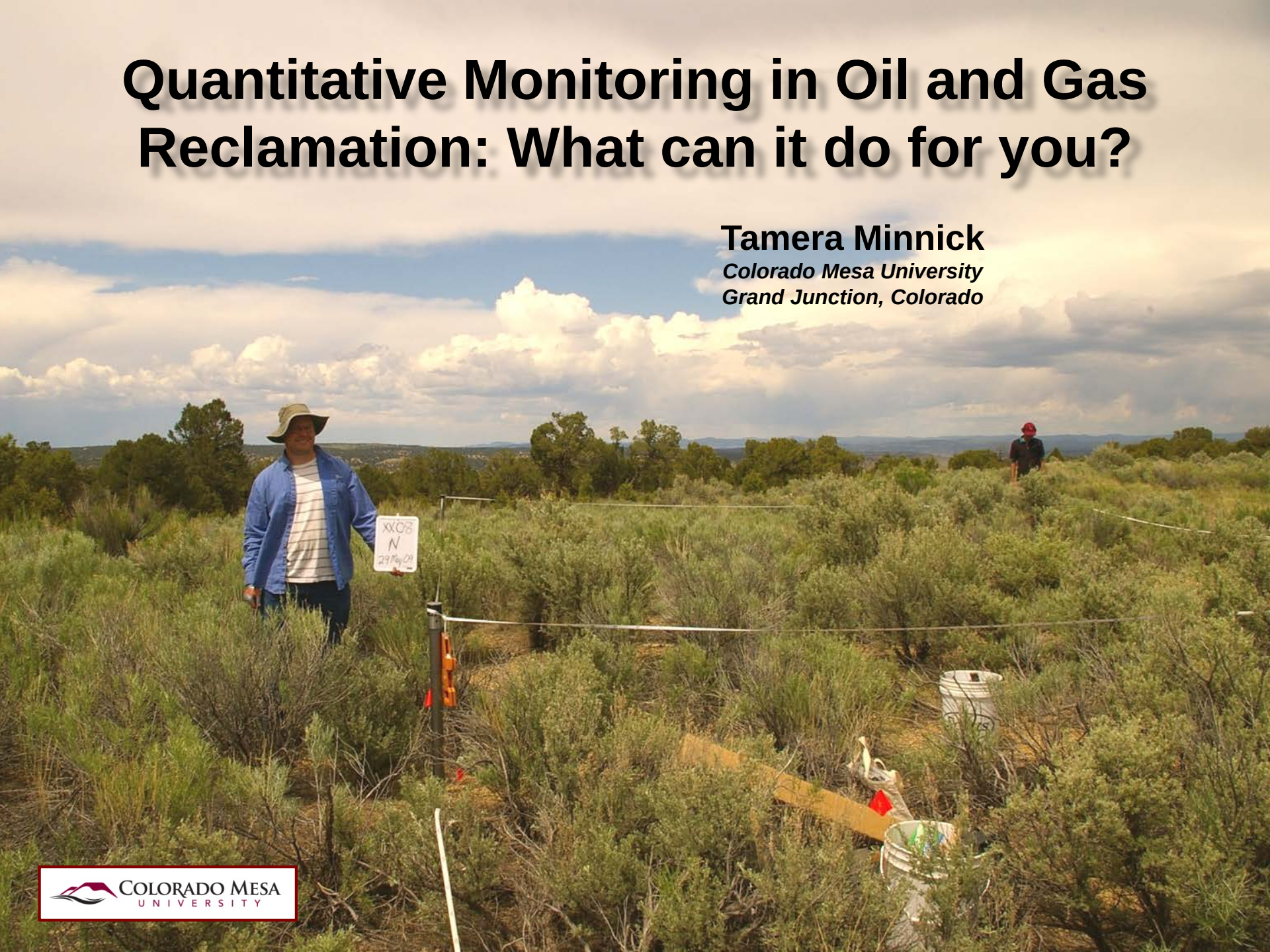
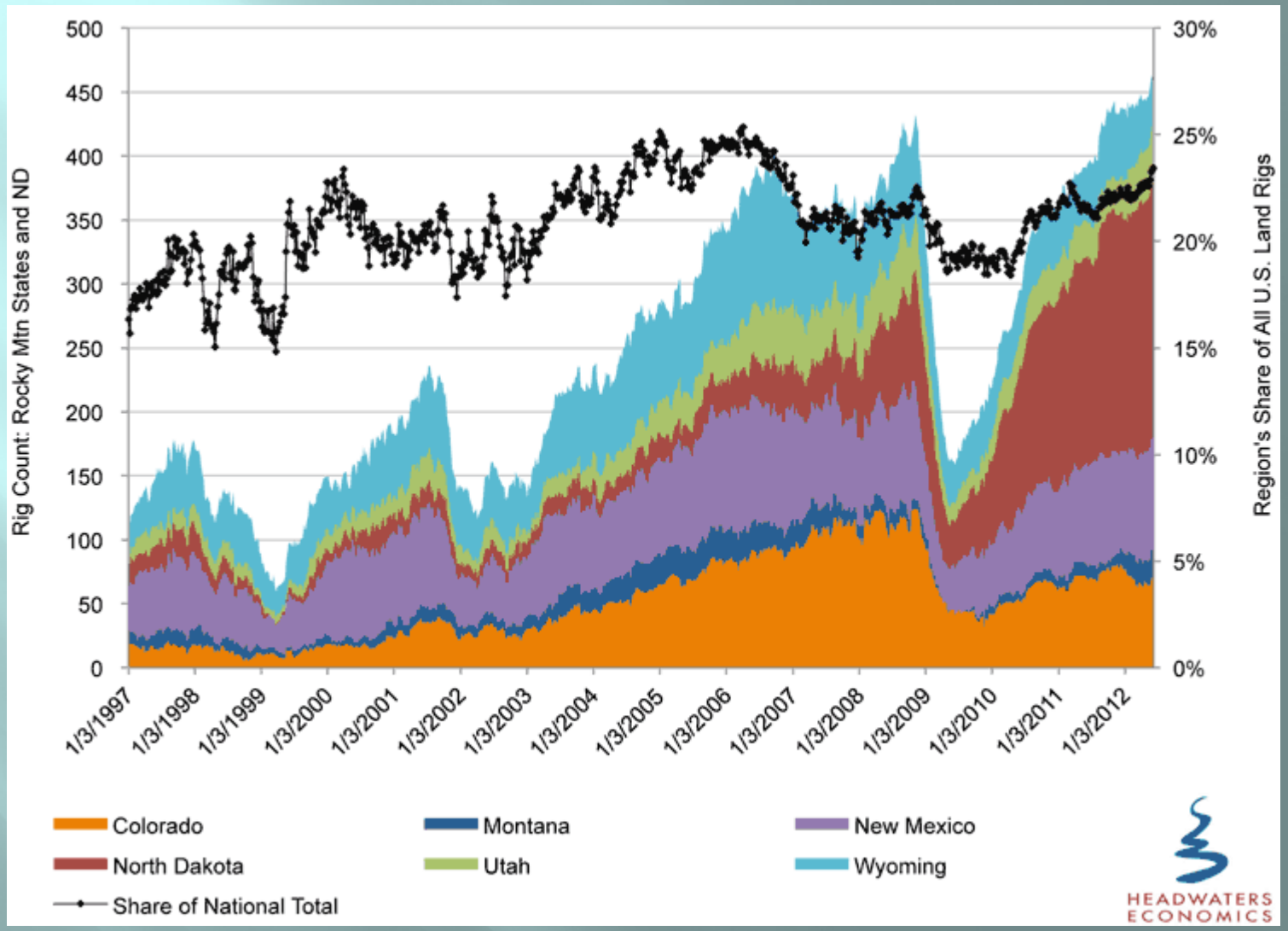
Quantitative Monitoring in Oil and Gas Reclamation: What can it do for you?

