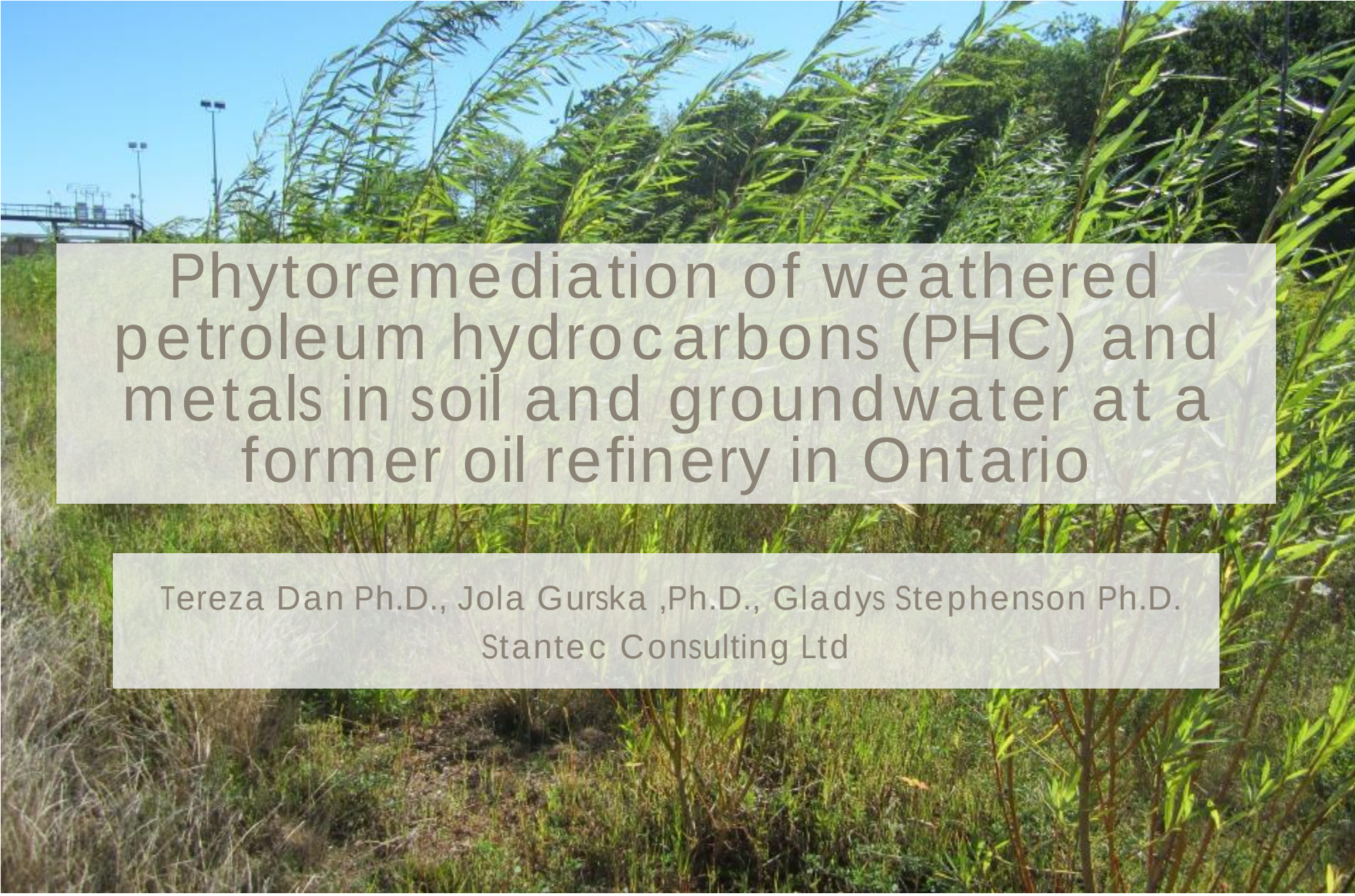

Phytoremediation of weathered petroleum hydrocarbons (PHC) and metals in soil and groundwater at a former oil refinery in Ontario

Tereza Dan Ph.D., Jola Gurska ,Ph.D., Gladys Stephenson Ph.D.
Stantec Consulting Ltd

October 16 2013
Remediation Technologies Conference

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Agenda

1 Phytoremediation

2 Stantec Projects

3 The Site: Refinery Landfarm

4 Soil Treatment

5 Groundwater Treatment

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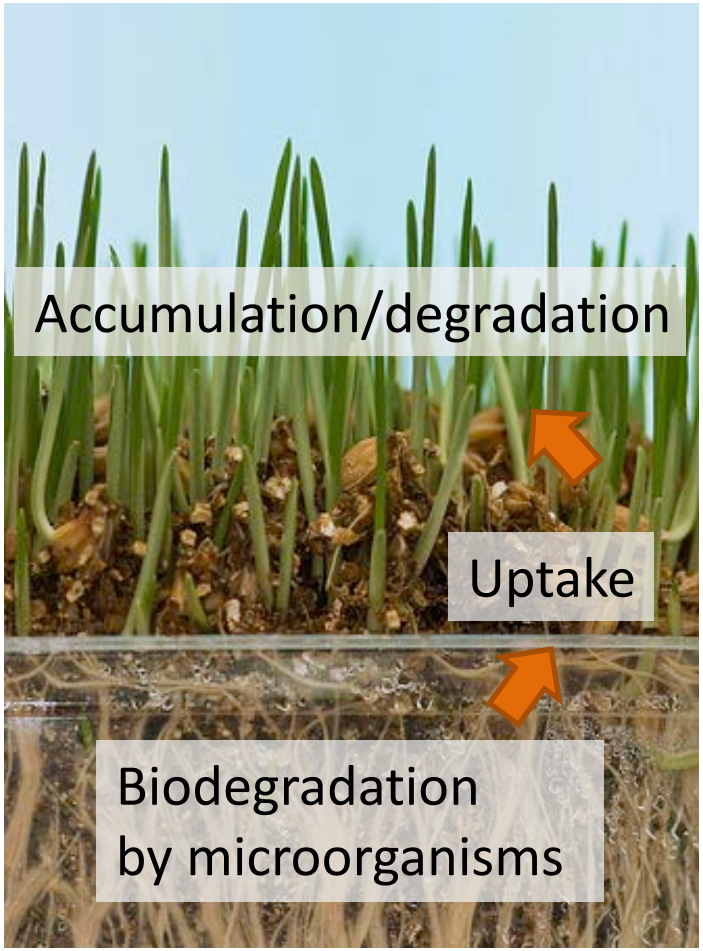
1 Phytoremediation: the biological concept...



- **Phytodegradation:** Plants uptake, store and biochemically degrade or transform organic compounds ("green liver model")

- **Rhizodegradation:** Microbial degradation occurs in the plant root zone, *the rhizosphere*.

- **Phytostabilization:** Revegetation to prevent erosion and pollutant transport

- **Phytotransformation:** Volatile compounds are taken up, modified and transpired.

