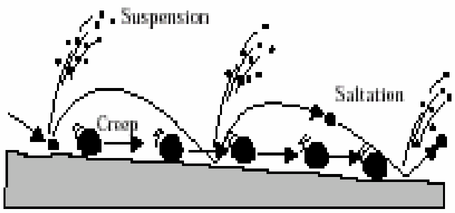
WEQ Introduction and Background

Wind erosion science
Wind is an erosive agent. It detaches and transports soil particles, sorts the finer from the coarser particles, and deposits them unevenly. Loss of the fertile topsoil in eroded areas reduces the rooting depth and, in many places, reduces crop yield. Abrasion by airborne soil particles damages plants and constructed structures. Drifting soil causes extensive damage and if deposited in drainage ditches or creeks it can impair water quality from phosphorus attached to the soil particles. Sand and dust in the air can harm animals, plants, humans, and equipment.

Wherever the soil surface is loose and dry, vegetation is sparse or absent, and the wind sufficiently strong, erosion will occur unless control measures are applied (1957 Yearbook of Agriculture). In Michigan, the regions subject to damaging wind erosion are the muck and sand textured soil types. In some areas, the primary problem caused by wind erosion is crop damage. Some crops are tolerant enough to withstand or recover from erosion damage. Other crops, including many vegetables and specialty crops, are especially vulnerable to wind erosion damage. Wind erosion may cause significant short-term economic loss where sensitive crops are easily damaged by abrasion and desiccation from saltation. Plants are often severely damaged even when erosion rates are below the soil loss tolerance (T) (see Crop Tolerances to Blowing Soil, Table 7).

Figure 502-1 The wind erosion process



The wind erosion process
The wind erosion process is complex. It involves detaching, transporting, sorting, abrading, avalanching, and depositing of soil particles. Turbulent winds blowing over erodible soils cause wind erosion. Field conditions conducive to erosion include:

- Loose, dry, and finely granulated soil;
- Smooth soil surface that has little or no vegetation present;
- Sufficiently large area susceptible to erosion; and
- Sufficient wind velocity to move soil.

Winds are considered erosive when they reach 13 miles per hour at 1 foot above the ground or about 18 miles per hour at a 30-foot height. This is commonly referred to as the threshold wind velocity (Lyles and Krauss 1971).

The wind transports primary soil particles or stable aggregates, or both, in three ways (Figure 502-1):

Saltation—Individual particles/aggregates ranging from 0.1 to 0.5 millimeter in diameter lift off the surface and follow distinct trajectories under the influence of air resistance and gravity and return to the surface. Whether they rebound or embed themselves, they initiate movement of other particles/aggregates to create the *avalanching* effect. Saltating particles are the abrading *bullets* that remove the protective soil crusts and clods. Most saltation occurs within 12 inches above the soil surface. From 50 to 80 percent of total transport is by saltation.

Suspension—The finer soil particles, less than 0.1 millimeter in diameter, are dislodged from an eroding area by saltation and remain in the air mass for an extended period. Some suspension-sized particles or aggregates are present in the soil, but many are created by abrasion of larger aggregates during erosion. From 20 percent to more than 60 percent of an eroding soil 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.

Surface creep—Sand-sized particles/aggregates are set in motion by the impact of saltating particles. Under high winds, the whole soil surface appears to be creeping slowly forward as particles are pushed and rolled by the saltation flow. Surface creep may account for 7 to 25 percent of total transport (Chepil 1945 and Lyles 1980).

Saltation and creep particles are deposited in vegetated strips, ditches, or other areas sheltered from the wind, as long as these areas have the capacity to hold the sediment. Particles in suspension, however, may be carried a great distance. The rate of increase in soil flow along the wind direction varies directly with erodibility of field surfaces.

The increase in erosion downwind (**avalanching*)*** is associated with the following processes:

- The increased concentration of saltating particles downwind increases the frequency of impacts and the degree of breakdown of clods and crusts, and
- The accumulation of erodible particles and breakdown of clods tends to produce a smoother (and more erodible) surface.

For any soil, the distance required for soil flow to reach a maximum soil is the same for any erosive wind and the more erodible the surface, the shorter the distance in which maximum flow is reached. Any factor that influences the erodibility of the surface influences the increase in soil flow.

