Standards-based Reclamation Evaluation and Action Framework for Adaptive Management

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OUR WORK'S NOT DONE! – EXAMINED – MINE LANDS

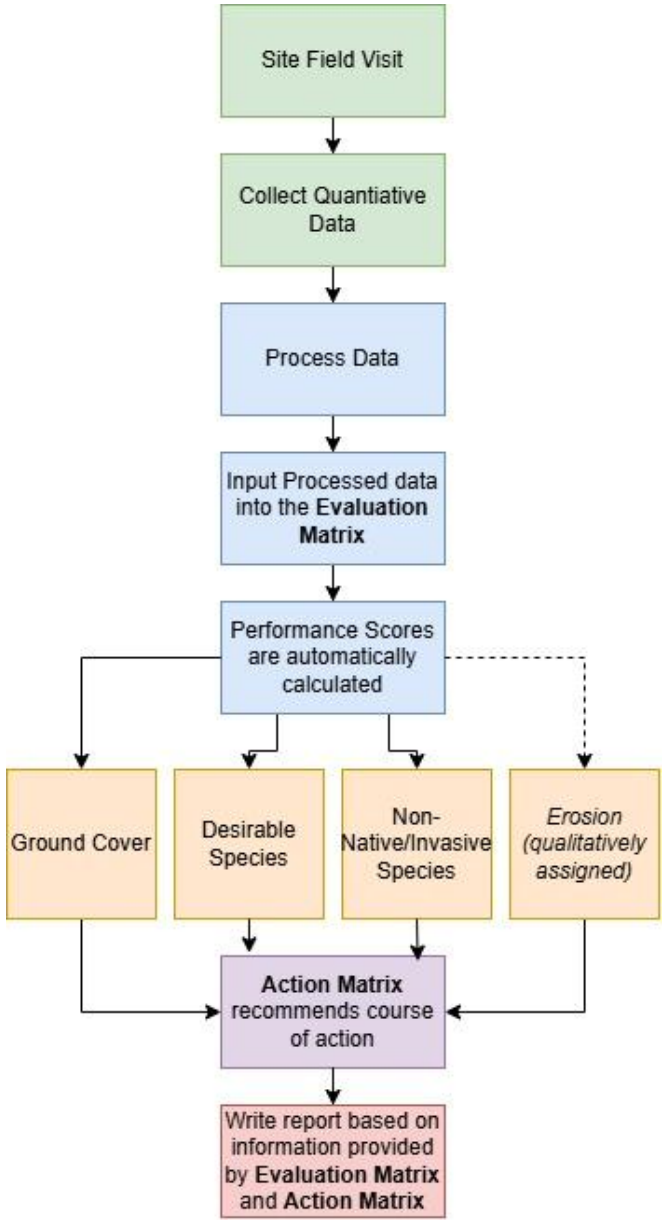
DEQ WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY

Evaluation Matrix and Action Matrix: Context

- The Wyoming DEQ Abandoned Mine Land Database contains **4300+** mine sites
- We inspect approximately 50 AML sites a field season to determine:
  - What are the current biotic/abiotic conditions and how have they changed over time?
  - Can the Site be recommended for certification or is intervention needed?
- Additional requirements:
  - Describe a Site's status using a dashboard risk ranking
  - Provide an impartial and auditable ranking of Site performance
- **How can we accurately and consistently measure Site performance?**
- **How can we provide effective management recommendations?**
- **Through the Evaluation Matrix and the Action Matrix**

Monitoring and Certification Program Overview

- The **Evaluation Matrix** allows us to adopt standard metrics when examining Sites and reporting on outcomes
- The **Action Matrix** allows us to provide standard reclamations based on those Site outcomes



Total Raw Score	
170.0	
Scientific Name	**Abundance * Desirability**
Artemisia tridentata ssp. wyomingensis	12.375
Astragalus cicer	15
Astragalus spatulatus	7.5
Atriplex gardneri	29
Bouteloua curtipendula	6
Bromus tectorum	-10
Chaenactis douglasii	4.125
Chrysothamnus viscidiflorus	7.5
Elymus elymoides	6
Elymus trachycaulus	6
Gutierrezia sarothrae	6.5
Hedeoma drummondii	7.5
Koeleria macrantha	6
Oenothera caespitosa	7.5
Oxytropis campestris	7.5
Pascopyrum smithii	
Penstemon angustifolius	
Penstemon eatonii	
Poa secunda	
Pseudoroegneria spicata	12
Rhus trilobata	0

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Section 1

Evaluation Matrix

– Improve Data Interpretation and Analysis

Evaluation Matrix – Vegetation Monitoring Points and Data Inputs

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Turning Field Observations Into Data:

- Tetra Tech conducts Site surveys using vegetation monitoring points (VMPs) collected in FieldMaps
  - Photograph points
  - Identify species in the field
  - sync data with AGOL
- Process VMPs through SamplePoint
- Output: data summary sheet with list of species codes and cover values

Create inputs for the Evaluation Matrix

Evaluation Matrix – Data Summary and Site Info

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Input Data to be Evaluated and Provide Site-relevant Info

