Phytoremediation and Bioremediation on Brownfields

Ohio Brownfield Conference 2012
Greater Columbus Convention Center

Wednesday, May 23, 2012

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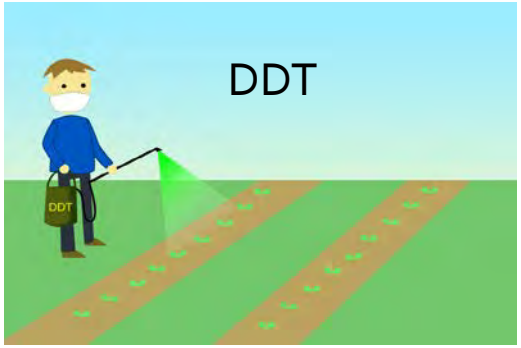
Phytoremediation & Bioremediation Concepts

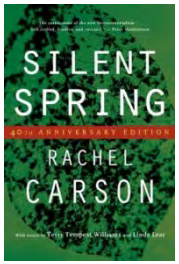
Daryl Dwyer, Ph.D., University of Toledo

Phytoremediation & Bioremediation Concepts

- Solving some intractable environmental problems through engineering solutions
- Problem?
- Money?
- Appropriate Tools

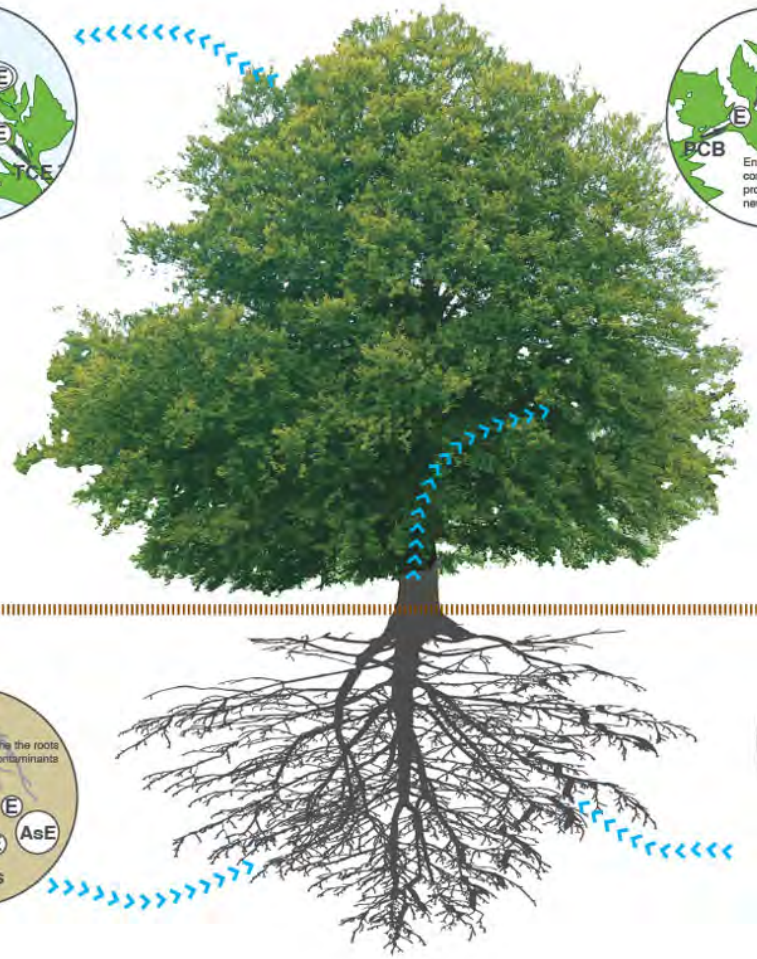
Why Do We Need New Tools?

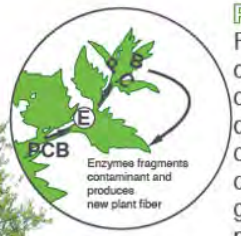




Phytoremediation may prevent the spread of contaminants and eliminate those already in the environment while restoring natural habitats.

PHYTO VOLATILIZATION:
Some plants take up volatile contaminants and release them into the atmosphere through transpiration. The contaminant is transformed or degraded within the plant to create a less toxic substance before and then released into the air.

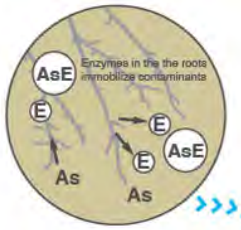


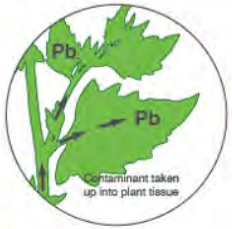


PHYTO DEGRADATION:
Plants take up and break down contaminants through the release of enzymes and metabolic processes such as photosynthetic oxidation/reduction. In this process organic pollutants are degraded and incorporated into the plant or broken down in the soil.

PHYTO EXTRACTION:
Plants take up contaminants - mostly metals, metaloids and radionucleids- with their roots and accumulate them in large quantities within their stems and leaves. These plants have to be harvested and disposed as special waste.

