

# Navajo Nation Navajo Tribal Utility Authority

## Wind Energy Feasibility Study on the Navajo Nation

Office of Energy Efficiency and Renewable Energy

TRIBAL ENERGY PROGRAM

2005 Program Review Meeting

Denver, Colorado

October 19, 2005

Presenter: Larry Ahasteen-NTUA  
Grant Brummels-NAU



# Navajo Nation

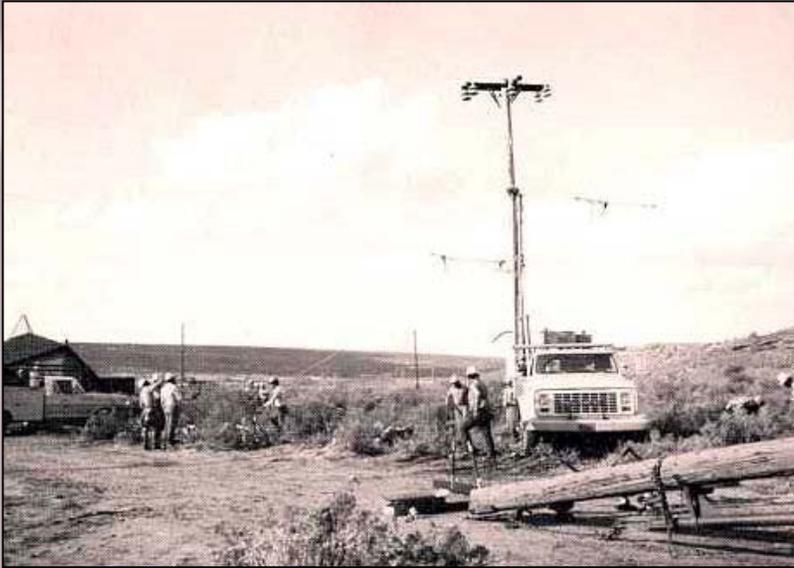


- Dine Bikeyah, or Navajo land, is larger than 10 of the 50 states in America
- The reservation includes approximately 27,000 square miles. Its boundaries extend from northwestern New Mexico into northeastern Arizona and southeastern Utah, larger than many states.
- The Navajo Nation consists of more than 298,000 members





# Navajo Tribal Utility Authority



- Navajo Nation Council created NTUA in 1959 to provide modern utility services to the Navajo people.
- NTUA operates under a Plan of Operation as a non-profit Tribal Enterprise charged with providing utility services at a reasonable rates to the public
- NTUA is governed by a Management Board to direct the operation of the Authority.
- The Board is appointed and confirmed by the Government Services Committee.
- The Board was granted certain powers thru Section 7 of Title 21 of the Navajo Nation Code.

# Navajo Tribal Utility Authority



- Electric Utility of NTUA (Authority) is the major revenue source of the Authority
- NTUA provide 703 GWH of energy
- NTUA has 37,426 customers
- NTUA operates 7,124 miles of overhead distribution lines,
- 65 miles of underground distribution lines
- 531 miles of sub-transmission lines ,serving the Navajo people.

**Electric Operation**

# Navajo Tribal Utility Authority



- In 1960's NTUA begin to distribute natural gas to 4 major Navajo communities.
- Over years other major natural gas suppliers constructed high pressure gas thru Navajo land.
- This gave NTUA an opportunity to coordinating delivery points off these high pressure lines.
- NTUA has 21 taps from these delivery point to serve Navajo Nation.
- NTUA serve 7,500 customers through 600 miles of distribution lines

**Natural Gas Operations**

# Navajo Tribal Utility Authority



- For 40 years NTUA has operated water and waste water systems which was constructed and financed by the Indian Health Service.
- Other Financial assistance were provided by US Environmental Protection Agency, Economic Development Administration and most recently Rural Utilities Services.
- Presently water systems are constructed by I.H.S. and then transferred to NTUA for operation and maintenance of these system.
- NTUA has 236 water wells, 139 booster pump stations, 330 steel storage reservoirs connected to 5,474 miles of water lines that makes up 89 water systems.
- NTUA has 34,942 customers and 12,616 water water customers.

Water-Waste Water Operations

# Navajo Tribal Utility Authority



## NTUA Solar Energy Program



- WAPA assisted NTUA in providing residential Solar PV Systems as a cost effective means of providing Utility services to Navajo people.
- Due to Navajo families living in remote areas NTUA participated in Solar Energy and other alternative electric power generation technologies .
- NTUA intends to bring into the lives of thousands of Navajo who will benefit from Solar Energy and other Renewable Energy Program.
- WAPA funded \$300,000.00 grant to procure Solar PV systems for lightning-small AC systems.
- Sandia National Laboratory of Albuquerque New Mexico played a key role in providing technical assistance.
- 72 Solar PV units were purchased- 1000 watts per day systems
- NTUA Management Board approved the appropriation of \$2 million dollars to purchase an additional of 200 PV units -1.7 KWh day
- Congress appropriated \$ 800,000 in 2002 and \$ 1,150,000.00 in 2003 – Navajo Electrification Demonstration Program- Hybrid Solar-Wind System

**Solar Energy**

# Project Overview



- NTUA is proposing to conduct a 24 months comprehensive wind energy resources evaluation and development of a Wind Farm feasibility study
- Navajo Nation Council directed to all Tribal Programs and Enterprise to develop ,research ,and seek new plans to generate outside revenue for the Nation.
- Navajo Nation Council oversight committee approved resolution for NTUA to build electric generating facilities to services its load and not depend on off – reservation electric generating facilities.
- This Plan will expedite the development of wind energy sites, implementation of sites plan and engineering detail design of a wind farm for the Nation.
- The Nation and NTUA has the experience in carrying out this feasibility project and take the lead role to conduct this wind energy study

# Navajo Wind Project



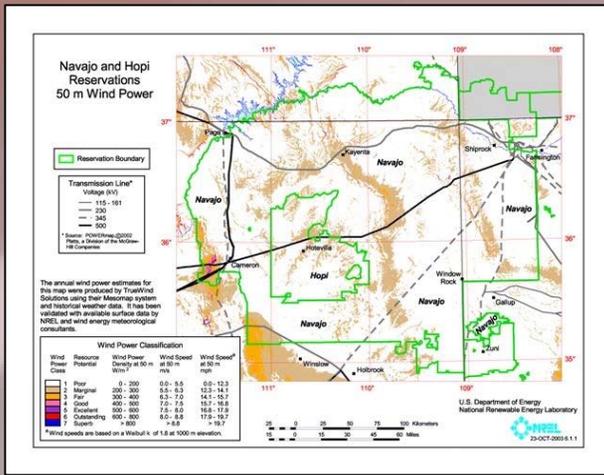
- NTUA and Navajo Wind Project Team will evaluate six sites with a meteorologist.
- Study will monitor and analyze six proposed tribal land within the States of Arizona and New Mexico
- Wind Project Team will coordinate all activities in reviewing and evaluating these proposed sites.
- NTUA primary objective is to evaluate the wind energy potential of the six (6) sites.
- Determine if there are sufficient wind energy resources to generate electric power.

# Project Narrative

- NTUA in partnership with NAU will determine the most feasible sites on the reservation. With the highest wind energy potential.
- NTUA will assign Electric Engineer-ROW specialist and GIS crews to survey and map out the most feasible route to extend transmission line.
- NTUA and NAU will monitor the sites for twelve months period to develop comprehensive site studies of the topography.
- A meteorologist will assist the team in choosing proper site, review and analysis data – every months at the end of the year

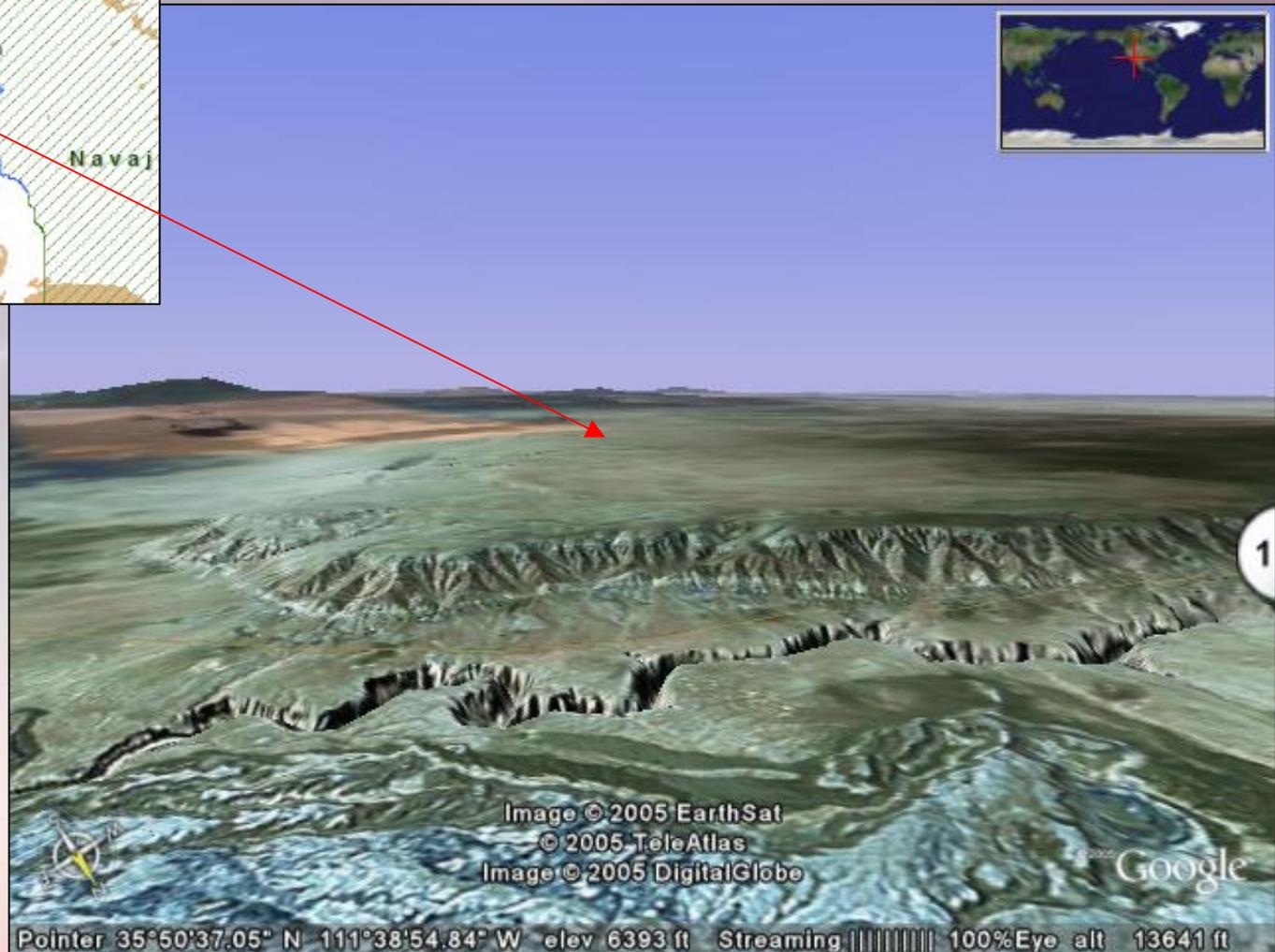
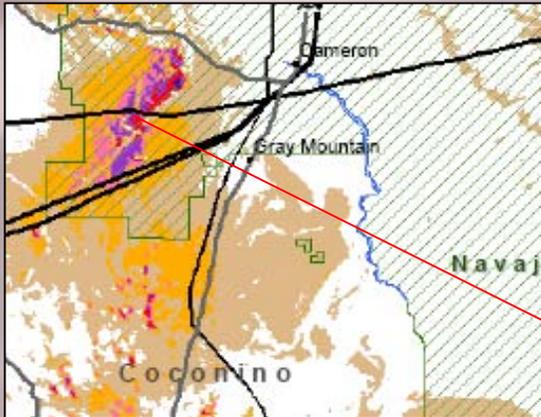


# NTUA Wind Assessment



# Project Location

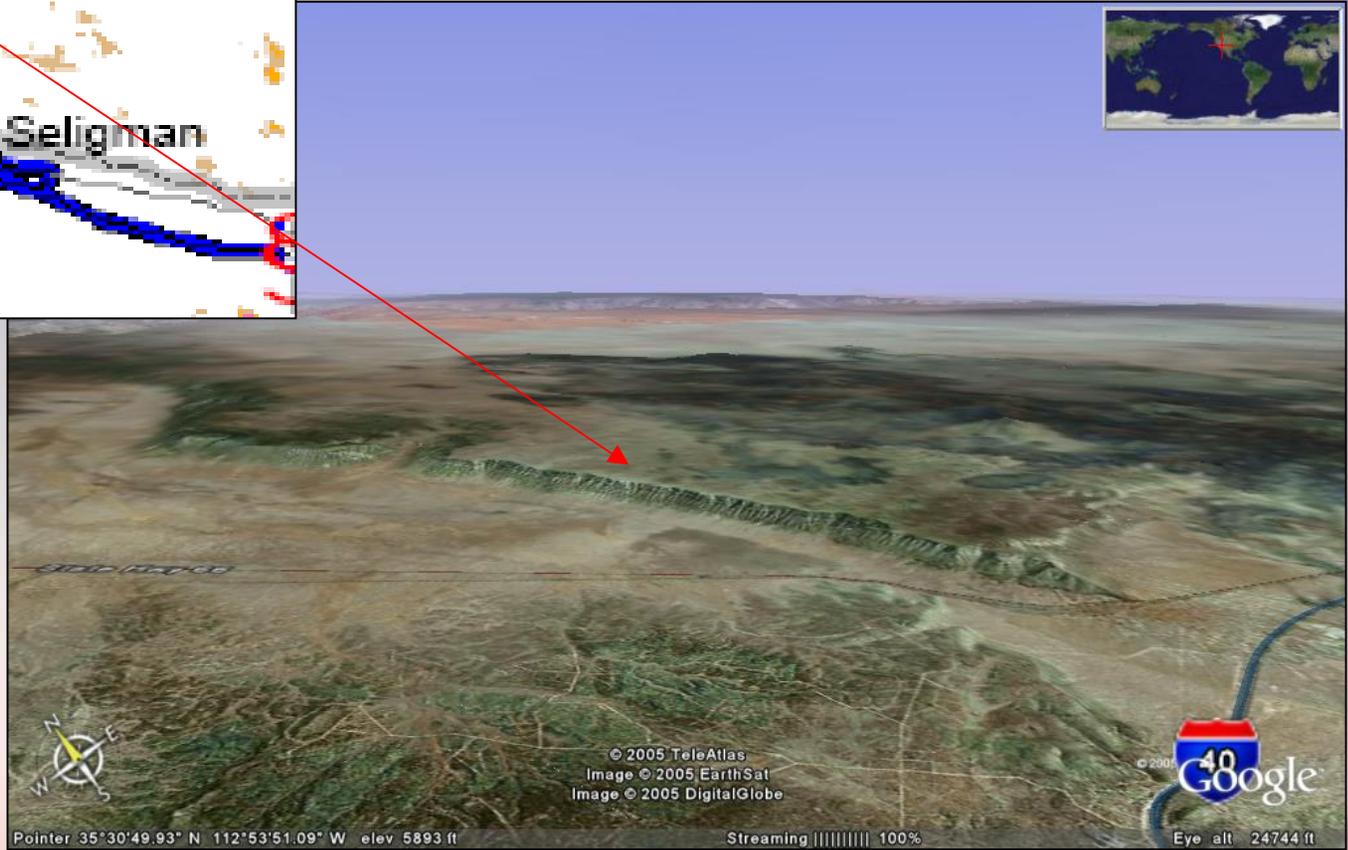
## Gray Mountain Wind Site



Wind Power Class and Resource Potential		
1 - Poor	4 - Good	7 - Superb
2 - Marginal	5 - Excellent	
3 - Fair	6 - Outstanding	

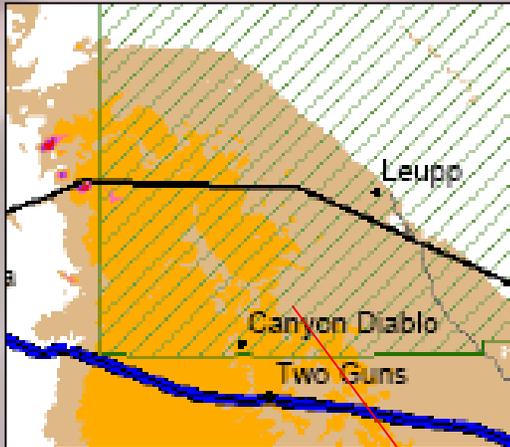
# Project Location

## Aubrey Cliff Wind Site



# Project Location

## Luepp Wind Site



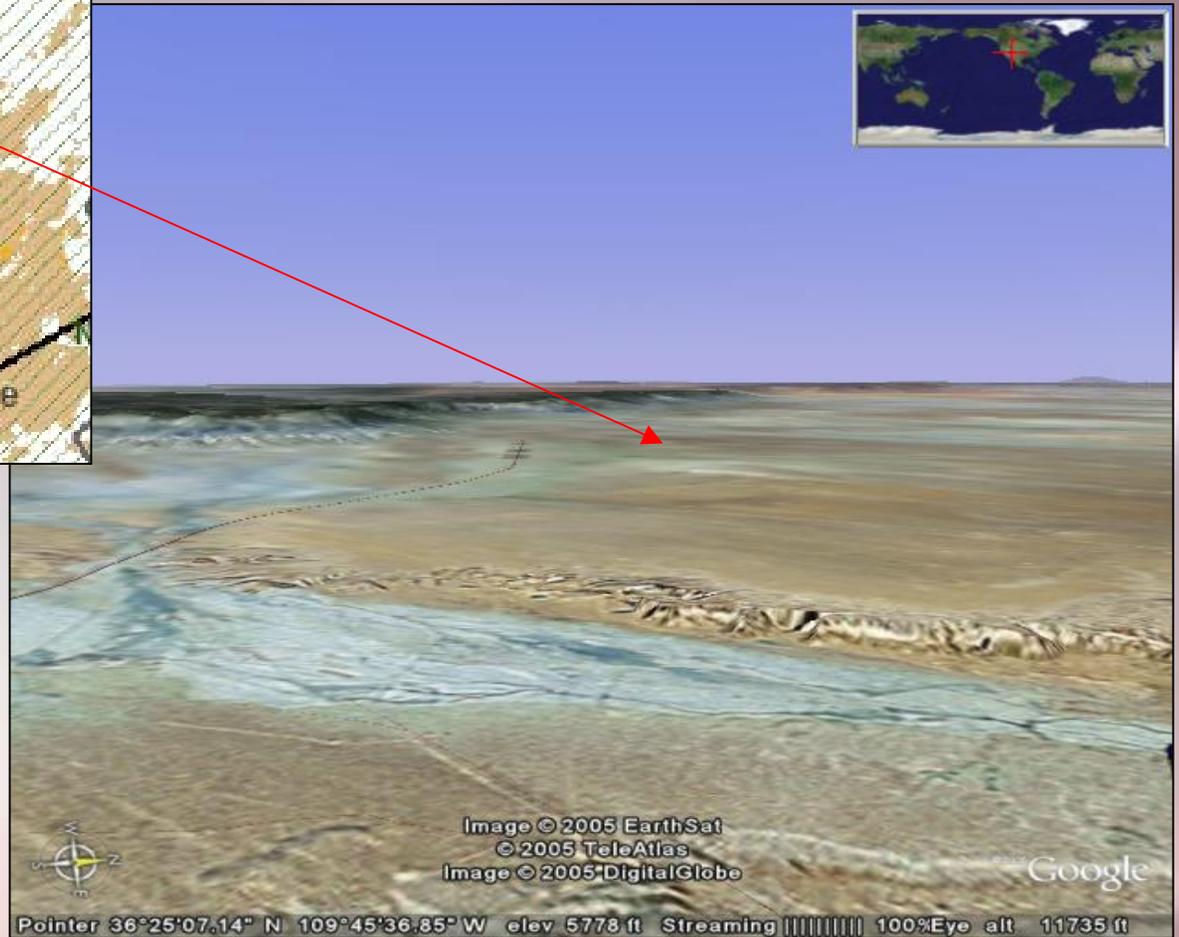
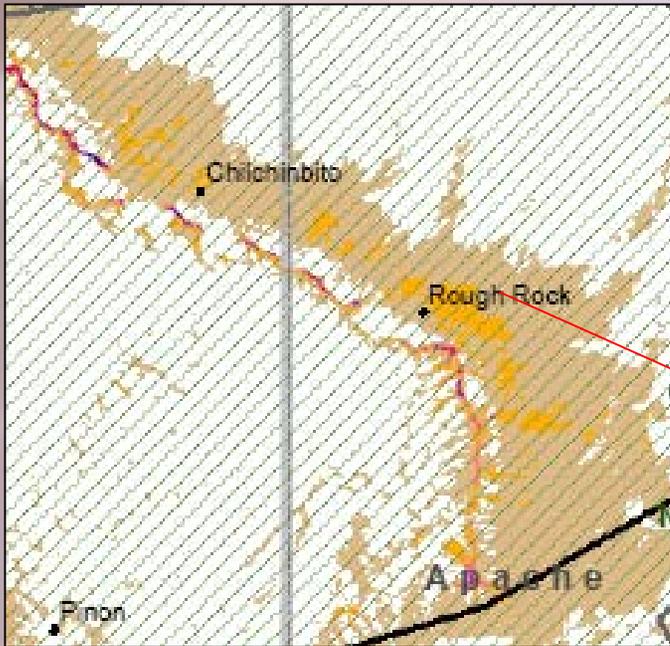
© 2005 TeleAtlas  
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# Project Location

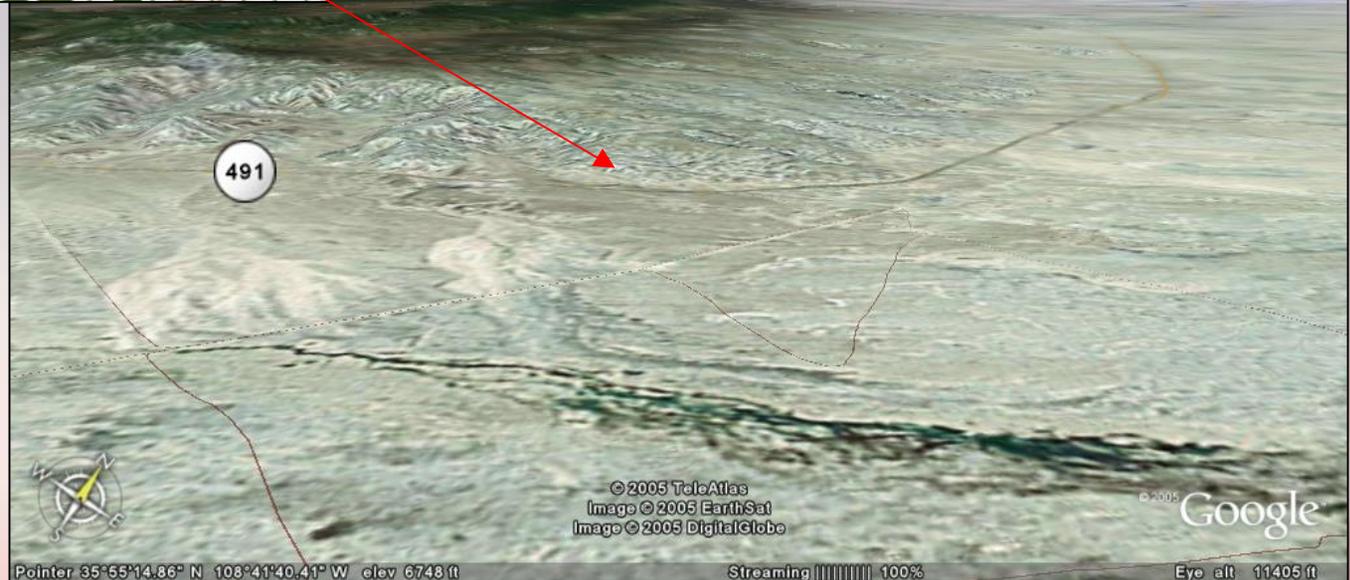
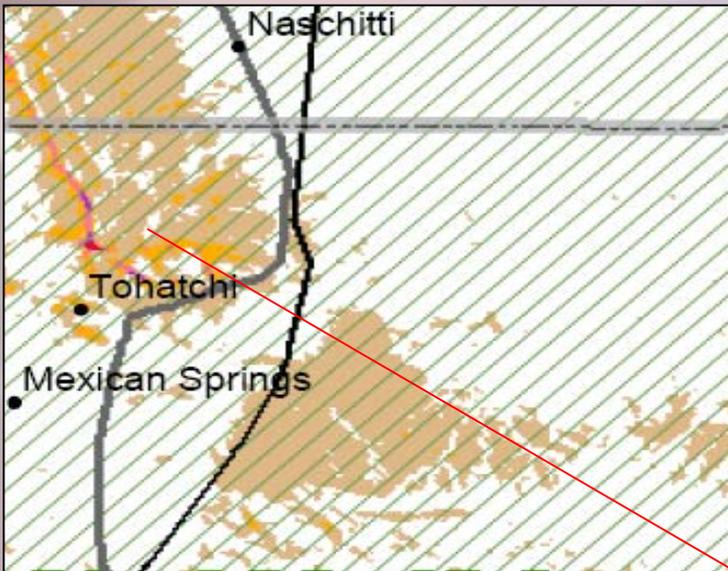
## Wind Valley Wind Site

1 - Poor	4 - Good	7 - Superb
2 - Marginal	5 - Excellent	
3 - Fair	6 - Outstanding	



# Project Location

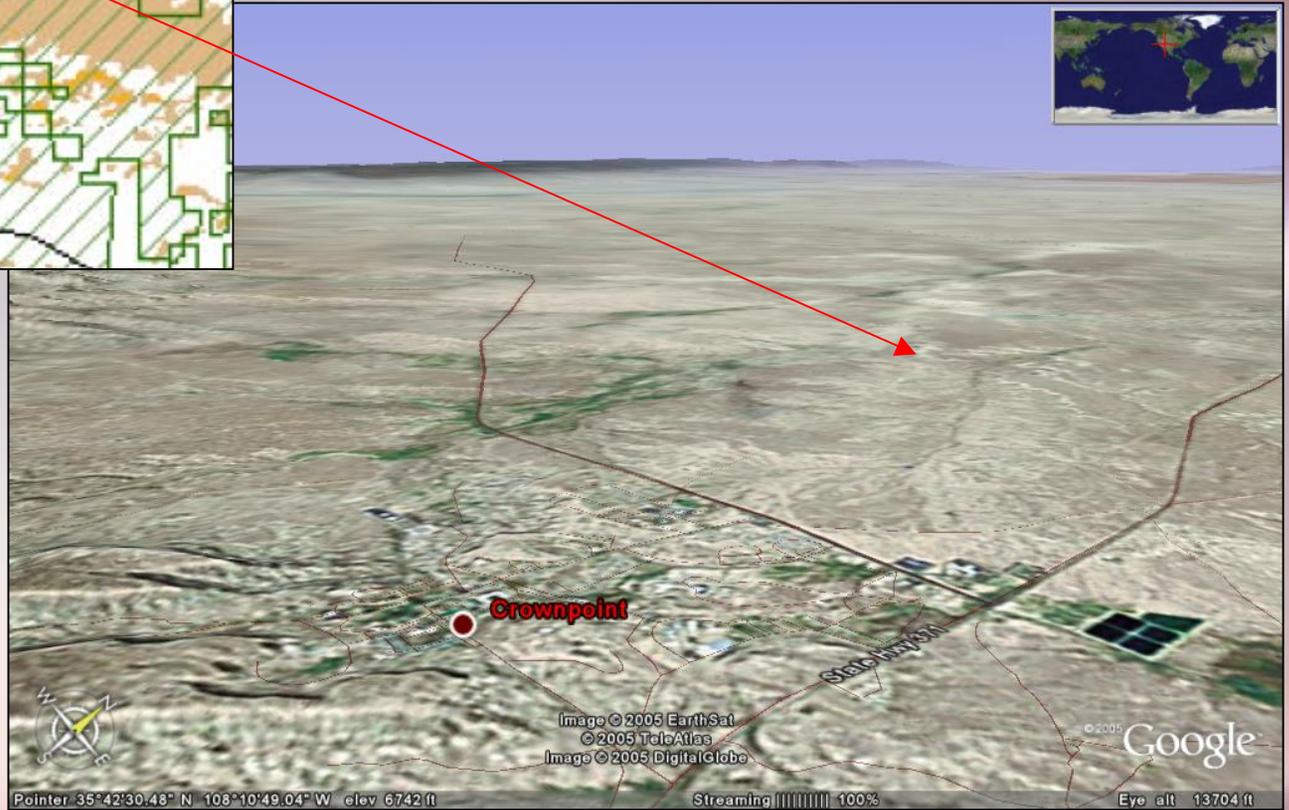
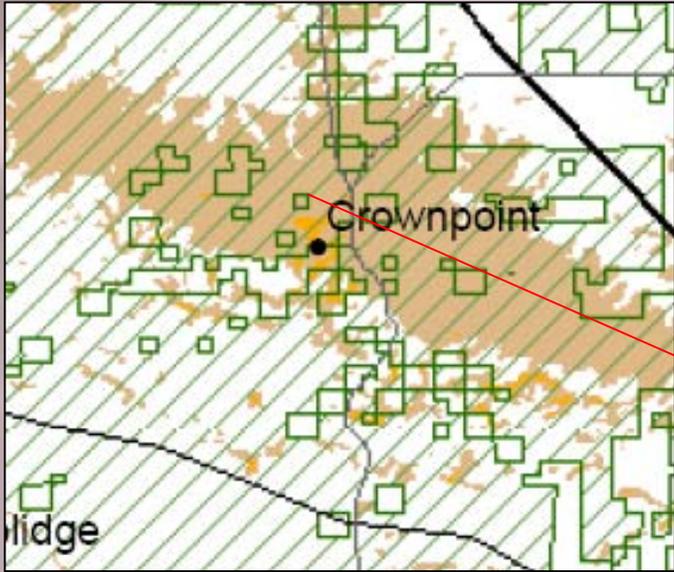
## Tohatchi Wind Site





# Project Location

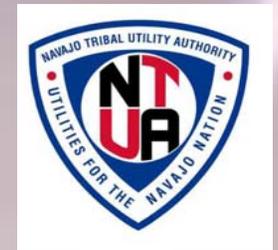
## Crownpoint Wind Site



# Project Participants



- NTUA -Selection of Navajo Wind Team to guide the Project
- Wind Team and Advisors are selected from ,
  - \* NTUA Engineering Dept.
  - \* Northern Arizona University
  - \* Navajo Nation Government
  - \* Dine' CARE
  - \* NREL-Advisor
  - \* Sandia National Lab.-Advisor
- September 09, 2005 Kickoff meeting –Window Rock, Arizona
- Revised the timeline – Activities
- Future Plan- Provide more educational information to Navajo Tribal Leaders on Wind Energy.



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# Navajo Windy Land

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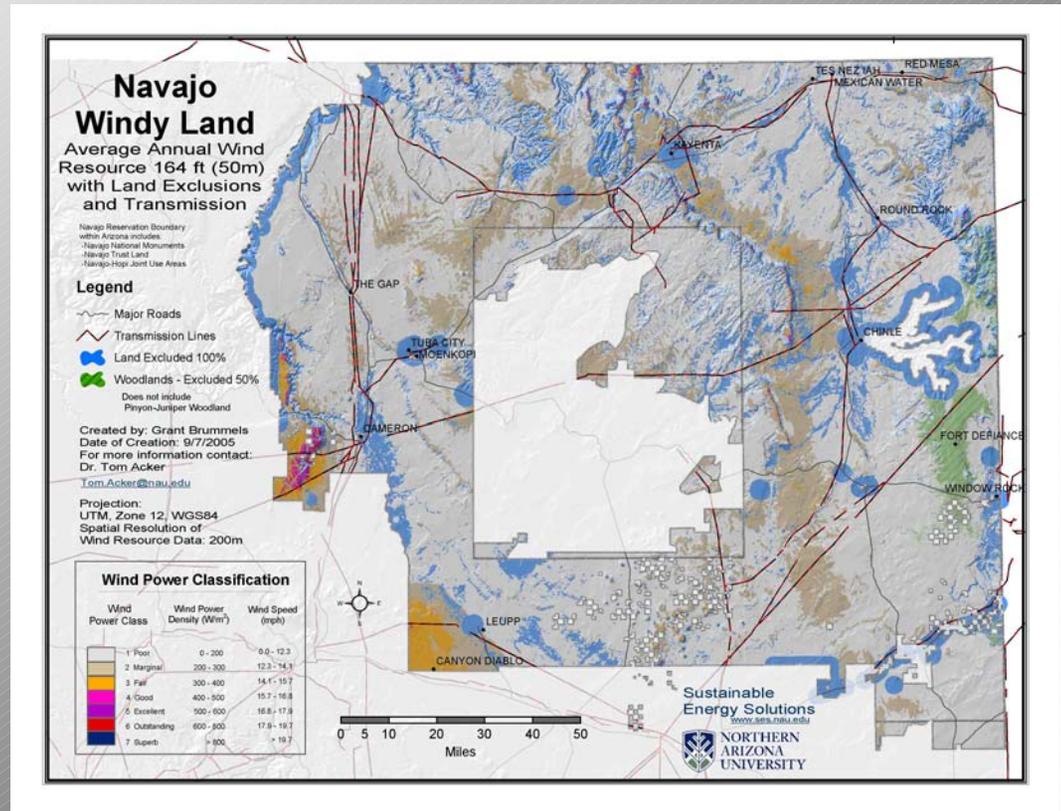


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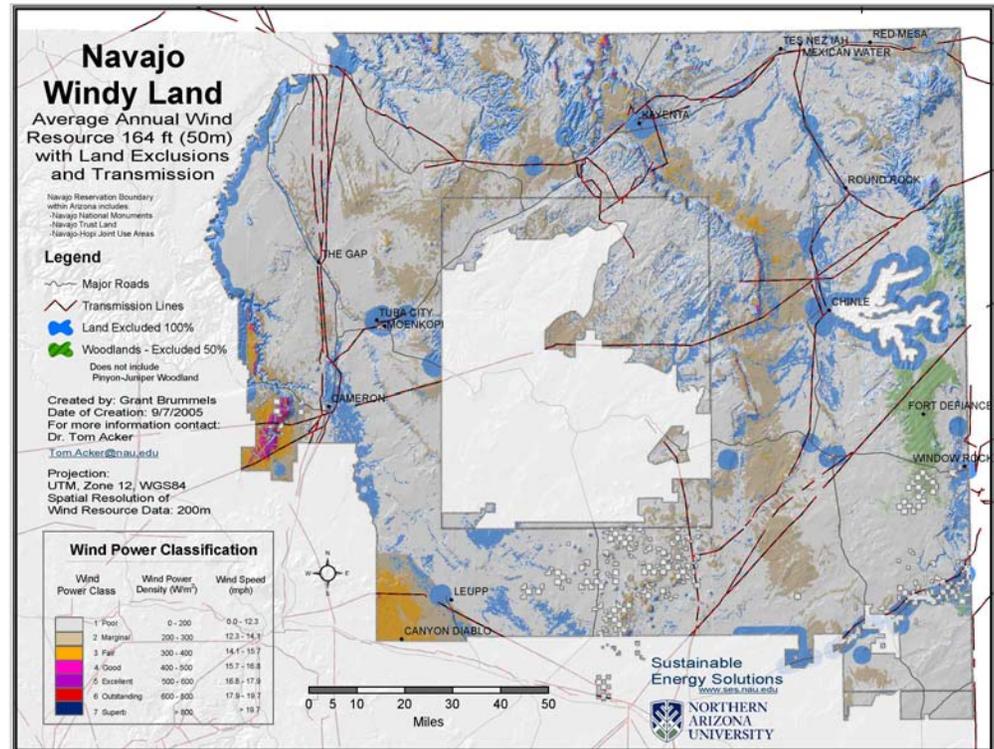
[www.wind.nau.edu/maps](http://www.wind.nau.edu/maps)

<http://134.114.64.98/website/windy/viewer.htm> (AZ Interactive Wind Map)



# Navajo Windy Land

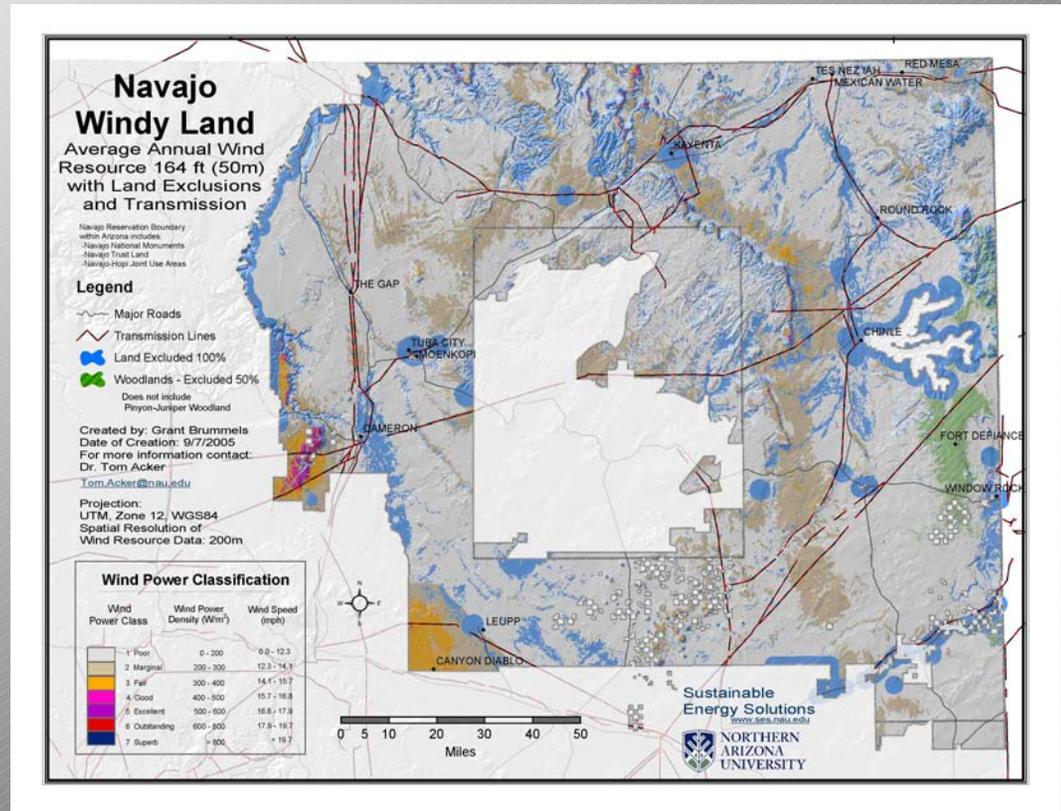
- Wind Maps and Arizona Geography
- Development Exclusions
- Results From Navajo Windy Land
- Discussion of Key Findings



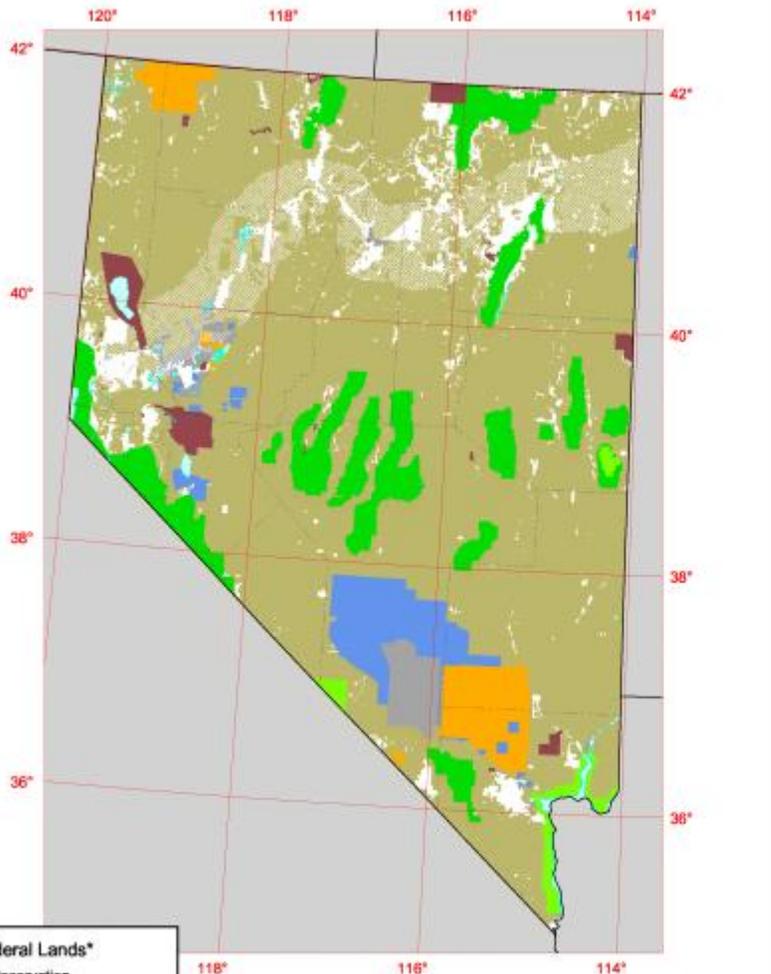
# Navajo Windy Land

Where can we develop wind energy?

What areas are unsuitable for wind energy development?



### Nevada - Federal Lands Map

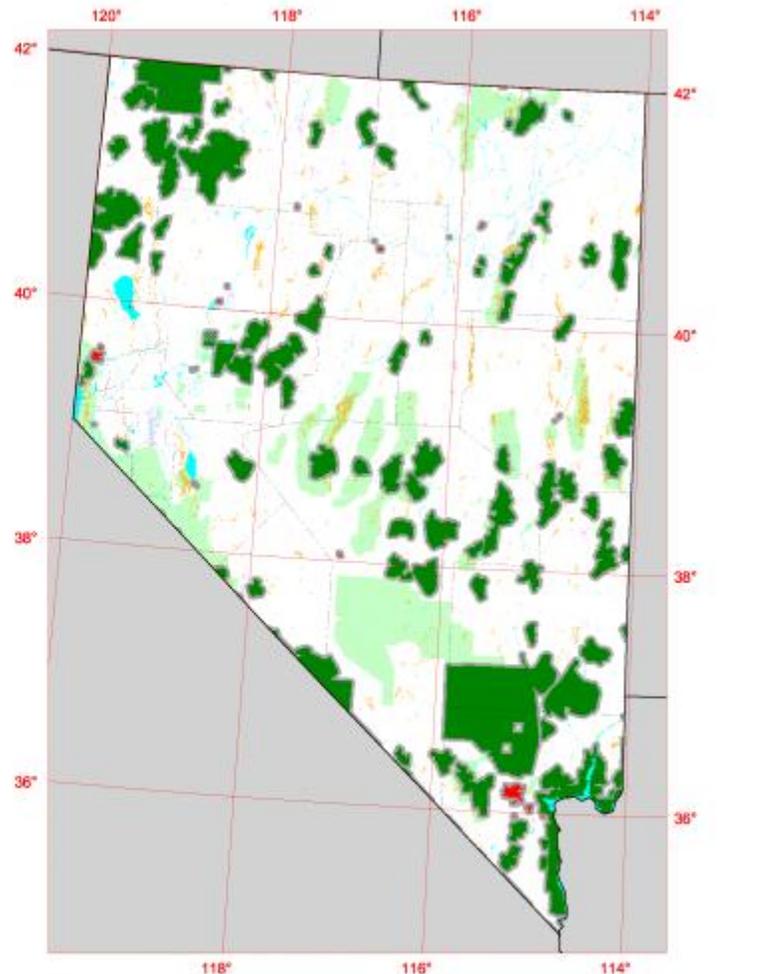


- Federal Lands\***
- Indian Reservation
  - Department of Defense
  - Forest Service
  - National Park Service
  - Bureau of Land Management
  - Fish and Wildlife Service
  - Other



\*Source: Federal Lands and Indian Reservations of the United States (USGS, April 2003)

### Nevada - Map of Wind Resource Exclusions



- 100% Exclusions**
- Slope > 20%
  - Urban or Airports
  - Water
- 50% Exclusions**
- Sensitive Environmental Lands
  - Other Forest Service or Dept. of Defense Lands
  - Non-ridgecrest Forest
- 3 Kilometer Buffer for Urban and Environmental Lands



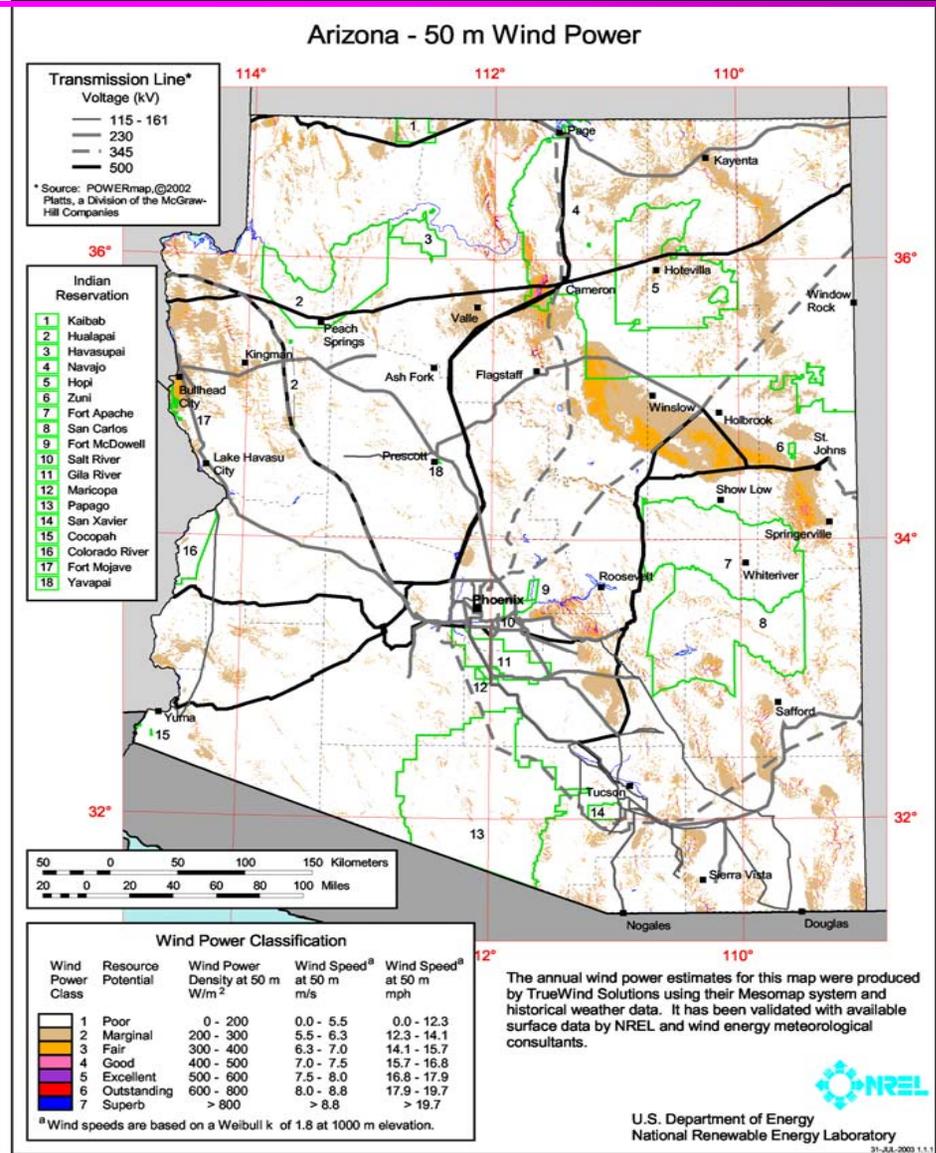
# Definitions

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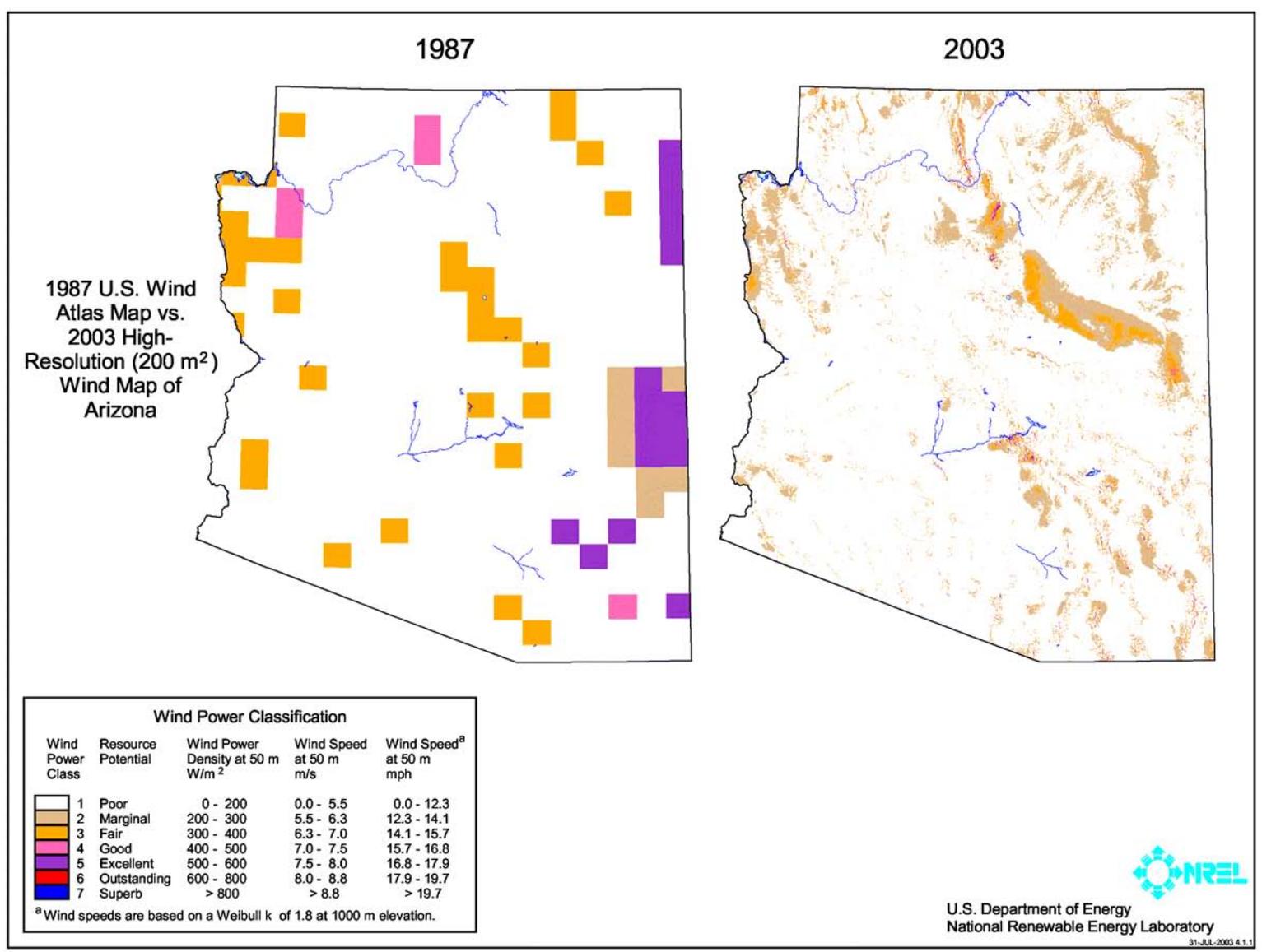
- **windy land** = land with wind resource  $\geq$  class 3
- **development exclusions** = areas of land unsuitable for wind energy development
- **developable windy land** = windy land left over after removing all development exclusions
- **excluded windy land** = windy land ( $\geq$  class 3) *that falls within a development exclusion*

# 2003 Arizona Wind Power Map

- Preliminary map produced by TrueWind Solutions
- Preliminary map validated by NREL and wind energy consultants
- Final map produced by TrueWind with approval by NREL



