

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

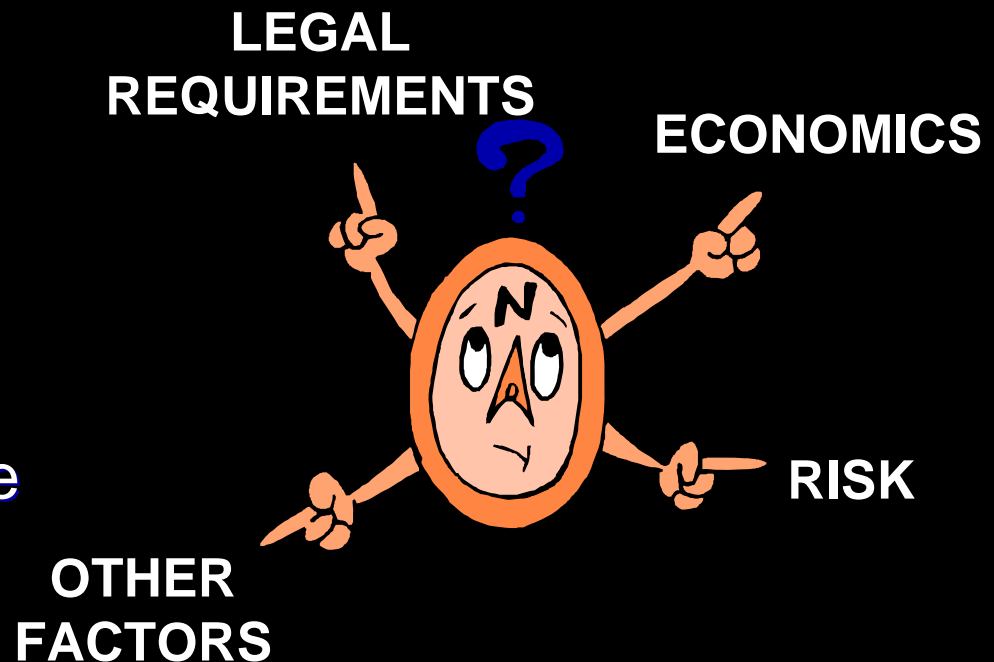
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Where to focus the effort?

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



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

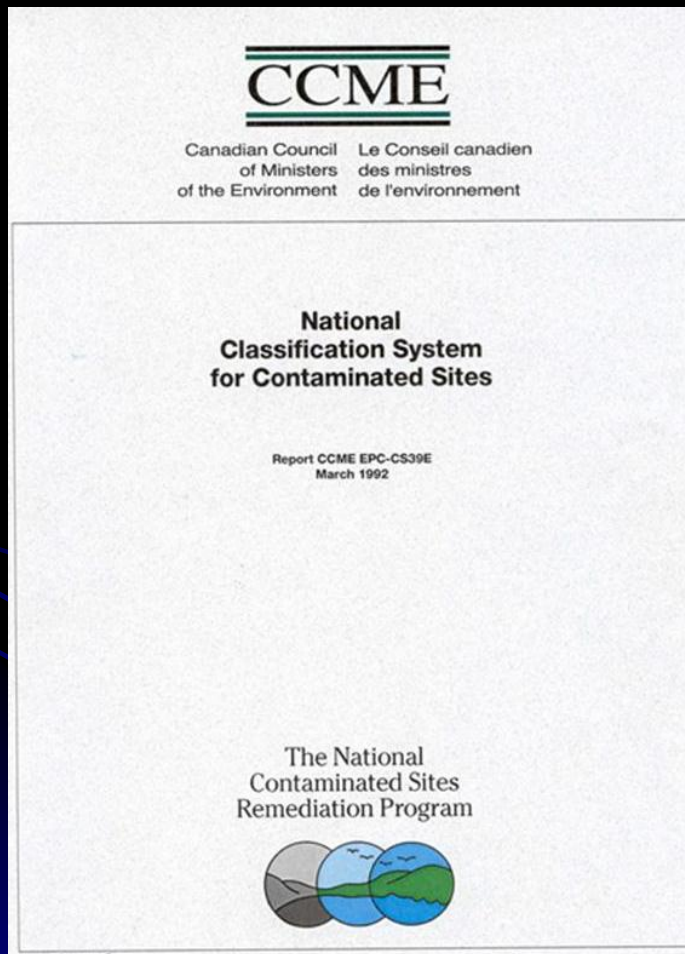
Comparative Risk Evaluation Tool

- 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

Manifestation of Risk



Assessing Risk Scores



CCME, 1992:

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

Add: total out of 100

Assessing Risk Scores

Matrix, 2007:

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

Multiply: total out of 1,000



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

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

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

Data Entry: Example

Microsoft Excel - COMPARATIVE RISK EVALUATION.xls

File Edit View Insert Format Tools Data Bluebeam Window Help

Type a question for help

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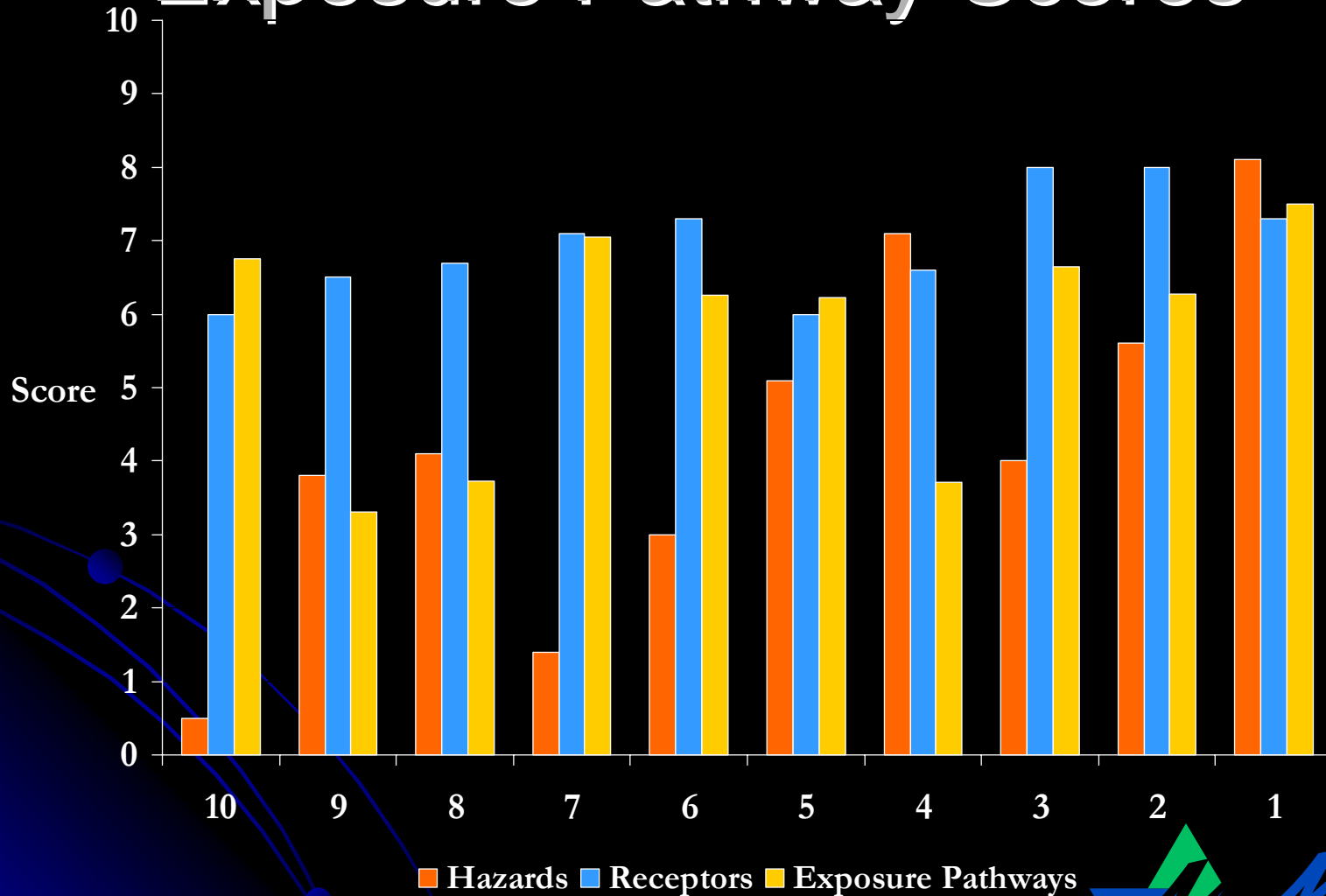
G23 1.2

	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 3.2×10^{-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	

