Groundwater Contamination

GEOL-304

Hydrogeology

Walkerton, Ont.,
Escherichia coli
(*O157:H7*)

Sources of GW contamination

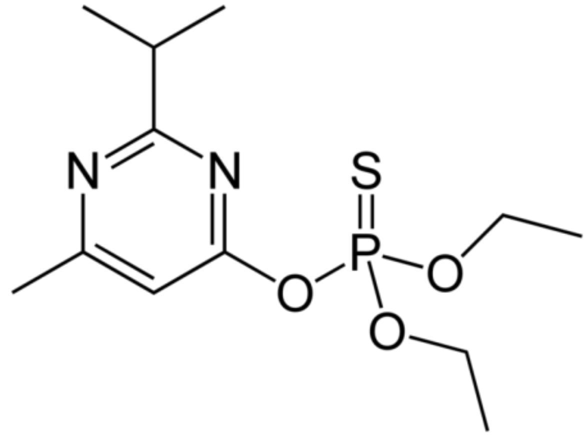
Agriculture	Human waste (septic)
Golf Courses, gardens etc.	Underground storage tanks
Industry (pulp and paper, mining)	Landfills

Agricultural activity	Impacts	
	Surface water	Groundwater
Fertilizing	Runoff of nutrients, especially phosphorus, leading to eutrophication, excess algae growth leading to deoxygenation of water and fish kills.	**Leaching of <u>nitrate</u> to groundwater; excessive levels are a threat to public health.**
Manure spreading	Spreading on frozen ground results in high levels of contamination of receiving waters by pathogens, metals, phosphorus and nitrogen leading to eutrophication and potential contamination.	**Contamination of ground-water, especially by <u>nitrogen</u> and <u>pathogens</u>**
Pesticides	Runoff of pesticides leads to contamination of surface water and biota; dysfunction of ecological system in surface waters by loss of top predators due to growth inhibition and reproductive failure	**Pesticides (e.g. <u>diazinon</u>, <u>atrazine</u>, <u>2,4-D</u>) may leach into groundwater causing human health problems from contaminated wells**
Feedlots	Contamination of surface water with many pathogens (bacteria, viruses, etc.) leading to chronic public health problems. Also contamination by metals contained in urine and faeces.	**Potential leaching of <u>nitrogen</u>, <u>metals</u>, etc. to groundwater.**
Irrigation	Runoff of salts leading to salinization of surface waters; runoff of fertilizers and pesticides to surface waters. High levels of trace elements such as selenium can occur with serious ecological damage.	**Enrichment of groundwater with <u>salts</u>, <u>nutrients</u> (especially <u>nitrate</u>).**

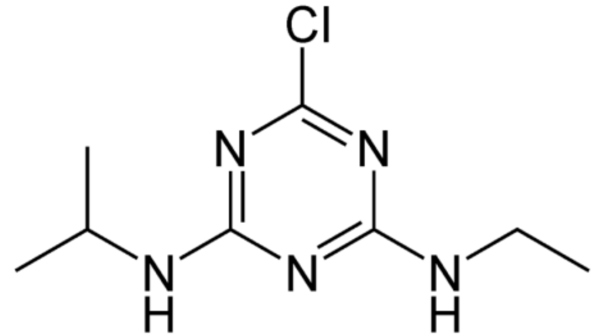
http://www.fao.org

Some common pesticides

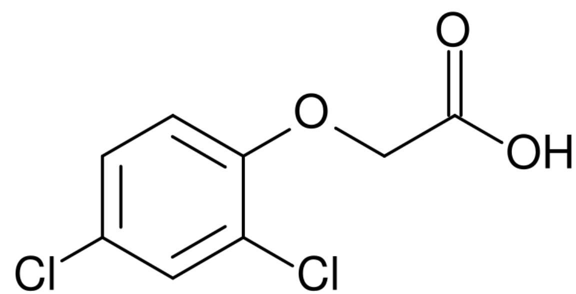
- **Diazinon** (*O*,*O*-Diethyl *O*-[4-methyl-6-(propan-2-yl)pyrimidin-2-yl] phosphorothioate) (insecticide, soluble)