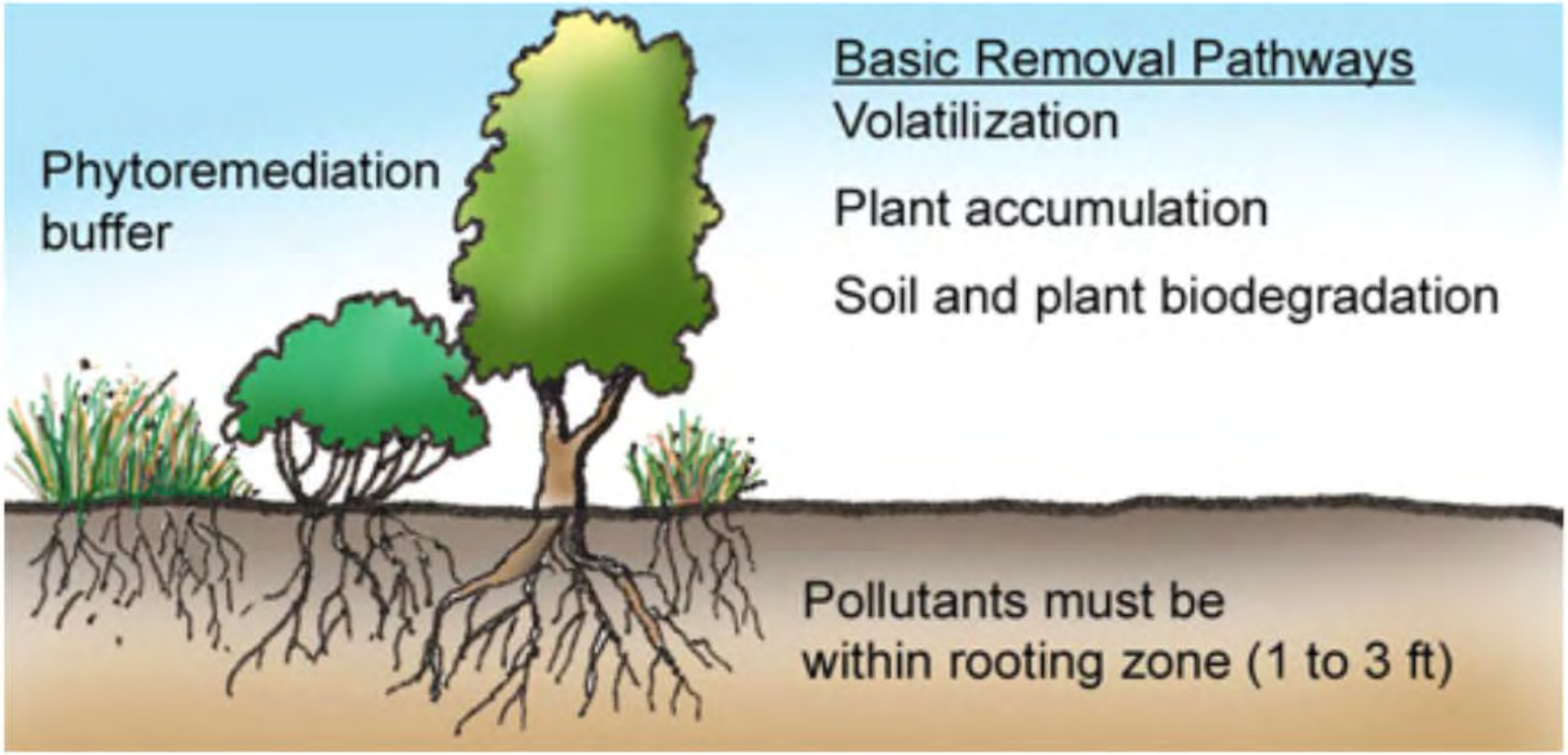
PHYTO STABILIZATION:
Some plants can sequester or immobilize contaminants by absorbing them into their roots and releasing a chemical that converts the contaminant to a less toxic state. This mechanism limits the migration of contaminants through water erosion, leaching, wind, and soil dispersion.



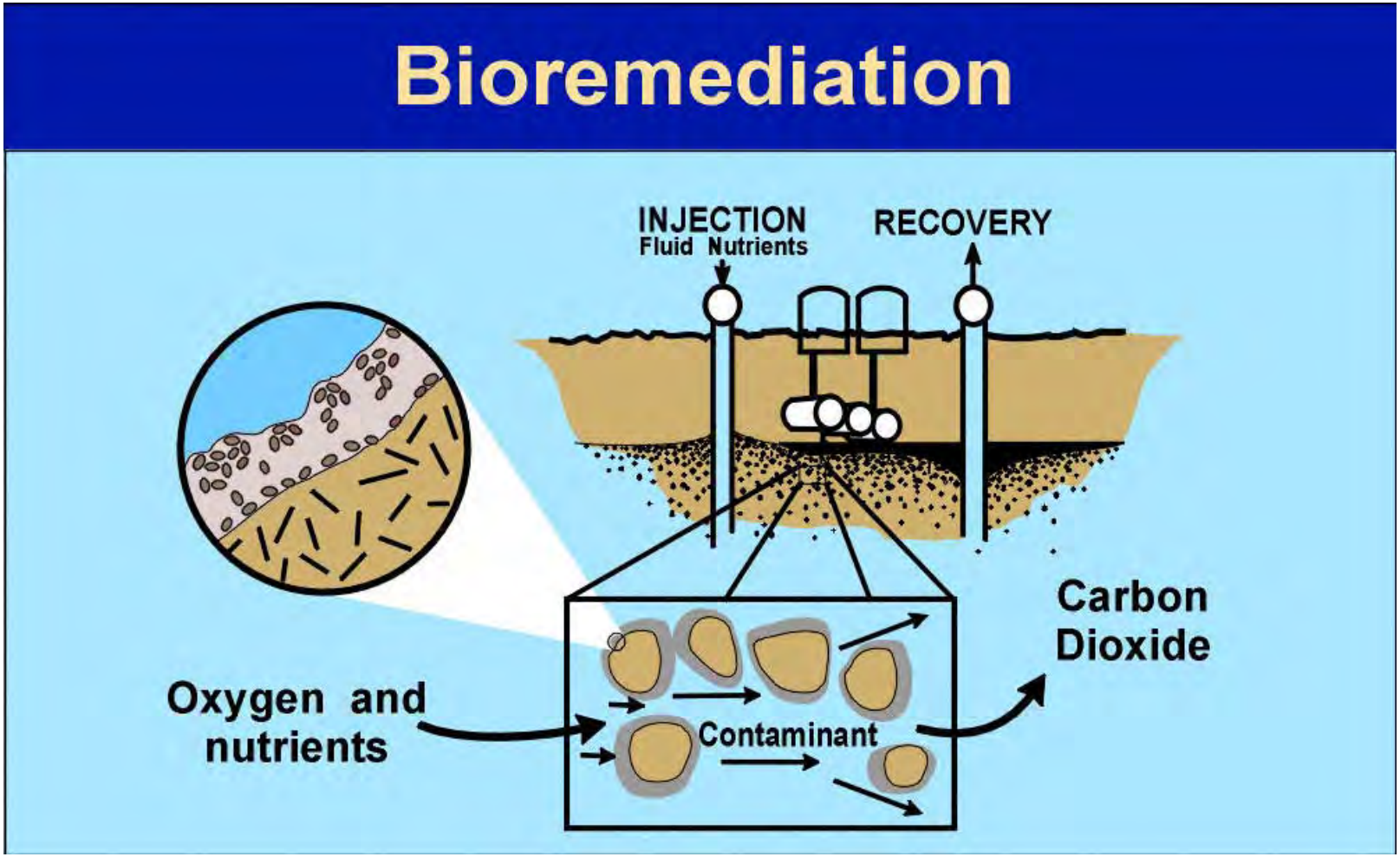


http://urbanomnibus.net/2010/11/from-brownfields-to-greenfields-a-field-guide-to-phytoremediation/

Science of Phyto & Bioremediation



Typical Application Mode for *In situ* Bioremediation: Microbial-Based



http://agrotechno-park.blogspot.com/2011/10/advantage-and-disadvantages-of.html

Science of Phyto & Bioremediation

- Industrial Applications
  - Bioremediation has been used by large and small companies: fuel distributors, gas stations, precision engineers, automotive manufacturers, fleet maintenance companies, auto repair companies, chemical companies, farms, civil engineering firms, trucking companies, aviation and aircraft companies, food and drink manufacturers, mining companies, and others.

