediation/risk management
- Typically = cost savings
- Accepted method to obtain site closure

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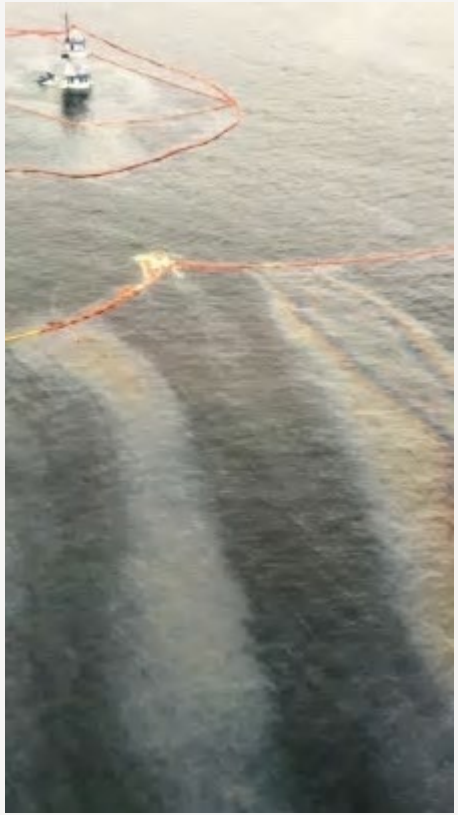
Where else does it work?

- Contaminated sites (mines, landfills, upstream O&G, harbours, maintenance yards, military bases…)
- Environmental assessments for proposed projects
  - Evaluate potential effects to human health or ecological health from proposed project construction, operations, maintenance etc.
- Spill response
  - Understand short- and long-term impacts resulting from a spill
  - Inform decision-making process throughout clean-up, monitoring and recovery phases
  - New RA-based guidance: Environmental Monitoring & Impact Assessment Guidance for Marine Oil Spills on the Pacific Coast (DFO/SNC-Lavalin/Azimuth)



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How Do We Use It?

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Lines of Evidence vs Weight of Evidence

General Principles

Gathering “All” Available Evidence

Assessing Individual Studies

Assembling Lines of Evidence

Integrating Multiple Lines of Evidence

“Differences in legislation and program goals impact time available for assessment of each particular product or activity, the amount and quality of information that is available to date for assessment, and the degree of flexibility in interpretation and application of WoE as a risk assessment approach.”

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What's in a Guideline?

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What's in a Guideline?

- 3 Tiers – each incorporating different amount of information
- Additional site-specific information increases with Tiers
- Protection goals **DO NOT** change between Tiers.

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Alberta Framework

- Tier 1 – generic remediation guidelines
- Tier 2 – site specific remediation guidelines based on the modifications of Tier 1 guidelines
- Exposure Control (Tier 3????)

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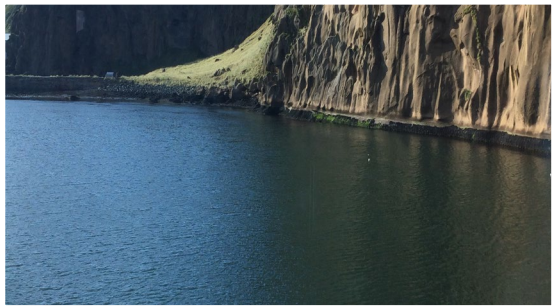
Requirements for Tier 1

Land use and Sensitivity Factors

- Proximity of site to surface water and drinking water supplies
- Actual and potential uses of groundwater
- Human and Ecological Receptors

Physical Conditions

- Soil particle size
- Stratigraphy and properties of surficial materials
- Depth to groundwater
- Presence and types of building and infrastructure



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Land Uses - 5 vs 4 Generic Categories

Alberta Tier 1

- Agricultural
- Residential/Parkland
- Commercial
- Industrial
- Natural Areas

CCME

- Agricultural
- Residential/Parkland
- Commercial
- Industrial

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Tier Principles – Exposure Pathways

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Human Health Exposure Pathways

Groundwater Quality Guidelines	Soil Quality Guidelines
Protection of potable Groundwater	Soil Ingestion
Vapour Inhalation	Dermal Contact
Dermal Contact – usually Worker Scenarios	Vapour Inhalation
Incidental Ingestion – usually Worker Scenarios	Protection of DUA

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Human Health Exposure Pathways

- Soil Ingestion (<1.5 m)
- Dermal Contact (<1.5 m)
- Vapour Inhalation (<30 m)
- Protection of Potable Water

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Ecological Exposure Pathways

Groundwater Quality Guidelines	Soil Quality Guidelines
Protection of soil dependent organisms (plants and inverts) from direct contact with contaminated groundwater	Protection of soil dependent organisms (plants, inverts, and nutrient cycling processes (i.e. microbes) from direct contact with contaminated soil.
Protection of aquatic life (SW) from contact with contaminated groundwater after discharge to a SW body	Protection of aquatic life (surface water) from contaminated soil after leaching into groundwater and discharging to surface water.
Protection of agricultural uses of water from contaminated groundwater (irrigation and livestock watering)	Protection of agricultural uses of water from soil contamination (livestock, irrigation).
	Protection of livestock and wildlife (mammals and birds) from ingestion of contaminated soil and food.

