GIS and Spatial Analyst for Topsoil Regulatory Compliance

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U.S. Department of Interior

2010 ESRI International User Conference
July 11 – 16, 2010
San Diego CA

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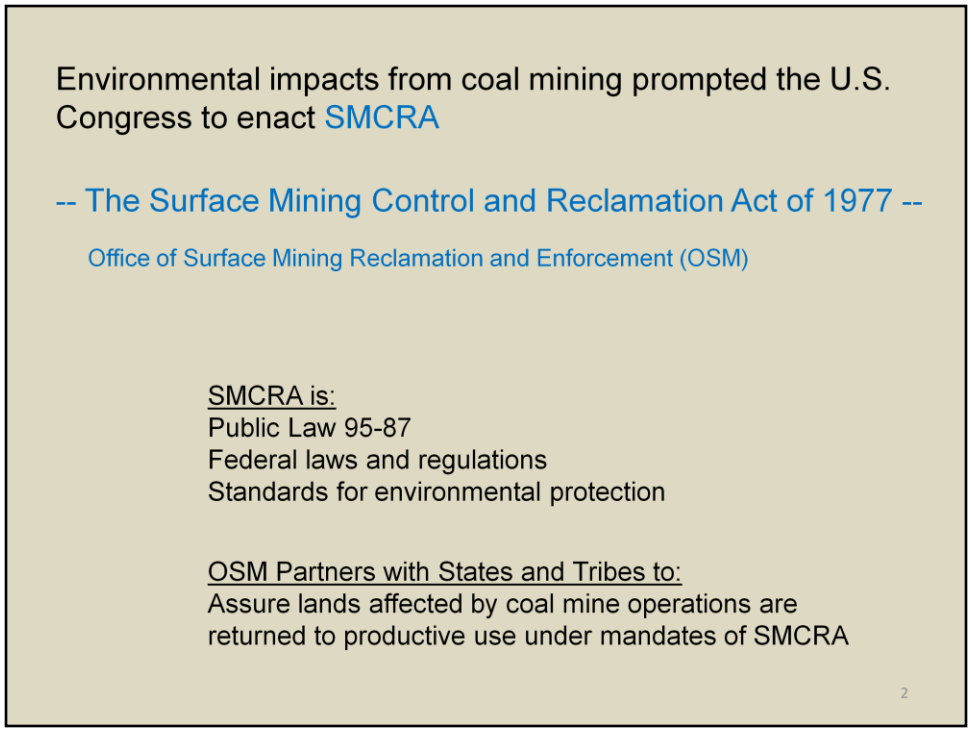

SMCRA are federal laws and regulations defining the minimum requirements for the performance of specific activities during coal mining operations.

SMCRA sets standards for environmental protection that must be met to ensure that lands affected by coal mine operations are returned to productive use.

Sound science and proper application of technology are foundations for effectively implementing SMCRA

Use of geospatial technology can be a valuable tool towards the application of SMCRA

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One common SMCRA activity concerns regulations addressing the removal, storage, and redistribution of topsoil

For example…

Regulatory Specialist visits mine site to monitor topsoil depth

Location and depth of topsoil samples collected using GPS

Coordinates and data converted into a point feature class

Using ESRI's Spatial Analyst extension the point feature can be interpolated to a raster surface

Implement statistical methods, classification schemes, and surface analysis functions

To derive models of topsoil depth distribution

5

This presentation will describe modeling surface coal mine topsoil distribution using ESRI's Spatial Analyst extension

- Methodology for surface creation using interpolated points representing topsoil depth measurements
- Discuss classification schemes
- Value of cartography to aid in visual interpretation
- Statistical method to evaluate interpolation performance
- Illustrate a real-world example

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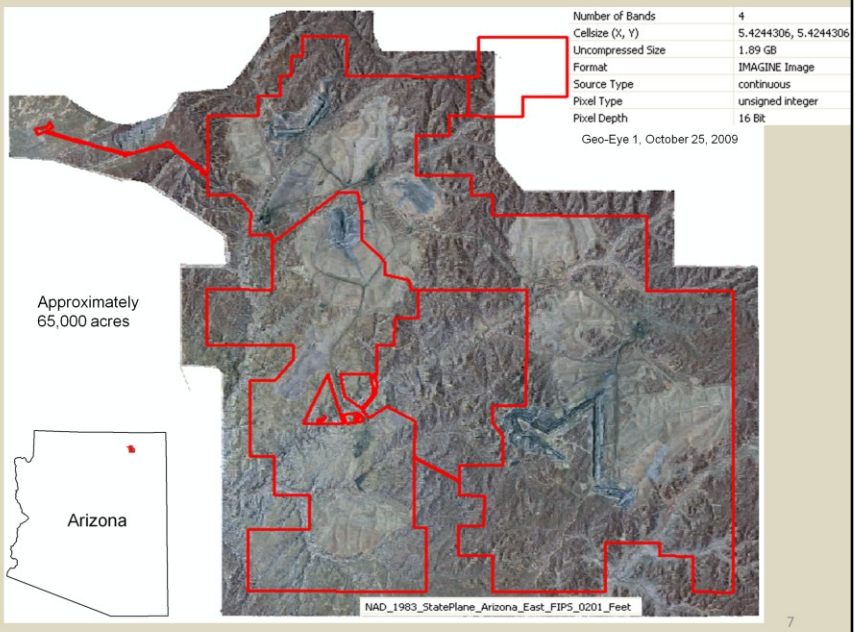
Blackmesa Complex Mine



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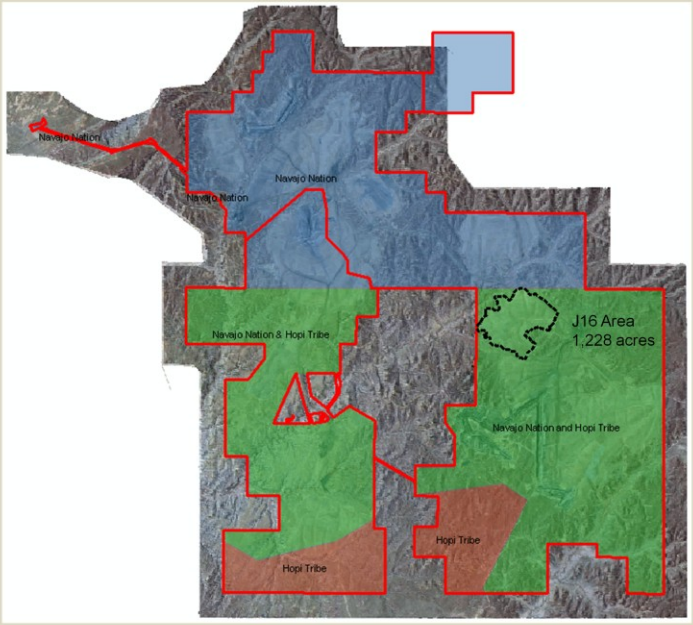
Area of Interest – J16



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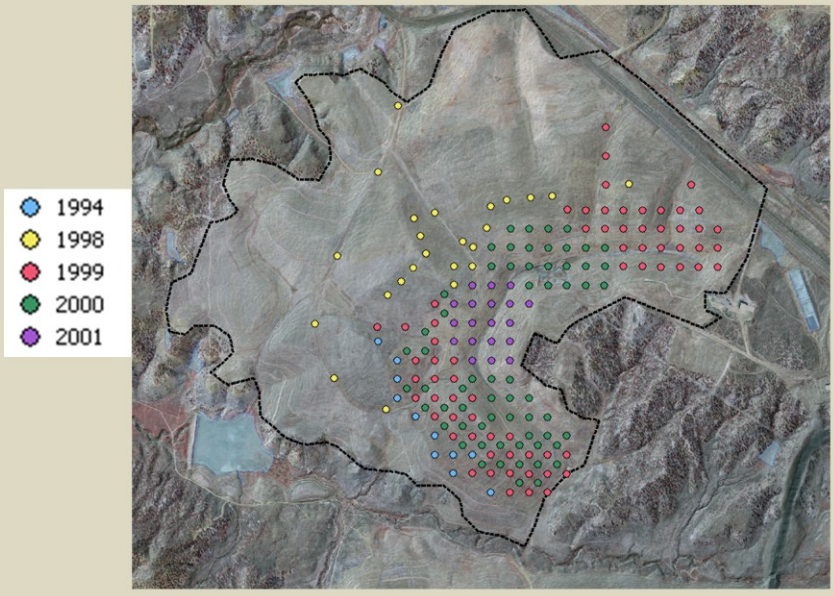
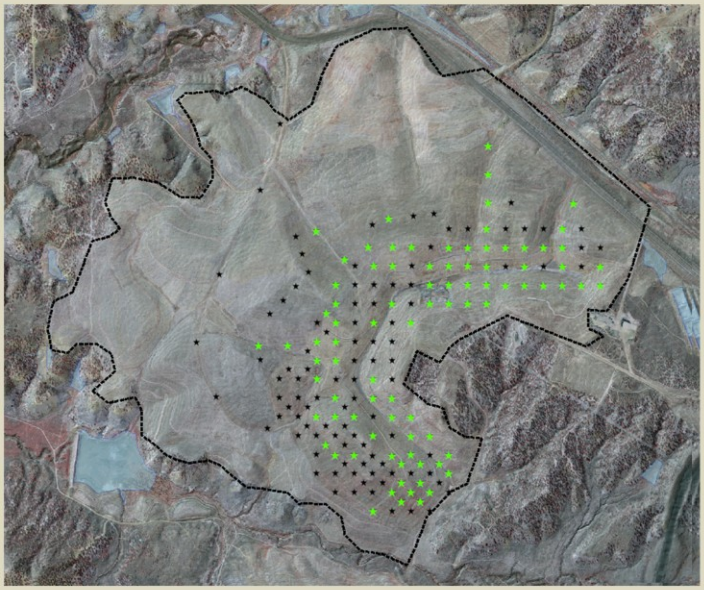
185 topsoil samples collected by PWCC

