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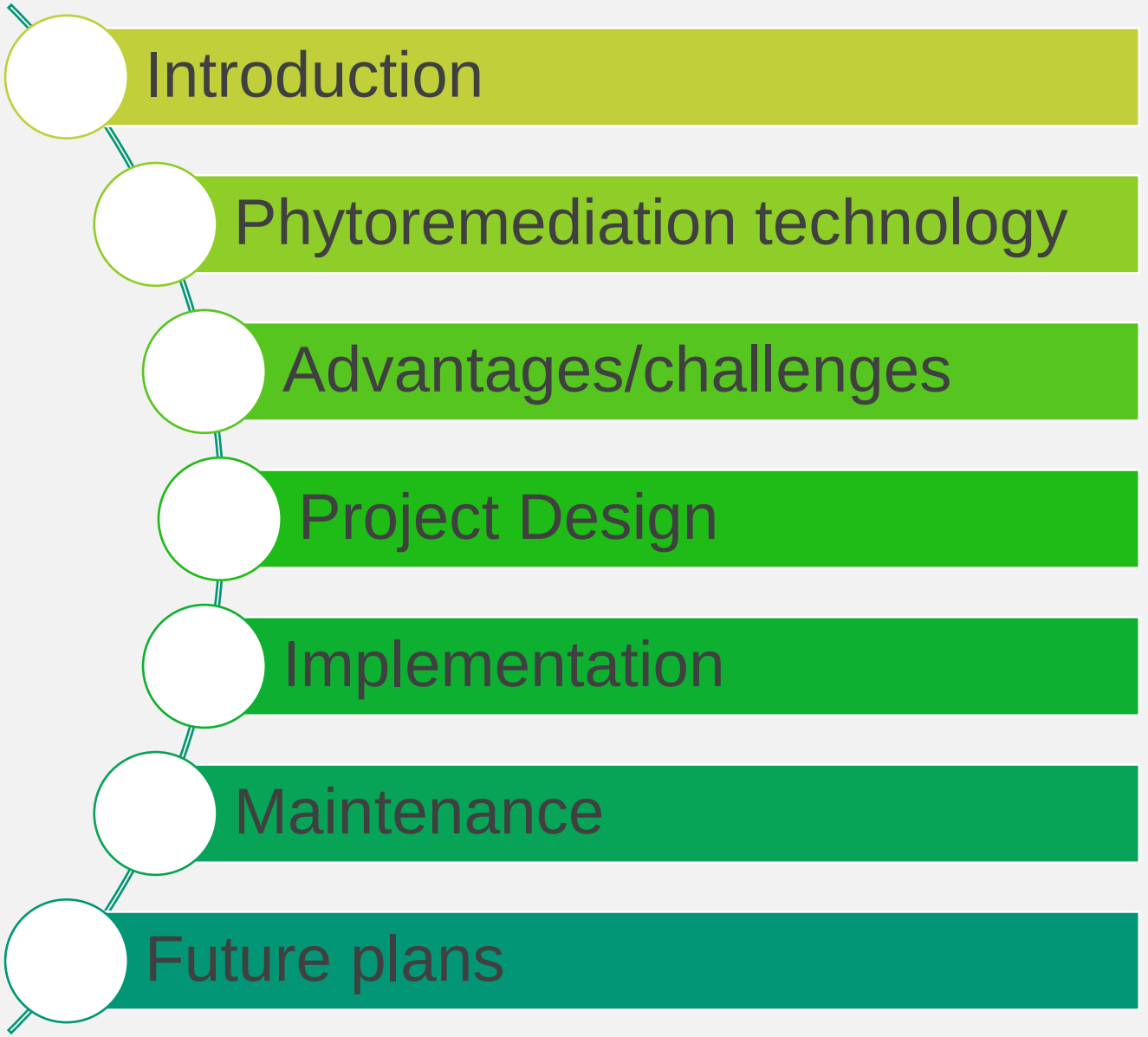
PHYTOREMEDIATION:
A Green and Sustainable Technology for the Remediation of Urban Brownfields Contaminated with Organic Compounds

RemTech 2024

Presentation → Outline



Introduction

→ Urban brownfields

Urban Brownfields are abandoned and vacant industrial and commercial lands within the cities:

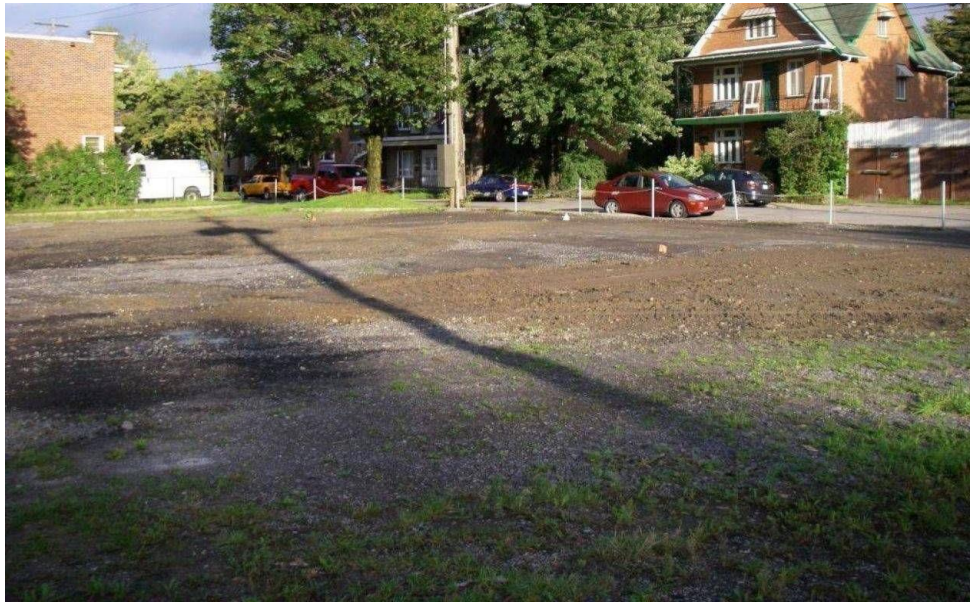
- Contaminated (real or perceived)
- Costly remediation
- Complex redevelopment
- Nuisance to humans and ecology

Introduction

→ Urban brownfields

USA: **500,000** brownfield Sites
Canada: **30,000** brownfield Sites
Europe: difficult to quantify

Sources: Ahmad et Al. (2018) ; Cappai et Al. (2019)



Regeneration of these brownfields has great potential including social, environmental, biodiversity and economic benefits

Introduction

→ Conventional remediation technologies

Remediation technologies:

- ❖ In-situ vs Ex-situ
- ❖ Vadose vs saturated zone

<u>Conventional remediation technologies</u>:

- ❑ Excavation and off-site disposal
- ❑ In-situ technologies such as:
  - In-situ chemical oxidization
  - Air sparging/soil vapor extraction
  - In situ thermal treatment
  - Enhanced aerobic remediation

Introduction

→ Conventional remediation technologies

Disadvantages of conventional Remediation technologies:

- Potential of spills
- Site inaccessible and aesthetically unpleasant
- High cost of implementation and maintenance

High environmental footprint

Use of chemical reagent

Consumption of fuel-based energy supply

Natural-based remediation: Phytoremediation

Image source: https://wwf.panda.org/discover/knowledge_hub/teacher_resources/webfieldtrips/ecological_balance/eco_footprint/

Phytoremediation

→ Definition

Phytoremediation is a green and sustainable technology that uses plants and their associated microorganisms to decontaminate soil and ground water.

