Shale Gas Development in Canada

Potential Health Risks

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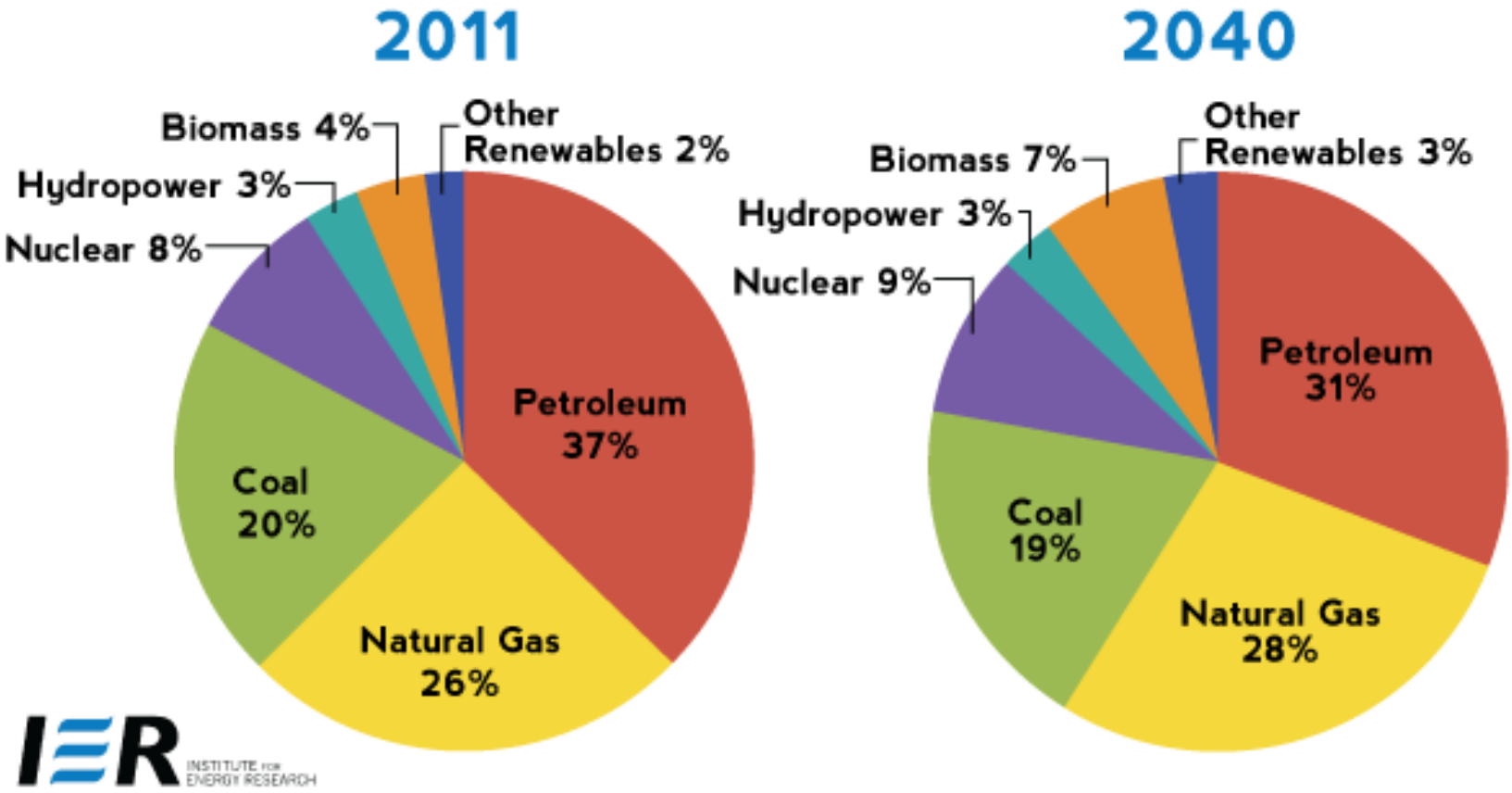
Outline of Presentation

- Brief Overview: Public Understanding
  - What is Natural Gas?
  - Where is it found?
  - Conventional vs Unconventional
  - Shale gas and Hydraulic Fracturing
- Potential Sources of Contamination
- Principles of Toxicology:
  - Understanding Risks to Human Health
- Knowledge Gaps

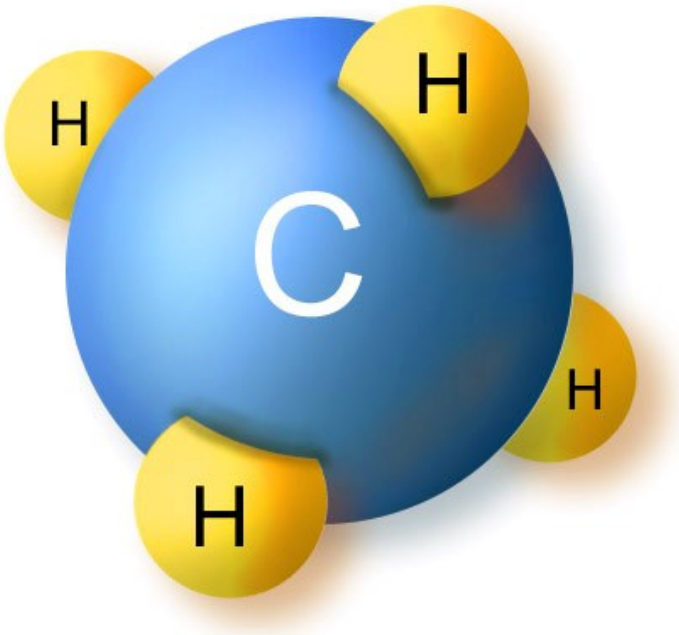
World: Energy Consumption



IER INSTITUTE FOR ENERGY RESEARCH

Source: Energy Information Administration, Annual Energy Outlook 2013, http://www.eia.gov/forecasts/aeo/er/pdf/appa.pdf and http://www.eia.gov/forecasts/aeo/er/pdf/tbla17.pdf