Tamera Minnick
Colorado Mesa University
Grand Junction, Colorado



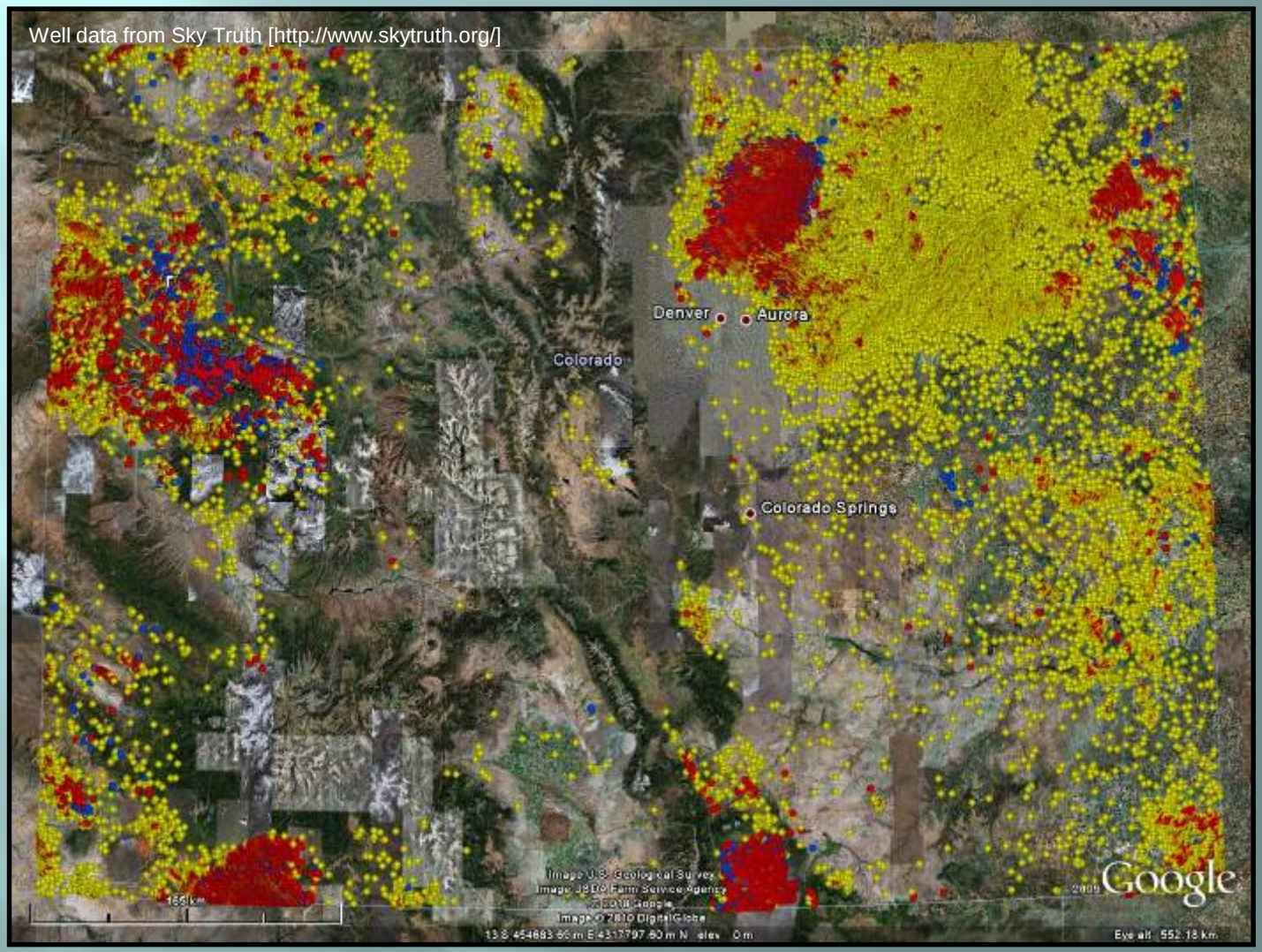
COLORADO MESA UNIVERSITY

Oil and Gas Activity in Western North America is Extensive and Increasing

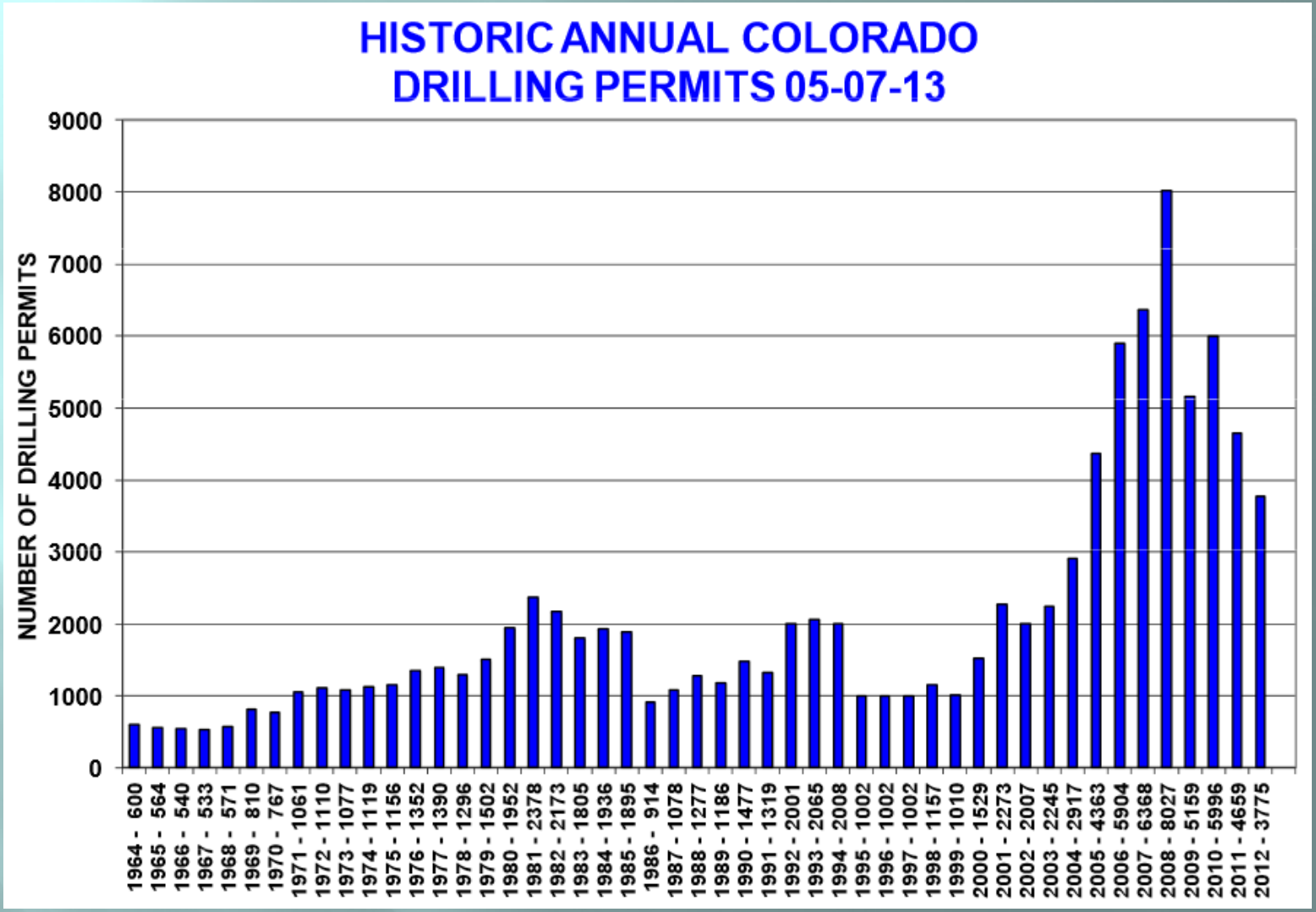


Challenges for Restoration in Colorado

Active, Abandoned and Permitted Oil & Gas Wells



Challenges for Restoration in Colorado



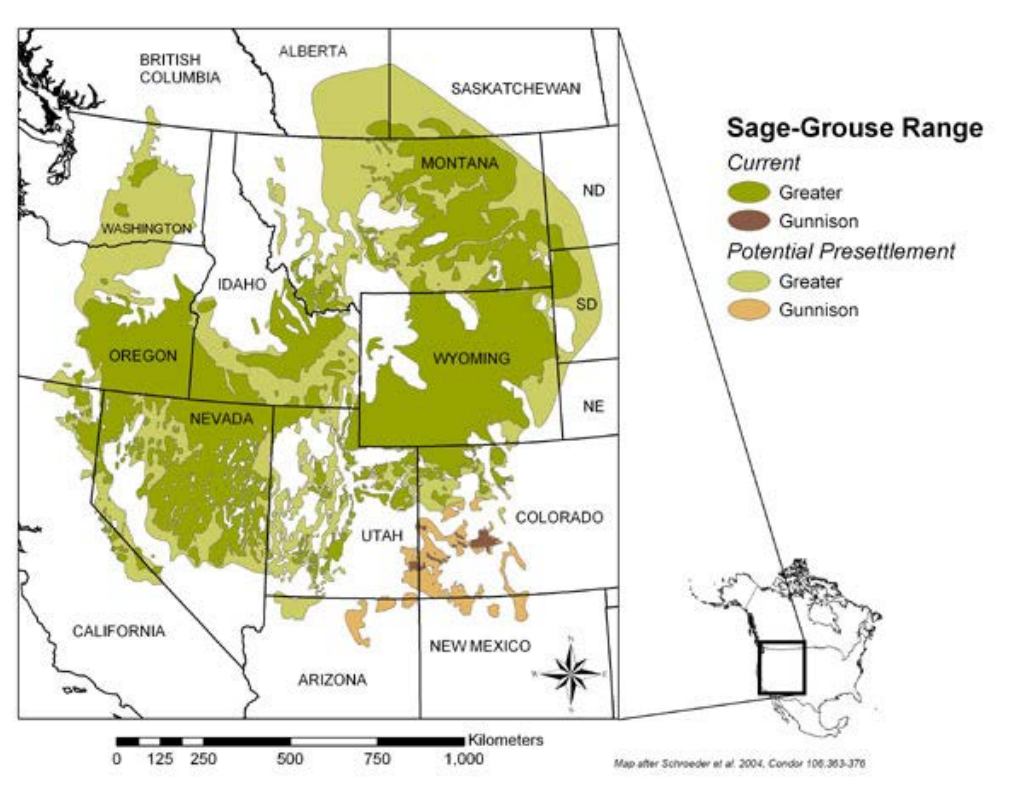
(www.colorado.gov/cogcc)

Challenges for Restoration in western U.S.

- **Dispersed energy development**
  - 1-16 well pads per 640 acres
  - Numbers of new wells/yr
  - Linear disturbances of roads and pipelines
  - Repeat disturbance
- **Arid and Semi-arid climate**
- **Weeds**
- **Remoteness**
  - 50-100 miles from nearest towns

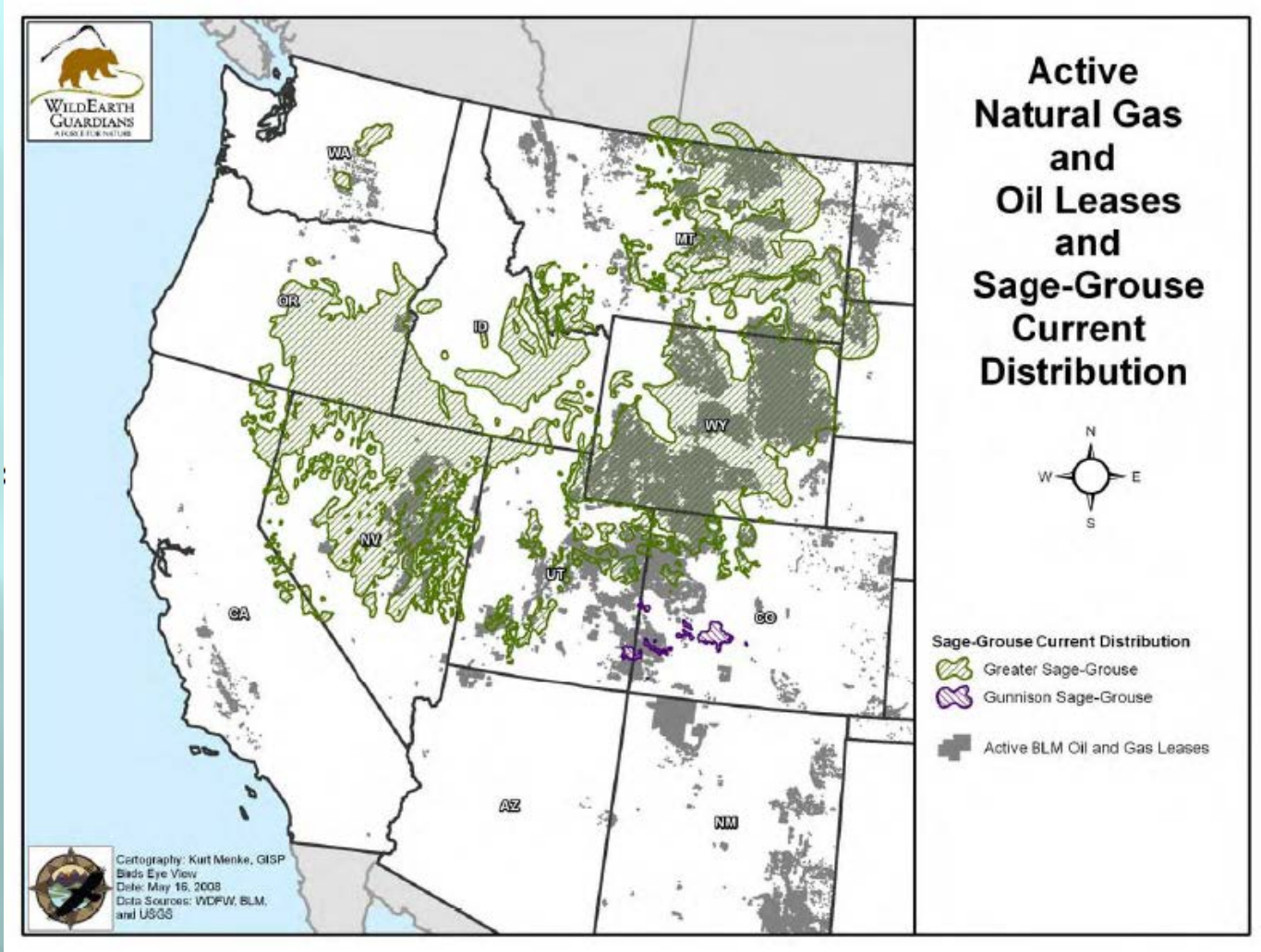
Impacts of Natural Gas Development on Wildlife

- Sagebrush steppe has been reduced by > 50% since before European settlement
- Greater sage-grouse distribution decreased by 56% and abundance by 93%
- Only 3% of sage-grouse habitat is federal land
- More than 81% of its range impacted by grazing, oil and gas development and cheatgrass



(after Schroeder et al. 2004. Condor 106:363-376)

Impacts of Natural Gas Development on Wildlife Habitat: Sage Grouse



The Shrinking Sagebrush Sea by Mark Salvo of WildEarth Guardians, 2008

Impacts of Natural Gas Development on Wildlife Habitat: Mule Deer

- **Impacts of natural gas development on mule deer habitat**
  - **Direct loss** of habitat through surface disturbances
  - **Indirect loss** of habitat use due to increased human activity (noise, traffic)
- Pinedale, WY development from 2000: 700 well pads, 645 km pipeline, 444 km roads located in prime winter range habitat with one of the largest densities (19-30 deer/km2)
  - Primarily big sagebrush and sagebrush-grassland communities
- **No evidence that mule deer acclimated or habituated to development**
  - Tracked radio-collared deer before development (winters 1998-1999 and 1999-2000), during development (winters 2000-2001, 2001-2002, and 2002-2003)
  - Used a GIS with 5 predictor of winter mule deer distribution: elevation, slope, aspect, road density and distance to well pad to estimate habitat use throughout area

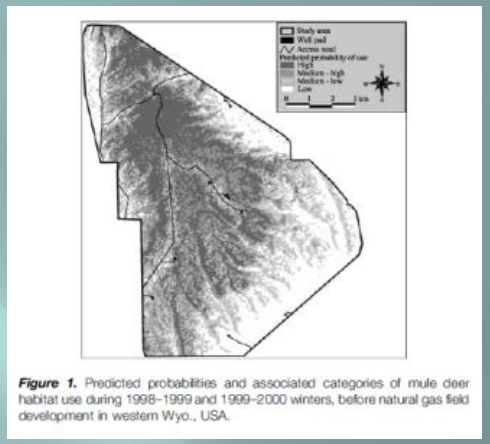


Figure 1. Predicted probabilities and associated categories of mule deer habitat use during 1998–1999 and 1999–2000 winters, before natural gas field development in western Wyo., USA.

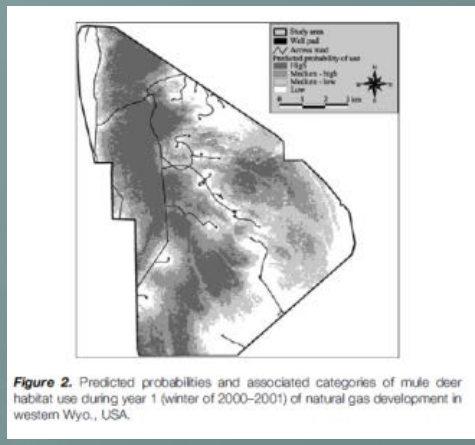


Figure 2. Predicted probabilities and associated categories of mule deer habitat use during year 1 (winter of 2000–2001) of natural gas development in western Wyo., USA.

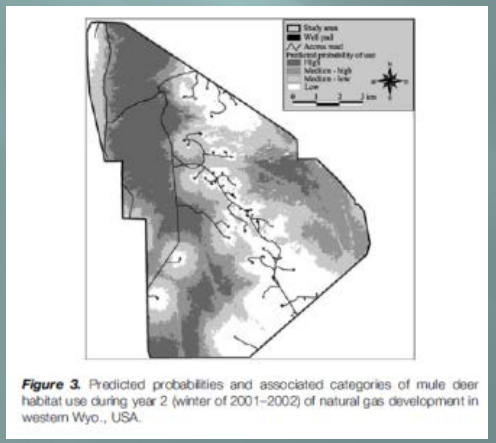


Figure 3. Predicted probabilities and associated categories of mule deer habitat use during year 2 (winter of 2001–2002) of natural gas development in western Wyo., USA.

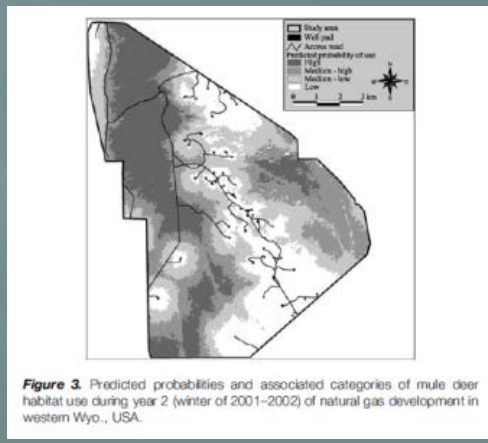
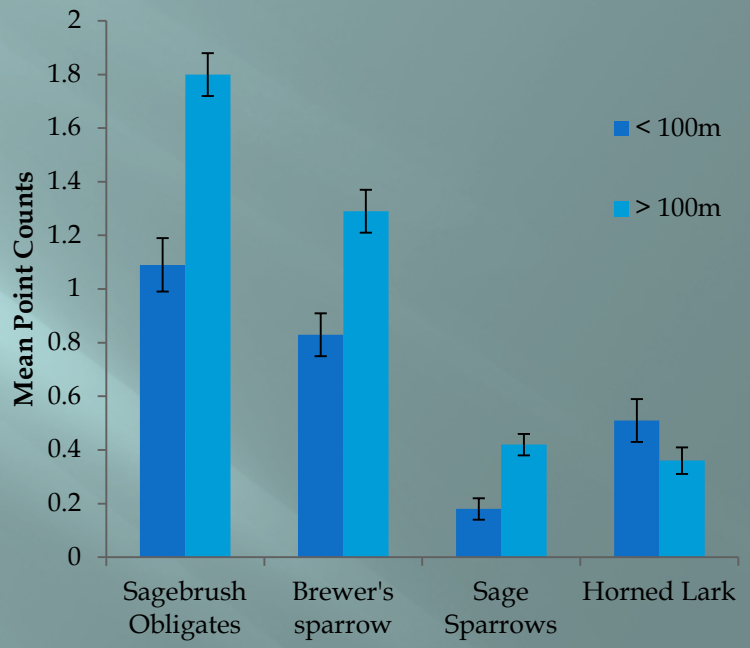


Figure 3. Predicted probabilities and associated categories of mule deer habitat use during year 2 (winter of 2001–2002) of natural gas development in western Wyo., USA.

Sawyer, H., R.M. Nielson, F. Lindzey and L.L. McDonald. 2006. Winter habitat selection of mule deer before and during development of a natural gas field. Journal of Wildlife Management 70:396-403.

