Contaminated Site Assessment Overview

Module 1

Objectives

Provide an overview of the Contaminated Site Assessment Framework, with brief introductions to Risk Assessment and Remedial Action Planning.

Topics

- Definitions of Contaminated Sites
- Types of Contaminants
- Overview of Contaminated Site Assessment Framework
- Oil in the environment; Receptors, sources of Contaminants and Impacts
- Conceptual Site Models (CSMs)
- Introduction to Sources of Errors & Risk Assessment
- Remedial Action Planning Options and Closure

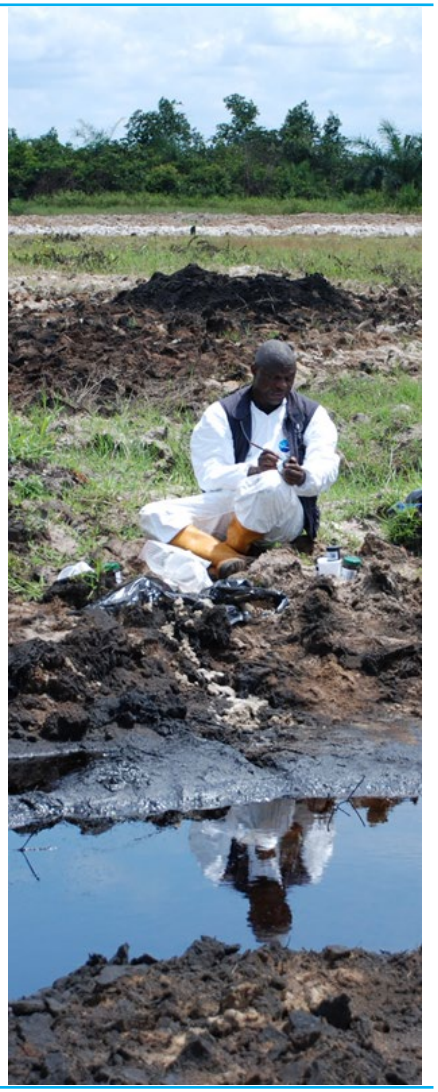
What is a Contaminated Site?

Areas of land, water, groundwater, or sediments that have levels of contaminants exceeding background concentrations that may present risk to people and/or the environment (**RECEPTORS**).

Contaminant **SOURCES** include on-site burial of wastes, small, frequent drips and spills, stockpiling and storage of materials, major spills, and releases during fires. They may migrate or be carried along **PATHWAYS** to reach the **RECEPTORS**.

Contamination may also occur from illegal dumping of contaminated soil.

Contaminated sites may have short- or long-term consequences on people's health and the quality of the environment.



Source: Dept Environment Government of Nunavut Guideline for Contaminated Site Remediation 2009 http://www.gov.nu.ca/env/environment

Definitions

"**Site**" means an area of land and includes both underground and surface water.

"**Source site**" means a site on which contamination has occurred; or on which a substance has originated and from.

"**Affected site**" means a site on which contamination is received or affected.

"**Contaminated**" in relation to land, water or a site, means having a substance present in or on that land, water or site at above background concentrations that presents, or has the potential to present, a risk of harm to human health, the environment or any environmental value.

"**Background concentrations**" means the naturally occurring, ambient concentrations of a substance in the local area of a site.

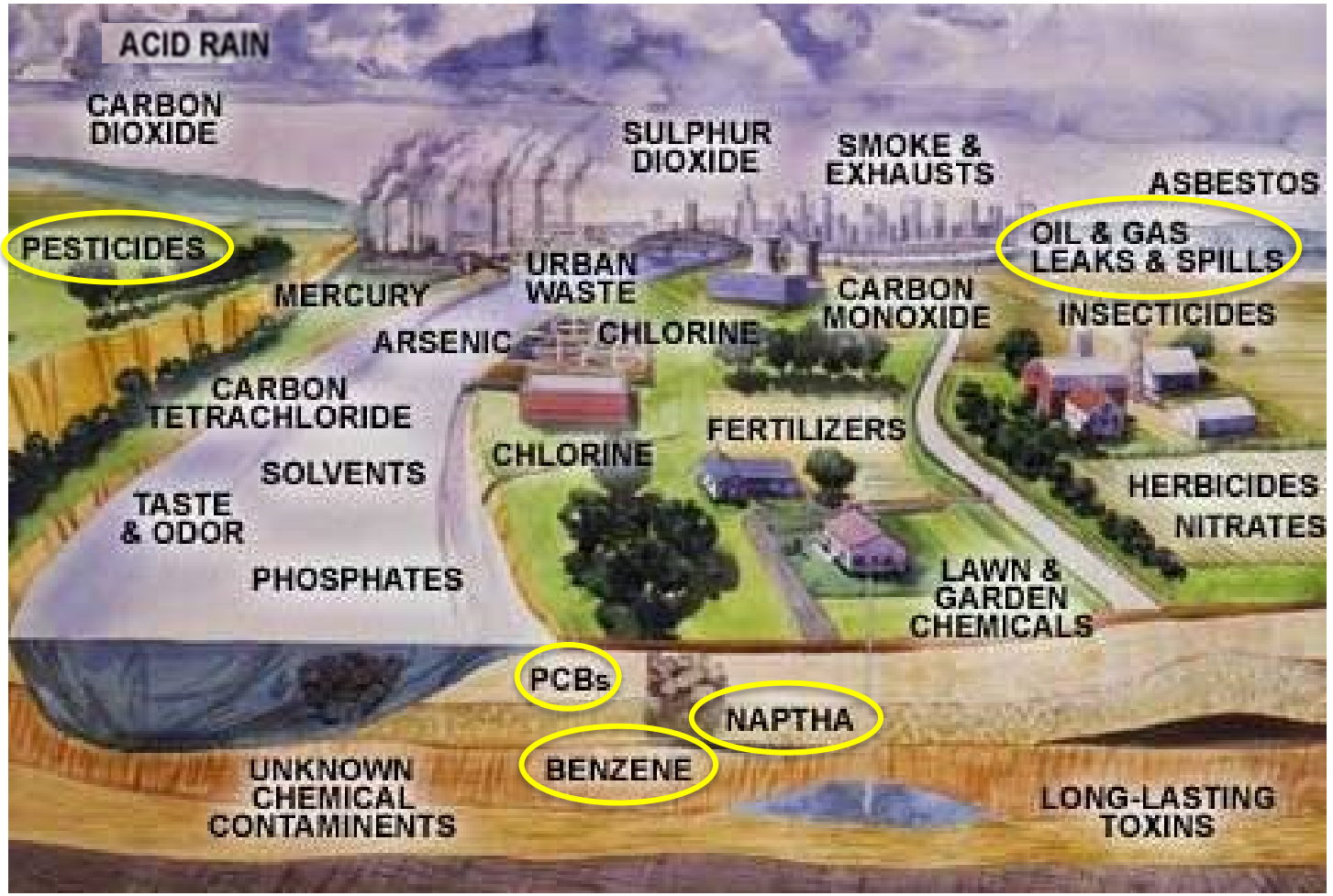
Govt Western Australia Dep Environmental Regulation Assessment and management of contaminated sites. Contaminated sites guidelines. 2014

Contaminated - what?

Contaminants can be present in:

- **Drinking water** reservoirs under ground or in lakes/rivers
- **Soil** used for farming or through which water percolates
- **Air** we breathe

Common Contaminants in Land & Water



Source: https://greenplanetethics.com/wordpress/list-of-drinking-water-contaminants-their-maximum-contaminant-level-disinfectants/

