Decision Analyses
for ARD Waste Cover Selection

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Decision Analyses

RISK

COST

REWARD

Minuses	vs	Pluses
Losses	vs	Gains
Costs	vs	Benefits
$	vs	$

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Geological, Mining & Metallurgical Risk has been recognized by the Canadian Security Exchange Commissions
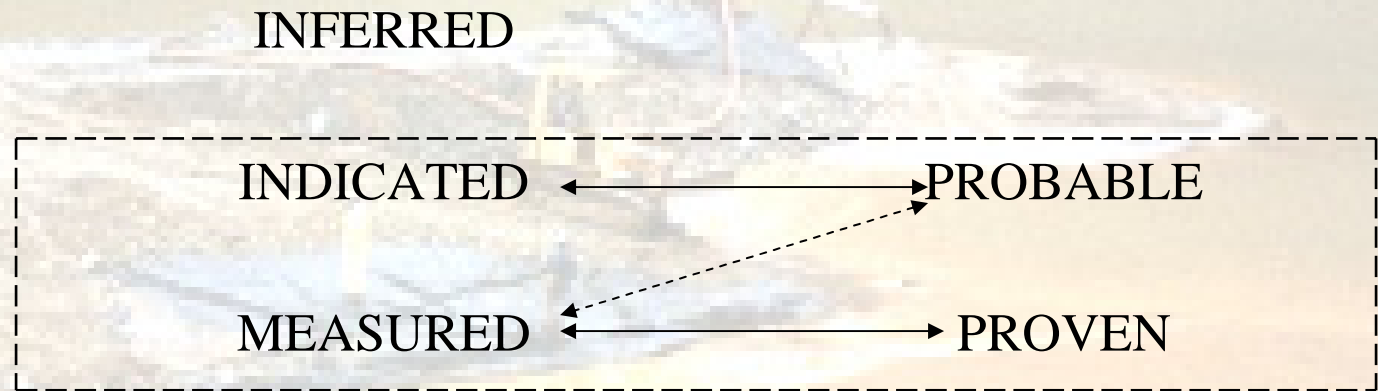
RISK

DEPOSIT

MINE/ NO MINE
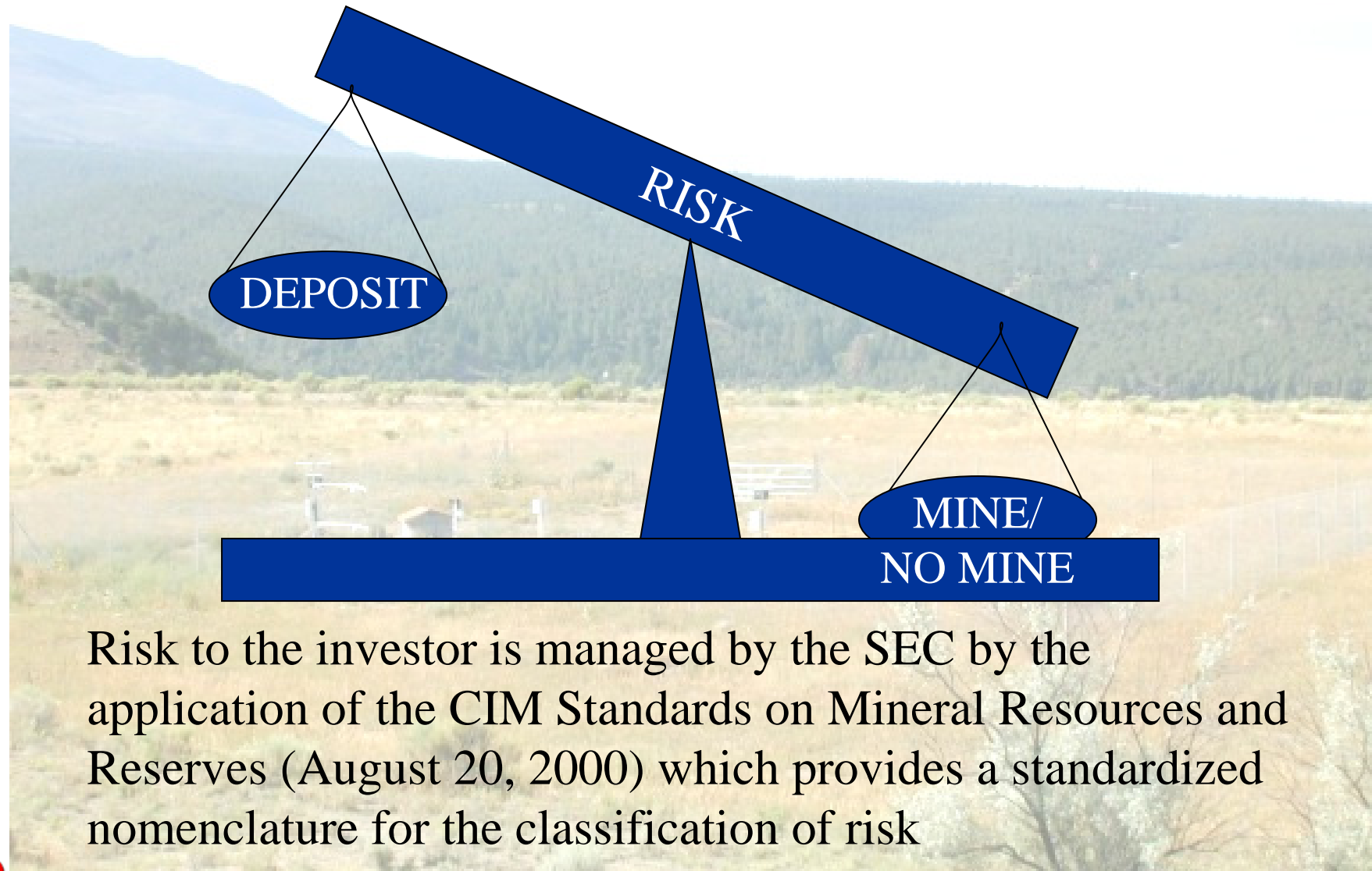
Risk to the investor is managed by the SEC by the application of the CIM Standards on Mineral Resources and Reserves (August 20, 2000) which provides a standardized nomenclature for the classification of risk

