Assessing, Comparing and Prioritizing Contaminated Sites: Application of a Multiplicative Risk Assessment Model

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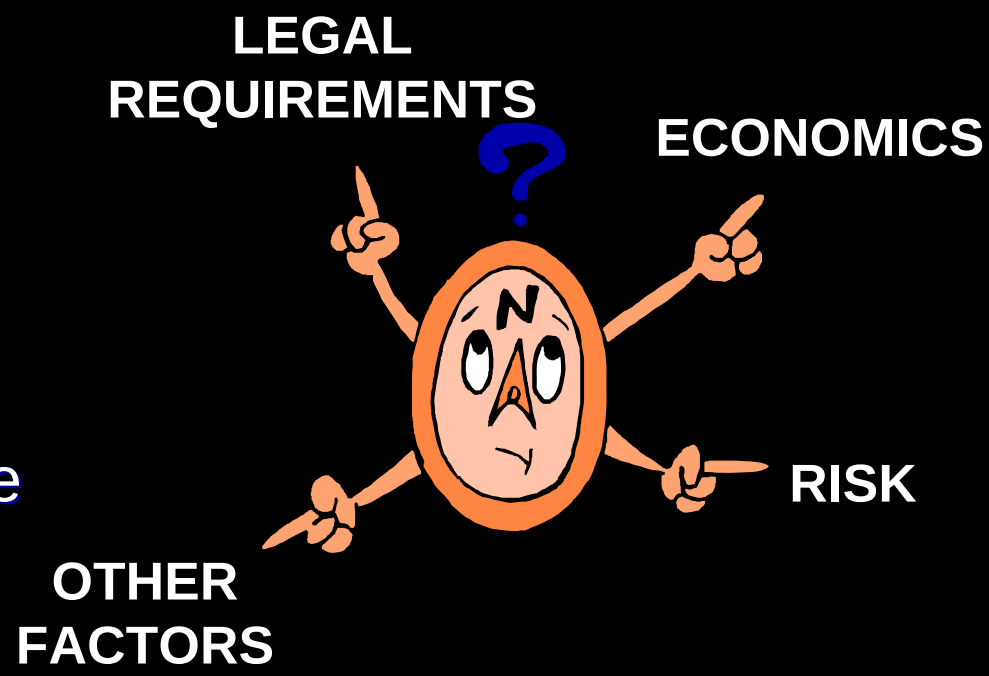
Where to focus the effort?

- Financial/personnel resources are limited
- Some projects must come before others: which ones?
- Following a rigorous process is non-subjective and defensible



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Presentation Outline

- Drivers for expenditures on contaminated sites
- History and use of our comparative risk evaluation tool
  - hazard, receptor and exposure pathway scoring
  - risk categories and recommended actions
  - uncertainty assessment
- Case studies

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Comparative Risk Evaluation Tool

- Allows comparison of sites on the basis of their risk potential
- Consistent, unbiased, and based on principles of risk assessment
- Modified from the National Classification System for Contaminated Sites (CCME, 1992)
  - accommodate upstream sites, data typically available
  - multiplicative scoring
  - uncertainty assessment

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Manifestation of Risk

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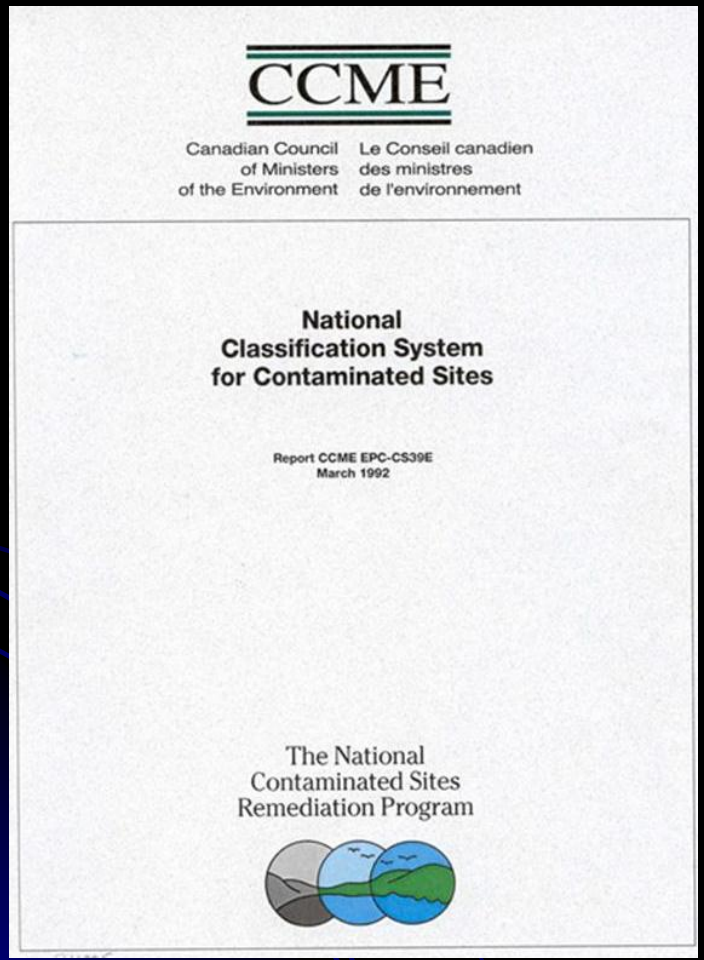
Assessing Risk Scores


