Integrated Site Assessment and Risk Assessment for a Proposed Real Estate Transaction at a PCE-impacted Drycleaner Site

by B.J. Min, M.Eng.,P.Eng and Geordie Clyde, P.Biol.
Jacques Whitford Ltd., Calgary, AB

October 21, 2005
Presentation Outline

• Project Overview
• Background
• Introduction of Integrated Risk Based Approach and Components
• Supplementary Investigation
• Tier II Modification and Quantitative Risk Assessment
• Discussion and Conclusions
Project Overview

• Project Period - December 2004 to March 2005

• Project Initiator - Due diligence of a proposed real estate transaction and obtaining required financing and necessary Insurance

• Chemicals of Potential Concern identified from Phase I and II ESAs:
  - PCE

Breakdown products:
  - TCE
  - DCE (cis/trans)
  - VC
Background

• Previous Environmental Work - 1996 and 2003

• Phase I and II ESA – December 2004 by Jacques Whitford

• Soil stratigraphy – sand/gravel fill to 4.4 meters below grade underlain by fractured sandstone bedrock

• Land use
  - Onsite: Commercial
  - Offsite: commercial (N), commercial (E), residential (W) and Commercial/residential (S)
Background

- Regional groundwater flow and nearest surface water body
  - West towards Nose Creek, 80 m west of the dry cleaner location
- PCE exceedance in soil and groundwater underneath the dry cleaner location
- Soil: at depths from 2.3 (1.26 mg/kg) to 3.8 meter below grade (2.48 mg/kg) in borehole MW 1 inside the dry cleaning premises
- Groundwater
  - 339 μg/L at MW1 inside the dry cleaner premises
  - 153 μg/L at MW2 east of the dry cleaner premises
Components of the Integrated Site Assessments and Risk Assessment

- Supplementary Soil and Groundwater Investigation
- Indoor Air Quality Assessment
- Tier II Modification and Quantitative Human Health Risk Assessment
Integrated Site Assessments and Risk Assessment Process

Phase I/II ESAs

Further Soil and Groundwater Delineation
Indoor Air Quality Assessment

Problem Formulation
- Receptor / Exposure pathways
- Guidelines
- Site-specific Conceptual Model

Tier II Modification of Generic Guidelines (PCE)

Quantitative Risk Assessment
- Exposure Assessment
- Toxicity Assessment
- Risk Characterization
- Uncertainty Assessment (Breakdown Products)

Risk Management Plan
Advantages of Using Risk Assessment

• Flexibility - risk-based approach allows an examination of management options that best fit with client or site priorities.

• Well-accepted - Process has been approved by regulators and accepted by clients and lenders.

• Remediate only those sites or areas where there is an “actual risk” to either humans or the environment.
Supplementary Investigation

- Installation of five additional monitoring wells
- CCME Commercial Soil Quality Guidelines
- CCME Drinking Water and Freshwater Aquatic Life Guidelines
- Spatial Distribution of PCE soil impact is localized primary beneath the foot print of the dry cleaning space and east towards the monitoring well location MW2 (5 m east)
- The worst case concentrations appear to exist in the shallow soil layer underlying the dry cleaning machine.
Supplementary Investigation
Indoor Air Quality Assessment

- Indoor air samples were collected using a SKC Universal XR sample pump and thermal desorption tubes
- Risk based reference values indicating concentrations of the parameters showing no human health adverse effects
- Occupational Health and Safety Guidelines (8 hr Threshold Limit Value)
- Detectable PCE concentrations were recorded in the dry cleaner premises and adjoining tenant locations
Tier II Modification & Quantitative Risk Assessment

• Alberta Environment allows modification of generic regulatory guidelines by replacing generic parameters with site-specific information

• Modification of generic guidelines is also known as the Tier II approach

• Tier II modification uses similar methods and assumptions as those used to develop the Canadian Soil Quality Guidelines

• The modified criteria must be protective of both current and reasonably foreseeable future land uses
## Tier II Modification & Quantitative Risk Assessment

