CALIFORNIA WIND EROSION PREDICTION GUIDE

UNITED STATES
DEPARTMENT OF
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NATURAL
RESOURCES
CONSERVATION
SERVICE

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$$E = f(I\ K\ C\ L\ V)$$

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WIND EROSION IN CALIFORNIA

Some wind erosion has always occurred as a natural land forming process, but in specific locations it has become more detrimental due to human activities. This "accelerated" erosion is primarily due to improper land use and management. Loss of fertile topsoil can reduce rooting depth and crop yields. Abrasion by airborne soil particles damages plants and structures. Sand and dust in the air can harm animals, humans, and equipment.

The parts of California most affected by wind erosion include the Tulelake area and Butte Valley in Siskiyou County, the Sacramento-San Joaquin Delta area, western part of Kern County, Antelope Valley in Los Angeles County, the Mojave Desert areas of Inyo, San Bernardino and Riverside Counties, the Coachella Valley and Palo Verde Valley in Riverside County, Imperial Valley, the Ontario area in western San Bernardino County, and beach areas along the California coast. The 1980 County Resources Inventory conducted by the USDA Natural Resources Conservation Service found 1,303,000 acres of irrigated cropland, 36,000 acres of non-irrigated cropland, and 1,625,000 acres of grazing land impacted by wind erosion.

On many of the impacted areas, the primary problem caused by wind erosion is sand blast damage to young seedling plants. Some crops are more vulnerable to wind erosion damage than others with vegetable crops being especially vulnerable. The economic consequences include higher production costs, lower yields, and less income. Other crops are tolerant enough that changes made in tillage or other crop production techniques would increase their ability to withstand or recover from wind erosion damage. Crop damage often occurs at predicted wind erosion rates less than the soil loss tolerance T value. Replanting cotton because the first seedlings were sand blasted is a typical example. In other areas, high winds result in reduced crop quality and gross income.

THE WIND EROSION PROCESS

The soil erosion process by wind forces is complex. The process involves the detachment, transport, sorting, abrasion, avalanching, and deposition of soil aggregates. Field conditions conducive to soil erosion by wind include:

1. Loose, dry, and finely granulated soil;
2. Smooth soil surface with little or no vegetation present;
3. Sufficiently large area susceptible to erosion; and
4. Sufficient wind velocity to move soil.

Winds that are considered to be erosive are those with velocities that reach 13 miles per hour at a height of one foot above the soil surface. Considering the logarithmic wind profile this translates into a velocity of about 18 miles per hour at a 30 foot height. This is commonly referred to as the threshold wind velocity.

The wind transports primary soil particles and stable aggregates in three ways-saltation, suspension, and surface creep. These are illustrated in Figure 1, and discussed separately in the following paragraphs.

Saltation. Individual aggregates/particles ranging from 0.1 to 0.5 mm in diameter lift off the surface at an approximate 50 to 90 degree angle. The aggregates/particles then follow distinct trajectories under the influence of air resistance and gravity. The aggregates/particles fall back to the soil surface at impact angles of 6 degrees to 14 degrees from the horizontal. At the point of impact with the soil surface, the rebounding and embedded aggregates/particles initiate movement of other aggregates/particles. This has been commonly referred to as the "avalanching" effect. Most saltation occurs within 12 inches above the soil surface and typically, the length of the saltating trajectory is about 10 times the height. It has been suggested that from 50 to 80 percent of the total soil transport is by saltation.

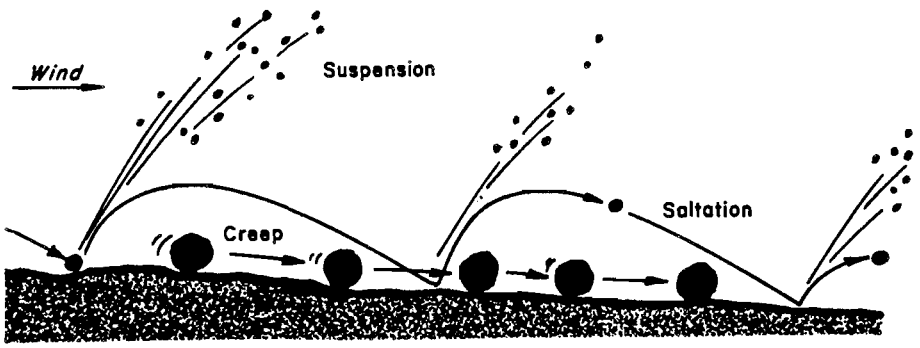


Figure 1. Wind Erosion Processes

Suspension. The finer particles, less than 0.1 mm in diameter, that are dislodged from an eroding area by saltation can be moved upward by diffusion and remain in the air mass for an extended period. Some suspension-sized particles are present in the soil, but many are created by abrasion during an erosion event. From 20 percent to more than 60 percent may be carried in suspension, depending on soil texture. As a general rule, suspension increases downwind, and on long fields can easily exceed the amount of soil moved in saltation and creep. Current research suggests that the range for suspension sized aggregates/particles can be divided into two categories-coarse (0.05-0.1 mm) and fine (< 0.05 mm).

Surface Creep. Sand-sized aggregates/particles are set in motion by the impact of saltating aggregates/particles. Under high winds, the whole soil surface appears to be creeping slowly forward as the aggregates are pushed and rolled by the flow. It has been noted that surface creep may account from 7 to 25 percent of total transport.

DEVELOPMENT OF THE WIND EROSION EQUATION (WEQ)

Drought and soil erosion by wind during the 19th century caused wind erosion to be recognized as an important geological phenomenon. By the late 1930's, systematic and scientific research into wind erosion was being pioneered in several states including California, South Dakota, and Texas. Additional investigations also were conducted in England and Canada. The products of these efforts included information on the mechanics of soil transport by wind, the influence of cultural treatment on rates of soil movement, and the influence of windbreaks on windflow patterns. One of the first publications, **The Physics of Blown Sand and Desert Dunes**, by R. A. Bagnold was published in 1941.

The current form of the WEQ was first released in 1963. Other enhancements were added in 1965, and 1968 to account for preponderance and monthly climatic factors. The management period technique for computing soil erosion by periods using wind energy distributions was introduced in 1981.

PRESENT FORM OF THE WIND EROSION EQUATION

The Wind Erosion Equation (WEQ)

The present wind erosion equation is expressed as:

$$E = f[(IKC)LV]$$

where,

E is equal to the estimated average annual soil loss expressed as tons per acre per year. It is very important to note that the erosion rate (E) estimated by the WEQ is the average annual erosion rate from the field, and that annual erosion varies widely from year to year.

f is a function and indicates that the equation includes functional relationships that are not straight-line mathematical calculations.

I is the soil erodibility index and represents the potential annual wind erosion for a given soil under a given set of field conditions. This factor, expressed as the average annual soil loss (t/ac/yr) from a field area accounts for the inherent soil properties affecting erodibility. These properties include texture, organic matter, and calcium carbonate percentage. The given set of field conditions for which "I" is referenced is that of an isolated area that is unsheltered, wide, bare, smooth, level, loose, and uncrusted at a location where the climatic factor, C is equal to 100. This value is assigned to each soil mapping unit and appears on the HEL Soils List published for each soil survey area. Values range from 310 down to 12.

K is the ridge roughness factor and is a measure of the effect of ridges made by tillage and planting implements compared to a standard ridge height to ridge spacing ratio of 1:4. Distance between ridges is measured parallel to the erosive wind direction. Values range from 1.0 for smooth surfaces to 0.5 for the most effective ridging.

When using the annual prediction method, the erosive wind direction can be based on published data or local knowledge for the critical erosion period. When using the management period prediction method, base the erosive wind direction on published data or local knowledge for each period.

C is the climatic factor and characterizes the climatic variables affecting erosivity, specifically the average annual wind velocity plus the average monthly precipitation and temperature for locations with long term weather records. Values are extrapolated to cover areas between climate stations and displayed on maps as a percentage of the C factor for Garden City, Kansas, which has a value of 100 percent. Values in California range from 5 percent to 1000 percent.

L is the unsheltered distance and is the unprotected distance along the prevailing erosive wind direction across the area to be evaluated and the preponderance of the prevailing erosive winds. This is the distance across the field measured parallel to the erosive wind direction and ending at the downwind border of the field.

If the area upwind from the field is stable (not eroding), measurement starts at the beginning of the field border. However, if there is a barrier (trees, shrubs, or wind resistant fencing) along the upwind edge of the field, subtract ten times the barrier height from the distance across the field. It the area upwind from the field is not stable, measurement starts upwind of the field at the edge of a stable area.

V is the vegetative cover factor and combines three conditions: (1) the amount of residue (dry weight); (2) the kind of residue/vegetative cover; and (3) the orientation of the residue/vegetative cover. Charts are used to convert this data to an equivalent amount of flat small grain residue equivalent (SGe) in pounds per acre.

The most easily modified Wind Erosion Equation (WEQ) factors are:

- K = the ridge roughness along the soil surface and orientation to the wind.
- L = the unsheltered distance across the field parallel to the wind.
- V = the vegetative cover amount and orientation to the wind.

Figure 2 illustrates the different forces involved in the wind erosion process.

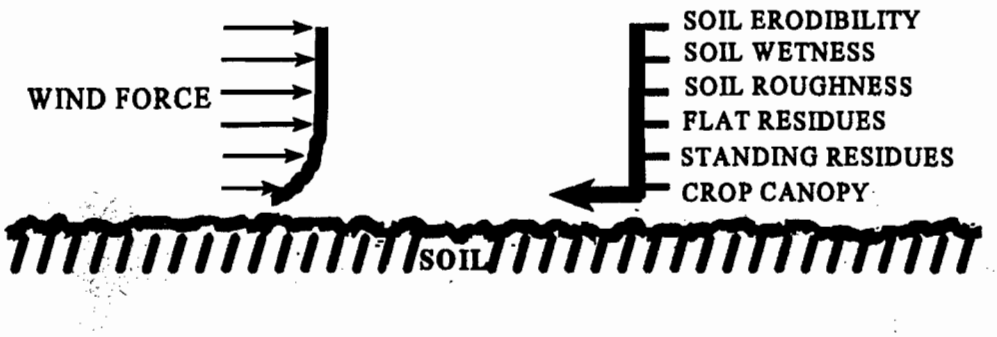


Figure 2. Opposing Forces in the Wind Erosion Process

Steps in Solving WEQ

Solving the wind erosion equation involves five successive steps as follows:

E1= (I) - Factor I is established for the specific soil. The value of I may be increased for knolls less than 500 feet long facing into the prevailing wind, or decreased to account for surface soil crusting, cloddiness, and irrigation.

E2= (IK) - Factor K adjusts E1 for tillage-induced oriented roughness, K_{rd}, (ridges) and random roughness, K_{rr}. The value of K is calculated by multiplying K_{rd} times K_{rr} ($K= K_{rd} \times K_{rr}$).

E3= (IKC) - Factor C adjusts E2 to account for the local climate in relation to the reference condition (C=100).

Steps 1 through 3 can be solved by multiplying the values of factors I, K, and C.

E4= *f*[(IKC)L] - Factor L adjusts E3 for the unsheltered distance.

E5= *f*[(IKC)LV] - Factor V adjusts E4 for the vegetative cover.

Limitations of the WEQ

When the unsheltered distance, "L", is sufficiently long, the transport capacity of the wind for saltation and creep is reached. If the wind is transporting all of the soil it can carry across a given surface, the inflow into the downwind is equal to the outflow for saltation and creep. The net soil loss is then only the suspension component. This does not imply a reduced soil erosion problem because theoretically there is still the estimated amount of soil loss in creep, saltation, and suspension leaving the downwind edge of the field.

Another limitation is that surface armoring by non-erodible gravel is not usually addressed in the soil erodibility factor ("I"). Other limitations of the WEQ include the non-accounting for snow cover and inherent seasonal changes in the soil erodibility. The conservationist using the WEQ should also remember that the equation does not estimate soil erosion from single storm events.

Summary

Wind Erosion Equation $E = f[(IKC)LV]$

"E" - Estimated Average Annual Soil Loss in Tons per Acre per Year

The value "E" is an estimate of average annual tons of soil per acre that the wind will erode from an area represented by an unsheltered distance "L", for the soil, climate, and site conditions represented by "I", "K", "C", and "V". The equation is an empirical formula developed by relating wind tunnel data to observed field erosion during a 3-year period in the mid 1950's.

The field data was normalized to reflect long term average annual erosion assuming given conditions during the critical period without reference to changes in those conditions throughout the year. This calibration procedure accounted for minor changes expected to occur during a normal crop year at that time in history.

SOIL ERODIBILITY INDEX - "I"

Wind Erosion Equation $E = f\,[(IKC)LV]$

"I" is the soil erodibility index for the dominant soil on a selected site.

"I" Factor Objectives

- Be able to define the WEQ "I" Factor
- Understand the adjustments to "I" that may:
  - increase "I" factor values
  - decrease "I" factor values
- Explain the effect "I" has on soil erosion rates

"I" Soil Erodibility Index

"I" expresses the average annual wind erosion soil loss in tons per acre per year that would occur on a given soil and site assuming that the site were:

- "Wide" (the distance at which the flow of eroding soil reaches its maximum and does not increase with field width)
- Level (there are no knolls present)
- Unsheltered (there are no barriers present)
- Isolated (there is no incoming saltation)
- Bare (there is no vegetative cover present)
- Smooth (there are no effects from ridge roughness)
- Loose and non crusted (the soil aggregates are not bound together and the surface is not crusted)
- At a location where "C" is 100 (Garden City, Kansas)

This factor is related to the percentage of non-erodible surface soil aggregates larger than 0.84 mm in diameter. The percentage of non-erodible soil aggregates is determined by sieving an air dry sample of soil through a sieve with a mesh that is .84 mm. The sample is weighed first and the aggregates that do not sieve though the screen are weighed again. A percentage can then be calculated. This procedure is outlined in Exhibit 502.61(b) in Part 502 of the National Agronomy Manual. Table 1 illustrates the relationship of the percent of non-erodible aggregates (> 0.84 mm) to assigned "I" factors. For example, the "I" value for a soil with 25 percent non-erodible of aggregates percentage is 86.

TABLE 1. SOIL ERODIBILITY INDEX (I) DETERMINED BY PERCENTAGE OF NON-ERODIBLE AGGREGATES

Units → / ↓Tens	0	1	2	3	4	5	6	7	8	9
0	---	310	250	220	195	180	170	160	150	140
10	134	131	128	125	121	117	113	109	106	102
20	98	95	92	90	88	86	83	81	79	76
30	74	72	71	69	67	65	63	62	60	58
40	56	54	52	51	50	48	47	45	43	41
50	38	36	33	31	29	27	25	24	23	22
60	21	20	19	18	17	16	16	15	14	13
70	12	11	10	8	7	6	4	3	3	2
80	2	---	---	---	---	---	---	---	---	---

Wind Erodibility Groups and Soil Erodibility Index

The "I" value is assigned for named soils based on Wind Erodibility Groups (WEG). The WEG is included on Soil Interpretation Records. Table 2 shows the eight Wind Erodibility Groups and associated "I" values. Note that the "I" values for WEG 1 vary from 310 to 160. In California, an "I" of 310 is for soils with a very fine sand surface texture. An "I" of 220 is for soils with a fine sand surface texture. An "I" of 160 is for soils with a sand or coarse sand surface texture.

A soil erodibility index based solely on the percentage of aggregates larger than 0.84 mm has several potential sources of error. These include: a) changes in erodibility due to crusting, b) the fact that some aggregates are more stable than others, c) the size of the aggregates is not accounted for, d) erodibility for a given soil can change with a change in wind velocity, and e) the equation is based on volume while the index is based on weight. These potential sources of error are outlined in Section 502.31(d) in Part 502 of the National Agronomy Manual.

Field "I" Factor

Select the "I" value assigned to the dominant soil mapping unit in the field. The largest, contiguous soil mapping unit in the field is considered the dominant soil. The acreage from two adjacent soil mapping units that have the same "I" and "T" values can be combined for the dominant soil determination. When the two largest soil mapping units in the field have the same acreage, use the soil mapping unit with the highest "I" value as the dominant soil.

TABLE 2. WIND ERODIBILITY GROUPS AND SOIL ERODIBILITY INDEX

Predominant Soil Texture Class of Surface Layer	Wind Erodibility Group (WEG)	Soil Erodibility Index (I) (Tons/Acre/Year)[1]
Very fine sand,	1	310[2]
Fine sand,		220
Sand, or coarse sand		160
Loamy very fine sand, loamy fine sand, loamy sand, loamy coarse sand, or sapric organic soil materials	2	134
Very fine sandy loam, fine sandy loam, sandy loam, or coarse sandy loam	3	86
Clay, silty clay, noncalcareaous clay loam, or silty clay loam with more than 35 % clay	4	86
Calcareous loam and silt loam, or calcareous clay loam and silty clay loam	4L	86
Noncalcareous loam and silt loam with less than 20% clay, or sandy clay loam, sandy clay, and hemic organic soil materials	5	56
Noncalcareous loam and silt loam with more than 20% clay, or non-calcareous clay loam with less than 35% clay	6	48
Silt, non-calcareous silty clay loam with less than 35% clay, and fibric organic soil material	7	38
Soils not susceptible to wind erosion due to coarse surface fragments or wetness	8	---

[1] The soil erodibility index is based on the relationship of dry soil aggregates greater then .84 mm to potential soil erosion.

[2] The "I" factors for WEG 1 vary from 160 for coarse sands to 310 for very fine sands. For sand with gravel and coarse sand with gravel, use 160.

Adjustments to "I"

Adjustments to "I" factors can be made for knolls, surface soil crusting, and cloddiness created by tillage operations designed to bring non-erodible clods (>0.84 mm) to the soil surface. An additional adjustment is currently being considered for irrigation. Adjustments for knolls will increase "I" factors, while adjustments for crusting and clod-forming tillage will decrease "I" factors. The irrigation adjustment will decrease "I" factors.

Adjustments to "I" - Knolls

Knolls are topographic features characterized by short, abrupt windward slopes. Wind erosion potential is greater on knoll slopes than on level or gently rolling terrain because wind flow lines are compressed and wind velocity increases near the crest of the knoll. This is illustrated in Figure 3.

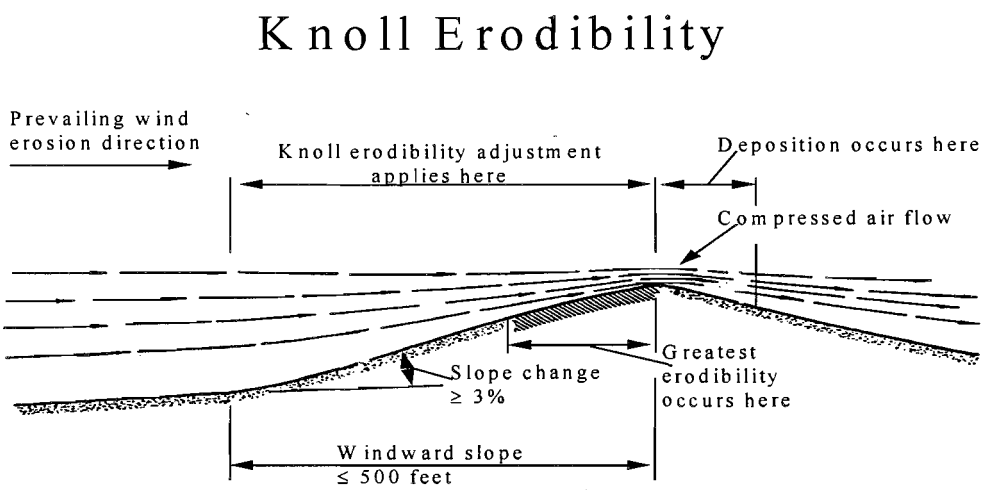


Figure 3. Knoll Erosion

Adjustments of the "I" factor for knolls is used where windward facing slopes are less than 500 feet long and the increase in slope gradient from the adjacent upwind landscape is 3 percent or greater. Both slope length and change in slope gradient are determined along the direction of the prevailing erosive wind.

To adjust the "I" factor for knoll erodibility the "I" factor for the soil on the windward facing part of the knoll is multiplied by the factor shown in Column A of Table 3. Column B in the same table shows the increased erodibility near the crest (upper 1/3 of the slope), where the effect is most severe. This adjustment applies only to that portion of the knoll exposed to the prevailing wind erosion direction.

TABLE 3. KNOLL ERODIBILITY ADJUSTMENT FACTOR FOR I

Slope Change in Prevailing Wind Erosion Direction	A Knoll Adjustment to I	B Increase at Crest Area Where Erosion Is Most Severe
3	1.3	1.5
4	1.6	1.9
5	1.9	2.5
6	2.3	3.2
8	3.0	4.8
10	3.6	6.8
10 - 15*	2.0	--
15 - 20	1.4	--
20 +	1.0	--

*Factors above 10% slope change based on NRCS judgment. No research data available.

On level fields or on rolling terrain where slopes are longer and slope changes are less than those used to describe a knoll, the wind flow pattern tends to conform to the surface and does not exhibit the flow constriction typical of knolls, as illustrated in Figure 4.

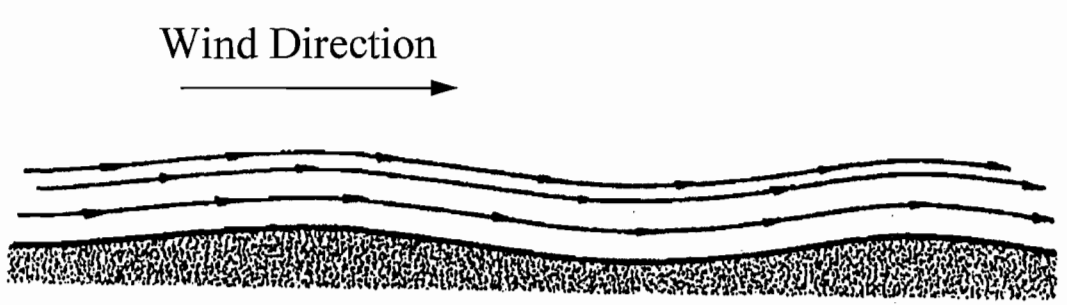


Figure 4. Wind Flow Pattern over Level to Rolling Terrain

Adjustments to "I" - Surface Crusting

A surface crust forms when a bare soil is wetted and dried. Although the crust may be so weak that it has virtually no influence on the size distribution of dry aggregates determined by sieving, it can make the soil less erodible.

The resistance of the crust to erosion depends on the nature of the soil, intensity of rainfall, and kind and amount of cover on the soil surface. Under erosive conditions, the surface crust and surface clods on fine sands and loamy fine sands tend to break down readily. On silt loams and silty clay loams the surface crust and surface clods may persist.

A fully crusted soil will erode an average of only one-sixth as much as non-crusted soil. However a smooth crusted soil with loose sand grains on the surface is more erodible than the same field with a cloddy or ridged surface.

Because of the temporary nature of crusts, no adjustment for crusting is made in the annual method calculation since it is based on the critical wind erosion period. Crust characteristics may be estimated and an adjustment to "I" may be made when using the management period method calculation when no traffic, tillage, or other disruption of crusts is anticipated. Adjustments for crusts may not exceed the amount shown in Table 4.

TABLE 4. I ADJUSTMENT GUIDELINES FOR CRUSTS

WEG	I	Maximum Management Period Adjustment for Crust [1]	Minimum Crusted I	Available E Table
1	310	.7	217	220
	220	.7	154	160
	160	.7	112	134
2	134	.5	67	86
3	86	.4	34	38
4	86	.4	34	38
4L	86	.4	34	38
5	56	.3	17	21
6	48	.3	14	21
7	38	.3	11	12

[1] The management period adjustment to I has not been validated by research and is based on NRCS judgment.