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…with many design possibilities

Groundwater
Hydraulic Control

Engineered
Wetlands

Soil
phytoremediation

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Phytoremediation Design

Review Site Conditions and Local Vegetation Survey

Phytoremediation System Selection

Suitable Vegetation

Hybrid Willow

Hybrid Poplar

White Pine

Soil and Groundwater

Tall Fescue

Barley

Soil

Sunflower

Metals

Tall Wheatgrass

Salt

Image sources:
www.plants.usda.gov
and dutchgrowers.ca

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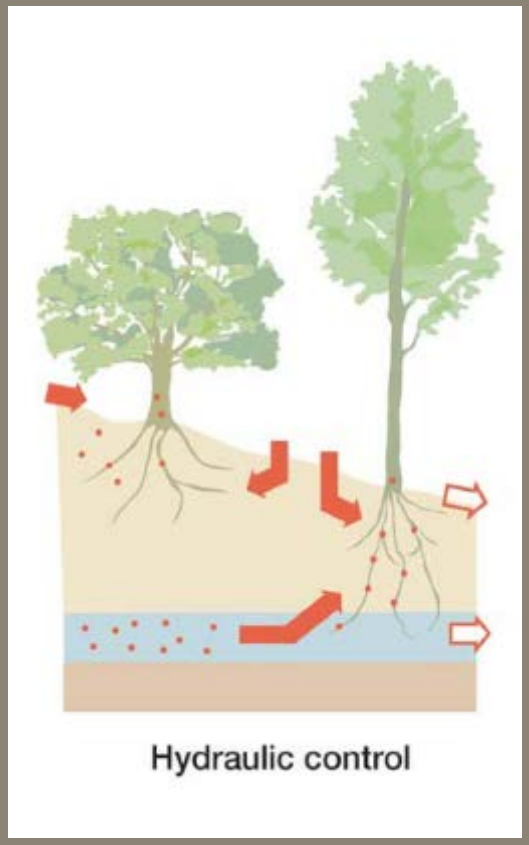
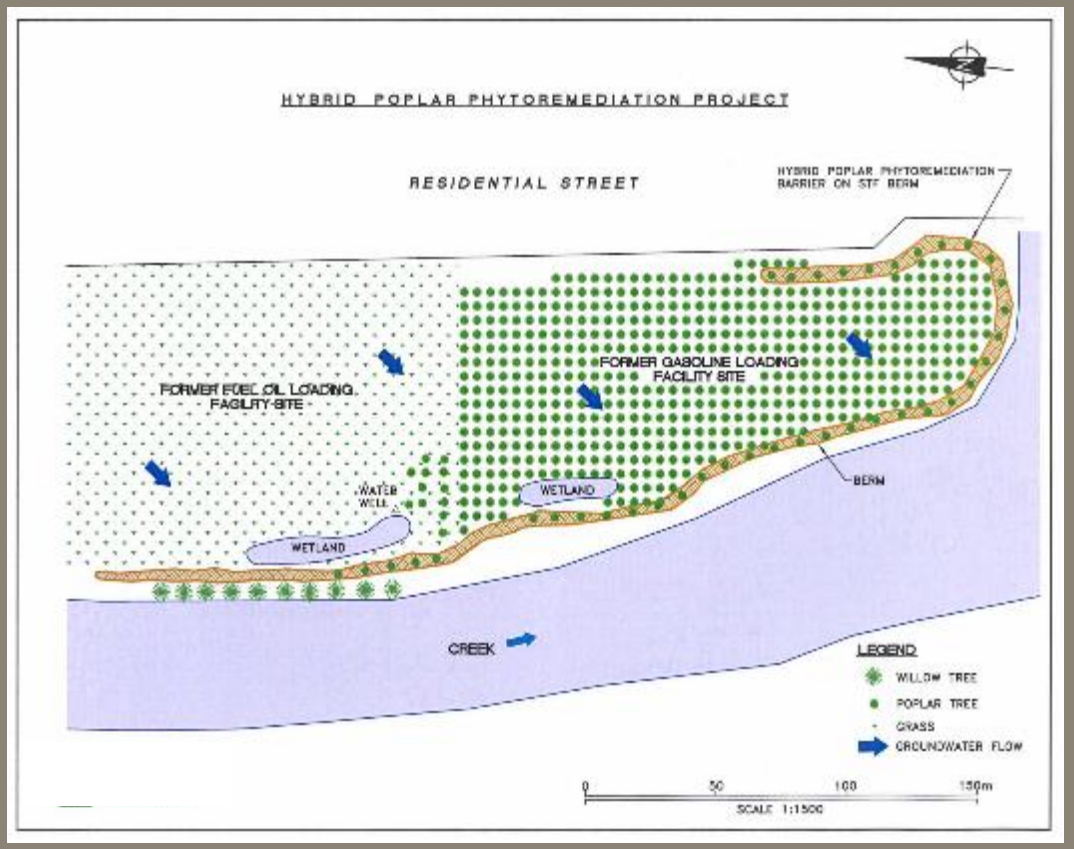
2 Phytoremediation at Stantec

Port Stanley, ON





Phytoextraction + Rhizodegradation

+ Phytodegradation

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Port Stanley, ON
Pump and Treat Phytoremediation

Initial Planting

Year Two

Year Seven

Year Nine

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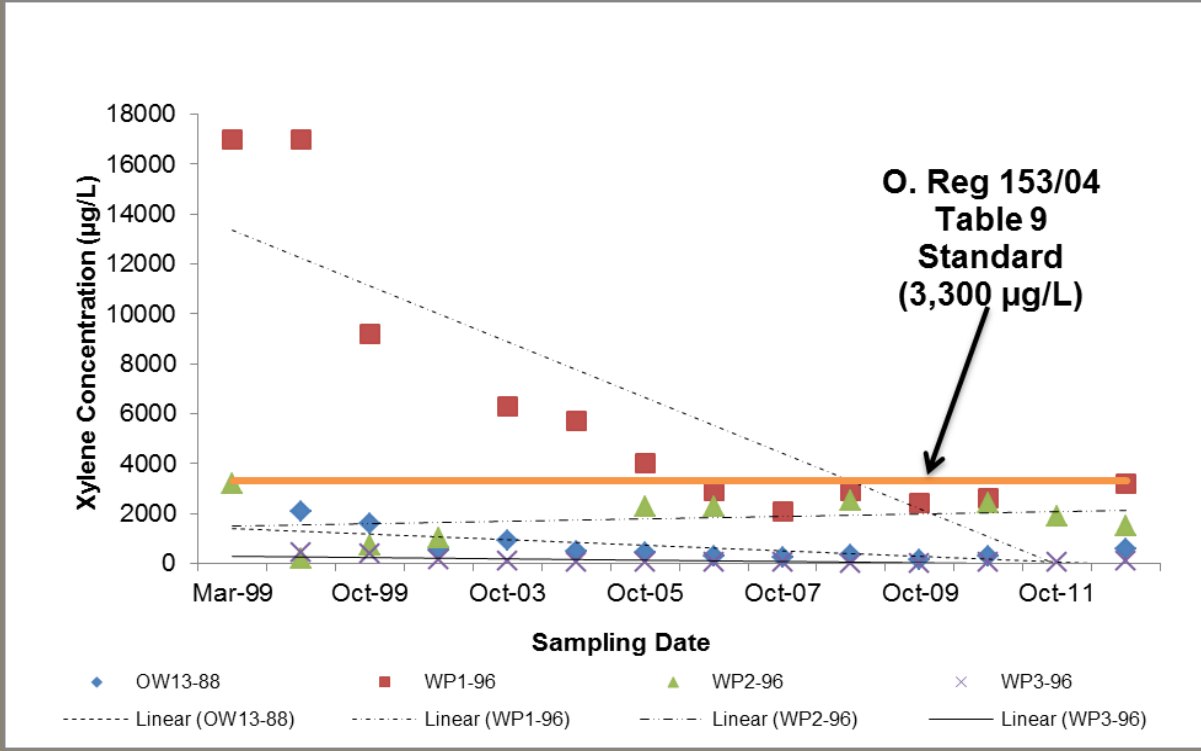
Performance Evaluation



