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# Incorporating Sustainability into Remediation of Indian Ridge Marsh, Chicago, IL

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**Lafayette, Indiana**
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# Presentation Overview

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- Site Background
  - Location & Restoration Initiatives
  - Site Characterization
  - Identified Site Contamination
- Human and Ecological Risk Assessment
  - Establishment of Remedial Objectives
- Remedy Selection
  - Site-specific Considerations & Remedial Options
  - Sustainability Metrics & Remedy Selection
- Remedial Design
- Final Recommendations

# Site Location: Southeast Chicago

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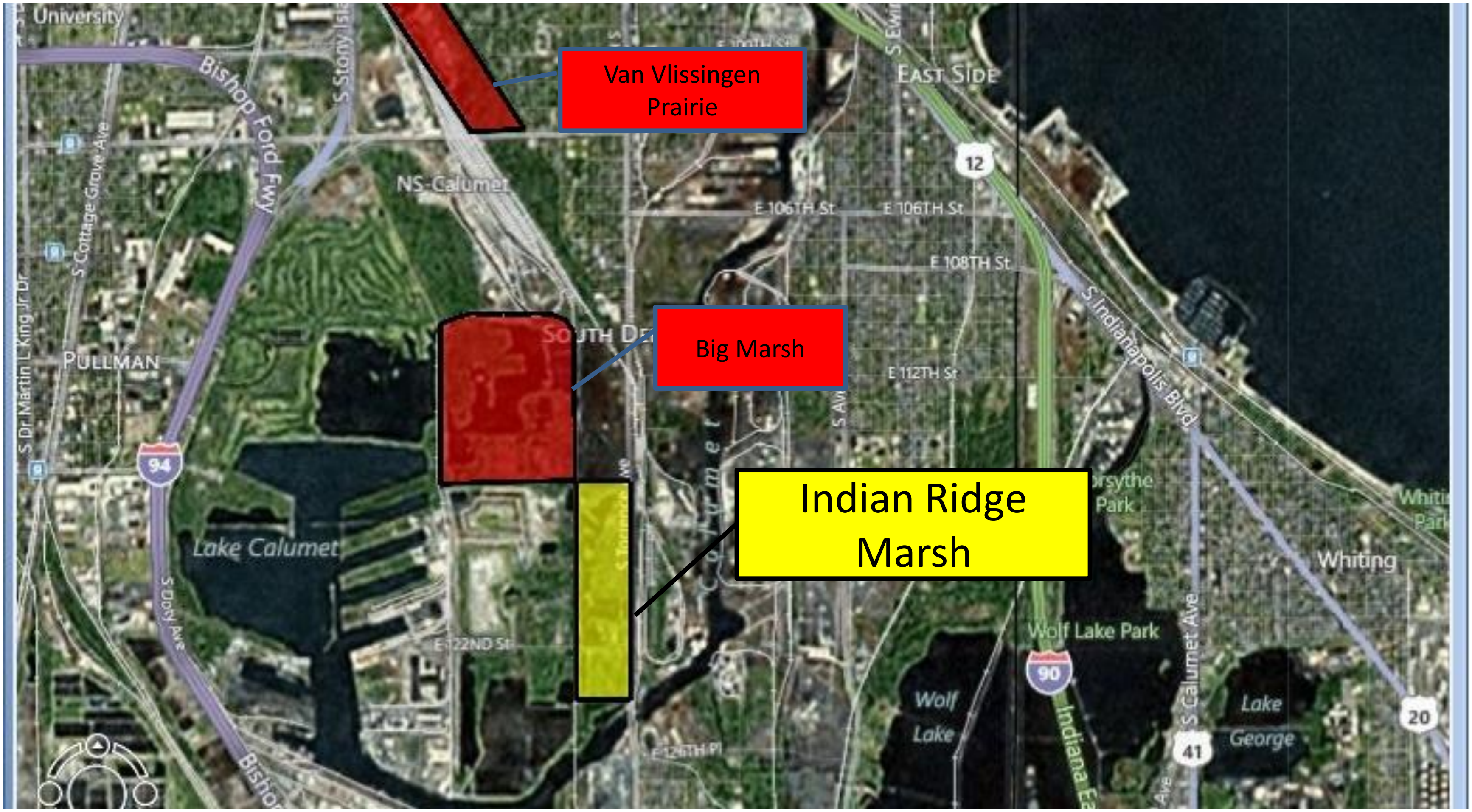

# Site Description & Sources of Contamination

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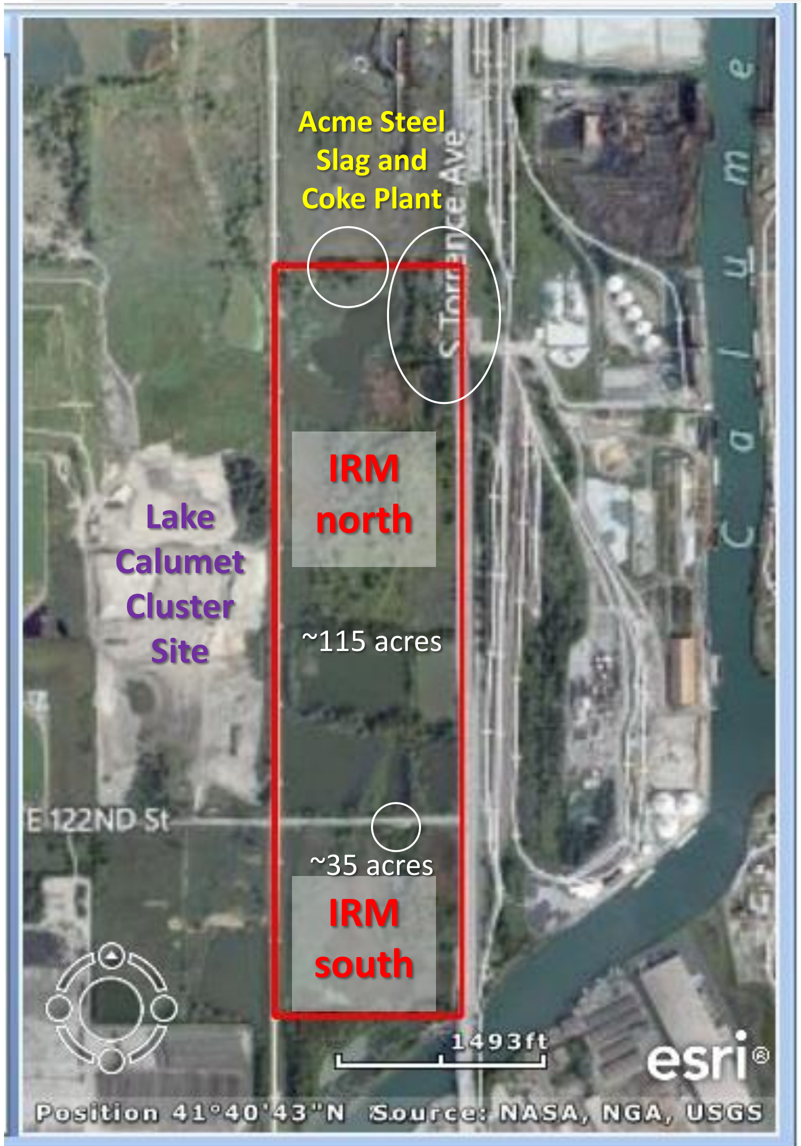


- Indian Ridge Marsh (IRM) (~150 acres) is bounded by:
  - *North*: E. 116th Street
  - *East*: S. Torrence Avenue
  - *South*: Calumet River
  - *West*: Norfolk & Southern Railroad
- Mixed wetland/marsh, prairie, and woodland
  - IRM has existed primarily as wooded marsh and swamp land since about 1930
- **Residential parcels** along 116th St. and at northeast corner of site; industrial structure on 122nd St.
- Contamination sources:
  - Onsite: Dumping /infilling (illegal and historic legal)
  - Offsite: Fomer/current heavy manufacturing, use/presence of USTs, landfills, illegal dumping
    - **Lake Calumet Cluster Site** (Superfund) – west of IRM
    - **Acme Steel Slag and Coke Plant** (listed in CERCLIS, but not on NPL) – north of IRM