Ecological Exposure Pathways

- Protection of Groundwater for Aquatic Life (500 m for PHCs)
- Ecological Direct Contact
- Non-Potable Groundwater Standards
- Management Limits (PHC Fractions)

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Receptors of Concern (CCME, 1999)

Route of Exposure	Agricultural	Residential Parkland	Commercial	Industrial
Soil Contact	› Crops/plants › Invertebrates › Nutrient Cycling Processes › Livestock/wildlife	› Plants › Invertebrates › Nutrient Cycling Processes › Wildlife	› Plants › Invertebrates › Nutrient Cycling Processes	› Plants › Invertebrates › Nutrient Cycling Processes
Soil and food Ingestion	› Livestock/wildlife			
Multimedia exposure (human health)	› Toddler	› Toddler	› Toddler	› Adult

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Soil Exposure Pathways by Land Use - SK

	PW	Dermal Contact	VI (bas/ SOG)	FAL	ECO	LW	Soil Ingestion	ML
Agricultural	?	Y	Y	Y	Y	Y	Y	Y
Residential	?	Y	Y	?	?		Y	Y
Commercial	?	Y	Y	?	?		Y	Y
Industrial	?	Y	Y	?	Y		Y	Y

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Guidelines – Groundwater

	Health Canada	FIGQGs			
	DUA	VI	DC (Soil Organisms)	FAL	LW or WW
Agricultural	Y	Y	Y	Y	Y
Residential/Parkland	Y	Y	Y		
Commercial/Industrial	Y	Y	Y		
Natural Lands (Alberta)				Y	Y

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Groundwater Exposure Pathways by Land Use - SK

	PW	VI	FAL	ECO	LW	Irrigation	Non-Potable
Agricultural	If App	Y	If App	Y	Y	Y	Y
Residential	If App	Y	If App	Y			Y
Commercial	If App	Y	If App	?			Y
Industrial	If App	Y	If App	?			Y

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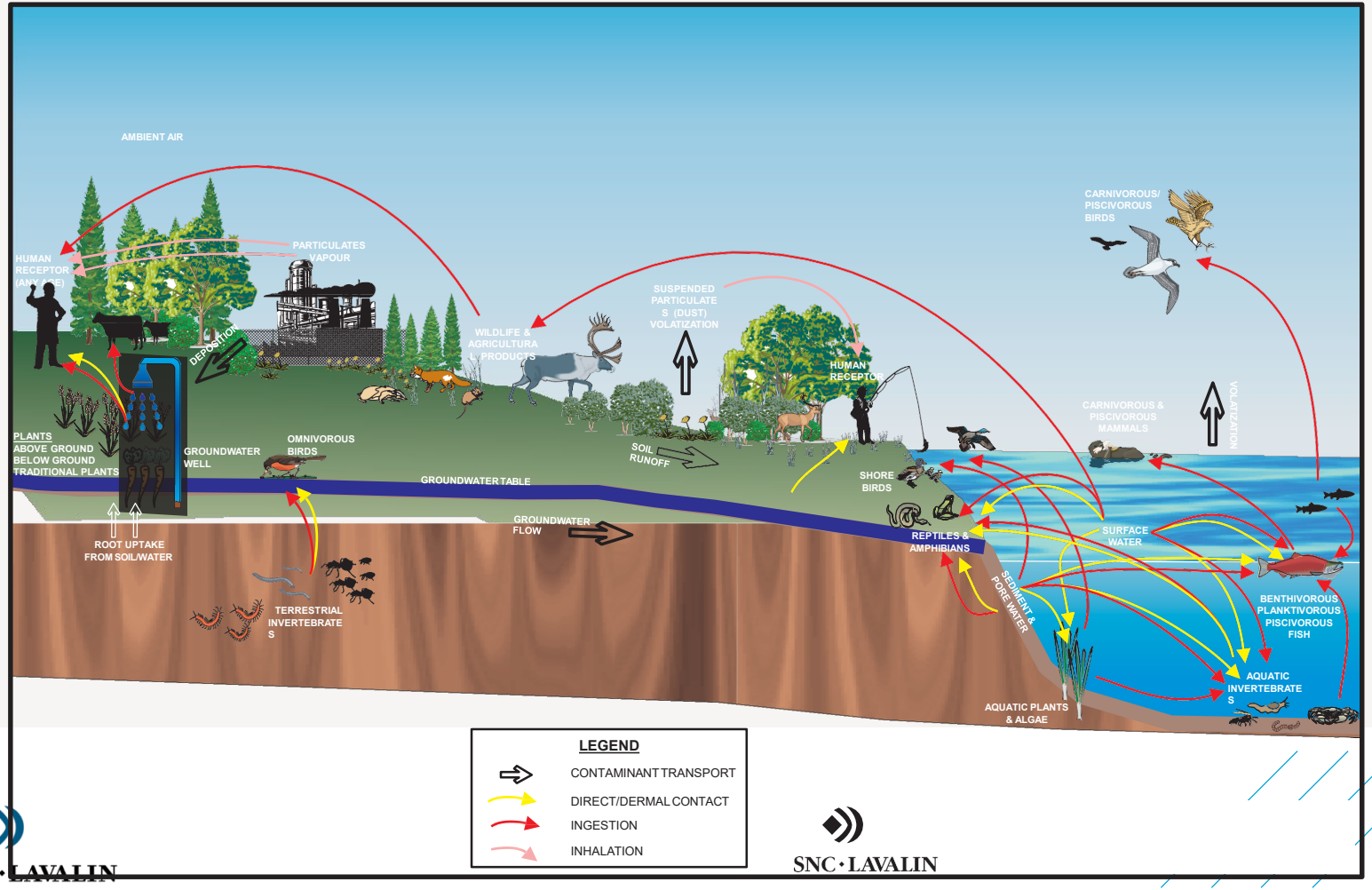