Adjustments to "I" - Clod-forming tillage

In some situations, there is a need to manage for erosion control on fields with little or no vegetative cover, where the surface crust has been destroyed, or where loose grains are on the surface and can abrade an existing crust. Emergency or planned tillage to roughen the soil surface can increase the non-erodible clods on the soil surface and reduce the erosion hazard as shown in Figure 5. This is accomplished by:

- Working the surface to create a ridge-furrow configuration (ridge roughness). This usually forms clods (random roughness) in the process.
- Working the soil surface to create clods. The clods create crevices where loose erodible sand grains can be trapped.
- Deep plowing to bring up finer textured soil material that will form more persistent clods, where soils are finer textured in the deeper layers.

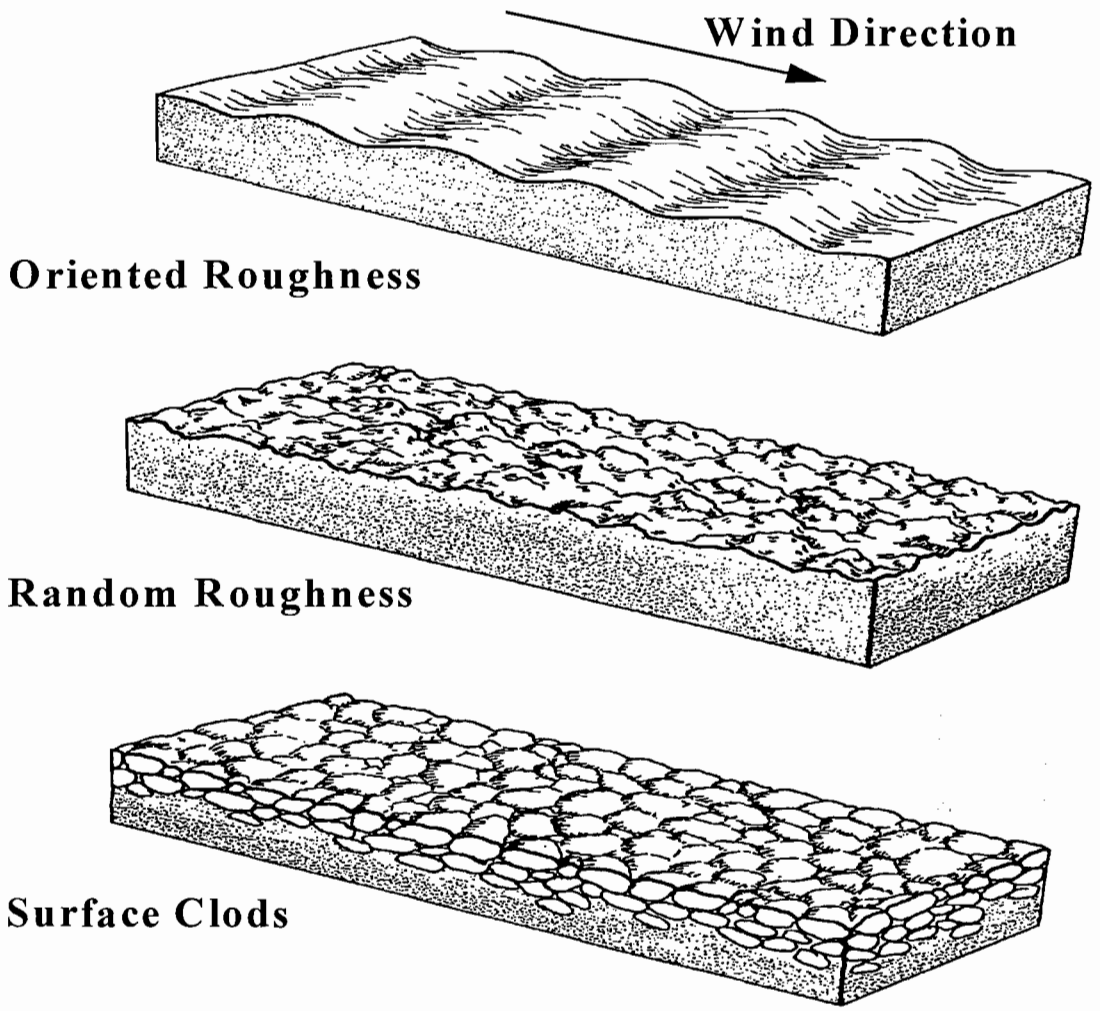


Figure 5. Erosion Resistant Surfaces.

Tillage patterns perpendicular or at an angle to the erosive winds leave ridges and valleys that help trap moving soil particles. Tillage also creates random roughness in addition to clods. Both random roughness and clods help trap moving soil particles.

Research has established the expected change in the non-erodible surface fraction during certain management periods, and a procedure has been developed by researchers to include the effects of random roughness in reducing erosion. The random roughness credit is given through an adjustment to the "K" factor value.

The adjustments to "I" reflect specific soil and management conditions and therefore are only applicable in the area from which samples were obtained and on sites with very similar soil and management conditions.

Studies to adjust "I" should be made systematically and include all related soils in a given area. Multiple-year sieving data is required before adjustments are to be considered. Use of adjusted soil erodibility "I" factors, arrived at by using standard rotary sieving procedures, is warranted provided they represent soil surface conditions during the appropriate management period. Adjustments to "I" must be approved and correlated across state and regional boundaries before implementation and must be within the framework of existing "E" Tables.

Adjustments to "I" for clod-forming tillage may be made up to, but should not exceed the limits assigned for crusting. This adjustment applies only to the management periods when the soil surface is influenced by the clod-forming tillage. "I" can be adjusted for cloddiness, based on sieving data, during the same period that the "K" factor value is adjusted for random roughness. These adjustments should not be used for predictions using the annual method which is based on the critical wind erosion period.

Adjustment to "I" - Irrigation

Data is limited on the amount of decrease in soil erodibility due to irrigation. NRCS field personnel have long observed this decrease in erodibility when the soil is wet. This relationship applies to all soils except the fine and very fine sands. Table 5 shows the adjustment that should be made on irrigated soils only. The table also includes the necessary information to adjust the Erosive Wind Energy (EWE) for irrigation. This proposed adjustment will be discussed in the "C" factor section.

TABLE 5. WIND ERODIBILITY GROUPS AND SOIL ERODIBILITY INDEX IRRIGATION ADJUSTMENT

Soil Texture[1]	EWE Texture Wetness Factor[2]	Predominant Soil Texture Class of Surface Layer	Wind Erodibility Group (WEG)	Soil Erodibility Index (I)[3] (T/Ac/Yr)	Soil Erodibility Index (I) for Irrig. Soils[4] (T/Ac/Yr)
C	1	Very fine sand,	1	310	310
		Fine sand ,		220	220
		Sand or coarse sand		160	134
C	1	Loamy very fine sand, loamy fine sand, loamy sand, loamy coarse sand, or sapric organic soil materials.	2	134	104
C	1	Very fine sandy loam, fine sandy loam, sandy loam, or coarse sandy loam.	3	86	56
F	3	Clay, silty clay, noncalcareous clay loam, or silty clay loam with more than 35% clay.	4	86	56
M	2	Calcareous loam and silt loam, or calcareous clay loam and silty clay loam.	4L	86	56
M	2	Noncalcareous loam and silt loam with less than 20% clay, or sandy clay loam, sandy clay, and hemic organic soil materials.	5	56	38
M	2	Noncalcareous loam and silt loam with more than 20% clay, or noncalcareous clay loam with less than 35% clay.	6	48	21
M	2	Silt, noncalcareous silty clay loam with less than 35% clay and fibric organic soil material.	7	38	21

[1] Soil Texture: C = Coarse; M = Medium; F = Fine

[2] Texture wetness factor for adjustment of Erosive Wind Energy (EWE) for the period. (Irrigated fields only)

[3] The Soil Erodibility Index is based on the relationship of dry soil aggregates greater than 0.84 mm to potential soil erosion. For sand with gravel and coarse sand with gravel, use 160.

[4] Value for irrigated soils is applicable throughout the year. Values for irrigated soils determined by Dr. E. L. Skidmore, USDA ARS, Wind Erosion Research Unit, Manhattan, KS.

"I" Factor Summary

The "I" factor represents soil loss in tons per acre per year as modified by the other equation factors "K", "C", "L", and "V". The "I" factor is determined by sieving to establish the percent of the non-erodible fraction (>0.84 mm). These results are used to establish assigned "I" factors.

Adjustments that can be made to "I" include : Knolls, which increase "I" ; Surface crusts, which decrease "I" ; Clod-forming tillage, which decreases "I" ; and Irrigation, which decreases "I .

The I factor has a significant effect on the erosion rate. Tables 6 and 7, with the same K and C values, but with different I values, illustrate this.

TABLE 6. E - SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR

C = 90
I = 134

SURFACE - K = 1.0
V - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

L UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	120.6	107.1	88.8	70.8	46.3	30.0	17.1	9.9	6.0	2.9	1.4	0.1	0.0
8000	120.6	107.1	88.8	70.8	46.3	30.0	17.1	9.9	6.0	2.9	1.4	0.1	
6000	120.6	107.1	88.8	70.8	46.3	30.0	17.1	9.9	6.0	2.9	1.4	0.1	
4000	120.6	107.1	88.8	70.8	46.3	30.0	17.1	9.9	6.0	2.9	1.4	0.1	
3000	120.6	107.1	88.8	70.8	46.3	30.0	17.1	9.9	6.0	2.9	1.4	0.1	
2000	120.6	107.1	88.8	70.8	46.3	30.0	17.1	9.9	6.0	2.9	1.4	0.1	
1000	115.5	102.4	84.6	67.1	43.5	27.9	15.7	9.0	5.3	2.5	1.3	0.1	
800	114.1	101.0	83.4	66.0	42.7	27.3	15.3	8.7	5.2	2.4	1.2	0.1	
600	108.7	96.1	79.0	62.1	39.8	25.1	13.9	7.8	4.6	2.1	1.0	0.1	
400	103.2	91.0	74.5	58.3	37.0	22.9	12.5	7.0	4.0	1.8	0.9	0.1	
300	98.9	87.1	71.0	55.2	34.8	21.3	11.5	6.3	3.6	1.6	0.8	0.1	
200	90.1	79.0	64.0	49.2	30.4	18.2	9.6	5.1	2.9	1.1	0.4		
150	82.6	72.2	58.1	44.1	26.8	15.6	8.1	4.2	2.3	0.9	0.3		
100	76.1	66.3	52.9	39.8	23.8	13.6	6.9	3.5	1.9				
80	71.0	61.6	48.9	36.5	21.6	12.0	6.0	3.0	1.6				
60	62.5	54.0	42.4	31.1	18.0	9.7	4.7	2.2	1.1				
50	57.9	49.9	38.9	28.3	16.1	8.5	4.0	1.9	0.9				
40	54.0	46.4	36.0	25.9	14.6	7.5	3.5	1.6	0.8				
30	47.3	40.4	31.0	22.0	12.0	6.0	2.7	1.2	0.4				
20	38.3	32.5	24.5	16.9	8.9	4.2	1.8	0.6					
10	26.8	22.4	16.5	10.9	5.4	2.3	0.9						

TABLE 7. E - SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR

C = 90
I = 56

SURFACE - K = 1.0
V - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

L UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	50.4	43.2	33.3	23.8	14.1	6.7	3.1	1.4	0.8				
8000	50.4	43.2	33.3	23.8	14.1	6.7	3.1	1.4	0.8				
6000	50.4	43.2	33.3	23.8	14.1	6.7	3.1	1.4	0.8				
4000	49.1	42.0	32.4	23.0	13.6	6.4	2.9	1.3	0.6				
3000	47.6	40.7	31.3	22.2	13.0	6.1	2.7	1.2	0.5				
2000	45.3	38.7	29.6	20.9	12.1	5.6	2.5	1.1	0.5				
1000	39.3	33.3	25.2	17.4	9.9	4.4	1.9	0.8	0.4				
800	37.6	31.8	24.0	16.5	9.3	4.0	1.7	0.6					
600	34.3	29.0	21.7	14.7	8.2	3.5	1.4	0.5					
400	30.9	26.0	19.3	12.9	7.1	2.9	1.2	0.4					
300	27.5	23.1	16.5	11.2	6.0	2.4	0.9						
200	23.0	19.1	13.8	9.0	4.7	1.7	0.6						
150	19.7	16.2	11.6	7.4	1.7	1.3							
100	16.2	13.3	9.3	5.8	2.9	1.0							
80	14.0	11.5	8.0	4.8	2.3	0.8							
60	10.9	8.8	6.0	3.5	1.6	0.3							
50	8.2	7.4	5.0	2.9	1.3	0.3							
40	7.5	6.0	4.0	2.2	0.9								
30	4.8	3.8	2.4	1.3	0.5								
20	3.0	2.3	1.4	0.7									
10	1.1	0.8	0.4										

SURFACE ROUGHNESS - "K"

Wind Erosion Equation $E=f[(IKC)LV]$

"K" Factor Objectives

- Be able to define the WEQ "K" factor.
- Be able to credit "Ridge Roughness" in planning wind erosion control systems.
- Be able to credit "Random Roughness" in planning wind erosion control systems.

"K" - Ridge Roughness

Ridge roughness "K" is a measure of the effect of patterns of ridges and furrows created by tillage and planting implements. Ridges absorb and deflect wind energy and trap moving soil particles. It is expressed as a value ranging from 0.5 to 1.0. The two types of roughness are shown in Figure 6.

Ridge roughness is a pattern of oriented ridges and furrows created by field operations that is predictable in terms of height, spacing, and durability.

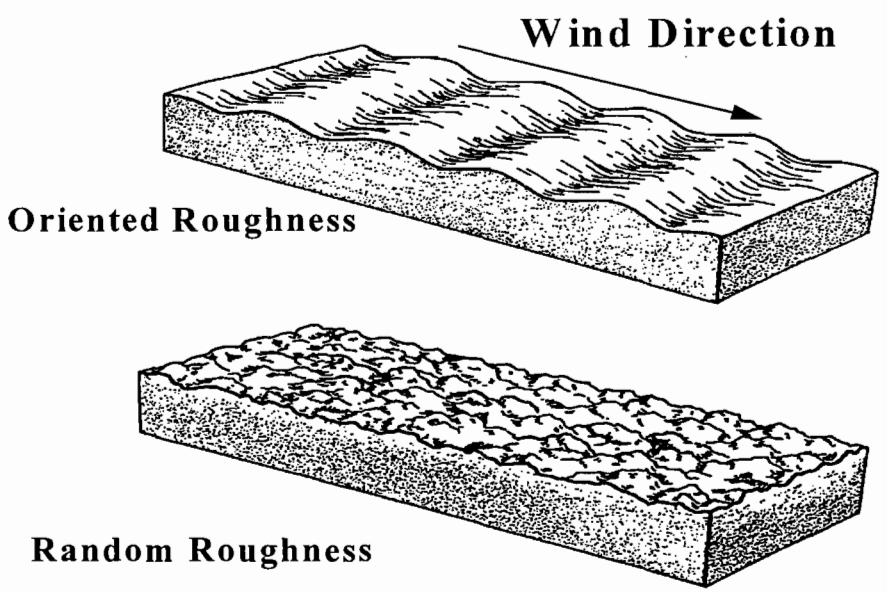


Figure 6. Comparison of Roughness Types

Ridges absorb and deflect wind energy as well as trap moving soil particles. The trapped soil particles flow over the ridge, to the zone of accumulation. Some soil particles flow back and downward from the ridge, go into suspension, or begin the saltation process as shown in Figure 7.

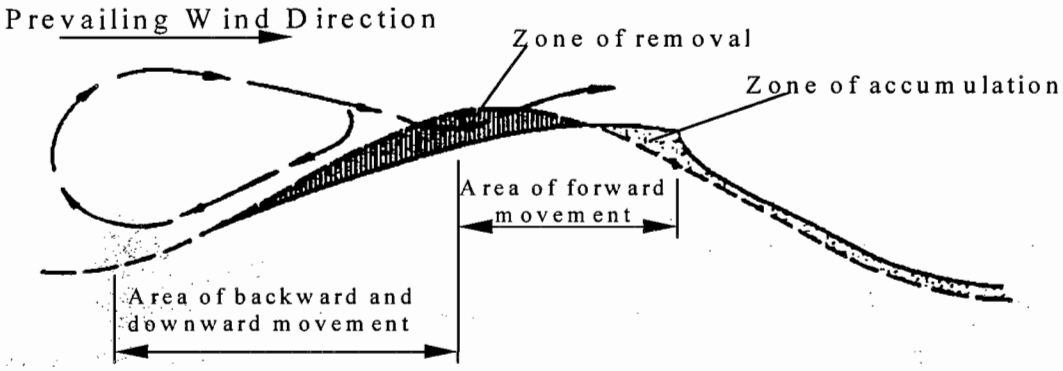


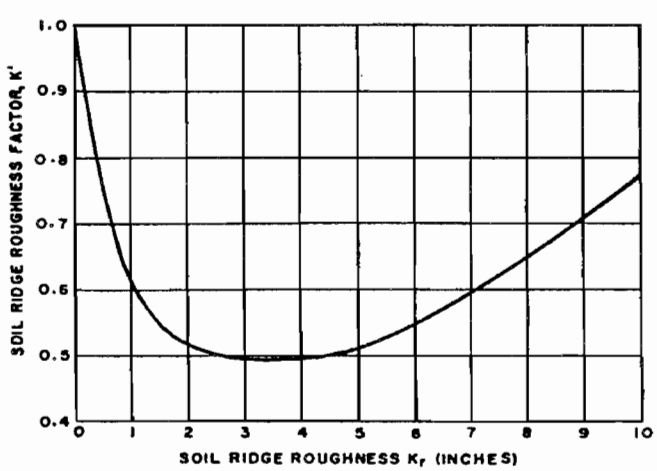
Figure 7. Soil Movement on Ridges

Information Needed to Determine the "K" Factor for Ridge Roughness

- Angle of Deviation
  - Prevailing wind erosion direction
  - Ridge-furrow direction
- Ridge Height
- Ridge Spacing

The "K" factor is based on a standard ridge height to ridge spacing ratio of 1:4. Calibrations of wind tunnel studies led to the development of the curve in Figure 8 that relates ridge-furrow roughness to the "K" factor.

This curve is the basis for the "K" factor values in Table 8 and Tables 10 through 14 taken from Exhibit 502.62 in Part 502 of the National Agronomy Manual.



$$K_r = \frac{4h^2}{s}$$

where:
h = ridge height in inches
s = ridge spacing (inches) measured in the wind erosion direction

Figure 8. Graph to determine soil ridge roughness factor K from soil ridge roughness Kr.

TABLE 8. EXAMPLE K FACTOR TABLE

Angle of Deviation = 0°

Ridge Spacing (inches)	Ridge Height (inches)										
	1	2	3	4	5	6	7	8	9	10	11
7	0.7	0.5	0.5								
10	0.8	0.5	0.5	0.6							
14	0.8	0.6	0.5	0.5	0.6						
18	0.9	0.6	0.5	0.5	0.5	0.7					
20	0.9	0.6	0.5	0.5	0.5	0.6	0.8	0.8			
24	0.9	0.7	0.5	0.5	0.5	0.5	0.7	0.8	0.8		
30	0.9	0.7	0.6	0.5	0.5	0.5	0.6	0.7	0.8		
36	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8	
38	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8	
40	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8	0.8

Prevailing Wind Erosion Direction

The prevailing wind erosion direction (PWED) is the direction from which the greatest amount of winds exceeding threshold velocity (13 mph at 1 foot above the soil surface or 18 mph at 30 feet of height) occur. The prevailing wind erosion direction is based on wind direction and wind speed

Erosive winds may blow in either direction along this wind directional line but are dominated by winds from the indicated direction.

When making predictions using the annual method, the prevailing wind erosion direction can be based on published data from an official weather station or local knowledge for the critical erosion period.

When making predictions using the management period method, base the prevailing wind erosion direction on published data or local knowledge for each period.

Angle of Deviation

Figure 9 illustrates the angle of deviation as the angle between the prevailing wind erosion direction (PWED) and a line perpendicular to the ridge-furrow direction.

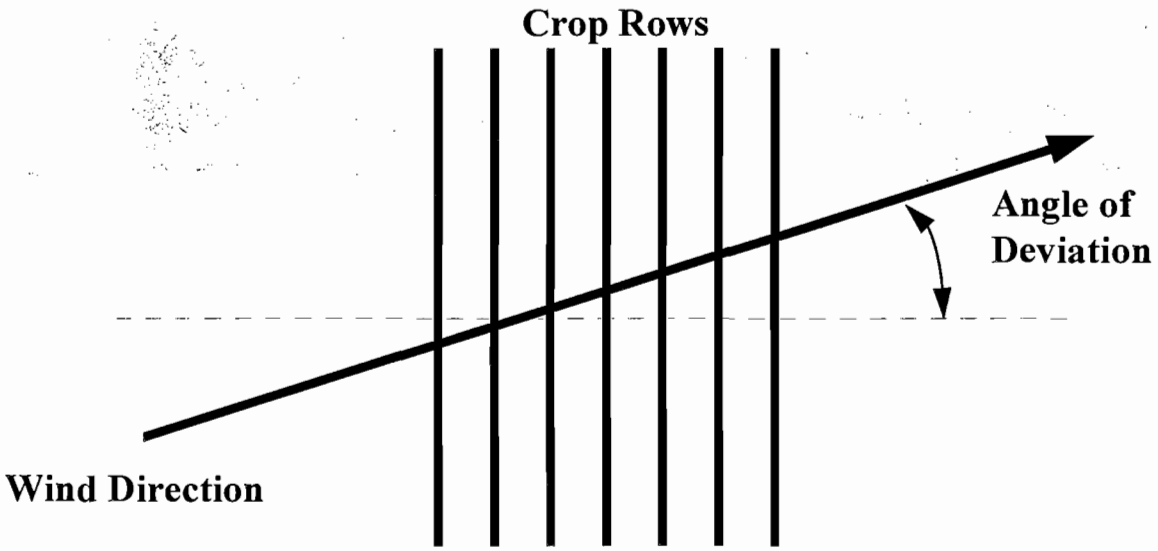


Figure 9. Angle of Deviation

The wind direction diagram in Figure 10 can be used to determine the angle of deviation when computing the K factor.

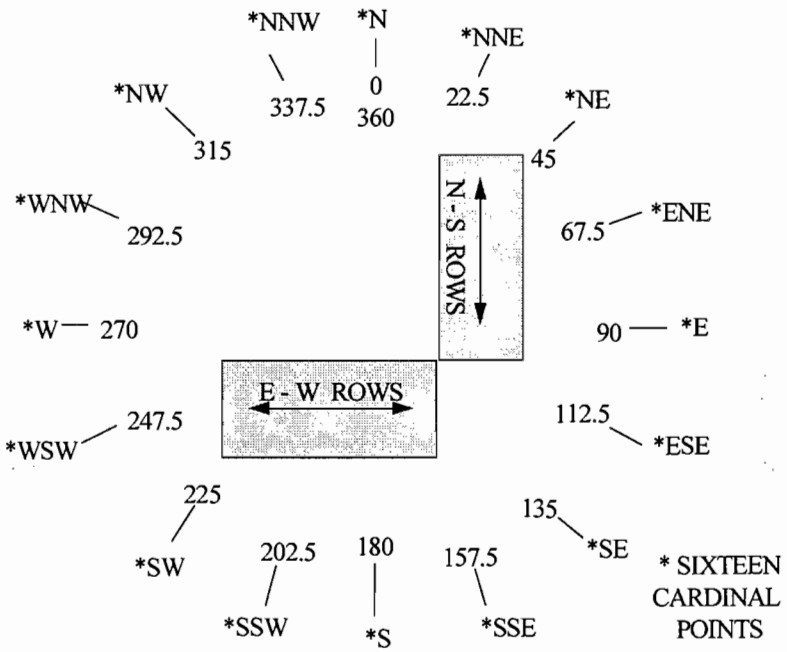


Figure 10. Wind Directions

Figure 11 shows that the effect of ridges varies as the wind direction changes. When an erosive wind is perpendicular (angle of deviation is 0°) to ridges 4 inches high and 30 inches apart, and assuming no random roughness, then "K" is 0.5.