Depth range 6 – 39 inches



9

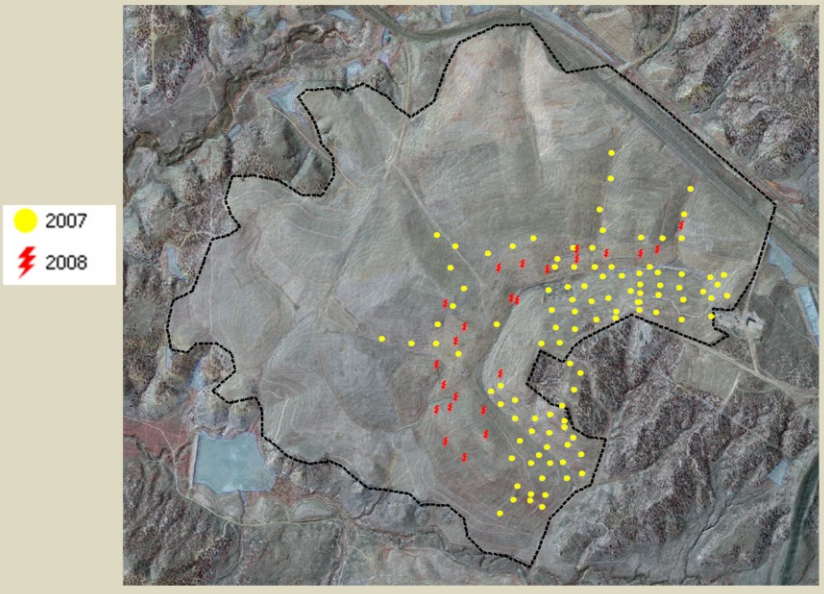
86 of 185 PWCC collected samples report depth values



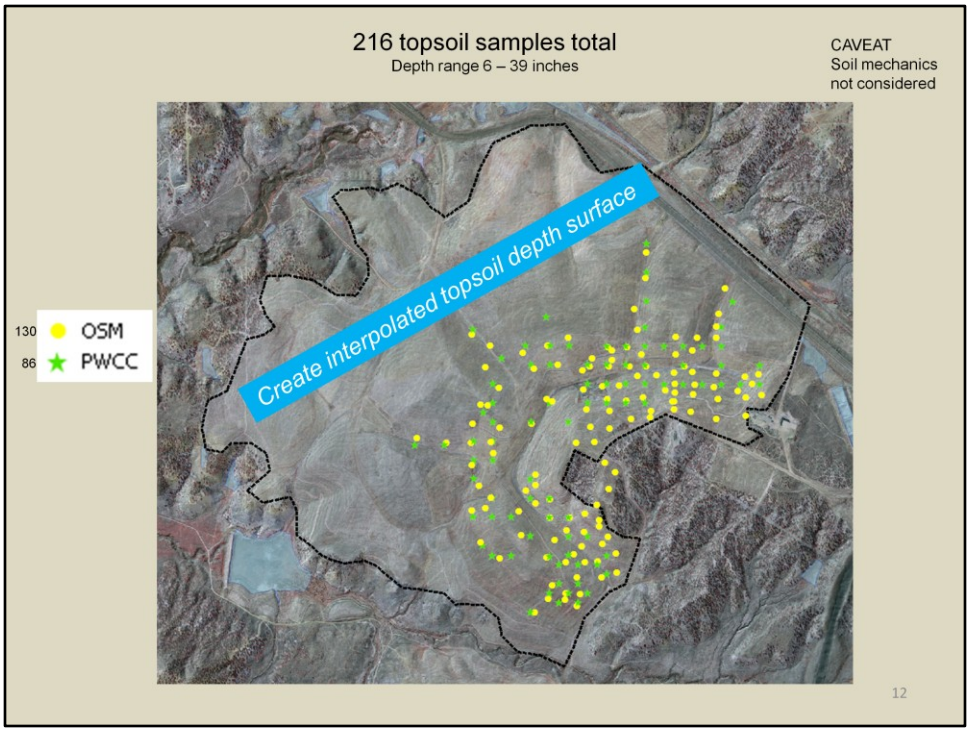
10

130 topsoil samples collected by OSM

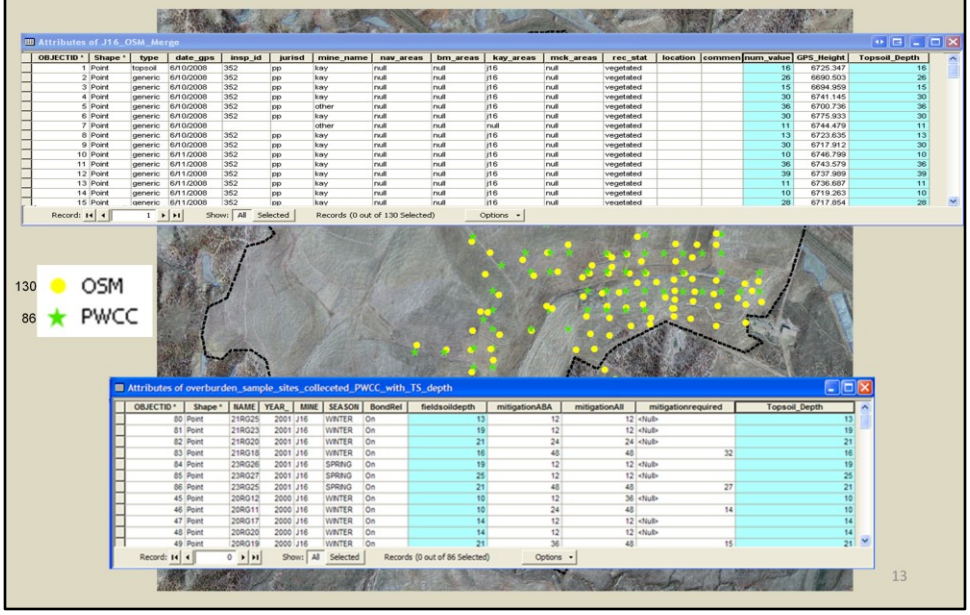
Depth range 6 – 38 inches



11


216 topsoil samples total
Depth range 6 – 39 inches
CAVEAT
Soil mechanics
not considered
130
OSM
86
PWCC
Create interpolated topsoil depth surface
12

MERGE tables with unlike schema
Create new field in each table named Topsoil_Depth, data type double
Use Field Calculator to transfer values



