OPERATIONALIZING PHYTOREMEDIATION

Best Management Practices

Remediation Technologies Symposium 2017 (RemTech 2017)

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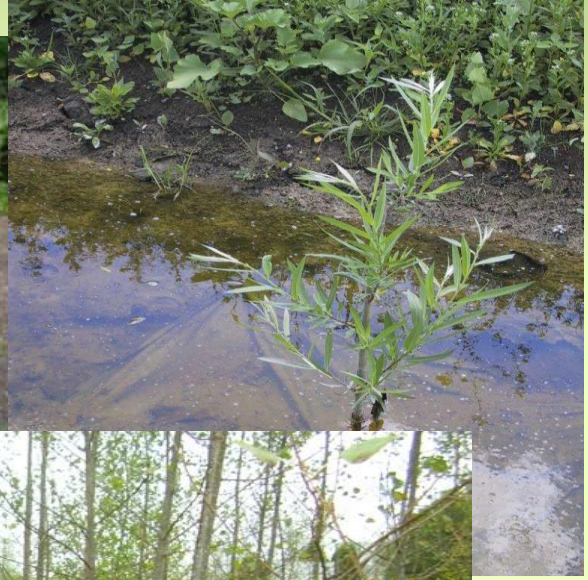
Fairmont
Banff Springs Hotel
Banff, Alberta

LandSaga Biogeographical INCORPORATED

Phytoremediation beginnings - 1999

•Former bulk fuel loading facility with BTEX and diesel-range organics

•1.3 ha site planted with hybrid poplar



- Over 20 projects in four provinces and the US
- On sites measuring in square feet and hundreds of acres
- In soil and groundwater
- For petroleum hydrocarbons, BTEX, phosphates, nitrates, metals, solvents, dioxane, perchlorate, TCE and leachate.

What is Phytoremediation?

The use of selected ecologically appropriate plants to degrade, transform or stabilize selected undesirable elements or compounds in soil and/or water through their usual physiological processes.

Applications

- Oil and gas well pads, flare pits, processing facilities or spill sites
- Abandoned gas stations
- Orphan sites
- Waste water treatment (stormwater, septage, nutrient runoff, waste lagoons)
- Pesticides/Fertilizers
- Explosives
- Landfill covers, leachate treatment

Typical Procedure

- Feasibility Review
- Site Assessment
- Plant Selection
- Greenhouse Trials
- Treatment Design
- Installation
- Active Management
- Vegetation Monitoring
- Treatment Monitoring

Feasibility Desktop Review

- Phase I, II ESAs and monitoring reports
- Current and historical aerial imagery
- What are the CoCs? What are the levels? Are they phytotoxic?
- Is there previous evidence that plants treat the CoC? Are they available or appropriate for the site?
- What is the contaminated media?
- How deep is the contamination?
- What is the volume?
- Other complications/opportunities?

Candidate CoCs

- Light and heavy hydrocarbons (F1-F4)
- VOCs, PAHs
- Trace metals, salts and PCBs to some extent (phytoextraction, polishing)
- Any compound(s) that can be shown to be significantly treated by selected plant species (e.g. landfill leachate)

Candidate Sites

- Where CoCs are known or can be shown to be treatable
- CoCs are in the rootzone of plants or can be made to be in the rootzone of plants (< 2m bgl)
- Large impacted area or remote sites that make other technologies expensive
- Where there is no time pressure to clean up
- CoCs are contained on-site, or regulatory approval for phyto

Some (currently) Non-candidate Contaminants

- Lead – treatment time measured in decades or centuries
- Sulphur and other elements
- PCBs – too many congeners for phytodegradation, some of which are treated and some not
  - Phyto-extraction treatment time of heavily impacted sites measured in thousands of years based on current research

Assemble your project team

Are there professionals who understand the:

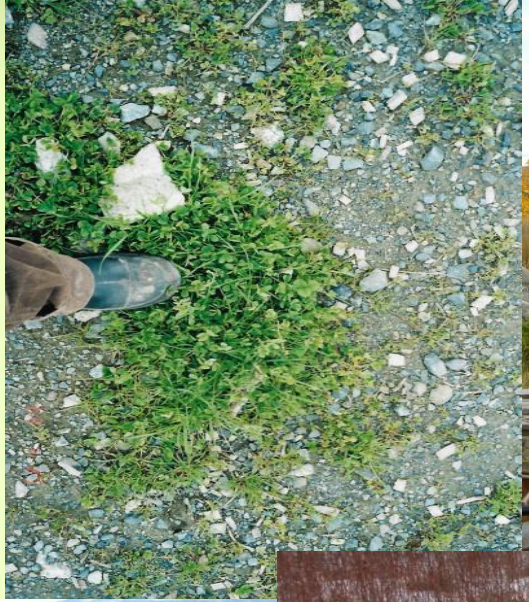
- breakdown chemistry of the CoC (chemist, chemical engineer)
- treatment pathway from contaminated media to plant, (plant pathologist)
- soil and hydrogeologic properties and how they affect treatment (eg: pH, hydrology, organic matter)
- physiology and ecology of the candidate species, its propagation, installation, maintenance requirements, pathology
- is knowledgeable about the biogeography of the site at the regional and site-specific scale.

Cost factors depend on:

- Contaminant and treatment time
- Site size and accessibility
- Ease or difficulty of planting
- Cost of plant material
- Length of O&M period

Site Visit

- Opportunities
- Constraints
- Soil conditions
- Landscape features
- Hotspots
- Seeps
- What is the existing vegetation telling you about the site?



Plant selection:
some known remediating plants

- Hybrid poplars and willows/TPH etc

- Forage and other grasses, alfalfa, TPH

- Groups of plants tend to be used for types of contaminants: eg brakefern (*Pteris vittata*) and arsenic; *Alyssum* species and nickel

- Other plants selected because they have been found to grow naturally in contaminated media: eg. Mulberry and PAHs, ox-eye daisy, curly dock, and Canada goldenrod for PCB accumulation.

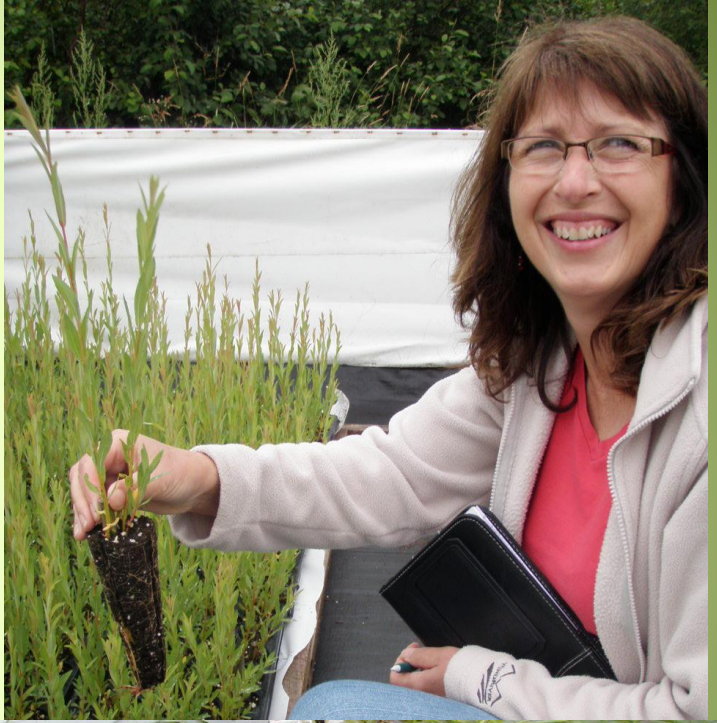
- Little bluestem (*Schizachyrium scoparium*) and switchgrass (*Panicum virgatum)* phytoextractors of DDT