CCME

Canadian Council of Ministers of the Environment

Le Conseil canadien des ministres de l'environnement

National Classification System for Contaminated Sites

Report CCME EPC-CS39E
March 1992

The National Contaminated Sites Remediation Program

CCME, 1992:

- Hazards / 33
- Receptors / 34
- Exposure pathways / 33

Add: total out of 100

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Assessing Risk Scores

Matrix, 2007:

- Hazards / 10
- Receptors / 10
- Exposure pathways / 10

Multiply: total out of 1,000

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Hazard Factors

SOIL

H1 Petroleum hydrocarbon (BTEX and F1-F4) concentrations relative to soil quality criteria

H2 Salinity (EC) and sodicity (SAR) relative to soil quality criteria

H3 Acidity/alkalinity (pH) relative to soil quality criteria

H4 Metals concentrations relative to soil quality criteria

H5 Naturally occurring radioactive material (NORM) relative to criteria

H6 Volume of impacted soil

H7 Special considerations

WATER

H8 Primary domestic water supply contamination relative to drinking water criteria

H9 Secondary groundwater supply contamination relative to drinking water criteria

H10 Surface water contamination relative to usage criteria

H11 Groundwater quality in groundwater monitoring wells

H12 Total area with a groundwater plume

H13 Special considerations

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Receptor Factors

ECOLOGICAL

R1 Distance to natural area, agricultural land use or residential land use

R2 Distance to perennial surface water

R3 Special considerations

HUMAN

R4 Distance to agricultural land use or residential land use

R5 Distance to commercial land use or industrial land use

R6 Distance to wellhead (active, suspended or abandoned)

R7 Distance to nearest domestic water well or spring

R8 Availability of alternate domestic water supply

R9 Distance to secondary groundwater user

R10 Usage of secondary groundwater supply

R11 Usage of surface water

R12 Special considerations

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Exposure Pathway Factors

SUBSURFACE TRANSPORT

E1 Hydraulic conductivity of the site soils

E2 Range of average yield of wells in the aquifer(s) of concern

E3 Thickness of confining layer over the aquifer(s) of concern

E4 Hydraulic conductivity of the confining layer

E5 Annual rainfall

E6 Special considerations

SURFICIAL TRANSPORT

E7 Topography

E8 Vegetative cover

E9 Surface water controls

E10 Runoff potential (precipitation component)

E11 Runoff potential (infiltration component)