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What's in a Guideline Calculation?

Threshold Substance

$$SEQS_{HH} = \frac{(TDI - EDI) \times SAF \times BW}{[(AF_G \times SIR) + (AF_L \times IR_S \times ET_2) + (AF_S \times SR)] \times ET_1} + [BSC]$$

Background soil concentration

Exposure Terms
ET_1 = (d/wk)/7*(wk/yr)/52
ET_2 = (hr/d)/24

Soil Ingestion

Inhalation of Particulate Matter

Dermal Contact

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Vapour Inhalation Equation

Soil Guidelines for Threshold Substances

$$SRG_I = \frac{(TC - C_a) \times [\theta_w + (K_{oc} \times f_{oc} \times \rho_b) + (H' \times \theta_a)] \times SAF \times DF_i \times 10^3 \times AF}{H' \times \rho_b \times ET \times 10^6} + BSC$$

Groundwater Guidelines for Threshold Substances

$$GWRG_I = \frac{(TC - C_a) \times SAF \times DF_i \times AF}{H' \times ET \times 10^3}$$

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Vapour Inhalation Equation (cont'd)

Dilution Factor Calculation:

$$DF_i = \frac{1}{\alpha} \qquad \alpha = \frac{\left(\frac{D_T^{eff} A_B}{Q_B L_T}\right) exp\left(\frac{Q_{soil} L_{crack}}{D_{crack} A_{crack}}\right)}{exp\left(\frac{Q_{soil} L_{crack}}{D_{crack} A_{crack}}\right) + \left(\frac{D_T^{eff} A_B}{Q_B L_T}\right) + \left(\frac{D_T^{eff} A_B}{Q_B L_T}\right)\left[exp\left(\frac{Q_{soil} L_{crack}}{D_{crack} A_{crack}}\right) - 1\right]}$$

Calculation of D_T^{eff}:

$$D_T^{eff} \approx D_a \times \left(\frac{\theta_a^{10/3}}{\theta_t^2}\right)$$

Warning: Do Not Try This At Home

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SVSLs

Soil Vapour Screening Levels

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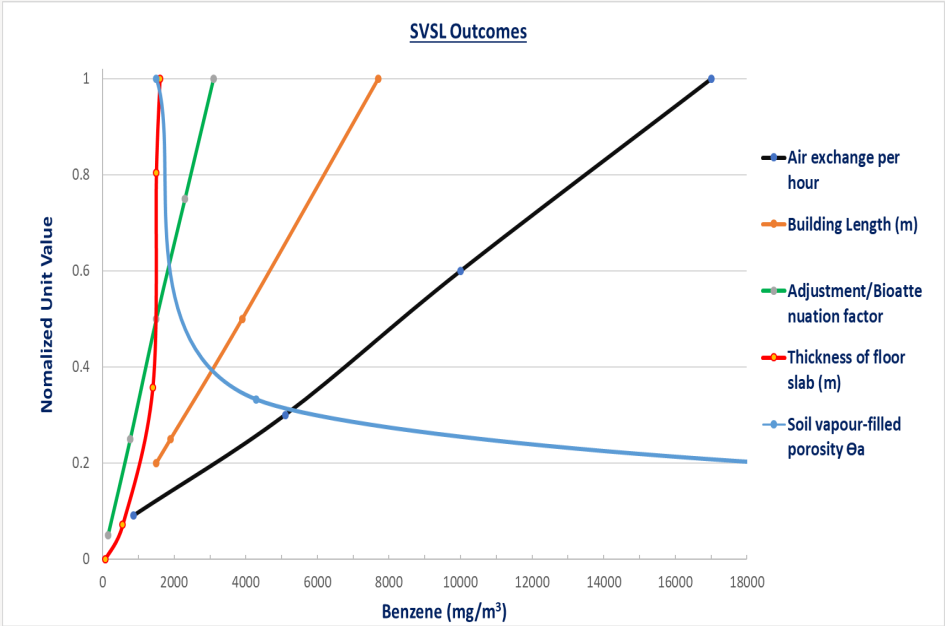
Soil Vapour Screening Levels

What Matters?

- Building Factors (Length 20 m – 100 m)
- Air Exchange Rate (0.9 – 10 air ex./h)
- Bioattenuation Factor (1 – 20)
- Thickness of Floor Slab (0 – 0.14 m)
- Vapour Filled Soil Porosity (0.302 – 0.03)



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CCME FAL SSTL Equation

$$SSTL_{FAL} = C_L(DF1)$$

C_L – Concentration of allowable leachate

DF1 – Soil to soil leachate dilution factor

A , B, C and D – Calculated by distances to surface water, soil and hydraulic parameters, physicochemical properties of contaminant

DF3 – Vertical transport of leachate to groundwater table dilution factor

DF4 – Horizontal groundwater transport to discharge point dilution factor

$$DF1 = K_{oc} \times f_{oc} + \frac{\theta_w + H' \times \theta_a}{\rho_b}$$

$$C_L = C_{gw}(DF3)$$

$$DF3 = 1 + \frac{Z_d \times V}{I \times X}$$

$$Z_d = r + s$$

$$s = d_a \left\{1 - exp\left(\frac{-2.178 \times X \times I}{V \times d_a}\right)\right\}$$

$$V = K \times i$$

$$C_{gw} = C_w(DF4)$$

$$DF4 = \frac{4}{\exp(A) \times \mathrm{erfc}(B) \times [\mathrm{erf}(C) - \mathrm{erf}(D)]}$$

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CCME FAL SSTL Equation - Groundwater

SWQG – Surface water quality guideline for COPC

DF4 – Horizontal groundwater transport to discharge point dilution factor

$$SSTL_{FAL} = SWQG_{FAL} \times DF4$$

$$DF4 = \frac{4}{\exp(A) \times \operatorname{erfc}(B) \times [\operatorname{erf}(C) - \operatorname{erf}(D)]}$$

