Historical Landfills:

Not Your Regular Brownfield sites

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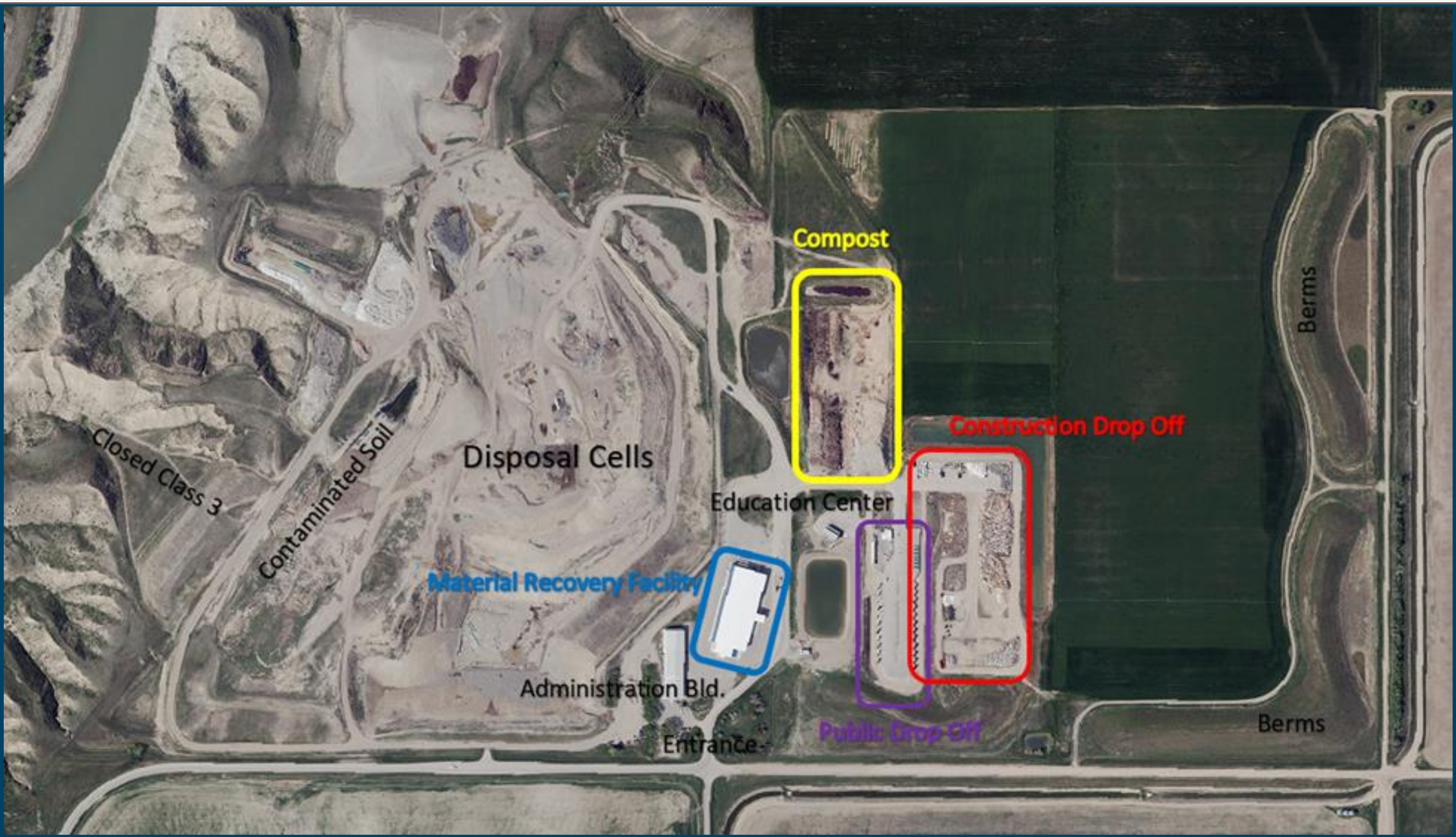
Modern Landfills

- Integrated waste management facilities for safe disposal
- Often provide recycling and composting options
- Designed to contain waste long-term, manage leachate and landfill gas
- Have adequate setback distances from receptors
- Monitored performance; minimize impacts
- Generate revenue, closure and post-closure cost covered

Municipal Solid Waste

Modern Setup



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Historical Landfills

- Often just a dump located where it was cost effective and convenient, including in depressions, gravel pits
- Seldom adequate containment and often poor record keeping
- May now be surrounded by commercial and residential developments
- Potential groundwater quality or vapour migration issues