- Summary sheet:
  - Species functional groups
  - Species and non-vegetation cover
  - Average cover values throughout Site
  - Individual value by VMP
- Site-Specific Info:
  - Site name
  - Date of reclamation and date of monitoring
  - Site county location
  - Species included in seed mix

Select species seeded below. Click here for link to Desirable Ref tab

Species Seeded on Site - Scientific Name dropdown list	Common Name	Functional Group
Pascopyrum smithii	western wheatgrass	NPG
Pseudoroegneria spicata	bluebunch wheatgrass	NPG
Bouteloua curtipendula	sideoats grama	NPG
Schizachyrium scoparium	little bluestem	NPG
Andropogon gerardii	big bluestem	NPG
Elymus elymoides	bottlebrush squirreltail	NPG
Poa secunda	Sandberg bluegrass	NPG
Astragalus sp.	milkvetch	NPF
Krascheninnikovia lanata	winterfat	NS
Rhus trilobata	skunkbush sumac	NS
Artemisia tridentata ssp. wyomingensis	Wyoming big sagebrush	NS

Evaluation Matrix – Invasive Species on Site

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Highlight state and county-specific species of concern to reclamation

- State-wide and county specific (23 counties) noxious weed lists
- Allows for manual user input if invasive species seen on Site but not within a VMP
- Species ranked from A to G – represent level of concern

Enter species code below if invasive species seen on Site but was not collected in photo plot	Select County Name by clicking on cell D2	Plant Code	Was County Listed Species Found on site?	Species Code	State-listed Code	Was State Listed Species Found on site?	Number of County Noxious Species Found on Site	Number of State Noxious Species Found on Site	Total Number of Invasive Spp on Site
	Big Horn	CALA20	0	ACRE3	B	0	0	0	0
		CAPY2	0	AMPA	C	0			
		CECA2	0	AMTO3	C	0			
		CEIB	0	ARMI2	C	0			
		CEPR2	0	CAAC	A	0			
		CEVI2	0	CANU4	C	0			
		CHJU	0	CEDI3	B	0			
		COMA2	0	CESO3	A	0			
		CRVU2	0	CEST8	B	0			
		CUPE3	0	CIAR4	C	0			
		CYSC4	0	COAR4	C	0			
		DIFU2	0	CYOF	C	0			
		ECPU2	0	ELAN	C	0			
		ERCI6	0	ELRE4	C	0			
		GAOF	0	EUES	C	0			
		GYPA2	0	HYNI	C	0			
		HIAU	0	HYPE	A	0			
		HIFL3	0	ISTI	A	0			
		HITR	0	LEDR	B	0			
		POCU6	0	LELA2	C	0			
		PORE5	0	LEVU	B	0			
		SEJA	0	LIDA	B	0			
		SPSA3	0	LIVU2	A	0			
		TRPE21	0	LYSA2	A	0			
		TRTE	0	ONAC	B	0			
		ULEU	0	SOAR2	C	0			

Evaluation Matrix – Invasives Species Cover

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Determine level of risk based on Site age and species-specific severity

- Variation in risk level depending on age of Site – proxy for level of native vegetation establishment
- Allows user to decrease level of prescribed action if cheatgrass has already become widespread outside of the Site

