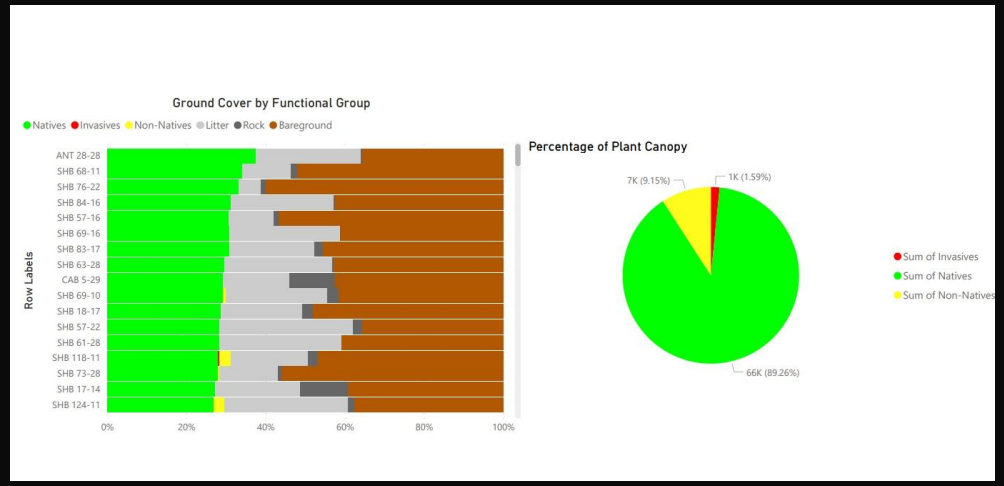
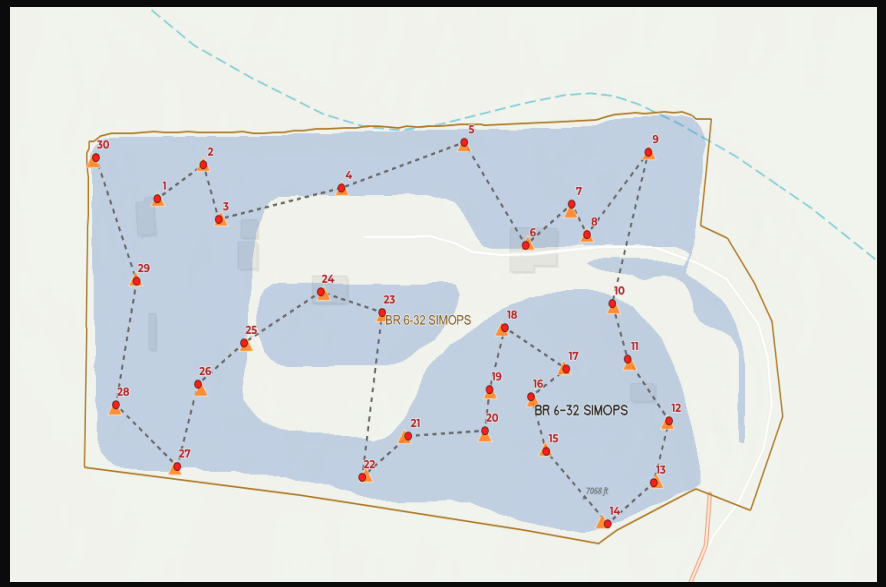




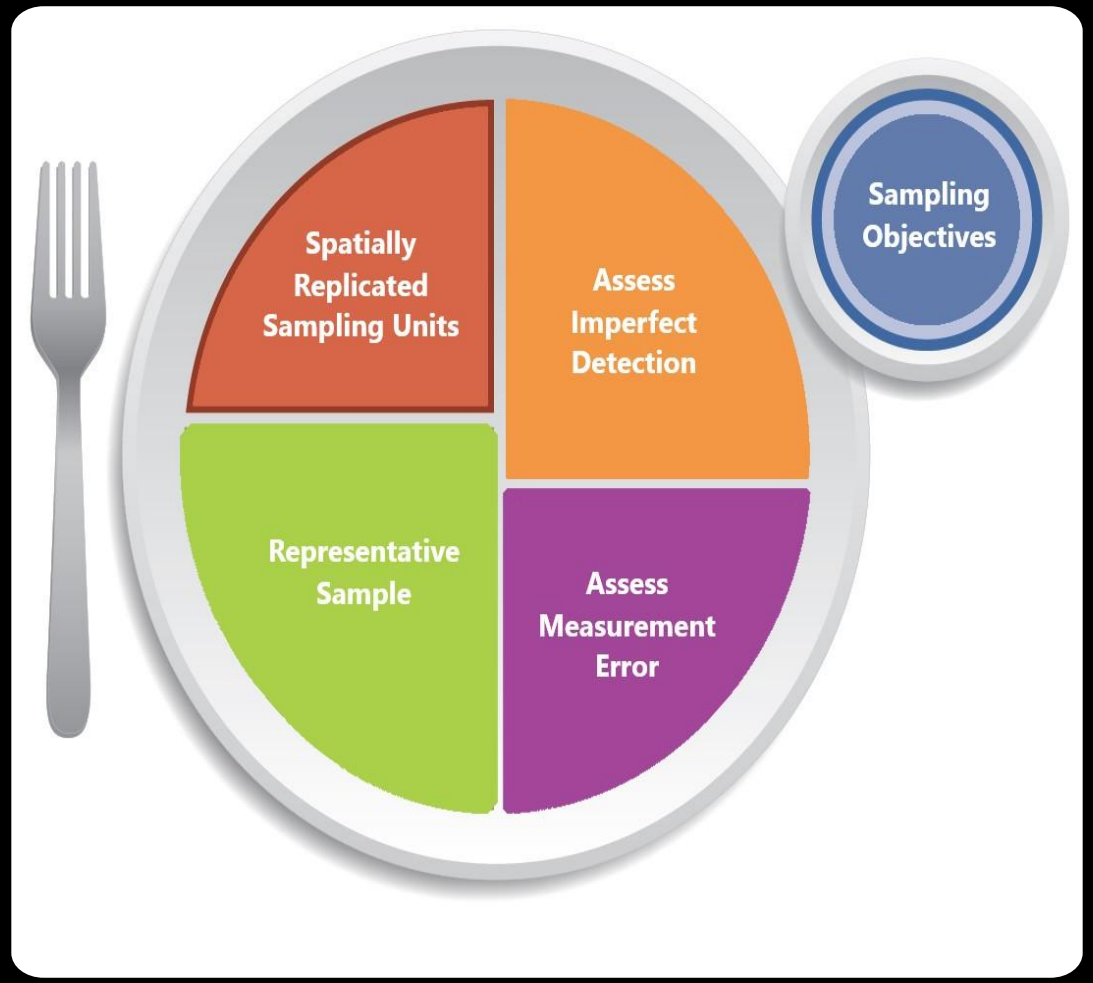
Use of Digital Technologies and GIS to Improve Reclamation Monitoring and Reporting

Zachary Farmer – Abnova Ecological Solutions
Michael Curran – Abnova Ecological Solutions

Overview

- Discuss 5 Necessities of Monitoring Programs
- Discuss Issues Associated with Reclamation Monitoring Across Oil and Gas Sites
- Improved Sampling Designs, GIS Tools, Digital Technologies
- Discuss Reporting and Dashboards
- Provide Examples from Recent Efforts
- Concluding Remarks & Questions

Five Essentials for Monitoring Programs

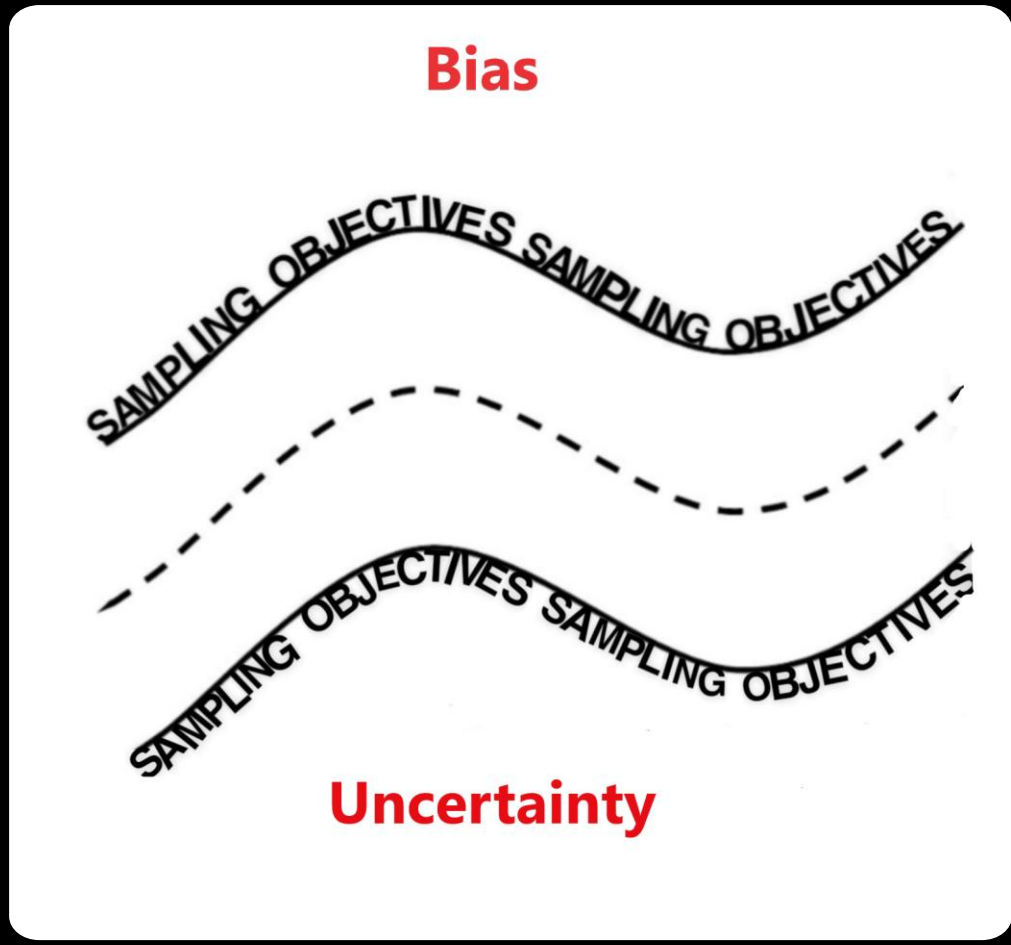


1. Sampling Objectives (Assists with all other aspects)
   - Provide guard rails for monitoring program to reduce bias and uncertainty
   - Understand stakeholder needs
2. Select a Representative Sample
   - Reduce bias
   - Ensure sample looks similar to target population
3. Replication to Assess Spatial Variation
   - Reduce uncertainty
   - Spatial variation – need multiple sampling units per area of interest
   - Measurement error – how similar are repeated measures
4. Assess Imperfect Detection
   - Type I and Type II Errors
     - False Positives (e.g., double counts)
     - False Negatives (e.g., missed what was there)
   - Misclassification
5. Assess Measurement Error