E12 Flood potential

E13 Special considerations

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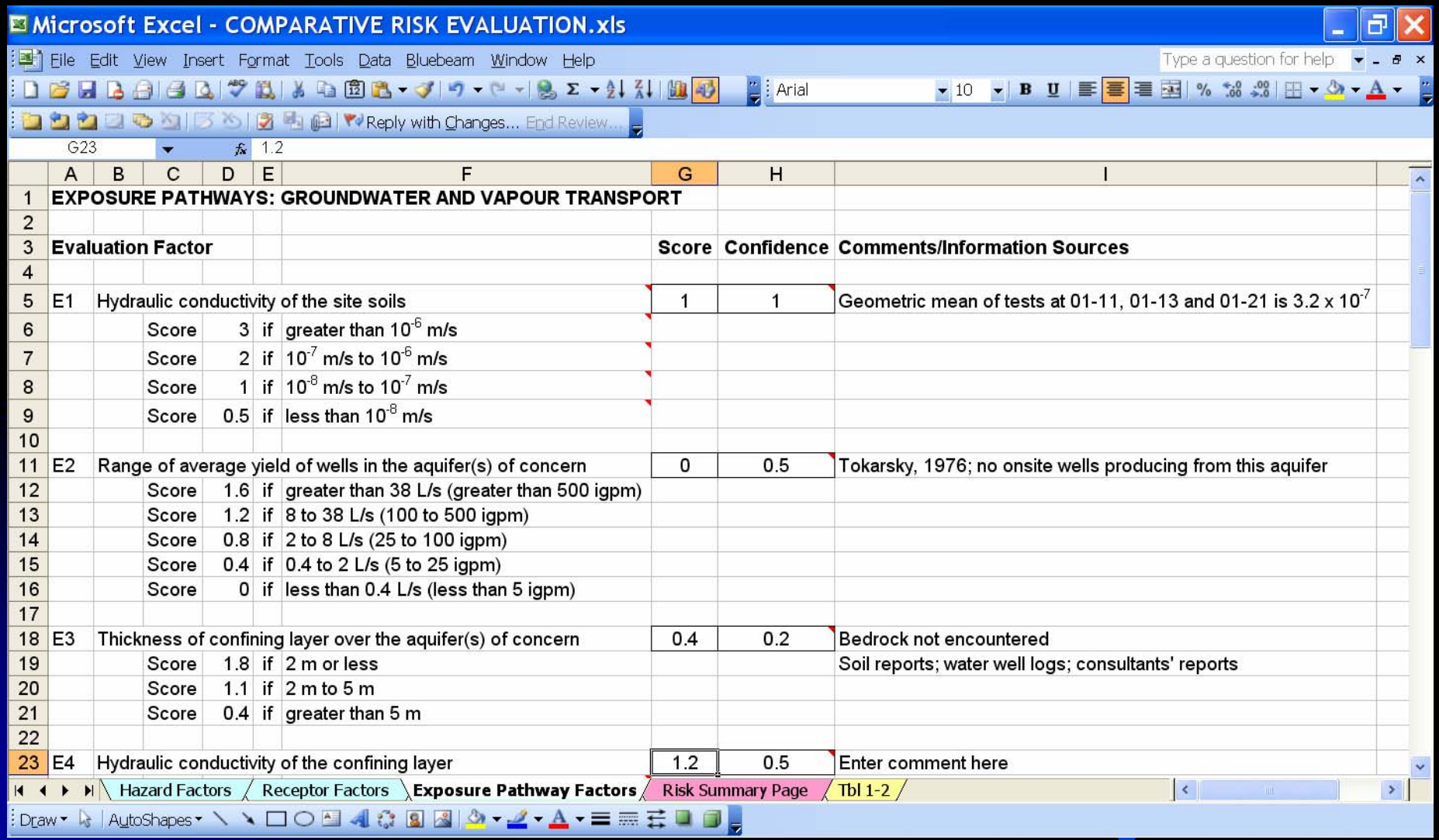
Data Entry: Example



Microsoft Excel - COMPARATIVE RISK EVALUATION.xls

File Edit View Insert Format Tools Data Bluebeam Window Help

Type a question for help

Arial 10

Reply with Changes... End Review...