INVASIVE/NOXIOUS SPECIES EVALUATION MATRIX

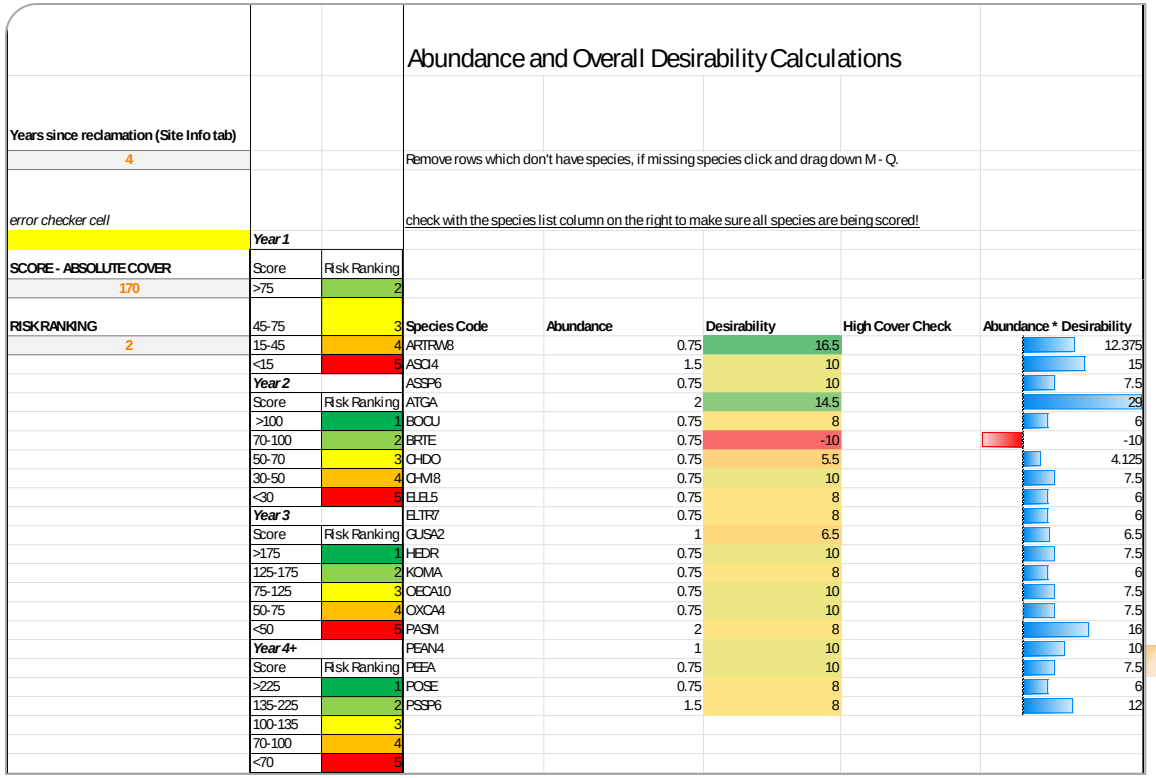
Noxious Species Present	Growing Seasons Post Reclamation						
	1	2	3	4	5	6	
	Risk Factors						
No Invasives	1						
Class A	5						
Class B (>5% Cover)	5						
Class B (<5% Cover)	5	5	4	4	4	4	
Class C (>5% Cover)	5						
Class C (<5% Cover)	4	4	4	3	3	3	
Class D (>8% Cover)	5	5	5	4	4	4	
Class D (2-8% Cover)	4	4	4	4	4	3	
Class D (<2% Cover)	3	3	3	3	3	2	
Class E (>20% Cover)	3	3	3	3	3	3	
Class E (10-20% Cover)	3	3	3	3	3	3	
Class E (<10% Cover)	3	3	3	2	2	2	
Class F (>5% Cover)	3	3	3	3	3	3	
Class F (<5% Cover)	2	2	2	2	2	2	
Class G	2	2	2	2	2	2	

Growing seasons post reclamation	4.0		
	Carbon County	Risk Factor	Action Level
State Noxious Class A cover	0.00%	1	Very Low
State Noxious Class B cover	0.00%	1	Very Low
State Noxious Class C cover	0.00%	1	Very Low
County Class D cover	0.00%	1	Very Low
County Class E cover	0.00%	1	Very Low
County Class F cover	0.00%	1	Very Low
County Class G cover	0.00%	1	Very Low
Cheatgrass common in reference community? (TRUE or FALSE):		FALSE	
	Max Risk Factor	1	

Evaluation Matrix – Calculate Desirable Species Ranking

Measure the quality of the existing vegetation community

- Assign a score based on both presence and abundance of desirable species on Site
- Thresholds determined by running matrix for multiple high-confidence level Sites
- Accounts for dominance, richness, and evenness – community properties driving resistance and resilience (Ajowele *et al* 2026)



Abundance and Overall Desirability Calculations

Years since reclamation (Site Info tab)						
4			Remove rows which don't have species, if missing species click and drag down M - Q.			
error checker cell			check with the species list column on the right to make sure all species are being scored!			
	Year 1					
SCORE - ABSOLUTE COVER	Score	Risk Ranking				
170	>75	2				
RISK RANKING	45-75	3	**Species Code**	**Abundance**	**Desirability**	**High Cover Check**	**Abundance * Desirability**
2	15-45	4	ARTRW8	0.75	16.5		12.375
	<15	5	ASCI4	1.5	10		15
	Year 2		ASSP6	0.75	10		7.5
	Score	Risk Ranking	ATGA	2	14.5		29
	>100	1	BOCU	0.75	8		6
	70-100	2	BRTE	0.75	-10		-10
	50-70	3	CHDO	0.75	5.5		4.125
	30-50	4	CHVI8	0.75	10		7.5
	<30	5	ELEL5	0.75	8		6
	Year 3		ELTR7	0.75	8		6
	Score	Risk Ranking	GUSA2	1	6.5		6.5
	>175	1	HEDR	0.75	10		7.5
	125-175	2	KOMA	0.75	8		6
	75-125	3	OECA10	0.75	10		7.5
	50-75	4	OXCA4	0.75	10		7.5
	<50	5	PASM	2	8		16
	Year 4+		PEAN4	1	10		10
	Score	Risk Ranking	PEEA	0.75	10		7.5
	>225	1	POSE	0.75	8		6
	135-225	2	PSSP6	1.5	8		12
	100-135	3					
	70-100	4					
	<70	5					

Evaluation Matrix – Desirable Species Reference Sheet

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Determine each species' contribution to the community

- List of all species (423) previously observed at a Site or commonly observed in the area and their desirability score alongside functional group, common name, and species symbol
- Includes column identifying all species that have been previously seeded on Site