- Benzene and Xylene (1999-2006) and F3 (1999-2012) below regulatory standards
- F2 decreasing steadily

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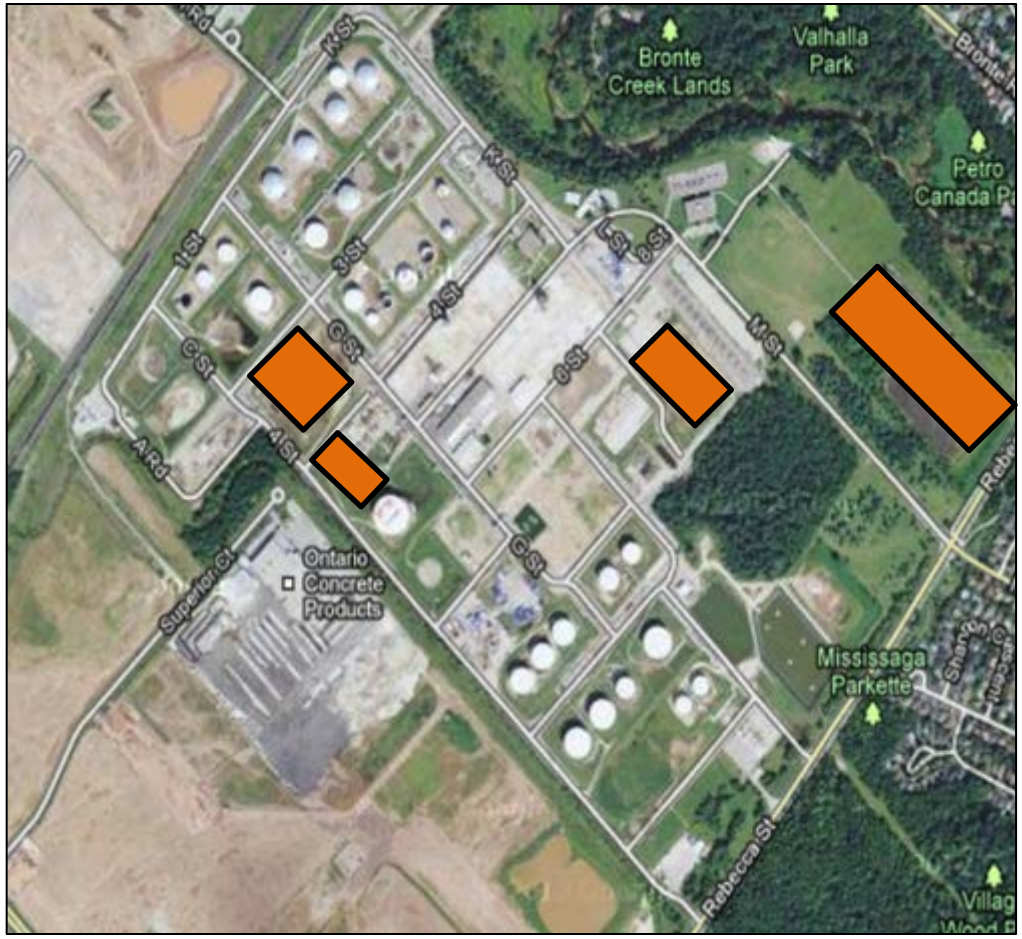
3 The Site – Refinery Landfarm Oakville, ON



- Former landfarm (1972-2006)
- Decommissioned and functioning as a terminal
- Four parcels with varying PHC concentrations
- Soil - metals, PHC
- Groundwater: F1, F3, benzene, Na

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Site Soil Characterization

- Test pitting and soil monitoring program was conducted to characterize the four parcels
- Site soil characterized on a 30 m grid, 84 test pits were advanced to a maximum of 2.4 m below grade

Parameter	Part 7	Part 13	Part 20	Part 21
Soil Type	Loam	Loam	Silt loam	Sandy loam
EC* [mS/cm]	0.15-0.93	0.4-1.3	0.17-0.98	0.28-1.9
SAR	0.5	0.1	0.3	0.3
Organic matter [%]	3.7	11	7	13.3
pH	7.76	7.25	7.43	6.99
*Industrial, Commercial, Community Property Use: EC **1.4**, SAR **12**				

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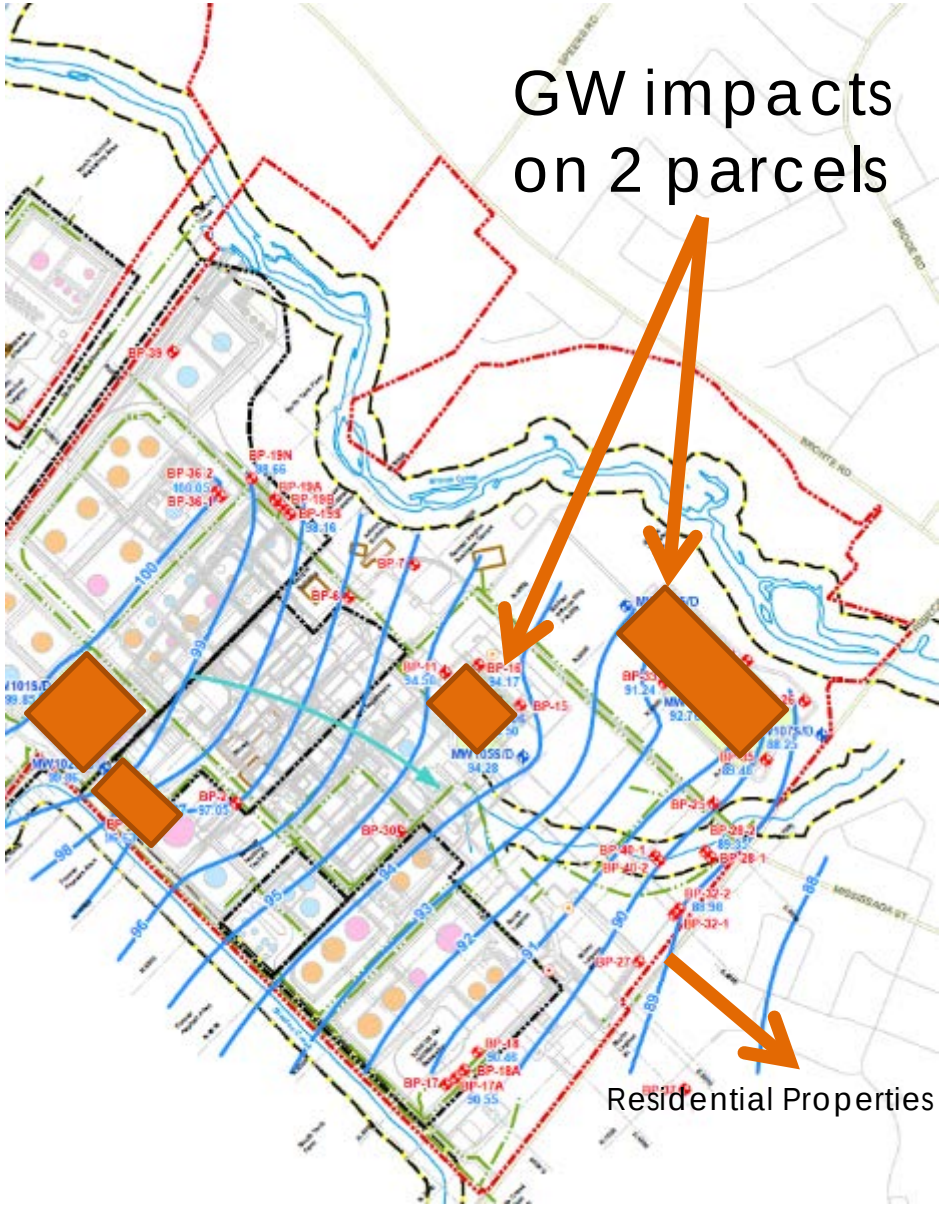
Groundwater Characterization