Impacts of Natural Gas Development on Wildlife Habitat: Birds

- Bird response to roads for natural gas development
  - Ingelfinger, F., and S. Anderson. 2004. Passerine response to roads associated with natural gas extraction in a sagebrush steppe habitat. Western North American Naturalist 64:385-395.
- Jonah Field and Pinedale Project Area
- Density of sagebrush obligates (especially Brewer's and Sage Sparrows) reduced 39-60% within a 100m buffer around dirt roads with low traffic volumes (< 700 vehicles per day)



Mean point counts for various bird species within or beyond 100m from dirt roads in natural gas developments in southwestern Wyoming. * indicates p < 0.05, ** indicates p < 0.01, * indicates p < 0.001 (Error bars are +/- 1 SD). (Data from Ingelfinger an**

SUCCESSFUL RECLAMATION BY ALL CAN ENHANCE INDUSTRY

- **International Energy Agency "Golden Rules" to usher in "Golden Era of Natural Gas"**

level of environmental performance and public acceptance that can maintain or earn the industry a "social license to operate

- **"Reclamation and rehabilitation of oil and gas exploration and production activities is a key part of the process of ensuring continued access to oil and natural gas resources in the United States."**

-Comprehensive Reclamation Strategy for Oil & Gas Exploration and Production Operations by Heather N. Smith, University of Denver, Capstone Project for Master of Applied Science,

UINTA BASIN HOOKLESS CACTUS, http://www.cnhp.colostate.edu

Bill targets concerns with UTEC

By C. PATRICK CLEARY
The Daily Sentinel

Explaining who runs the show at Grand Junction's technical education campus will not be hard to do, a Grand Junction legislator says.

"The governance issue, I think, is not a major concern," said state Rep. Matt Smith. The Grand Junction Republican and former alumni association president will introduce a bill to try and resolve the Legislature's concern about ownership, operation and funding for the Tilman Bishop Unified Technical Education Campus.

The Capital Development Committee this fall agreed to push for $2.4 million in equipment money as long as the campus agrees formally to go through channels with future requests. The committee also required the campus to spell out in detail who governs the institution.

The technical education campus is a joint project put together by Mesa State College, School District 51 and the business community.

Smith said its success in the changing role of education and the workforce is coveted by many interests in the state.

"Right now, it is one of the most dynamic institutions in the state," Smith said. The changing needs of the workforce will require more students obtaining the broad range of technical skills provided at UTEC, he said.

Smith said he will point out that the cost of student education for the jobs at UTEC is one of the lowest in the state. The basic concept of Smith's bill is directed toward the campus' curriculum.

"The core curriculum is approved by the community colleges board," Smith said about the ultimate decision about what happens on campus.

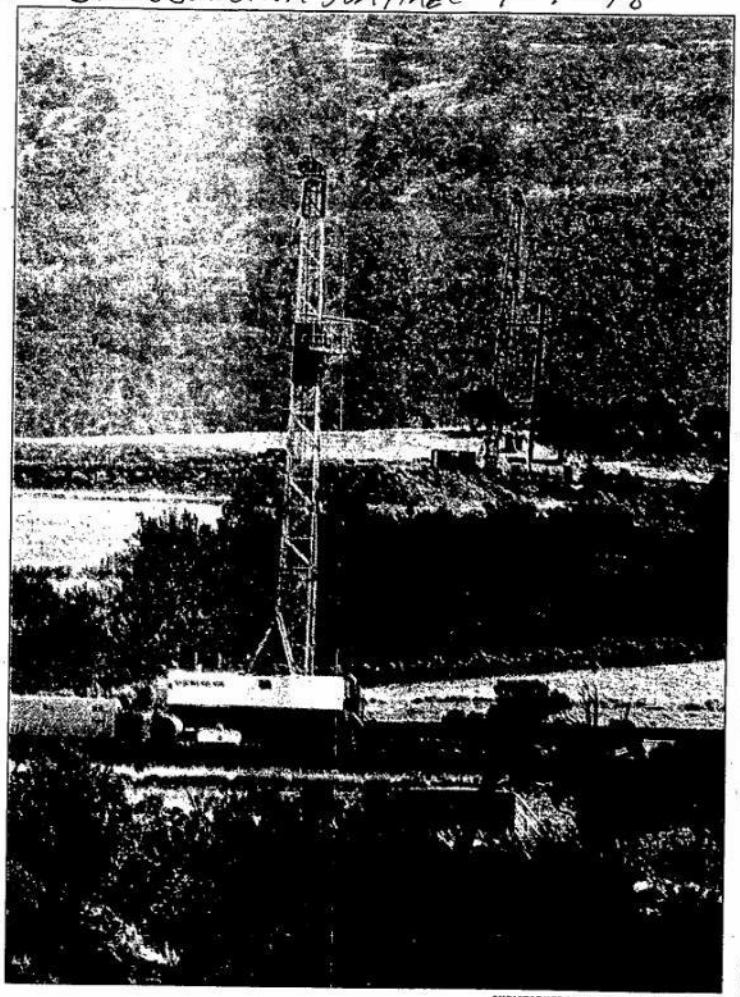
That happens, though, after a series of other boards peruse the request. There are three boards that govern the campus. Mesa State College, School District 51 and the campus' own Board of Cooperative Education Services would all have to agree to the curriculum concept before it is submitted to the community colleges board, Smith said.

The curriculum request also would be submitted to Mesa's governing board as an information item only, he said.

The same scenario is spelled out for review of the $2.4 million request and any future requests, Smith said.

Well-site reclamation failing

Grand Junction Sentinel 1-7-98



CHRISTOPHER TOMLINSON/The Daily Sentinel

DRILLING ACTIVITY IN THE RULISON AND BATTLEMENT MESA areas of western Garfield County has come under the scrutiny of the Colorado Oil & Gas Commission which Tuesday said that most of the well sites are well below reclamation standards.

Only 4 of 21 west-Garfield locations halfway acceptable

By HEATHER McGREGOR
The Daily Sentinel

DENVER — A state government survey analyzing reclamation success at 21 producing gas wells in western Garfield County gives the industry a failing grade.

Just four of the 21 well sites were found to be at least halfway to an acceptable level of reclamation, according to the Colorado Oil & Gas Conservation Commission.

Loren Avis of the Oil & Gas Commission staff visited well sites on private land on Parachute, Porcupine and Divide creeks and in Sharrard Park in November.

He used a measure established earlier by the U.S. Bureau of Land Management in a wider survey of wells on federal land. Key indicators are growth of desirable plants, weeds, erosion, size, oil staining of soil and condition of access roads.

The wells are owned by Barrett Resources Inc., Tom Brown Inc., Vessels Energy Co., and Bonneville Fuels Co. They averaged 2.4 acres of disturbed area, and half that area was to be reclaimed for the 30 to 40 years that the well is expected to produce gas.

A pair of Barrett wells on Parachute and Porcupine creeks were found to have been successfully reclaimed. Two other Barrett wells on Unocal Corp. property on Parachute Creek were found to have been about halfway successful.

The remaining 17 wells had no successful reclamation, or just a small fraction of success, according to the survey. The survey was prompted by industry requests for increased well density.

"As the commission addresses density applications, it becomes even more critical that industry work to achieve successful well-site reclamation to provide better stewardship of the land, and to avoid the negative perceptions that are being created," wrote Rich Griebling, Oil & Gas Commission director, in a follow-up memo to operators.

Griebling said the state's existing rules governing reclamation are adequate, and instead called for voluntary compliance by industry with four recommendations made by Avis in his analysis of survey results.

To remedy the reclamation problems, the Oil & Gas Commission recommends that well operators:

- Immediately seed disturbed soil and soil stockpiles to prevent the spread of weeds.
- Move drill pads to cut back on slope cuts needed to create a level drilling platform.
- Fence well sites for at least three years to keep cattle out and give new vegetation a good start.

Higher well density request approved by commission

By HEATHER McGREGOR
The Daily Sentinel

DENVER — The Colorado Oil & Gas Conservation Commission approved a gas company's request Tuesday for increased well density in La Plata County, foreshadowing debate today over a similar request for more drilling in Garfield County.

La Plata County Commissioner Josh Joswick asked the seven-member Oil & Gas Commission to put off its decision on the request by J.M. Huber Corp. He wanted the agency to first deal with the cumulative impacts of drilling and the rights of surface owners to influence drilling plans.

See DRILLING, page 2B ➤

From COGCC website

GarCo: Gas rules not tough enough

County assails state in fight with Antero over two projects

By DENNIS WEBB
Dennis.Webb@gjsentinel.com

Garfield County has told the Colorado Oil and Gas Conservation Commission in a legal filing that its new rules "fail entirely" to address cumulative effects on the public of increasing the density of natural gas development.

The county lays out a litany of areas where it says the rules come up short in addressing not just disturbances and nuisances but also the "increased risk of accidents that result in exposures and other contamination" when the density of development increases.

"No agency, including the COGCC, can guarantee the Garfield County residents that exposures to oil and gas emissions will not produce illness or latent effects, including death," the county said.

It cited the cases of three people — Chris Mobaldi, Verna Wilson and energy industry worker Jose Lara — who died after suffering from what they said were drilling-related maladies in the county.

See GAS, page 7A ➤

GAS: County says rewritten rules deficient

➤ Continued from Page One

The county makes its case in a document challenging applications by Antero Resources, which wants state regulators allow gas development of one well per 10 acres on square-mile sections on Silt Mesa and in Peach Valley north of Silt. The oil and gas commission is scheduled to hear the applications next month.

The document led Ken Wonstolen, an attorney representing Antero, to seek and obtain assurances during a recent oil and gas commission meeting that its staff would make a case countering the county's assertions. He said it would be unfair for Antero to be left with the entire burden of defending the rules against such "wide-ranging attacks."

"This, commissioners, is a fundamental indictment of your rules," Wonstolen said during a commission meeting this past week.

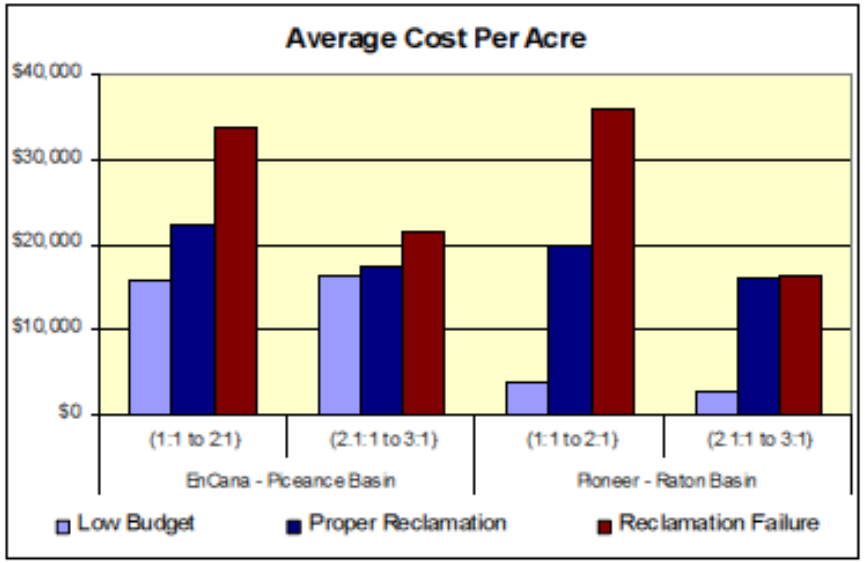
The oil and gas commission in 2009 began implementing rewritten rules that were designed to provide more protections of public health and the environment.

But the county contends the rules fall short in areas such as:

- Addressing the disturbances of well-pad lighting and truck traffic.
- Establishing dust and volatile-organic-compound-emissions standards.
- Protecting ground and surface water from contamination of the kind that has occurred in the county as a result of improper well construction and from spills, including recent ones from pipelines.
- Requiring any inspections of well facilities and pipelines.
- Establishing adequate company bonding and other financial assurances for cleanup projects.

Colorado Oil and Gas Conservation Commission Director David Neslin said he couldn't comment because the hearing on Antero's applications is pending. Commission staff previously said they can adequately address cumulative effects on residents when considering permit applications for wells and pads.

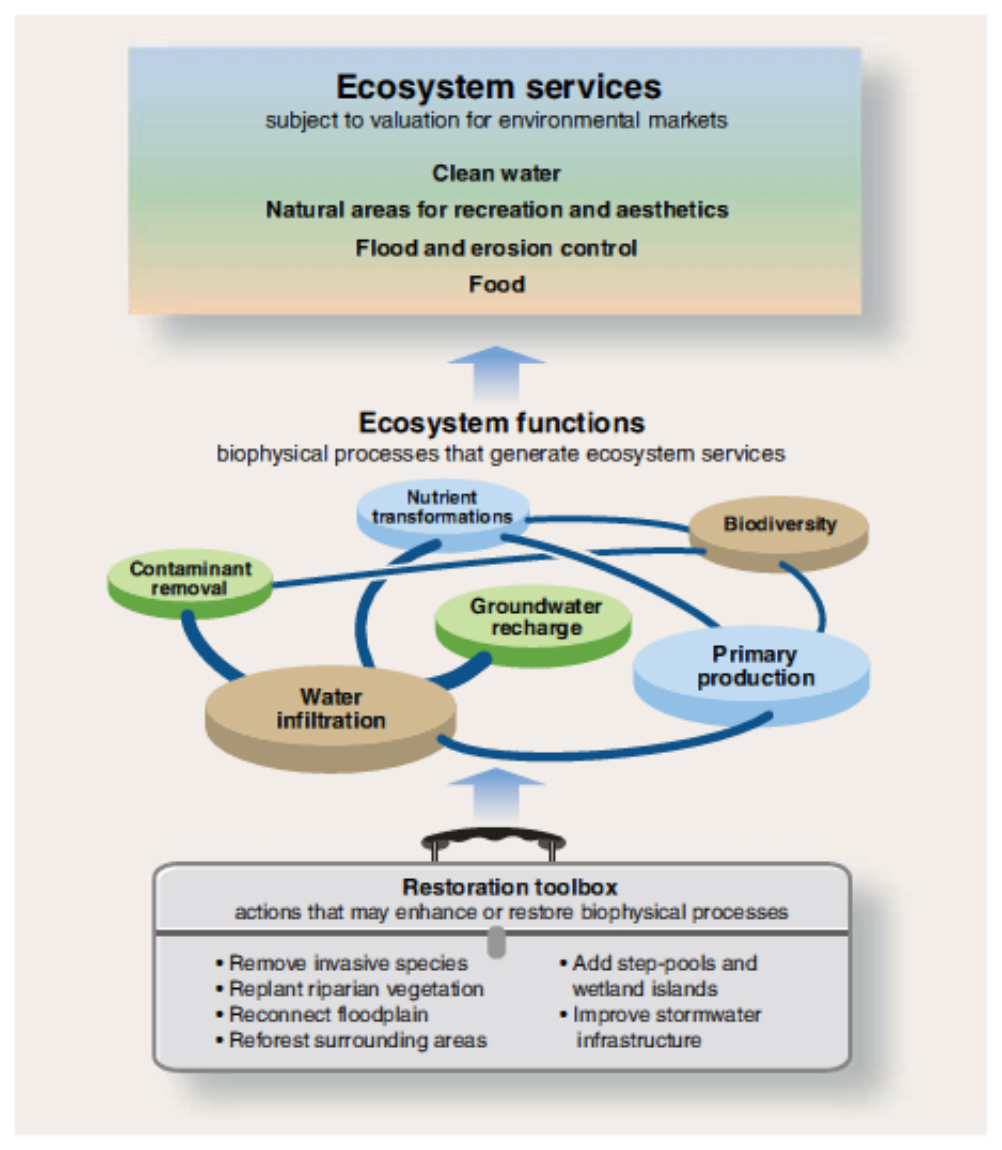
SUCCESSFUL RECLAMATION CAN REDUCE COSTS TO INDUSTRY



When comparing the total cost of initial low budget reclamation and associated reclamation work due to site failure, we find that generally, the cost per acre is significantly higher than implementing adequate reclamation on the first attempt (Chart 2). Pioneer, being relatively youthful with respect to the data available for this case study, demonstrates similar trends as EnCana with respect to higher costs for steeper slope reclamation operations. EnCana has collected data on a much more intensive and larger area, approximately three times the area of Pioneer's operations. These experiences represent the norm for operators as they have adjusted their approach over time based on better tracking of reclamation and stormwater maintenance costs.