source: OVAM, 2019 Phytoremediation – Code of Good Practice

Phytoremediation

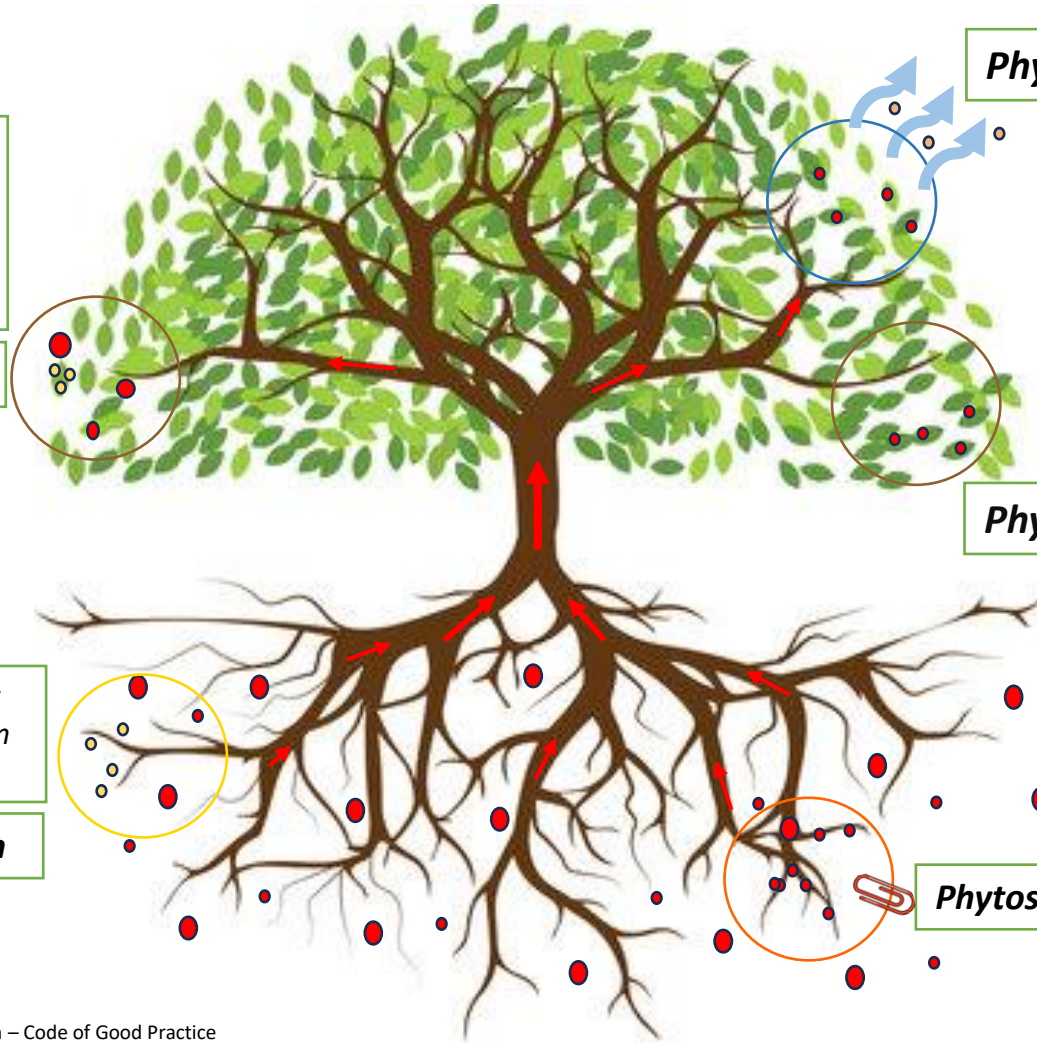
→ Mechanisms

Phytovolatilization

Pollutants uptake, transformation in volatile compounds and the transpiration into atmosphere as a gas

Pollutants uptake and breakdown of complex organic compounds into less complex/toxic compounds in plant tissues (or rhizophere) using plant enzymes

Phytodegradation



Phytoextraction

Pollutants adsorption and uptake by the roots and accumulation in harvestable areal biomass

Breakdown of pollutants in the soil by microbial activity (bacteria or fungi) in the vicinity of plant roots

Rhizodegradation

Phytostabilization

Immobilization and reduction of pollutant stability in the rhizophere

source: Guidi Nissim & Labrecque, 2021; OVAM, 2019 Phytoremediation – Code of Good Practice

Phytoremediation

→ Advantages / Challenges

Phytoremediation Advantages:

Biodiversity	Soil protection	Air Quality
Sustainability	Land Value	Social benefits
Human Health	Cost-effective	Climate Change mitigation

source: OVAM, 2019 Phytoremediation – Code of Good Practice

Phytoremediation

→ Advantages / Challenges

Phytoremediation Challenges:

→

Slow Pace (couples of years to multiple decennia)