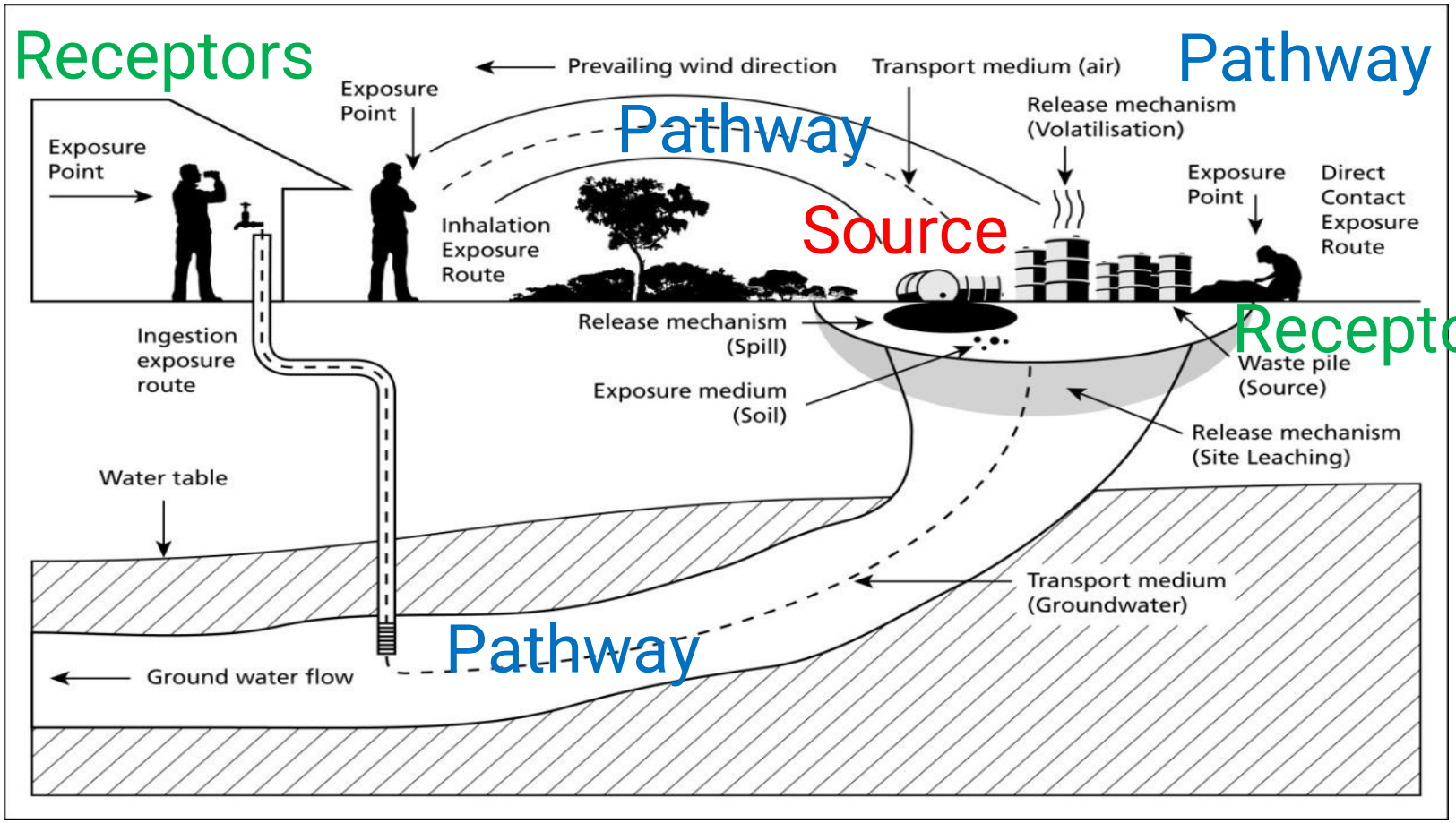
Contaminated sites - where?

How **much** and **where** is the contaminated land?
Global data is incomplete, but there are many sites.

- In the UK alone, estimates vary from **50,000 ha to 200,000 ha.**
- The UK Environment Agency (1999) estimates that some 300,000 ha of land across the UK may be affected either by industrial or “natural” contamination.
- Although not all sites will pose immediate concerns, the Agency estimates that there may be between **5,000 and 20,000 “problem sites”.**
- Every year, more than **30,000 emergencies** involving the release (or threatened release) of oil and hazardous substances are reported in the USA. The US EPA works with other federal agencies, state and local responders to eliminate danger to the public.

Source: Contaminated land and risk assessment: A guide to good practice. CIRIA C552 London 2001; and https://www.epa.gov/aboutepa/office-land-and-emergency-management-olem-accomplishment-reports-and-benefits

Conceptual Site Models (CSM)



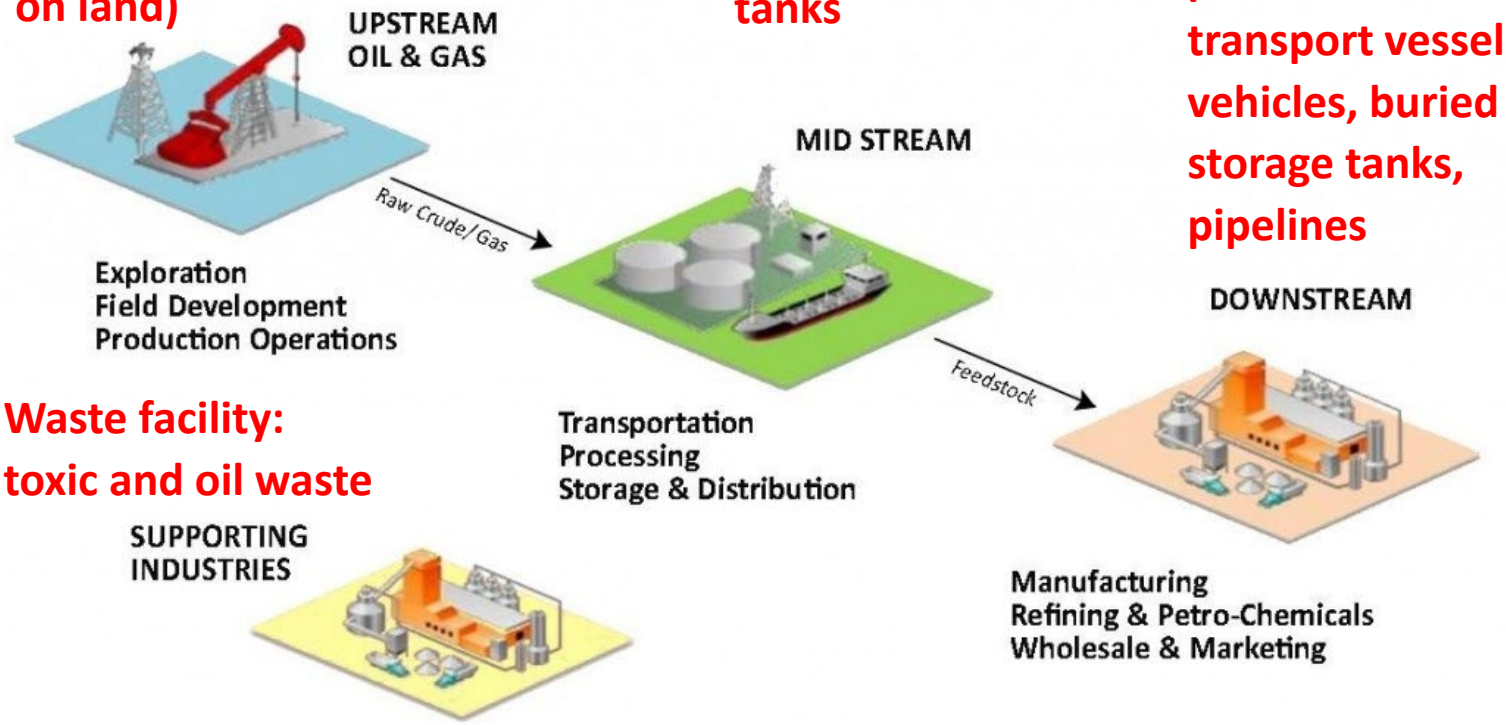
Example of a simple CSM illustrating potential source>pathway>receptor linkages

Potential contaminants in O&G value chain

Drilling and fracking chemicals, incl. toxins, radioactive compounds, oils, surfactants, fuel from vessels/rigs (at sea and on land)

Crude oil: from transport vessels, pipelines, storage tanks

Crude oil and numerous refined products: from transport vessels/ vehicles, buried storage tanks, pipelines



Waste facility: toxic and oil waste

Where, what, when, how? Think: Sources > Pathways > Receptors

Source: https://avata.com/oil-gas

How do oil contaminants get there?