# “Old” vs. “New” Arizona Wind Maps

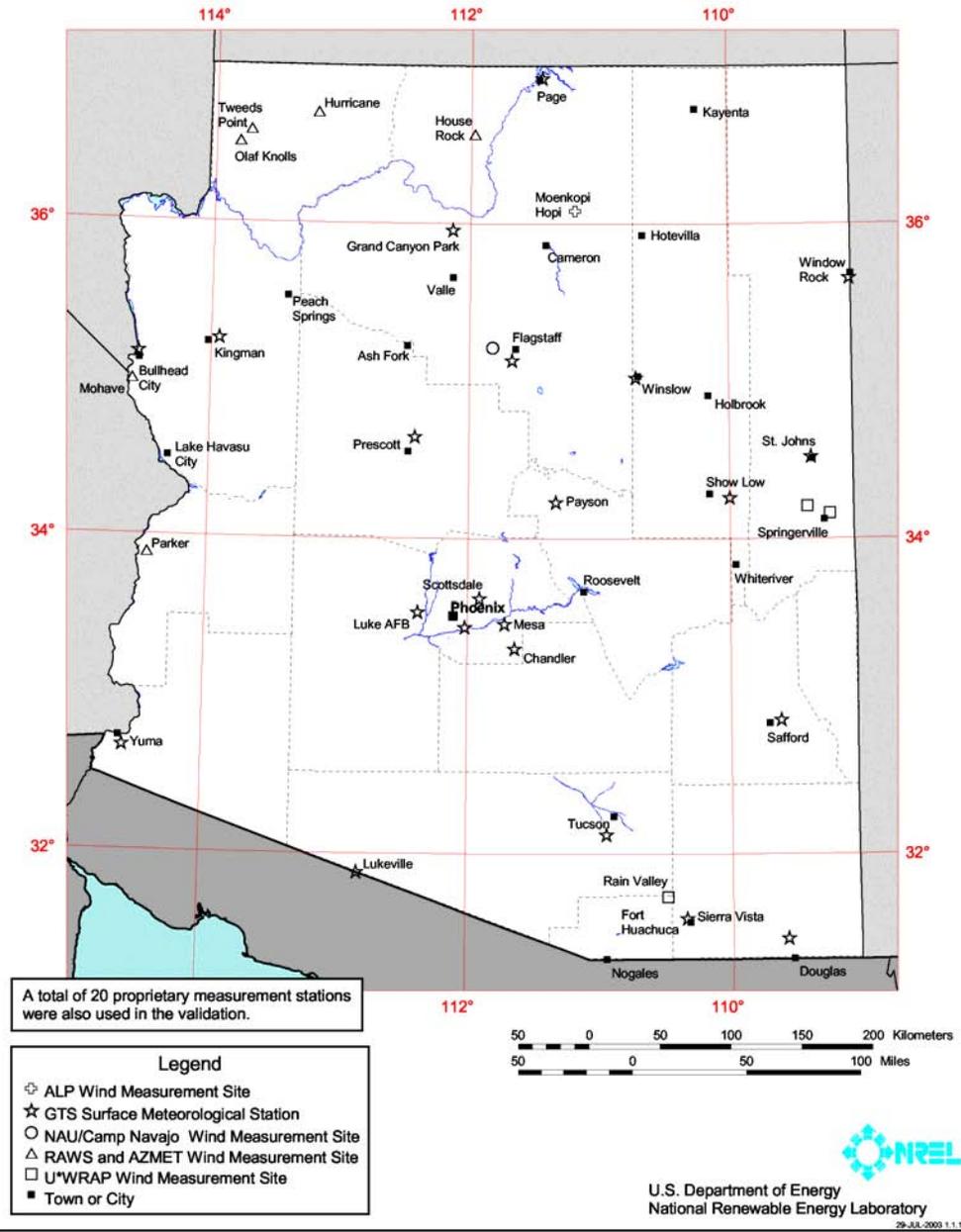


## Arizona Validation

- Over 50 measurement stations used for validation
  - 20 Airport
  - 3 U\*WRAP (Tucson Electric)
  - 4 RAWS (U.S Forest Service and BLM)
  - 2 AZMET
  - 1 NAU/Camp Navajo
  - 2 Tribal Anemometer Loan Program
  - 20 Proprietary stations from developers, and utilities
- Accuracy comparable to other updated state maps
  - Within 10% of annual speed and 20% of annual power at 80+% of individual sites

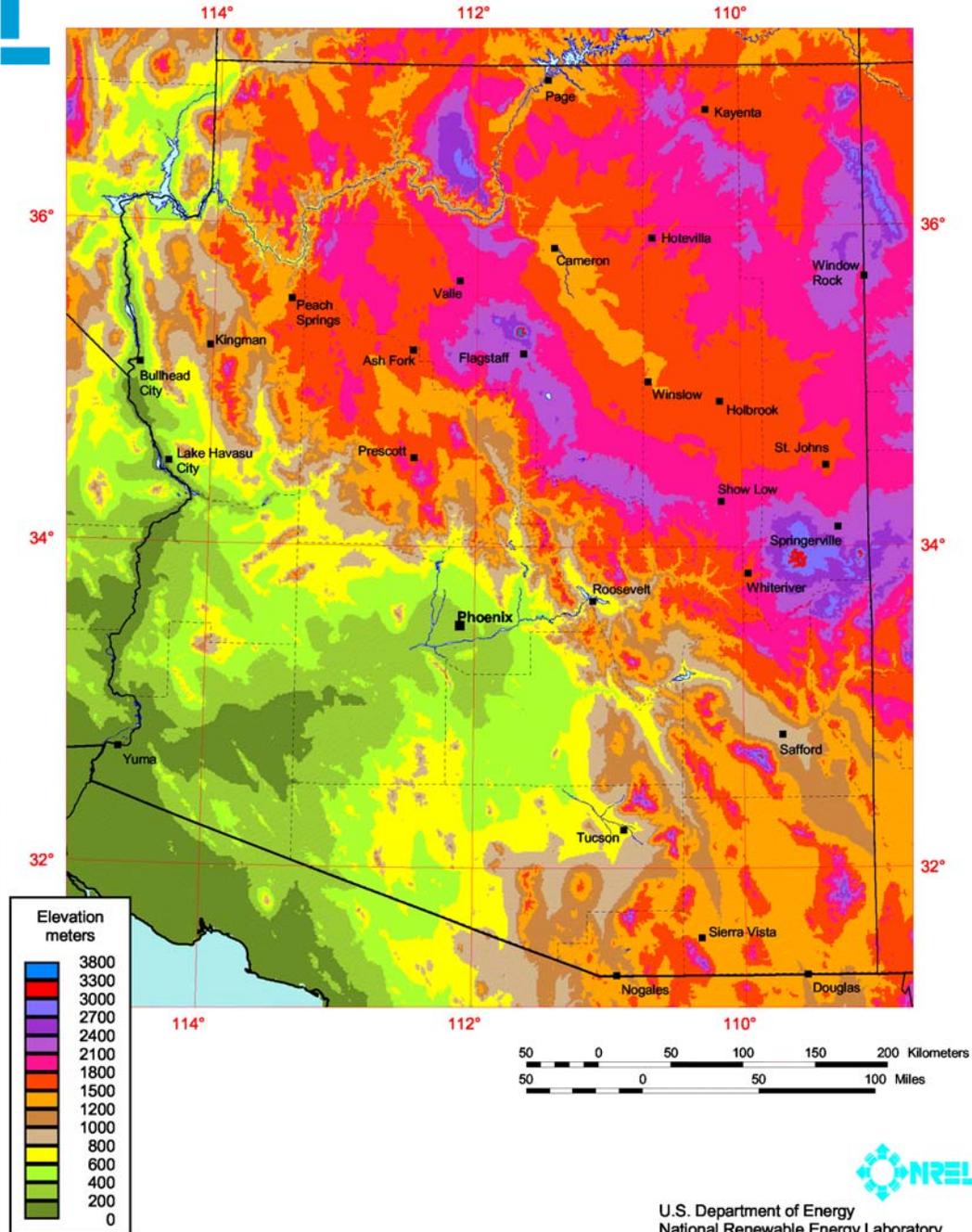


# Arizona - Wind Mapping Validation Sites



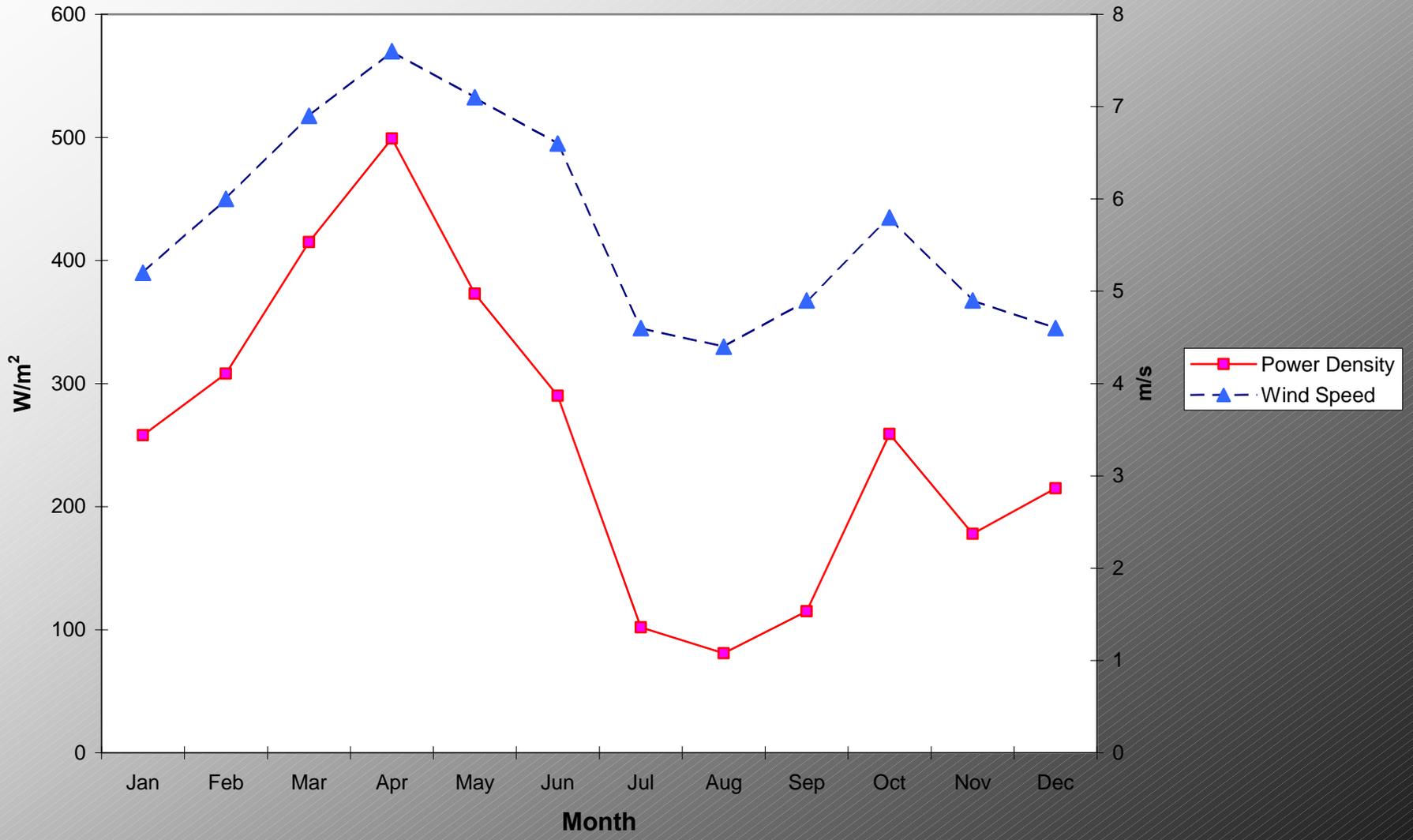


# Arizona - Elevation Map



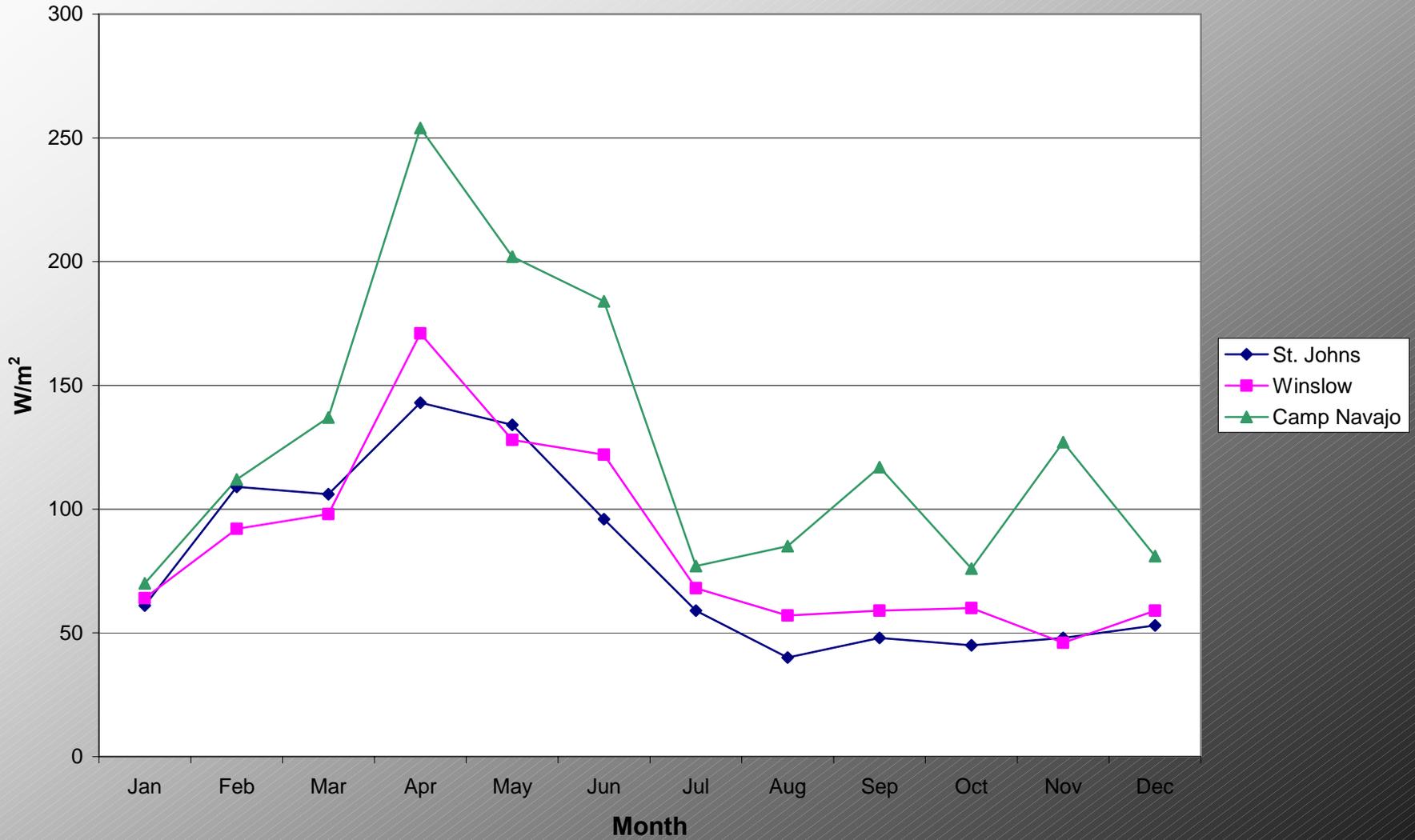


# Springerville U\*WRAP Station





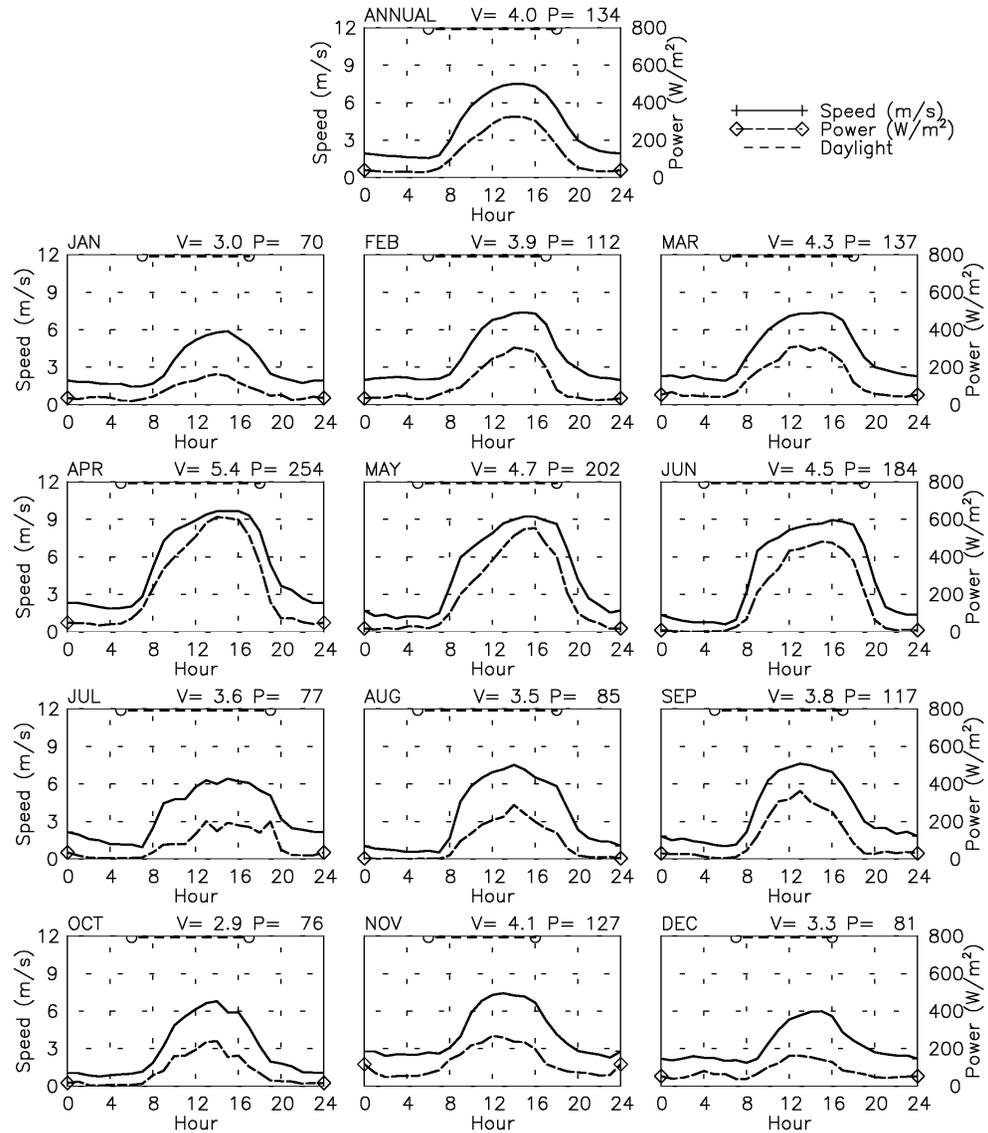
## Northern Arizona Wind Power





# SPEED AND POWER BY HOUR

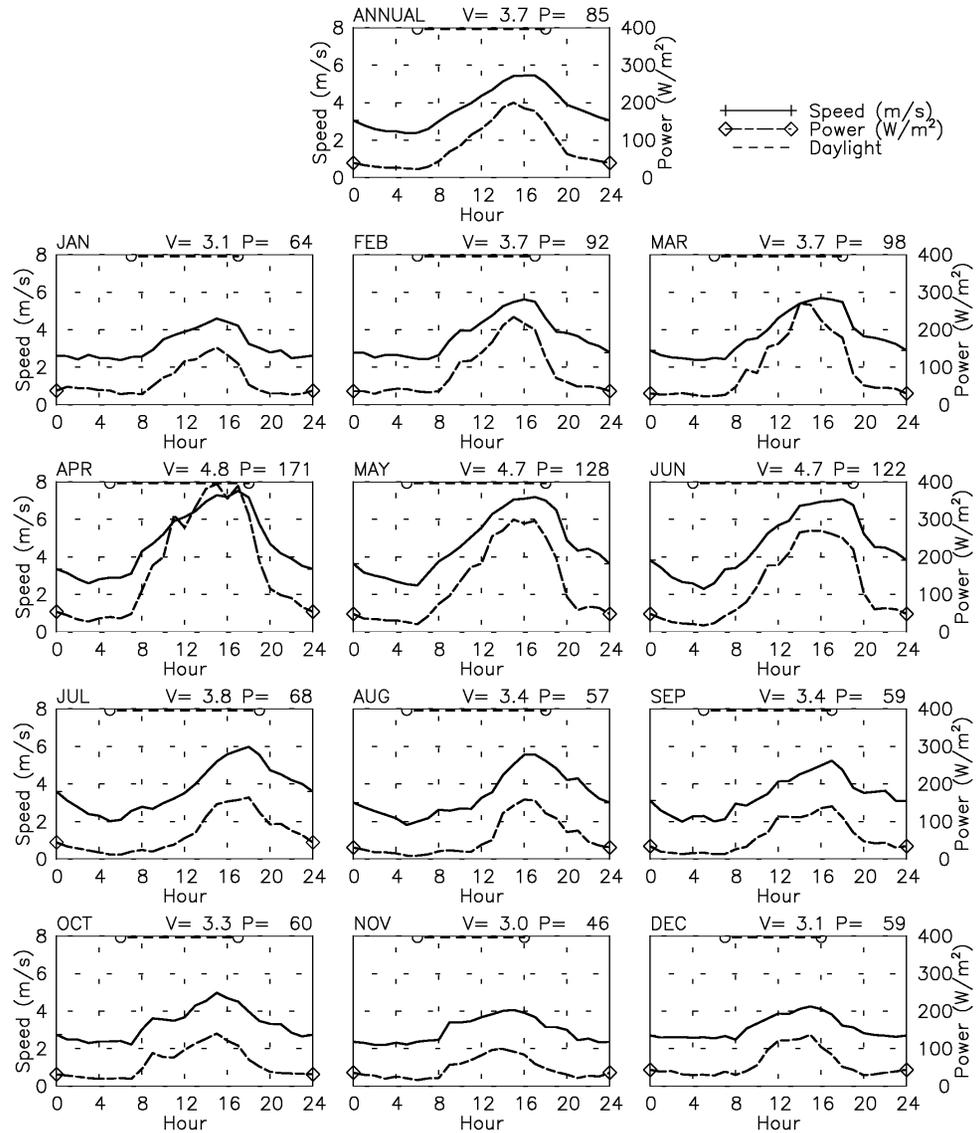
Camp Navajo AZ 13.4m - 000005  
35° 12' N 111° 50' W - Elev 2195m LST=GMT+99 hours \*NT= -7  
01/02-04/03





# SPEED AND POWER BY HOUR

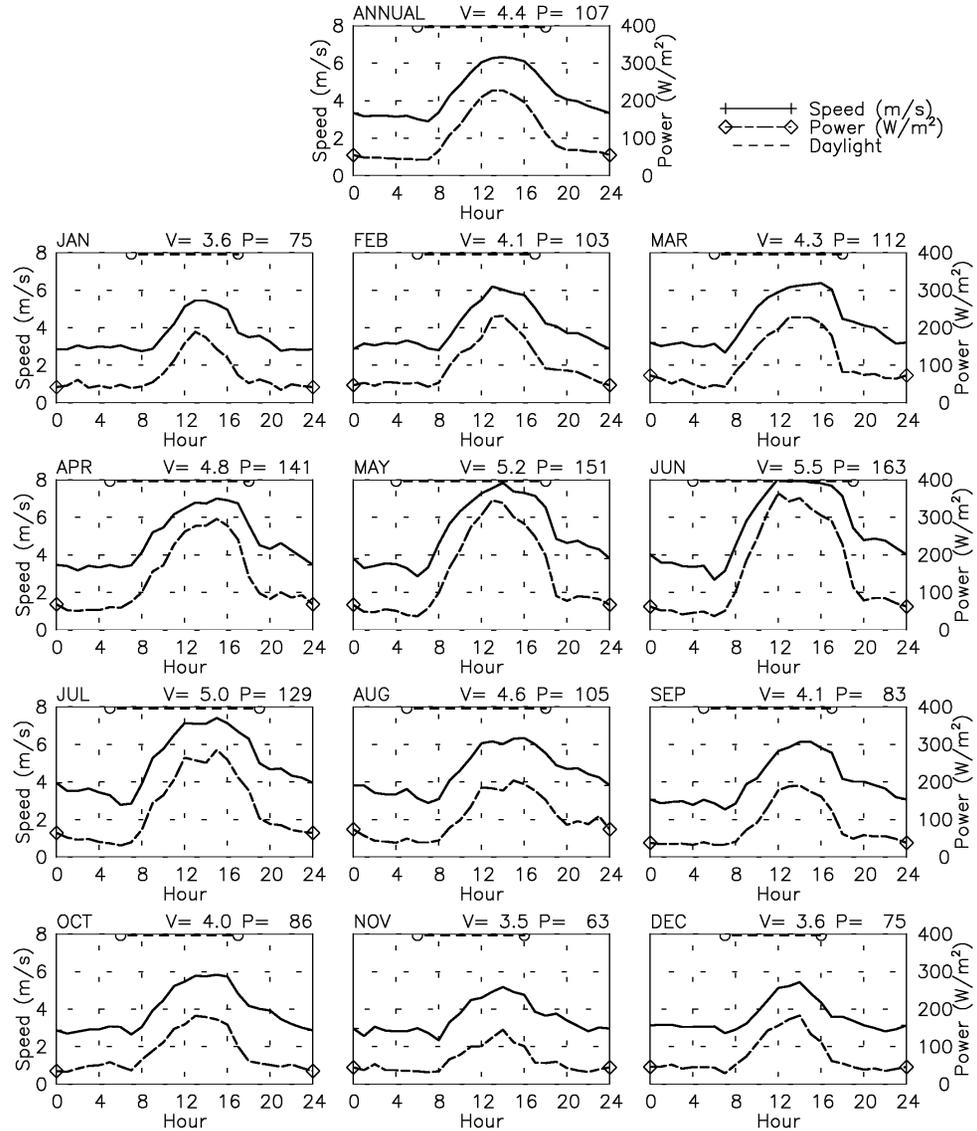
WINSLOW (AUT) AZ - 723740  
35° 01' N 110° 44' W - Elev 1488m \*LST=GMT -7 hours NT= -7  
01/96-12/01





# SPEED AND POWER BY HOUR

KINGMAN (AMOS) & AZ - 723700  
35° 16' N 113° 57' W - Elev 1033m LST=GMT+99 hours \*NT= -8  
01/96-12/01

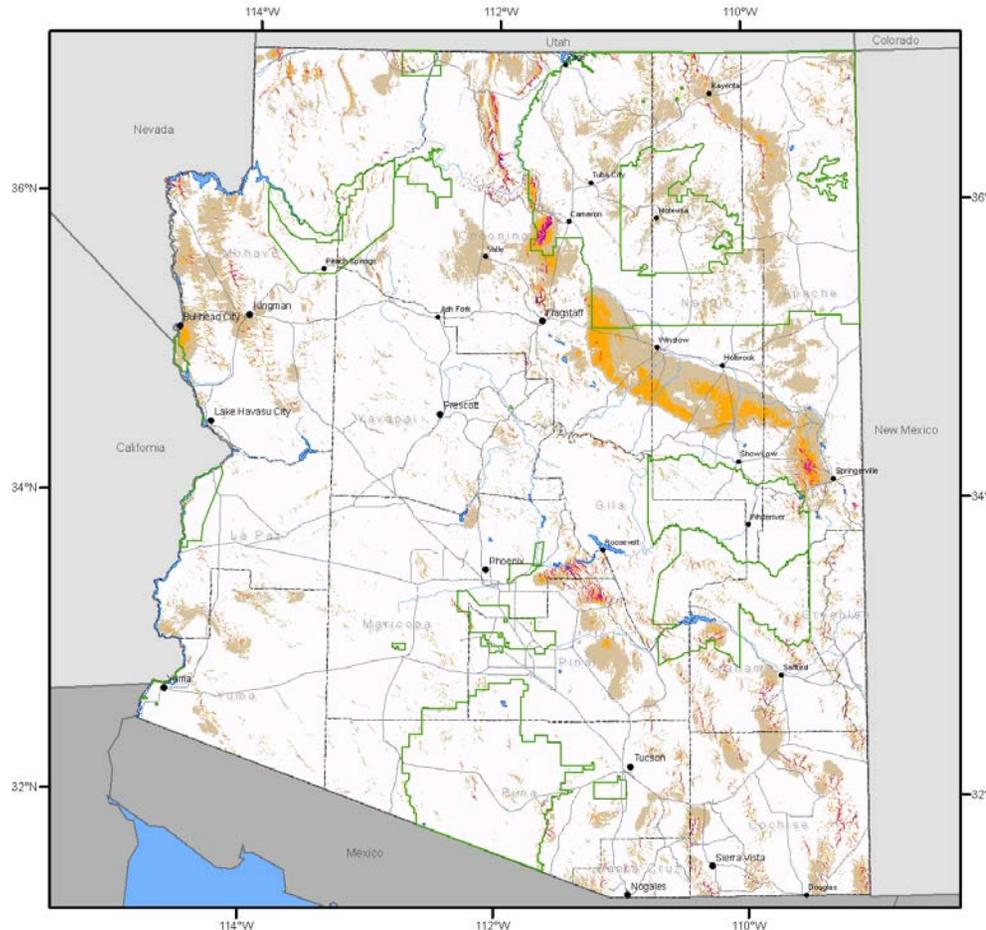


# State of Arizona

## Average Annual Wind Resource 164 ft (50m)



*Sustainable  
Energy  
Solutions*



Created by: Grant Brummels  
Date of Creation: 7/6/2005  
For more information contact:  
Dr. Earl Duque  
Earl.Duque@nau.edu

Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

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Energy Solutions**  
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### Wind Power Classification

Wind Power Class	Wind Power Density ( $W/m^2$ )	Wind Speed (mph)
1 Poor	0 - 200	0.0 - 12.3
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6 Outstanding	600 - 800	17.9 - 19.7
7 Superb	> 800	> 19.7

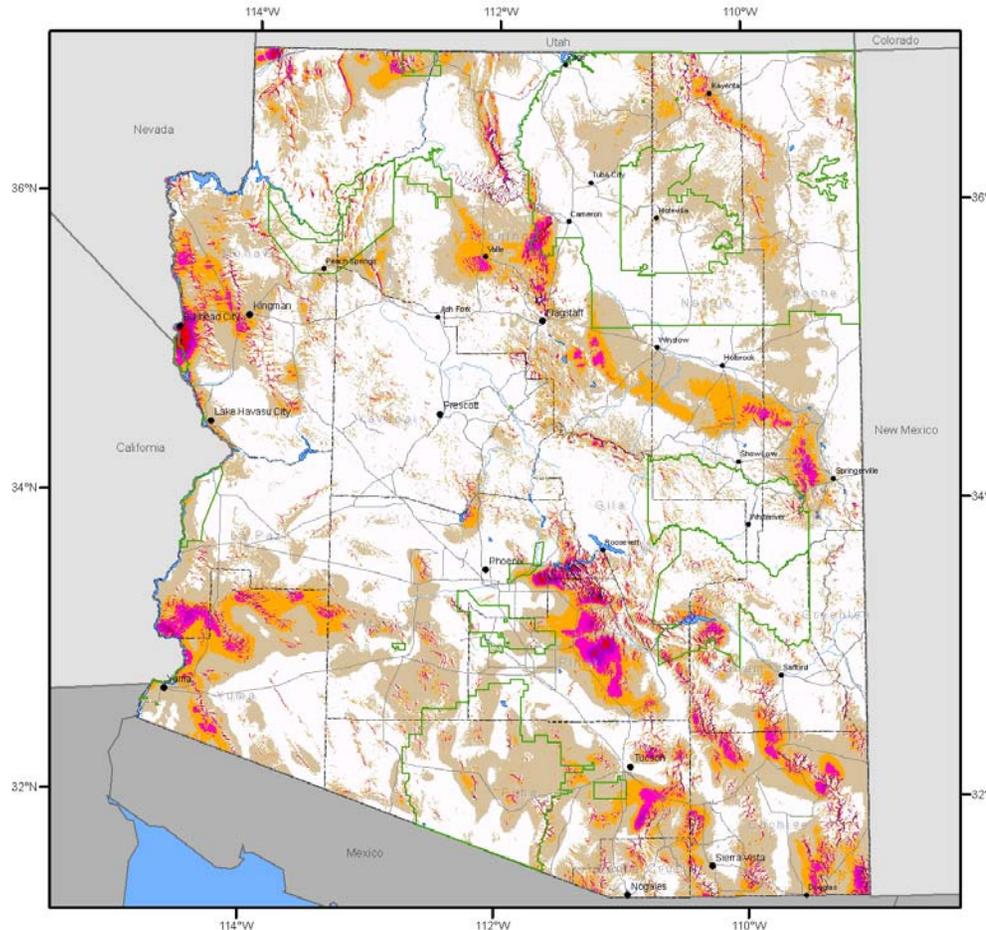
### Legend

- County Boundary
- Indian Reservation
- Rivers and Water Bodies
- Major Roads



# State of Arizona

## January Wind Resource 164 ft (50m)



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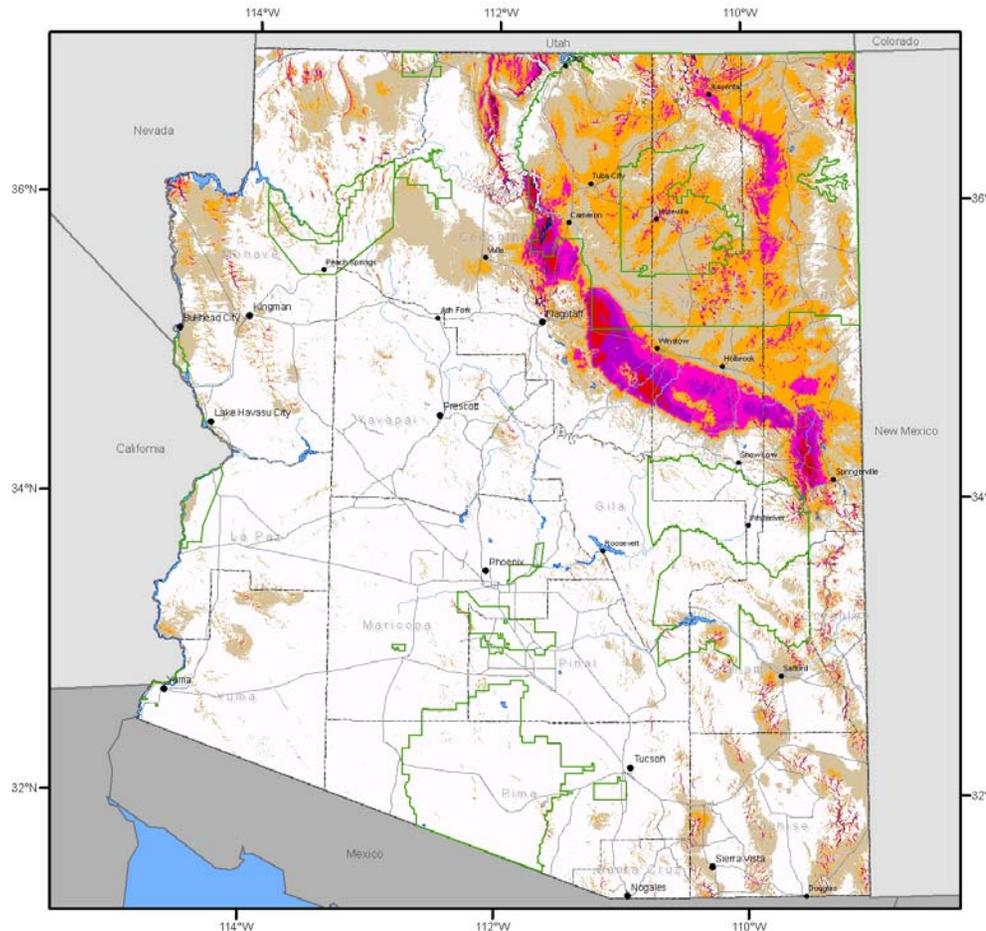


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## April Wind Resource 164 ft (50m)



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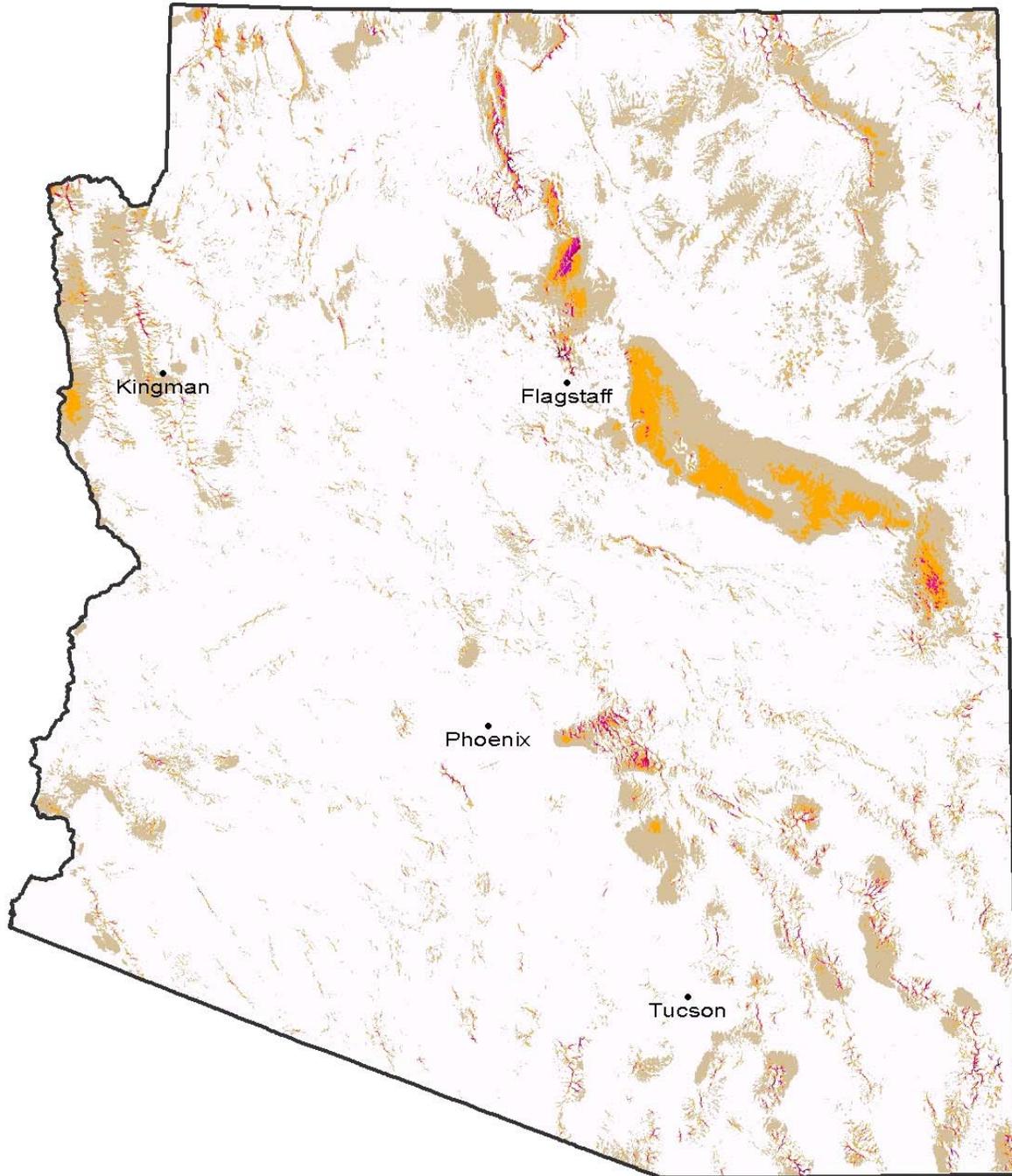
### Wind Power Classification

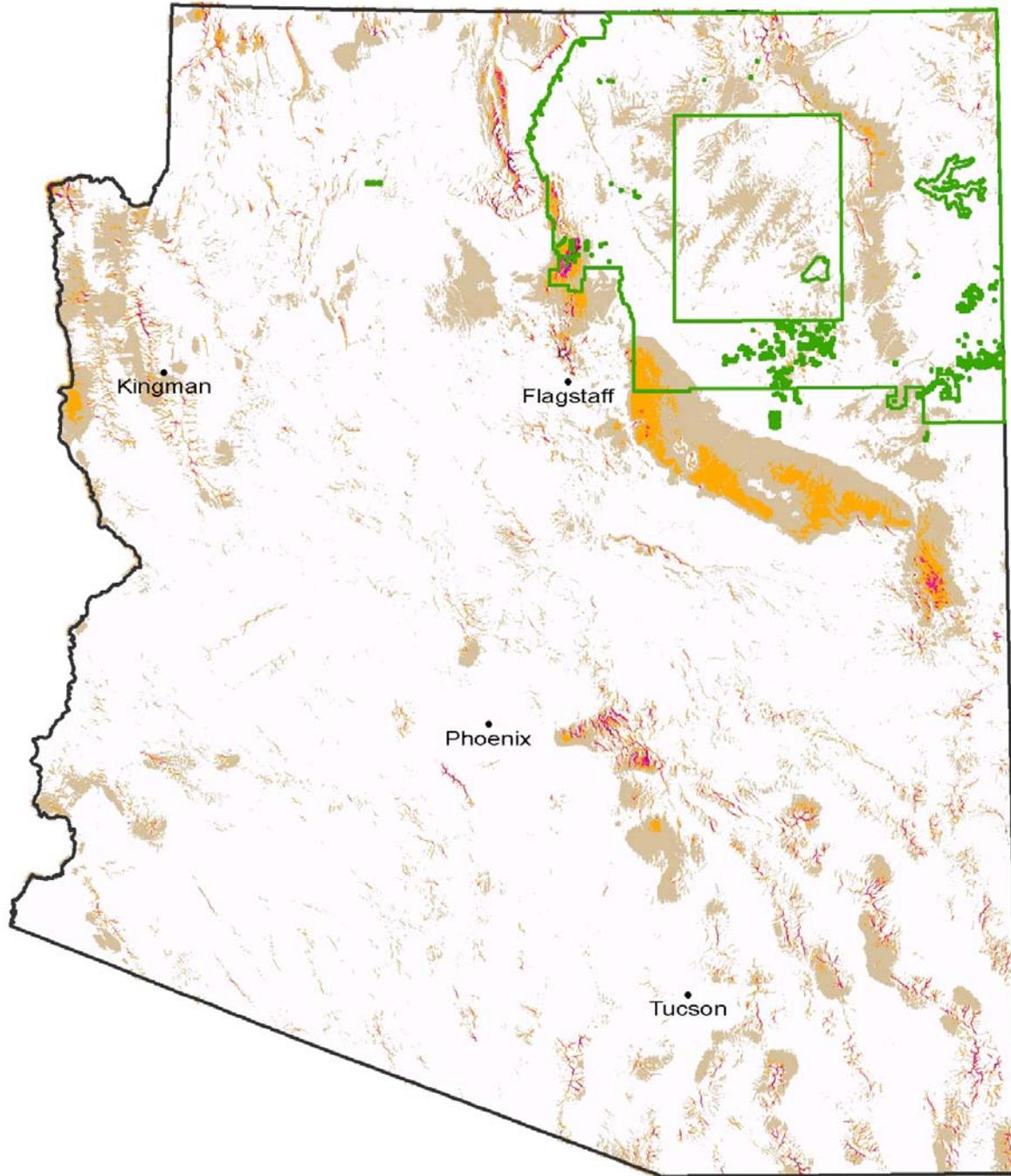
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### Legend

- County Boundary
- Indian Reservation
- Rivers and Water Bodies
- Major Roads







# Windy Land Exclusions

- National Park Service
  - Fish and Wildlife Service
  - Specially Designated Areas
  - Inventoried Roadless Areas
  - Sensitive Environmental lands
  - Airports
  - Urban/Developed Land (30m ReGAP)
- 3km buffer

- Wetlands (30m ReGAP)
- 100m buffer

- Open Water (30m ReGAP)
  - Slopes > 20% (90m Digital Elevation Model)
- NO buffer

# Non-ridge Crest Forest Exclusion (50%)

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**Non-ridge Crest forest exclusion was generated from 30m satellite data (USGS ReGAP, 2003).**

# Navajo Woodland Comparison

## within Arizona

Navajo Reservation  
Boundary includes:  
-Navajo National Monuments  
-Navajo Trust Land  
-Navajo-Hopi Joint Use Areas

### Legend

-  Major Roads
-  Pinyon-Juniper Woodland
-  Woodlands - Excluded 50%  
Does not include  
Pinyon-Juniper Woodland

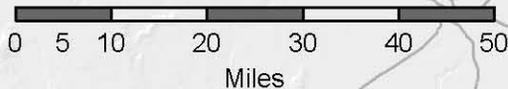
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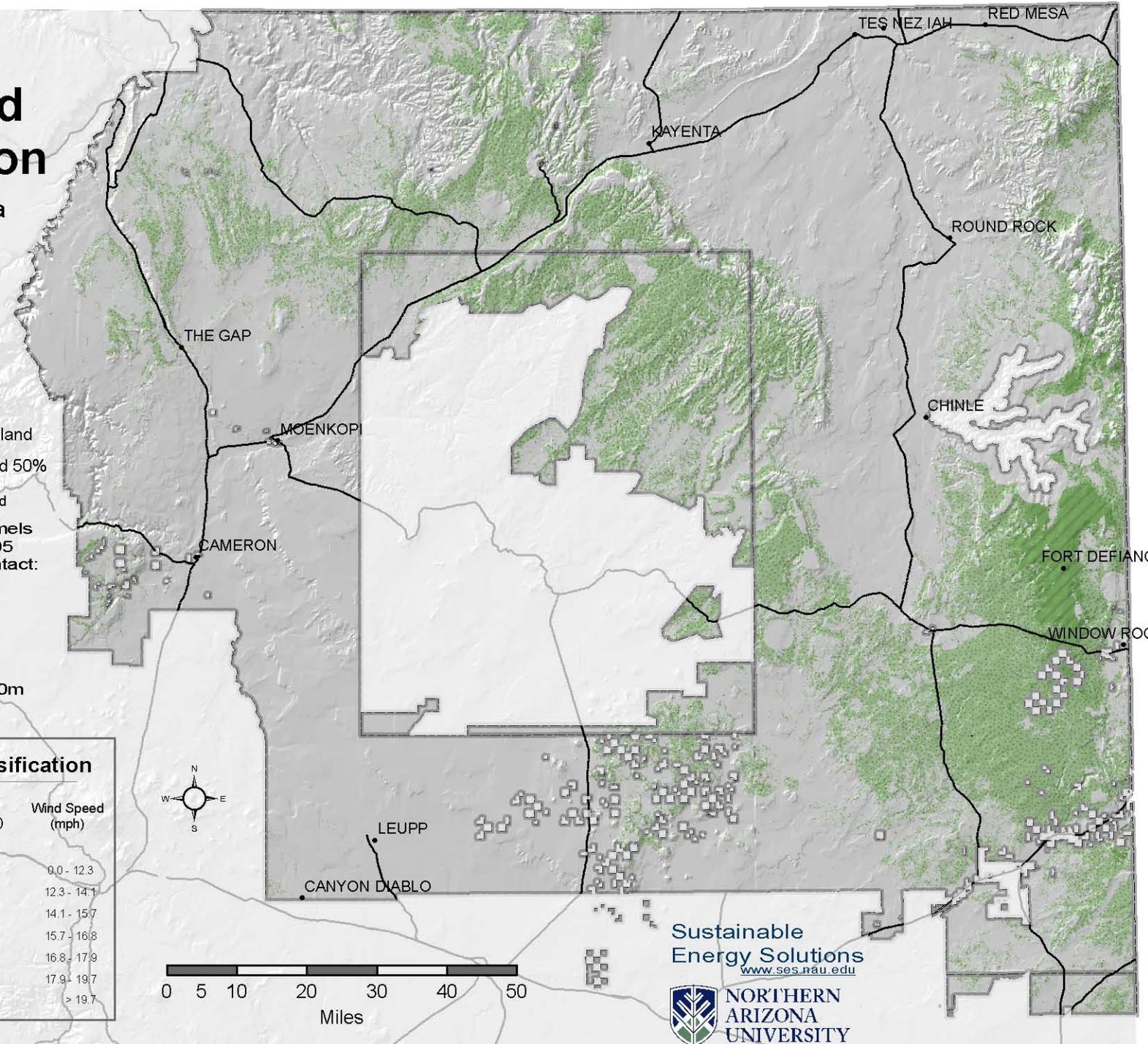
Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

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# **Non-ridge Crest Forest Exclusion (50%)**

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**Non-ridge Crest forest exclusion was generated from 30m satellite data (USGS ReGAP, 2003).**

**It was determined that of the areas considered ‘Woodland’ by the satellite data, over 90% of those areas were Pinyon-Juniper Woodland.**

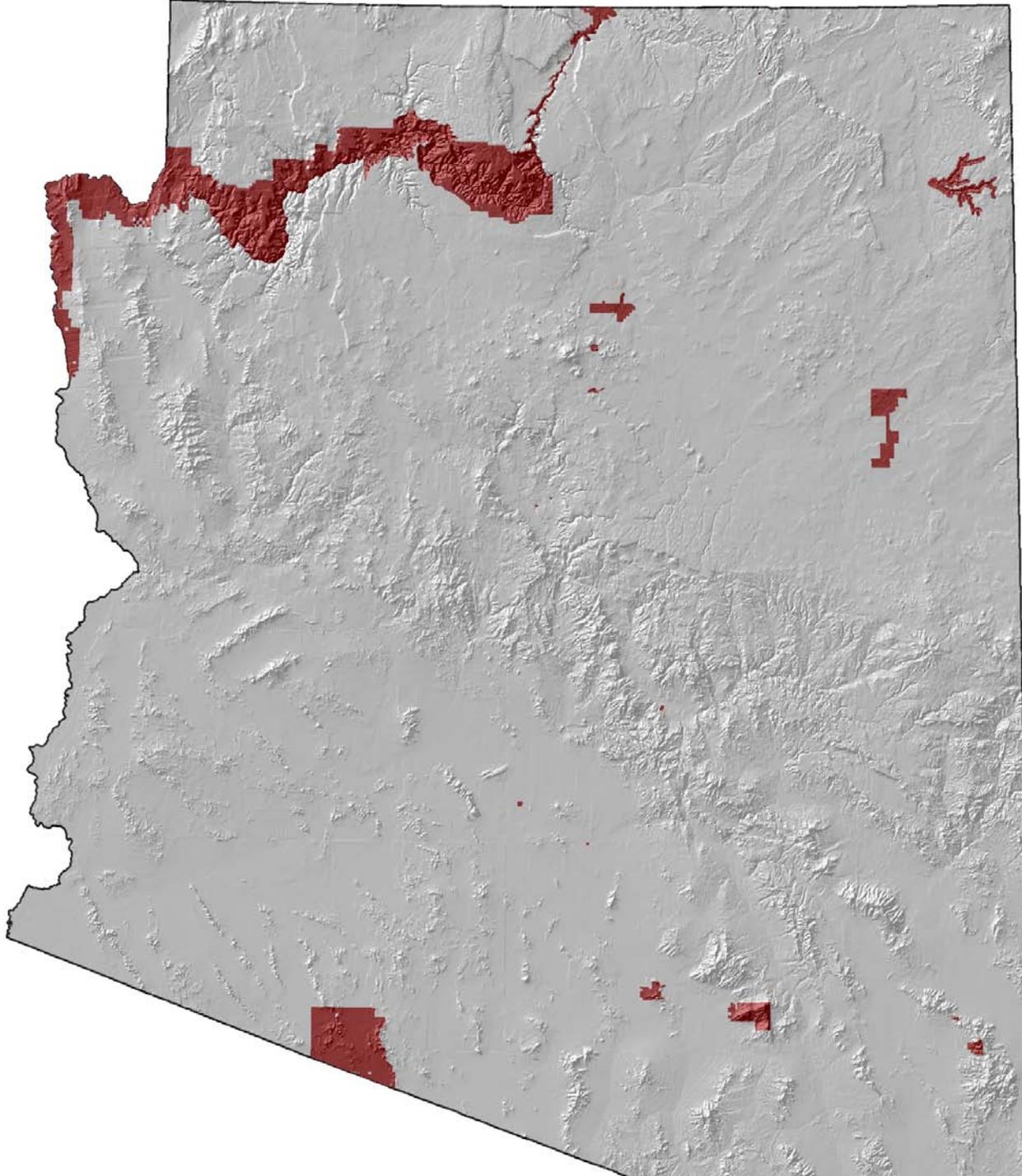
**Pinyon-Juniper woodland is not the same as Ponderosa Woodland or other woodlands with tall canopies. It may have different development potential that allows these areas to be included in developable windy land, *not* excluded by 50%.**