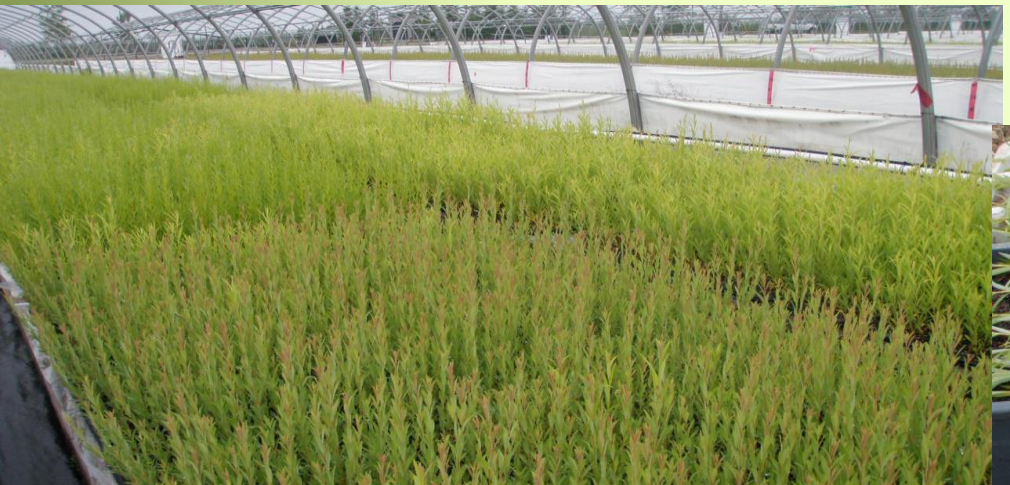
Why hybrid poplars and hybrid willows?

- Early successional species
- Hybrid vigour =fast growers = rapid transformation of CoCs
- Use many different transformation/degradation pathways
  - “biological pump and treat” (volatilization)
  - Rhizodegradation
  - Sequestration
- Economical material and installation costs for large sites.
- Not known to be invasive
- “Because that’s what everybody uses”