Contaminants enter the environment through in several ways:

- **Fires or explosions of fuel** e.g. of oil or gas wells on land or in the sea
- **Road accidents** e.g. involving fuel tankers
- **Shipping accidents** leading to oil spills at sea/coastline
- **Leaking storage tanks, equipment or pipelines** underground or on surface
- Municipal infrastructure e.g. sewage systems

Contaminated Sites: e.g. Niger delta

Illegal refineries leaving crude oil spills directly onto land and nearby rivers

Contaminated Sites: e.g. Iraq desert

Oil well blow-out from sabotage causing spill directly onto land and air emissions

Contaminated Sites: e.g. Iraq river

River-crossing crude oil pipeline failure causing spillage directly into river

Contaminated Sites: e.g. Mauritius

MV Wakashio September 2020 spilling 1000 tonnes of heavy oil

Contaminated Sites and Receptors

Types of Sites	Receptors
Housing	People, materials, private assets
Offices	People, materials, commercial assets, businesses
Factories	People, materials, commercial assets, businesses
Warehouses	People, materials, commercial assets, businesses
Parks and recreation areas	People, wildlife, soil, water, social and conservation values
Archaeological sites	People, cultural value
Farmland	People, crops, soil, water, businesses
Public land	People, wildlife, soil, water
Protected areas (e.g. wetlands, forest)	Endangered plants/animals, tourism businesses
River, lakes and shoreline	People, wildlife, sediment, water, recreational businesses
Oceans and deep-sea	Wildlife, sediment, water, fisheries and tourism businesses

When does contamination = pollution?

- **Contamination** is simply the presence of a substance where it should not be, reducing the purity of the surrounding area.
- **Pollution** is contamination that results in adverse biological effects upon resident communities.

Note. All pollutants are contaminants, but not all contaminants are pollutants.

Chapman (2007)

Differentiating pollution from contamination requires:

- Chemical analyses to establish presence of contaminants and their concentrations
- Studies of bioavailability and/or toxicity
- Laboratory or field toxicity tests directed towards key species

Contaminant effects may be **direct** e.g. on health or activity of a species, or **indirect** (also called secondary), typically if a predator or grazer is killed by a direct effect, more resistant prey species may become abundant.

Source: Chapman, 2007. Determining when contamination is pollution — Weight of evidence determinations for sediments and effluents. Envir. Intern. 33(4): 492-501

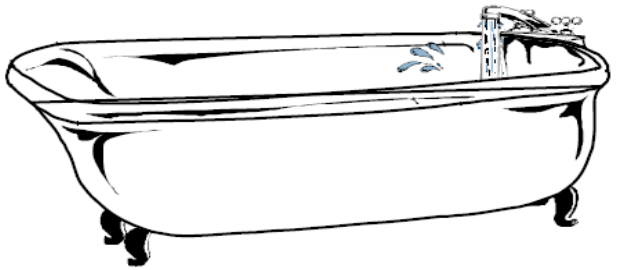
Concentrations of ppts and ppms

The **guiding measures** to avoid effects from contamination, and as indicators of pollution, are usually expressed as **concentrations** of the amounts of most chemical pollutants and toxins that can be considered safe in the environment, tissues of fish, in drinking water etc. Most are represented in values of part per million (ppm). How big is this amount?

Chlorine in drinking water: US EPA requires treated tap water to have a detectable level of chlorine to help prevent contamination, with allowable chlorine levels in drinking water (up to 4 parts per million, or 4 ppm).

Oil Operational pollution at sea, from shipping, using MARPOL's discharges of bilge water at 15 ppm of oil in water.

Note: contaminants in water often measured in milligrams per liter (mg/L). 1 mg/L = 1 ppm.



1 drop in a bathtub full of water = 2 ppm

Source: Alaska Department of Environmental Conservation - Spill Prevention and Response Division - Contaminant Concentrations. Series 1, Fact Sheet # 7 ENVIRONMENTAL CLEANUP EDUCATIONAL TOOLS SERIES June 2009

Toxicity of Contaminants

Contaminants of Land and Water	Uses	Effects
Heavy hydrocarbons: crude oil, bulk fuel	Various: e.g. fuels, solvents, paints, plastics	Smothering; toxic fractions enter ground/surface waters
Light hydrocarbons: diesel, petrol, benzene	Fuel, solvents, paints, plastics	Toxic fractions enter water systems
Carbon tetrachloride (or tetra-chloromethane)	Solvent, fumigant, industrial chemicals	In water, mostly sinks; through drinking, toxic to liver and kidneys; cancer, death; greenhouse gas.
Nutrients: phosphates, nitrates	Fertilisers	Eutrophication (fish kills)
Heavy metals: e.g. Cr, Pb, Hg, Ni, Ar, Cd, Cu..	Various: electronics, paints, pesticides, batteries	Accumulate to lethal levels in animals, mutations, cancer

Toxicity of Contaminants

Contaminants of Land and Water	Uses	Effects
Herbicides e.g.	To kill unwanted plants	Enter water and soil systems, affecting wildlife and humans
Pesticides e.g. DDT	To kill unwanted pests	Accumulate to lethal levels in animals, mutations, cancer
Polychlorinated biphenyl (PCBs)	Transformer/coolant oils, also in paints, sealants	Bio-accumulates, reduced immunity; thyroid, liver, mental problems, death
Chlorine	Bactericide in pools, cleaning, and bleach in paper industry	Toxic when ingested, or gas inhaled leading to breathing risks, death

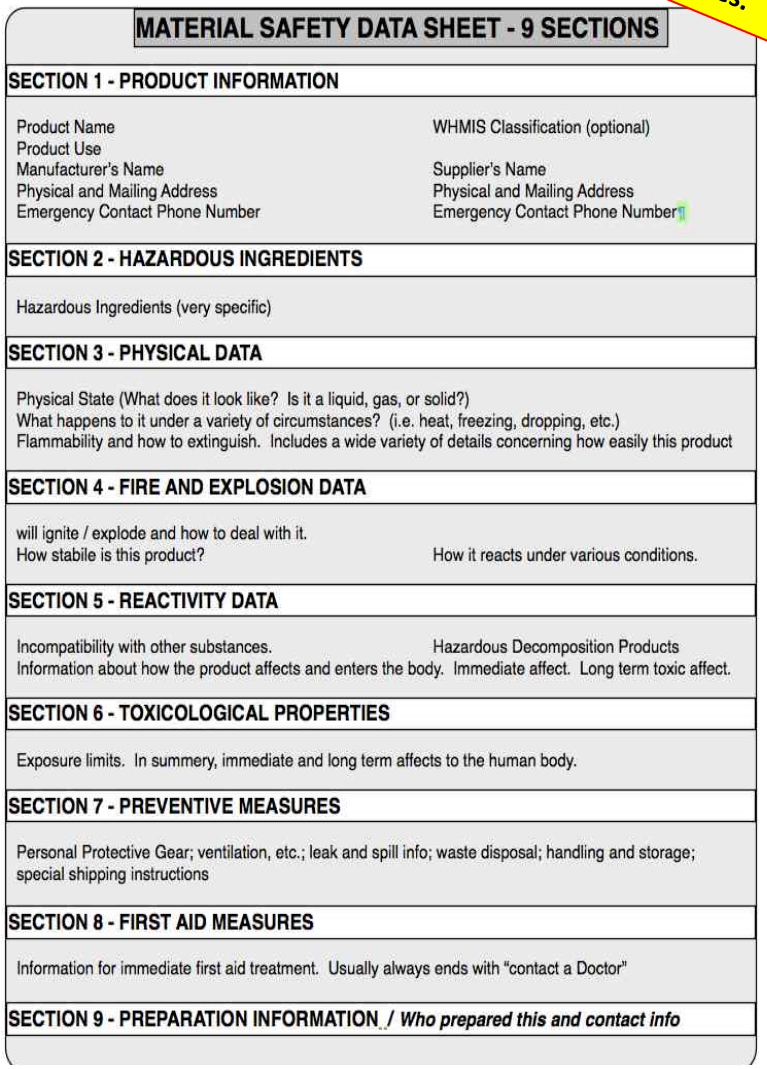
Material Safety Data Sheets - MSDS

MSDS should be available on site for all hazardous products used in O&G and other industries.

A MSDS, or Safety Data Sheet provides info on properties of hazardous chemicals and how they affect health and safety in the workplace. Typical info includes:

- The identity of the chemical
- Health & physicochemical hazards
- Safe handling & storage procedures
- Emergency procedures, & disposal considerations

Most countries require manufacturers or importers of a hazardous chemical to prepare an MSDS for the chemical.
Suppliers must provide current MSDS for hazardous chemicals on first supply to a workplace and upon request.
MSDS must be reviewed periodically, kept up to date, or, be reviewed and re-issued every 5 years.