# Current Site Uses & Future Redevelopment

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## Currently not open for public use

- Prior/Current Human Uses
  - Historic Illegal dumping throughout site
  - Adjacent landfills; Cluster Sites
- Ecological Value
  - Nesting site for endangered wetland bird species (e.g. black-crowned night heron)

## Future Uses:

- *Human* - Recreation & Open Space
  - Calumet Open Space Reserve (COSR)
- *Ecological* – Habitat Preservation
  - Calumet Wetland Unit

***Right*: Previously proposed restoration design plan**

**(Ecotoxicology Report, 1999)**

***- Plan proposed:***

- Prairie rehabilitation
- Naturalization of marsh & pond shorelines
- Enhancement of pond habitat

- Deep and Shallow marsh
- Wet Prairie/shoreline
- Mesic Prairie
- Mesic Woodland
- Wet Woodland
- Shrub Shoreline
- Shoreline Grading
- Trail (10' wide)
- Boardwalk
- Staging Area
- Black-crowned Night Heron Protection Area

# Applicable Regulations



- Not federally mandated
- Voluntary State Remediation Program (SRP)
- Illinois Administrative Code (IAC)
  - Title 35, Part 742
    - *Tiered Approach to Corrective Action Objectives (TACO)*
  - Title 35, Part 302, Section 407
    - *Water Quality Standards, Secondary Contact and Indigenous Aquatic Life Standards*

# Site Characterization - Prior Site Investigations

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| Year | Type | Performed By |
|---|---|---|
| 1998 | Phase I ESA | DOE |
| 1999 | Phase I ESA | Mostardi-Platt Associates, Inc. |
| 1999 | Phase II ESA | Earth Tech, Inc. |
| 2001 | Phase II ESA | Harza Engineering Co. |
| 2002 | Additional sediment data | MWH Americas, Inc. |
| 2007 | Additional groundwater data from cluster site | Ecology & Environment (E&E) |
| 2009 | Ecotoxicology Evaluation | Tetra Tech Inc. |
| 2011 | Phase I ESA | Terracon, Inc. |

## Phase I Results:

- Formerly SWDS
- Illegal fly/open dumping of slag and other materials
- Adjacent properties: solid waste disposal sites
- Northern property (offsite): Acme Steel Slag & Coke Plant (no longer in operation; listed in CERCLIS database)

## Phase II Results:

- Samples taken & analyzed (140+ soil; 20+ GW, 25+ sediment, 25+ SW)
- Documented contamination with **SVOCs, VOCs** (TCE, PCE, Vinyl Chloride)**, heavy metals**
- LNAPL found in one borehole (Well#20) with Total Petroleum Hydrocarbons (TPH), e.g. gasoline, diesel, oil

# Sampling Locations

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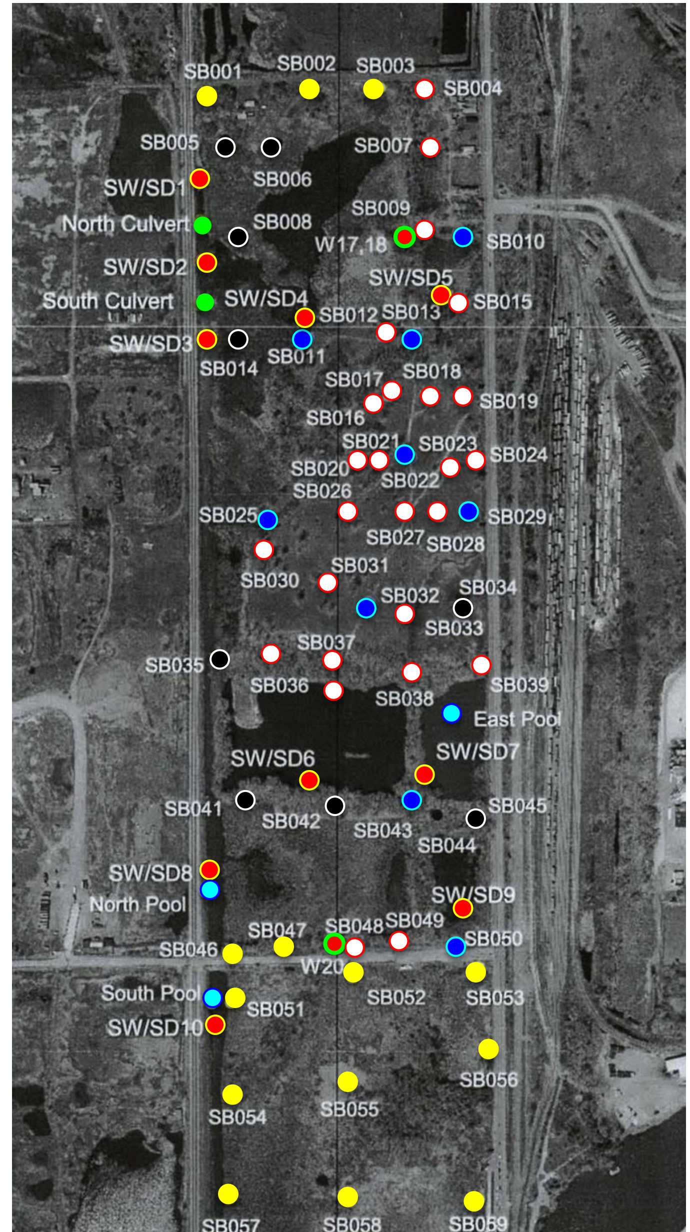
- Site contains sediments & surface water samples that exceeded allowable criteria for SVOCs, VOCs, RCRA metals, and TPH.
- Chlorinated solvent impact to the groundwater in the vicinity of Well #20.





# Documented Contaminants & Impacted Media

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| | SOIL | GROUNDWATER | SEDIMENT | SURFACE WATER |
|---|---|---|---|---|
| **PAHs** | Benzo(a)pyrene (C; GI)<br>Benzo(a)anthracene (C; GI)<br>Benzo(b)fluoranthene (C; GI)<br>Benzo(k)fluoranthene (C; GI)<br>Dibenzo(a,h)anthracene (C; GI)<br>Indeno(1,2,3-cd)pyrene (C; GI) | Benzo(a)pyrene (C; GI)<br>Benzo(a)anthracene (C; GI)<br>Benzo(b)fluoranthene (C; GI)<br>Benzo(k)fluoranthene (C; GI)<br>Bis(2-Ethylhexyl) Phthalate (C; L)<br>Chrysene (C; GI)<br>*1991-92 GW data: trans-1,2-trans-Dichloroethene, cis-1,2-Dichloroethene, 1,1-Dichloroethene, Benzene* | Benzo(a)anthracene (C; GI)<br>Benzo(a)pyrene (C; GI)<br>Dibenz(a,h)anthracene (C; GI)<br>Naphthalene (C; R) | |
| **VOCs** | Tetrachloroethene (PCE) (C; L)<br>Trichloroethene (TCE) (C; L)<br>Vinyl chloride (C; L, RS) | Vinyl chloride (C; L, RS)<br>LNAPL *(containing total petrolium hydrocarbons (TPH) gasoline, diesel, and oil)* | | |
| **METALS** | Lead<br>Mercury (NC; CNS, IS) | Iron<br>Lead<br>Manganese (NC; CNS) | Antimony (NC; CS)<br>Arsenic (C; RS)<br>Cadmium (NC; K)<br>Chromium<br>Copper<br>Lead<br>Nickel<br>Thallium<br>Zinc (NC; CS) | Iron<br>Manganese (NC; CNS) |

| | | | |
|---|---|---|---|
| **C** | Carcinogen | **NC** | Non-Carcinogen |

| | | | | | |
|---|---|---|---|---|---|
| **CS** - | Circulatory System | **IM** - | Immune System | **L** - | Liver |
| **GI** - | Gastrointestinal System | **K** - | Kidney | **RS** - | Respiratory System |