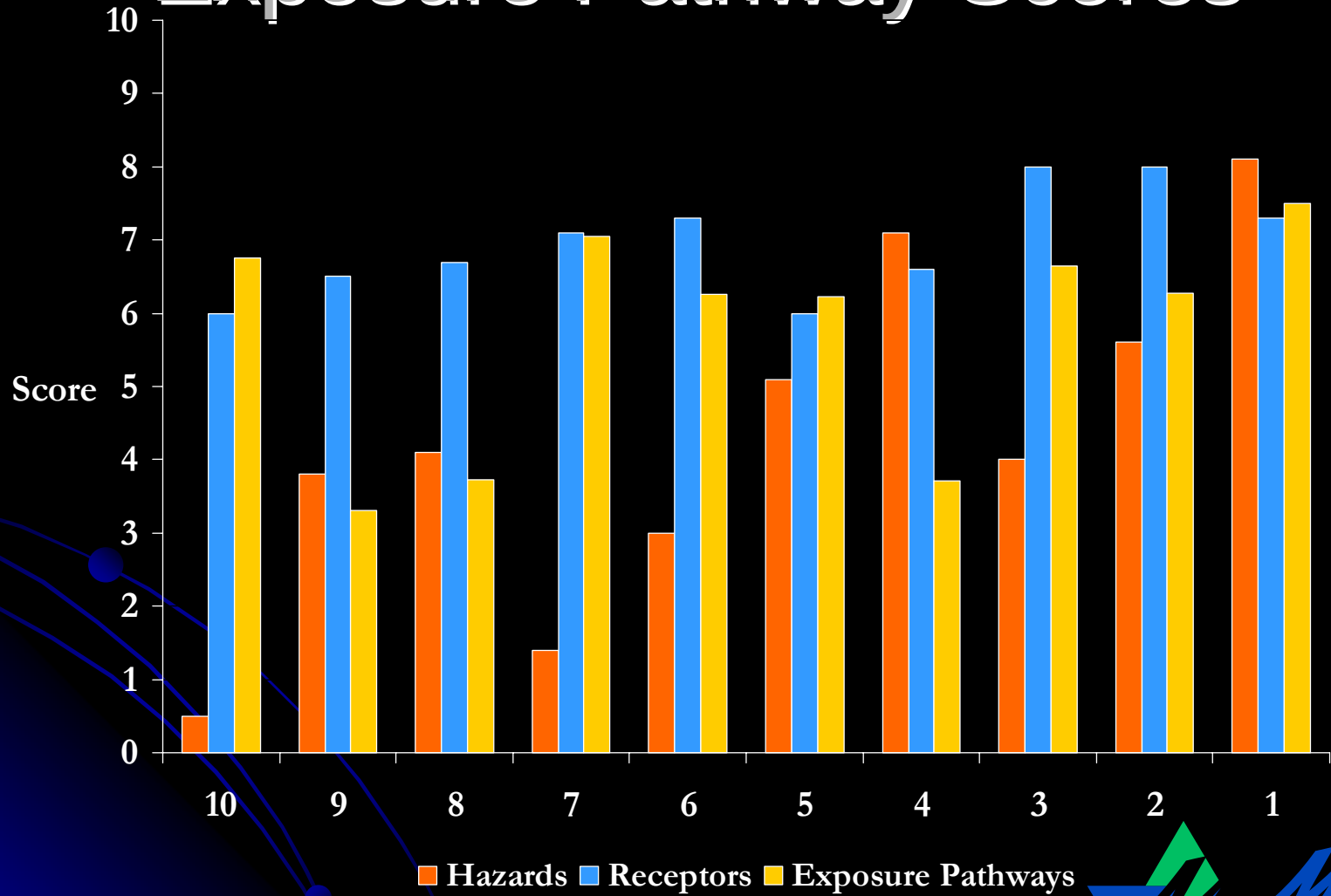
G23 1.2

	A	B	C	D	E	F	G	H	I
1	**EXPOSURE PATHWAYS: GROUNDWATER AND VAPOUR TRANSPORT**								
2									
3	**Evaluation Factor**						**Score**	**Confidence**	**Comments/Information Sources**
4									
5	E1	Hydraulic conductivity of the site soils					1	1	Geometric mean of tests at 01-11, 01-13 and 01-21 is 3.2 x 10^{-7}
6			Score	3	if	greater than 10^{-6} m/s			
7			Score	2	if	10^{-7} m/s to 10^{-6} m/s			
8			Score	1	if	10^{-8} m/s to 10^{-7} m/s			
9			Score	0.5	if	less than 10^{-8} m/s			
10									
11	E2	Range of average yield of wells in the aquifer(s) of concern					0	0.5	Tokarsky, 1976; no onsite wells producing from this aquifer
12			Score	1.6	if	greater than 38 L/s (greater than 500 igpm)			
13			Score	1.2	if	8 to 38 L/s (100 to 500 igpm)			
14			Score	0.8	if	2 to 8 L/s (25 to 100 igpm)			
15			Score	0.4	if	0.4 to 2 L/s (5 to 25 igpm)			
16			Score	0	if	less than 0.4 L/s (less than 5 igpm)			
17									
18	E3	Thickness of confining layer over the aquifer(s) of concern					0.4	0.2	Bedrock not encountered
19			Score	1.8	if	2 m or less			Soil reports; water well logs; consultants' reports
20			Score	1.1	if	2 m to 5 m			
21			Score	0.4	if	greater than 5 m			
22									
23	E4	Hydraulic conductivity of the confining layer					1.2	0.5	Enter comment here

Hazard Factors | Receptor Factors | **Exposure Pathway Factors** | Risk Summary Page | Tbl 1-2