MATERIAL SAFETY DATA SHEET - 9 SECTIONS

SECTION 1 - PRODUCT INFORMATION

Product Name
Product Use
Manufacturer's Name
Physical and Mailing Address
Emergency Contact Phone Number

WHMIS Classification (optional)

Supplier's Name
Physical and Mailing Address
Emergency Contact Phone Number

SECTION 2 - HAZARDOUS INGREDIENTS

Hazardous Ingredients (very specific)

SECTION 3 - PHYSICAL DATA

Physical State (What does it look like? Is it a liquid, gas, or solid?)
What happens to it under a variety of circumstances? (i.e. heat, freezing, dropping, etc.)
Flammability and how to extinguish. Includes a wide variety of details concerning how easily this product

SECTION 4 - FIRE AND EXPLOSION DATA

will ignite / explode and how to deal with it.
How stabile is this product?

How it reacts under various conditions.

SECTION 5 - REACTIVITY DATA

Incompatibility with other substances.

Hazardous Decomposition Products

Information about how the product affects and enters the body. Immediate affect. Long term toxic affect.

SECTION 6 - TOXICOLOGICAL PROPERTIES

Exposure limits. In summery, immediate and long term affects to the human body.

SECTION 7 - PREVENTIVE MEASURES

Personal Protective Gear; ventilation, etc.; leak and spill info; waste disposal; handling and storage; special shipping instructions

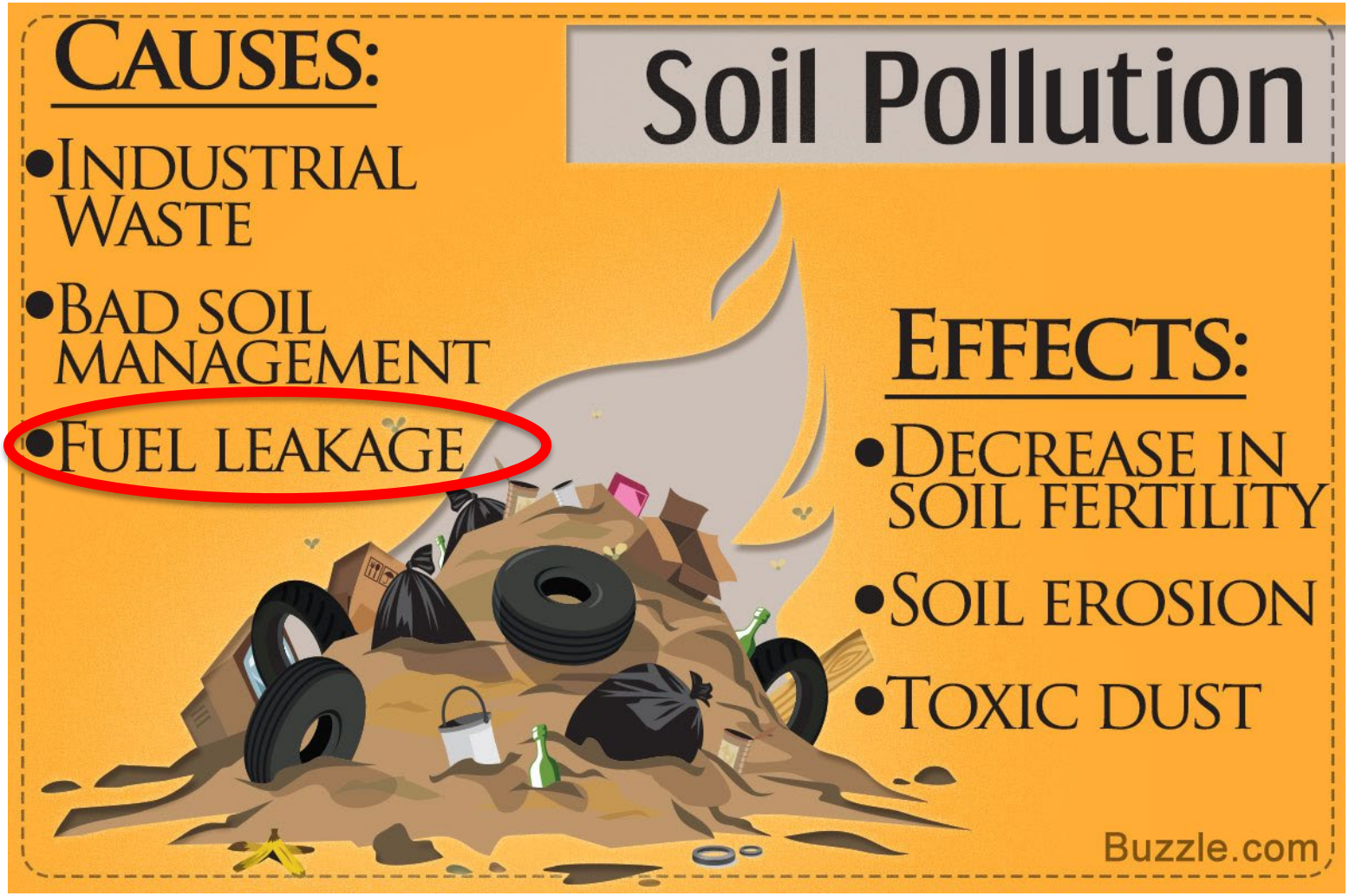
SECTION 8 - FIRST AID MEASURES

Information for immediate first aid treatment. Usually always ends with "contact a Doctor"

SECTION 9 - PREPARATION INFORMATION / ***Who prepared this and contact info***

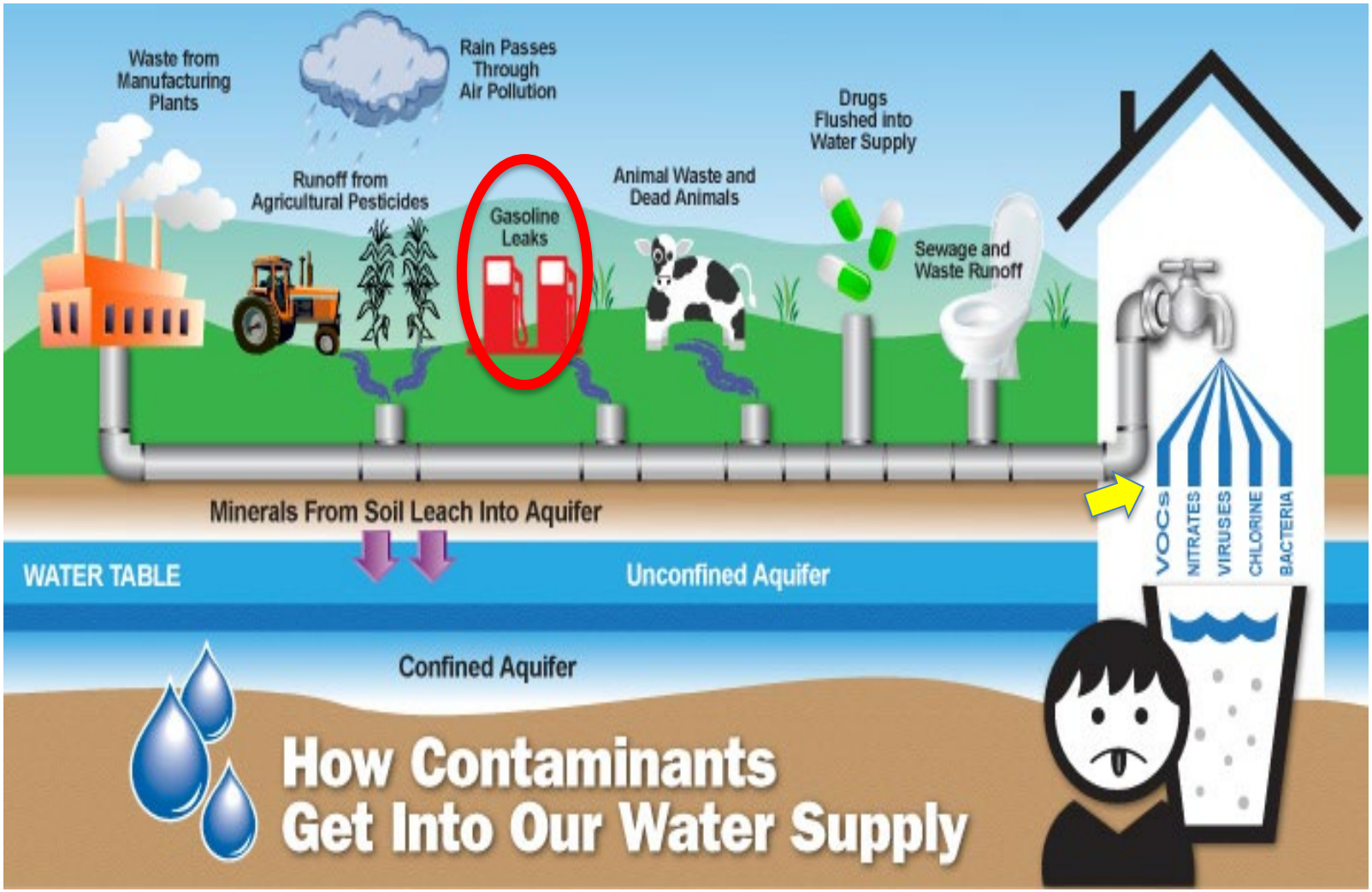
Source: https://www.farmco.com.au/blog/farm-basics---what-is-an-msds-

Soil Pollution - Effects



Source: https://helpsavenature.com/soil-pollution-causes-effects

Water Pollution – Sources and Effects



Source: https://h2theno.files.wordpress.com/2014/05/pollutants-in-water.jpg

Water Pollution – Sources

• Four litres (1 gallon) of gasoline can contaminate approximately 2.8 million litres (750,000 gallons) of water (that equal 1:750,000, which is >1 ppm). Note: the US EPA Max Contaminant Level for Benzene allowed in drinking water is 0.005 ppm.