Chenowith, D., D. Holland, G. Jacob, L. Kruckenberg, J. Rizza, and B. Whiteley. 2010. The economic benefits of completing reclamation successfully the first time for oil and gas sites. Proceedings of the 19th High Altitude Revegetation Workshop. March 2-4, 2010, Ft. Collins, CO.

Reclamation of Disturbed Lands Returns Ecosystem Function and Ecosystem Services



(Palmer and Filoso, Science 2009)

Reclamation Enhances Biodiversity and Ecosystem Services

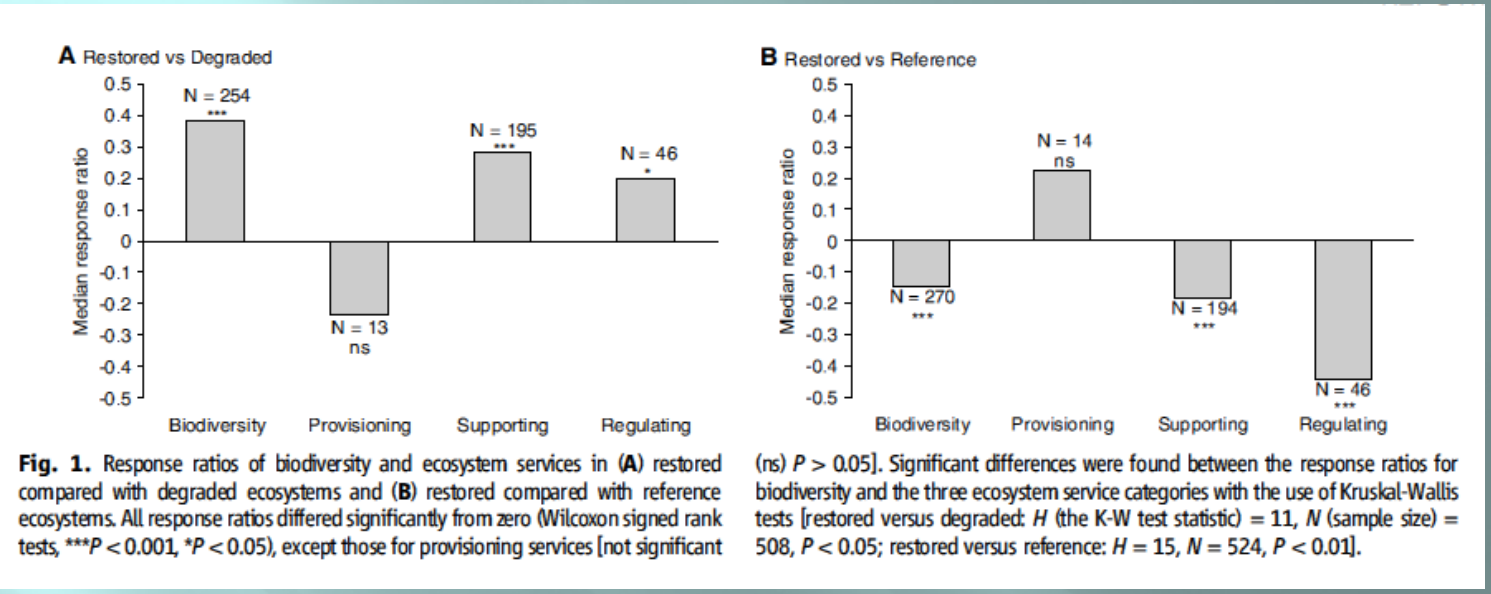
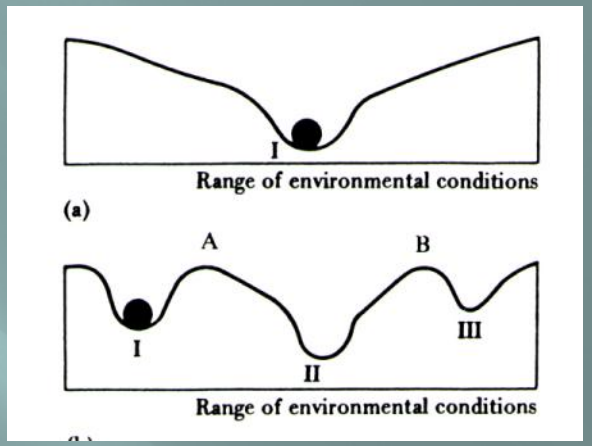


Fig. 1. Response ratios of biodiversity and ecosystem services in (**A**) restored compared with degraded ecosystems and (**B**) restored compared with reference ecosystems. All response ratios differed significantly from zero (Wilcoxon signed rank tests, ***$P < 0.001$, *$P < 0.05$), except those for provisioning services [not significant (ns) $P > 0.05$]. Significant differences were found between the response ratios for biodiversity and the three ecosystem service categories with the use of Kruskal-Wallis tests [restored versus degraded: H (the K-W test statistic) = 11, N (sample size) = 508, $P < 0.05$; restored versus reference: $H = 15$, $N = 524$, $P < 0.01$].

- 89 studies (< 5 – 300 years)
- Categories from Millenium Ecosystem Assessment
  - Supporting – nutrient cycling and primary production
  - Provisioning – timber, fish, food crops
  - Regulating – climate, water supply, soil characteristics
- Rey Benayas, J.M., A.C. Newton, A. Diaz, and J.M. Bullock. 2009. Enhancement of biodiversity and ecosystem services by ecological restoration: A meta-analysis. Science 325:1121-1124.

Biodiversity Enhances Resistance to and Resilience after Disturbance

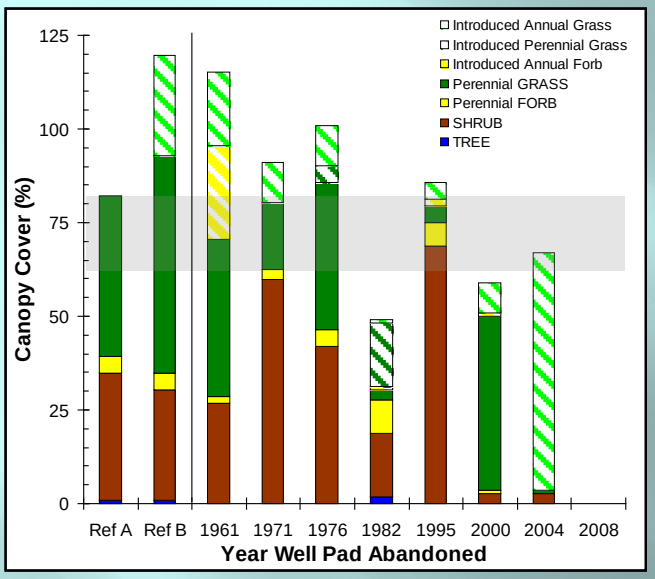
- Resistance to change in the first place
- Resilience to initial conditions after a perturbation
- No resilience if a threshold has been passed – new stable state (Laycock 1991)
  - State and Transition models

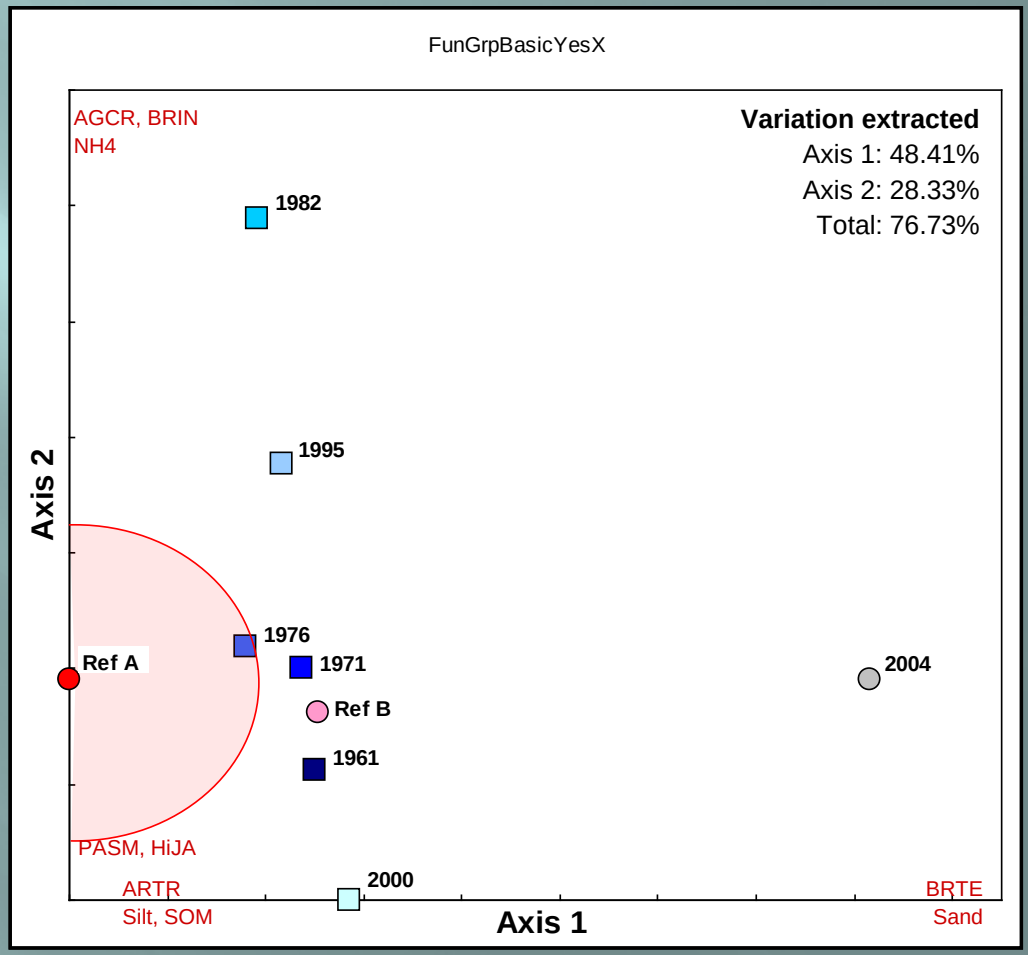


(Laycock 1991)