*Robinson, TJ. Five Essentials of Survey Sampling Designs. PAW 2024 (Casper, WY, USA)

Sampling Objectives

- Reduce Bias
  - Non-representative Samples
    - Sample doesn't look like population
  - Imperfect Detection
    - Type I Errors – False Positives
    - Type II Errors – False Negatives
- Reduce Uncertainty
  - Spatial Variation
    - Need multiple sampling units per spatial region of interest
  - Measurement Error
    - Differences across repeated measures



*Robinson, TJ. Five Essentials of Survey Sampling Designs. PAW 2024 (Casper, WY, USA)

Sampling Objectives

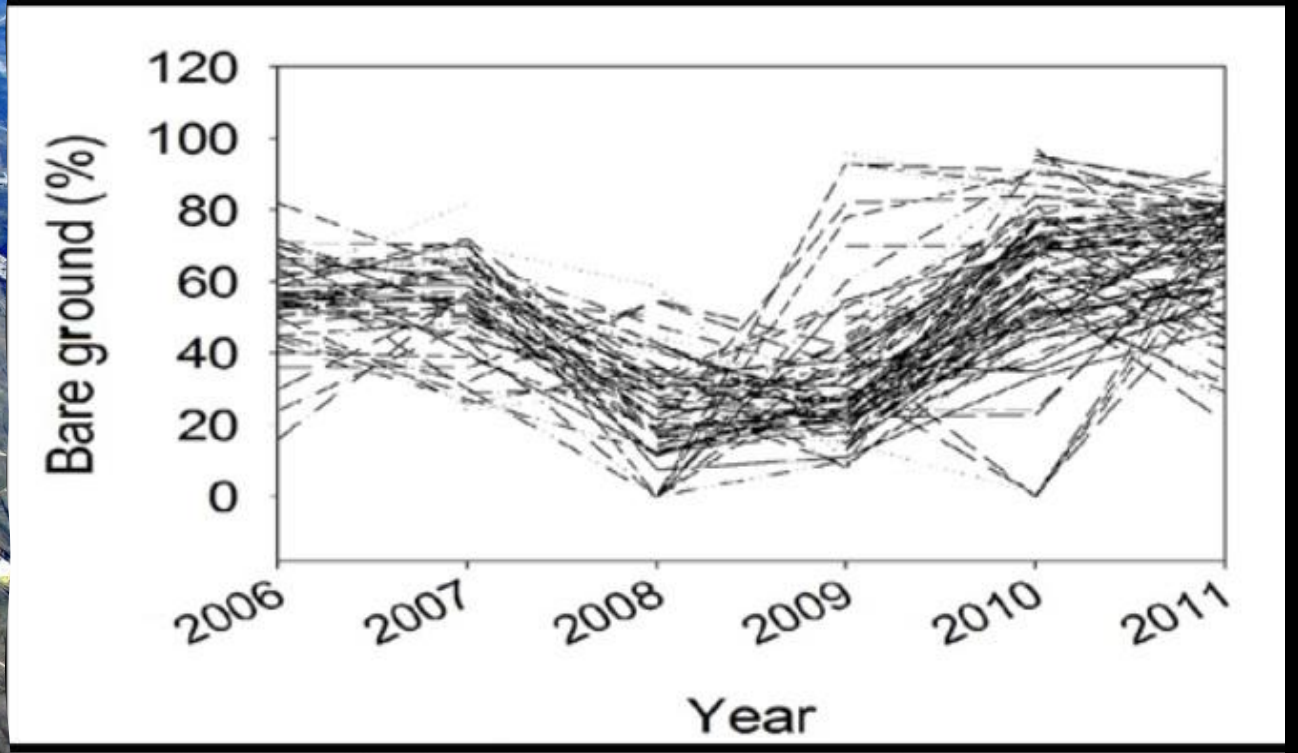
- Understand Stakeholders and Needs
  - Operators
    - Decision Making
    - Compliance
    - Right to Operate
    - Investor Relations
  - Government Agencies
    - Compliance
    - Improve Policies
  - Practitioners & Scientists
    - Improve seed mixes
    - Erosion Control
    - Weed Treatment
    - Expand Knowledge of Reclamation
  - General Public (Federal Lands)

Issues with Oil and Gas Monitoring

- Large number of sites over large areas (Issues with Point #2)
  - How and what to monitor at each site?
  - How to select reference sites?
  - What sites to monitor (well pads)? What portions of linear disturbance to monitor (pipelines/roads)?
- Inconsistent regulatory requirements (Confounds Issues Across the Board)
  - E.g., 70% cover for Stormwater Pollution Prevention Plans vs. various criteria across BLM Field Offices (80-100% relative cover, sometimes species diversity, etc.)
  - Qualitative vs. Quantitative
- Inconsistent monitoring techniques and timing
- Inconsistent personnel
  - Field Technicians
  - Government Agents
  - Operators
- Inconsistent monitoring timing
- Short growing seasons (limited window to collect data)

Commonly Used Monitoring Techniques at the Site Location

- Ocular estimates
  - High observer variability, but fast
- Daubenmire frames
  - Time consuming, haphazard locations
- Line-point intercept (along transect)
- Step-point



Curran, M. F., & Stahl, P. D. (2015). Database management for large scale reclamation projects in Wyon Developing better data acquisition, monitoring, and models for application to future projects. *Journal Environmental Solutions for Oil, Gas, and Mining*, 1(2), 31-43.

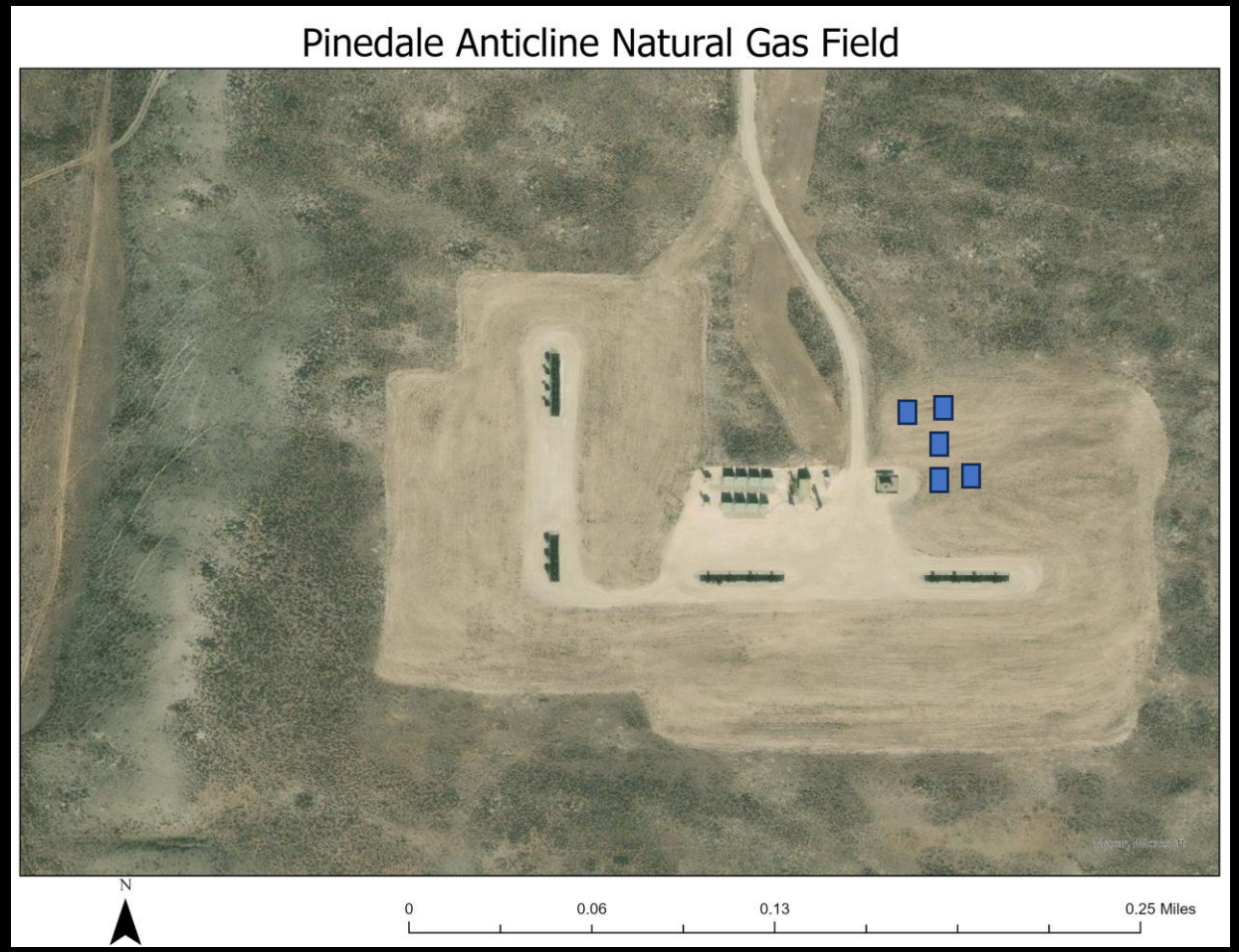
Will adopting new methods ruin our ability to assess trends?