• Groundwater supplies serve about 80% of the population, whereas up to 4% of usable groundwater is already polluted.

• There are 12,000 different toxic chemical compounds in industrial use today, and more than 500 new chemicals are developed each year.

• Over 70,000 different water contaminants have been identified.

• If all new sources of contamination could be eliminated, in 10 years, 98% of all available groundwater would then be free of pollution.

Source: https://h2theno.wordpress.com/2014/05/05/fresh-water-pollution/

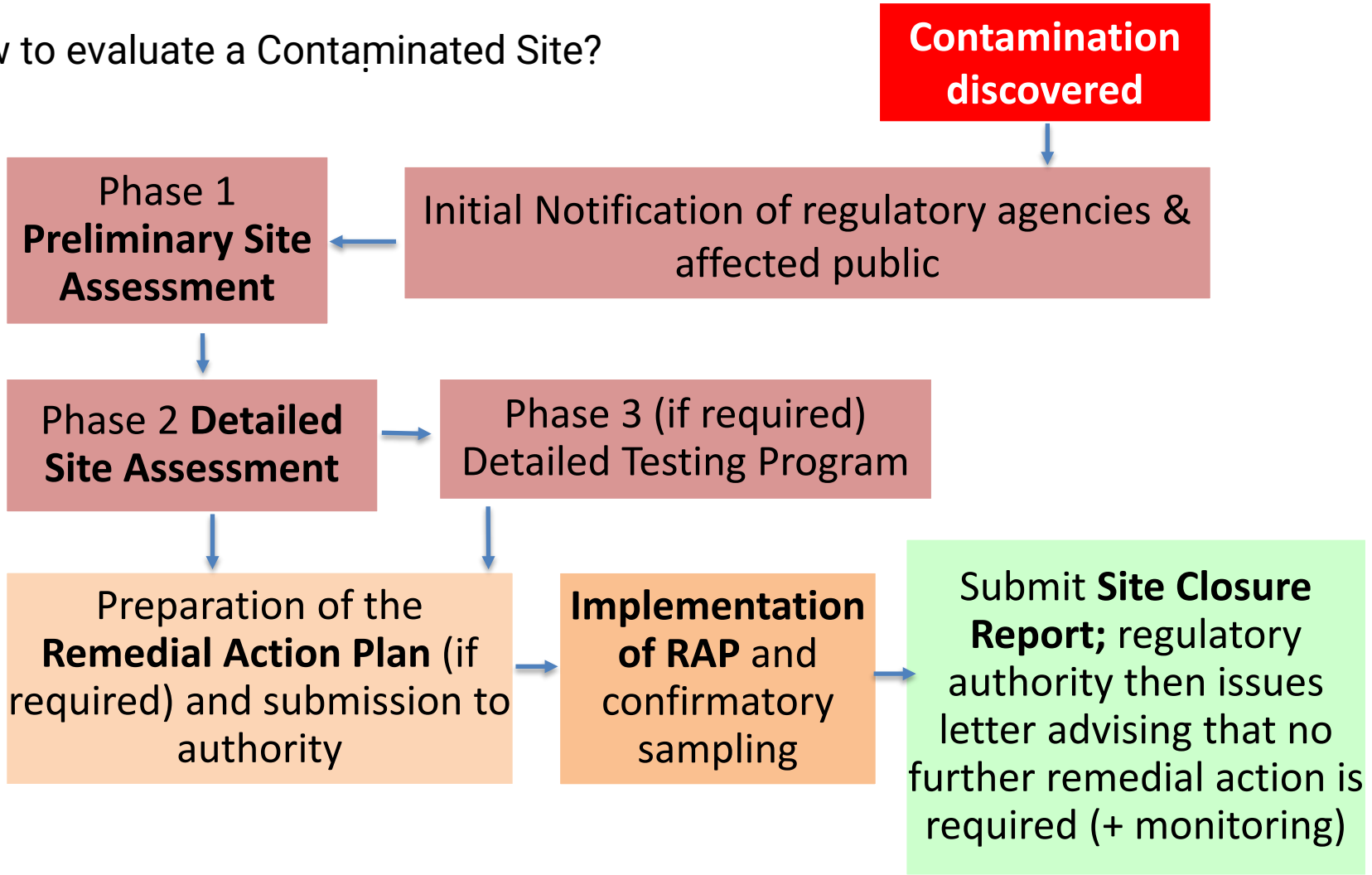
Marine Oil Pollution - Effects

After a marine oil spill, the effects on marine organisms range across a toxicity spectrum (especially for light oils and oil products – affecting plankton and fish very quickly) to smothering (particularly for intermediate and heavy fuel oils and weathered residues) – that can kill mangroves and other shoreline habitats and creatures.

Source: http://www.itopf.org/knowledge-resources/documents-guides/document/tip-13-effects-of-oil-pollution-on-the-marine-environment/

Framework of a CSA

How to evaluate a Contaminated Site?

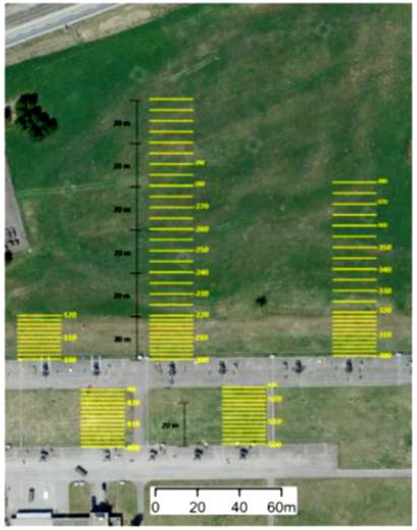


Source: Dept Environment Government of Nunavut Guideline for Contaminated Site Remediation 2009 http://www.gov.nu.ca/env/environment

Overall Objectives of a CSA

Traceability – Representativeness – Trust

Sampling Plan → Reality → Laboratory / Report



Prüfbericht Nr. UA-2017-20

Auftraggeber

Armasuisse Kompetenzzentrum Boden, Rolf Keiser

Auftrag

Analyse des Bodens im Abschussbereich des Fliegerabwehrschiessplatz S-Charef hinsichtlich Metallen

Zusammenfassung

Die Proben wurden auf Schwermetalle hin untersucht. Die Metalle Molybdän und Cadmium sind in erhöhten Mengen in Geschoßzerteilungsnähe vorzufinden (Mo: bis 70 mg/kg; Cd: bis 1.7 mg/kg). Die Metalle Zink und Thallium sind im Vergleich zur Referenz erhöht (Zn: bis 450 mg/kg; Tl: bis 5.8 mg/kg).

Physik | Physik | Physik

Dr. Mario Burger, Chef Physik | Marc Stauffer, Chef Umweltanalytik | Cédric von Gunten, Umweltanalytik

– Armasuisse Immobilien, Umweltmanagement, Normen & Standards, Rolf Keiser, Blumenbergstrasse 39, CH-3003 Bern

– STM → PAN → VGCE → OSJA → Dok STS 0101
– BURG → Reg

EPA Sampling Guideline

i.e. EPA 6000 series

ISO 17025

Overview of CSA Framework

Also known as "Environmental Site Characterization"

CSA is a scientific approach to understanding and characterizing contamination in an area

Based on historical and current events and land use

The information will change based on new events and activities in the area

A CSA can have many projects within – land, water, air, indoors

Typical steps:

- Priority site selection
- Preliminary site assessment
  - Desk Study
  - Site Reconnaissance
  - Formulate initial CSM
- Detailed site assessment
- Laboratory Analysis
- Risk assessment
- Remedial Action Plan
  - Options appraisal
  - Implementation
  - Verification

CSA Investigations - definitions

Preliminary site investigation (PSI) consists of a desktop study, a detailed site inspection and interviews with relevant personnel. A PSI may also include limited sampling and analysis. The information is used to develop an initial CSM. If contamination or sources of contamination (potential areas of concern) are identified, further detailed site investigation is necessary.

