Screening-level Assessment of Uncapped Landfills in the Pinelands Area

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Project Background

- There are at least 60 closed, uncapped landfills in the New Jersey Pinelands.
- Which of these pose environmental or health concerns, based on down-gradient water quality?
- Which need more monitoring or remediation before redevelopment?”
Project objectives

- Develop a screening tool for assigning *levels of concern* for closed, uncapped landfills
  - Based solute transport from landfills to receptors
  - Must consider concentrations of contaminants at receptors relative to regulatory concentrations
- Apply screening tool to landfills in the New Jersey Pinelands
  - Predict contaminant concentrations reaching receptors
  - Assess level of concern
Principal sources of Information

- Monitoring Well Lab Results
- GIS data (NJDEP and USGS)
- State and Federal Water-Quality Standards
- Published chemical property data for contaminants
- Solute transport model
Domenico approach to groundwater-transport model

- Based on widely used transport equations
- Supported by the USEPA.
  - USEPS Center for Subsurface Modeling Support
    - BIOSCREEN, BIOCHLOR, FOOTPRINT, and REMChlor
- Spreadsheet version developed by PA DEP
  - “Quick Domenico”
- Estimates contaminant concentration down-gradient from a source
Receptors were defined as:

- Nearest *stream* to landfill
- Nearest *wetlands* to landfill
- Nearest *residential area* to landfill
Geographical Information System (GIS) Map showing a Landfill in the Pinelands and Receptors.
Quick Domenico model spreadsheet

Limitations: Only one scenario per worksheet, no provision for archiving scenarios, several input parameters could be calculated automatically (dispersivities, time to steady-state), graphics of limited value
Quick Domenico is a classic, But our new model is a Rolls Royce!

Under the hood:
- Up to 50 simulations on a single spreadsheet
- Automatic calculation of appropriate run time and dispersivity
- Regulatory values of contaminants for comparison to model outputs
A simulation (from numbers 1-50 is selected, and all parameters and results for that simulation are shown in the spreadsheet. Results as a percent of a regulatory value also are shown.
<table>
<thead>
<tr>
<th>Simulation Number</th>
<th>Receptor</th>
<th>Contaminant</th>
<th>Source Concentration (ug/L)</th>
<th>Decay constant (days(^{-1}))</th>
<th>Source Width (ft)</th>
<th>Source Thickness (ft)</th>
<th>Hydraulic Conductivity (ft/day)</th>
<th>Hydraulic Gradient (ft/ft)</th>
<th>Porosity (dimensionless)</th>
<th>Soil Bulk Density (g/cm(^3))</th>
<th>KOC</th>
<th>Fraction Organic Carbon x(ft) y(ft) z(ft)</th>
<th>Regulatory Value (ug/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stream</td>
<td>Chloride</td>
<td>40666.7</td>
<td>0</td>
<td>868</td>
<td>10</td>
<td>50</td>
<td>0.010</td>
<td>0.358</td>
<td>1.70</td>
<td>0.0</td>
<td>0.001</td>
<td>230000.00</td>
</tr>
<tr>
<td>2</td>
<td>Wetlands and Hydric So</td>
<td>Chloride</td>
<td>40666.7</td>
<td>0</td>
<td>868</td>
<td>10</td>
<td>50</td>
<td>0.010</td>
<td>0.358</td>
<td>1.70</td>
<td>0.0</td>
<td>0.001</td>
<td>230000.00</td>
</tr>
<tr>
<td>3</td>
<td>Residential</td>
<td>Chloride</td>
<td>40666.7</td>
<td>0</td>
<td>868</td>
<td>10</td>
<td>50</td>
<td>0.010</td>
<td>0.358</td>
<td>1.70</td>
<td>0.0</td>
<td>0.001</td>
<td>250000.00</td>
</tr>
<tr>
<td>4</td>
<td>Stream</td>
<td>Nitrogen, Amm</td>
<td>17100.0</td>
<td>0.1</td>
<td>868</td>
<td>10</td>
<td>50</td>
<td>0.010</td>
<td>0.358</td>
<td>1.70</td>
<td>3.1</td>
<td>0.001</td>
<td>7</td>
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<td>Nitrogen, Amm</td>
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<td>0.1</td>
<td>868</td>
<td>10</td>
<td>50</td>
<td>0.010</td>
<td>0.358</td>
<td>1.70</td>
<td>3.1</td>
<td>0.001</td>
<td>7</td>
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<tr>
<td>6</td>
<td>Residential</td>
<td>Nitrogen, Amm</td>
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<td>0.1</td>
<td>868</td>
<td>10</td>
<td>50</td>
<td>0.010</td>
<td>0.358</td>
<td>1.70</td>
<td>3.1</td>
<td>0.001</td>
<td>250</td>
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<tr>
<td>7</td>
<td>Stream</td>
<td>Nitrogen, Nitrat</td>
<td>500.0</td>
<td>0.001265753</td>
<td>868</td>
<td>10</td>
<td>50</td>
<td>0.010</td>
<td>0.358</td>
<td>1.70</td>
<td>0.0</td>
<td>0.001</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>Wetlands and Hydric So</td>
<td>Nitrogen, Nitrat</td>
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<td>0.001265753</td>
<td>868</td>
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<td>0.010</td>
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<td>0.001</td>
<td>7</td>
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<td>10</td>
<td>50</td>
<td>0.010</td>
<td>0.358</td>
<td>1.70</td>
<td>0.0</td>
<td>0.001</td>
<td>250</td>
</tr>
</tbody>
</table>