- Commonly used methods not doing a good job at accurately assessing trends
- Technicians and techniques inconsistent
- Monitoring metrics inconsistent
- Timing varies from year to year

Convenience Sampling - Bias

Goal: assess vegetation species composition for this study area

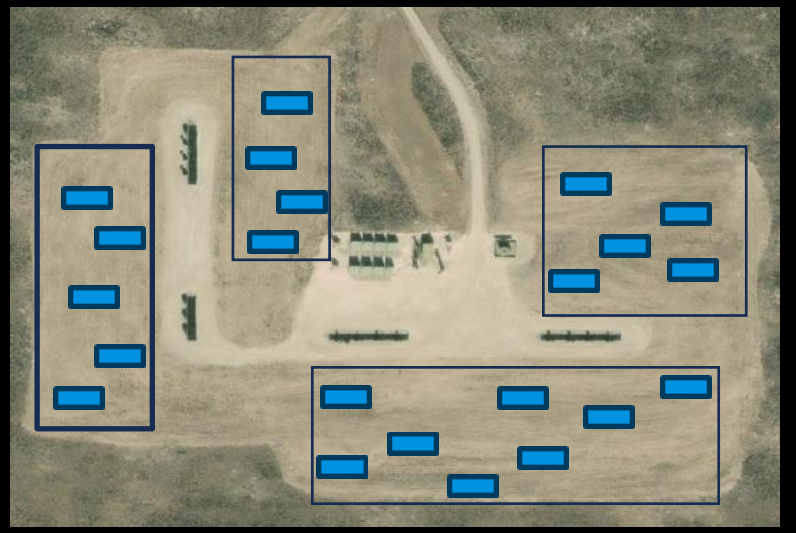
Quadrats observed from road – **NOT** representative of entire area



Common Representative Sampling Designs

Random Sample
Buffered Points

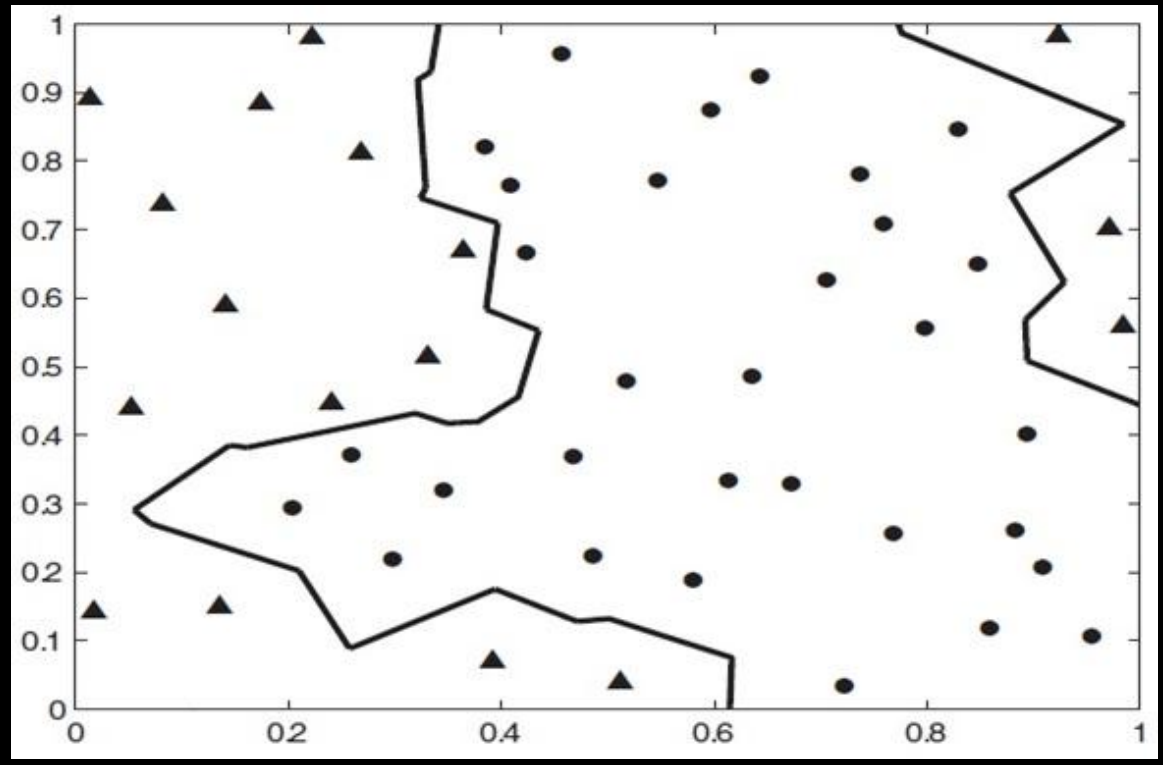
Systematic Sample



Stratified Sample

Balanced Acceptance Sampling (BAS)

- Spatially balanced sampling design
  - Well suited for natural resource sampling
    - Nearby units similar due to environmental and management inputs
  - Sample well spread across study area
  - Allows for strong estimates of population
- Quasi random
- Computationally efficient



Robertson, B.L. et al. 2013. BAS: Balanced Acceptance Sampling of Natural Resources. *Bioinformatics.*

Spatially balanced sampling and ground-level imagery for vegetation monitoring on reclaimed well pads

- Spatial verification method introduced
- 7-10x faster than LPI techniques
- Increased statistical power
- One-time data collection satisfies all existing regulatory criteria
  - Jonah Interagency Office
  - WY DEQ – Stormwater Pollution Prevention Plan (SWPPP)
  - WY Sage-grouse Executive Order
- Species specific report allows for seed mix assessment
- Spatially explicit weed information
- Increased variability in reference area accounted for
- Allows for spatially-explicit dashboard systems to be created

Curran, M. F., Cox, S. E., Robinson, T. J., Robertson, B. L., Rogers, K. J., Sherman, Z. A., Adams, T.A., Strom, C.F. & Stahl, P. D. (2019). Spatially balanced sampling and ground-level imagery for vegetation monitoring on reclaimed well pads. *Restoration Ecology*, 27(5), 974-980.

Image based monitoring

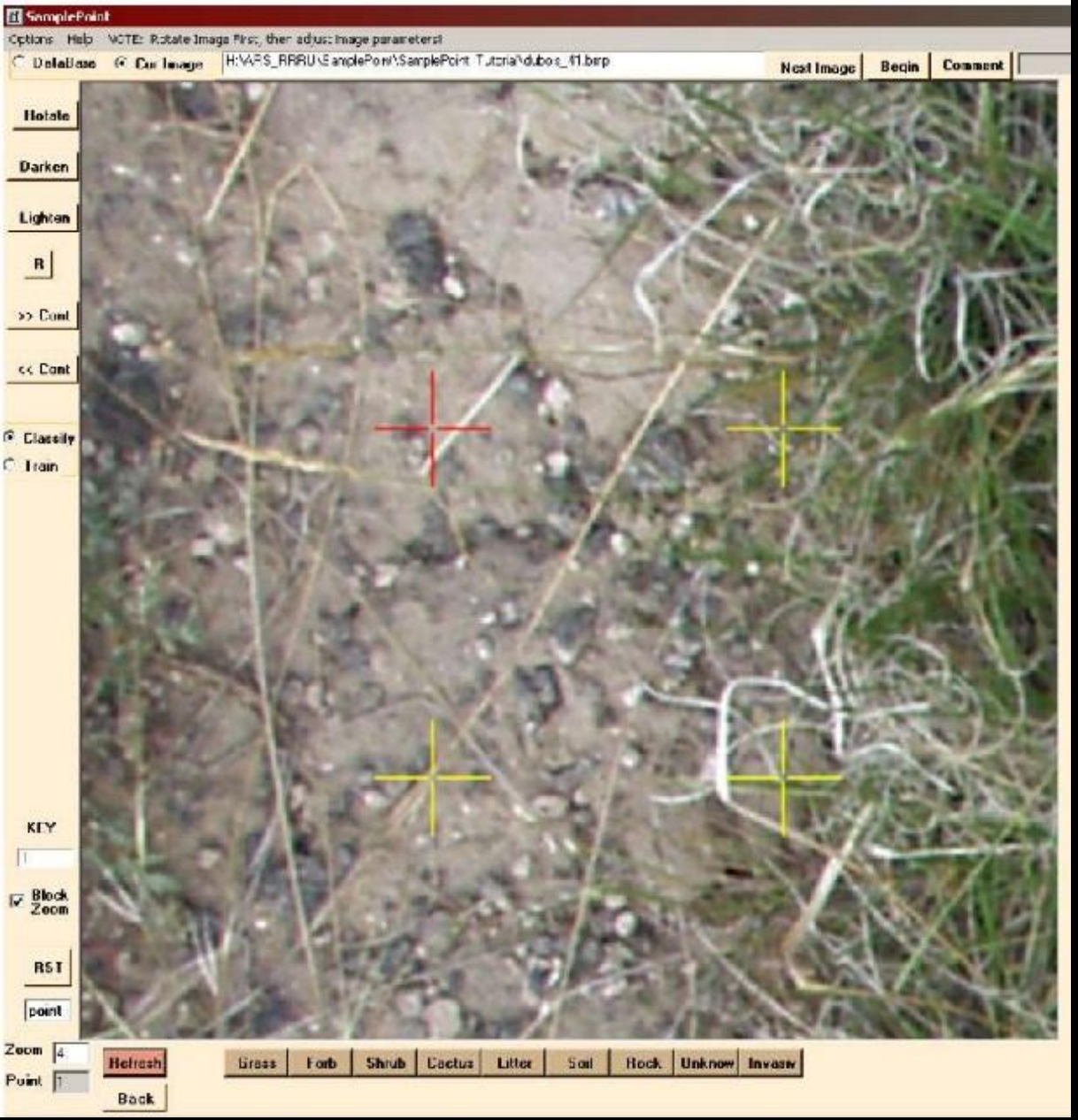
- Faster than LPI
- Less biased than LPI to wind, bright colors, moving pointing devices
- Permanent records
- Ability for multiple people to analyze
- As technology advances, so can image analysis
- With smart phones we can obtain 0.2 millimeter resolution data

Cox, S. E., Booth, D. T., & Berryman, R. D. (2021). Measuring nested frequency of plants from digital images with SampleFreq. *Ecological Indicators*, *121*, 106946.

Cagney, J., Cox, S. E., & Booth, D. T. (2011). Comparison of point intercept and image analysis for monitoring rangeland transects. *Rangeland Ecology & Management*, *64*(3), 309-315.

