

Jack Kline, Ron Nierenberg, 1989 California

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MACRO—SCALE WAKE EFFECTS

About five years ago a perplexing new phenomenon was noticed by several wind energy meteorologists. Each year the winds in certain parts of the Altamont Pass, in northern California, decreased. Initially the cause was thought to be climatological; for instance, in 1984 the low winds were blamed on the "El Niño" (abnormally warm waters in the equatorial Pacific Ocean). As more time passed, the winds at many locations still have not returned to earlier levels, while other areas have remained at historical conditions. Variations in climatological conditions can result in improved or reduced winds from year to year, another explanation for the diminished wind resource has emerged.

Our hypothesis is that the large arrays of wind turbines installed in the Altamont Pass produce significant wake energy deficits that persist much further than 10 or 20 row diameters (RD) downwind. This article will present evidence that supports this hypothesis. The supporting data was collected and analyzed by Howden Wind Parks Inc. Results from a Department of Energy (DOE) funded wake deficit study performed by the Altamont Energy Corporation are also presented. We shall focus first on the impact downwind of the U.S. Windpower (USWP) 50 MW windfarm, which was installed upwind of Howden's windfarm in 1985. The mean wind trajectory passes from USW to Howden about 90 percent of the time on an annual basis. The attached figure shows a number of interesting things:

- 1) The one square mile (2.6 sq. km) Howden Wind Park is directly downwind of the USW (late 1985) installation. Note the prevailing wind direction of the 50 RD immediately downwind of the 50 MW array, the energy decrease or deficit is 20 percent.
- 2) A large area, extending several miles (250 + RD) downwind of the 50 MW array, has a deficit of about 15 percent.
- 3) The areas to the northwest and southwest of the 50 MW array (crosswind) have negligible (0 to 1 percent) changes. These deficits are for the summer only



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predominantly
are slightly
as one
anti-
their
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sults from that study (1) that relate to this
topic.
1) Energy deficits were inversely propor-
tional to wind speed, i.e., higher winds
yield lower energy deficits.
2) In typical summer winds with an av-
erage speed of 23 mph (10.2 m/s), the
wind energy deficit from the row at 8 RD
upwind was 13 percent.
3) In 23 mph winds, the energy deficit
from the row at 16 RD upwind was 12
percent, almost the same as from the 8 RD
row.
A possible explanation for the per-
sistent wake deficits measured by How-
den and Altamont Energy Corporation, is
the temperature inversion (warm air
above cold air) found in the Altamont
Pass. This inversion is a persistent climo-
logical feature, the dynamics of which
contribute significantly to the high winds
found in the Altamont Pass. Measure-
ments by Howden and others have
shown that the inversion can be found
from near the surface to several hundred
feet above ground level. The high wind
layer in the Altamont Pass lies beneath
the inversion, with wind speeds decreas-
ing very rapidly above the inversion. The
stabilizing nature of the inversion inhibits
the downward mixing of momentum from
above. Thus, the amount of wind energy
flux in the Altamont is finite and each row
of wind turbines removes a portion of this
energy, permanently.

can amplify downward trends in wind
speed caused by climatological varia-
tions. That is, in a low wind year, wake
effects will be worse, and downwind sites
will experience larger energy deficits.
Third, long-term estimates of the wind re-
source must be adjusted of the wind re-
source wake deficits.
A historical wind data record at one site
spanning many years but subjected to up-
stream development for some portion of
the total duration cannot be treated as
one continuum. The data need to be an-
alyzed in discrete time segments, cor-
responding to periods with and without
upstream wake effects. Otherwise the
counted wake effects will not be ac-
curate for and estimates will not be ac-
curate. Developers should keep in mind the
size of the installed upstream effects of
future projects.
The extent of any macro-scale wake ef-
fects will depend on the local atmospheric
structure, overall wind resource, per-
centage of time the wind trajectory is from
the upstream development, and the size of
the energy deficits in the Altamont
Pass may be higher than would occur in
other parts of the world. Nevertheless,
the macro-scale energy deficits could be
significant.

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Nierenberg, R. 1989, Wake Deficit Mea-
sures on the Jess and Sousa Ranches, Al-
tamont Pass, Solar Energy Research Institute,
Golden Colorado.

