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Assessing wind energy potential for Nevada

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Energy Symposium

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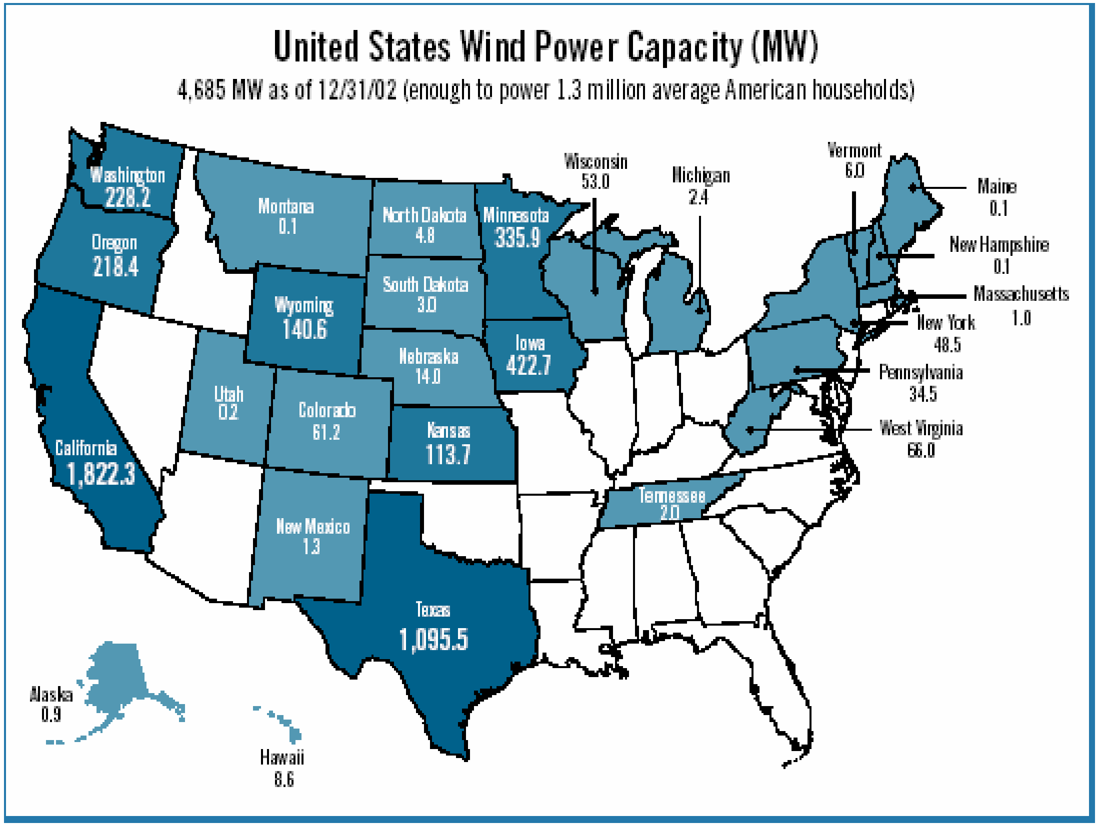
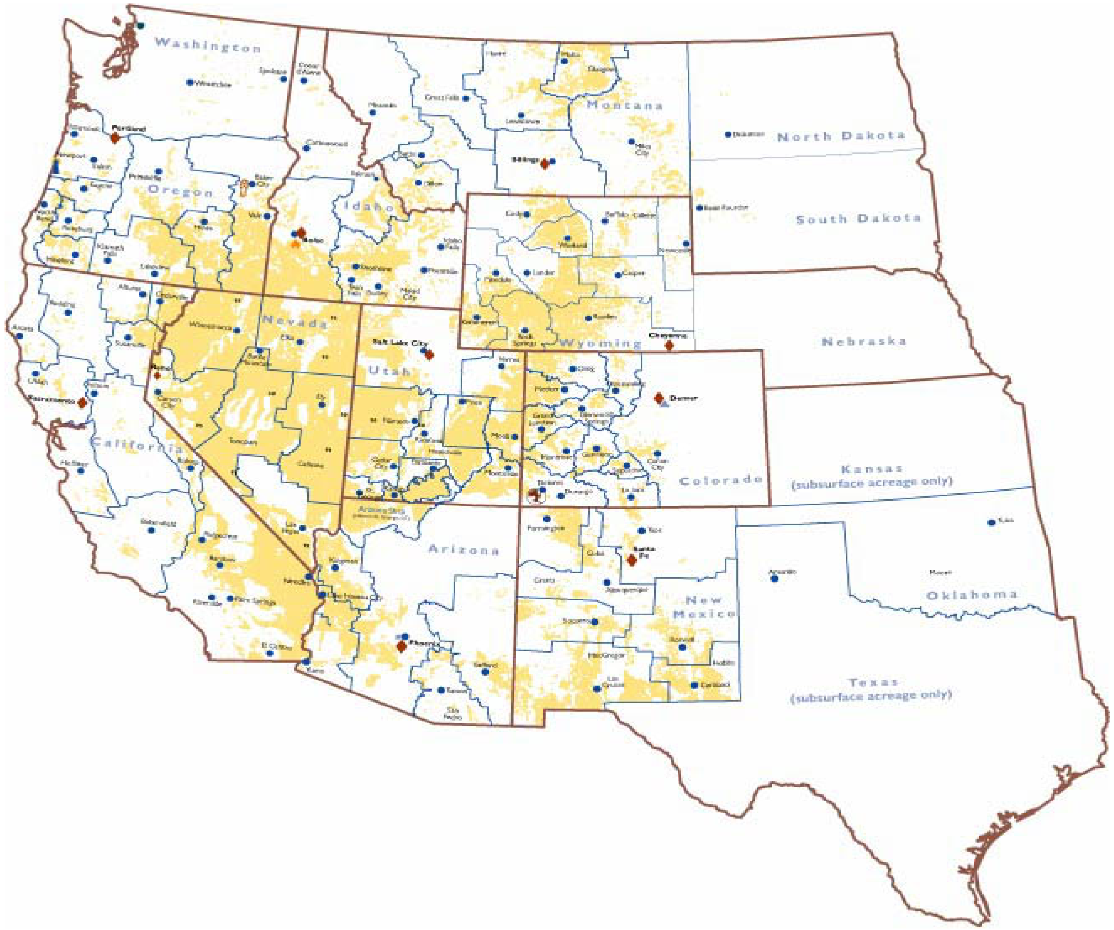
An easy name to remember

United States Wind Power Capacity

2005 – 16 states
2010 – 30 states



BLM Lands



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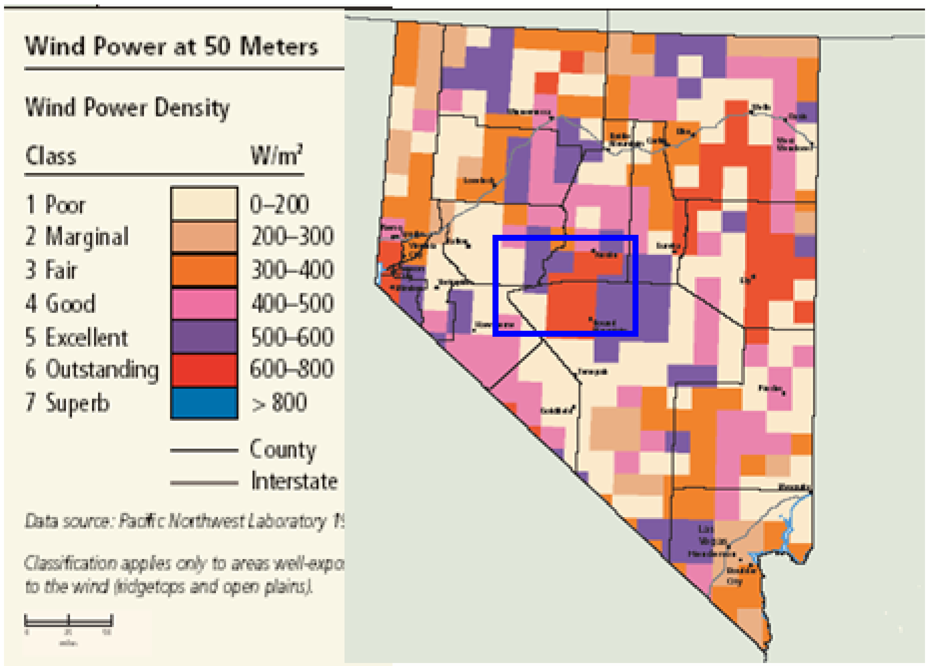
Wind Energy Assessment for Nevada



Wind power density map

Notice:

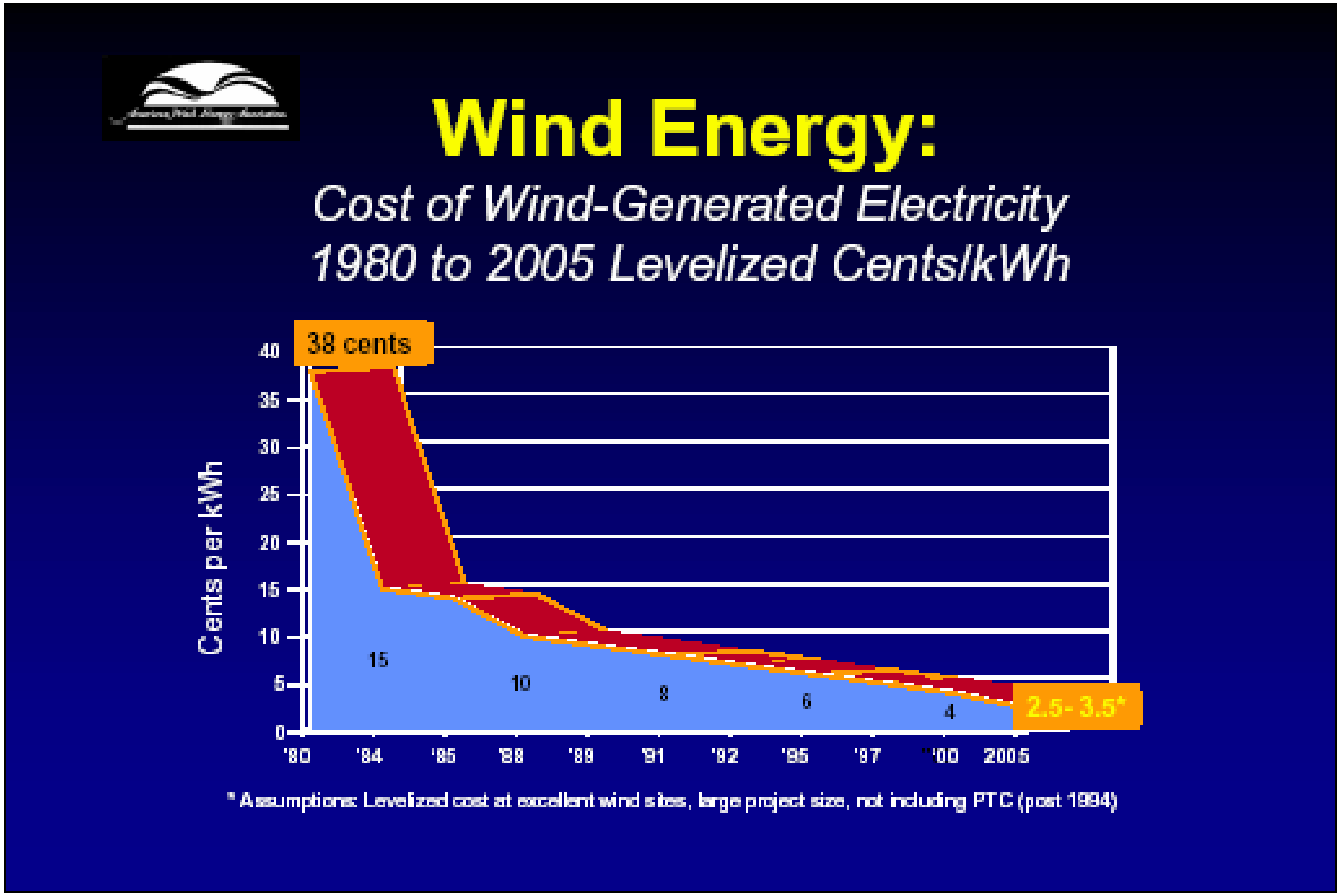
1.Southwestern U.S. as an area of untapped renewable energy resources

2.Application of numerical models to develop of an annual wind power density map.

A few facts about wind energy

- Winds are produced by uneven solar heating of the land and sea
- The ratio of total wind power to incident solar power is ~ 2%
- Power in moving air is proportional to the cube of velocity, $P=\rho V^3/2$ (W/m^2)
- Wind increases with height to the 1/7 power, $(V_2/V_1)=(h_2/h_1)^{1/7}$
- Topography and vegetation alter the wind
- There is less fluctuation in air at greater heights

Wind Energy Cost of Wind-Generated Electricity



Dutch wind mill

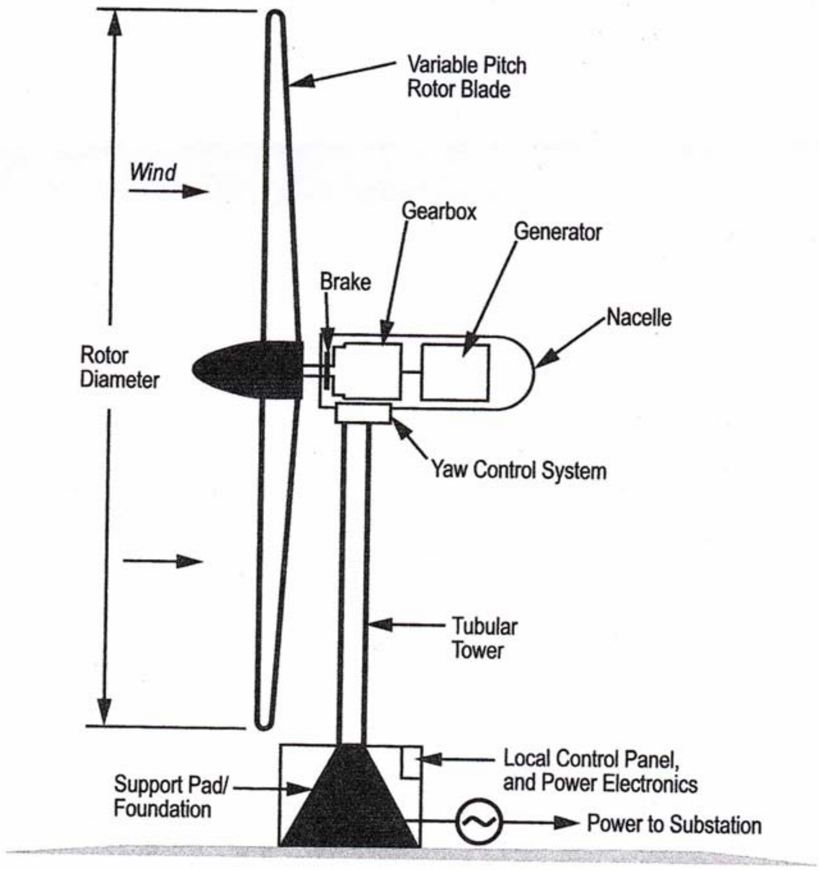
Western wind mill

Darrieus wind turbine

H-Darrieus wind turbine

Horizontal axis wind turbine

Wind turbine



Principal elements of a wind turbine electric generator.

Maximum efficiency

- The maximum efficiency for a wind turbine is **59.3%**
- This is based on the Betz value for an aerodynamic efficiency attributed to flow of blades in air
- 3-bladed units have a slight advantage over 2-bladed turbines; increasing the number of blades decreases the rate of rotation – but increases cost
- Power rating: $P = C^{op} \rho A V^3 / 2 \times 10^{-3}$ kW (C^{op} for modern turbine ~ 0.30; Dutch windmill ~ 0.05) – $A = \pi D^2/4$ and $\rho = 1.205$ kg/m^3 for air at 20^{o}C

Wind Power Class

	10 m (33 ft)		50 m (164 ft)	
Wind Power Class	Wind Power Density (W/m^2)	Mean Speed range (b) m/s (mph)	Wind Power Density (W/m^2)	Mean Speed range (b) m/s (mph)
1	<100	<4.4 (9.8)	<200	<5.6(12.5)
2	100 - 150	4.4 (9.8)/5.1 (11.5)	200 - 300	5.6 (12.5)/6.4 (14
3	150 - 200	5.1 (11.5)/5.6 (12.5)	300 - 400	6.4 (14.3)/7.0 (15
4	200 - 250	5.6 (12.5)/6.0 (13.4)	400 - 500	7.0 (15.7)/7.5 (16
5	250 - 300	6.0 (13.4)/6.4 (14.3)	500 - 600	7.5 (16.8)/8.0 (17
6	300 - 400	6.4 (14.3)/7.0 (15.7)	600 - 700	8.0 (17.9)/8.8 (19
7	>400	>7.0 (15.7)	>800	>8.8 (19.7)

(a) Vertical extrapolation of wind speed based on the 1/7 power law
(b) Mean wind speed is based on the Rayleigh speed distribution of equivalent wind power density. Wind speed is for standard sea-level conditions. To maintain the same power density, mean wind speed must increase 3%/1000 m (5%/5000 ft) of elevation. (from the Battelle Wind Energy Resource Atlas)

Land potential

- **For Class 4 winds (~12.5 mph) – 1300 km^2 of land available**
- **For Class 3 winds (~11.5 mph) – 4700 km^2 of land available**
- **Land usually not readily accessible**