Species on site checker	Desirability Score	Symbol	Common Name	Scientific Name	Functional Grou
0	8	ACHY	Indian ricegrass	*Achnatherum hymenoides*	NPG
0	10	ACLE9	Letterman's needlegrass	*Achnatherum lettermanii*	NPG
0	10	ACMI2	common yarrow	*Achillea millefolium*	NPF
0	8	ACOC3	western needlegrass	*Achnatherum occidentale*	NPG
0	-10	ACRE3	Russian knapweed	*Acroptilon repens*	IPF
0	1	ADENO5	dogweed	Adenophyllum sp.	NAF
0	14	AGAU2	orange agoseris	*Agoseris aurantiaca*	NPF
0	0	AGCR	crested wheatgrass	*Agopyron cristatum*	NNPG
0	10	AGOSE	agoseris	*Agoseris* sp.	NPF
0	14	AGGL	pale agorisis	*Agoseris glauca*	NPF
0	10	ALAC4	tapertip onion	*Allium acuminatum*	NPF
0	0	ALAL3	pale madwort	*Alyssum alyssoides*	NNAF
0	0	ALDE	desert alyssum	*Alyssum desertorum*	NNAF
0	10	AMAL2	Saskatoon serviceberry	*Amelanchier alnifolia*	NS
0	0	AMBRO	ragweed	*Ambrosia* sp.	NNAF
0	-5	AMPA	Palmer amaranth	*Amaranthus palmeri*	NNAF
0	10	AMPS	Cuman ragweed	*Ambrosia psilostachya*	NPF
0	-10	AMTO3	skeletonleaf bursage	*Ambrosia tomentosa*	IPF

Evaluation Matrix – Non-Native Species Cover

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Account for Non-Native Species Abundance Levels

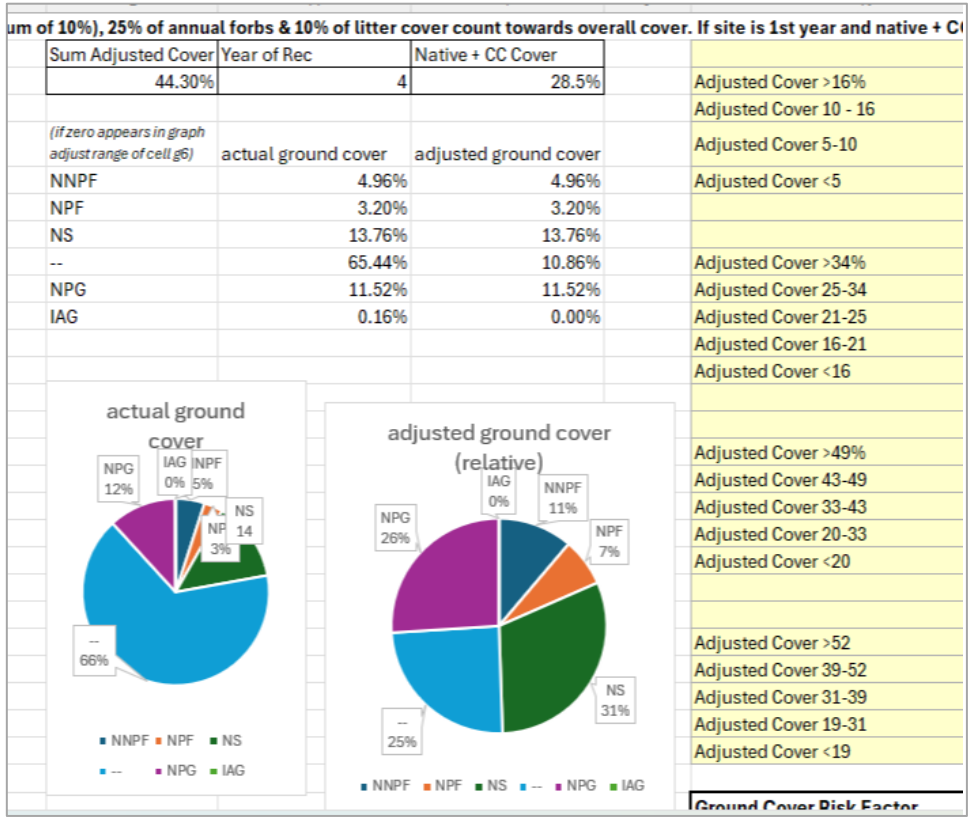
- Assign a score based on both presence and abundance of non-native species on Site
- Based on series of thresholds – developed from observations on other sites
- Contributes to overall NNIS ranking, Invasive ranking can overrule non-native ranking if non-natives low but particularly concerning invasive is present