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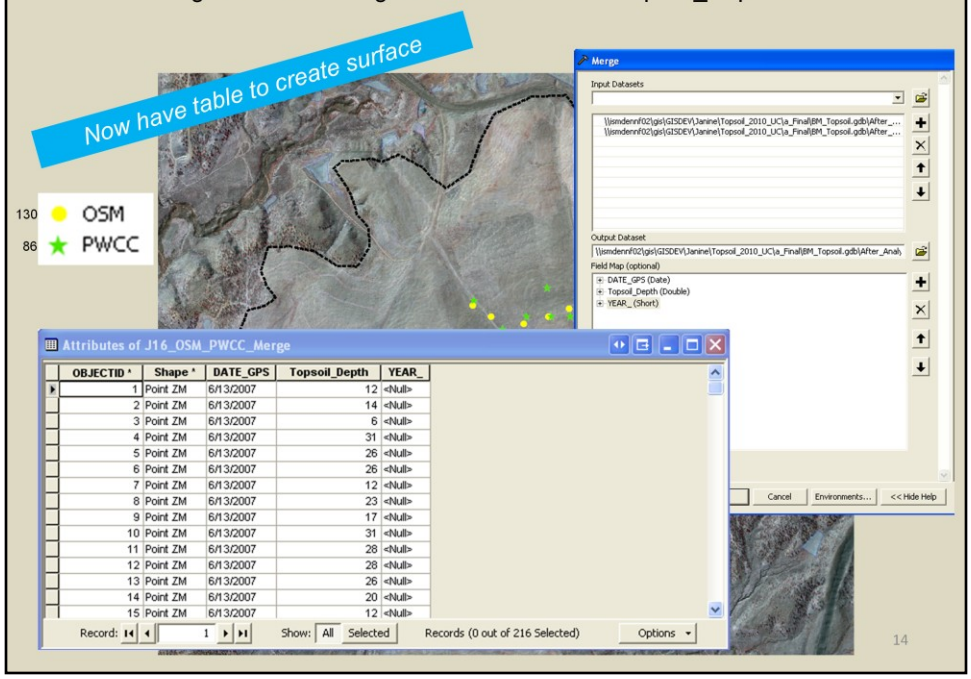
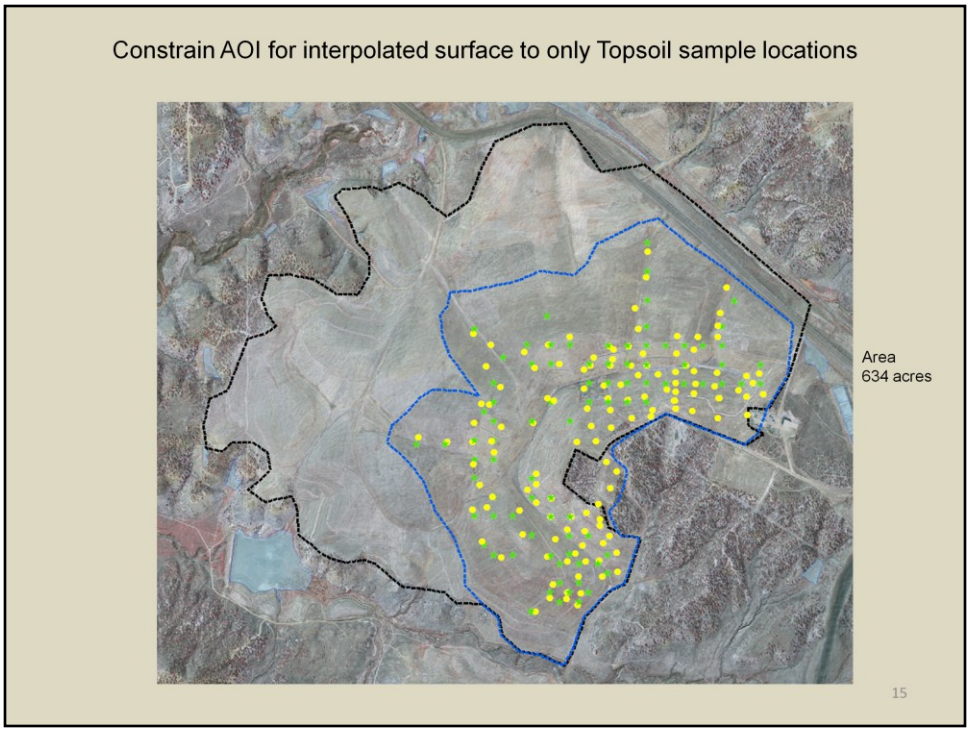
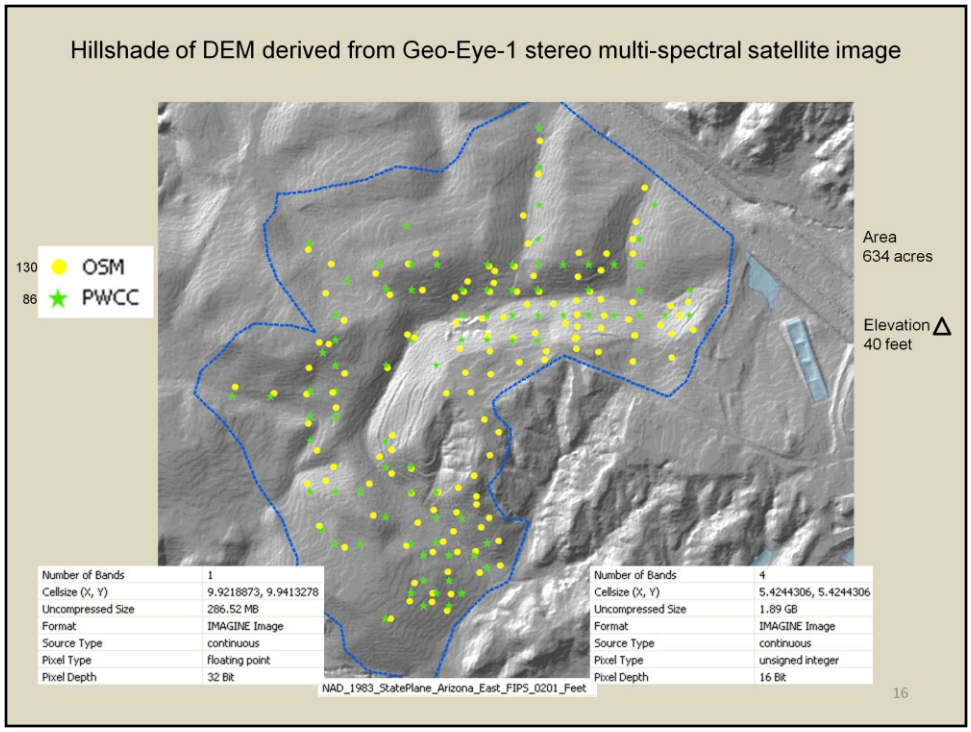
Merge tables retaining date information and Topsoil_Depth field





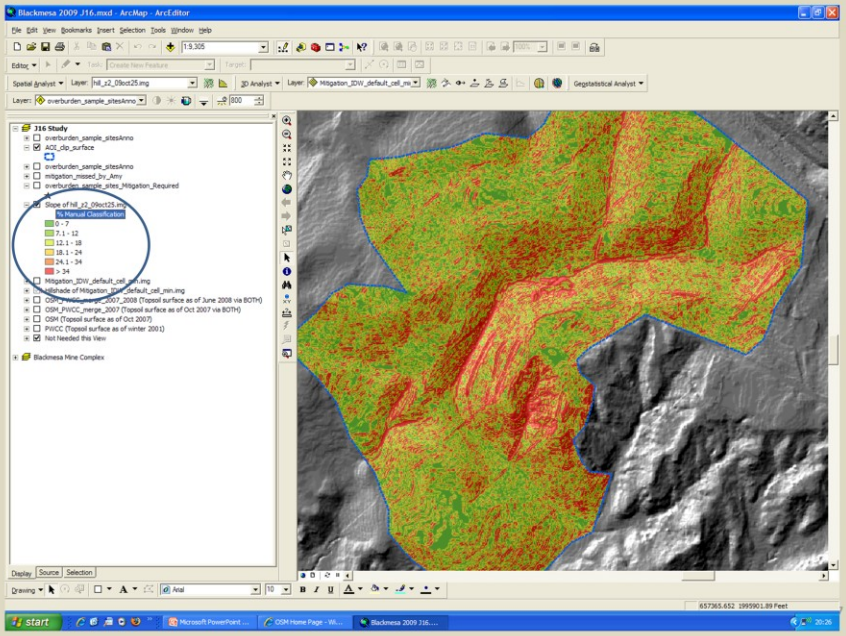
The interpolated surface will just “wang” extrapolate out to the edge of the black AOI if not constrained by the blue polygon mask. There’s no information out there so why plot it.

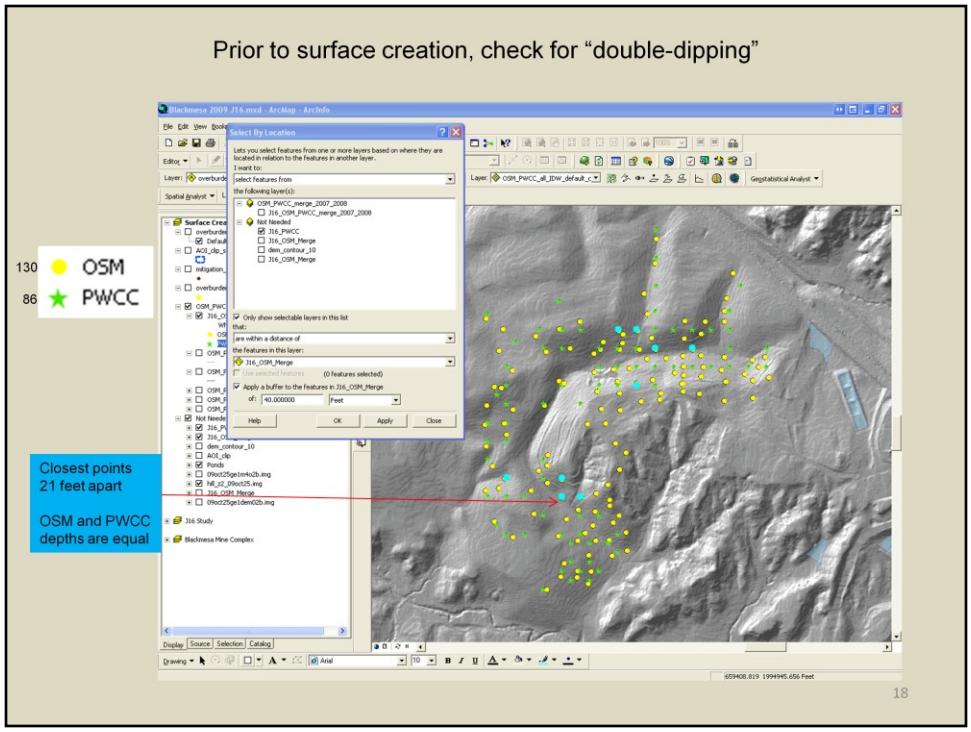


Diagonal distance SW to NE is 6600 ft. (about 1.25 miles, one and a quarter mile.)
Distance W to E is about the same.
Low contour 2040 ft., high contour 2080 ft. Area is 634 acres.