# N-S Geologic Cross Section

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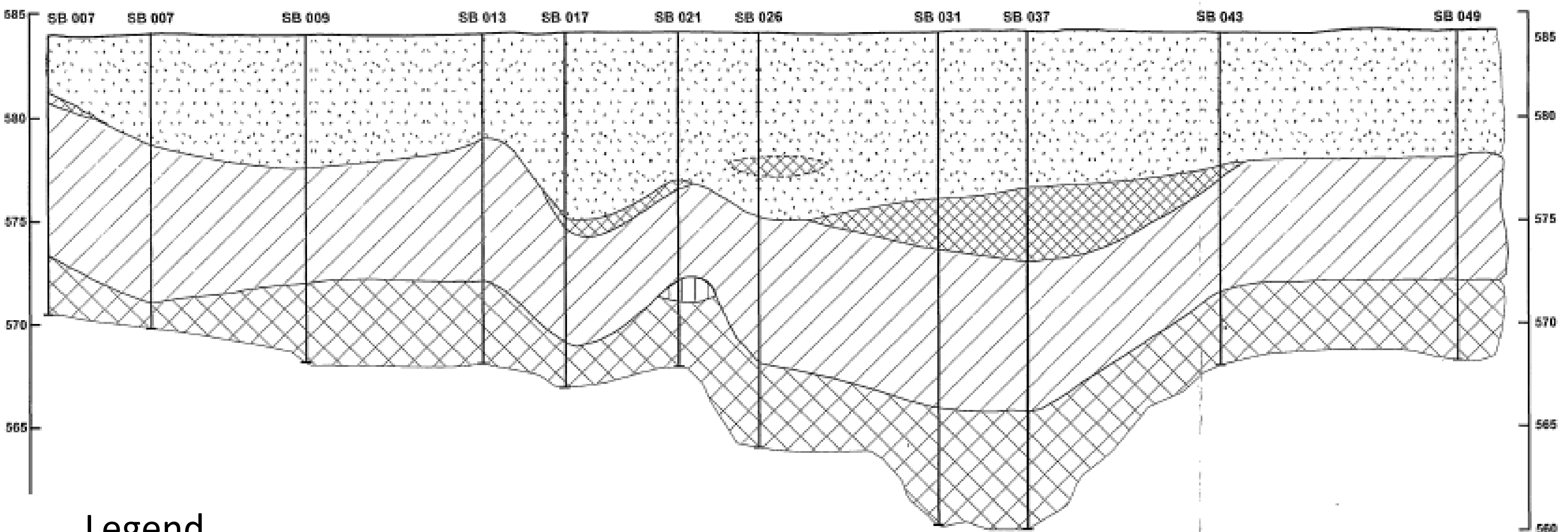



Legend

- Fill
- Sand with silt
- Organic clay with sand
- Gravel with sand
- Silty clay
- Contact uncertain

*Harza Engineering Company June 2001*

| Sediment Type | Depth | Thickness | Hydraulic Conductivity |
|---|---|---|---|
| Fill | Surface to 4-12 ft depth (variable) | 0-12 ft | Variable |
| Silty Sand | ~5-15 ft | < 20 ft | $10^{-5}$ to $10^{-3}$ cm/s |
| Clayey till/Clay | ~15-40 ft | 12-20 ft | $10^{-9}$ to $10^{-7}$ cm/s |

# Hydrogeologic Considerations - Groundwater

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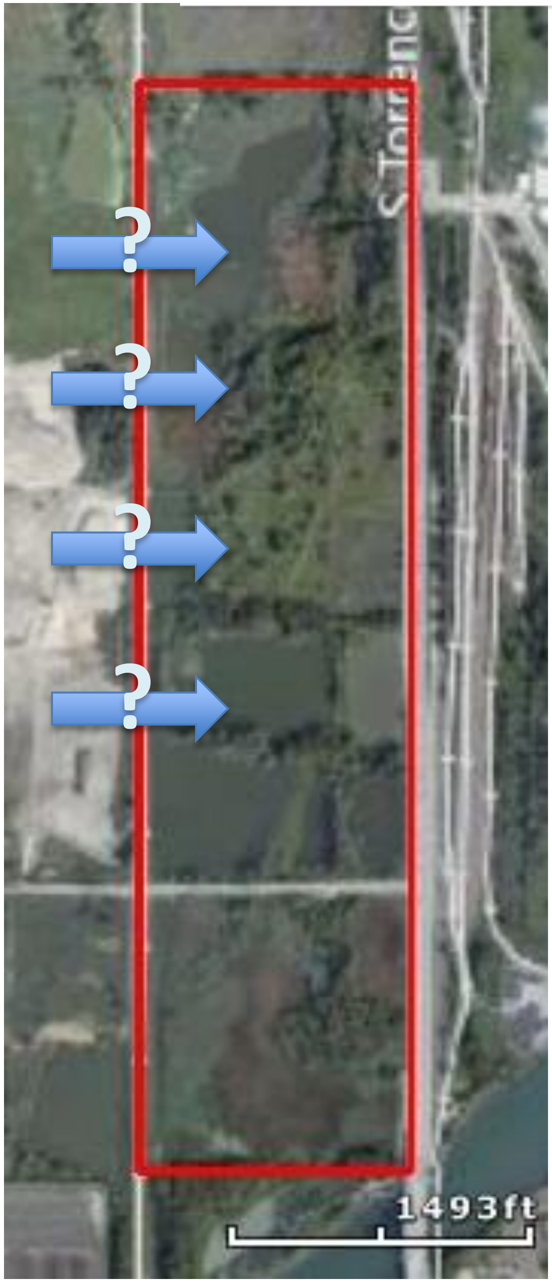
- Hydrogeology strongly influenced by **heterogeneous distribution of fill materials** throughout pre-existing wetland complex
  - **GW flow & direction not easily quantified; highly variable**
- Higher permeability surface soils, fill, and till (12-20 ft) overly a clay-rich layer

  → acts as an **aquitard limiting vertical groundwater migration**
- Primary Bedrock Aquifer:
  - Silurian Dolomite (Top elevation ~ 500ft)
- **Seasonal groundwater fluctuation of ±3.5 ft**
- Possible groundwater contribution from LCCS to the west following E-NE topographic gradient. **Actual seepage not observed.**
  - ***Potential off-site source of contamination***
- **Low hydraulic gradient estimated at 0.002 – 0.025 cm/cm**



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# Purpose:

- ***Identify remedial goals by assessing risk to human and ecological health***
  - Harza (2001) – human health COPCs
  - Tetra Tech (2009) - ecotoxicological COPCs

# Approach:

- Compare human health and ecotoxicological RBSLs to chemical concentrations
  - Tiered Approach to Corrective Action Objectives (TACO) (IAC, Title 35, Part 742)
    - ***Tier 1 - Residential***
  - Calumet Area Ecotoxicological Protocol (CAEP)
    - ***Benchmark***
  - IAC, Title 35, Part 302, Section 401, Secondary Contact and Indigenous Life Standards

# Assumptions:

- Soil
  - Ingestion and inhalation only (no dermal)
- Groundwater
  - Direct ingestion only (no soil component to groundwater)
  - Human Health – Class II
  - Ecotoxicological – surface water

# Results:

- Table of media specific ROs
- 6 soil and groundwater remedial areas

# Exposure Pathways & Sensitive Receptors

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## Primary Human Exposure Pathways