SamplePoint

- Free ImageAnalysis Software
  - www.SamplePoint.org
- Pixel Classification
  - Functional Group or Species
- Time Savings
- Reports Automatically Generated


SamplePoint
Options Help NOTE: Rotate Image First, then adjust image parameters!
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Cur Image
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Next Image
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Train
KEY
Block Zoom
RST
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Zoom
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Refresh
Back
Grass
Forb
Shrub
Cactus
Litter
Soil
Rock
Unknow
Invasiv


SamplePoint
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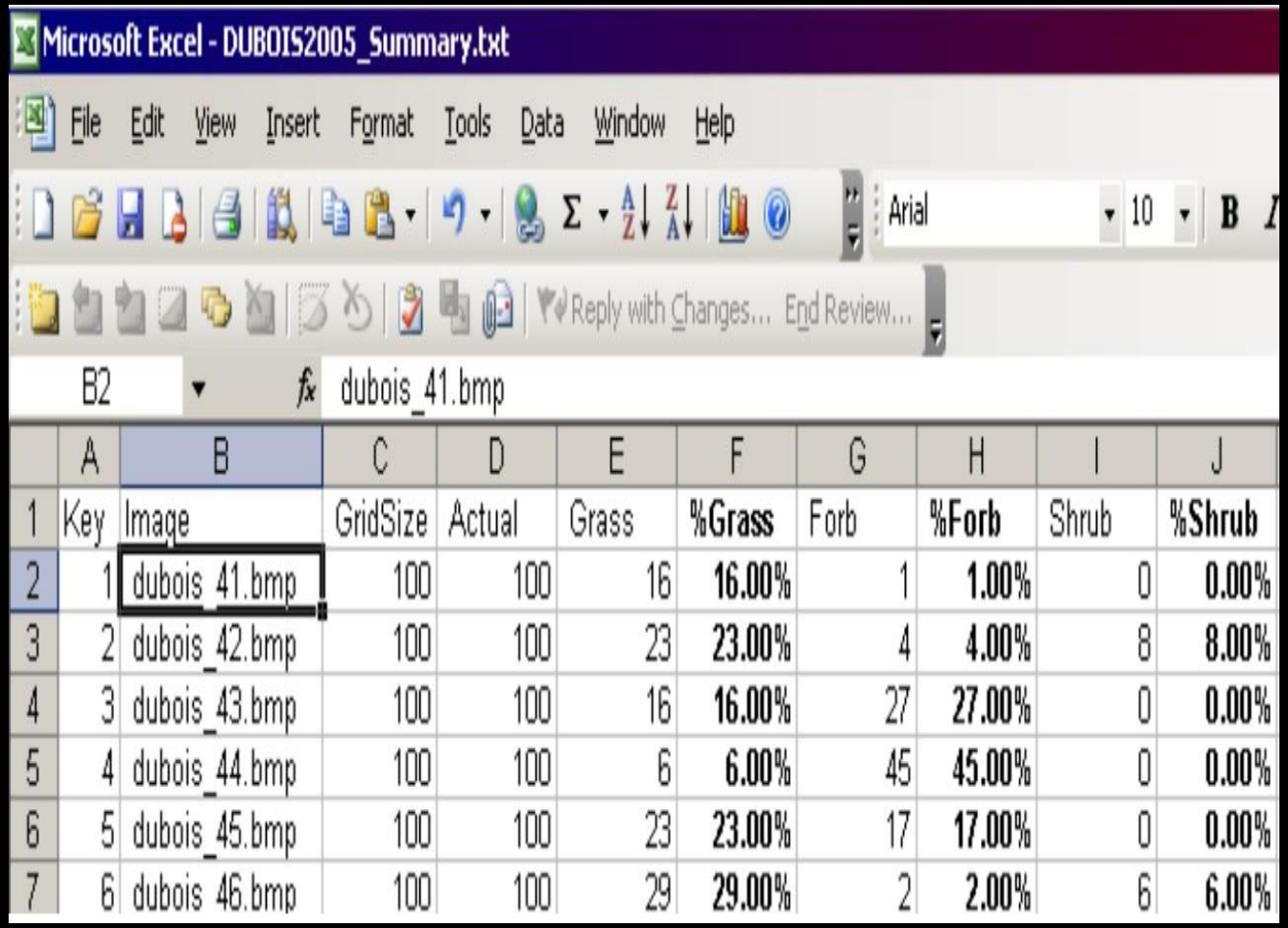
Train
KEY
Block Zoom
RST
point
Zoom
Point
Refresh
Back
Grass
Forb
Shrub
Cactus
Litter
Soil
Rock
Unknow
Invasiv

SamplePoint Report

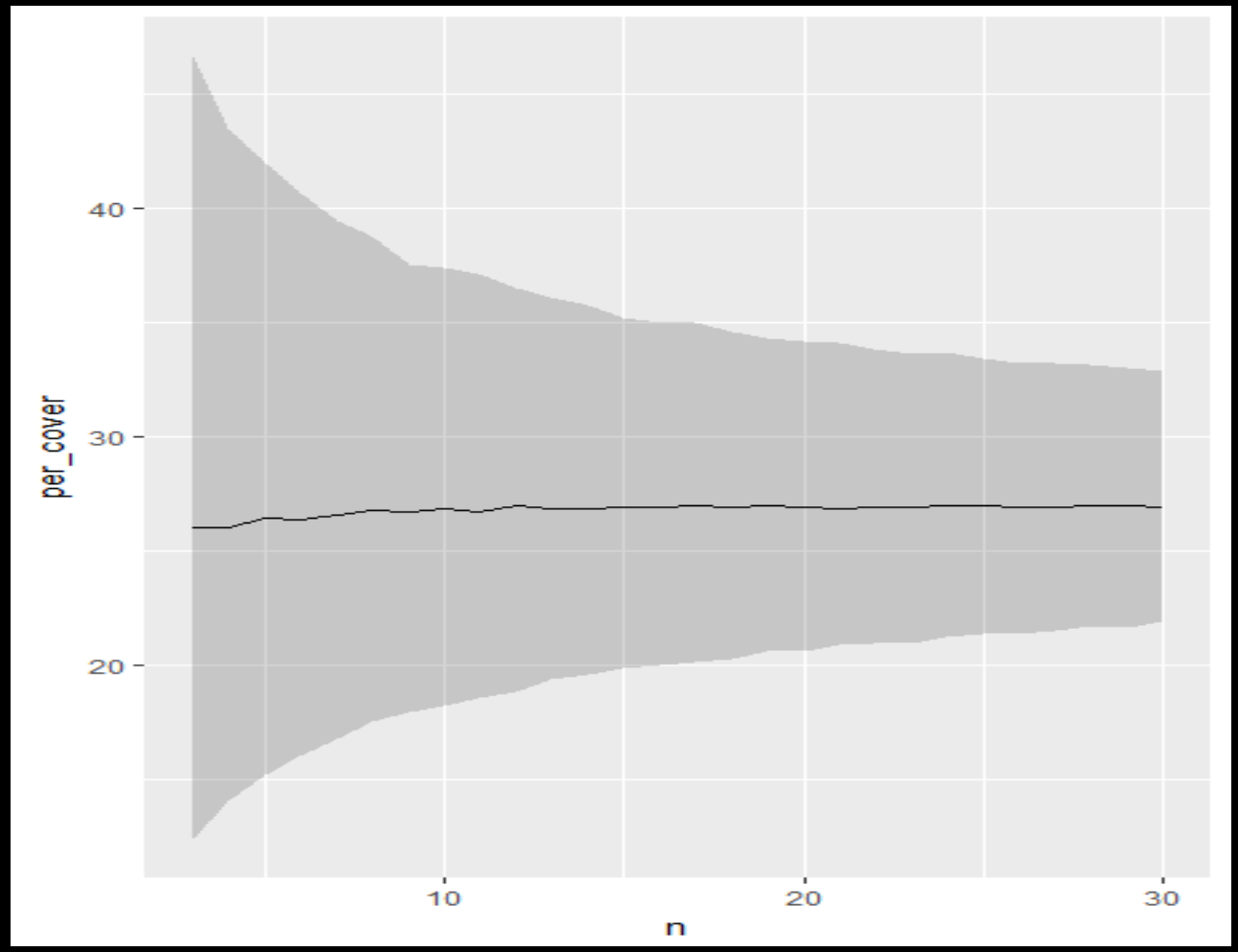
- .csv spreadsheet autogenerated
- Total ‘clicks’ per image
- Percent cover by group
  - Functional group
  - Species specific
- Allows for percent cover variance to be estimated
- Species richness



	A	B	C	D	E	F	G	H	I	J
1	Key	Image	GridSize	Actual	Grass	%Grass	Forb	%Forb	Shrub	%Shrub
2	1	dubois_41.bmp	100	100	16	16.00%	1	1.00%	0	0.00%
3	2	dubois_42.bmp	100	100	23	23.00%	4	4.00%	8	8.00%
4	3	dubois_43.bmp	100	100	16	16.00%	27	27.00%	0	0.00%
5	4	dubois_44.bmp	100	100	6	6.00%	45	45.00%	0	0.00%
6	5	dubois_45.bmp	100	100	23	23.00%	17	17.00%	0	0.00%
7	6	dubois_46.bmp	100	100	29	29.00%	2	2.00%	6	6.00%

What is the optimal sample size?

Using a non-parametric bootstrap model, we found ~30 1m^2 photos with 25 pixels per photo sampled gives us ~95% confidence in estimating percent vegetation cover on a 6 acre pad




Default Path
Optimized Path
N
BAS Points
Sample Path
Interim Reclamation Area
0
25
50
100
Meters