- **Atrazine** (2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine) (herbicide, weakly soluble)

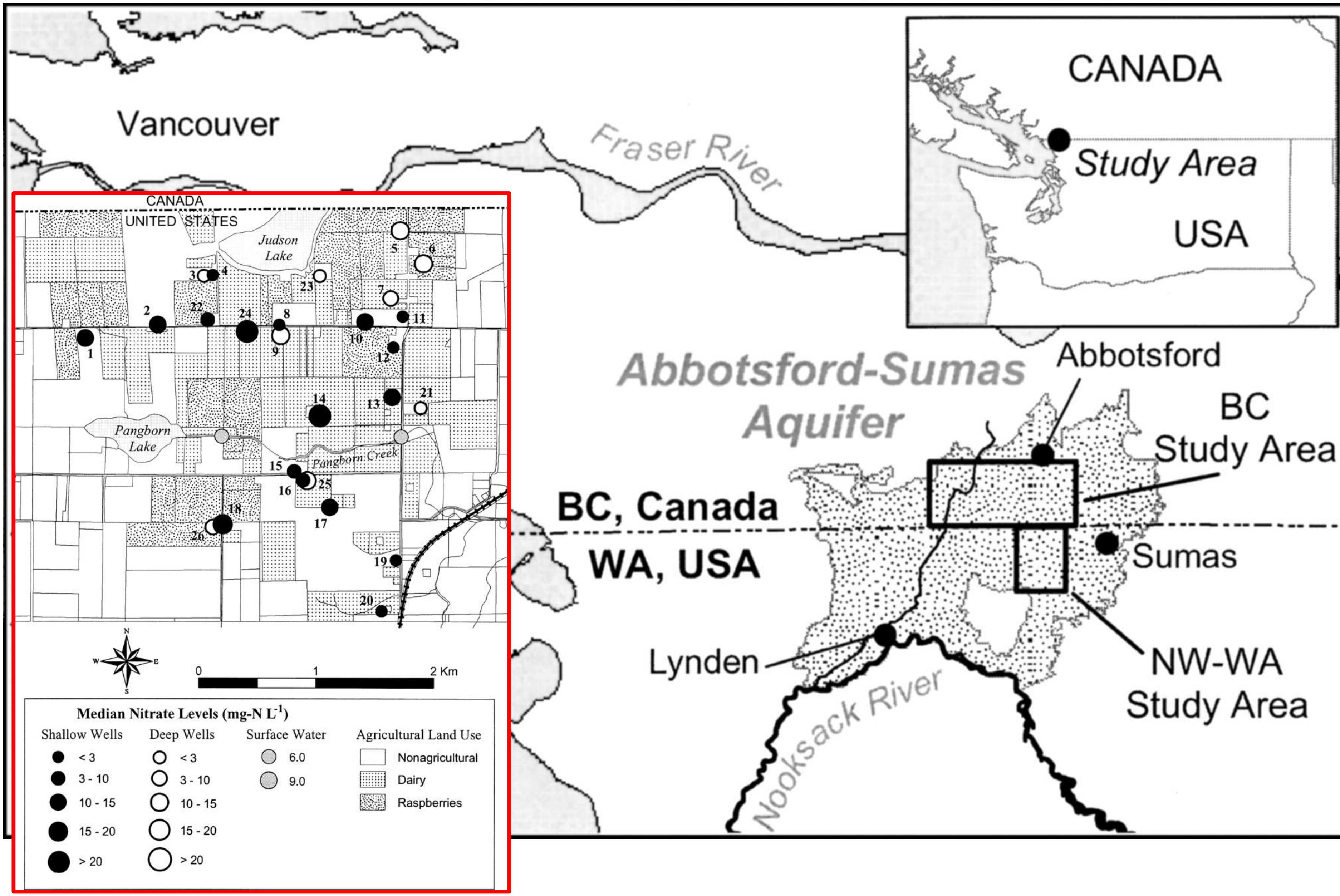


- **2,4-D** (2,4-Dichlorophenoxyacetic acid) (herbicide, soluble)




NO DOGS
ALLOWED.
CHEMICAL
TREATED LAWN

Nitrogen contamination – Abbotsford aquifer



Nitrogen additions exceeded N removals by 134, 185, and 245 kg N ha^{-1} in 1971, 1981, and 1991, respectively, indicating a high potential for nitrate leaching to occur. The increase in the nitrogen surplus was primarily the result of changes in land use.

