DEVELOPING A GOOD CONCEPTUAL MODEL FOR FEDERAL CONTAMINATED SITES – COMMON SHORTFALLS AND DATA NEEDS

Presented by: Pierre Maheux, M.Sc., P.Geo.

Technical contributors: Francois Lauzon, M.Eng., P.Eng., David Wilson, M.A.Sc., P.Eng., Sonny Sundaram, Ph.D., P.Geo., Marc Bouchard, P.Eng.

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Stantec

Outline

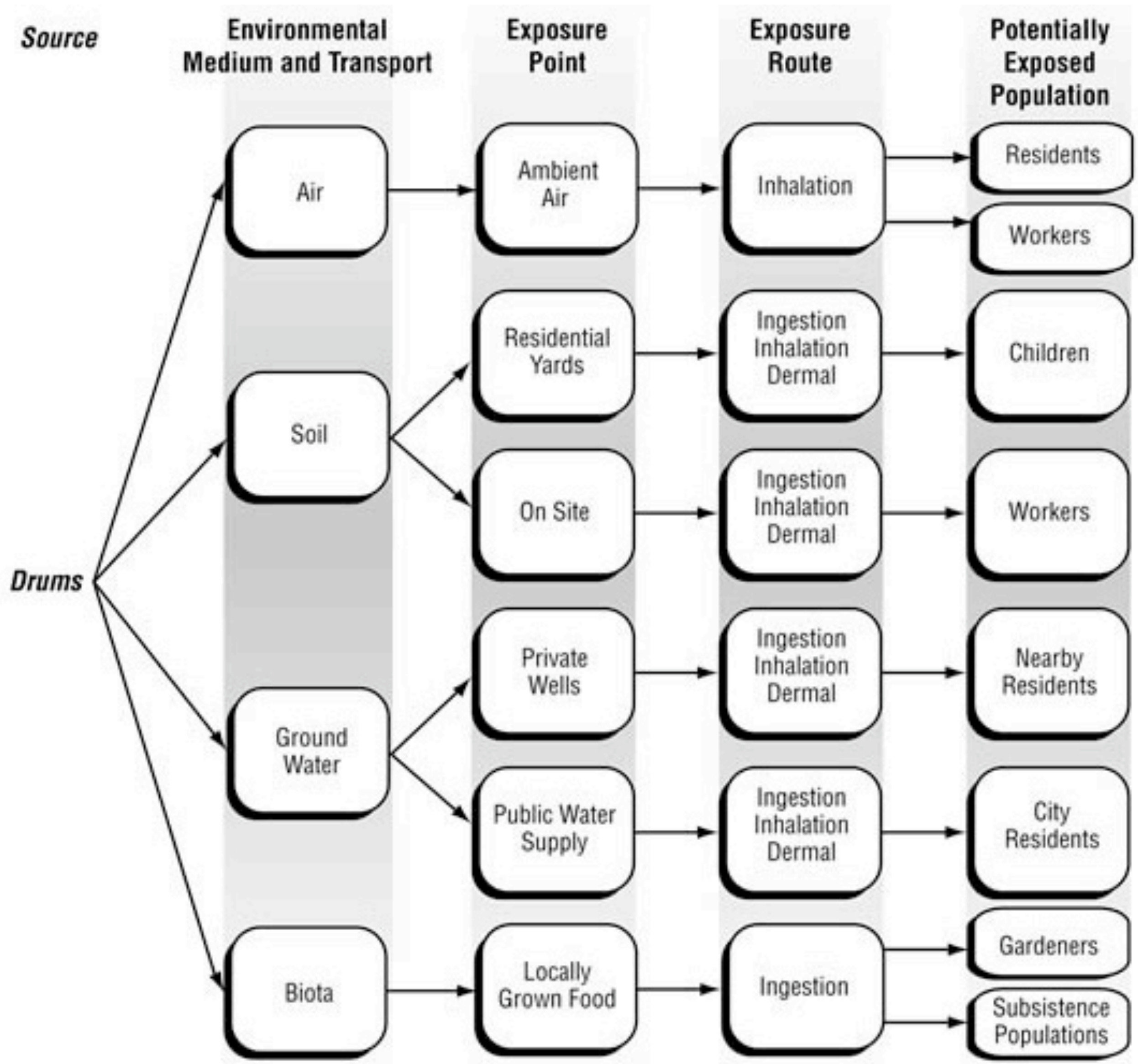
- Introduction

- Background:
  - What is a Conceptual Site Model (CSM)?
  - When and how should it be developed?