- Shallow and deep groundwater aquifers
- Depth to bedrock ranges from 0.6 – 2.4 m
- Downward vertical groundwater gradient at Part 20 and neutral vertical gradients at the other parts.



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Why Phytoremediation?

- Limited impact on current facility operations
- Concurrent remediation of multiple media
- Program developed as a part of **landfarm closure plan**
- Soil and groundwater conditions
- Cost effective

Two-pronged Phytoremediation Approach at the Oakville Terminal

Groundwater – *deep planting* of hybrid willows for hydraulic control

Plant Growth Promoting Rhizobacteria (PGPR) Enhanced Phytoremediation System (PEPS) on all four Parts

Waterloo Environmental Biotechnology Inc.

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Soil Remediation:

Greenhouse Treatability Study (2012)

Representative soils collected from each of the four parcels

Phytoremediation with a mixture of grasses using PEPS – 60 day test

7 0.8% PHC DW soil

13 2.1% PHC DW soil

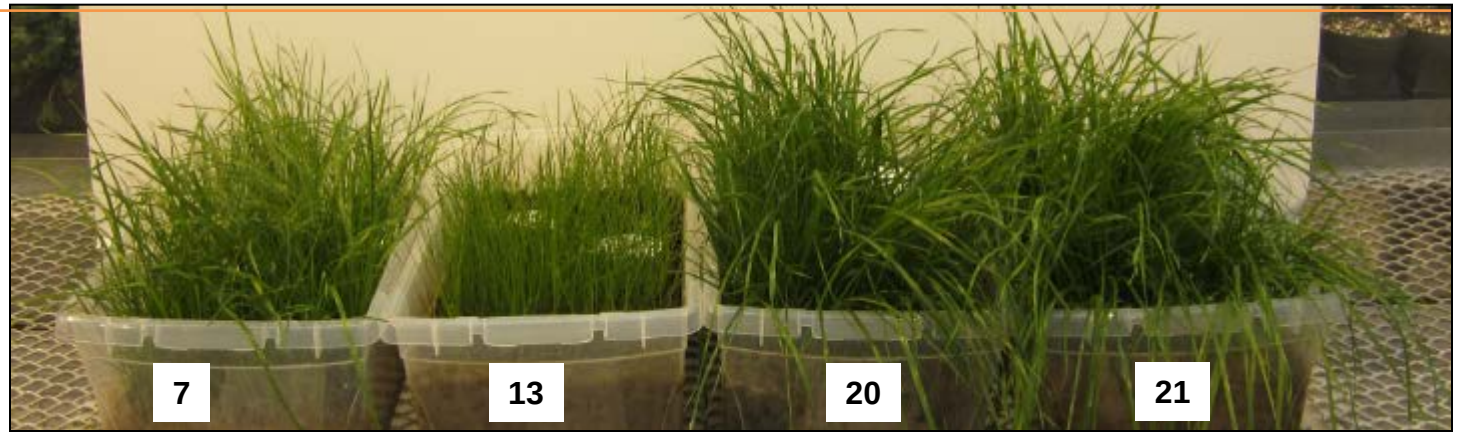
2.4 % PHC DW soil 20

0.4 % PHC DW soil 21

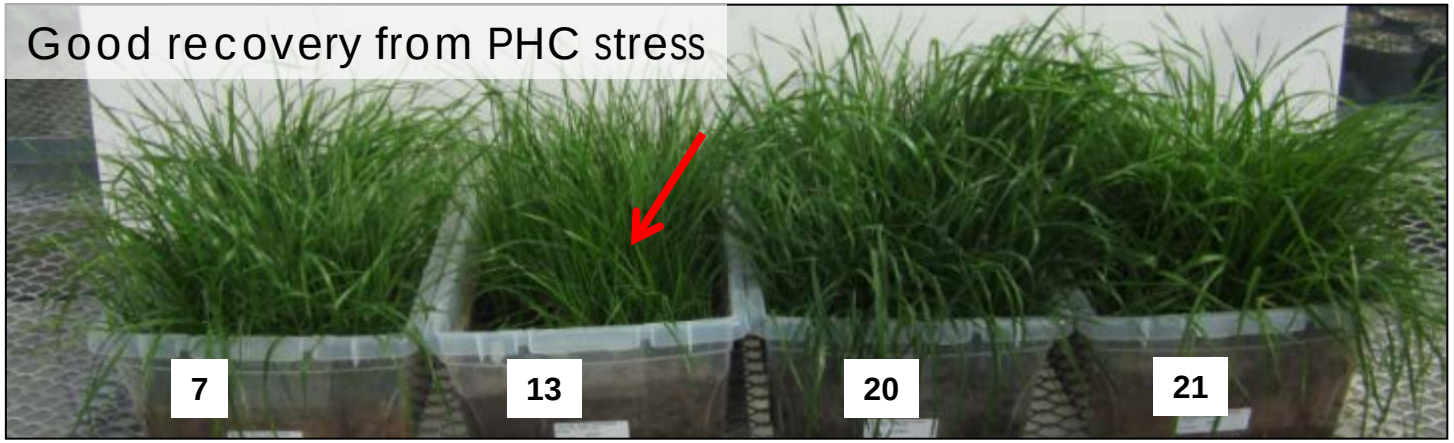
Greenhouse Treatability Study (2012)

	Parcel 7	Parcel 13	Parcel 20	Parcel 21
PHC % DW Soil	0.8 %	2.1 %	2.4 %	0.4 %
Remediation	10-20 %	20-30 %	20 %	20-60 %

Day 30



Day 38



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4 Soil Phytoremediation 2012

Performance monitoring

- 50-90% groundcover at the end of the season
- Toxicity symptoms minimal (e.g. stunted growth)
- Plant growth was satisfactory

The 2012 growing season - elevated temperatures and lower than normal precipitation in some months

~ 20 to 60 mm less precipitation for these months compared to the 30-year climate normals