CANOPY COVER OF VEGETATION FUNCTIONAL GROUPS ON ABANDONED GAS WELL PADS OF VARYING AGE

Weeds, the 80% threshold, & "reflecting" reference area vegetation

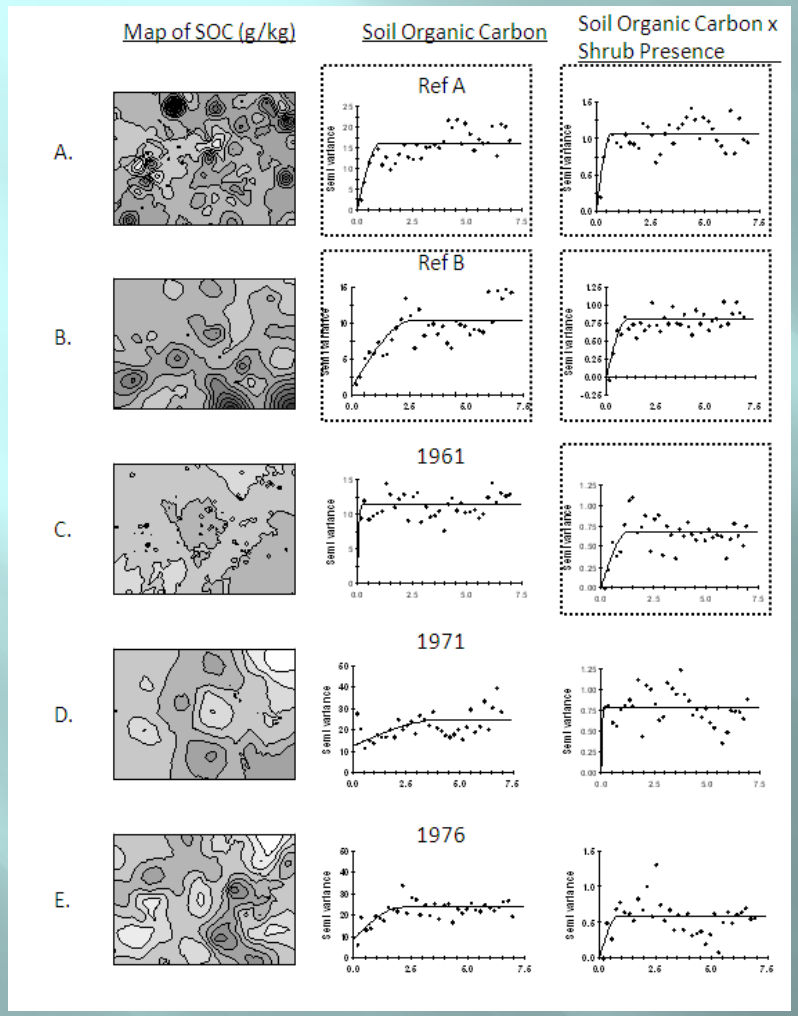


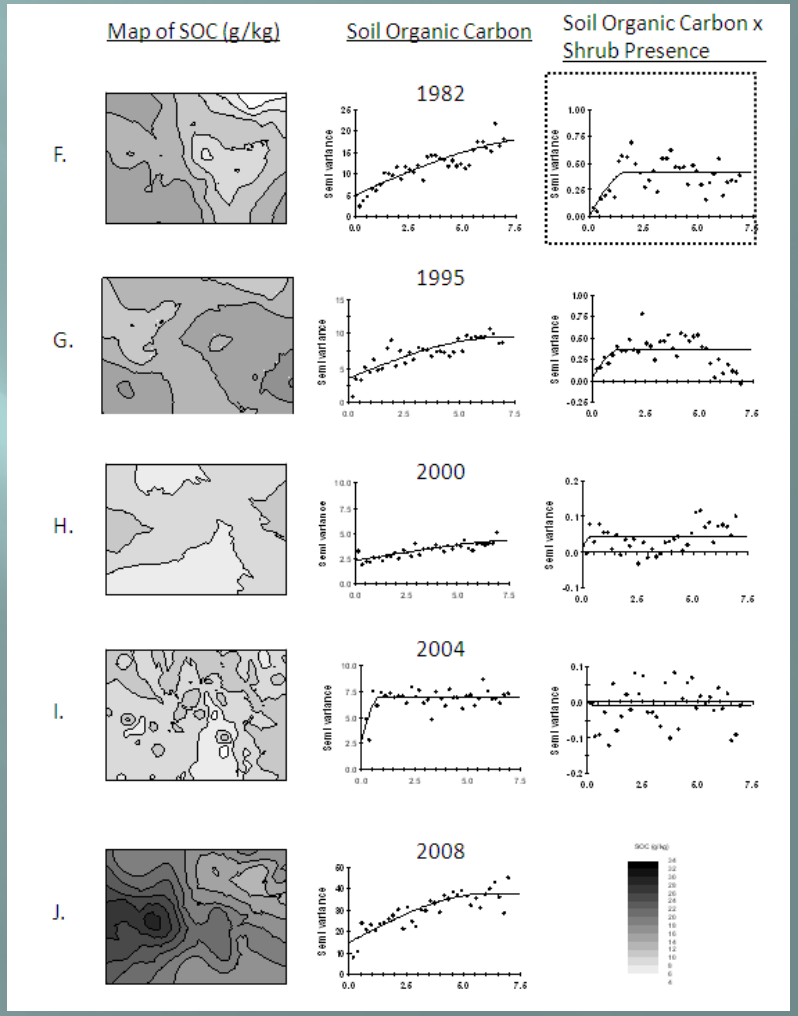


If novel species alter ecosystem functions away from desired objectives, they need to be explicitly and quantitatively evaluated

Only 1 site (1976) "reflects" the composition of Reference A

SOIL FUNCTION ON ABANDONED GAS WELL PADS OF VARYING AGE





BEST WAY TO ENSURE RECLAMATION IS PERFORMANCE BASED STANDARDS

- Performance-Based Standards:
  - A performance based standard states goals and objectives to be achieved and describes methods that can be used to demonstrate whether or not products and services meet the specified goals and objectives.
- Best Management Practices:
  - Contrast a prescriptive standard, which typically prescribes materials, design and construction methods frequently without stating goals and objectives.

PERFORMANCE BASED STANDARDS ARE FAVORED FOR ALL INDUSTRIES

- US Executive Order 12866 in 1993 (Clinton Administration)
  - "(8) Each agency shall identify and assess alternative forms of regulation and shall, to the extent feasible, specify performance objectives, rather than specifying the behavior or manner of compliance that regulated entities must adopt."
  - Retained by Presidents Bush and Obama

ADVANTAGES OF PERFORMANCE BASED STANDARDS

- New Technology
  - Performance based standards allow earlier use of new technology. The users of these standards are free to implement new technology as soon as it is demonstrated, without waiting for standards development committees to modify standards to explicitly permit use of new technology.
- Innovation
  - Performance based standards encourages people to find optimum ways to meet performance criteria, which results in building the knowledge base and developing the entrepreneurial spirit, which in turn leads to economic development (more successful reclamation)
- Barriers to Trade
  - Performance based standards permit the use of new or nontraditional parts and methods when their use meets the performance criteria. This widens the marketplace, no longer limiting the acceptable suppliers to those manufacturers or countries with specific resources.

ADVANTAGES OF PERFORMANCE BASED STANDARDS

- Transparency
  - Performance based standards that have clearly stated goals and objectives answer the question of what is to be achieved. For most prescriptive standards, the goals and objectives are implied at best and unknown at worst. For many rules in prescriptive standards, we cannot answer with certainty the question of what end function is to be achieved.
- Efficiency
  - The development and maintenance of performance based standards ultimately requires less effort. While initially more difficult to establish goals and objectives, the decision for inclusion or not of various requirements is much simpler. Maintenance can be simpler as well. For example, a standard that describes the properties of acceptable materials of construction is much easier to maintain than one that lists acceptable materials by reference to various material standards.

EXAMPLE

- Performance Based
  - Bolted flanged joints shall be leak-free for the intended service. The joint shall be hydrotested at 1.5 times the design pressure without leaking, and shall be demonstrated to be able to withstand expected external forces without leakage while at design pressure and temperature.
  - Advantage – allows users complete freedom to use any suitable products
  - Disadvantage – testing and calculations are required for proven solutions
- Prescriptive
  - Bolted flanged joints shall meet the requirements of ASME B16.5, or ASME B&PV Code Section VIII, Division 1, Appendix 2
  - Advantage – gives clear guidance on what is required
  - Disadvantage – does not allow users to use suitable innovative products that may be available
- Example from reclamation (Colorado):

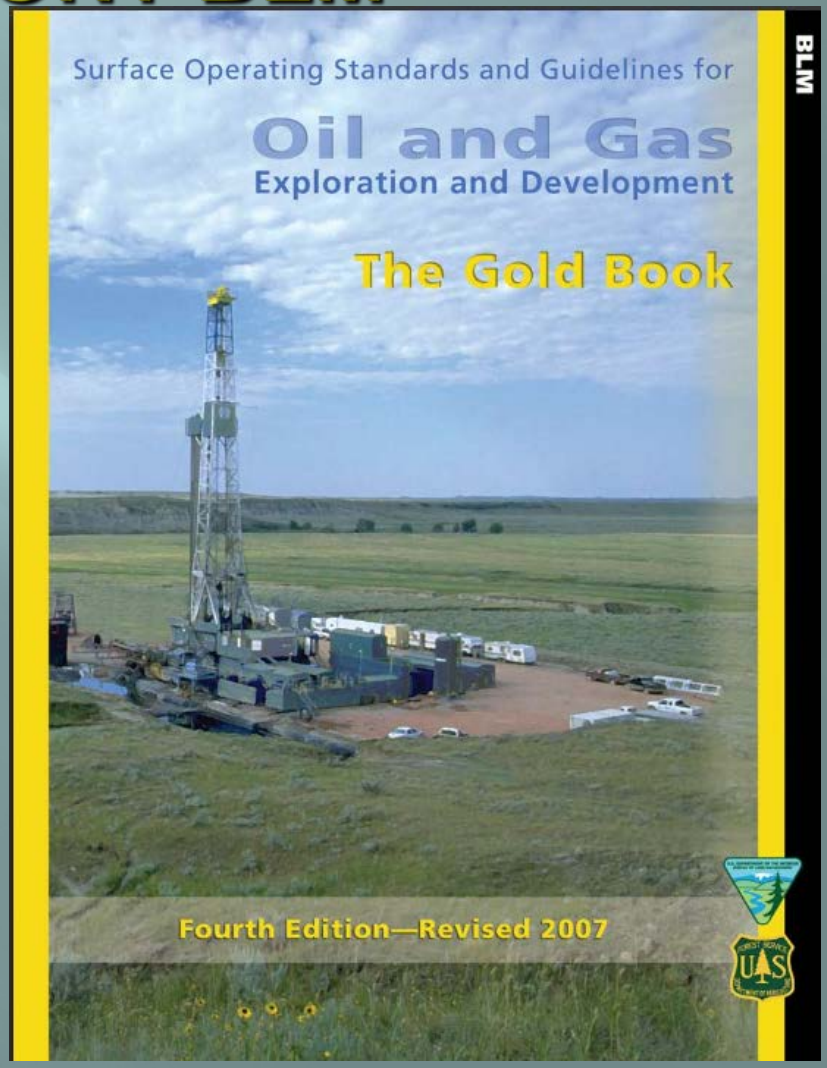
"Interim reclamation shall occur no later than three (3) months on crop land or six (6) months on non-crop land after such operations unless the Director extends the time period because of conditions outside the control of the operator."

ESTABLISHING PERFORMANCE-BASED STANDARDS

- Establish goals for the standard: broad, qualitative statement
- Specify assumptions: state of equipment, state of area to be reclaimed (i.e., sodic soils)
- Establish objectives and performance criteria: more specific than goals, quantitative
- Verification: monitor and report

USE OF PERFORMANCE-BASED STANDARDS IN OIL AND GAS RECLAMATION? BLM

- Bureau of Land Management's Surface Operating Standards and Guidelines for Oil and Gas Exploration and Development (The Gold Book)
  - Ch 6 Reclamation and Abandonment
  - BMPs

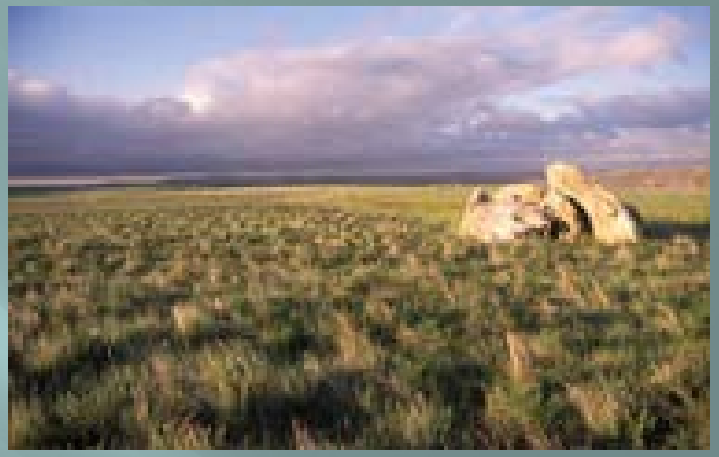


USE OF PERFORMANCE-BASED STANDARDS IN OIL AND GAS RECLAMATION? COLORADO

- Interim Reclamation
  - a uniform vegetative cover has been established that reflects pre-disturbance or reference area forbs, shrubs, and grasses with total percent plant cover of at least eighty percent (80%) of pre-disturbance levels or reference areas, excluding noxious weeds. Re-seeding alone is not sufficient.
  - a minimum four (4) photographs taken during the growing season facing each cardinal direction which document the success of the interim reclamation and one (1) photograph which documents the total cover of live perennial vegetation of adjacent or nearby undisturbed land or the reference area.
- Final
  - a uniform vegetative cover has been established that reflects pre-disturbance or reference area forbs, shrubs, and grasses with total percent plant cover of at least eighty percent (80%) of pre-disturbance or reference area levels, excluding noxious weeds
  - determined by the Director through a visual appraisal.

COAL IS REQUIRED TO MEET PBS

- Surface Mining Control and Reclamation Act (SMCRA) of 1977
- Regulations of the Colorado Mined Land Reclamation Board for Coal Mining, 1980



http://www.archcoal.com/images/reclamation-5.jpg

Revegetation Success Criteria Depends On Post-Mining Use of Disturbed Area

4.15.9 Revegetation Success Criteria: Cropland.

For areas to be used as cropland, success of revegetation shall be determined on the basis of crop production from the mined area as compared to approved reference areas or other approved standard(s). Crop production from the mined area shall not be less than that of the approved reference area or standard for two of the last four years of the liability period established in 3.02.3. Crop production shall not be considered prior to year nine of the liability period. With respect to annual grain crops for which the cropping cycle may incorporate a summer fallow year, two of the last four cropping years will be considered. This liability period shall commence on the date of initial planting of the crop being grown. Production shall be considered equal if it is not less than 90% of the production as determined from the reference area or approved standard with 90% statistical confidence.

4.15.10 Revegetation Success Criteria: Previously Mined Lands; Areas to be Developed for Industrial or Residential Use.

(1) For previously mined areas that were not reclaimed to the requirements of these Rules as a minimum ground cover of living plants shall not be less than can be supported by the best available topsoil or other suitable material in the reaffected areas, shall not be less than the ground cover existing before redisturbance, and shall be adequate to control erosion;

(2) With the exception of areas specified in 4.15.10(3), for areas to be developed for industrial or commercial, or residential use less than 2 years after regrading is completed, or less than 2 years after approval of such use, whichever is later, the ground cover of living plants shall not be less than required to control erosion. Final bond release shall not occur prior to satisfactory cover establishment.

(3) For mine support facilities located within areas where the pre-mining land use was industrial or commercial, and the approved post-mining land use is industrial or commercial, the vegetation requirement of 4.15.10(2) may be waived if requested in writing by the landowner, and if the Division determines that revegetation is not necessary to control erosion.

4.15.11 Revegetation Sampling Methods and Statistical Demonstrations for Revegetation Success

(1) All aspects of the vegetation sampling program must be conducted to ensure a repeatable, unbiased estimate of the appropriate population parameter. Consistency in sampling shall be required in comparisons between the reclaimed area and the undisturbed areas. Both random and systematic sampling designs are acceptable. Double sampling (involving measurements and estimations as equivalent sample data) is not acceptable.

(a) Vegetation cover shall be sampled using one of the following methods.

(i) Point intercept in which the observational unit is a series of points along a transect. The transect is a minimum of 5 meters in length, with at least 50 data points at regular intervals along the transect. A point sampling device supported by a rigid frame must be utilized to ensure unbiased point placement; or

(ii) Line intercept in which the observational unit is a transect tape at least 5 meters in length; or

(iii) Quadrat sampling in which the observational unit is a plot frame at least ¼ square meter and large enough to encompass individual plants of the larger species being sampled. Quadrats can be distributed independent of transects or treated as subsamples when associated with other quadrats along a transect. Plot frames must be marked in discrete increments appropriate for the level of accuracy required for unbiased, repeatable estimates of cover by species.

(b) Herbaceous Production shall be sampled using one of the following methods.