- Application:
  - How can it be used?
  - How should it be used?

- Case Study:
  - Deloro Mine, ON

CSM:
RA vs RAP



Exposure Pathway Evaluation

Source: *Public Health Assessment Guidance Manual*, ATSDR (2005 Update)

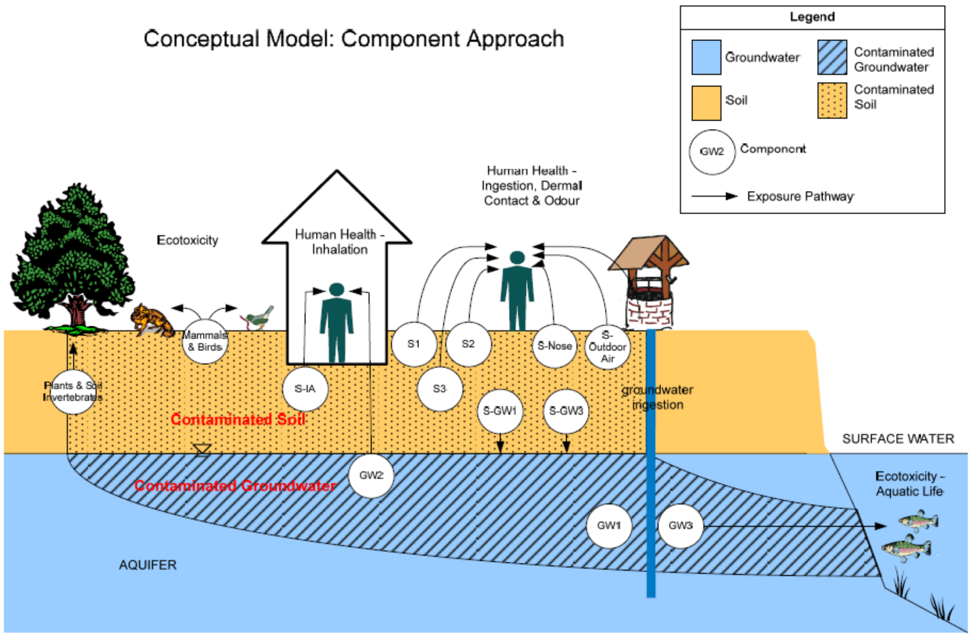
Introduction to CSM

Why?

Need to organize information to facilitate identification of data and information gaps.

What?

Tool to develop an approach to manage and remediate contaminated lands.



Source: Ontario MOE, 2009 [7]

Definitions [1]

- preliminary stage of computer or physical model
- focused risk assessment or (hydro)geological evaluation
- an integration of all relevant information assembled for the purposes of investigating or **remediating** a site

Background

What is a CSM?

- Generic understanding – qualitative tool (incorporating quantitative data) that identifies contaminants of concern (COCs), potential sources, media affected (soil, groundwater, surface water, sediment), and potential receptors.

Health Canada Guidance [6]

A visual representation and narrative description of the physical, chemical, and biological processes occurring, or that have occurred, at a contaminated site.