- Chemicals of Potential Concern identified from Phase I and II ESAs

<table>
<thead>
<tr>
<th>Chemicals of Concern</th>
<th>Potential Source</th>
<th>Maximum Measured Concentration</th>
<th>Carried Forward in Risk Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Indoor Air (mg/m³)</td>
<td>Soil (mg/kg)</td>
</tr>
<tr>
<td>PCE</td>
<td>Operations</td>
<td>0.056</td>
<td>2.48</td>
</tr>
<tr>
<td></td>
<td>associated with</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>on-site dry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TCE</td>
<td>Operations</td>
<td>&lt; 0.002</td>
<td>&lt; 0.03</td>
</tr>
<tr>
<td></td>
<td>associated with</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>on-site dry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,1-DCE</td>
<td>Operations</td>
<td>NS</td>
<td>&lt; 0.03</td>
</tr>
<tr>
<td></td>
<td>associated with</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>on-site dry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cis-1,2-DCE</td>
<td>Operations</td>
<td>&lt; 0.002¹</td>
<td>&lt; 0.03</td>
</tr>
<tr>
<td></td>
<td>associated with</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>on-site dry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trans-1,2-DCE</td>
<td>Operations</td>
<td>&lt; 0.003</td>
<td>&lt; 0.03</td>
</tr>
<tr>
<td></td>
<td>associated with</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>on-site dry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vinyl Chloride</td>
<td>Operations</td>
<td>&lt; 0.003</td>
<td>&lt; 0.03</td>
</tr>
</tbody>
</table>
Receptor Identification

• Human Receptors
  – Non-carcinogens – Toddler (6 months – 4 years)
  – Carcinogens – Adult Worker (56 years)
  – Receptors assumed to be on the site 10 hr/day, 5 day/yr, 48 wks/yr

• Ecological Receptors
  – Based on site conditions no ecological receptors are anticipated to be impacted by the CoPCs
  – Ecological receptors were not assessed further
### Potential Exposure Scenarios

<table>
<thead>
<tr>
<th>Exposure Pathway Description (On-site and Off-site)</th>
<th>Likelihood of Exposure</th>
<th>Carried Forward for Quantitative Analysis?</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inhalation of subsurface soil vapours indoors</td>
<td>Possible on-site</td>
<td>Yes</td>
<td>• soil &amp; groundwater vapours may migrate into the on-site buildings</td>
</tr>
<tr>
<td>Inhalation of groundwater vapours indoors</td>
<td>Nothing off-site.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inhalation of subsurface soil vapours outdoors</td>
<td>Unlikely</td>
<td>No</td>
<td>• soil &amp; groundwater vapours may migrate into outdoor air becoming diluted</td>
</tr>
<tr>
<td>Inhalation of groundwater vapours outdoors</td>
<td></td>
<td></td>
<td>• exposure minimal when compared to indoor air</td>
</tr>
</tbody>
</table>
# Exposure Pathway Evaluation

## Potential Exposure Scenarios Considered Very Unlikely

<table>
<thead>
<tr>
<th>Exposure Pathway Description (On-site and Off-site)</th>
<th>Carried Forward for Further Analysis?</th>
<th>Justification</th>
</tr>
</thead>
</table>
| Ingestion, Dermal Contact, Inhalation of surface soil/dust | No | • Site is Covered  
• CoPCs at a depth of 2.0 m |
| Ingestion, Dermal Contact of surface water | No | • no surface water bodies on-site  
• transport to surface water is not expected  
• closest surface water is Nose Creek |
| Ingestion, Dermal Contact of groundwater | No | • Groundwater not used as a potable drinking water source. |
| Ingestion of vegetation, garden produce | No | • soil and groundwater impacts below the root uptake zone  
• commercial site with no grown produce |
Conceptual Exposure Model
Tier II Modification & Quantitative Risk Assessment

• Conceptual Exposure Model
  – VOC vapours from the impacted soil and groundwater diffuse upward through the soil and into the dry cleaner building through cracks in the floor slab. On-site receptors may inhale the vapours in indoor air.
Tier II Modification Procedures – Indoor Inhalation Pathway

\[
\text{SQG}_{II} = \frac{(\text{RfC} - C_a) \times \left(\theta_w + (K_{oc} \times f_{oc} \times \rho_b) \times \left(\frac{H}{RT} \times \theta_a\right)\right)}{\frac{H}{RT} \times \rho_b \times 10^6 \text{cm}^3/\text{m}^3 \times \text{ET}} \times \text{SAF} \times \text{DF}_i \times 10^3 \text{g/kg} + \text{BSC}
\]