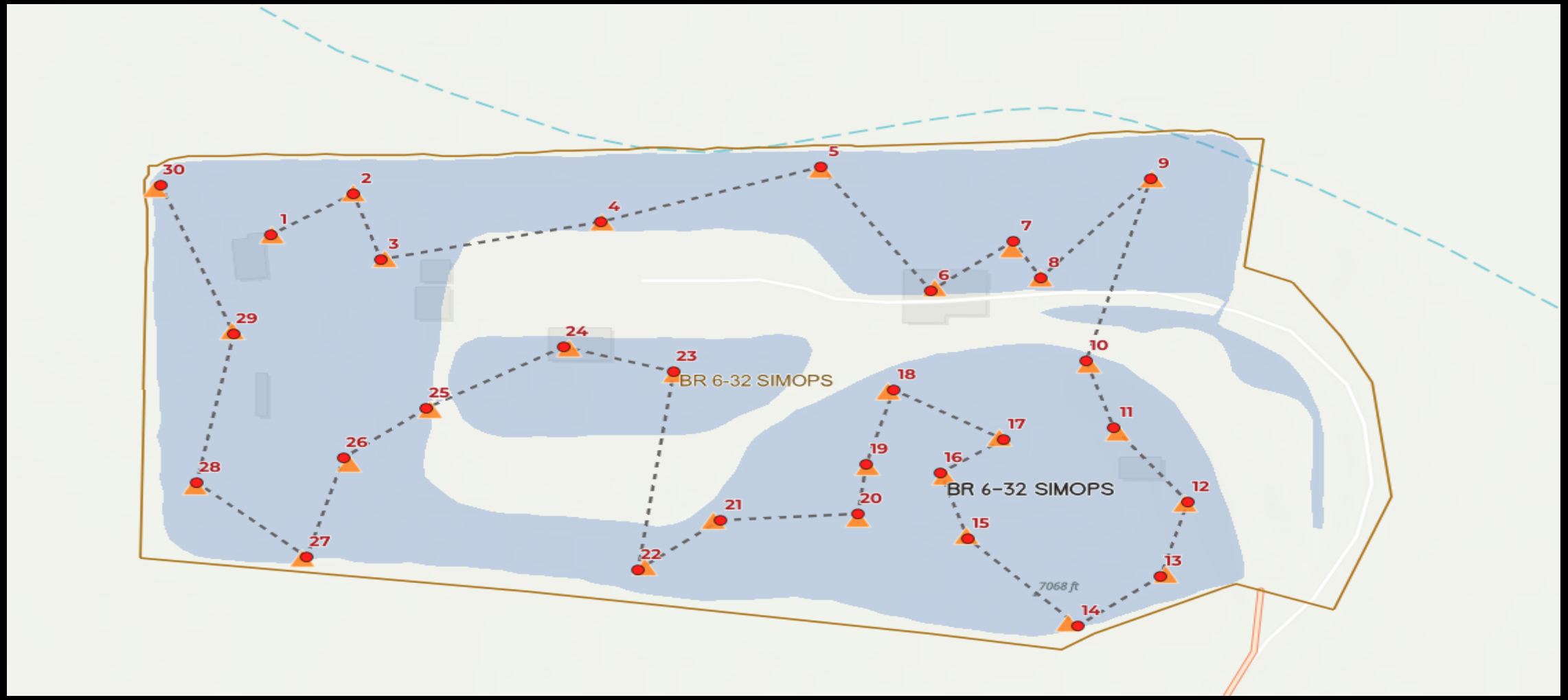
Conclusions

- Our methodology and sampling technique satisfies all needs for a sound monitoring program
- Able to rapidly adjust sampling objectives based on task at hand
- More efficient data collection and product delivery
- Now…. How to report?

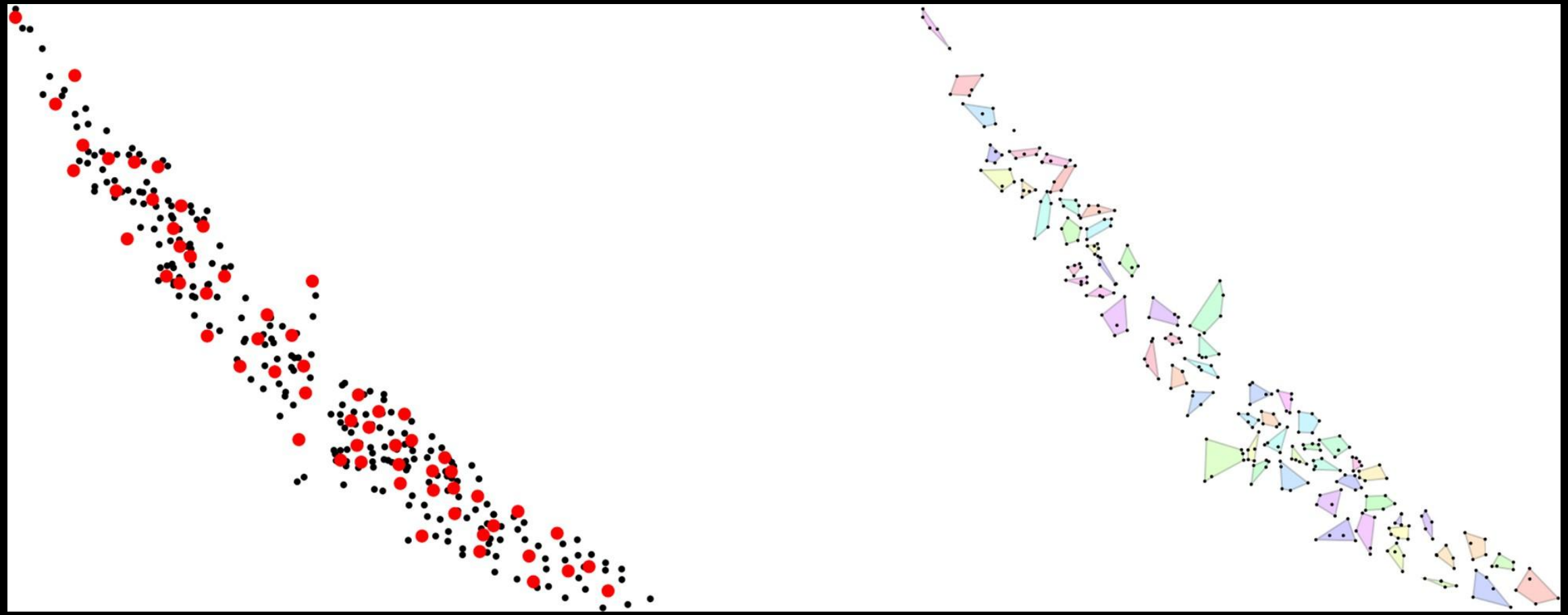
GIS Tools to Collect Data in the Field

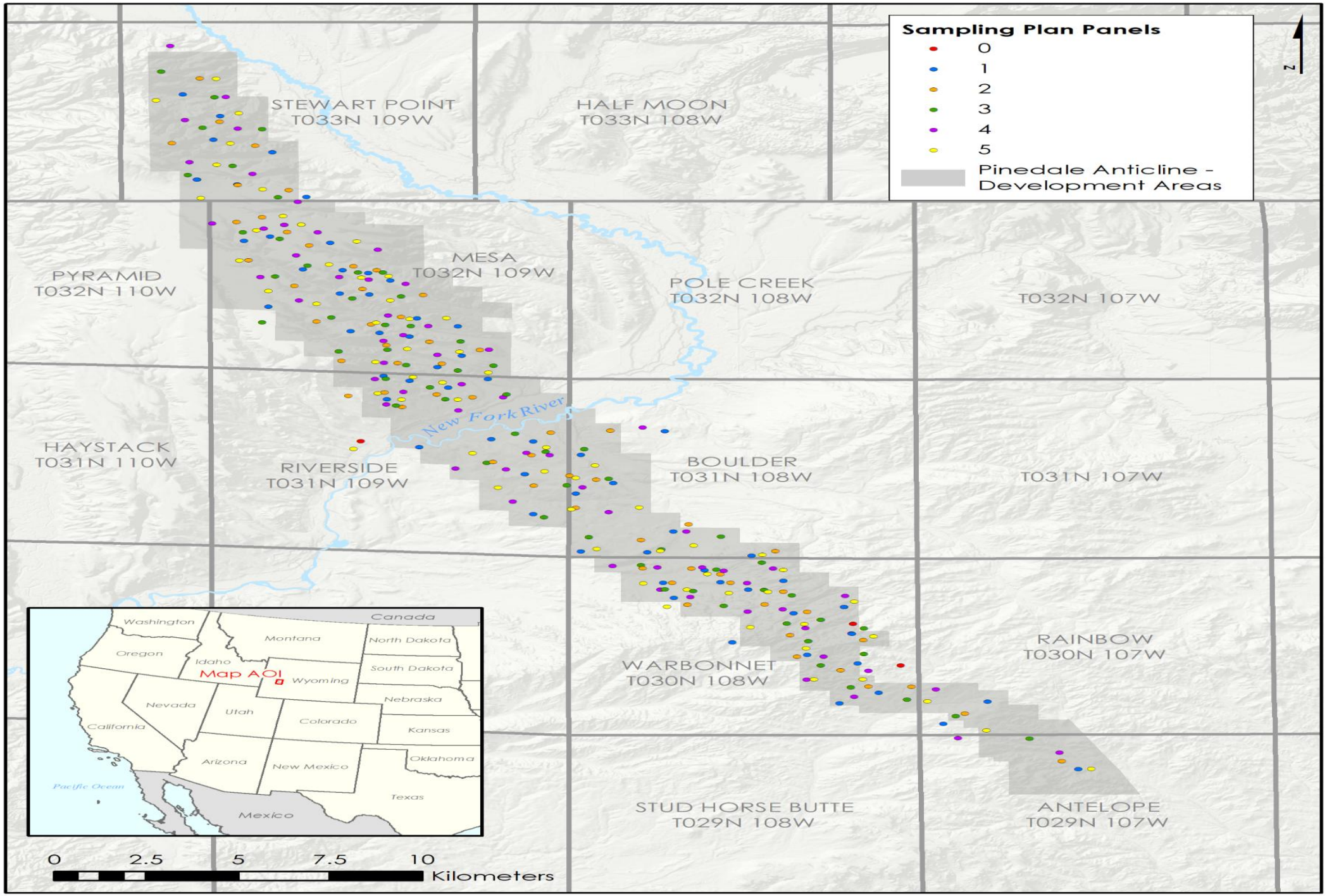
- ArcGIS Field Maps (ESRI)
  - For quantitative data and mapping polygons around weeds and erosion
  - Allows for custom forms and data entry
- Quick Capture (ESRI)
  - Rapid image collection
  - Ability to write notes or populate dropdowns
  - Polygons also possible