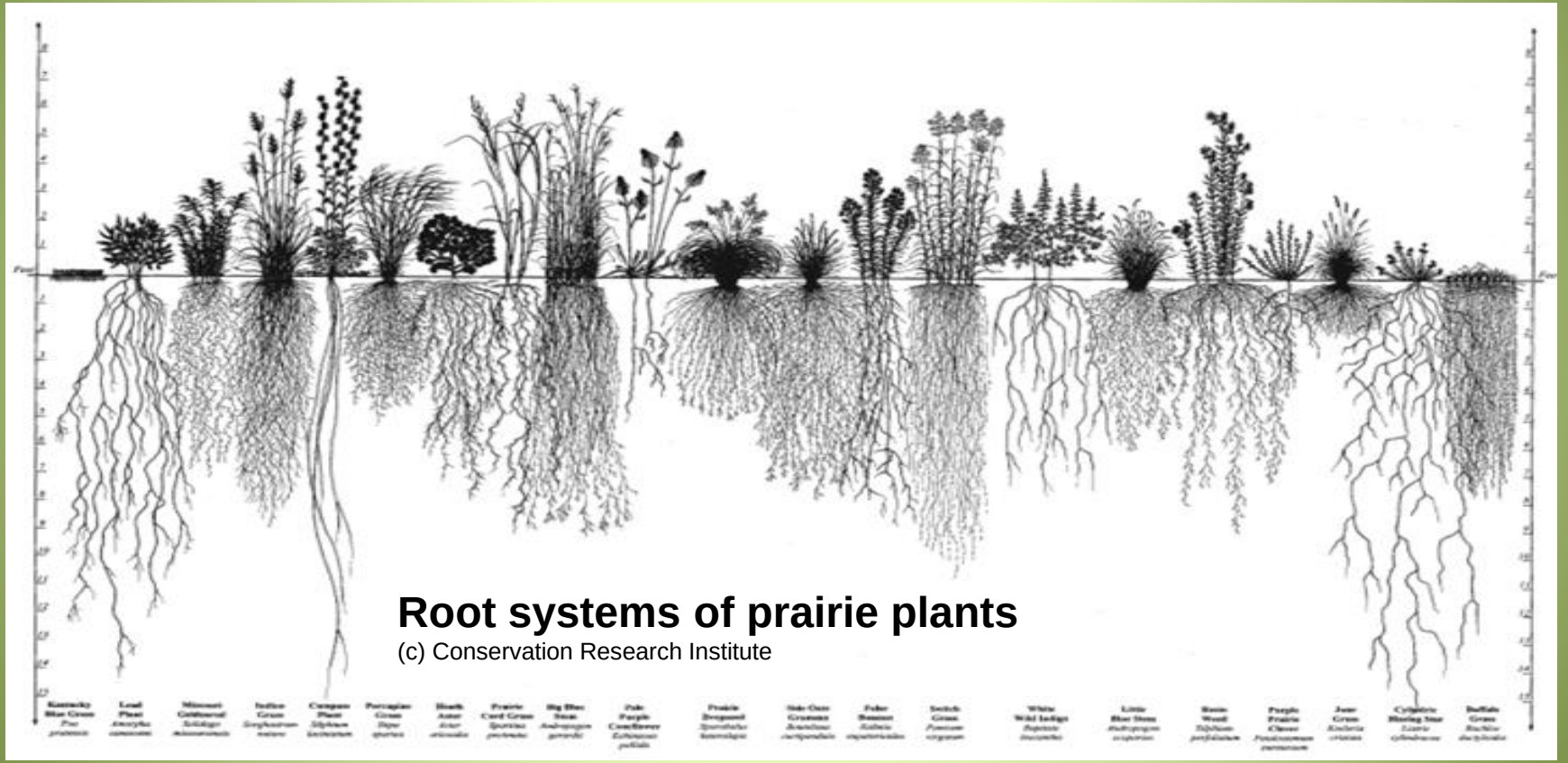
Dormant cuttings

Containerized Planting Stock





Many plants are remediation candidates that have not yet been tested. As more are tested, we increase our diversity of options and offset ecological risks.



Root systems of prairie plants

(c) Conservation Research Institute

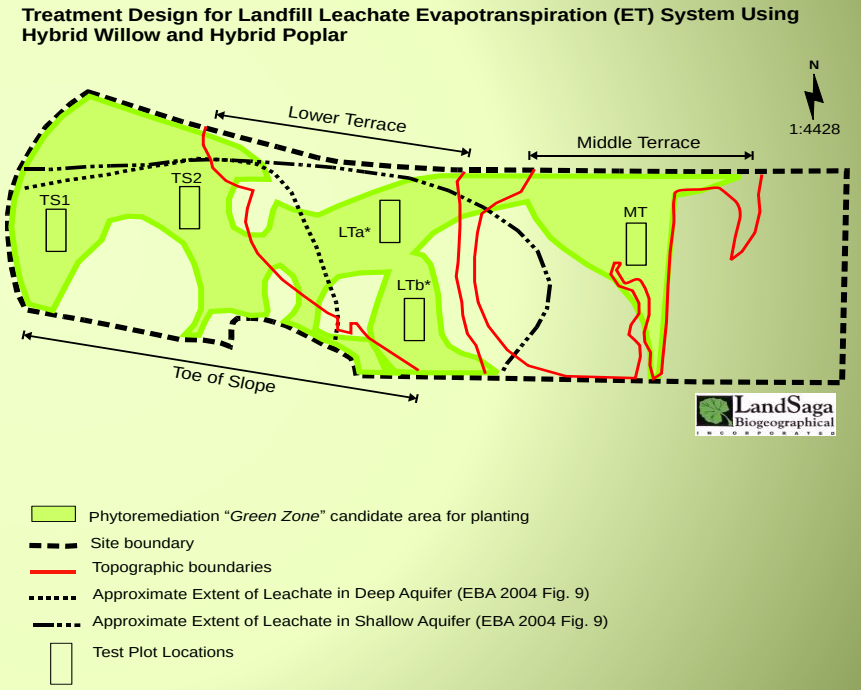
Greenhouse/Bench Trial

Where there is no previous evidence of treatment by vegetation, a greenhouse trial can show:

- phytotoxic levels (dose-response),
- treatment ability and
- indicate treatment time.