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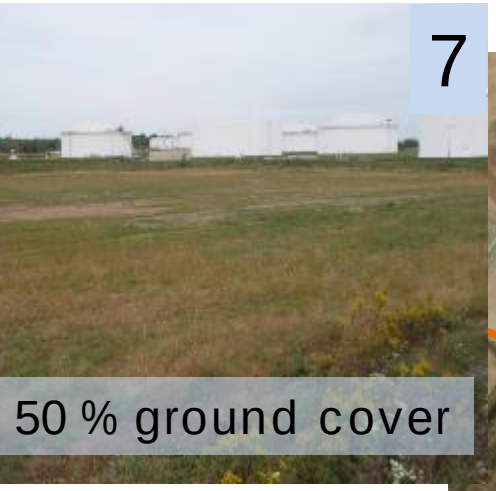
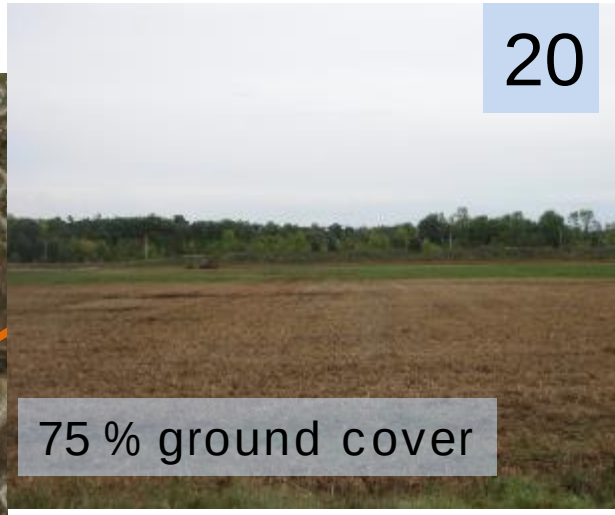
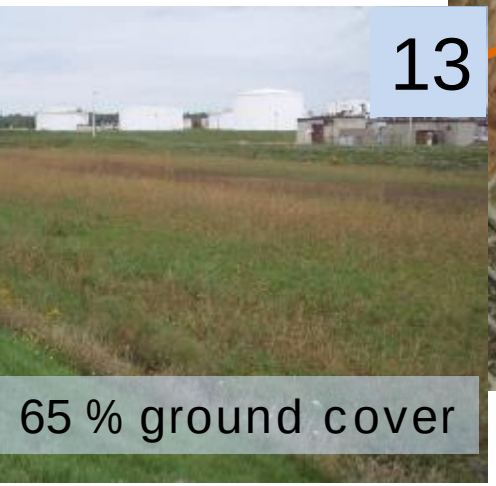
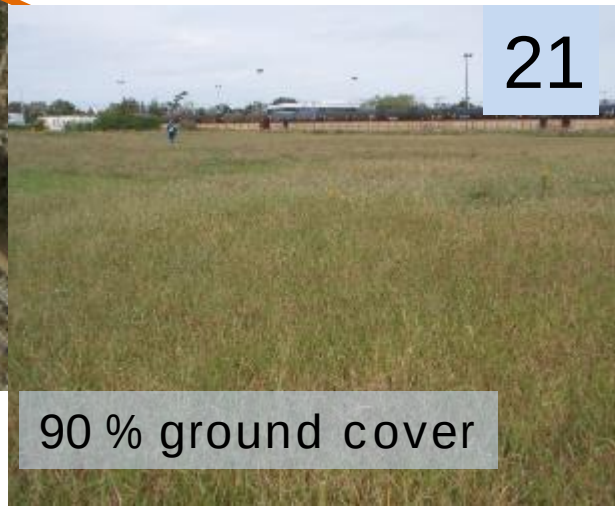
Phytoremediation Performance Fall 2012

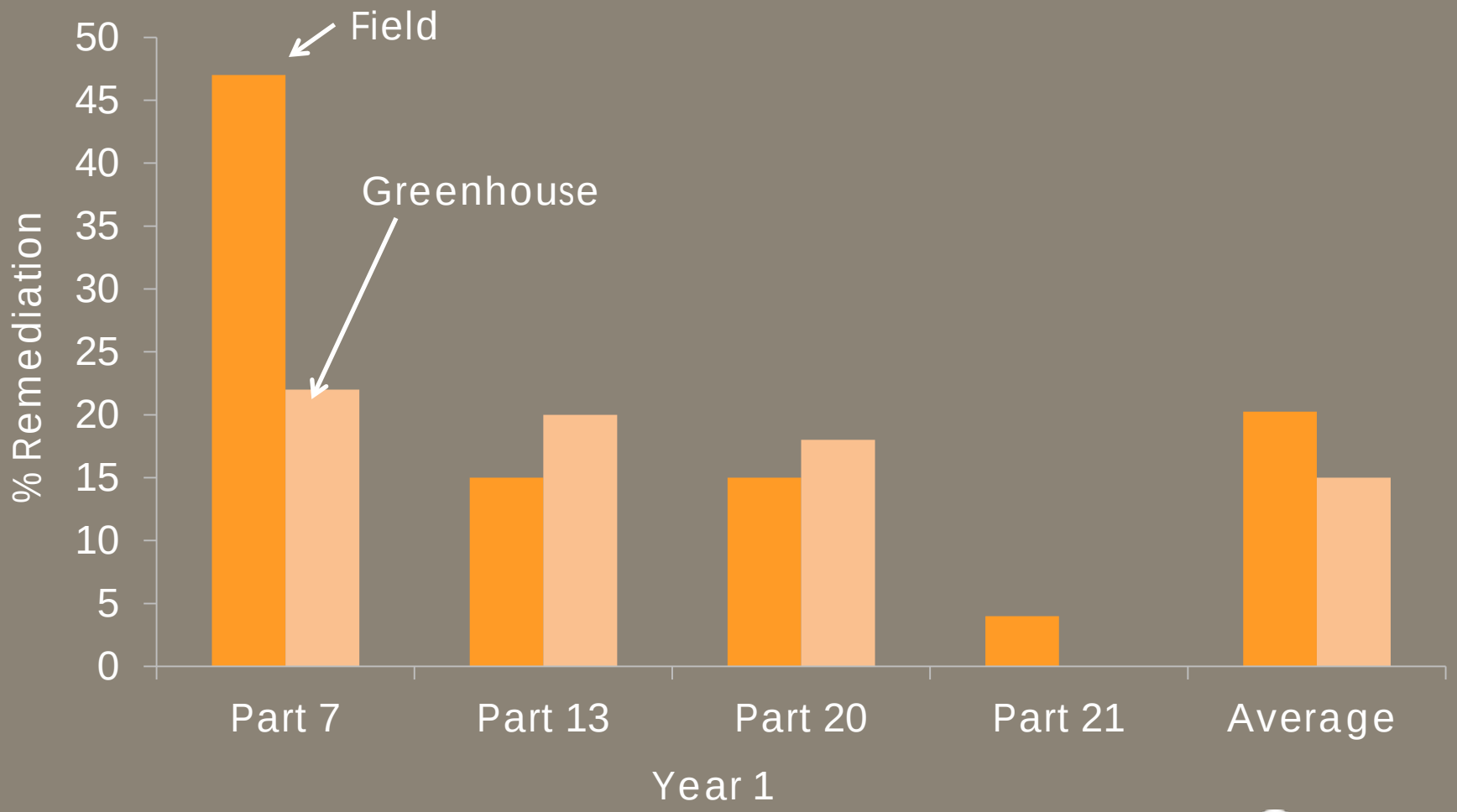








F3 phytoremediation was observed in the field (year 1) and greenhouse



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Remediation on Part 7 and Part 13