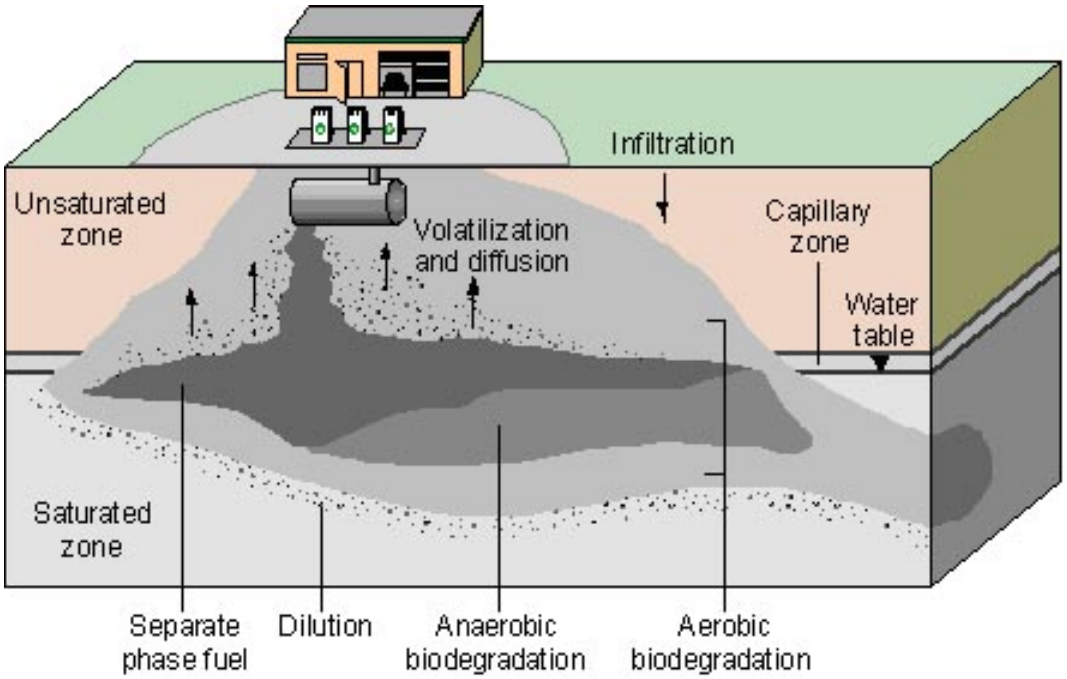


Image Source: San Francisco Bay Regional Water Quality Control Board

CSMs are not Static

- A dynamic model

  Varying levels of maturity during its life cycle.

- Maturity levels

  Level 1 *Is there a potential threat to human or ecological health?*

  Level 2 *Is there a risk greater than tolerable levels based on default criteria?*

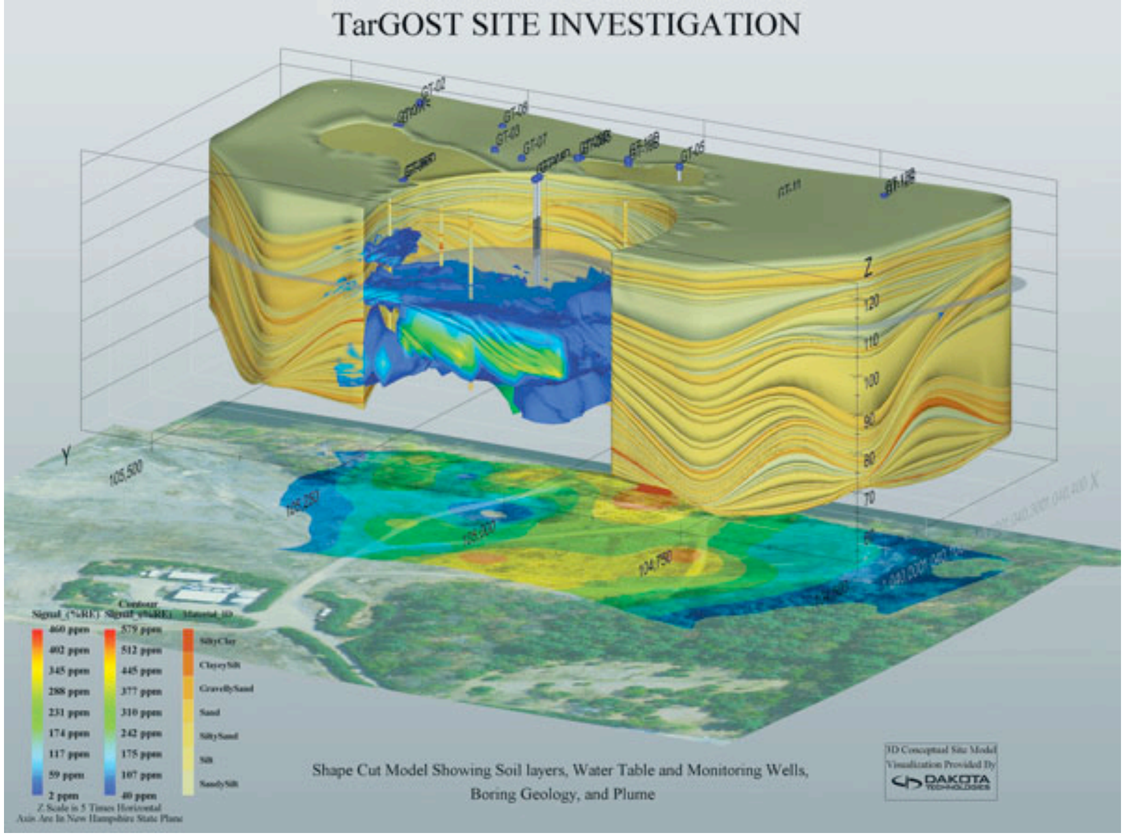


Image Source: Pollution Engineering, St. Germain, 2011

Data and Information Requirements

How should it be developed?