Mineral Reserve Definition

MINERAL RESOURCES   **MINERAL RESERVES**

Increasing
level of
geological
knowledge
& confidence

INFERRED

INDICATED ←——————→ PROBABLE

MEASURED ←——————→ PROVEN

Consideration of mining, metallurgical, economic, marketing,
legal, environmental, social and governmental factors

(the "modifying factors")

CIM Standards on Mineral Resources and Reserves, August 20, 2000

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Decision Analysis to Minimize Risks and Impacts

- The list of "modifying factors" includes:
  - Mining,
  - Metallurgical,
  - Economic,
  - Marketing,
  - Legal,
  - Environmental,
  - Social and
  - Governmental factors

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Decision Analysis to Minimize Risks and Impacts

- Mine waste management and closure issues including waste covers can significantly influence 6 of the modifying factors.

Mining	including	Waste Management Constraints
Metallurgical		
Economic	"	Costs of Waste Management
Marketing		
Legal	"	Permitting Constraints
Environmental	"	Monitoring and Closure Requirements
Social	"	Public issues and image
Governmental	"	Moving goalposts of regulations

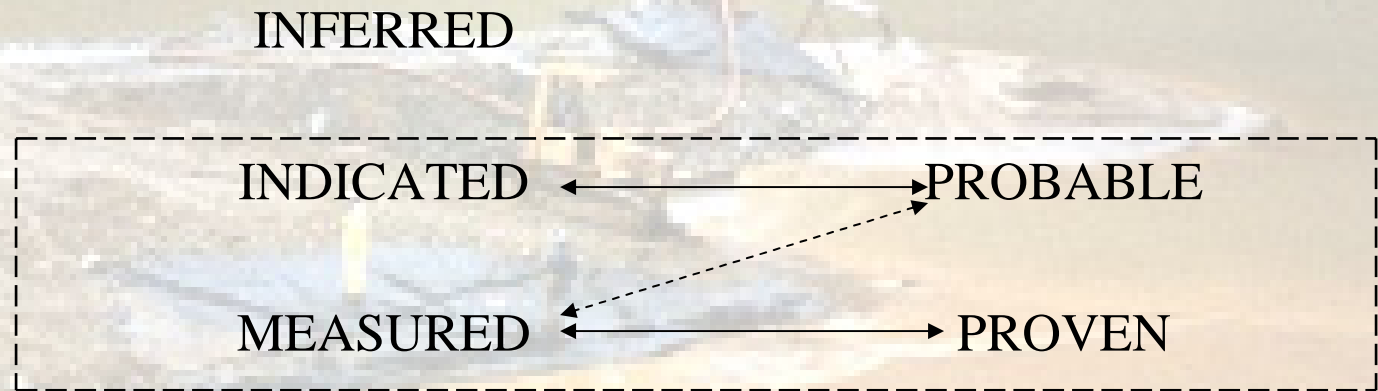- How are these factors accounted for in decision analysis?