- Soil
  - Ingestion
  - Inhalation of particulates
  - Inhalation of volatiles
- Excluded pathways for RA
  - Dermal, sediment, surface water
  - Groundwater ingestion

## Ecological Pathways *(media exposure)*

- Soil
- Groundwater/surface water
- Sediment

## Sensitive Receptors

- Ecological
  - Wetland birds - 6 T&E species
    1) **Black-crowned night heron**
    2) Least bittern
    3) Pied-billed grebe
    4) King rail
    5) Black tern
    6) Common moorhen
- Human
  - Visitors
  - Remediation workers (including construction)
  - Long-term monitors & researchers
  - Volunteers

# Identified Areas of Concern (AOCs)

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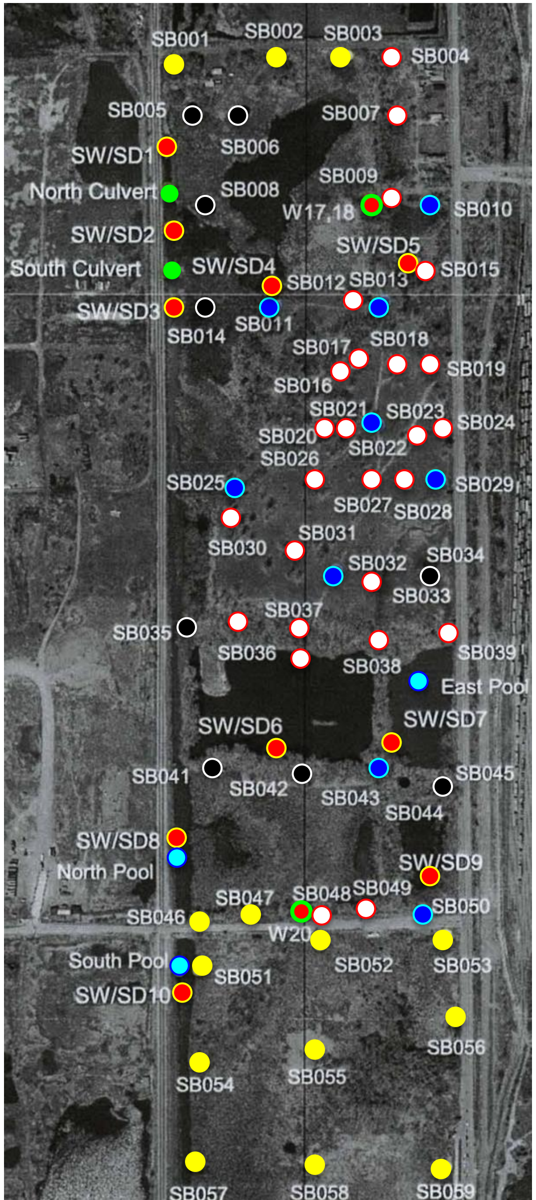


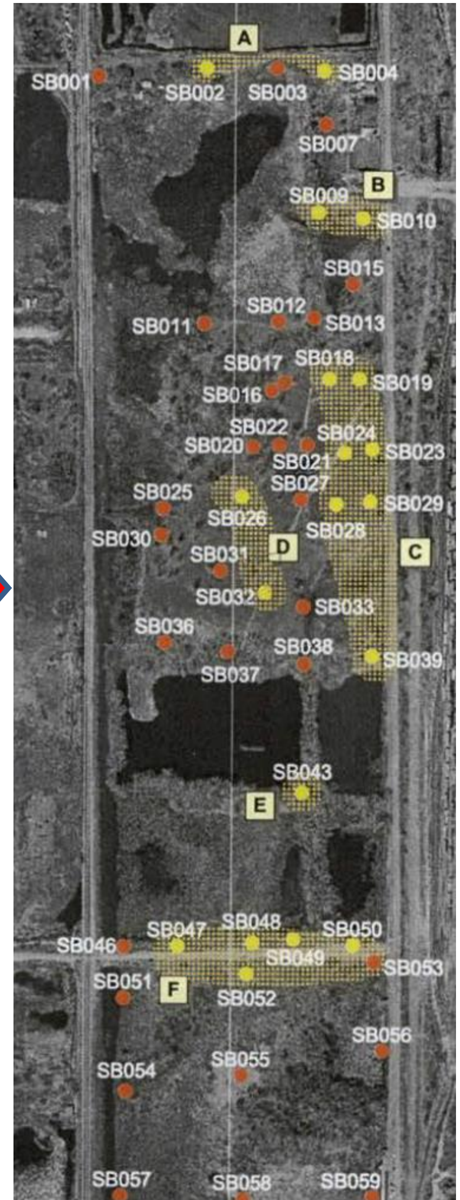


# Contaminated AOCs Summary




| | Surface area | | Media for Remediation | | Maximum Depth to Contaminant (ft) | | Average Depth to Water Table (ft) |
|---|---|---|---|---|---|---|---|
| | ft² | acres | Soil | GW | Soil | GW | |
| A | 60,000 | 1.4 | x | -- | 2.0 | -- | 1.3 |
| B | 27,000 | 0.6 | x | x | 3.0 | 14 | 2.8 |
| C | 320,000 | 7.3 | x | x | 6.5 | 13 | 6.6 |
| D | 85,000 | 2.0 | x | -- | 7.0 | --- | 4.1 |
| E | 50,000 | 1.1 | x | x | 2.0 | 13 | 2.5 |
| F | 186,000 | 4.3 | x | x | 2.0 | 19 | 2.3 |
| Total | 728,000 | 16.7 | | | | | |

| pH | Dissolved $O_{2(g)}$ | Hydraulic Conductivity (K) |
|---|---|---|
| 7.8 - 9.0* | 7.9 - 12.0 mg/L | $10^{-5} – 10^{-3}$ |

*In some areas, pH as high as 12

# Soil Remedial Objectives



| Contaminants of Potential Concern (COPC) | Sample ID (Maximum Concentration) | Data Source | Sample Depth (ft bgs) | Concentration (mg/kg) | TACO Tier 1 Residential SROs | | Calumet Area Ecotoxicology Protocol (CAEP) SROs | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Ingestion (mg/kg) | Inhalation (mg/kg) | Background (mg/kg) | Threshold (mg/kg) | Benchmark (mg/kg) |
| **Area A** | | | | | | | | | |
| Benzo(a)pyrene | SB002 | Harza (2001) | *2* | 0.22 | 0.09 | -- | 0.68 | -- [1] | -- |
| **Area B** | | | | | | | | | |
| Benzo(a)anthracene | SB009 | Harza (2001) | *3* | 3.62 | 0.9 | -- | 1.1 | -- | -- |
| Benzo(a)pyrene | SB009 | | *3* | 3.13 | 0.09 | -- | 0.0013 | 0.0113 | 0.113 |
| Benzo(b)fluoranthene | SB009 | | *3* | 3.41 | 0.9 | -- | 1.5 | 1 | 10 |
| Dibenzo(a,h)anthracene | SB009 | | *3* | 0.47 | 0.09 | -- | 0.2 | -- | -- |
| Indeno(1,2,3-c,d)pyrene | SB009 | | *3* | 1.49 | 0.9 | -- | 0.86 | 1 | 10 |
| **Area C** | | | | | | | | | |
| Benzo(a)anthracene | SB028 | Harza (2001) | *6.5* | 44.1 | 0.9 | -- | 1.1 | -- | -- |
| Benzo(a)pyrene | SB028 | | *6.5* | 29.5 | 0.09 | -- | 0.68 | -- | -- |
| Benzo(b)fluoranthene | SB028 | | *6.5* | 26.8 | 0.9 | -- | 1.5 | 1 | 10 |
| Benzo(k)fluoranthene | SB028 | | *6.5* | 31.8 | 9 | | | | |
| Dibenzo(a,h)anthracene | SB029 | | *2.5* | 8.43 | 0.09 | -- | 0.2 | -- | -- |
| Indeno(1,2,3-c,d)pyrene | SB028 | | *6.5* | 12.9 | 0.9 | -- | 0.86 | 1 | 10 |
| Lead | SB023 | | *5.5* | 1800 | 400 | -- | 36 | 16 | 430 |
| Mercury | SB023 | | *5.5* | 81.3 | 23 | 10 | 0.06 | 0.07 | 1.3 |
| **Area D** | | | | | | | | | |
| Benzo(a)pyrene | SB032 | Harza (2001) | *7* | 0.21 | 0.09 | -- | 0.0013 | 0.0113 | 0.113 |
| **Area E** | | | | | | | | | |
| Lead | SB043 | Harza (2001) | *2* | 499 | 400 | -- | 36 | 16 | 430 |
| **Area F** | | | | | | | | | |
| Benzo(a)pyrene | SB050 | Harza (2001) | *2* | 1.23 | 0.09 | -- | 0.0013 | 0.0113 | 0.113 |
| Tetrachloroethylene | SB050 | | *2* | 21.1 | 12 | 11 | -- | -- | -- |
| Trichloroethylene | SB049 | | *1* | 41.2 | 58 | 5 | -- | -- | -- |
| Benzo(a)anthracene | SB050 | | *2* | 2.6 | 0.9 | -- | 1.1 | -- | -- |
| Benzo(b)fluoranthene | SB050 | | *2* | 1.2 | 0.9 | -- | 1.5 | 1 | 10 |
| Dibenzo(a,h)anthracene | SB050 | | *2* | 0.28 | 0.09 | -- | 0.2 | -- | -- |
| Vinyl Chloride | SB050 | | *2* | 0.64 | 0.46 | 0.28 | -- | -- | -- |
| Lead | SB049 | | *1* | 648 | 400 | -- | 36 | 16 | 430 |