**We chose to include Pinyon-Juniper Woodland as Developable Windy Land.**

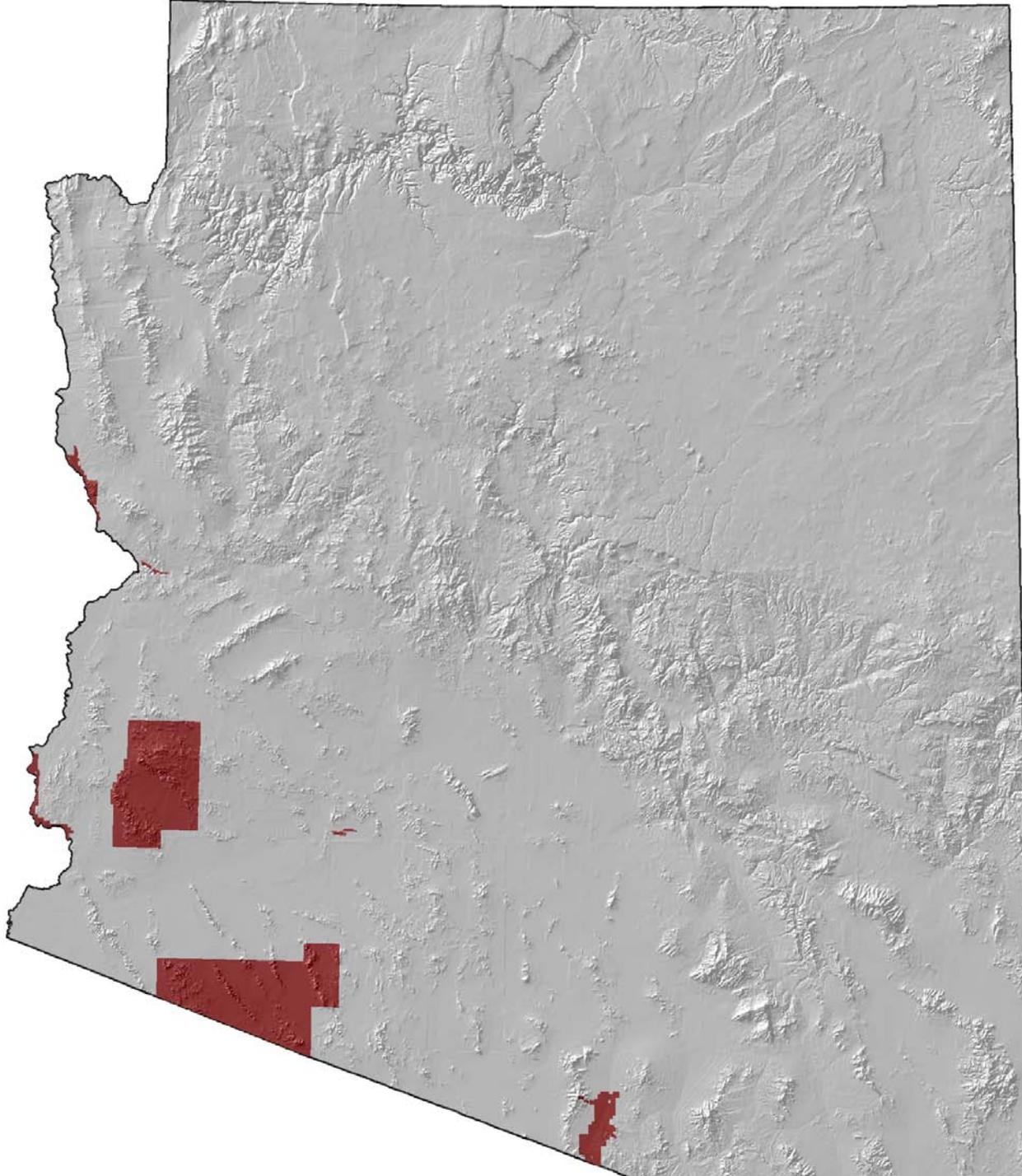


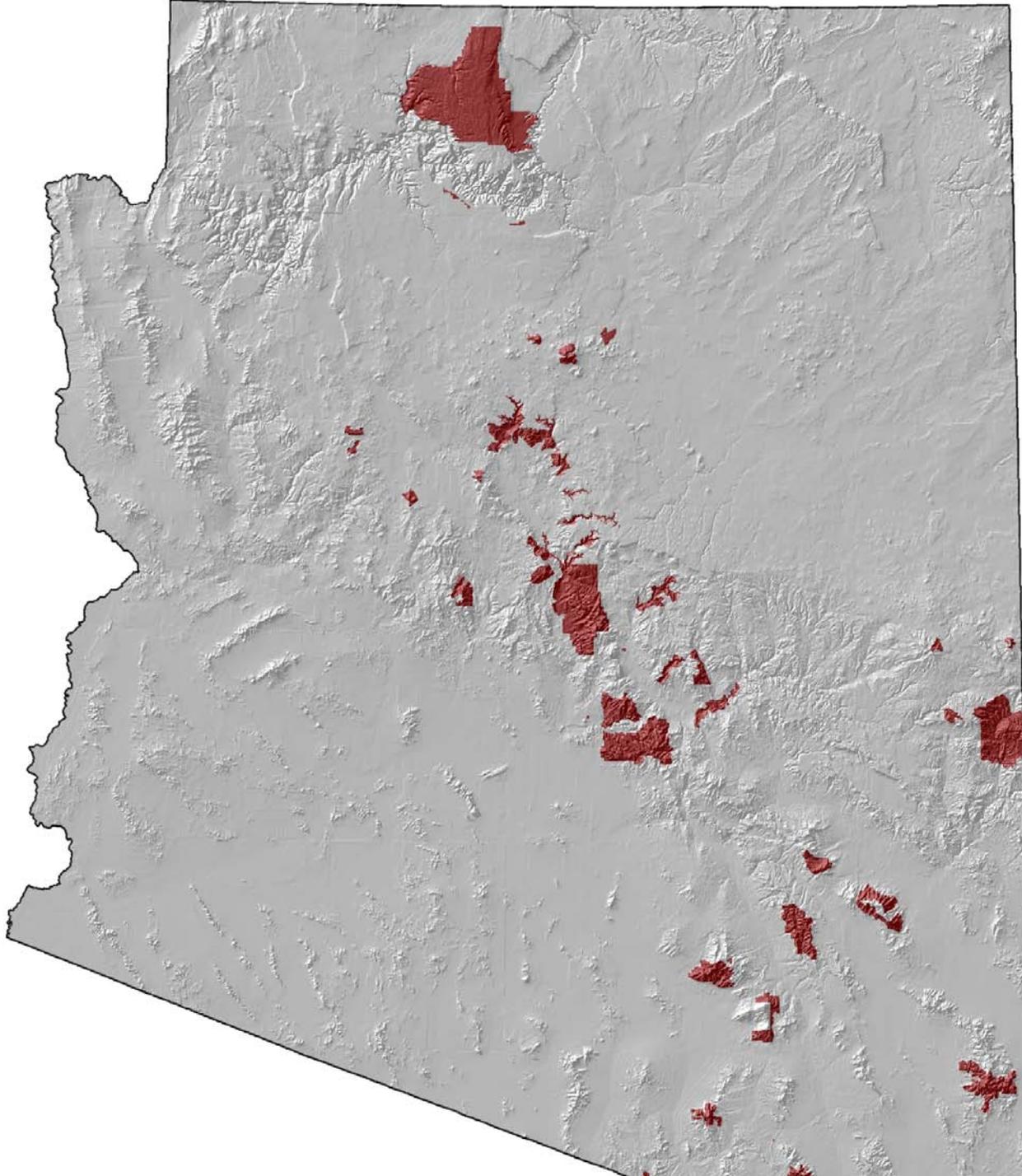
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**National  
Park  
Service**



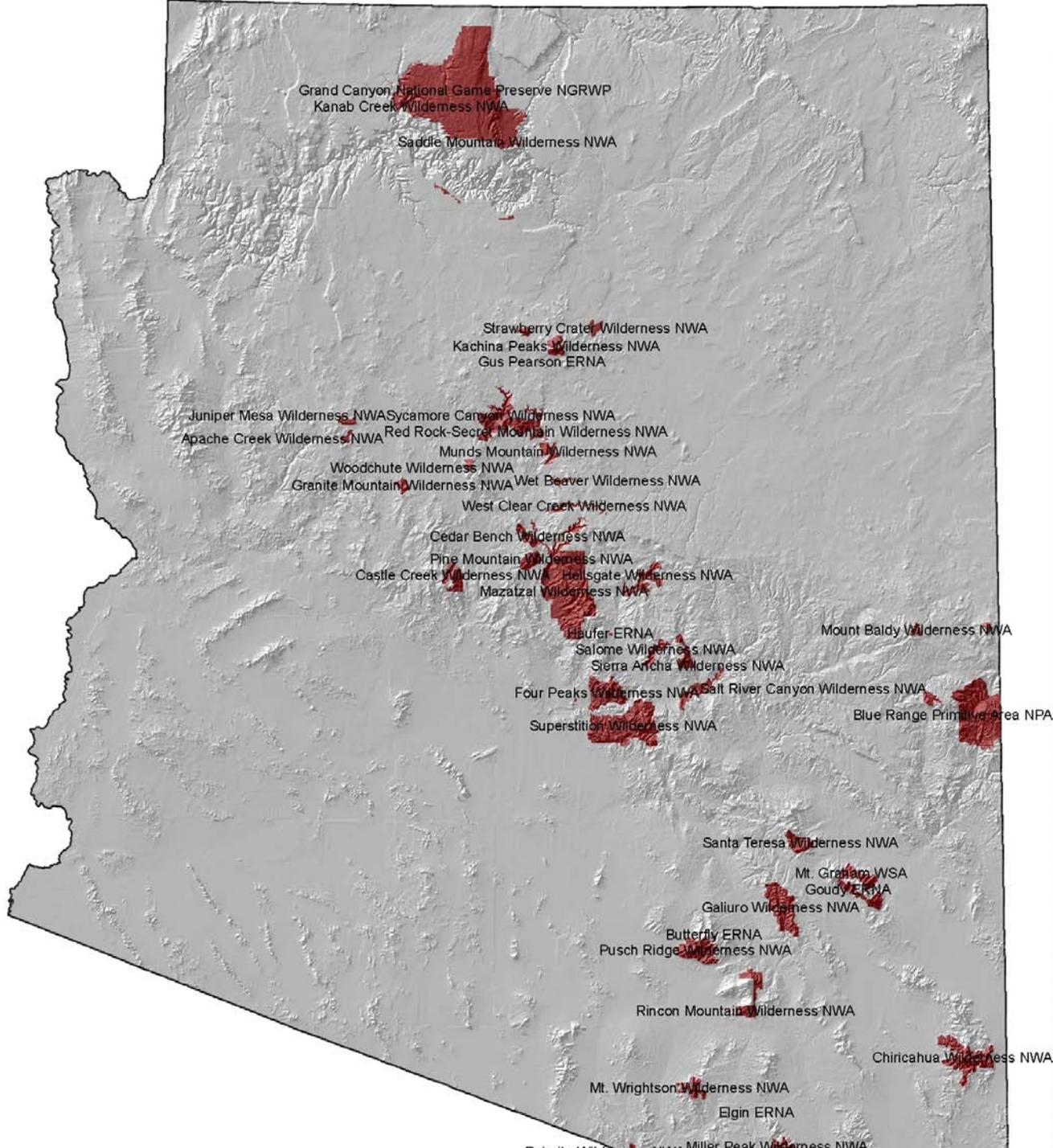
# Fish and Wildlife

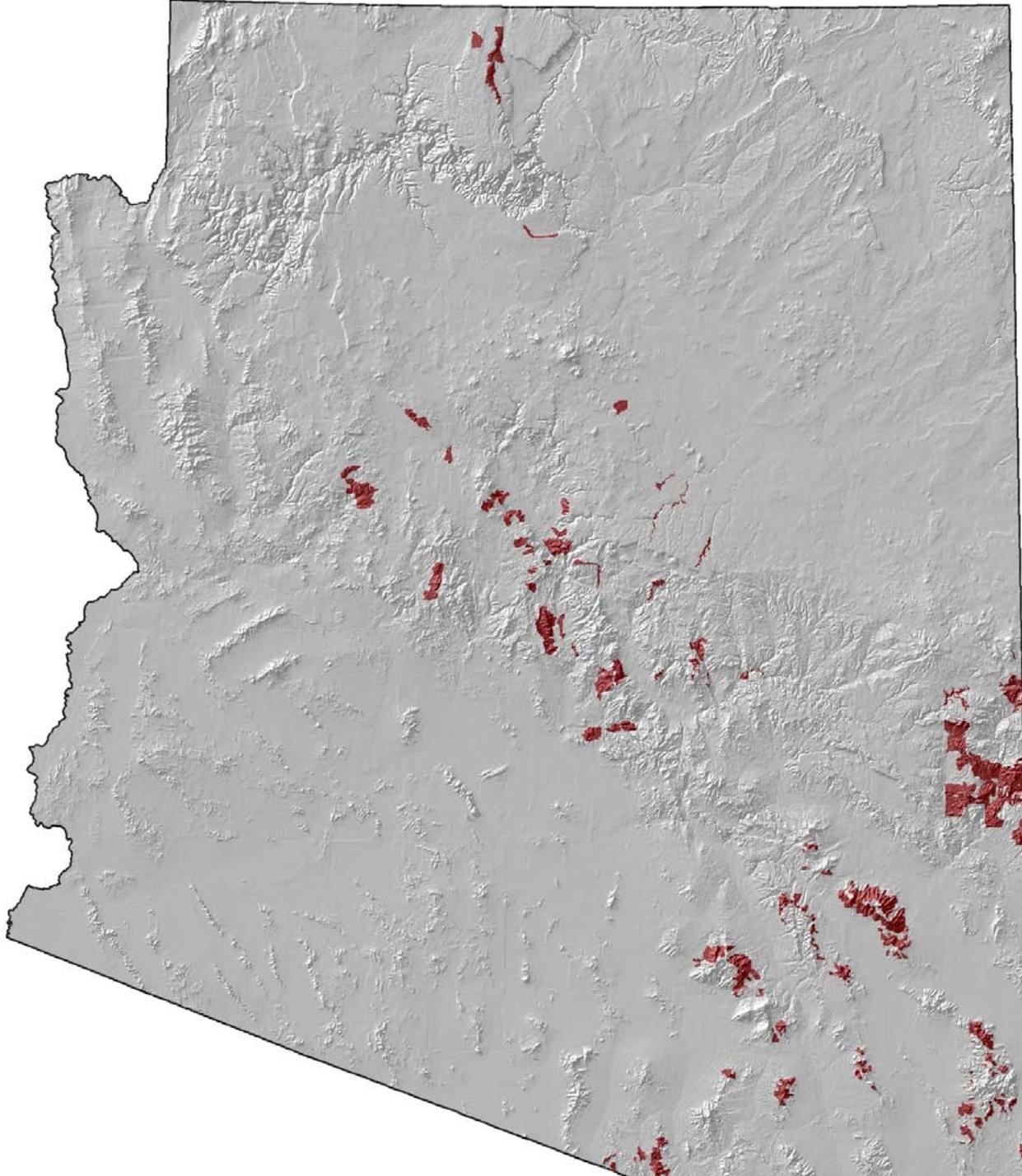




## **Specially Designated Areas**

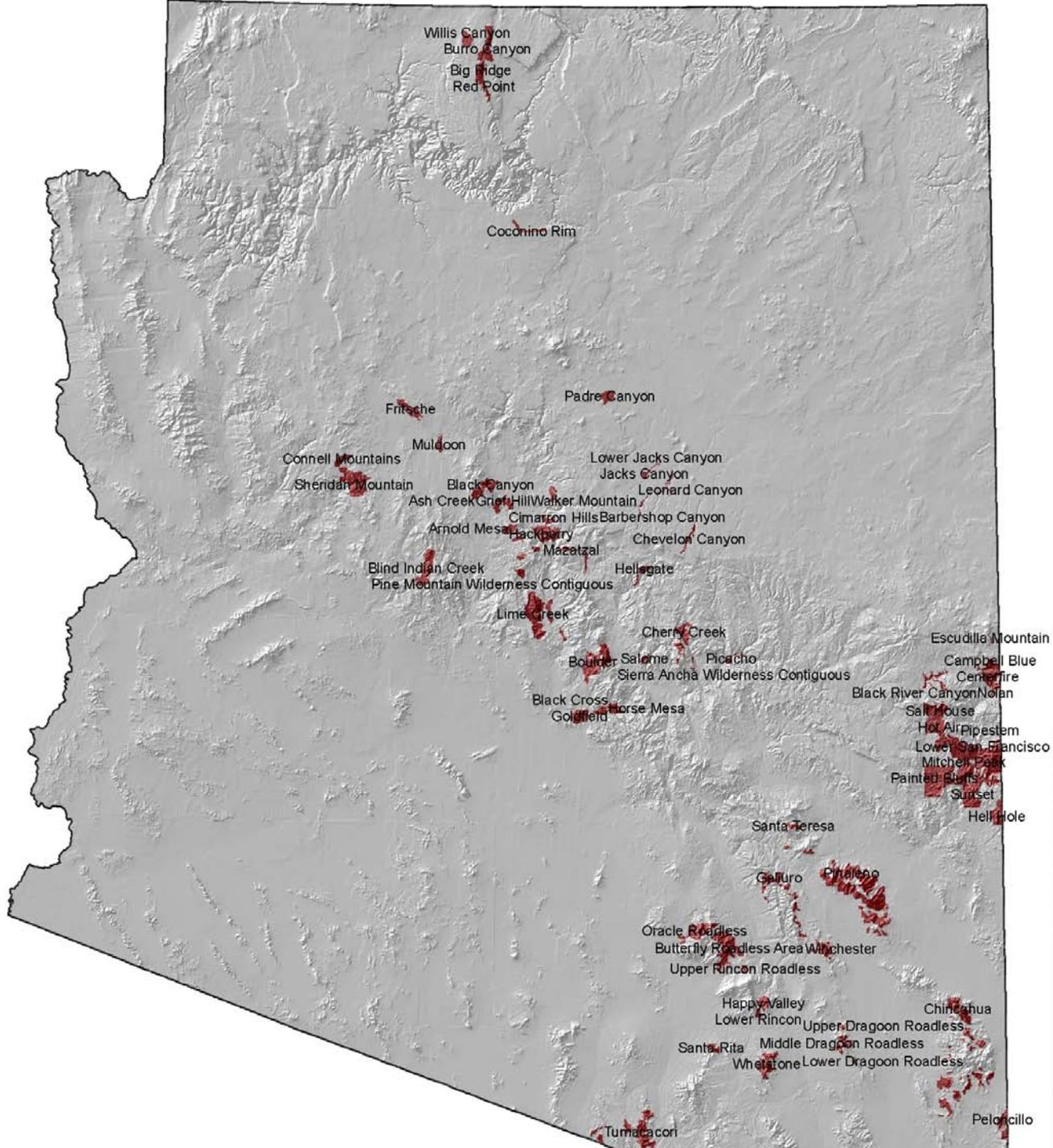
## Specially Designated Areas

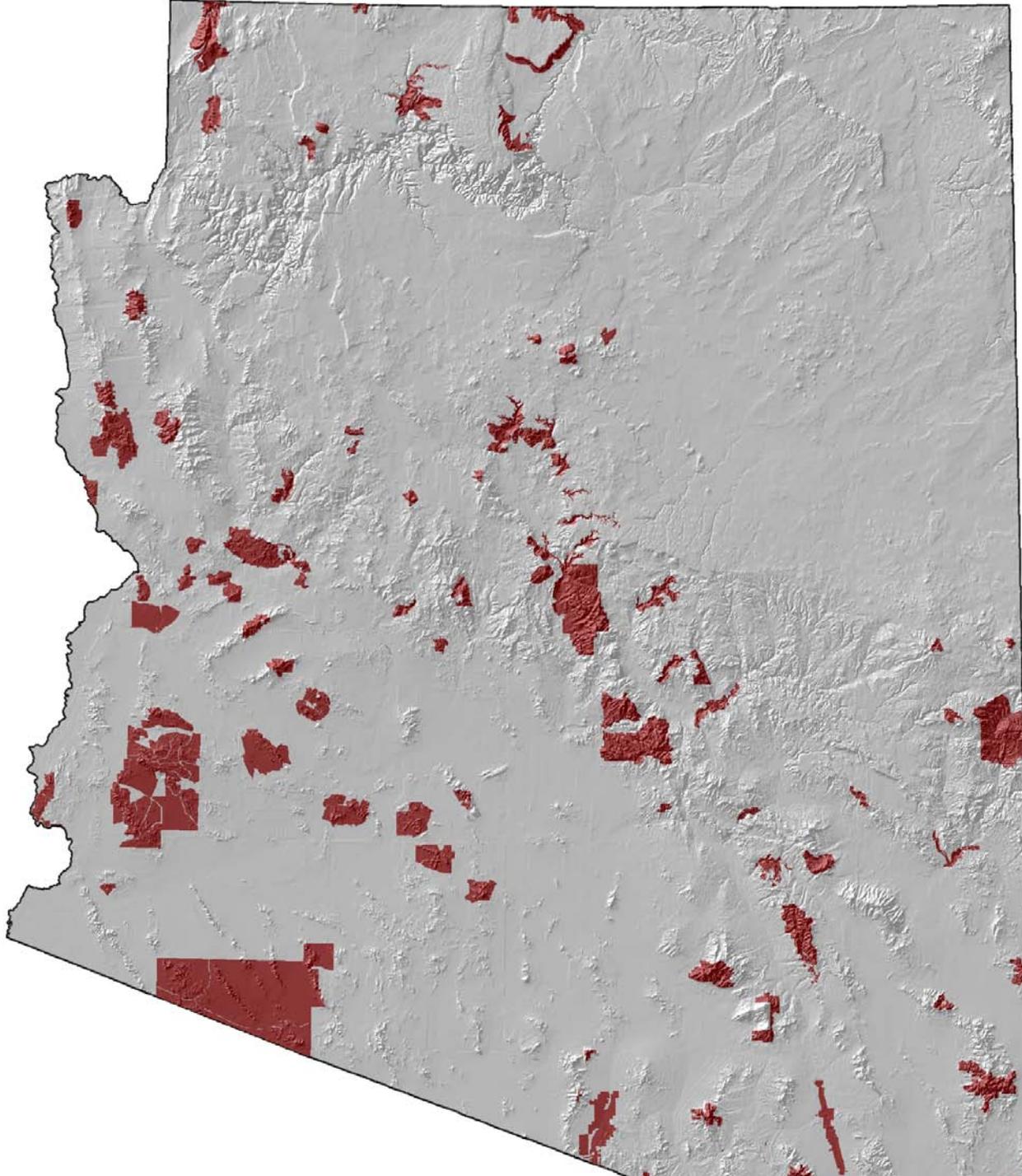




## **Inventoried Roadless Areas**

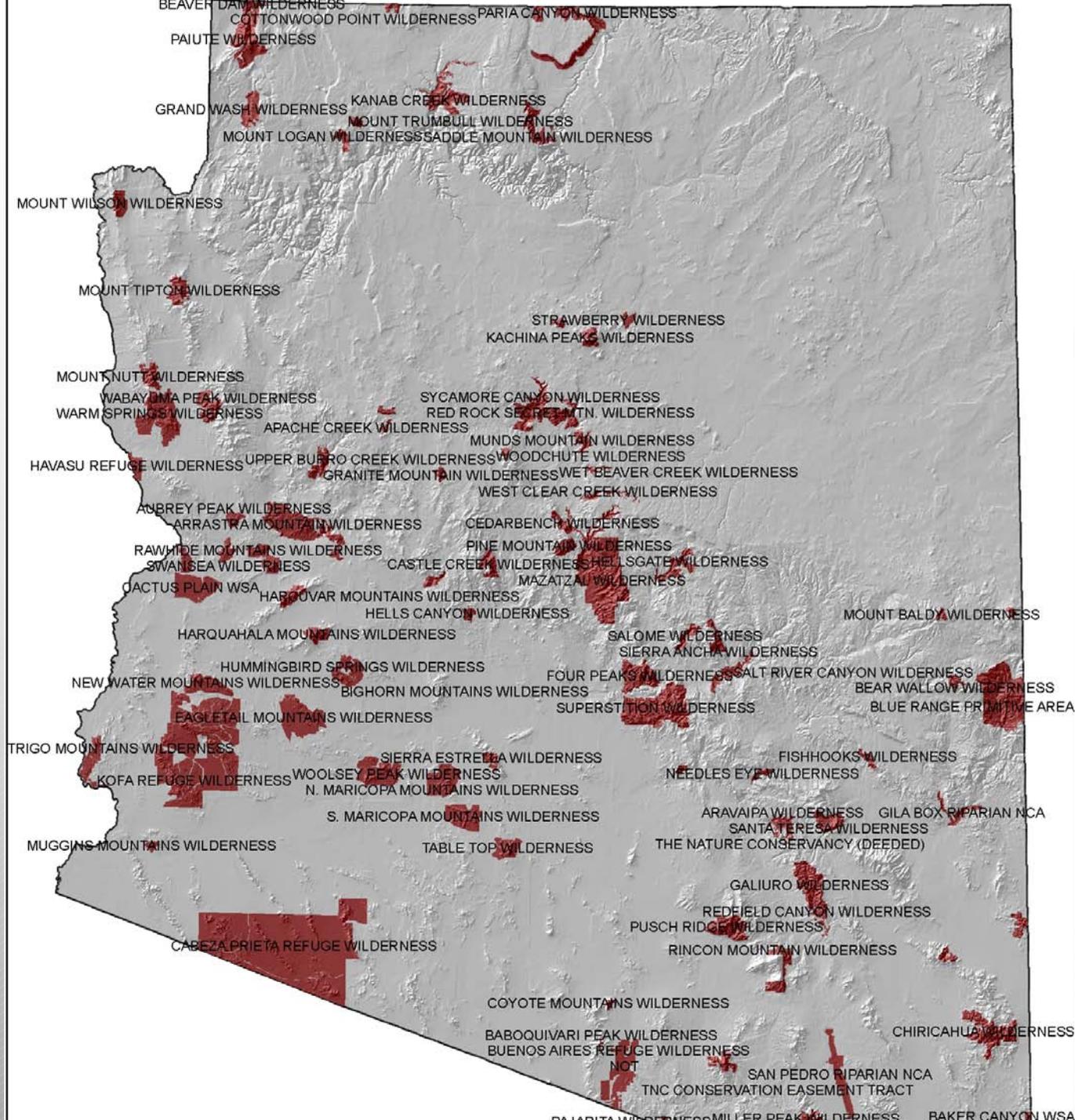
# Inventoried Roadless Areas

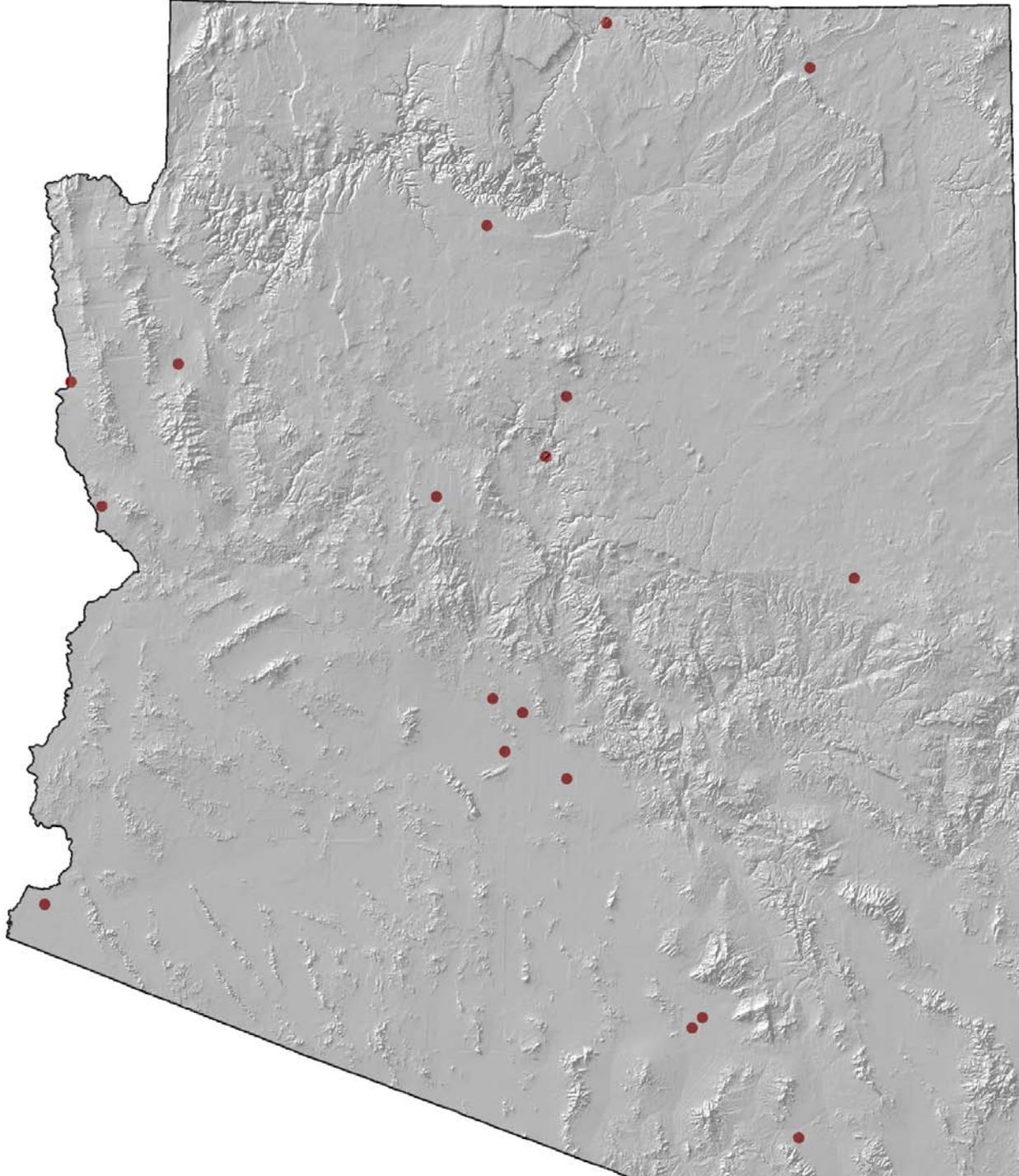




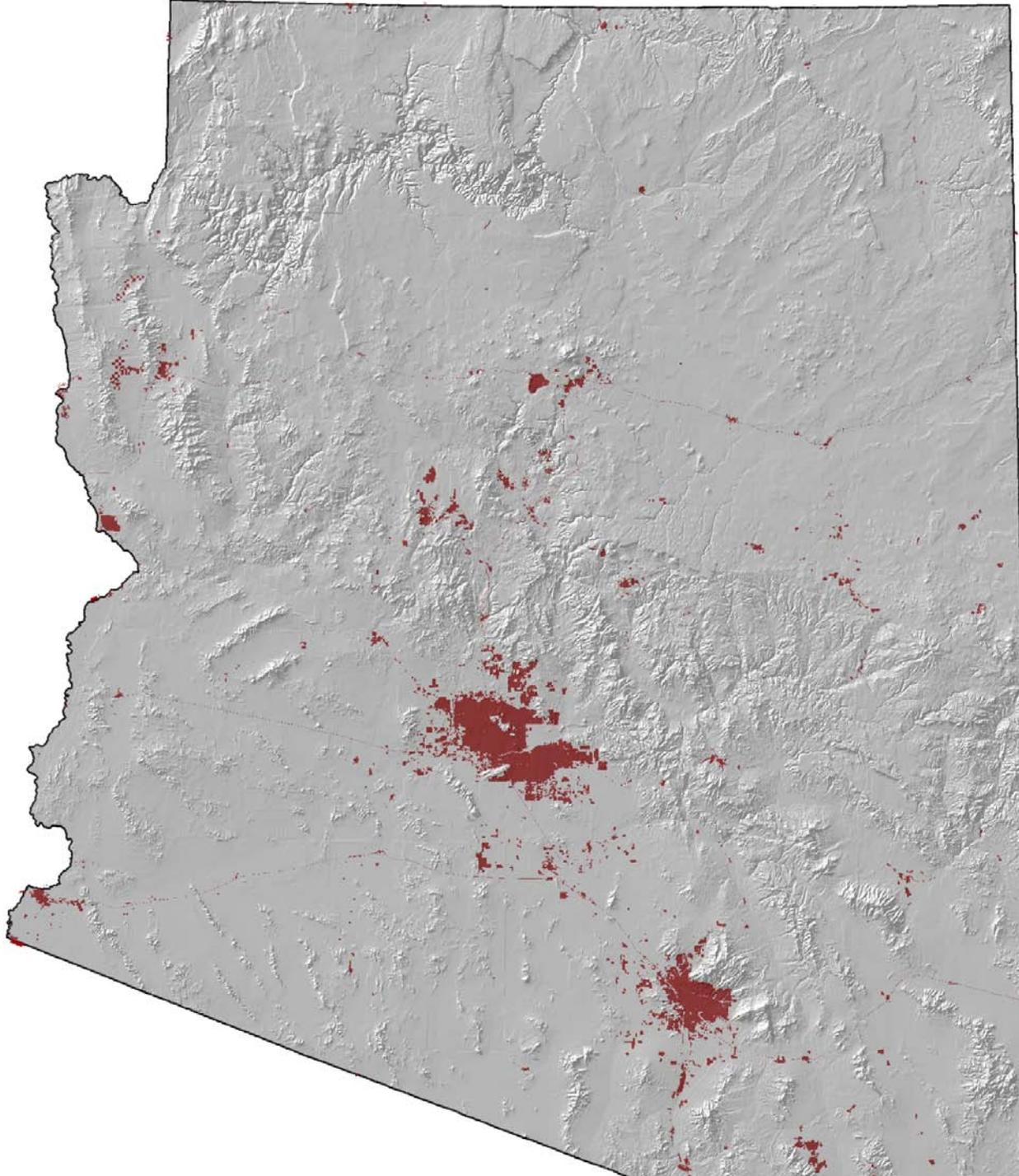
## **Sensitive Environmental Lands**

# Sensitive Environmental Lands



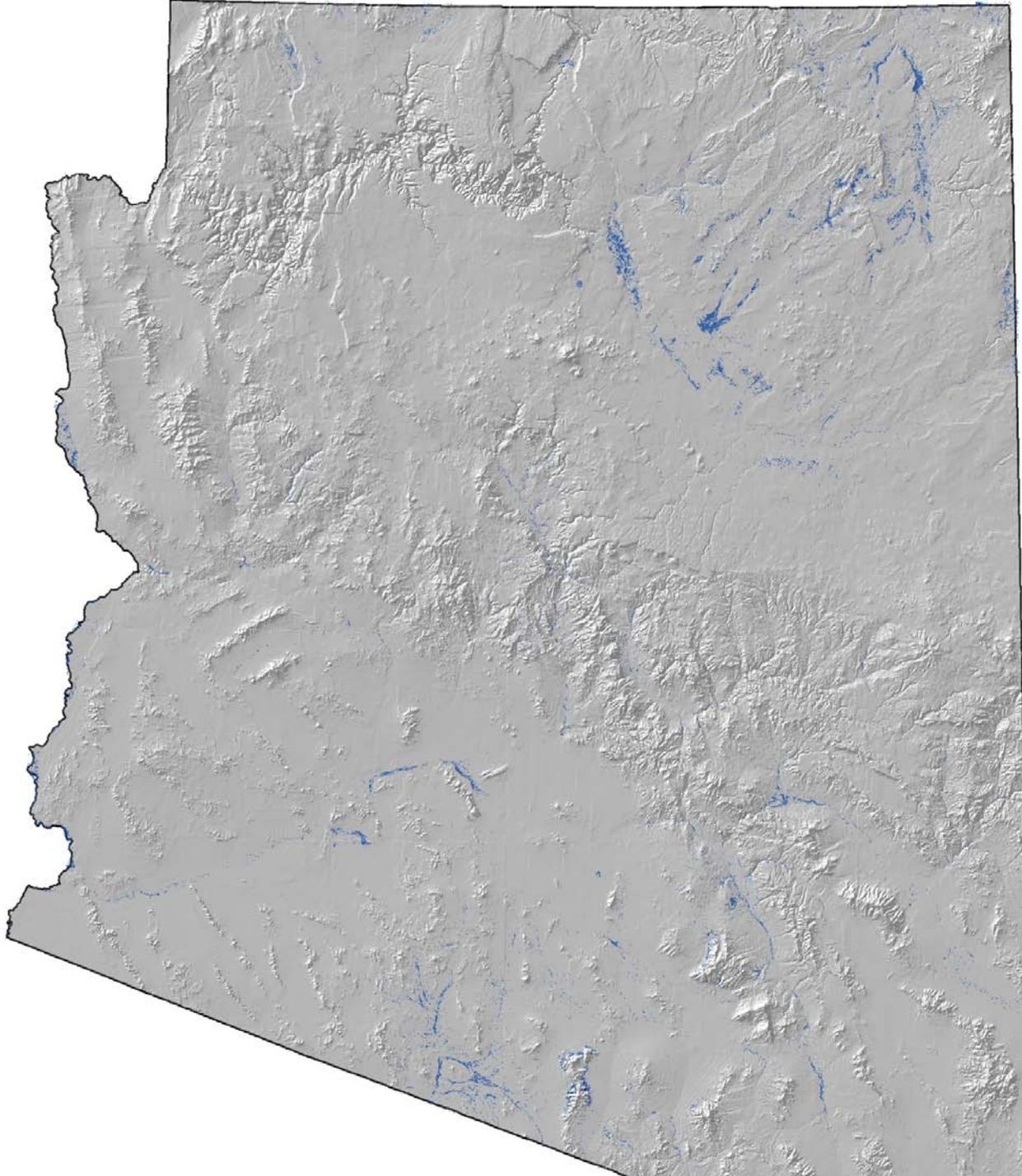


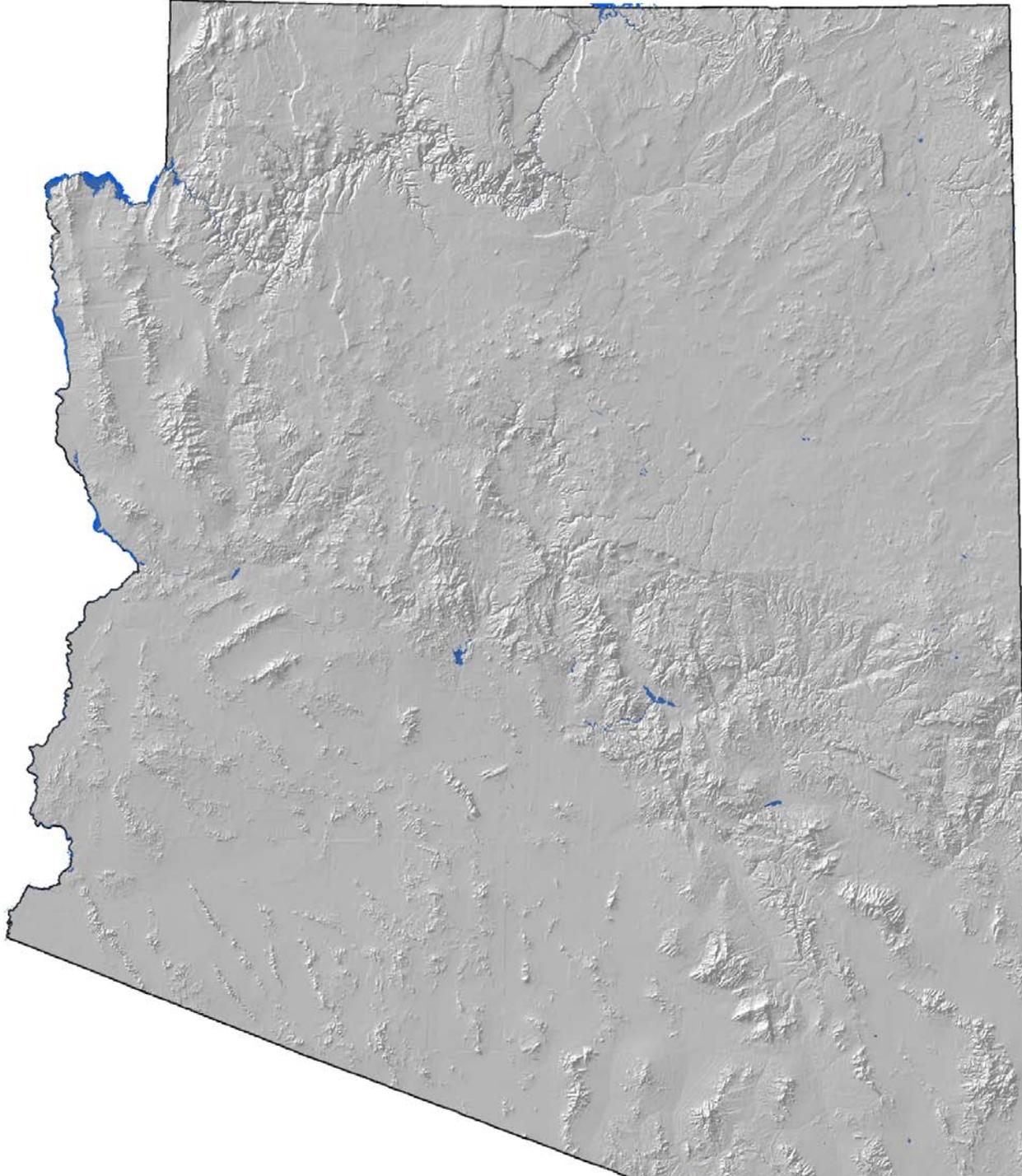
## Airports



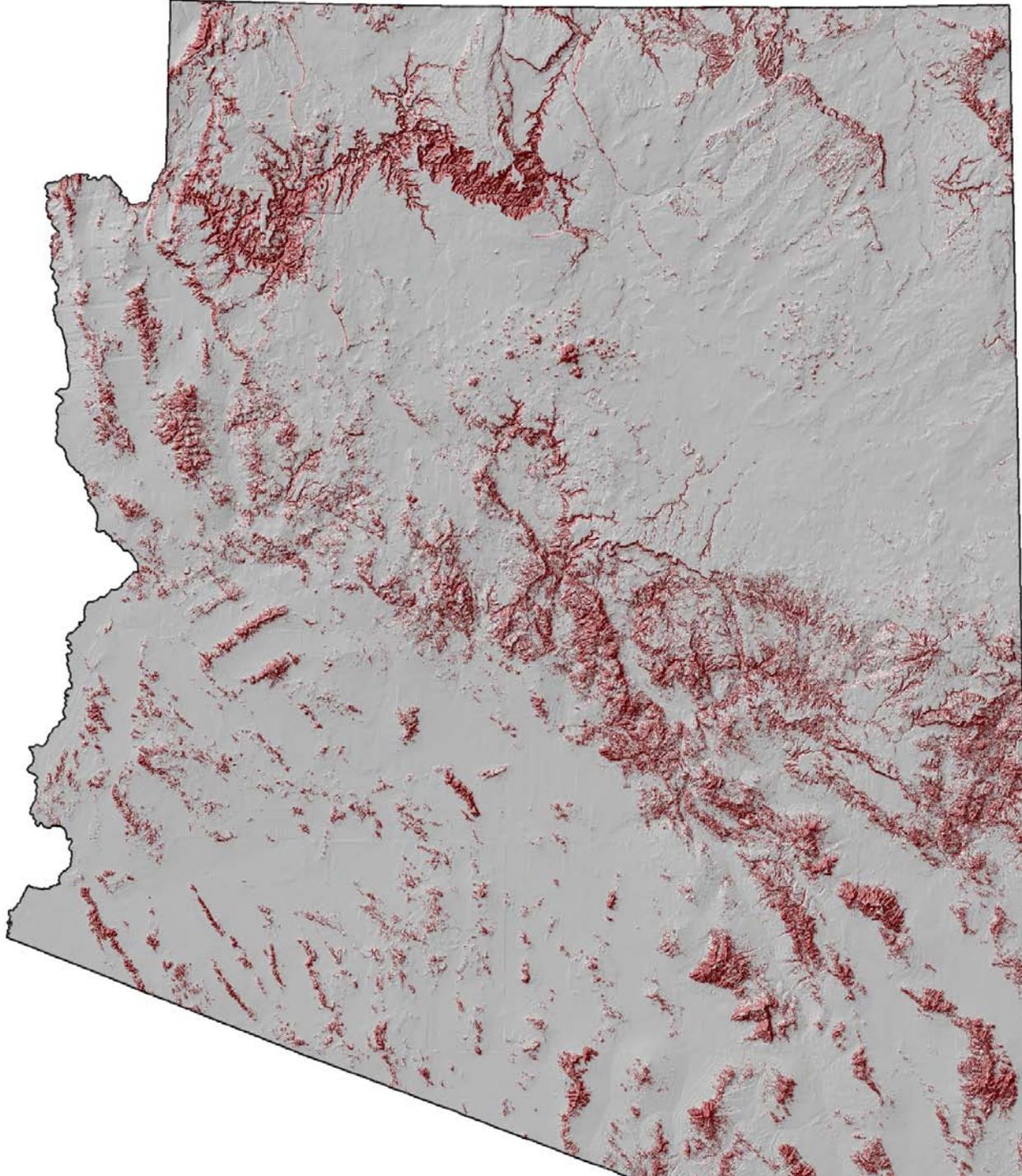
**Urban /  
Developed  
Land**

## Wetlands

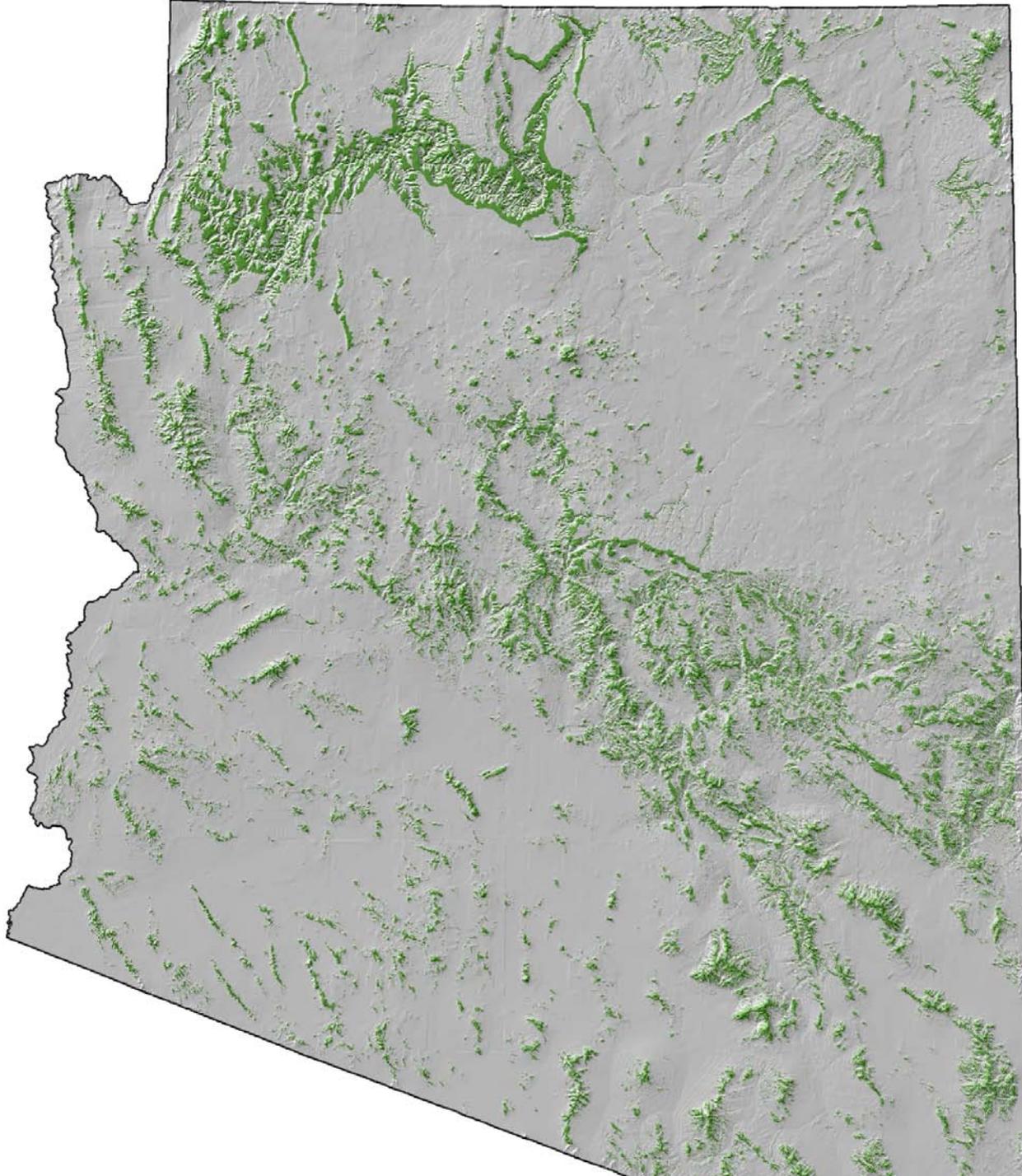




## Open Water



**Slopes  
>20%**



## Ridge crests



## **Ridge Crests and non-ridge crests**

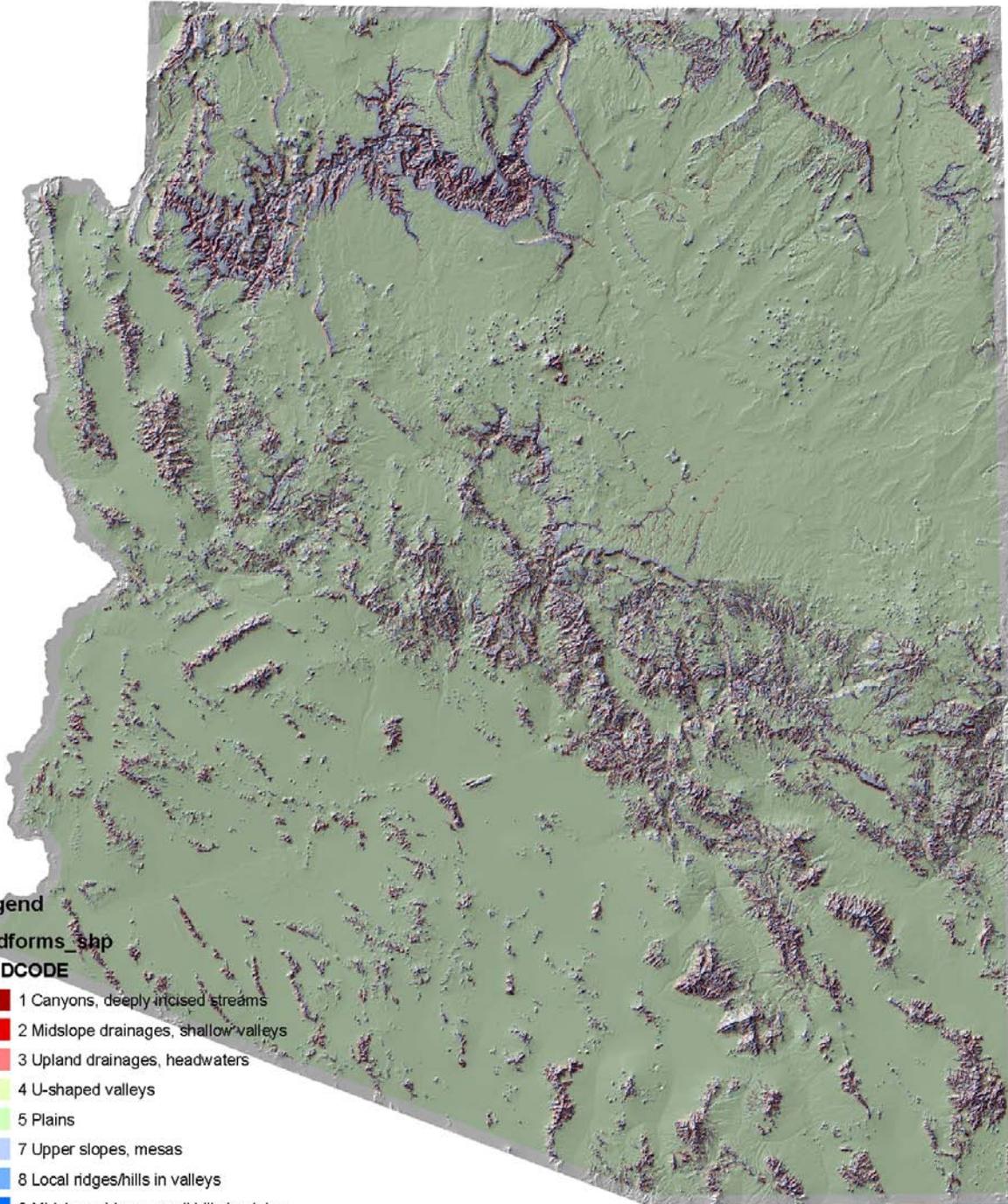
# TPI Topographic Position Index

## Legend

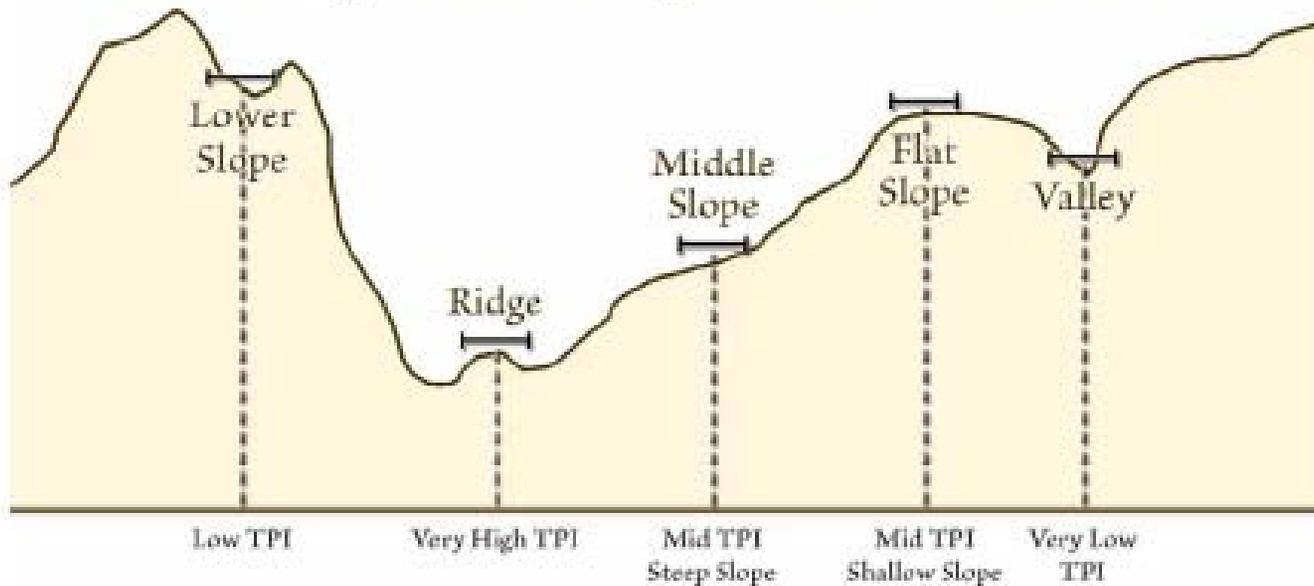
landforms\_shp

GRIDCODE

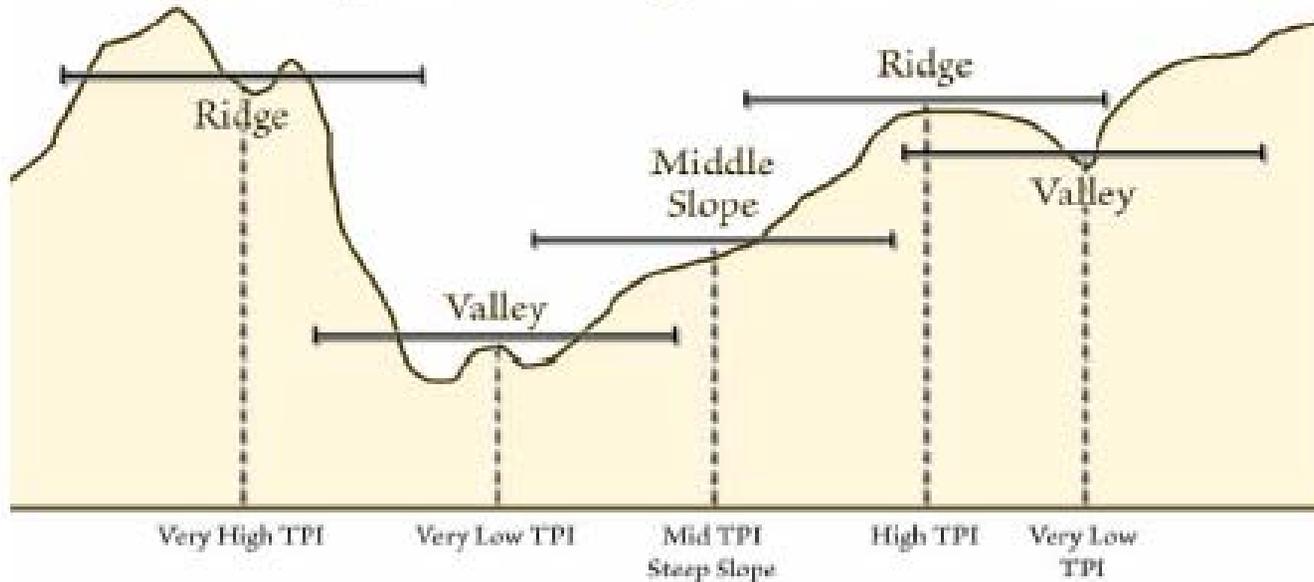
-  1 Canyons, deeply incised streams
-  2 Midslope drainages, shallow valleys
-  3 Upland drainages, headwaters
-  4 U-shaped valleys
-  5 Plains
-  7 Upper slopes, mesas
-  8 Local ridges/hills in valleys
-  9 Midslope ridges, small hills in plains
-  10 Mountain tops, high ridges