When the erosive wind is blowing parallel to those same ridges, "K" is 1.0 (angle of deviation = 90 degrees). Since erosive winds seldom blow exactly perpendicular nor exactly parallel to ridges, the angle of deviation is used to adjust the ridge spacing to the distance along the prevailing wind direction.

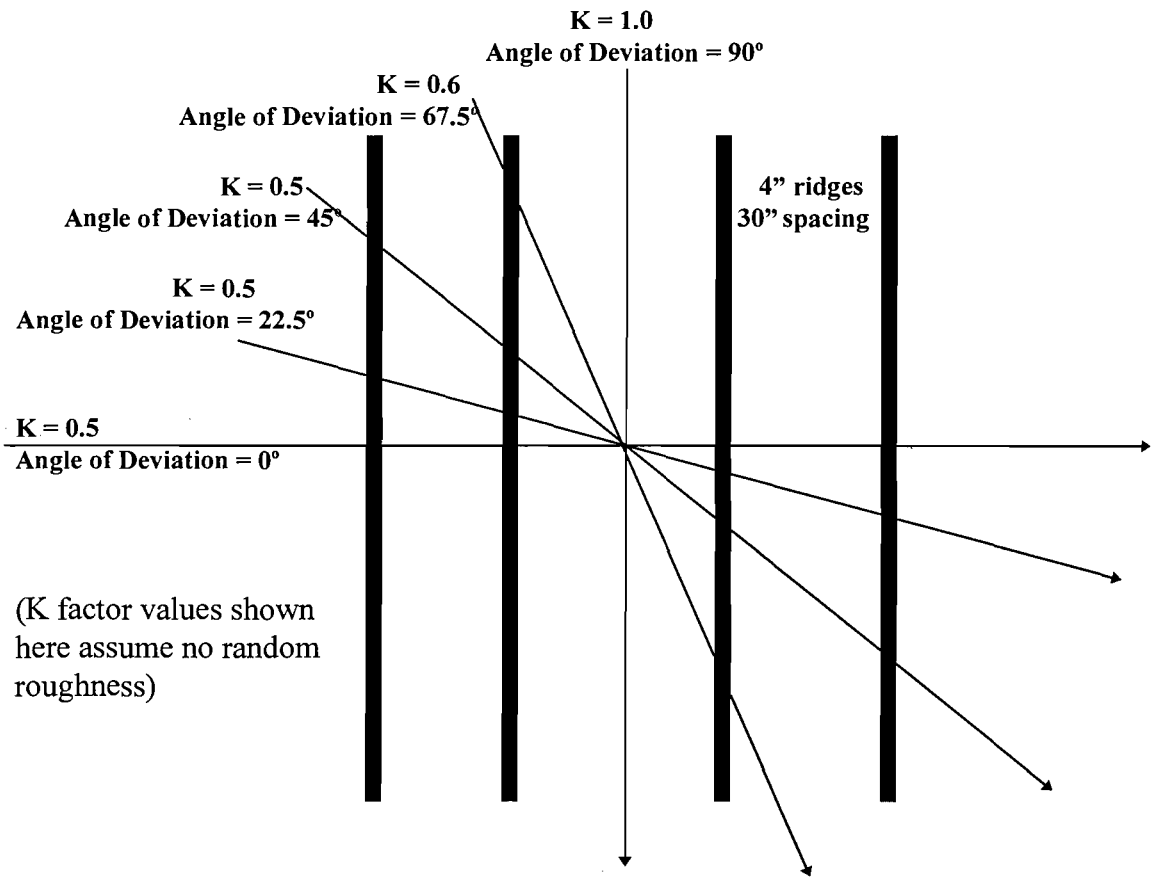


Figure 11. Effect of Angle of Deviation on K Factor Value

Table 9 gives you a quick reference to find the angle of deviation of the prevailing wind erosion direction when ridges are oriented either north-south or east-west.

TABLE 9. ANGLE OF DEVIATION FOR E-W OR N-S ROWS WITH VARYING PREVAILING WIND EROSION DIRECTIONS

Prevailing Wind Erosion Direction, in Degrees	Angle of Deviation, Rows Planted E - W	Angle of Deviation, Rows Planted N - S
22.5	22.5	67.5
45	45	45
67.5	67.5	22.5
90	90	0
112.5	67.5	22.5
135	45	45
157.5	22.5	67.5
180	0	90
202.5	22.5	67.5
225	45	45
247.5	67.5	22.5
270	90	0
292.5	67.5	22.5
315	45	45
337	22.5	67.5
360	0	90

"K" Factor Tables

The "K" factor value can be obtained from Table 10, 11, 12, 13 or 14 once the angle of deviation, ridge height, and ridge spacing are determined.

TABLE 10. K FACTOR VALUES

Angle of Deviation = 0°

Ridge Spacing (inches)	Ridge Height (inches)										
	1	2	3	4	5	6	7	8	9	10	11
7	0.7	0.5	0.5								
10	0.8	0.5	0.5	0.6							
14	0.8	0.6	0.5	0.5	0.6						
18	0.9	0.6	0.5	0.5	0.5	0.7					
20	0.9	0.6	0.5	0.5	0.5	0.6	0.8	0.8			
24	0.9	0.7	0.5	0.5	0.5	0.5	0.7	0.8	0.8		
30	0.9	0.7	0.6	0.5	0.5	0.5	0.6	0.7	0.8		
36	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8	
38	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8	
40	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8	0.8

TABLE 11. K FACTOR VALUES

Angle of Deviation = 22.5°

Ridge Spacing (inches)	Ridge Height (inches)										
	1	2	3	4	5	6	7	8	9	10	11
7	0.7	0.5	0.5								
10	0.8	0.6	0.5	0.5							
14	0.8	0.6	0.5	0.5	0.6						
18	0.9	0.6	0.5	0.5	0.5	0.6					
20	0.9	0.7	0.5	0.5	0.5	0.6	0.7	0.8			
24	0.9	0.7	0.6	0.5	0.5	0.5	0.6	0.7	0.8		
30	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.7	0.8		
36	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8	
38	1.0	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.6	0.8	
40	1.0	0.8	0.6	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8

TABLE 12. K FACTOR VALUES

Angle of Deviation = 45°

Ridge Spacing (inches)	Ridge Height (inches)										
	1	2	3	4	5	6	7	8	9	10	11
7	0.8	0.5	0.5								
10	0.8	0.6	0.5	0.5							
14	0.9	0.6	0.5	0.5	0.5						
18	0.9	0.7	0.6	0.5	0.5	0.5					
20	0.9	0.7	0.6	0.5	0.5	0.5	0.6	0.7			
24	0.9	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.8		
30	1.0	0.8	0.6	0.5	0.5	0.5	0.5	0.5	0.6		
36	1.0	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.6	0.6	
38	1.0	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.6	
40	1.0	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.6	0.7

TABLE 13. K FACTOR VALUES

Angle of Deviation = 67.5°

Ridge Spacing (inches)	Ridge Height (inches)										
	1	2	3	4	5	6	7	8	9	10	11
7	0.9	0.6	0.5								
10	0.9	0.7	0.6	0.5							
14	0.9	0.8	0.6	0.6	0.5						
18	1.0	0.8	0.7	0.6	0.5	0.5					
20	1.0	0.8	0.7	0.6	0.5	0.5	0.5	0.5			
24	1.0	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5		
30	1.0	0.9	0.8	0.6	0.6	0.5	0.5	0.5	0.5		
36	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5	
38	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5	
40	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5

TABLE 14. K FACTOR VALUES

Angle of Deviation = 90°

The soil ridge roughness "K" is always 1.0 when the prevailing wind erosion direction is parallel to the ridge pattern (angle of deviation = 90°).

"K" - Random Roughness

Random roughness is the non-oriented surface roughness that is sometimes referred to as cloddiness. It is usually created by the action of tillage implements. Random roughness is defined as the standard deviation of elevation from a plane across a tilled area, after oriented roughness is accounted for. Random roughness values are represented as the *standard deviation* of roughness heights.

Random roughness (inches) from the machine operations database in RUSLE can be used to determine random roughness values. These values are given in Table 15. It is important to remember that these RUSLE random roughness values were determined from medium textured soils tilled at optimum moisture conditions for creating roughness. Under most circumstances, random roughness should be determined by comparing a field surface to the random roughness (standard deviation) photos in Agriculture Handbook 703, *Predicting Soil Erosion By Water: A Guide To Conservation Planning With The Revised Universal Soil Loss Equation (RUSLE).* These photos are provided at the end of this Subpart.

The major effects of random roughness on wind erosion are to raise the threshold wind speed at which erosion begins, and to provide some sheltered area among clods where moving soil can be trapped. Hence, as random roughness values increase, the K value decreases.

Random roughness is subject to much faster degradation by rain or wind erosion than large tillage ridges. Therefore, the WEQ management period during which random roughness is effective may be of short duration.

The WEQ "K_{rr}" factor for Random Roughness has been developed for various levels of "I" values and surface random roughness (see Figure 12).

When both random roughness and ridge roughness are present in the field, they are complementary. Random roughness, particularly in furrows, reduces wind erosion which occurs along wind directions parallel to the ridges.

When both are present, the K factors for ridge roughness and random roughness are to be multiplied together to obtain the total roughness K factor value. Until the complete K factor routine is changed in the NRCS National Agronomy Manual, a total roughness K factor value of 0.5 will be the lowest allowed for estimating wind erosion.

TABLE 15. RANDOM ROUGHNESS VALUES FOR "CORE" FIELD OPERATIONS [1, 2]

Field Operations	Random Roughness (in)	Field Operations	Random Roughness (in)
Chisel, sweeps	1.2	Fertilizer applicator, anhydrous knife	0.6
Chisel, straight points	1.5	Harrow, spike	0.4
Chisel, twisted shovels	1.9	Harrow, tine	0.4
Cultivator, field	0.7	Lister	0.8
Cultivator, row	0.7	Manure injector	1.5
Cultivator, ridge till	0.7	Moldboard plow	1.9
Disk, one way	1.2	Mulch treader	0.4
Disk, heavy plowing	1.9	Planter, no-till	0.4
Disk, tandem	0.8	Planter, row	0.4
Drill, double disk	0.4	Rodweeder	0.4
Drill, deep furrow	0.5	Rotary hoe	0.4
Drill, no-till	0.4	Vee ripper	1.2
Drill, no-till into sod	0.3		

[1] These values are typical and representative for operations in medium textured soils tilled at optimum moisture conditions. Many of the machines may vary by cropping region, farming practice, soil texture, or other conditions.

[2] These values may be used in WEQ for random roughness. However, the use of the nine random roughness photos at the end of this Subpart taken from Agriculture Handbook 703 is preferable.

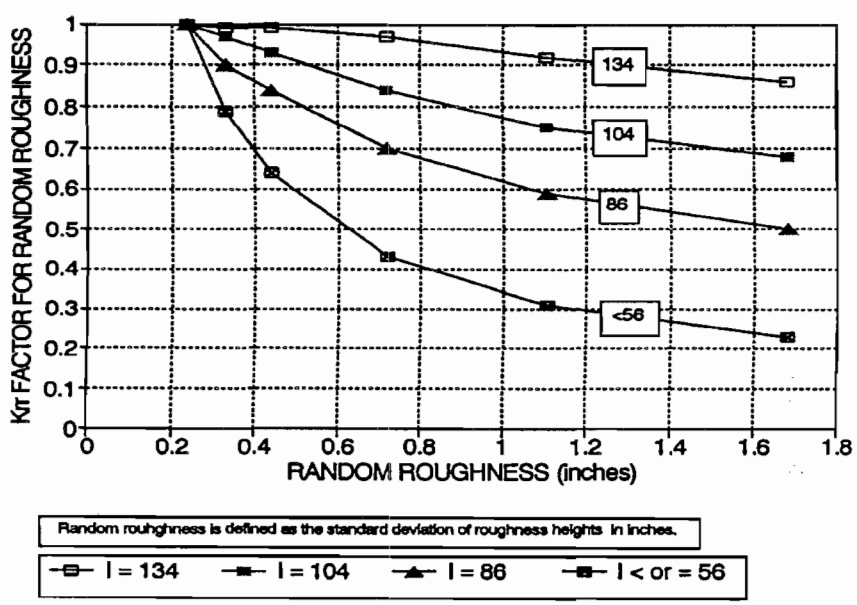


Figure 12. Graph to Determine K_{rr} from Random Roughness and "I" Factor Values

Tables 16 and 17 illustrate the effect of surface roughness on predicted soil erosion rates.

TABLE 16. E - SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR

C = 90
I = 134

SURFACE - K = 1.0

V - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

L UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
8000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
6000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
4000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
3000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
2000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
1000	115.5	102.4	84.6	67.1	45.5	27.9	15.7	9.0	6.0	2.5	1.3	0.2	
800	114.1	101.0	83.4	66.0	46.7	27.3	15.3	8.7	5.8	2.4	1.2	0.2	
600	108.7	96.1	74.0	62.1	41.7	25.1	13.9	7.8	5.1	2.1	1.0	0.2	
400	103.2	91.0	74.5	58.3	38.8	22.9	12.5	7.0	4.5	1.8	0.9	0.1	
300	98.9	87.1	71.0	55.2	36.5	21.3	11.5	6.3	4.1	1.6	0.8	0.1	
200	90.1	79.0	64.0	49.2	32.0	18.2	9.6	5.1	3.2	1.2	0.4		
150	82.6	72.2	58.1	44.1	28.3	15.6	8.1	4.2	2.6	0.9	0.3		
100	76.0	66.3	52.9	39.8	25.2	13.6	6.9	3.5	2.1	0.7			
80	71.0	61.6	48.9	36.5	22.8	12.0	6.0	3.0	1.8	0.6			
60	62.9	56.0	42.4	31.1	19.1	9.7	4.7	2.2	1.3				
50	57.8	49.9	38.9	28.3	17.1	8.5	4.0	1.9	1.1				
40	54.0	48.4	36.0	25.9	15.5	7.5	3.9	1.6	0.9				
30	47.3	40.4	31.0	22.0	12.9	6.0	2.7	1.2	0.5				
20	38.3	32.9	24.5	16.9	9.6	4.2	1.8	0.6					
10	26.8	22.4	16.5	10.9	5.8	2.3	0.9						

TABLE 17. E - SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR

C = 90
I = 134

SURFACE - K = 0.5

V - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

L UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	60.3	52.0	40.8	29.8	18.1	9.1	4.3	2.1	1.2				
8000	60.3	52.0	40.8	29.8	18.1	9.1	4.3	2.1	1.2				
6000	60.3	52.0	40.8	29.8	18.1	9.1	4.3	2.1	1.2				
4000	58.6	50.6	39.5	28.8	17.4	8.7	4.1	1.9	1.1				
3000	57.5	49.5	38.6	28.1	17.0	8.4	4.0	1.9	1.1				
2000	56.3	48.5	37.7	27.3	16.5	8.1	3.8	1.8	1.0				
1000	49.4	42.7	33.4	23.5	13.9	6.6	3.0	1.3	0.6				
800	48.2	41.2	31.2	22.5	13.2	6.2	2.8	1.2	0.5				
600	44.8	38.2	29.2	20.5	11.9	5.5	2.4	1.1	0.5				
400	39.9	33.9	25.7	17.8	10.1	4.5	1.9	0.8	0.4				
300	36.8	31.2	23.4	16.1	9.0	3.9	1.6	0.6					
200	31.8	26.8	19.9	13.4	7.4	3.0	1.2	0.4					
150	27.5	23.1	16.9	11.2	6.0	2.6	0.9						
100	23.6	19.7	14.3	9.3	4.9	1.8	0.7						
80	21.1	17.5	12.6	8.1	4.2	1.9	0.5						
60	17.2	14.1	10.0	6.2	3.1	1.1							
50	14.8	12.1	8.5	5.2	2.5	0.8							
40	13.1	10.7	7.4	4.5	2.1	0.4							
30	10.1	8.1	5.5	3.2	1.5	0.3							
20	6.3	5.0	3.3	1.8	0.7								
10	2.2	1.6	1.0	0.4									

Rules of Thumb

- The angle of deviation value is always from 0 to 90 degrees.
- Ridges in a field have two directions. The second direction of a ridge can be computed by adding 180 degrees to (or subtracting 180 degrees from) the known ridge direction. This applies to the line perpendicular to the ridge direction as well as the ridge direction. For example, the second direction for 45 degrees (opposite cardinal point) is 225 degrees.
- The angle of deviation is computed by relating the prevailing wind erosion direction to the direction of the perpendicular line.
- K factor charts are available for the following angles of deviation:

  * 0
  * 22.5
  * 45
  * 67.5
  * 90

"K" Factor Summary

- Ridges and furrows affect the detachment, transport and deposition of soil particles.
- Ridges are most effective when they are perpendicular to the prevailing wind erosion direction.
- The "K" factor accounts for both oriented roughness and random roughness.
- The "K" factor values for oriented roughness and random roughness are multiplied together to arrive at the final "K" factor value (minimum allowable "K" is 0.5).

CLIMATIC FACTOR - "C"

Wind Erosion Equation $E=f[(IKC)LV]$

"C" Factor Objectives

- Be able to define the WEQ "C" factor
- Explain the climatic effects that are used to determine the "C" factor
- Understand the meaning and use of erosive wind energy (EWE) distribution

"C" Climatic Factor

The "C" factor is an index of the relative climatic erosivity, specifically wind speed and surface soil moisture. The factor for any given location is based on long-term climatic data and is expressed as a percentage of the "C" factor for Garden City, Kansas which has been assigned a value of 100. It is based on long term data (temperature, precipitation, and windspeed), and is expressed as a percentage. Example: A "C" factor of 40 is equal to 40 percent or 0.40.

The information required to calculate the "C" factor includes:

- Average annual wind speed in miles per hour adjusted to a height of 30 feet
- Average monthly precipitation with values less than 0.5 inches adjusted to 0.5 inches
- Average monthly temperature in °F - 10°F with values less than 18.4 adjusted to 18.4°F

Two different calculations are required in order to determine a "C" factor. The first calculation determines the Thornthwaite precipitation effectiveness (PE) index or effectiveness of surface soil moisture. The annual PE is the sum of the 12 monthly PE indices, and is determined using the following equation:

$$PE = \Sigma^{12} 115 \left(\frac{P}{T - 10} \right)^{10/9}$$

PE = precipitation-effectiveness index

P = average monthly precipitation

T = average monthly temperature

The second calculation, below, determines the annual "C" factor. It uses the annual precipitation effectiveness index. This equation is based on the assumption that soil movement is proportional to the windspeed cubed. A small change in velocity can make a large difference in the "C" factor. It also assumes that soil movement varies inversely with the surface soil moisture.

$$C = \frac{(34.48)V^3}{(PE)^2}$$

where C is the annual climatic factor expressed as a percentage of the C factor for Garden City, KS, which has been assigned a value of 100

V is the average annual wind velocity corrected to a standard height of 30 feet

PE is the annual Thornthwaite precipitation effectiveness index

34.48 is the constant used to adjust local values to a common base (Garden City, KS)

"C" Climatic Factor Concepts

- As average annual wind speed increases, "C" factor values increase
- As average monthly precipitation increases, "C" factor values decrease
- As average monthly temperature increases, "C" factor values increase

Annual Climatic Factor

A national "C" factor isoline map was developed by NRCS in 1987. The isolines were drafted using 1951-1980 weather data and were correlated across state and regional boundaries. NRCS state agronomists may develop local or county isolines where local data is available. Precipitation, temperature, and wind velocity data must be available in order to support locally developed "C" factors. The influence of topography may also be considered. Locally developed isolines must be consistent with the national isoline map. Interpolation between national or state developed isolines is generally done in increments of not less than 5.

"C" is an index of the relative climatic erosivity by geographic location. It considers average annual wind speed, average monthly precipitation, and average monthly temperature. "C" is expressed as a percentage of a factor of 100.

A sample "C" factor calculation is shown in Table 18. The formula can be solved manually or by use of a computer spreadsheet program.

TABLE 18. ANNUAL EFFECTIVE PE AND ESTIMATED C

Constraints: Monthly P = > 0.5 inches
Monthly T = > 28.4 degrees F

MONTH	P	ADJ. P	T	ADJ. T-10	PE
JANUARY	0.41	0.5	26.7	18.4	2.1
FEBRUARY	0.60	0.60	32.6	22.6	2.0
MARCH	1.33	1.33	39.7	29.7	3.7
APRIL	1.83	1.83	52.4	42.4	3.5
MAY	3.42	3.42	62.3	52.3	5.6
JUNE	3.68	3.68	72.2	62.2	5.0
JULY	3.35	3.35	77.8	67.8	4.1
AUGUST	2.61	2.61	76.3	66.3	3.2
SEPTEMBER	2.16	2.16	66.8	56.8	3.1
OCTOBER	1.41	1.41	55.7	45.7	2.4
NOVEMBER	0.73	0.73	40.3	30.3	1.8
DECEMBER	0.46	0.50	31.1	21.1	1.8
Avg. Annual	21.99		52.8		38.2

Estimated V = 13 mph
Estimated C = 51.8
Therefore use C = 50

Figure 13 shows the California portion of the Annual Climatic Factor C (Percent) nationwide map developed in May 1987.