Estimating wind erosion

Using the Wind Erosion Equation (WEQ), NRCS estimates erosion rates to:

- Provide technical assistance to land users,
- Inventory natural resources, and
- Evaluate the effectiveness of conservation programs and conservation treatment applied to the land.

Wind erosion is difficult to measure. Wind moves across the land in a turbulent, erratic fashion. Soil may blow into, within, and out of a field in several directions in a single storm. The direction, velocity, duration, and variability of the wind all affect the erosion that occurs from a windstorm. Much of the soil eroding from a field bounces or creeps near the surface; however, some of the soil blown from a field may be high above the ground in a dust cloud by the time it reaches the edge of a field (Chepil 1963).

Methods of estimating wind erosion

No precise method of measuring wind erosion has been developed. However, various dust collectors, remote and in-place sensors, wind tunnels, sediment samplers, and micro-topographic surveys before and after erosion have been used. Each method has its limitations. Research is continuing on new techniques and new devices, on modifications to older ones, and on means to measure wind erosion.

Estimates of wind erosion can be made by assigning numerical values to the site conditions describing wind erosion conditions and expressing their relationships mathematically. This is the basis of the current Wind Erosion Equation (WEQ) that considers soil erodibility, ridge roughness, climate, unsheltered distance, and vegetative cover.

The wind erosion equation (WEQ)

The Wind Erosion Equation (WEQ) erosion model is designed to predict long-term average annual soil losses from a field having specific characteristics. With appropriate selection of factor values, the equation will estimate average annual erosion.

The present Wind Erosion Equation is expressed as: **$E = f(IKCLV)$** where:
E = estimated average annual soil loss in tons per acre per year
f = indicates relationships that are not straight-line mathematical calculations
I = soil erodibility index
K = soil surface roughness factor

C = climatic factor
L = the unsheltered distance
V = the vegetative cover factor

The **I** factor is the average annual soil loss in tons per acre per year from a field area. The "I" factor accounts for the inherent soil properties affecting erodibility. These properties include texture, organic matter, and calcium carbonate percentage. "I" is the potential annual wind erosion for a given soil under a given set of field conditions. The given set of field conditions for which "I" is referenced is that of an isolated, unsheltered, wide, bare, smooth, level, loose, and noncrusted soil surface, and at a location where the climatic factor (C) is equal to 100. For a particular location, the following factors are used to estimate the wind erosion rate:

The **K** factor is a measure of the effect of ridges made by tillage and planting implements. It is expressed as a decimal from 0.4 to 1.0. "K" is obtained using the ridge spacing and height and defining the angle of deviation of the wind compared to equipment operation across the field.

The **C** factor is characterizes climatic wind speed and surface soil moisture. It is a percentage of the wind forces measured by ARS research at Garden City, Kansas, that has an assigned C value of 100.

The **L** factor considers the unprotected distance along the prevailing erosive wind direction across the area to be evaluated. It starts where no surface creep or saltation occurs and ends at the downwind edge of the contributing area. If the windward edge of the field is not stable, the measurement starts at the nearest stable point upwind. It is measured across the field along the prevailing wind erosion direction on a map to scale. If the barrier is present on the windward side of the field, "L" is adjusted for the barrier's sheltered distance. Examples of stable areas include grass, hedges, roadways with grass borders at least 12 feet wide and 1 foot tall, or drainage ditches (see Figure 502-7).

The **V** factor considers the kind, amount, and orientation of vegetation on the surface. The vegetative cover is expressed in pounds per acre of a flat small-grain residue equivalent (SGE). It is obtained by determining the amount, kind, and orientation of cover, then converting to Flat Small Grain Equivalent (SGE), in lbs/acre, to SGE (see charts at the end of this section).

Solving the equation involves five successive steps: Steps 1, 2, and 3 are solved by multiplying the factor values, and Steps 4 and 5, determining the effects of "L" and "V," involve more complex functional relationships.

Step 1: Determine the Soil Erodibility Index **(I)** for the soil type from Exhibit 502-5 (or Table 4 in the Water Erosion Prediction, Section I, NRCS, Michigan eFOTG).