In particular, the agricultural land base decreased by almost 20%, and there was a shift from animal production systems which require a local land base for crop production and grazing to animal production where the feed is imported.

Zebarth et al, 1998

Western North America distribution of Cretaceous shale deposits with potential for high selenium levels

Irrigation can lead to significant mobilization of salts, as wells as nutrients such as nitrate, and to the turbidity of surface waters.

Selenium in soils can be mobilized by irrigation water. In central California irrigation run-off water, which flows back into an irrigation canal, has created serious selenium contamination in a wildlife refuge known as the Kesterton Reservoir.

Golf Courses and gardens

Superior Rd
Harby Rd
Harby Rd
West Coast
Motor Sport
Forest Turn
Harwood Dr
Andrea Crescent
Elizabeth Wa
Andrea Cr
Fernmar Rd
Fernmar Rd
Clark Crescent

Pulp mills

Jackson Rd
International Composting Corp
Canexus Chemical Canada LP
Macphee Rd
Maughan Rd
Duke Point Hwy
Newalta Corporation
Eddi's Wholesale Garden Supplies
Hooker Rd
Harmac
Wave Pl
Pope & Talbot LTD-Harmac Pulp Operations
Phoenix Way
Phoenix Way
Phoenix Way
19
Duke Point Hwy
MacMillan Rd
19

Kraft pulping, also known as sulphate, or chemical pulping, uses sulphur to get fibre out of trees. The sulphur chemicals account for the rotten egg smell of many pulp mills. Kraft pulping uses less than 50% of the tree. The rest ends up as sludge which is burned, spread on land or landfilled. A bonus of kraft pulping is that the chemicals can be recycled and re-used in the mill. Another is that kraft fibre is exceptionally strong ("kraft" means "strong" in German).

Mechanical pulping mills physically shred trees into pulp with grind stones and/or heat. Mechanical processes use about 90% of the tree. Unfortunately, mechanical pulp has weaker fibres, tends to discolour over time, and the process uses a lot of water and energy. Mechanical pulp is commonly used for newspapers and is often bleached with hydrogen peroxide or other chlorine-free alternatives.

http://www.rfu.org/cacw/basic.html

Materials used in the pulp/paper industry

Process/Operation	Materials Used	Types of Waste Generated
Chemical Pulping	Acids/alkalies, lime, sulfurous acid, sodium hydroxide, sodium sulfide	Acid/alkaline waste
Bleaching	Chlorine bleaches, sulfate bleaches, chloroform, solvents	Toxic wastewater and wastewater treatment sludge, Acid/alkaline waste, Chlorine compounds such as Dioxin
Papermaking	Pigments	Wastewater treatment sludge
Sizing and Starching	Waxes, glues, synthetic resins, hydrocarbons	Toxic waste, including wastewaters add sludges
Coating, Coloring, and Dyeing	Inks, paints, solvents rubbers, dyes	Solvent waste Ink waste Paint waste, Ignitable waste, Toxic waste
Cleaning and Degreasing	Tetrachloroethylene, Trichloroethylene, methylene chloride, trichloroethane, carbon tetrachloride	Solvent waste, Toxic rinse water

Acid Mine Drainage

Mt Washington copper mine

Septic systems

Composition of sewage

Organic matter (measured as biochemical oxygen demand or BOD)

Disease-causing microorganisms (pathogens) – see below

Nutrients (nitrogen and phosphorus)

Toxic contaminants (both organic and inorganic)

Dissolved minerals (including heavy metals)

Bacteria: The feces of a healthy person contains large numbers of bacteria (> 10^{10}/g), most of which are not pathogenic. Pathogenic or potentially pathogenic bacteria are normally absent from a healthy intestine unless infection occurs. When infection occurs, large numbers of pathogenic bacteria will be passed in the faeces thus allowing the spread of infection to others. Diarrhoea is the most prevalent type of infection, with cholera the worst form. Typhoid, paratyphoid and other *Salmonella* type diseases are also caused by bacterial pathogens.