Draw AutoShapes

Summary of Hazard, Receptor and Exposure Pathway Scores



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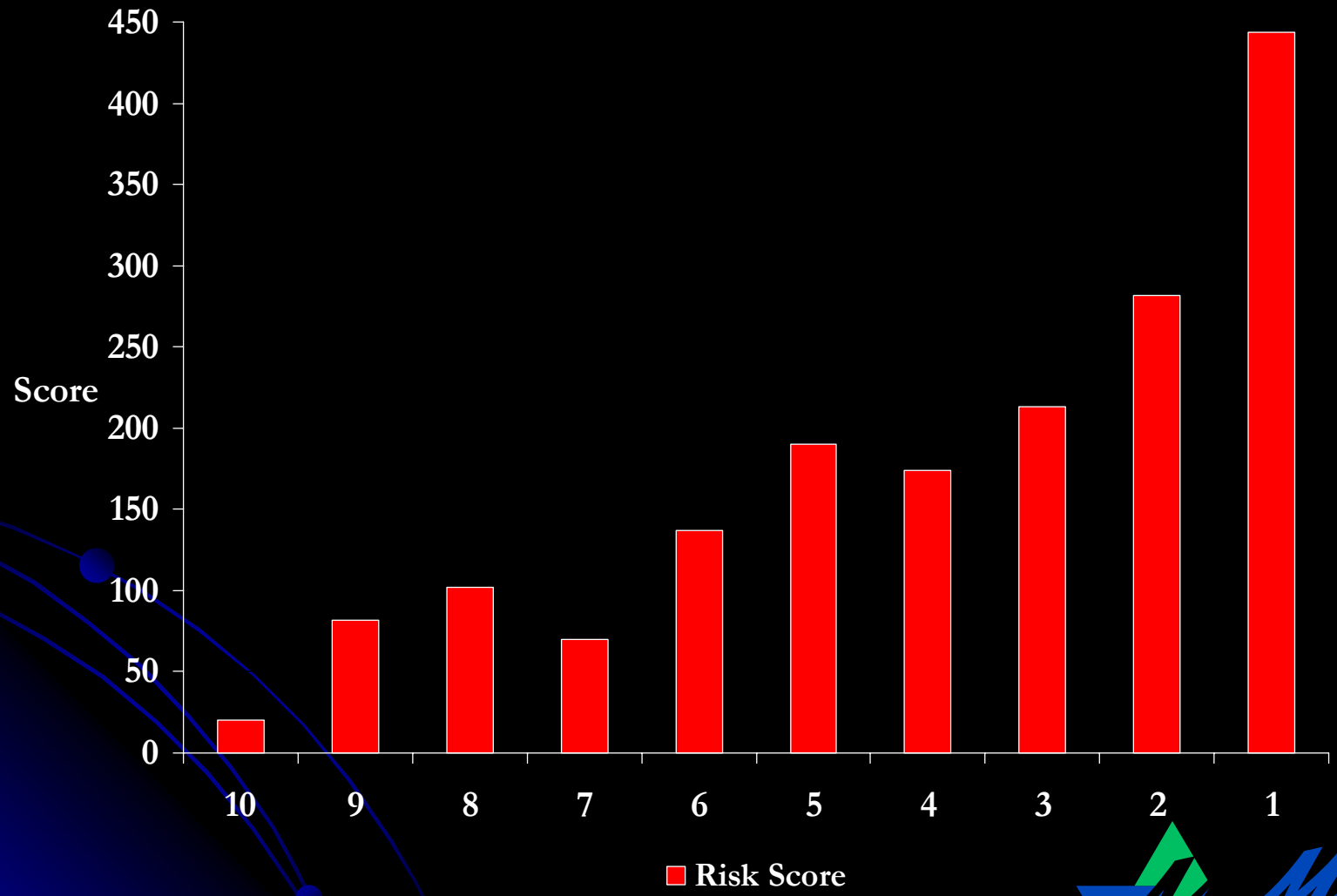
Risk Scores



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Uncertainty Assessment

- "Best guesses" can be useful if coupled with uncertainty assessment.
- Uncertainty is tracked through confidence scores assigned to each hazard, receptor and exposure pathway aspect
- Overall confidence in the total score is sensitivity-weighted
- Sensitivity ranking identifies the "best guesses" that warrant groundtruthing

$$\begin{aligned}\text{Risk} &= \Sigma H \cdot \Sigma R \cdot \Sigma E \\ &= (H_1 + H_2 + H_3 + \ldots + H_{13}) \cdot \Sigma R \cdot \Sigma E \\ &= H_1(\Sigma R \cdot \Sigma E) + H_2(\Sigma R \cdot \Sigma E) + H_3(\Sigma R \cdot \Sigma E) + \ldots + H_{13}(\Sigma R \cdot \Sigma E)\end{aligned}$$