10 30 '01

Mineral Reserve Definition

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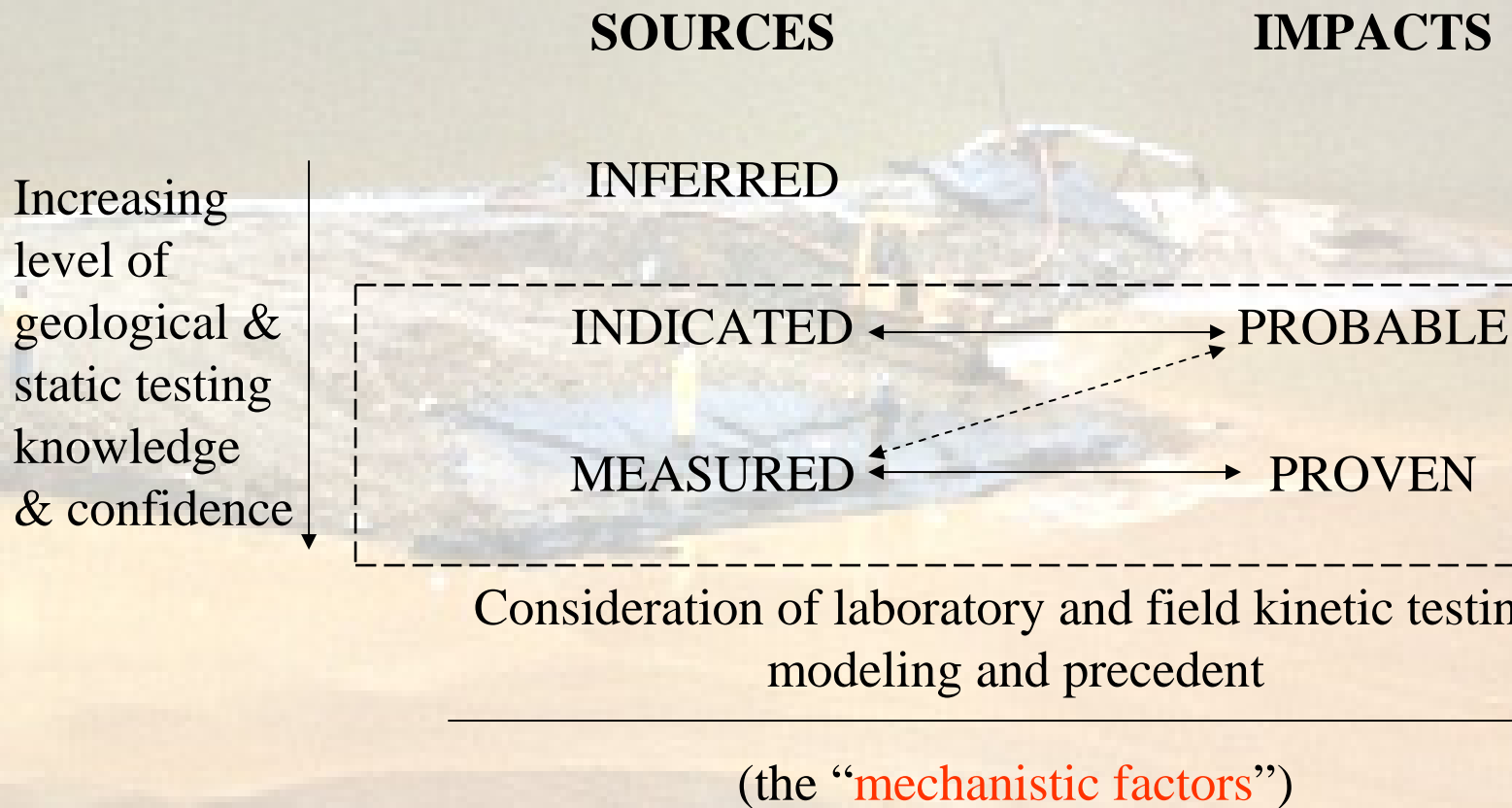INDICATED ←——————→ PROBABLE

MEASURED ←——————→ PROVEN

Consideration of mining, metallurgical, economic, marketing,
legal, environmental, social and governmental factors

(the "modifying factors")