Ecological Trap – Attractive Nuisance

End of Remediation Plan

source: OVAM, 2019 Phytoremediation – Code of Good Practice

Phytoremediation project

→ Site Description

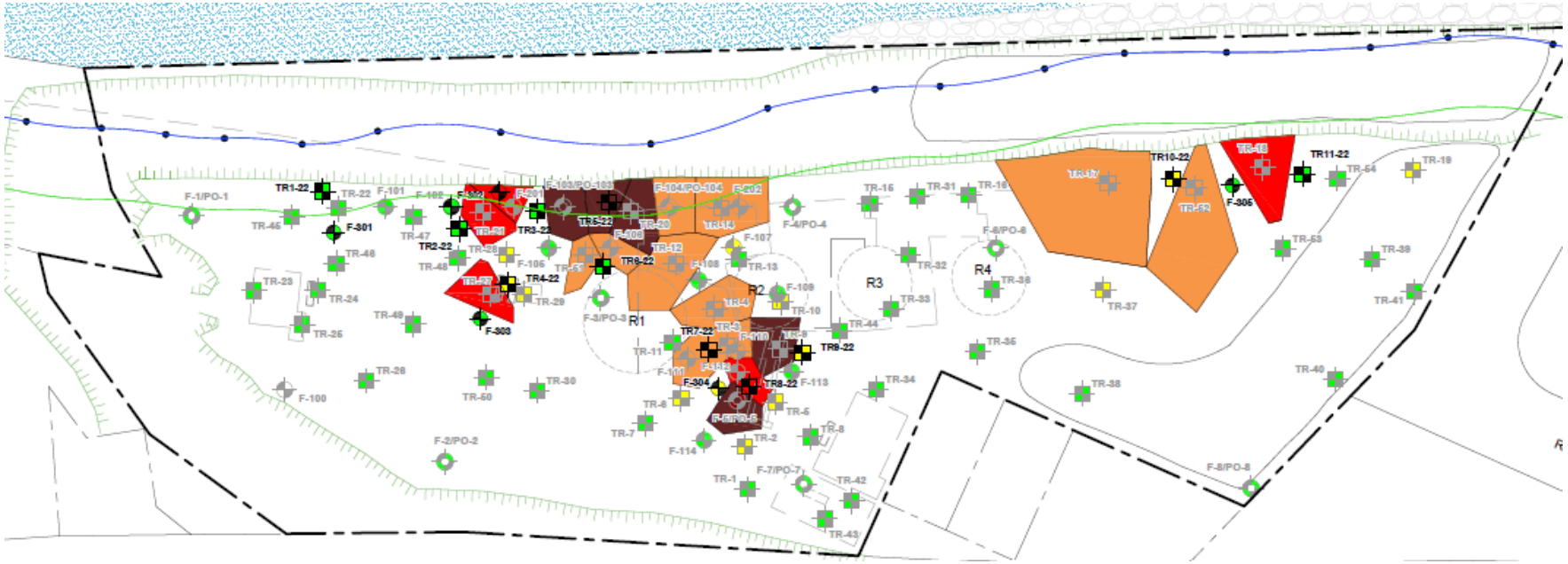
Project Site :Urban brownfield (former bulk plant) in Quebec

- Site area: 30,000 m^2
- GWL: 3.7-4.2 mBGS
- Soil: sandy up to 4 m
- Soil Contamination:
  - PH (C_{10}-C_{50})
  - PAH
  - MAH
  - Mn
- Contamination depth: 3.5 m
- Estimated contamination volume: 13,000 m3 (including B-C soils)

Phytoremediation project

→ Site Description

Site plan – soil contamination polygons



CLASSIFICATION ENVIRONNEMENTALE DES SOLS		
ZONES	Critères génériques du *"Guide d'intervention - protection des sols et réhabilitation des terrains contaminés"* du MELCCFP	Valeurs limites des Annexes I et II du *"Règlement sur la protection et la réhabilitation des terrains"* du MELCCFP
	≤A	<VL-AI
	A - B	≤VL-AI
	B - C	>VL-AI / ≤VL-AII
	> C	>VL-AII
	> C (≥RESC)	>VL-AII

Main Soil contaminants	Max Conc. Max (mg/kg)	Avg. Conc. (mg/kg)	C Criteria of MELCCFP
HP C_{10}-C_{50}	16 100	804.6	3 500
1,3-Diméthylnaphtalène	75.2	1.29	10
Xylènes	101	0.83	50
Mn	6 600	829.2	2 200

Main GW contaminants	Max Conc. Max (µg/l)	Avg. Conc. (µg/l)	Seepage Critera
HP C10-C50	3 630	804.6	2 800
Mn	6 600	829.2	3 591[1]

Note 1: based on hardness of 84.5 mg/l

Phytoremediation project

→ Remediation Plan - Design

Phytoremediation was selected as the appropriate option for site remediation based on :

- Site location, surface area and conditions
- Sustainability, cost-effective and social benefits
- Type, concentration and depth of the contaminants
- Phytoremediation treatability study

- ✓ HP C10-C50, HAP, COV, metals
- ✓ TOC
- ✓ pH and Redox
- ✓ P, N, available nutrients (Melich-III)
- ✓ Mircotoxicity, Heterotrophic Plate Count (BHAA), Hydrocarbonoclastes Plate Count
- ✓ Column adsorption/desorption test

Phytoremediation project

→ Remediation Plan - Design

Phytoremediation plants

Willows (*Salix* genus)

(shrubs - main species for the treatment of organic compounds – root system1- 3m deep indigene)

Poplars (*Populus* gen.)