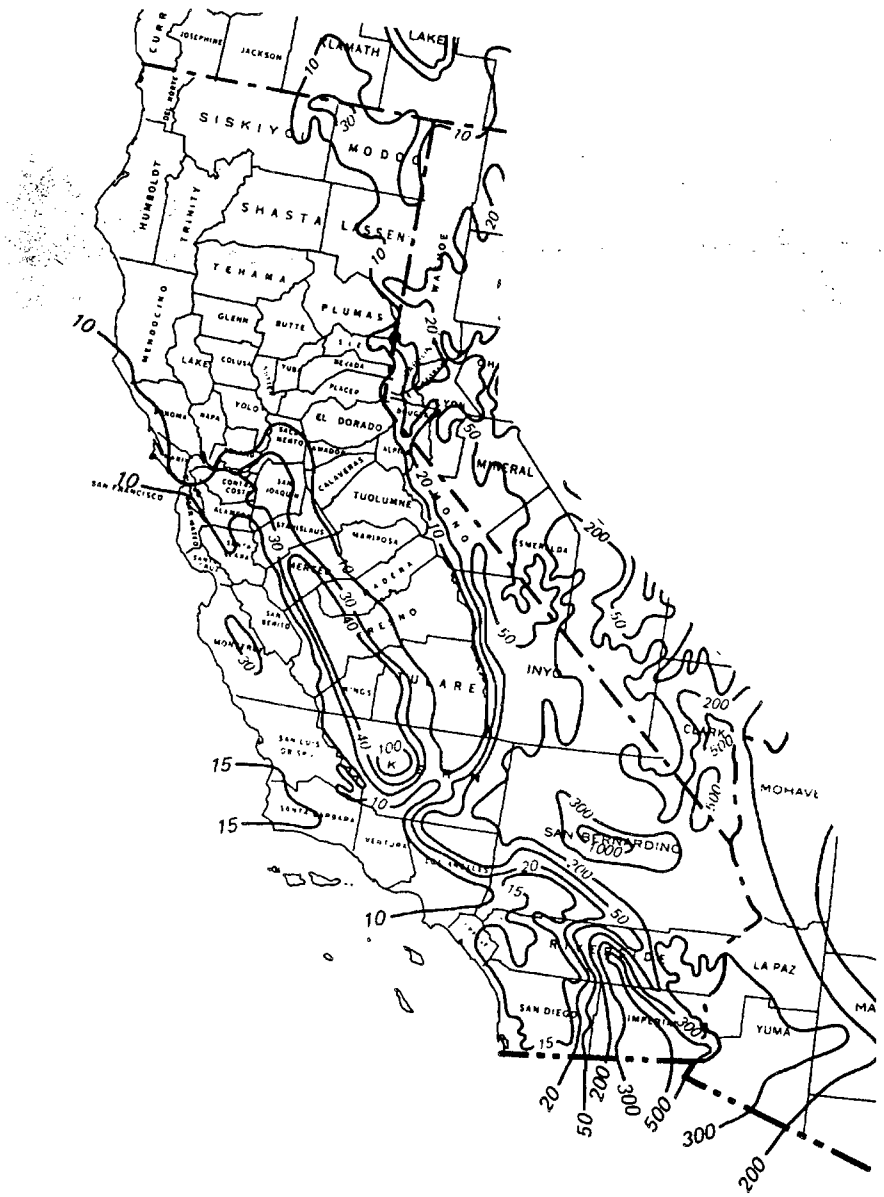


Figure 13. Annual Climatic Factor C Values (Percent) of the Wind Erosion Equation

Figure 14 is an example of the County Annual Climatic Factor C maps in use in California that were used to develop the California portion of the nationwide map. The County maps were developed by the NRCS State Agronomist using long- term benchmark weather station data plus C factors supplied by the USDA Agricultural Research Service located at Manhattan, KS. Isolines were located through extrapolation, topography, and wind flow patterns. Minor adjustments were then made in response to recommendations from NRCS area and field office staffs. County maps can be found at the end of this Subpart.

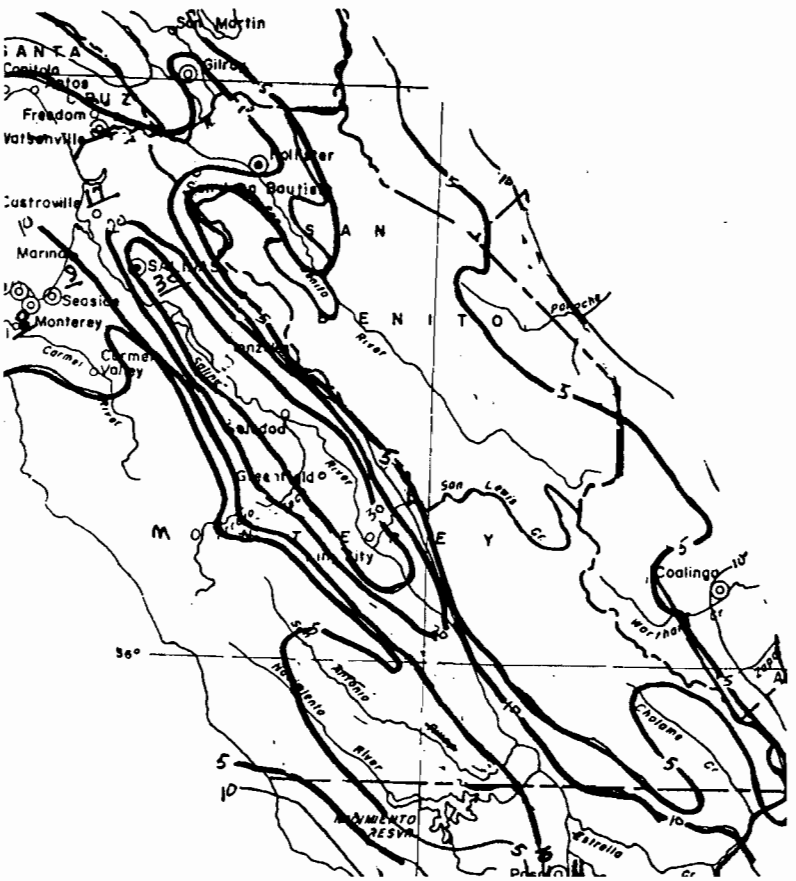


Figure 14. Annual Climatic Factor C Values (Percent) of the Wind Erosion Equation for Monterey and San Benito Counties

Erosive Wind Energy Distribution

Erosive wind energy distribution (EWE) is used in the management period method to weight annual erosion rates based on the amount of erosive wind energy occurring during each management period.

This is the expected distribution, by month, of erosive wind energy at a given geographic location. Using the monthly erosive wind energy values, planners can identify the months with the greatest potential for erosion, and develop conservation systems that will minimize erosion. When using the management period method, the erosion rate as obtained from the "E" tables, for the period, is multiplied by the percent of erosive wind energy for the same time period.

The percent of erosive wind energy for different time periods can be obtained by plotting the data from Table 19A on the EWE Distribution Curve Worksheet. A reproducible copy of the EWE Distribution Curve Worksheet is located at the end of this Subsection. Monthly erosive wind energy values are shown in Table 19B.

Proposed Adjustment to EWE During Irrigation - Irrigation Factor - (IF)

On irrigated fields, the EWE can be adjusted for management periods during which irrigation occurs. This Irrigation Factor (IF) is based on the soil Texture Wetness Factor (TWF). Wetting of soil by irrigation makes it less erodible. This effect can be accounted for by adjusting the Erosive Wind Energy (EWE). Research has shown that **wet** bare soil remains non-erodible about 1 day for coarse textured soils, 2 days for medium textured soils, and about 3 days for fine textured soils. Soils are given a Texture Wetness Factor (TWF) of 1, 2, or 3 for coarse, medium, and fine textured soils respectively as shown on Table 5. This factor will apply only during periods that irrigation occurs.

The irrigation factor (IF) is determined by multiplying the management period EWE by the fraction of the management period when the soil is considered non-erodible from being wetted by irrigation. The "IF" is calculated with the following equation:

IF = # of days in period - (# of irrigations in period x TWF) / # of days in period

Example: A fine textured soil was irrigated 3 times during a 45 day period. 12% of the EWE occurred during this same 45 day period.

IF = 45 - (3 x 3) / 45 = 0.80

The adjusted EWE for this period would be: 0.80 x 12% = 9.6%.

TABLE 19A. CUMMULATIVE PERCENTAGE OF THE AVERAGE ANNUAL EWE

Location	Feb. 1	Mar. 1	Apr. 1	May 1	June 1	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Dec. 1	Jan. 1
CALIFORNIA												
Bakersfield	2.9	7.6	17.8	33.9	58.0	78.0	84.6	90.9	94.2	95.5	97.1	100
Beale	18.7	31.1	42.9	51.3	57.0	62.3	63.5	65.0	68.8	76.0	83.9	100
Bishop	4.2	13.1	30.9	45.9	58.5	65.8	70.6	75.6	81.1	88.9	95.0	100
China Lake	5.9	14.3	27.5	41.3	54.3	65.3	72.0	78.9	84.7	90.7	95.5	100
Daggett	3.2	11.8	27.8	42.7	62.6	72.9	79.4	84.4	89.6	94.0	98.1	100
El Centro	5.4	13.8	27.9	45.0	64.9	79.9	83.0	85.6	88.9	92.7	97.0	100
Eureka	9.1	20.6	35.3	49.2	65.8	75.8	79.7	81.8	84.3	88.3	93.3	100
Fairfield	2.5	6.4	11.1	17.7	28.5	44.4	63.8	79.7	90.3	95.6	98.2	100
Fresno	3.7	9.4	25.0	41.8	64.9	86.4	91.4	93.1	94.2	96.6	98.0	100
Imperial Beach	9.9	22.5	36.6	50.3	61.2	68.8	74.4	78.5	82.2	85.7	93.5	100
Lemoore	9.2	22.0	37.7	51.0	61.5	71.5	73.8	75.1	77.4	86.3	91.8	100
Livermoore	7.1	14.3	22.1	30.6	42.6	56.7	70.1	80.7	87.8	93.0	96.2	100
Long Beach	5.6	19.9	40.2	59.2	69.4	73.5	76.3	80.3	84.8	89.2	95.7	100
Merced	13.2	29.3	45.5	58.3	65.1	72.6	74.1	75.3	77.3	83.1	90.0	100
Montague	11.7	24.6	39.4	53.0	61.8	65.9	69.6	72.5	76.1	83.1	92.5	100
Monterey	8.1	17.6	32.8	49.2	64.7	73.5	76.9	81.0	83.2	86.5	90.0	100
Needles	9.5	22.0	34.2	45.3	54.9	63.0	66.8	71.2	74.6	81.1	89.8	100
Oakland	6.9	19.6	30.9	44.0	58.8	70.2	75.4	80.1	85.2	91.1	95.2	100
Oceanside	17.1	32.7	45.5	52.8	57.7	61.3	63.7	66.2	71.0	75.8	85.8	100
Oxnard	14.5	27.5	38.5	47.9	56.5	58.9	59.4	60.0	61.3	65.9	76.8	100
Palmdale	5.4	12.2	25.7	39.2	52.5	65.3	74.1	80.7	85.2	89.0	94.0	100
Paso Robles	3.4	6.9	12.5	21.5	34.9	53.6	70.9	82.7	89.9	94.2	97.5	100
Redding	7.6	18.5	31.0	40.3	51.1	62.0	68.0	72.6	78.7	84.7	92.4	100
Riverside	7.4	17.0	24.7	33.5	42.9	52.5	63.9	74.9	82.6	88.0	93.5	100
Sacramento	16.9	32.9	44.9	51.6	58.1	64.9	66.8	68.6	70.9	78.1	87.5	100
San Francisco	3.4	9.1	18.1	29.8	44.4	59.4	70.9	80.9	88.3	94.6	97.3	100
San Rafael	13.4	25.0	36.3	46.4	54.3	62.0	66.0	70.5	74.3	80.7	87.3	100
Sunnyvale	8.6	17.4	25.9	35.6	46.3	60.3	69.0	76.8	82.4	87.7	92.0	100
Thermal	1.2	4.7	11.8	25.8	45.0	59.5	70.4	79.6	89.7	95.4	98.9	100
Vandenberg	6.3	13.5	29.8	46.7	68.4	76.5	78.1	79.7	83.6	89.0	94.9	100
Williams	19.3	39.7	61.1	66.2	72.3	77.8	80.5	82.2	84.8	89.4	94.4	100
ARIZONA												
Yuma	6.2	15.8	26.7	40.0	49.4	57.4	72.3	82.0	84.3	96.8	98.9	100
OREGON												
Klamath Falls	13.4	24.5	38.7	50.8	58.0	62.1	64.7	67.5	70.8	78.0	88.0	100
Siskiyou Summit	6.4	15.5	22.7	27.4	38.4	52.3	69.4	79.4	86.7	89.8	95.3	100

TABLE 19B. MONTHLY PERCENTAGE OF THE AVERAGE ANNUAL EWE

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Bakersfield	2.9	4.7	10.2	16.1	24.1	20.0	6.6	6.3	3.3	1.3	1.6	2.9
Beale	18.7	12.4	11.8	8.4	5.7	5.3	1.2	1.5	3.8	7.2	7.9	16.1
Bishop	4.2	8.9	17.8	15.0	12.6	7.3	4.8	5.0	5.5	7.8	6.1	5.0
China Lake	5.9	8.4	13.2	13.8	13.0	11.0	6.7	6.9	5.8	6.0	4.8	4.5
Daggett	3.2	8.6	16.0	14.9	19.9	10.3	6.5	5.0	5.2	4.4	4.1	1.9
El Centro	5.4	8.4	14.1	17.1	19.9	15.0	3.1	2.6	3.3	3.8	4.3	3.0
Eureka	9.1	11.5	14.7	13.9	16.6	10.0	3.9	2.1	2.5	4.0	5.0	6.7
Fairfield	2.5	3.9	4.7	6.6	10.8	15.9	19.4	15.9	10.6	5.3	2.6	1.8
Fresno	3.7	5.7	15.6	16.8	23.1	21.5	5.0	1.7	1.1	2.4	1.4	2.0
Imperial Beach	9.9	12.6	14.1	13.7	10.9	7.6	5.6	4.1	3.7	3.5	7.8	6.5
Lemoore	9.2	12.8	15.7	13.3	10.5	10.0	2.3	1.3	2.3	8.9	5.5	8.2
Livermore	7.1	7.2	7.8	8.5	12.0	14.1	13.4	10.6	7.1	5.2	3.2	3.8
Long Beach	5.6	14.3	20.3	19.0	10.2	4.1	2.8	4.0	4.5	4.4	6.5	4.3
Merced	13.2	16.1	16.2	12.8	6.8	7.5	1.5	1.2	2.0	5.8	6.9	10.0
Montague	11.7	12.9	14.8	13.6	8.8	4.1	3.7	2.9	3.6	7.0	9.4	7.5
Monterey	8.1	9.5	15.2	16.4	15.5	8.8	3.4	4.1	2.2	3.3	3.5	10.0
Needles	9.5	12.5	12.2	11.1	9.6	8.1	3.8	4.4	3.4	6.5	8.7	10.2
Oakland	6.9	12.7	11.3	13.1	14.8	11.4	5.2	4.7	5.1	5.9	4.1	4.8
Oceanside	17.1	15.6	12.8	7.3	4.9	3.6	2.4	2.5	4.8	4.8	10.0	14.2
Oxnard	14.5	13.0	11.0	9.4	8.6	2.4	0.5	0.6	1.3	4.6	10.9	23.2
Palmdale	5.4	6.8	13.5	13.5	13.3	12.8	8.8	6.6	4.5	3.8	5.0	6.0
Paso Robles	3.4	3.5	5.6	9.0	13.4	18.7	17.3	11.8	7.2	4.3	3.3	2.5
Redding	7.6	10.9	12.5	9.3	10.8	10.9	6.0	4.6	6.1	6.0	7.7	7.6
Riverside	7.4	9.6	7.7	8.8	9.4	9.6	11.4	11.0	7.7	5.4	5.5	6.5
Sacramento	16.9	16.0	12.0	6.7	6.5	6.8	1.9	1.8	2.3	7.2	9.4	12.5
San Francisco	3.4	5.7	9.0	11.7	14.6	15.0	11.5	10.0	7.4	6.3	2.7	2.7
San Rafael	13.4	11.6	11.3	10.1	7.9	7.7	4.0	4.5	3.8	6.4	6.6	12.7
Sunnyvale	8.6	8.8	8.5	9.7	10.7	14.0	8.7	7.8	5.6	5.3	4.3	8.0
Thermal	1.2	3.5	7.1	14.0	19.2	14.5	10.9	9.2	10.1	5.7	3.5	1.1
Vandenberg	6.3	7.2	16.3	16.9	21.7	8.1	1.6	1.6	3.9	5.4	5.9	5.1
Williams	19.3	20.4	21.4	5.1	6.1	5.5	2.7	1.7	2.6	4.6	5.0	5.6
Yuma	6.2	9.6	10.9	13.3	9.4	8.0	14.9	9.7	2.3	12.5	2.1	1.1
Klamath Falls	13.4	11.1	14.2	12.1	7.2	4.1	2.6	2.8	3.3	7.2	10.0	12.0
Siskiyou Summit	6.4	9.1	7.2	4.7	11.0	13.9	17.1	10.0	7.3	3.1	5.5	4.7

Tables 20 and 21 illustrate the effect of the "C" Factor on predicted soil erosion rates.

TABLE 20. E - SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR

C = 100
I = 86

SURFACE - K = 1.0
V - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

L UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	86.0	75.3	60.7	46.4	30.0	16.8	8.8	4.6	2.9	1.1	0.3		
8000	86.0	75.3	60.7	46.4	30.0	16.8	8.8	4.6	2.9	1.1	0.3		
6000	86.0	75.3	60.7	46.4	30.0	16.8	8.8	4.6	2.9	1.1	0.3		
4000	86.0	75.3	60.7	46.4	30.0	16.8	8.8	4.6	2.9	1.1	0.3		
3000	85.6	74.9	60.4	46.1	29.7	16.6	8.7	4.6	2.9	1.1	0.3		
2000	82.7	72.3	58.1	44.2	28.3	15.7	8.1	4.2	2.6	1.0			
1000	76.4	66.5	53.1	40.0	25.3	13.7	6.9	3.5	2.2	0.7			
800	74.2	64.6	51.5	38.6	24.3	13.0	6.6	3.3	2.0	0.7			
600	69.3	60.1	47.7	35.4	22.1	11.6	5.7	2.8	1.7	0.5			
400	62.2	53.7	42.4	31.0	19.0	9.6	4.6	2.2	1.3				
300	57.6	49.6	38.7	28.1	17.0	8.4	4.0	1.9	1.1				
200	51.4	44.1	34.1	24.4	14.5	6.9	3.2	1.4	0.8				
150	45.6	38.9	29.8	21.0	12.1	5.6	2.5	1.1	0.5				
100	39.8	33.8	25.6	17.7	10.1	4.5	1.9	0.8	0.4				
80	36.6	31.0	23.2	16.0	9.0	3.9	1.6	0.5					
60	31.4	26.4	19.6	13.2	7.2	3.0	1.2	0.4					
50	27.9	23.4	17.2	11.4	6.1	2.4	0.9						
40	24.4	20.4	14.8	9.7	5.1	1.9	0.7						
30	21.0	17.4	12.5	8.0	4.1	1.5	0.5						
20	15.9	13.0	9.1	5.6	2.8	0.9							
10	9.4	7.5	5.1	2.9	1.3	0.3							

TABLE 21. E - SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR

C = 50
I = 86

SURFACE - K = 1.0
V - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

L UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	43.0	36.6	27.9	19.5	11.3	5.1	2.2	1.0	0.4				
8000	43.0	36.6	27.9	19.5	11.3	5.1	2.2	1.0	0.4				
6000	43.0	36.6	27.9	19.5	11.3	5.1	2.2	1.0	0.4				
4000	43.0	36.6	27.9	19.5	11.3	5.1	2.2	1.0	0.4				
3000	42.7	36.3	27.7	19.4	11.1	5.0	2.2	0.9	0.4				
2000	40.7	34.6	26.2	18.2	10.4	4.6	2.0	0.8	0.4				
1000	36.6	30.9	23.3	16.0	9.0	3.9	1.6	0.5					
800	35.1	29.6	22.2	15.2	8.5	3.6	1.5	0.5					
600	32.2	27.1	20.2	13.6	7.5	3.1	1.3	0.4					
400	28.0	23.5	17.3	11.5	6.2	2.4	1.0						
300	24.1	20.6	15.0	9.8	5.2	2.0	0.7						
200	21.2	17.6	12.6	8.1	4.2	1.5	0.5						
150	18.0	14.8	10.5	6.6	3.3	1.1							
100	14.8	12.1	8.4	5.2	2.5	0.8							
80	13.2	10.8	7.4	4.5	2.1	0.4							
60	10.4	8.4	5.7	3.3	1.5	0.3							
50	8.7	7.0	4.7	2.7	1.2	0.2							
40	7.0	5.5	3.6	2.0	0.8								
30	4.8	3.8	2.4	1.3	0.5								
20	3.3	2.5	1.6	0.7									
10	1.4	1.1	0.6										

UNSHELTERED DISTANCE "L"

Wind Erosion Equation $E=f[(IKC)\mathbf{L}V]$

In the Wind Erosion Equation, the "L" factor represents the unsheltered distance along the prevailing wind erosion direction for the field or area to be evaluated. Its place in the equation is to relate the "isolated, unsheltered, and wide" field condition of "I" to the size and shape of the field for which the erosion estimate is being prepared. Because "V" is considered after "L" in the 5-step solution of the equation, the unsheltered distance is always considered as if the field were bare.

Definition of Unsheltered Distance

As shown in Figure 15, "L" begins at a point upwind where no saltation or surface creep occurs and ends at the downwind edge of the area being evaluated.

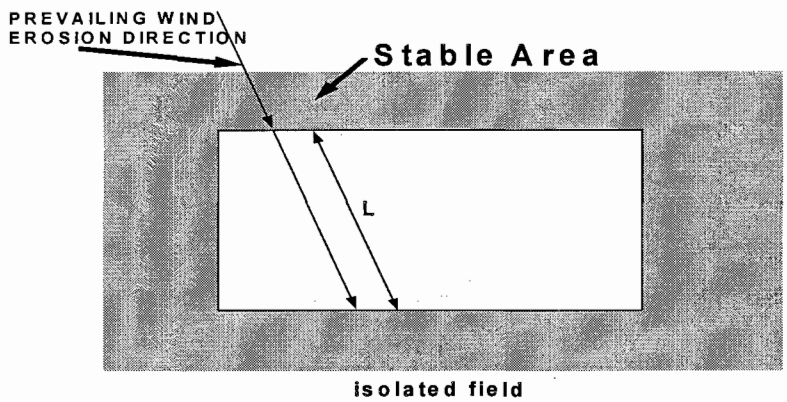


Figure 15. Isolated Field - "L" Calculated Using Field Width

The upwind point may be at the field border when a stable condition is present or it may be upwind where vegetation is sufficient to eliminate the erosion process. Where the stable condition is upwind of the field border as shown n Figure 16, a "new" field area is created for determining "L". A strip of vegetation should be considered stable only if it can trap or hold virtually all expected saltation and surface creep from upwind.

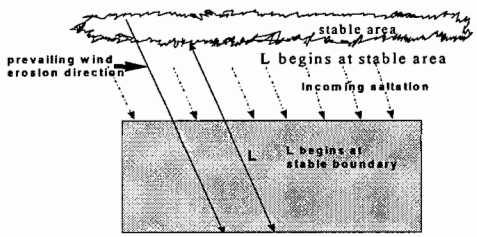


Figure 16. Field Not Isolated - "L" Begins Upwind of Field Boundary

When a properly designed wind stripcropping system as shown in Figure 17 is applied, alternate strips are protected during erosive periods by a growing crop or by crop residue. These strips are considered stable and "L" is measured across each erosion-susceptible strip, along the prevailing wind erosion direction.

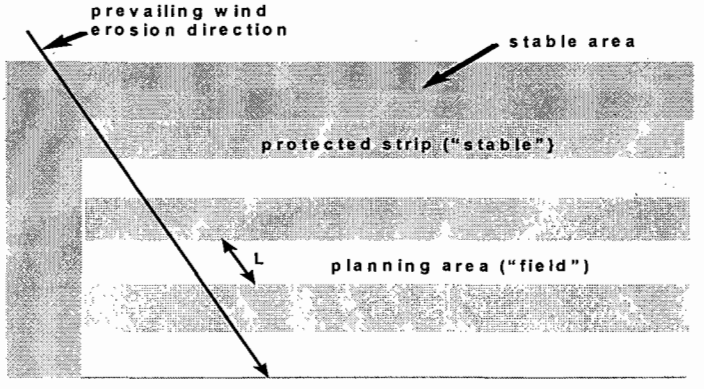


Figure 17 Properly Installed Wind Stripcropping System

Where vegetative barriers, grassed waterways as shown in Figure 18, or other stable areas divide the field being evaluated, each subdivision is "isolated" and is evaluated as a separate "field."