Species on Site List	Functional Group	Cover	Non-natives Cover		Growing Seasons Since Recla	Total Non-natives Cover
					4	4.96%
					Russian thistle does not get counted for years 1 through 3.	
					%	Year of Reclamation 1
ASCI4	NNPF	4.96%	4.96%	yes	Non-Natives Cover 0 - 10	2
ASSP6	NPF	0.16%		no	Non-Natives Cover 11-25	2
ATGA	NS	12.00%		no	Non-Natives Cover 26-55	3
BARE	--	NA		no	Non-Natives Cover 56-75	4
BOCU	NPG	0.80%		no	Non-Natives Cover above 75	5
ASCA11	IAG	0.16%		no		
CHDO	NPF	0.16%		no	%	Year of Reclamation 2
CHVI8	NS	0.16%		no	Non-Natives Cover 0 - 5	1
ELEL5	NPG	0.32%		no	Non-Natives Cover 6-20	2
ELTR7	NPG	0.48%		no	Non-Natives Cover 21-45	3
GUSA2	NS	1.28%		no	Non-Natives Cover 46-60	4
HEDR	NPF	0.32%		no	Non-Natives Cover above 60	5
KOMA	NPG	0.48%		no		
LITTER	--	NA		no	%	Year of Reclamation 3
OECA10	NPF	0.32%		no	Non-Natives Cover 0 - 5	1
OXCA4	NPF	0.96%		no	Non-Natives Cover 6-15	2
PASM	NPG	6.08%		no	Non-Natives Cover 16-35	3
PEAN4	NPF	1.12%		no	Non-Natives Cover 36-50	4
PEEA	NPF	0.16%		no	Non-Natives Cover above 50	5
POSE	NPG	0.64%		no		
PSSP6	NPG	2.72%		no	%	Year of Reclamation 4+
RHTR	NS	0.32%		no	Non-Natives Cover 0 - 5	1
ROCK	--	NA		no	Non-Natives Cover 6-10	2
					Non-Natives Cover 11-30	3
					Non-Natives Cover 31-40	4
					Non-Natives Cover above 40	5

Evaluation Matrix – Ground Cover

Weight by Functional Group to Determine Ground Cover Risk

- Functional groups weighted by contribution to long-lasting ground cover and erosion resistance
- Based on series of thresholds – developed from observations on other sites



um of 10%), 25% of annual forbs & 10% of litter cover count towards overall cover. If site is 1st year and native + C

Sum Adjusted Cover	Year of Rec	Native + CC Cover	
44.30%	4	28.5%	Adjusted Cover >16%
			Adjusted Cover 10 - 16
(if zero appears in graph adjust range of cell g6)	actual ground cover	adjusted ground cover	Adjusted Cover 5-10
NNPF	4.96%	4.96%	Adjusted Cover <5
NPF	3.20%	3.20%	
NS	13.76%	13.76%	
--	65.44%	10.86%	Adjusted Cover >34%
NPG	11.52%	11.52%	Adjusted Cover 25-34
IAG	0.16%	0.00%	Adjusted Cover 21-25
			Adjusted Cover 16-21
			Adjusted Cover <16
			Adjusted Cover >49%
			Adjusted Cover 43-49
			Adjusted Cover 33-43
			Adjusted Cover 20-33
			Adjusted Cover <20
			Adjusted Cover >52
			Adjusted Cover 39-52
			Adjusted Cover 31-39
			Adjusted Cover 19-31
			Adjusted Cover <19
			Ground Cover Risk Factor

Evaluation Matrix – Dashboard Rankings

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Summarize Results and Assist in Report Development

- Rankings range from 1 (Very Low) to 5 (Very High) and are assigned based on the series of thresholds earlier in the sheet
- Assist in development of Site Evaluation Reports
  - List of all species seen on site – functional group, common name, scientific name, species symbol
  - List of ground cover by functional group
  - List all species from the seed mix which were observed on Site (and # by functional group)
  - List of non-native and invasive species observed on Site and their cover %
- Provides an easily interpretable snapshot of Site performance

Rankings Dashboard

Site Name: Horseshoe			
		RANKING	**ACTION LEVEL**
	STATUS - manually select		
HAZARD(S) MITIGATED?	Yes		
EROSION - manually enter number		2	Low
DESIRABLE SPECIES		2	Low
GROUND COVER		2	Low
NNIS		1	Very low
OVERALL		2	Low

NNIS Dashboard			
Risk Ranking - Overall	**Action Level**		
1	Very low		
Risk Ranking - Non-natives	*Total Cover - Non-natives*	*Risk Ranking - Invasive Species*	*Total Cover - Invasive Species*
1	4.96%	*1*	0.00%
Non-native Species On Site	**Non-natives Cover**	**Invasive Species on Site**	**Invasive Species Cover**
ASCI4	4.96%		0.00%
	#N/A		

Number of Species Observed on Site	*error checker*	**Functional Groups in Seed Mix**	**Count of Functional Groups in Seed Mix**
21		NPG	7
Number of Species Seeded on Site	*error checker*	NPF	1
11		NS	3

Evaluation Matrix – Main Takeaways

- **Develop agreed-upon set of performance standards to serve as a basis for thresholds**
  - Use other sites as examples
  - Thresholds can be adjusted – with valid reasoning
  - Large-scale changes to certain dashboards may occur
- **Matrix has been a long-term "work in progress"**
  - Improve workflow – reduce per-site analysis time
  - Change based on policy-aligned responses
- **Saves time by contributing to a standardized system of ranking and dashboards**
  - Consistency over time and between different Sites
- **Provide clarity and transparency on dashboard rankings – increasing level of objectiveness**
  - Easy tracing of "why" a Site received the score it did