7

Parameters with Exceedances	Units	O.Reg. 153/04 Table 7 SCS	Spring Average	Fall Average	% Remediation
Depth			**0 - 0.2 m**	**0- 0.2 m**	**0 - 0.2 m**
PHC F1	µg/g	65	< 10	< 10	0
PHC F2	µg/g	250	102	23	77
PHC F3	µg/g	2,500	2,010	1,068	47
PHC F4	µg/g	6,600	1,100	595	46

13

Parameters with Exceedances	Units	O.Reg. 153/04 Table 7 SCS	Spring Average	Fall Average	% Remediation
Depth			**0 - 0.2 m**	**0- 0.2 m**	**0 - 0.2 m**
PHC F1	µg/g	65	38	12	69
PHC F2	µg/g	250	1,395	444	68
PHC F3	µg/g	2500	12,500	10,575	15
PHC F4	µg/g	6600	5,108	4,325	15

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Phytoremediation in year 2

- Overseeding was performed to maintain and increase growth
- Two fertilization events were carried out to increase microbial activity in the soil
- Optimal precipitation/temperatures
- Expected comparable or enhanced remediation rates due to increased plant growth and optimal climatic conditions

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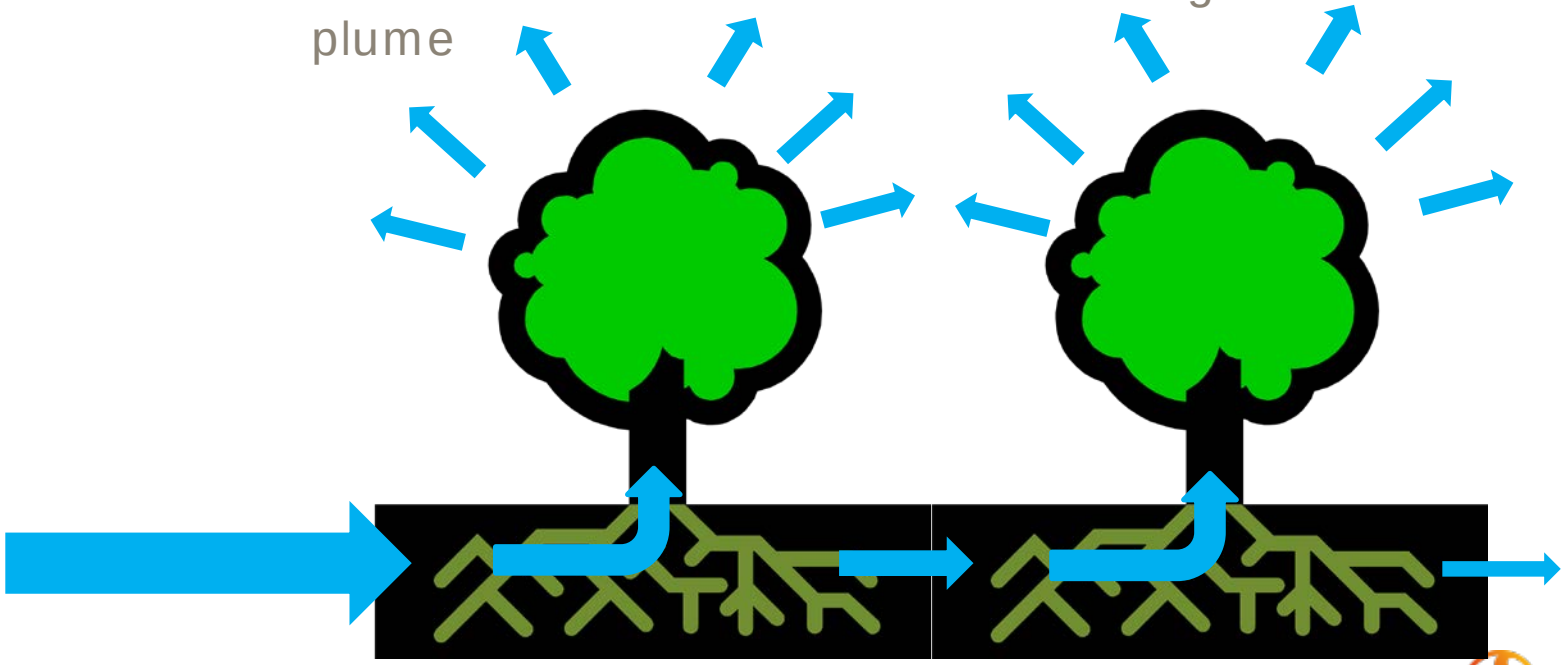
5 Groundwater Phytoremediation

Hydraulic Control and Evapotranspiration

- mitigate/stop the flow of contaminated groundwater
- groves of phreatophyte trees placed perpendicular to the flow direction of a contaminated groundwater plume



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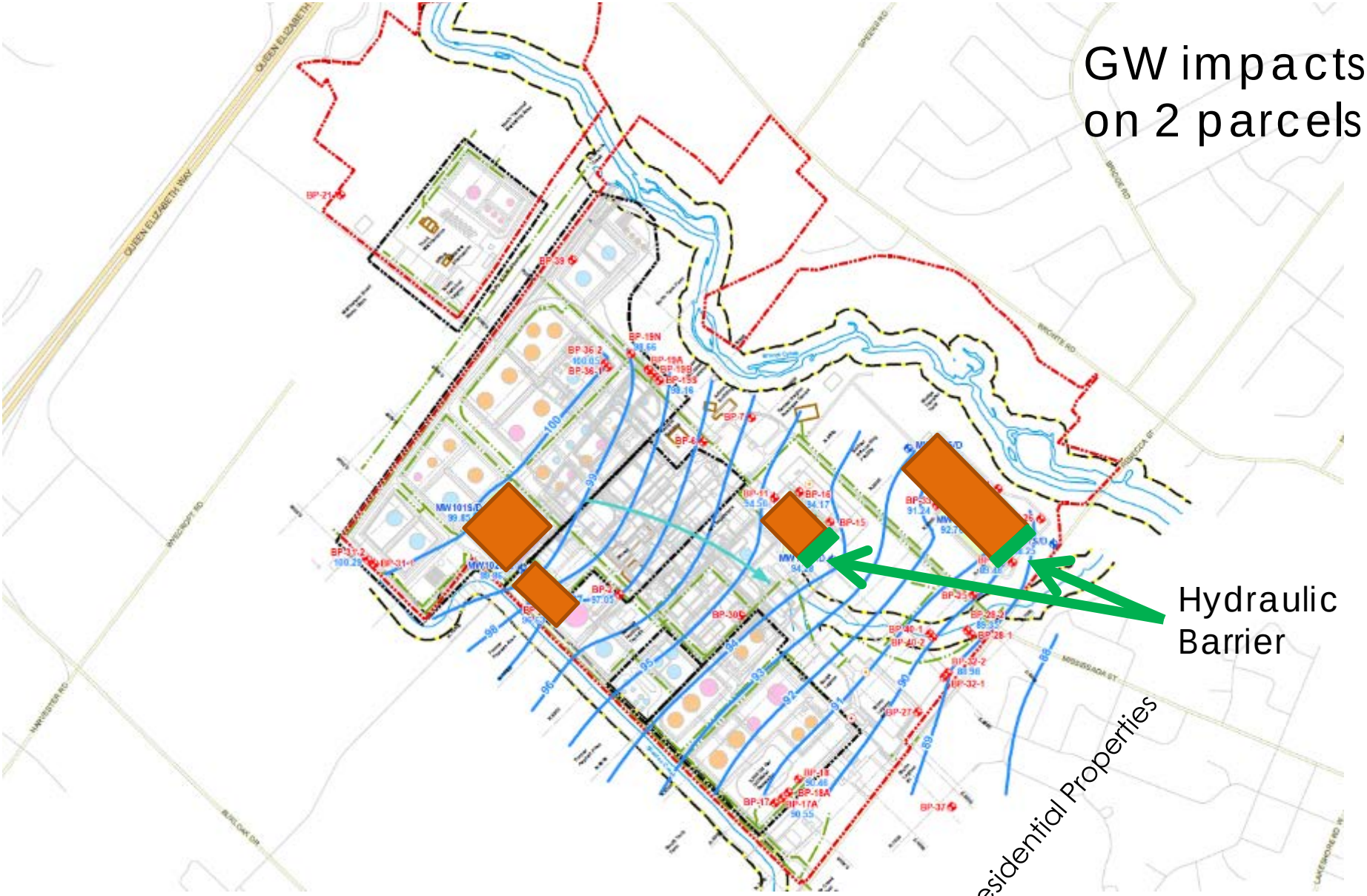
GW impacts on 2 parcels