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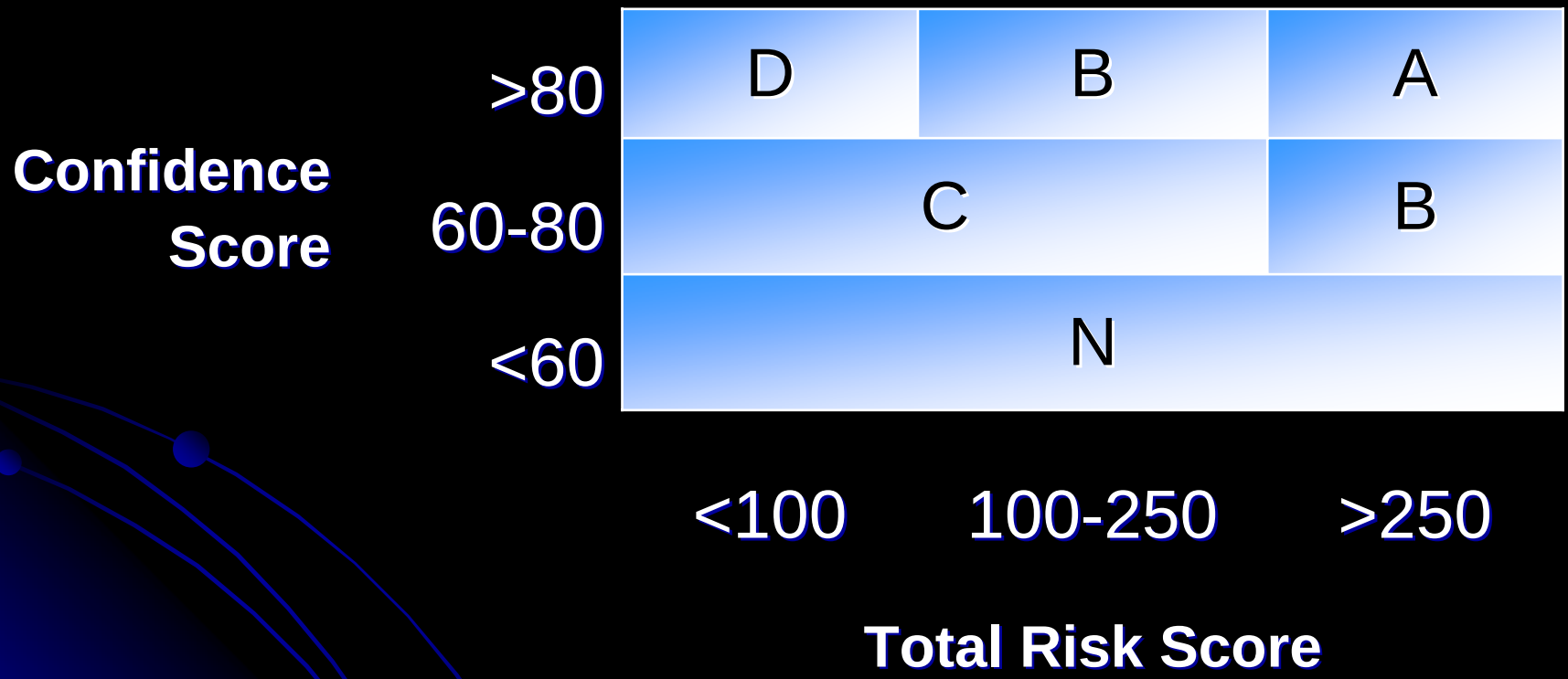
Determination of Risk Category