Where:
- \(\text{SQG}_{II}\) = soil quality guideline by indoor infiltration for volatiles using RfC mg/kg
- \(\text{RfC}\) = reference air concentration mg/m³
- \(\text{Ca}\) = background indoor/outdoor air concentration mg/m³
- \(\text{SAF}\) = soil allocation factor unitless
- \(\theta_a\) = vapour filled porosity unitless
- \(\theta_w\) = moisture filled porosity unitless
- \(K_{oc}\) = organic carbon partition coefficient mL/g
- \(f_{oc}\) = soil organic carbon fraction in contaminant partitioning zone g/g
- \(\rho_b\) = soil dry bulk density in contaminant partitioning zone g/cm³
- \(H\) = Henry’s Law Constant atm-m³/mol
- \(R\) = universal gas constant atm-m³/mol-K
- \(T\) = annual average soil temperature K
- \(\text{DF}_i\) = dilution factor from soil gas to indoor air unitless
- \(\text{ET}\) = exposure term (8/24*5/7*48/52) unitless
- \(\text{BSC}\) = background soil concentration (CCME, 1996b) mg/kg
Tier II Modification

- Maximum concentrations of PCE in both soil and groundwater were below Risk Based Quality Guidelines (RBQG)

| Modified Risk-Based Soil and Groundwater Quality Guidelines for Inhalation of Vapours in Indoor Air |
|-------------------------------------------------|-------------------------------------------------|
| Parameter | Soil (mg/kg) | Groundwater (mg/L) |
|           | Maximum Measured Concentration | RBQG | Maximum Measured Concentration | RBQG |
| PCE       | 2.48          | 18    | 0.339                        | 22    |
## Tier II Modification vs. Generic Guidelines

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Generic</th>
<th>Modified Risk Based</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Guideline</td>
<td>Source</td>
</tr>
<tr>
<td>Subsurface Soil (mg/kg)</td>
<td>0.5¹</td>
<td>CCME, 2004 Soil Quality Guidelines for Commercial Land Use</td>
</tr>
<tr>
<td>PCE</td>
<td></td>
<td>18</td>
</tr>
<tr>
<td>Groundwater (mg/L)</td>
<td>0.111</td>
<td>CCME, 2004 Canadian Guidelines for Freshwater Aquatic Life</td>
</tr>
<tr>
<td>PCE</td>
<td></td>
<td>22</td>
</tr>
</tbody>
</table>
Quantitative Risk Assessment

- Conducted to derive risk based remediation criteria (RBRC) for PCE breakdown products
- Assumed maximum CoPC concentrations in soil and groundwater present beneath the entire floor slab
- Predicted indoor air concentrations were greater than measured indoor air concentrations indicating the conservatism of the modelling
## Dose-Response Assessment

### Toxicity Reference Values

<table>
<thead>
<tr>
<th>Chemical</th>
<th>RfC (inhalation) (mg/m³)</th>
<th>RSC (inhalation) (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCE</td>
<td>NA</td>
<td>1.64E-02&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>cis-1,2-DCE</td>
<td>1.77E-02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>NA</td>
</tr>
<tr>
<td>trans-1,2-DCE</td>
<td>3.55E-02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>NA</td>
</tr>
<tr>
<td>1,1-DCE</td>
<td>2.00E-01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>NA</td>
</tr>
<tr>
<td>Vinyl Chloride</td>
<td>NA</td>
<td>2.30E-03&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

**Notes:**
- <sup>a</sup> US EPA IRIS database, 2004
- <sup>b</sup> US EPA PPRTV, 2002
- <sup>c</sup> Health Canada, 2003
Estimation of Receptor Dose

CDI = \frac{C \times CR \times EF \times ED}{BW \times AT}

Where

CDI = Chronic Daily Intake (mg per kg of body weight per day)
C = Exposure Point Concentration (e.g. mg/L or mg/kg)
CR = Contact rate (e.g. L/day or m³/day)
EF = Exposure frequency (days/year)
BW = Body weight (kg)
AT = Average time (days)
Hazard Assessment
(non-carcinogens)

Hazard Quotient (HQ) = \( \frac{\text{Chronic Daily Intake (CDI)}}{\text{Tolerable Daily Intake (TDI)}} \)

Acceptable Hazard Levels

HQ < 1.0 if all pathways are considered, then the intake is not considered to pose a health threat.