(i) Quadrat sampling in which the observational unit is a rectangular or circular plot frame at least ¼ square meter and large enough to encompass individual plants of the larger species being sampled. Production estimates are made by clipping current annual growth of herbaceous, non-woody, species within each quadrat, and bagging, drying and weighing the clippings. Drying must be consistent with the technical standard where applicable (i.e. air-dry or oven-dry). Where reference areas are used, samples will be dried at 105 degrees Celsius to constant weight. For non-forage crops such as grain, fruit or vegetables, the plant material sampled shall be restricted to the harvested commodity. Quadrats can be distributed independent of transects or treated as subsamples when associated with other quadrats along a transect. If quadrats are used to sample non-forage crops such as grain, fruit, or vegetable crops, the plant material sampled shall be restricted to the primary harvested commodity; or

(ii) Total harvest method. If the total harvest method is used for non forage crops such as grain, fruit, or vegetable crops, the plant material sampled shall be restricted to the harvested comodity.

(c) Woody plant density shall be sampled using one of the following methods.

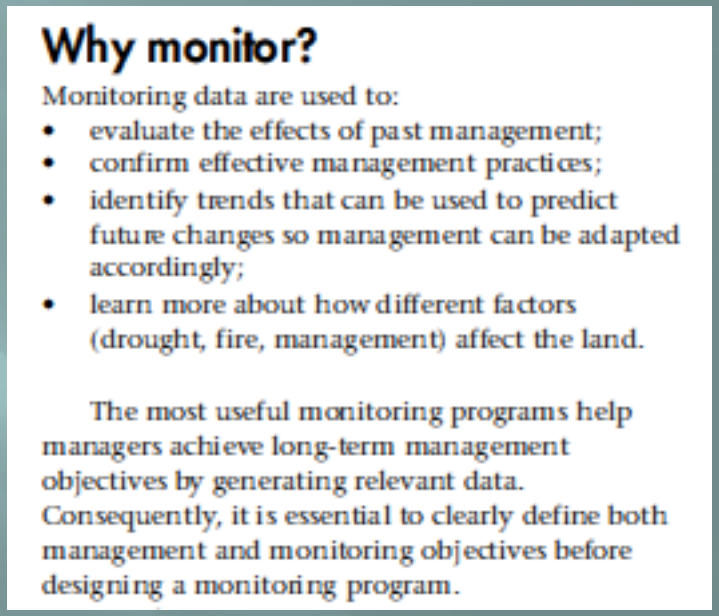
(i) Belt transects which are elongate quadrats at least 1 meter wide by at least 5 meters long. Woody plants rooted in the quadrat are counted.

(ii) Circular or rectangular quadrats at least one meter squared which can be distributed independent of transects or treated as subsamples when associated with other quadrats along a transect. Woody plants rooted in the quadrat are counted.

Regulations of the Colorado Mined Land Reclamation Board for Coal Mining, August 30, 1980

MONITORING REQUIRED TO VERIFY MEETING PBS

- Ensure successful reclamation is occurring
- Provide information on methods to increase success in future



Why monitor?

Monitoring data are used to:

- evaluate the effects of past management;
- confirm effective management practices;
- identify trends that can be used to predict future changes so management can be adapted accordingly;
- learn more about how different factors (drought, fire, management) affect the land.

The most useful monitoring programs help managers achieve long-term management objectives by generating relevant data. Consequently, it is essential to clearly define both management and monitoring objectives before designing a monitoring program.

MONITORED AND NONMONITORED GAS WELL SITES

- Smith, K.A., and J.C. Chambers. 1993. Comparing revegetation success on monitored and nonmonitored gas well sites in Southwestern Wyoming. USDA Forest Service, Research note INT-417.
- Monitoring programs for oil and gas industry are vague and vary among Federal land management agencies, regions, districts, and projects.
  - Soil stability and vegetation
- Riley Ridge Natural Gas area in SW Wyoming, Exxon Corporation's LaBarge Fogarty Creek Unit
  - 7800-9700 ft in elevation
  - Mountain big sagebrush or Wyoming big sagebrush and bluebunch wheatgrass
  - 8 nonmonitored and 5 monitored well sites reclaimed in 1984, 1985 or 1986 with 13 adjacent reference sites
- Cover by vegetation or litter was higher in the monitored vs. nonmonitored sites, while bareground was higher in the monitored site

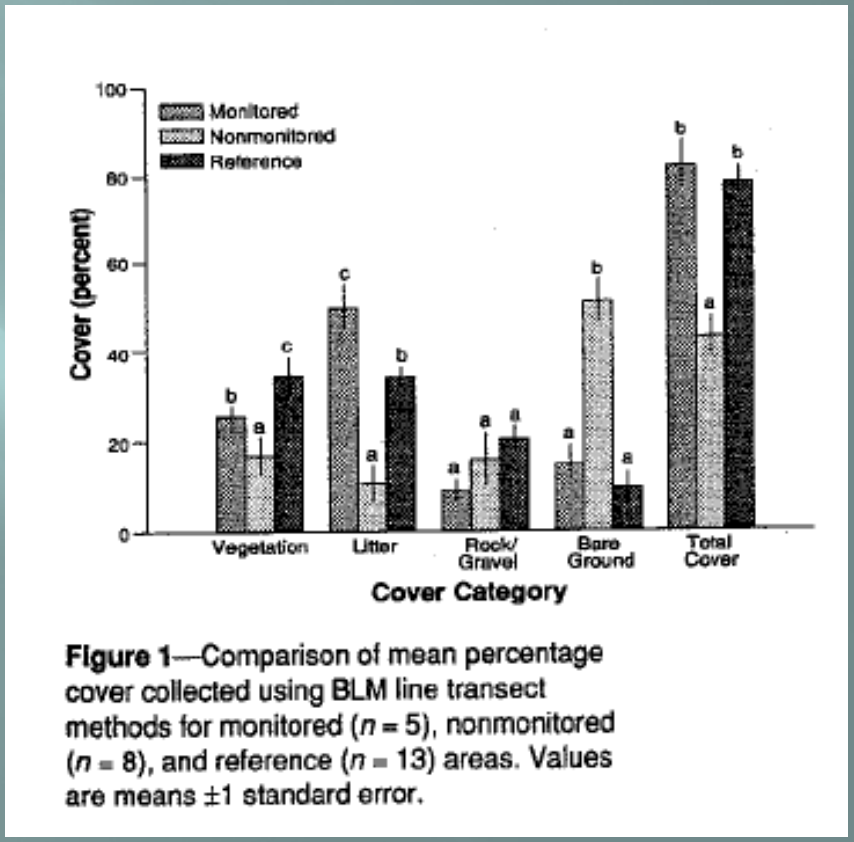


Figure 1—Comparison of mean percentage cover collected using BLM line transect methods for monitored ($n = 5$), nonmonitored ($n = 8$), and reference ($n = 13$) areas. Values are means ±1 standard error.

- Other results
  - There were more seeded species on monitored (3.2) vs. nonmonitored (1.3) sites
  - Relative percent cover by desirable species was higher on the monitored (92.4%) vs nonmonitored sites (55.9%)
  - Mean number of species was higher on monitored (9.0) vs. nonmonitored (4.6) sites, although reference sites were higher than either of these (14)
  - There was > 5% weed cover on 1 monitored site and 4 nonmonitored sites
- Sites which were monitored showed better reclamation success

Table 5—Mean aerial and basal cover and frequency of common species present on intensively sampled monitored and nonmonitored gas well sites and adjacent reference areas

	Quadrats[1]		Transects[2]	
	Aerial cover	Frequency	Basal cover	Frequency
	Percent			
Monitored (14-05)				
Phleum pratense	10.18	68.0	11.17	9.0
*Agropyron dasystachyum**	7.84	32.0	5.17	4.0
Bromus inermus	5.72	24.0	2.50	3.0
Poa compressa	4.42	84.0	7.83	6.7
*Agropyron trachycaulum**	4.26	36.0	2.50	3.7
*Agropyron smithii**	1.52	16.0	.83	1.7
*Alopecuris pratensis**	1.26	12.0	.16	.3
*Linum lewisii**	.48	16.0	—	—
Descurania spp.	.44	4.0	—	—
*Astragalus cicer**	.22	12.0	1.00	1.3
Salsola kali	.04	2.0	—	—
*Achillea millefolium**	.02	4.0	—	—
Nonmonitored (43-20)				
Bromus inermus	19.08	93.3	13.80	13.0
Agropyron intermedium	1.82	30.0	—	—
*Agropyron dasystachyum**	1.45	23.3	1.83	2.0
*Agropyron smithii**	.92	23.3	—	—
Agropyron trichophorum	.77	20.0	1.00	1.0
*Agropyron trachycaulum**	.43	6.7	—	—
Poa compressa	.35	3.3	—	—
*Artemisia tridentata**	.17	6.7	—	—
*Sitanion hystrix**	.03	3.3	.17	.3
Reference (43-20)				
*Artemisia tridentata**	36.33	96.7	20.50	10.7
Lupinus spp.*	2.97	56.7	7.17	5.3
Erigonium spp.*	2.80	66.7	7.83	10.7
*Linum lewisii**	1.38	13.3	—	—
*Sitanion hystrix**	.72	36.7	1.83	2.0
*Phlox hoodii**	.30	20.0	—	—
Astragalus spp.*	.28	30.0	1.00	1.0
Castilleja spp.*	.15	13.3	—	—
Geranium spp.*	.13	26.7	.16	1.0
*Stipa comata**	.05	3.3	—	—
*Poa secunda**	.02	3.3	.83	1.0
*Agropyron smithii**	—	—	2.50	3.0
Arenaria spp.*	—	—	.83	1.3
*Achillea millefolium**	—	—	.16	.3
*Amelanchier alnifolia**	—	—	.16	.3

[1]Monitored (n = 25 quadrats); nonmonitored (n = 30 quadrats); reference (n = 30 quadrats).
[2]Three transects (n = 300 points).
*Denotes native status.

QUALITATIVE VS QUANTITATIVE

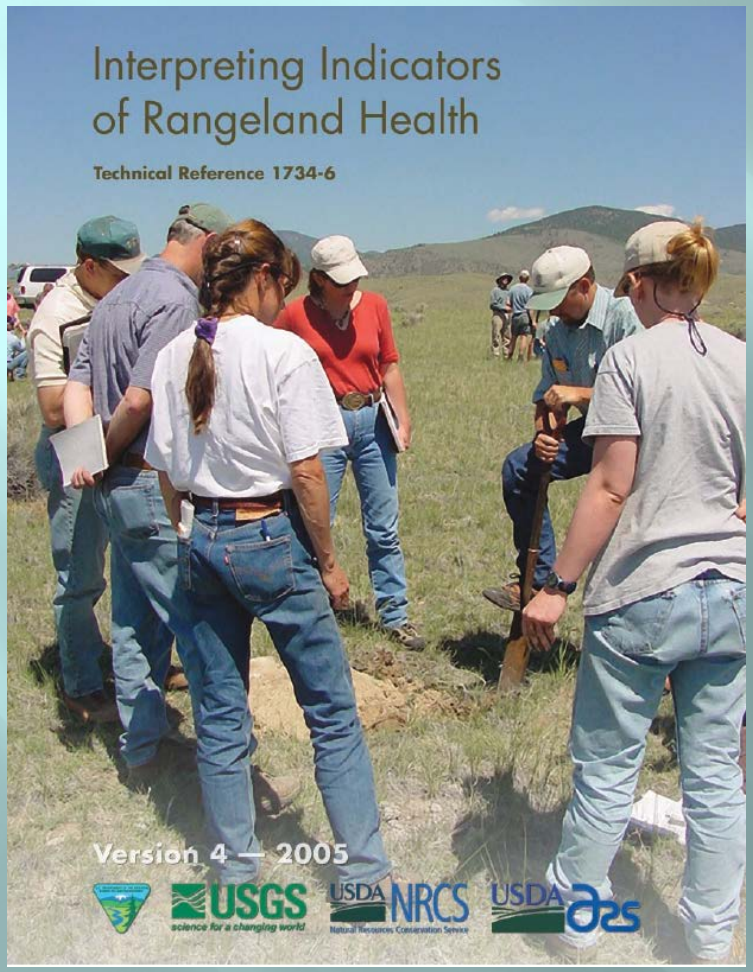
Indicator selection

Table 4.1. Levels of monitoring intensity.

Level	Objective	Measurements
I	Qualitative documentation of large changes in vegetation structure.	Photographs at standard photo points.
II	Semi-quantitative documentation of changes in vegetation composition, structure and soil stability (less repeatable than Level III).	Semi-quantitative alternatives to basic measurements (described in Quick Start).
III	Quantitative documentation of changes in vegetation composition, structure and soil stability.	One or more of four basic quantitative measurements described in Quick Start: Line-point intercept, Gap intercept, Soil stability test and Belt transect.
IV	Quantitative documentation of changes in the status of specific issues (e.g., compaction, water infiltration, vegetative production or streambank stability).	Various. See Chapters 7-15.

- Although Qualitative Data Collection seems easier, it may actually take more training to have consistent results

QUALITATIVE MONITORING



The protocol described in this technical reference IS designed to:

- Be used only by knowledgeable, experienced people.
- Provide a preliminary evaluation of soil/site stability, hydrologic function, and biotic integrity (at the ecological site level).
- Be used to communicate fundamental ecological concepts to a wide variety of audiences.
- Improve communication among interest groups by focusing discussion on critical ecosystem properties and processes.
- Select monitoring sites in the development of monitoring programs.
- Provide early warnings of potential problems and opportunities by helping land managers identify areas that are potentially at risk of degradation or where resource problems currently exist.

The protocol is NOT to be used to:

- Identify the cause(s) of resource problems.
- Independently make grazing and other management changes.
- Monitor land or determine trend.
- Independently generate national or regional assessments of rangeland health.

QUALITATIVE MONITORING

Definitions of these three interrelated attributes are:

Soil/Site Stability

The capacity of an area to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water.

Hydrologic Function

The capacity of an area to capture, store, and safely release water from rainfall, run-on, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity when a reduction does occur.

Biotic Integrity

The capacity of the biotic community to support ecological processes within the normal range of variability expected for the site, to resist a loss in the capacity to support these processes, and to recover this capacity when losses do occur. The biotic community includes plants, animals, and microorganisms occurring both above and below ground.