Viruses: Numerous viruses may infect humans and are passed in the faeces (> 10^9/g). Five groups of pathogenic excreted viruses are particularly important: adenoviruses, enteroviruses (including polioviruses), hepatitis A virus, reoviruses and diarrhoea-causing viruses.

Protozoa: Many species of protozoa can infect humans and cause diarrhoea and dysentery. Infective forms of these protozoa are often passed as cysts in the faeces and humans are infected when they ingest them. Only three species are considered to be pathogenic: *Giardia lamblia, Balantidium coli* and*Entamoeba histolytica*.

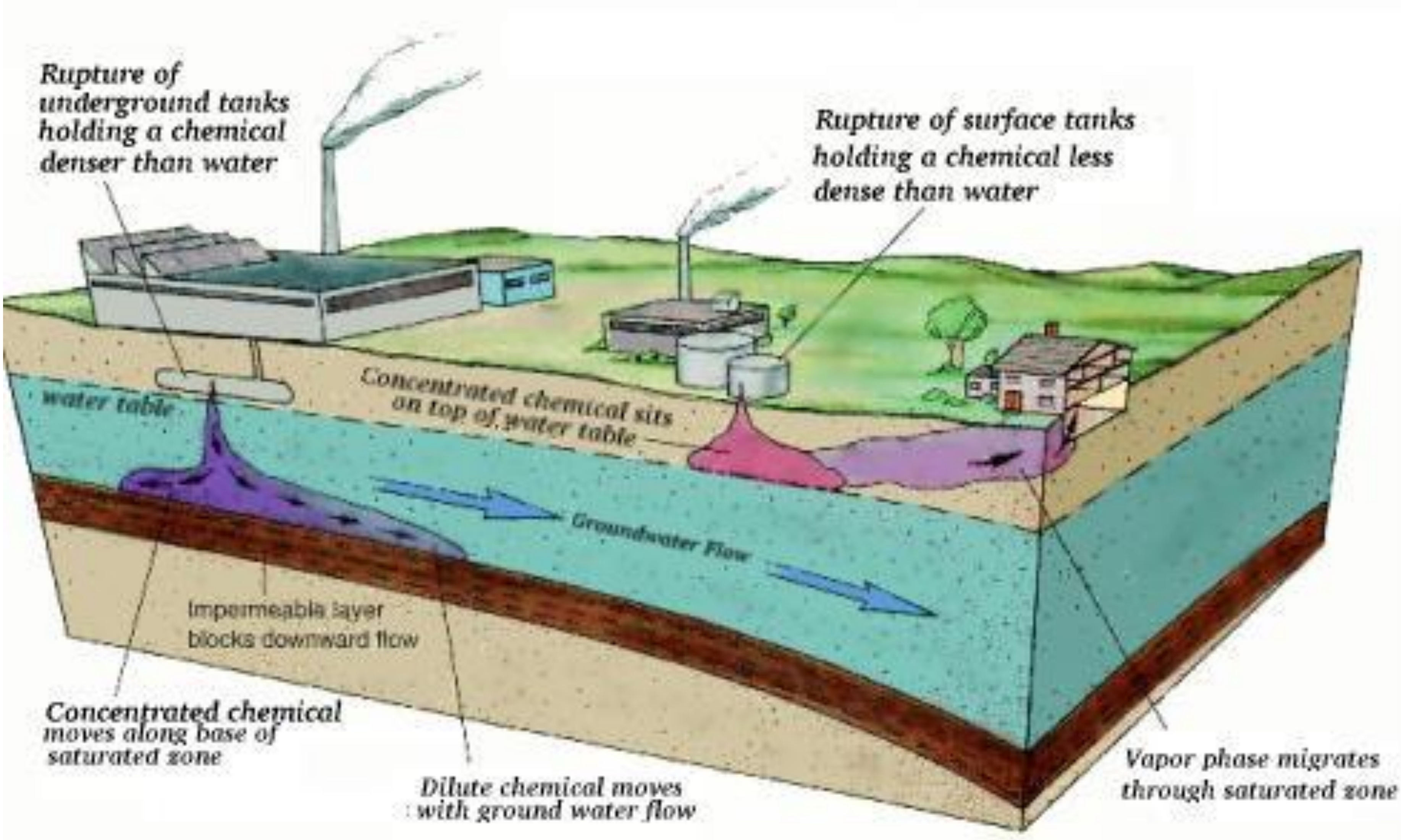
Composition of Secondary Treated Municipal Wastewater Effluents and Irrigation Water