- What else can benefit from Bioremediation?
  - Routine industrial maintenance, including cleaning of machines, vehicles, and floors. Removing oil from oil-stained concrete. Parts washing and degreasing. Absorbing, containing & removing spills of oil or acids on land, concrete or water. Dealing with leaking oil drums and tanks. De-blocking grease traps and drains. Industrial hand care. Bioremediation of sludge and wastes from various industrial processes. Simple on-site bioremediation of oil-contaminated land.

http://bioremediationinc.com/ABOUT_US.htm

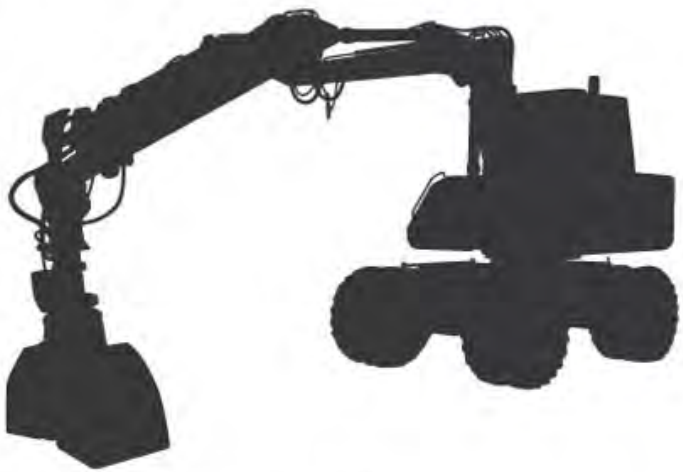
Science of Phyto & Bioremediation

- Key Design Considerations:
  - Select vegetation that is fast growing, easy to maintain, and capable of transforming the pollutants to a non-toxic form.
  - May need to conduct screening studies and field plot trials to determine suitable plants.
  - Avoid monocultures to reduce risk to disease and pests.
  - Pollutants need to be within the upper rooting zone.
  - Plants with different rooting types and depths may be used together to treat a greater soil depth. A fibrous root system is usually the most efficient.
  - Determine and mitigate potential exposure risks for wildlife.
  - Harvesting vegetation and proper disposal may be necessary.

http://www.unl.edu/nac/bufferguidelines/guidelines/3_productive_soils/5.html

Science of Phyto & Bioremediation

Excavation and Fill



$50,000 - 100,000

Phytoextraction

$5,000 - 8,000

Science of Phyto & Bioremediation

Location	Application	Pollutant	Medium	Plant(s)
Ogden, UT	Phytoextraction & Rhizodegradation	Petroleum & HCs	Soil & Groundwater	Alfalfa, poplar, juniper, fescue
Anderson, ST	Phytostabilization	Heavy Metals	Soil	Hybrid poplar, grasses
Ashtabula, OH	Rhizofiltration	Radionuclides	Groundwater	Sunflowers
Upton, NY	Phytoextraction	Radionuclides	Soil	Indian mustard, cabbage
Milan, TN	Phytodegradation	Explosives waste	Groundwater	Duckweed, parrotfeather
Amana, IA	Phytodegradation	Nitrates	Groundwater	Hybrid poplar

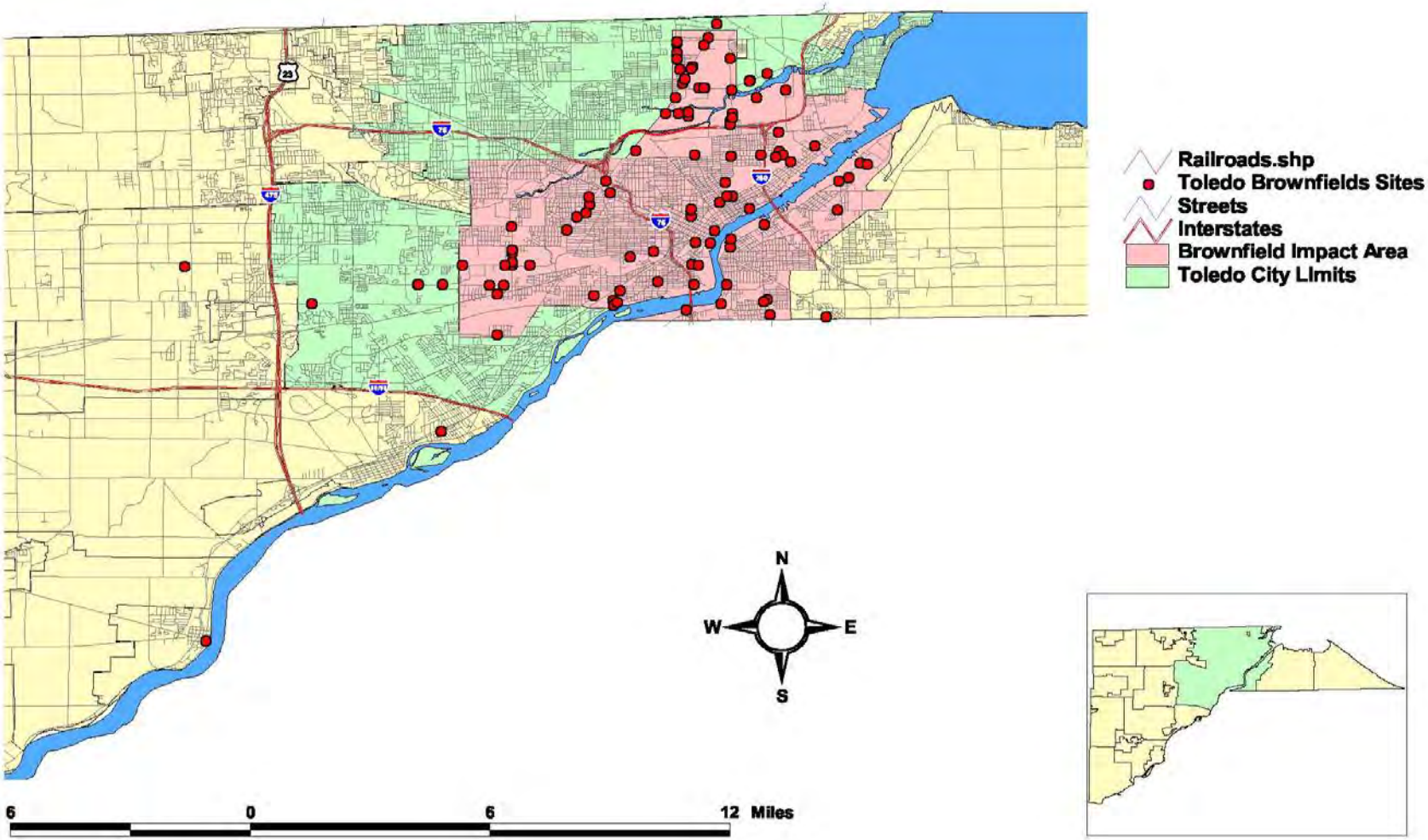
Case Studies

Case Studies

Toledo's Brownfields and Bio/Phytoremediation Grants

Joel Mazur, City of Toledo

Toledo Brownfields



Toledo Brownfields

- Toledo's brownfield inventory includes 576 brownfield sites
  - Range from less than one acre to over 100 acres, averaging 4.7 acres
- Rich industrial history
- Variety of prior uses:
  - Many auto parts/steel products manufacturers
  - Several auto repair shops, gas stations, junk yards
  - Power plants, manufactured gas plants and supporting infrastructure
- Many of the oldest sites are surrounded by densely populated residential neighborhoods
- Contaminants of concern include:
  - Metals
  - Volatile organic compounds
  - Total petroleum hydrocarbons (diesel range organics and gasoline range organics), polychlorinated biphenyls
  - Pesticides, herbicides
  - Asbestos