Treatment Design

Once the treatability of CoCs has been demonstrated through a desktop review and/or greenhouse study, this is combined with the site specific parameters to produce a treatment design.



Questions to Ask

- Is phytoremediation cost-effective over the long term compared to other options?
- Does the treatment system differ significantly from the rate of natural attenuation?
- Does the rate occur for the candidate site that is appropriate?
- Will the limiting factors which influence the reaction rates in soils be managed by the treatment system?, eg. anaerobic soils that limit microbial activity.
- Is the candidate species able to survive on the subject site at a regional and site specific scale?

Some approaches to installation

- Phyto-scaping
- Phyto-forestry
- Phyto-restoration
- Phyto-cropping
- Phyto-energy

Phyto-scaping

Suitable for garden-sized hotspots in areas with high visibility.

Remediation species can be combined with showy landscape specimens in a formal setting.

Phyto-forestry

- Traditional approach suitable for medium to large sites
- Relies on most established BMPs from agroforestry appiications
- Deploys one or more hybrid poplar clones planted at densities of about 1000/ha
- Former bulk fuel loading facility with BTEX and diesel-range organics
- 1.3 ha site planted in 1999 with hybrid poplar DN74

October 1999 – one growing season

2007
nine
growing
seasons

Summer 2016 – 17 years

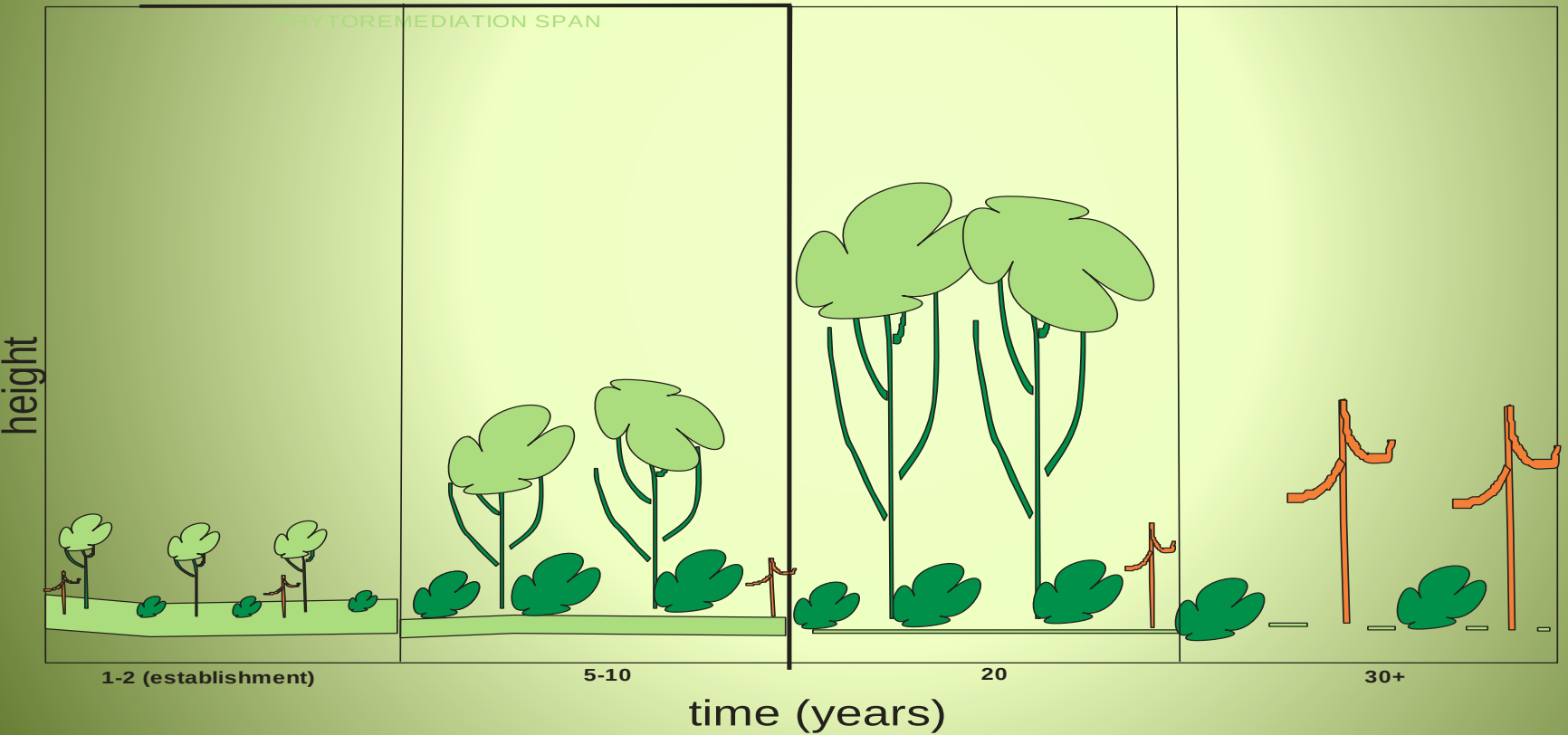
17 years

Phyto-restoration

- One approach when a long lasting ecological community is the post-remediation end-point.

- Gifted to another owner such as a city, municipality, or conservation authority as a naturalized area or park**.**