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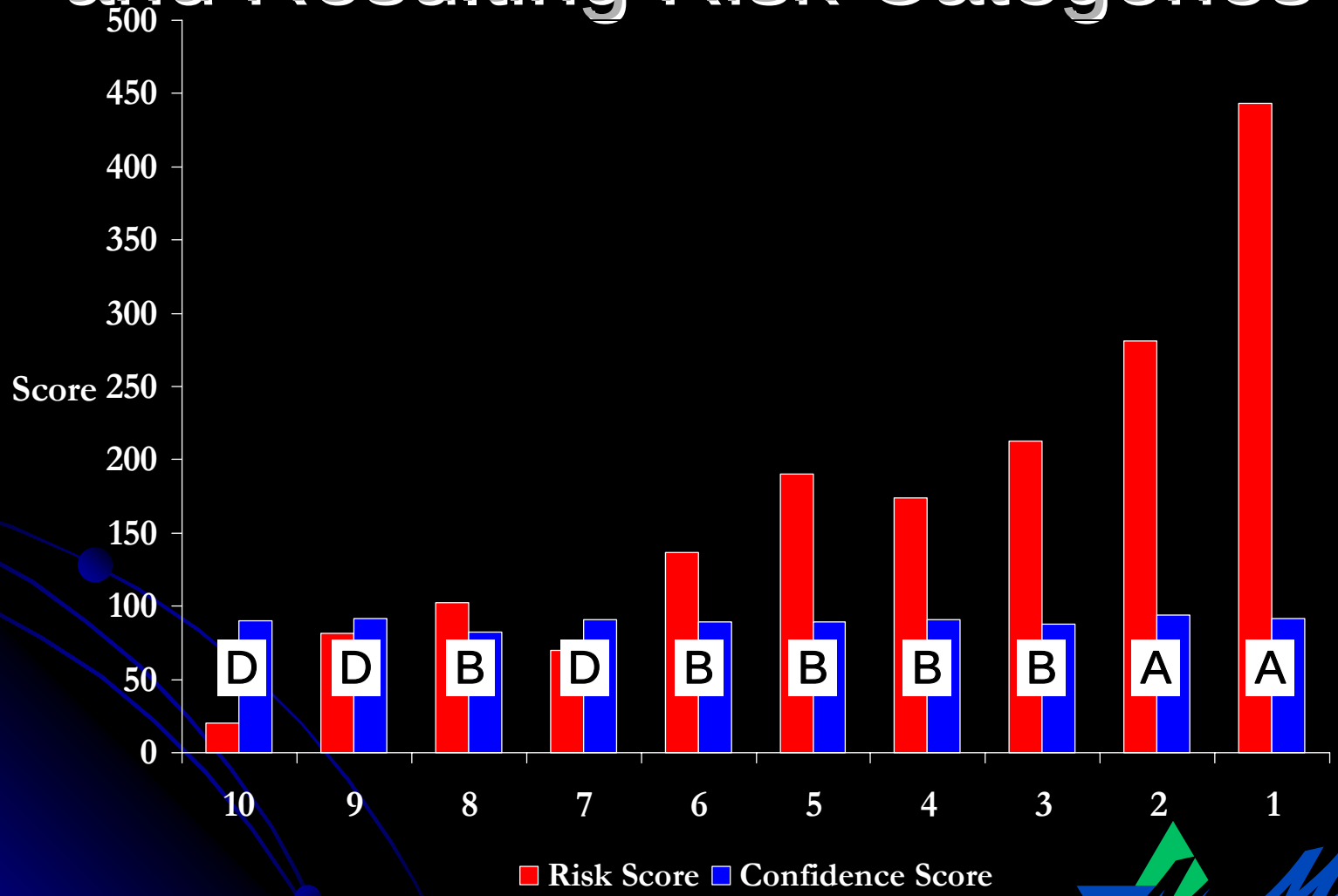
Risk and Confidence Scores and Resulting Risk Categories



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Recommended Courses of Action: Risk Category "A"

Recommended Courses of Action	Anticipated Risk Reduction Effectiveness
Develop and implement remediation plans.	Remediation reduces risk.
Consider hazard, receptor and exposure pathway risk factors and propose an action that will adequately reduce risk.	Effective when focused on key sources of risk.
Conduct a site-specific risk assessment.	May demonstrate that risk is acceptable.

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Recommended Courses of Action: Risk Category "B"

Recommended Courses of Action	Anticipated Risk Reduction Effectiveness
Consider hazard, receptor and exposure pathway risk factors and propose an action that will adequately reduce risk.	Effective when focused on key sources of risk.
Assess remediation options.	Risk is reduced when remediation is implemented.
Acquire additional information to improve the confidence score and re-evaluate the risk.	No change in risk, but improved understanding.
Consider hazard, receptor and exposure pathway risk factors and develop a monitoring program that will identify when changes occur.	Enables identification of increased risk.

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Recommended Courses of Action: Risk Category "C"

Recommended Courses of Action	Anticipated Risk Reduction Effectiveness
Acquire additional information to improve the confidence score and re-evaluate the risk.	No change in risk, but improved understanding.
Consider hazard, receptor and exposure pathway risk factors and develop a monitoring program that will identify when changes occur.	Enables identification of increased risk.