Select factor "I" for the specific soil. "I" is increased for knolls less than 500 feet long facing into the prevailing wind, or decreased to account for irrigation where irrigation scheduling is used.

Step 2: Determine the Soil Surface Roughness Factor **(K)** (see Table 5).
Factor "K" adjusts the "I" factor for tillage-induced oriented roughness.

Step 3: Determine the Climatic Factor **(C)** (see Table 2).
Factor "C" adjusts "I" and "K" for the local climatic factor.

Step 4: Determine the Length of the Unsheltered Distance **(L)**. "L" is either calculated or measured along the prevailing wind erosion direction. Factor "L" adjusts "I," "K," and "C" for unsheltered distance.

Step 5: Determine the Vegetative Factor **(V)** Small grain equivalent or (SGE) (see Table1).
Factor "V" adjusts "I," "K," "C," and "L" for vegetative cover present on the soil surface.

Step 6*:* Lookup the Estimated Annual Erosion **(E)**. See (Table 6) with the correct “C,” “I,” and “K” values.

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 moving all the soil it can carry across a given surface, the inflow into a downwind area is equal to the outflow for saltation and creep. The net soil loss from this specific area of the field 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. Surface armoring by gravel is not usually addressed in the **I** factor. The equation does not account for snow cover or seasonal changes in soil erodibility. The equation does not estimate erosion from single storm events.

Alternative procedures for using the WEQ

The WEQ Critical Period Procedure is based on use of the Wind Erosion Equation as described by Woodruff and Siddoway in 1965 (Woodruff and Siddoway 1965). The conditions during the critical wind erosion period are used to derive the estimate of annual wind erosion. This is the method used in Michigan and surrounding states. Farther west a "Management Period Method" is used. The "Critical Period Method" best fits Michigan's climate situation.

- The Critical Wind Erosion Period is described as the time of year when the greatest wind erosion can be expected to occur from a field under an identified management system. It is the period when vegetative cover, soil surface conditions, and expected erosive winds result in the greatest potential for wind erosion.
- Erosion estimates developed using the critical period procedure are made using a single set of factor values in the equation to describe the critical wind erosion period conditions.
- The critical period procedure is currently used for resource inventories. NRCS usually provides specific instructions on developing wind erosion estimates for resource inventories.

Using WEQ estimates with Revised Universal Soil Loss Equation 2 (RUSLE2) calculations

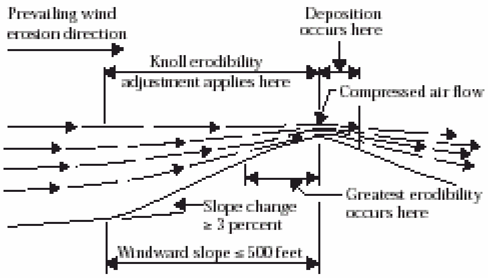
The WEQ provides an estimate of average wind erosion from the field width along the prevailing wind erosion direction (L) entered in the calculation. RUSLE 2 calculations provide an estimate of average sheet and rill water erosion from the slope length (L) entered for water erosion calculation. Although both wind and water erosion estimates are in tons per acre per year, they are only additive when L in the two equations represent identical flow paths and land areas.

Tools for using the WEQ - To determine average tons of soil loss per acre per year by wind erosion.

Graphs and tables are used to determine factor values and the needed charts and graphs are included in this document.

E tables - The ARS WEROS (Wind Erosion) computer program generates tables that give estimated erosion (E values) for most of the possible combinations of I, K, C, L, and V. Additional E tables are available for specific locations across the nation in the NRCS National Agronomy Manual.

Figure 502-2 Graphic of knoll erodibility



Knoll erodibility—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 knolls. Erosion that begins on knolls often affects field areas downwind.

Adjustments of the Soil Erodibility Index (**I**) are used where windward-facing slopes are less than 500 feet long and the increase in slope gradient from the adjacent landscape is 3 percent or greater. Both slope length and slope gradient change are determined along the direction of the prevailing erosive wind (Figure 502–2).