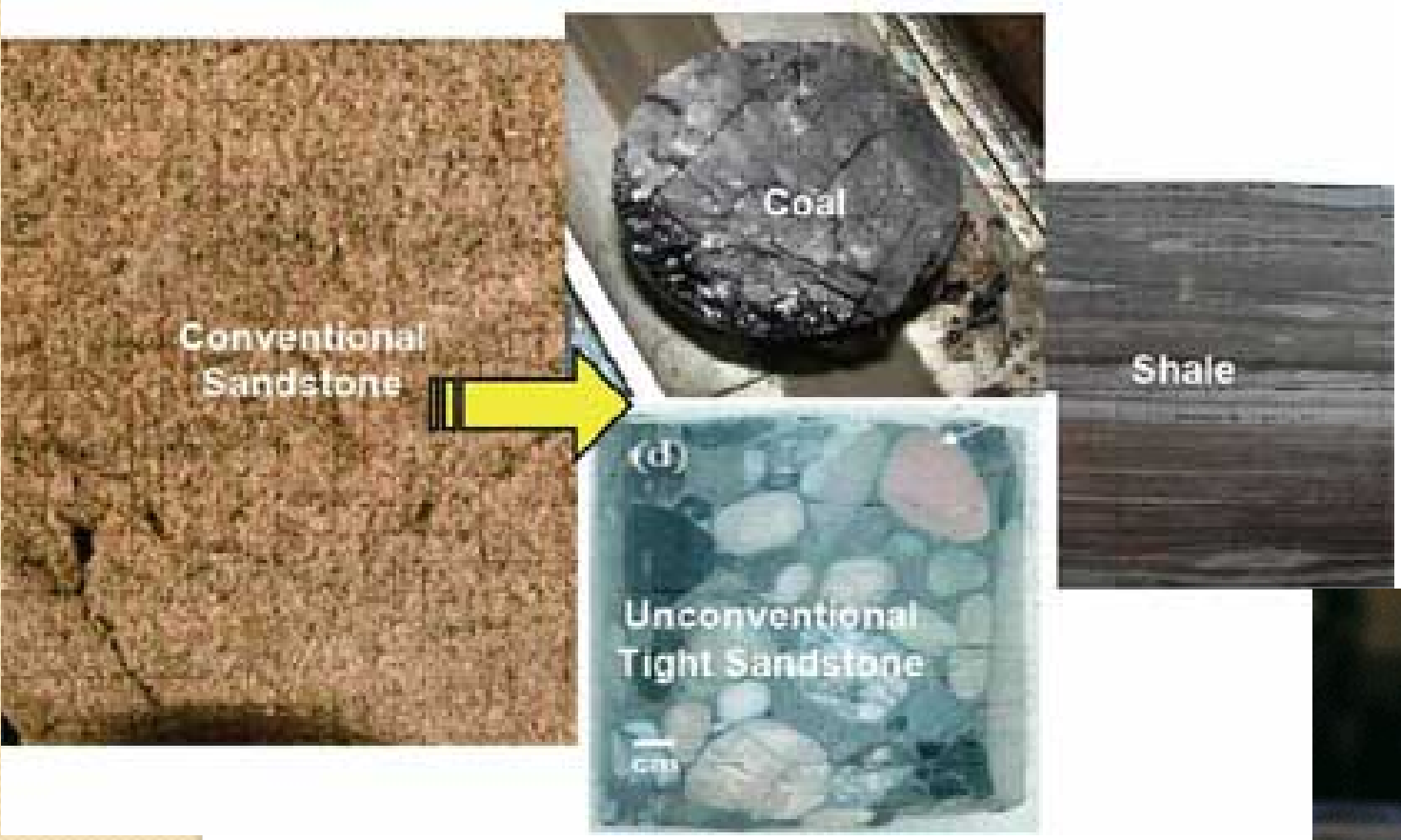
Natural Gas



- Fossil Fuel
- Clean, Safe Energy
- Hydrocarbon (HC)
  - PrimarilyMethane
  - Other HC:
    - Ethane, Propane, Butane
    - Impurities:
      - Water, Oil, Sulphur, CO2, and others.

- CO2- Horn River
- Well Completions/Leakages

Natural Gas: Geological Formations

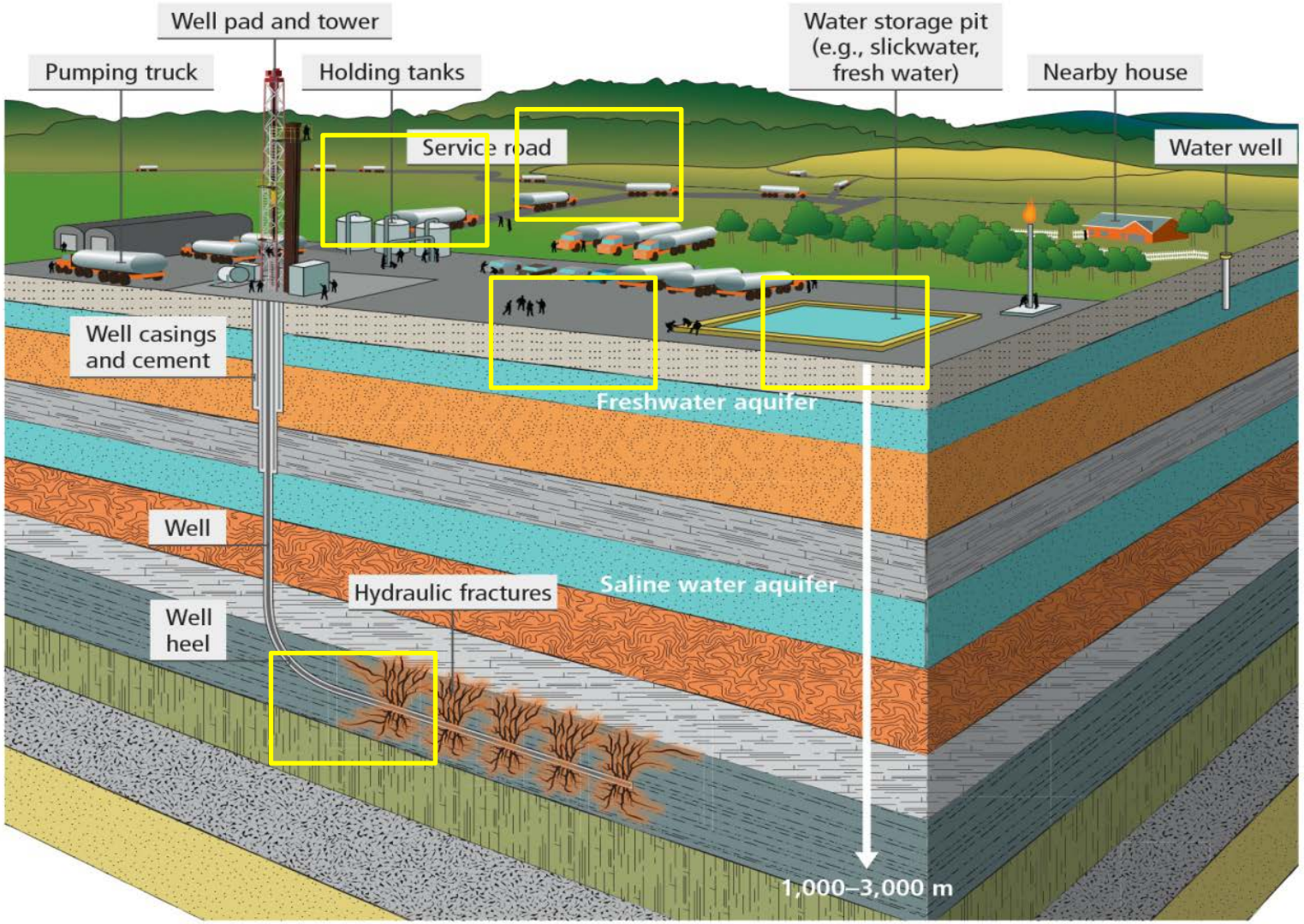


Unconventional

Gas Hydrates

Ocean deep lake sediments

Conventional and Unconventional Natural Gas



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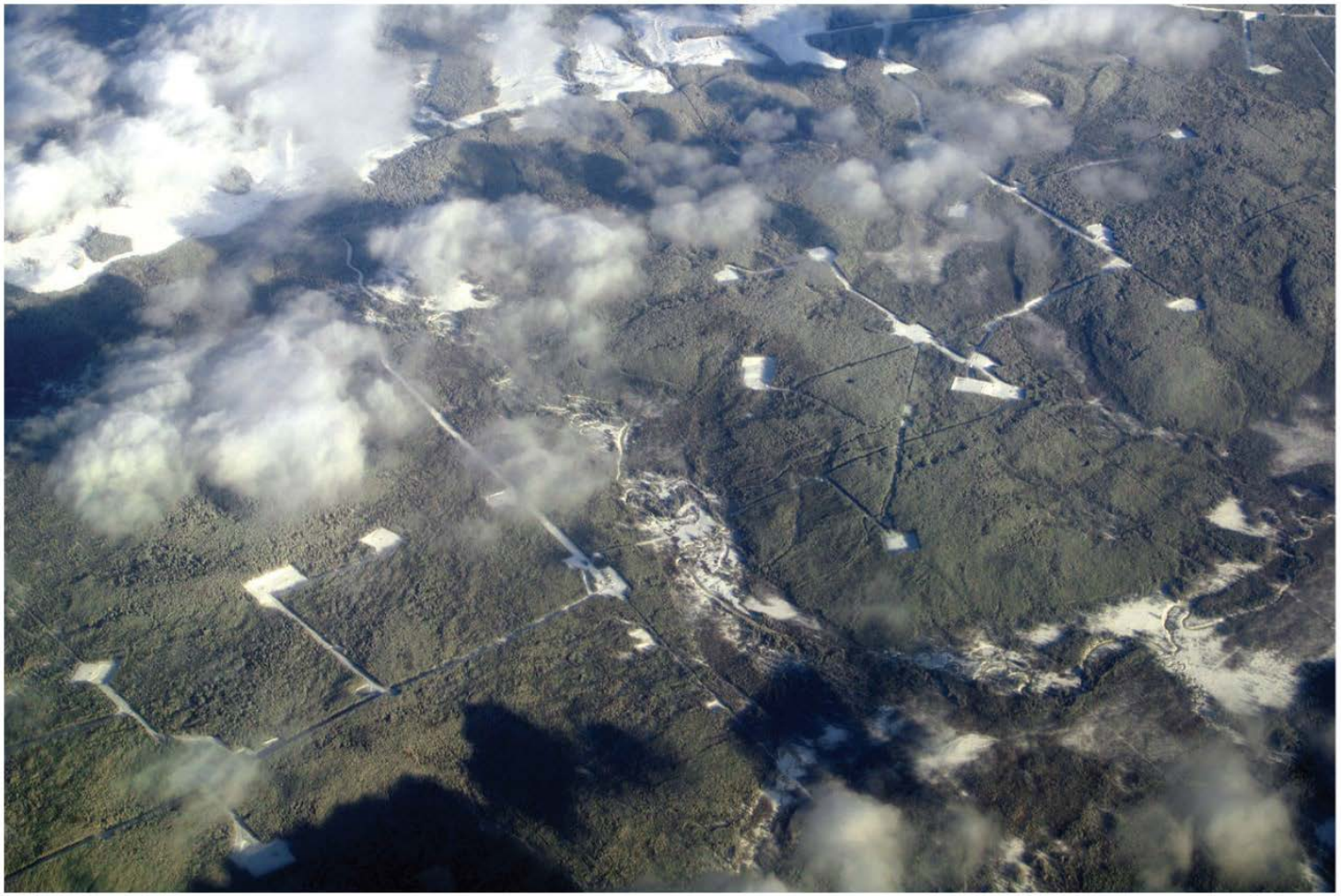
CCA (2014) Environmental Impacts of Shale Gas Extraction in Canada. Ottawa Ontario (ON): The Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction, Council of Canadian Academies.