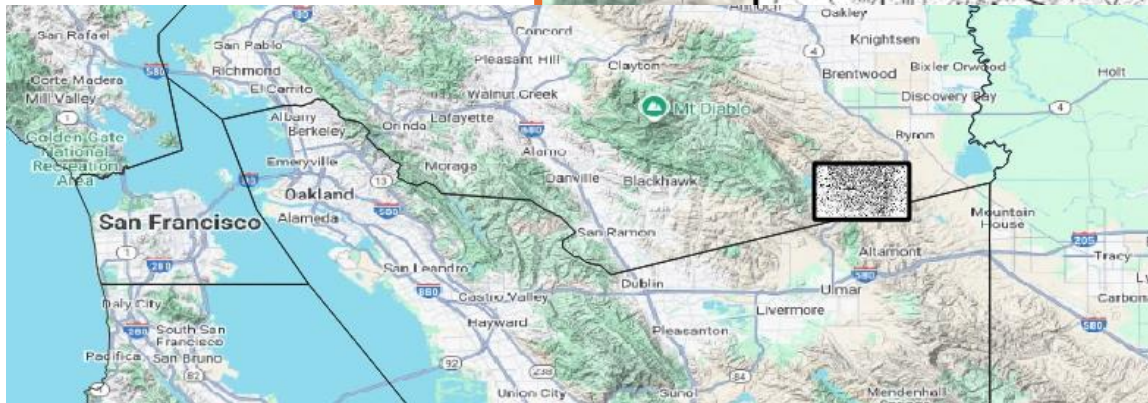
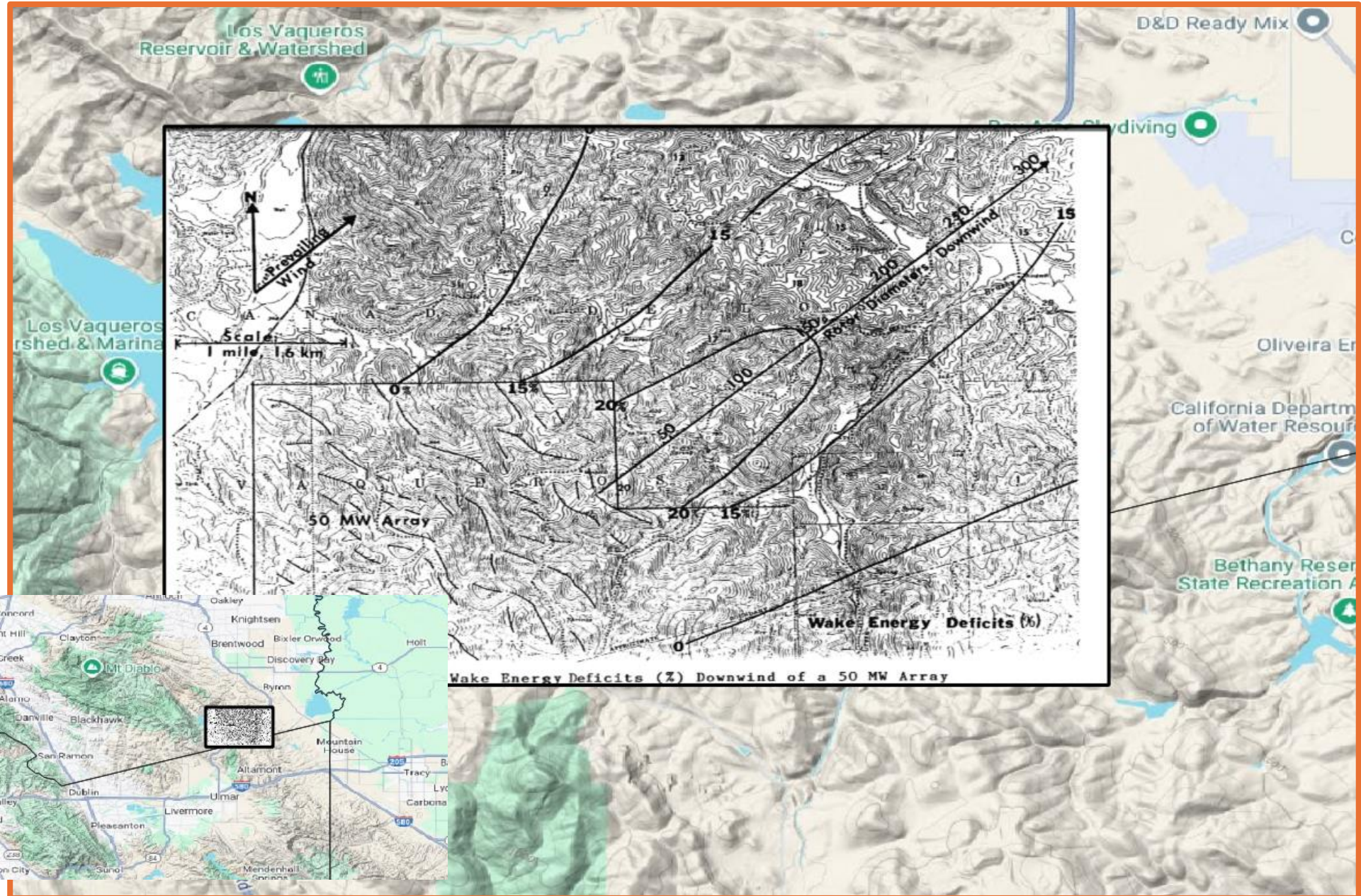
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