# Small-Neighborhood Slope Position Classification

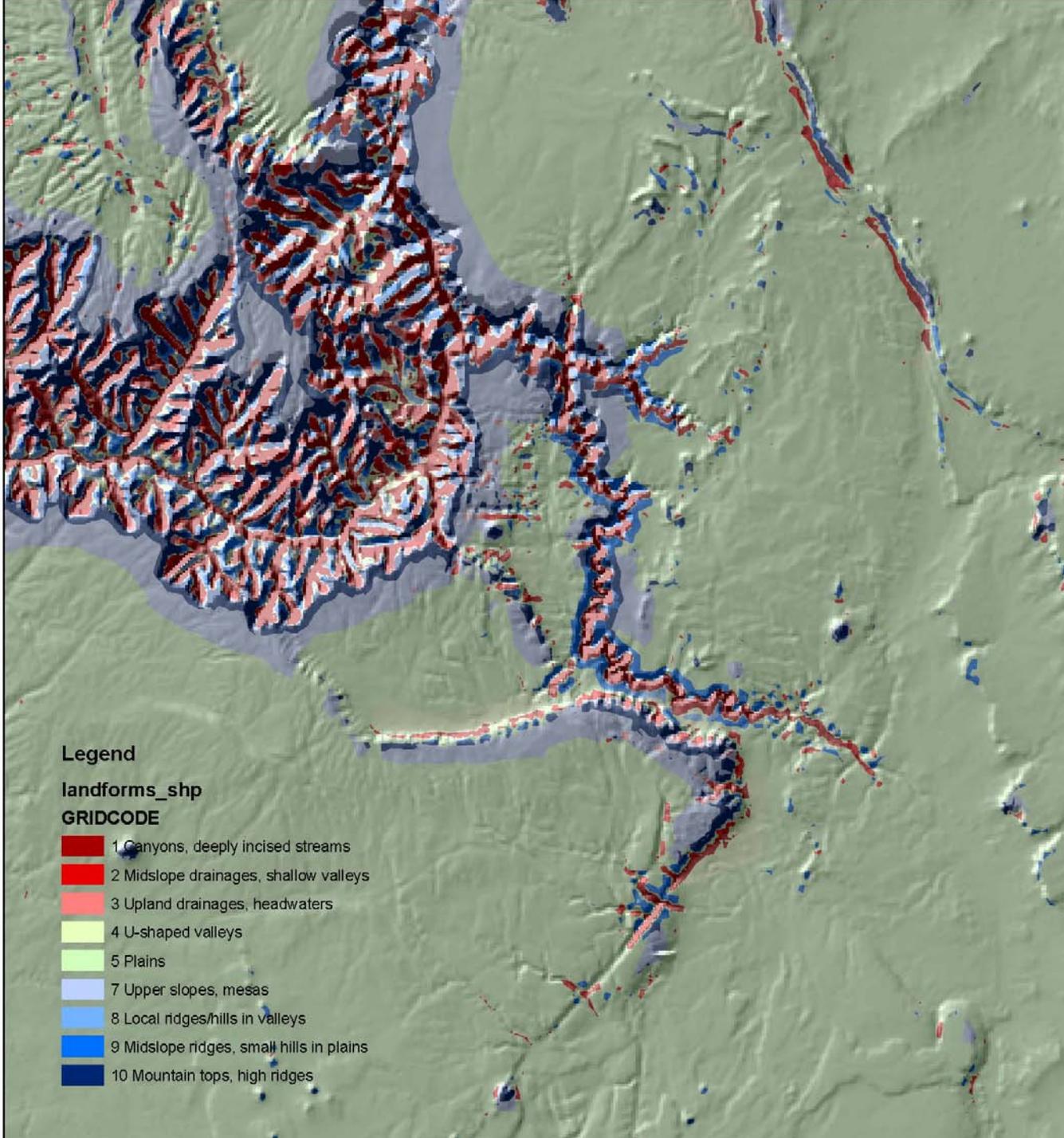


# Large-Neighborhood Slope Position Classification

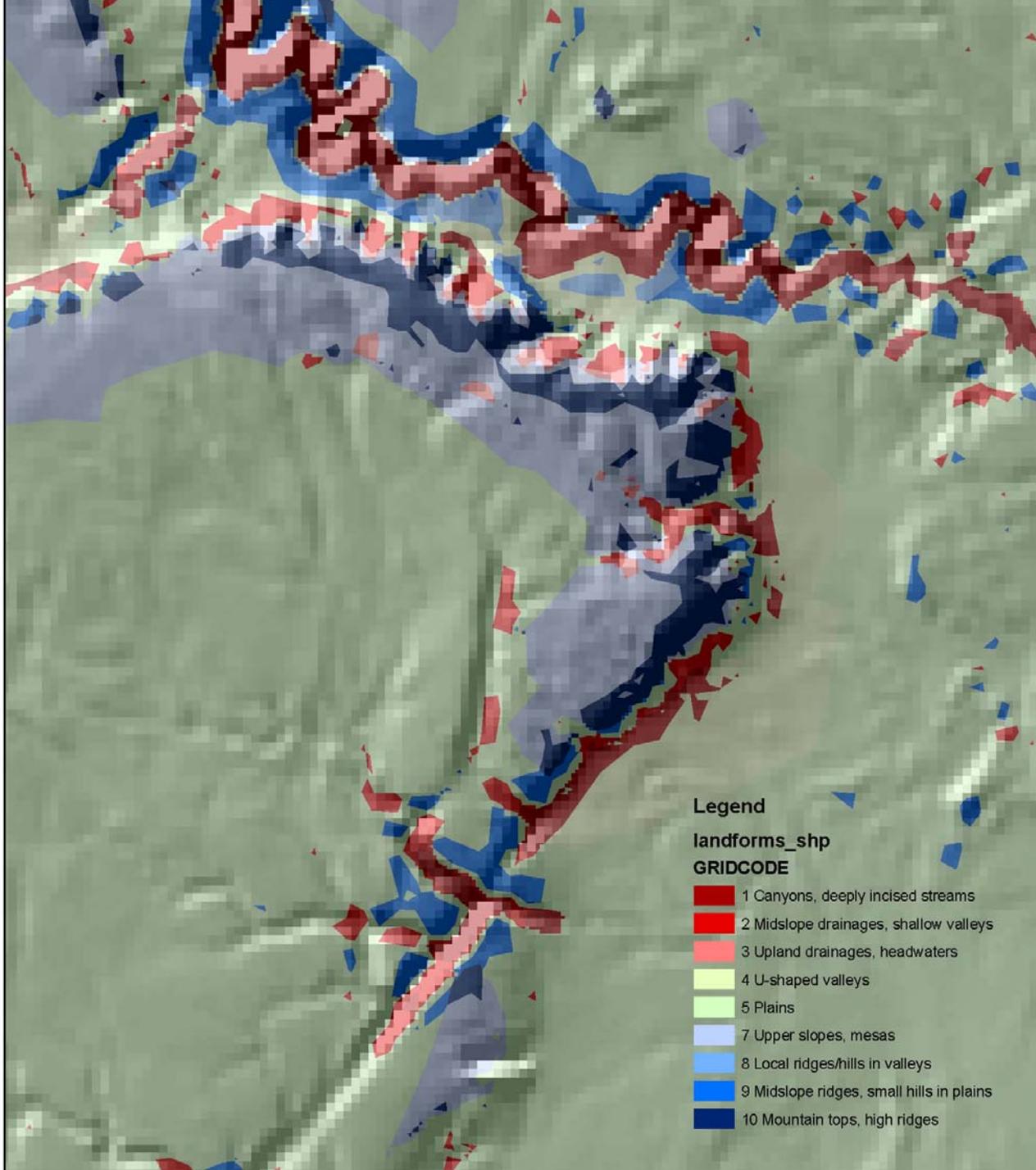


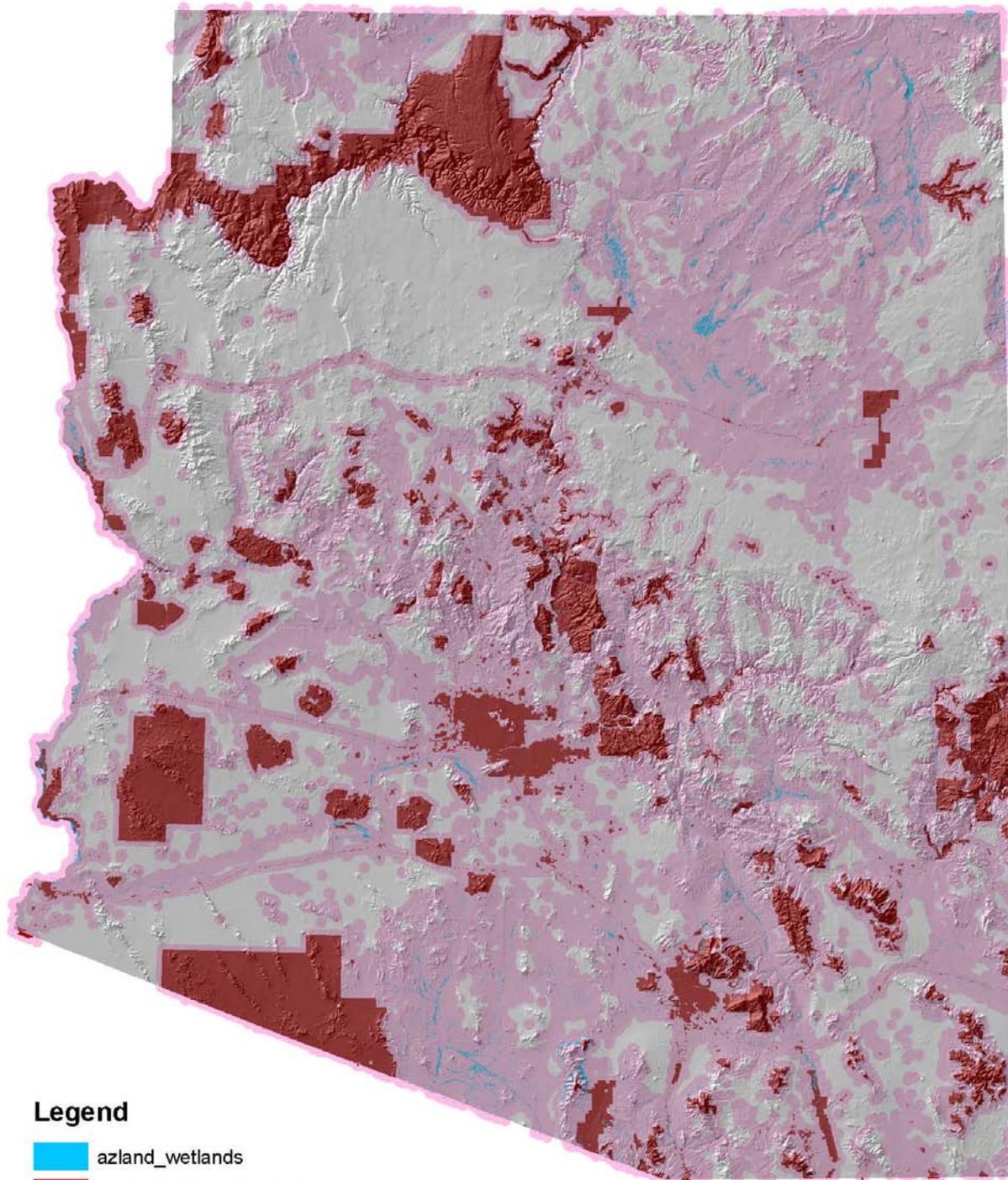
**TPI**  
**Topographic Position Index**

# TPI Topographic Position Index



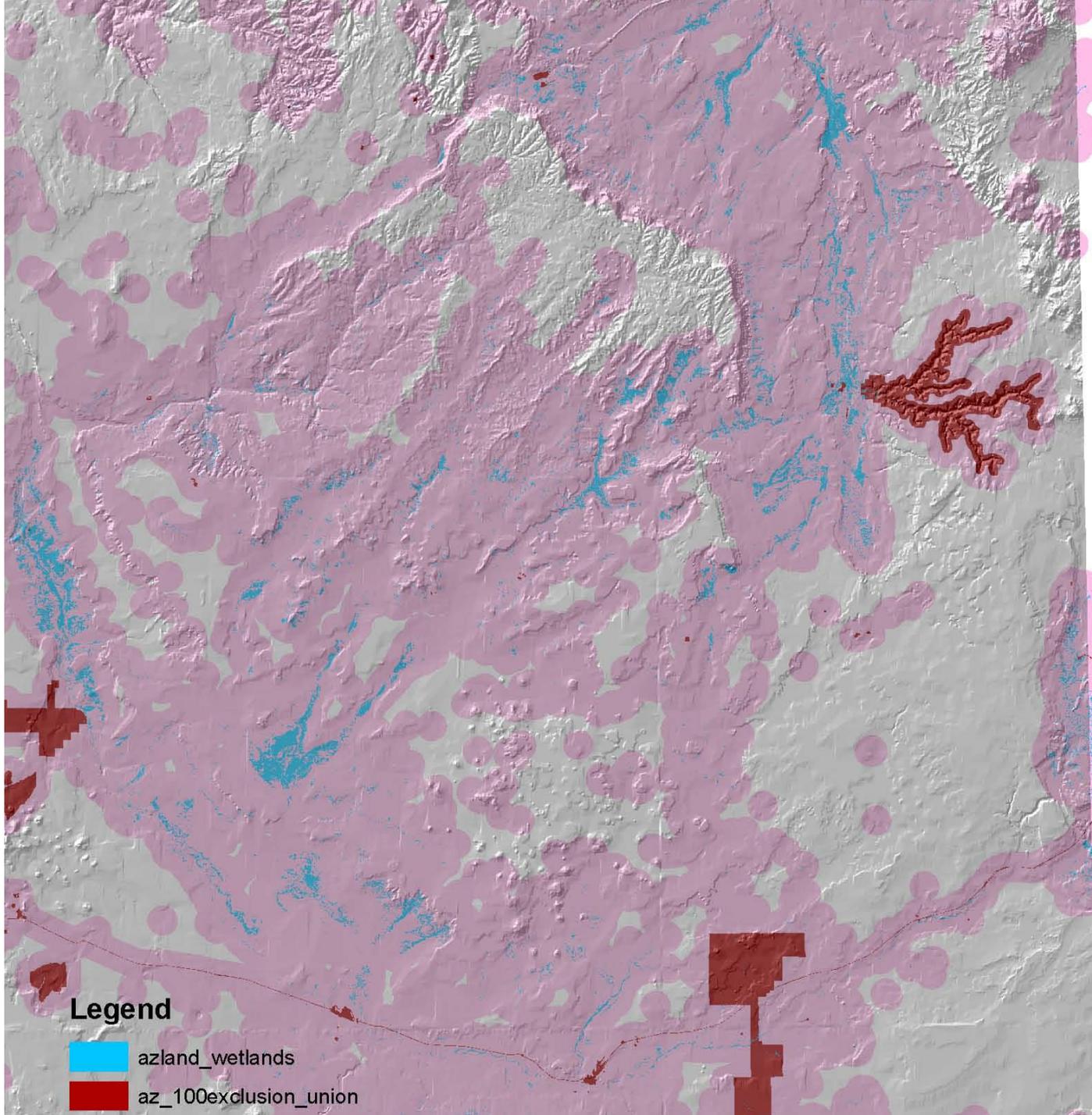
# TPI Topographic Position Index





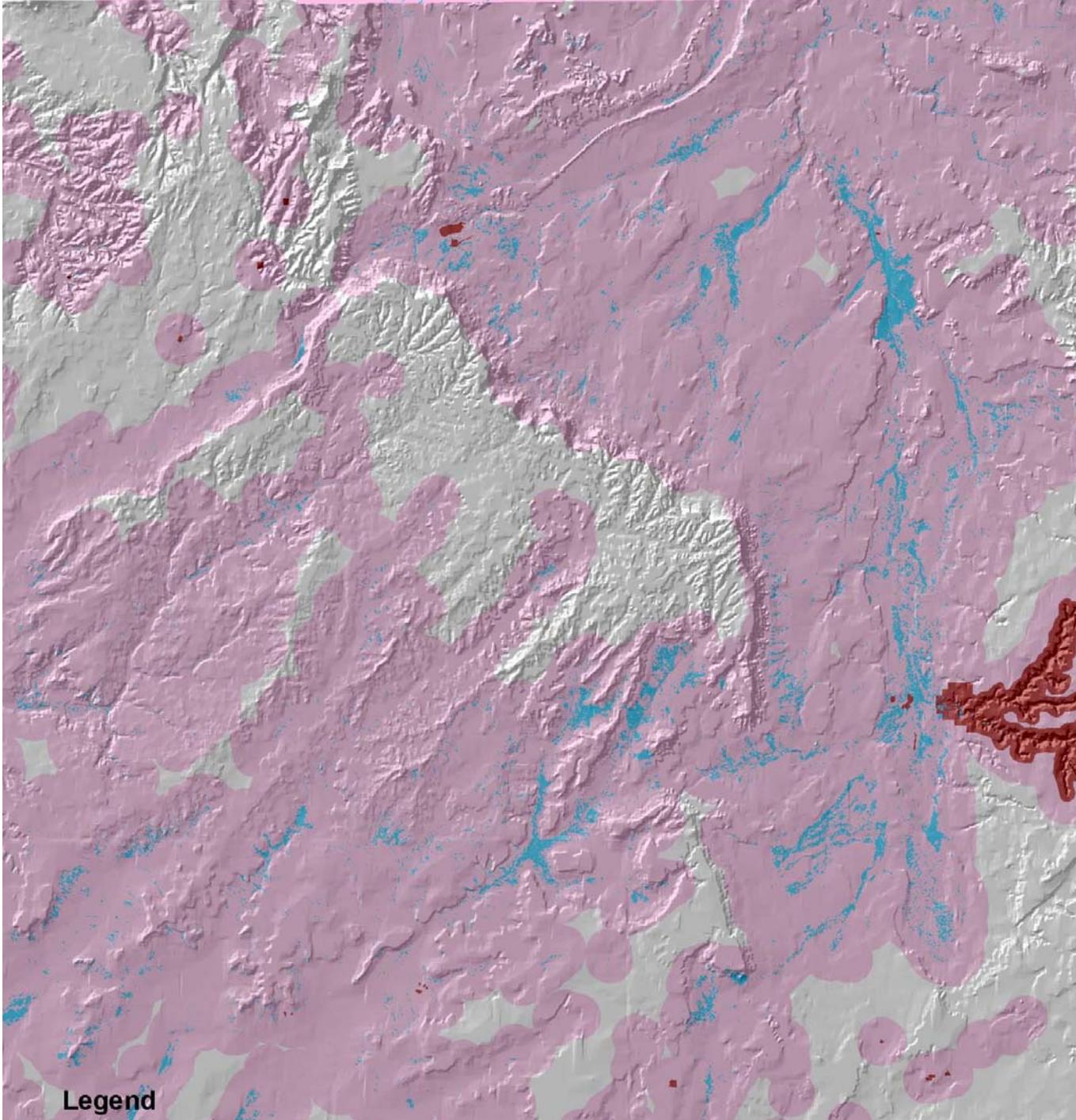
**Legend**

-  azland\_wetlands
-  az\_100exclusion union



**Legend**

-  azland\_wetlands
-  az\_100exclusion\_union



**Legend**

# Windy Land Exclusions

- National Park Service
  - Fish and Wildlife Service
  - Specially Designated Areas
  - Inventoried Roadless Areas
  - Sensitive Environmental lands
  - Airports
  - Urban/Developed Land (30m ReGAP)
- 3km buffer

- Wetlands (30m ReGAP)
- 100m buffer

- Open Water (30m ReGAP)
  - Slopes > 20% (90m Digital Elevation Model)
- NO buffer

# Navajo Windy Land Exclusions

## within Arizona

Navajo Reservation  
Boundary includes:  
-Navajo National Monuments  
-Navajo Trust Land  
-Navajo-Hopi Joint Use Areas

### Legend

-  Major Roads
-  Land Excluded 100%
-  Woodlands - Excluded 50%  
Does not include  
Pinyon-Juniper Woodland

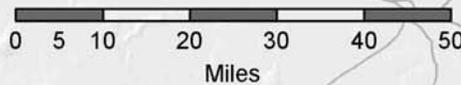
Created by: Grant Brummels  
Date of Creation: 9/7/2005  
For more information contact:  
Dr. Tom Acker

[Tom.Acker@nau.edu](mailto:Tom.Acker@nau.edu)

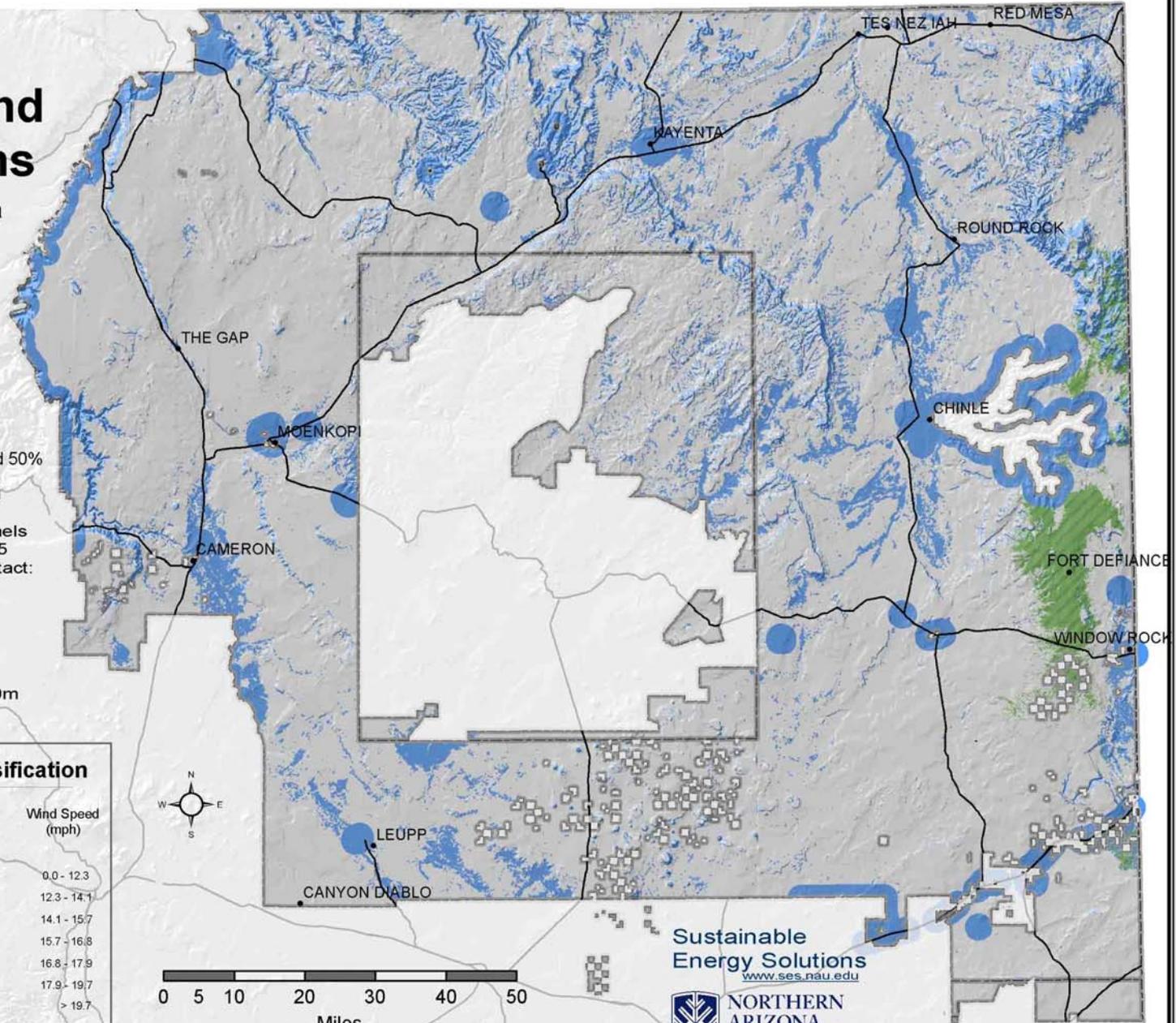
Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

### Wind Power Classification

Wind Power Class	Wind Power Density (W/m <sup>2</sup> )	Wind Speed (mph)
	1 Poor 0 - 200	0.0 - 12.3
	2 Marginal 200 - 300	12.3 - 14.1
	3 Fair 300 - 400	14.1 - 15.7
	4 Good 400 - 500	15.7 - 16.8
	5 Excellent 500 - 600	16.8 - 17.9
	6 Outstanding 600 - 800	17.9 - 19.7
	7 Superb > 800	> 19.7



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# Navajo Woodland Comparison

## within Arizona

Navajo Reservation  
Boundary includes:  
- Navajo National Monuments  
- Navajo Trust Land  
- Navajo-Hopi Joint Use Areas

### Legend

-  Major Roads
-  Land Excluded 100%
-  Pinyon-Juniper Woodland
-  Woodlands - Excluded 50%  
Does not include:  
Pinyon-Juniper Woodland

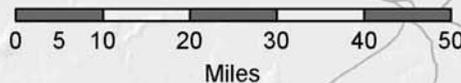
Created by: Grant Brummels  
Date of Creation: 9/7/2005  
For more information contact:  
Dr. Tom Acker

[Tom.Acker@nau.edu](mailto:Tom.Acker@nau.edu)

Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

### Wind Power Classification

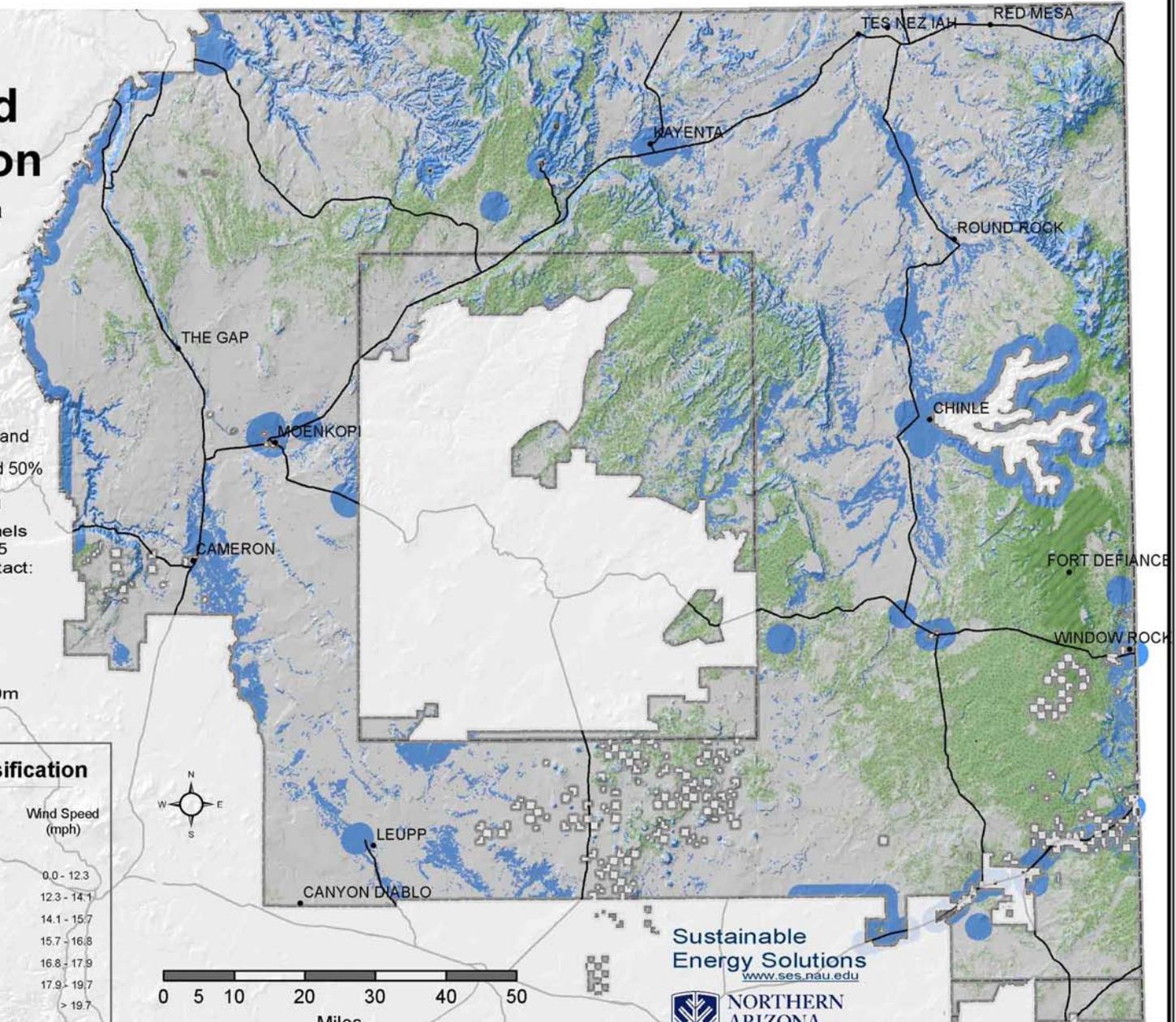
Wind Power Class	Wind Power Density (W/m <sup>2</sup> )	Wind Speed (mph)	
	1 Poor	0 - 200	0.0 - 12.3
	2 Marginal	200 - 300	12.3 - 14.1
	3 Fair	300 - 400	14.1 - 15.7
	4 Good	400 - 500	15.7 - 16.8
	5 Excellent	500 - 600	16.8 - 17.9
	6 Outstanding	600 - 800	17.9 - 19.7
	7 Superb	> 800	> 19.7



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# Navajo Land Slopes > 20%

Southwest ReGAP Data  
30m resolution

Navajo Reservation Boundary  
within Arizona includes:  
-Navajo National Monuments  
-Navajo Trust Land  
-Navajo-Hopi Joint Use Areas

## Legend

-  Major Roads
-  Slopes > 20%
-  Land Excluded 100%
-  Pinyon-Juniper Woodland
-  Woodlands - Excluded 50%  
Does not include  
Pinyon-Juniper Woodland

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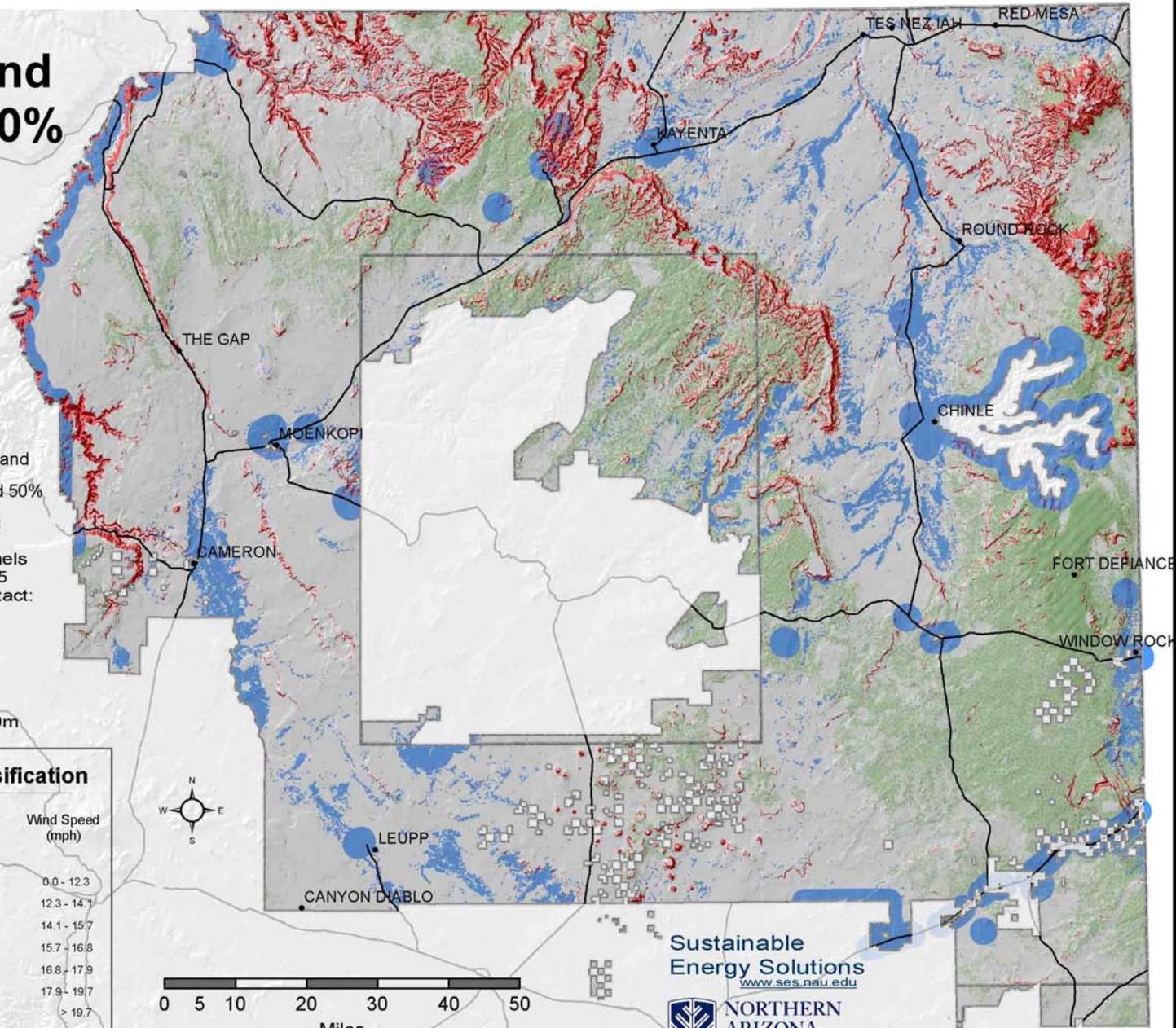
Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

## Wind Power Classification

Wind Power Class	Wind Power Density ( $W/m^2$ )	Wind Speed (mph)
	1 Poor 0 - 200	0.0 - 12.3
	2 Marginal 200 - 300	12.3 - 14.1
	3 Fair 300 - 400	14.1 - 15.7
	4 Good 400 - 500	15.7 - 16.8
	5 Excellent 500 - 600	16.8 - 17.9
	6 Outstanding 600 - 800	17.9 - 19.7
	7 Superb > 800	> 19.7



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# Navajo Wetlands

## Woody and Emergent Herbaceous Wetland Types

Southwest ReGAP Data  
30m resolution

Navajo Reservation Boundary within Arizona includes:  
-Navajo National Monuments  
-Navajo Trust Land  
-Navajo-Hopi Joint Use Areas

### Legend

-  Major Roads
-  Land Excluded 100%
-  Wetlands
-  Pinyon-Juniper Woodland
-  Woodlands - Excluded 50%  
Does not include Pinyon-Juniper Woodland

Created by: Grant Brummels  
Date of Creation: 9/7/2005  
For more information contact:  
Dr. Tom Acker

[Tom.Acker@nau.edu](mailto:Tom.Acker@nau.edu)

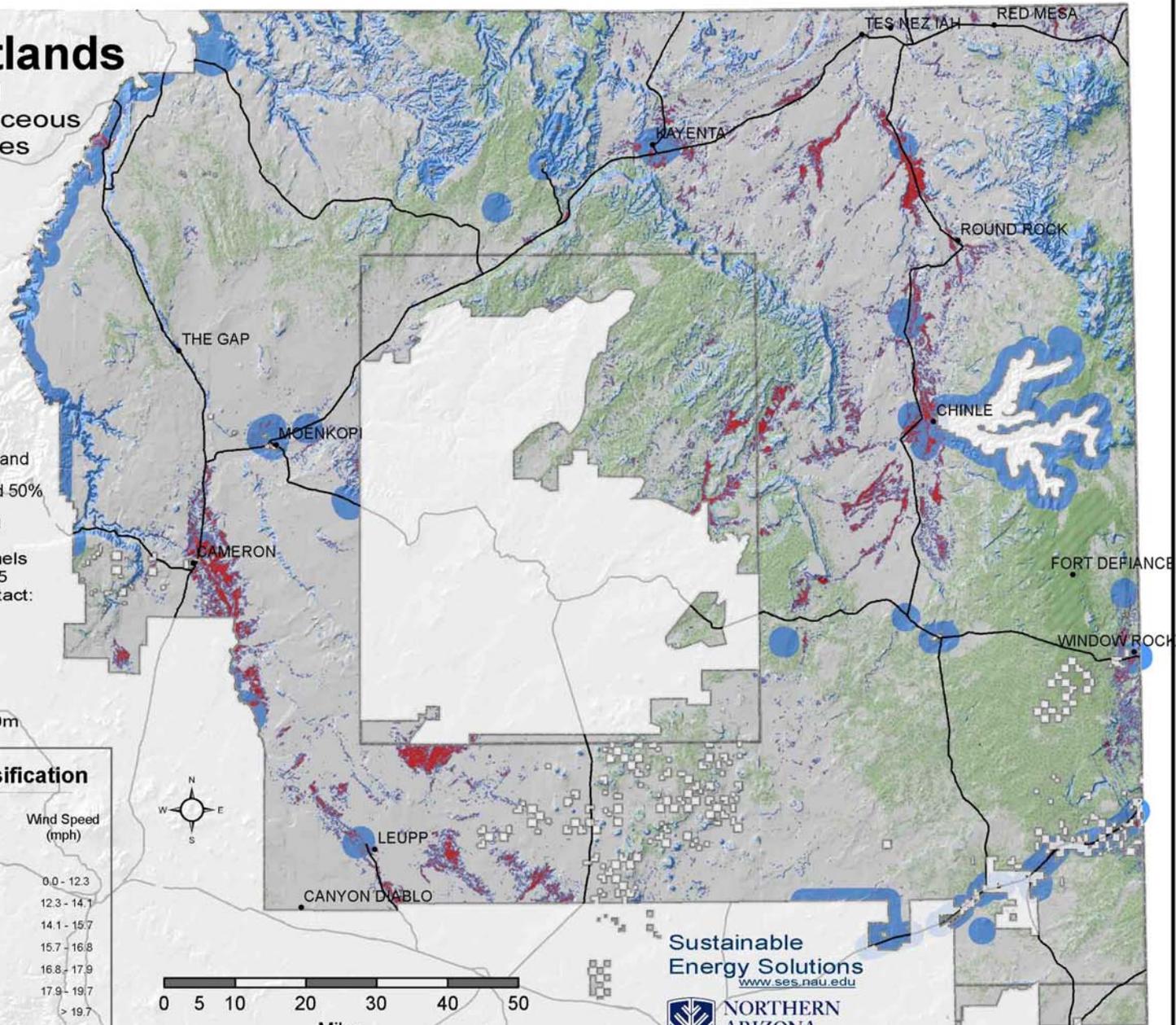
Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

### Wind Power Classification

Wind Power Class	Wind Power Density ( $W/m^2$ )	Wind Speed (mph)
	1 Poor	0 - 200
	2 Marginal	200 - 300
	3 Fair	300 - 400
	4 Good	400 - 500
	5 Excellent	500 - 600
	6 Outstanding	600 - 800
	7 Superb	> 800



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<b>NLCD Woody Wetland Types .....</b>	<b>133</b>
S091 Rocky Mountain Subalpine-Montane Riparian Shrubland .....	133
S092 Rocky Mountain Subalpine-Montane Riparian Woodland .....	136
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S094 North American Warm Desert Lower Montane Riparian Woodland and Shrubland .....	140
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S108 Western Great Plains Saline Depression Wetland .....	161

# Navajo Windy Land

Average Annual Wind Resource 164 ft (50m) with Land Exclusions

Navajo Reservation Boundary within Arizona includes:  
 -Navajo National Monuments  
 -Navajo Trust Land  
 -Navajo-Hopi Joint Use Areas

## Legend

-  Major Roads
-  Land Excluded 100%
-  Woodlands - Excluded 50%  
Does not include Pinyon-Juniper Woodland

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 For more information contact:  
 Dr. Tom Acker  
[Tom.Acker@nau.edu](mailto:Tom.Acker@nau.edu)

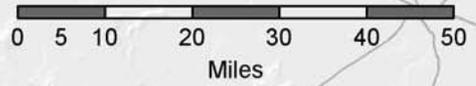
Projection:  
 UTM, Zone 12, WGS84  
 Spatial Resolution of  
 Wind Resource Data: 200m

**Total Windy Land (MW) 4562 MW**  
**79%**

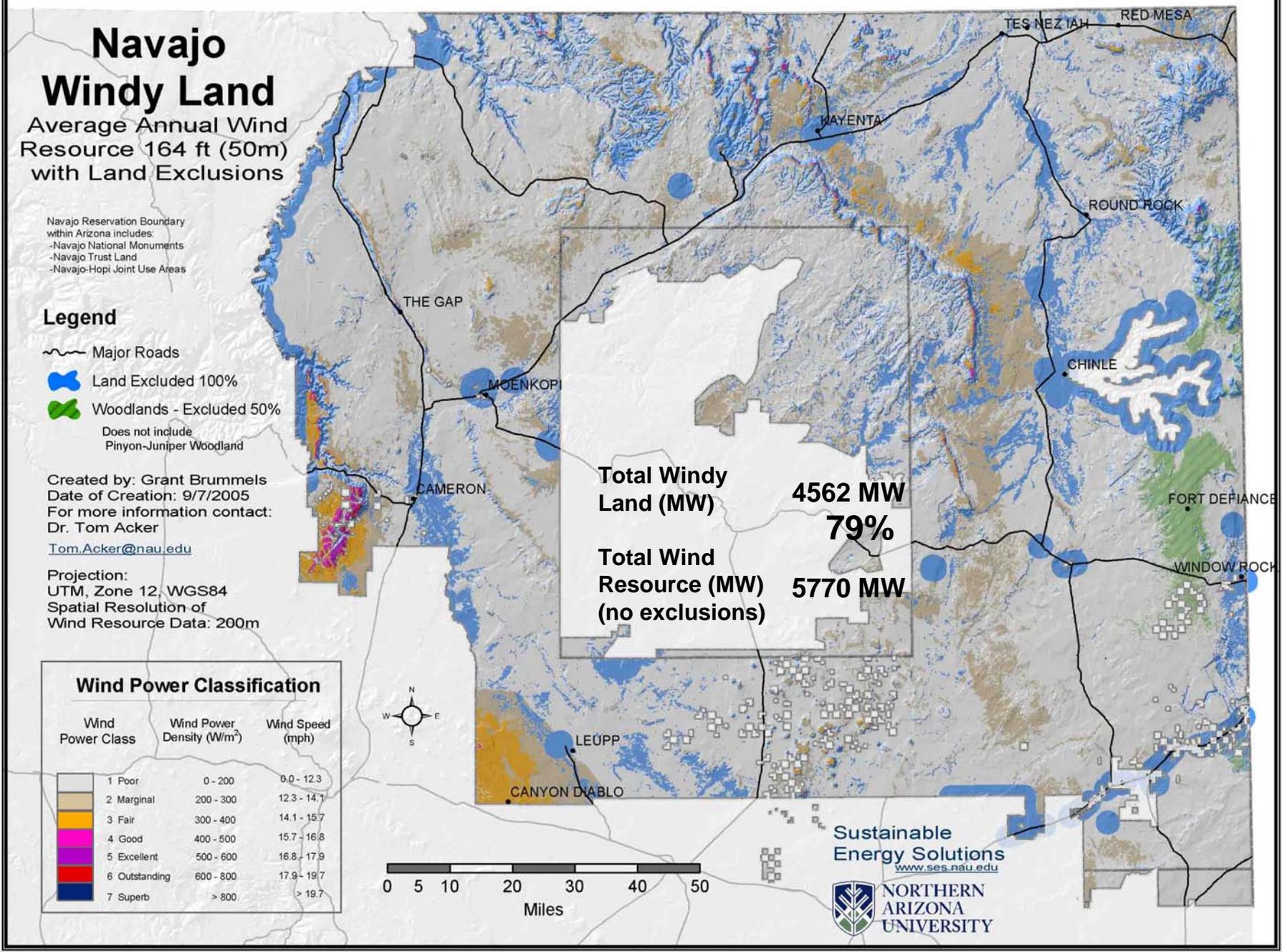
**Total Wind Resource (MW) 5770 MW**  
**(no exclusions)**

## Wind Power Classification

Wind Power Class	Wind Power Density (W/m <sup>2</sup> )	Wind Speed (mph)
	1 Poor 0 - 200	0.0 - 12.3
	2 Marginal 200 - 300	12.3 - 14.1
	3 Fair 300 - 400	14.1 - 15.7
	4 Good 400 - 500	15.7 - 16.8
	5 Excellent 500 - 600	16.8 - 17.9
	6 Outstanding 600 - 800	17.9 - 19.7
	7 Superb > 800	> 19.7



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# Navajo Windy Land

Average Annual Wind Resource 230 ft (70m) with Land Exclusions

Navajo Reservation Boundary within Arizona includes:  
 -Navajo National Monuments  
 -Navajo Trust Land  
 -Navajo-Hopi Joint Use Areas

## Legend

-  Major Roads
-  Land Excluded 100%
-  Woodlands - Excluded 50%  
Does not include Pinyon-Juniper Woodland

Created by: Grant Brummels  
 Date of Creation: 9/7/2005  
 For more information contact:  
 Dr. Tom Acker  
[Tom.Acker@nau.edu](mailto:Tom.Acker@nau.edu)

Projection:  
 UTM, Zone 12, WGS84  
 Spatial Resolution of  
 Wind Resource Data: 200m

## Wind Power Classification

Wind Power Class	Wind Power Density ( $W/m^2$ )	Wind Speed (mph)
	1 Poor 0 - 200	0.0 - 12.3
	2 Marginal 200 - 300	12.3 - 14.1
	3 Fair 300 - 400	14.1 - 15.7
	4 Good 400 - 500	15.7 - 16.8
	5 Excellent 500 - 600	16.8 - 17.9
	6 Outstanding 600 - 800	17.9 - 19.7
	7 Superb > 800	> 19.7

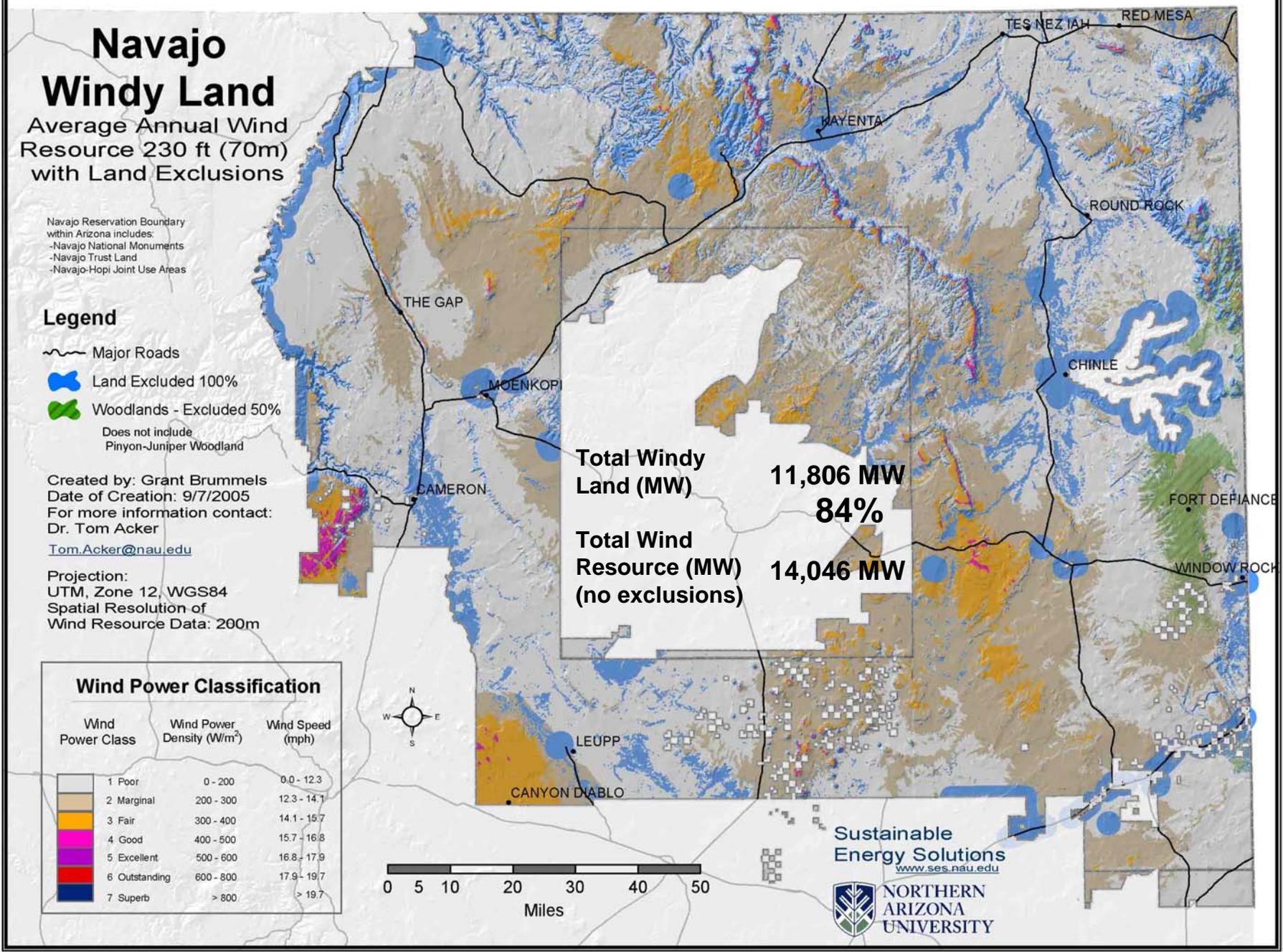


Total Windy Land (MW) **11,806 MW**

**84%**

Total Wind Resource (MW) (no exclusions) **14,046 MW**

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# Navajo Total Windy Land

Average Annual Wind  
Resource 50m (164 ft)

Navajo Reservation Boundary  
within Arizona includes:  
-Navajo National Monuments  
-Navajo Trust Land  
-Navajo-Hopi Joint Use Areas

Elevation Data 90m resolution  
Southwest ReGAP Data 30m resolution

Created by: Grant Brummels  
Date of Creation: 10/16/2005  
For more information contact:  
Dr. Tom Acker  
[Tom.Acker@nau.edu](mailto:Tom.Acker@nau.edu)