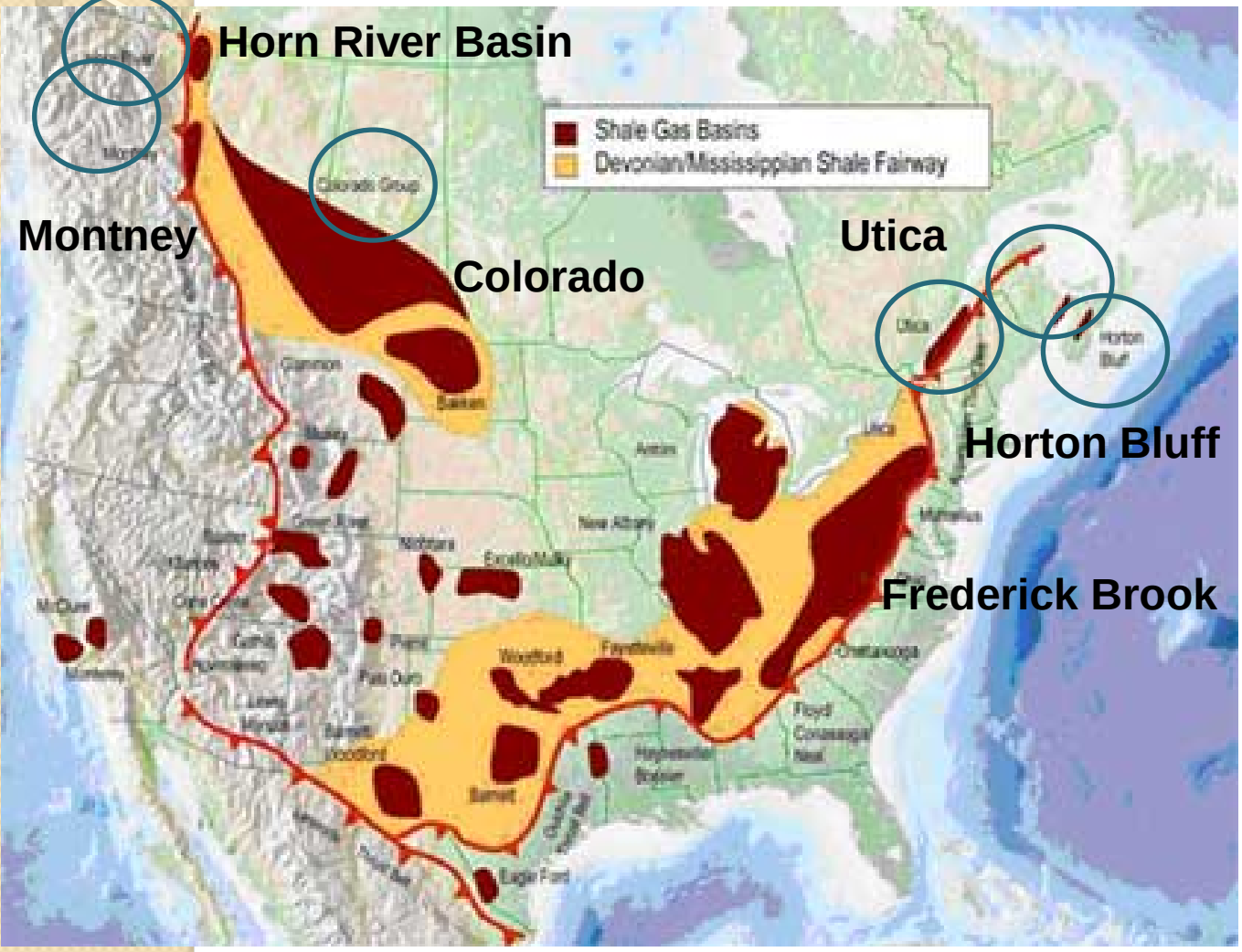
Shale Gas Infrastructure: Northeastern British Columbia



Courtesy of Hayley Dunning

CCA (2014) Environmental Impacts of Shale Gas Extraction in Canada. Ottawa Ontario (ON): The Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction, Council of Canadian Academies.

Shale Gas



- Biogenic (shallow depths)
- Thermogenic
  - Primary Shale Gas
- Sweet
- Dry
- Wet

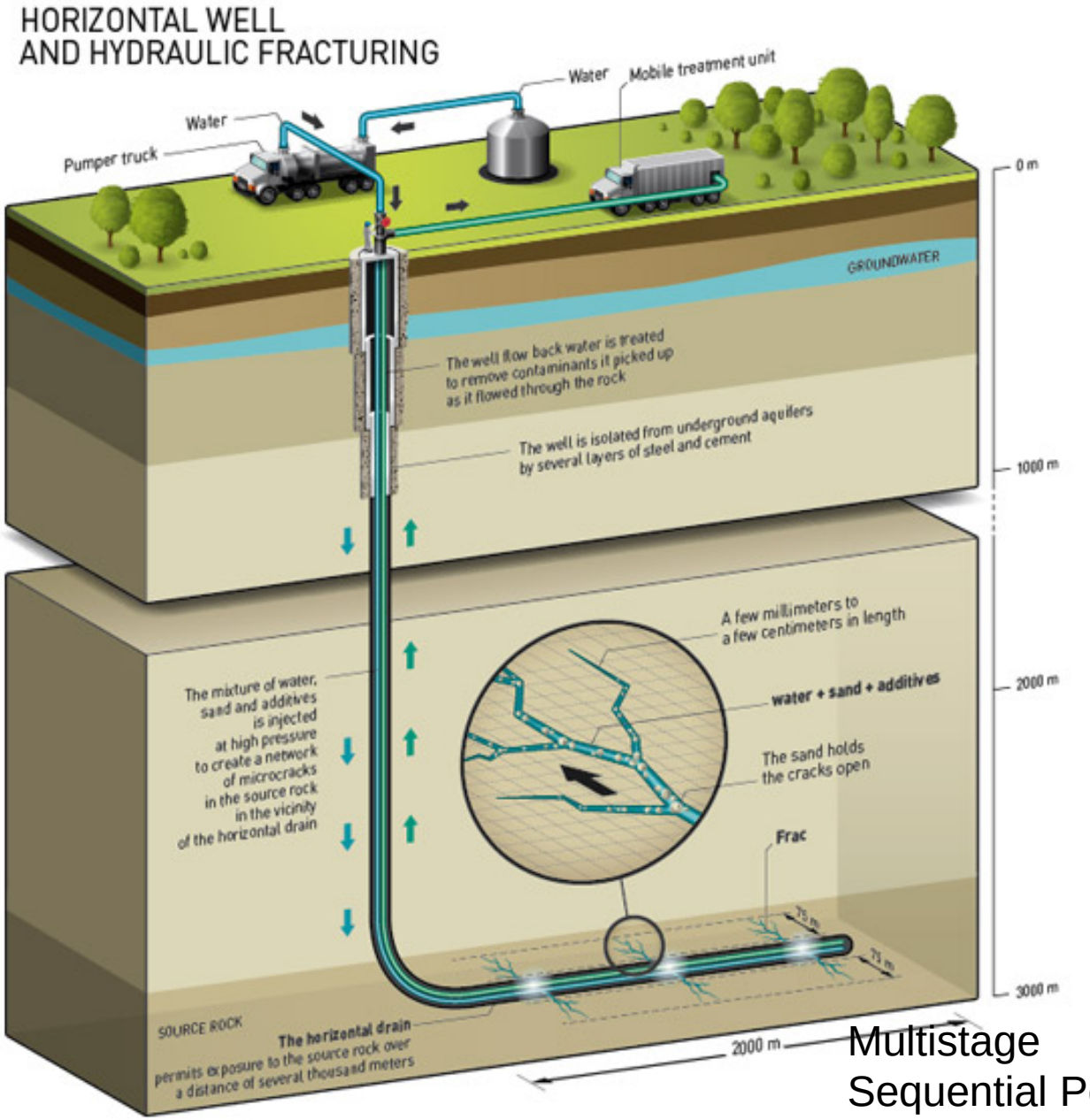
Shale Gas Development

- **Seismic Exploration**
  - Geological Characterization
- **Site Preparation**
  - Land Clearing (Pad)
- **Drilling**
  - Borehole
- **Well Completion**
  - Casing installment
  - Cementing
- **Production**
  - Hydraulic Fracturing
- **Re-Stimulation**
  - Re-fracturing (40 years)
- **Abandonment**
  - Cement Plug
  - Restoration of site.