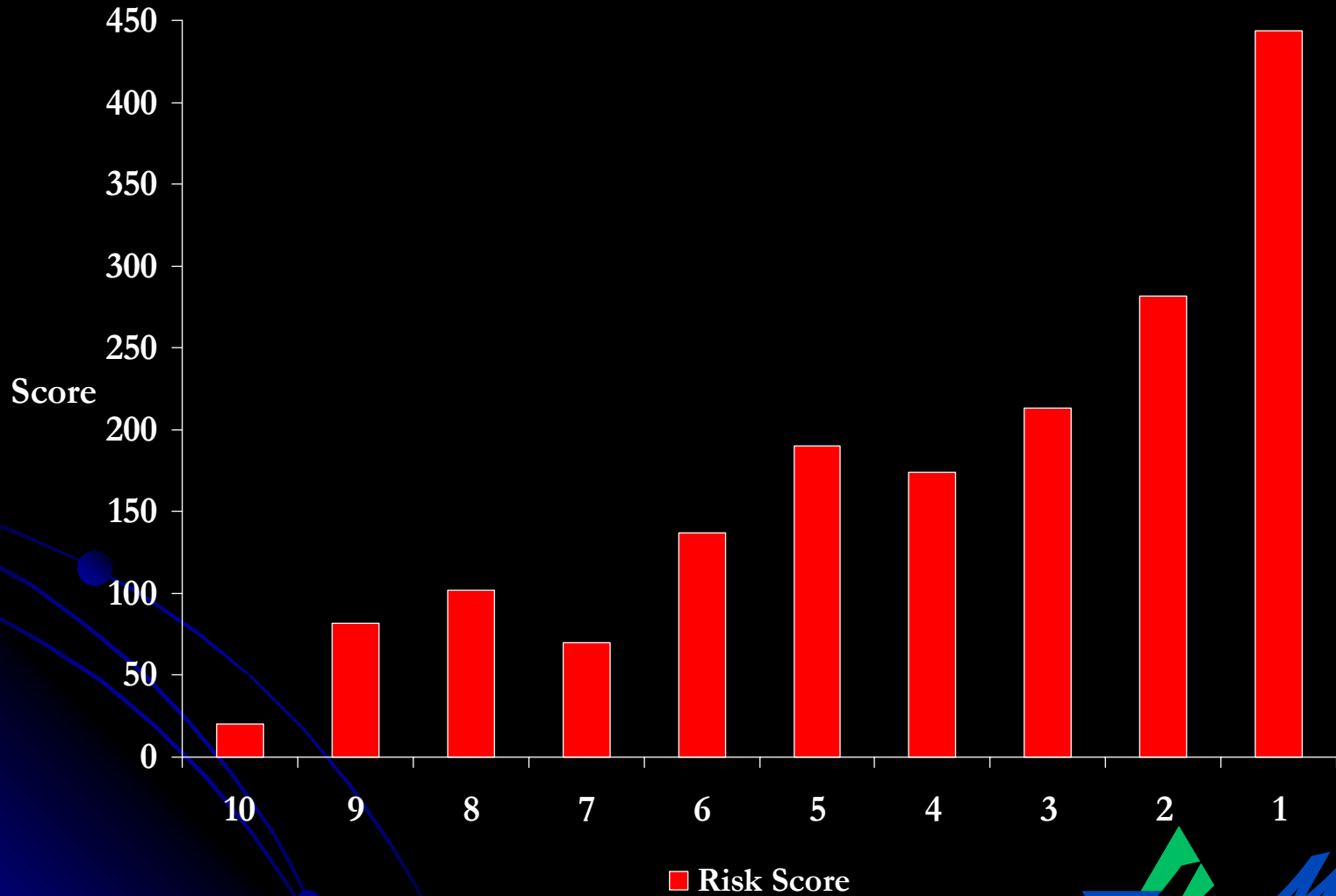
Hazard Factors Receptor Factors Exposure Pathway Factors Risk Summary Page Tbl 1-2