Common Issue: Modern vs. Historical

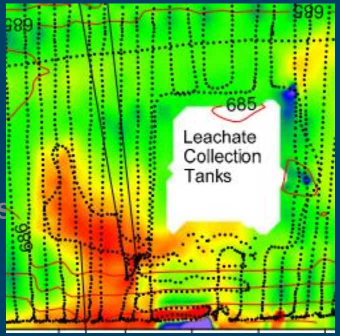
- Landfills are “permanent”
- Seldom is source removal an option
- Care and control needed for decades
- There are hundreds of closed landfills
- Pragmatic and cost-effective approach needed

Building a Conceptual Site Model
(Closed) Landfills are Unique

- Not your "regular" contaminated site
- Consider how they are constructed, how they behave and interact with surroundings
  - Foundation properties and local geology/hydrogeology?
  - What is the nature of waste and how was it placed?
  - How is it capped/closed?
  - What is the waste doing now? (leachate, LFG, waste exposure)
  - How do we prioritize public safety and the environment?
  - How do we balance with limited resources?

- They don't go away; monitoring and management programs need to be pragmatic, simple and effective

Assessments - Building a CSM



EM pics

- Historical operations (Phase I) – where, what, how
- Focus on receptors, groundwater flow, vapour migration pathways
- Possible use of non-intrusive tools - geophysics
- Drill and install monitoring wells, vapour probes
- Monitor, sample, chemical analyses
- Data evaluation

Conceptual Site Model Summary

Release Mechanism	COPC	Migration Pathway	Potential Receptor	Exposure Pathway
Leachate infiltration into foundation or through cover	Nutrients and inorganics; metals; PHCs; VOCs.	Migration vertically to groundwater then carried with groundwater flow.	Human users of water (i.e., water well); aquatic life.	P1 - Migration to off-site groundwater user or receptor (i.e., well/waterbody).
		Direct seepage from landfill to runoff.	Aquatic life; human users of site.	P2 - Migration to surface waterbody (e.g., river) or direct exposure to human users of site.
LFG emissions	Methane, H_2S, NMOCs; climate change effects.	Migration upwards through cover.	Human users of site; terrestrial receptors.	P3 - On-site surface emissions.
		Migration laterally above water table, or volatilization from dissolved constituents in groundwater.	Human users of site; enclosed buildings.	P4 - Migration to on-site or off-site receptors.
Erosion	Nutrients and inorganics; metals; PHCs; VOCs.	Carried with runoff or via dust.	Human users of site; terrestrial receptors; aquatic receptors.	P5 - Direct exposure to waste or leaching to surface water.

Note:

PHC – petroleum hydrocarbons

NMOC – non-methane organic compounds

VOC – volatile organic compounds

Prioritization and Characterization of Risks

- Risk management strategy based on exposure control – engineering measures; monitoring; contingency response planning based on ongoing management and monitoring programs
- Possible components or options:
  - Focused monitoring; groundwater, LFG, leachate, erosion
  - Engineering measures
    - Cover improvements; positive drainage, limit infiltration
    - LFG management; passive or active
    - Leachate management
  - Administrative controls to limit activity and development
- Source will remain – needs to be understood and managed

Focussed Monitoring Programs

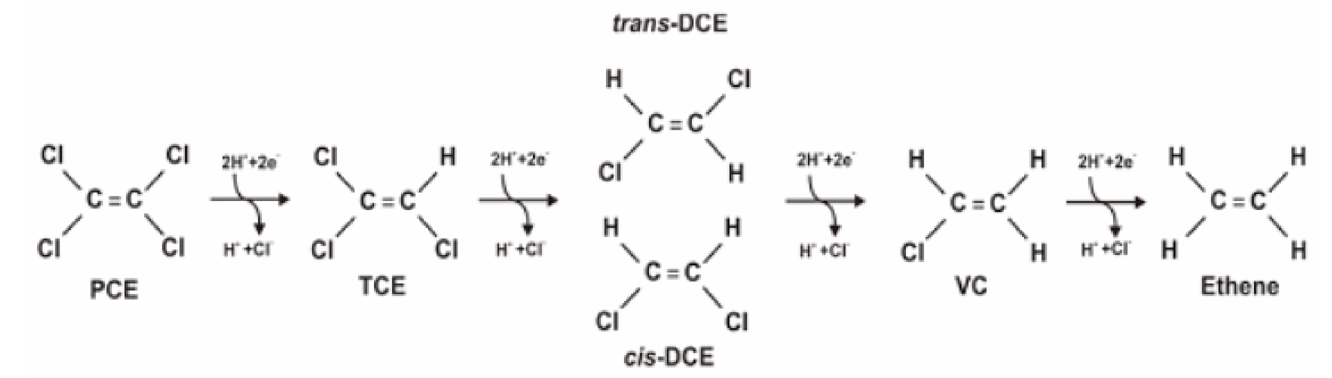
- LFG monitoring
- Leachate monitoring and sampling
- Groundwater monitoring and sampling
- Monitor seepage, erosion, settlement


Let's start with the source...