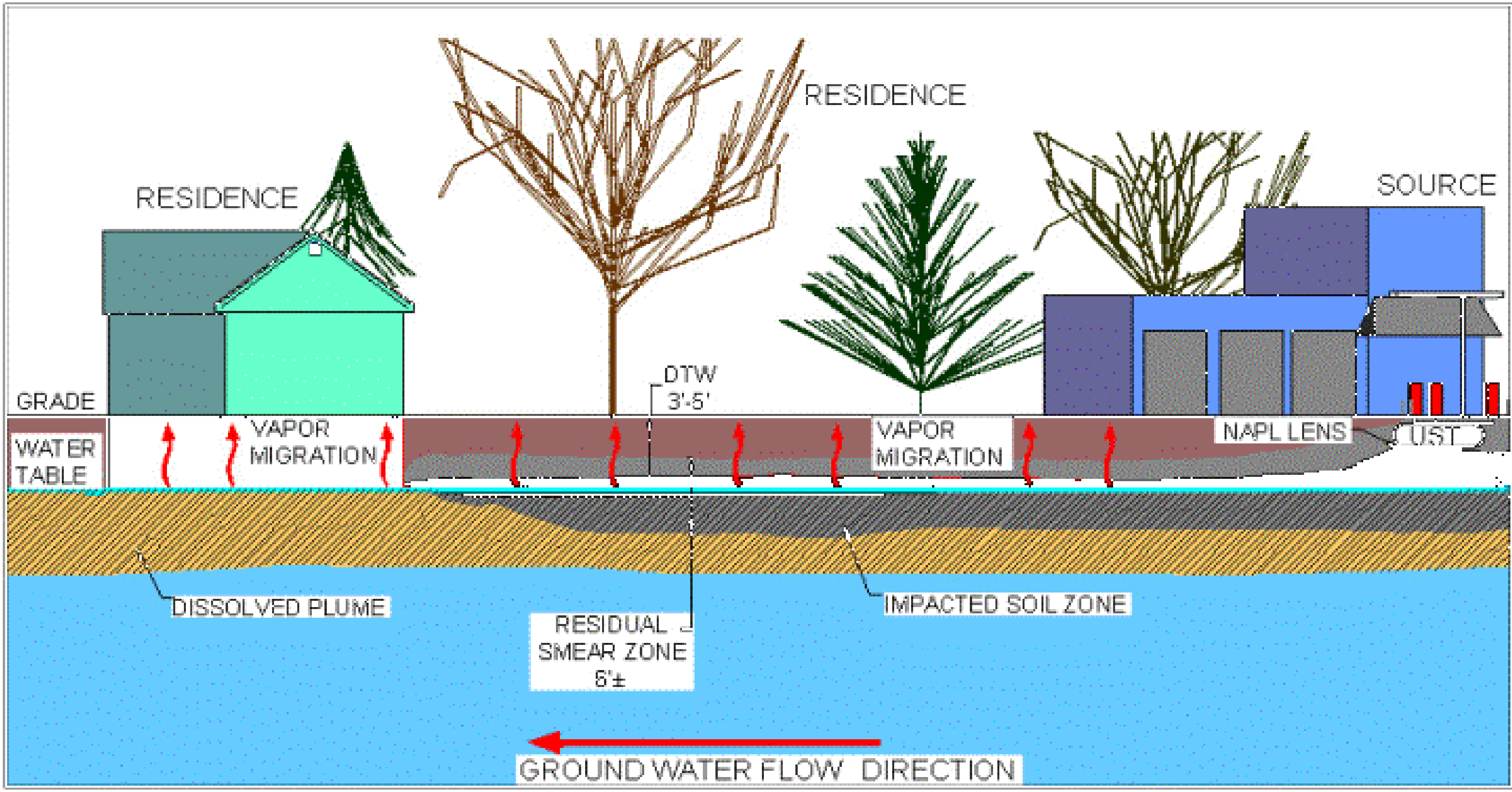
Parameter	Secondary Effluent	Colorado River
Biochemical Oxygen Demand	25	U
Chemical Oxygen Demand	70	U
Nitrate Nitrogen	8	0.1–1.2
Total Phosphorus	10	<0.02
Potassium	15	4–6
Copper (*u*g/L)	20	<10–10
Nickel (*u*g/L)	10	<1–4
Lead (*u*g/L)	5	<5
Zinc (*u*g/L)	40	<3–12
Mercury (*u*g/L)	2	<0.1–0.1