Toledo Brownfields

- Successful Brownfields Program
  - Toledo and Toledo-Lucas County Port Authority received 16 U.S. EPA grants worth $5,250,000
    - 11 assessment grants: $2.2 million
    - 2 job training grants: $350,000
    - 1 cleanup grant: $200,000
    - 2 revolving loan fund grants: $2.5 million
  - Toledo received 5 Clean Ohio Assistance Fund Grants worth $3,243,282
  - Toledo and Toledo-Lucas County Port Authority received 10Clean Ohio Revitalization Fund Grants worth $25,365,256
  - Also secured, or helped secure, EDA, HUD and other funds to complete and supplement brownfields projects

GLRI Grant Programs

- City of Toledo's $500,000 GLRI Grant, 2010
  - Grant from ODNR Division of Forestry with GLRI funding from U.S. Forest Service
  - Projects committed to:
    - Reduce toxic substances on brownfields using phytoremediation
    - Divert runoff, plant trees and grasses for buffers and stabilization, and install rain gardens
  - Current projects underway or recently completed: Doehler Jarvis, Edison Park, Kraus Street Rain garden

- University of Toledo's $498,276 GLRI Grant, 2011
  - Grant from ODNR Division of Forestry with GLRI funding from U.S. Forest Service
  - Projects committed to:
    - Install a plant-based pump-and-treat system to remove organic contaminants from soil/groundwater at MGP site
    - Plant native trees, grasses, and forbs to accumulate metals, enhance degradation of organics, and control storm water infiltration at a former foundry
    - Plant native trees, grasses, and forbs to stimulate degradation of organic contaminants and minimize stormwater infiltration at a former coking facility.
  - Current projects underway: Columbia Gas, Unitcast, Beazer

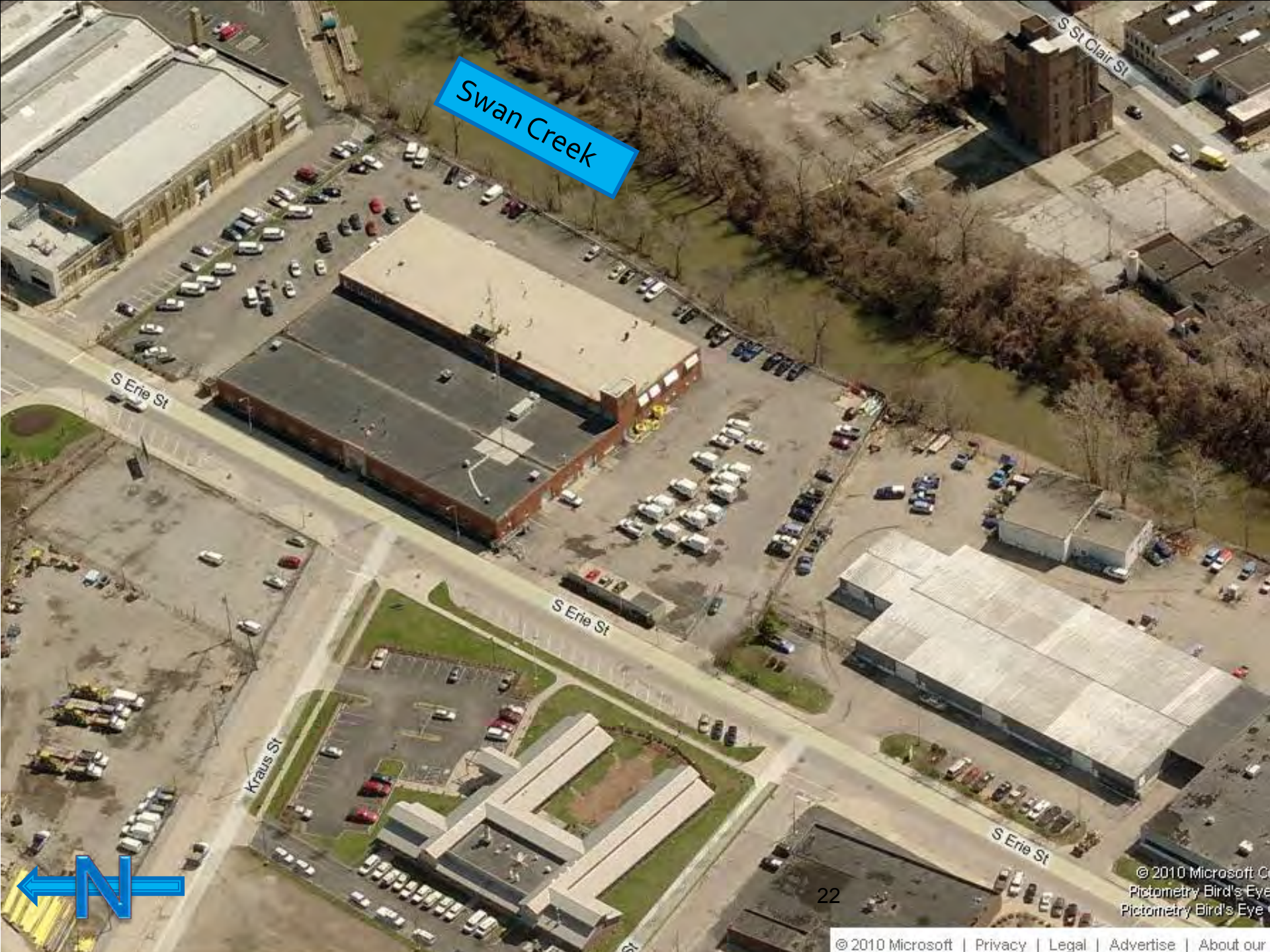
Erie Street Redevelopment Project Example

Bill Petruzzi, P.G., Hull & Associates, Inc.