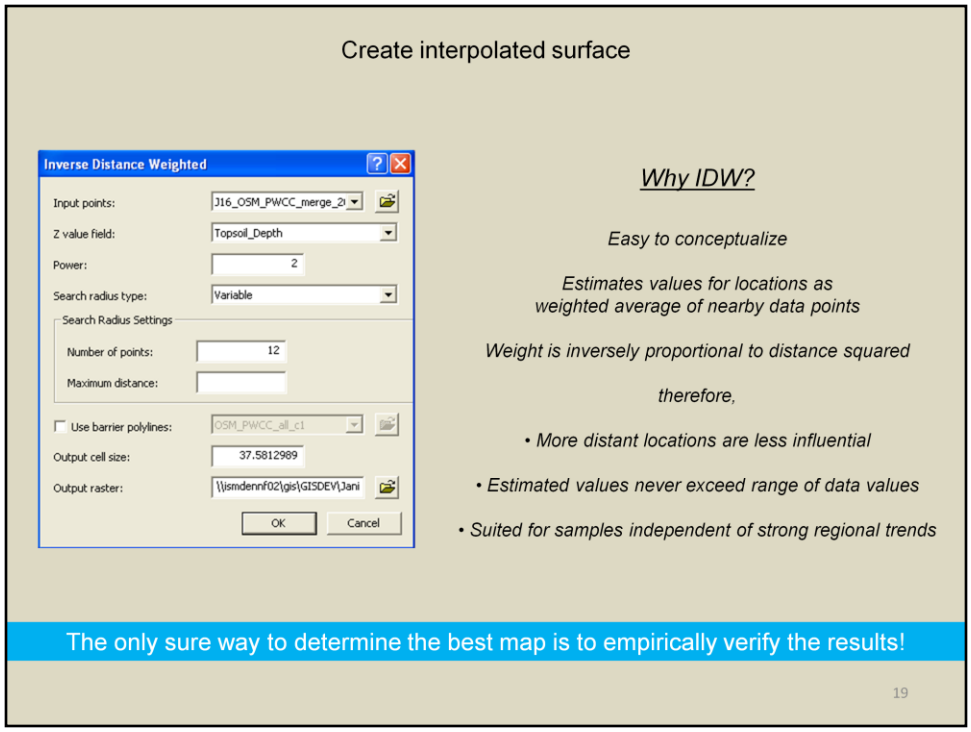
Distance W to E is about the same.

% Slope (Manual Classification)





I checked all samples, OSM vs. PWCC that are within 40 feet of each other to make sure they were equal. My topsoil grid cell size is 39 ft.



The IDW algorithm first uses the Pythagorean Theorem to calculate the Distance from a Grid Location to each of the data samples within the summary window. Then the distances are converted to weights that are inversely proportional to the distance ($1/D^2$) effectively making more distant locations less influential. The sample values are multiplied by their corresponding computed weights and the "sum of the products" is divided by the "sum of the weights" to calculate a weighted average estimate. The estimate is assigned to the center cell location and the process is repeated for all map locations. The IDW procedure uses a fixed, geometric-based method to estimate map values at locations that were not sampled.

Classify the surface -- using which scheme?

Natural Breaks (Jenk's)	Finds inherent groupings and patterns	Data unevenly distributed and gaps between groups of values
Standard Deviation	Each class defined by its distance from mean of all	Data evenly distributed and emphasize difference between features
Quantile	Each class has equal number of features in it	
Equal Interval	Each class has equal range of values	Data evenly distributed and emphasize relative difference between features
Manual		

Place features with similar values into the same class
Make the difference in values between classes as great as possible

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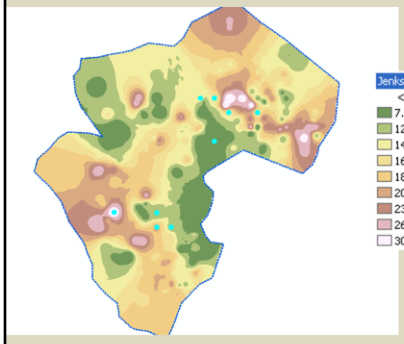
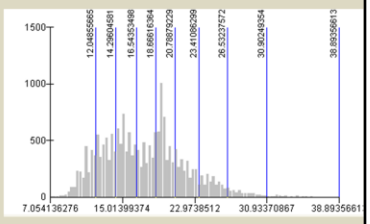
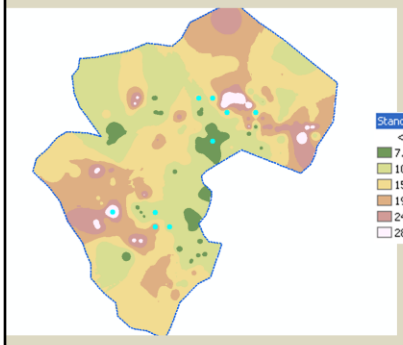
Default Classification Schemes

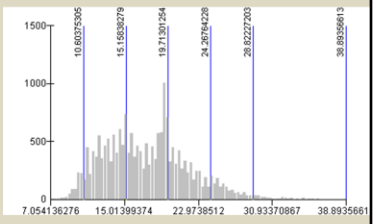


Jenks (Natural Breaks)
<VALUE>
7.054136276 - 12.04855665
12.04855666 - 14.29604581
14.29604582 - 16.54353498
16.54353499 - 18.66616364
18.66616365 - 20.78879229
20.7887923 - 23.41086299
23.410863 - 26.53237572
26.53237573 - 30.90249354
30.90249355 - 38.89356613





Standard Deviation
<VALUE>
7.054136276 - 10.60375305
10.60375306 - 15.15838279
15.1583828 - 19.71301254
19.71301255 - 24.26764228
24.26764229 - 28.82227203
28.82227204 - 38.89356613



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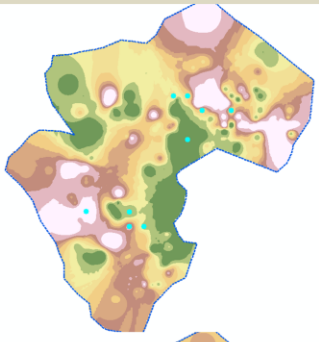
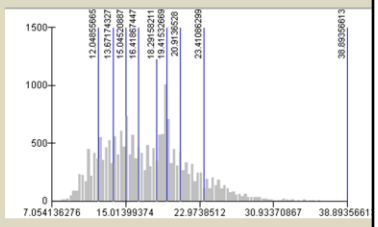
Default Classification Schemes

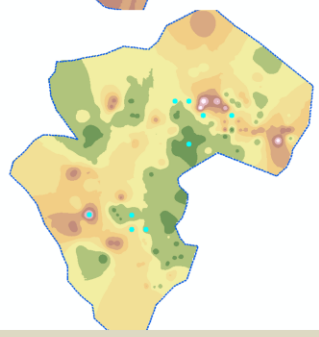


Quantile

<VALUE>

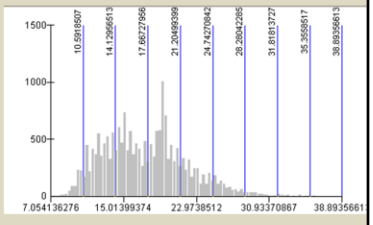
- 7.054136276 - 12.04855665
- 12.04855666 - 13.67174327
- 13.67174328 - 15.04520887
- 15.04520888 - 16.41867447
- 16.41867448 - 18.29158211
- 18.29158212 - 19.41532669
- 19.4153267 - 20.9136528
- 20.91365281 - 23.41086299
- 23.410863 - 38.89356613





Equal Interval

- 7.054136276 - 10.5918507
- 10.59185071 - 14.12956513
- 14.12956514 - 17.66727956
- 17.66727957 - 21.20499399
- 21.204994 - 24.74270842
- 24.74270843 - 28.28042285
- 28.28042286 - 31.81813727
- 31.81813728 - 35.3558517
- 35.35585171 - 38.89356613