Detailed site investigation (DSI) assesses potential or actual contamination through an appropriate sampling and analysis program. Several phases of investigation (including risk assessment) may be required to adequately characterise the site, particularly for complex sites. The CSM is refined on an iterative basis until there is sufficient information on the site to devise risk-based strategies to manage the identified risks.

Some advantages of using CSMs

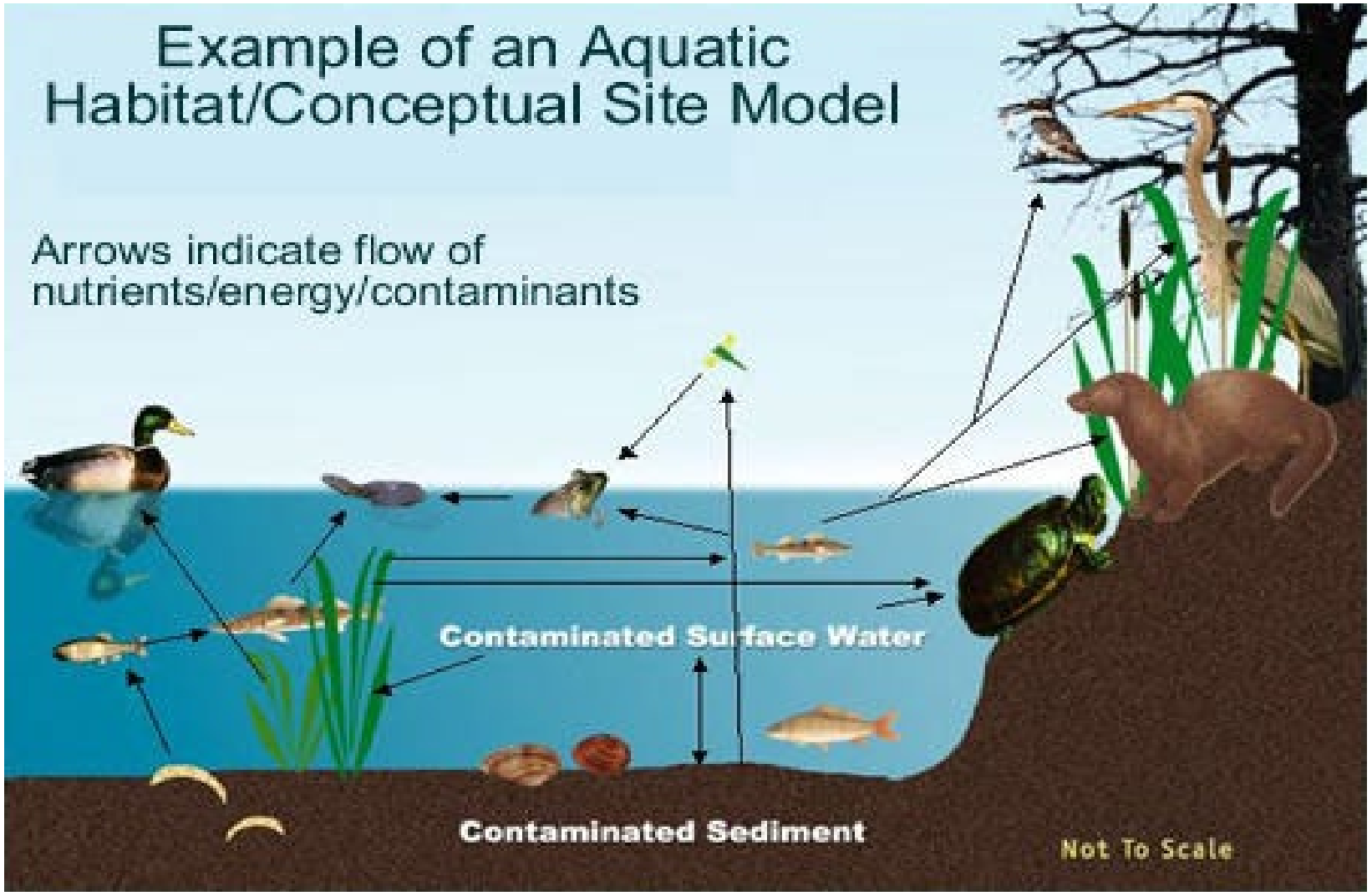
- Represents characteristics of site and shows relationship between S-P-R
- Allows targeting of subsequent investigation
  - Use the model iteratively – it should be an active process, and be refined and improved as more information becomes available
  - And is a requirement for Site Investigation
- Provides the context for quantitative risk assessment
- Demonstrates an appreciation of the problem beyond the purely factual data gathering
- Aids communications
- Is a good Q&A tool

! Key term:

S-P-R = Source – Pathway – Receptor

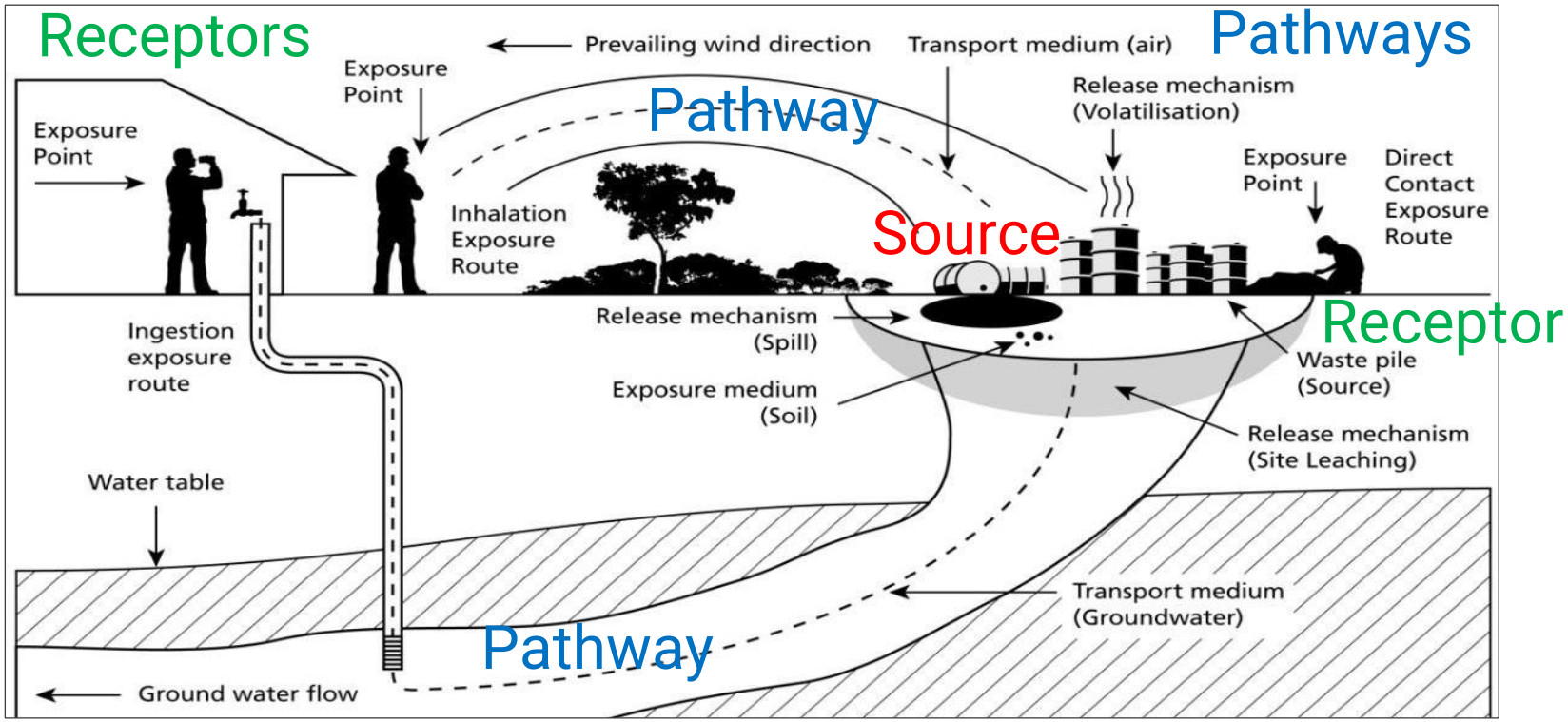
e.g. oil spill in river – oil entering drinking water intake – people drinking the water.