Toledo Warehouse District

Erie Street Redevelopment Project

- 1887-1918 MGP
- 1919-2011 Natural gas redistribution and service center


Swan Creek
S St Clair St
S Erie St
S Erie St
Kraus St
S Erie St
N
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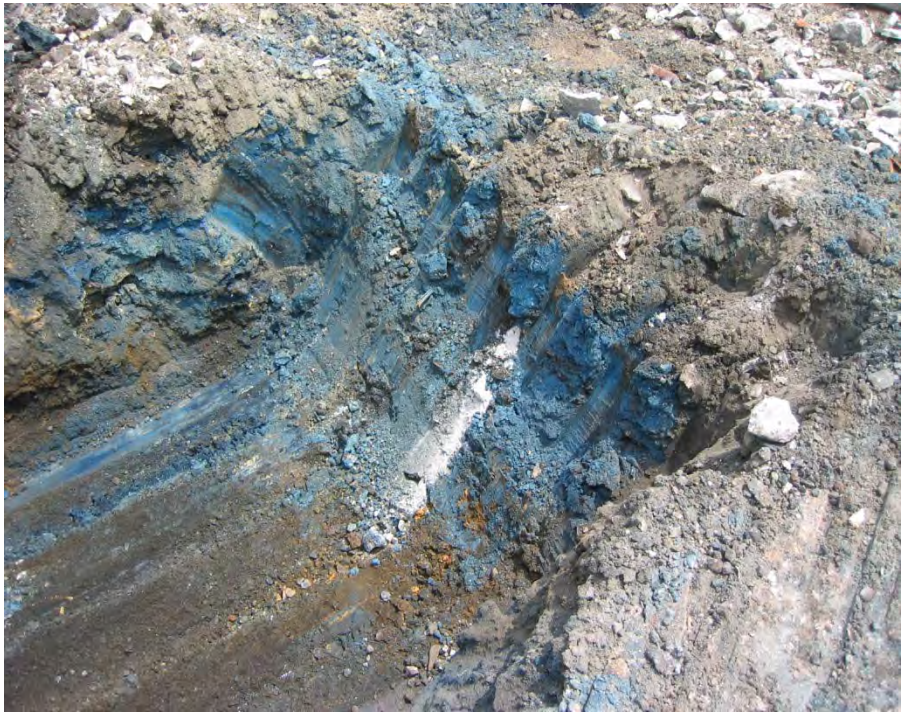
Chemicals of Concern – Pre-Remedy Maximum Concentrations (mg/kg)



Monocyclic Aromatic Hydrocarbons

- Benzene (2,700)
- Toluene (2,500)
- Ethylbenzene (240)
- Xylenes (1,800)

Polycyclic Aromatic Hydrocarbons

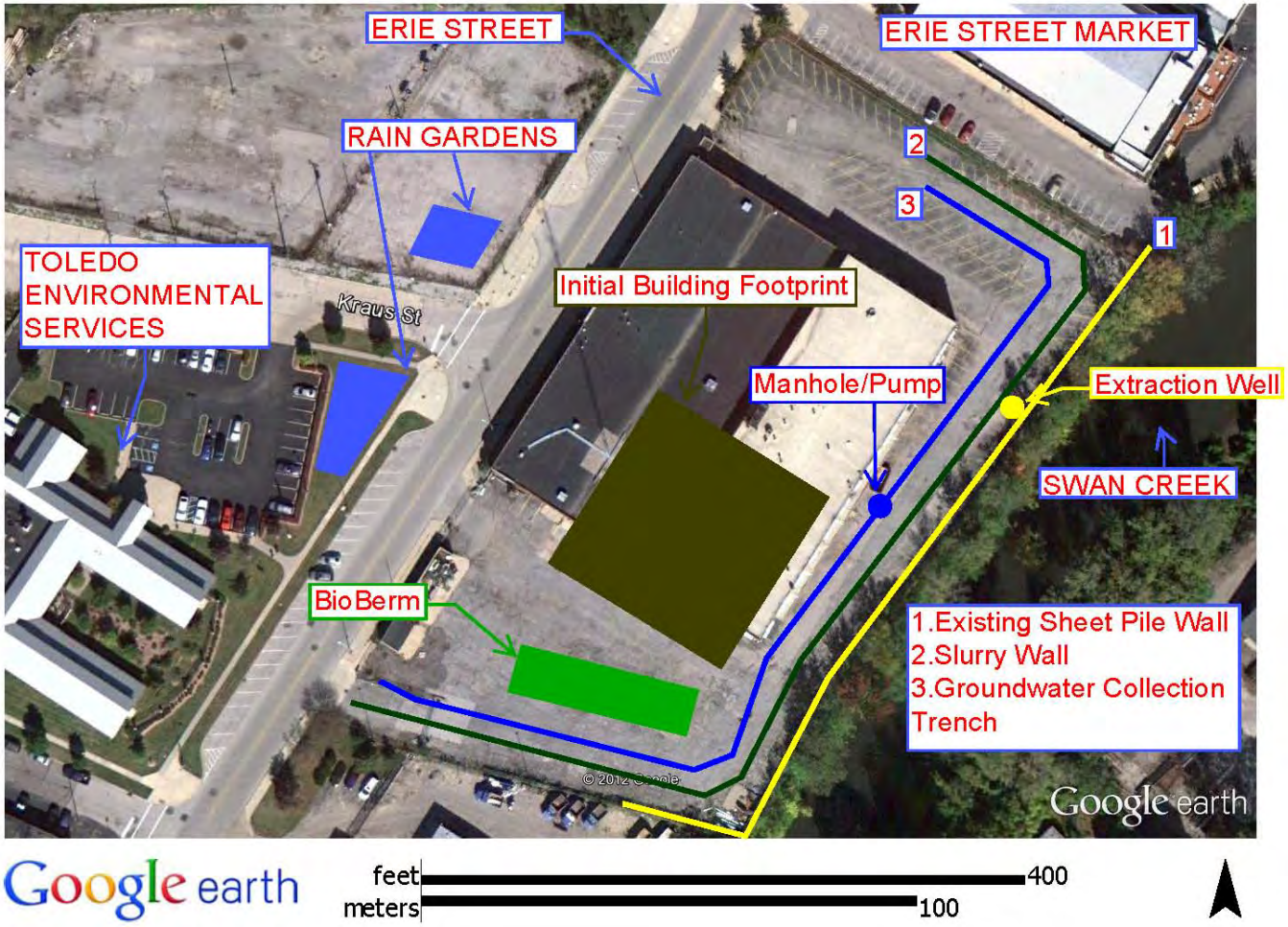
- Naphthalene (22,000)
- Benzo[a]anthracene (1,000)
- Benzo[a]pyrene (1,100)
- Benzo[b]fluoranthene (890)
- Dibenz[a,h]anthracene (360)
- Indeno[1,2,3-cd]pyrene (480)

Total Petroleum Hydrocarbons (C_6 – C_{34} (330,000))