Phyto-restoration



May 2008 pre-installation

183 Hybrid poplar (3 clones)

55 Hybrid willow

34 Black Locust

18 Eastern Red Cedar

13 White Spruce

19 Black Oak

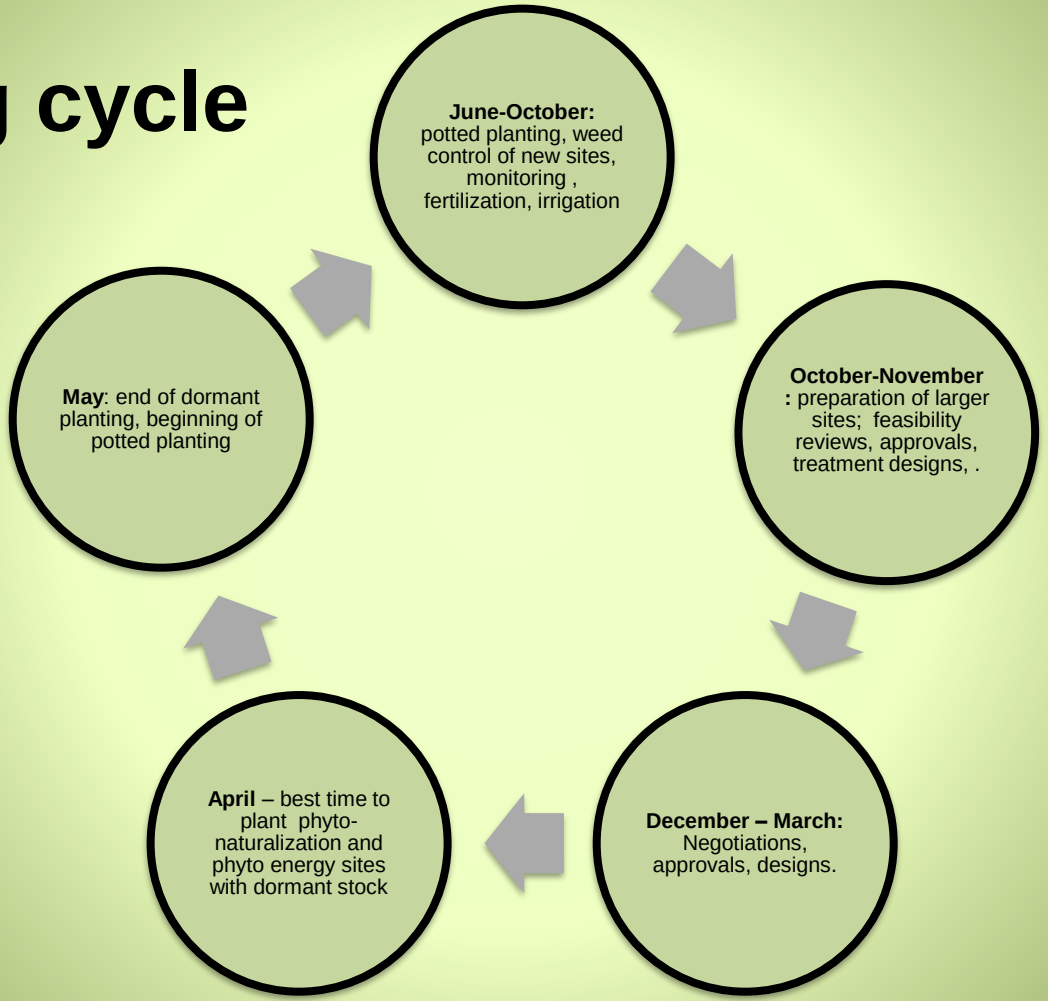
6 Red Pine

July 2016

July 2016

Installation

Planting cycle




GATX 55072
KUBOTA

Common Pitfalls

- Wrong species for site *eg*. hybrid poplars on wet site, or regionally unsuitable, eg. not winter-hardy
- Incorrectly planted, or planted at wrong time.
- No competition (weed and grass) control
- Removing existing mature vegetation that could be contributing to Natural Attenuation

Best Management Practices for O&M

- Over plant
- Fence & protect
- Control weeds and grass
- Irrigate
- Fertilize
- Monitor and Measure
- Adapt

Overplant

Mortality is always higher in brownfield sites due to challenging soil and contaminant conditions.


Fence
to protect from browsers and grazers....

....and humans (and their vehicles and equipment)

…and rodents
(squirrels and mice)

Monitor monthly and control competition at least three times in the first year

Mulching

Competing vegetation will need to be controlled into the second and possibly third year until vegetation (especially trees) are established

Planting containerized stock

Fertilize

Be prepared to irrigate if necessary

Measure growth and assess health annually

•How will vegetation be monitored and measured?

• Is there mortality? How much? Why? (phytotoxicity, installation or maintenance issues, climate). Are there controls planted offsite? Is onsite growth satisfactory?

•Consider tree/plant excavation to inspect below ground root development and conditions

Deliverables:
Measuring Performance