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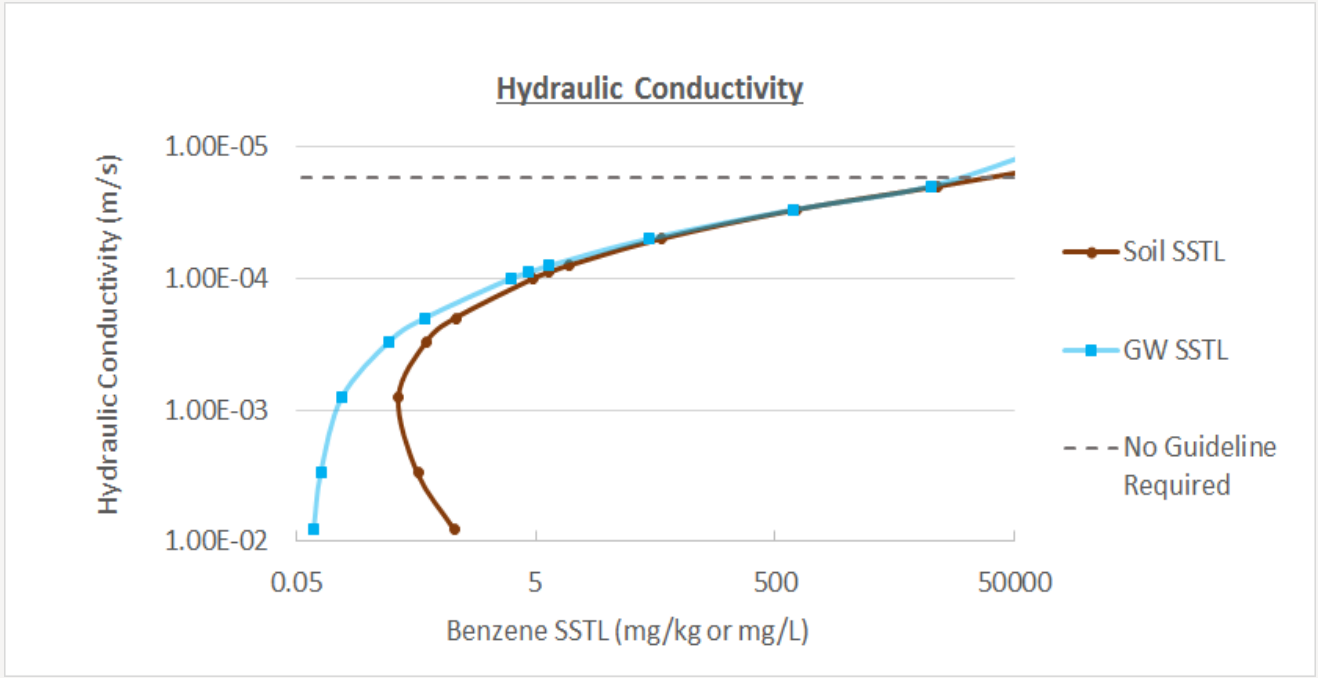
CCME FAL – Guideline Modification



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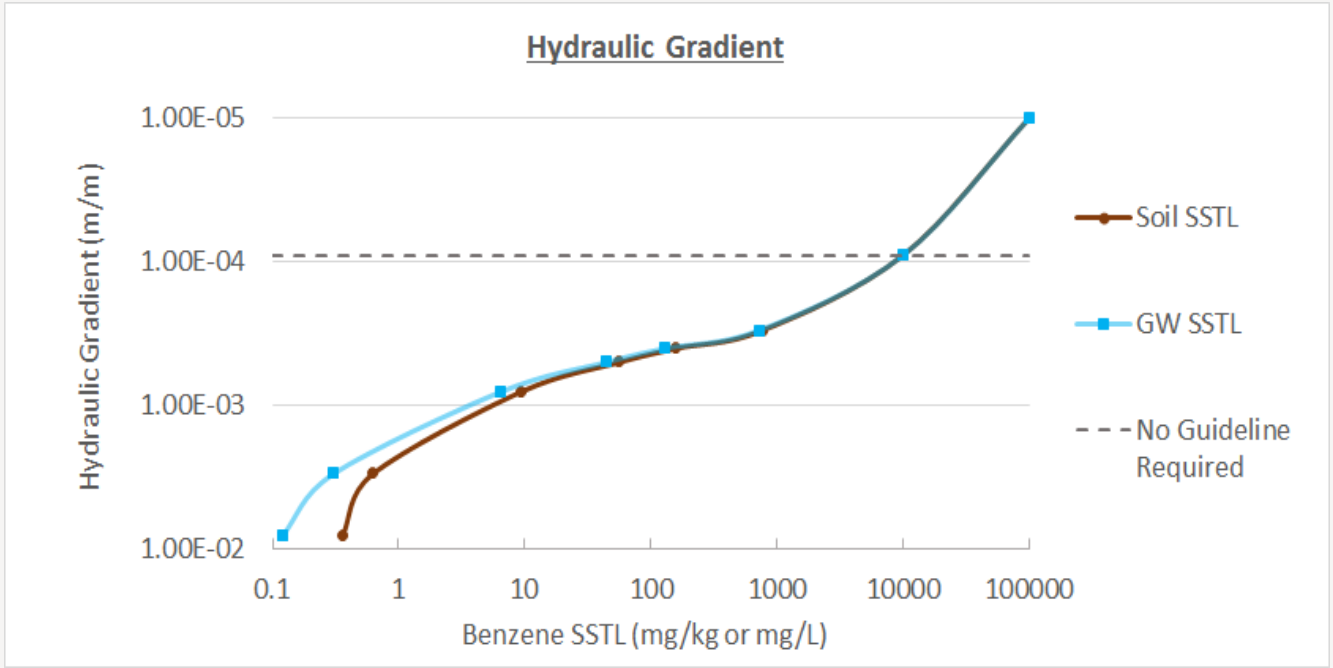