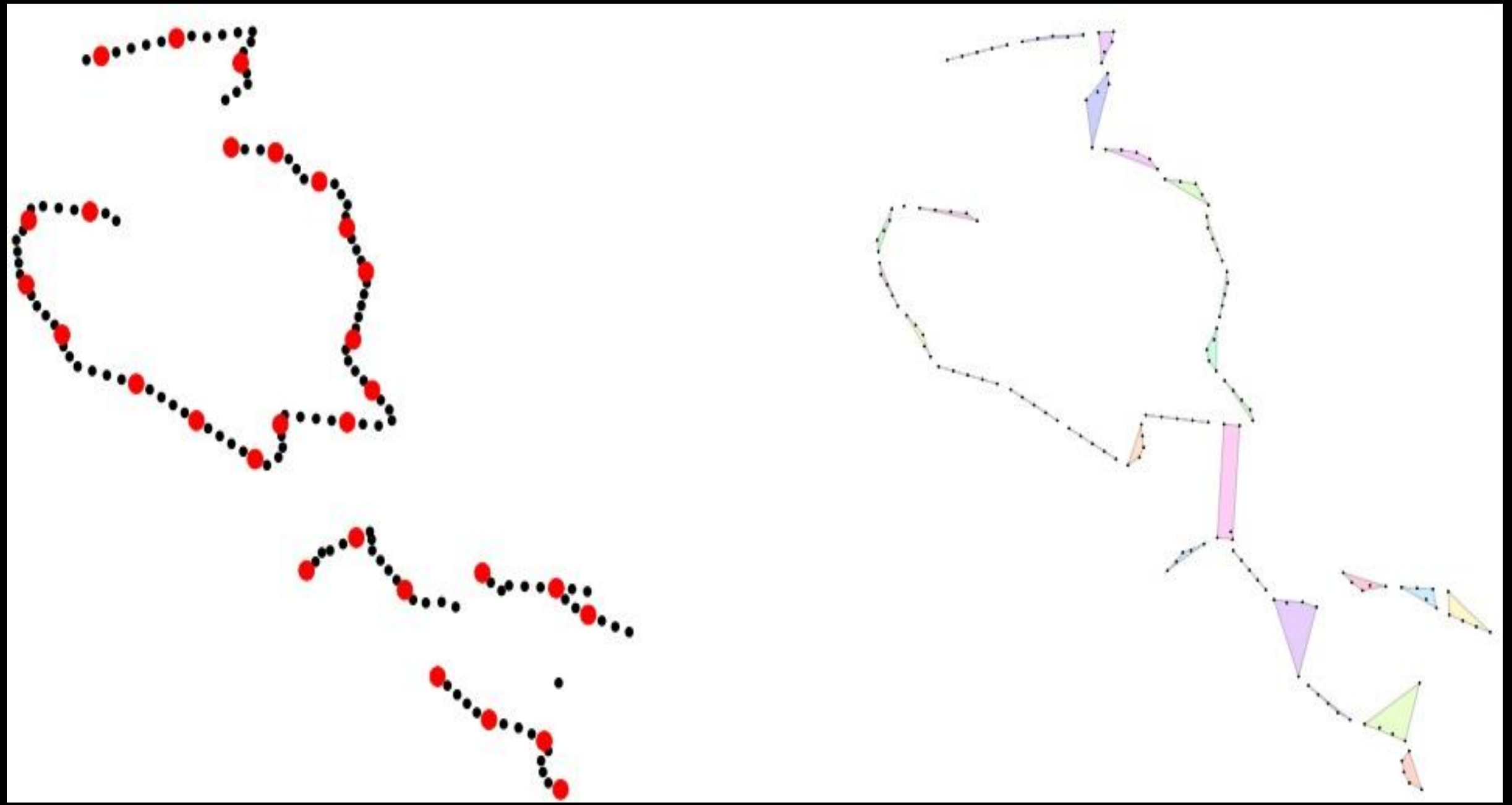
Field Maps - Example

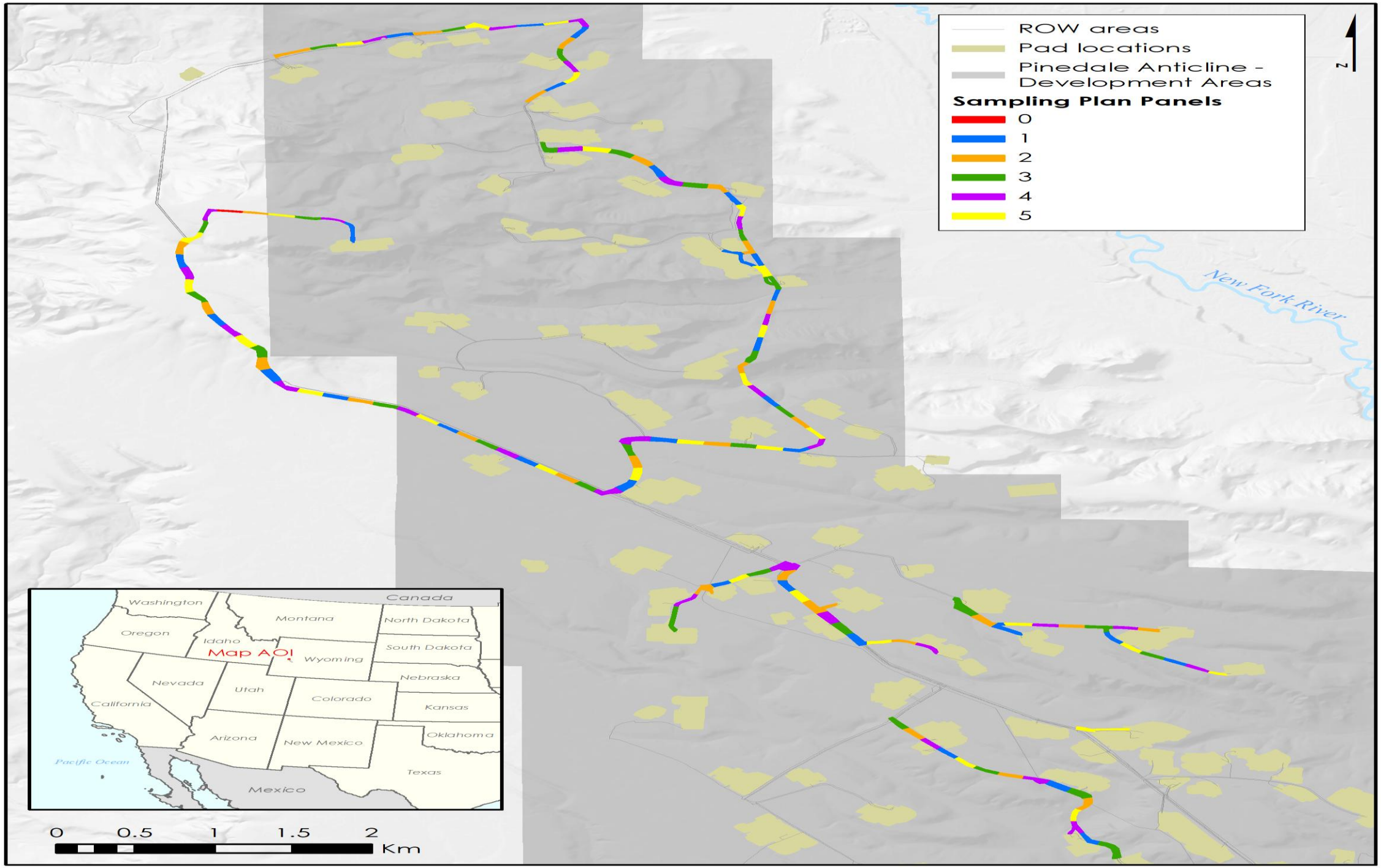


Long-term monitoring strategies for ecological reclamation programmes using spatially balanced rotating panel designs (Curran et al. 2025, *Ecological Solutions and Evidence)*

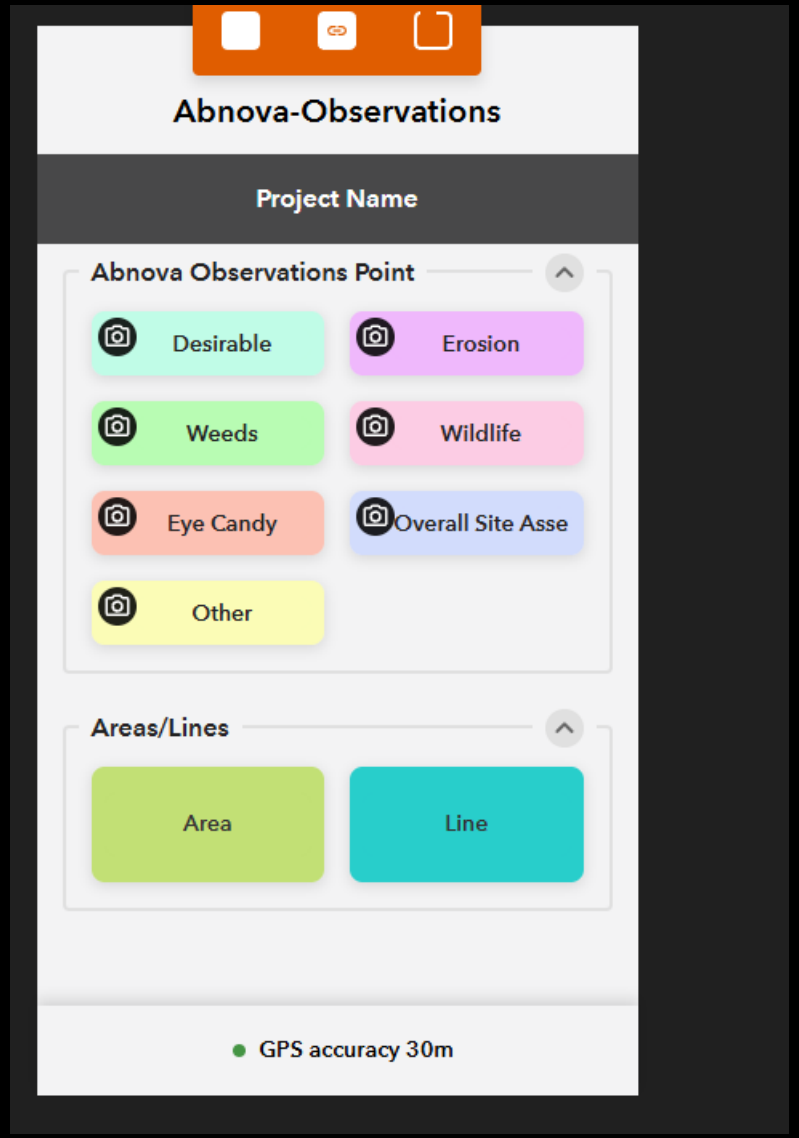



Sampling Plan Panels
0
1
2
3
4
5
Pinedale Anticline - Development Areas
N
STEWART POINT T033N 109W
HALF MOON T033N 108W
MESA T032N 109W
PYRAMID T032N 110W
POLE CREEK T032N 108W
T032N 107W
New Fork River
HAYSTACK T031N 110W
RIVERSIDE T031N 109W
BOULDER T031N 108W
T031N 107W
WARBONNET T030N 108W
RAINBOW T030N 107W
STUD HORSE BUTTE T029N 108W
ANTELOPE T029N 107W
Canada
Washington
Montana
North Dakota
Oregon
Idaho
Map AOI
Wyoming
South Dakota
Nebraska
Nevada
Utah
Colorado
Kansas
California
Arizona
New Mexico
Oklahoma
Texas
Pacific Ocean
Mexico
0
2.5
5
7.5
10
Kilometers