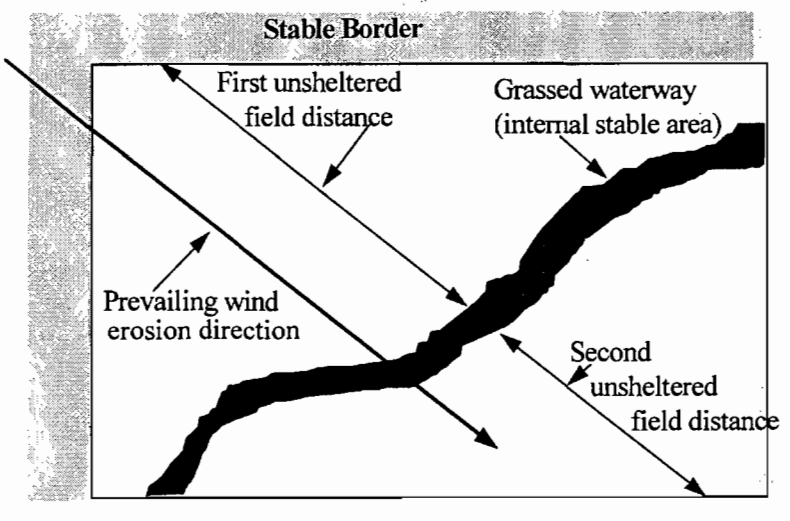


Figure 18. Stable Area Inside Field Starts a New "L"

Stable Condition

A stable condition is present when an area has sufficient vegetative cover to trap and hold expected saltation and surface creep from upwind. Factors to consider when evaluating an area for stability are width of vegetated strip as well as density and height of vegetation. Strips 12-15 feet in width with a dense stand of upright, ridged vegetation standing one foot tall or taller as shown in Figure 19 are considered stable. When vegetation is less than one foot in height, strips should be at least 25 feet wide to be considered stable.

Cross Wind Trap Strips, Vegetative Buffer Strips, and low Herbaceous Wind Barriers must be wide enough to trap any saltating soil particles. Both annual and perennial vegetation can be used. Plants used must be tall enough to perform as a buffer or trap during the windy season. Growing a harvestable crop can reduce costs. Consider using wheat or barley since they would have good height by March when the windy season starts in many parts of California. Using the standing stubble of the previous wheat or barley crop is another alternative.

Strip widths should be in multiples of the width of the equipment the grower/client uses. If alfalfa is grown, gauge the width in multiples of the mower or swather cutter bar.

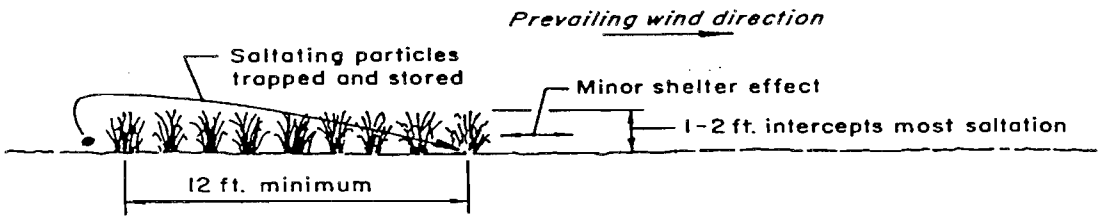


Figure 19. Trap Strip

When erosion estimates are being calculated for cropland or other relatively unstable areas, upwind pasture or rangeland should be considered a stable border. However, if the estimate is being made for a pasture or range area, "L" should be determined by measuring from the nearest stable point upwind of the area or field in question as shown in Figure 20. The only case where "L" is equal to zero is where the area is fully sheltered by a barrier.

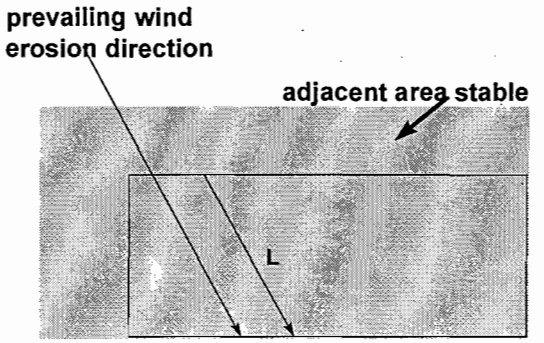


Figure 20. "L" Determination for Fields Surrounded by Perennial Vegetation

Barriers

Barriers can reduce "L". A barrier can be vegetative, such as one or more rows of trees, shrubs, or tall grass; or structural, such as a row of hay bales or snow fencing. Barriers with a density of 40-60 percent are considered to provide the greatest downwind area of protection.

Field corn and sunflowers have been used to protect green tomatoes in the Salinas Valley. They are usually destroyed just prior to harvest. Better pack out of higher quality tomatoes is claimed by growers using this system.

Both perennial and annual vegetation can be used. Two row plantings of tall wheatgrass 3.5 feet apart as shown in Figure 21 have been used effectively. Plants need to maintain their height during the windy period.

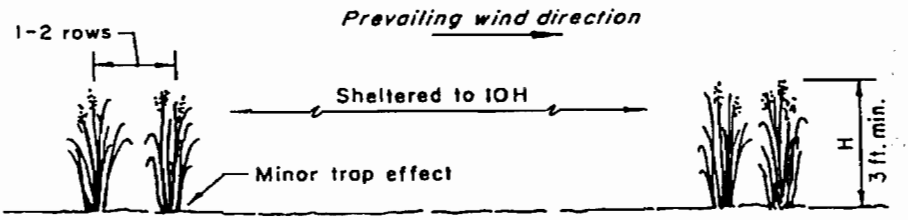


Figure 21. Vegetative Barriers

NRCS considers the sheltered or protected area to reduce wind erosion to be ten times the height of the barrier or 10H as illustrated in Figure 22. Within this sheltered zone soil erosion rates are considered to be zero and for planning purposes the wind erosion process and the unsheltered distance begins at a point downwind 10H from the barrier.

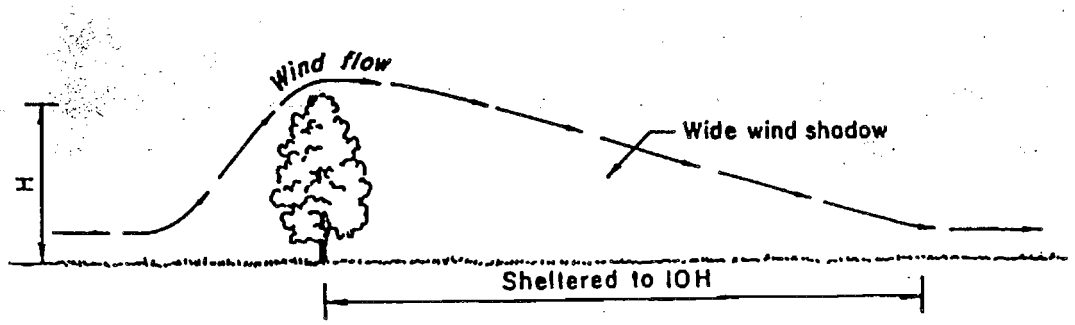


Figure 22. Barrier Effect

When a barrier is present on the upwind side of a field, as in Figure 23, measure "L" across the field along the prevailing wind erosion direction and subtract the distance sheltered by the barrier. Use ten times the barrier height (10H) for the sheltered distance.

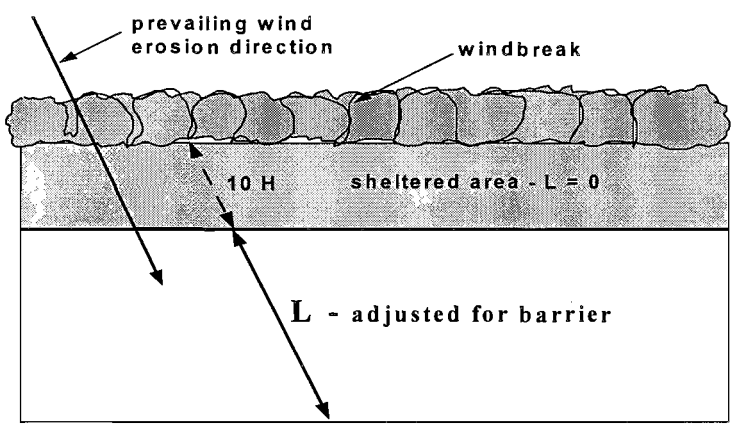


Figure 23. Barrier Effect on "L"

A barrier on a flat field (slopes of 2 percent or less) provides a sheltered distance of 10 times the height of the barrier (10H). For windbreaks, base the design height on the expected height in 20 years.

On fields with slopes of 3 percent or more that do not exceed 500 feet in length where the "I" factor was adjusted for knoll erodibility, the effective height of the barrier must be adjusted by multiplying the design height of the barrier by the barrier height correction factor for the specific slope as shown in Table 22.

TABLE 22. BARRIER HEIGHT CORRECTION FACTORS

Slope Change in Prevailing Wind Erosion Direction	Barrier Height Correction Factors
3 percent	0.77
4	0.72
5	0.67
6	0.62
8	0.56
10 or greater	0.50

Example:

A 10 foot barrier on flat land will provide a sheltered distance of 10 x 10 feet or 100 feet.

A 10 foot barrier protecting a 440 foot long field where the slope along the prevailing wind erosion direction rises 4 percent across the field will have an effective height 10 x 0.72 or 7.2 feet, and will provide a sheltered distance of 7.2 x 10 or only 72 feet.

"L" In Annual Method Calculations

For uses of the Wind Erosion Equation involving a single annual calculation, the prevailing wind erosion direction during the critical period is used. "L" should be the measured distance across the area along the prevailing wind erosion direction from the stable upwind edge of the field to the downwind edge of the field. When prevailing wind erosion direction is at an angle from perpendicular, "L" can measured along that angle or can be determined by multiplying the width of the field by the appropriate conversion factor obtained from the Table 23. "L" can also be measured using an Alignment Chart. A reproducible copy of an Alignment Chart is provided at the end of this Subpart.

TABLE 23. WIND EROSION DIRECTION FACTORS FOR CALCULATING "L"

ANGLE OF DEVIATION	ADJUSTMENT FACTOR*
0	1.00
22.5	1.08
45	1.41
67.5	2.61
90	"L" = LENGTH OF FIELD

* Use these adjustment factors only for the annual method of calculation. These adjustment factors are applicable only when preponderance is not considered.

"L" cannot exceed the longest possible measured distance across the field.

"L" In Management Period Method Calculation

The information needed to determine "L" for a management period method analysis includes: **Prevailing Wind Erosion Direction (PWED)** for each identified management period; **Preponderance** for each identified management period; **Field Length to Width ratio**; **Field Orientation**; **Angle of Deviation**; and a **Wind Direction Factor**.

For uses of the Wind Erosion Equation based on the management period method, "L" is a calculated value determined by multiplying a measured field width by a Wind Erosion Direction Factor determined from Table 25, 26, 27, 28, or 29 for the appropriate angle of deviation.

Prevailing Wind Erosion Direction

The Prevailing Wind Erosion Direction (PWED) is the direction from where the greatest amount of erosive wind occurs during the critical wind erosion period or the period being evaluated for the management period method. As shown in Figure 24, direction is expressed as one of the 16 compass points in degrees from true north. When predicting erosion by management periods, the prevailing wind erosion direction may be different for each period.

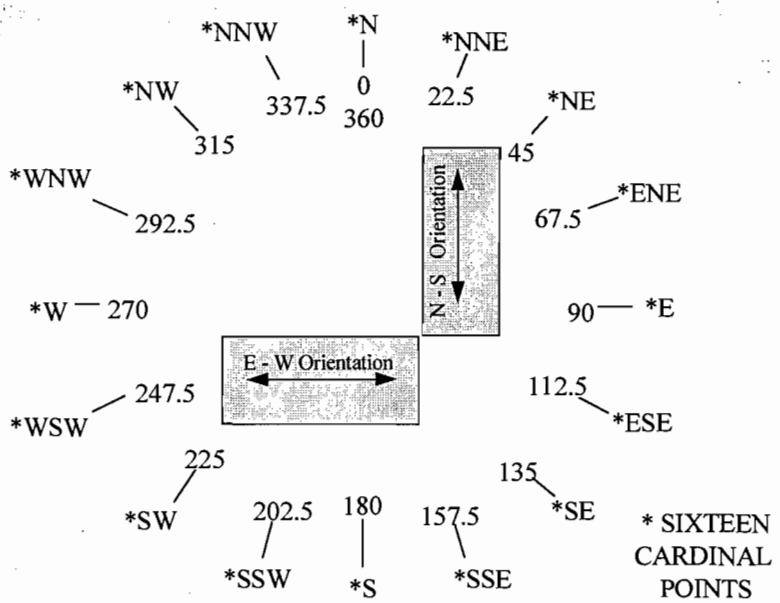


Figure 24. Graphic Representation of Wind Directions

Preponderance

Erosion estimates can be refined by analyzing management periods of the crop year and/or crop rotation. For "L" determinations, each period considers the variability in wind direction or **preponderance** during the period.

Preponderance is a ratio between wind erosion forces parallel and those forces perpendicular to the prevailing wind erosion direction. Wind forces considered include winds blowing in both directions along the identified direction.

A preponderance value of 1.0 indicates that as much erosive wind energy is exerted perpendicular to the prevailing wind direction as along that direction. Wind patterns are normally complex. A low preponderance indicates high complexity. A high preponderance value indicates that more of the force is parallel to the prevailing wind erosion direction. Research shows that using a preponderance value greater than 4.0 makes little difference in wind erosion estimates. Therefore, the FOCS WEQ application caps preponderance values at 4.0.

Values for prevailing wind erosion direction and preponderance are available in Exhibit 502.64(a) in Part 502 of the National Agronomy Manual. Portions relating to California are provided at the end of this Subpart. Select a location near the area being evaluated for these values. Table 24 shows these values for Fresno.

TABLE 24. PREVAILING WIND EROSION DIRECTION AND PREPONDERANCE FOR FRESNO, CALIFORNIA

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Prev Wind Direction	157	315	315	315	315	293	293	293	315	158	135	315
Preponderance	2.7	2.9	3.1	2.6	2.2	4.0	4.0	3.1	2.4	1.9	2.0	2.0

Field Length to Width Ratio, Field Orientation, and Angle of Deviation

The shape of the field or area being evaluated as well as the orientation relative to the prevailing erosive winds are used in determining "L". Divide the field length (long dimension) by the width (short dimension) to determine the length:width ratio. Round to the nearest ratio found in the Wind Erosion Direction Factor Tables.

For example, an 80 acre field is 2640 ft. long and 1320 ft. wide. The length to width ratio is calculated as follows: 2640/1320 = 2:1 ratio

When determining "L", the angle of deviation is the angle between the prevailing wind erosion direction and an imaginary line perpendicular to the long side of the field. The angle of deviation is determined for each identified management period.

Figures 24 and 25 illustrate the relationship between wind direction and field orientation, and how field orientation can affect "L".

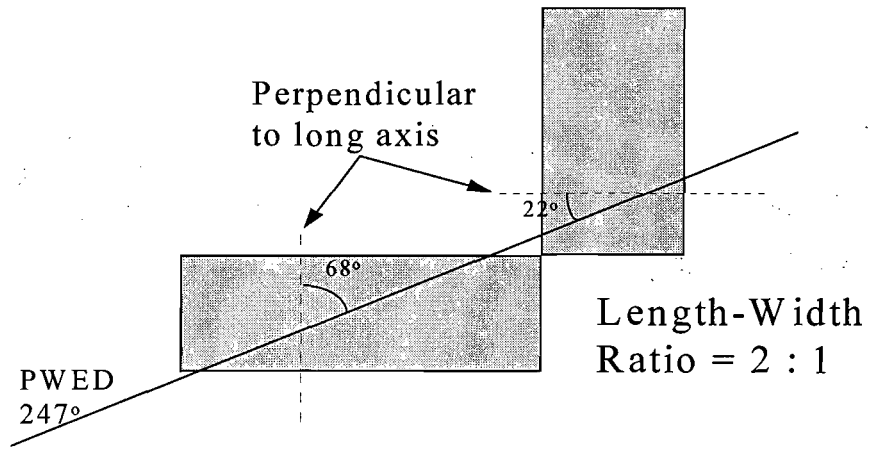


Figure 25. Effect of Field Orientation on Angle of Deviation

Management Periods Covering More Than One Month

Some management periods may extend over more than one month. This usually results in the need to consider more than one prevailing wind erosion direction and/or preponderance value when determining the wind erosion direction factor to calculate "L.

When this occurs, determine a wind erosion direction factor for each month or portion of a month using the applicable angle of deviation, preponderance, and field length to width ratio. Use the entire preponderance value listed for portions of a month. Choose the largest resulting wind erosion direction to calculate "L".

As a rule of thumb, on fields with a 1:1 length to width ratio the largest wind erosion direction factor occurs when the angle of deviation is 22.5° or 67.5°. For fields with a length to width ratio of 2:1 or greater, the wind erosion direction factor increases with an increased angle of deviation.

Steps in Determining Unsheltered Distance "L" Using Management Periods

1) Determine values for prevailing wind erosion direction and preponderance for the climate station best representing the planning site for each identified management period. Use the information from an appropriate location listed in Exhibit 502.64(a) in Part 502 of the National Agronomy Manual.

2) Measure the actual length and width of the field or area to be evaluated. Divide length by width to determine the length/width ratio. For example, an 80 acre field is 2640 ft. long and 1320 ft. wide. The length to width ratio is calculated as follows: 2640/1320 = 2:1 ratio

3) Determine the orientation of the field or area being evaluated. Determine the angle of deviation between the prevailing wind erosion direction and a line perpendicular to the long side of the field or area.

4) Using values from steps 1, 2, and 3 determine the wind erosion direction factor from the Wind Erosion Direction Factor Tables. These factors can be found in Tables 25 - 29.

5) Multiply the width of the field by the wind erosion direction factor to obtain "L" for the management period. For example, an 80 acre field oriented east to west has an angle of deviation of 22 degrees when the prevailing wind direction is 338 degrees. From Table 26, when the angle of deviation equals 22.5 degrees, the field length to width ratio is 2:1, and preponderance is 2.0; the wind erosion direction factor is 1.16. Multiply field width of 1320 by 1.16 to get an unsheltered "L" of 1530.

6) When a barrier is present, reduce the calculated "L" by a distance equal to ten times the height of the barrier 10H. For example, if a barrier 20 ft. in height is present along the north side of the field, the sheltered area from the barrier is 10H or 200 ft. "L" then becomes 1530 minus 200 or 1330. If "I" was adjusted for knoll erodibility, then adjust the height of barrier using the Barrier Height Correction Factor from Table 22.

7) For circular fields, "L" equals 0.915 times the diameter, regardless of direction or preponderance. For example, a center pivot on a quarter section, where the perimeter of the pivot is stable, has a diameter of 2640 ft. The diameter of 2640 ft. multiplied by 0.915 would be equal to an unsheltered distance of 2416 ft.

8) Use a measured "L" where irregular fields cannot be adequately represented by a circle, square, or rectangle, or where preponderance values are not available. Try to represent irregular fields by a square, rectangle, or circle that is close to the size and shape of the irregular field.

TABLE 25 - WIND EROSION DIRECTION FACTOR TABLE

Angle of Deviation = 0°

	FIELD LENGTH/WIDTH RATIO						
	1 : 1	2 : 1	4 : 1	8 : 1	10 : 1	12 : 1	16 : 1
Preponderance							
1.0	1.03	1.46	1.70	1.85	1.88	1.90	1.95
1.2	1.03	1.30	1.45	1.53	1.56	1.58	1.62
1.4	1.03	1.20	1.28	1.32	1.35	1.37	1.40
1.6	1.03	1.14	1.18	1.20	1.22	1.23	1.25
1.8	1.02	1.10	1.11	1.12	1.13	1.14	1.15
2.0	1.02	1.07	1.07	1.07	1.08	1.08	1.08
2.2	1.02	1.05	1.05	1.05	1.05	1.05	1.05
2.4	1.02	1.04	1.04	1.04	1.04	1.04	1.04
2.6	1.01	1.03	1.03	1.03	1.03	1.03	1.03
2.8	1.01	1.02	1.02	1.02	1.02	1.02	1.02
3.0	1.01	1.02	1.02	1.02	1.02	1.02	1.02
3.2	1.01	1.01	1.01	1.01	1.01	1.01	1.01
3.4	1.01	1.01	1.01	1.01	1.01	1.01	1.01
3.6	1.00	1.01	1.01	1.01	1.01	1.01	1.01
3.8	1.00	1.01	1.01	1.01	1.01	1.01	1.01
4.0	1.00	1.01	1.01	1.01	1.01	1.01	1.01

TABLE 26 - WIND EROSION DIRECTION FACTOR TABLE

Angle of Deviation = 22.5°

	FIELD LENGTH/WIDTH RATIO						
	1 : 1	2 : 1	4 : 1	8 : 1	10 : 1	12 : 1	16 : 1
Preponderance							
1.0	1.03	1.46	1.70	1.85	1.88	1.90	1.95
1.2	1.03	1.37	1.50	1.61	1.64	1.66	1.70
1.4	1.03	1.27	1.36	1.44	1.46	1.47	1.5
1.6	1.03	1.22	1.26	1.30	1.32	1.33	1.35
1.8	1.03	1.18	1.20	1.21	1.22	1.23	1.24
2.0	1.04	1.16	1.16	1.16	1.16	1.16	1.17
2.2	1.05	1.14	1.14	1.14	1.14	1.14	1.14
2.4	1.06	1.13	1.13	1.13	1.13	1.13	1.13
2.6	1.06	1.13	1.13	1.13	1.13	1.13	1.13
2.8	1.07	1.12	1.12	1.12	1.12	1.12	1.12
3.0	1.07	1.12	1.12	1.12	1.12	1.12	1.12
3.2	1.07	1.12	1.12	1.12	1.12	1.12	1.12
3.4	1.08	1.12	1.12	1.12	1.12	1.12	1.12
3.6	1.08	1.11	1.11	1.11	1.11	1.11	1.11
3.8	1.08	1.11	1.11	1.11	1.11	1.11	1.11
4.0	1.08	1.11	1.11	1.11	1.11	1.11	1.11

TABLE 27 - WIND EROSION DIRECTION FACTOR TABLE

Angle of Deviation = 45°

	FIELD LENGTH/WIDTH RATIO						
	1 : 1	2 : 1	4 : 1	8 : 1	10 : 1	12 : 1	16 : 1
Preponderance							
1.0	1.03	1.46	1.70	1.85	1.88	1.90	1.95
1.2	1.03	1.44	1.63	1.72	1.75	1.77	1.81
1.4	1.03	1.42	1.57	1.62	1.65	1.67	1.70
1.6	1.03	1.42	1.52	1.55	1.57	1.58	1.61
1.8	1.03	1.42	1.49	1.51	1.52	1.53	1.55
2.0	1.03	1.42	1.48	1.49	1.49	1.49	1.50
2.2	1.02	1.42	1.48	1.48	1.48	1.48	1.48
2.4	1.02	1.42	1.48	1.48	1.48	1.48	1.48
2.6	1.01	1.42	1.48	1.48	1.48	1.48	1.48
2.8	1.01	1.42	1.48	1.48	1.48	1.48	1.48
3.0	1.01	1.42	1.48	1.48	1.48	1.48	1.48
3.2	1.01	1.42	1.48	1.48	1.48	1.48	1.48
3.4	1.01	1.42	1.48	1.48	1.48	1.48	1.48
3.6	1.01	1.42	1.48	1.48	1.48	1.48	1.48
3.8	1.01	1.42	1.48	1.48	1.48	1.48	1.48
4.0	1.01	1.42	1.48	1.48	1.48	1.48	1.48

TABLE 28 - WIND EROSION DIRECTION FACTOR TABLE

Angle of Deviation = 67.5°

	FIELD LENGTH/WIDTH RATIO						
	1 : 1	2 : 1	4 : 1	8 : 1	10 : 1	12 : 1	16 : 1
Preponderance							
1.0	1.03	1.46	1.70	1.85	1.88	1.90	1.95
1.2	1.03	1.49	1.80	1.94	1.98	2.00	2.04
1.4	1.03	1.52	1.90	2.03	2.07	2.08	2.12
1.6	1.03	1.55	1.98	2.13	2.15	2.16	2.20
1.8	1.03	1.58	2.08	2.23	2.25	2.26	2.30
2.0	1.04	1.62	2.17	2.35	2.36	2.37	2.40
2.2	1.05	1.65	2.27	2.48	2.49	2.49	2.50
2.4	1.06	1.68	2.37	2.61	2.61	2.61	2.61
2.6	1.06	1.71	2.42	2.71	2.71	2.71	2.71
2.8	1.07	1.72	2.44	2.77	2.77	2.77	2.77
3.0	1.07	1.73	2.45	2.82	2.82	2.82	2.82
3.2	1.07	1.74	2.46	2.85	2.85	2.85	2.85
3.4	1.08	1.75	2.47	2.87	2.87	2.87	2.87
3.6	1.08	1.75	2.48	2.89	2.89	2.89	2.89
3.8	1.08	1.76	2.48	2.90	2.90	2.90	2.90
4.0	1.08	1.76	2.49	2.91	2.91	2.91	2.91

TABLE 29 - WIND EROSION DIRECTION FACTOR TABLE

Angle of Deviation = 90°

	FIELD LENGTH/WIDTH RATIO						
	1 : 1	2 : 1	4 : 1	8 : 1	10 : 1	12 : 1	16 : 1
Preponderance							
1.0	1.03	1.46	1.70	1.85	1.88	1.90	1.95
1.2	1.03	1.50	1.90	2.10	2.16	2.23	2.32
1.4	1.03	1.55	2.10	2.40	2.50	2.60	2.75
1.6	1.03	1.66	2.30	2.70	2.87	3.00	3.25
1.8	1.03	1.80	2.55	3.10	3.32	3.50	3.85
2.0	1.02	1.96	2.78	3.50	3.84	4.08	4.56
2.2	1.02	2.00	3.06	4.05	4.47	4.80	5.40
2.4	1.02	2.00	3.35	4.63	5.12	5.60	6.40
2.6	1.01	2.00	3.56	5.30	5.93	6.50	7.60
2.8	1.01	2.00	3.74	5.85	6.64	7.50	8.90
3.0	1.01	2.00	3.92	6.51	7.60	8.80	10.6
3.2	1.01	2.00	4.00	6.89	8.20	9.30	11.5
3.4	1.01	2.00	4.00	7.08	8.40	9.60	11.8
3.6	1.00	2.00	4.00	7.26	8.60	9.90	12.3
3.8	1.00	2.00	4.00	7.45	8.91	10.3	12.8
4.0	1.00	2.00	4.00	7.64	9.20	10.6	13.3

Reducing the Unsheltered Distance using Windbreaks

The common approach to reducing the unsheltered distance "L" is to consider windbreaks. With design heights of 50 to 60 feet, they can shelter 500 to 600 feet downwind as compared to 4 to 10 foot high vegetative barriers or creating stable areas by using either vegetative buffers or cross wind trap strips.