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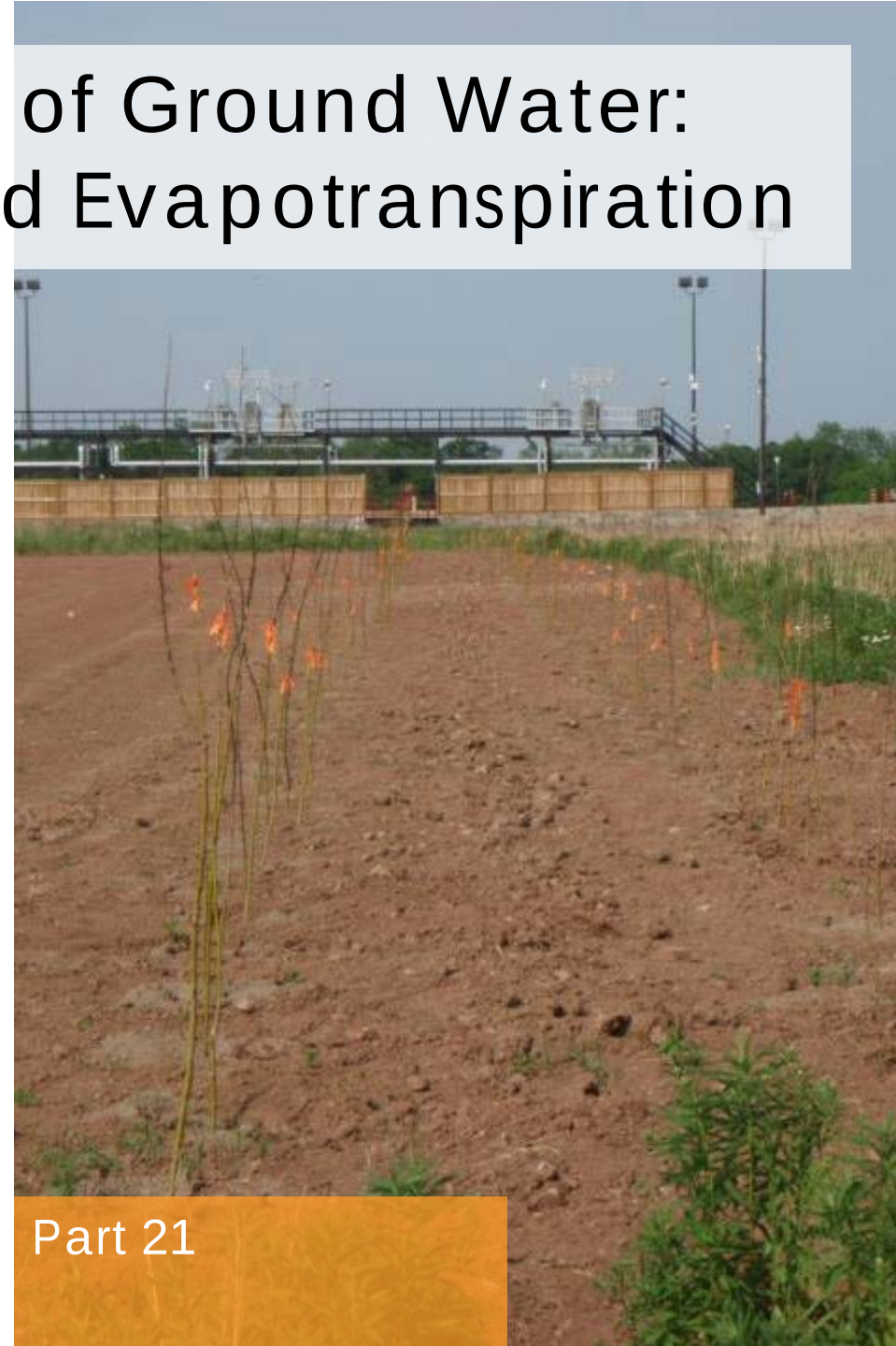
Phytoremediation of Ground Water: Hydraulic Control and Evapotranspiration

- Total willows planted = 465
  - Part 20: 266
  - Part 21: 199
- Average depth of deep-planted trees: 60-70cm