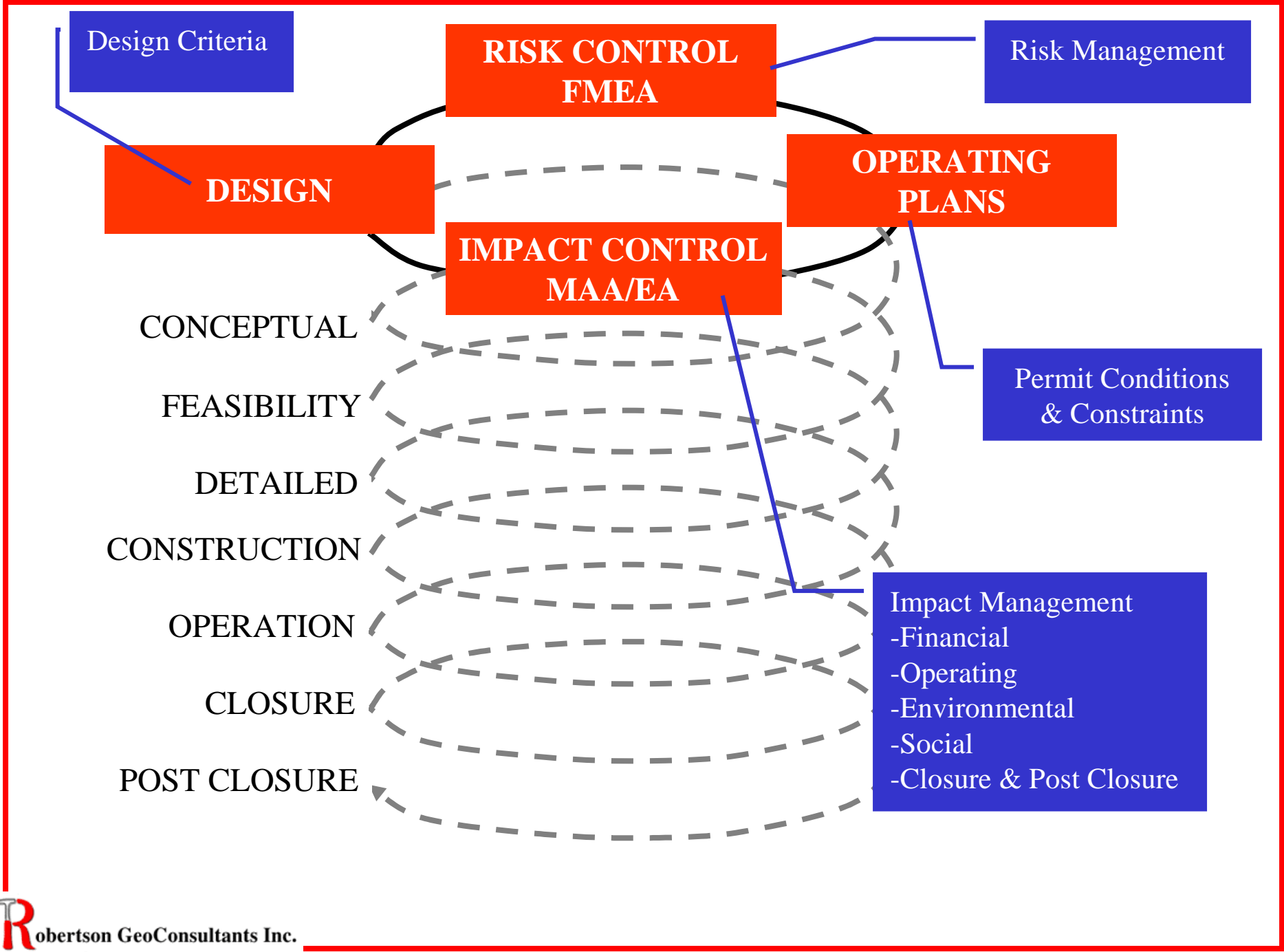**CIM Standards on Mineral Resources and Reserves, August 20, 2000**

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ML/ARD Control Definition

SOURCES   **IMPACTS**

Increasing
level of
geological &
static testing
knowledge
& confidence

INFERRED

INDICATED ←————————→ PROBABLE

MEASURED ←————————→ PROVEN

Consideration of laboratory and field kinetic testing,
modeling and precedent

(the "mechanistic factors")

Standards on ML/ARD Control Definitions, December 2, 2004

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Design Criteria

RISK CONTROL
FMEA

Risk Management

DESIGN

OPERATING
PLANS

IMPACT CONTROL
MAA/EA

CONCEPTUAL

FEASIBILITY

DETAILED

Permit Conditions
& Constraints

CONSTRUCTION

OPERATION

CLOSURE

POST CLOSURE

Impact Management
-Financial
-Operating
-Environmental
-Social
-Closure & Post Closure

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Evaluating Options

RISK CONTROL FMEA

DESIGN

OPERATING PLANS

IMPACT CONTROL MAA/EA

- Tools or processes available for these evaluations include:

    MAA = Multiple Accounts Analysis
    FMEA = Failure Modes and Effects Analysis
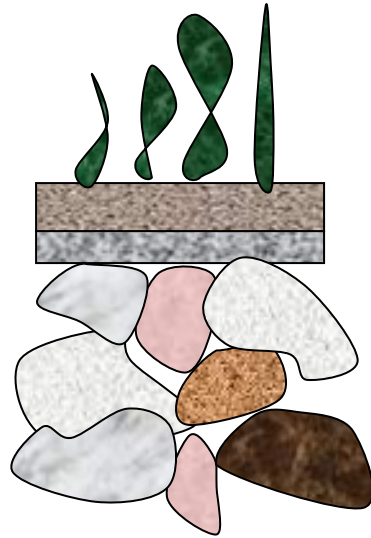   EA = Environmental Assessment

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The MAA: An Illustrative Example

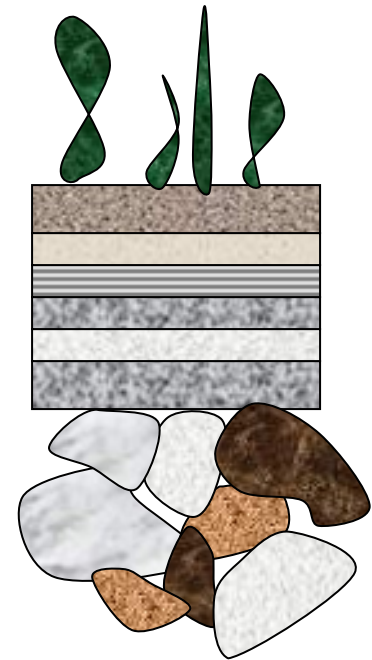Option A   Option B   Option C   Option D
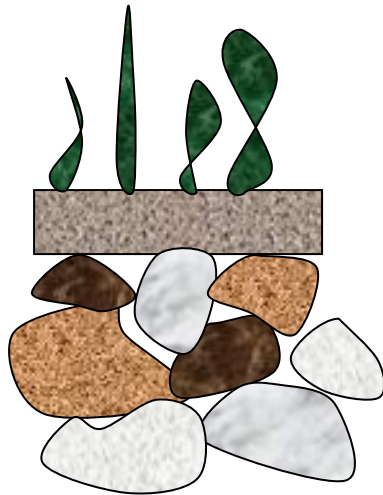
Simple Cover   Compound Cover   Geosynthetic Cover   Complex Cover

Utilizing the Multiple Accounts Analysis to Evaluate the Options

- The MAA provides a forum in which stakeholders or communities of interest can express their concerns and communicate and defend their assessments of the impacts of a specific option and compare the various options against each other.
- It also provides a tool to assess the relative merits (positive and negative) of the different options proposed, i.e. the modifying factors.
- This involves three basic steps:
  - Identify the impacts (benefits and costs) to be included in the evaluation
  - Quantify the impacts (benefits and costs);
  - Assess the combined or accumulated impacts for each alternative, and compare these with other alternatives to develop a preference list (ranking, scaling and weighting) of the alternatives.