Hydraulic Fracturing: Public Concern

High Pressure Fluid Injection

Fluid Design



Multistage Sequential Perforation

Drilling Rig in Rural Area

CCA (2014) Environmental Impacts of Shale Gas Extraction in Canada. Ottawa Ontario (ON): The Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction, Council of Canadian Academies.

Courtesy of www.marcellus-shale.us/

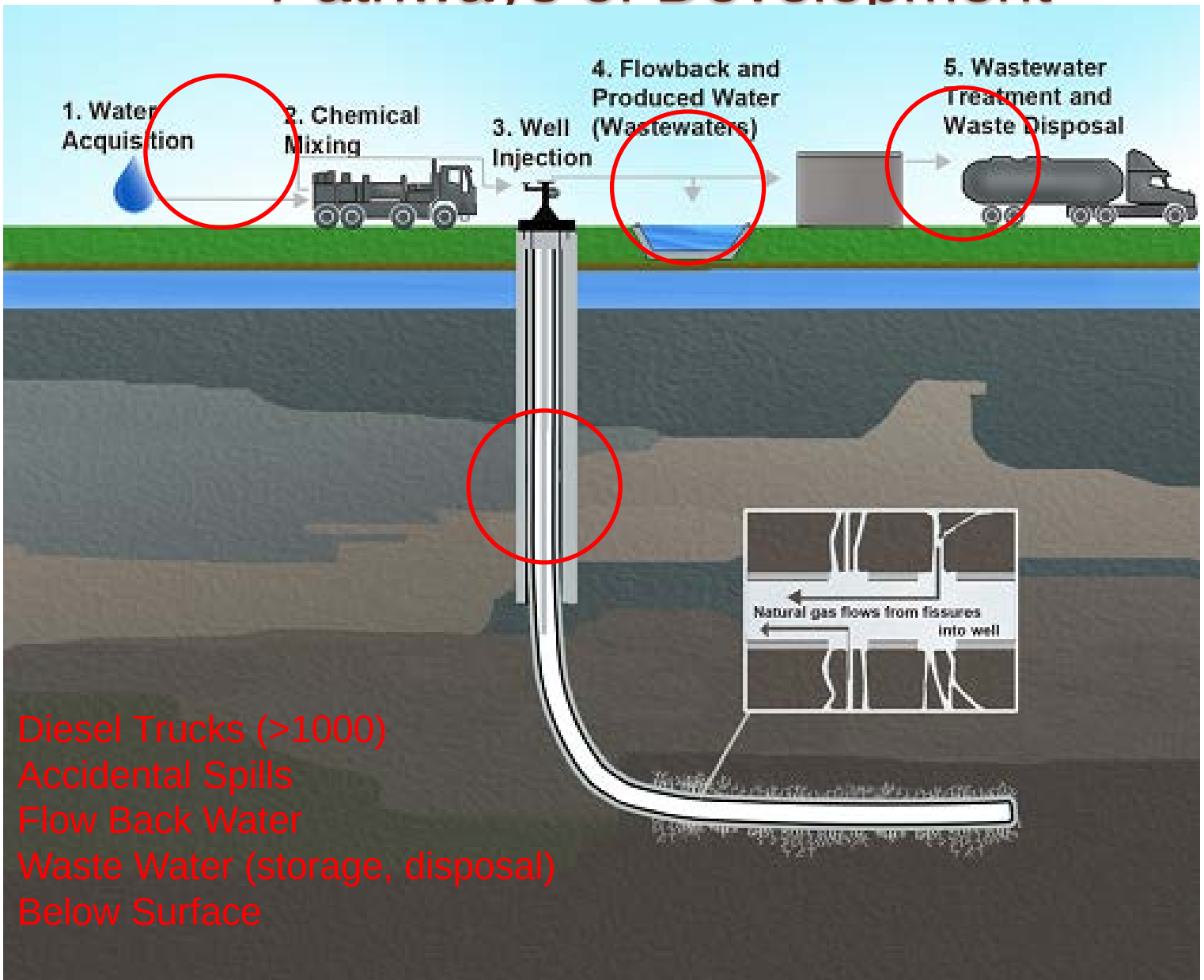
from:www.fractracker.org

Well Pad: Completion and Restoration

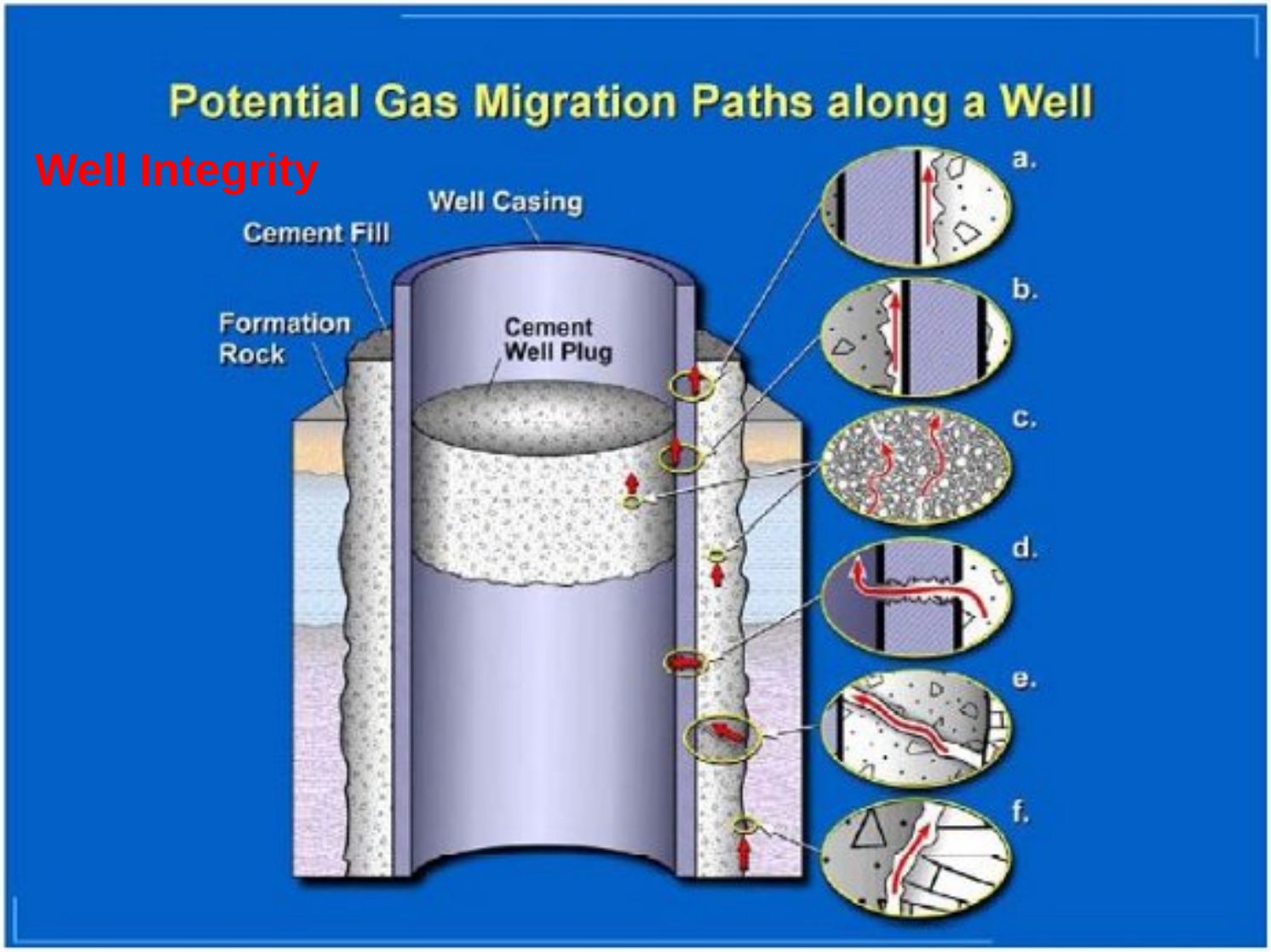
Courtesy of Nexen Energy ULC

CCA (2014) Environmental Impacts of Shale Gas Extraction in Canada. Ottawa Ontario (ON): The Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction, Council of Canadian Academies.