Data and information requirements include:

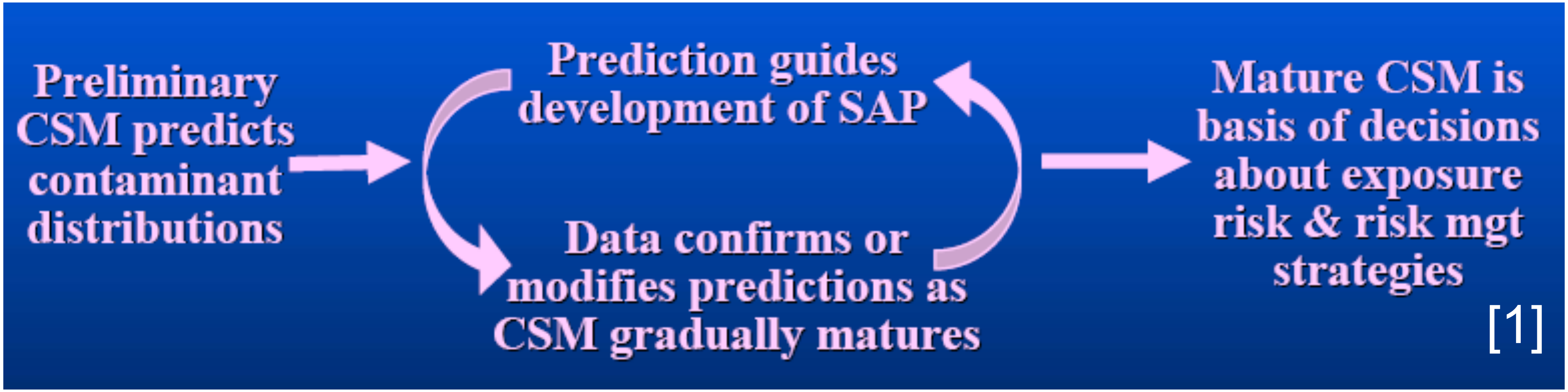
- Archaeology/historical land use
- Physiography and current built environment
- Climate and Hydrology
- Geology
- Hydrogeology

Develop the CSM

How should it be developed?

Dealing with uncertainty:

- Understand the data by doing exploratory analysis
- Identify and quantify uncertainty – revisions to the CSM are expected
- Question assumptions
- Supplement data where needed, re-analyze, update the CSM



Application – Goal

- Functions as "living" model to integrate supplemental data
- Enables an improved understanding of site characteristics
- Becomes a structure to identify, organize, quantify, and evaluate remediation design parameters

A mature CSM will better facilitate the selection of an appropriate and effective Remedial Action Plan (RAP)

Application – Geology/Hydrology

Key design parameters for RAP selection:

- Geological and Hydrological Remedial Design Parameters
  - Physical and chemical composition of media (grain size, organic carbon)
  - Stratigraphy, bedrock fracture geometry
  - Effective porosity, bedrock porosity model (double, triple)
  - Hydraulic gradients (lateral and vertical)
  - Hydraulic conductivities, aquifer connections
  - Surface recharge rates, flow rates to/from water bodies
  - Groundwater velocities and times of travel

Application – CoCs

Key design parameters for RAP selection:

- Nature and Extent of Contaminants in the Subsurface
    - Physical and chemical properties
    - Horizontal and vertical extent
    - Contaminant mass/volume
    - Physical and biological degradation indicators

Application – Fate and Transport

Key design parameters for RAP selection:

- Contaminant Fate and Transport
  - Flow, dispersion, first-order decay, sorption
  - Mass fluxes (transects)
  - Qualitative exposure assessment
- Data Gap Analysis
  - Spatial (e.g., hot spot, mean test)
  - Temporal (e.g., Mann-Kendall)
  - Chemical and physical

Application - Common Shortcomings

- **Some of the parameters are ignored or overlooked**

  Address each, otherwise they can become data gaps

- **Unknowns are not identified or quantified**

  Start with ranges, literature values, do basic statistics (std. dev., Q-Q plots, etc.)