HQ < 0.2 to account for 80% of exposure to a CoPC from the background environment.
Hazard Assessment (Carcinogens)

Incremental Life Cancer Risk (ILCR)
= Lifetime Average Daily Dose x Cancer Slope Factor

The ILCR is typically expressed:
  e.g. $3 \times 10^{-6}$ for three additional cases in a million

• Acceptable level of risk
  – 1 additional cancer case in 100 000 people ($1 \times 10^{-5}$)

• NOTE: 1 in 3 Canadians will get cancer in their lifetime so risk assessment allows for 0.40001 instead of 0.40000 cases in a population
### SUMMARY OF RISK ESTIMATES

<table>
<thead>
<tr>
<th>Parameter</th>
<th>HQ</th>
<th>ILCR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TCE</td>
<td>NA</td>
<td>8.57E-08</td>
</tr>
<tr>
<td>cis-1,2-DCE</td>
<td>1.01E-02</td>
<td>NA</td>
</tr>
<tr>
<td>trans-1,2-DCE</td>
<td>8.58E-03</td>
<td>NA</td>
</tr>
<tr>
<td>1,1-DCE</td>
<td>3.41E-03</td>
<td>NA</td>
</tr>
<tr>
<td>Vinyl Chloride</td>
<td>NA</td>
<td>5.31E-06</td>
</tr>
</tbody>
</table>
# Risk Based Soil and Groundwater Criteria

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Non-Carcinogen</th>
<th></th>
<th>Carcinogen</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum Measured Concentration</td>
<td>RBRC</td>
<td>Maximum Measured Concentration</td>
<td>RBRC</td>
</tr>
<tr>
<td><strong>Sub-Surface Soil (mg/kg)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TCE</td>
<td>NA</td>
<td>ND</td>
<td>ND</td>
<td>2.06</td>
</tr>
<tr>
<td>cis-1,2-DCE</td>
<td>ND</td>
<td>1.10</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>trans-1,2-DCE</td>
<td>ND</td>
<td>1.30</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>1,1-DCE</td>
<td>ND</td>
<td>3.30</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Vinyl Chloride</td>
<td>NA</td>
<td>ND</td>
<td>0.029</td>
<td></td>
</tr>
<tr>
<td><strong>Groundwater (mg/L)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TCE</td>
<td>NA</td>
<td>0.003</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>cis-1,2-DCE</td>
<td>ND</td>
<td>4.51</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>trans-1,2-DCE</td>
<td>ND</td>
<td>3.79</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>1,1-DCE</td>
<td>ND</td>
<td>7.35</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Vinyl Chloride</td>
<td>NA</td>
<td>ND</td>
<td>0.10</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

1. based on HI of 0.2 and ILCR of 1E-05 targets in coarse-grained soil.
2. NA – not applicable
3. ND – not detected
Conclusions

• Use of site-specific data to generate modified risk-based guidelines resulted in an increase of the generic guidelines.

• QRA did not predict unacceptable risks to receptors at the site under current land use scenario for any of the CoPCs.

• Using conservative assumptions presented in this report, there are no potential adverse health effects associated with the exposure of receptors to the maximum concentrations of CoPCs measured to date.
Project Postscript

• The integrated site assessment and risk assessment approach was successfully implemented to meet project stakeholders’ needs.

• The end result was “Win-Win” as the real estate transaction was completed and the purchaser was successful in obtaining the necessary insurance and financing to complete the transaction.

• A Risk Management Plan including groundwater monitoring and ventilation upgrading, was developed and is being implemented.
Questions?

Thank you!