- Leachate composition varies depending on age of landfill and type of waste – can vary across a landfill
- Often highly saline, with organic contaminants (e.g. hydrocarbons, solvents) and deeply anoxic (methanogenic)
- Useful parameters to evaluate potential groundwater quality impact: chloride, boron, indicators or anoxic conditions (nitrate, manganese, iron, sulphate, ammonia), DOC, VOCs
- Quality will change very slowly with various persistent compounds (e.g. PFAS)

Data Evaluation Considerations

- Comparing to generic guidelines is not necessarily useful if upgradient/background groundwater is naturally saline and/or has exceedances for various metals (e.g. manganese, selenium, uranium)
- Focus on parameters that are abundant in the leachate (DOC, ammonia) and mobile (chloride, boron)
- Understand which VOCs may be present in older landfills and why (e.g. chlorinated solvents and breakdown products like vinyl chloride)



Data Evaluation – Leachate and Groundwater

In leachate – redox processes rule:

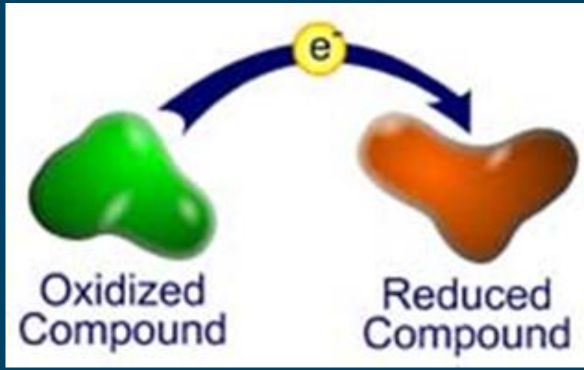
- Typically no nitrate due to denitrification
- Elevated manganese, iron and the release of co-precipitated arsenic
- High ammonium
- Sulphate reduction – forms sulphides that hold back metals
- Methanogenesis

In groundwater:

- Key indicators are conservative, mobile parameters abundant in leachate (chloride, boron)
- Supported by redox sensitive parameters nitrate, dissolved manganese, iron, arsenic, sulphate, ammonium
- Other COPCs like VOCs or gross indicators like DOC

Time and money wasters:

- Relying on field measurements of DO or ORP
- Using non-field filtered or total metals results
- Analyzing BOD, COD or TKN in groundwater



Design and Implement a Program

- Focus on good quality data
- More is not necessarily better
- Use CSM summary to focus on sampling:
  - Surface water
  - Downgradient monitoring wells
  - Water source wells
  - Vapour migration

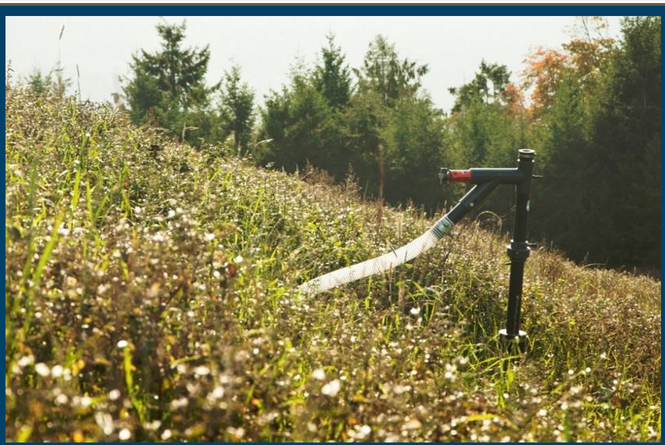
- Adjust frequency, sample locations, analytical program where needed to make the program more effective

Engineering measures and Site Uses

- Cover system improvements
  - Repair / correct issues
  - Positive drainage, limit infiltration
  - Evapotranspiration (ET) bio covers
- LFG management - Active / Passive
- Leachate management
- Future land use options

Cover Improvements

Manage Landfill Gas – Active or Passive



Manage Leachate

Land use examples

- Off-leash area
- Solar farm
- Cap and convert into transfer station

Being Pragmatic Into the Future

- Prepare a robust CSM get a better understanding of geology, COPCs, receptors
- Design an effective monitoring program to manage the site as efficiently and effectively as possible
- Ongoing evaluation of priorities for risk management:
    - Are the results in line with what the CSM suggests?
    - Is there a potential for other impacts? – slope stability; mobilization
    - Is the program still effective? Can it be reduced? (site there 'forever')
    - Do we need to implement contingency actions? Leachate? LFG?

Questions?

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