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Section 2

Action Matrix and Monitoring Geodatabase

– Recommend Course of Action based on Previous Results

Action Matrix – Context

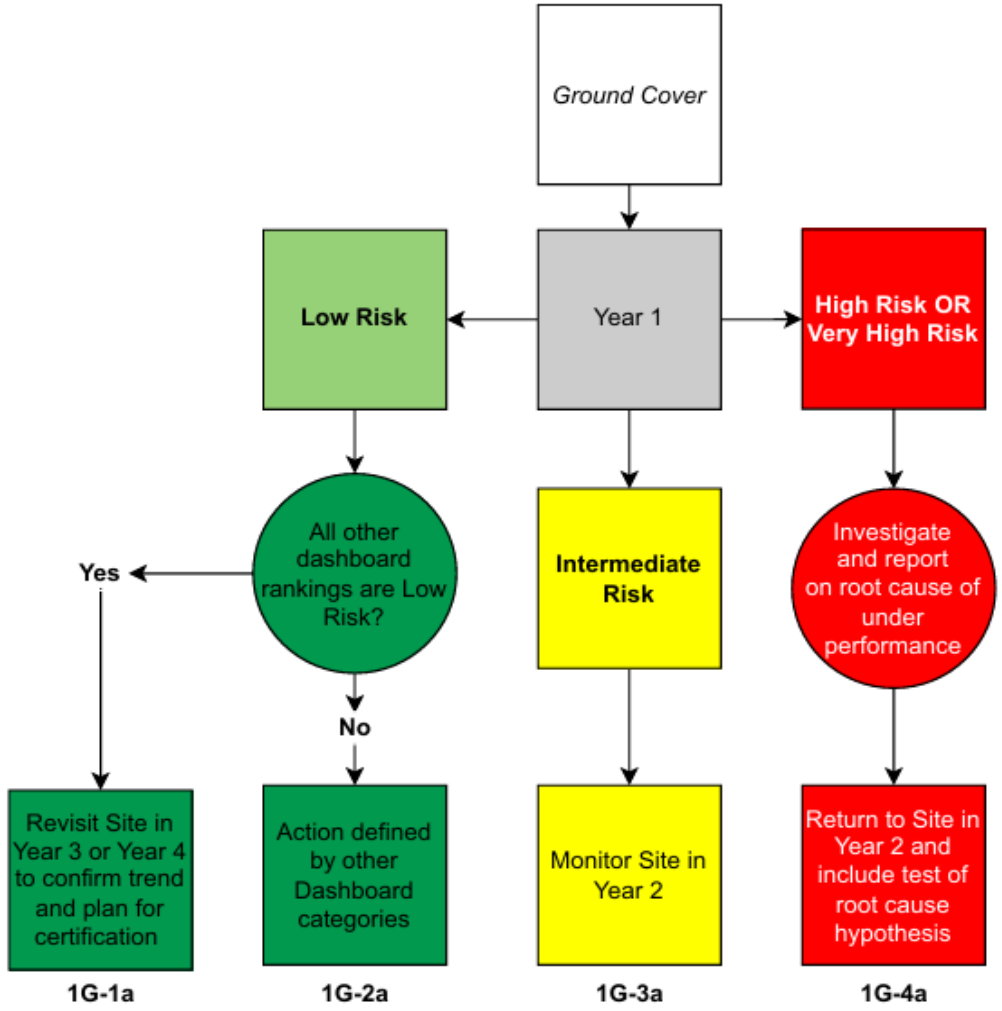
1. ***How do we consistently prescribe future actions based on Site conditions?***
2. ***How do we prioritize which Sites to assess?***

Using the **Action Matrix**, we can:

- Converts risk rankings from the Evaluation Matrix to real-world actions
- Decision trees developed from a review of previously evaluated sites and assigned actions
  - Divided by year: Year 1, Year 2, Year 3+
- Automatically and consistently assigns actions
- Determine status of reclamation and if further action is needed based on policy-aligned responses
  - Identifies when a Site may not fit into an automatic recommendation and further discussion with AML is needed