Application - Common Shortcomings (cont.)

- **Insufficient visualization**

  Subsurface environments are complex, multi-dimensional structures. Use cross-sections, fence diagrams, radar charts, time plots, etc., to communicate and understand clearly.

- **Poor data management, quality and efficiency, leads to data hostage situation**

  Use databases, electronic data deliverables, and GIS tools to transmit, store, analyze, interpret, and communicate data.

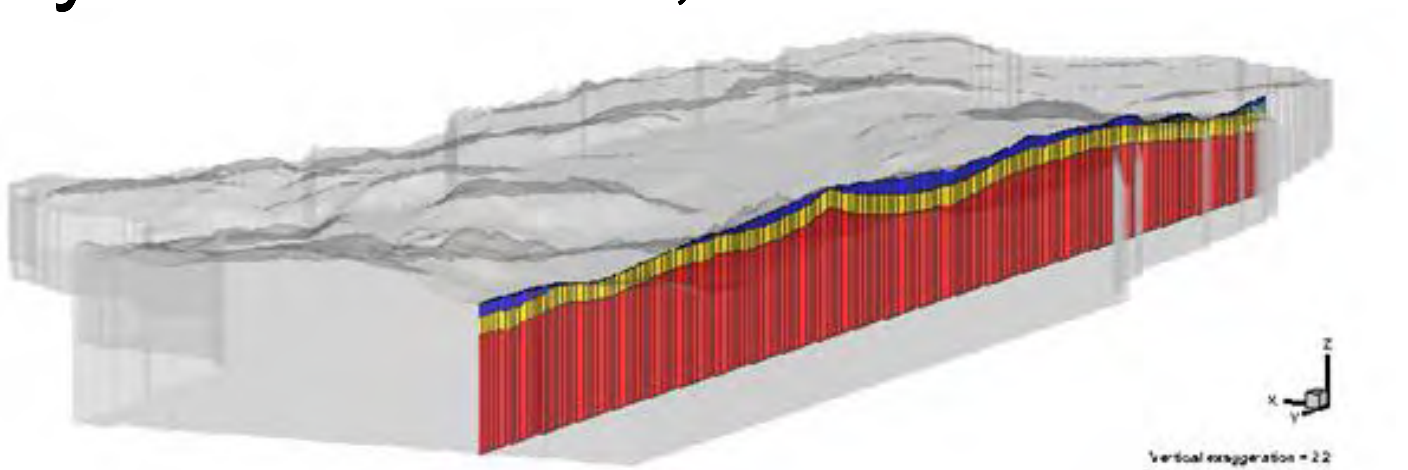
Application - Common Shortcomings (cont.)

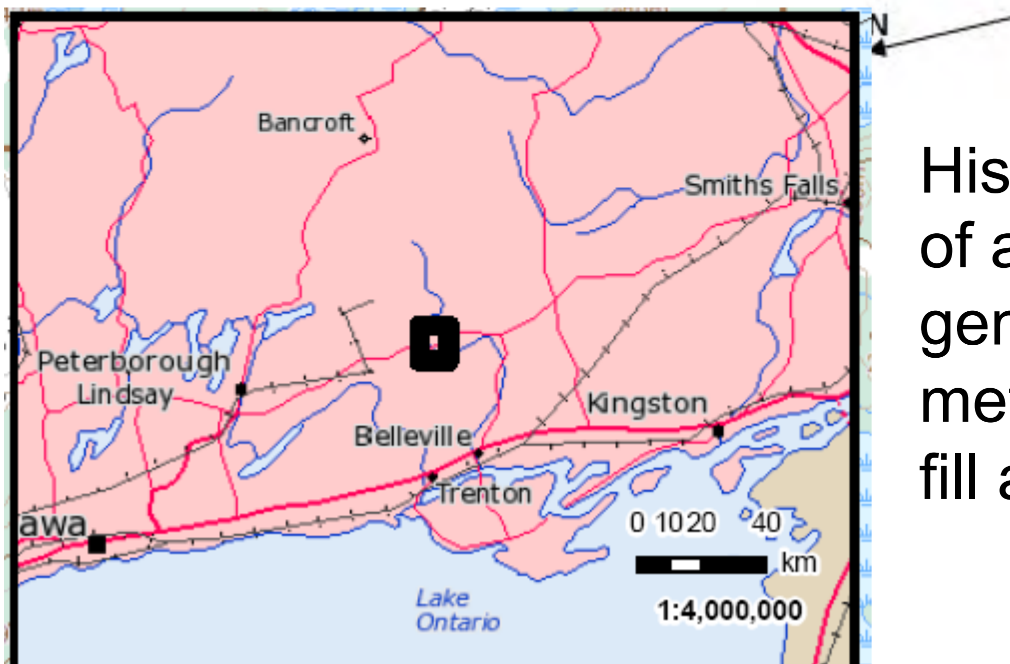
- **Insufficient data density due to high cost**