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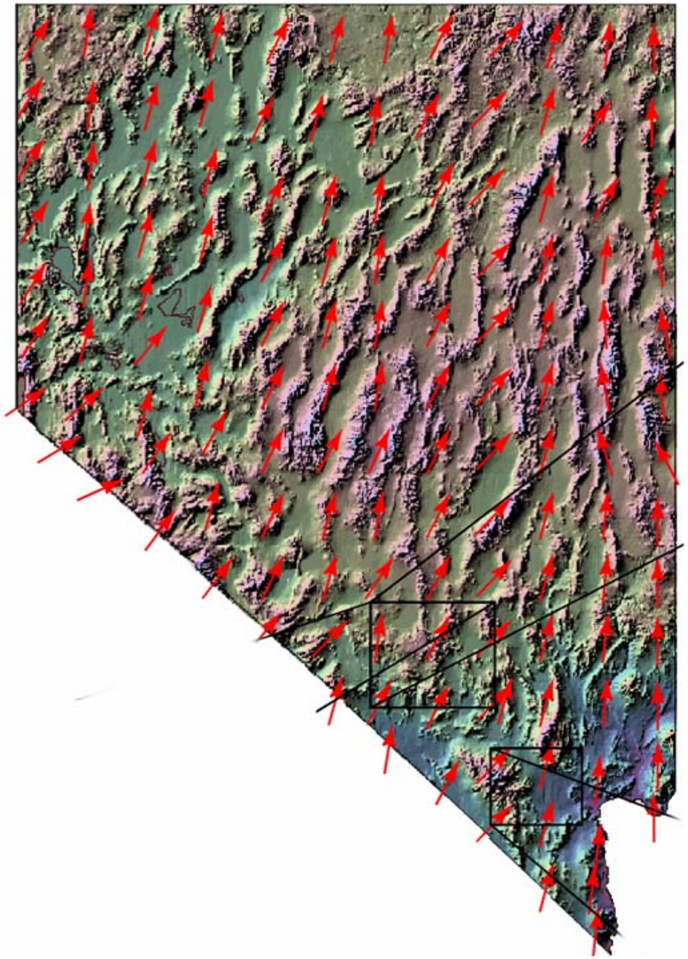
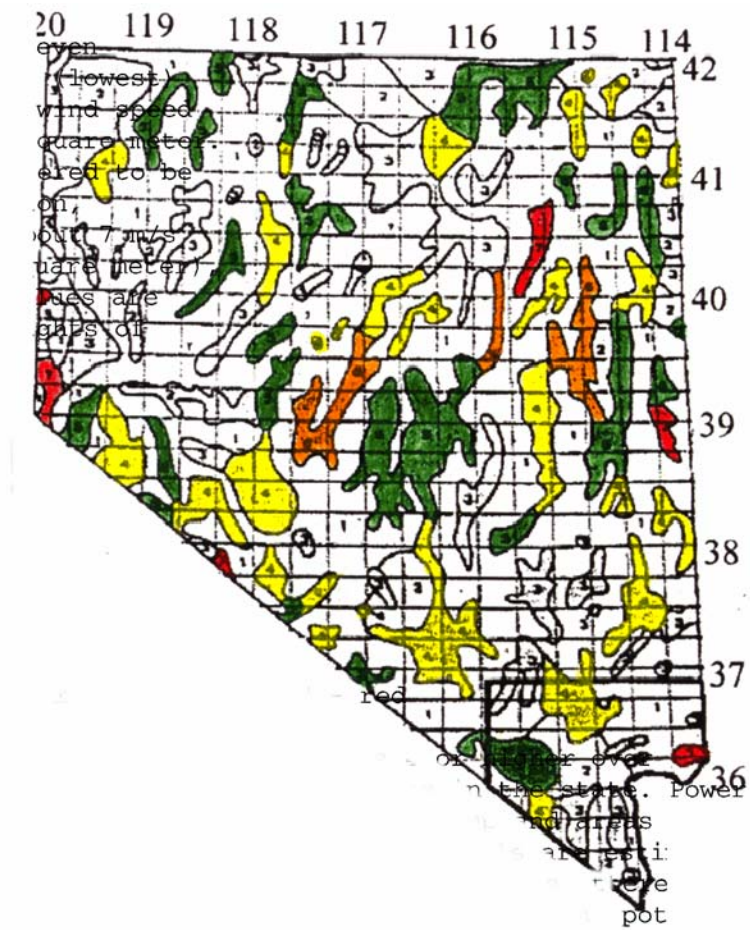
Wind Potential in Nevada