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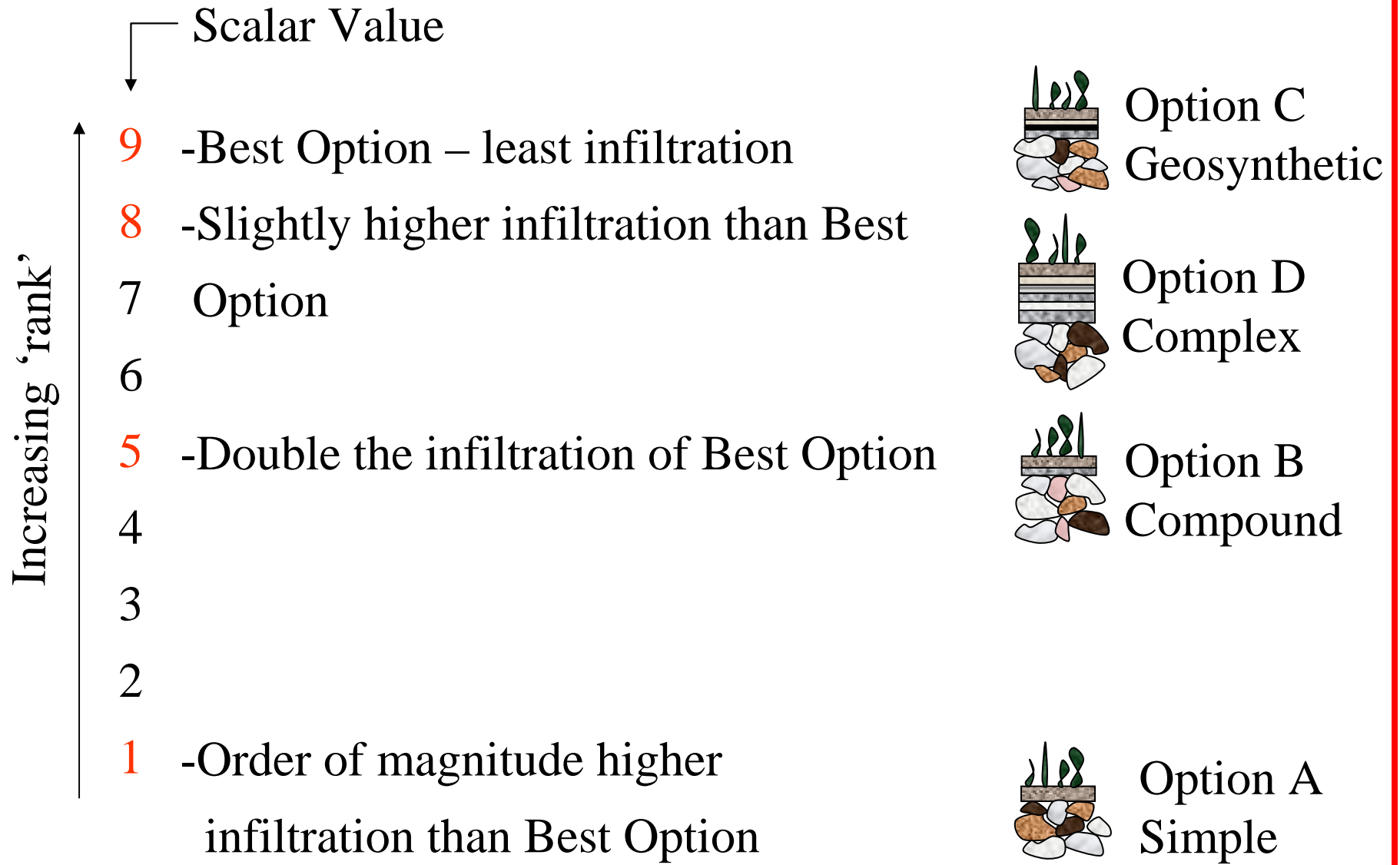Mining, Geotechnical and Environmental Engineers

Typical Structure

ACCOUNTS ⟶ SUB-ACCOUNTS ⟶ INDICATORS

Technical

a. Access / trafficability	i. High to Low
b. Erosion / sedimentation	ii. Good to Poor
c. Settlement / consolidation	iii. Numeric Values
d. Maintenance requirements	iv. Large to Small
e. Biota (fauna, flora) controls	v. Significant to Nil

Project Economic

a. Construction Costs	i. NPV $
b. Maintenance Costs	ii. NPV $

Environmental

a. Infiltration	i. mm/yr
b. Oxygen flux	ii. $mol/m^2/yr$
c. Air quality	iii. Good to poor
d. Water quality	iv. Tonnes per year
e. Biota quality	v. Productivity value

Socio-economic

a. Aesthetics	i. Unsightly to Appealing
b. Employment opportunities	ii. Jobs per annum

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Quantitative vs. Qualitative

- As a result of uncertainties such as long term water quality predictions, the reliability and durability of covers etc., much of the assessment was necessarily based on judgment rather than deterministic analysis.
- Therefore, having participants who were experienced with similar projects and/or dedicated to understanding and learning the realistic benefits and limitations of certain measures was critical to the success of these evaluations.
- Once the ledgers are complete, the Options are evaluated on the basis of all factors in the ledger by the method of Ranking, Scaling and Weighting (RSW).

Ranking & Scaling:

Scalar Value

Increasing 'rank'

9 -Best Option – least infiltration

8 -Slightly higher infiltration than Best

7 Option

6

5 -Double the infiltration of Best Option

4

3

2

1 -Order of magnitude higher

infiltration than Best Option

Option C
Geosynthetic

Option D
Complex

Option B
Compound

Option A
Simple

Weighting

Technical
W = 2

a.	Access / trafficability	W = 2
b.	Erosion / sedimentation	W = 5
c.	Settlement / consolidation	W = 3
d.	Maintenance requirements	W = 5
e.	Biota (fauna, flora) controls	W = 2

Project Economic
W = 3

a.	Construction Costs	W = 5
b.	Maintenance Costs	W = 3

Environmental
W = 5

a.	Infiltration	W = 5
b.	Oxygen flux	W = 2
c.	Air quality	W = 3
d.	Water quality	W = 5
e.	Biota quality	W = 4

Socio-economic
W = 5

a.	Aesthetics	W = 5
b.	Employment opportunities	W = 5

Calculating the Score

- Scores are calculated for each Sub-Account, each Account and a final MAA Score

$$\text{Score} = \frac{\sum \text{Scalar Values x Weights}}{\sum \text{Weights}}$$

- The higher the score, the more favorable the alternative in any one category.