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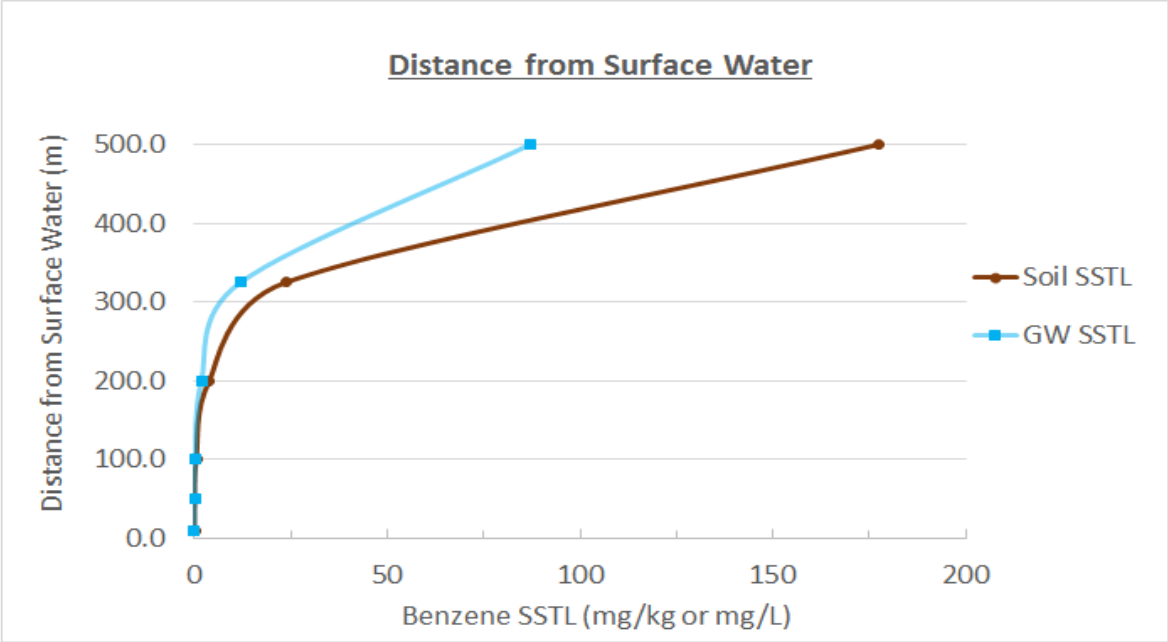

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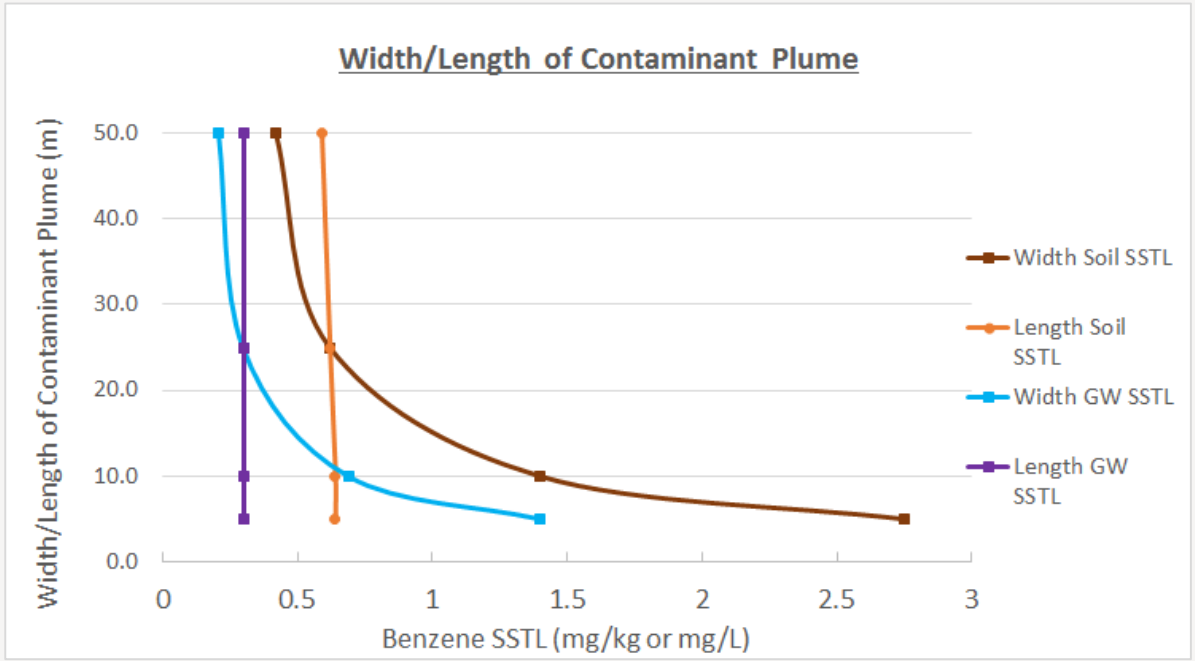