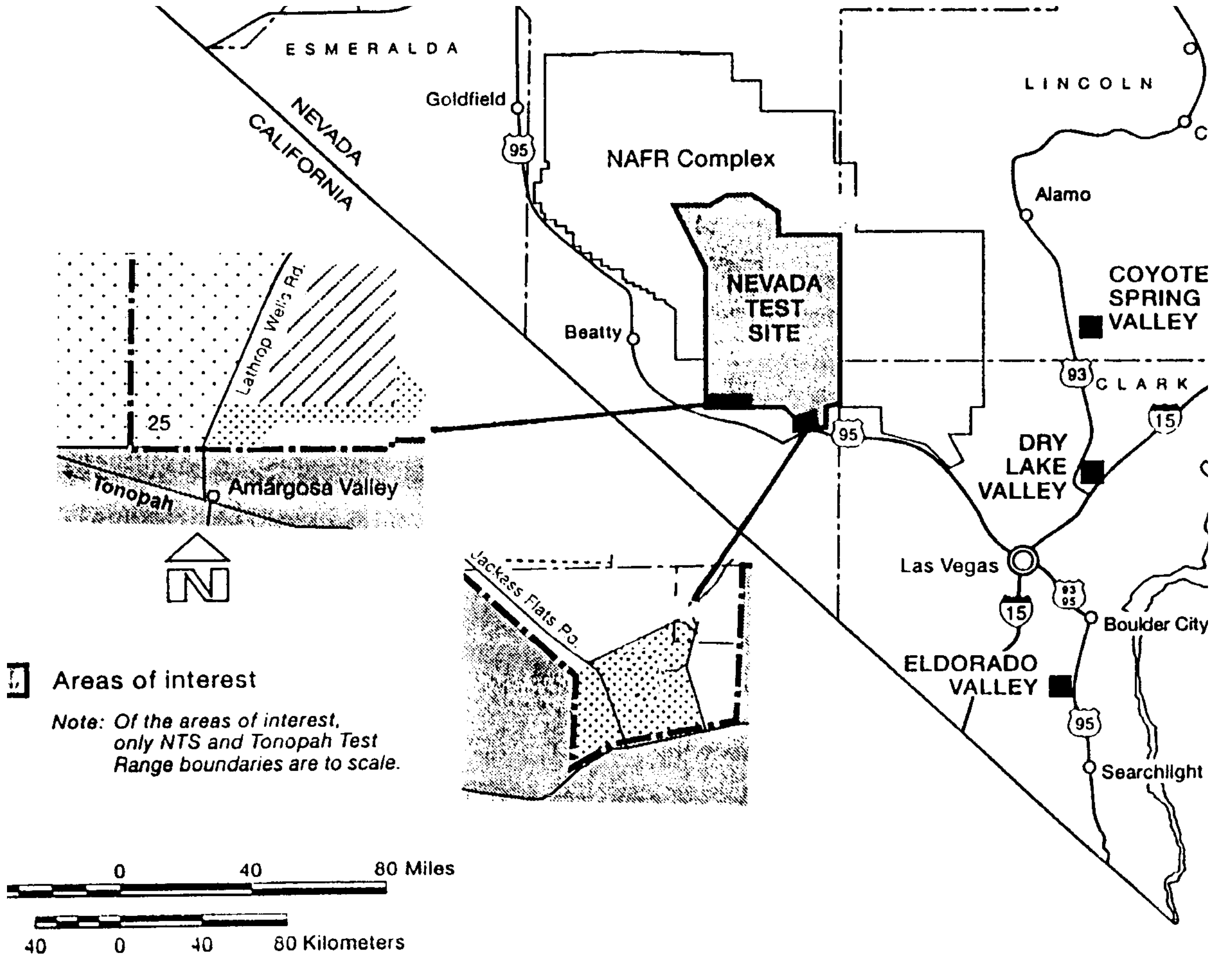




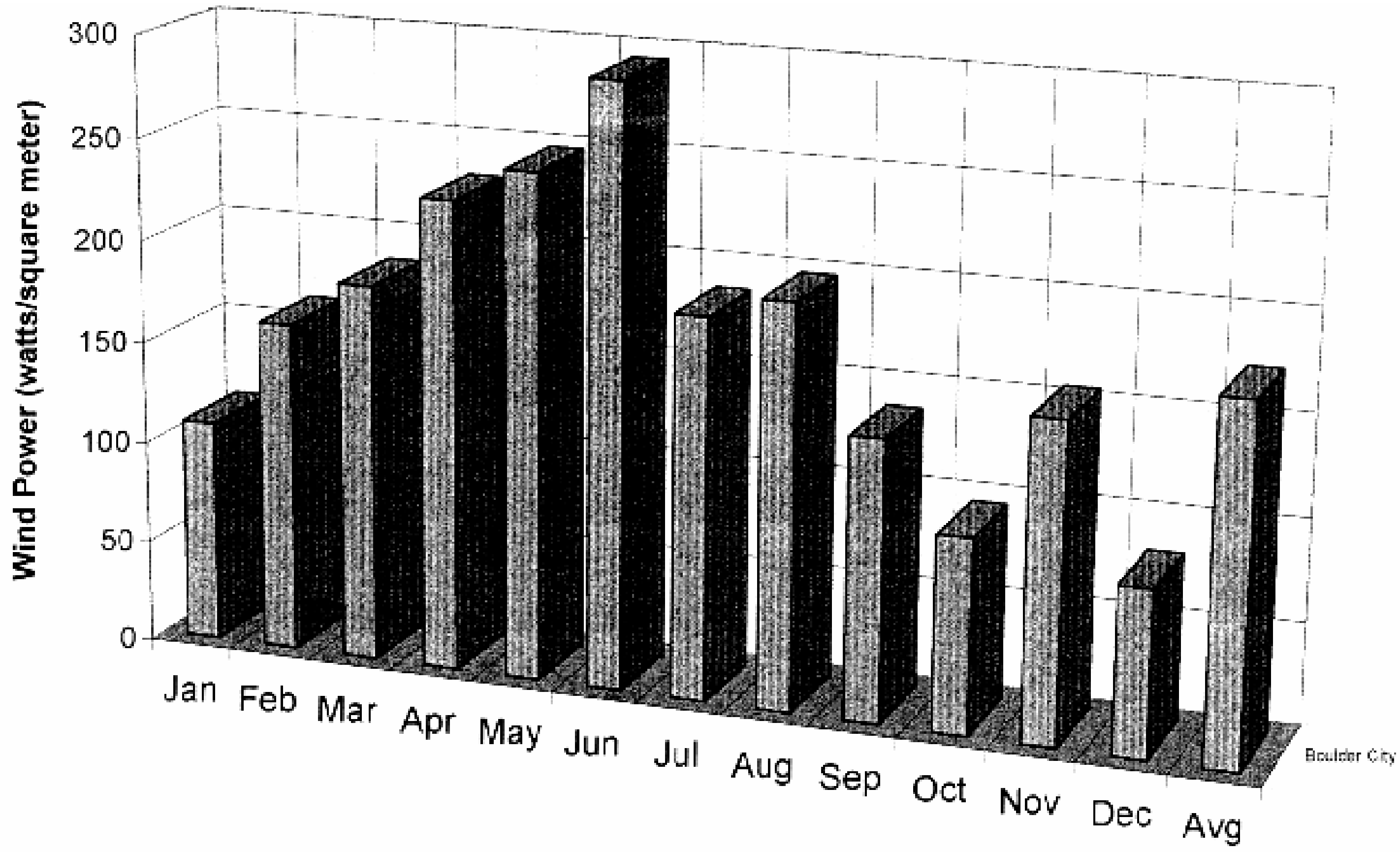
Early candidate sites

- Spring Mountain
- Piute Valley
- Searchlight
- Colorado River Valley
- Virgin Valley Hills
- Armagosa Desert
- Yucca Flats - NTS

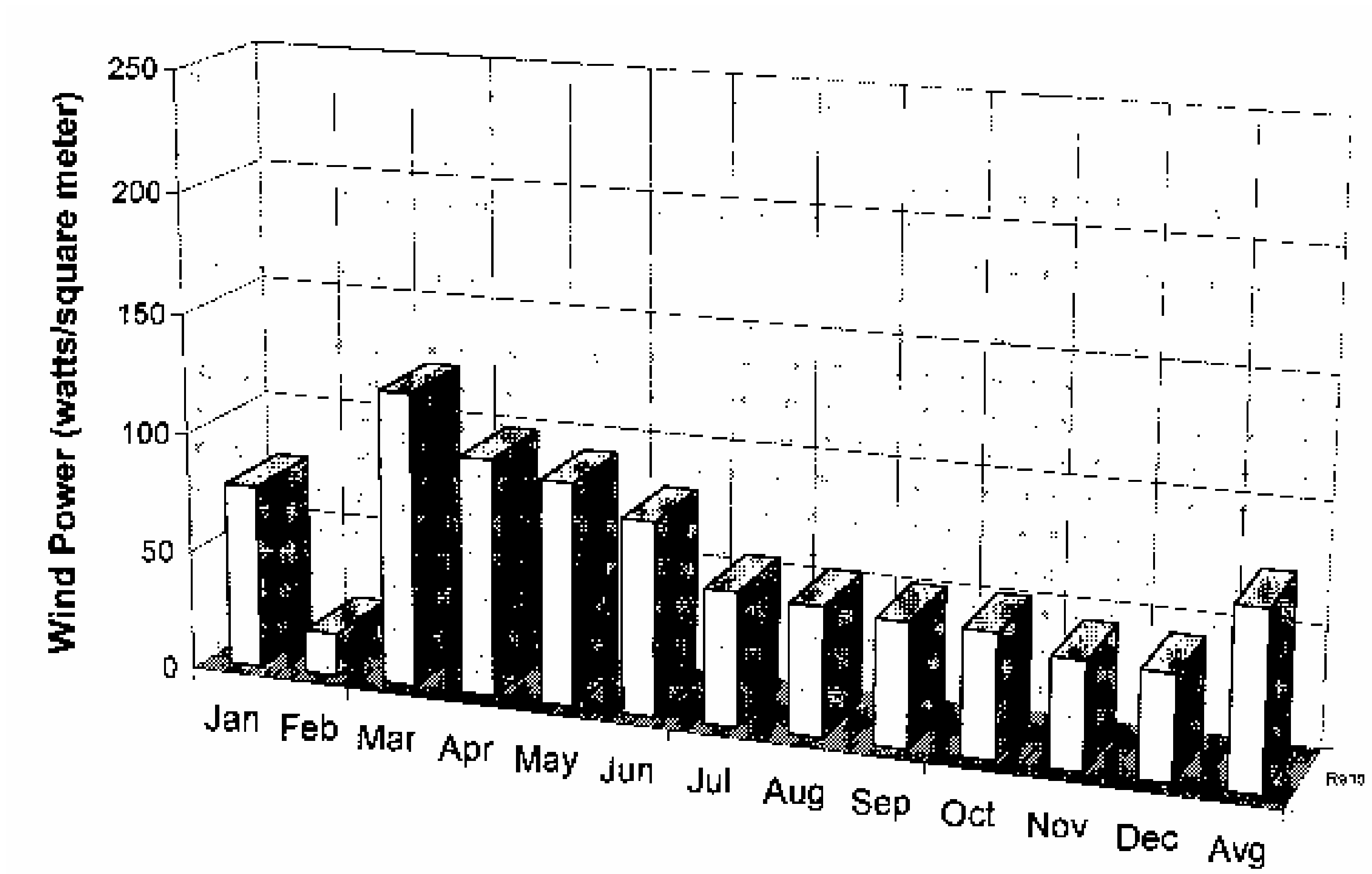
Five Potential Site Locations in Southern Nevada



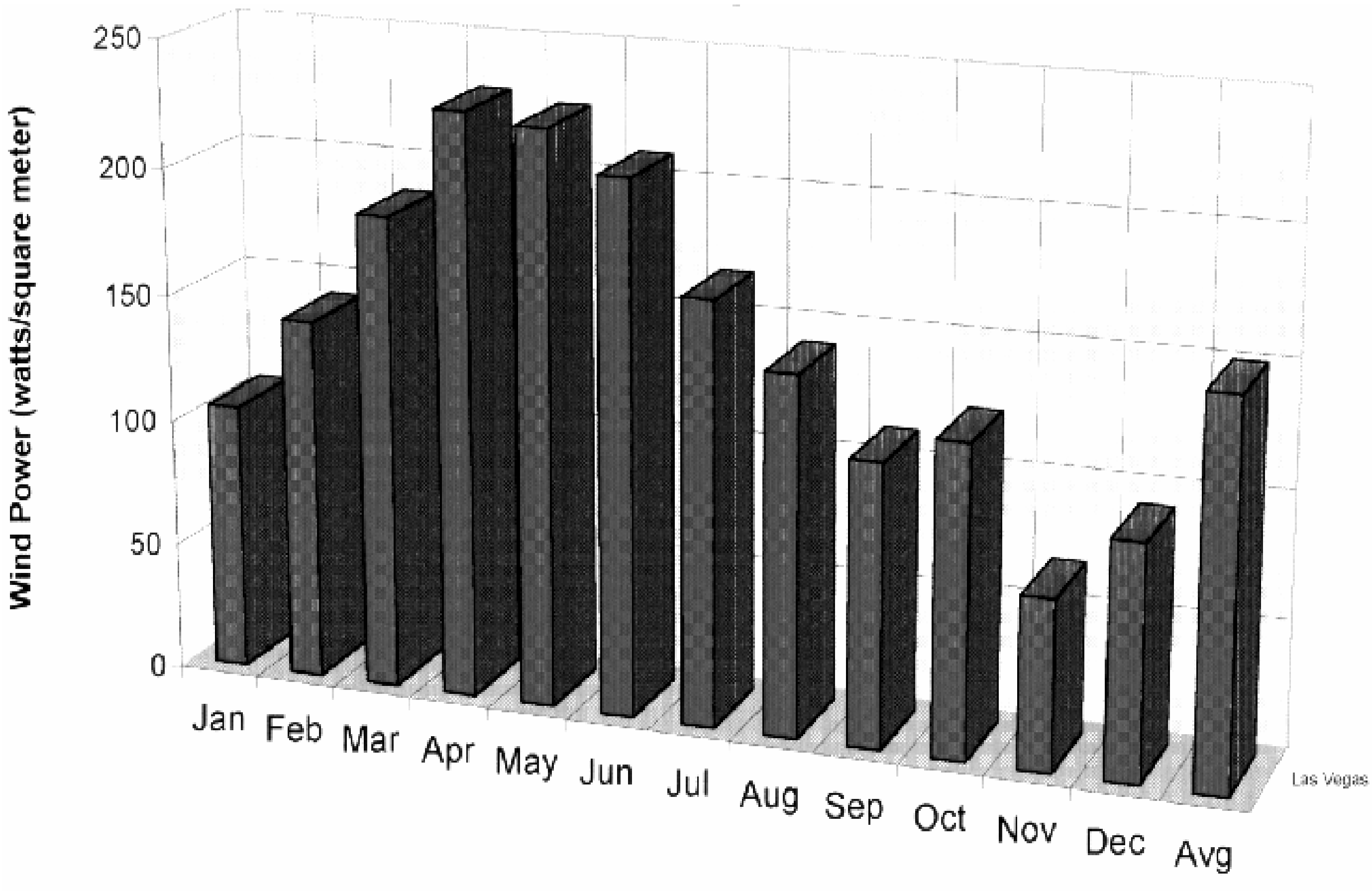
Monthly Average Wind Power for Boulder City