# Groundwater Remedial Objectives

| Contaminants of Potential Concern (COPC) | Sample ID (Max. Concentration) | Data Source | Maximum Contaminant Depth (ft bgs) | Concentration (mg/L) | TACO Tier 1 Residential GROs | Calumet Area Ecotoxicology Protocol Surface Water ROs | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Direct Ingestion of Class II GW (mg/L) | Background (mg/L) | Threshold (mg/L) | Benchmark (mg/L) |
| **Area B** | | | | | | | | |
| Manganese | SB010 | Harza (2001) | *14* | 1.11 | 10 | 0.042 | 1.0 | 1.0 |
| **Area C** | | | | | | | | |
| Manganese | SB029 | Harza (2001) | *13* | 1.19 | 10 | 0.042 | 1.0 | 1.0 |
| **Area E** | | | | | | | | |
| Manganese | SB043 | Harza (2001) | *13* | 1.48 | 10 | 0.042 | 1.0 | 1.0 |
| **Area F** | | | | | | | | |
| Benzo(a)anthracene | SB050 | | *10* | 1.50E-03 | 6.50E-04 | -- | 3.00E-05 | 2.00E-04 |
| Vinyl Chloride | SB056 | | *16* | 5.70E-02 | 1.00E-02 | -- | -- | -- |
| Iron | SB057 | Harza (2001) | *17* | 16 | 5 | 0.71 | 1 | 1 |
| Lead | SB058 | | *18* | 2.56 | 0.1 | < 0.002 | 1.67E-02 | 3.18E-01 |
| Manganese | SB059 | | *19* | 1.8 | 10 | 0.042 | 1.0 | 1.0 |
| **Additional Samples Outside of Areas of Soil Contamination** | | | | | | | | |
| Manganese | SB025 | Harza (2001) | *14* | 1.82 | 10 | 0.042 | 1.0 | 1.0 |

# Remedial Goals

| Area | Media | COPC | Maximum Depth of Contamination (ft bgs) | Contaminant Concentration (mg/kg or mg/L) | RO (mg/kg or mg/L) | % Exceedence | Governing RO HH | Governing RO Ecotox |
|---|---|---|---|---|---|---|---|---|
| A | Soil | Benzo(a)pyrene | 2 | 0.22 | 0.09 | 144 | X | |
| B | Soil | Benzo(a)anthracene | 3 | 3.62 | 0.9 | 302 | X | |
| | | Benzo(a)pyrene | | 3.13 | 0.09 | 3,378 | X | |
| | | Benzo(b)fluoranthene | | 3.41 | 0.9 | 279 | X | |
| | | Dibenzo(a,h)anthracene | | 0.47 | 0.09 | 422 | X | |
| | | Indeno(1,2,3-c,d)pyrene | | 1.49 | 0.9 | 66 | X | |
| | GW | Manganese | 14 | 1.11 | 1.0 | 11 | | X |
| C | Soil | Benzo(a)anthracene | 6.5 | 44.1 | 0.9 | 4,800 | X | |
| | | Benzo(a)pyrene | | 29.5 | 0.09 | 32,678 | X | |
| | | Benzo(b)fluoranthene | | 26.8 | 0.9 | 2,878 | X | |
| | | Benzo(k)fluoranthene | | 31.8 | 9 | 253 | X | |
| | | Dibenzo(a,h)anthracene | | 8.43 | 0.09 | 9,267 | X | |
| | | Indeno(1,2,3-c,d)pyrene | | 12.9 | 0.9 | 1,333 | X | |
| | | Lead | | 1800 | 400 | 350 | X | |
| | | Mercury | | 81.3 | 1.3 | 6,154 | | X |
| | GW | Manganese | 13 | 1.19 | 1.0 | 19 | | X |
| D | Soil | Benzo(a)pyrene | 7 | 0.21 | 0.09 | 133 | x | |
| E | Soil | Lead | 2 | 499 | 400 | 25 | x | |
| | GW | Manganese | 13 | 1.48 | 1.0 | 48 | | |
| F | Soil | Benzo(a)pyrene | 2 | 1.23 | 0.09 | 1,267 | X | |
| | | Tetrachloroethylene | | 21.1 | 11 | 92 | x | |
| | | Trichloroethylene | | 41.2 | 5 | 724 | x | |
| | | Benzo(a)anthracene | | 2.6 | 0.9 | 189 | X | |
| | | Benzo(b)fluoranthene | | 1.2 | 0.9 | 33 | X | |
| | | Dibenzo(a,h)anthracene | | 0.28 | 0.09 | 211 | X | |
| | | Vinyl Chloride | | 0.64 | 0.28 | 129 | x | |
| | | Lead | | 648 | 400 | 62 | x | |
| | GW | Benzo(a)anthracene | 19 | 1.50E-03 | 2.00E-04 | 650 | | X |
| | | Vinyl Chloride | | 5.70E-02 | 1.00E-02 | 470 | X | |
| | | Iron | | 16 | 1 | 1,500 | | X |
| | | Lead | | 2.56 | 0.1 | 2,460 | X | |
| | | Manganese | | 1.8 | 1.0 | 80 | | X |

# Remedial Technology Selection - Soil



| Technology | Disqualifying Site Conditions |
|---|---|
| **Soil Vapor Extraction** | Less effective for removal of SVOCs than VOCs; N/A for saturated soils; ineffective for heavy metals |
| **Soil Washing** | Ineffective for low-permeability soils; high cost ($$$) |
| **In-situ Chemical Oxidation** | Not appropriate for mixed contaminant classes |
| **Stabilization/ Solidification** | Shallow depth & large distribution of soil COPCs; potential for desorption of heavy metals (lead) from cement matrix over time; detrimental to plant growth & wetland restoration |
| **Monitored Natural Attenuation (MNA)** | Ineffective with some radioactive metals, and has potential for contaminant migration |
| **Electrokinetic Remediation** | Potential for significant soil pH changes incompatible with long-term habitat/wetland restoration goals |
| **Thermal Desorption** | Ineffective for heavy metals, high water table requires dewatering, Ineffective with silty soils |
| **Vitrification** | Inefficient with organic-rich soils, energy intensive, large treatment area |
| **Bioremediation** | Heavy metals resistant to degradation, partial degradation of organics generates potentially more toxic intermediaries, difficult to maintain optimal environmental conditions |