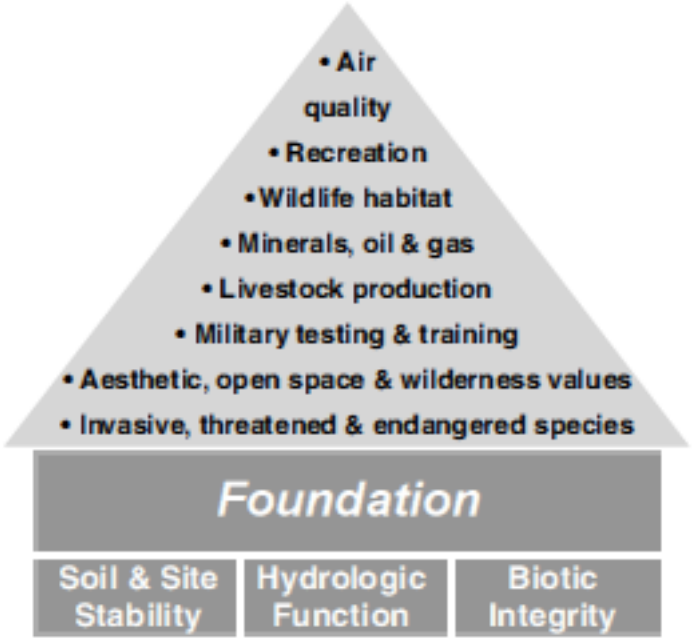


Figure Intro.1. Monitoring the three key attributes (primary monitoring objective) serves as the foundation for sustaining the potential to support diverse management objectives.

QUALITATIVE MONITORING

Evaluation Sheet (Example) (Front)

Aerial Photo: _____

Management Unit: Allotment I, pasture I State: NM Office: Las Cruces Range/Ecol. Site Code: 042XB999NM
(Allotment or pasture)

Ecological Site Name: Limy Soil Map Unit/Component Name: Nickel gravelly fine sandy loam

Observers: Joe Smith, Jose Garcia, and Thaddeus Jones Date: June 10, 2002

Location (description): Limy site two miles north of windmill in S.E. pasture

T. 11 S R. 23 W or _____ N. Lat. Or UTM E _____ m Position by GPS? Y / N No
UTM Zone ___, Datum ___

Sec. 12, NE1/4 _____ W. Long. N _____ m Photos taken? Y / N Yes

Size of evaluation area: Evaluation area is approximately 3 ac. and represents entire ecological site in this pasture

Composition (Indicators 10 and 12) based on: __Annual Production, X Cover Produced During Current Year or __Biomass

Soil/site verification:

Range/Ecol. Site Descr., Soil Surv., and/or Ecol. Ref. Area:	Evaluation Area:
Surface texture grsl, grlfs gl	Surface texture gsl
Depth: very shallow __, shallow __, moderate __, deep X	Depth: very shallow __, shallow __, moderate __, deep X
Type and depth of diagnostic horizons:	Type and depth of diagnostic horizons:
1. Calcic horizon w/in 20" 3. _____	1. Calcic horizon at 15" 3. _____
2. _____ 4. _____	2. _____ 4. _____
Surf. Efferv.: none __, v. slight __, slight __, strong X, violent __	Surf. Efferv.: none __, v. slight __, slight __, strong X, violent __

Parent material Alluvium Slope 0-5 % Elevation 4100 ft. Topographic position toeslope Aspect south

Average annual precipitation 8-12 inches Seasonal distribution Summer thunderstorms dominate

Recent weather (last 2 years) (1) drought ____, (2) normal __X__, or (3) wet ____.

Wildlife use, livestock use (intensity and season of allotted use), and recent disturbances:
Wildlife use is dominated by pronghorn antelope in the winter. Livestock use was extremely heavy yearlong during 1900-1930. Last 50 years, livestock use has been cow/calf moderate yearlong use.

Off-site influences on evaluation area:
None

Criteria used to select this particular evaluation area as REPRESENTATIVE (specific info. and factors considered; degree of "representativeness")
Area is located near a pasture Key area. It is located in the center of the ecological site and represents the typical amount of livestock, wildlife and recreational uses on this area. This ecological site dominates this pasture. The area is 3/4 of a mile from the closest water source.

Other remarks (continue on back if necessary)

Reference: (1) Reference Sheet: Limy SD--42B ; Author: J. Christensen ; Creation Date: 09/25/2002
or (2) Other (e.g., name and date of ecological site description; locations of ecological reference area(s)) Limy Ecological Site

Evaluation Sheet (Example) (Back)

Departure from Expected	Code
None to Slight	N-S
Slight to Moderate	S-M
Moderate	M
Moderate to Extreme	M-E
Extreme to Total	E-T

Instructions for Evaluation Sheet, Page 2
(1) Assign 17 indicator ratings. If indicator not present, rate None to Slight.
(2) In the three grids below, write the indicator number in the appropriate column for each indicator that is applicable to the attribute.
(3) Assign overall rating for each attribute based on preponderance of evidence.
(4) Justify each attribute rating in writing.

Indicator	Rating	Comments
1. Rills	S H / M	Active rill formation evident at infrequent intervals
2. Water-flow Patterns	S H / M-E	Flow patterns show cutting and deposition and some connectivity
3. Pedestals and/or terracettes	S H / S-M	Pedestaling in flow patterns only not common
4. Bare ground 48 %	S H / M	Bare ground rarely connected
5. Gullies	S H / N-S	
6. Wind-scoured, blowouts, and/or deposition areas	S / N-S	
7. Litter movement	S / M	Small litter shows sign of moderate movement, larger litter - slight movement
8. Soil surface resistance to erosion	S H B / M-E	Stability values average from 3-4 on surfaces under vegetation canopy and 1-2 in interspaces
9. Soil surface loss or degradation	S H B / M	Severe past erosion has left much of the site without much surface horizon
10. Plant community composition and distribution relative to infiltration	H / M-E	Change from grass dominated to shrub dominated has decreased infiltration and bare ground has increased run-off
11. Compaction layer	S H B / N-S	
12. Functional/structional groups	B / M	Subdominate group basically gone (warm season stoloniferous grass) and Subdominate group (warm season narrow leaf bunchgrass) and Minor group (Evergreen subshrub) have
13. Plant mortality/decadence	B / S-M	
14. Litter amount	H B / M-E	Very little litter is on the site for the time of year and rainfall for the year
15. Annual production	B / S-M	Production is about 70% of expected
16. Invasive plants	B / N-S	
17. Reproductive capability of perennial plants	B / S-M	Plants show some signs of stress that will reduce seed production and stolon production this year

Attribute Rating Justification
Soil & Site Stability:
Although there is some active erosion in flow patterns most is old and healing. Lots of water leaving the site but not much erosion. All erosion occuring as concentrated flow.

E-T	M-E	M	S-M	N-S
		9		
		7		11
	8	4		6
	2	1	3	5

S (10 indicators): Soil & Site Stability Rating: M

Attribute Rating Justification
Hydrologic Function:
Lots of water leaving the site. Runoff is increasing and all litter is being washed away.

E-T	M-E	M	S-M	N-S
	14			
	10	9		
	8	4		11
	2	1	3	5

H (10 indicators): Hydrologic Function Rating: M-E

Attribute Rating Justification
Biotic Integrity:
Shift in functional structural groups is significant justifying moderate rating.

E-T	M-E	M	S-M	N-S
			17	
	14	12	15	16
	8	9	13	11

B (9 indicators): Biotic Integrity Rating: M

QUALITATIVE MONITORING

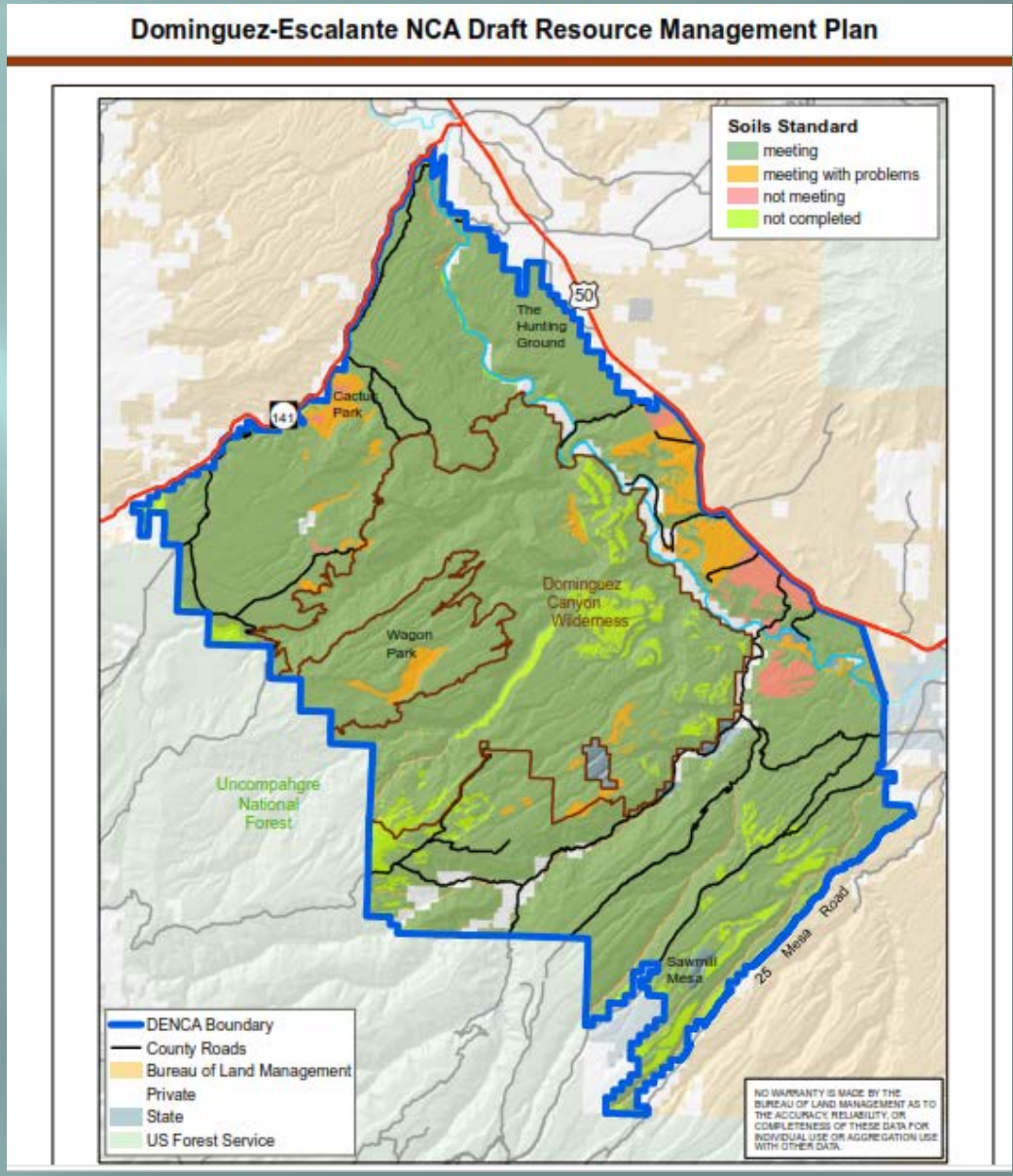
Indicator*	Extreme to Total	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight
1. Rills					Reference Sheet:
Generic Descriptor	Rill formation is severe and well defined throughout most of the site.	Rill formation is moderately active and well defined throughout most of the site.	Active rill formation is slight at infrequent intervals; mostly in exposed areas.	No recent formation of rills; old rills have blunted or muted features.	Current or past formation of rills as expected for the site.

1a - Rills are a natural component of this site due to erodible soils.

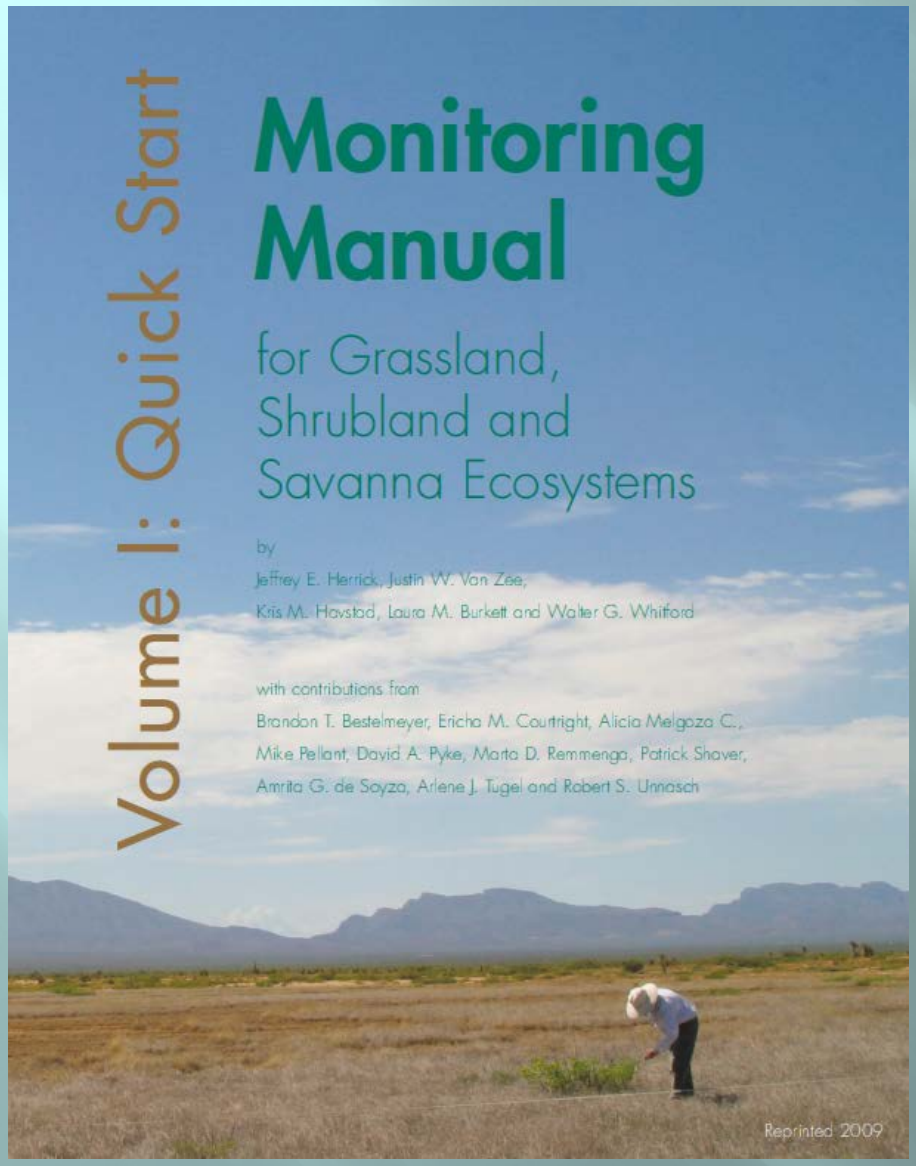
1b - Short linear rill caused by accelerated water flow.