Monthly Average Wind Power for Reno



Monthly Average Wind Power for Las Vegas



Preliminary Wind Assessment

- A preliminary wind assessment is inexpensive and can show if the wind project is worth pursuing
- Site specific wind resource monitoring is not required
- Data collected from neighboring areas or towers
- Wind speed and turbine output calculator can be found at www.energy.iastate.edu

Wind Energy Checklist

- A comparison of two locations shows a small increase in wind speed results in a much larger increase in electrical output
- Capacity factor is the actual power produced over a period of time – expressed as a % of rated turbine capacity

Model Mean Speed (miles/hour)	16.87	14.65
Model Air Density	1.222	1.229
Mean Wind Power Density (watts/meter squared)	422	287
Capacity Factor	33.83%	25.25%
Estimated Annual Output (kilowatt hours)	2,228,430	1,652,792

** On unobstructed ground at height of 164 feet*

Wind Feasibility Study

- A more comprehensive study should consider the following:
  - Wind speed data
  - Size, design, siting options, connection costs
  - Estimates of energy output
  - Cost assessments and savings
  - Economic analysis
  - Risk assessment

Wind Speed Data

- Measurements should be taken in accordance with American Wind Energy Association (AWEA) – www.awea.org
- Collect data as close to the intended turbine location and hub height as possible – meteorological tower
- Collect data for 1 – 3 years; if a long-term wind monitoring reference site is located nearby, 1 year may be sufficient
- Need to account for annual variations in wind speed and availability

Some considerations

- Topography of the land and surface obstructions – turbulence from surface roughness robs wind of power
- Access to transmission lines
- Zoning and permitting – above 200 feet, FAA permits required
- Environmental issues – noise, visual impact, birds

Modeling

- Numerical methods
  - Finite difference
  - Finite volume
  - Finite element
- MM5 NOAA model
- Finite element with adaptation
- Utilize available met data

Nevada Test Site

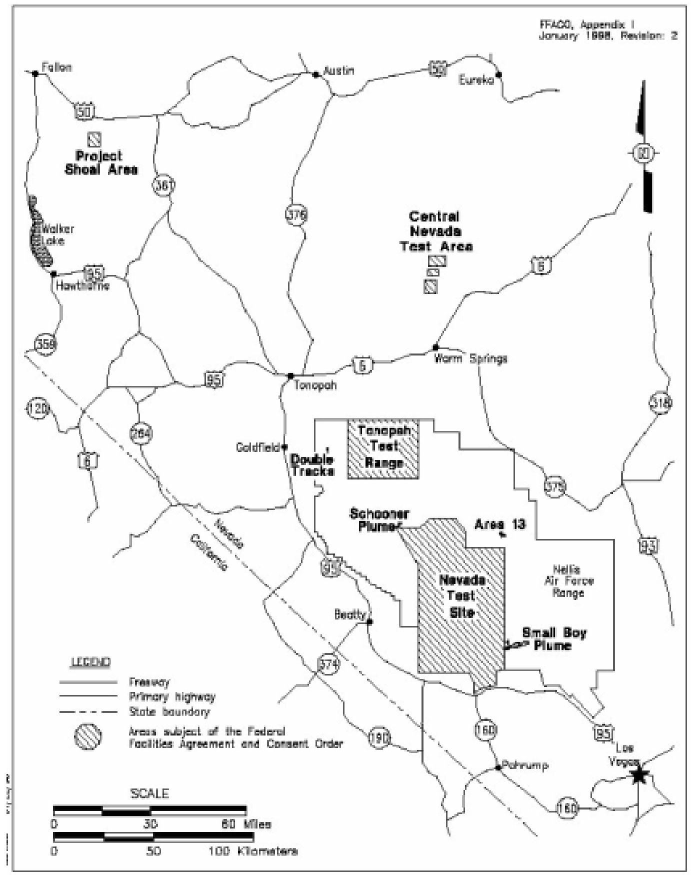
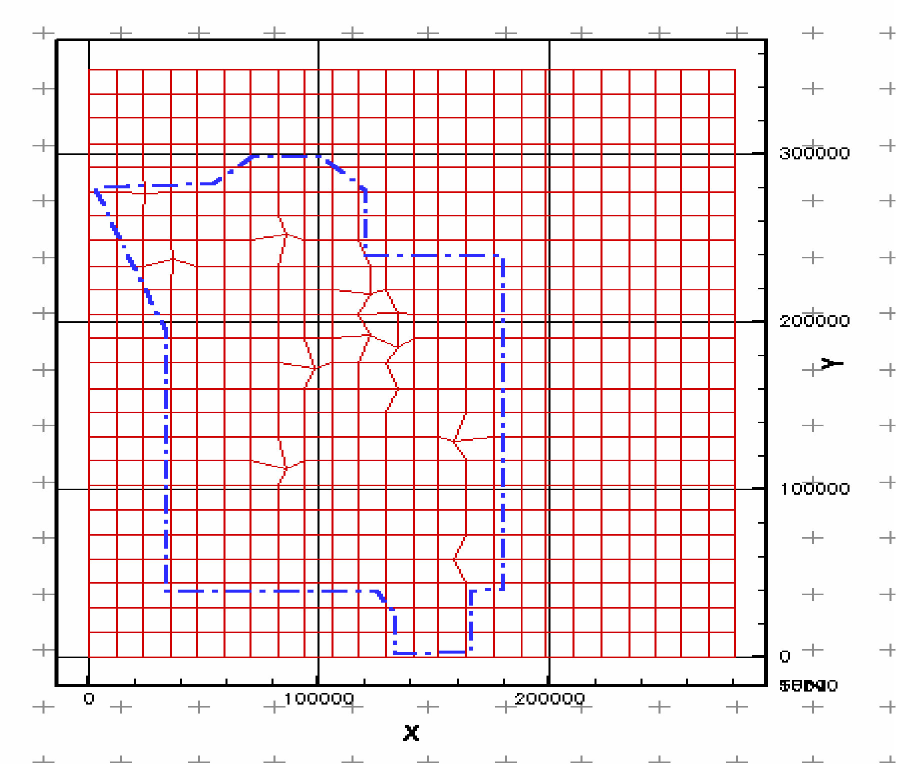