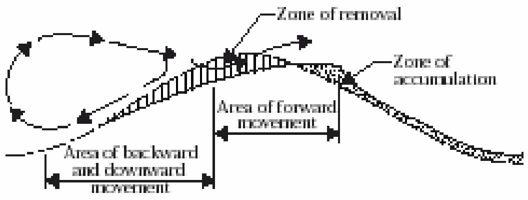
Table 3 contains knoll erodibility adjustment factors for the Soil Erodibility Index **I**. The **I** value for the Wind Erodibility Group is multiplied by the factor shown in column A. This adjustment expresses the average increase in erodibility along the knoll slope. For comparison, column B shows the increased erodibility near the crest (about the upper 1/3 of the slope), where the effect is most severe. No adjustment of **I** for knoll erodibility is made on level fields, or on rolling terrain where slopes are longer and slope changes are less abrupt. Where these situations occur, the wind flow pattern tends to conform to the surface and does not exhibit the flow constriction typical of knolls.

Surface crusting—Because of the temporary nature of crusts, no adjustment for crusting is made for annual estimates based on the critical wind erosion period method (Woodruff and Siddoway 1973).

Irrigation adjustments—The (**I)** values for irrigated soils, as shown in Exhibit 502–5 are applicable throughout the year. **I** value adjustments for irrigation are applicable only where assigned **I** values are 180 or less and in Michigan ***where irrigation scheduling via Irrigation Water Management (NRCS MI 449 standard) is followed.***

The **I** factor adjustment may be used where applicable in determining whether an adequate conservation system is being followed. Do not use **I** factor adjustments in the erodibility index (CI/T) when determining highly erodible land because this index is the potential erodibility and not an estimate of actual erosion. Follow current instructions when estimating wind erosion for the National Resources Inventory (NRI) These instructions do not allow for any adjustment of the **I** factor. This ensures uniformity between States and allows for better trend analysis.

Figure 502-3 Detachment, transport, and deposition on ridges and furrows



Soil roughness factor K, ridge roughness
K is a measure of the effect of ridges made by tillage and planting implements. Ridges absorb and deflect wind energy and trap moving soil particles (Figure 502–3). The Kr value is based on a standard ridge height to ridge spacing ratio of 1:4. Because of the difficulty of determining surface roughness by measuring surface obstructions, a standard roughness calibration using non-erodible gravel ridges in a wind tunnel was developed.

This calibration led to the development of curves (Figure 502–4 and Exhibit 502–4 - found in the National Agronomy Manual) that relate ridge roughness, Kr, to a soil ridge roughness factor, K, (Skidmore 1965; Skidmore and Woodruff 1968; Woodruff and Siddoway 1965; and Hagen 1996). The Kr curves are the basis for charts and tables used to determine K factor values in the field (see Table 5). The effect of ridges varies as the wind direction and erodibility of the soil change. To take into account the change in wind directions across a field, we consider the angle of deviation. The angle of deviation is the angle between the prevailing wind erosion direction and a line perpendicular to the row direction. The angle of deviation is 0 (zero) degrees when the wind is perpendicular to the row and is 90 degrees when the wind is parallel to the row.

For Wind Erodibility Groups 1 and 2, always use a K of 1.0 on soils with a soil erodibility factor I of 134 or higher. These soils will level off during wind storms and result in a smooth condition unless ridges are rebuilt.

Unsheltered distance, L

Figure 502-5 Unsheltered distance L

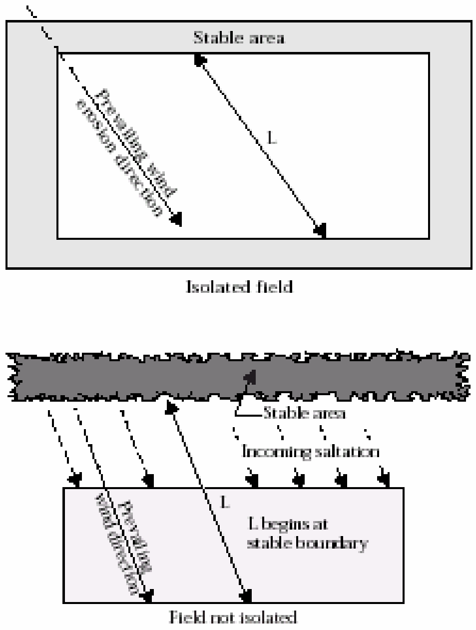


Figure 502-6 Unsheltered distance L, perennial vegetation (pasture or range)