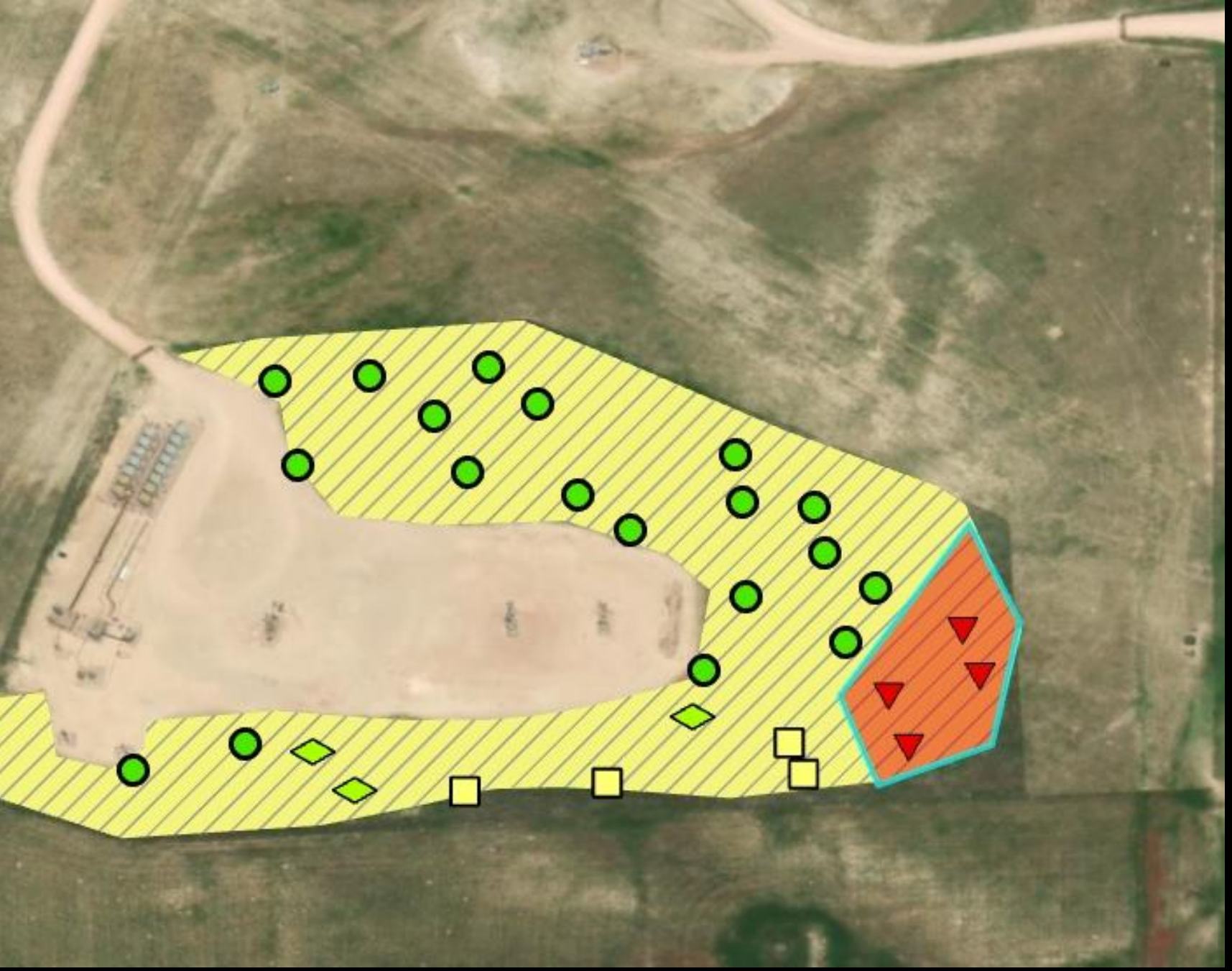

ROW areas
Pad locations
Pinedale Anticline - Development Areas
Sampling Plan Panels
0
1
2
3
4
5
N
New Fork River
Canada
Washington
Montana
North Dakota
Oregon
Idaho
Map AOI
Wyoming
South Dakota
Nebraska
Nevada
Utah
Colorado
Kansas
California
Arizona
New Mexico
Oklahoma
Pacific Ocean
Texas
Mexico
0
0.5
1
1.5
2
Km

Quick Capture - Template



Dashboard Example

	Overall Site Assessment	Weed Status	Erosion Control Status	Desired Vegetation Community Status
Extreme Risk Intense management necessary.	• Multiple issues including weed, erosion, bare ground, or desired species.	• Significant weed issues. E.g. Noxious/invasive species in high densities.	• Severe, widespread erosion with significant reclamation failures	• Absent or well below expected vegetation richness and density
High Risk Multiple issues Action likely needed.	• Marginal site condition with combinations of weed, erosion, bare ground, or desired species issues.	• Moderate densities of noxious/invasive species • Adjacent native plant community at risk of being overtaken	• Erosion issues exist on site that have or are likely to cause reclamation failure.	• One or two dominant species throughout the site.
Intermediate Risk Action may be necessary based on professional judgement.	• Moderate site conditions with singular or combinations issues	• Moderate invasive weed issues.	• Moderate erosion issues	• Several dominating species.
Low Risk No major action needed.	• Good site condition with very minor issues.	• Minor weed issues • Low invasion potential and density species exist on site	• Minor erosion issues. • Low to moderate erosion potential.	• Variety and density of vegetation near expectations. • No dominance by any species.
No/Very Low Risk No action needed.	• Very good site condition with no issues.	• Weed do not exist on site	• Erosion features do not exist • Low erosion potential	• Variety and density of vegetation meeting or exceeding expectations.



Legend

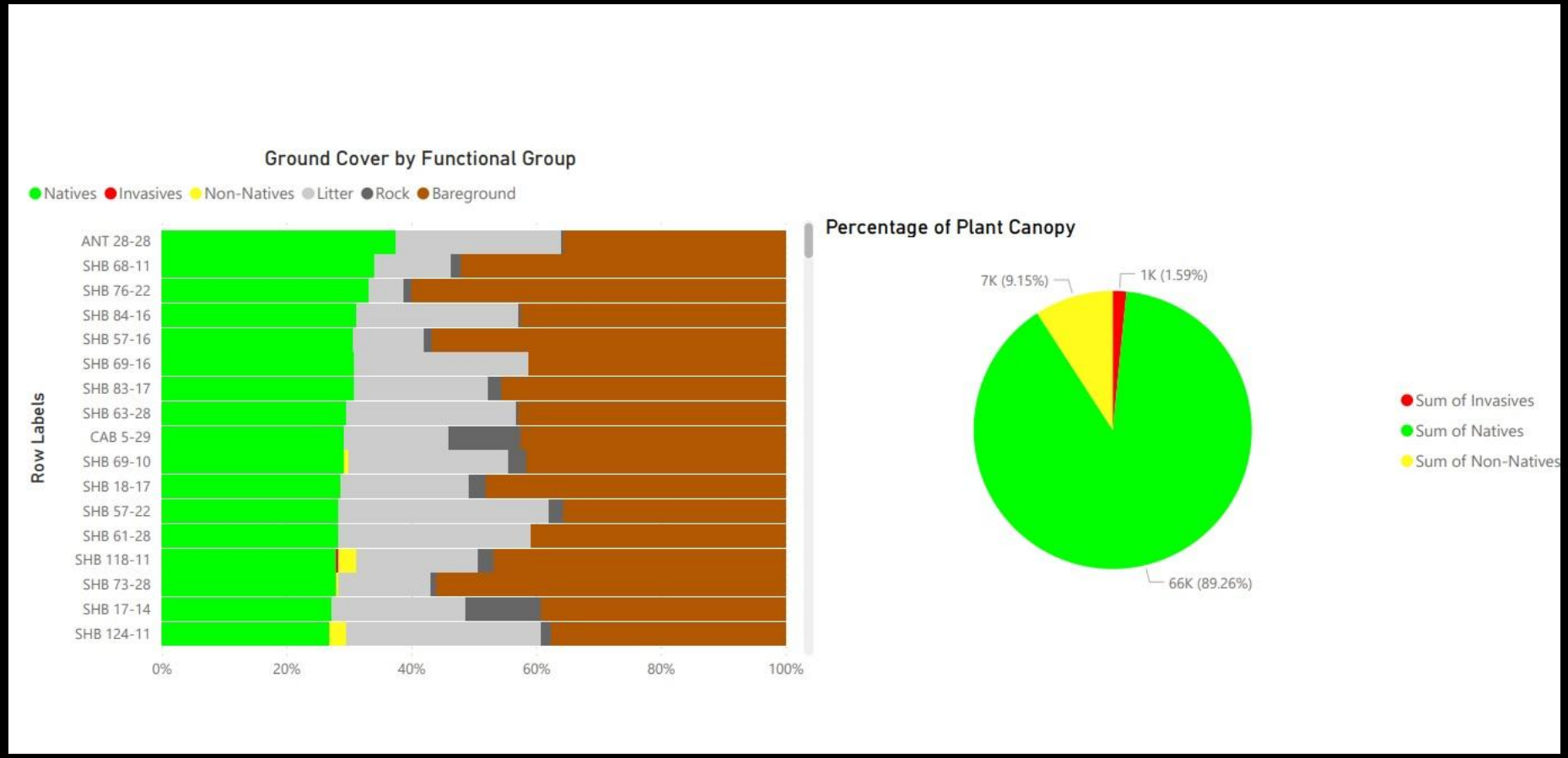
Native Vegetation

Native/Non-Native Mix

Non-Native Vegetation

Invasive Vegetation

Example of a dashboard from Jonah (200 sites)