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Recommended Courses of Action: Risk Category "D"

Recommended Courses of Action	Anticipated Risk Reduction Effectiveness
Schedule re-evaluation of risk in two years or when a known change occurs.	No change.

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Recommended Courses of Action: Risk Category "N"

Recommended Courses of Action	Anticipated Risk Reduction Effectiveness
Acquire additional information to improve the confidence score and re-evaluate the risk.	No change in risk, but improved understanding.

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Case Studies

…from the Matrix files….

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Case Study 1: Free Product at a Gas Processing Plant

- Sweet gas plant in south-central Alberta
- Historic flare pit
- Large groundwater plume with free product in over 40 monitoring wells
- Till underlain by fractured bedrock
- Agricultural land with water well users

Hazards:	8.10
Receptors:	7.30
Exposure pathways:	7.50
OVERALL RISK:	443
CONFIDENCE:	92
CATEGORY:	A

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Case Study 2: Produced Water Spills in SE Saskatchewan

- Two former oil batteries and many active wells in an area >100 ha
- Historic produced water spills have impacted a 20 ha area
- Clay, silt and sand with occasional sand channels
- Agricultural land with residence within 200 m of the site
- Farmer has a 7 m water well
- Creek and lake 1.5-2 km from site

Hazards:	5.60
Receptors:	8.00
Exposure pathways:	6.28
OVERALL RISK:	281
CONFIDENCE:	94
CATEGORY:	A

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Case Study 3: Salt at a Former Road Maintenance Yard

- Site is within a major Alberta city and was used for storing road salt
- Soil EC and chloride in water exceed criteria
- Glacial silt till over bedrock
- Intermittent and perennial ponds across highway
- Residential subdivision
- Municipal water supply but two wells 0.8-0.9 km from site

Hazards:	3.8
Receptors:	6.5
Exposure pathways:	3.3
OVERALL RISK:	82
CONFIDENCE:	92
CATEGORY:	D

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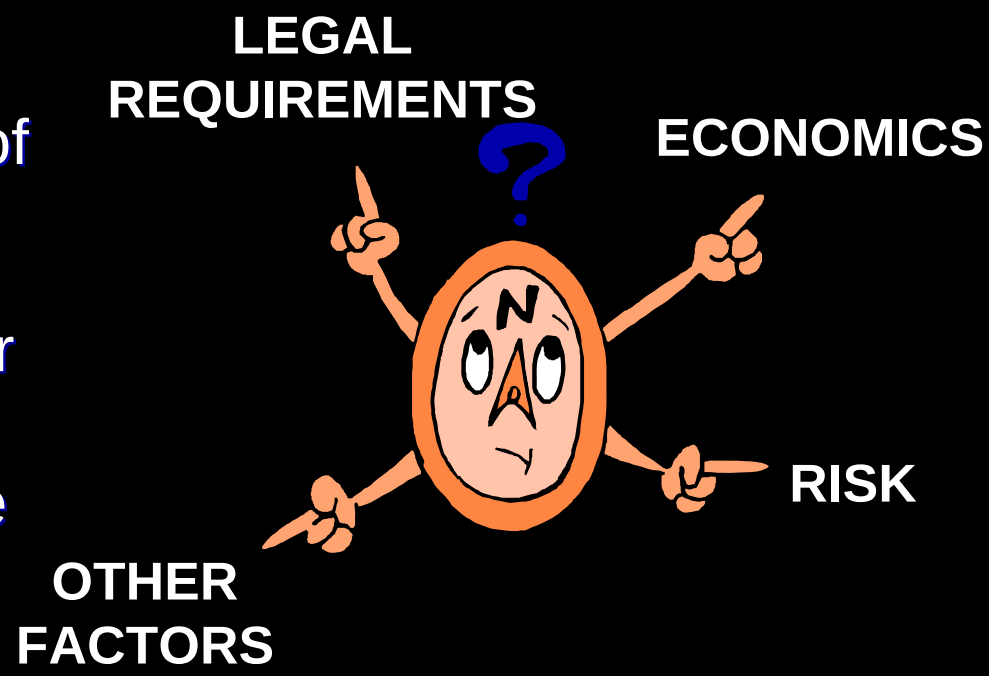
Conclusions

- The comparative risk evaluation model aids non-subjective and defensible prioritization of contaminated sites
- In combination with other factors, it helps decision makers determine where best to allocate limited financial resources



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