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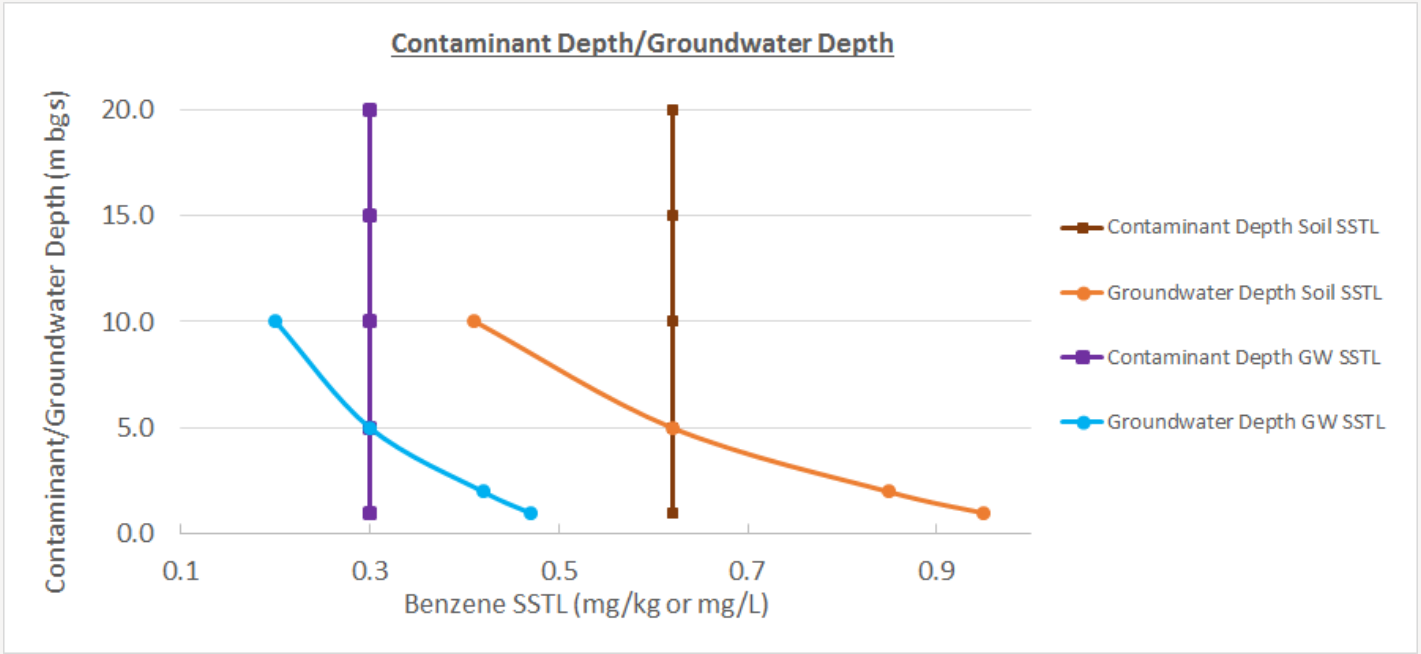

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Myths Busted

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Fact or Fiction? Tier 1 vs. Tier 2 vs. Tier 3

Is Tier 3 more protective or less protective than Tier 1?

a) More

b) Less

c) Same

d) Not sure

Answer: c

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Fact or Fiction? Vapour Inhalation Pathway

What is the maximum science-based distance to receptors for PHC vapour Intrusion?