All units in milligrams per liter unless otherwise noted as micrograms per liter (*u*g/L). U: unavailable.

From: National Research Council, National Academies Press, 1996

Leaking USTs


Rupture of underground tanks holding a chemical denser than water
Rupture of surface tanks holding a chemical less dense than water
water table
Concentrated chemical sits on top of water table
Groundwater Flow
Impermeable layer blocks downward flow
Concentrated chemical moves along base of saturated zone
Dilute chemical moves with ground water flow
Vapor phase migrates through saturated zone



NAPL: non aqueous-phase liquids
[e.g., petroleum: mostly C_8H_{18}]

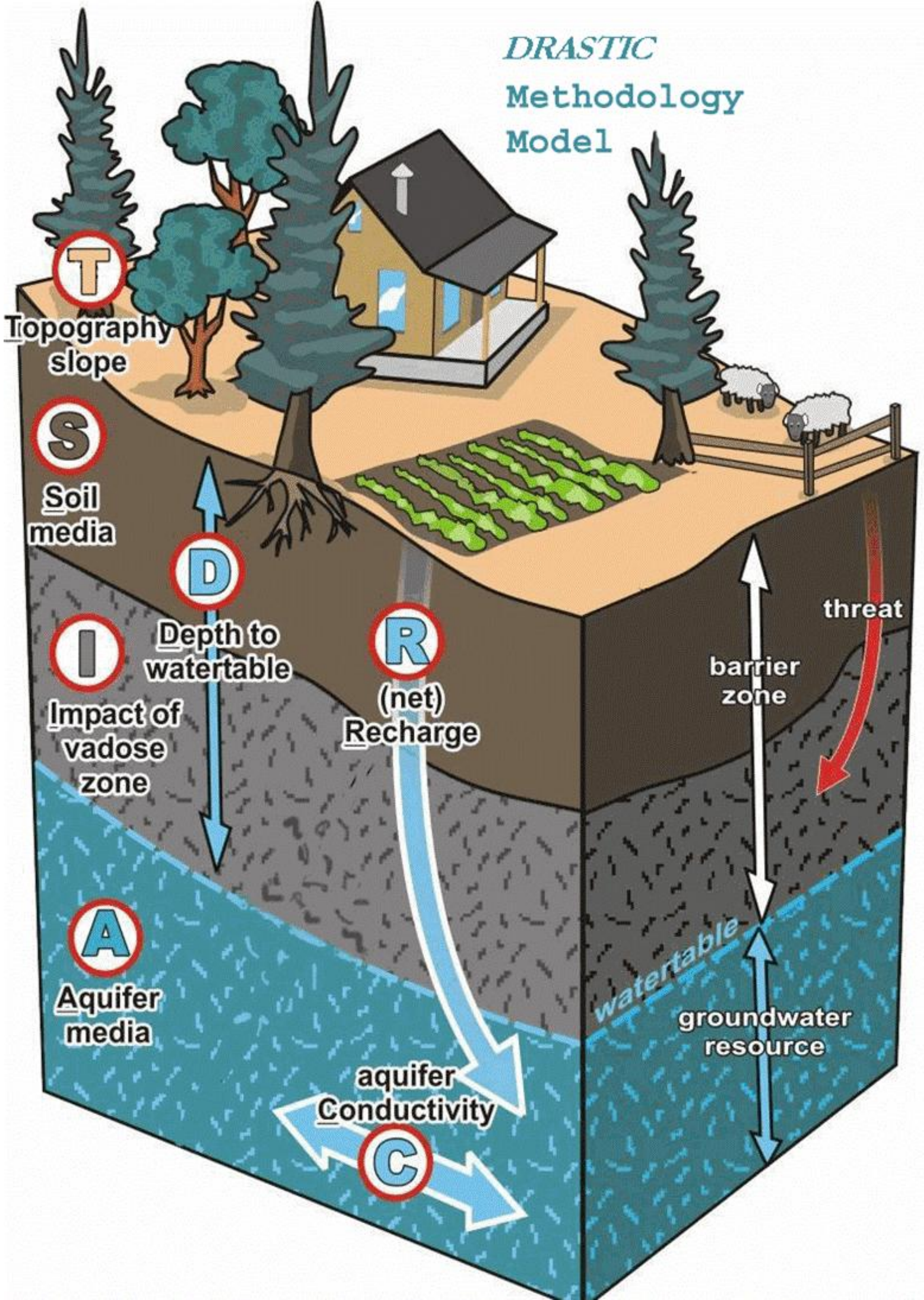
Landfills

Cedar Landfill – leachate vs background

Location	Date	pH	NH_3 mg/L	NO3 mg/L	Cl mg/L	SO_4 mg/L	HCO_3 mg/L	Al mg/L	As ug/L	B mg/L
15-1-1	2000 10 04	7.57	**924**	<1	**2,700**	**268**	**8,210**	**10.2**	**17**	**4.52**
15-1-1	2000 10 04	7.54	**866**	<1	**2,690**	**271**	**8,130**	**26.7**	**21**	**7.85**