Software default for this dataset

Try manual

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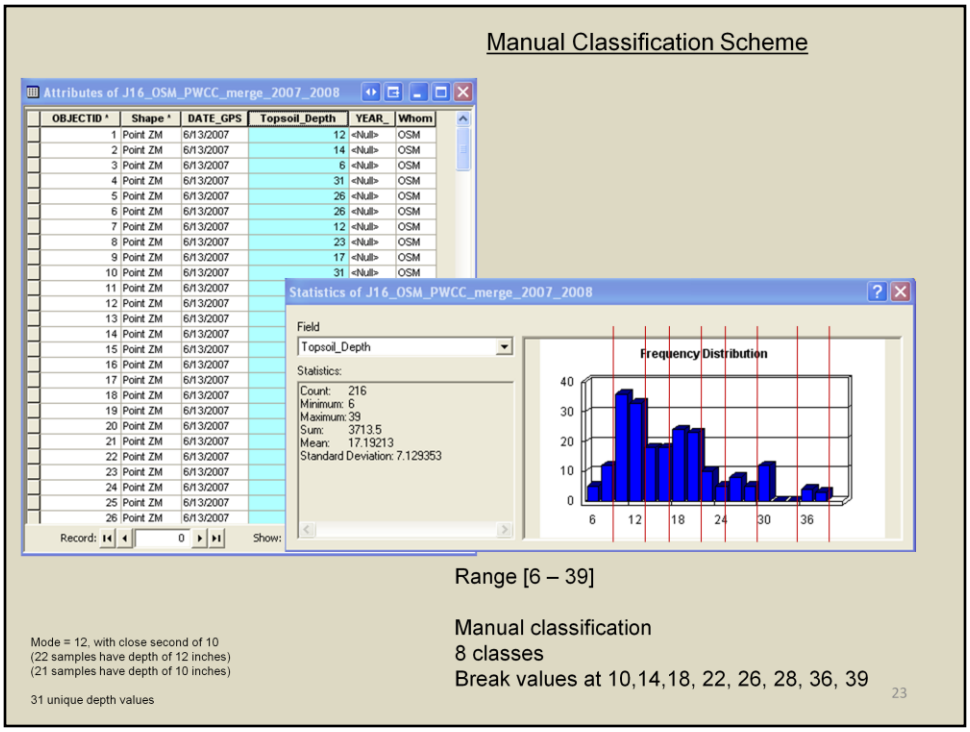
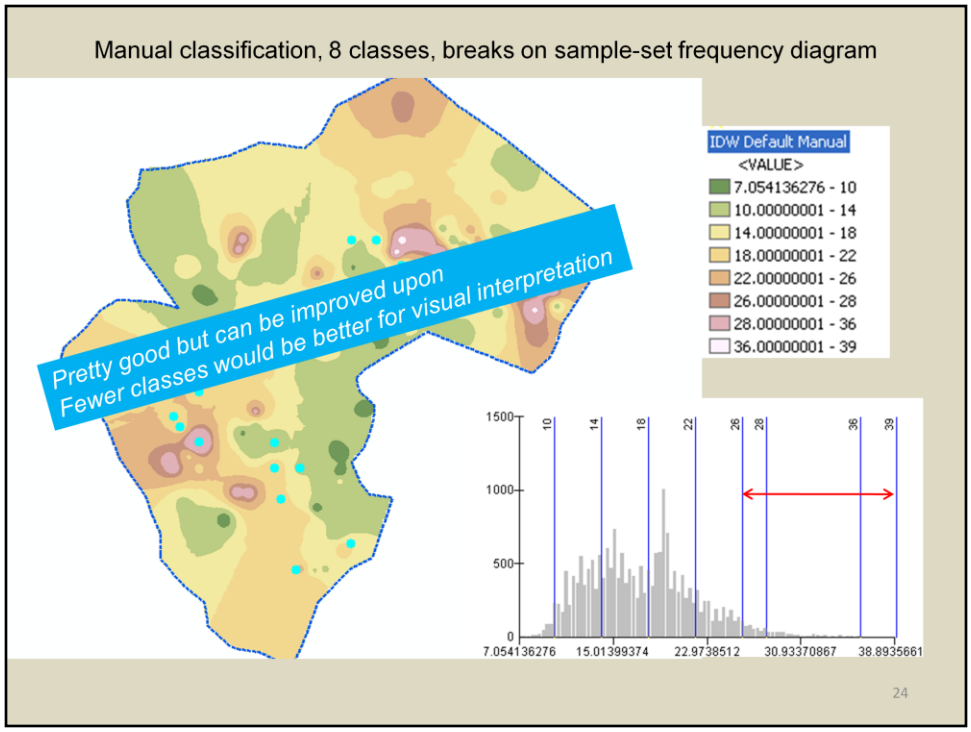


Mode = 12, with close second of 10

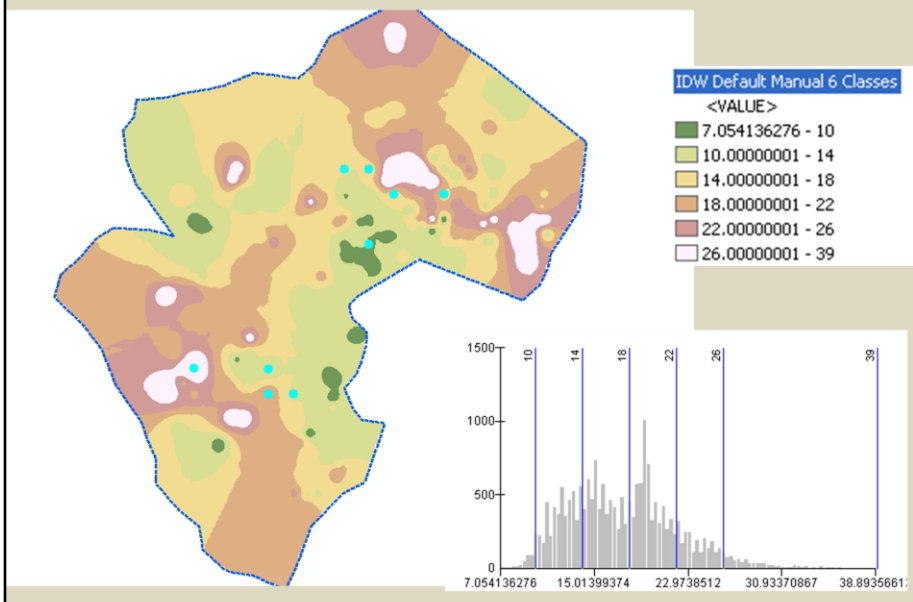
(22 samples have depth of 12 inches)

(21 samples have depth of 10 inches)



Combine the last three bins into a single class.

Manual classification, 6 classes, three highest bins combined



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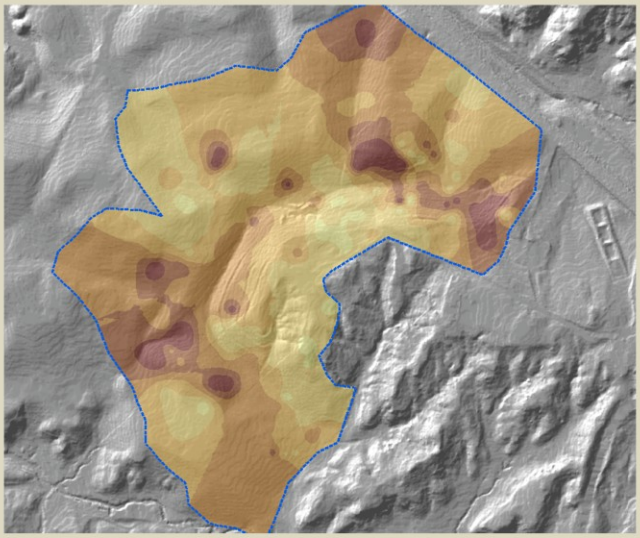
“Show me some cartography”



Color Ramp:
Yellow to Dark Red

Transparency:
60%

Overlay on hillshade of regional area

Adjust Legend precision

IDW Default Manual 6 Classes
Topsoil Depth inches
7.0 - 10.0
10.1 - 14.0
14.1 - 18.0
18.1 - 22.0
22.1 - 26.0
26.1 - 39.0

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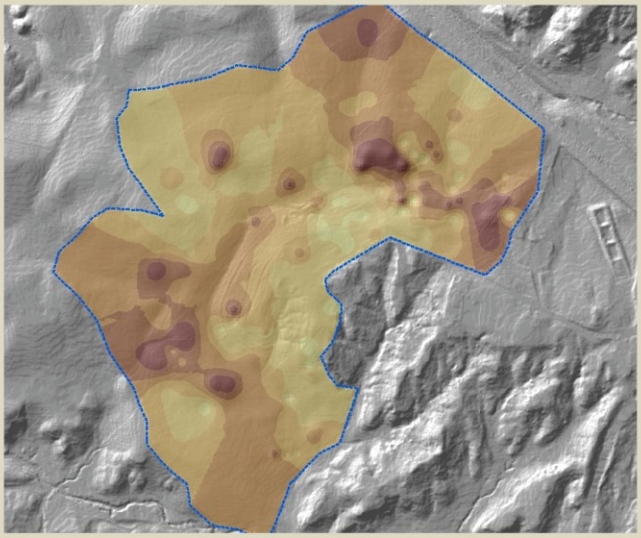
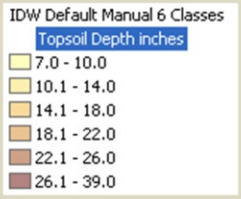
"Show me some cartography"



50 % transparent
Hillshade of topsoil surface
set in-between



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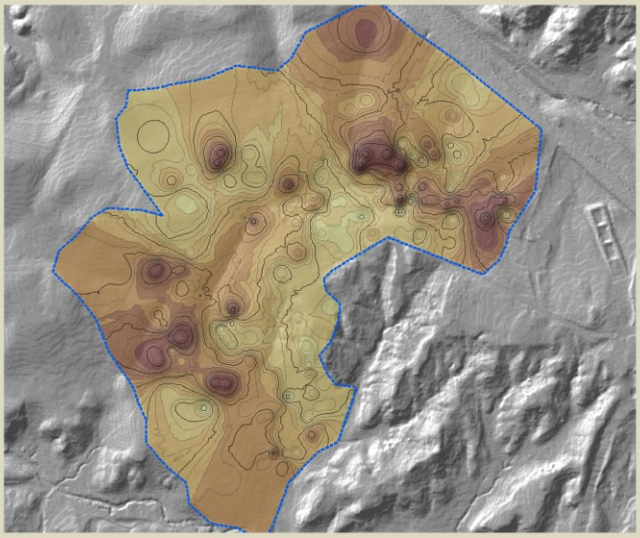
2008 Topsoil Depth Surface J-16 Blackmesa Mine Complex