(trees - treatment of organic compounds – root system can go deeper - indigene)

Sunflower (*Helianthus* gen.)

(annual plant- treatment of metals – Mn)

Images sources:
https://deeproot.com/blog/blog-entries/the-basics-of-phytoremediation/
https://www.gardenersworld.com/how-to/grow-plants/how-to-grow-sunflowers/

ref.: Guidi Nissim & Labrecque, 2021 and 2022

Phytoremediation project

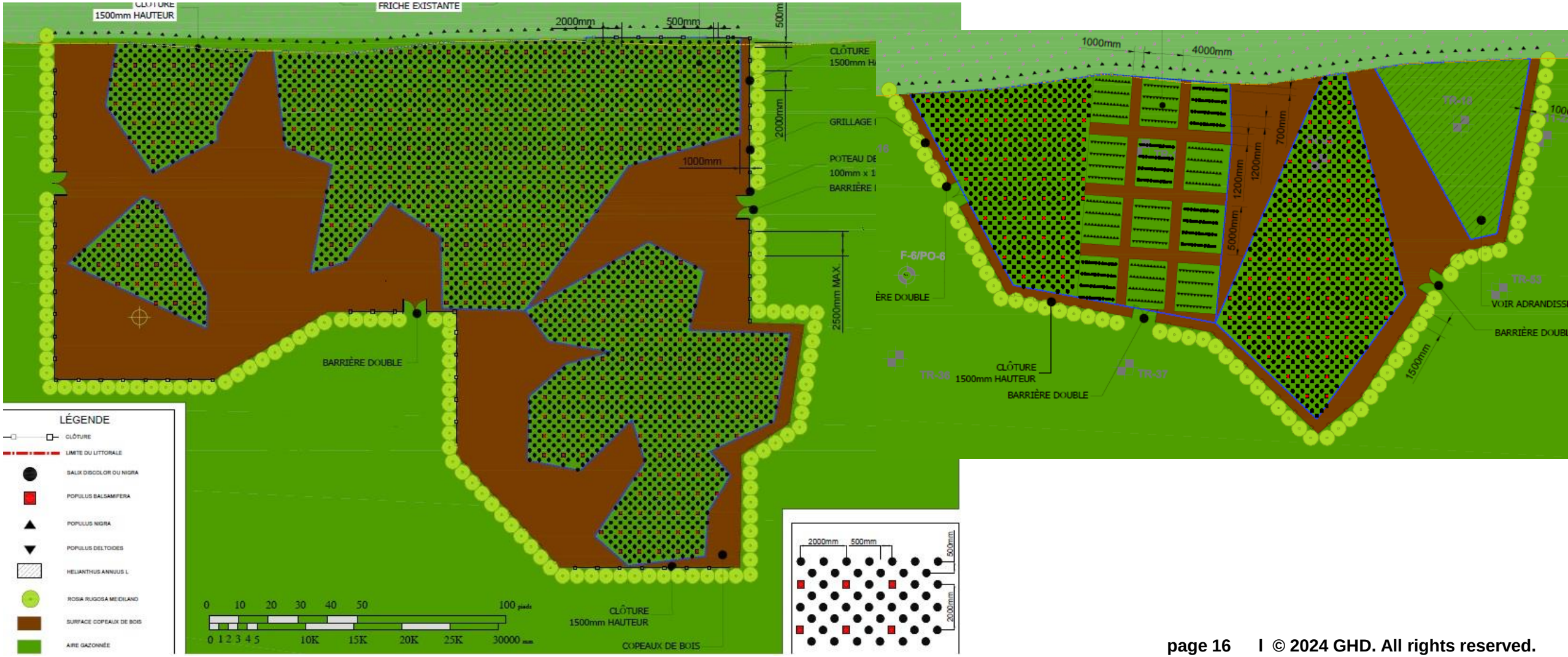
→ Remediation Plan - Design

Phytoremediation landscaping design plan

Estimated Project duration:7 to 9 years

Phytoremediation project

→ Remediation Plan - Design



Phytoremediation project

→ Implementation

Implementation sequence

1) Implantation of the polygons and delineation of the planation zones
2) Soil preparation – removal of any debris or sods