15-1-1	2000 12 21	7.70	**937**	<1	-	**256**	**7,920**	**9.8**	**27**	**4.71**
20-1-1	2000 06 22	7.29	0.08	<0.05	7.0	2.6	216	0.9	<1	0.06
20-1-1	2000 10 04	7.27	0.03	<0.05	7.7	2.9	204	<0.2	<1	0.05
20-1-1	2000 12 21	7.00	<0.02	<0.05	8.4	2.7	-	<0.2	<1	0.04
20-1-2	2000 06 22	6.32	0.02	0.15	2.0	5.0	39.5	<0.2	<1	0.02
20-2-1	2000 10 04	6.29	0.03	<0.05	7.5	3.1	41.5	<0.2	<1	0.02

Location	Date	Cr ug/L	Co ug/L	Cu ug/L	Fe mg/L	Ni ug/L	P mg/L	K mg/L	Na mg/L	Zn ug/L
15-1-1	2000 10 04	**92**	**70**	**280**	**31.0**	**280**	**22.7**	**833**	**2,000**	**1,910**
15-1-1	2000 10 04	**130**	**80**	**280**	**73.8**	**250**	**41.4**	**765**	**4,170**	**750**
15-1-1	2000 12 21	**170**	**90**	**90**	**43.1**	**300**	**22.5**	**782**	**991**	**360**
20-1-1	2000 06 22	<30	<20	<20	1.58	<30	0.4	0.21	23.1	<20
20-1-1	2000 10 04	<30	<20	<20	0.89	<30	<0.4	0.12	23.8	<20
20-1-1	2000 12 21	<30	<20	<20	0.68	<30	<0.4	0.14	18.4	<20
20-1-2	2000 06 22	<30	<20	<20	0.03	<30	<0.4	0.32	6.3	<20
20-2-1	2000 10 04	<30	<20	<20	0.13	<30	<0.4	0.44	7.9	<20