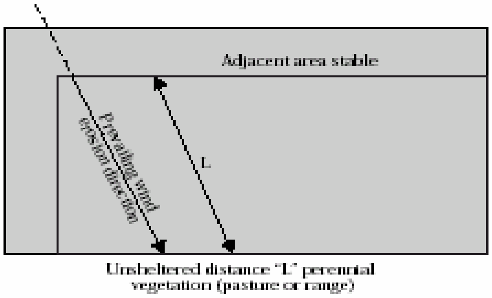
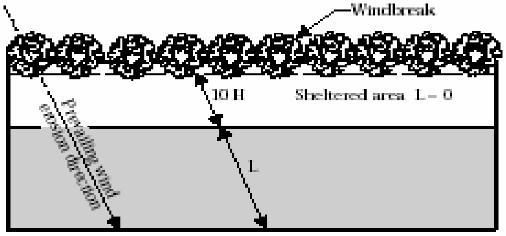


Figure 502-7 Unsheltered distaqnce L – windbreak or barrier



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 was bare except for vegetative barriers.

1. 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 502–5). The point may be at a field border or stable area where vegetation is sufficient to eliminate the erosion process. An area should be considered stable only if it is able to trap or hold virtually all expected saltation and surface creep from upwind. If vegetative barriers, grassed waterways, or other stable areas divide an agricultural field being evaluated, each are will be *isolated* and shall be evaluated as a separate *field*. For a grassed area to be stable it must meet the following criteria: 1) Width of 12-15 feet; and 2) Height of 1 to 2 foot. Refer to the appropriate NRCS Michigan Conservation Practice Standards to determine when practices are of adequate width, height, spacing, and density to create a stable area.

2. When erosion estimates are being calculated for cropland or other relatively unstable conditions, upwind pasture should be considered a stable border (Figure 502–6). The only case where L is equal to zero is where the area is fully sheltered by a barrier.

3. When a barrier is present on the upwind side of a field, measure L across the field along the prevailing wind erosion direction and subtract the distance sheltered by the barrier. Use 10 times the barrier height (10H) for the sheltered distance (Figure 502–7).

4. When a properly designed wind strip cropping system is applied, alternate strips are protected during critical wind erosion periods by a growing crop or by crop residue. These strips are considered stable. L is measured across each erosion-susceptible strip, along the prevailing wind erosion

direction. The prevailing wind erosion direction is the direction from which the greatest amount of erosion occurs during the critical wind erosion period. The direction is usually expressed as one of the 16 compass points. See Table 4A for historical Michigan Wind Erosion Direction data by month and Table 4B for the 16 compass points.

L can be measured directly on a map:

- For uses of the Wind Erosion Equation involving a single annual calculation, L should be the measured distance across the area in the prevailing wind erosion direction from the stable upwind edge of the field to the downwind edge of the field. Use the closest prevailing wind erosion direction location for the critical period being evaluated.
- When the prevailing wind erosion direction is at an angle that is not perpendicular to the long side of the field, L can be determined by multiplying the width of the field by the appropriate conversion factor obtained from Table 3. Multiply the width of the field by the "Adjustment Factor." This is the L for the field.
- If a barrier is on the upwind side of the field, reduce L by a distance equal to 10 times the height of the barrier.

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 small grain residue in reference condition Small Grain Equivalent (SGE). This condition is defined as 10-inch long stalks of small grain, parallel to the wind, lying flat in rows spaced 10 inches apart, perpendicular to the wind. ARS has tested several crops in the wind tunnel to determine their SGE.

For other crops, small grain equivalency has been computed using various regression techniques (Armbrust and Lyles 1985; Lyles and Allison 1980; Lyles 1981; Woodruff et al. 1974; Woodruff and Siddoway 1965). NRCS personnel have estimated SGE curves for other crops. SGE curves are referenced in this document. Orientation and anchoring of residue is important. In general, the finer and more upright the residue, the more effective it is for reducing wind erosion. Knowledge of these and other relationships can be used with benchmark values to estimate additional SGE values.