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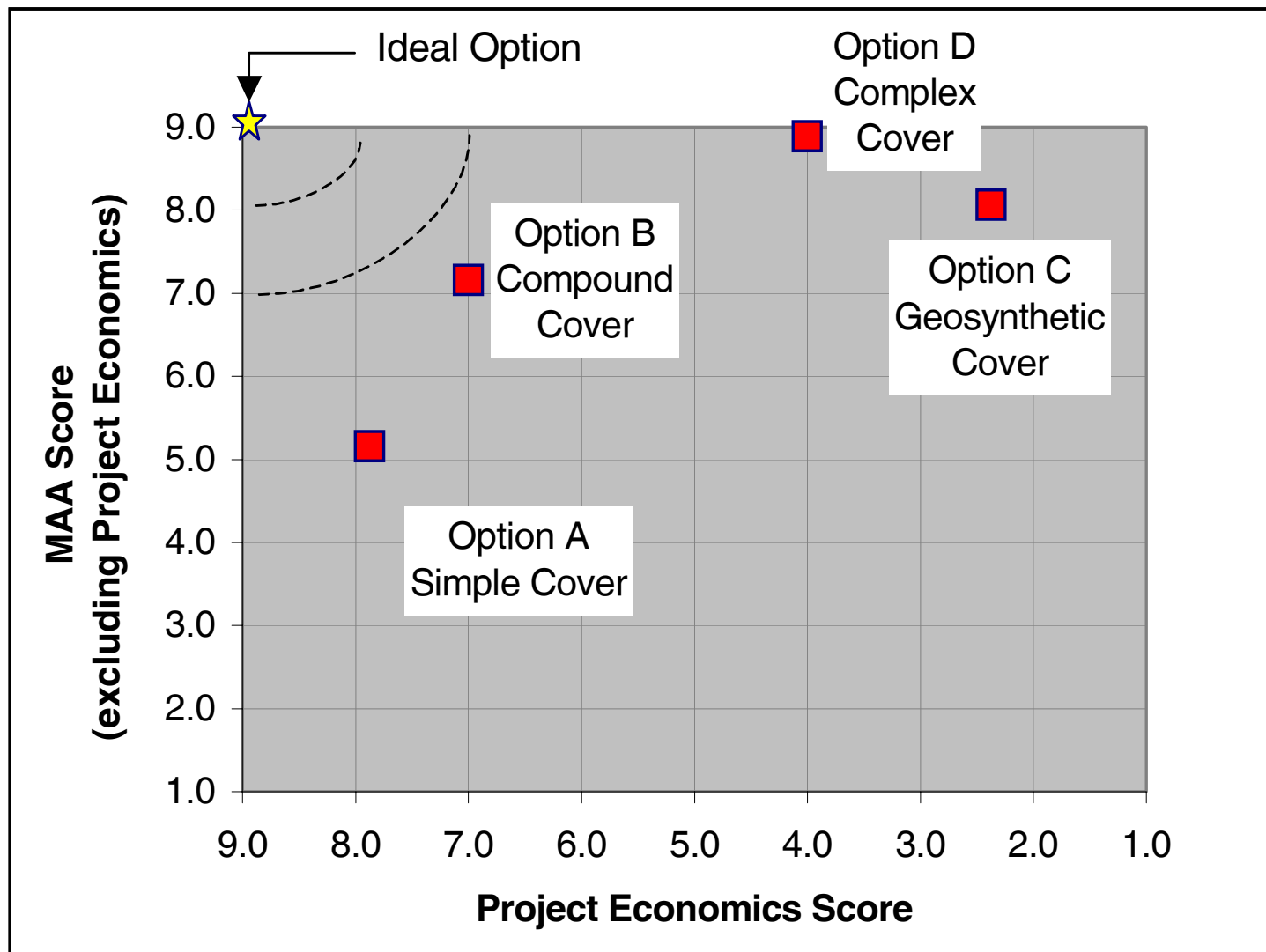| ACCOUNTS	WEIGHT	SUB-ACCOUNTS	WEIGHT	Option A Simple Cover	Option B Compound Cover	Option C Geosynthetic Cover	Option D Complex Cover	CONTROL DEFINITION
Technical	2	Access/ trafficability	2	9	9	9	9	PV
		Erosion/Sedimentation	5	4	7	8	9	PB
		Settlement/consolidation	3	9	9	9	9	PV
		Maintenance requirements	5	3	5	7	9	PB
		Biota controls	2	2	4	5	9	PB
		Technical Account Score		**4.9**	**6.6**	**7.6**	**9.0**	
Project Economics	3	Construction Costs	5	9	7	2	1	PV
		Maintenance Costs	3	6	7	3	9	PB
		Technical Account Score		**7.9**	**7.0**	**2.4**	**4.0**	
Environmental	5	Infiltration	5	1	5	9	8	PB
		Oxygen flux	2	5	7	9	9	PB
		Air quality	3	8	9	9	9	PB
		Water quality	5	3	6	9	9	I
		Biota quality	4	5	7	8	9	I
		Technical Account Score		**3.9**	**6.5**	**8.8**	**8.7**	
Socio-economics	5	Aesthetics	5	8	9	6	9	I
		Employment Opportunities	5	5	7	9	9	PB
		Technical Account Score		**6.5**	**8.0**	**7.5**	**9.0**	
		Multiple Account Score		**5.7**	**7.1**	**6.9**	**7.9**	