•How will performance (remediation) be objectively measured? eg. transpiration monitors, soil and water sampling, groundwater elevation modelling and monitoring.

•Based on bench scale trials or lit review, along with site-specific conditions, how much time is predicted until results are seen? How much time until closure? How does this compare to monitoring data?

•Consider a third party review of treatment plan or monitoring results.

Summary:
Applications and Advantages

Phytoremediation is ideal for some CoCs:

- on large or remote sites
- where the distance to landfill is significant
- where there is no urgency to remediate

Advantages:

- Is consistent with some reclamation/restoration objectives
- Reduces emissions by minimizing/avoiding trucking
- Reduces liability exposure and health and safety risks
- Is visually pleasing and presents a positive corporate image to the community in urban areas.
- Creates positive ecosystem services related to local cooling, hydrology, and species diversity

Summary:
BMPs for O&M

Successful phytoremediation relies on healthy plants!
Phytoremediating plants must be:

- Able to tolerate the kind and amount of contaminant
- Suitable for the region and site
- Planted correctly
- Protected from weedy competition, browsers and grazers, nibblers and humans
- Provided with adequate nutrients and moisture when those are deficient

Summary:
Ensuring Success

- Phytoremediation is a multidisciplinary practice that depends on qualified persons working together
- Performance can and must be measured objectively (eg. contaminant treatment and vegetation vigour and performance)
- Milestones of performance should be set and monitoring data assessed by these standards


Questions?
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