a) 30 m

b) 15 m

c) 0 – 2 m

d) 5 m

Answer: c or d

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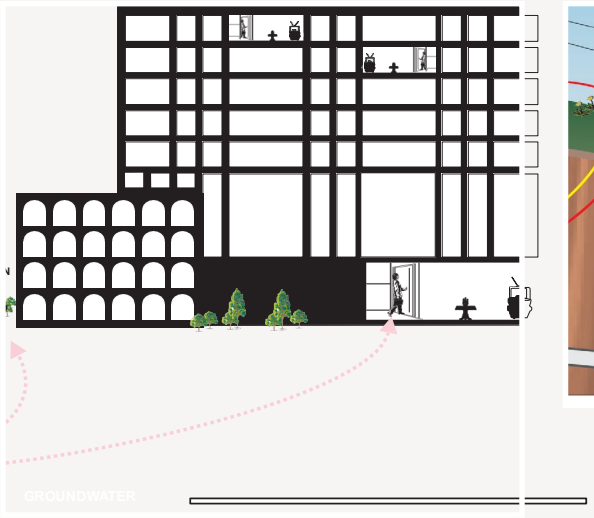
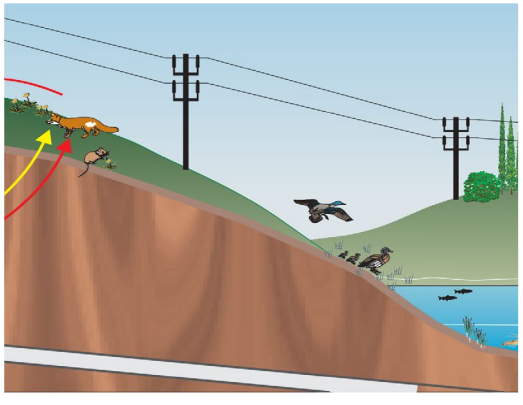
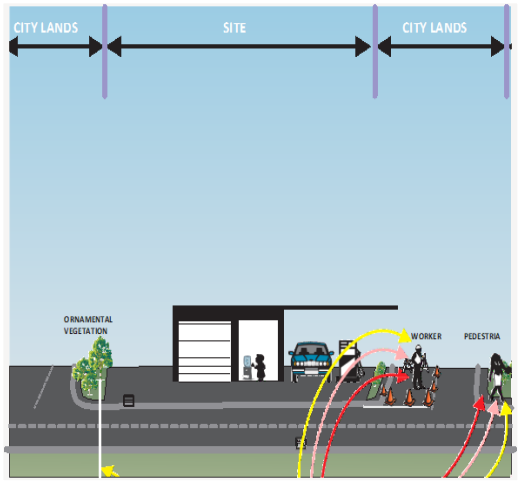
Vapour Intrusion Inclusion Zone vs. Sensitive Land Use Buffer



Vapour Transport Model



Adjacent Sensitive Land Use



Ontario (15 m lateral)
CCME 30 m

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Fact or Fiction? Distance of FAL/PW Receptor

- What distance applies to the dissolved PHC Plume in Groundwater?
- 300 m Downgradient
- 100 m Upgradient

a) Is this Unique to all COPCs?

b) Is this unique to AB Regs?

Answer: No and Yes

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Fact or Fiction? Management Limits Unveiled

What is the original basis for the Management Limit Guidelines?

a) Solubility

b) Half Solubility

c) Soil Gas Saturation Concentration

d) None of the Above

Answer: d

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Management Limits Described CCME 2008

- Management Limits stated to include considerations such as free phase formation, explosive hazards, and buried infrastructure effects – **Not Health Risk Based**
- **CCME Reference:** Eco soil contact: For depths between 0 and 1.5 m bgs, the terrestrial ecological pathway must be applied.
- A management limit has been developed for PHCs that must be applied at all depths ***if the ecological pathway is removed***.
- CCME does not specify for depths between 1.5 m and 3 m.

PHC Technical Supplement CCME, 2008

“ML are an artifact from a loop hole”

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Fact or Fiction? Guideline Values

What does a numeric exceedance of a Tier 1 or Tier 2 Guideline Mean?

a) Adverse effect?
b) Someone will die soon?
c) Nothing will happen?
d) Take a closer look?

Answer: d

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Summary

- Risk Assessment is intended to be a systematic quantitative process to help in making good decisions
- Risk Assessment is a powerful tool – ***dynamic / iterative***
- Uses highly conservative assumptions when used for guidelines
- Important to understand the process - ***Reality Check***
- Guidelines – screening mechanism and check balance

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Take Away

An Exceedance of a Guideline or any other reference value does not mean an adverse effect

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Acknowledgements

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ENVIRONMENTAL SERVICES ASSOCIATION OF ALBERTA

ESAA

Our values are the essence of our company's identity. They represent how we act, speak and behave together, and how we engage with our clients and stakeholders.

SAFETY

We put safety at the heart of everything we do, to safeguard people, assets and the environment.

INTEGRITY

We do the right thing, no matter what, and are accountable for our actions.

COLLABORATION

We work together and embrace each other's unique contribution to deliver amazing results for all.

INNOVATION

We redefine engineering by thinking boldly, proudly and differently.

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