When a planner proposes new alternatives within a grower's/client's field, it will require that person to perform at a higher management level. The planner needs to present alternatives that are as compatible as possible with that person's operations to improve acceptance and insure maintenance over the long-term.

Economic data on installation/establishment costs, operation and maintenance costs, the value of land that will be taken out of production, and the value of increased production and/or crop quality need to be presented for each alternative to help the grower/client reach a decision.

Windbreaks should be oriented at right angles to the prevailing erosive winds to maximize the length of the sheltered/protected zone. This would also minimize the number of windbreaks needed to protect a field. For planning purposes, base the windbreak design height on the expected plant height at 20 years of age. This is used in lieu of mature height, which may not be reached until some species are 50 years old.

If the erosive winds are extremely variable, the field may need to be divided into compartments with intersecting windbreaks. In many situations, single row windbreaks will be adequate. The major disadvantage of a single row windbreak is the potential loss of continuity from the loss of individual trees.

Plant spacing within the windbreak needs to be adjusted to achieve the desired 40 to 60 percent density. These moderately dense windbreaks do not cause as much downwind turbulence as dense windbreaks and are more effective over the 10H sheltered distance.

Foliage and branch characteristics of individual tree and shrub species are important in determining the degree of windbreak density. Tall, narrow crowned species or varieties usually provide the greatest benefit for the amount of land taken out of production.

Many factors influence the selection of tree and shrub species for windbreaks. Species adaptability is the most critical but compatibility with adjacent crops and pest problems must be considered. Select species that are relatively free of insect, disease and pest problems. An important consideration is possible contamination of the protected crops by leaves and parts of the windbreak trees and shrubs. Eucalyptus leaves blown into loose leaf lettuce and spinach crops cause off flavors and reduce crop quality.

VEGETATIVE COVER - "V"

Wind Erosion Equation E = f[(IKC)L**V**]

Vegetative Cover Factor "V"

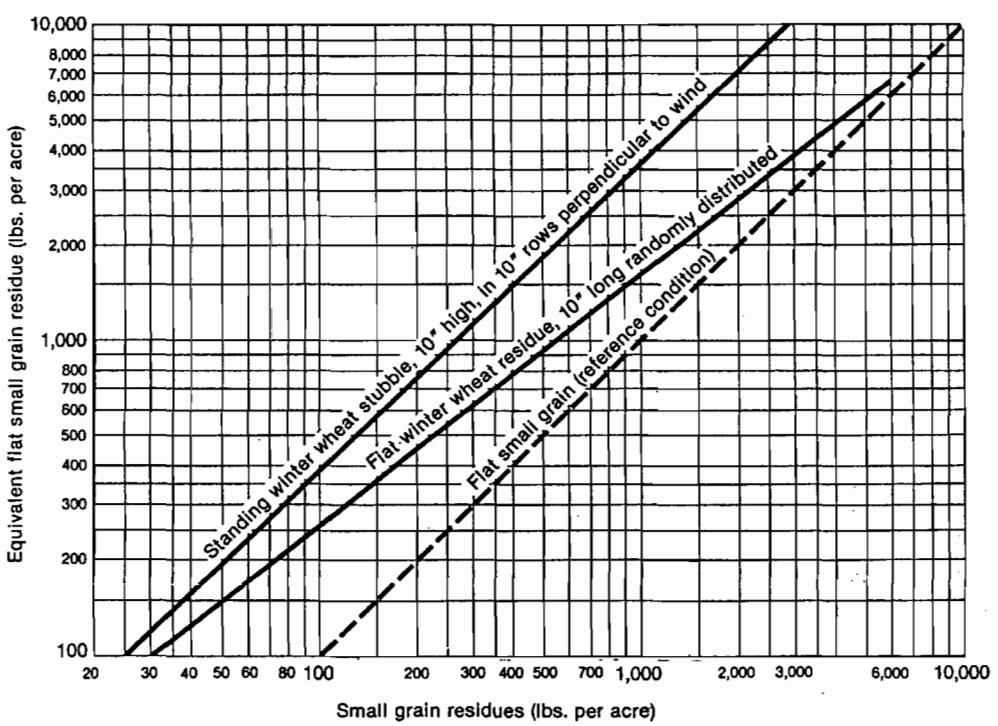
The effect of vegetative cover in the Wind Erosion Equation is expressed by relating the kind, amount, and orientation of vegetative material to its equivalent in pounds per acre of flat small grain residue in reference condition (SGe).

SGe Reference Condition

The term Flat Small Grain Equivalent (SGe) is based on a reference condition (dotted line in Figure 26) developed from wind tunnel research. It is defined as:

> 10-inch stalks of small grain lying parallel to the wind arranged in rows spaced 10 inches apart, oriented perpendicular to the wind. This is an artificial condition or reference condition to which other kinds, orientation, and amounts of residue have been compared as to their effectiveness.

Flat Small Grain Equivalents of Small Grain Residues
(Use for wheat, barley, rye and oats)



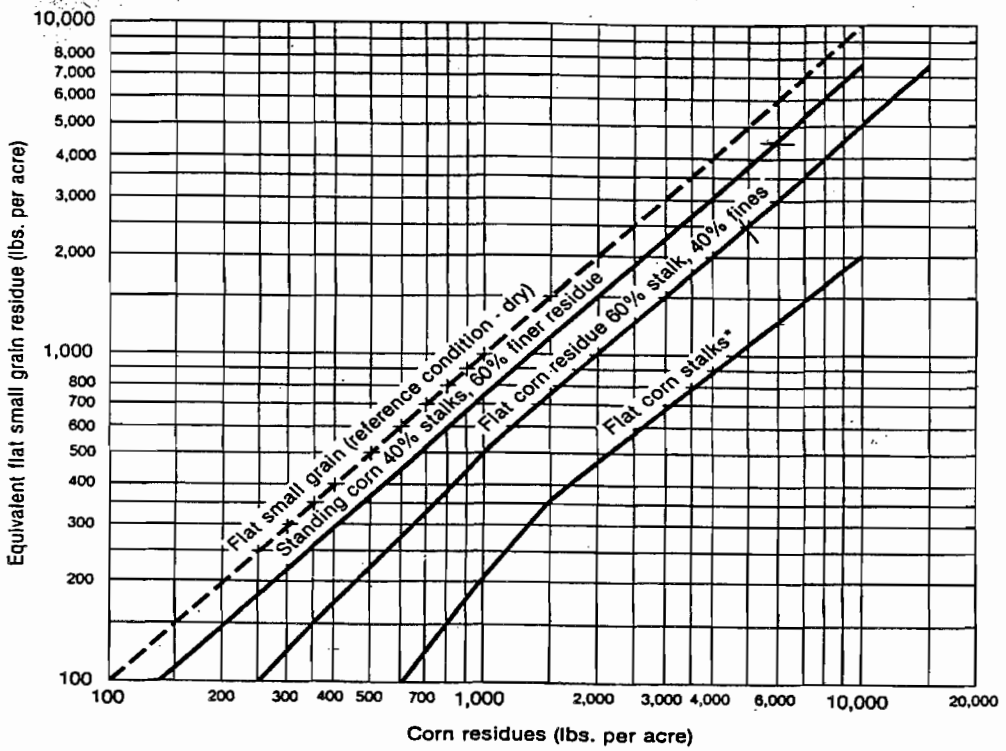
Reference condition - dry small grain stalks 10" long, lying flat on the soil surface in 10" rows, rows perpendicular to wind direction, stalks oriented to wind direction.
Source: Lyles and Allison—Trans. ASAE 1981, 24 (2): 405-408.
Residues are washed, air dried, and placed as described for wind tunnel tests.

Figure 26. Flat Small Grain Equivalents

Kind and Size of Residue

The kind and size of residue influence the effectiveness for wind erosion reduction. Generally, the finer the residue the more effective it is per pound. This is why an equal number of pounds of coarse residue like cornstalks is less effective than small grain residue. In Figure 27, you can see that 500 lb. of flat corn residue is equivalent to only 250 lb. of flat small grain residue.

Flat Small Grain Equivalents of Corn Residues



Source*: Lyles and Allison, Trans. ASAE 1981, 24(2): 405-408. (Flat to 2,000 lbs. standing to 3,500 lbs. Extended by SCS.)

Figure 27. Flat Small Grain Equivalents

Amount of Residue

The amount of residue influences erosion rate by either providing for a protective layer or by reducing wind velocity. The greater the amount, the more protection provided. There is not necessarily a linear relationship between residue amount and erosion reduction.

Orientation of Residue

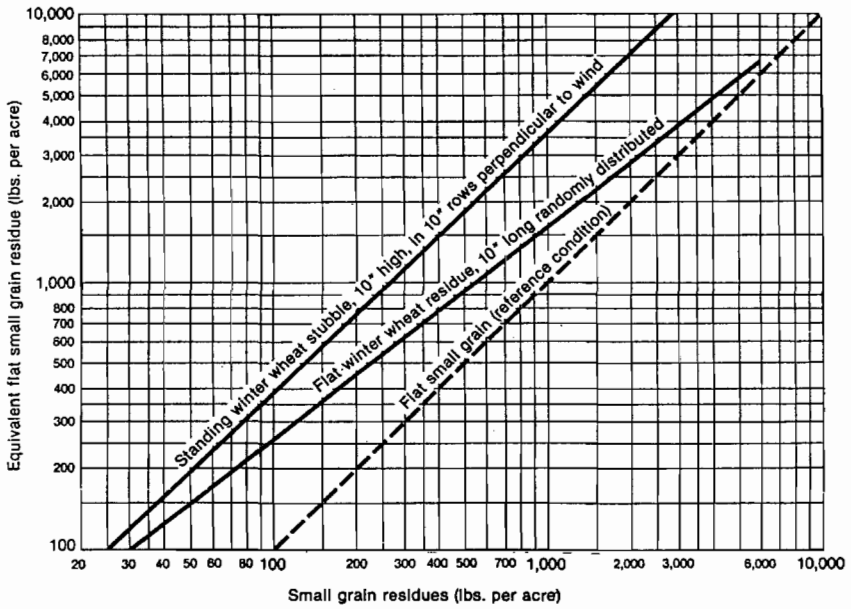
Since wind flows horizontally across the soil surface, the orientation of vegetative cover affects the rate of erosion losses in two ways:

1. Flat residues reduce erosion primarily by forming a protective layer or barrier between the soil surface and the forces of the wind and secondarily by reducing the wind velocity near the surface.

2. Leaning and standing residues reduce wind erosion primarily by reducing wind velocity at the soil surface and secondarily by forming a surface barrier.

In Figure 28, you can see that both standing winter wheat stubble and randomly distributed flat wheat stubble are more effective than the flat small grain reference condition.

Flat Small Grain Equivalents of Small Grain Residues
(Use for wheat, barley, rye and oats)



Reference condition - dry small grain stalks 10" long, lying flat on the soil surface in 10" rows, rows perpendicular to wind direction, stalks oriented to wind direction.
Source: Lyles and Allison—Trans. ASAE 1981, 24 (2): 405-408.
Residues are washed, air dried, and placed as described for wind tunnel tests.

Figure 28. Flat Small Grain Equivalents

Determination of SGe

1. Determine the kind of residue

2. Determine the amount of residue

Several acceptable methods are currently used to estimate or predict quantities of residue on the surface. These methods include:

- Line-transect method - used for estimating the amount of random flat residue on the field. See Section 503.53(a) in Part 503 of the National Agronomy Manual.

- Picture comparison method may be used for standing, flat and growing cover.
- Clip and weigh method for determining total above ground residues. Can be used to determine each portion (standing and flat).
- Using the Straw/Grain Ratio (Residue/Yield Ratio) in Table 30 for initial amounts.
- Using the Residue Retention-Burial values resulting from various tillage implements. See Section 503.52(b) in Part 503 of the National Agronomy Manual.

TABLE 30. DRY WEIGHT STRAW/GRAIN AND HARVEST INDEX OF SELECTED CROPS

CROP	STRAW/GRAIN RATIO [1]	HARVEST INDEX [2]
Alfalfa Hay (Full Bloom)	1.0	.50
Barley (Irrigated)	1.5	.40
(Nonirrigated)	1.0	.50
(Milk Stage)	1.0	.50
Beans, Dry	1.0	.50
Corn, Field (Irrigated)	1.5	.40
(Nonirrigated)	1.0	.50
Cotton	1.0	.50
Oats (Irrigated)	1.5	.40
(Nonirrigated)	1.0	.50
Peas (Irrigated)	1.0	.50
Rice	1.5	.40
Rye, Cereal	1.5	.40
Safflower (Irrigated)	2.0	.33
(Nonirrigated)	1.0	.50
Sorghum, Grain (Irrigated)	1.5	.40
(Nonirrigated)	1.0	.50
Soybeans	1.5	.40
Vetch (Full Bloom)	1.0	.50
Wheat (Irrigated)	1.5	.40
Winter (Nonirrigated)	1.7	.37
Spring (Nonirrigated)	1.3	.44

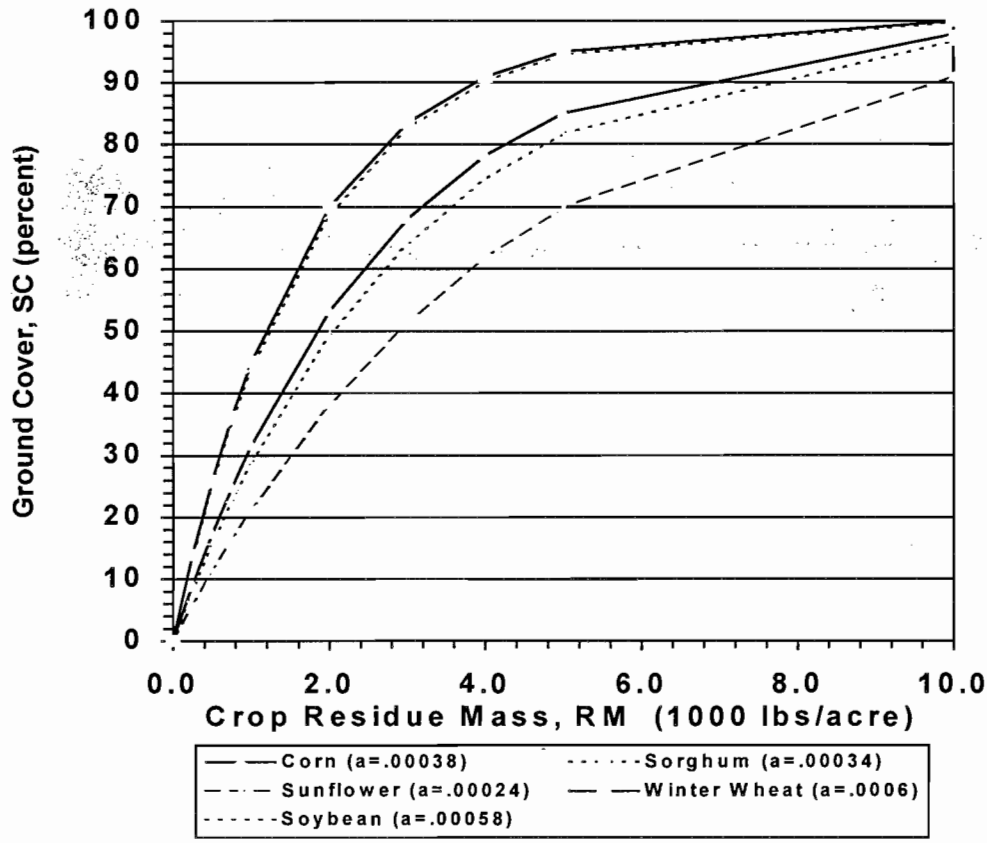
[1] Also called Residue/Yield Ratio
[2] Ratio of Yield/Yield plus Residue

3. Convert percent cover to pounds per acre. When values are expressed in percent cover they will need to be converted to pounds per acre. This can be done by using conversion graphs and tables. See Table 31 and Figures 29 and 30. Growers/clients and planners need to have some method of measuring or determining what the specified pounds per acre or percent cover looks like in the field. This requires the ability to convert freely between percent cover and pounds per acre.

TABLE 31. RELATIONSHIP OF FLAT RESIDUE WEIGHT TO PERCENT RESIDUE COVER FOR VARIOUS CROPS

	Wheat, Soybeans, Rye, Alfalfa, Bromegrass	Corn, Sorghum, Tobacco, Peanuts	Cotton, Sunflowers
Percent Cover	**lb/ac**	**lb/ac**	**lb/ac**
5	75	90	200
10	150	200	450
15	240	400	710
20	330	600	980
25	430	800	1260
30	530	1000	1550
35	660	1220	1870
40	800	1450	2200
45	990	1720	2570
50	1200	2000	2950
55	1420	2320	3440
60	1650	2650	3950
65	1890	3070	4590
70	2150	3500	5250
75	2460	4090	6165
80	2800	4700	7100
85	3390	5690	8000
90	4000	6700	
95	5000	8000	
99	7250		

Source: Agriculture Handbook 703 - *Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)*



SC= [1-exp(-a(RM)]100
RM= ln[1-(SC/100)]/-a

***For flat randomly oriented residues**

Figure 29. Conversion of Percent Ground Cover to Residue Weight

Several methods can be used to estimate the kind, amount, and orientation of vegetation in the field. Often the task is to predict what will be in the field in some future periods. The initial amounts can be estimated from production records, data from the grower/client, or estimates based on local knowledge. These amounts are reduced by the expected or planned tillage or grazing. Local data from field sampling and measuring existing residues or vegetation should be used where available.

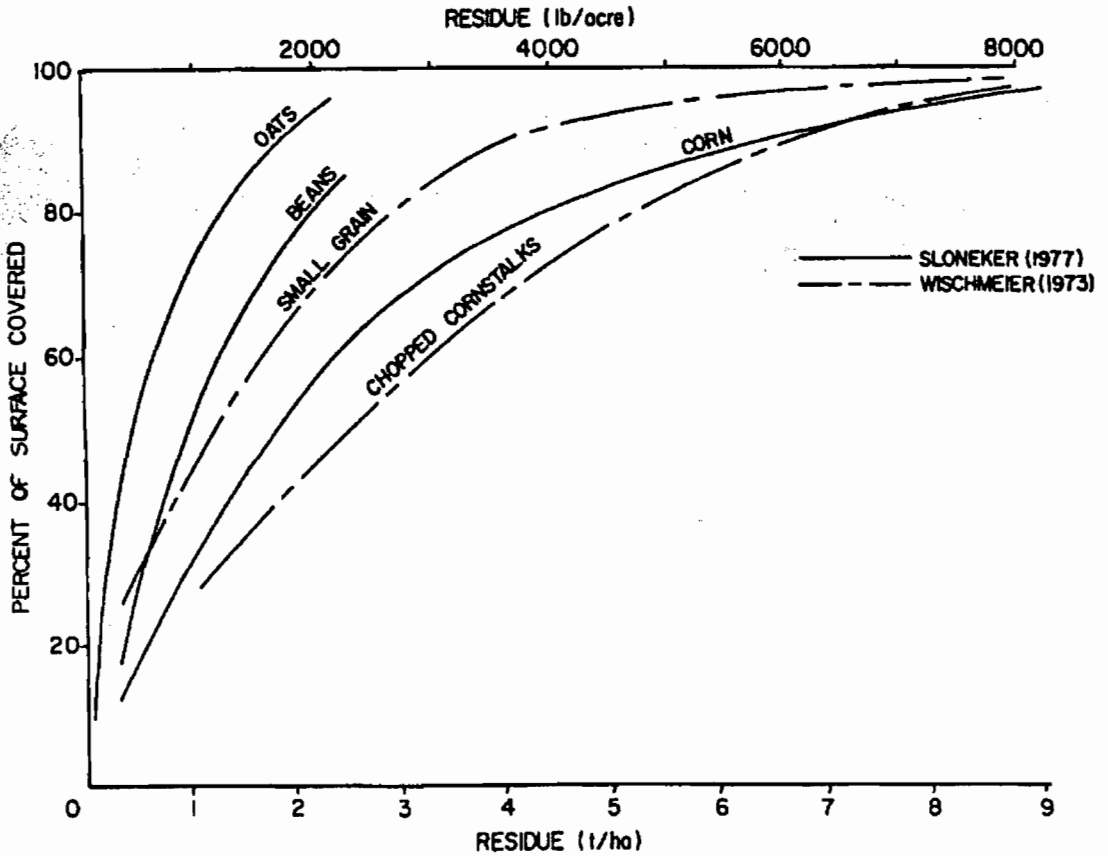
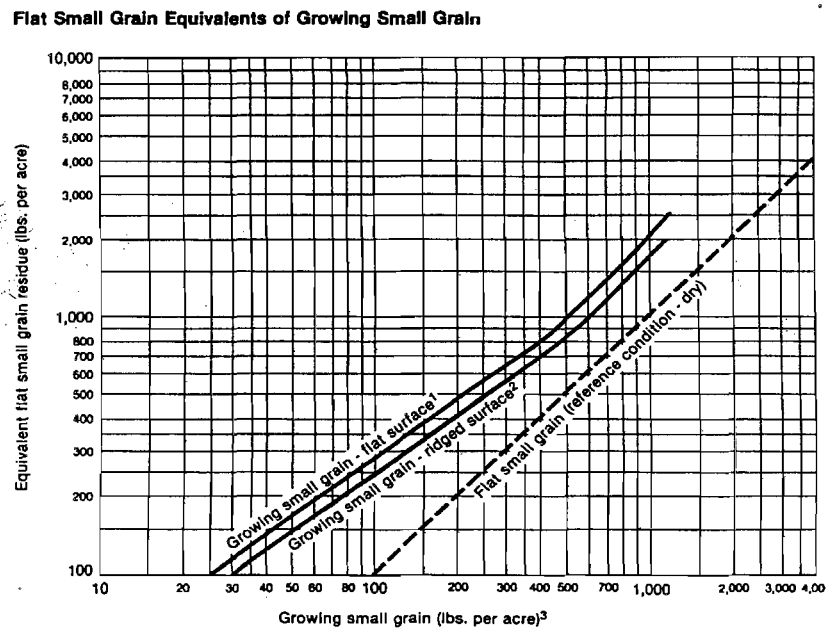


Figure 30. Relationship of the Percent of Surface Cover to Amount of Residue for Various Crops

4. Determine orientation. - Are the residues standing or flat and are they parallel or perpendicular to the wind direction?