Phytoremediation project

→ Implementation

Implementation sequence

3) Spreading of organic soil and compost on the top layer
4) Spreading mulch

Phytoremediation project

→ Implementation

Implementation sequence

5) Plant location marking using a plywood template
6) Installing wood stakes supports

Phytoremediation project

→ Implementation

Implementation sequence

7) Plantation of willows and poplars with protective barriers

Salix Discolor

Populus Balsamifera

Phytoremediation project

→ Implementation

Implementation sequence

8) Plantation of sunflower seeds in the eastern section

Installing straw mat ground cover in sunflower plantation area

About 6 weeks after seeding

About 3 months after seeding

Phytoremediation project

→ Implementation

Implementation sequence

9) Installation of permanent fencing
10) Plantation of rose shrubs

Phytoremediation project

→ Implementation

Phytoremediation project

→ Maintenance

Site Maintenance and follow-up

- Irrigation especially the first season and only if dry
- Weeding and pruning
- Removing the wilted roses after the first year
- Cleaning the soils around the plants every spring to removed dead materials
- Protecting the young plants from rodents
- Detection of phytosanitary symptoms
- If the plant are damaged by climate conditions, extreme weather or plant disease, they will be replaced by new plants or more resistant species
- In case specific issues are encountered, supplementary analysis for problem diagnosis will be carried out
- Annual GW and biomass sampling

Phytoremediation project

→ Implementation examples

Examples of mature phytoremediation trees

source: OVAM, 2019 Phytoremediation – Code of Good Practice

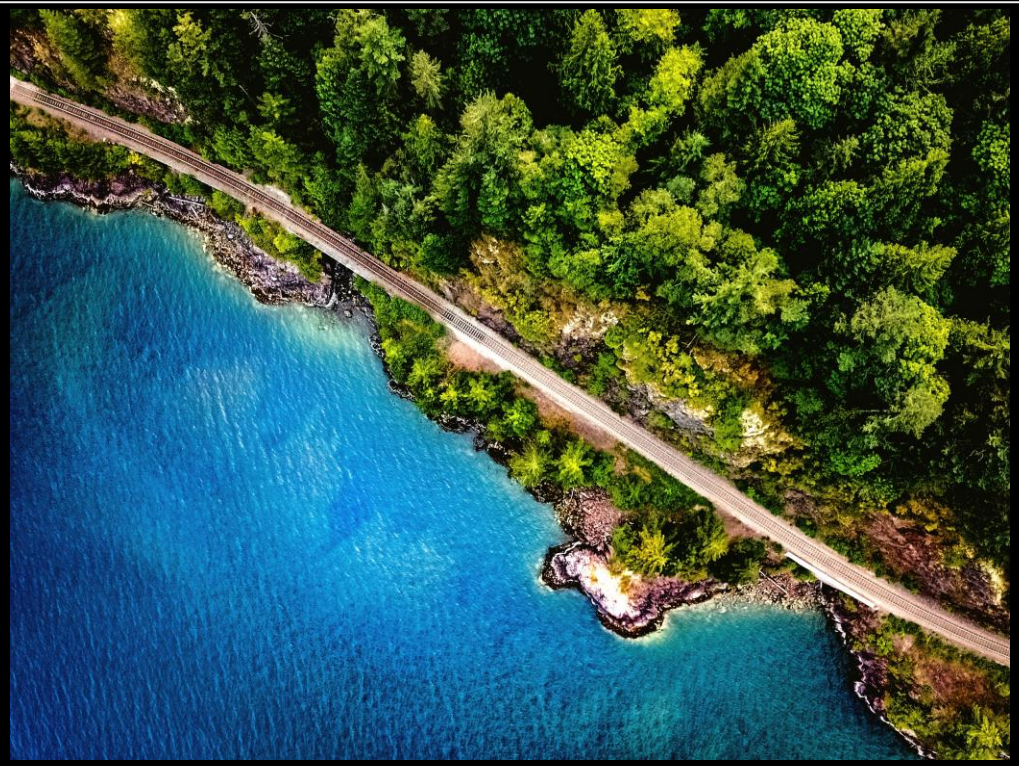
Phytoremediation project

→ Future plans

Future potential – Landscaping design - transformation to a park

Power of Commitment

Thank you for your attention



October 2024