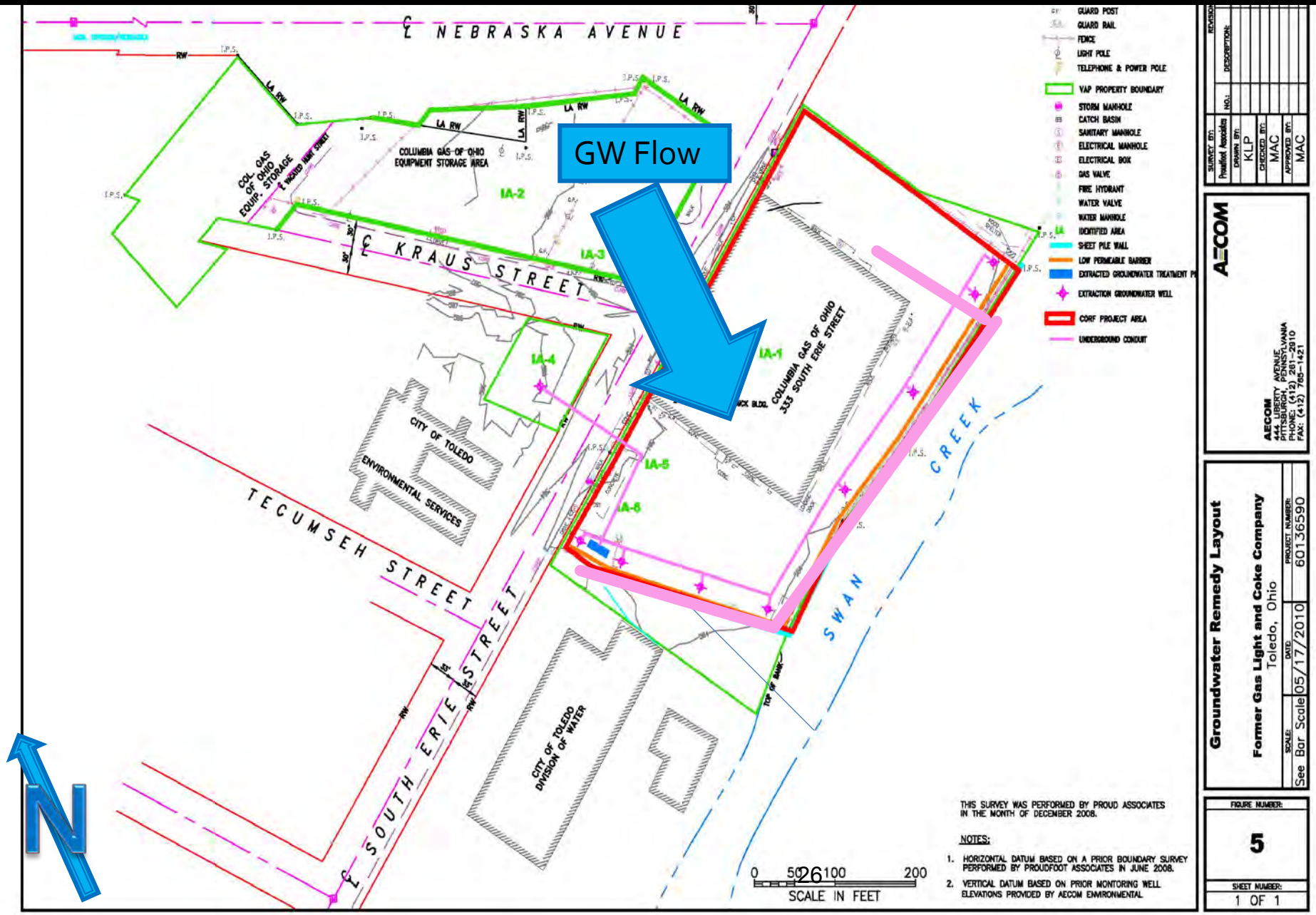
Inorganic Compounds

- Cyanide (310)

Base Map


ERIE STREET
ERIE STREET MARKET
RAIN GARDENS
2
3
1
TOLEDO ENVIRONMENTAL SERVICES
Kraus St
Initial Building Footprint
Manhole/Pump
Extraction Well
SWAN CREEK
BioBerm
1.Existing Sheet Pile Wall
2.Slurry Wall
3.Groundwater Collection Trench
Google earth
feet
meters
400
100

Groundwater Barrier and Collection System



Remediation Summary

- Soil Excavation
  - Approximately 30,000 ton disposed as solid waste and approximately 1,700 tons as hazardous waste
- Groundwater Management
  - Approximately 160,000 gallons of ground water disposed off-site
- Groundwater Flow Control Features
  - Existing sheet pile wall, groundwater barrier wall, groundwater collection system
- Property Activity and Use Limitations
  - To be recorded in an Environmental Covenant and filed with the property deed
- BioBerm
  - Constructed to further reduce the concentrations of target chemicals in groundwater
  - BioBerm is not relied upon to meet applicable VAP standards.
- Risk Mitigation Plan
  - Plan will be to be implemented during on-site construction and excavation activities

Residual Contamination

Monocyclic Aromatic Hydrocarbons

- Benzene (2.4)
- Toluene (3.5)
- Ethylbenzene (87)
- Xylenes (13.5)

Polycyclic Aromatic Hydrocarbons

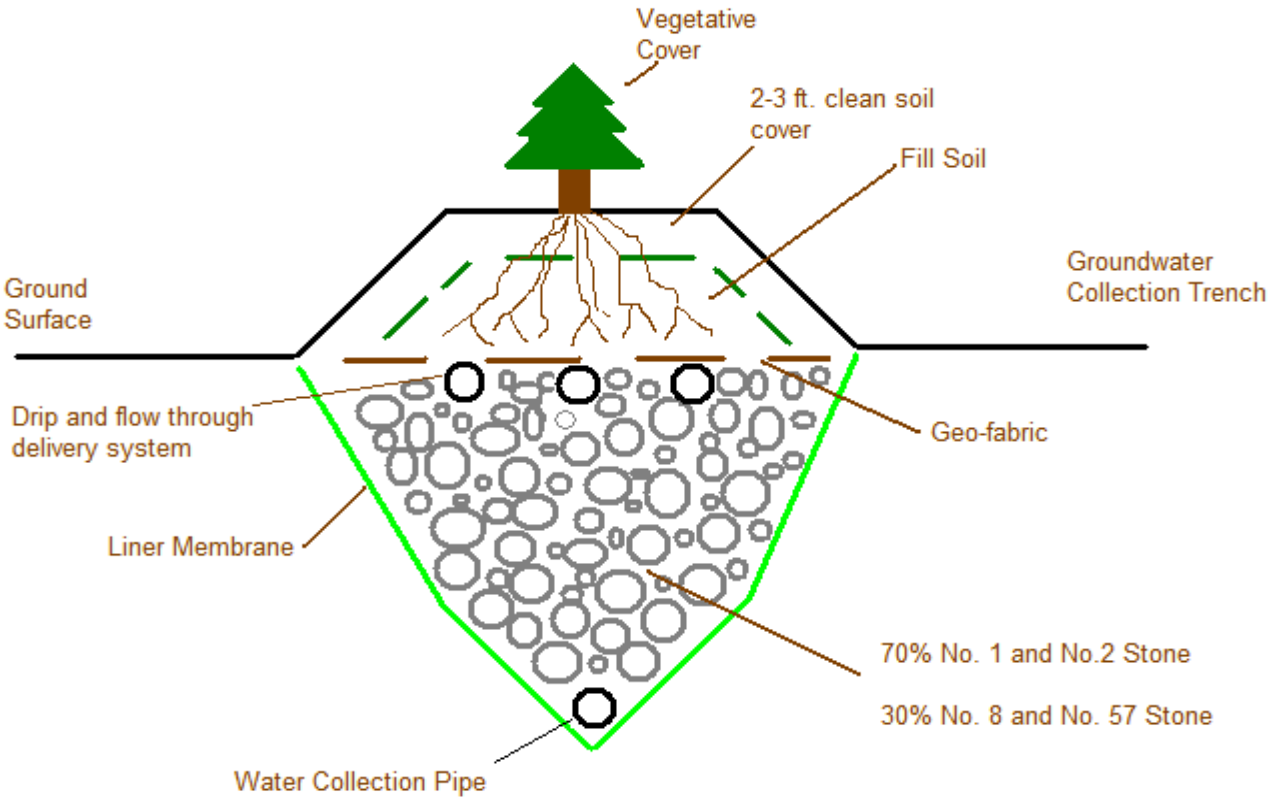
- Naphthalene (640)
- Benzo[a]anthracene (220)
- Benzo[a]pyrene (160)
- Benzo[b]fluoranthene (220)
- Dibenz[a,h]anthracene (32)
- Indeno[1,2,3-cd]pyrene (120)