  Some examples of potential solutions:

  - Statistically supported semi-quantitative field analyses (XRF, immunoassay, etc.)
  - Analyte correlations: use cheapest analysis
  - Nested and/or clustered wells, CMT
  - Drive-point profiler
  - Drive-point MIP (membrane interface probe), LIF (laser-induced fluorescence)
  - Down-hole geophysics
  - Statistically supported multi-increment sampling

Case Study: Deloro Mine, E. Ontario





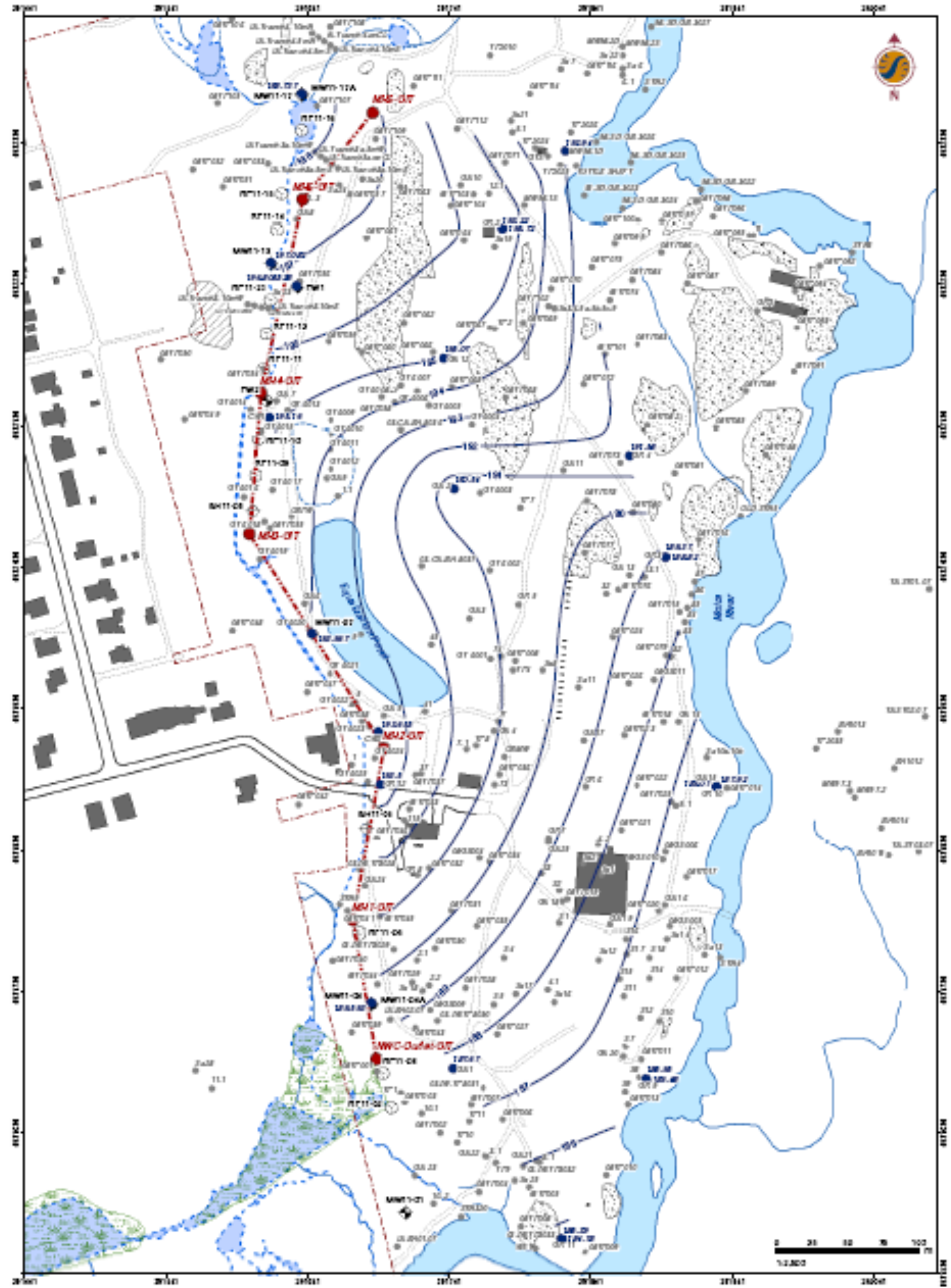
Historical smelting and refining of arsenic-bearing ore generated extensive heavy metal and arsenic-containing fill and surface waste.