# Remedial Technology Selection - Groundwater

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| Technology | Disqualifying Site Conditions |
|---|---|
| **Pump & Treat** | Residual contamination due to tailing, rebound; high cost ($$$), less effective in silty and heterogeneous soils |
| **In-Situ Flushing** | Ineffective for silty and heterogeneous soils, unintentional contaminant spread may occur; large treatment area |
| **Permeable Reactive Barrier (PRB)** | Low horizontal hydraulic gradient, potential for clogging due to iron precipitation, potential need for media replacement |
| **Air Sparging** | Ineffective for heavy metals, inefficient for silty and heterogeneous soils. |
| **Bioremediation** | Heavy metals resistant to degradation, partial degradation of organics generates potentially more toxic intermediaries, inefficient in low-permeability or heterogeneous soils, difficult to maintain optimal environmental conditions |

# Applicable Soil & GW Remedial Technologies

| Soil Technology | Qualifying Site Conditions |
|---|---|
| **Phytoremediation/ enhanced Biostimulation** | Effective with a variety of mixed contaminants (heavy metals, PAHs, VOCs, SVOCs) in soil and groundwater |
| **Excavate** | Effective with non-hazardous and hazardous soils (PCBs, chlorinated solvents, lead) |
| **Cap/Cover + vertical barrier** | Prevents infiltration, which can lead to leaching |

| GW Technology | Qualifying Site Conditions |
|---|---|
| **Phytoremediation/ enhanced Biostimulation** | Effective with a variety of mixed contaminants (heavy metals, PAHs, VOCs, SVOCs) in soil and groundwater |
| **In-situ Containment – Slurry Trench** | Effective for containing a variety of organic & inorganic contaminants, it's cost-effective |

# GREM Matrix

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| Stressors | Affected Media | Mechanism/Effect | Score | | | |
|---|---|---|---|---|---|---|
| | | | Excavate | Phytoremediation | Cap | Slurry Trench |
| **Substance Release/Production** | | | | | | |
| Airborne NOx & SOx | Air | Acid rain & photochemical smog | Average | Below Avg | Average | Average |
| Chloro-fluorocarbon vapors | Air | Ozone depletion | Below Avg | Below Avg | Average | Average |
| Greenhouse gas emissions | Air | Atmospheric warming | Above Avg | Below Avg | Average | Average |
| Airborne particulates/toxic vapors/gases/water vapor | Air | General air pollution/toxic air/humidity increase | Average | Below Avg | Average | Average |
| Liquid waste production | Water | Water toxicity/sediment toxicity/sediment | Average | Average | Below Avg | Below Avg |
| Solid waste production | Land | Land use/toxicity | Above Avg | Average | Below Avg | Average |
| **Thermal Releases** | | | | | | |
| Warm water | Water | Habitat warming | N/A | Average | N/A | N/A |
| Warm vapor | Air | Atmospheric humidity | N/A | Average | N/A | N/A |
| **Physical Disturbances/Disruptions** | | | | | | |
| Soil structure disruption | Land | Habitat destruction/ soil Infertility | Above Avg | Average | Above Avg | Above Avg |
| Noise/Odor/Vibration/Aesthetics | General environment | Nuisance & safety | Above Avg | Below Avg | Above Avg | Average |
| Traffic | Land; general environment | Nuisance & safety | Above Avg | Below Avg | Above Avg | Average |
| Land Stagnation | Land; general environment | Remediation time; cleanup efficiency;re-development | Above Avg | Above Avg | Average | Average |
| **Resource Depletion/Gain (Recycling)** | | | | | | |
| Petroleum (energy) | Subsurface | Consumption | Average | N/A | Average | Average |
| Mineral | Subsurface | Consumption | Average | N/A | Below Avg | Average |
| Construction materials (soil/concrete/plastic) | Land | Consumption/reuse | Above Avg | Below Avg | Above Avg | Average |
| Land & space | Land | Impoundment/reuse | Average | Above Avg | Above Avg | Average |
| Surface water & groundwater | Water, land (subsidence) | Impoundment/ sequester/reuse | Average | Average | Above Avg | Average |
| Biology resources (plants/trees/animals/microorganisms) | Air, water, land/forest, subsurface | Species disappearance/ diversity reduction regenerative ability reduction | Average | Average | Above Avg | Above Avg |

# Quantitative Assessment: SiteWise™ – Area C

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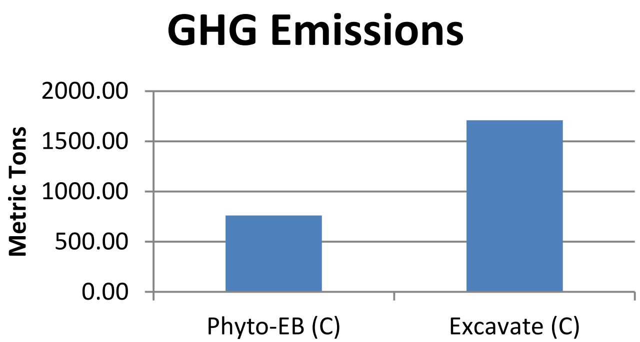
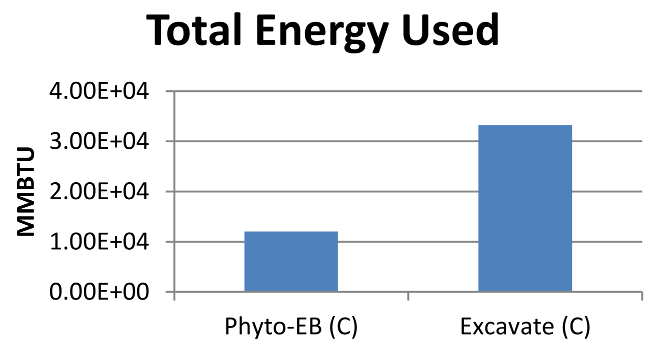
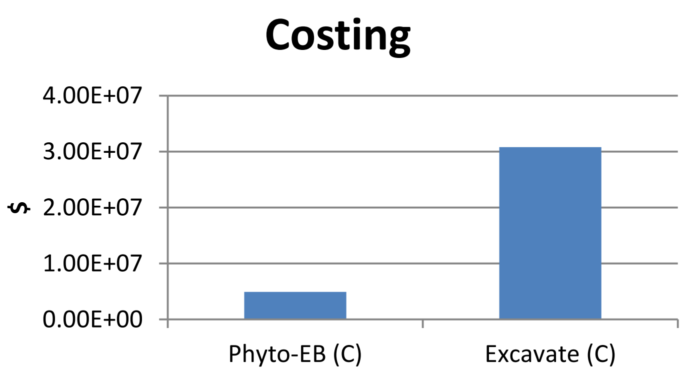
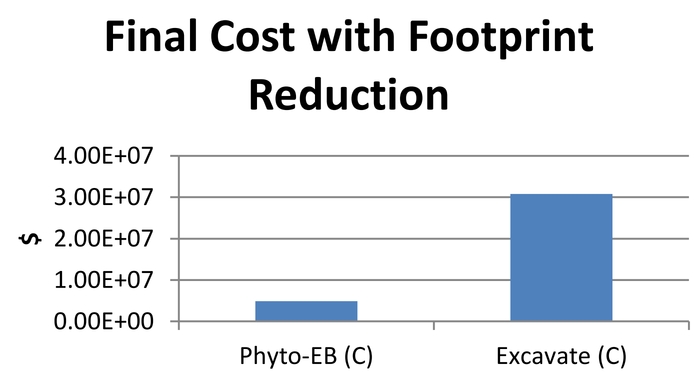
**Relative Impact**

| Remedial Alternatives | GHG Emissions | Energy Usage | Water Usage | NOx emissions | SOx Emissions | PM10 Emissions | *Accident Risk Fatality | *Accident Risk Injury |
|---|---|---|---|---|---|---|---|---|
| Phyto-EB (C) | Medium | Medium | High | Medium | Low | Low | High | High |
| Excavate (C) | High | High | Low | High | High | High | High | Medium |