Total Petroleum Hydrocarbons (C6 – C34 (11,230))

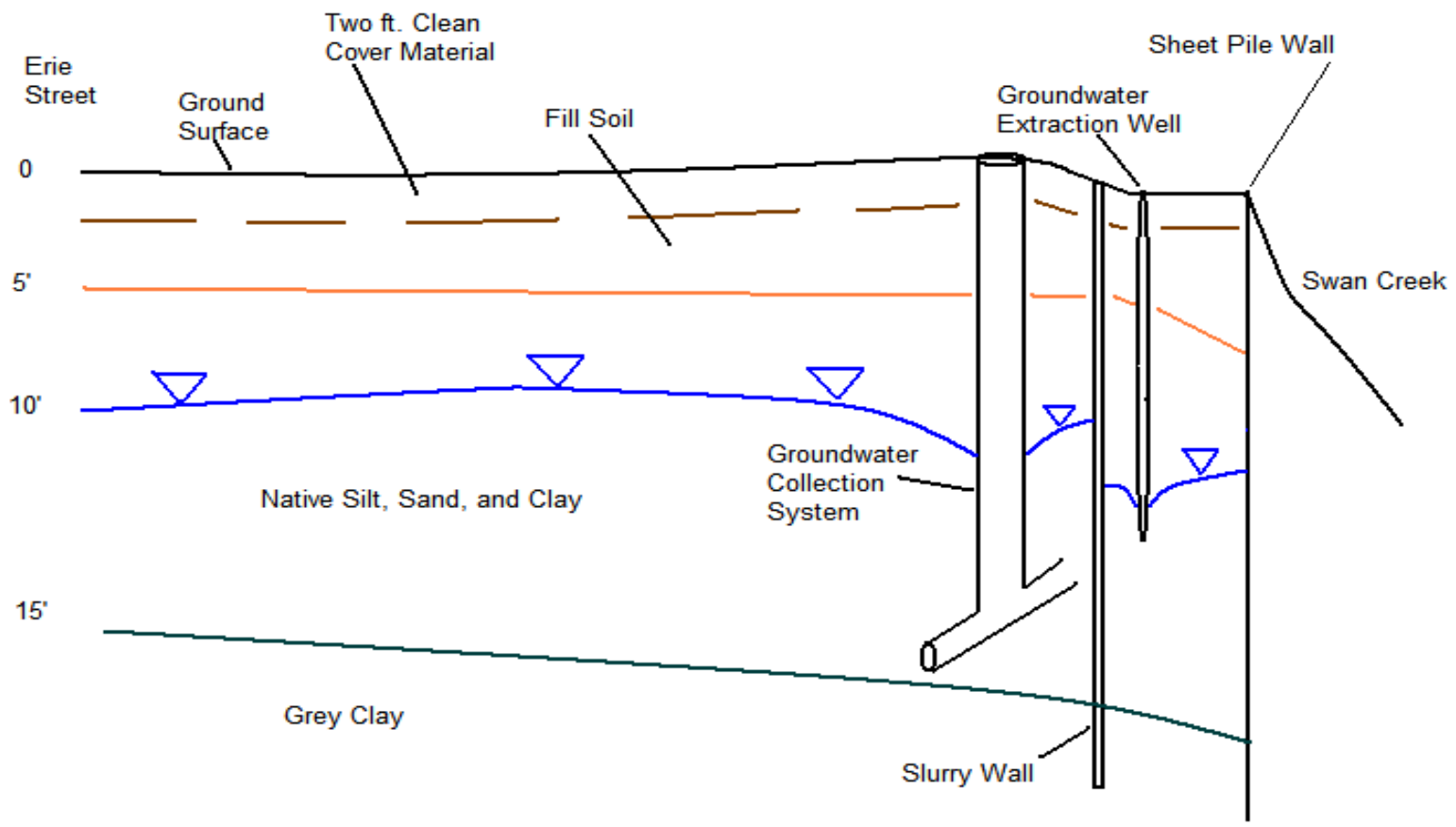
Inorganic Compounds

- Cyanide (72)