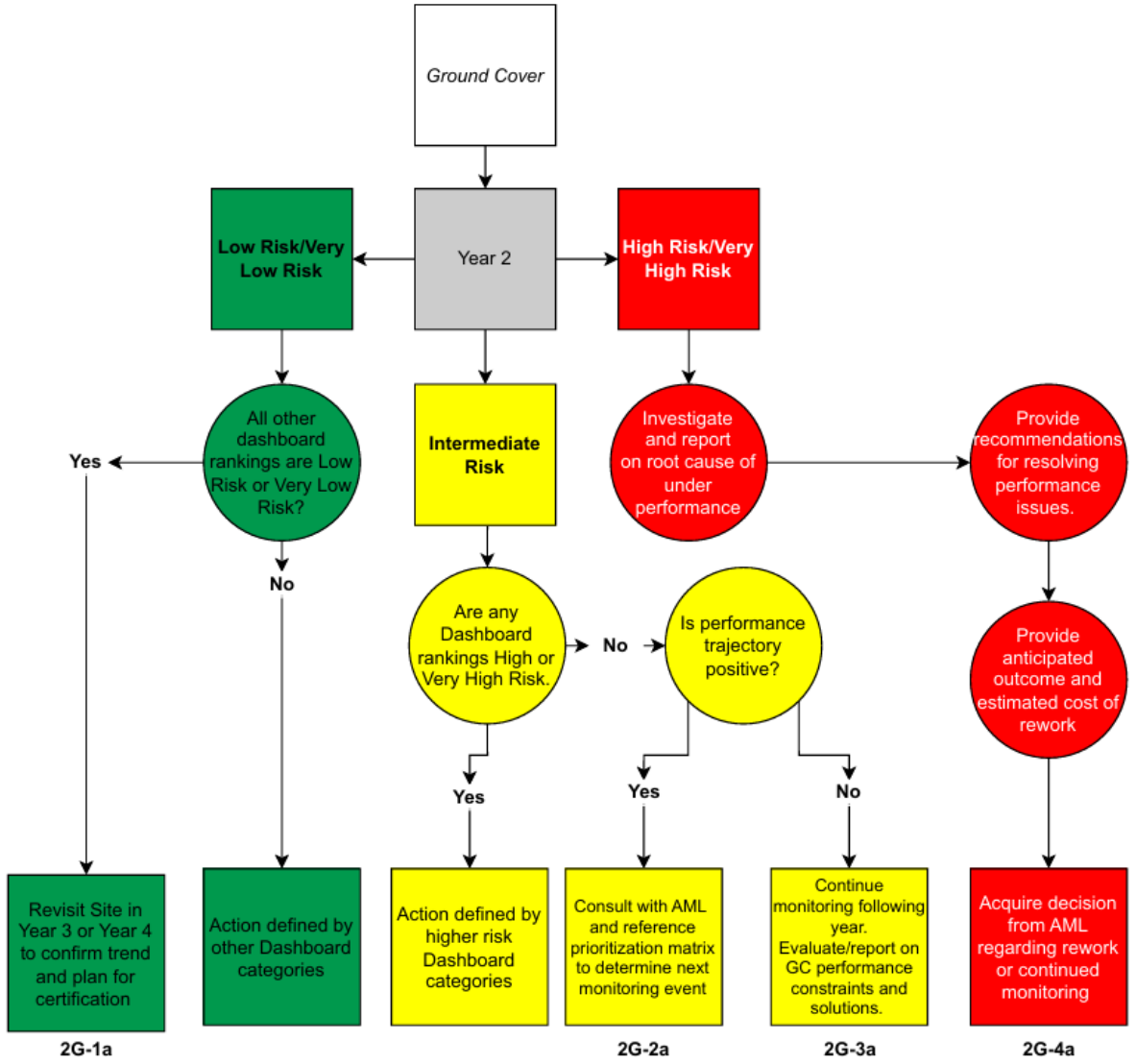
Action Matrix – *Example:* Year 1 Ground Cover

- Evaluation Matrix says a Year 1 Site is **High Risk** due to low levels of vegetation cover?
  - Investigate and report root causes
  - Return for monitoring next year
  - ***Outcome 1G-4a***



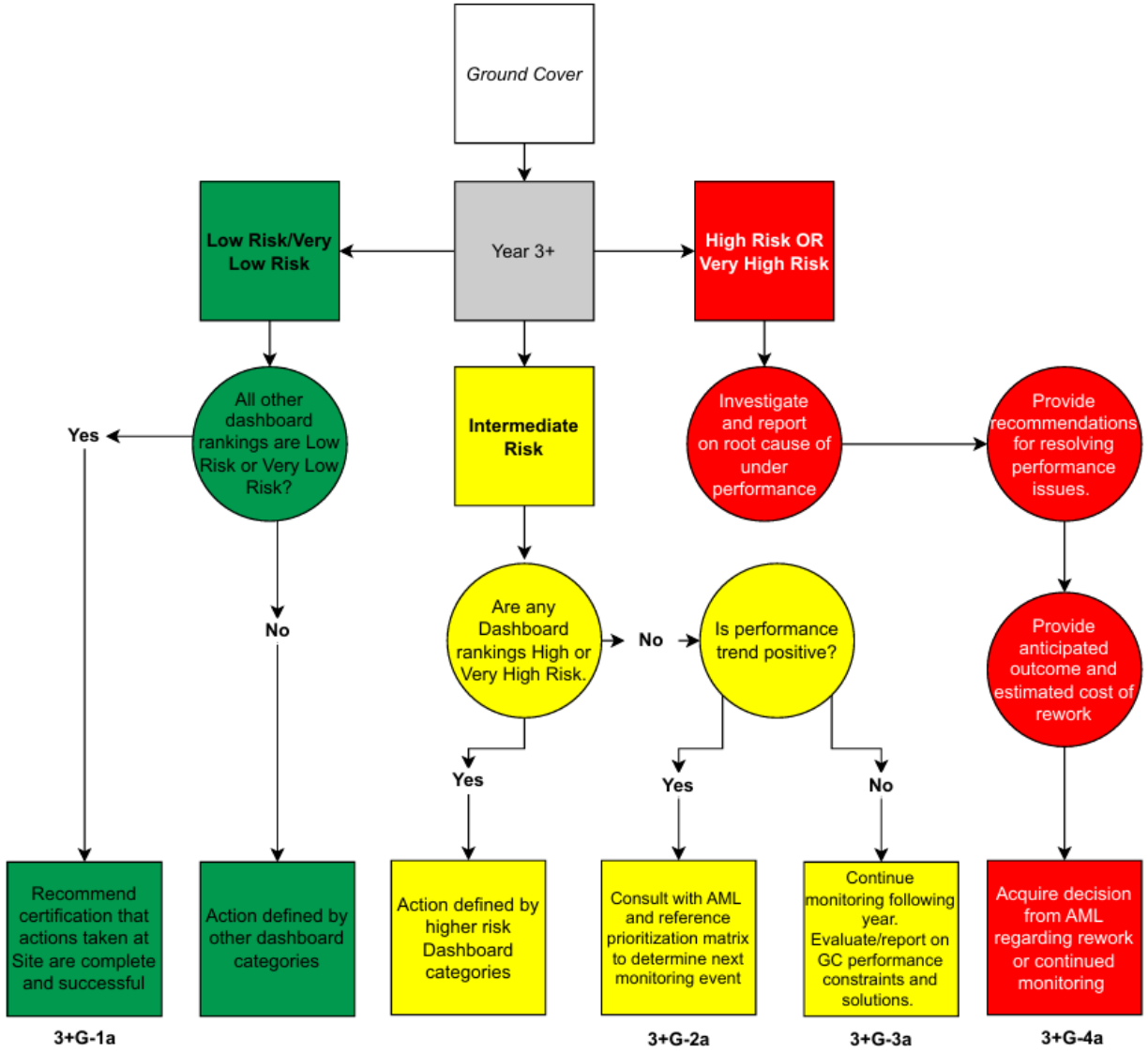
Action Matrix – *Example:* Year 2 Ground Cover