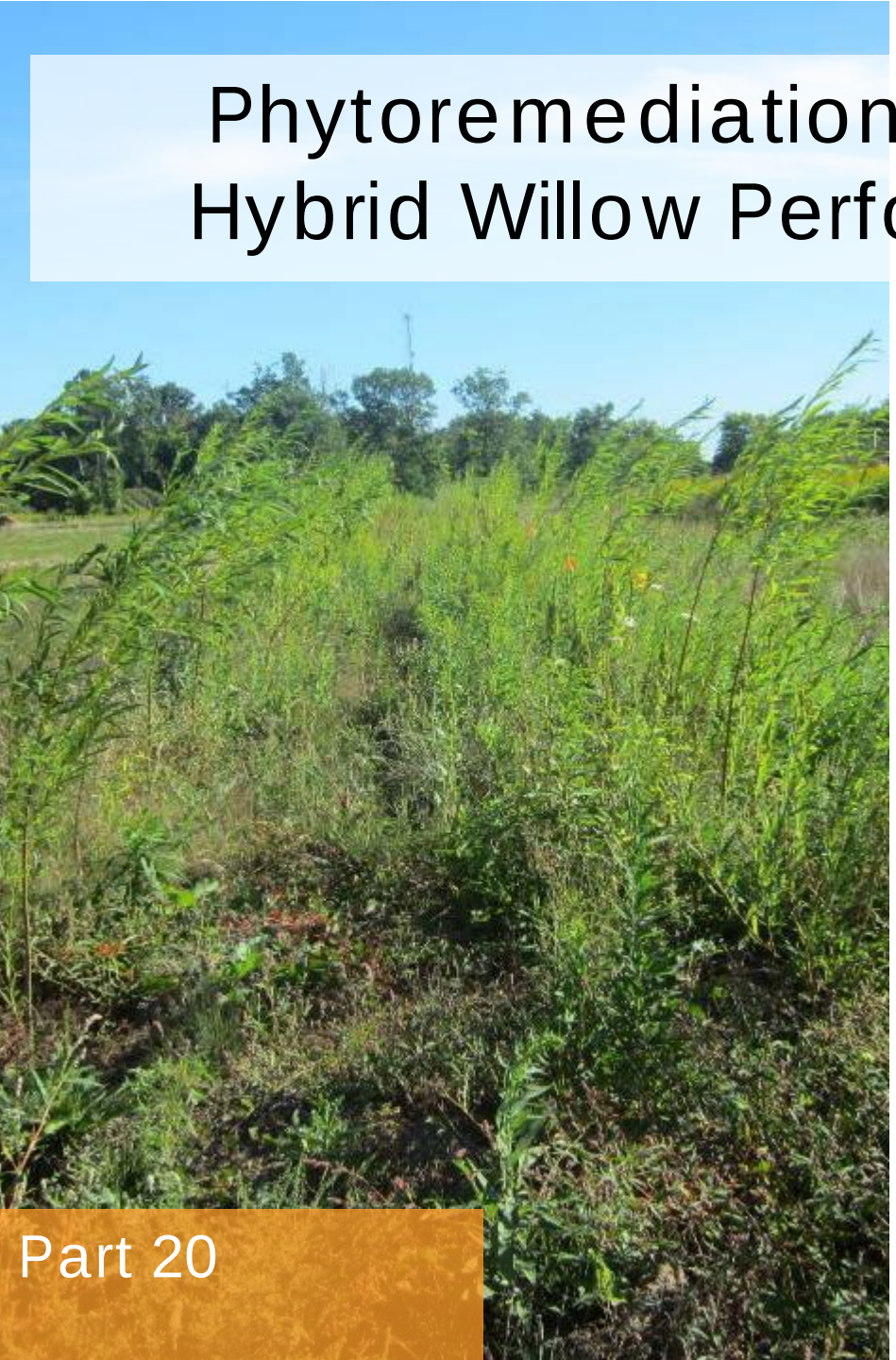
Phytoremediation of Ground Water: Hydraulic Control and Evapotranspiration

Part 20

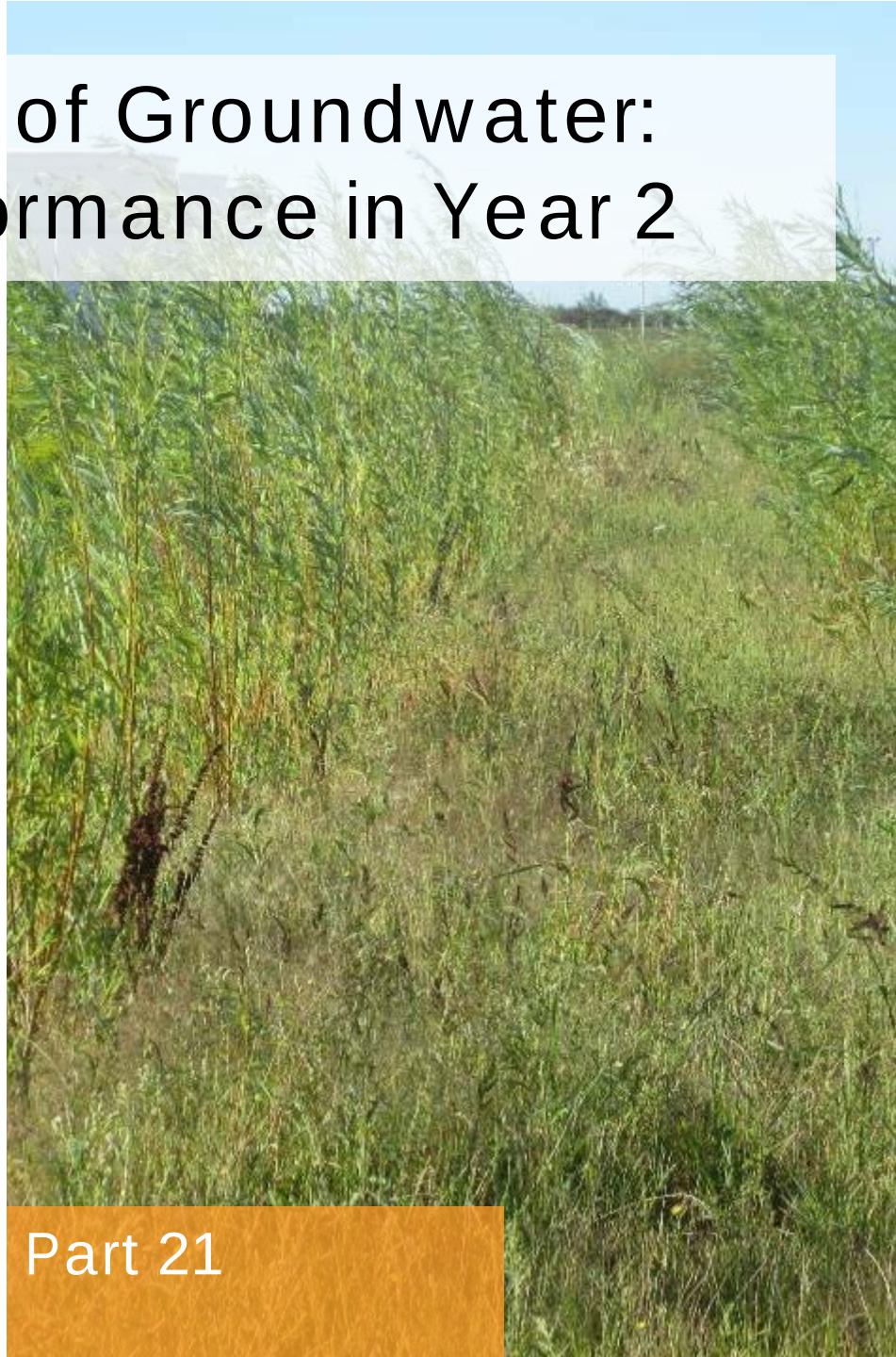


Part 21

Phytoremediation of Groundwater: Hybrid Willow Performance in Year 2



Part 20



Part 21


2012
2013
• Higher than normal willow mortality in 2012
• Irrigation and coppicing were performed
• Trees replaced as needed

Site closure process

1. Site Characterization
   - Phytoremediation System Design
2. Implementation
   - Performance Monitoring
3. Site closure

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Conclusions

Soil phytoremediation

- Optimal soil phytoremediation in year 1
- Monitored plant growth (e.g. ground cover) showed improvement in year 2, improved remediation rates expected

Groundwater Hydraulic Control

- Ecomonitoring of the hybrid willow phytoremediation system revealed good growth in 2011 and excellent growth in 2012 (% survival, DBH, toxicity symptoms)

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Acknowledgements

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