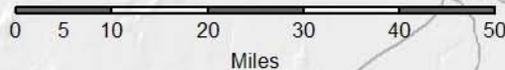
Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

## Legend

 Major Roads

## Wind Power Classification

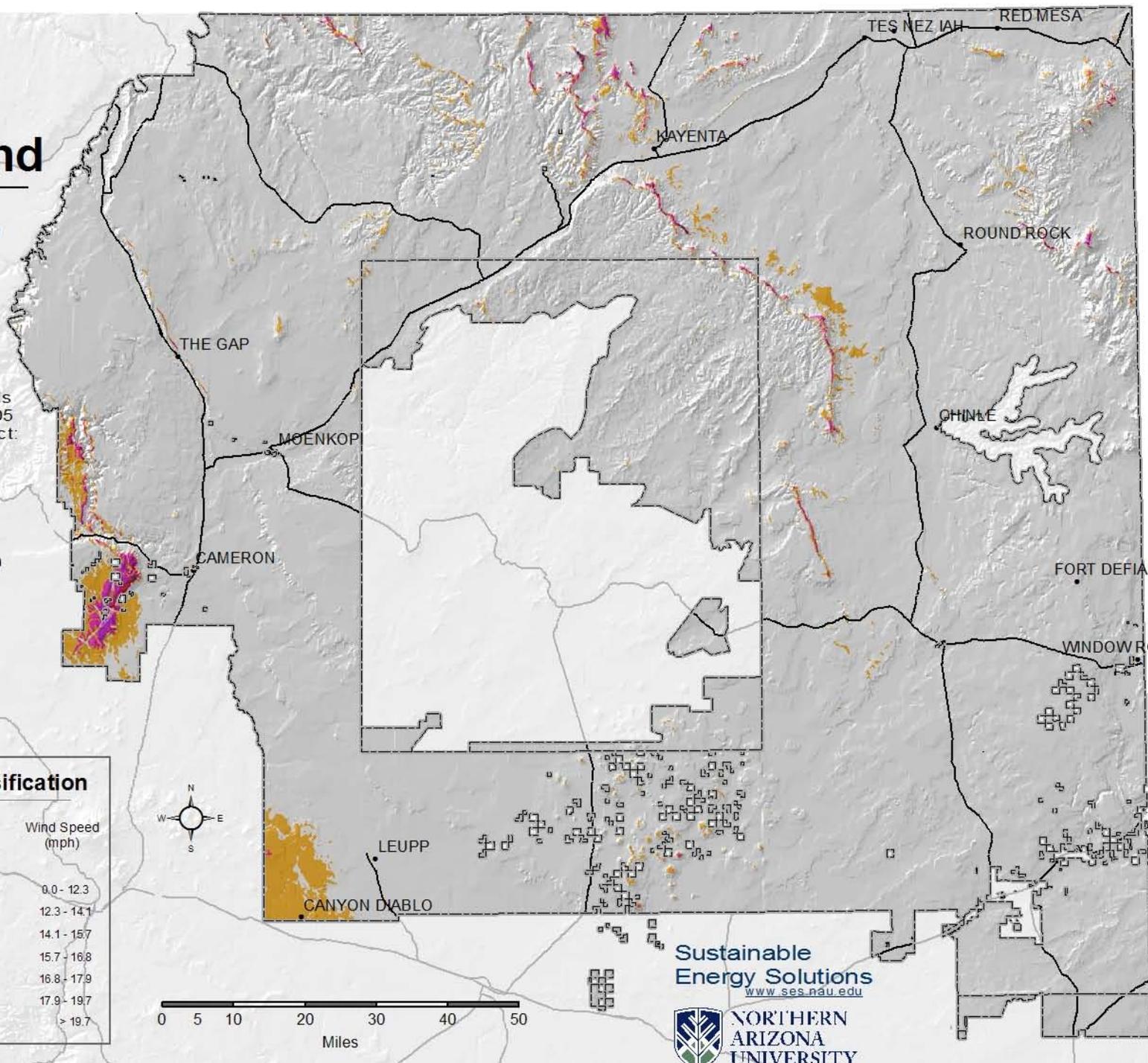
Wind Power Class	Wind Power Density ( $W/m^2$ )	Wind Speed (mph)
	1 Poor 0 - 200	0.0 - 12.3
	2 Marginal 200 - 300	12.3 - 14.1
	3 Fair 300 - 400	14.1 - 15.7
	4 Good 400 - 500	15.7 - 16.8
	5 Excellent 500 - 600	16.8 - 17.9
	6 Outstanding 600 - 800	17.9 - 19.7
	7 Superb > 800	> 19.7



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# Navajo Developable Windy Land

Average Annual Wind  
Resource 50m (164 ft)

Navajo Reservation Boundary  
within Arizona includes:  
-Navajo National Monuments  
-Navajo Trust Land  
-Navajo-Hopi Joint Use Areas

Elevation Data 90m resolution  
Southwest ReGAP Data 30m resolution

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Date of Creation: 10/16/2005  
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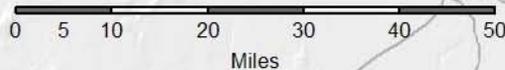
Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

## Legend

-  Major Roads
-  Excluded Windy Land (100%)
-  Non-ridge Crest Forests (50% Excluded)  
Does not include Pinyon-Juniper Woodland

## Wind Power Classification

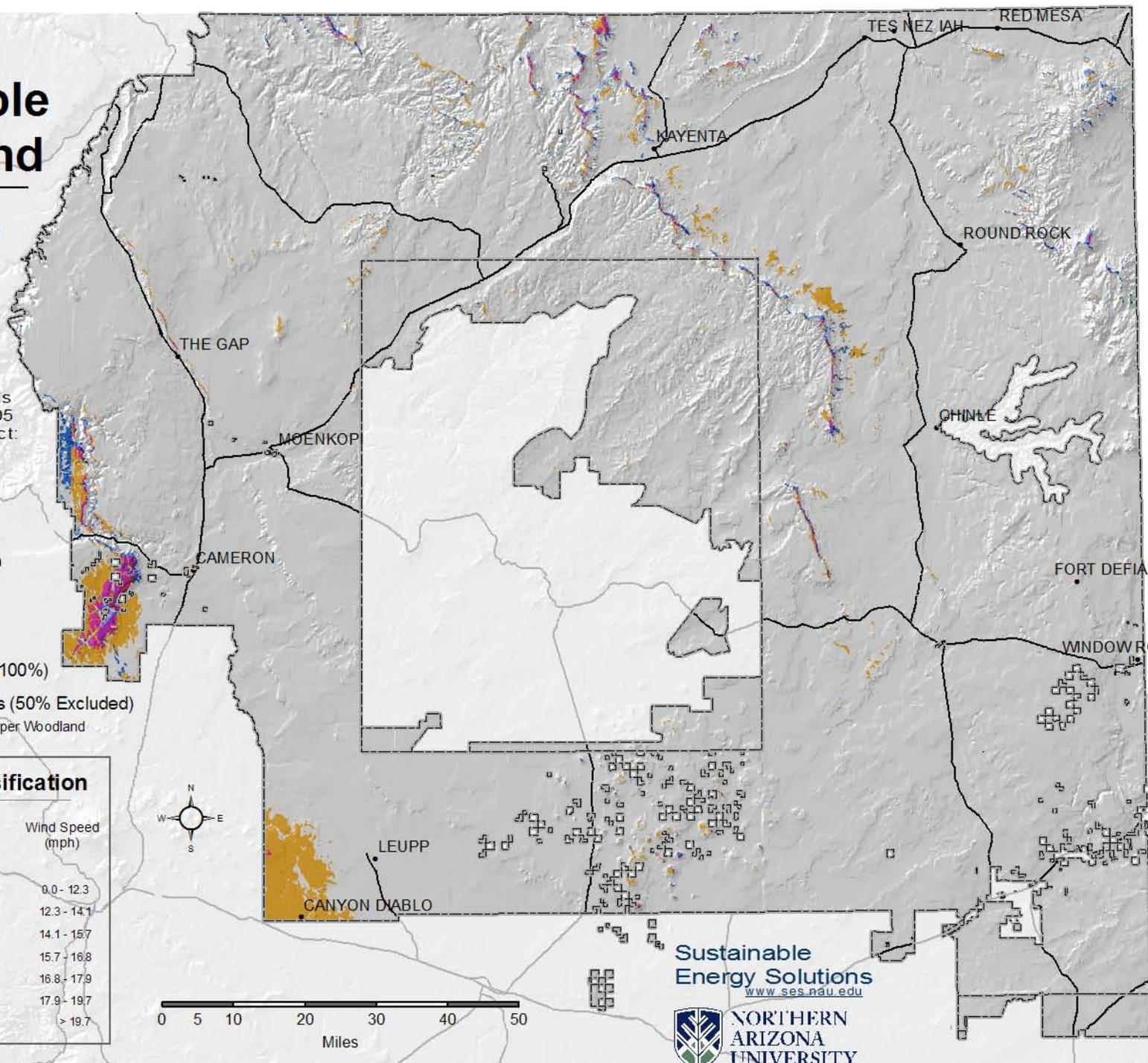
Wind Power Class	Wind Power Density ( $W/m^2$ )	Wind Speed (mph)
	1 Poor 0 - 200	0.0 - 12.3
	2 Marginal 200 - 300	12.3 - 14.1
	3 Fair 300 - 400	14.1 - 15.7
	4 Good 400 - 500	15.7 - 16.8
	5 Excellent 500 - 600	16.8 - 17.9
	6 Outstanding 600 - 800	17.9 - 19.7
	7 Superb > 800	> 19.7



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# Navajo Total Windy Land

Average Annual Wind  
Resource 70m (230 ft)

Navajo Reservation Boundary  
within Arizona includes:  
-Navajo National Monuments  
-Navajo Trust Land  
-Navajo-Hopi Joint Use Areas

Elevation Data 90m resolution  
Southwest ReGAP Data 30m resolution

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Date of Creation: 10/16/2005  
For more information contact:  
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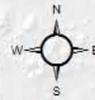
Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

## Legend

Major Roads

### Wind Power Classification

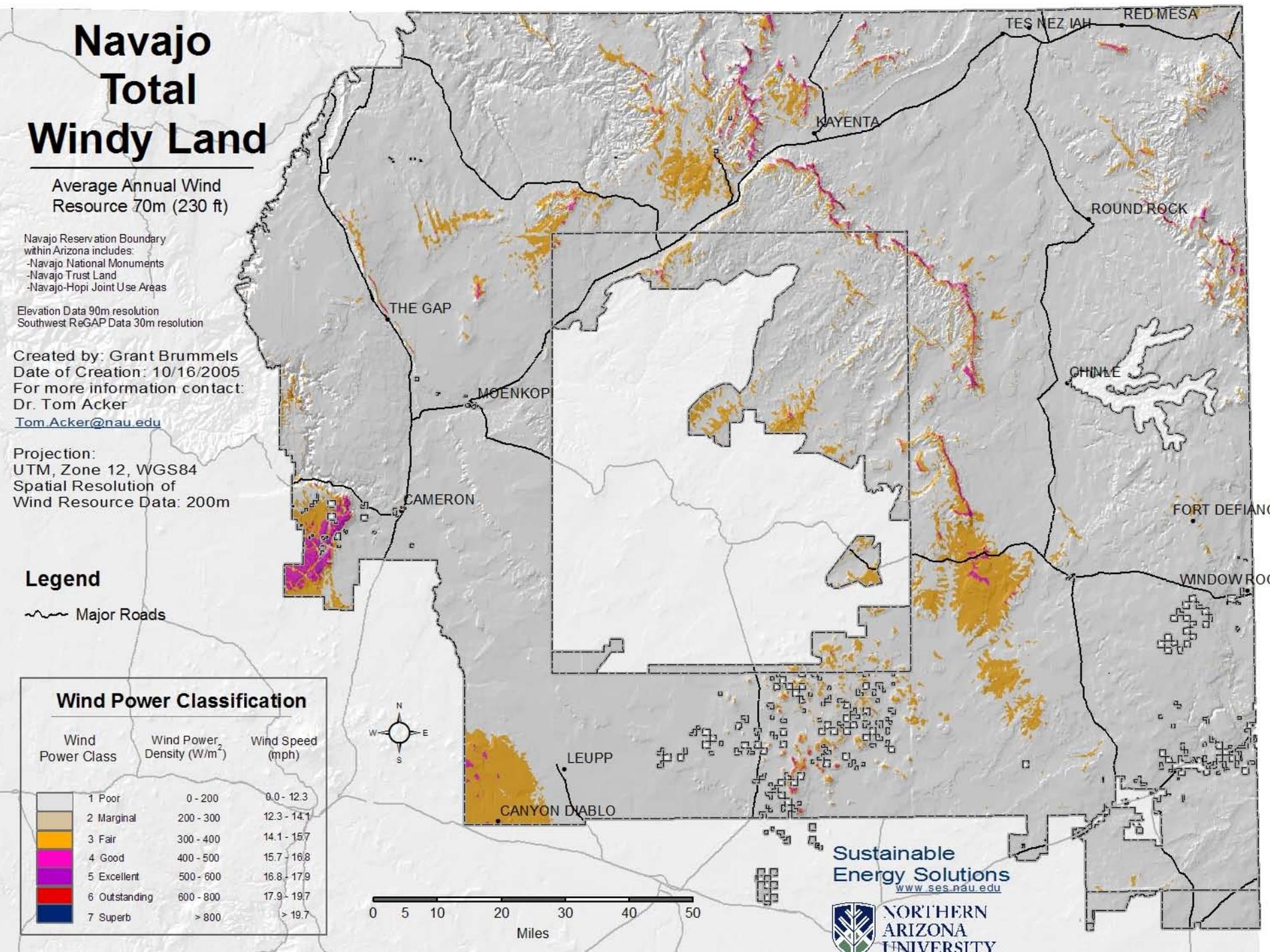
Wind Power Class	Wind Power Density ( $W/m^2$ )	Wind Speed (mph)
1 Poor	0 - 200	0.0 - 12.3
2 Marginal	200 - 300	12.3 - 14.1
3 Fair	300 - 400	14.1 - 15.7
4 Good	400 - 500	15.7 - 16.8
5 Excellent	500 - 600	16.8 - 17.9
6 Outstanding	600 - 800	17.9 - 19.7
7 Superb	> 800	> 19.7



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# Navajo Developable Windy Land

Average Annual Wind  
Resource 70m (230 ft)

Navajo Reservation Boundary  
within Arizona includes:  
-Navajo National Monuments  
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-Navajo-Hopi Joint Use Areas

Elevation Data 90m resolution  
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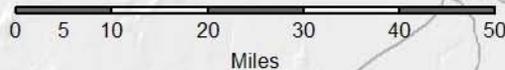
Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

## Legend

-  Major Roads
-  Excluded Windy Land (100%)
-  Non-ridge Crest Forests (50% Excluded)  
Does not include Pinyon-Juniper Woodland

## Wind Power Classification

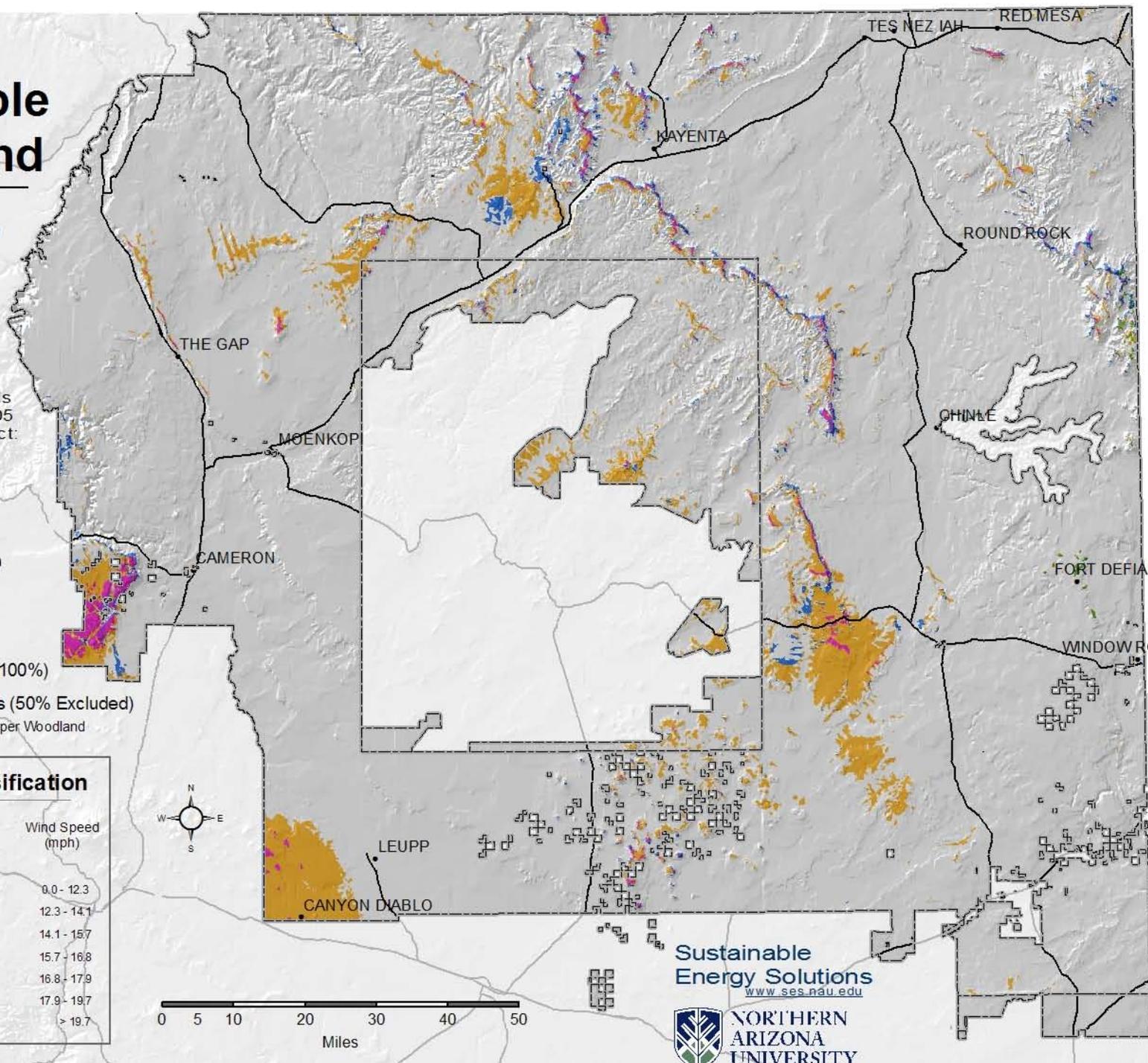
Wind Power Class	Wind Power Density ( $W/m^2$ )	Wind Speed (mph)
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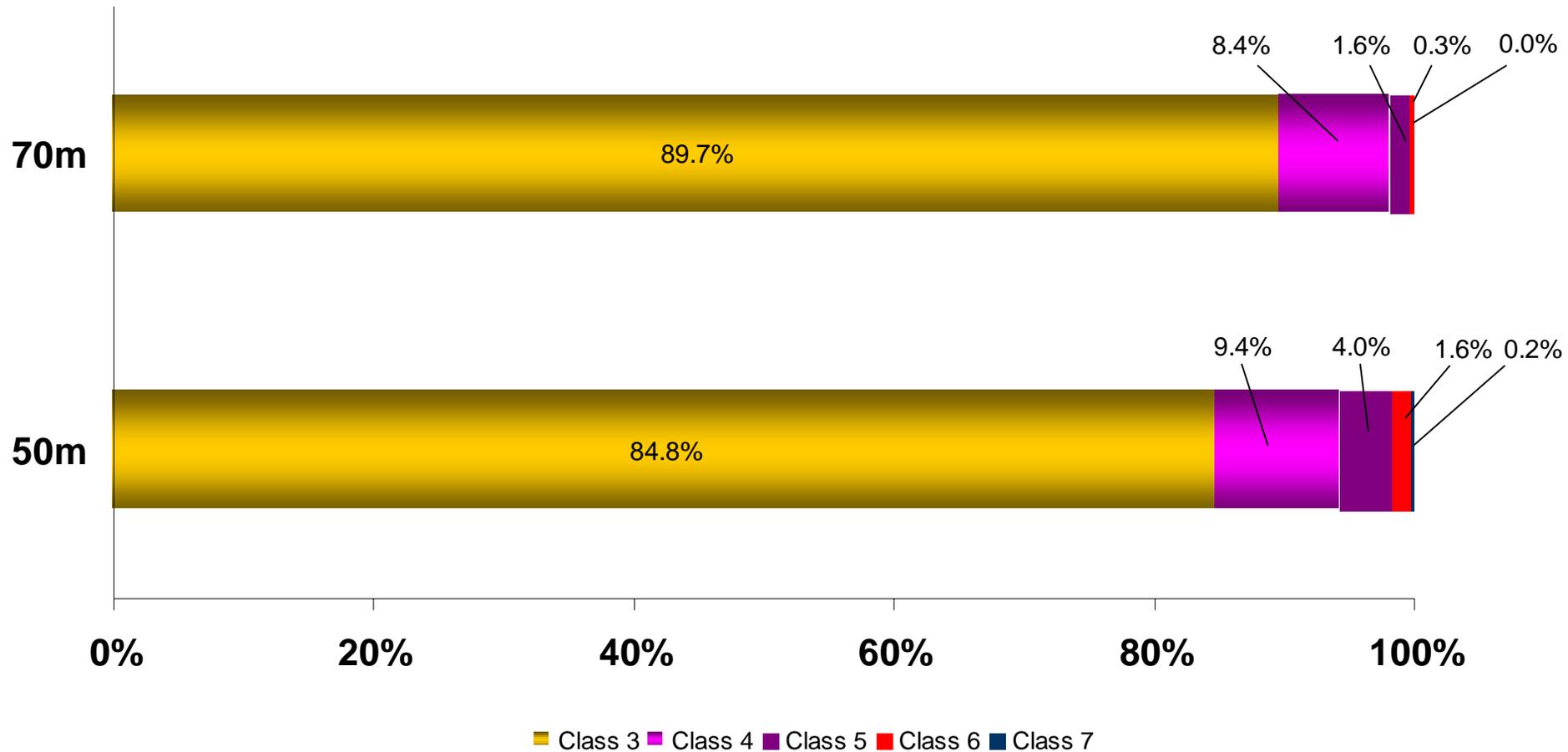


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Wind Class	50m			70m		
	Navajo Nation Potential Installed Capacity (MW) on Windy Land (no Exclusions)	Navajo Nation 50m Potential Installed Capacity (MW) on <i>Developable</i> Windy Land	% Developable Windy Land	Navajo Nation Potential Installed Capacity (MW) on Windy Land (no Exclusions)	Navajo Res. 70m Potential Installed Capacity (MW) on <i>Developable</i> Windy Land	% Developable Windy Land
3	4,751	<b>3,870</b>	81%	12,405	<b>10,591</b>	85%
4	636	<b>428</b>	67%	1,282	<b>990</b>	77%
5	256	<b>183</b>	71%	276	<b>184</b>	66%
6	110	<b>71</b>	65%	73	<b>38</b>	52%
7	17	<b>10</b>	60%	10	<b>4</b>	43%
	<b>5,770</b>	<b>4,562</b>	<b>79%</b>	<b>14,046</b>	<b>11,806</b>	<b>84%</b>

## Navajo Developable Windy Land by Wind Class



### Navajo Reservation County Wind Class Area Analysis 50m

Wind Class	Power (w/m <sup>2</sup> )	Total Area (km <sup>2</sup> )	Windy Land as Percent of Total Land Area	Developable Windy Land (km <sup>2</sup> )#	Developable Windy Land as Percent of Total Land Area	Installed Capacity (MW)*
3	300-400	950	2.34%	774	1.906%	3,870
4	400-500	127	0.31%	86	0.211%	428
5	500-600	51	0.13%	37	0.090%	183
6	600-800	22	0.05%	14	0.035%	71
7	>800	3	0.01%	2	0.005%	10
		40,616		<b>50m Total</b>		<b>4,562</b>

**2.84%**

**2.246%**

Navajo Reservation County Wind Class Area Analysis 70m						
Wind Class	Power (w/m <sup>2</sup> )	Total Area (km <sup>2</sup> )	Windy Land as Percent of Total Land Area	Developable Windy Land (km <sup>2</sup> ) <sup>#</sup>	Developable Windy Land as Percent of Total Land Area	Installed Capacity (MW)*
3	300-400	2,481	6.11%	2,118	5.215%	10,591
4	400-500	256	0.63%	198	0.487%	990
5	500-600	55	0.14%	37	0.090%	184
6	600-800	15	0.04%	8	0.019%	38
7	>800	2	0.00%	1	0.002%	4
		40,616	<b>70m Total</b>			<b>11,806</b>

**6.92%**

**5.814%**

# Navajo Windy Land

Spring Wind Resource  
164 ft (50m)  
with Land Exclusions

Navajo Reservation Boundary within Arizona includes:  
-Navajo National Monuments  
-Navajo Trust Land  
-Navajo-Hopi Joint Use Areas

## Legend

-  Major Roads
  -  Land Excluded 100%
  -  Woodlands - Excluded 50%
- Does not include  
Pinyon-Juniper Woodland

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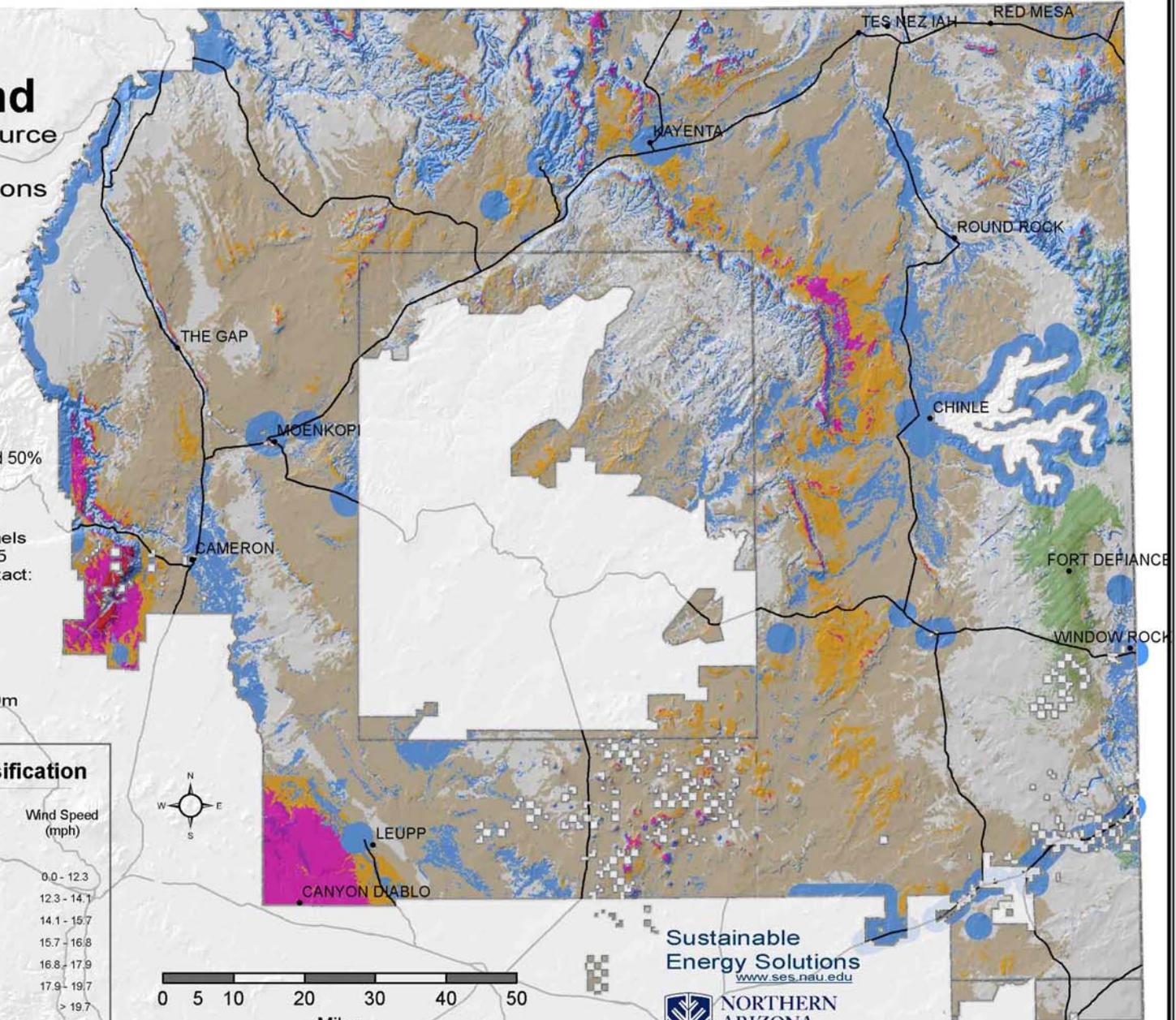
Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

## Wind Power Classification

Wind Power Class	Wind Power Density ( $W/m^2$ )	Wind Speed (mph)
	1 Poor 0 - 200	0.0 - 12.3
	2 Marginal 200 - 300	12.3 - 14.1
	3 Fair 300 - 400	14.1 - 15.7
	4 Good 400 - 500	15.7 - 16.8
	5 Excellent 500 - 600	16.8 - 17.9
	6 Outstanding 600 - 800	17.9 - 19.7
	7 Superb > 800	> 19.7



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# Navajo Windy Land

Summer Wind Resource  
164 ft (50m)  
with Land Exclusions

Navajo Reservation Boundary  
within Arizona includes:  
-Navajo National Monuments  
-Navajo Trust Land  
-Navajo-Hopi Joint Use Areas

## Legend

-  Major Roads
  -  Land Excluded 100%
  -  Woodlands - Excluded 50%
- Does not include  
Pinyon-Juniper Woodland

Created by: Grant Brummels  
Date of Creation: 9/7/2005  
For more information contact:  
Dr. Tom Acker  
[Tom.Acker@nau.edu](mailto:Tom.Acker@nau.edu)

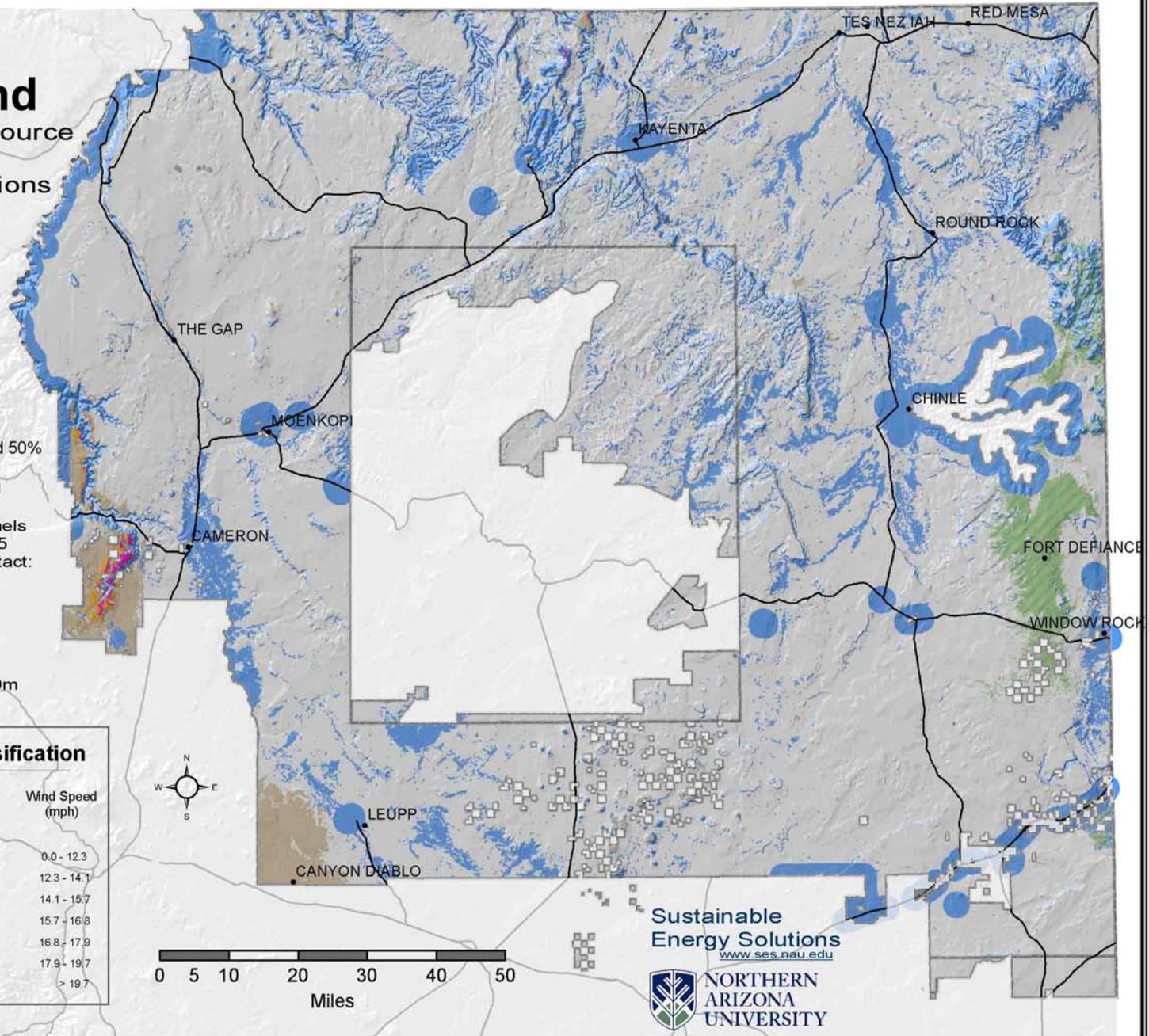
Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

## Wind Power Classification

Wind Power Class	Wind Power Density ( $W/m^2$ )	Wind Speed (mph)
	1 Poor 0 - 200	0.0 - 12.3
	2 Marginal 200 - 300	12.3 - 14.1
	3 Fair 300 - 400	14.1 - 15.7
	4 Good 400 - 500	15.7 - 16.8
	5 Excellent 500 - 600	16.8 - 17.9
	6 Outstanding 600 - 800	17.9 - 19.7
	7 Superb > 800	> 19.7



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# Navajo Windy Land

Fall Wind Resource  
164 ft (50m)  
with Land Exclusions

Navajo Reservation Boundary within Arizona includes:  
-Navajo National Monuments  
-Navajo Trust Land  
-Navajo-Hopi Joint Use Areas

## Legend

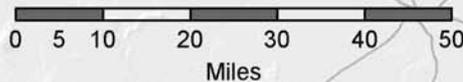
-  Major Roads
-  Land Excluded 100%
-  Woodlands - Excluded 50%  
Does not include Pinyon-Juniper Woodland

Created by: Grant Brummels  
Date of Creation: 9/7/2005  
For more information contact:  
Dr. Tom Acker  
[Tom.Acker@nau.edu](mailto:Tom.Acker@nau.edu)

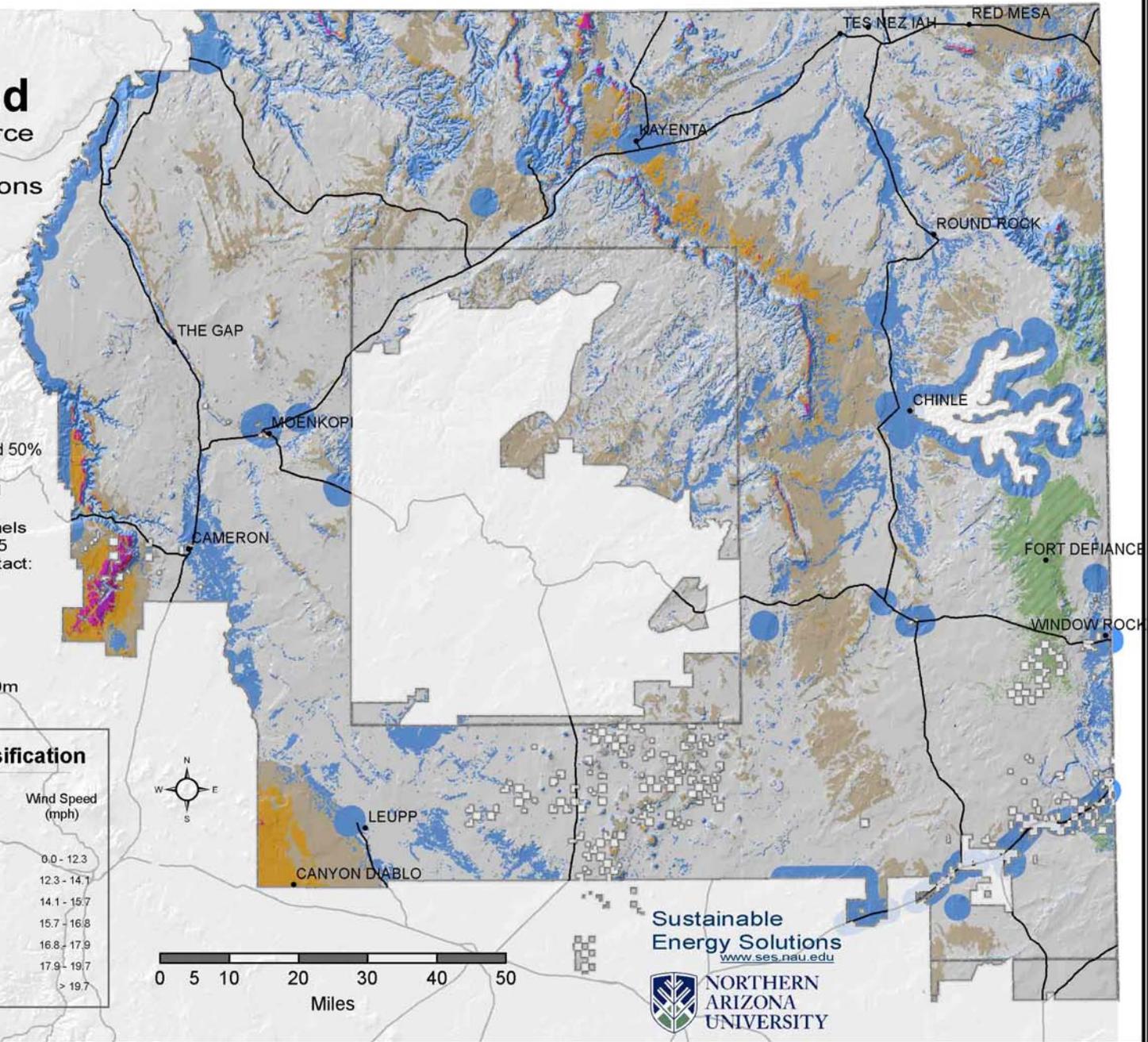
Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

## Wind Power Classification

Wind Power Class	Wind Power Density ( $W/m^2$ )	Wind Speed (mph)
	1 Poor 0 - 200	0.0 - 12.3
	2 Marginal 200 - 300	12.3 - 14.1
	3 Fair 300 - 400	14.1 - 15.7
	4 Good 400 - 500	15.7 - 16.8
	5 Excellent 500 - 600	16.8 - 17.9
	6 Outstanding 600 - 800	17.9 - 19.7
	7 Superb > 800	> 19.7



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# Navajo Windy Land

Winter Wind Resource  
164 ft (50m)  
with Land Exclusions

Navajo Reservation Boundary  
within Arizona includes:  
-Navajo National Monuments  
-Navajo Trust Land  
-Navajo-Hopi Joint Use Areas

## Legend

-  Major Roads
  -  Land Excluded 100%
  -  Woodlands - Excluded 50%
- Does not include  
Pinyon-Juniper Woodland

Created by: Grant Brummels  
Date of Creation: 9/7/2005  
For more information contact:  
Dr. Tom Acker  
[Tom.Acker@nau.edu](mailto:Tom.Acker@nau.edu)

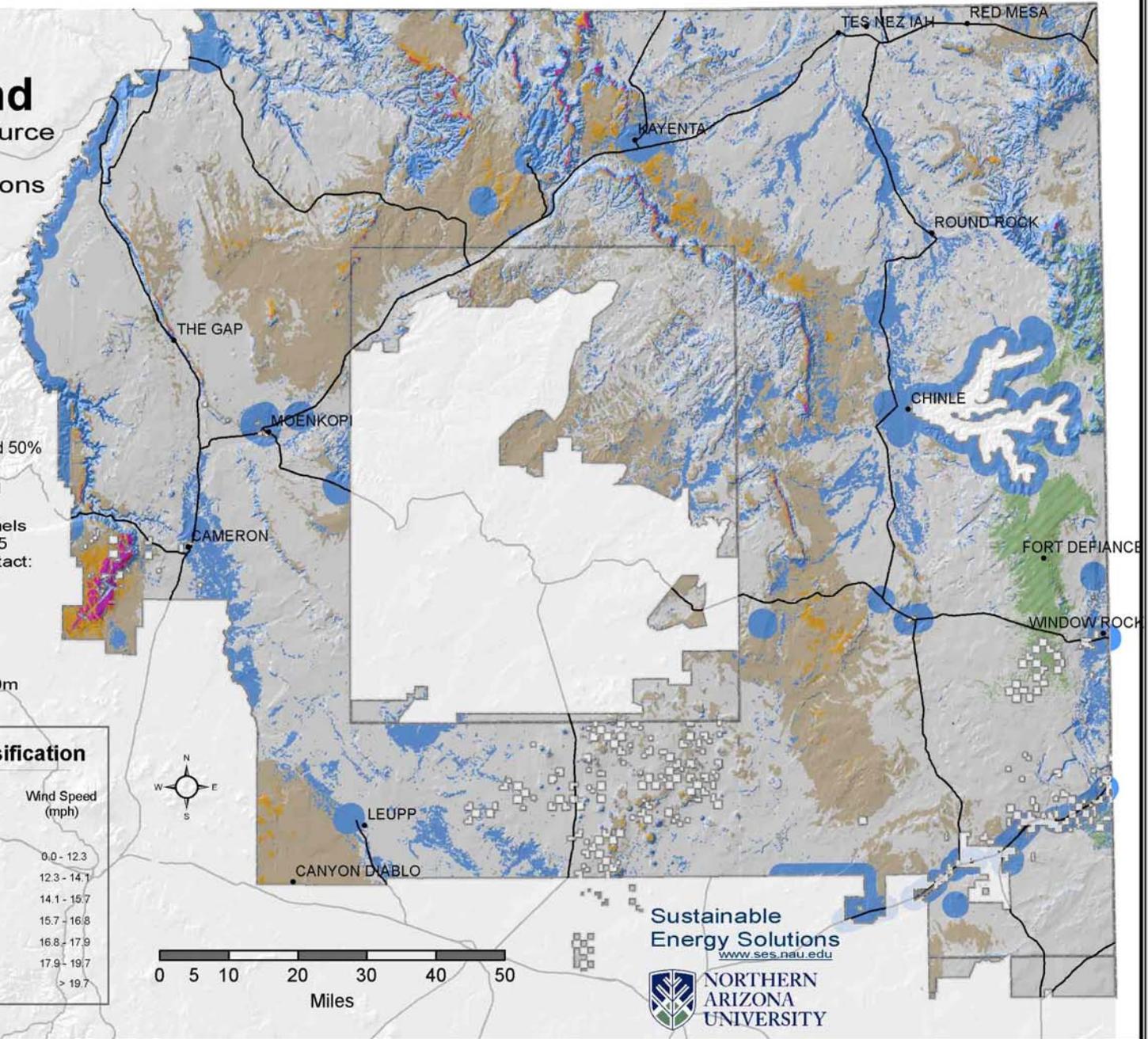
Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

## Wind Power Classification

Wind Power Class	Wind Power Density ( $W/m^2$ )	Wind Speed (mph)
	1 Poor 0 - 200	0.0 - 12.3
	2 Marginal 200 - 300	12.3 - 14.1
	3 Fair 300 - 400	14.1 - 15.7
	4 Good 400 - 500	15.7 - 16.8
	5 Excellent 500 - 600	16.8 - 17.9
	6 Outstanding 600 - 800	17.9 - 19.7
	7 Superb > 800	> 19.7



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# Navajo Windy Land

Average Annual Wind Resource 164 ft (50m) with Land Exclusions and Transmission

Navajo Reservation Boundary within Arizona includes:  
 -Navajo National Monuments  
 -Navajo Trust Land  
 -Navajo-Hopi Joint Use Areas

## Legend

-  Major Roads
-  Transmission Lines
-  Land Excluded 100%
-  Woodlands - Excluded 50%  
Does not include Pinyon-Juniper Woodland

Created by: Grant Brummels  
 Date of Creation: 9/7/2005  
 For more information contact:  
 Dr. Tom Acker  
[Tom.Acker@nau.edu](mailto:Tom.Acker@nau.edu)

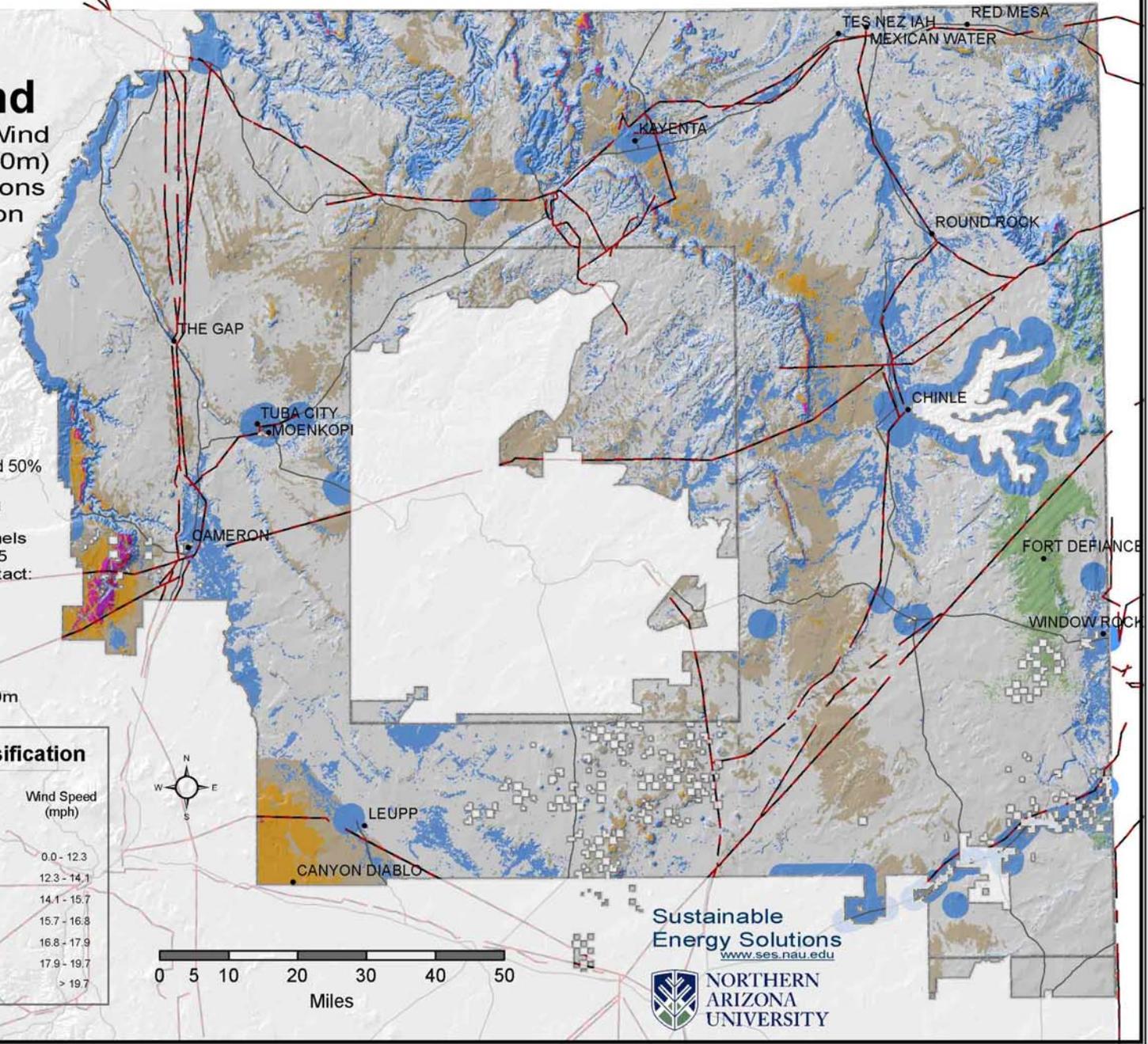
Projection:  
 UTM, Zone 12, WGS84  
 Spatial Resolution of  
 Wind Resource Data: 200m

## Wind Power Classification

Wind Power Class	Wind Power Density (W/m <sup>2</sup> )	Wind Speed (mph)
	1 Poor 0 - 200	0.0 - 12.3
	2 Marginal 200 - 300	12.3 - 14.1
	3 Fair 300 - 400	14.1 - 15.7
	4 Good 400 - 500	15.7 - 16.8
	5 Excellent 500 - 600	16.8 - 17.9
	6 Outstanding 600 - 800	17.9 - 19.7
	7 Superb > 800	> 19.7



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# Navajo Windy Land

Average Annual Wind Resource 230 ft (70m)  
with Land Exclusions  
and Transmission

Navajo Reservation Boundary  
within Arizona includes:  
-Navajo National Monuments  
-Navajo Trust Land  
-Navajo-Hopi Joint Use Areas

## Legend

-  Major Roads
  -  Transmission Lines
  -  Land Excluded 100%
  -  Woodlands - Excluded 50%
- Does not include  
Pinyon-Juniper Woodland

Created by: Grant Brummels  
Date of Creation: 9/7/2005  
For more information contact:  
Dr. Tom Acker  
[Tom.Acker@nau.edu](mailto:Tom.Acker@nau.edu)

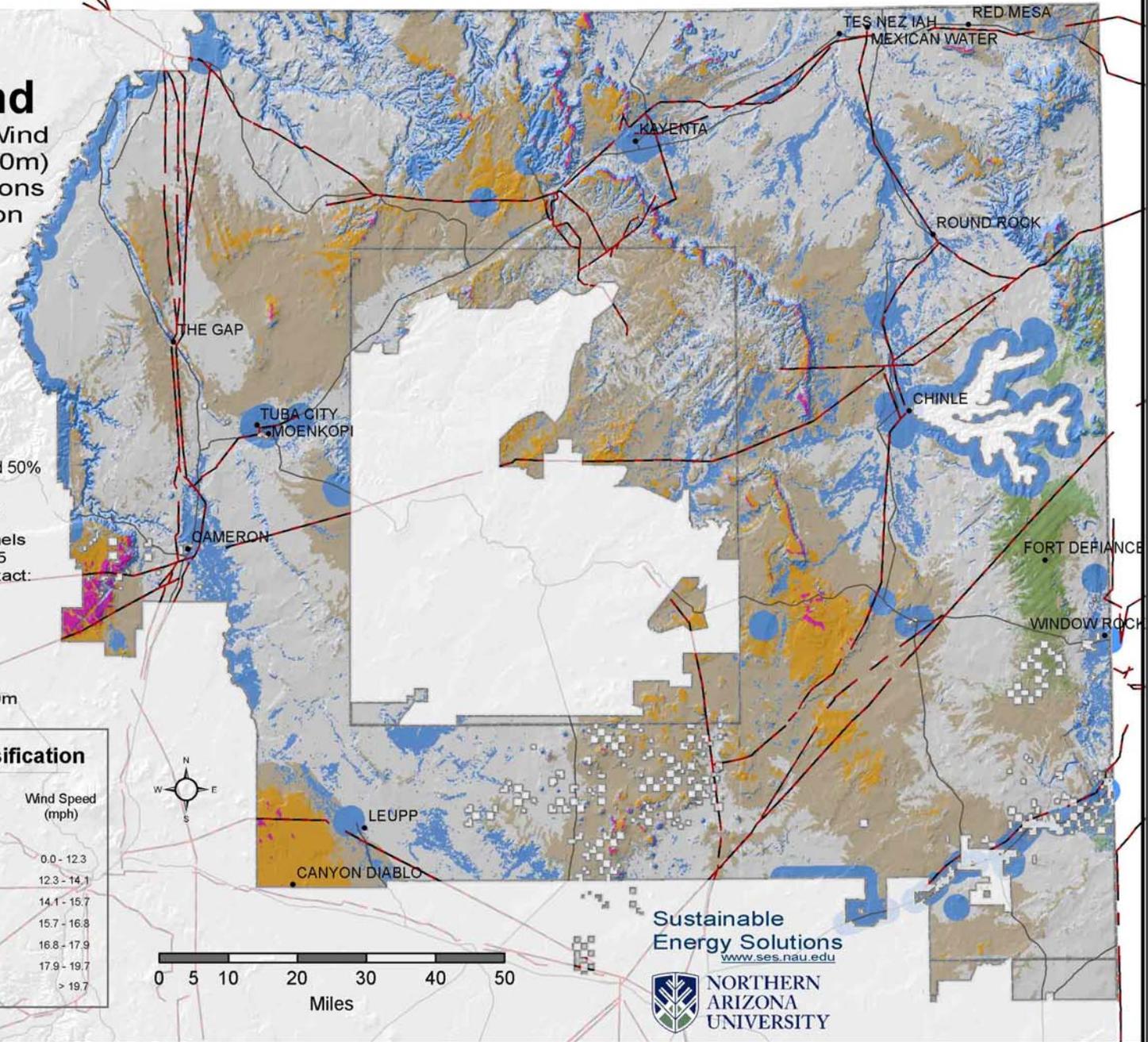
Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