I=INFERRED
PB=PROBABLE
PV=PROVEN

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MAA Score (excluding Project Economics) vs **Project Economics Score**

- Ideal Option
- Option A — Simple Cover
- Option B — Compound Cover
- Option C — Geosynthetic Cover
- Option D — Complex Cover

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Utilizing the Failure Modes and Effects Analysis to Evaluate Risks

- The FMEA provides an analysis technique that can be used to assess the potential for, or likelihood of, failure of structures, equipment or processes as well as predictions and the effects of such failures on the system which they form a part of.
- It is systematic and comprehensive
- In our example the FMEA can evaluate the potential for failures of either Cover Option that could result in Biological/Land Use Impacts, Regulatory Impacts/Censorship, Public Concern/Image and Health and Safety Impacts as well as Cost.
- The result is a risk profile for each option for decision making and mitigation planning

		LIKELIHOOD				
		NOT LIKELY	LOW	MODERATE	HIGH	EXPECTED
CONSEQUENCE	EXTREME					
	HIGH					
	MODERATE					
	LOW					
	NEGLIGIBLE					

http://technology.infomine.com/enviromine/Issues/cls_FMEA.html

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| COMPONENT | ID | FAILURE MODE | EFFECTS | LIKELIHOOD | CONSEQUENCES | | | | | LEVEL OF CONFIDENCE* |
					BIOLOGICAL IMPACTS & LAND USE	REGULATORY IMPACTS & CONCERNS	PUBLIC CONCERN & IMAGE	HEALTH & SAFETY	DIRECT COSTS	
OPTION B - COMPOUND COVER										
	B1	Substantial erosion	TSS standard exceeded	H	M	M	M	N	M	PV
	B2	Increased infiltration	Increased dump seepage	M	H	H	M	L	H	PB
	B3	Vegetation failure	Aesthetic value not realized	L	M	L	L	N	L	PB
OPTION D - COMPLEX COVER										
	D1	Substantial erosion	TSS standard exceeded	M	M	M	M	N	M	PV
	D2	Increased infiltration	Increased seepage	L	M	M	L	N	M	PB
	D3	Vegetation failure	Aesthetic value not realized	L	M	L	L	N	L	PB

* LEVEL OF CONFIDENCE DEFINED USING STANDARDS:

I = INFERRED; PB = PROBABLE; PV = PROVEN

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Ideal Option

Option D Complex Cover

Option B Compound Cover

Option C Geosynthetic Cover

Option A Simple Cover

MAA Score (excluding Project Economics)

9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0

9.0 8.0 7.0 6.0 5.0 4.0

Project Economics Score

	LIKELIHOOD				
	NOT LIKELY	LOW	MODERATE	HIGH	EXPECTED
EXTREME					
HIGH			B2		
MODERATE		B3, D2, D3	D1	B1	
LOW					
NEGLIGIBLE					

CONSEQUENCE

Thank you.

Additional References
http://technology.infomine.com/enviromine/Issues/cls_FMEA.html
http://technology.infomine.com/enviromine/Issues/cls_MAA.html
http://www.robertsongeoconsultants.com/papers/MAA%20at%20Zortman_Landusky.pdf
http://www.robertsongeoconsultants.com/papers/MAA_SME_2004.pdf
http://www.edumine.com/xedumine/toolcat.htm?category=management

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