- Evaluation Matrix says a Site is **Intermediate Risk** in Year 2 due to an improvement in vegetation cover and diversity?
  - Are other dashboards high or very high? – ***No***
  - Has performance improved? – ***Yes***
  - <u>Consult With AML and determine when next monitoring event will occur</u>
  - ***Outcome 2G-2a***



Action Matrix – *Example:* Year 3+ Ground Cover

- Evaluation Matrix says a Site is **Low Risk** in Year 3 due to continued improvement?
  - Are all other dashboard rankings Low Risk or Very Low Risk? – **Yes**
  - <u>Recommend certification that Actions taken at the Site are complete and successful</u>
  - ***Outcome 3G-1A***



Monitoring Geodatabase

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Master database for all collected Site information

- Supports in:
  - Data collection
  - Data analysis
  - Reporting of vegetation monitoring data
- Assists in presenting key information to AML
- Tracks the following for all Sites:
  - Current conditions
  - Required actions
  - Certification status
- Database contains the past 5 years of Site evaluations, allowing for easy comparison and tracking conditions over time

Feature Dataset Name	Feature Class Name	Feature Class Type
Not Applicable	All AML Monitoring Sites	Point
Not Applicable	AML Site Boundaries	Polygon
Monitoring	General Data Collection	Point, Line & Polygon
	Erosion Data Collection	Point, Line & Polygon
	Weeds Data Collection	Point & Polygon
	Mine Rock Waste	Polygon
	Dashboards	Polygon
	Seedling Density	Point
	VMP Photo Collection	Point
	VMP SamplePoint 2022-2023	Point
	VMP SamplePoint 2024	Point
Seeding	As Seeded	Polygon
	As Seeded Point	Point
	Design	Polygon
	General	Polygon
	Historical Seeded Areas Pre-2022	Polygon
Weed Management	Master Weed Data	Point
	Weed Action Boundaries	Polygon
AML Consultants CSS Deliverables (2022-2023 & 2024)	See **Appendix A** for full list	Polygons

Action Matrix and Monitoring Geodatabase – Main Takeaways

- Perform review of previously evaluated sites and actions taken
  - Determine best responses based on previous results
- Determining future site visits and what actions are needed
  - Prioritization
- Sites perpetually stuck in “revisit next year”?
  - Discussion on what success looks like
  - Policy-aligned responses

Action Matrix and Monitoring Geodatabase – Main Takeaways cont.

- Importance of organizing and summarizing results for multiple sites over multiple years
- Improve comparability, produce dashboards and audit-ready records
- Provides perspective on the performance of reclamation within Wyoming
- Facilitates analysis of conditions
    - Multi-component Site over multiple years -> single photo plots

Evaluation Matrix and Action Matrix - Conclusions

Tools to increase consistency, reliability, and transparency of both dashboard rankings and recommended actions

- Matrices based on previously evaluated sites and recommended actions
- Transferrable to multiple sites in different environments and over different years
- Allows for adjustments as needed for site-specific and/or unusual circumstances
    - e.g., site has cattle grazing it during evaluation - ground cover dashboards may not be entirely accurate
- Lessons Learned:
    - Early professional oversight
    - Iterative calibration of decision rules
    - Attention to accuracy and performance
    - Discussions on how to best improve system and have policy-aligned responses

Thank you!