Potential Sources of Contamination: Pathways of Development



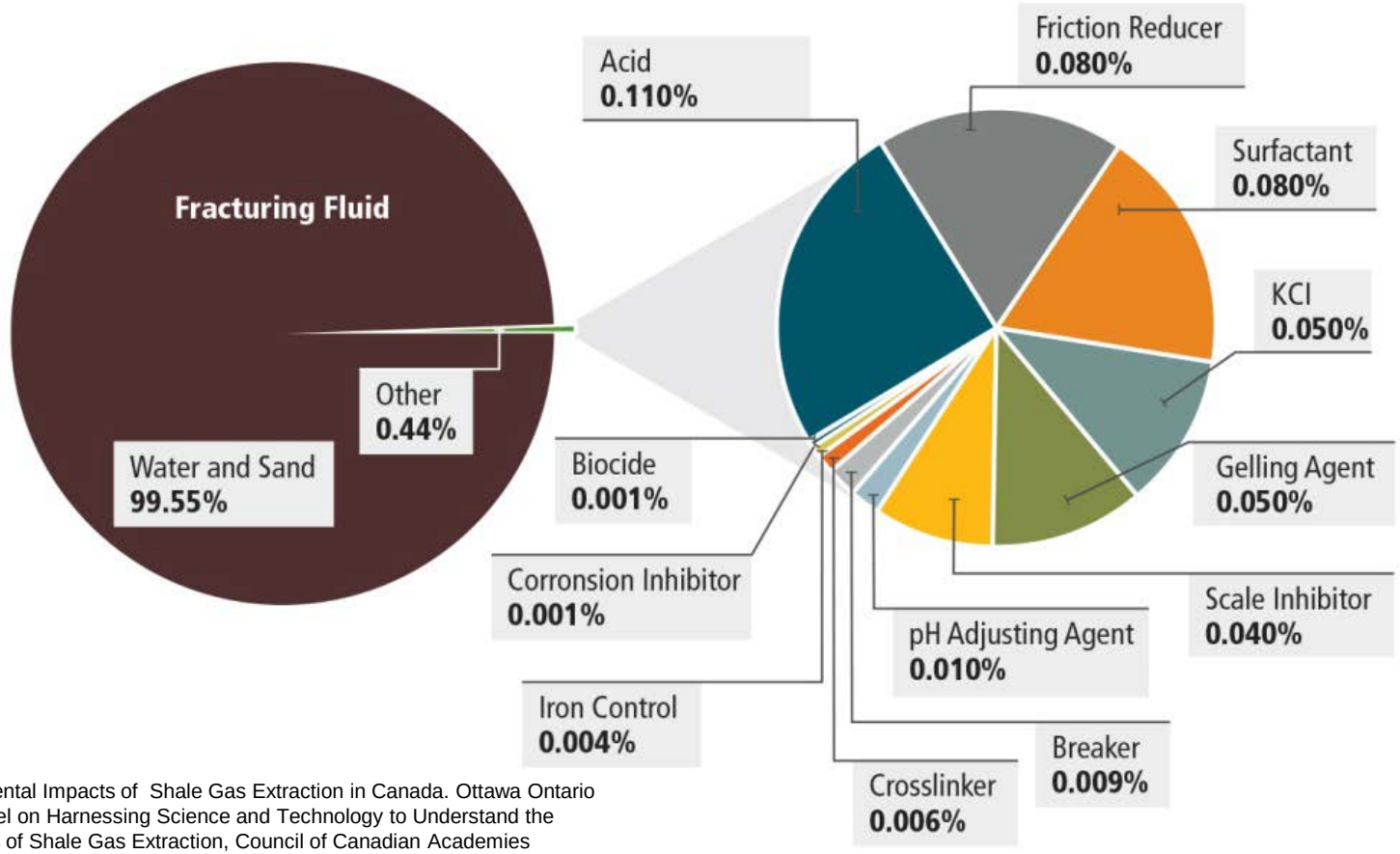
Potential Sources of Contamination:



Source: Alberta Energy Utilities Board

GHG
Ground
Water

Fracturing Fluid Composition



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Adapted with permission from Arthur *et al.*, 2008

Water

2000m3 –Fracturing Stage
- 20 backyard pools
15,000 to 20,000m3 Water/well
- 200 backyard pools

20,000m3 Total Fracturing Fluid
1 million kg proppant
80m3 acid, 900kg Friction reducer, 700kg disinfectant, 0.2m corrosion inhibitor

Water
Sand

Purpose:
Reduce Friction
Lower Viscosity
Suspend Sand
Disinfection

Typical Chemical Additives Used in Frac Water

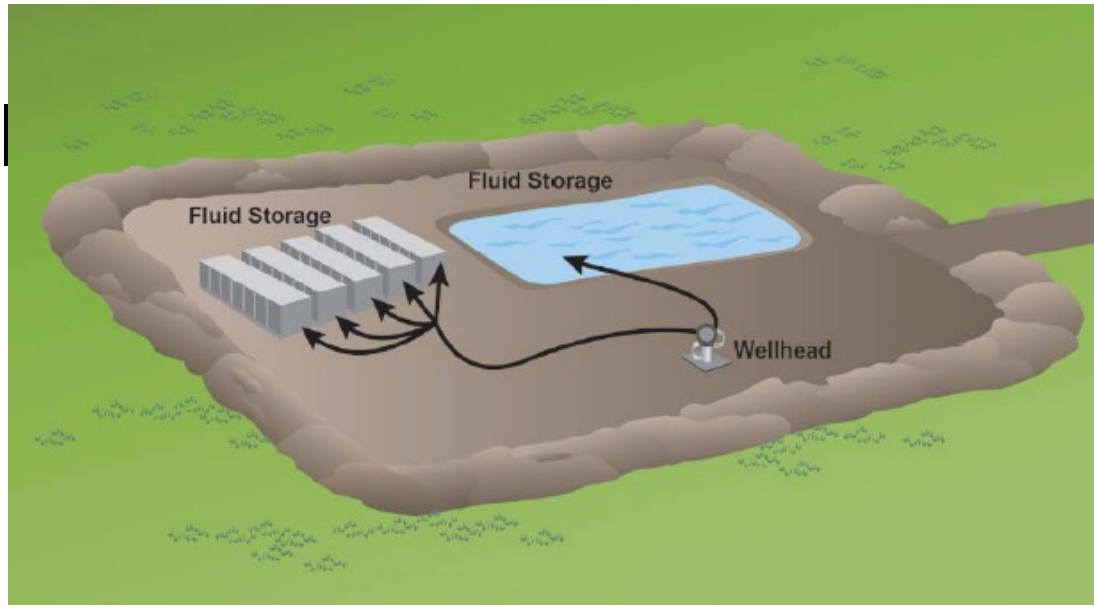
Slickwater

Compound	Purpose	Common application
Acids	Helps dissolve minerals and initiate fissure in rock (pre-fracture)	Swimming pool cleaner
Sodium Chloride	Allows a delayed breakdown of the gel polymer chains	Table salt
Polyacrylamide	Minimizes the friction between fluid and pipe	Water treatment, soil conditioner
Ethylene Glycol	Prevents scale deposits in the pipe	Automotive anti-freeze, deicing agent, household cleaners
Borate Salts	Maintains fluid viscosity as temperature increases	Laundry detergent, hand soap, cosmetics
Sodium/Potassium Carbonate	Maintains effectiveness of other components, such as crosslinkers	Washing soda, detergent, soap, water softener, glass, ceramics
Glutaraldehyde	Eliminates bacteria in the water	Disinfectant, sterilization of medical and dental equipment
Guar Gum	Thickens the water to suspend the sand	Thickener in cosmetics, baked goods, ice cream, toothpaste, sauces
Citric Acid	Prevents precipitation of metal oxides	Food additive; food and beverages; lemon juice
Isopropanol	Used to increase the viscosity of the fracture fluid	Glass cleaner, antiperspirant, hair coloring

Source: DOE, GWPC: Modern Gas Shale Development in the United States: A Primer (2009).