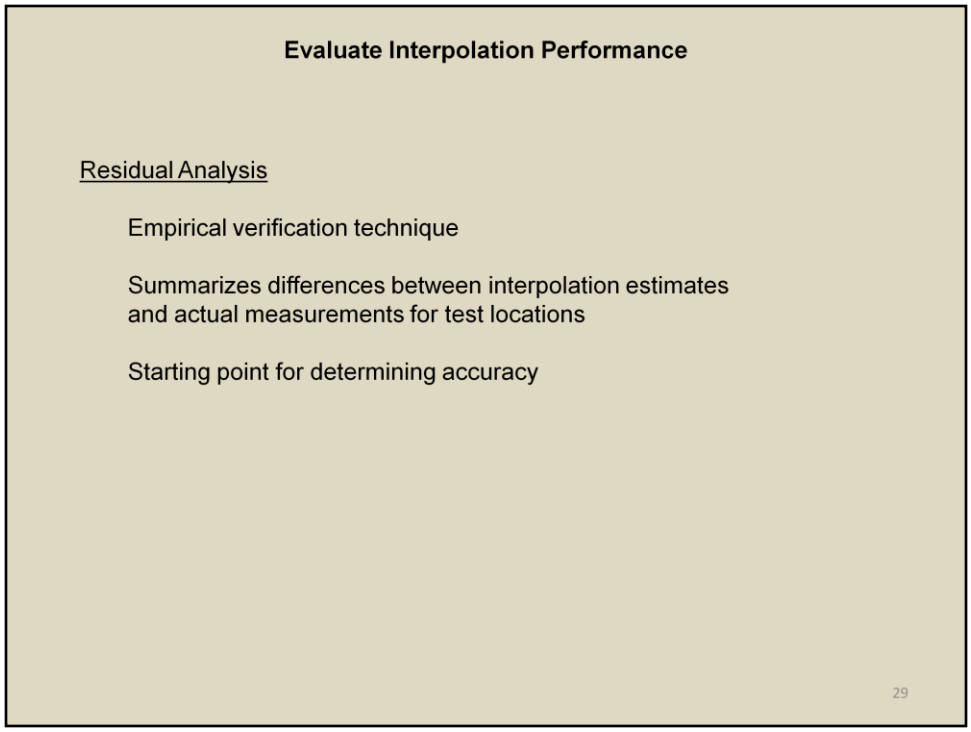


1-inch contours
80% Gray, width 1
65% transparent

4-inch contours
Black, width 0.40
40% transparent

IDW Default Manual 6 Classes
Topsoil Depth inches
7.0 - 10.0
10.1 - 14.0
14.1 - 18.0
18.1 - 22.0
22.1 - 26.0
26.1 - 39.0

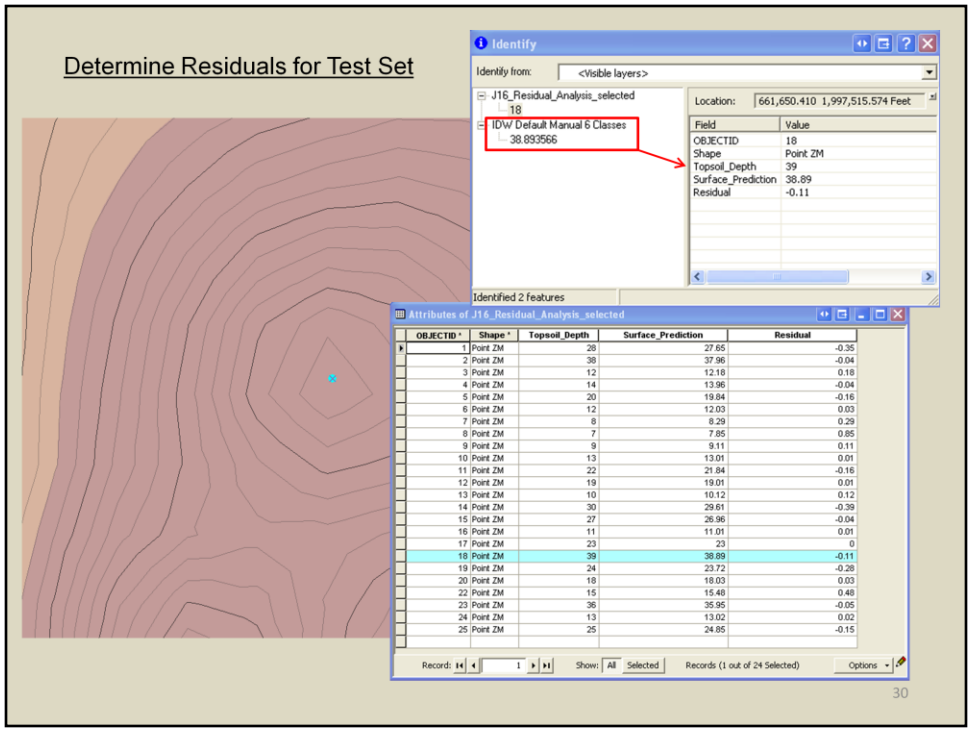
28



How accurate is the map. A pretty surface does not necessarily imply a valid surface!

Choose test set that contains at least one point for each unique data group. In this IDW interpolated surface there were 11 unique groups, so I chose 25 test points. ALSO, must assure test points are spatially distributed.

In a strict, rigorous analysis you would carry out this performance evaluation on other interpolation methods and choose the best.



Residual = (Surface Prediction – Topsoil Depth)

Calculate Statistics for Test Samples

J16_Residual_Analysis_selected.xls

	A	B	C	D	E	F
1	TEST SAMPLE ID	Topsoil_Depth	Surface_Prediction	Residual		
2	1	28	27.65	-0.35		
3	2	38	37.96	-0.039999		
4	3	12	12.18	0.18		
5	4	14	13.96	-0.039999		
6	5	20	19.84	-0.16		
7	6	12	12.03	0.029999		
8	7	8	8.29	0.289999		
9	8	7	7.85	0.85		
10	9	9	9.11	0.109999		
11	10	13	13.01	0.009999		
12	11	22	21.84	-0.16		
13	12	19	19.01	0.01		
14	13	10	10.12	0.119999		
15	14	30	29.61	-0.39		
16	15	27	26.96	-0.039999		
17	16	11	11.01	0.009999		
18	17	23	23	0		
19	18	39	38.89	-0.109999		
20	19	24	23.72	-0.28		
21	20	18	18.03	0.03		
22	22	15	15.48	0.48		
23	23	36	35.95	-0.049999		
24	24	13	13.02	0.019999		
25	25	25	24.85	-0.149999		
26	Average value =	19.71	19.72			
27	Residual sum =			0.37		
28	Average error =			0.02		
29	Normalized error =			0.04		0.02 / 19.72

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Residual = (Surface Prediction – Topsoil Depth)

Average value is actual measured topsoil depth

Residual sum is a measure of bias. A negative value indicates underestimation.

Average error is absolute value of (bias/n)

Normalized error is (Average error/Average value). It calculates average error as a proportion of the average value for the set of test samples. It is the most useful index because it enables the comparison of the relative map accuracies between different maps.

Generally speaking, maps with normalized errors of ore than .30 are suspect and one might not want to make important decisions using them.

In a rigorous analysis you would map the surface of residuals to determine WHERE the interpolated surface is over or under estimating.

IDW Interpolated Surface is Accurate

Classification Scheme and Cartography to Aid Visual Interpretation

Have Confidence in Using Surface for Decision Making

Put the Surface to Work!

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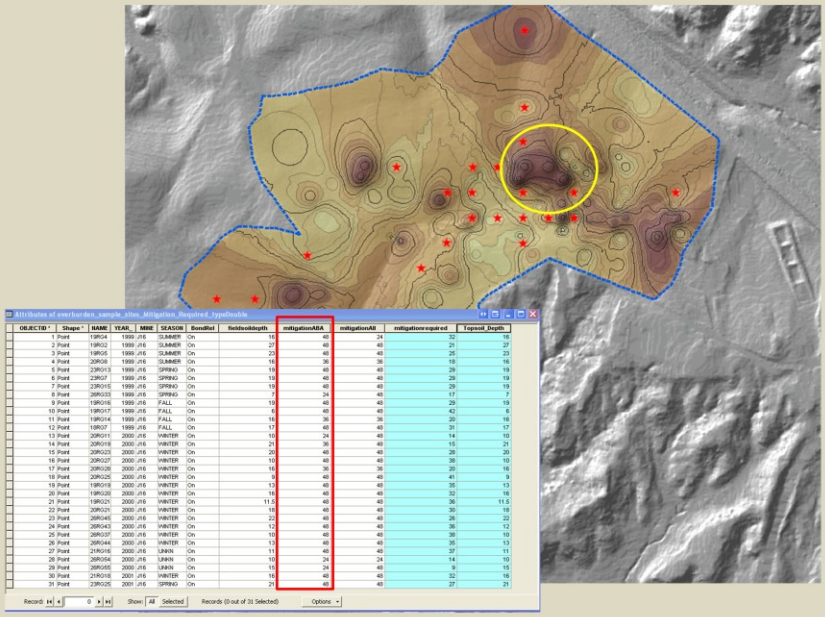
Current Concerns