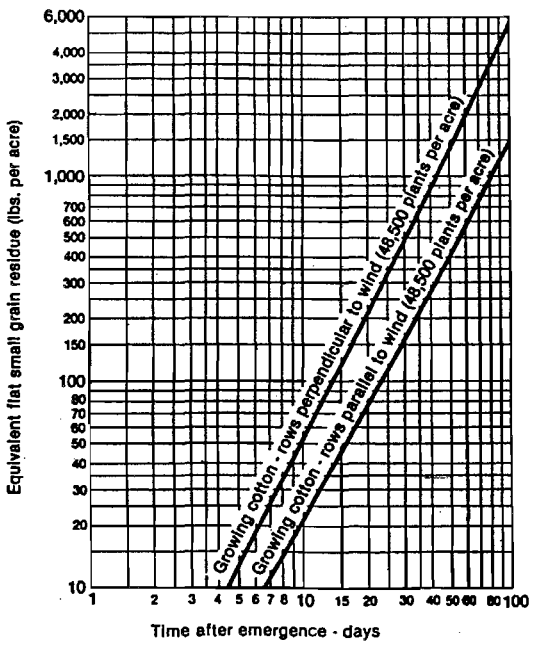
5. Select the appropriate SGe chart for crop type, residue orientation, whether the crop is growing, and days after emergence. Figures 31 and 32 are examples of the SGe charts contained in Exhibit 502.65 in Part 502 of the National Agronomy Manual.

6. Determine SGe using appropriate curve on the chart.



Reference condition - dry small grain stalks 10" long, lying flat on the soil surface in 10" rows, rows perpendicular to wind direction, stalks oriented to wind direction.
Sources
[1] Siddoway, F.H., W.S. Chepil, and D.V. Armbrust 1965
[2] Estimates by Best Judgement of SCS Personnel.

Figure 31. Flat Small Grain Equivalents



Source: Armbrust & Lyles, 1984-unpublished.

Figure 32. Flat Small Grain Equivalents

Weighted SGe Calculations for Mixed Vegetative Cover

When residues consist of different kinds of residue, or residues with different orientations, a different procedure is used to estimate SGe, as follows below.

1. Describe each major component (by kind or orientation) and estimate the percentage of total air-dry weight of each component.

2. Add the components together to get total air-dry weight.

3. Using the appropriate curve, the total air-dry weight of all components, determine the SGe value of each component.

4. Multiply the SGe value of each component by the percentage of air-dry weight.

5. Add the products of each component. The sum is the weighted average SGe for the mixed cover.

Example: Mixed orientation (standing and flat)

- 2,500 lb. total air-dry winter wheat residue after harvest
  - 1,500 lb./acre (60 %) standing
  - 1,000 lb./acre (40%) flat)

- Using SGe curves based on total residue:
  - SGe contribution from standing component
    - 2,500 lb./acre standing = 8,500 lb. SGe x 60% = 5,100 lb./acre SGe

  - SGe contribution from flat component
    - 2,500 lb./acre flat = 3,000 lb. SGe x 40% = 1,320 lb./acre SGe

- Weighted average = 5,100 lb. + 1,320 lb. = 6,420 lb./acre SGe

The same procedure can be followed for other mixed components, such as residues in combination with growing crops.

Increasing the Amount of Vegetative Cover

Start with a review of the E Table you used to obtain the predicted erosion rate. For the same unsheltered distance, read to the right until the erosion rate is within "T". Now read up to find the pounds of SGe that would be needed.

Use the SGe charts and other tables to determine the actual dry weight of additional residues or vegetation the would be needed. Reducing or delaying tillage operations can maintain more vegetative cover. Delaying or reducing any grazing may provide enough cover for the critical period or management period. If more growth or residue is needed, consider changing the planting date, adding a cover crop, and changing the crop rotation.

When residues are being reduced by tillage during the period, work backwards to see what difference changing dates of tillage would make.

When growing vegetation is inadequate, check the possibility of planting earlier so there will be more cover during that period. Two weeks might provide the additional cover needed for protection.

Cover crops can be added to some rotations. If a legume could be included, the benefits of Nitrogen fixation would be a selling point. If the next crop is planted on beds, consider bedding the field before planting the cover crop. This would also reduce the K factor. When growers object to the large amount of residue produced by the cover crop, consider use of a herbicide after there is enough growth to provide the needed cover.

In the potato growing area in Siskiyou County, we recognize the need for a cover crop when potatoes follow potatoes. Due to the late harvest dates, it is difficult to plant the cover crop on time. Overseeding before harvest may be an alternative. When weather conditions dictate that planting cereal rye would not be successful, the field could still be listed to reduce the K factor.

In cotton growing areas of the San Joaquin, Coachella, and Imperial Valleys, any spring blowout problems result in replanting. Besides using buffer strips and cross wind trap strips, another alternative would be to plant a row of barley or wheat on the edge of each bed about five weeks before the cotton. After the barley or wheat gets 10 inches high, it could be treated with a herbicide before cotton emergence. The standing stubble would prevent sand blast damage to young cotton seedlings. If the grower/client elects to knock down the growth as part of the planting operation, there should be enough vegetation still exposed to achieve the erosion reduction. It may be necessary to plant the barley or wheat earlier in these situations.

Changing the amount vegetative cover "V" may be enough to reduce the erosion rate. However, if "K" is also reduced, then a smaller change in "V" may be adequate.

E TABLES

The E Tables located at the end of this Subpart provide the predicted average annual soil erosion rate for the field or area described by the factor values I, K, C, L and V. Table 32 is an example of an E Table. Each NRCS Field Office only needs to maintain those E Tables for the C values found within its service area.

After selecting the appropriate E Table for the C, I, and K values, the planner can readily determine what unsheltered distance "L" is wide, as well as alternative combinations of "L" and "V" that will achieve an acceptable soil erosion rate.

When using the management period method, the annual erosion rate E is multiplied by the management period Erosive Wind Energy (EWE) to determine the period erosion rates.

TABLE 32 - E TABLE - SOIL LOSS FROM WIND EROSION IN TONS /ACRE /YEAR

C = 90
I = 134

SURFACE - K = 1.0

V - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

L UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
8000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
6000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
4000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
3000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
2000	120.6	107.1	88.8	70.8	48.4	30.0	17.1	9.9	6.6	2.9	1.4	0.2	
1000	115.5	102.4	84.6	67.1	45.5	27.9	15.7	9.0	6.0	2.5	1.3	0.2	
800	114.1	101.0	83.4	66.0	46.7	27.3	15.3	8.7	5.8	2.4	1.2	0.2	
600	108.7	96.1	74.0	62.1	41.7	25.1	13.9	7.8	5.1	2.1	1.0	0.2	
400	103.2	91.0	74.5	58.3	38.8	22.9	12.5	7.0	4.5	1.8	0.9	0.1	
300	98.9	87.1	71.0	55.2	36.5	21.3	11.5	6.3	4.1	1.6	0.8	0.1	
200	90.1	79.0	64.0	49.2	32.0	18.2	9.6	5.1	3.2	1.2	0.4		
150	82.6	72.2	58.1	44.1	28.3	15.6	8.1	4.2	2.6	0.9	0.3		
100	76.0	66.3	52.9	39.8	25.2	13.6	6.9	3.5	2.1	0.7			
80	71.0	61.6	48.9	36.5	22.8	12.0	6.0	3.0	1.8	0.6			
60	62.9	56.0	42.4	31.1	19.1	9.7	4.7	2.2	1.3				
50	57.8	49.9	38.9	28.3	17.1	8.5	4.0	1.9	1.1				
40	54.0	48.4	36.0	25.9	15.5	7.5	3.9	1.6	0.9				
30	47.3	40.4	31.0	22.0	12.9	6.0	2.7	1.2	0.5				
20	38.3	32.9	24.5	16.9	9.6	4.2	1.8	0.6					
10	26.8	22.4	16.5	10.9	5.8	2.3	0.9						

E Tables are provided for the following C values: 5, 10, 15, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100, 120, 150, 200, 250, 300, 500, and 1,000 in combination with the following I values: 310, 220, 160, 134, 104, 86, 56, 48, 38, 21, and 12.

There is a set of E Tables for each combination of C and I values and each set includes an E Table for K values: 1.0, 0.9, 0.8, 0.7, 0.6, and 0.5.

CROP TOLERANCE

Crop Tolerance

Wind and/or blowing soil can have an adverse effect on growing crops. Crop tolerance can be defined as the maximum erosion that a growing crop can tolerate, from crop emergence to harvest, without an economic loss to crop stand, crop yield, or crop quality.

- Crops vary in their ability to tolerate blowing soil or wind. Many common crops have been classified based on their tolerance to blowing soil. These are shown in Table 33.
- Crop tolerances to blowing soil are usually less than soil loss tolerance "T".

Blowing Soil Effects on Crops

Some of the adverse effects of soil erosion and blowing soil on crops include:

- Blow outs that remove planted seeds, tubers, or seedlings.
- Exposure of plant root systems.
- Sand blasting and plant abrasion resulting in:
  - Crop injury
  - Crop mortality
  - Lower crop yields
  - Lower crop quality
- Wind damage to seedlings, vegetables, and orchard crops.

Evaluating Erosion rates

The planner needs to be aware of a specific crop's tolerance to blowing soil. Soil erosion rates, determined using the Management Period Method, during critical crop development and growth periods can be evaluated to identify time periods when additional measures to protect the crop may be needed.

- Base the evaluation on the most sensitive crop in the rotation.
- Look at the management periods when the crop is most sensitive.
- Analyze if the "K", "L", or "V" factors can be modified during the management periods when soil erosion rates exceed crop tolerance levels.
- Round the erosion rate for any one management period to the nearest 0.1 Ton.
- Round the predicted average annual erosion rate to the nearest 0.5 Tons/acre/year.

TABLE 33. ESTIMATED CROP TOLERANCES TO WIND EROSION

Crop	Estimated Crop* Tolerance T/Ac
Alfalfa	0.0
Asparagus	1.0
Barley	**
Beans-green, lima, navy, snap	0.5
Beets, table	0.0
Bluegrass	0.0
Broccoli	1.0
Buckwheat	**
Cabbage	1.0
Cantaloupes	0.0
Carrots	0.0
Corn	2.0
Cotton	0.0
Cucumbers	0.0
Eggplant	1.0
Lettuce and Romaine	0.0
Oats	**
Onions	0.0
Peanuts	0.0
Peas	0.5
Peppers	1.0
Potatoes, Irish, Sweet	1.0
Rye	**
Sorghum	2.0
Soybeans	1.0
Spinach	0.0
Squash	0.0
Sugar Beets	0.0
Sweet corn	2.0
Sweet Potatoes	1.0
Tomatoes	0.5
Watermelons	0.0
Wheat	**

*No Tolerance	Alfalfa (seeded alone) Beets Bluegrass Cantaloupes Carrots Cucumber Lettuce and Onions Spinach Squash Watermelons
*0.5 Tons	Beans, Green Beans, Lima Beans, Navy Peas Tomatoes
*1.0 Tons	Asparagus Broccoli Cabbage Eggplant Peppers Potatoes Sweet Potatoes Soybeans
*2.0 Tons	Corn, field Corn, Sweet Sorghum
**Will probably tolerate soil blowing equal to or greater than tolerable soil loss "T".	Barley Buckwheat Oats Rye Wheat

* Crop tolerance values are the maximum rate of soil loss expressed as T/Ac which a crop can tolerate without suffering irreversible damage, while soil loss tolerances are expressed as average T/Ac/Yr. for the cropping sequence. Therefore, when designing a system for protection of a specific crop, the system should be designed to prevent the soil loss from exceeding the crop tolerance the year the crop is grown. Note that values are estimates.

ACCEPTABLE SOIL LOSS

Soil Loss Tolerance

The average annual soil erosion rate that can occur with little or no long term degradation of the soil resource on the field thus permitting crop productivity to be sustained economically for an indefinite period of time is called the Soil Loss Tolerance "T".

- Soil loss tolerance is assigned for each soil map unit.
- Soil loss tolerance values are published on the HEL Soils List for each soil survey area.

Acceptable Erosion Rates

When the predicted average annual erosion rate exceeds soil loss tolerance levels, the Management Period Method should be used to evaluate which management periods have the highest soil erosion rates. The planner can then help the grower/client consider alternatives to reduce the erosion during those periods to bring the average annual erosion rate down to an acceptable level.

- The WEQ is best used as a comparative tool to evaluate different conservation systems.
- At the Resource Management System (RMS) level of planning, the predicted average annual erosion rate for the conservation system cannot exceed the soil loss tolerance for the dominant soil plus one ton ("T" + 1).
- For other Conservation Management System (CMS) levels of planning authorized for specific programs or within designated areas, the predicted average annual erosion rate for the conservation system may be allowed to exceed the soil loss tolerance.

Local WEQ Modifier Procedure for Irrigated Cropland

Section 502.33 in the National Agronomy Manual allows States to list acceptable systems for irrigated cropland in Section III of the Field Office Technical Guide. These systems should adequately reduce wind erosion on irrigated cropland, based on field observation and past experience, even though the predicted average annual erosion rate exceeds soil loss tolerance. These situations are usually encountered in areas with Annual Climatic Factor "C" values of 30 or greater.

- This procedure is to be used only with predictions calculated by the Annual Method.
- Develop separate local WEQ modifiers for an acceptable conservation system for each combination of Annual Climatic Factor "C" zone and Soil Erodibility "I" Factor where needed, based on field judgment that WEQ predictions are excessive.
- Local WEQ modifiers need to be reviewed and approved by the State Agronomist.

Develop local WEQ modifiers to compare conservation systems as follows:

$$m = a / E$$

Where: m = local wind erosion prediction management modifier. (Round to two decimal places)

a = estimated (NRCS judgment) average annual erosion rate in whole Tons or nearest 0.5 Tons/acre/year of the acceptable conservation system. (Use the soil loss tolerance "T" value as a maximum.)

E = WEQ predicted average annual erosion rate in Tons/acre/year of the acceptable conservation system. (Round to nearest 0.5 Tons)

To compare an alternative conservation system to the acceptable system listed in Section III of the Field Office Technical Guide, the WEQ predicted average annual erosion rate of the alternative is multiplied by the local WEQ modifier developed for that acceptable system in the same "C" zone for the same "I" Factor.

If the result does not exceed the soil loss tolerance "T" value for the dominant soil plus one Ton/acre/year ("T" + 1), then the alternative conservation system is considered to be an acceptable system.

Example

Based on field observations and discussion with growers/clients in "C" zone 50, NRCS estimates that Conservation System 12 controls wind erosion to the soil loss tolerance level of 5 Tons/acre/year ("a") on fields where the dominant soil has an "I" Factor of 86. Using the Annual Method, the WEQ predicted average annual erosion rate is 20 Tons/acre/year ("E"). Then m = 5/20 = 0.25

Later, a planner was helping another grower/client evaluate an alternative conservation system for a field in "C" zone 50 where the dominant soil has an "I" Factor of 86. Using the Annual Method, the WEQ predicted average annual erosion rate is 24 Tons/acre/year. Multiplying by the local WEQ modifier of m = 0.25 produces a modified erosion rate of 6 Tons/acre/year.

If the soil loss tolerance "T" value for the dominant soil is 5 Tons/acre/year, then this alternative is considered to be an acceptable conservation system because the modified erosion rate does not exceed "T" + 1 Ton.

If the soil loss tolerance "T" value for the dominant soil is 4 Tons/acre/year or less, then this alternative is not an acceptable conservation system because the modified erosion rate exceeds "T" + 1 Ton.

ESTIMATING WIND EROSION BY THE ANNUAL METHOD

Start with the Annual Method first when doing conservation planning to see if the predicted erosion rate does not exceed the soil loss tolerance. If it does exceed the soil loss tolerance, then use the Management Period Method.

In California, document predictions based on the Annual Method using the March 1998 Revision of CA-CPA-14 Worksheet: WIND EROSION PREDICTION BY THE ANNUAL METHOD. There is a reproducible copy of this Worksheet at the end of this Subpart.

Use a separate Worksheet for each field having a different crop rotation. More than one Worksheet may be needed depending on the length of the rotation. Remember to document the whole crop rotation so the average annual predicted erosion rate can be calculated. For a three year crop rotation, the Worksheets need to cover all three years.

Always show a field sketch on the back of one worksheet with dimensions in feet plus:

- the crop row direction or directions if that changes between crops;
- the erosive wind direction or directions if that changes during different the year;
  - (The farther away the field is from a known weather station, the more important is to use your knowledge and that of the grower/client.)
- location of the stable area along the upwind edge of the field; and
- location of any windbreaks or other wind barriers.

Enter the symbol and name for the largest, contiguous soil map unit in the field. This is considered to be the dominant soil. The acreage from two adjacent soil mapping units having the same I and T values can be combined for the dominant soil determination. The HEL Soils List developed for each soil survey area contains the assigned I and T values for each soil mapping unit. Enter the I and T values assigned to the dominant soil. For irrigated fields, remember to use the adjusted I value from Table 5. A recheck is needed if 310 is the assigned I value because all soil mapping units in Wind Erodibility Group 1 were assigned the highest I value.

If the soil is a very fine sand,	then use I = 310
If the soil is a fine sand,	then use I = 220
If the soil is a sand or coarse sand,	then use I = 160 or 134 if irrigated

Enter the annual C factor value that best fits the field(s). Use the County Annual Wind Erosion Climatic Factor C (Percent) Map. Interpolation will be required in some cases; however, there needs to be an E Table available for that C value.

For the Critical Period, list the months with the highest percent of erosive winds. The farther away the field is from a known weather station, the more important is to use your knowledge and that of the grower/client.

ESTIMATING WIND EROSION BY THE MANAGEMENT PERIOD METHOD

Use the Management Period Method when doing conservation planning if the Annual Method predicted an erosion rate greater than the soil loss tolerance. Predictions using the Annual Method are generally higher than the Management Period Method.

In California, document predictions based on the Management Period Method using the March 1998 Revision of CA-CPA-15 Worksheet: WIND EROSION PREDICTION BY THE MANAGEMENT PERIOD METHOD. There is a reproducible copy of this Worksheet at the end of this Subpart.

This method is an excellent planning tool. Problem periods in a crop rotation are readily identifiable and alternative treatments become apparent to planners and growers/clients. Use this method when crop tolerance is a major concern and for fields where it was necessary to replant a crop due to sandblast damage.

Use a separate Worksheet for each field having a different crop rotation. More than one Worksheet may be needed depending on the length of the rotation and the number of management periods used. Remember to document the whole crop rotation so the average annual predicted erosion rate can be calculated. For a three year crop rotation, the Worksheets need to cover all three years.

Always show a field sketch on the back of one worksheet with dimensions in feet plus:

- the crop row direction or directions if that changes between crops;
- the erosive wind direction or directions if that changes during different the year;
  - (The farther away the field is from a known weather station, the more important is to use your knowledge and that of the grower/client.)
- location of the stable area along the upwind edge of the field; and
- location of any windbreaks or other wind barriers.

Enter the annual C factor value that best fits the field(s). Use the County Annual Wind Erosion Climatic Factor C (Percent) Map. Interpolation will be required in some cases; however, there needs to be an E Table available for that C value.

Enter the symbol and name for the largest, contiguous soil map unit in the field. This is considered to be the dominant soil. The acreage from two adjacent soil mapping units having the same I and T values can be combined for the dominant soil determination. Enter the I and T values assigned to the dominant soil. The HEL Soils List developed for each soil survey area contains the assigned I and T values for each soil mapping unit. A recheck is needed if 310 is the assigned I value because mapping units in Wind Erodibility Group 1 were ass assigned the highest I value.

If the soil is a very fine sand,	then use I = 310
If the soil is a fine sand,	then use I = 220
If the soil is a sand or coarse sand,	then use I = 160

CA-CPA-14 WORKSHEET
Rev. 3/98

USDA - NRCS
California

ESTIMATING WIND EROSION BY THE ANNUAL METHOD

Client/Cooperator: _____ Case File # _____ Planner : _____

County: _____ Tract #_____ Field # _____ Date: _____

Crop Rotation: _____

Tillage and Timing: _____

Soil Symbol and Name: _____ Soil Erodibility I = _____T/AC/YR

Knoll erodibility correction factor = ___ x I = ____ Corrected I (windward slope ≤ 500 FT&slope change ≥ 3 %)

Soil Loss Tolerance = _____ T/AC/YR Estimated Crop Tolerance = ____ T/AC/YR

Climatic Factor C = _____ Critical Period (Months): _____

Surface Roughness K = _____ Based on Furrow Spacing = ____ IN and Ridge Height = _____ IN

Effective Barrier Height = _____ FT x 10 = _____ FT Sheltered Distance

Barrier Height Correction Factor (if Knoll) = _____ x Barrier Height = _____ FT Sheltered Distance

Perpendicular field width of _____ FT x prevailing wind deviation angle factor of _____ = _____ FT and

Subtract Sheltered Distance protected by a barrier = _____ FT for Unsheltered Distance L

Critical Period Crop: _____ has an average of _____ LB/AC residue or cover (dry wt.)