# Final Remedial Selection

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- **Preliminary evaluation of potential remedial technologies allowed disqualification of multiple methods based on site-specific conditions:**
  - Incompatibility with heterogeneous and silty soils
  - Saturated soils due to high water table
  - Chemical impacts on soil composition unsuitable for habitat rehabilitation
  - Uncertainty of long-term containment
  - Incompatibility with particular COC's and Mixtures
  - Low or uncertain groundwater flow

- **Qualitative (GREM) and Quantitative analysis (Sitewise™, Sustainable Remediation Tool™) allowed comparison of energy inputs and environmental sustainability of remaining technologies :**
  - Site disturbance
  - Material, energy, and total water inputs
  - Particulate ($PM_{10}$) and GHG emissions (i.e. $CO_2$, $NO_x$, $SO_x$)
  - Cost estimate comparison
  - Long-term waste disposal and treatment needs
  - Worker health & safety risks

- **Site-Specific engineering requirements: 122$^{nd}$ St. causeway located within remediation Area F poses technical challenges influencing final cost and input projections**

## Final Remedial Selection:

**Phytoremediation & Enhanced Biostimulation**

# Quantitative Assessment – SiteWise™ – Area C

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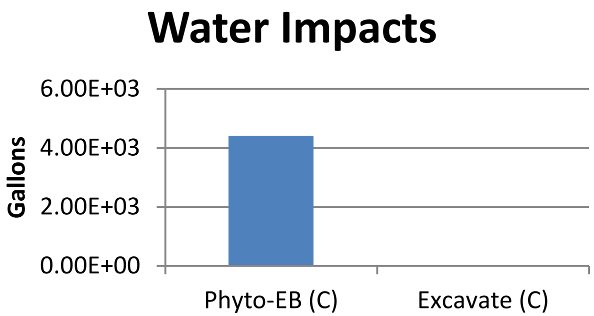


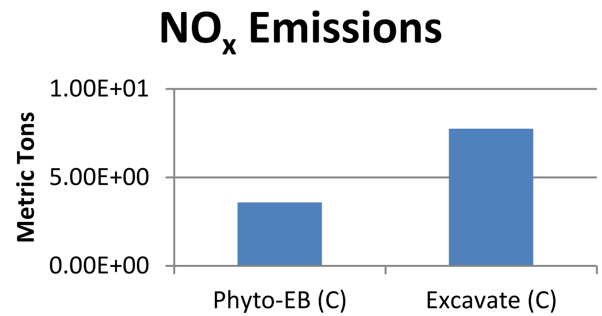


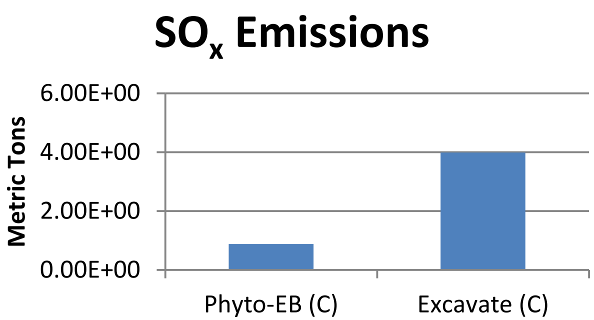


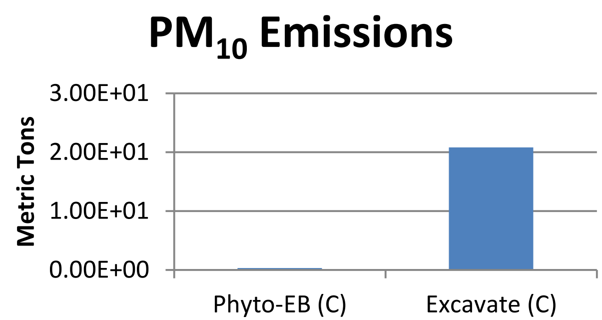


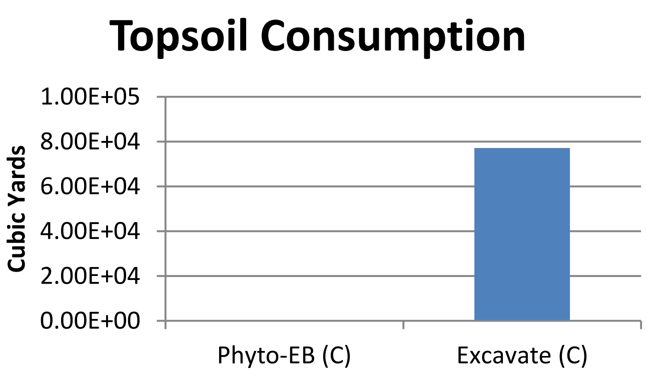


Other Metrics Evaluated with SiteWise™:

- Accident Risk of Fatality & Injury
- Lost hours due to Injury
- Hazardous & Non-Hazardous Landfill Space (tons)

# Phytotechnology Mechanisms & Remedial Goals

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| Mechanism | Description | Remedial Goal |
|---|---|---|
| Phytosequestration | Sequestration of some contaminants in rhizosphere via exudation of phytochemicals & transport proteins & cellular processes on root | Containment |
| Rhizodegradation | Exudation of phytochemicals enhances microbial degradation of contaminants in the rhizosphere | *In-Situ* degradation of contaminants |
| Phytohydraulics | Ability of plants to evapotranspire sources of surface water and groundwater | Containment via hydrologic controls; will be applied at riparian buffer zones* |
| Phytoextraction | The ability of plant roots to extract, transport & accumulate contaminants aboveground in the shoots/leaves | Removal of COPC by disposal of plants* |
| Phytodegradation | Ability of plants to break down contaminants in the transpiration stream via internal enzymatic activity & photosynthetic oxidation/reduction | *In-Situ* degradation of contaminants |
| Phytovolatilization | Ability of plants to translocate & transpire volatile contaminants | Removal of COPCs (VOC, PAHs) through plants |

ITRC - *Phytotechnology Technical and Regulatory Guidance and Decision Trees* (2009).

# Phytoremediation - Design Specifications



**Selected Tree & Plant Species:**

- Chosen based on maximum uptake of organic and inorganic contaminants
- Demonstrated remedial efficacy at sites in the region
  - Argonne National Laboratory-East : nearby site; similar climate, local flora & fauna, and hydrogeology

- **Phreatophyte tree stands** (Willows, Cottonwoods, and Poplars)
  - High transpiration and growth rates; high water consumption
  - Long root systems that maximize contact with pollutants in groundwater
- Grasses and legumes used as **vegetative cover** within and around treated areas
  - Minimize erosion and stabilize soil; also serve to remediate shallow subsurface contamination
  - Enhance overall water consumption and reduce infiltration (minimizing leachate production)
  - Keep shallow soils dry to promote deeper rooting depths of the phreatophytic trees
- **Riparian buffer** of Reeds, Bulrush & Cattails around surface waters
  - Increase infiltration & minimize erosion of wetland shores; minimize runoff & migration of contaminated surface waters

**Existing Vegetation:**

- Native vegetation with known phytoremedial properties left in place
- Vegetation not applicable for phytoremediation AND not considered an invasive species will be cleared and chipped for compost
- Non-native invasive species will be removed completely (not composted to reduce possibility of reincorporation of invasive species into soil)