## Wind Power Classification

Wind Power Class	Wind Power Density ( $W/m^2$ )	Wind Speed (mph)
1 Poor	0 - 200	0.0 - 12.3
2 Marginal	200 - 300	12.3 - 14.1
3 Fair	300 - 400	14.1 - 15.7
4 Good	400 - 500	15.7 - 16.8
5 Excellent	500 - 600	16.8 - 17.9
6 Outstanding	600 - 800	17.9 - 19.7
7 Superb	> 800	> 19.7



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# Gray Mountain Windy Land

Average Annual Wind Resource 230 ft (70m) with Land Exclusions and Transmission

Navajo Reservation Boundary within Arizona includes:  
 -Navajo National Monuments  
 -Navajo Trust Land  
 -Navajo-Hopi Joint Use Areas

## Legend

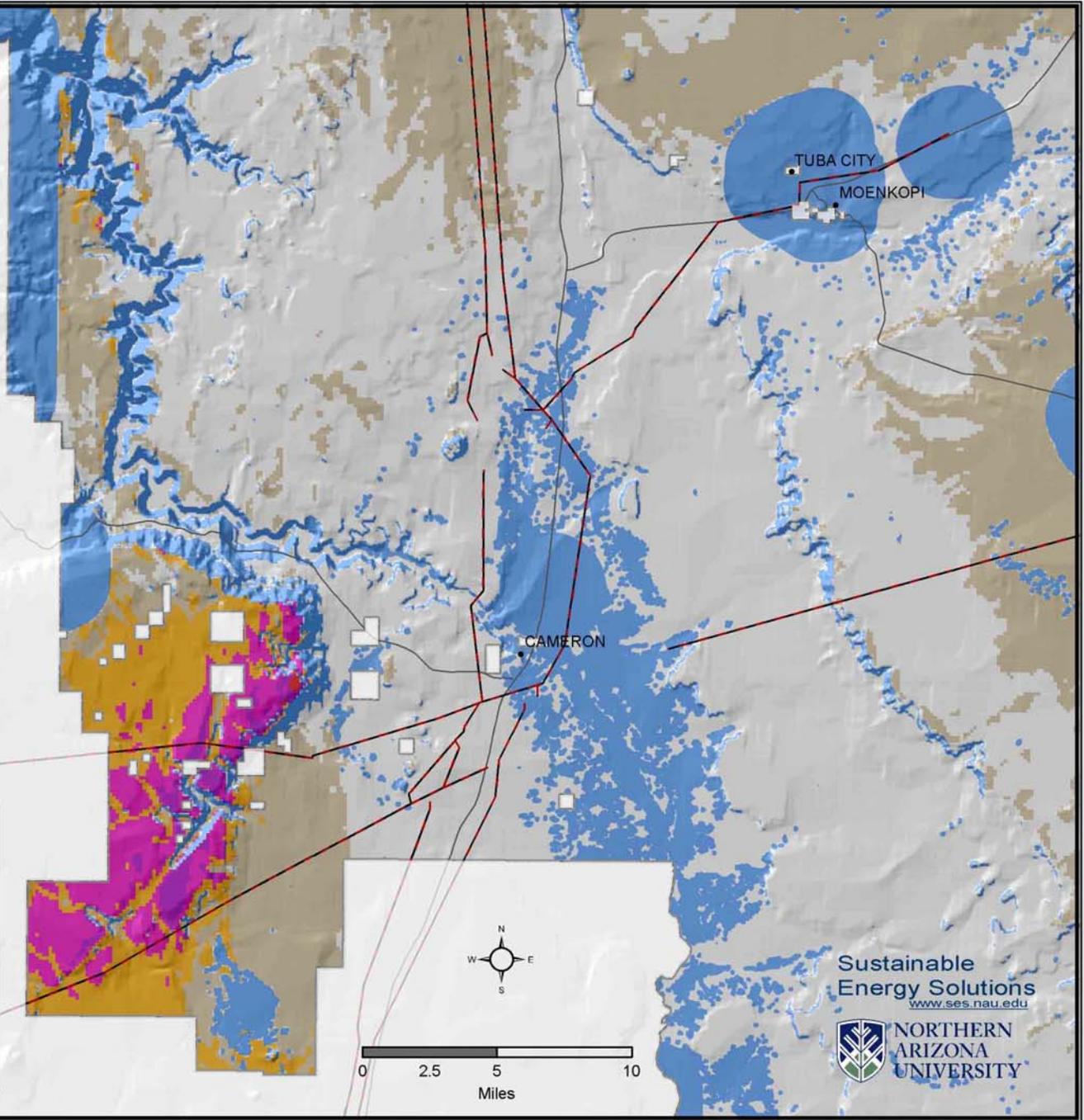
-  Major Roads
-  Transmission Lines
-  Land Excluded 100%
-  Woodlands - Excluded 50%  
Does not include Pinyon-Juniper Woodland

Created by: Grant Brummels  
 Date of Creation: 9/7/2005  
 For more information contact:  
 Dr. Tom Acker  
[Tom.Acker@nau.edu](mailto:Tom.Acker@nau.edu)

Projection:  
 UTM, Zone 12, WGS84  
 Spatial Resolution of  
 Wind Resource Data: 200m

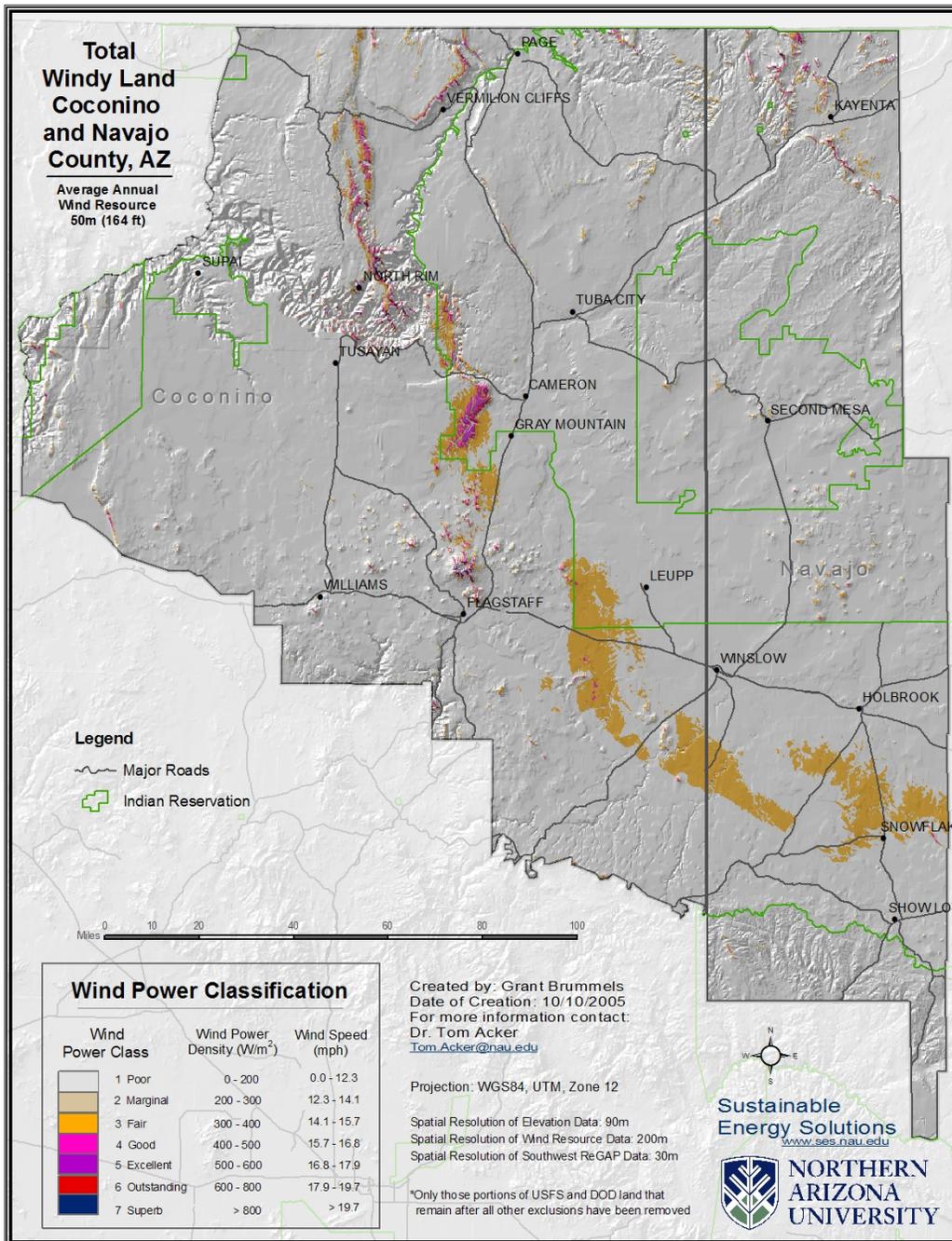
## Wind Power Classification

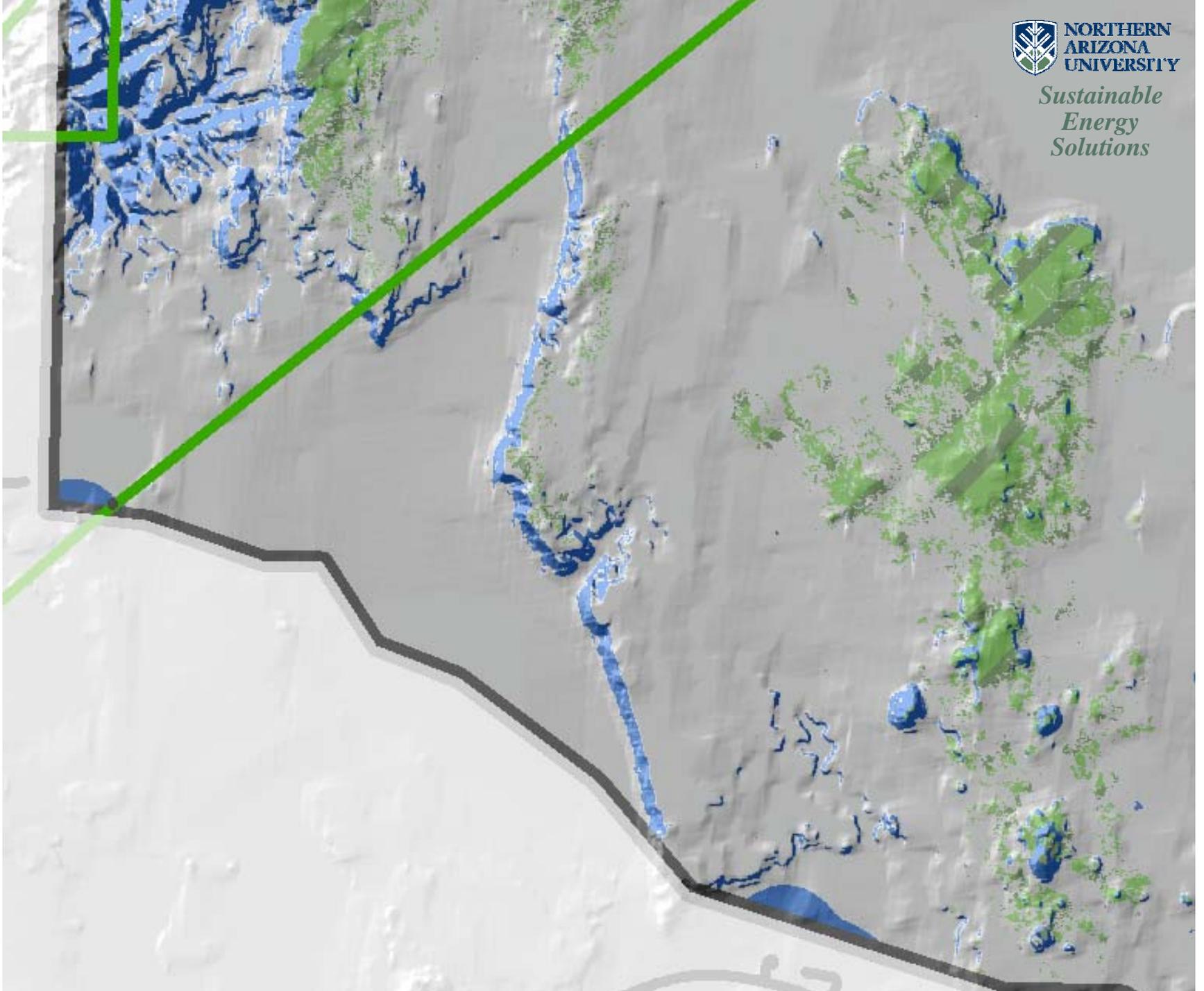
Wind Power Class	Wind Power Density (W/m <sup>2</sup> )	Wind Speed (mph)	
	1 Poor	0 - 200	0.0 - 12.3
	2 Marginal	200 - 300	12.3 - 14.1
	3 Fair	300 - 400	14.1 - 15.7
	4 Good	400 - 500	15.7 - 16.8
	5 Excellent	500 - 600	16.8 - 17.9
	6 Outstanding	600 - 800	17.9 - 19.7
	7 Superb	> 800	> 19.7

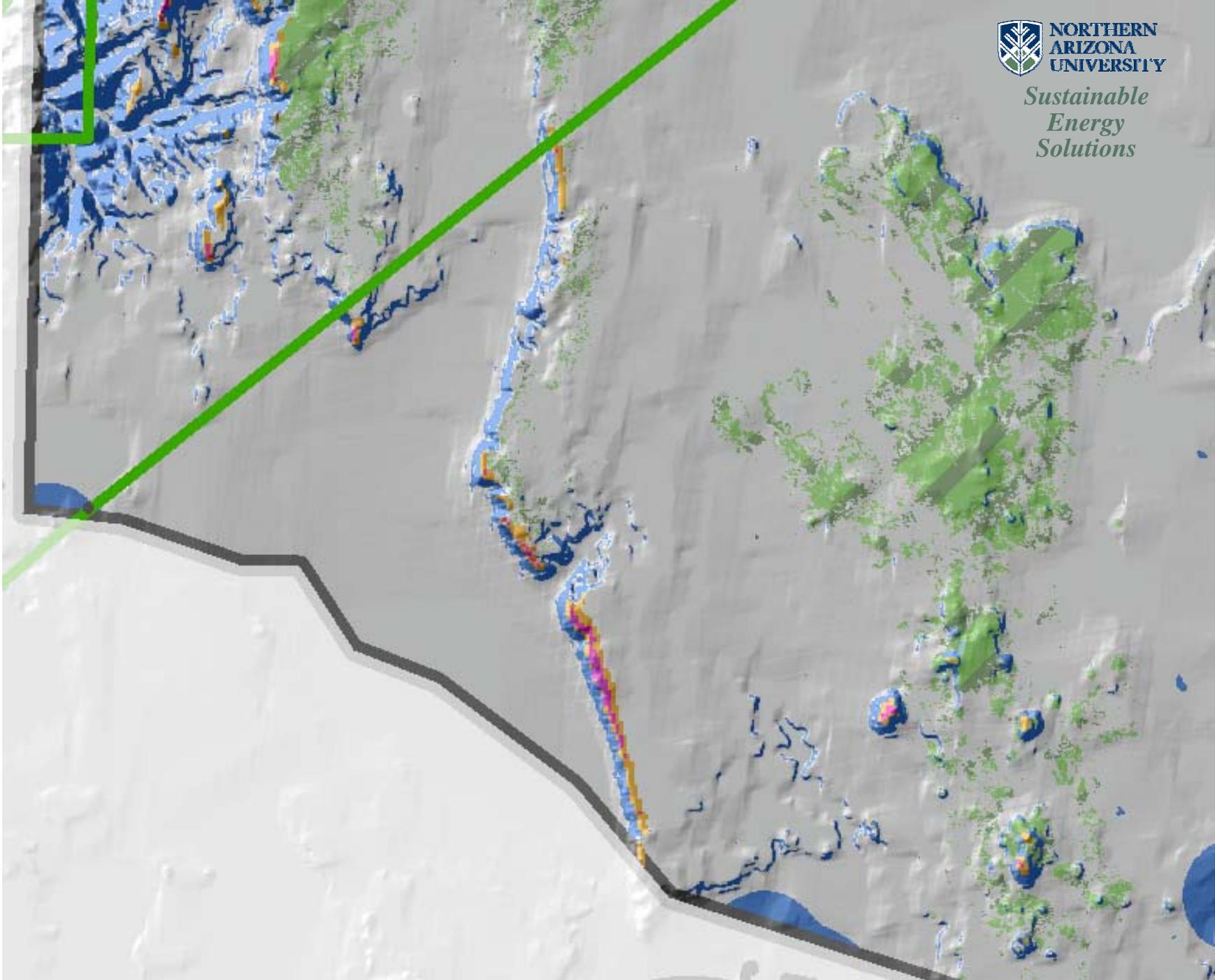


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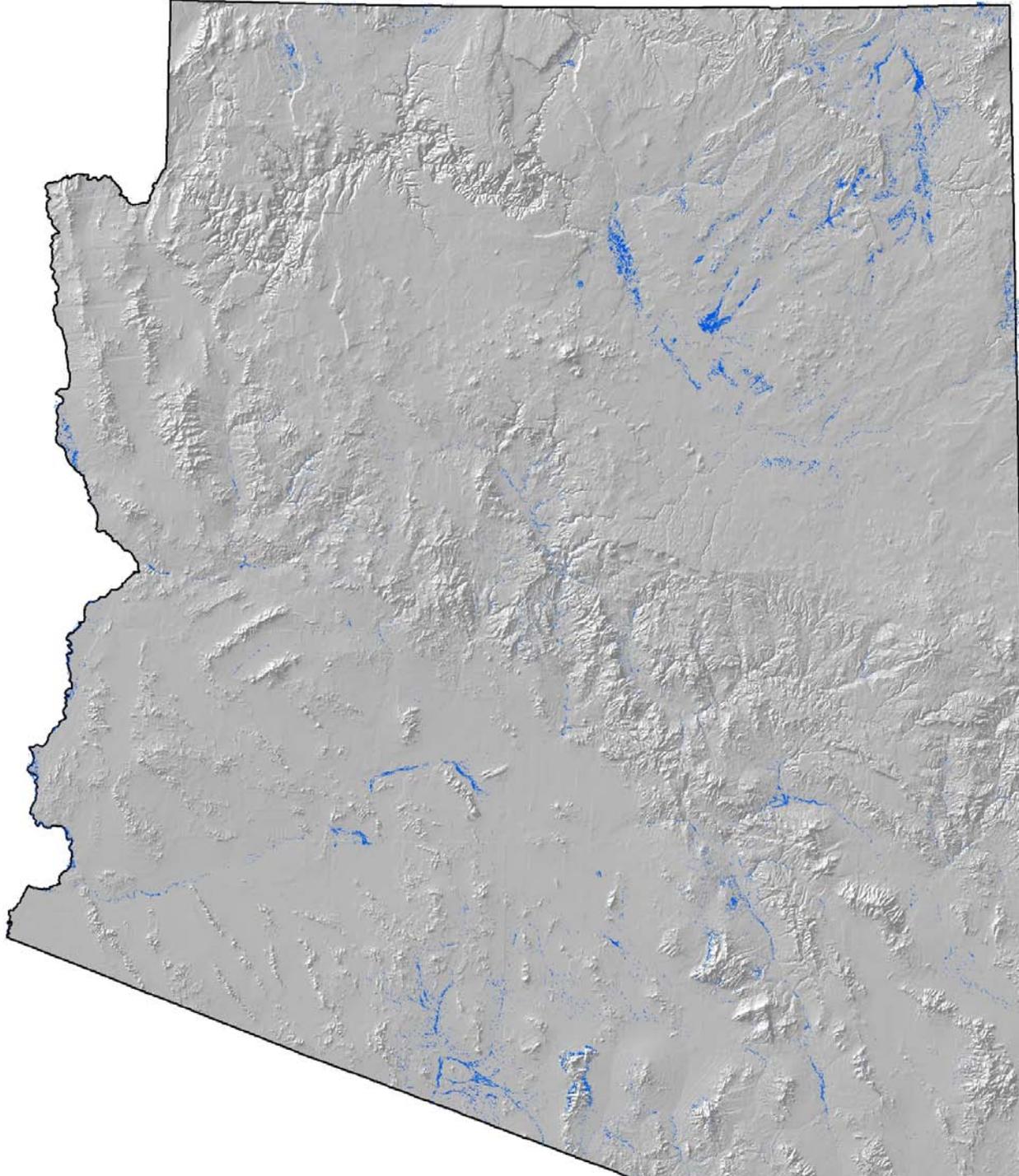








## Wetlands

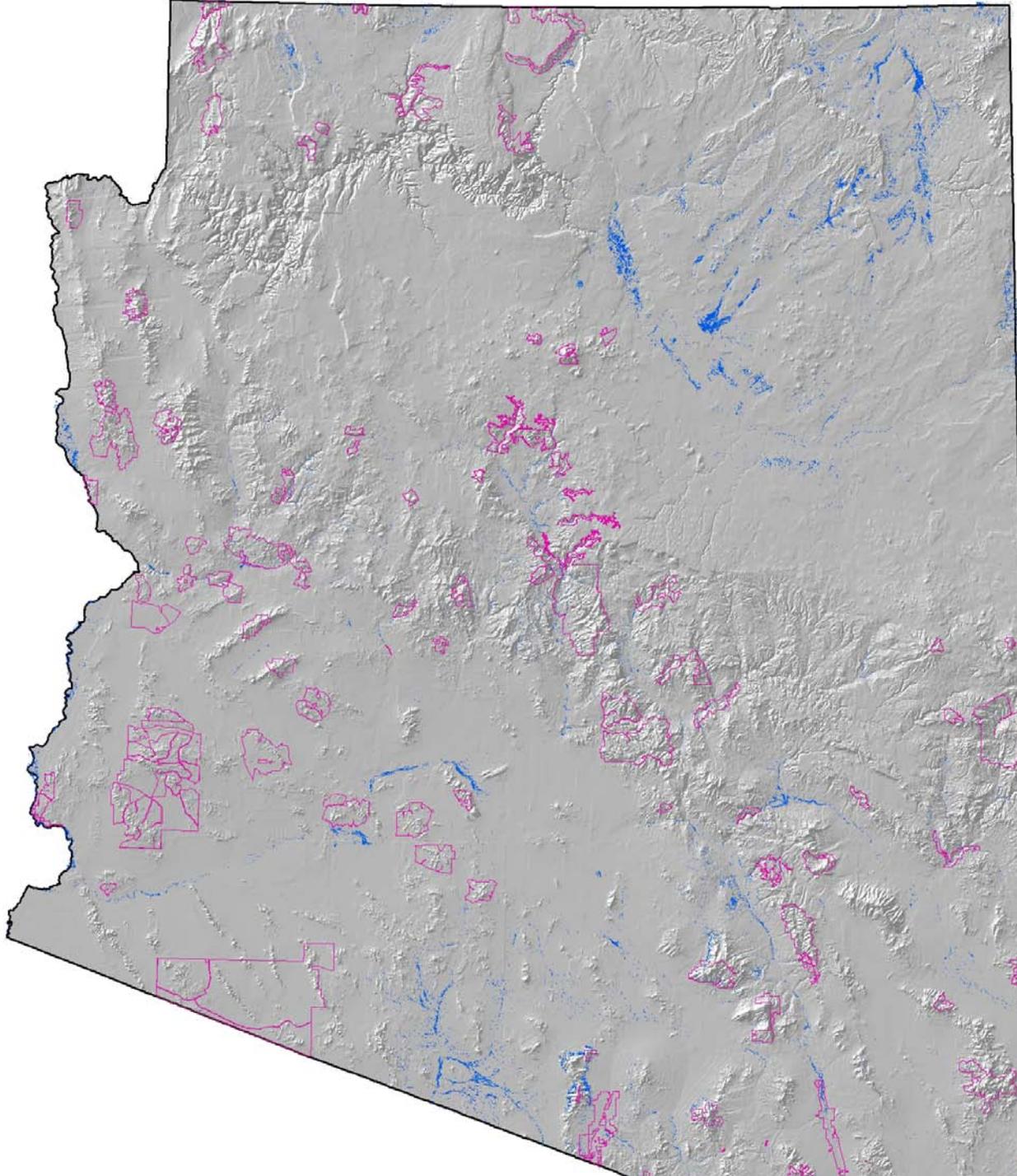




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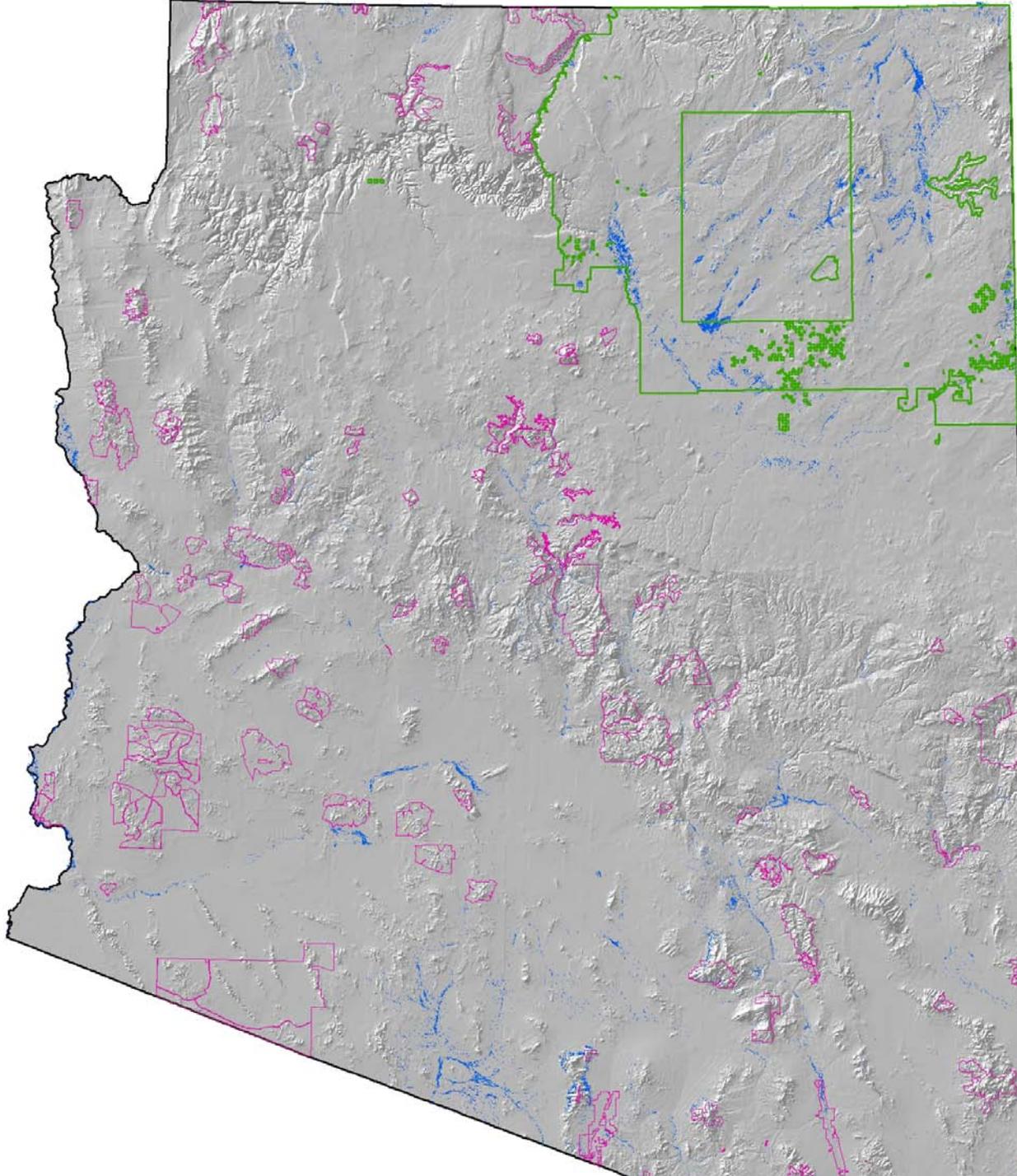
# **Wetlands and Sensitive Environmental Lands**





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Solutions*

# **Wetlands and Sensitive Environmental Lands and Navajo Lands**



# Navajo Allotments

Southwest ReGAP Data  
30m resolution

Navajo Reservation Boundary within Arizona includes:  
-Navajo National Monuments  
-Navajo Trust Land  
-Navajo-Hopi Joint Use Areas

## Legend

-  Major Roads
-  Land Excluded 100%
-  Indian Allotments
-  Woodlands - Excluded 50%  
Does not include Pinyon-Juniper Woodland

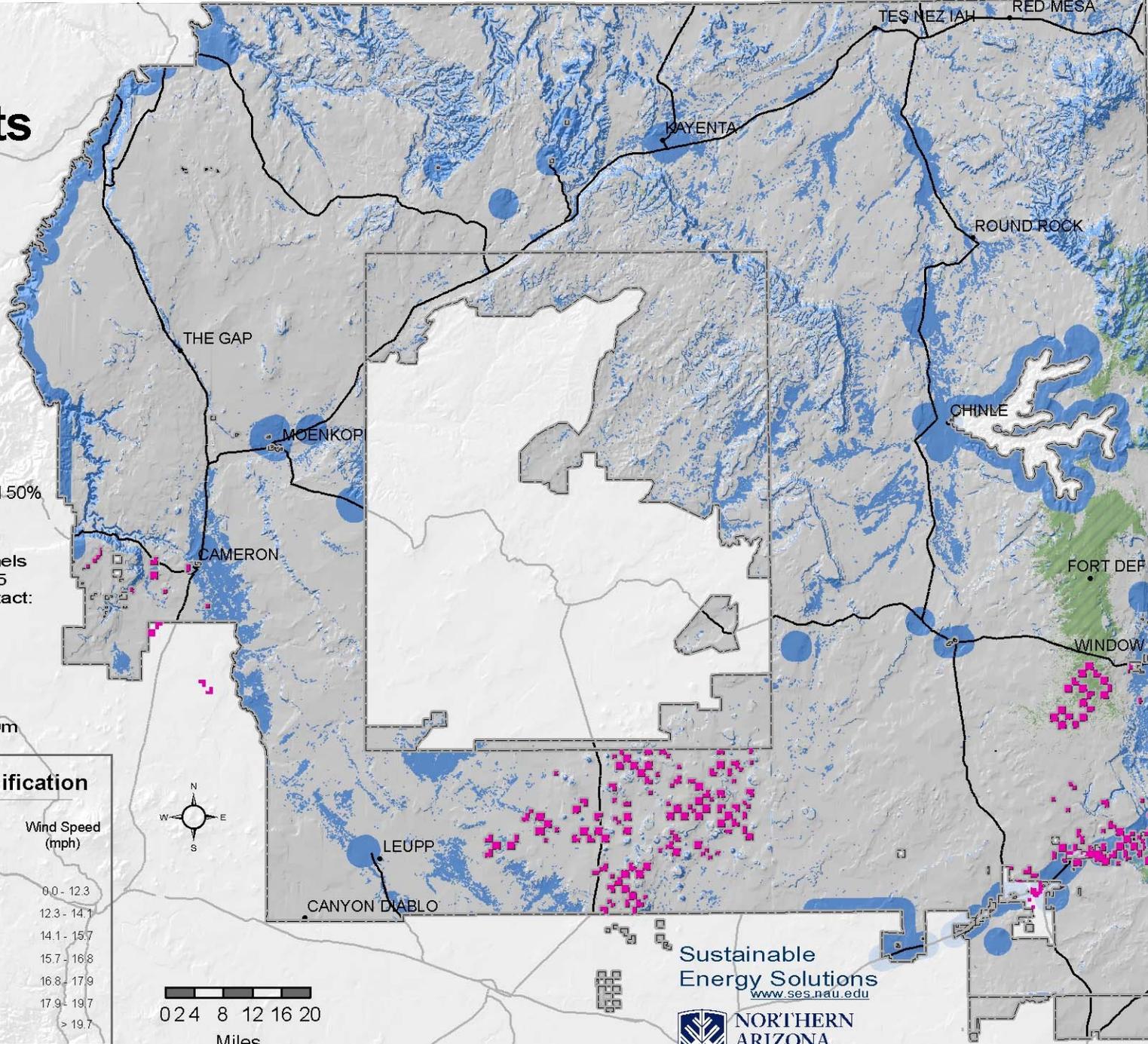
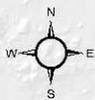
Created by: Grant Brummels  
Date of Creation: 9/7/2005  
For more information contact:  
Dr. Tom Acker

[Tom.Acker@nau.edu](mailto:Tom.Acker@nau.edu)

Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

## Wind Power Classification

Wind Power Class	Wind Power Density (W/m <sup>2</sup> )	Wind Speed (mph)	
	1 Poor	0 - 200	0.0 - 12.3
	2 Marginal	200 - 300	12.3 - 14.1
	3 Fair	300 - 400	14.1 - 15.7
	4 Good	400 - 500	15.7 - 16.8
	5 Excellent	500 - 600	16.8 - 17.9
	6 Outstanding	600 - 800	17.9 - 19.7
	7 Superb	> 800	> 19.7



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# Navajo Allotments 50m Wind

Southwest ReGAP Data  
30m resolution

Navajo Reservation Boundary  
within Arizona includes:  
-Navajo National Monuments  
-Navajo Trust Land  
-Navajo-Hopi Joint Use Areas

## Legend

-  Major Roads
  -  Land Excluded 100%
  -  Woodlands - Excluded 50%
  -  Indian Allotments
- "Woodlands" Does not include Pinyon-Juniper Woodland

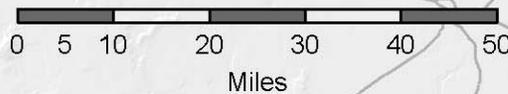
Created by: Grant Brummels  
Date of Creation: 9/7/2005  
For more information contact:  
Dr. Tom Acker

[Tom.Acker@nau.edu](mailto:Tom.Acker@nau.edu)

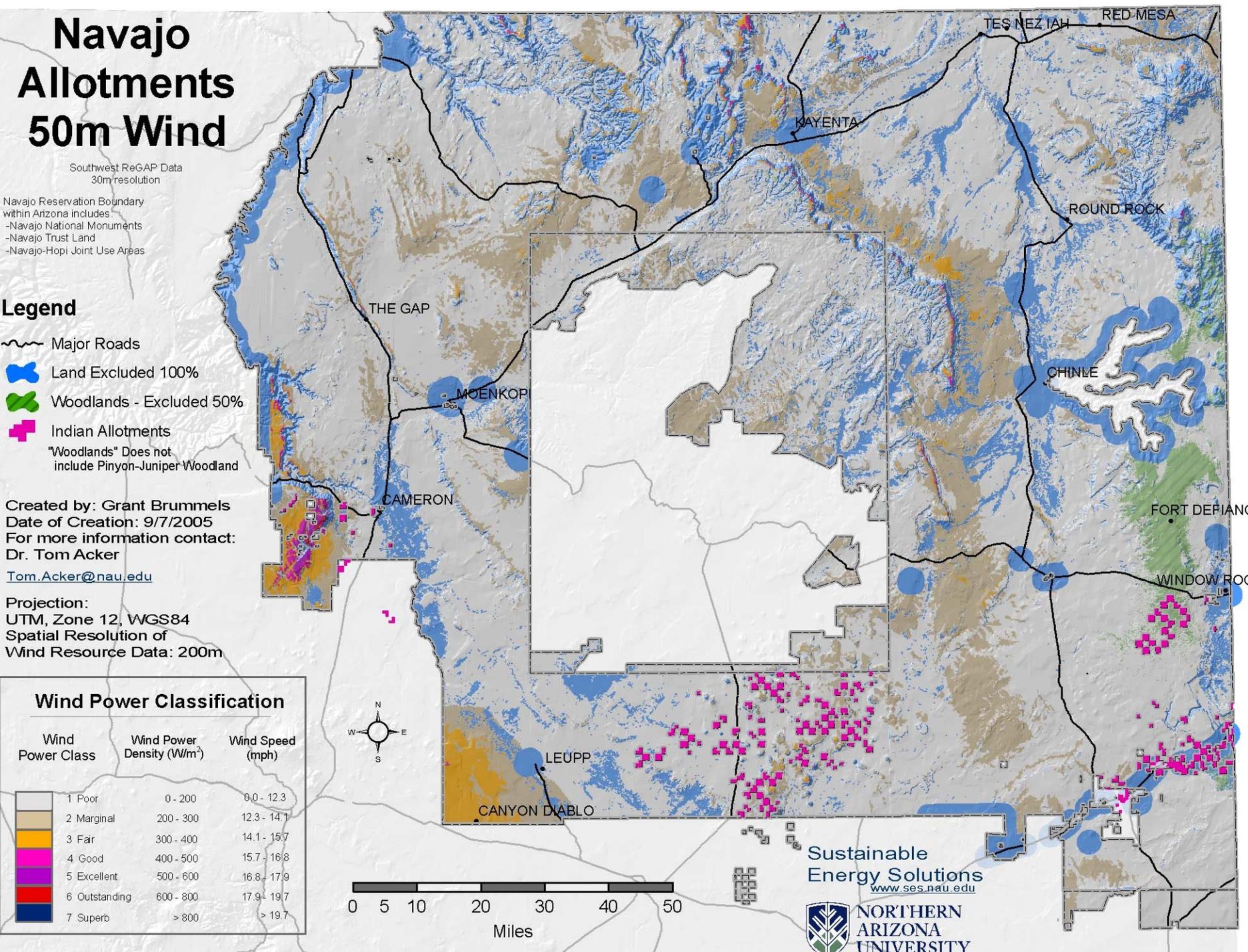
Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

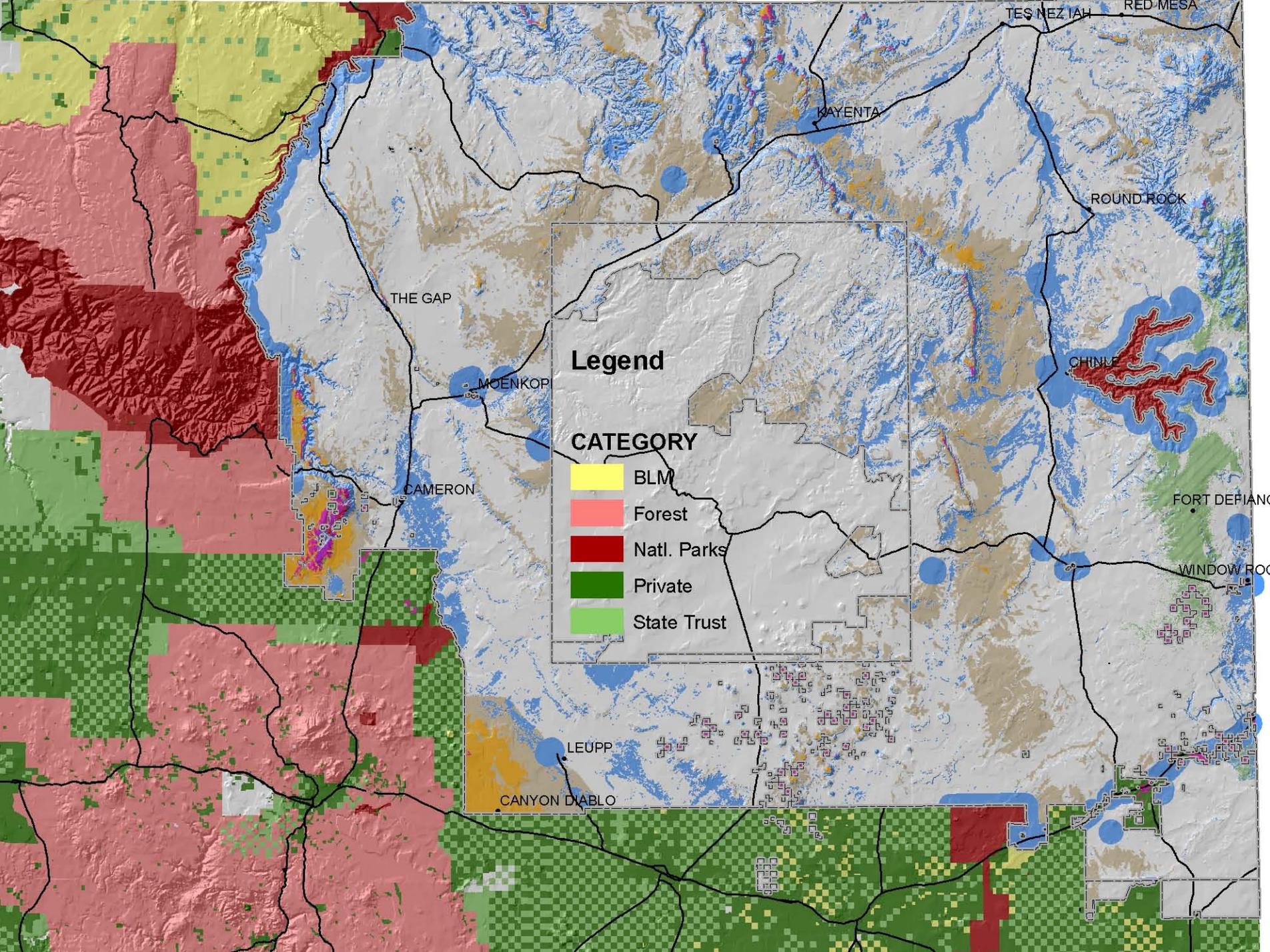
## Wind Power Classification

Wind Power Class	Wind Power Density (W/m <sup>2</sup> )	Wind Speed (mph)	
	1 Poor	0 - 200	0.0 - 12.3
	2 Marginal	200 - 300	12.3 - 14.1
	3 Fair	300 - 400	14.1 - 15.7
	4 Good	400 - 500	15.7 - 16.8
	5 Excellent	500 - 600	16.8 - 17.9
	6 Outstanding	600 - 800	17.9 - 19.7
	7 Superb	> 800	> 19.7



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### Legend

#### CATEGORY

- BLM
- Forest
- Natl. Parks
- Private
- State Trust

THE GAP

MOENKOP

CAMERON

LEUPP

CANYON DIABLO

KAYENTA

TES NEZ IAH

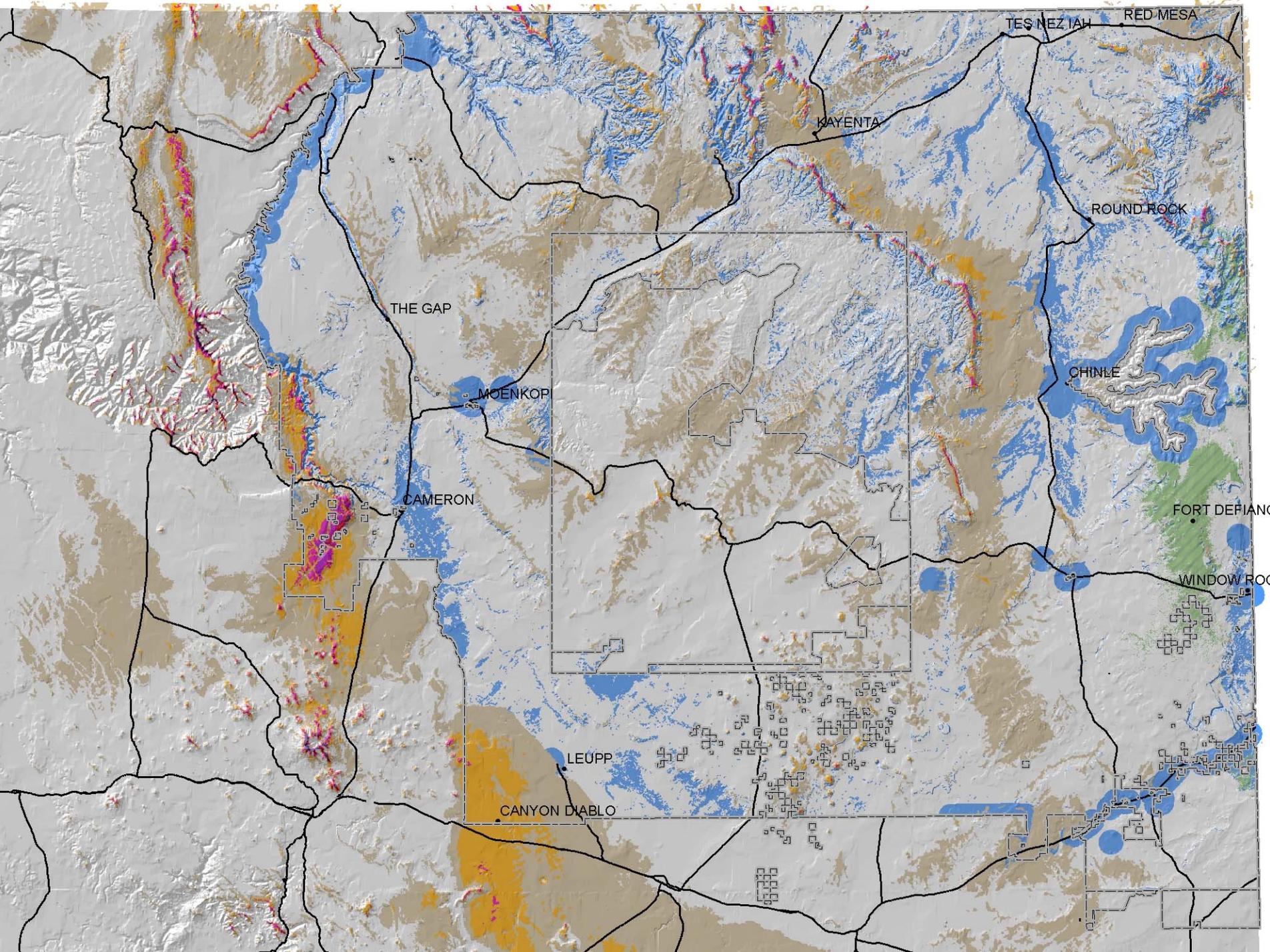
RED MESA

ROUND ROCK

CHINLE

FORT DEFIANCIA

WINDOW ROCK



TES NEZ IAH RED MESA

KAYENTA

ROUND ROCK

THE GAP

MOENKOP

CHINLE

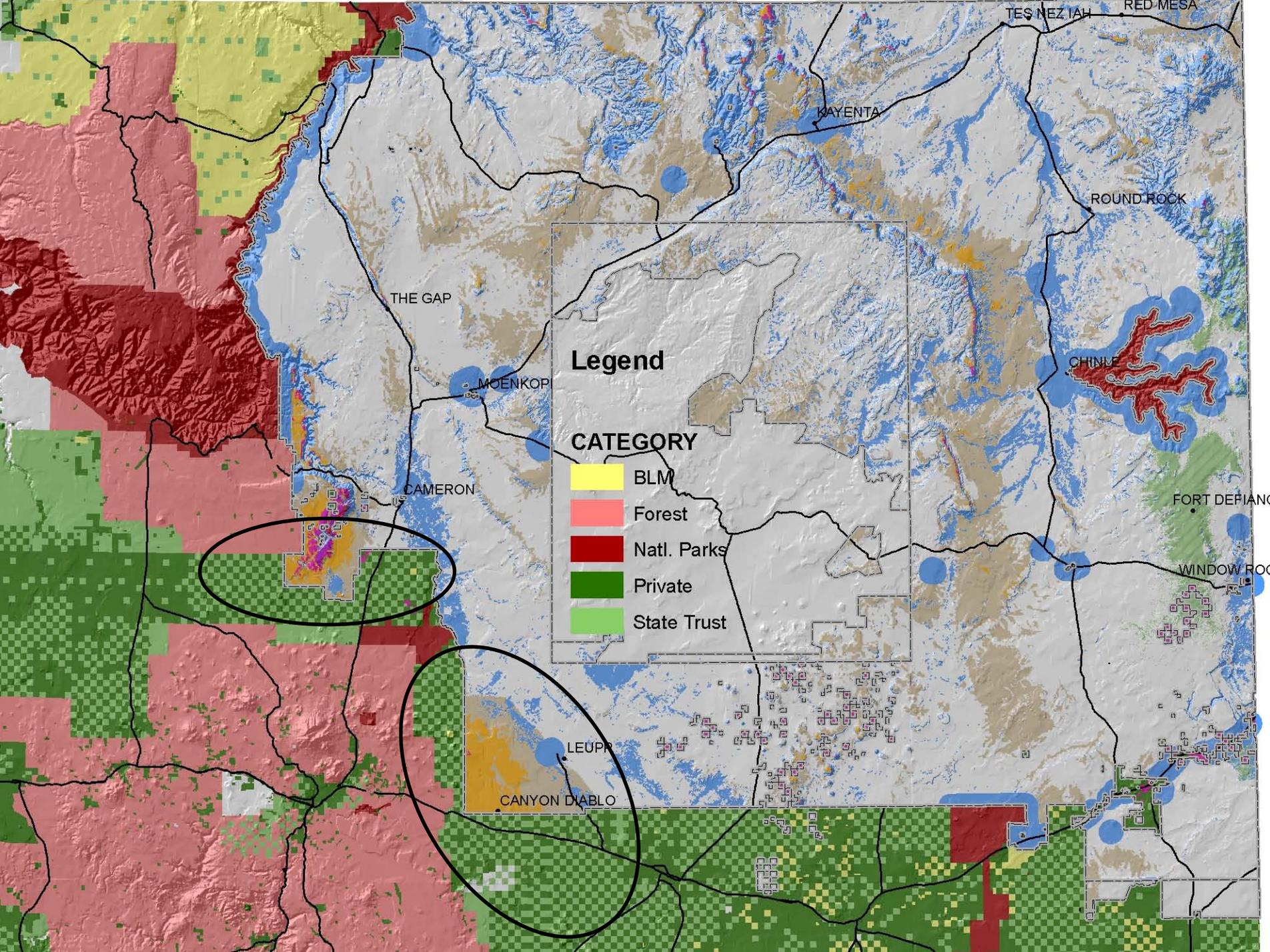
CAMERON

FORT DEFIANCE

LEUPP

WINDOW ROCK

CANYON DIABLO



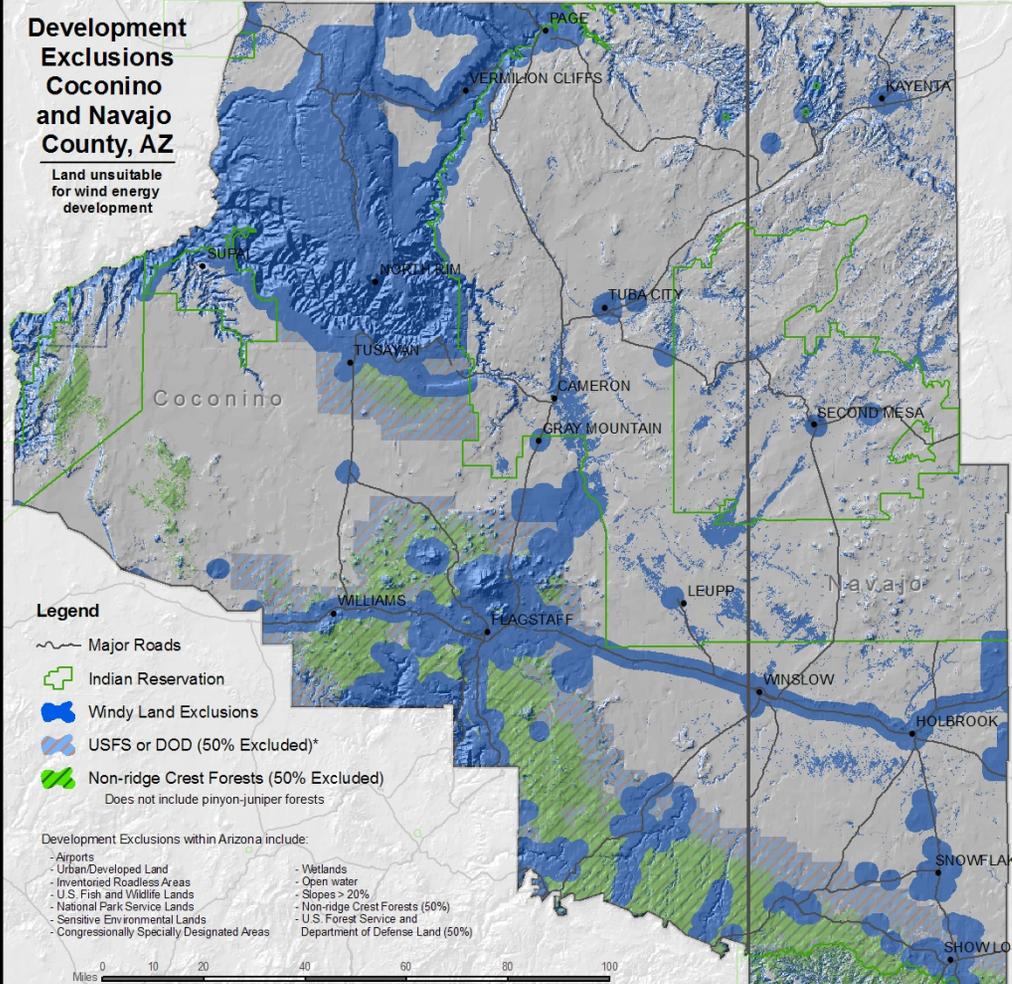
### Legend

#### CATEGORY

- BLM
- Forest
- Natl. Parks
- Private
- State Trust

## Development Exclusions Coconino and Navajo County, AZ

Land unsuitable for wind energy development



### Legend

-  Major Roads
-  Indian Reservation
-  Windy Land Exclusions
-  USFS or DOD (50% Excluded)\*
-  Non-ridge Crest Forests (50% Excluded)  
Does not include pinyon-juniper forests