Case Study

Deloro Mine, Ontario

Preliminary CSM

- Topography: relatively flat and slopes towards the Moira River
- Stratigraphy: bedrock outcrops and relatively impermeable silty clay overburden materials
- Groundwater: assumed to enter Site on western boundary and flow towards Moira River



Case Study – Deloro Mine, Ontario

Preliminary RAP

- 900 m Groundwater Interceptor Trench (GIT)
- engineered cover
- estimated cost: $2M

Intent

- Divert or limit uncontaminated groundwater from entering Site and minimize groundwater contact with waste materials, thereby reducing probability of contaminated groundwater impacting Moira River.

Case Study – Deloro Mine, Ontario

- Issues (need for more mature CSM)
  - Unrealistic assumptions regarding groundwater flow direction, flux, and water levels
  - Boundaries and nature of arsenic plume in groundwater remained undefined
  - Some key hydrologic components contributing to annual water balance of Site were not considered
  - Preliminary RAP based on assumption that groundwater flow sole contributor to mobility of arsenic

Case Study – Deloro Mine, Ontario

- Revised CSM (Stantec) based on *limited* new data
  - Site was identified as groundwater discharge area with strong upward hydraulic gradients
  - Potential recharge values were estimated to range from 30 to 68 mm/year
  - Groundwater flows to south/southwest
  - Groundwater principally enters Site in northwest, negating need for interception at west boundary
- Proposed cost of additional data for *complete* CSM: $300K
- Likely *revised* RAP recommendation: Permeable Reactive Barrier adjacent to Moira River
- Estimated Cost (design/build/O&M): $4.5M vs $6.5M…

Conclusions

- Understanding which factor (geological, hydrological, hydrogeological, and geochemical) or combination of factors, is most responsible for mobilization of contaminants is key to any CSM exercise involving large contaminated sites

- A mature CSM is likely to result in known outcomes with known probabilities of success for remediation

- Investing in sufficient site characterization on complex contaminated sites will reduce uncertainty within the CSM and facilitate the development of a more reliable and cost-effective RAP

References

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2 Conceptual Site Model for Evaluating Contaminant Mobility and Pump-and-treat Remediation, Nikolaos P. Nikolaidis and Huiying Shen, Global Nest: the Int. J. Vol 2, No 1, pp 67-76, 2000.

3 U.S. EPA Superfund Soil Screening Guidance, Attachment A Conceptual Site Model Summary at www.epa.gov /superfund/health/conmedia/soil/index.htm.

4 Groundwater Investigation in Site Assessment, 2nd Edition, Technical Guidance for Contaminated Sites, Golder Associates, 2010.

5 Recommended Guidance and Checklist for Tier 1 Ecological Risk Assessment of Contaminated Sites in British Columbia - Appendix A. Introduction to the Conceptual Models.

6 Federal Contaminated Site Risk Assessment in Canada, Part VII: Guidance for Soil Vapour Intrusion Assessment at Contaminated Sites, Health Canada, 2010.

7 Rationale for the development of soil and ground water standards for use at contaminated sites in Ontario. OMOE, December 22, 2009.

Q & A

Pierre Maheux, MSc, PGeo
Stantec Consulting Ltd.