Acid Base Accounting (ABA) poor in many locations

Mitigation: additional soil required at problem sites

31 of the topsoil depths are problematic and require mitigation

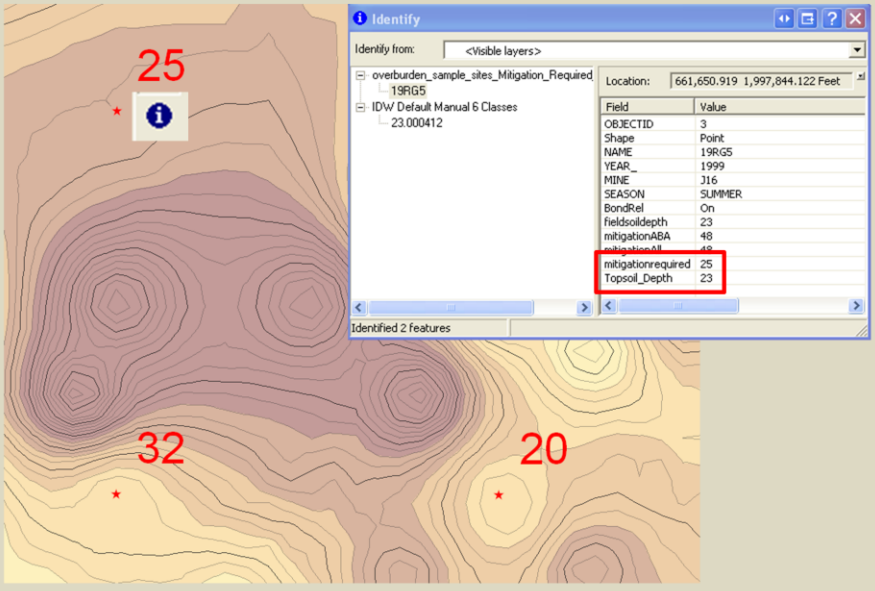


Attributes of overburden_sample_sites_Mitigation_Required_typeDouble

OBJECTID *	Shape *	NAME	YEAR_	MINE	SEASON	BondRef	fieldsoildepth	mitigationABA	mitigationAll	mitigationrequired	Topsoil_Depth
1	Point	19R04	1999 J16		SUMMER	On	18	48	24	32	18
2	Point	19R02	1999 J16		SUMMER	On	27	48	48	21	27
3	Point	19R05	1999 J16		SUMMER	On	23	48	48	25	23
4	Point	20R08	1999 J16		SUMMER	On	16	36	36	18	16
5	Point	23R013	1999 J16		SPRING	On	19	48	48	29	19
6	Point	23R27	1999 J16		SPRING	On	19	48	48	29	19
7	Point	23R015	1999 J16		SPRING	On	19	48	48	29	19
8	Point	26R033	1999 J16		SPRING	On	7	24	48	17	7
9	Point	19R016	1999 J16		FALL	On	19	48	48	29	19
10	Point	19R017	1999 J16		FALL	On	6	48	48	42	6
11	Point	19R014	1999 J16		FALL	On	18	36	36	20	16
12	Point	16R07	1999 J16		FALL	On	17	48	48	31	17
13	Point	20R031	2000 J16		WINTER	On	10	24	48	14	10
14	Point	20R018	2000 J16		WINTER	On	21	36	48	15	21
15	Point	20R023	2000 J16		WINTER	On	20	48	48	28	20
16	Point	20R027	2000 J16		WINTER	On	10	48	48	38	10
17	Point	20R028	2000 J16		WINTER	On	16	36	36	20	16
18	Point	20R025	2000 J16		WINTER	On	9	48	48	41	9
19	Point	19R019	2000 J16		WINTER	On	13	48	48	35	13
20	Point	19R020	2000 J16		WINTER	On	16	48	48	32	16
21	Point	19R021	2000 J16		WINTER	On	11.5	48	48	36	11.5
22	Point	20R021	2000 J16		WINTER	On	18	48	48	30	18
23	Point	26R045	2000 J16		WINTER	On	22	48	48	26	22
24	Point	26R043	2000 J16		WINTER	On	12	48	48	36	12
25	Point	26R037	2000 J16		WINTER	On	10	48	48	38	10
26	Point	26R044	2000 J16		WINTER	On	13	48	48	35	13
27	Point	21R016	2000 J16		UNKN	On	11	48	48	37	11
28	Point	26R054	2000 J16		UNKN	On	10	24	24	14	10
29	Point	26R055	2000 J16		UNKN	On	15	24	48	9	15
30	Point	21R018	2001 J16		WINTER	On	16	48	48	32	16
31	Point	23R025	2001 J16		SPRING	On	21	48	48	27	21

Record: 0 | Show: All | Selected | Records (0 out of 31 Selected) | Options

Problematic and require mitigation



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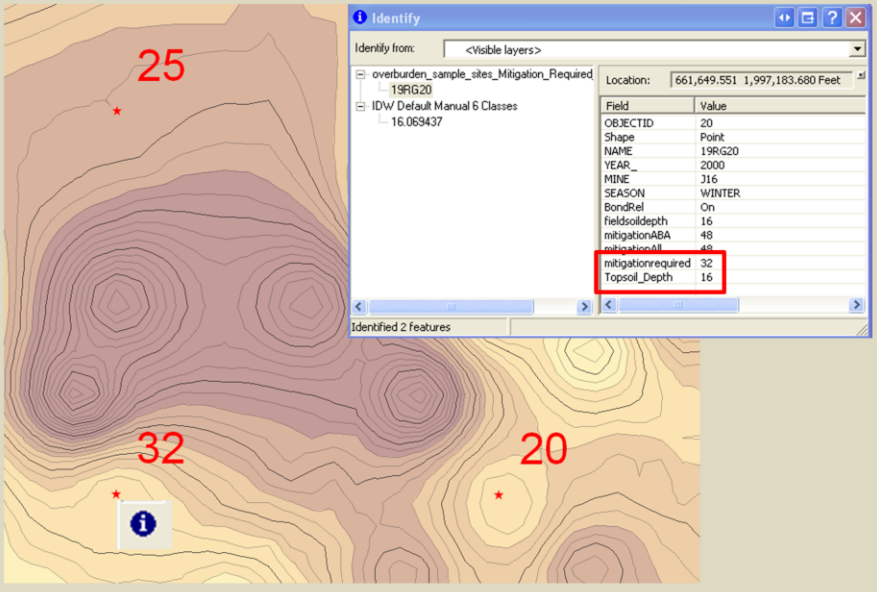
Problematic and require mitigation



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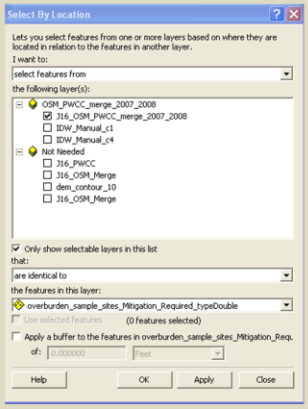
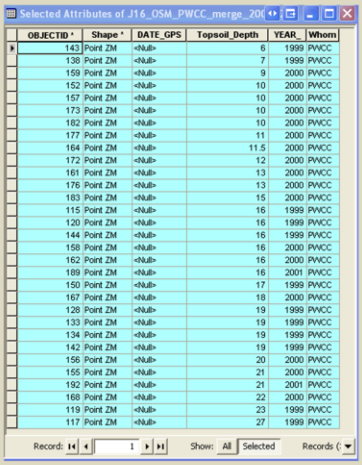
Create interpolated surface using mitigation sites

Compare this new surface to the as-built surface





Select points in common

Switch selection to exclude sites requiring mitigation

Export to new file

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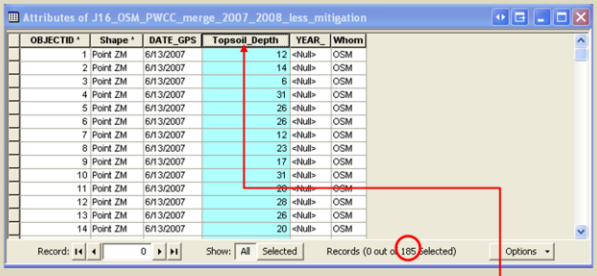
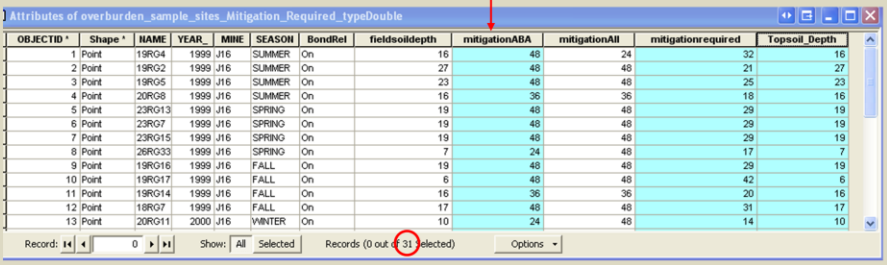
Merge excluded sites with mitigation sites