Draw AutoShapes

Summary of Hazard, Receptor and Exposure Pathway Scores



Risk Scores



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

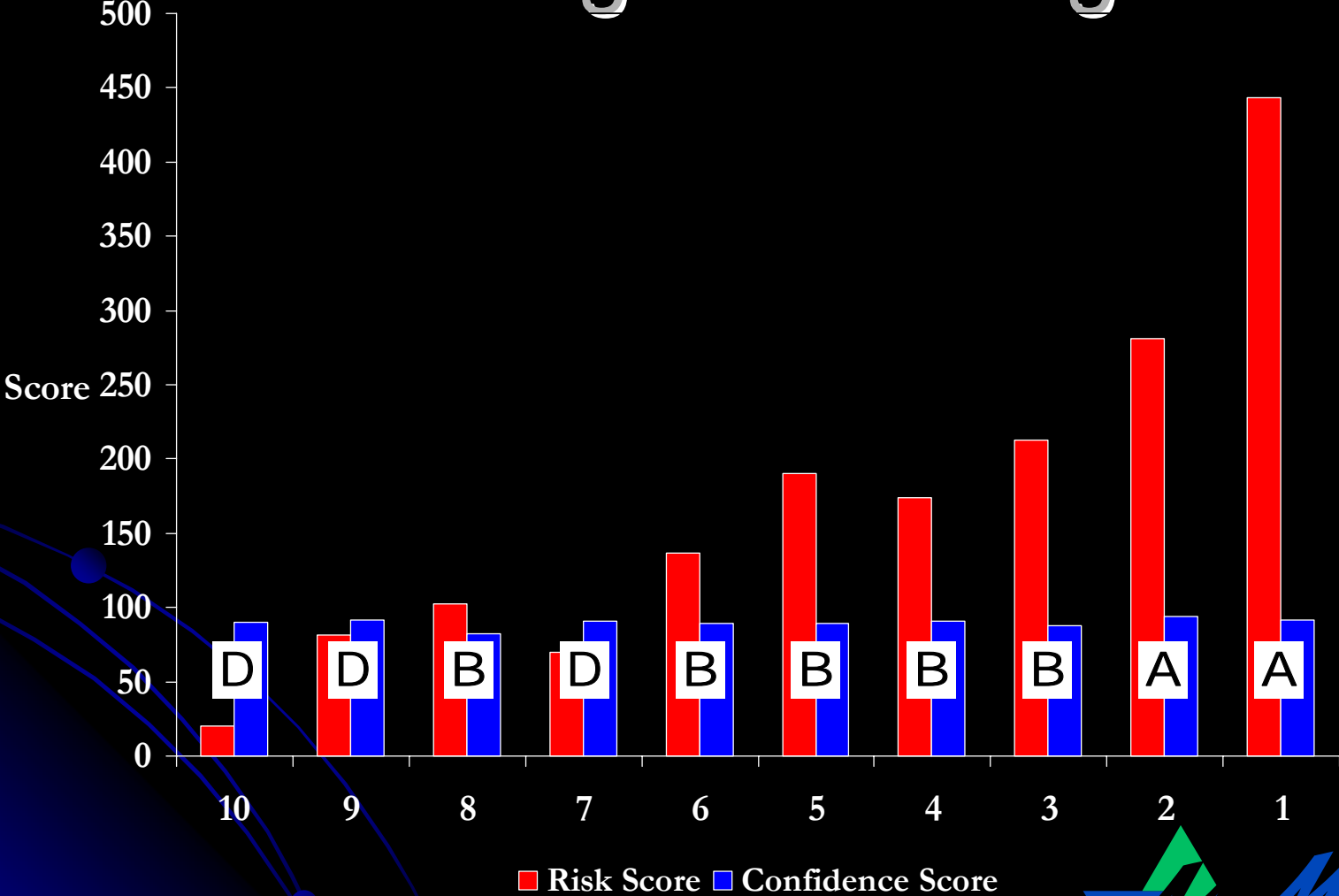
$$\begin{aligned}\text{Risk} &= \Sigma H \cdot \Sigma R \cdot \Sigma E \\ &= (H_1 + H_2 + H_3 + \dots + H_{13}) \cdot \Sigma R \cdot \Sigma E \\ &= H_1(\Sigma R \cdot \Sigma E) + H_2(\Sigma R \cdot \Sigma E) + H_3(\Sigma R \cdot \Sigma E) + \dots + H_{13}(\Sigma R \cdot \Sigma E)\end{aligned}$$



Determination of Risk Category

Confidence Score	>80	D	B	A
	60-80	C		B
	<60	N		
		<100	100-250	>250
		Total Risk Score		

Risk and Confidence Scores and Resulting Risk Categories



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.

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.

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.

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.

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.

Case Studies

...from the Matrix files....



Case Study 1: Free Product at a Gas Processing Plant

- Sweet gas plant in south-central Alberta

Hazards: 8.10

- Historic flare pit

Receptors: 7.30

- Large groundwater plume with free product in over 40 monitoring wells

Exposure pathways: 7.50

- Till underlain by fractured bedrock

OVERALL RISK: 443

- Agricultural land with water well users

CONFIDENCE: 92

CATEGORY: A

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

Case Study 3: Salt at a Former Road Maintenance Yard

- Site is within a major Alberta city and was used for storing road salt

Hazards: 3.8

- Soil EC and chloride in water exceed criteria

Receptors: 6.5

- Glacial silt till over bedrock

Exposure pathways: 3.3

- Intermittent and perennial ponds across highway

OVERALL RISK: 82

- Residential subdivision

CONFIDENCE: 92

- Municipal water supply but two wells 0.8-0.9 km from site

CATEGORY: D

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