Conceptual Site Model in a lake



 Source: https://archive.epa.gov/reg5sfun/ecology/web/html/erastep3.html

CSM and common exposure pathways



Common exposure pathways at oil-contaminated sites include **soil** (direct contact, leaching into ground water, runoff into surface water, migration of vapors into structures), **groundwater** (drinking, discharge to surface water), **surface water** (direct contact, consumption of aquatic life), **air/vapors** (breathing).

Receptors and Sources of Uncertainty

Receptors

Who/what?

- Humans
- Controlled waters: aquifers, surface waters
- Water supply (plastic pipelines)
- Utility structures (cabling, sewers)
- Ecosystems
- Buildings

Uncertainty

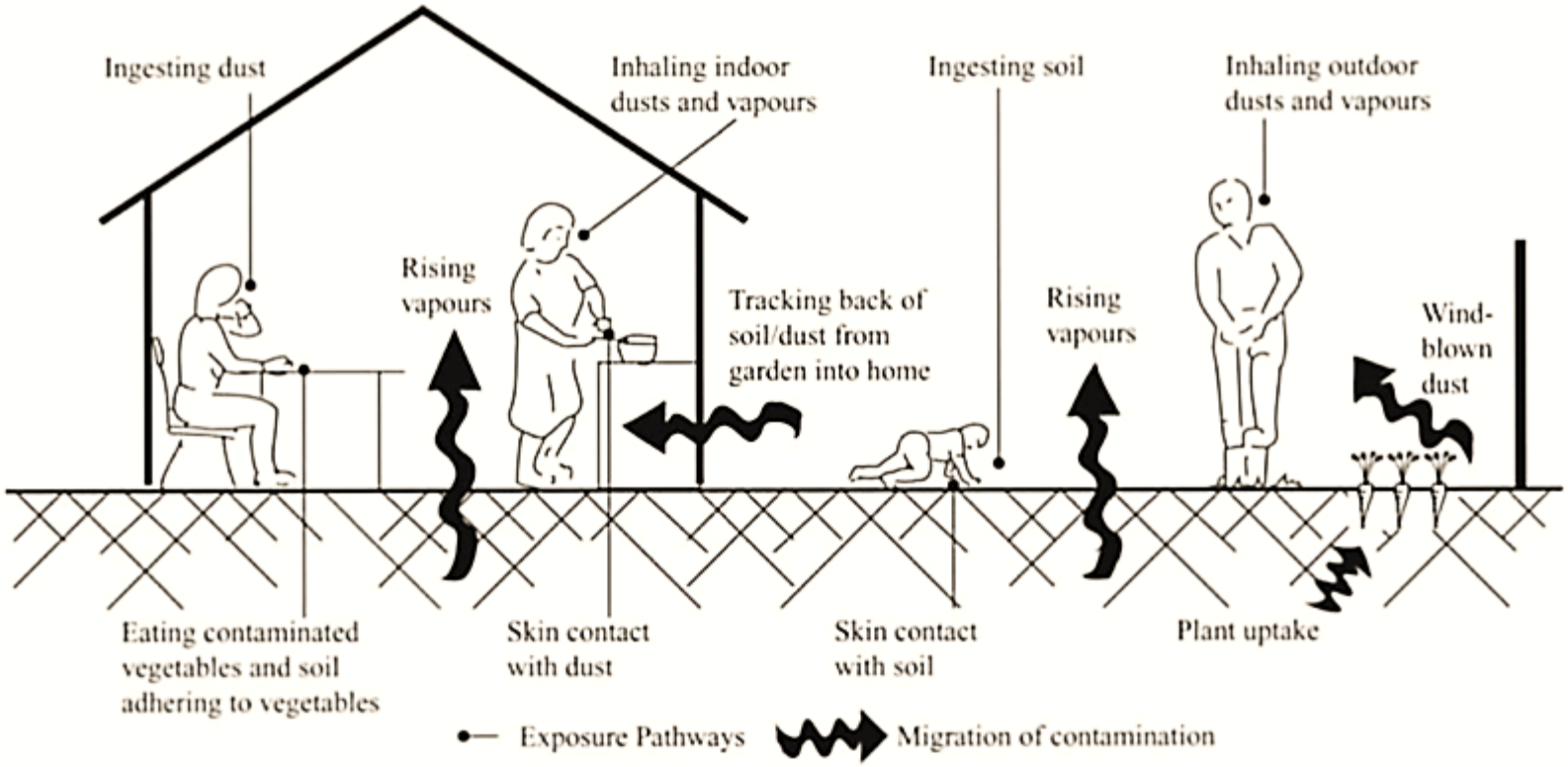
- **Heterogeneity of the site**: failure to investigate the significant pollutant linkages
- **Sampling error**: sample properties are not representative, too few samples
- **Handling, storage and transport:** cross-contamination, degradation, loss
- **Laboratory specific:** sub-sampling, loss in preparation and extraction, accuracy and prevision of analytical technique used

Conclusion: don't try to save money at the site assessment phase; save it at remediation phase.

Uncertainty in Conceptual Site Models

Which pathways are potentially active?

What are the critical receptors?

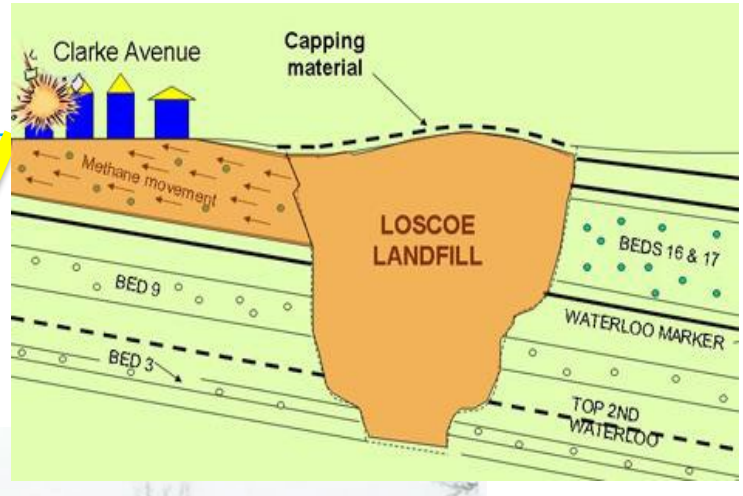


Details of migration pathways?

Have we considered all potential pathways?

Risk Assessment: why?

Boom!



Phased approach

PHASE	OBJECTIVES	METHODOLOGY	OUTPUT	KEY ISSUES
PRELININARY SITE ASSESSMENT	Identify potential hazards	Mapping; Interviews with site owners/operators; Visual observations	Assessment of setting and site sensitivity; Information to assist in the design of the intrusive investigation	Cannot assess actual contamination or need for remediation at this stage; Pre-requisite for intrusive investigation
DETAILED SITE INVESTIGATION	Provide data need to characterise and assess risks	Sampling of soil, water, gas	Description of nature, degree and extent of contamination	Stage approach; on-going monitoring may be needed
RISK ASSESSMENT	Identify and assess risks	Comparison of concentrations from laboratory analysis with assessment criteria	Assessment of the nature, degree and significance of risks	Require relevant and reliable data; Requires careful selection and use of generic assessment criteria

Risk Assessment

Conceptual Site Model

Contaminants of potential

Exposure Assessment

- Representative exposure concentration
- Exposure scenarios
- Intake modelling
- Relative bioavailability

Toxicological Assessment

- Hazard identification
- Dose-response
- Uncertainty factors
- Health-based guidance value