DRASTIC parameters



Selected DRASTIC parameters

D – depth to water

(ft)	(m)	Rating
100+	30.5+	1
75 – 100	22.9 – 30.5	2
50 – 75	15.2 – 22.9	3
30 – 50	9.5 – 15.2	5
15 – 30	4.6 – 9.5	7
5 – 15	1.5 – 4.6	9
0 – 5	0 – 1.5	10

R – recharge

Net Recharge (in/yr)	Net Recharge (mm/yr)	Rating
0 – 2	0 – 51	1
2 – 4	51 – 102	3
4 – 7	102 – 178	6
7 – 10	178 – 254	8
10 +	254 +	9

S - Soil medium

Soil Drainage	Rating
Very poor	1
Poor, poor to very poor	2
Imperfect	3
Moderately well to imperfect	5
Moderately well	6
Well to moderately well	7
Well, rapid to moderately well	8
Rapid to well	9
Rapid, absent/thin	10

T - Topography

Topography (Slope %)	Rating
18+	1
12 – 18	3
6 – 12	5
2 – 6	9
0 – 2	10

C - Conductivity

Bedrock Formation	Bedrock Material	Surficial Aquifer Material	Terrain Map Material	Rating
• Grp (Fm) • Vancouver Group (Daonella Beds, Quatsino Fm, Parson Bay Fm, undivided Vancouver Grp) • Bonanza Grp (Harbledown Fm) • Kyuquot Grp • Nanaimo Grp (Sidney Island Fm, Comox Fm, Extension Fm, Protection Fm, De Courcy Fm, Geoffrey Fm, Gabriola Fm) *	Limestone, fine grained sedimentary rock (non-Nanaimo Grp), coarse grained sedimentary rock (Nanaimo Grp) - limestone bioherm/reef, mudstone, siltstone, shale, limestone, slate, argillite, marine sedimentary and volcanics, undivided sedimentary, sandstone, conglomerate, arenite		Silt, bouldery silt, sandy silt	5
• Buttle Lake Group (Nanoose Complex, St. Mary's , undivided Buttle Lake Grp) • Mixed Grp and Mount Hall Gabbro • Queen Charlotte Grp • Nanaimo Grp (Haslam Fm, Pender Fm, Cedar District Fm, Northumberland Fm, Spray Fm, Suquash Sequence, undivided Nanaimo Grp) * • Chuckanut Fm • Carmanah Grp	Coarse grained sedimentary (Non-Nanaimo Grp) and fine grained sedimentary (Nanaimo Grp) - undivided sedimentary, coarse clastic sedimentary, argillite, limestone, sandstone, conglomerate, greywacke, siltstone, mudstone, arenite, shale		Alluvium, organics, undifferentiated, silty sand	6
		Sand	Sand	7
		Sand and gravel,	Colluvium, fluvial, bouldery sand, gravelly sand, rubbley sand, sandy boulders, sandy gravel	8
* Note, all of the Nanaimo Group, and Sicker Group are rated one value higher than in the (Denny et al. 2007 to fit into ratings once other rocks and materials were considered.		Gravel	Mixed fragments, gravel, gravely boulders, gravelly mixed fragments, rubble	9
				10

Calculating a DRASTIC score

	Parameter	Units	Value		Rating		Weight			Rating
D	Depth	depth to water (m)		:		x	5	=	**D**	0
R	Recharge	precipitation (mm)		:		x	4	=	**R**	0
A	Aquifer medium	medium type		:		x	3	=	**A**	0
S	Soil type	Soil type		:		x	2	=	**S**	0
T	Topography	slope (%)		:		x	1	=	**T**	0
I	Influence of vadose zone	medium type		:		x	5	=	**I**	0
C	Conductivity	m/d		:		x	3	=	**C**	0

Overall rating: **0**

RDN and CVRD vulnerability