Figure I-1
Areas Subject to the Federal Facilities Agreement and Consent Order

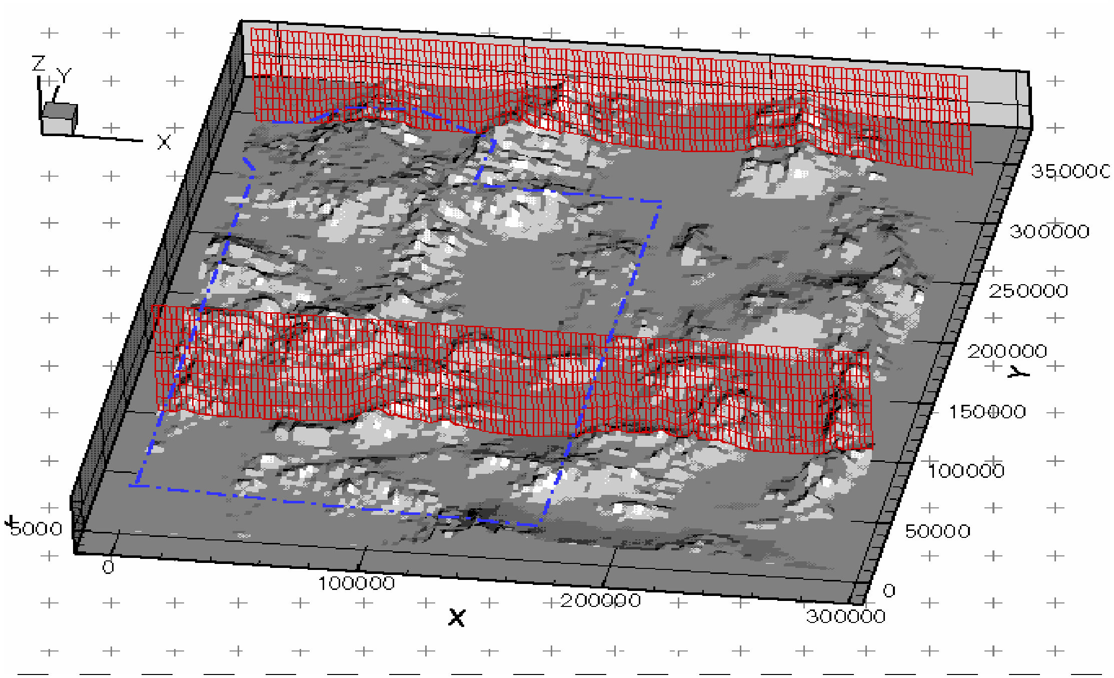
Mesh Generation - NTS

Non-orthogonal mesh incorporating NTS Met towers at grid points



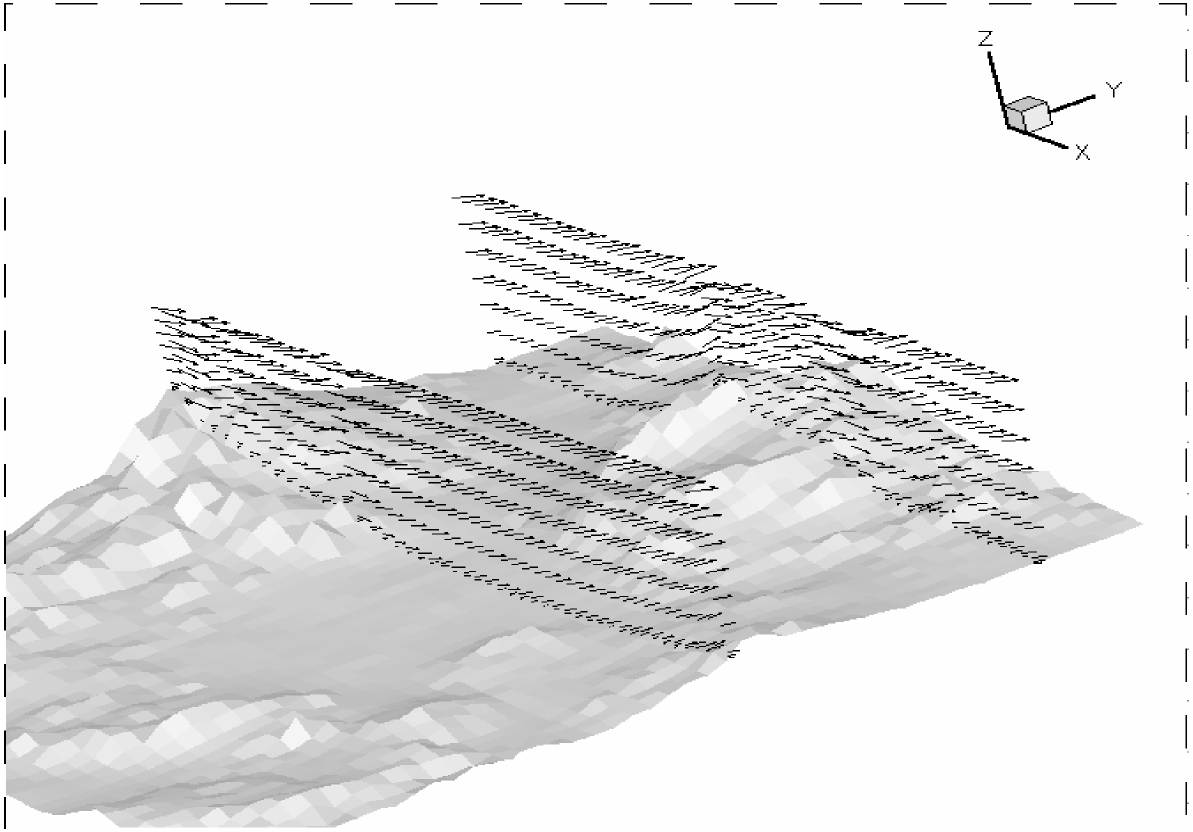
NTS Topography

3-D terrain of the Nevada Test Site generated from USGS DEM files. Resolution shown is 1km with 12 layers to 500 mb