Flow Back Water

- Fracturing fluid
- Dissolved solids (TDS)
- Naturally Occurring Radioactive Materials (NORMS)
- Trace metal



Air Emissions

Substance	Source	Impact
NOx, SOx, VOCs	Diesel engines, natural gas compressors, fluid evaporation	Ozone precursors (smog)
BTEX (VOC)	Venting, fugitive emissions, flaring, fluid evaporation	Air Quality
Particulates (PM 2.5 µM)	Diesel engines, flaring	Air Quality
Methane	Venting, fugitive emissions	GHG emissions
CO_2	Diesel aggregates, flaring, fugitive emissions	GHG emissions

NO, → NO2-red/brown haze SO2, SO3-volcanoes
N2O-laughing gas
Forest fires Acid rain

Canadian Air Quality Management System

October 2011

- Improving air quality in Canada
- Establish Canadian Ambient Air Quality Standards (CAAQS)
- Address emissions from mobile sources.
  - reduce emissions with technologies, vehicle maintenance, and to reduce emissions from in-use diesel vehicles and engines, by greening fleets
- Base-level Industrial Emissions Requirements (BLIERs)
  - Emissions requirements proposed for new and existing major industrial sectors

Canadian Ambient Air Quality Standards (CAAQS)
Fine Particulate Matter (PM2.5) and Ozone (June 2000)

Management Level	Management Actions	Proposed Air Management Threshold Values					
		Ozone (ppb)		$PM_{2.5}$ Annual ($\mu g/m^3$)		$PM_{2.5}$ 24h ($\mu g/m^3$)	
		2015	2020	2015	2020	2015	2020
RED	**Actions for Achieving Air Zone CAAQS**						
Threshold		63 ppb	62 ppb	10.0 µg/m3	8.8 µg/m3	28 µg/m3	27 µg/m3
ORANGE	**Actions for Preventing CAAQS Exceedance**						
Threshold		56 ppb		6.4 µg/m3		19 µg/m3	
YELLOW	**Actions for Preventing AQ Deterioration**						
Threshold		50 ppb		4.0 µg/m3		10 µg/m3	
GREEN	**Actions for Keeping Clean Areas Clean**						

Summary: Chemicals of Concern

- Hydro-fracturing Chemicals
- Air Pollutants
- Hydrocarbons and Gases present in Shale
- Natural constituents of Flow Back Water
- Mixtures of Chemicals
- Chemical Reactions between chemicals:
  - New Chemicals of concern.
  - Frequency and Intensity of development
  - Ambient environmental conditions
  - Geology

Reasons given by those not in favor of UGD

(Goldstein et al, Env Hlth Persp 120:483-486, 2012)

Washington, PA public meeting with Natural Gas Subcommittee of the Secretary of Energy Advisory Board. N=59

Reason	Percent (%)
Environmental Concerns	76.3
Negative Effects on Water	66.1
Negative Effects on Air	42.4
Chemicals in Water	30.5
General Health Concerns	61.0
Health Problem in Family member attributed to drilling	20.3
Personal legal rights have been infringed upon by companies	11.9
Concerns about safety of drilling operations	33.9
Concerns about lack of regulation of industry	42.4
Bias, conflict of interest, or lack of expertise in desired subject area by members of the committee	18.6
Export of domestic natural gas resources	10.2
Depreciation in property values	3.4

Human Health: Shale Gas Development

Geographical

Political
Regulatory

Framework

Social
Support
Culture

Gender,

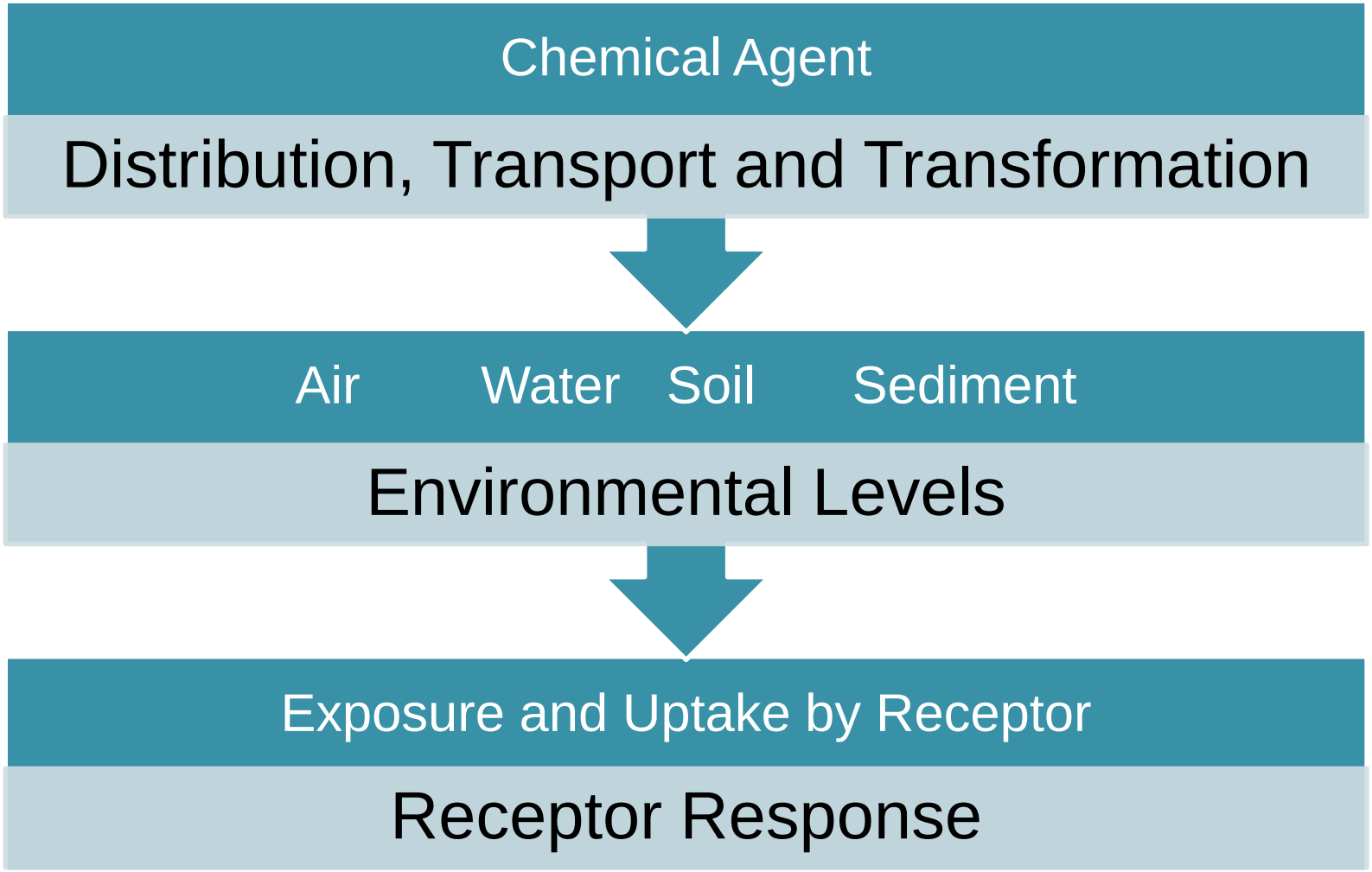
What are Potential Health Risks?

- Direct
  - Physical
- Indirect
  - Well-being
  - Cultural
  - Social
  - Psychological
  - Economic
  - Equity

Nature
Magnitude, Frequency and Intensity of Development

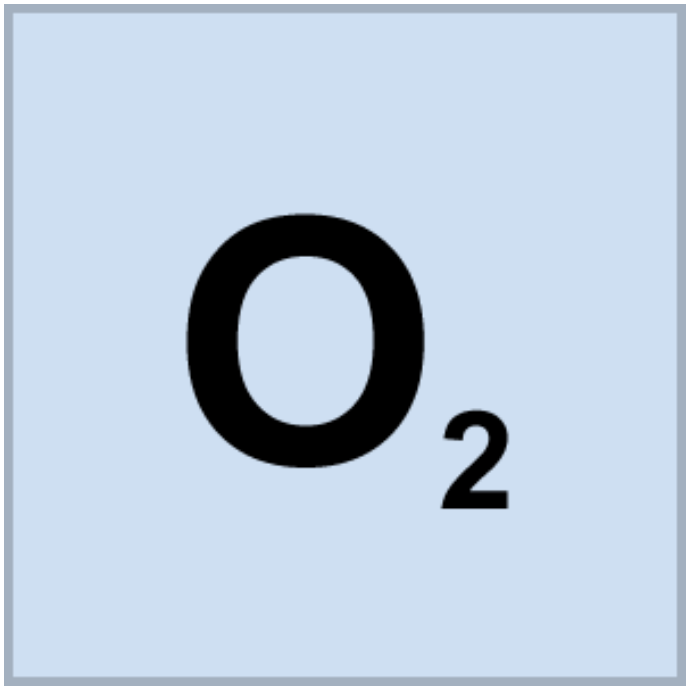
Improved Understanding of Potential Health Risks