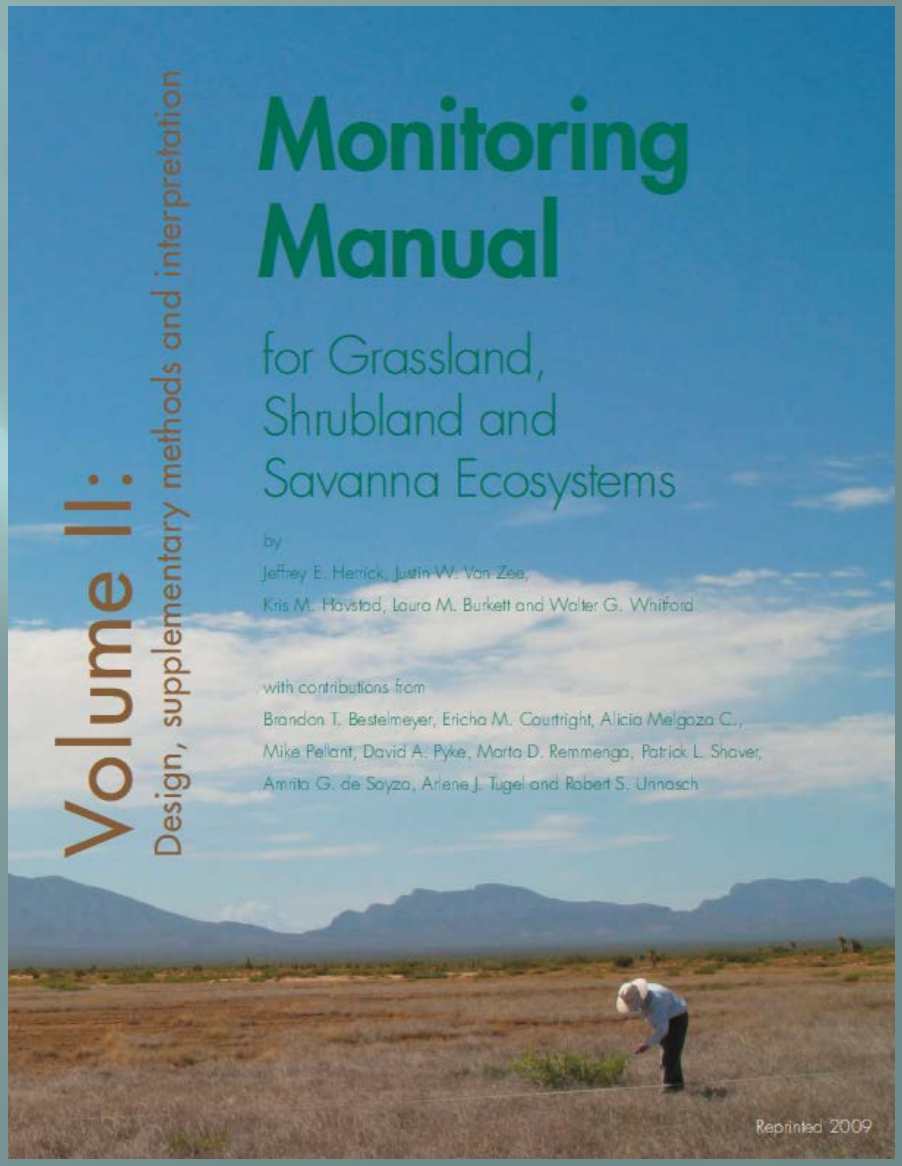
IS QUALITATIVE MONITORING EASIER?

- More time to train
- Results less standardized among groups



QUANTITATIVE MONITORING





QUANTITATIVE MONITORING

Estimated time requirements for *Quick Start* long-term measurement options.

Method–page	No.*	Time** (hours)	No. of people	Indicators generated
Photos (for visual record of data), page 6	3	0.1	2	None
Line-point intercept (for plant cover and composition), page 9	150 pts. (50/line)	0.5	2	Foliar cover (%) Plant basal cover (%) Bare ground (%)
Canopy gap intercept (to monitor areas that are susceptible to wind erosion and/or weed invasion), page 16	3 lines	0.4	2	Proportion of line covered by large gaps between plant canopies
Basal gap intercept page 16	3 lines	0.4	2	Proportion of line covered by large gaps between plant bases
Soil stability test (for soil susceptibility to water erosion), page 23	18 samples	0.5	1	Average surface stability: • total • under canopy • not under canopy
Belt transect (for invasive species), page 30	3 belts	0.2	2	Number of invasive plants per hectare


Photos


Line-point intercept


Canopy and basal gap intercept


Soil stability test


Belt transect

QUANTITATIVE MONITORING

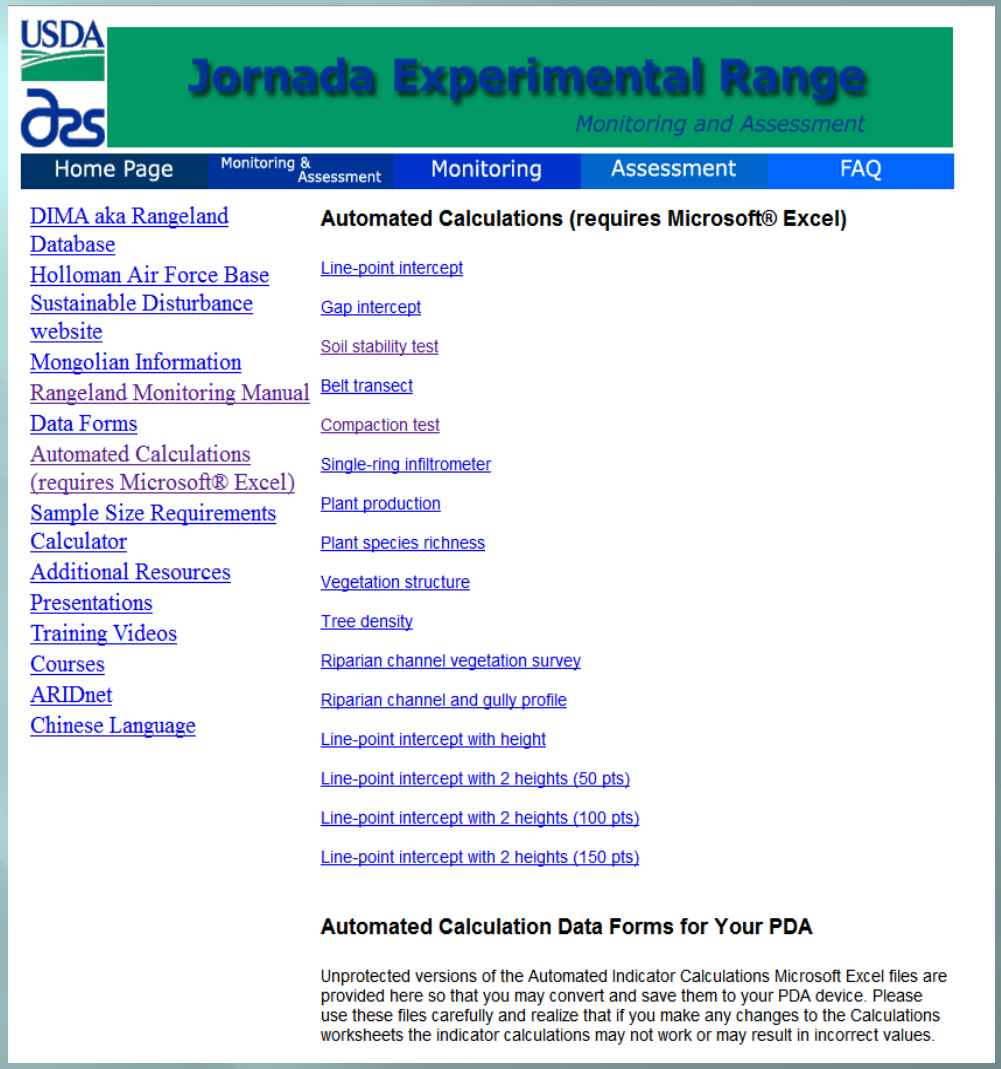
Line-point intercept

Line-point intercept is a rapid, accurate method for quantifying soil cover, including vegetation, litter, rocks and biotic crusts. These measurements are related to wind and water erosion, water infiltration and the ability of the site to resist and recover from degradation. For a detailed discussion of this and other methods for measuring plant cover and/or composition, see Elzinga et al. 2001[2]. For alternative Line-point intercept methods (including height measurements) see Volume II.

Materials

- Measuring tape (length of transect)—if using a tape measure in feet, use one marked in tenths of feet.
- Two steel pins for anchoring tape
- One pointer—a straight piece of wire or rod, such as a long pin flag, at least 75 cm (2.5 ft) long and less than 1 mm (1/25 in) in diameter
- Clipboard, Line-Point Intercept Data Form (page 12) and pencil(s)

QUANTITATIVE MONITORING



http://usda-ars.nmsu.edu/monit_assess/index.html

QUANTITATIVE MONITORING

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Site: | Observers: JWS TLM | *Gray cells for indicator calculations*

Plot: 1 | Line: 1 | Recorder JTW | Line Length: 25 | m or ft?: m

Direction: 275 deg. magnetic | Date: mm/dd/yyyy | Intercept (Point) Spacing Interval: 50 | cm or in?: cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	POAN-T	CHNA-S	PF01-PF		L	13.5	ACRE-PFX	FEOC-AG	ASTER1-PF		S
1.5	POAN-T	BRTE-AGX			L	14	ACNE-T	PRVI-S	CLLI-PF	W	ACNE
2	ARTR-S	PUTR-S	BRTE-AGX		L	14.5	ACNE-T	MARE-PF	ELTR-PG	BRTE-AGX	L
2.5	ACHY-PG	L			S	15	ACNE-T	ELTR-PG			S
3	ARTR-S	CHNA-S	ACHY-PG	COMP1-PF	L	15.5	CHNA-S	ACHY-PG	L		L
3.5	NONE				L	16	ACHY-PG	L			S
4	NONE				S	16.5	ARTR-S	CHNA-S	ACHY-PG	COMP1	L
4.5	PF01-PF	BRTE-AGX	AF01-AF		L	17	NONE				L
5	ACRE-PFX	FEOC-AG	ASTER1-PF		S	17.5	NONE				S
5.5	ACNE-T	PRVI-S	CLLI-PF	W	ACNE	18	PF01-PF	BRTE-AGX	AF01-AF		L
6	ACNE-T	MARE-PF	ELTR-PG	BRTE-AGX	L	18.5	POAN-T	CHNA-S	PF01-PF		L
6.5	ACNE-T	ELTR-PG			S	19	POAN-T	BRTE-AGX			L
7	CHNA-S	ACHY-PG	L		L	19.5	POAN-T	PRVI-S	W		POAN
7.5	ACHY-PG	BRTE-AGX			M	20	POAN-T	ELTR-PG	COMP1-PF		L
8	BRTE-AGX	PFO1-PF			P	20.5	TARA-TX	CIAR-PFX	BRTE-AGX		L
8.5	NONE				S	21	TARA-TX	CIAR-PFX	L		L
9	NONE				C	21.5	CESO-AFX	BRTE-AGX			S
9.5	ARFR-S	ACHY-PG			ARFR	22	NONE				S
10	PUTR-S	BRIN-PGX			EL	22.5	NONE				C
10.5	NONE				P	23	ARFR-S	ACHY-PG			ARFR
11	CIAR-PFX	COMP1-PF	BRTE-AGX		L	23.5	PUTR-S	BRIN-PGX			EL
11.5	NONE				S	24	NONE				P
12	NONE				R	24.5	CIAR-PFX	COMP1-PF	BRTE-AGX		L
12.5	TARA-TX	CIAR-PFX	BRTE-AGX		L	25	NONE				S
13	TARA-TX	CIAR-PFX	L		L	25.5	NONE				R

NOTES:

Transect01 | Calculations01 | **Sample** | CalculationsSample

QUANTITATIVE MONITORING

NOTES:

Transect parallel to dry stream bed, running mostly east/west. Little topography. Weedy - evidence of previous disturbance.
All unknowns collected and labelled. COMP1 <30cm tall, remnants of many small yellow flowers. ASTER1 - ~40cm tall, looks like purple flowers, maybe Erigeron? PF01 - ~10cm tall, no flowers or fruits, does have rhizomes.

Top canopy codes:
Species Code,
Common Name, or
NONE (no canopy).

Lower canopy layer codes:
Species Code,
Common Name,
L =herbaceous litter,
W =woody litter, >5 mm (~1/4 in diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual grass
PG# = perennial grass
SH# = shrub
TR# = tree

Functional Group Codes:
-AF = annual forb
-PF = perennial forb
-AG = annual grass
-PG = perennial grass
-S = shrub
-T = tree
X = weed

Soil Surface (may use L = litter again):
Species Code (for basal intercept), or
R = rock fragment (>5 mm (~1/4 in) diameter),
BR = bedrock,
C = biological soil crust / lichens on soil,
S = soil without *any* other soil surface code,
EL = embedded litter, **M** = moss,
D = duff, **P** = poop.

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Data Summary

% Canopy Cover =	72
% Bare Ground =	12
% Basal Cover =	16
Ave. Species/Pt =	2.02
Ave. Bio Lyrs =	2.62
% Tree Cover =	32
% Shrub Cover =	28
% Perennial Forb Cover =	38
% Annual Forb Cover =	6
% Perennial Grass Cover =	32
% Annual Grass Cover =	32
% Weed Cover =	40

Last updated on 15 September 2009.

WHO IS USING PBS AND REQUIRING MONITORING?

- 467 documents, primarily in western US, 2001-2010
- 185 hits on the word "monitor"
  - Required vs. recommended
  - Pre & post
  - Quantitative
- 6 EIS/Record of Decision primarily in Wyoming
  - Atlantic Rim, Jonah Infill, Powder River Basin, Desolation Flats
  - Roan Plateau, CO (recommended)
- State Wildlife Divisions recommended
  - Colorado, New Mexico, Wyoming

CONCLUSION

- Oil and gas activity in western North America is extensive and increasing
- These activities have impacts on wildlife and ecosystem function
- It is important to successfully reclaim these areas to achieve ecosystem function
  - This may also allow industry continued access to these resources
- The best way to insure reclamation is through the use of Performance-Based Standards
- PBS requires monitoring
  - Quantitative monitoring is preferred.