BioBerm Detail



Cross Section

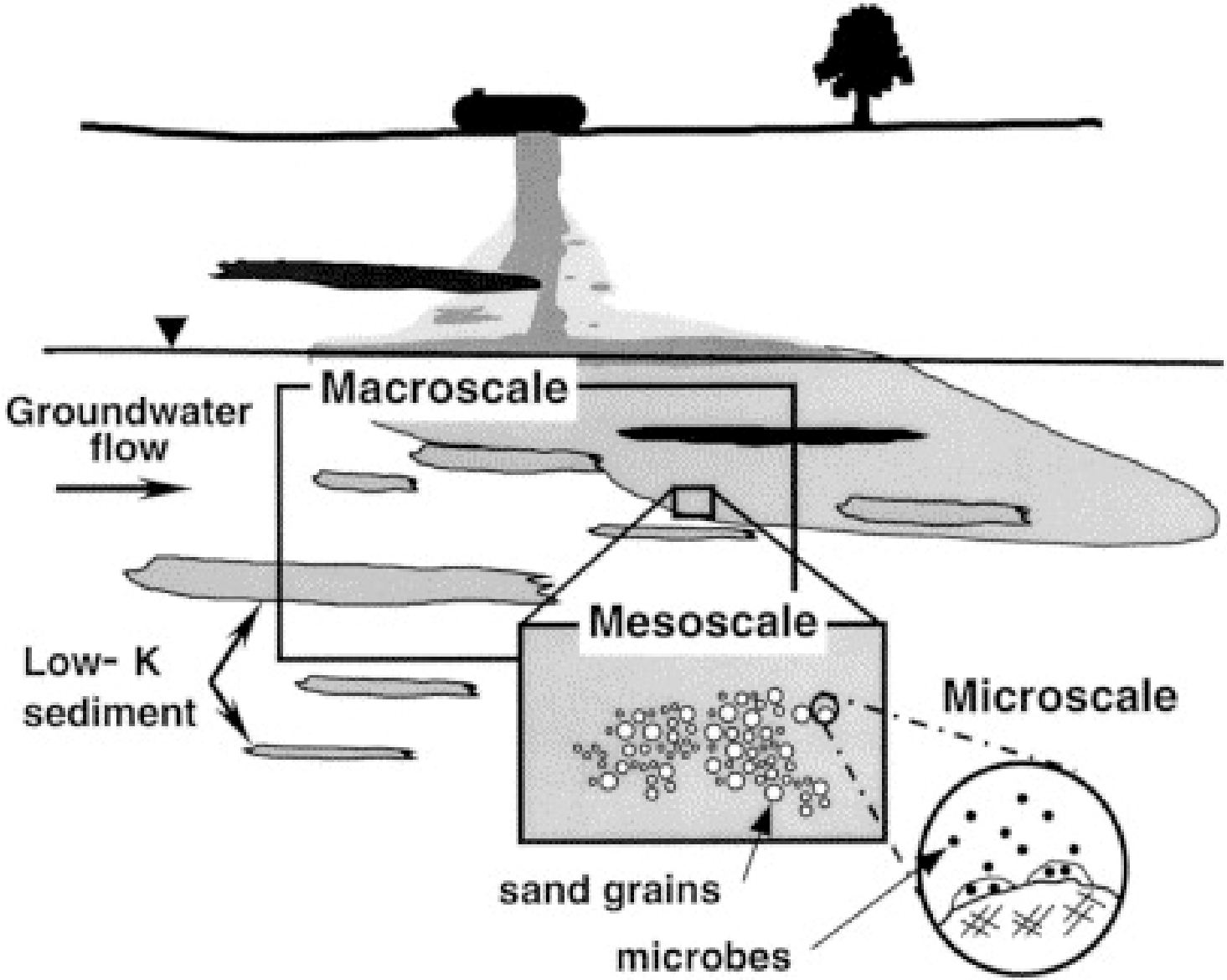


KOBELCO

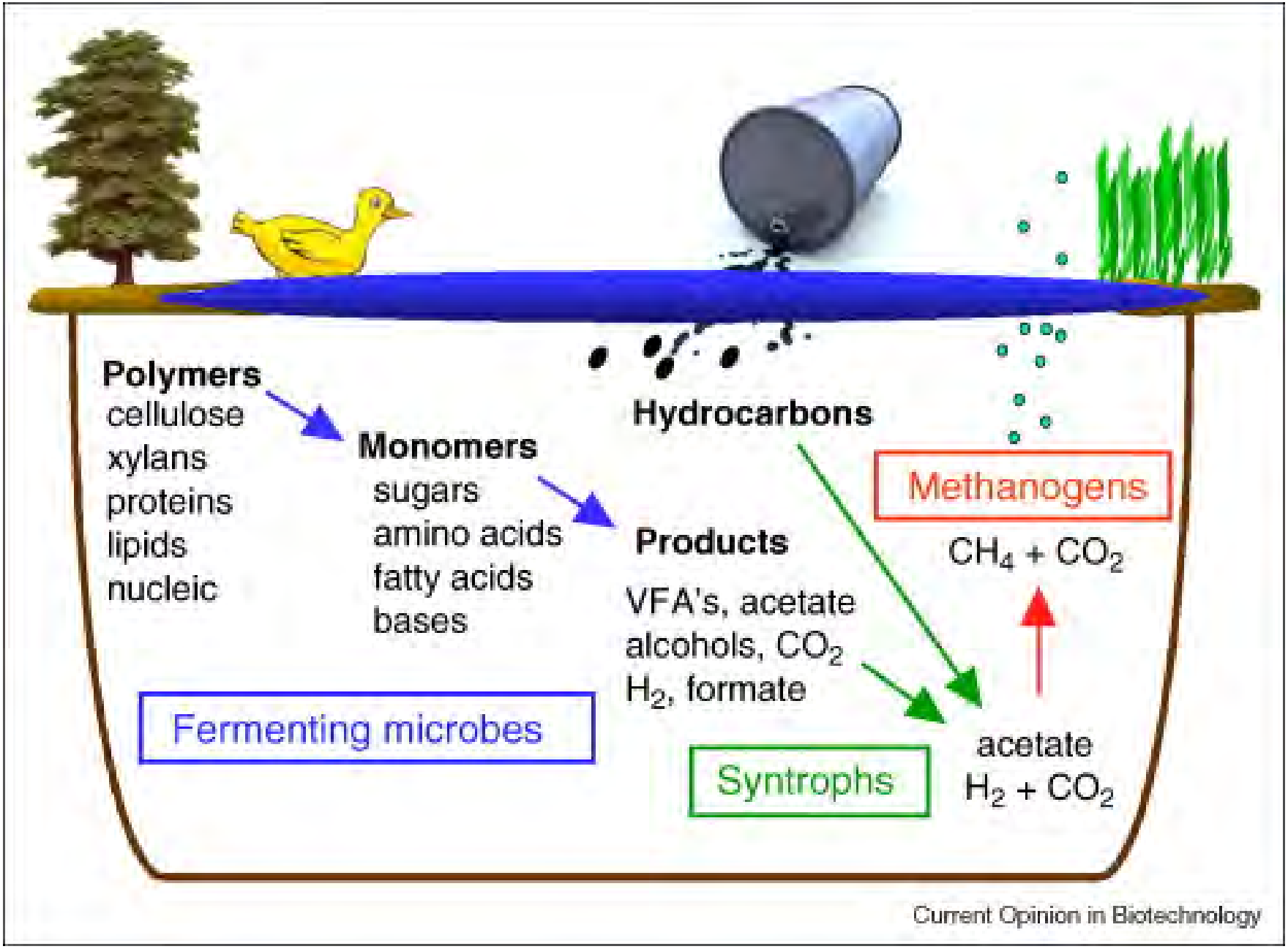
Hull
& associates, inc.

Applied Bioremediation Concepts

Daryl Dwyer, Ph.D., University of Toledo



Journal of Contaminant Hydrology, 2000, Vol 46, pp 339-374


Polymers
cellulose
xylans
proteins
lipids
nucleic
Monomers
sugars
amino acids
fatty acids
bases
Hydrocarbons
Products
VFA's, acetate
alcohols, CO_2
H_2, formate
Methanogens
$CH_4 + CO_2$
Fermenting microbes
Syntrophs
acetate
$H_2 + CO_2$
Current Opinion in Biotechnology

Other Projects Underway

Bill Petruzzi, P.G., Hull & Associates, Inc.

Other City of Toledo, University of Toledo, Hull Projects

Doehler Jarvis

Edison Park

Questions?

For More Information

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