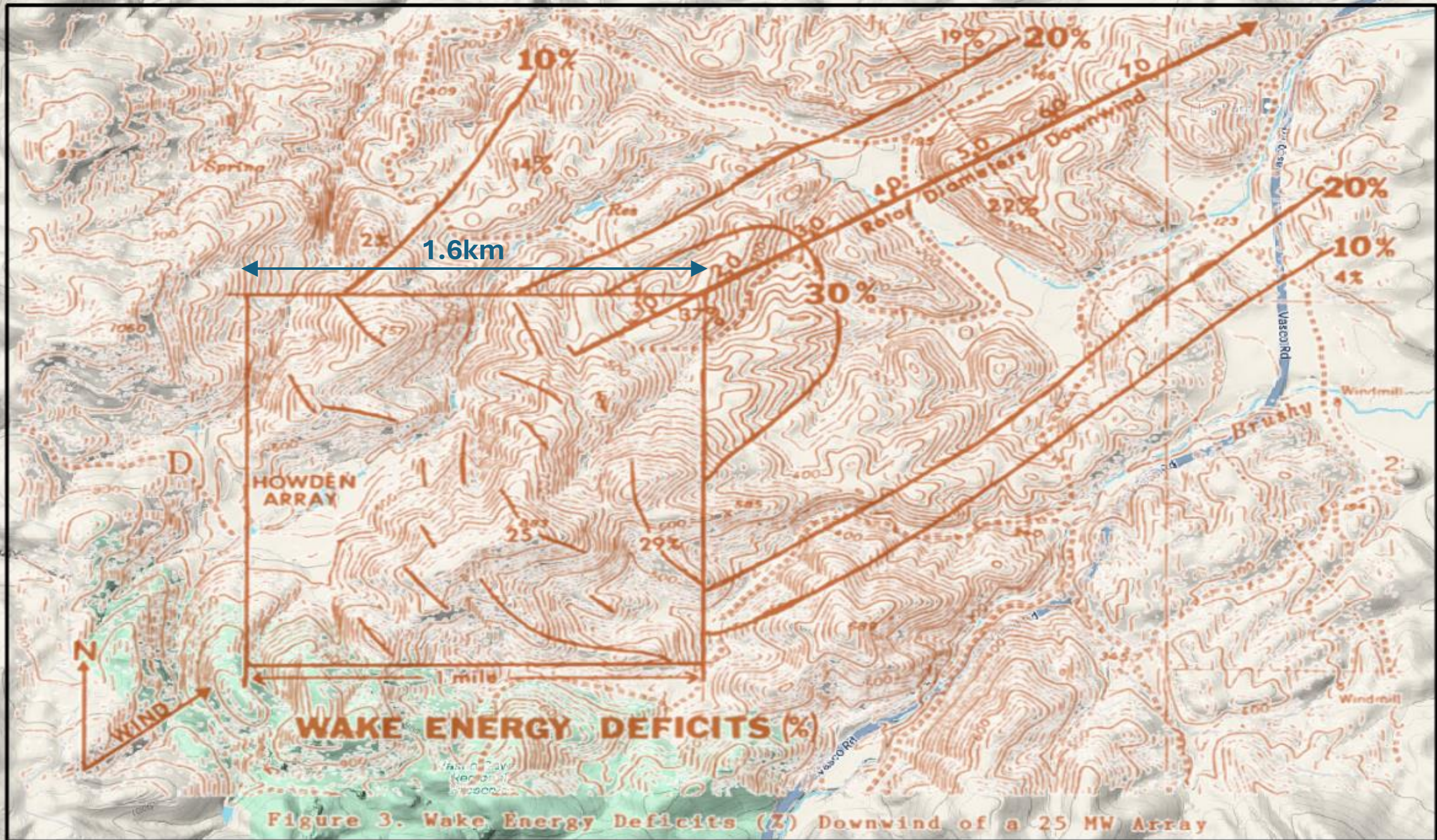
There are several important implica-
tions of these findings to wind energy de-
velopers. First, it helps to explain the de-