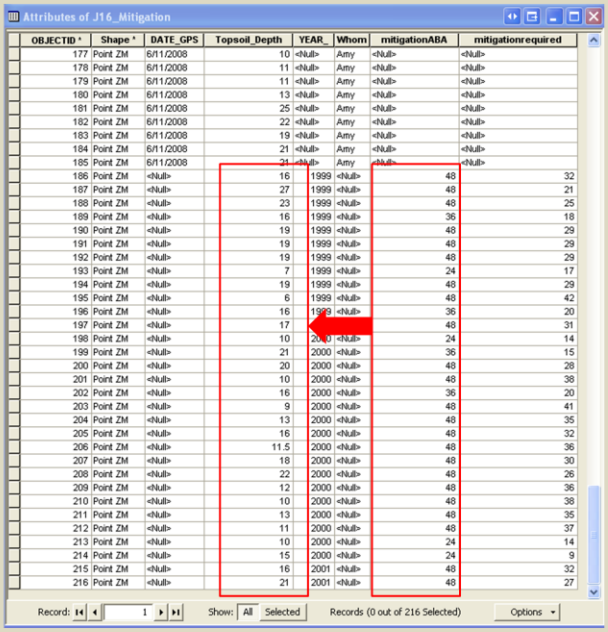


Use mitigation depth for new Topsoil_Depth

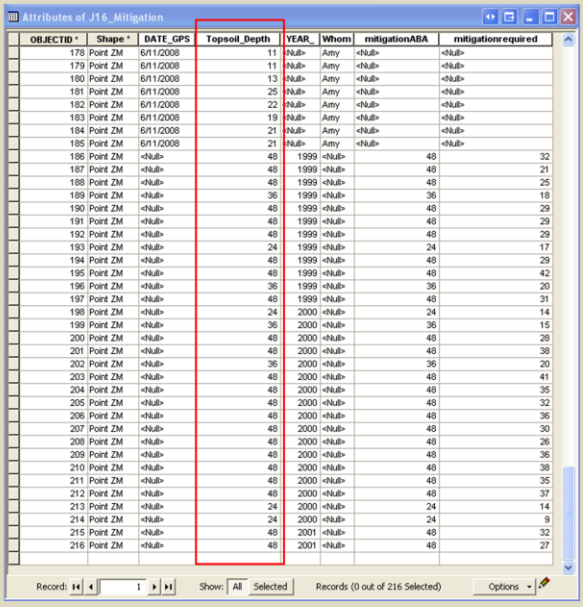
Still have 216 samples



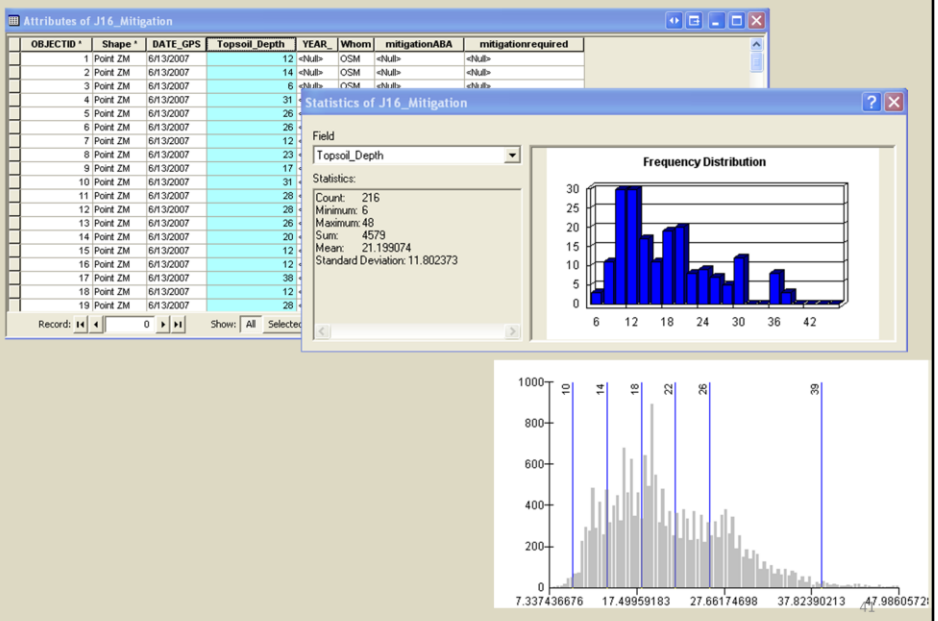
In other words…



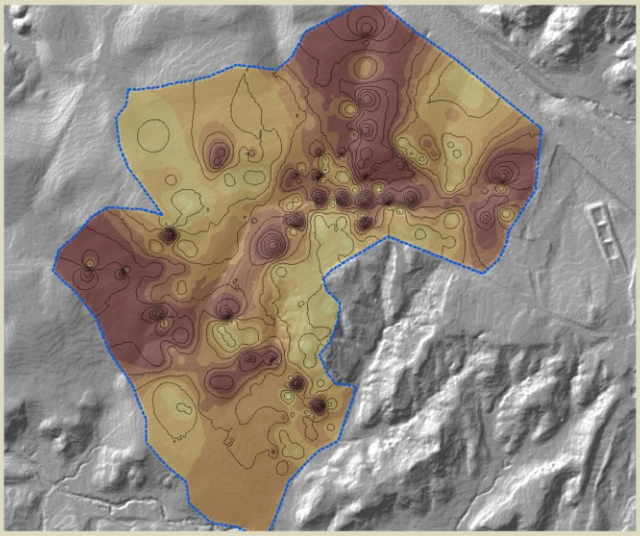
Create interpolated surface which includes mitigation and will represent “should-be”



Manual classification, 6 classes, use same breaks as previous classification



“Should-be” Topsoil Depth Surface J-16 Blackmesa Mine Complex



50 % transparent
Hillshade of topsoil surface set in-between

4-inch contours
Black, width 0.40
40% transparent

IDW of J16_Mitigation
Topsoil Depth inches
7.0 - 10.0
10.1 - 14.0
14.1 - 18.0
18.1 - 22.0
22.1 - 26.0
26.1 - Greater than 39.0

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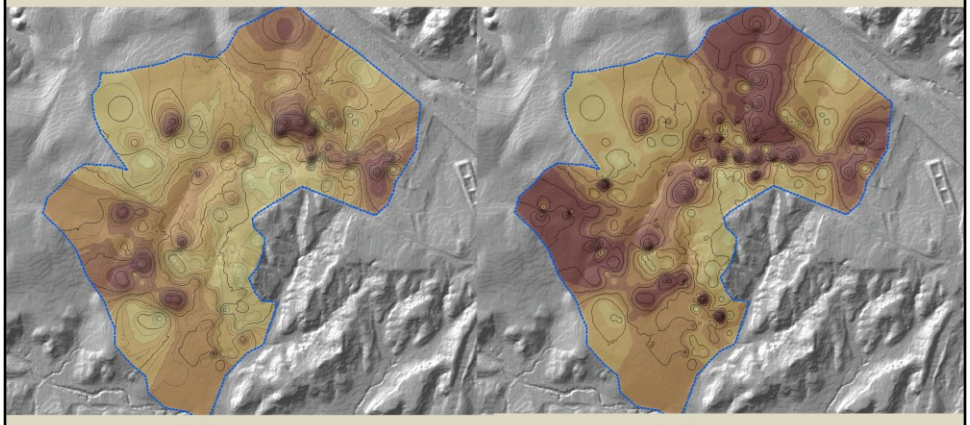
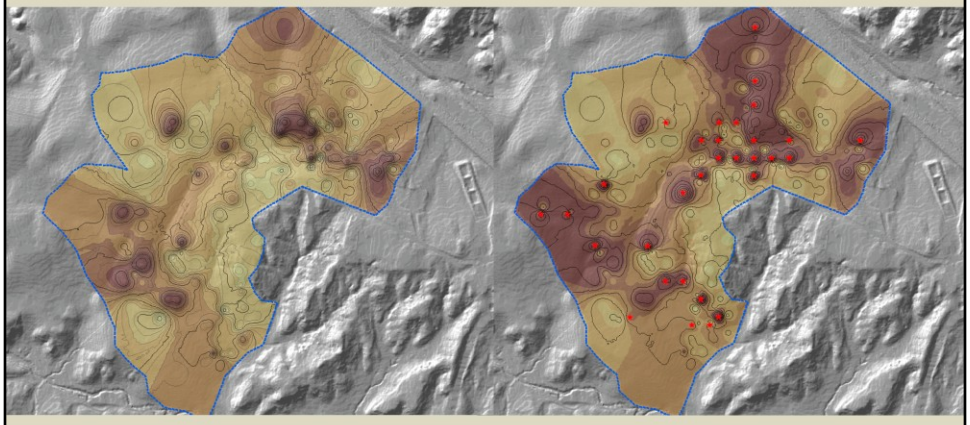
As-built

“Should-be”



As-built

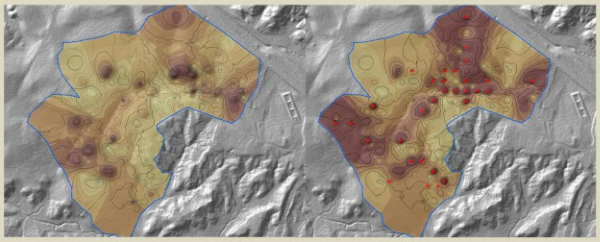
“Should-be”



Conclusion

Science and the proper application of technology are foundations for effectively implementing SMCRA

GIS technology and ESRI's Spatial Analyst extension software can be used to create a visually pleasing, easily interpreted topsoil depth distribution surface from interpolated points



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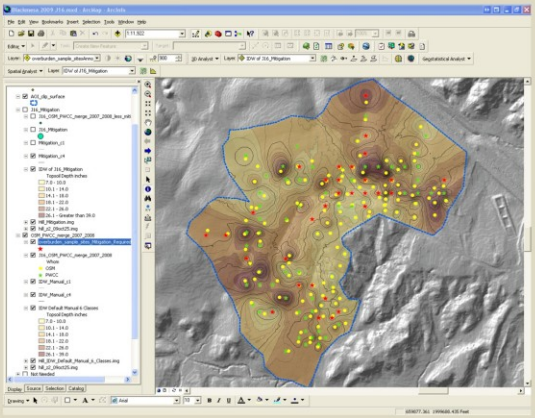
Sound Science + Accurate Technology =



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Best Practices

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Thank-you for your attention

OFFICE OF SURFACE MINING RECLAMATION AND ENFORCEMENT