# Existing Vegetation

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- Only 51% of on-site vegetation identified as native species (marked by an *)
- Dominant existing vegetation – Common Reed (*Phragmites* spp.) - is more tolerant to high salinity (~20,000 mg/kg) than native vegetation
  - Common Reed also provides interim nesting habitat for black-crowned night heron

| **Plant Name/Species** | **Targeted Contaminants** | **Recommendation for Use?** |
|---|---|---|
| Common water plantain (*Alisma subcordatum*)* | TBD or N/A | Determination based on analysis |
| Path rush (*Juncus tenuis)** | TBD or N/A | Determination based on analysis |
| Small duckweed (*Lemna minor*)* | Pb, Cr(VI), certain pesticides | **Yes** |
| Switchgrass (Panicum virgatum) | Anthracene, PAHs, Pyrene | **Yes** |
| Common reed (*Phragmities* spp.) | Benzene, Trichloroethane, Toulene, PCE, TCE, Cu, Fe, Mn | **Yes** |
| Eastern cottonwood (*Populus deltoides*) | TCE, PCE | **Yes** |
| Box elder (*Acer negundo*) | TBD or N/A | Determination based on analysis |
| Hackberry (*Celtis occidentalis*) | TBD or N/A | Determination based on analysis |
| Green ash (*Fraxinus penn.*) | TBD or N/A | Determination based on analysis |

# Enhanced Biostimulation



**Purpose:**

- Support plant growth & enhance phytoremedial processes
- Stimulate the natural microbial population in rhizosphere of trees
- Improve overall soil quality & stimulate soil microbial community

**Strategy**: Incorporation of $O_2$ and nutrients in tilled soil

- $O_2$ Amendment
  Supplied via **ORC**s (Oxygen Release Compounds – $MgO_2$)
  - Instead of direct injection (reducing energy and equipment costs)
  - Soil pH must be monitored ($MgO_2$ can raise pH)
- NPK fertilizer (10-10-10)
  - One initial application after tree installation
  - Further applications as needed to prevent excessive losses
- Additional amendments as needed
  - Granular Sulfur or $Al_2(SO_4)_3$ to reduce soil pH to levels for optimal tree growth (ex: Poplar grows optimally with pH of 5.5-8.0) at select locations
  - Additional organic compost each spring to promote optimal plant growth & maintain pH

# Phytoremediation – Implementation



## Time of Year

- Trees and plants installed early in year (spring) to take advantage of entire growing season; remedial progress greatest during growth

## Soil Preparation

- Areas to be tilled to aerate soil prior to planting (12-24 in); soil amendments added during tilling, eliminating need for injection wells
- Soil should be damp during installation to minimize dust production & potential exposure of contaminated soils/sediments to workers

## Dimensions & Placement

- Each tree placed in <u>2 ft diameter trench</u> dug to <u>variable depths 10-15 ft bgs</u>
- In areas with GW contamination, 50% of trees will be lined with tree wells to promote downward root growth into the aquifer
- Trees <u>spaced ~10 feet apart</u> to achieve high growth density → maximum remedial efficiency

***Area E Only:** Installation of 1 injection well for application of EDTA (chelating agent) to enhance Pb uptake

# Planting Scheme

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| | Seed Mix (lbs) | Willows | Cottonwoods | Hybrid Poplars | Fencing (yards) | Fertilizer (lbs) | Rows | Columns |
|---|---|---|---|---|---|---|---|---|
| **Area A** | 128 | 48 | 48 | 96 | 481 | 180 | 6 | 32 |
| **Area B** | 54 | 21 | 21 | 43 | 280 | 81 | 5 | 17 |
| **Area C** | 640 | 250 | 250 | 500 | 1040 | 960 | 69 | 13 |
| **Area D** | 170 | 67 | 67 | 135 | 270 | 255 | 27 | 10 |
| **Area E** | 100 | 40 | 40 | 80 | 225 | 150 | 10 | 10 |
| **Area F (North)** | 141 | 36 | 36 | 72 | 780 | 325 | 4 | 35 |
| **Area F (South)** | 202 | 82 | 82 | 165 | 805 | 250 | 6 | 55 |
| Sum | 1435 | 544 | 544 | 1091 | 3381 | 2201 | 127 | 299 |

# Planting Scheme

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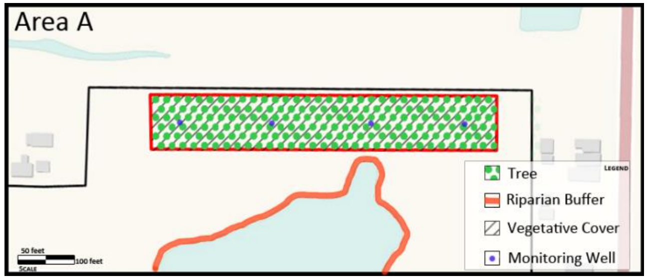
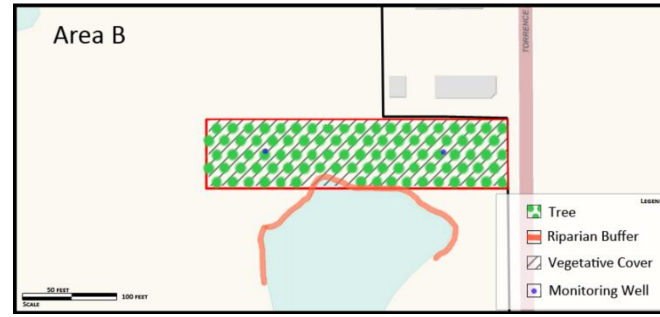
Total Phytoremedial Area

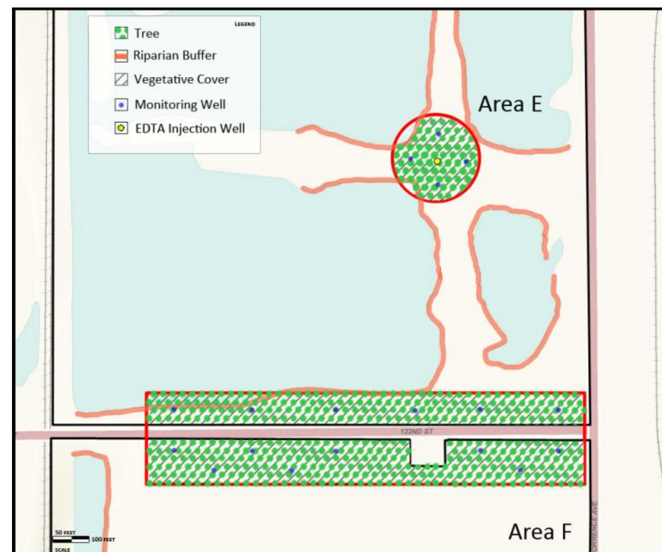
A + B + C + D + E + F(soil)

728,000 ft$^2$ = 16.7 acres







# Final Recommendations



- Initiate phytoremediation at all Areas of Concern
  - Mixed tree stands of Willows, Cottonwoods, and Poplars → Soil/GW
  - Vegetative cover of grasses and legumes to address shallow subsurface soils
  - Riparian buffer zones of cattails, bulrush, and reeds around surface water bodies to minimize runoff and interaction with contaminated groundwater

- Long-term Monitoring:
  - Minimize potential adverse effects on native vegetation and wildlife
  - Ensure non-native/invasive species are not introduced into seedbank
  - Install additional monitoring wells at under-represented areas for LTM

- Ensure adequate habitat is preserved for seasonal migratory birds during earthwork & agricultural activities

- Gain public support & awareness of phytoremediation and sustainable practices used at Indian Ridge Marsh
  - Community involvement through educational activities & bulletins describing habitat restoration, native species and phytoremedial progress

# Thanks for listening!

## Acknowledgements:

**Purdue Geotechnical Society**

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