Wake effects far downstream... 10D, 20D

The study looked at 50MW array upstream of a 25MW array (Howden).

Since the 1989, a reservoir was created, and the old Vasco road decommissioned, plus an airport was built nearby ...





1992 aerial image

50MW array

North

Howden
25MW

Image Landsat / Copernicus
Image © 2024 Maxar Technologies
Image U.S. Geological Survey

Google Earth



Ron Nierenberg, 1989

Just South of Howden.

Study on freestream
wind speed variability.

Free-Flow Variability on the Jess and Souza Ranches, Altamont Pass

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Altamont Energy Corporation
San Rafael, California

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SERI Technical Monitor: W. Bollmeier

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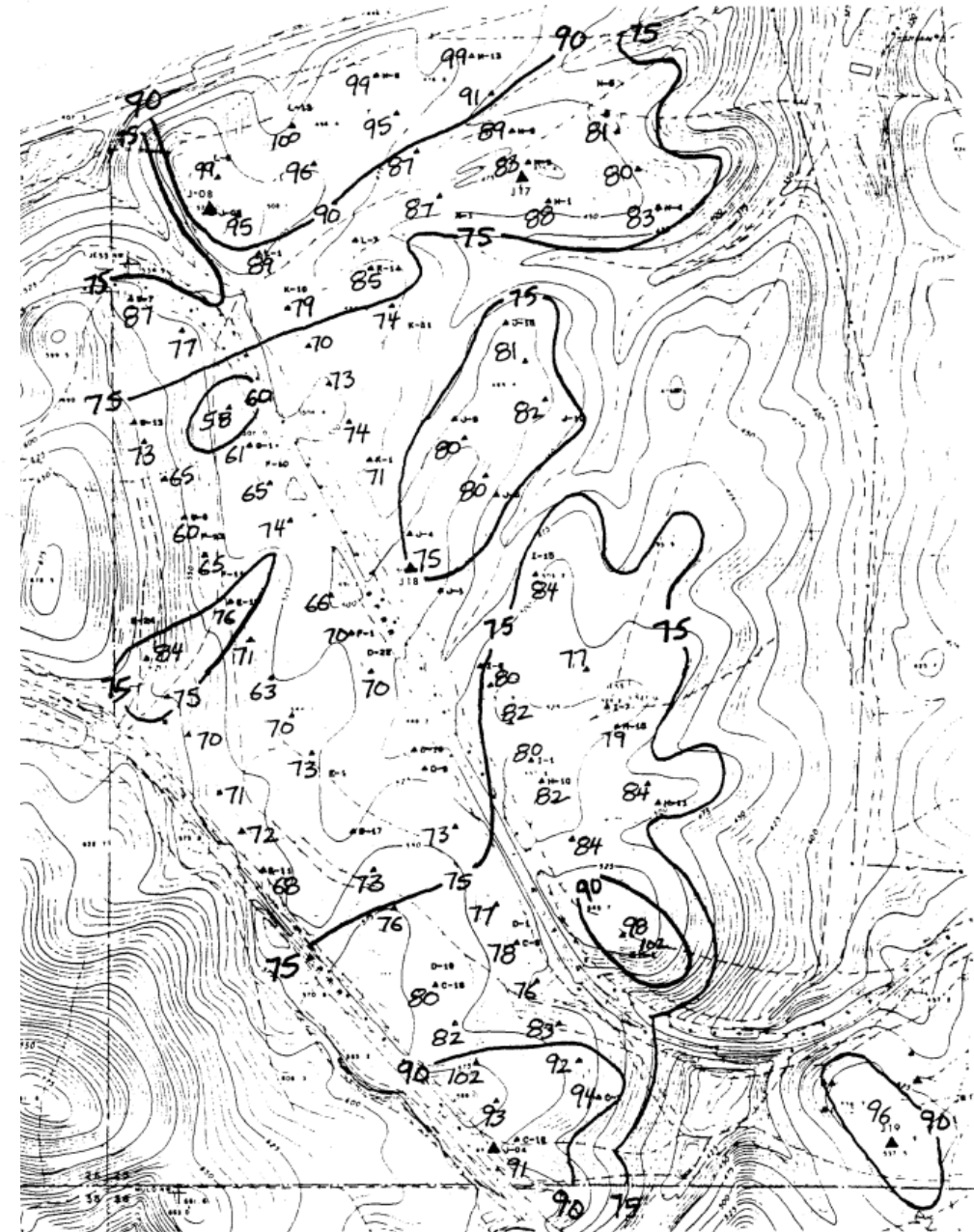


Figure 3-8. Normalized Speed Ratios (Z) to J-08 for All Hours

**Of course without
reanalysis to help
figure out the synoptic
conditions ☺**