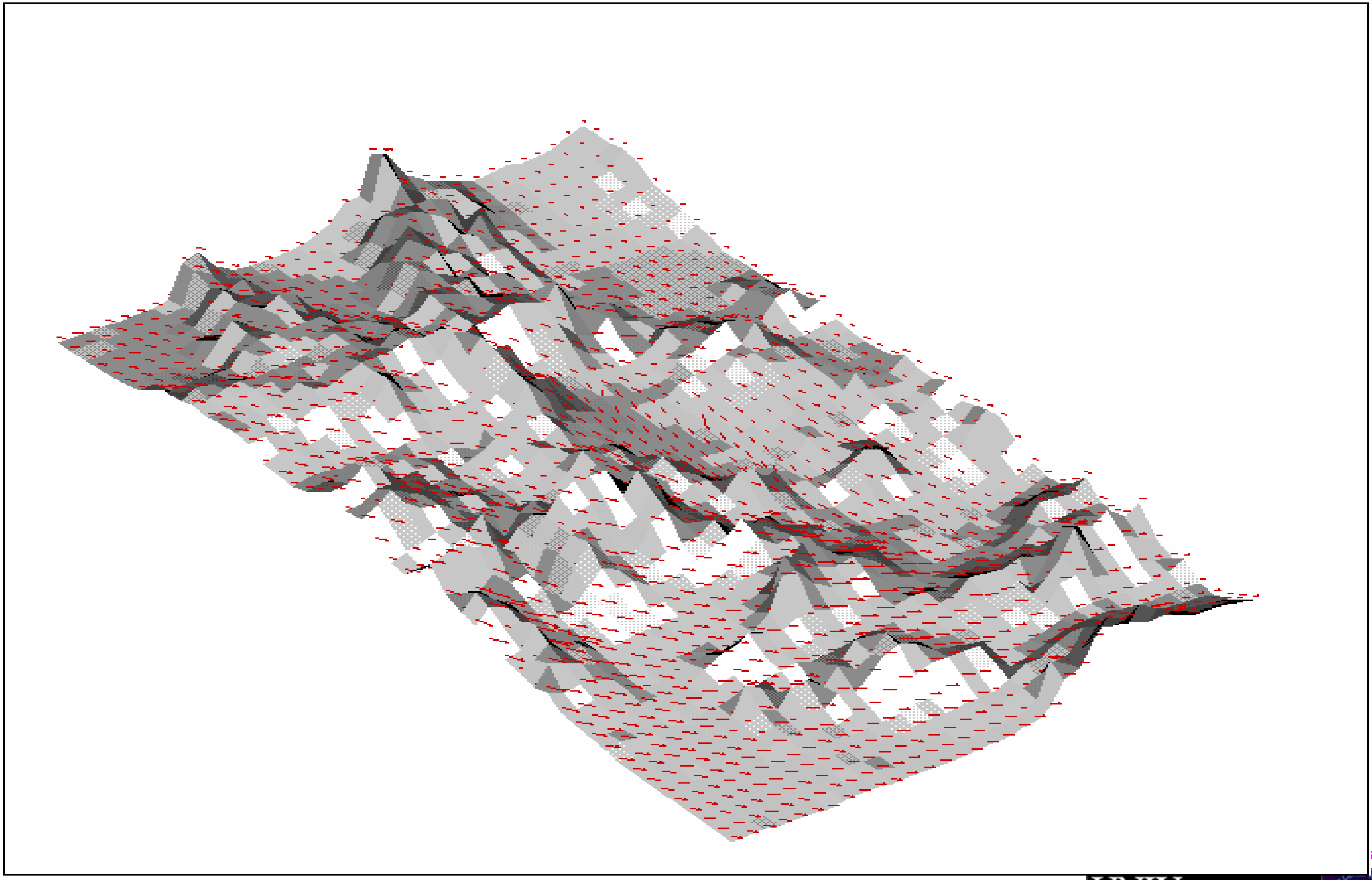


Diagnostic Winds

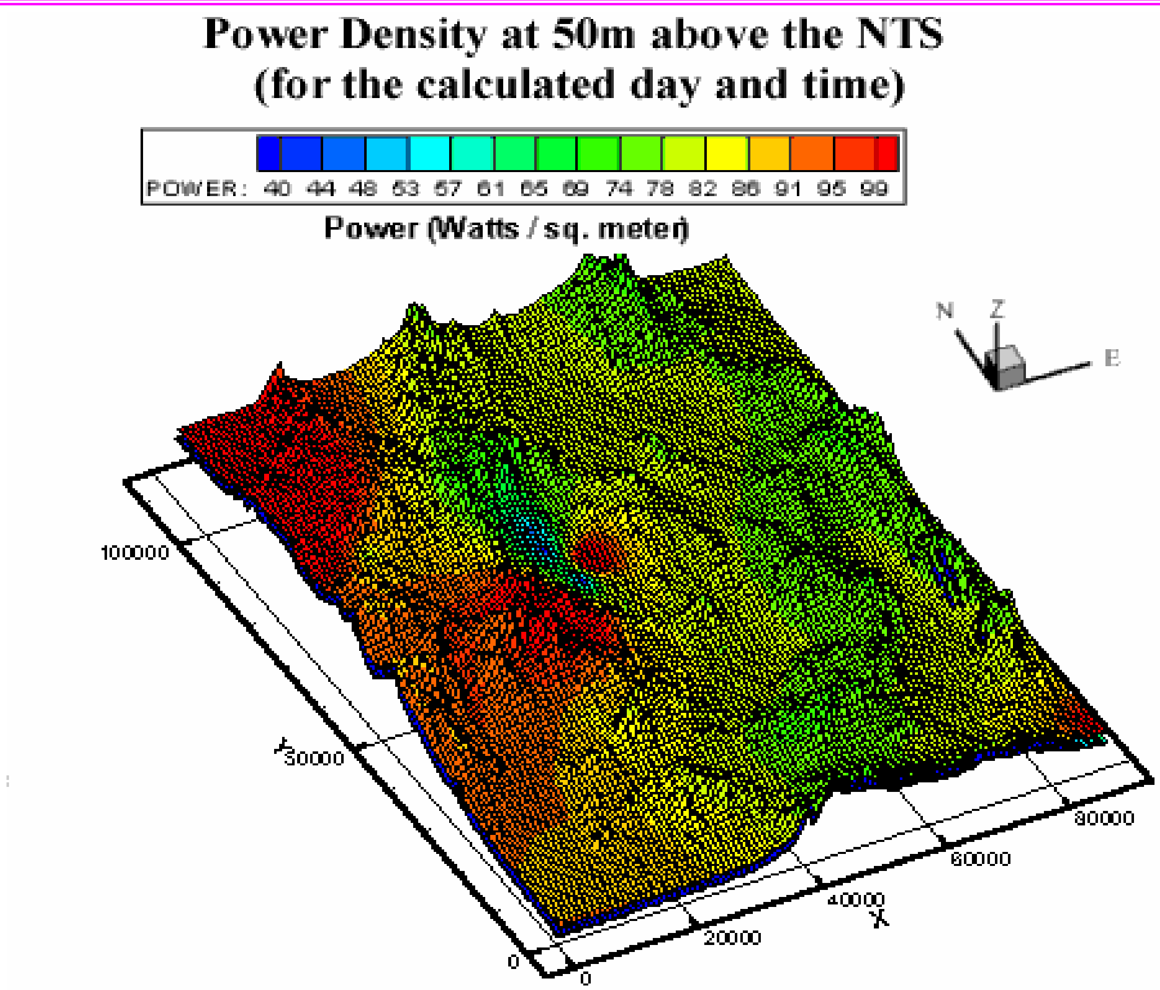
3-D mass consistent analysis



Wind field - 50 m above terrain



Wind Power Density Watts/m^2 - 50 m layer



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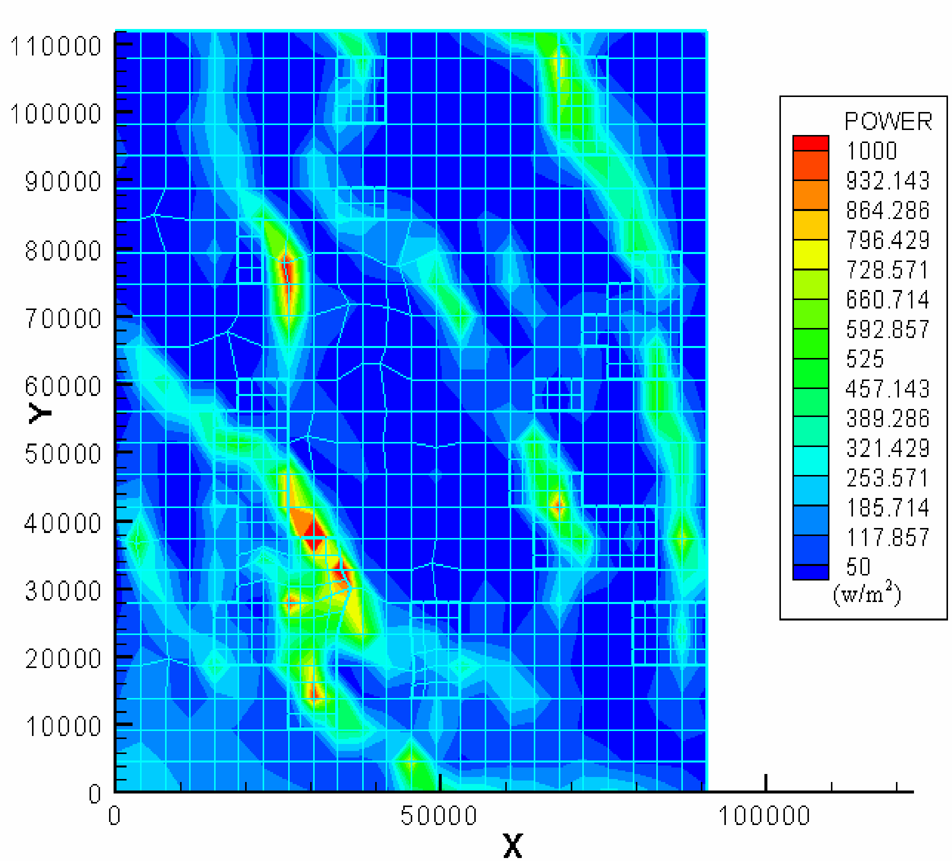
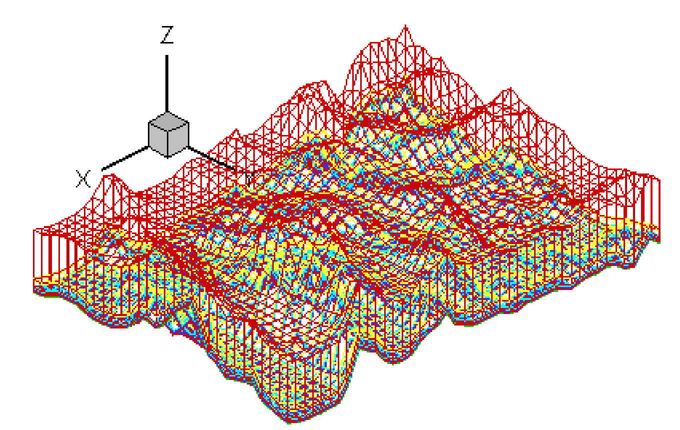
Power Density -- 50m Layers

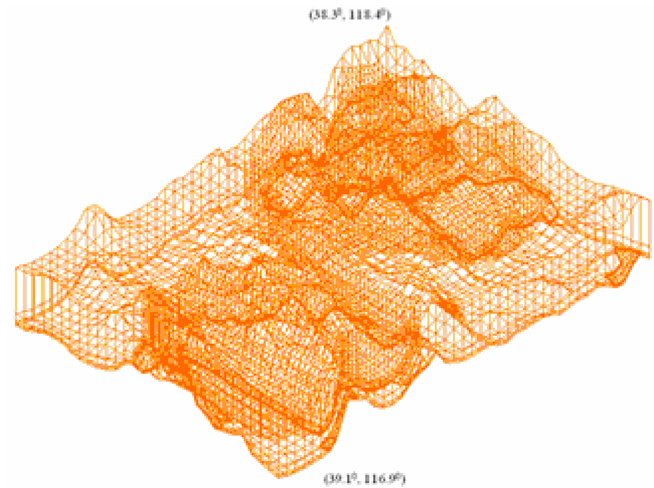


Central Nevada

◆ Wind Energy assessment in Nevada



Initial mesh



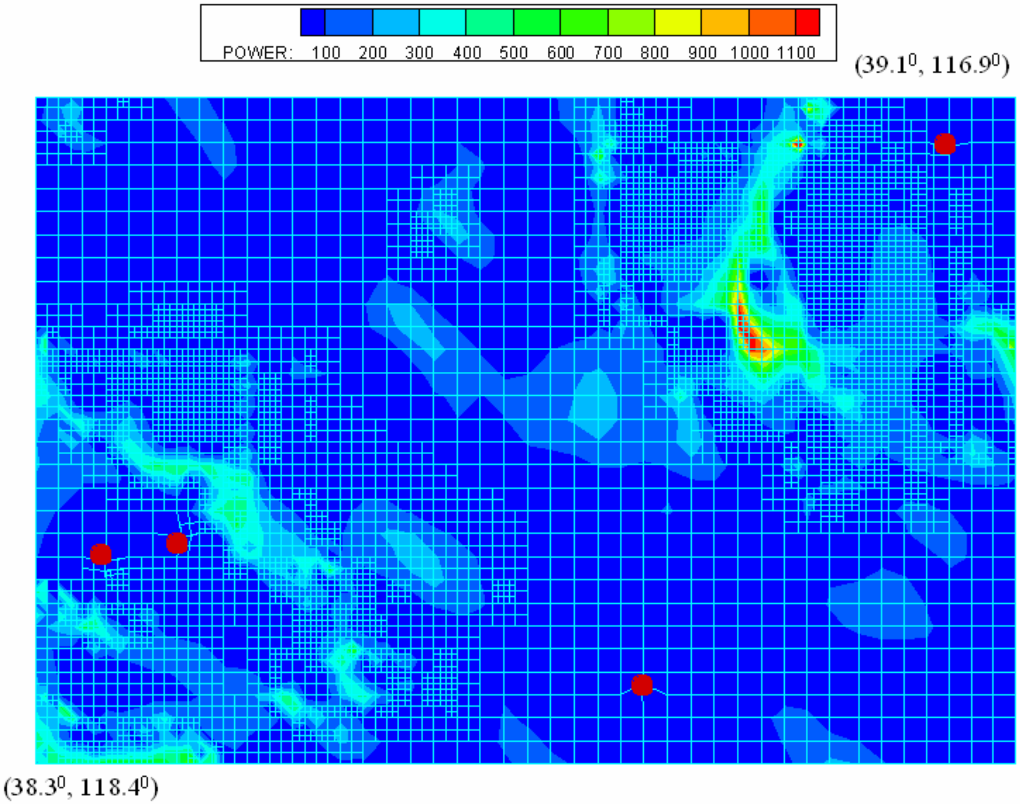
h-adaptive mesh

Mesh for central Nevada Region

Notice: The region ranges from north latitude 38.3^{o} to 39.1^{o} and west longitude 116.9^{o} to 118.4^{o}.