Release of Chemical to Environment



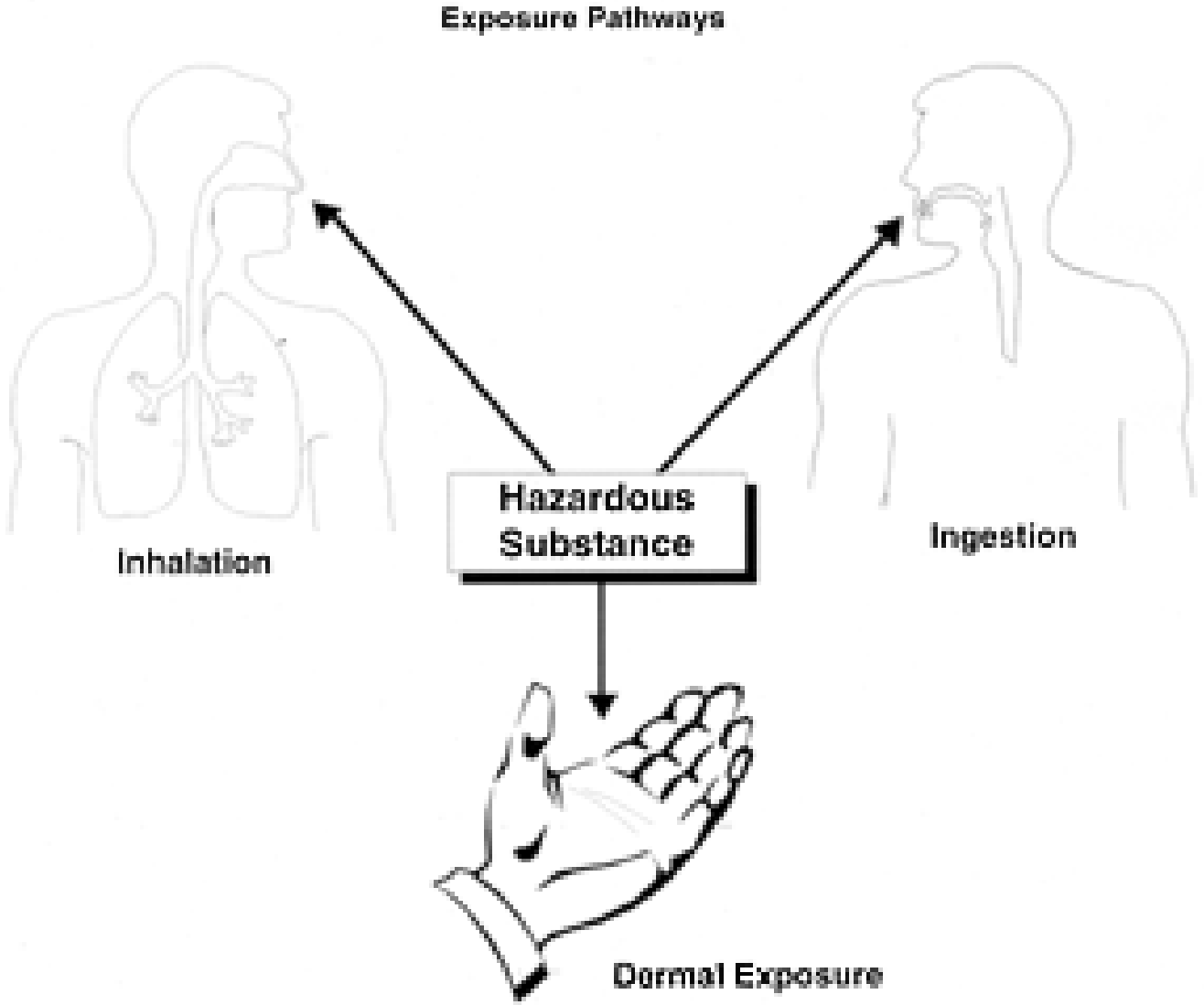
Chemical and Physical Properties

Oxygen



Ozone

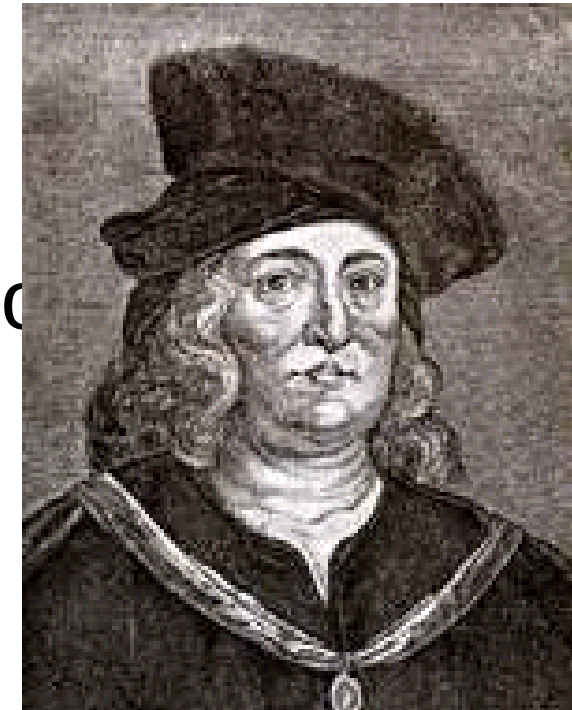
Human Exposure Pathways



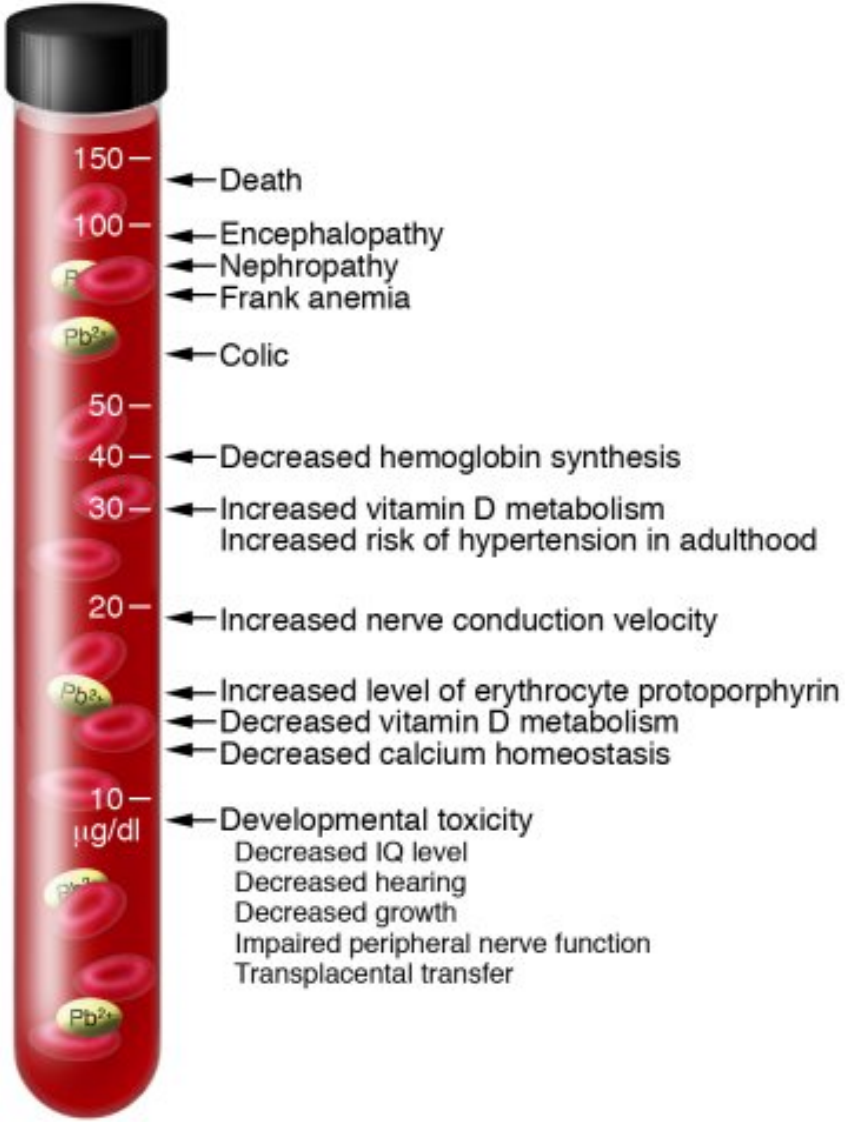
Evidence of Exposure

What is a toxic agent?