Risk characterisation

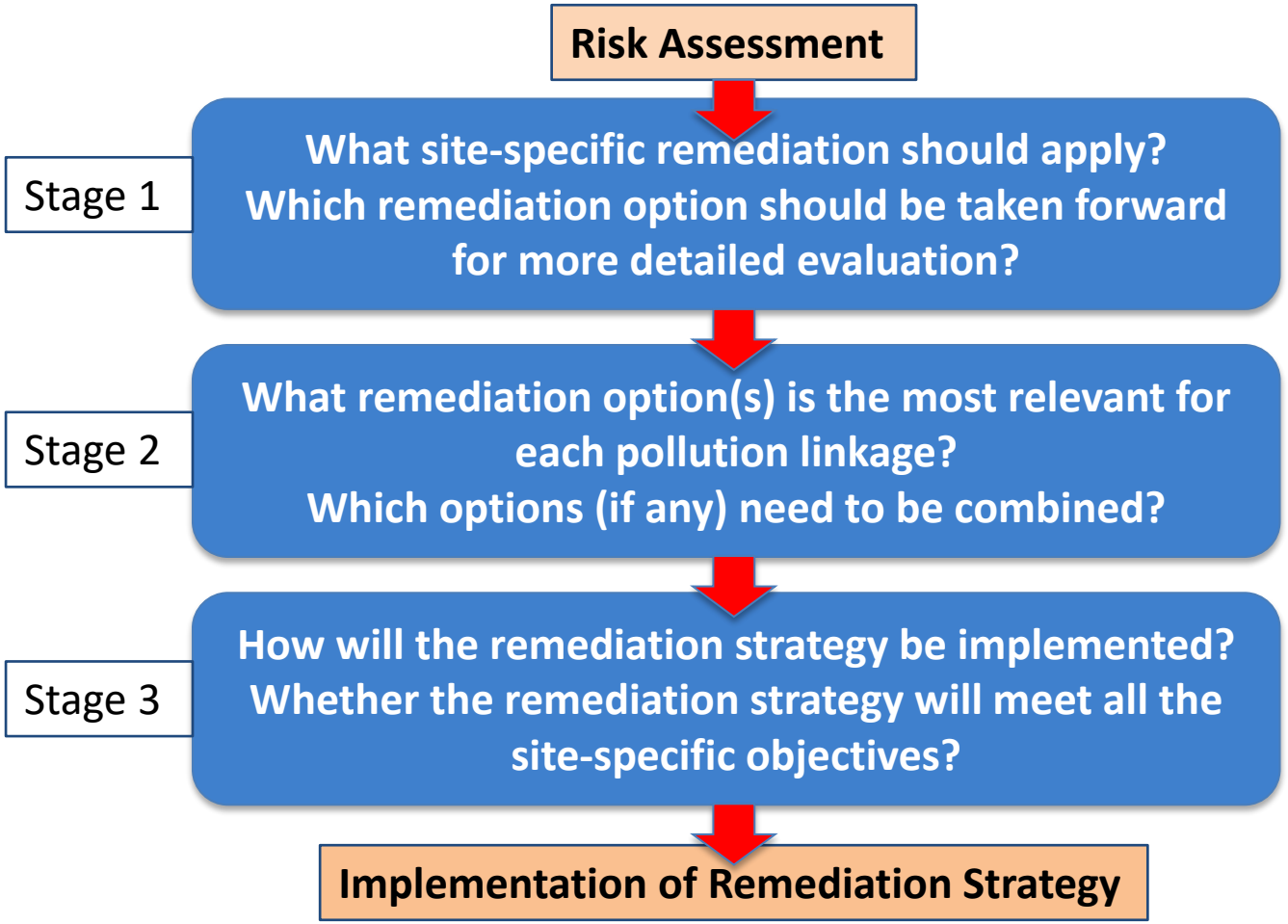
Estimated Exposure vs Health-Based Guidance Value

Measured concentrations vs Assessment criteria

Uncertainty analysis

Risk evaluation

Remediation options appraisal



Preparing the RAP

When Site Assessments are completed, we move on to:

Preparation of the site-specific **Remedial Action Plan** (RAP) and submission to the regulatory authority

Preparing a **RAP** requires review of **Detailed Site Assessment** (and any updated **Conceptual Site Model)** [remember CSM?] by qualified experts.

A **Remedial action plan** (RAP):

- Explains the type and extent of remediation required to ensure site is suitable for its current or intended future use.
- Describes how to protect the surrounding environment and land uses.
- Describes the clean-up techniques proposed.
- Explains criteria for assessing effectiveness of clean-up.

Note: the goal is to attempt restoration of the site to the state it was before contamination occurred; or to agreed levels of residual contamination acceptable to the future use of the site.

Source: Dept Environment Government of Nunavut Guideline for Contaminated Site Remediation 2009 http://www.gov.nu.ca/env/environment

Remediation Methods

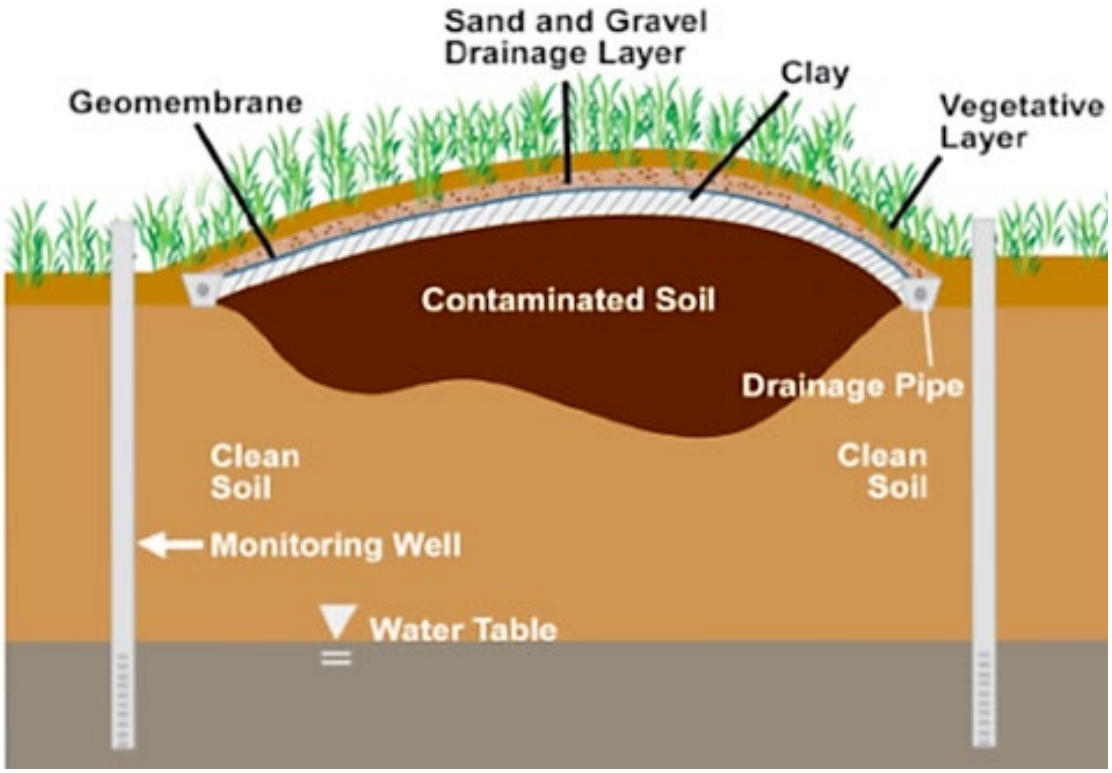
There are > **30 methods** for contaminated **Soils e.g.** capping, soil washing, soil vapour extraction, landfarming, phytoremediation.
There are > **30 methods** to treat **Groundwater and Surface Water.**

Classification of different processes can be made in accordance with the **mechanism** for cleaning up: non-organic (chemical, physical or thermal) or biological.

The choice of different types of treatment is linked to several factors related to the **nature of the pollutant**, the **polluted site**, the **type of technology** (basically to its efficiency and cost).

REMEMBER: no single remediation technology is considered the best solution for oil contaminated soil; sometimes methods are combined; and new and improved methods are being developed by governments and the private sector.

Simplest Remediation Method: Capping



This property has been cleaned

We apologise for any inconvenience caused

Then Closure

Submit **Site Closure Report;** regulatory authority then issues letter advising that no further remedial action is required (+ monitoring)

Key messages

- Contamination of land, water, plants and air threatens humans and the environment.
- The oil and gas sector is responsible for many instances of contamination, with hydrocarbons and other chemicals.
- A structured contamination site assessment (CSA) framework exists to document contamination and develop strategies for restoration.
- It is better and cheaper to undertake a comprehensive CSA process than to spend more money on clean-up and restoration measures.

Thank you

UN environment

(Insert the below information if required)
Name of the presenter / division / unit / office
Address / email / contact information
(Maximum 5 lines of text is permitted)
All in Roboto Regular 9pt..

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