### Development Exclusions within Arizona include:

- Airports
- Urban/Developed Land
- Inventoried Roadless Areas
- U.S. Fish and Wildlife Lands
- National Park Service Lands
- Sensitive Environmental Lands
- Congressionally Specially Designated Areas
- Wetlands
- Open water
- Slopes > 20%
- Non-ridge Crest Forests (50%)
- U.S. Forest Service and Department of Defense Land (50%)



### Wind Power Classification

Wind Power Class	Wind Power Density (W/m <sup>2</sup> )	Wind Speed (mph)
1 Poor	0 - 200	0.0 - 12.3
2 Marginal	200 - 300	12.3 - 14.1
3 Fair	300 - 400	14.1 - 15.7
4 Good	400 - 500	15.7 - 16.8
5 Excellent	500 - 600	16.8 - 17.9
6 Outstanding	600 - 800	17.9 - 19.7
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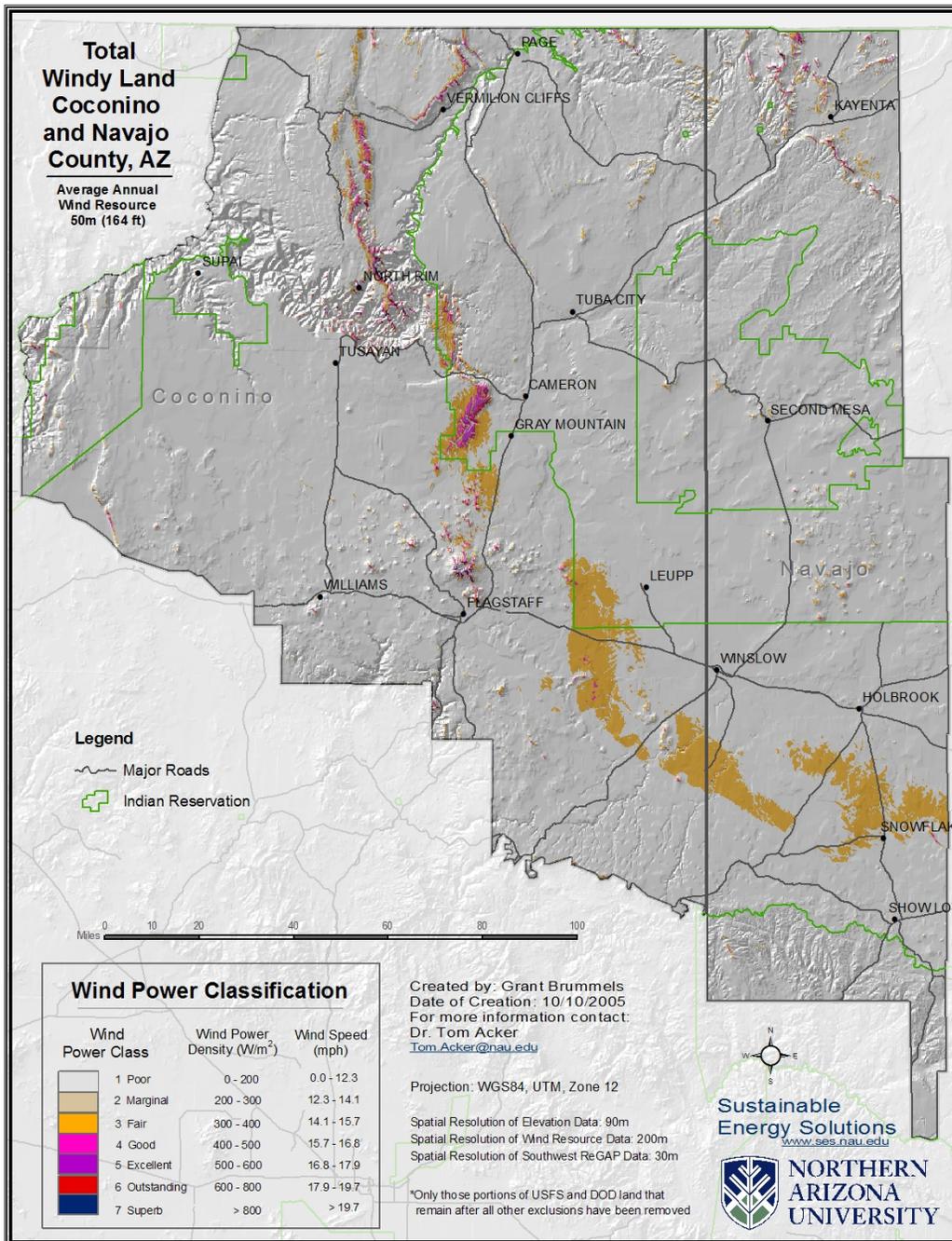
Projection: WGS84, UTM, Zone 12

Spatial Resolution of Elevation Data: 90m  
Spatial Resolution of Wind Resource Data: 200m  
Spatial Resolution of Southwest ReGAP Data: 30m

\*Only those portions of USFS and DOD land that remain after all other exclusions have been removed

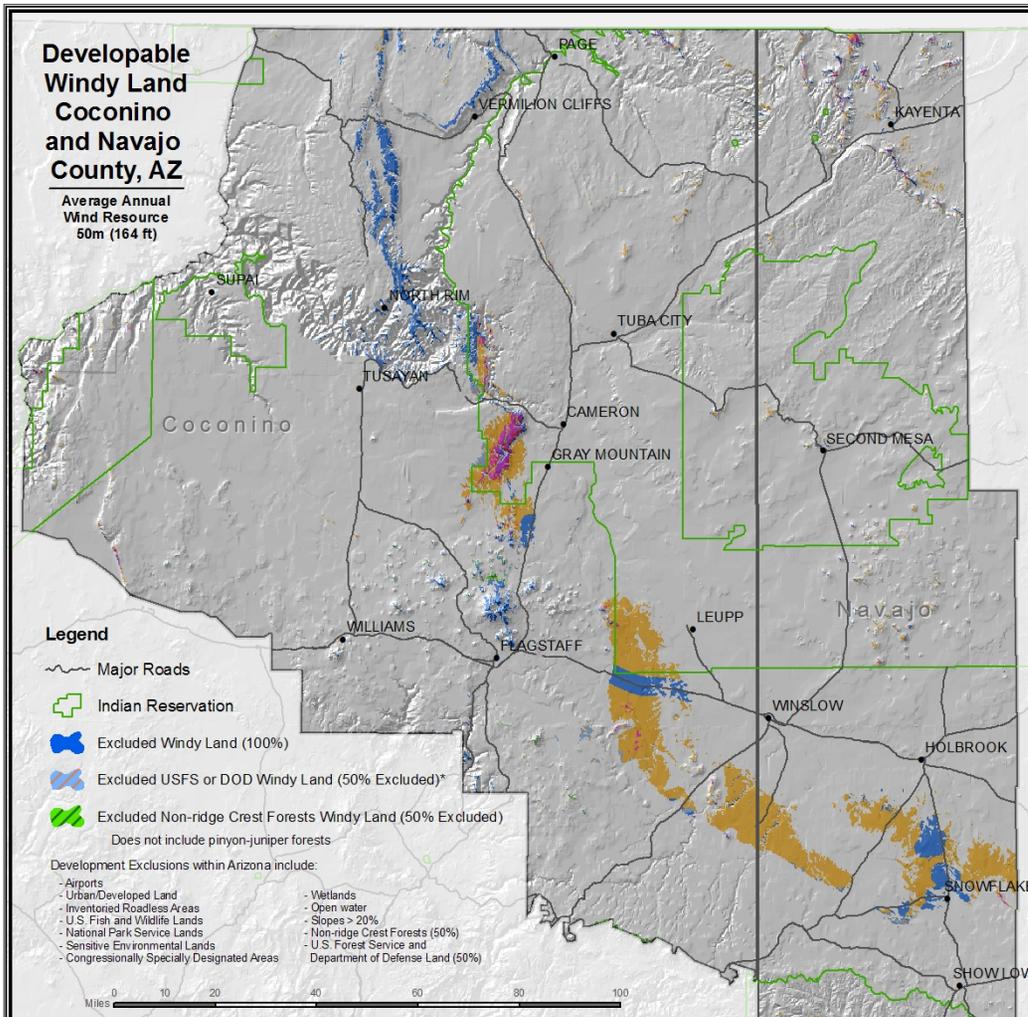


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# Developable Windy Land Coconino and Navajo County, AZ

Average Annual  
Wind Resource  
50m (164 ft)



### Legend

- Major Roads
- Indian Reservation
- Excluded Windy Land (100%)
- Excluded USFS or DOD Windy Land (50% Excluded)\*
- Excluded Non-ridge Crest Forests Windy Land (50% Excluded)  
Does not include pinyon-juniper forests

Development Exclusions within Arizona include:

- Airports
- Urban/Developed Land
- Inventoried Roadless Areas
- U.S. Fish and Wildlife Lands
- National Park Service Lands
- Sensitive Environmental Lands
- Congressionally Specially Designated Areas
- Wetlands
- Open water
- Slopes > 20%
- Non-ridge Crest Forests (50%)
- U.S. Forest Service and Department of Defense Land (50%)



### Wind Power Classification

Wind Power Class	Wind Power Density (W/m <sup>2</sup> )	Wind Speed (mph)
	1 Poor	0 - 200
	2 Marginal	200 - 300
	3 Fair	300 - 400
	4 Good	400 - 500
	5 Excellent	500 - 600
	6 Outstanding	600 - 800
	7 Superb	> 800

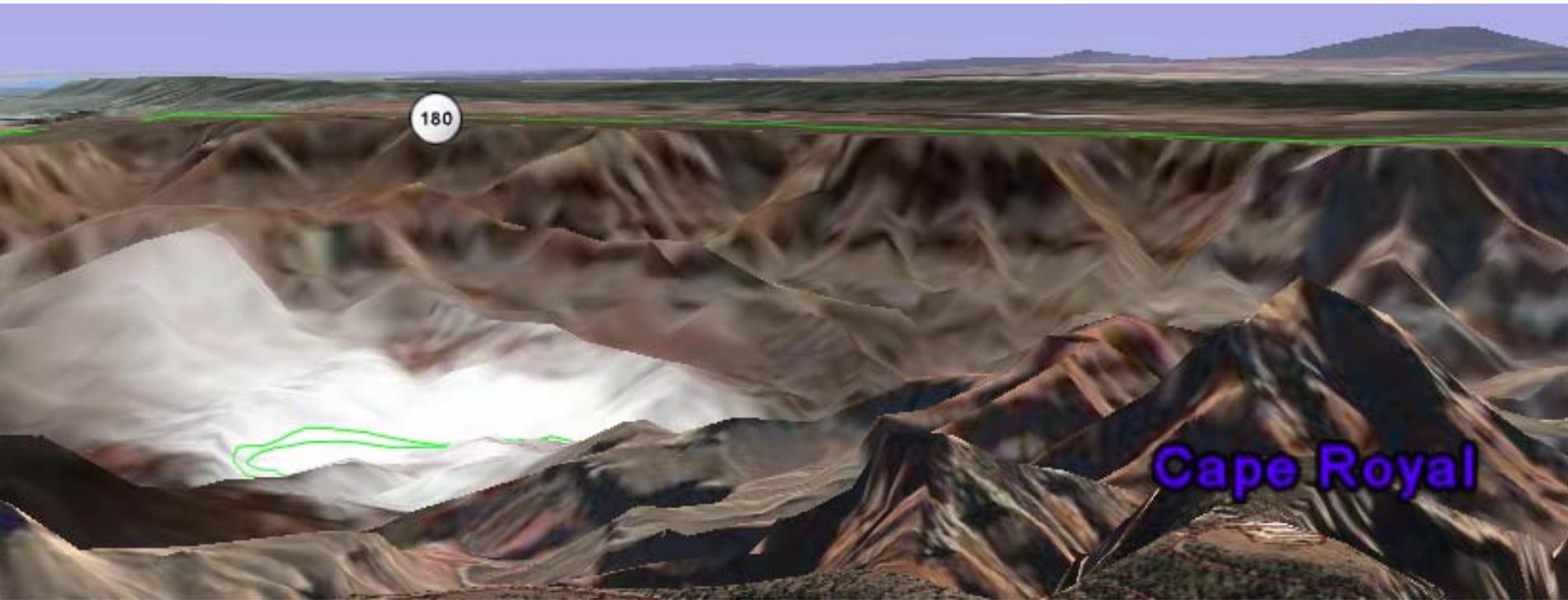
Created by: Grant Brummels  
Date of Creation: 10/10/2005  
For more information contact:  
Dr. Tom Acker  
[Tom.Acker@nau.edu](mailto:Tom.Acker@nau.edu)

Projection: WGS84, UTM, Zone 12  
Spatial Resolution of Elevation Data: 90m  
Spatial Resolution of Wind Resource Data: 200m  
Spatial Resolution of Southwest ReGAP Data: 30m

\*Only those portions of USFS and DOD land that remain after all other exclusions have been removed



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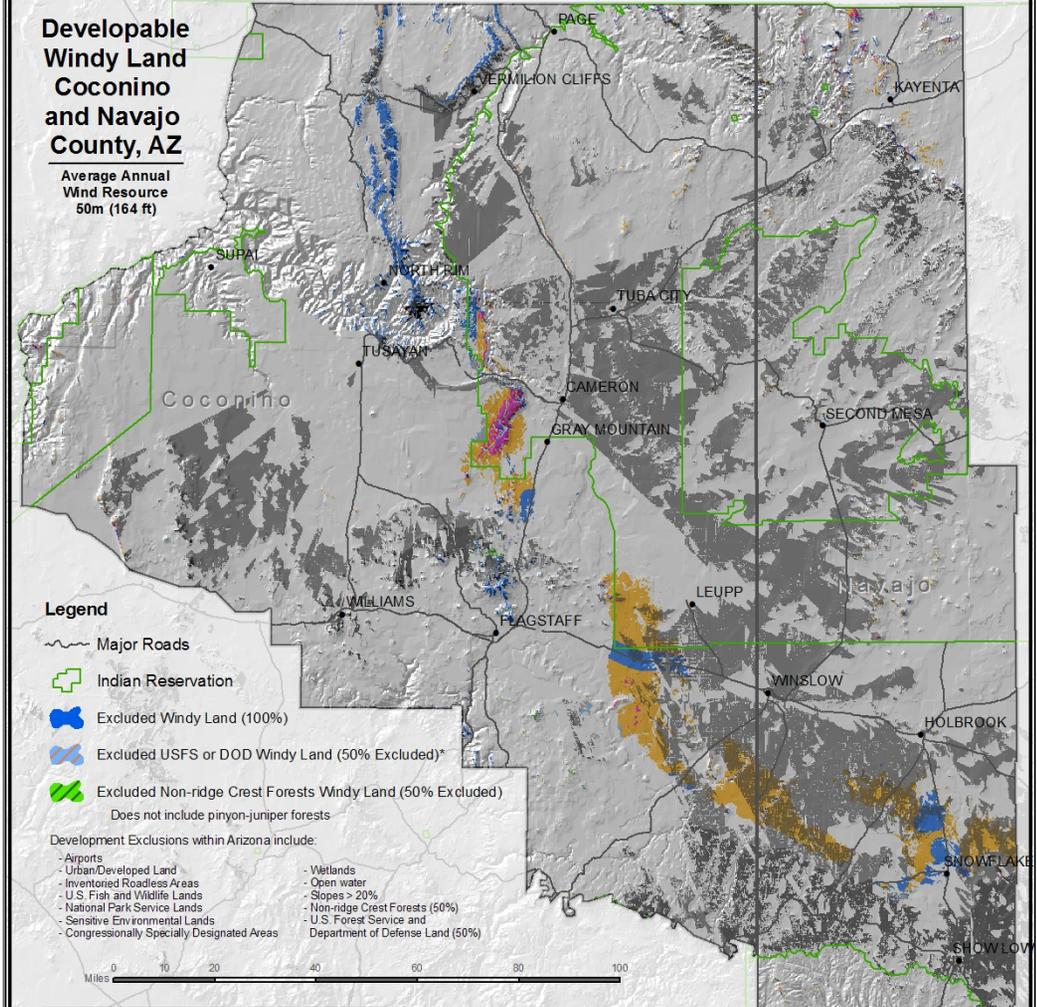


Eye alt 9875 ft



# Developable Windy Land Coconino and Navajo County, AZ

Average Annual  
Wind Resource  
50m (164 ft)



### Legend

-  Major Roads
-  Indian Reservation
-  Excluded Windy Land (100%)
-  Excluded USFS or DOD Windy Land (50% Excluded)\*
-  Excluded Non-ridge Crest Forests Windy Land (50% Excluded)  
Does not include pinyon-juniper forests

Development Exclusions within Arizona include:

- Airports
- Urban/Developed Land
- Inventoried Roadless Areas
- U.S. Fish and Wildlife Lands
- National Park Service Lands
- Sensitive Environmental Lands
- Congressionally Specially Designated Areas
- Wetlands
- Open water
- Slopes > 20%
- Non-ridge Crest Forests (50%)
- U.S. Forest Service and Department of Defense Land (50%)



### Wind Power Classification

Wind Power Class	Wind Power Density (W/m <sup>2</sup> )	Wind Speed (mph)
1 Poor	0 - 200	0.0 - 12.3
2 Marginal	200 - 300	12.3 - 14.1
3 Fair	300 - 400	14.1 - 15.7
4 Good	400 - 500	15.7 - 16.8
5 Excellent	500 - 600	16.8 - 17.9
6 Outstanding	600 - 800	17.9 - 19.7
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Projection: WGS84, UTM, Zone 12

Spatial Resolution of Elevation Data: 90m  
Spatial Resolution of Wind Resource Data: 200m  
Spatial Resolution of Southwest ReGAP Data: 30m

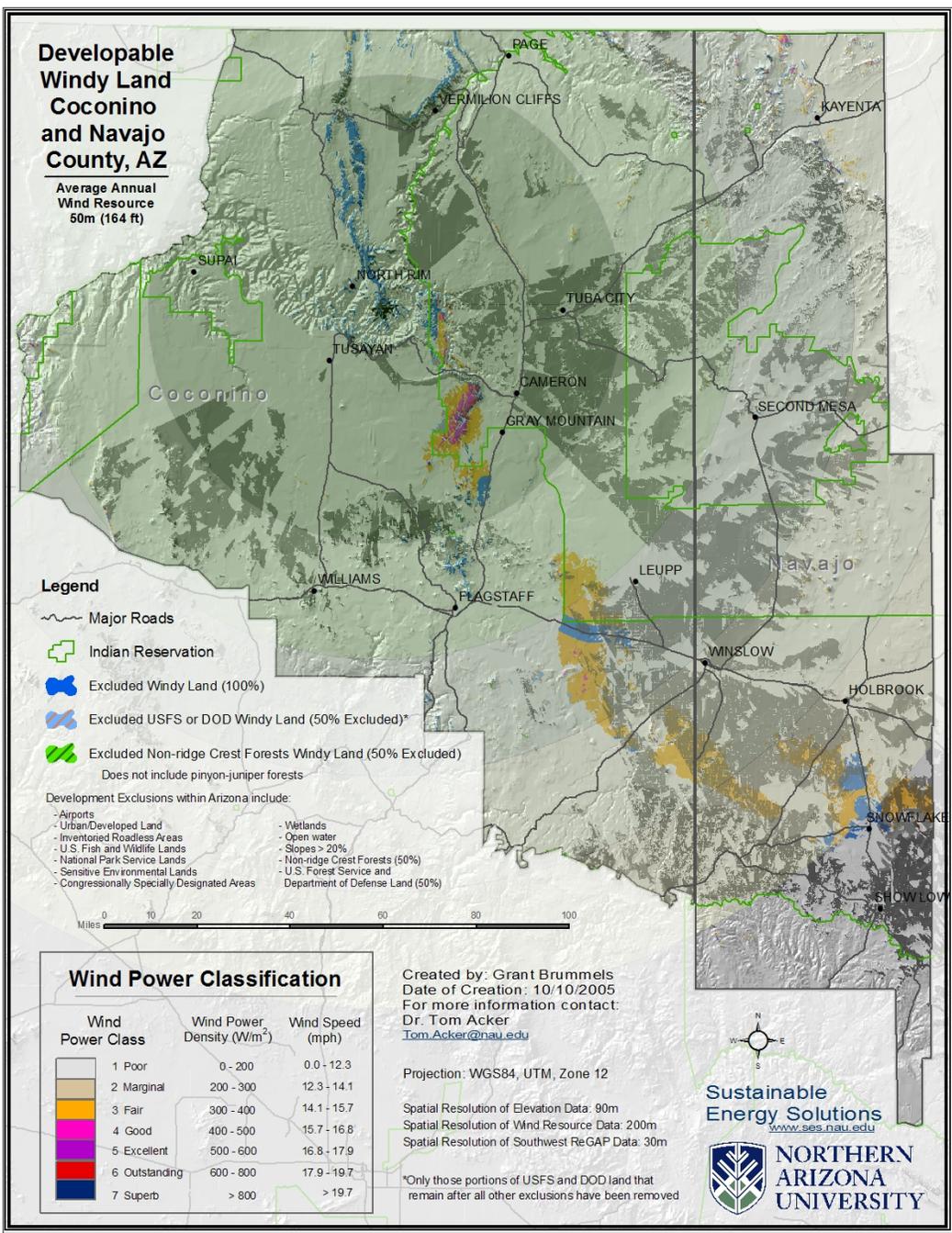
\*Only those portions of USFS and DOD land that remain after all other exclusions have been removed



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**Developable Windy Land  
Coconino  
and Navajo  
County, AZ**

Average Annual  
Wind Resource  
50m (164 ft)



**Legend**

-  Major Roads
-  Indian Reservation
-  Excluded Windy Land (100%)
-  Excluded USFS or DOD Windy Land (50% Excluded)\*
-  Excluded Non-ridge Crest Forests Windy Land (50% Excluded)  
Does not include pinyon-juniper forests

Development Exclusions within Arizona include:

- Airports
- Urban/Developed Land
- Inventoried Roadless Areas
- U.S. Fish and Wildlife Lands
- National Park Service Lands
- Sensitive Environmental Lands
- Congressionally Specially Designated Areas
- Wetlands
- Open water
- Slopes > 20%
- Non-ridge Crest Forests (50%)
- U.S. Forest Service and Department of Defense Land (50%)



**Wind Power Classification**

Wind Power Class	Wind Power Density (W/m <sup>2</sup> )	Wind Speed (mph)
1 Poor	0 - 200	0.0 - 12.3
2 Marginal	200 - 300	12.3 - 14.1
3 Fair	300 - 400	14.1 - 15.7
4 Good	400 - 500	15.7 - 16.8
5 Excellent	500 - 600	16.8 - 17.9
6 Outstanding	600 - 800	17.9 - 19.7
7 Superb	> 800	> 19.7

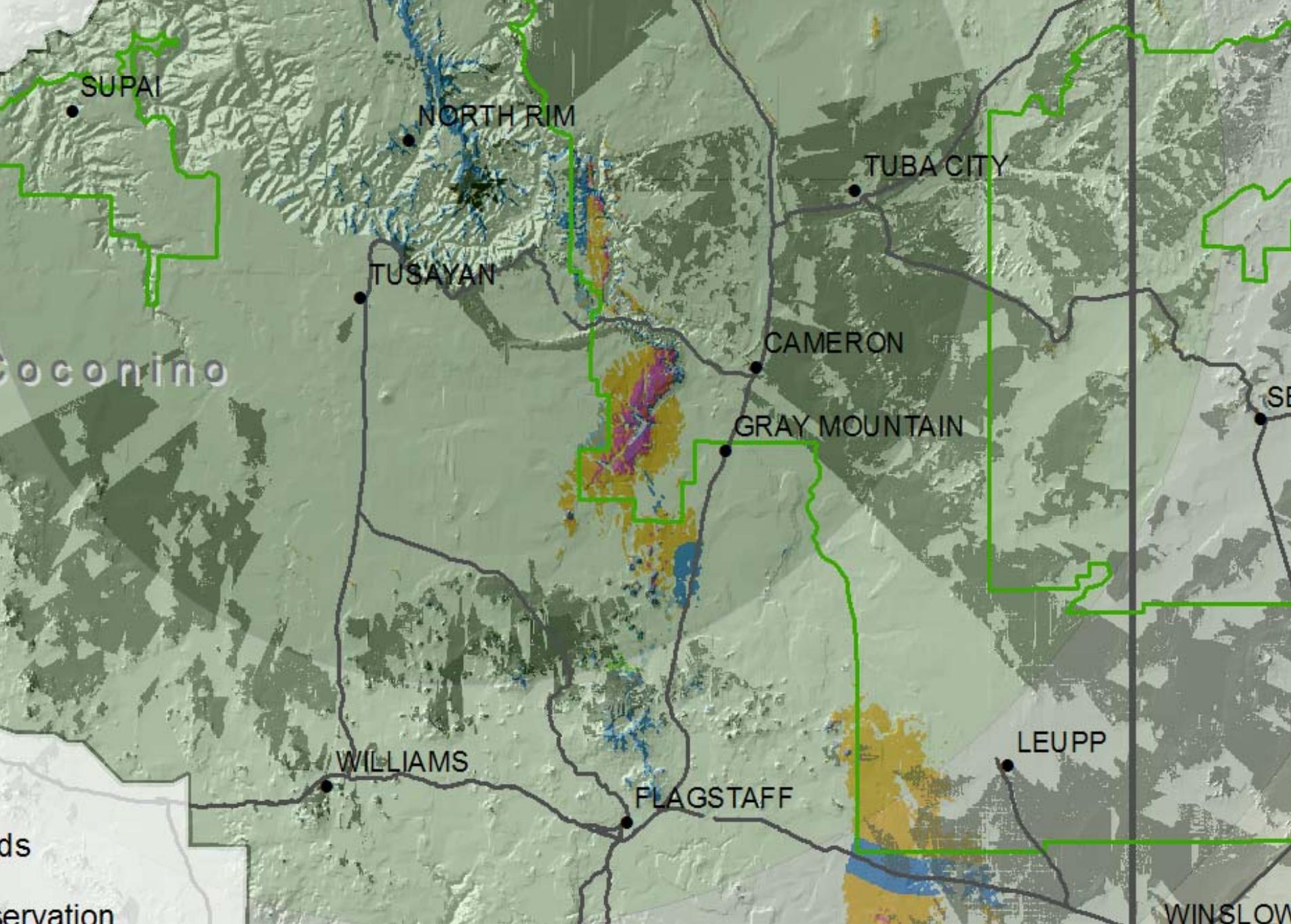
Created by: Grant Brummels  
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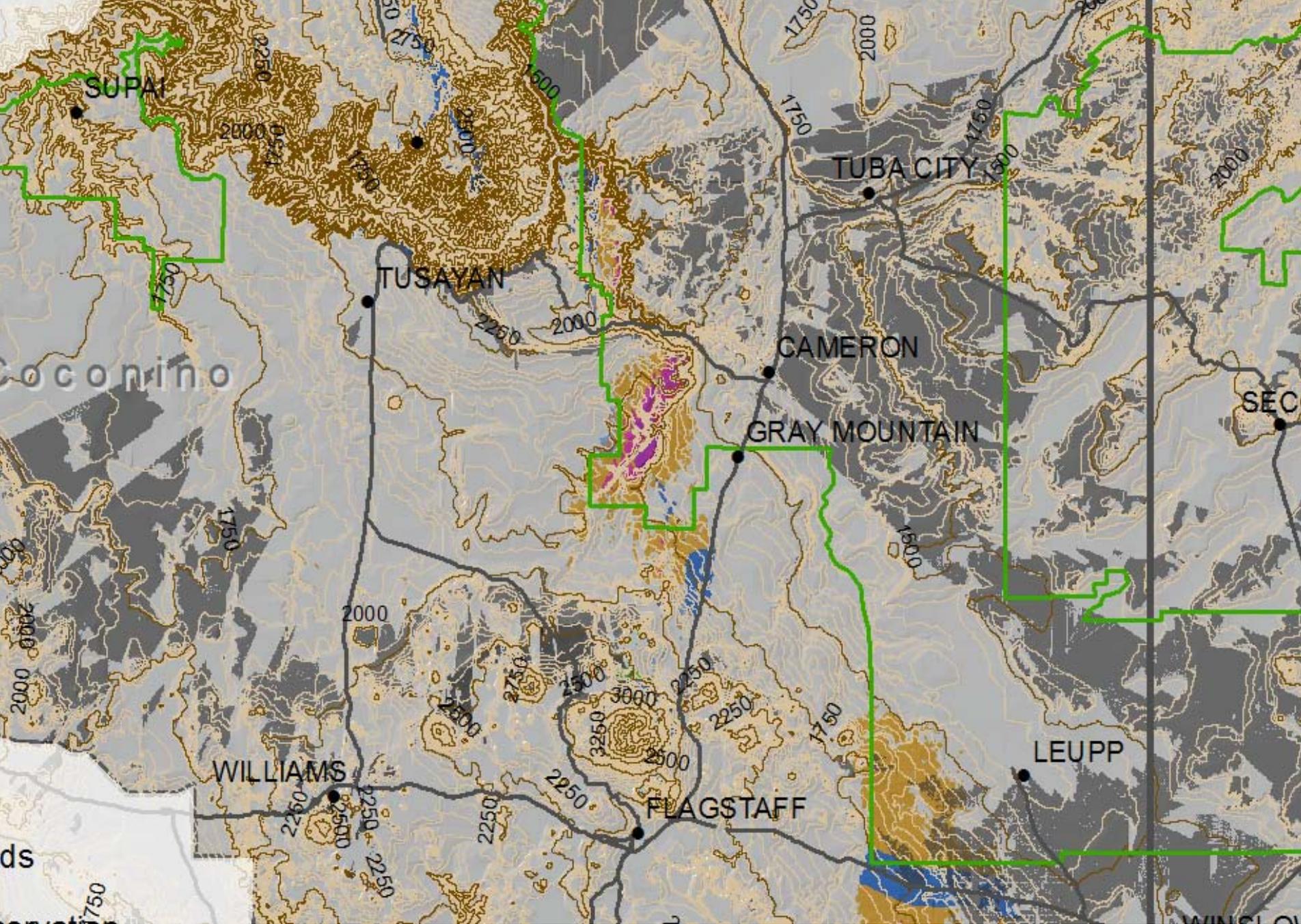
Projection: WGS84, UTM, Zone 12  
Spatial Resolution of Elevation Data: 90m  
Spatial Resolution of Wind Resource Data: 200m  
Spatial Resolution of Southwest ReGAP Data: 30m

\*Only those portions of USFS and DOD land that remain after all other exclusions have been removed



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# Navajo Woodland Comparison

## within Arizona

Navajo Reservation Boundary includes:  
 -Navajo National Monuments  
 -Navajo Trust Land  
 -Navajo-Hopi Joint Use Areas

### Legend

-  Major Roads
-  Pinyon-Juniper Woodland
-  Woodlands - Excluded 50%  
Does not include Pinyon-Juniper Woodland

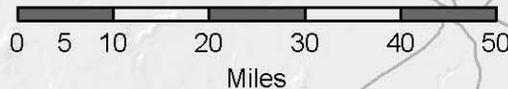
Created by: Grant Brummels  
 Date of Creation: 9/7/2005  
 For more information contact:  
 Dr. Tom Acker

[Tom.Acker@nau.edu](mailto:Tom.Acker@nau.edu)

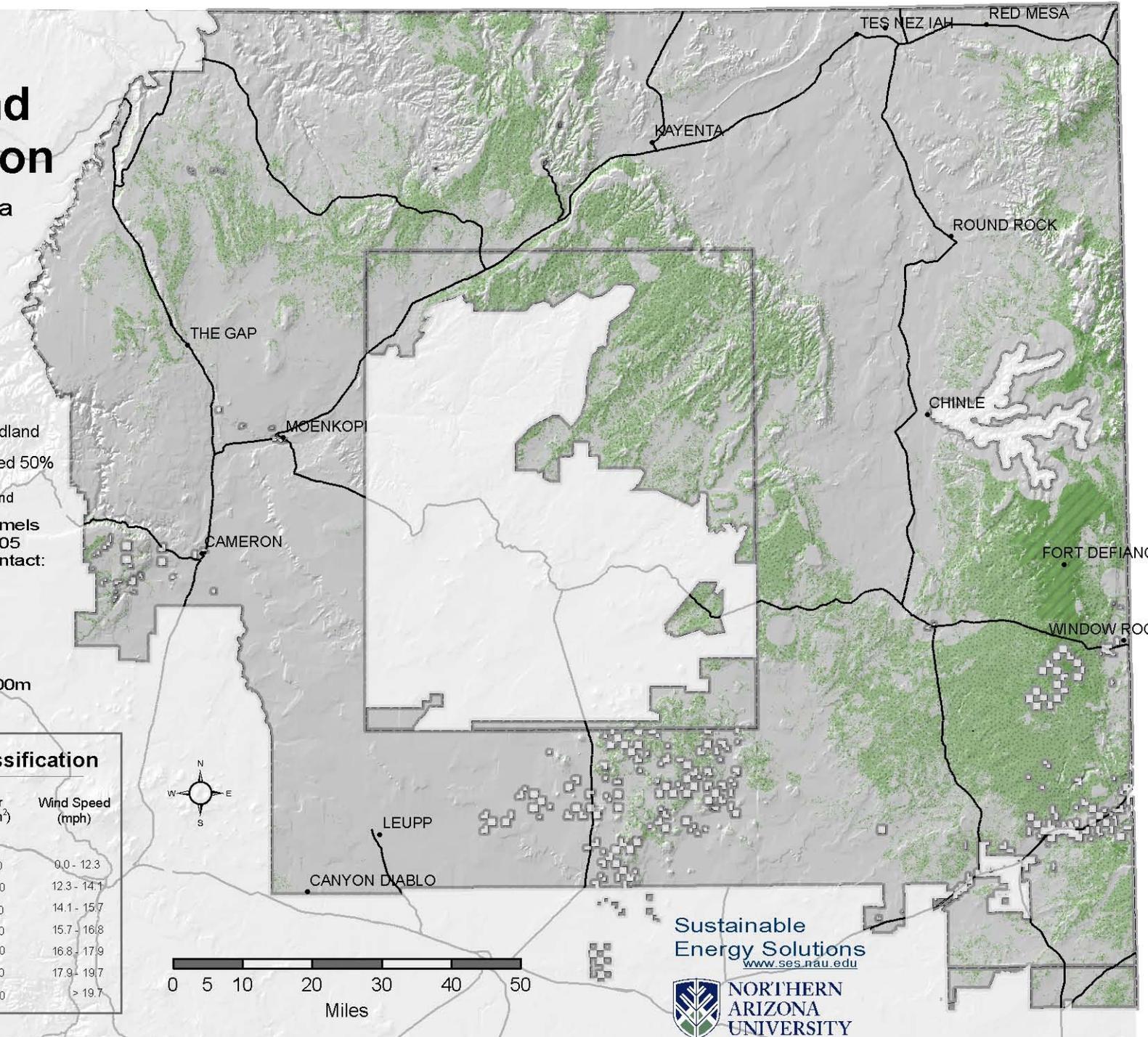
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 UTM, Zone 12, WGS84  
 Spatial Resolution of  
 Wind Resource Data: 200m

### Wind Power Classification

Wind Power Class	Wind Power Density ( $W/m^2$ )	Wind Speed (mph)	
	1 Poor	0 - 200	0.0 - 12.3
	2 Marginal	200 - 300	12.3 - 14.1
	3 Fair	300 - 400	14.1 - 15.7
	4 Good	400 - 500	15.7 - 16.8
	5 Excellent	500 - 600	16.8 - 17.9
	6 Outstanding	600 - 800	17.9 - 19.7
	7 Superb	> 800	> 19.7



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# Little Colorado River







# Navajo Windy Land

Average Annual Wind Resource 230 ft (70m)  
with Land Exclusions  
and Transmission

Navajo Reservation Boundary  
within Arizona includes:  
-Navajo National Monuments  
-Navajo Trust Land  
-Navajo-Hopi Joint Use Areas

## Legend

-  Major Roads
  -  Transmission Lines
  -  Land Excluded 100%
  -  Woodlands - Excluded 50%
- Does not include  
Pinyon-Juniper Woodland

Created by: Grant Brummels  
Date of Creation: 9/7/2005  
For more information contact:  
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Projection:  
UTM, Zone 12, WGS84  
Spatial Resolution of  
Wind Resource Data: 200m

## Wind Power Classification

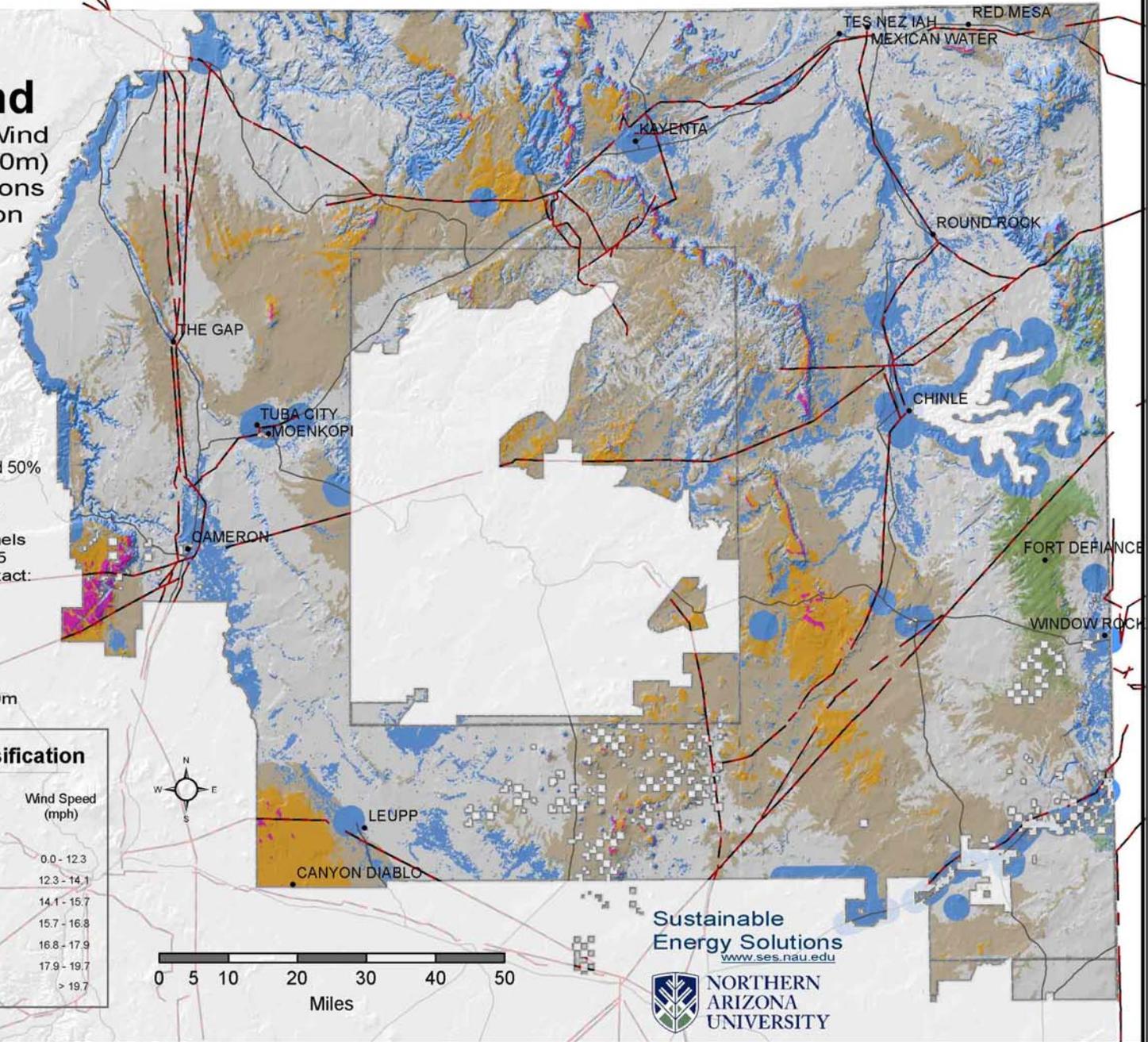
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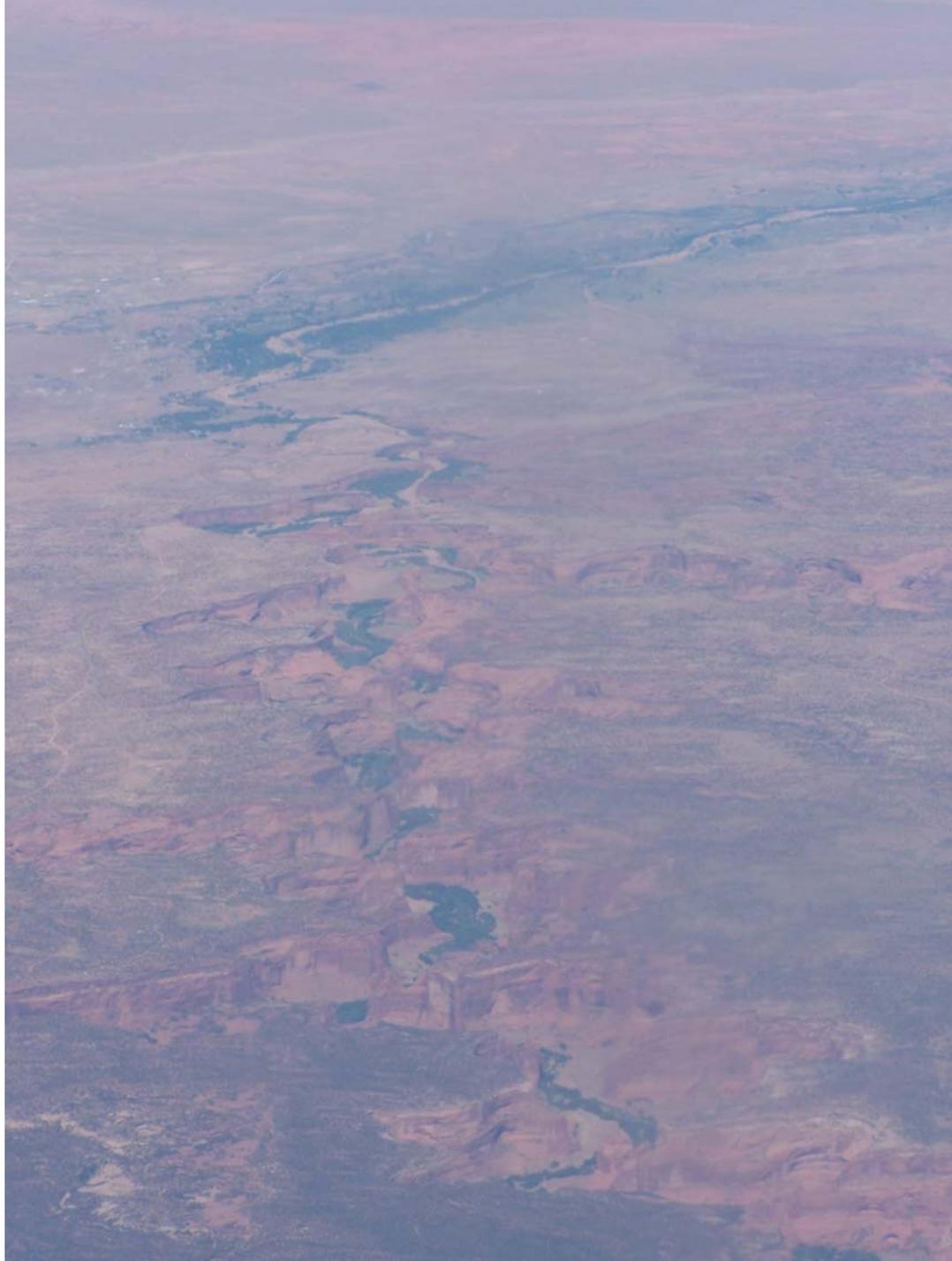




# Little Colorado River











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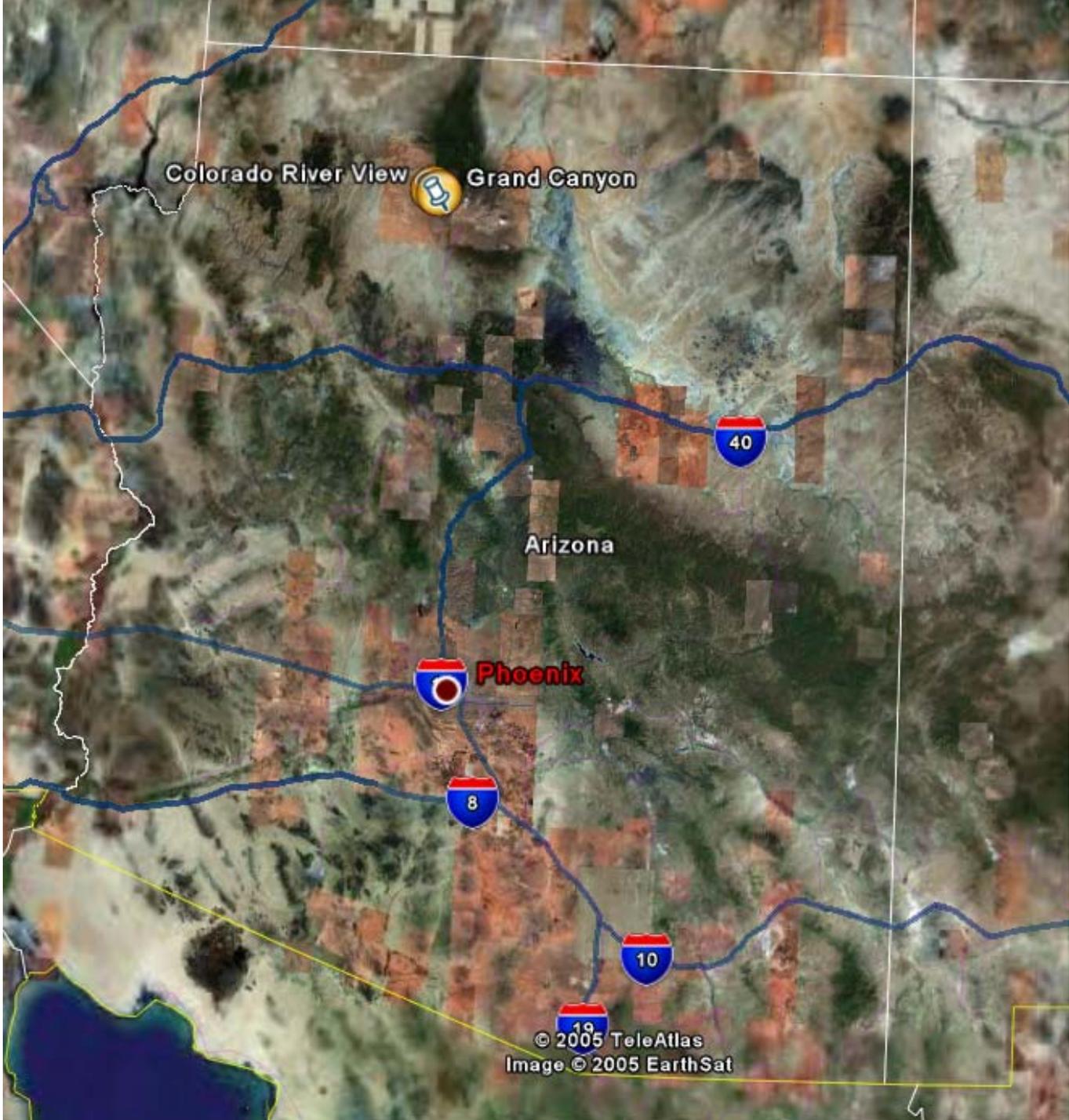
[Grant.Brummels@nau.edu](mailto:Grant.Brummels@nau.edu)

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[www.wind.nau.edu/maps](http://www.wind.nau.edu/maps)

<http://134.114.64.98/website/windy/viewer.htm> (AZ Interactive Wind Map)