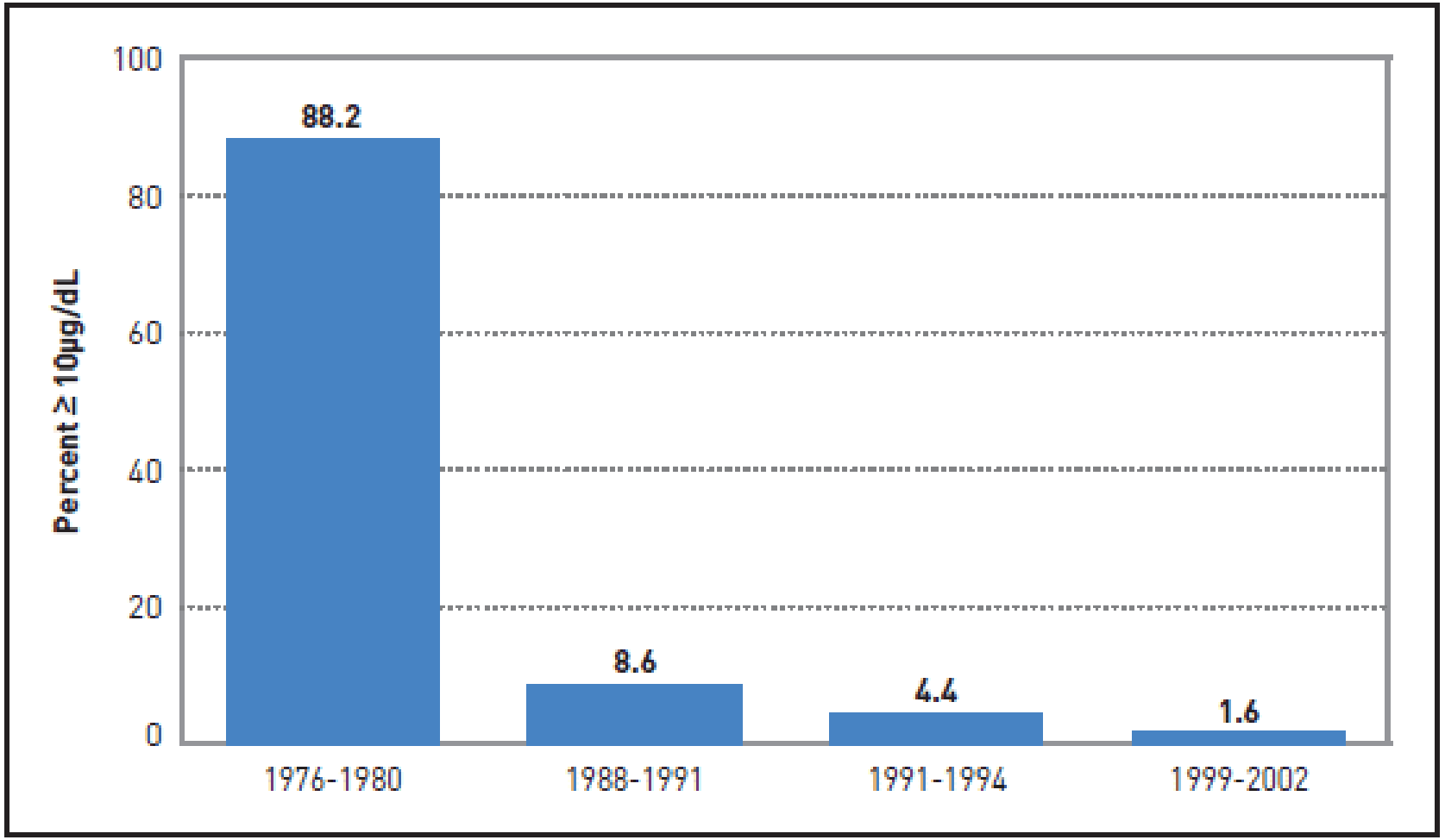
- Paracelsus (1493-1541)
- “ All substances are poisons; there is none which is not a poison. The right dose differentiates a poison and a remedy”
- The dose makes the poiso



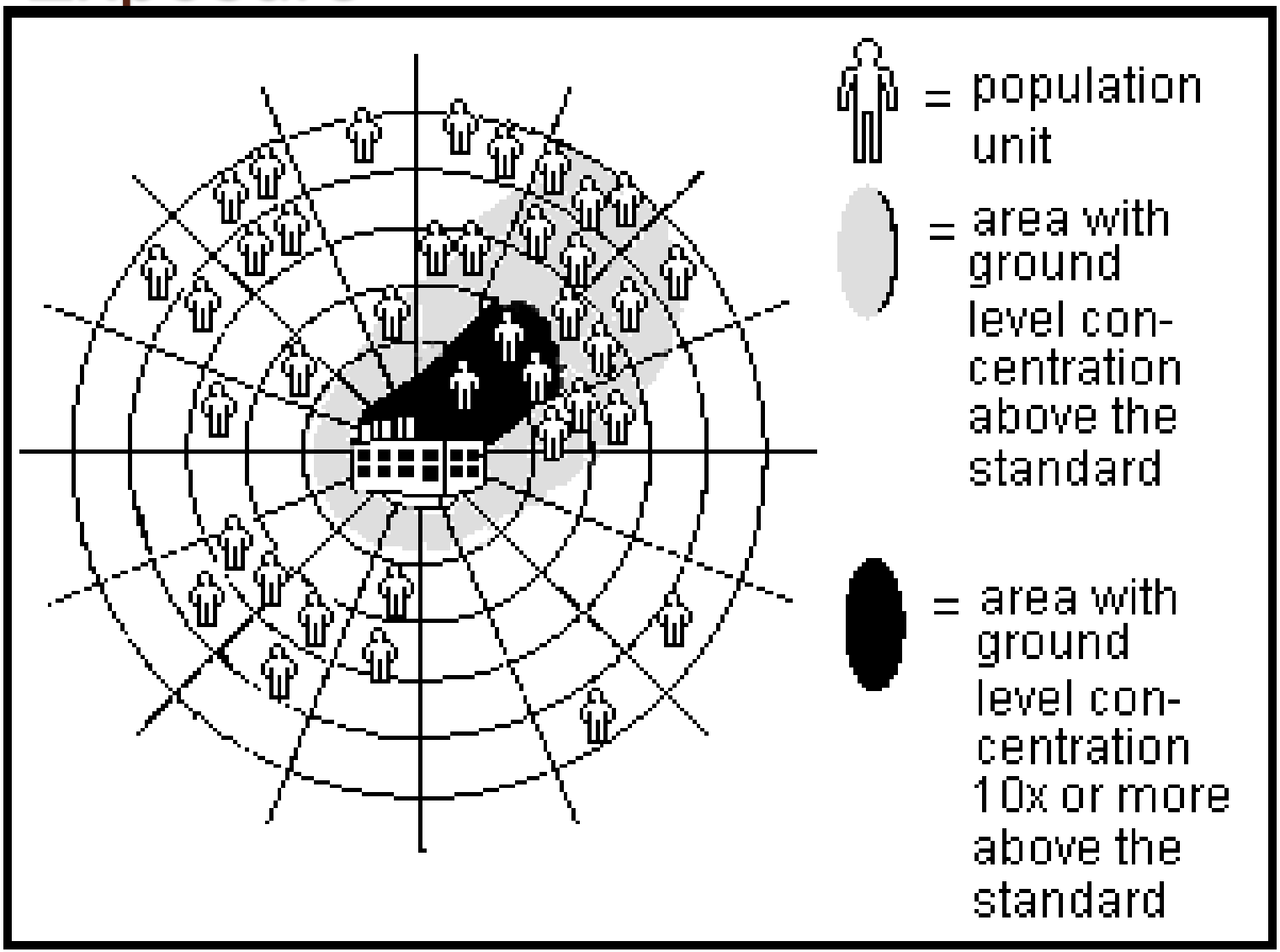
Lead: Dose Related Health Effects



Children with Elevated Blood Lead



Duration and Frequency of Exposure



Water drinking contest blamed in death of California woman

Sunday, January 14, 2007
CBC News

What are the Knowledge Gaps?

- Baseline information
- Chemical Mixtures
  - Additive Risks
- Unanticipated Chemical Constituents
- Fate and Transport
- Magnitude, Frequency and Durations of Exposure
- Dose Response Assessments

Significance of Human Health Impacts

- Population density and proximity
- Demographic Characteristics
- Baseline Health Status
- Ambient Environmental Conditions
- Geology
- Legal/Regulatory Framework
- Frequency and Intensity of Development

Challenges to Risk Assessment

- Limited evidence, limited access to it, and uncertainty about it
- Evolving research and conflicting literature
- Rapidly evolving technology but minimal independent assessments of performance to reduce impacts
- Regional variation
- Some impacts may take decades to become evident