Central Nevada – cont.

- **Wind Energy assessment in Nevada**



Power Density (w/m²) for 100m layer (December, 2001 data) with *h*-adaptation

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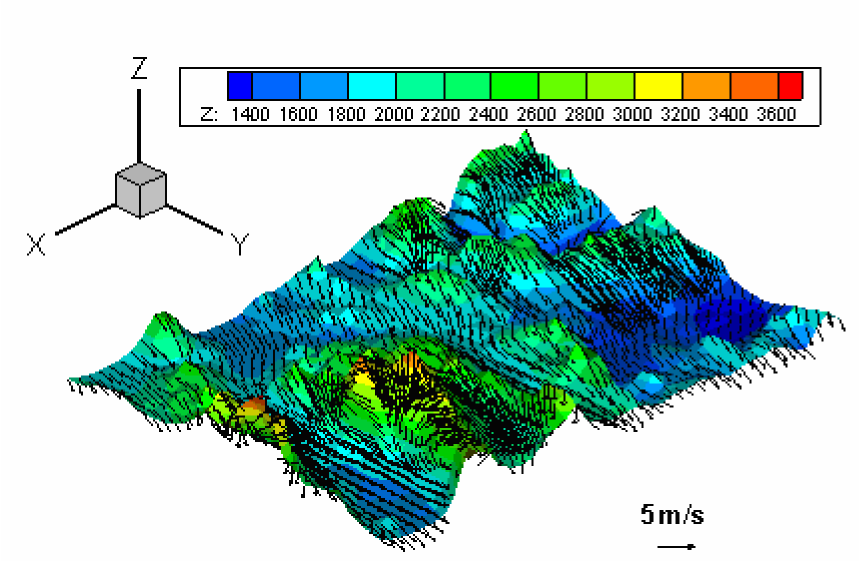
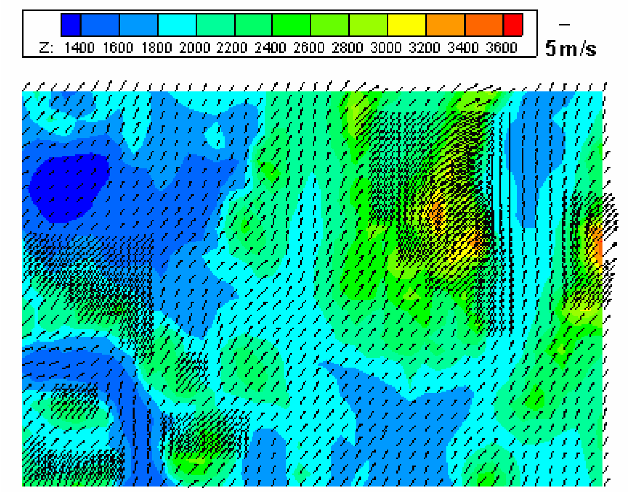
Central Nevada

◆ Wind Energy assessment in Nevada



3D wind fields



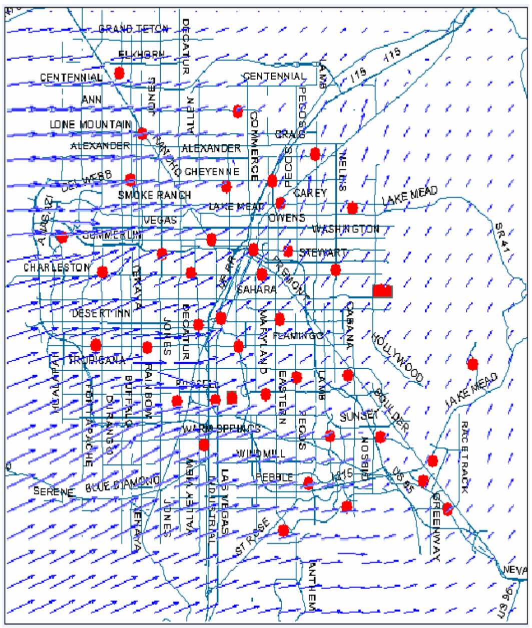
2D wind fields

Wind fields for central Nevada

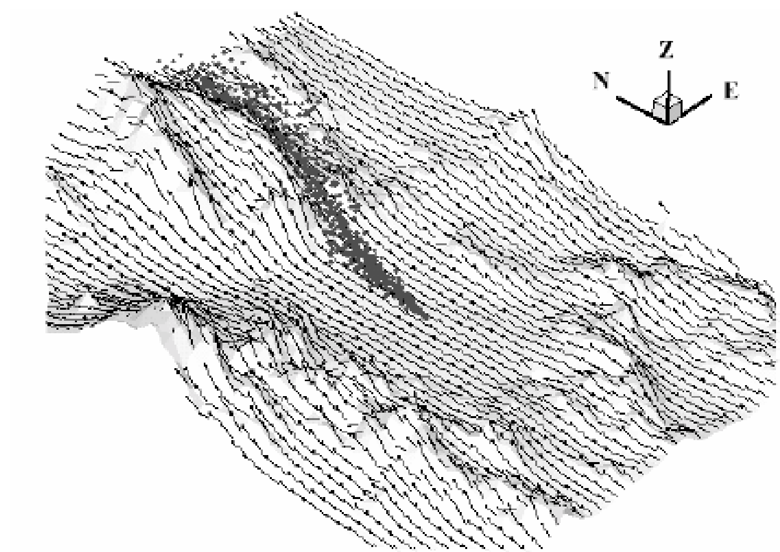
Note: The contours show the terrain topography.

Other Applications– Cont.

- **Contaminant dispersion in Las Vegas valley**

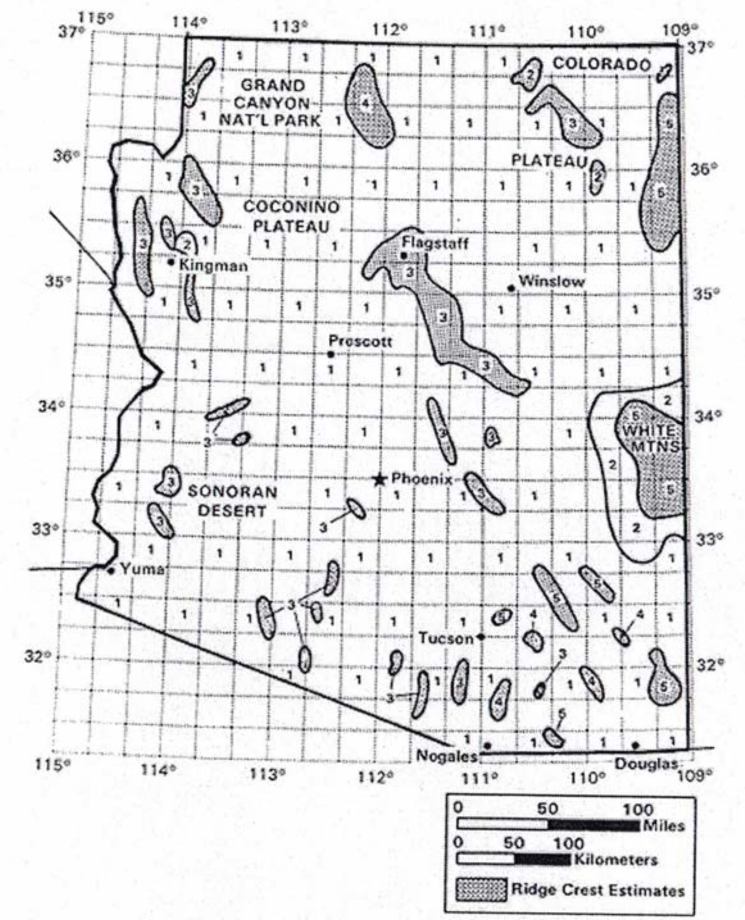


(a). Wind fields for Las Vegas Valley



(b). Contaminant dispersion path

Arizona – wind potential



Economic impact

- The greatest potential for increasing the local economic impact of wind energy may be local ownership.
- Revenue from non-locally owned wind farms does not seem to reach the local economy.
- Resident investors are more likely to finance projects through local lenders and utilize suppliers in their communities.
- If local capital could be used to support local ownership of wind turbines, the economic impact of wind power development could become significant

Contact

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