Residue or Cover converted to flat Small Grain equivalent = _____ LB/AC of Vegetative Cover Factor V

Enter appropriate E Table for : C factor = _____ I factor = _____ K factor = _____

Predicted Average Annual Erosion = _____ T/AC/YR [BEFORE]

TREATMENT DECISION _____

_____

New K factor = _____ New V factor = _____ LB/AC New L factor = _____ FT

New Predicted Average Annual Erosion = _____ T/AC/YR [AFTER]

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ADD FIELD SKETCH ON BACK

CA-CPA-15 Worksheet
Rev. 3/98

USDA - NRCS
California

ESTIMATING WIND EROSION BY THE MANAGEMENT PERIOD METHOD

Client/Cooperator: _____ Case File # _____ Annual C = _____ Planner : _____ Date : _____

County: _____ Dominent Soil : _____ Soil I: _____ Soil T: _____

Tract # _____ Field # _____ Barrier Height = _____ FT x 10 = _____ FT of Sheltered Distance

Crop Rotation : _____

Tillage and Timing: _____

Crops & Cultural Operations	Period Begin/End Dates		I with Adj.	Ridge Roughness						Unsheltered Distance					Vegetation V		E T/AC	EWE %	Adj. EWE	Period Erosion
				Ht. x Spacing	Prev. Wind	Dev	K	Krr	K x Krr	Dev	Prep	Field Width	WDF	L	Kind, Amount Orientation	SGe				

Notes:

Crop Tolerance = ____ T/Ac for _____ Years in Rotation = _____ Total Predicted Erosion in Tons = _____

Crop Tolerance = ____ T/Ac for _____

Average Annual Erosion in T/Ac/Yr = _____

TREATMENT DECISION : _____

ADD FIELD SKETCH ON BACK

Page ____ of ____

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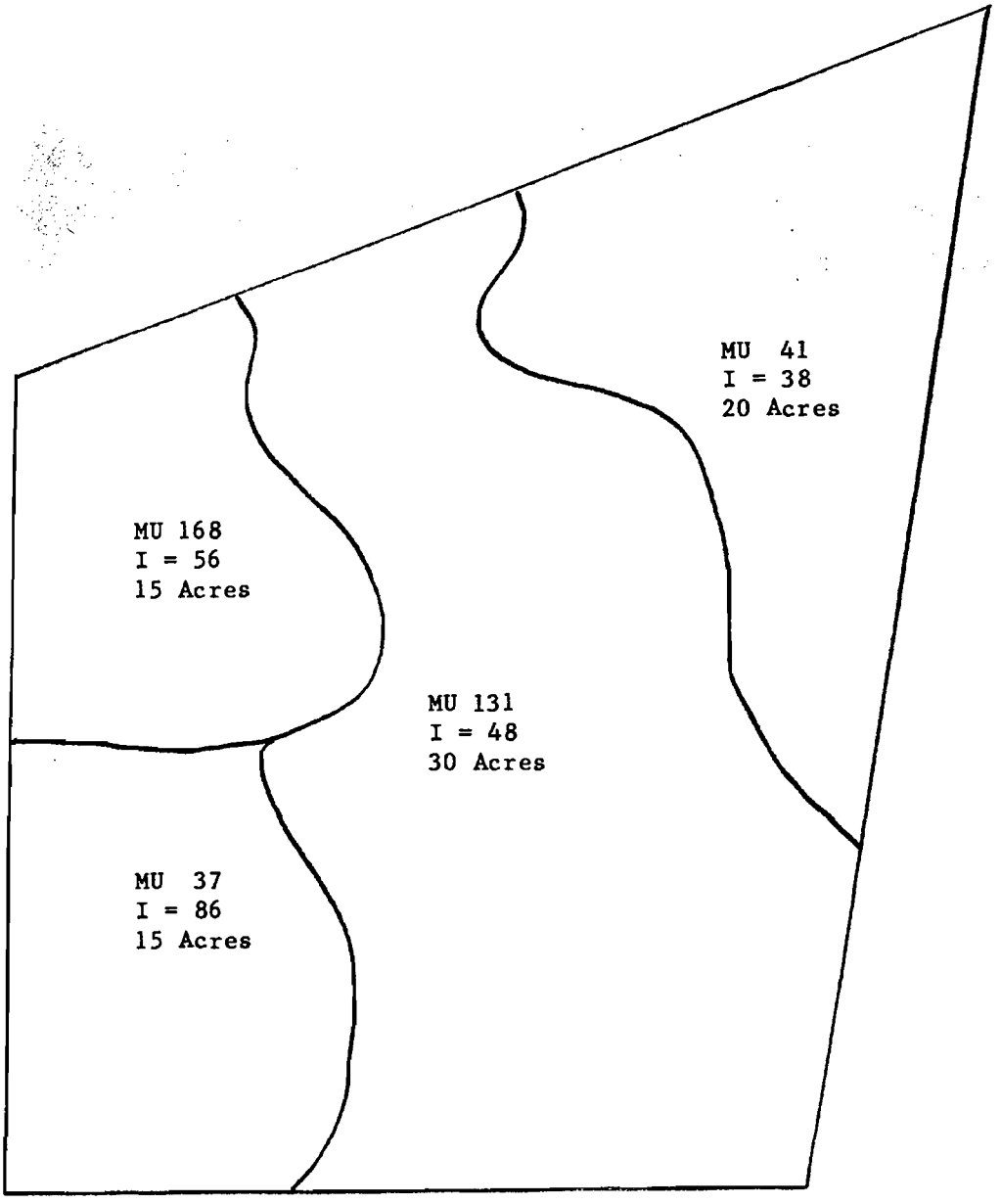
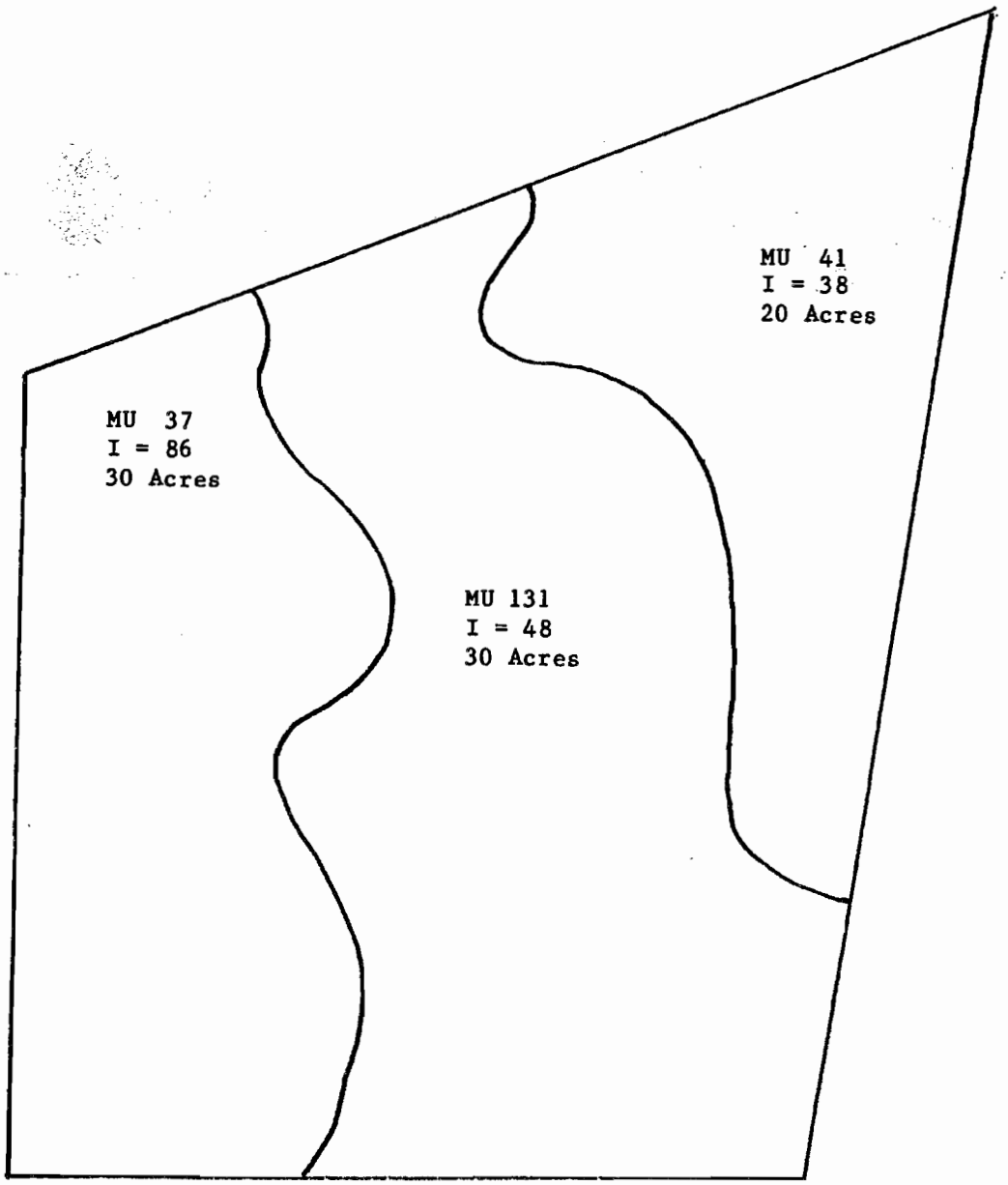
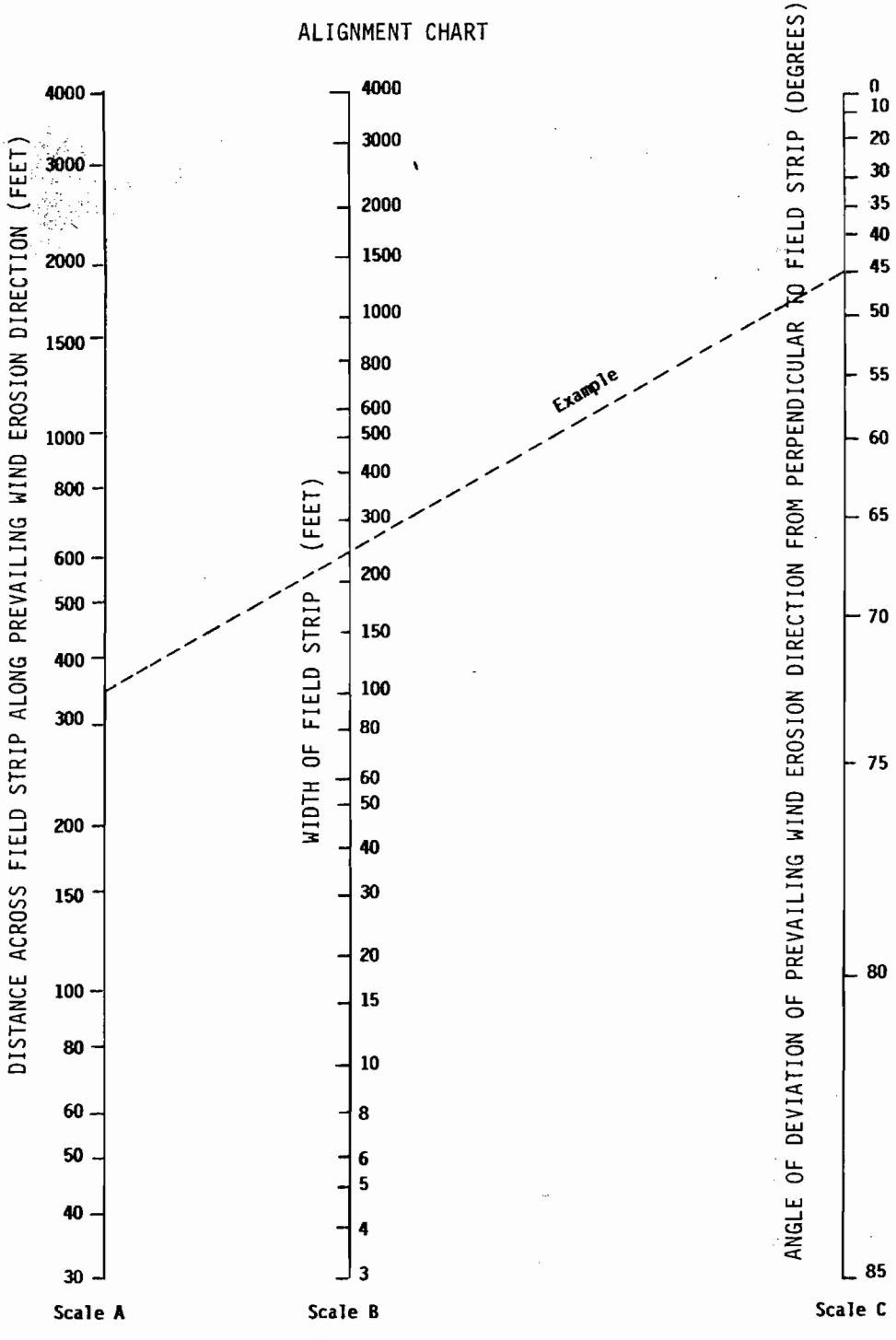


DOMINANT SOIL IS MU 131 - THE LARGEST, CONTIGUOUS SOIL MAPPING UNIT



DOMINANT SOIL IS MU 37 - EQUALLY LARGE, CONTIGUOUS SOIL MAPPING UNIT BUT HAS THE HIGHER "I" VALUE

ALIGNMENT CHART



Instructions - Select the angle of deviation (Scale C). Run a straight line through the numbers representing field or strip width (Scale B) to Scale A. Scale A gives the distance across the field or strip along the path traveled by the wind.

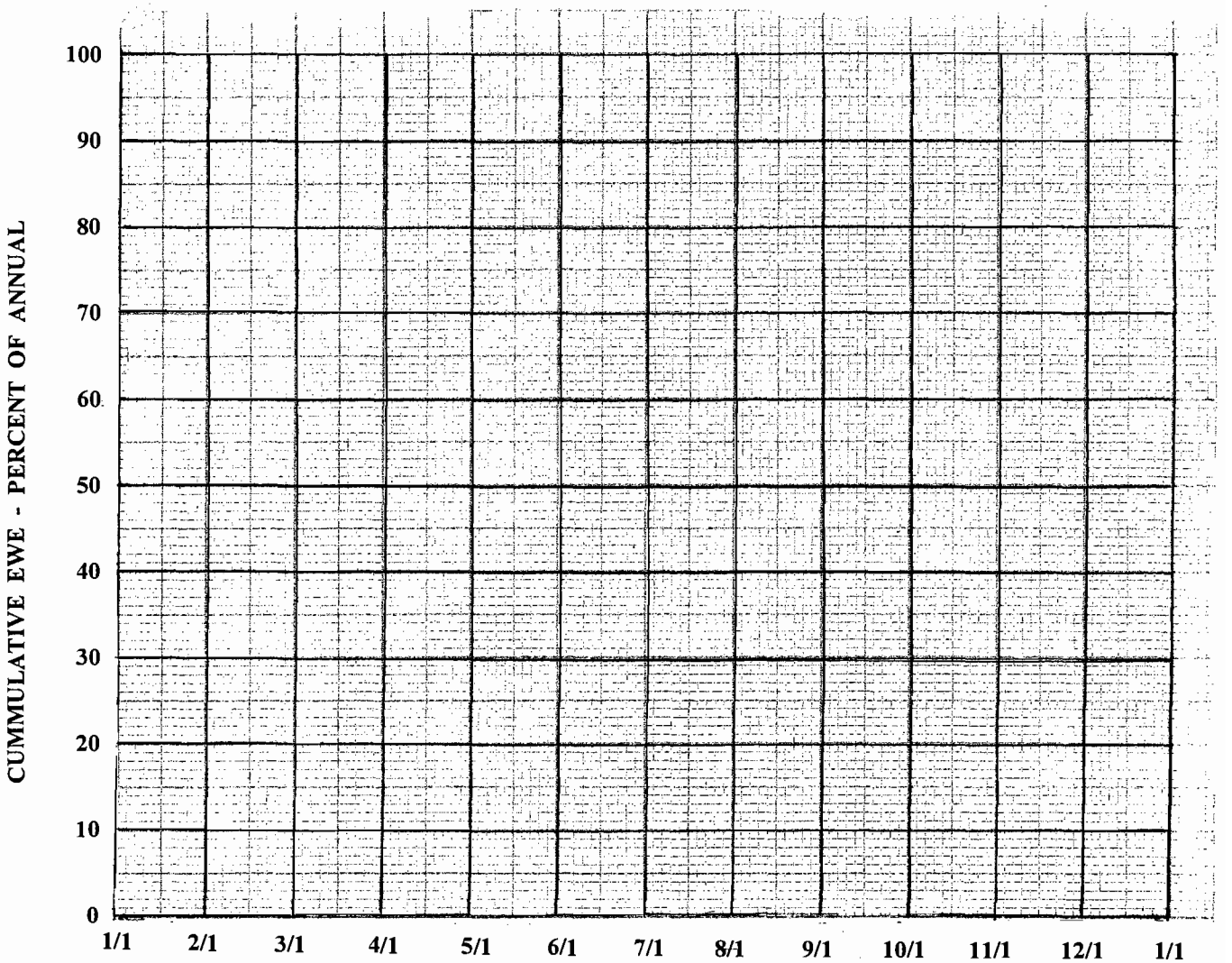
CA-CPA WORKSHEET
Rev. 3/98

USDA - NRCS
California

AVERAGE ANNUAL EROSIVE WIND ENERGY (EWE) DISTRIBUTION CURVE

Station/Location: _____ **Planner :** _____

Reference: _____ **Date:** _____



CUMMUL. EWE: _____

MONTHLY EWE:

POINTS ON CURVE:

Exhibit 502.64(a) Prevailing Wind Erosion Direction and Preponderence of Wind Erosion Forces in Prevailing Wind Erosion Direction

ITEM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
YUMA, ARIZONA (SEPT. 1952 - JAN. 1963)												
DIRECTION	0	0	337	293	135	157	157	157	158	337	0	0
PREPONDERANCE	2.6	2.1	1.5	1.5	1.7	2.2	3.0	2.5	1.9	1.4	2.4	2.7
ARCATA, CALIFORNIA (DEC. 1949 - NOV. 1958)												
DIRECTION	135	315	315	315	315	315	315	315	315	336	135	135
PREPONDERANCE	2.3	2.8	3.3	3.9	4.4	6.6	6.9	5.0	3.6	2.1	3.1	2.5
BISHOP, CALIFORNIA (JAN. 1948 - JAN. 1957)												
DIRECTION	0	0	0	0	0	180	158	180	180	180	0	0
PREPONDERANCE	4.1	4.0	3.2	2.6	2.0	2.4	2.1	2.3	2.5	3.6	5.7	3.9
BLYTHE, CALIFORNIA (AUG. 1942 - MAY 1944)												
DIRECTION	0	0	0	225	180	225	180	180	180	203	0	337
PREPONDERANCE	2.3	2.4	2.2	2.3	1.4	2.1	1.9	3.9	1.8	1.9	4.2	1.9
CHINA LAKE, CALIFORNIA (APR. 1945 - DEC. 1959)												
DIRECTION	203	225	225	225	225	225	225	203	225	225	225	225
PREPONDERANCE	1.6	1.7	1.7	1.6	1.8	2.0	2.1	2.4	2.4	1.9	1.6	1.7
EL CENTRO, CALIFORNIA (FEB. 1945 - APR. 1946, NOV. 1946 - FEB. 1958)												
DIRECTION	248	248	248	248	248	270	270	270	270	270	270	248
PREPONDERANCE	1.6	2.0	2.9	3.6	3.8	3.7	2.1	2.3	2.6	4.1	1.6	1.4

Exhibit 502.64(a) (continued)

ITEM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
FORT BRAGG, CALIFORNIA (JUNE 1943 - MAY 1945)												
DIRECTION	113	315	315	315	337	315	338	337	337	135	113	135
PREPONDERANCE	2.3	2.3	2.3	4.3	4.1	4.5	3.9	3.7	4.5	3.6	1.7	1.6
FRESNO, CALIFORNIA (MAY 1950 - APR. 1955)												
DIRECTION	157	315	315	315	315	293	293	293	315	158	135	315
PREPONDERANCE	2.7	2.9	3.1	2.6	2.2	4.6	4.2	3.1	2.4	1.9	2.0	2.0
MARYSVILLE, CALIFORNIA (AUG. 1943 - OCT. 1944)												
DIRECTION	157	135	315	135	135	135	135	157	315	135	315	338
PREPONDERANCE	3.3	4.3	3.0	3.2	6.4	4.6	3.6	3.2	4.9	4.6	9.3	1.9
MERCED, CALIFORNIA (JAN. 1942 - NOV. 1946, DEC. 1947 - DEC. 1952)												
DIRECTION	135	135	337	337	337	337	337	337	337	337	315	135
PREPONDERANCE	3.8	3.5	3.3	4.2	3.3	3.6	4.0	4.0	3.6	3.6	3.5	4.1
PALMDALE, CALIFORNIA (JAN. 1934 - DEC. 1941, NOV. 1948 - NOV. 1952)												
DIRECTION	247	225	247	225	225	225	225	225	225	225	248	225
PREPONDERANCE	1.8	2.1	1.6	2.0	2.4	4.2	5.7	5.0	4.3	2.4	1.9	1.7
RIVERSIDE, CALIFORNIA (JAN. 1933 - DEC. 1934, FEB., APR. - JUNE 1935, FEB. 1936 - JULY 1941, SEP. 1941 - MAY 1953)												
DIRECTION	23	338	293	293	293	293	315	293	293	293	67	69
PREPONDERANCE	1.2	1.2	1.6	2.0	2.5	2.8	3.6	3.7	3.1	2.3	1.1	1.4
SALINAS, CALIFORNIA (AUG. 1941 - DEC. 1944)												
DIRECTION	135	135	135	293	292	292	292	315	315	315	135	135
PREPONDERANCE	6.8	4.5	3.5	2.8	3.0	3.3	3.4	3.2	4.2	3.0	4.2	5.3

Exhibit 502.64(a) (continued)

ITEM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SAN DIEGO, CALIFORNIA (JAN. 1951 - DEC. 1960)												
DIRECTION	180	180	180	202	248	203	293	248	293	203	180	337
PREPONDERANCE	1.5	1.5	1.4	1.3	1.1	1.2	1.3	1.1	1.5	1.4	1.4	1.3
SAN MIGUEL ISLAND, CALIFORNIA (FEB. 1940 - JUNE 1942)												
DIRECTION	157	157	337	337	315	315	293	315	315	293	294	337
PREPONDERANCE	2.8	4.0	2.6	4.0	3.2	4.1	5.4	2.6	2.6	4.6	3.5	3.6
SANTA ROSA, CALIFORNIA (APR. 1943 - DEC. 1945)												
DIRECTION	315	0	202	315	202	159	180	158	180	180	180	0
PREPONDERANCE	3.1	1.9	1.6	1.6	1.4	1.4	2.7	2.1	1.6	1.7	1.5	4.8
STOCKTON, CALIFORNIA (FEB. 1941 - JUNE 1946)												
DIRECTION	235	316	315	315	270	270	270	270	292	315	135	135
PREPONDERANCE	4.0	2.2	2.5	2.0	1.7	2.4	3.1	2.9	2.5	3.7	2.1	2.3
THERMAL, CALIFORNIA (JULY 1943 - FEB. 1945)												
DIRECTION	337	157	337	337	337	337	337	157	337	337	337	315
PREPONDERANCE	2.4	2.6	2.3	4.3	3.0	4.4	3.7	4.3	4.1	2.6	2.8	3.4
VICTORVILLE, CALIFORNIA (JAN. 1942 - FEB. 1946, MAY - SEPT. 1948, SEPT. 1950 - JUNE 1957)												
DIRECTION	193	270	251	270	270	225	180	180	180	248	248	248
PREPONDERANCE	1.1	1.2	1.3	1.4	1.3	1.1	2.0	1.8	1.4	1.2	1.3	1.4
KLAMATH FALLS, OREGON (JAN. 1948 - DEC. 1954, SEPT. 1959 - AUG. 1962)												
DIRECTION	180	158	157	157	337	320	337	337	158	159	158	158
PREPONDERANCE	1.8	1.8	1.3	1.5	1.6	1.3	2.0	1.8	1.4	1.9	2.0	1.4