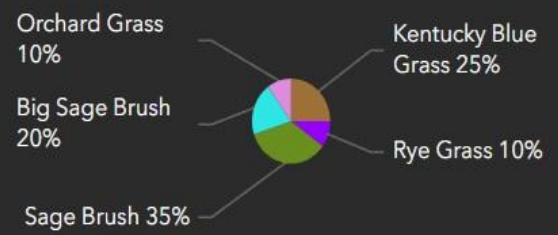


Reclamation Dashboard v2

Approval Table

BLM Approved	State Approved	PAPO Ap
No	Yes	N

Seeding Mix



1 of 2

Total Insect Abundance
79

1 of 2

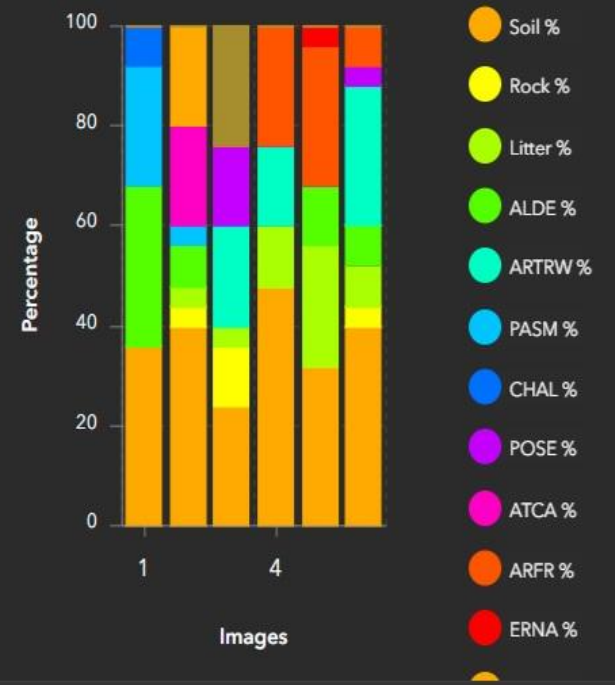
Family Richness
17

Criteria	Pass/Fail
TotalCover	Pass
ForbRichness	Fail
ForbDensity	Fail

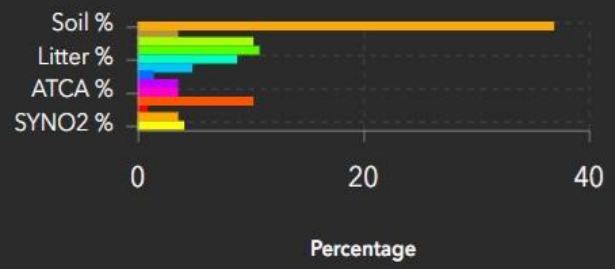
Pad List

Mesa 11-17

Ground Cover breakdown (by image)



Total Ground Cover (in map view)



Recent Quick Capture Examples

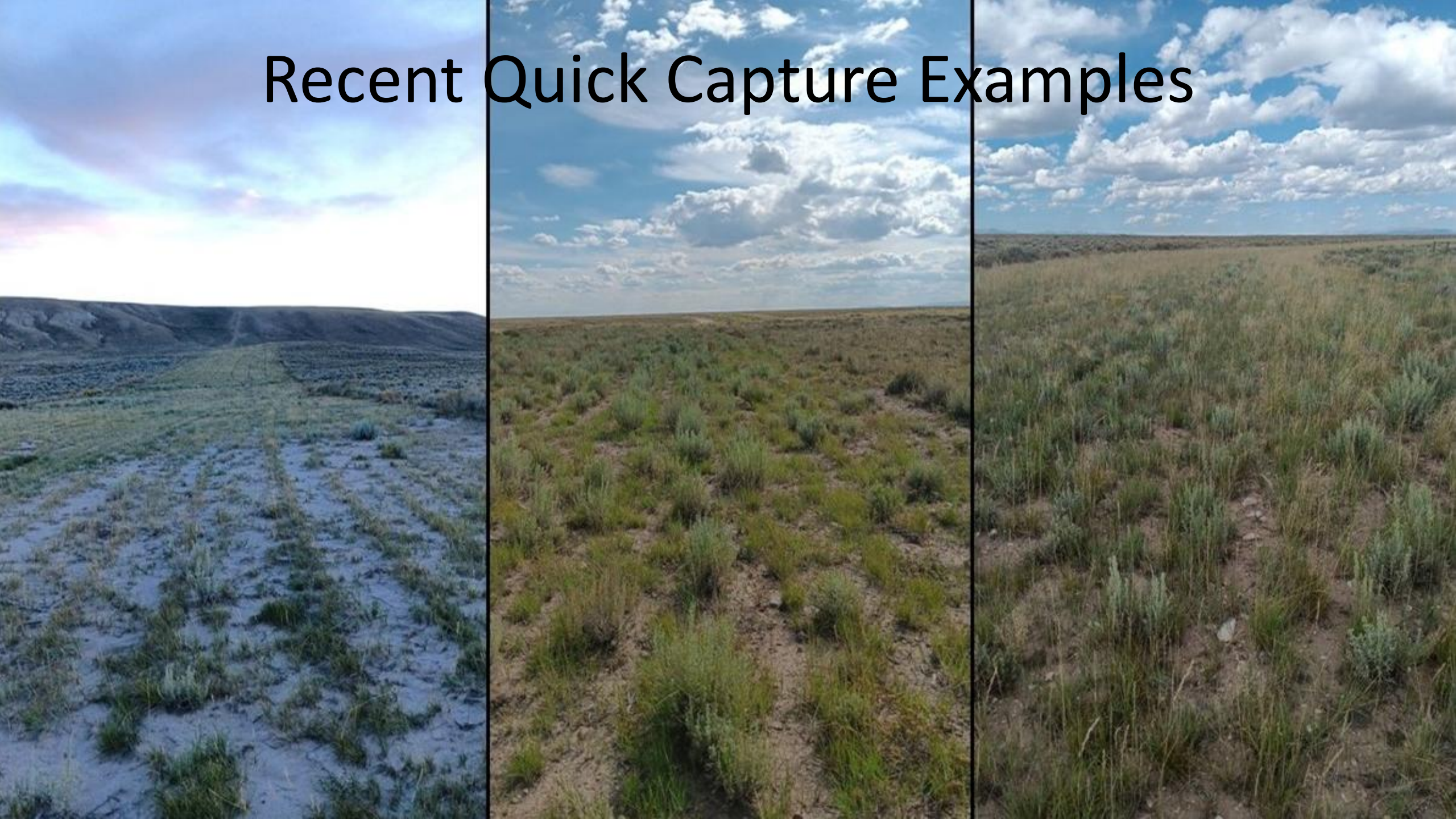


Photo Example 3

Photo

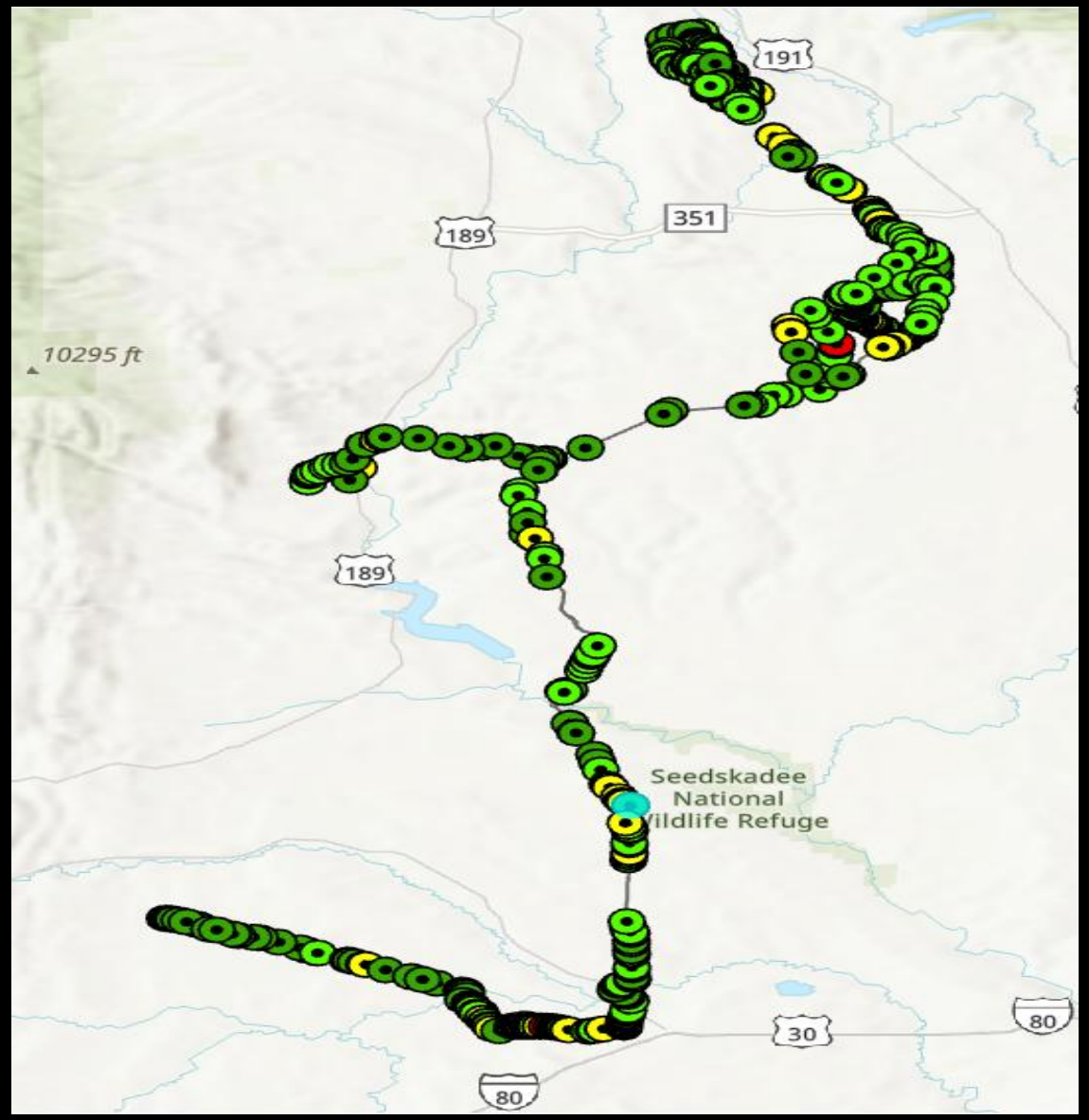
Table Edit Get directions Zoom to

Comments	Good stability and native diversity. Cheatgrass ranges from low to high density from here to next well pad. Mainly in the center of the line. See fieldmaps for area.
Priority	Moderate priority

Photo

Table Edit Get directions Zoom to

Year End Report – 9 Pages, based on dashboard



Benefits of utilizing GIS tools

- Turned >90 page report to 7-9 page report
- Interactive map
- ArcGIS Online allows us to share data in real or near-real time with client
- Allows us to transfer weed information and erosion control information with high spatial resolution to other contractors
- Dashboard allows for easy understanding of where sites are meeting or exceeding goals and where corrective actions are needed

Acknowledgements

PureWest, MPLX, Tim Robinson, Blair Robertson

Zachary Farmer – zfarmer@abnovaecology.com
Michael Curran – mike@abnovaecology.com