- Up to 50 scenarios are entered and archived per landfill
- Regulatory values are input
### QDM: Automatically-calculated input parameters

<table>
<thead>
<tr>
<th>Simulation Number</th>
<th>Dispersivity</th>
<th>Simulation Time</th>
<th>Model Length</th>
<th>Model Width</th>
<th>Conc. At Steady State</th>
<th>Velocity</th>
<th>Regulatory Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15.44 1.5 0.001</td>
<td>1355 3.7</td>
<td>1136 868</td>
<td>1.40</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.00 0.0 0.001</td>
<td>13 0.0</td>
<td>11 868</td>
<td>1.40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8.13 0.8 0.001</td>
<td>448 1.2</td>
<td>375 868</td>
<td>1.40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>15.44 1.5 0.001</td>
<td>587 1.6</td>
<td>1136 868</td>
<td>1.38</td>
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<tr>
<td>5</td>
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<td>13 0.0</td>
<td>11 868</td>
<td>1.38</td>
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</tr>
<tr>
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<td>8.13 0.8 0.001</td>
<td>248 0.7</td>
<td>375 868</td>
<td>1.38</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>15.44 1.5 0.001</td>
<td>1319 3.6</td>
<td>1136 868</td>
<td>254.13 79.4</td>
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</tr>
<tr>
<td>8</td>
<td>0.00 0.0 0.001</td>
<td>13 0.0</td>
<td>11 868</td>
<td>1.40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>8.13 0.8 0.001</td>
<td>441 1.2</td>
<td>375 868</td>
<td>1.40</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Dispersivities, time to steady-state and model dimensions are calculated.
- Contaminant concentration and % of regulatory value are calculated for the selected simulation number (in this case 7).
Model limitations

• Non-varying dispersivity
• Assumption of receptors being down-gradient (model allows for other options)
• Literature reaction rates and KOC values apply
• No attenuation from precipitation, storage, or discharge into streams between source and receptor
• Source contaminant concentrations are constant and not depleted
• Source geometry = landfill geometry
Applying QDM to Pinelands landfills

- Identify distance from landfill to nearest receptors:
  - Stream
  - Wetlands
  - Residential

- Simulate concentration of Cl⁻ at each receptor:
  - Most conservative, “worst case” scenario

- Select other contaminants to be simulated
  - Based on concentration and detection frequency
Criteria for Selecting contaminants to simulate

- Frequently detected
- High concentration relative to regulatory standards
- Informed judgment
Concentrations of contaminants used in models

- Highest average daily concentration among all monitoring wells samples
Assessing Vulnerability of Groundwater to Contaminants of Concern (COCs) from Landfills

- **Level of Concern = Unknown**  
  - Data are insufficient to characterize the presence of COCs.

- **Level of Concern = Low**  
  - COCs do not reach receptors at concentrations greater than the Practical Quantitation Limit (PQL).

- **Level of Concern = Moderate**  
  - COCs reach receptors at concentrations greater than the PQL but less than 50% of any relevant regulatory standard.