Colorado River View



Grand Canyon

Arizona

Phoenix



Grand Canyon

40

Arizona

New Mexico



Grand Canyon





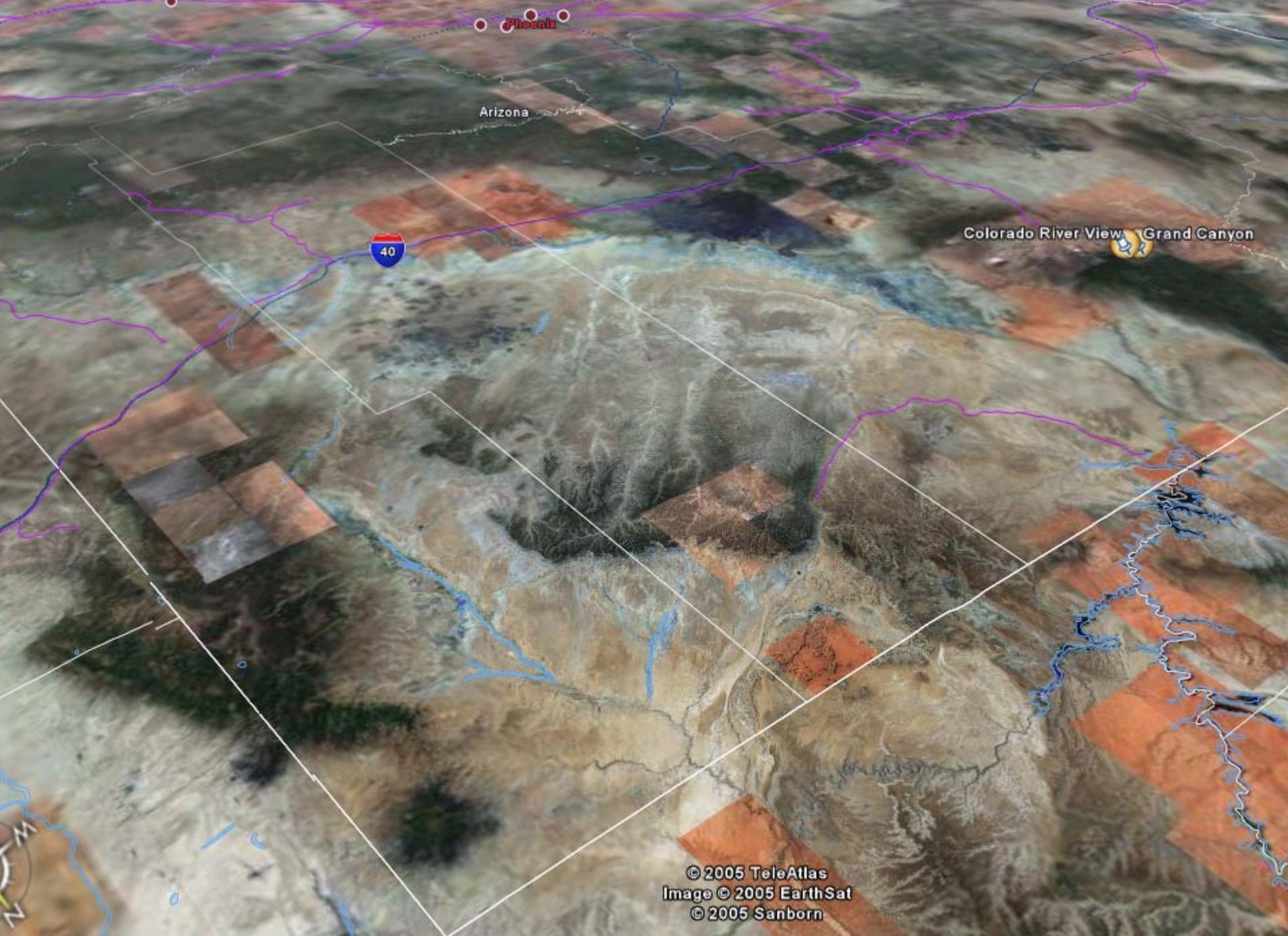
Grand Canyon



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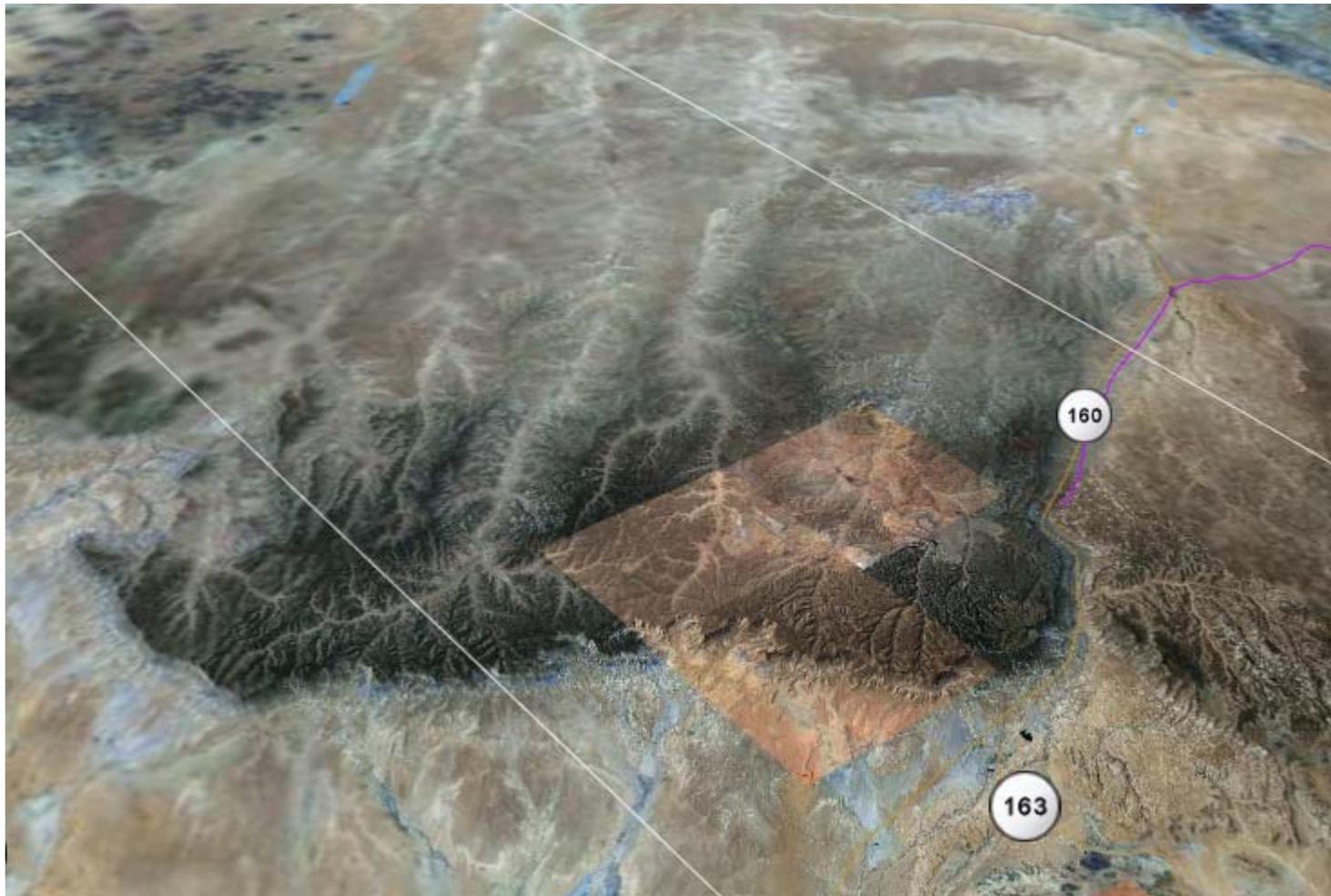
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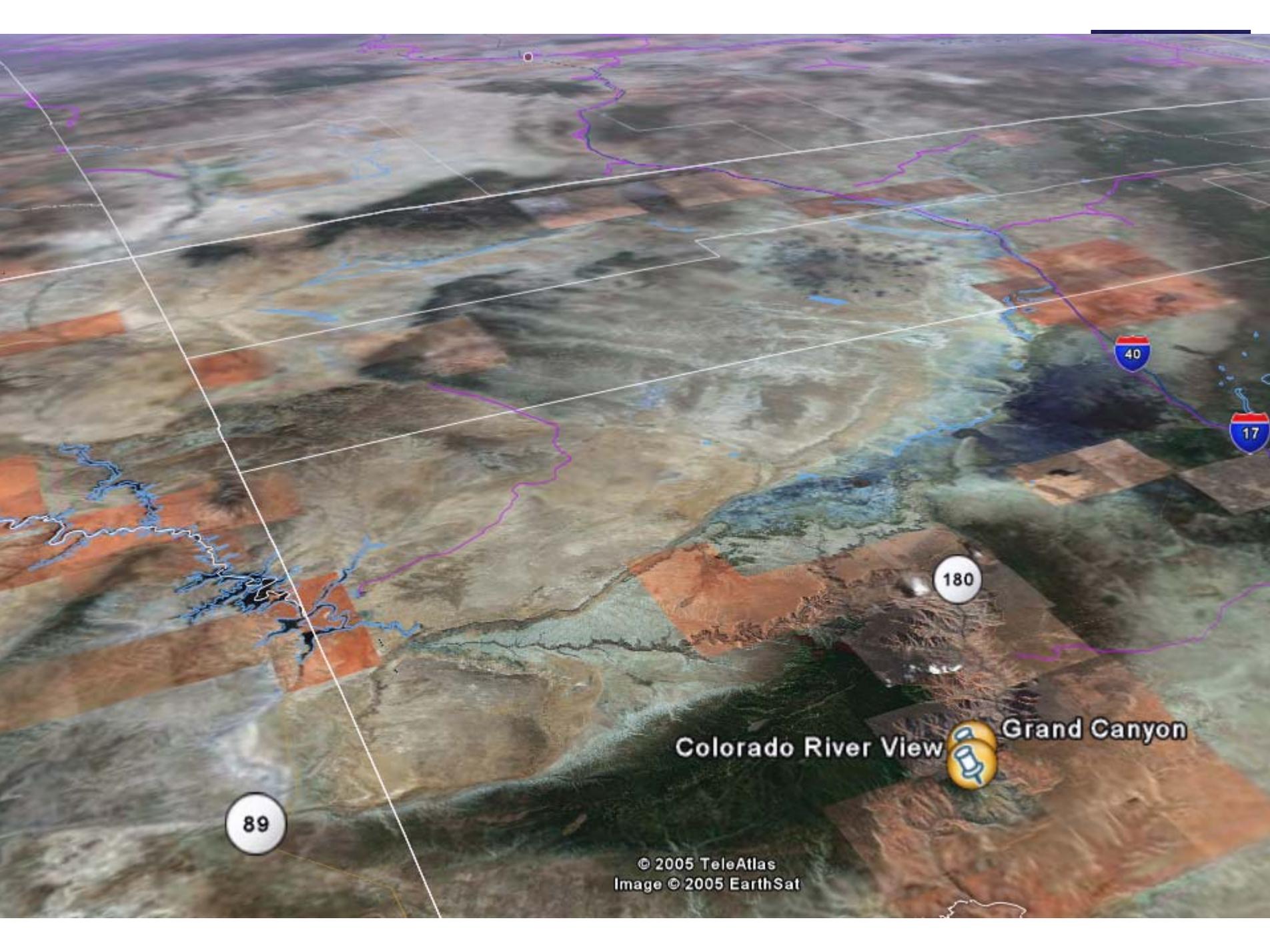
Phoenix

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Colorado River View Grand Canyon

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Colorado River View  Grand Canyon

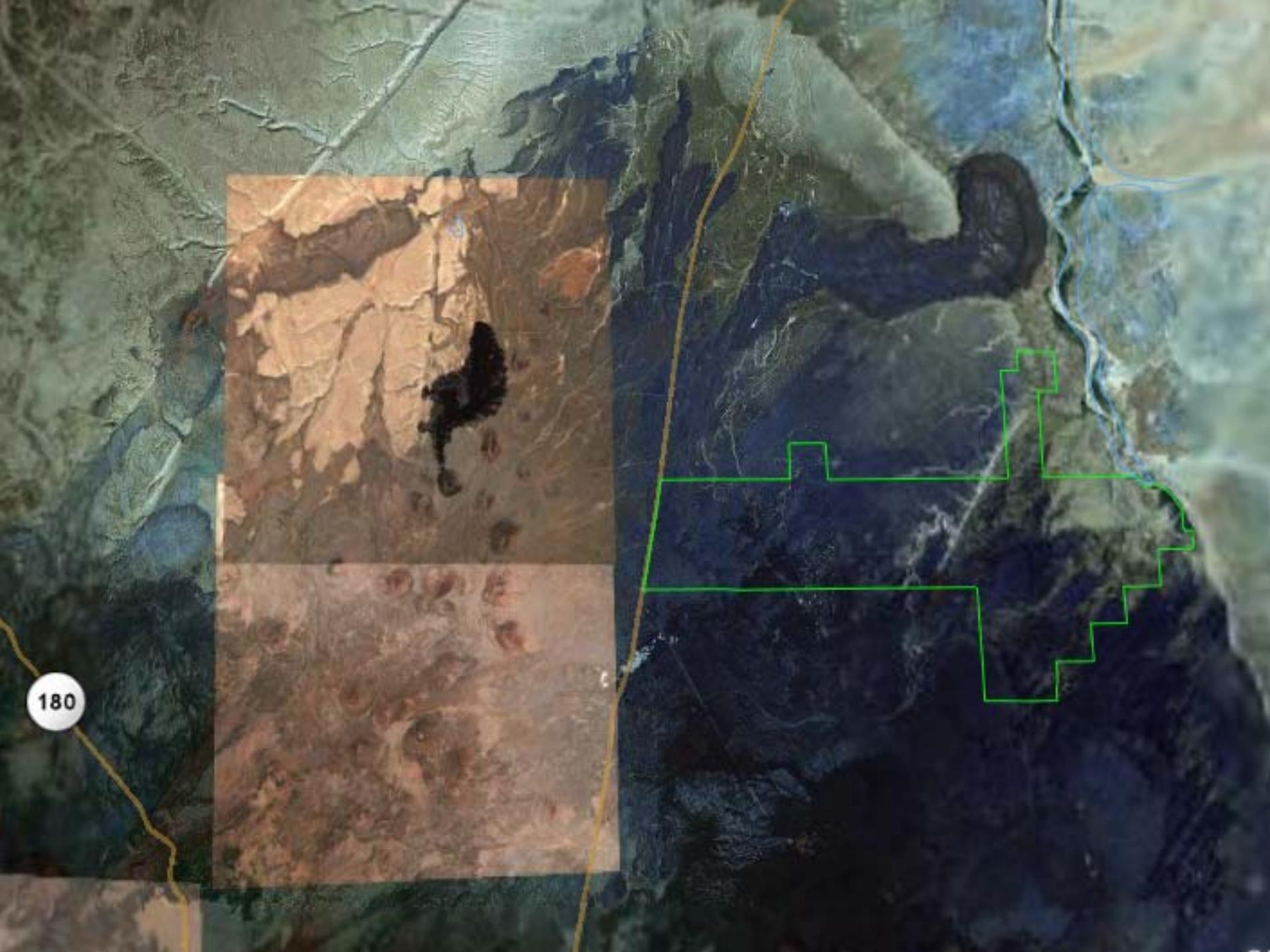
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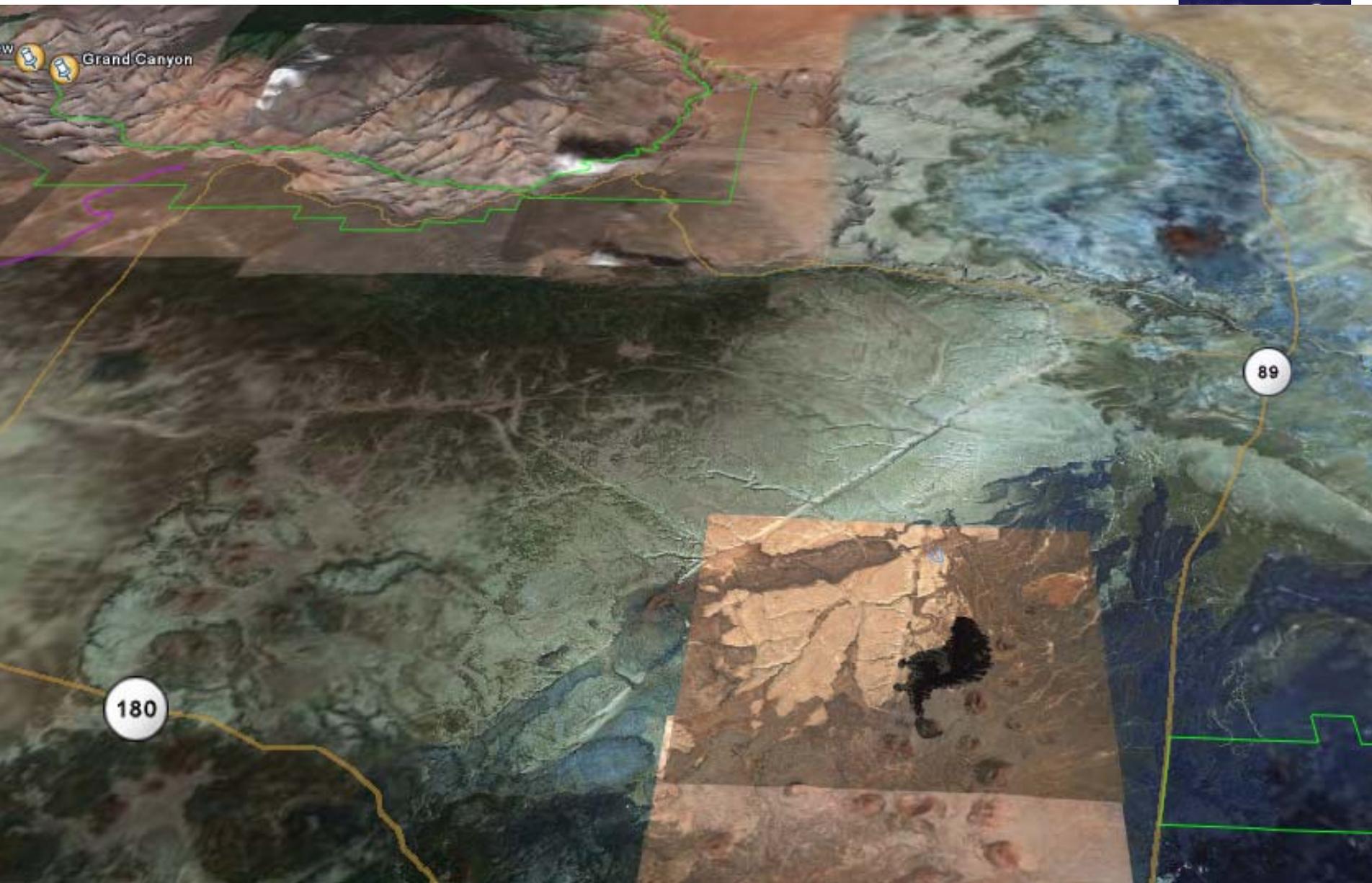
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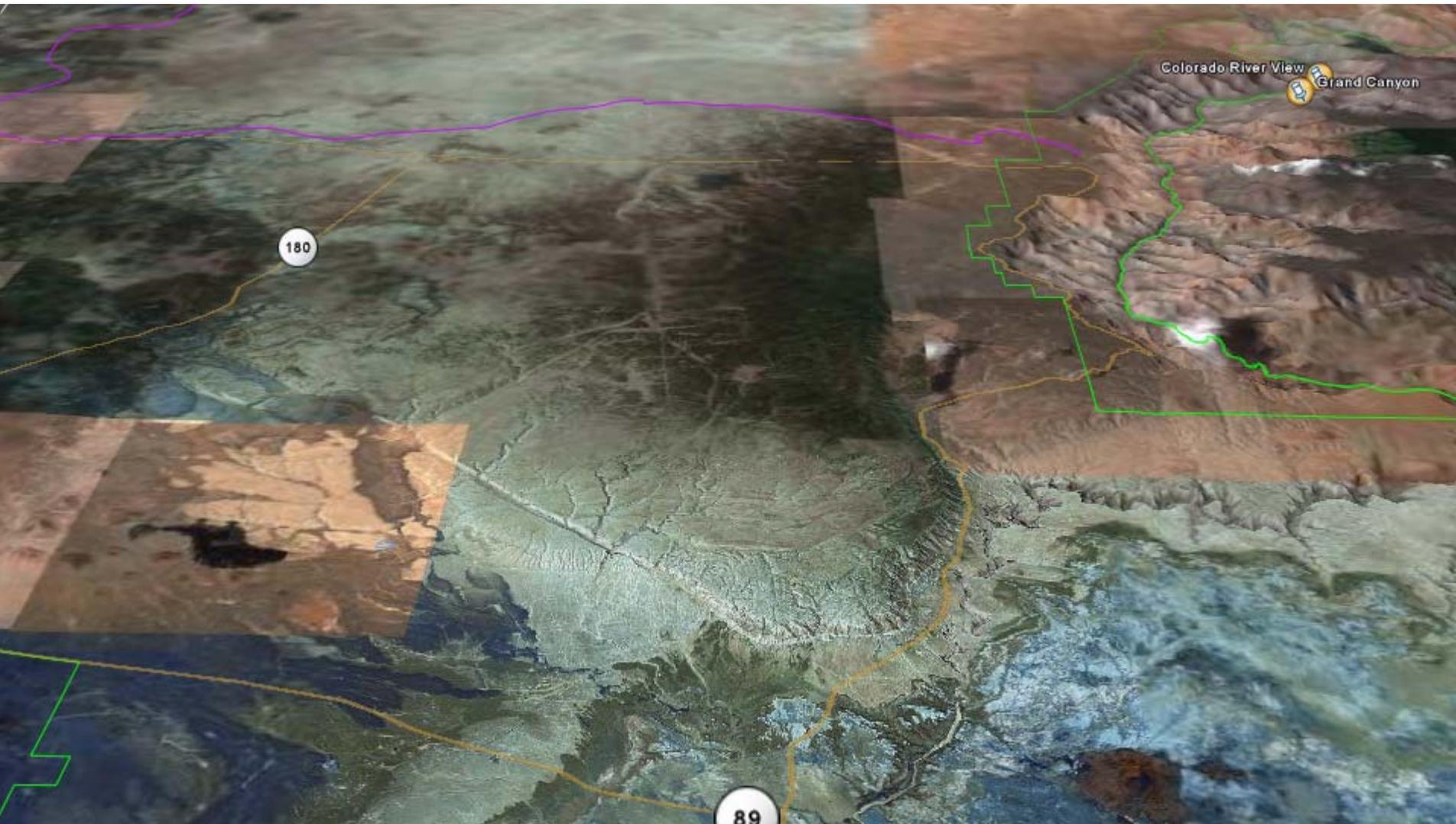
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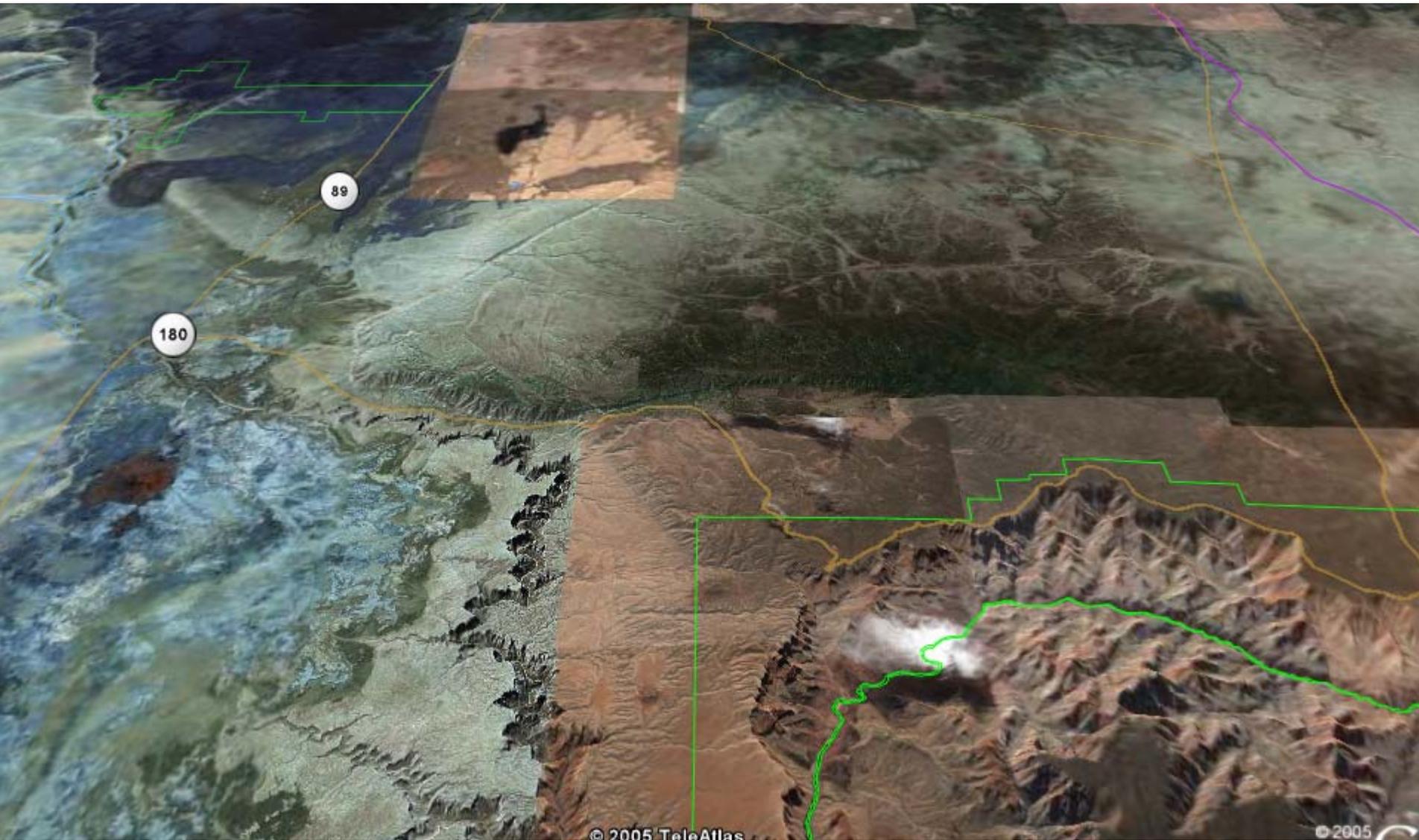




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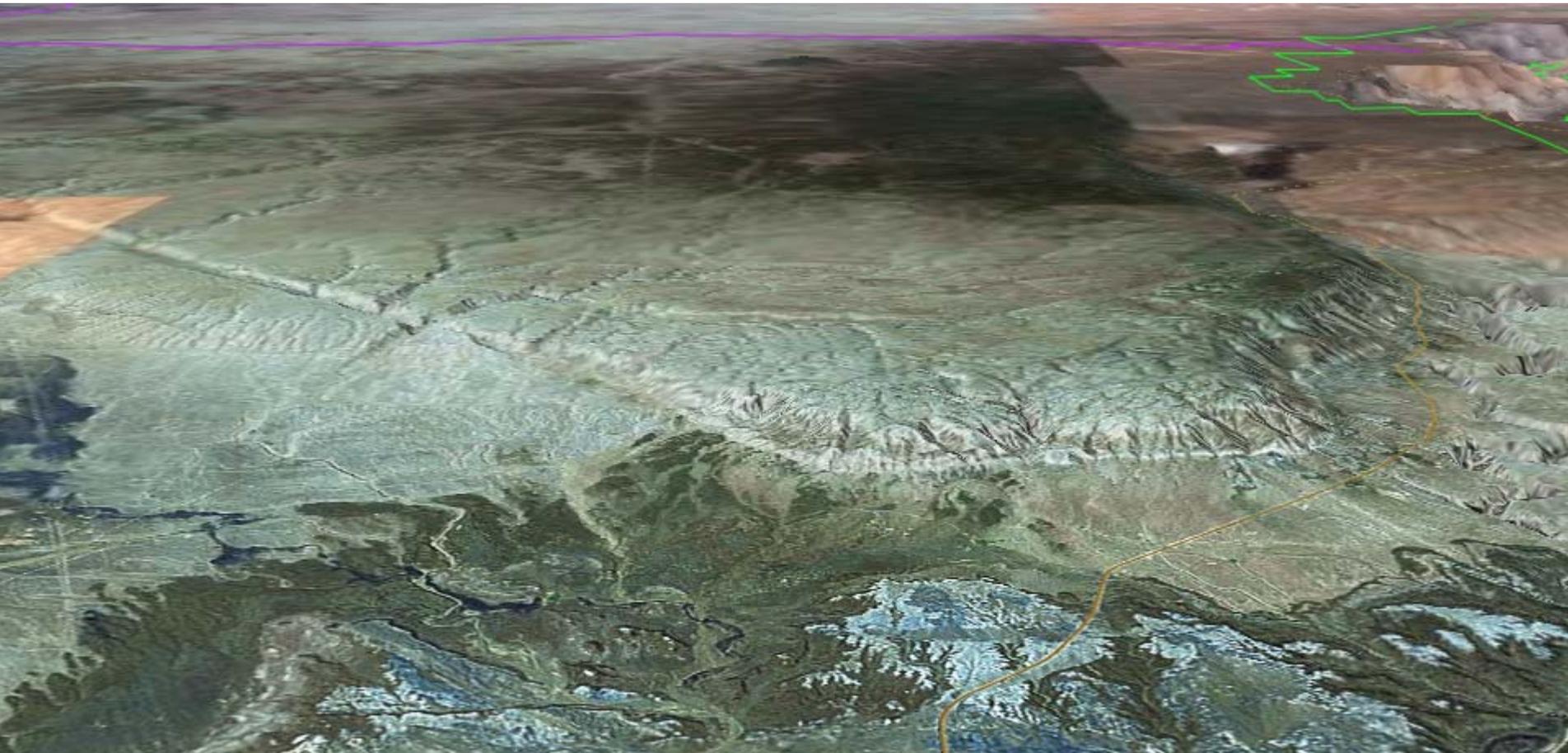


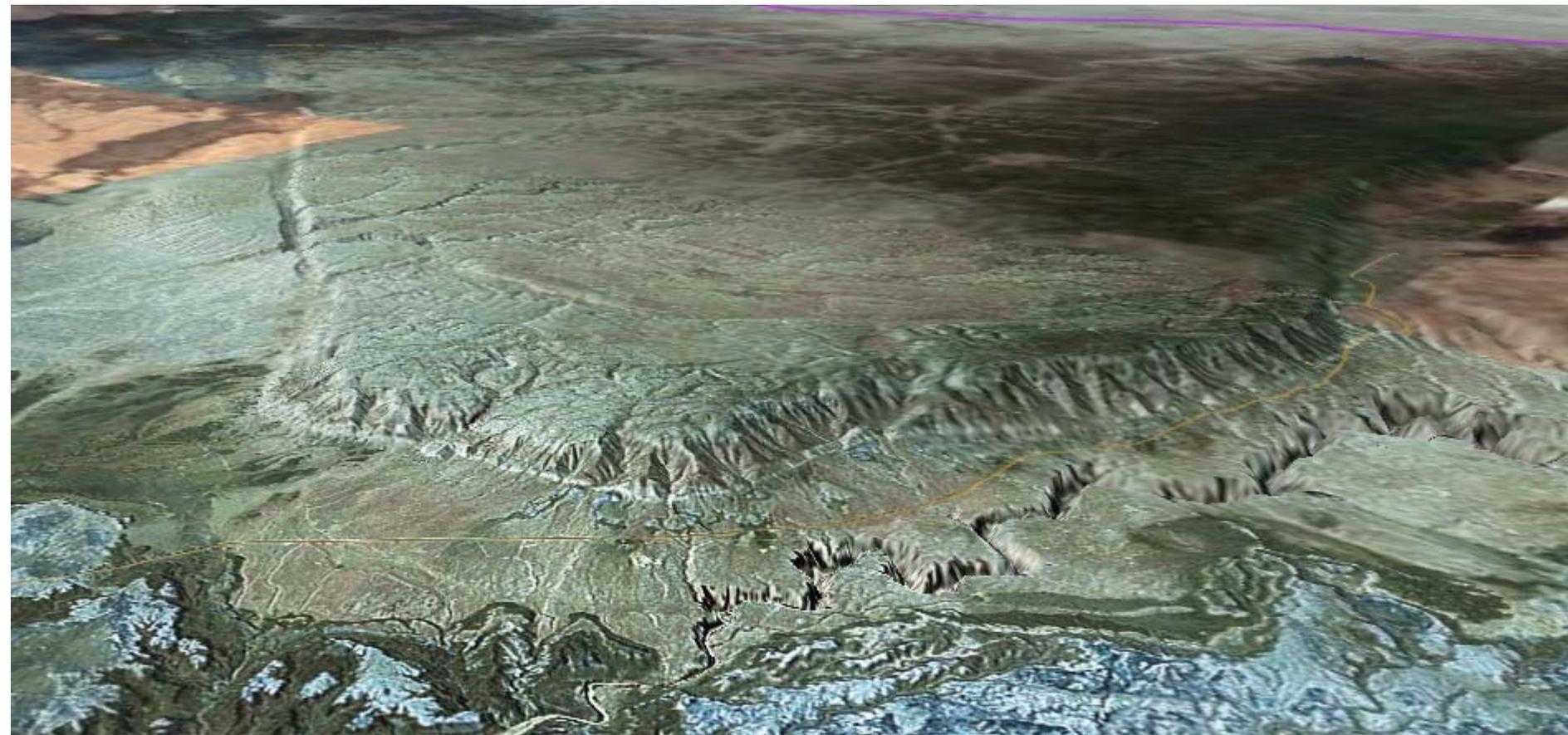


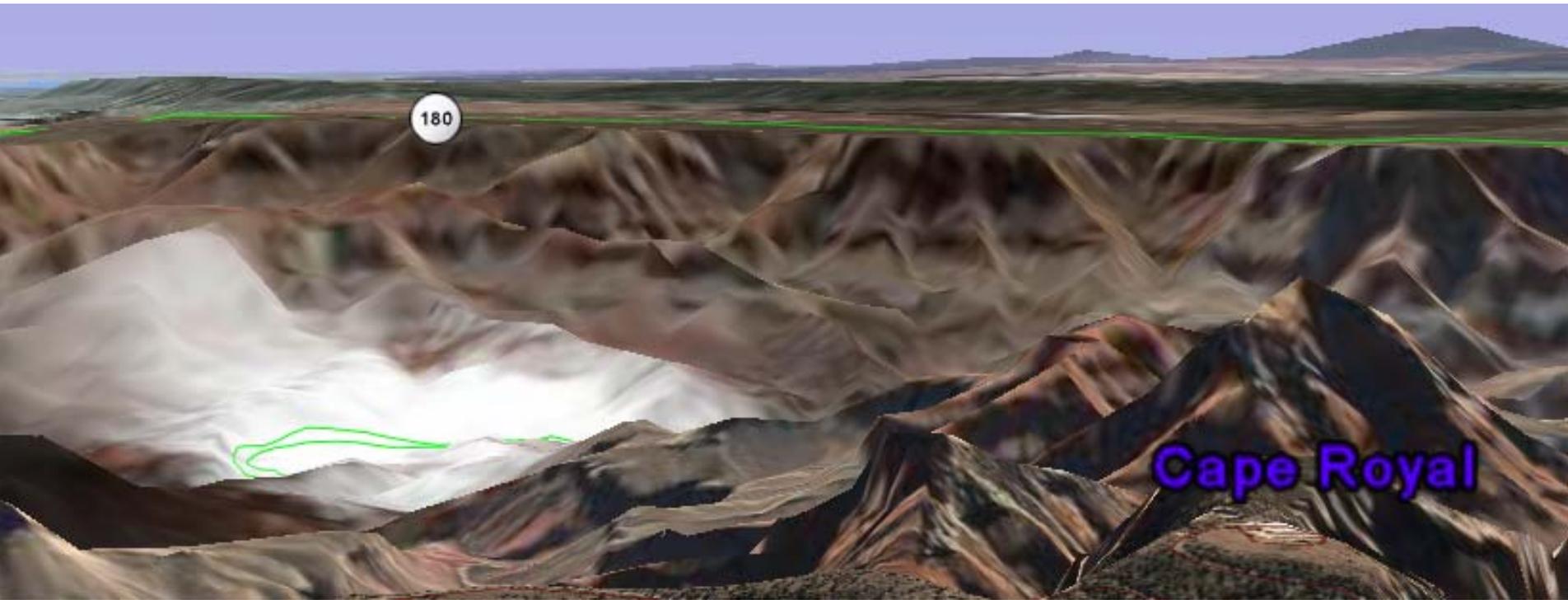




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Eye alt 9875 ft



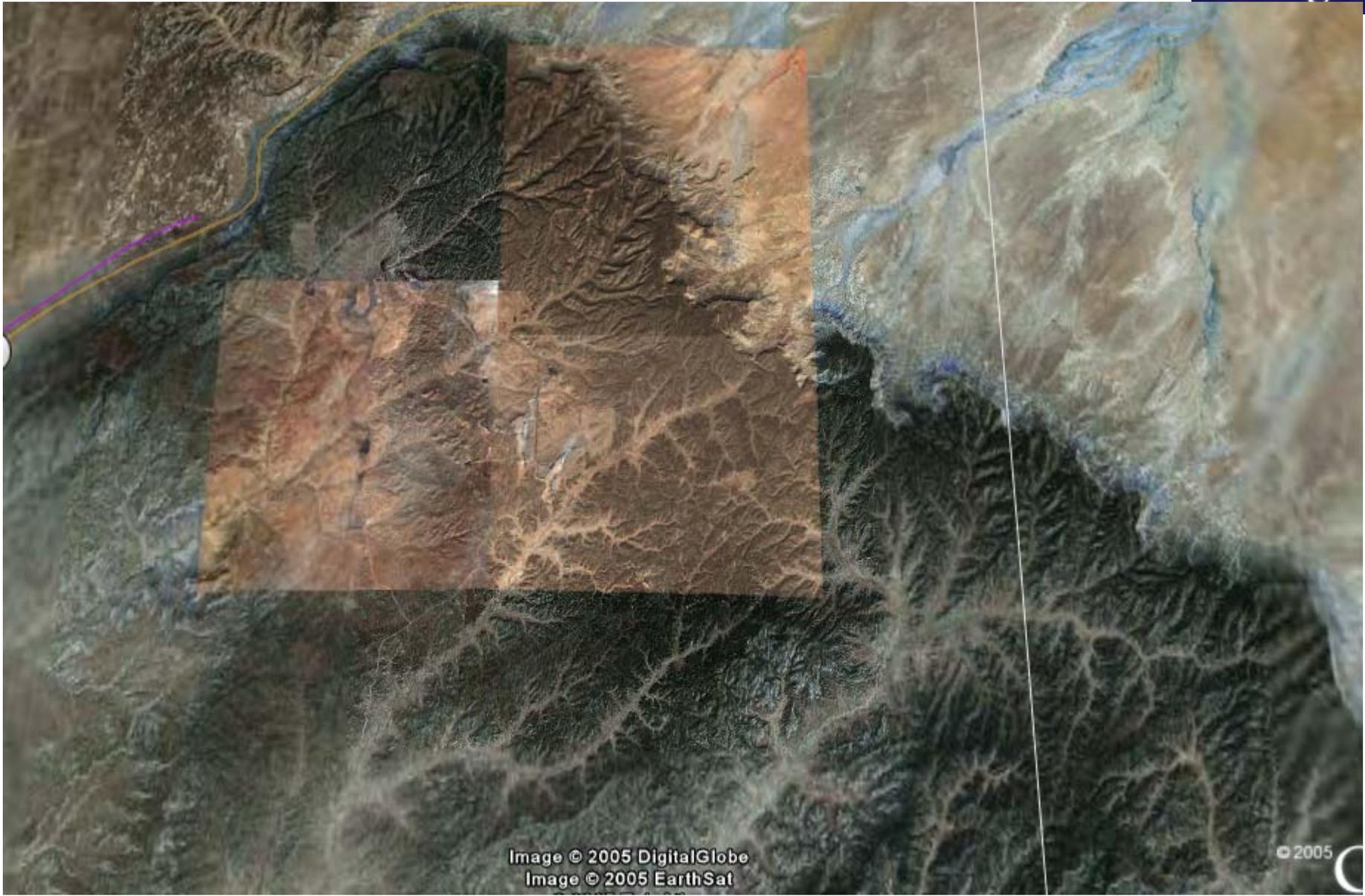


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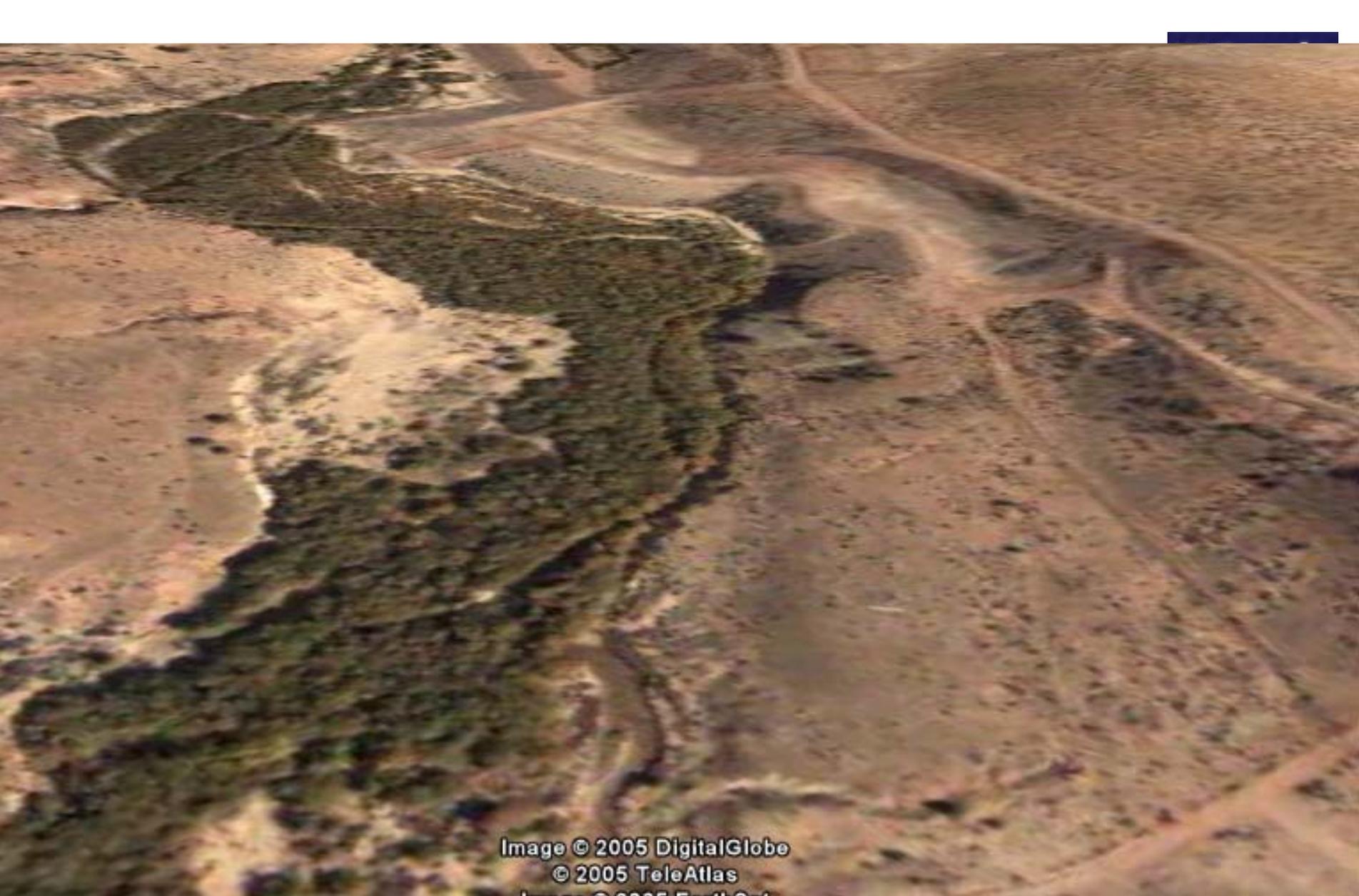
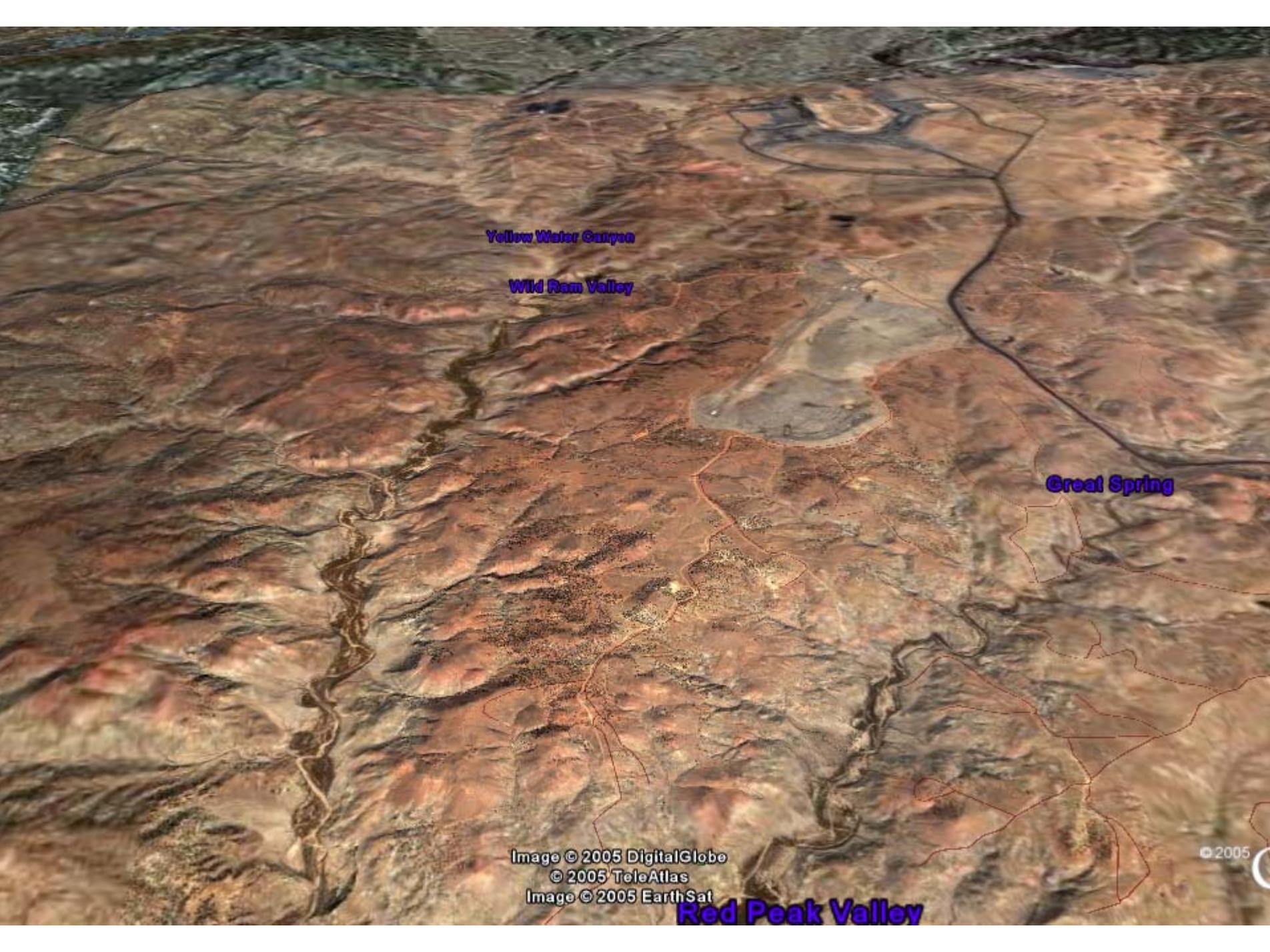


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Yellow Water Canyon

Wild Ram Valley

Great Spring

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Red Peak Valley

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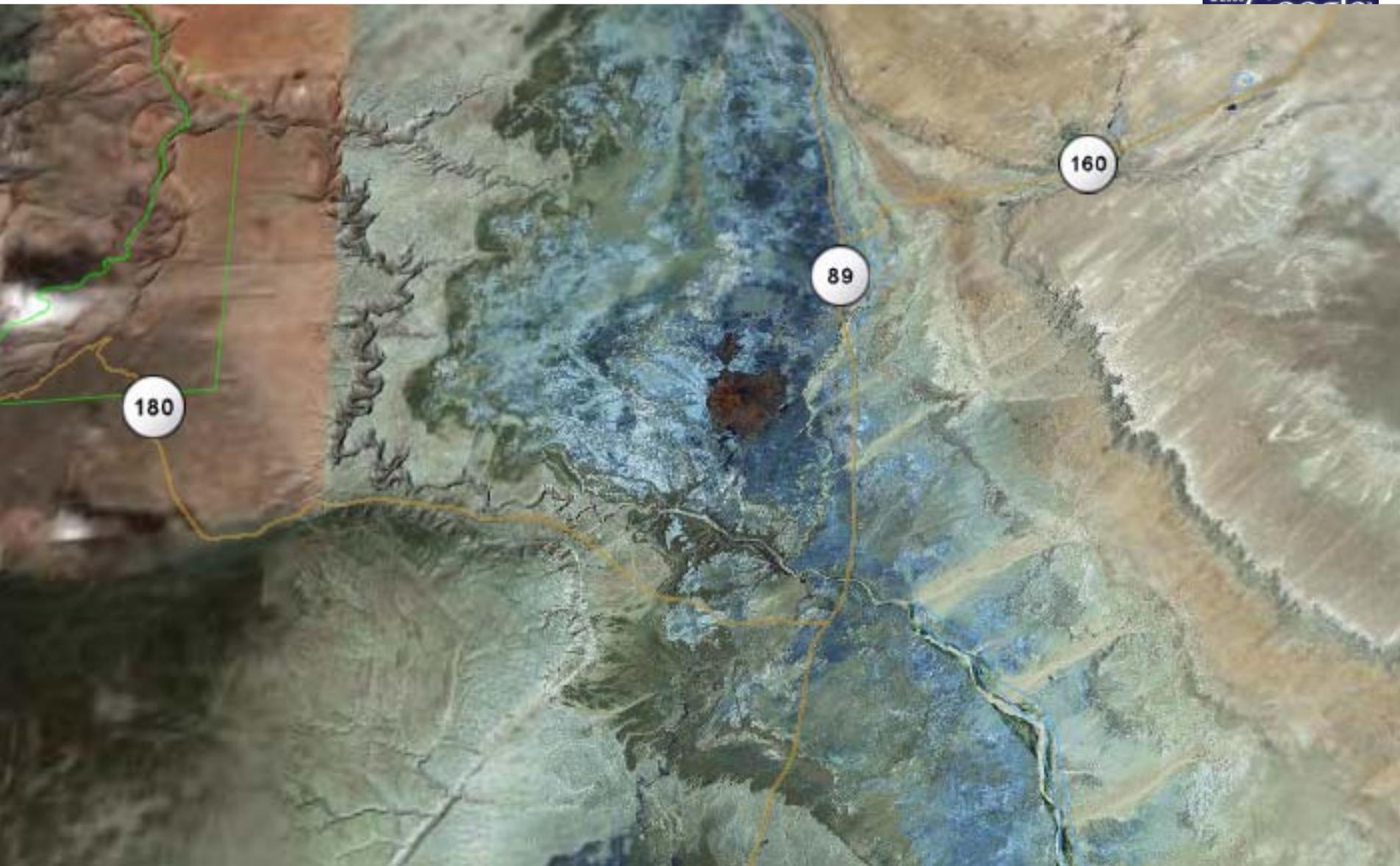


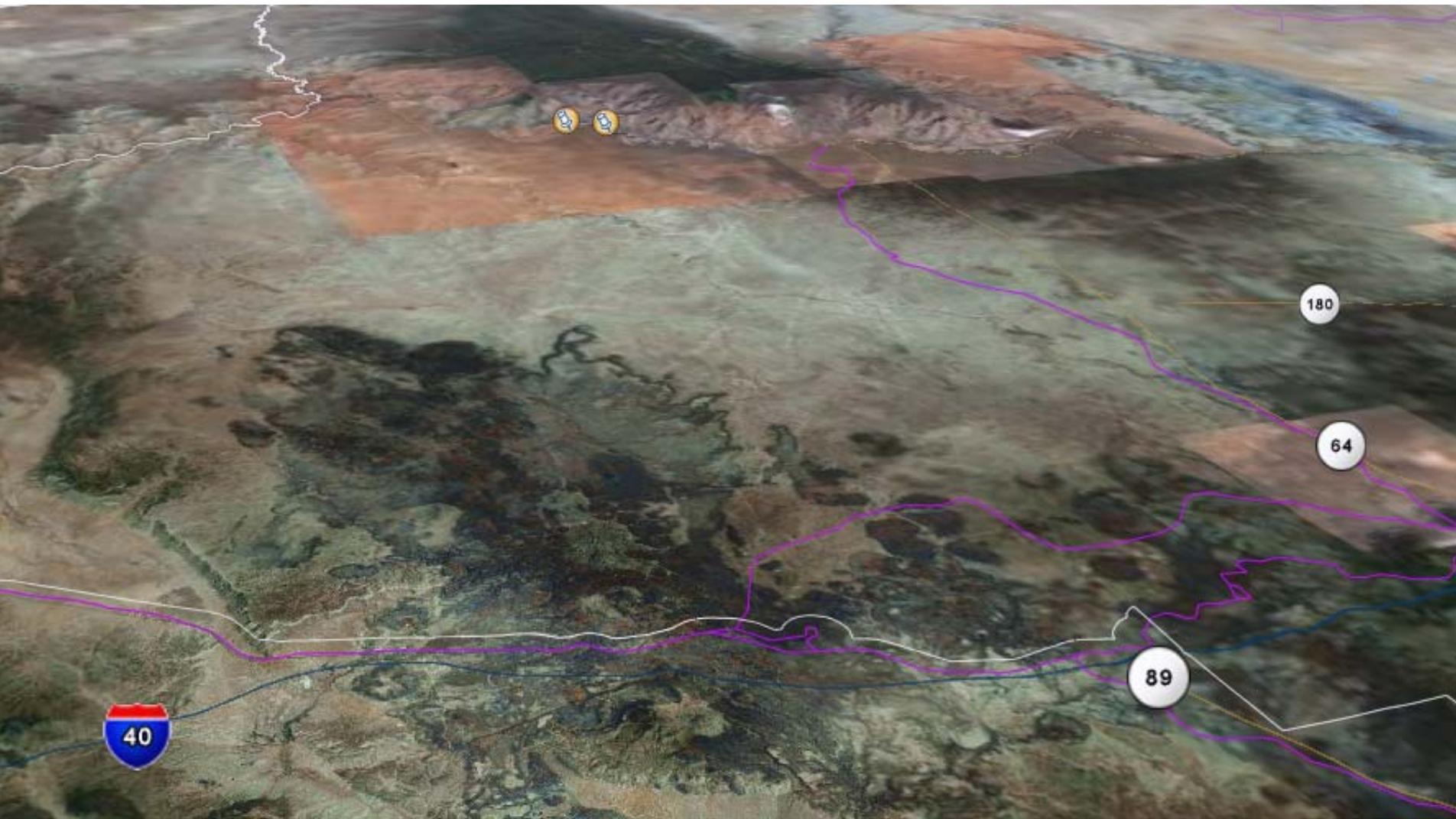




ew **Grand Canyon**









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# Navajo Windy Land



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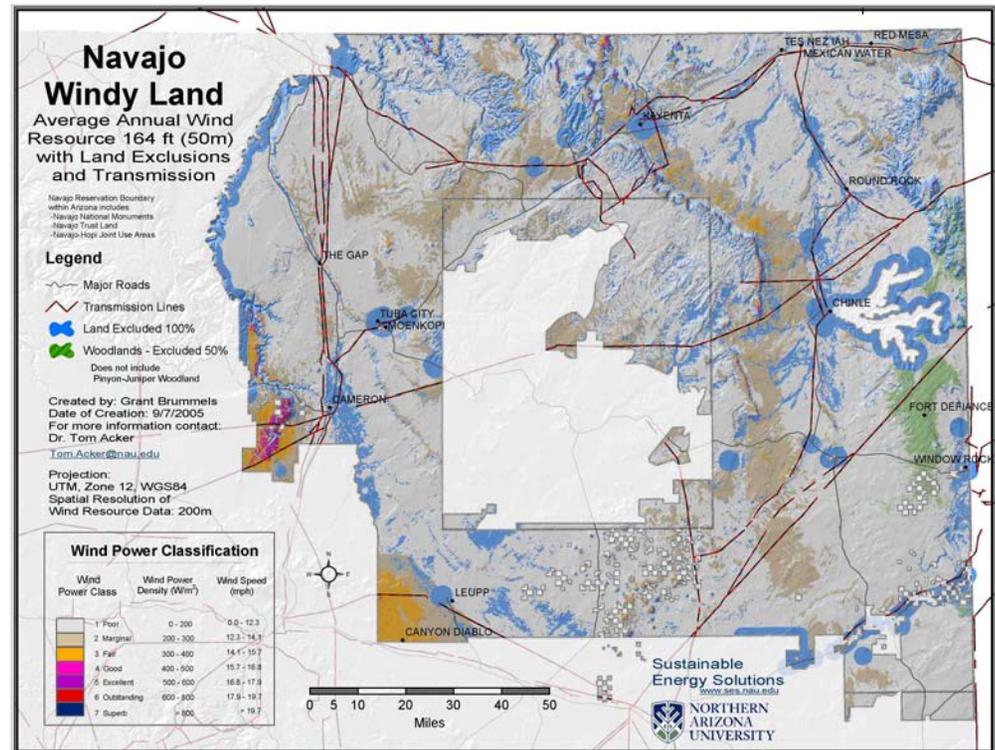


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<http://134.114.64.98/website/windy/viewer.htm> (AZ Interactive Wind Map)



All NREL slides were from the following two presentations:



# Arizona Wind Resources

Marc Schwartz

National Renewable Energy Laboratory

Golden, CO

Arizona Wind Working Group

Flagstaff, Arizona

August 6, 2003



# Hawaii Wind Mapping and Validation Project

Dennis Elliott

National Renewable Energy Laboratory

Golden, CO

Hawaii Wind Working Group Meeting

Honolulu, Hawaii

January 6, 2004



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