- **Level of Concern = High**  
  - COCs reach receptors, which may be coincident with the landfill, at concentrations greater than or equal to 50% of one or more relevant regulatory standards.
Vulnerability assessment

<table>
<thead>
<tr>
<th>Level of Concern for Specific Analytes and Receptors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organics and Inorganics Excluding Nutrients</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Stream</td>
</tr>
<tr>
<td>High (A), but not a COC</td>
</tr>
<tr>
<td>Wetland or Hydric Soil</td>
</tr>
<tr>
<td>High (A), but not a COC</td>
</tr>
<tr>
<td>Residential</td>
</tr>
<tr>
<td>High (A), but not a COC</td>
</tr>
</tbody>
</table>

**Summary of Domenico Results: Level of Concern (Excluding Nutrients)**

<table>
<thead>
<tr>
<th>Level of Concern</th>
<th>Criteria</th>
<th>Meets criteria?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown</td>
<td>Data are insufficient to characterize the presence of COCs.</td>
<td>No</td>
</tr>
<tr>
<td>Low</td>
<td>COCs do not reach receptors at concentrations greater than the practical quantitation limit (PQ).</td>
<td>Yes (non-nutrients)</td>
</tr>
<tr>
<td>Moderate</td>
<td>COCs reach receptors at concentrations greater than the PQL but less than 50% of any relevant regulatory standard.</td>
<td>No</td>
</tr>
<tr>
<td>High (A)</td>
<td>COCs reach receptors at concentrations greater than or equal to 50% of one or more relevant regulatory standards.</td>
<td>Yes (nutrients)</td>
</tr>
<tr>
<td>High (B)</td>
<td>Receptor coincides with landfill location, where COC concentration is greater than or equal to 50% of one or more relevant regulatory standards.</td>
<td>No</td>
</tr>
</tbody>
</table>

Domenico simulation indicates that the level of concern for this landfill is of low for non-nutrients and high for nutrients.
## Summary of Model Results: Number of Landfills for Each Level of Concern

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total landfills studied</td>
<td>48</td>
</tr>
<tr>
<td>Unknown level of concern (insufficient data)</td>
<td>18</td>
</tr>
<tr>
<td>Low level of concern</td>
<td>12</td>
</tr>
<tr>
<td>Moderate level of concern</td>
<td>0</td>
</tr>
<tr>
<td>High level of concern</td>
<td>18</td>
</tr>
</tbody>
</table>
Summary of Model Results (continued)

- Contaminants responsible for high level of concern
  - Arsenic (2 landfills)
  - Barium (3 landfills)
  - Benzene (1 landfill)
  - Cyanide (1 landfill)
  - Lead (8 landfills)
  - Mercury (2 landfills)
  - Selenium (1 landfill)
Summary: Results of This Study

- Groundwater quality under 30 landfills
  - Based on historical water-quality data
- Modeling tool to assess down-gradient threat levels
  - Screening-level Microsoft Excel application “Quick Domenico Multiscenario”
- Results of modeling for 30 landfills
  - Water quality at down-gradient receptors
- Levels of concern at 30 landfills
  - Based on regulatory contaminant concentration and modeling results
- Journal article
- Potential future related projects with NJDEP
Determining time required to reach steady state conditions

- Domenico model can be solved for time required to achieve 50% of the steady-state concentration at a specified distance from the source:
  - \( t_{1/2} = \frac{R x}{V_s (1+4\alpha_x \lambda R / V_s)^{0.5}} \)
- A simulation for time = \( t_{1/2} \) gives \( \frac{1}{2} \times C_{(\text{steady state})} \)
- Determine the factor \( F \) which, when multiplied by \( t_{1/2} \), is the simulation time needed to achieve \( C_{(\text{steady state})} \)
- \( F \times t_{1/2} = \text{time to reach steady-state conditions} \)
Determining time required to reach steady state conditions

- Chloride, distance = 50 ft.
- Chloride, distance = 1000 ft.
- Methylene chloride, distance = 300 ft.
- Mercury, distance = 500 ft.
Model (contaminant concentration) is relatively insensitive to longitudinal dispersivity for conservative contaminants at distances of 200-4000 ft from source.
Model (contaminant concentration) is highly sensitive to contaminant reaction rate (\(\lambda\)), which varies widely among environments and is an important source of uncertainty in this and other reactive transport models.
Simulated concentration is highly sensitive to KOC when the contaminant is not conservative ($\lambda > 0$)