Often the task is to predict what will be in the field in some future season or seasons. Amounts of vegetation may be predicted from production records or estimates and these amounts are then reduced by the expected or planned tillage. It may be desirable to sample and measure existing residue to determine quantity of residue. Local data should be developed to estimate surface residue per unit of crop yield and crop residue losses caused by tillage. (For Michigan, use the charts that use the Residue Conversion Procedure to Convert % Residue Cover to SGE.)

Principles of wind erosion control

Five principles of wind erosion control have been identified (Lyles and Swanson 1976; Woodruff et al. 1972; and Woodruff and Siddoway 1965). They are as follows:

1. Establish and maintain adequate vegetation or other land cover.
2. Reduce unsheltered distance along wind erosion direction.
3. Produce and maintain stable clods or aggregates on the land surface.
4. Roughen the land with ridge and/or random roughness.
5. Reshape the land to reduce erosion on knolls where converging wind flow causes increased velocity and shear stress.

The *cardinal rule* of wind erosion control is to strive to keep the land covered with vegetation or crop residue at all times (Chepil 1956). This leads to several principles that should be paramount as alternative controls are considered:

1. Return all land unsuited to cultivation to permanent cover.

2. Maintain maximum possible cover on the surface during wind erosion periods.
3. Maintain stable field borders or boundaries at all times.

Relation of control to WEQ factors

The Wind Erosion Equation (WEQ) was developed to relate specific field conditions to estimated annual soil loss. Of the five factors, two (**I** and **C**) are often considered to be *fixed* while the other three (**K**, **L**, and **V**) are generally considered *variable* or management factors.

The **I** factor is related to the percentage of dry surface soil fractions greater than 0.84 millimeters. Its derivation is usually based on the Wind Erodibility Group.

Ridge roughness (**K**) relates to ridge spacing in the wind erosion direction. Even with optimum orientation of rows, some of the winds will be blowing parallel to the rows when preponderance is low.

The **C** factor is based on long-term weather records. Conservation treatment should be planned to address the critical climatic conditions when high seasonal erosive wind energy is coupled with highly erodible field conditions.

The unsheltered distance **L** is a management factor that can be changed by altering field arrangement, stripcropping, or establishing windbreaks or other barriers. **L** is a function of field layout as it relates to prevailing wind direction and preponderance of erosive winds in the prevailing direction. When preponderance values are high (more than 2.5 and approaching 4.0), conservation treatment should be concentrated on addressing potential erosion from the prevailing wind erosion direction.

When preponderance values are low (approaching 1.0), knowledge of local seasonal wind patterns becomes more important in planning treatment. Conservation treatment should be planned to allow for the effect of seasonal changes in the prevailing wind erosion direction.

A stable strip across an agricultural field divides the area into separate fields. Examples of stable areas include grass waterways, hedges and their sheltered area, brushy draws or ravines, roadways with grass borders, grass strips, and drainage or irrigation ditches. A stable area must stop and hold virtually all of the expected saltation and surface creep. If an area is stable during one crop stage, it may not be stable in other seasons.

V is the equivalent vegetative cover maintained on the soil surface. It is directly related to the management functions of crop establishment, tillage, harvesting, grazing, mowing, or burning.

Tolerances in wind erosion control

In both planning and inventory activities, NRCS compares estimated erosion to soil loss tolerance (T). T is expressed as the average annual soil erosion rate (tons/acre/year) that can occur in a field with little or no long-term degradation of the soil resource, thus sustaining crop productivity for an indefinite period.

Soil loss tolerances for a named soil are recorded in the soil survey database, in NASIS. The normal planning objective is to reduce soil loss by wind or water to T or lower. In situations where treatment for both wind and water erosion is needed, soil loss estimates using the WEQ or RUSLE 2 are not added together to compare to T.

Consider additional potential offsite damaging impacts of wind erosion such as air and water pollution or the deposition of soil particles.

Also, crop tolerance to soil blowing is an important consideration in wind erosion control. Wind or blowing soil, or both, can have an adverse effect on growing crops. Most crops are more susceptible to abrasion or other wind damage at certain growth stages than at others. Damage can result from desiccation and twisting of plants by the wind.

Crop tolerance is defined as the maximum wind erosion that a growing crop can tolerate, from crop emergence to field stabilization, without an economic loss to crop stand, crop yield, or crop quality.

(a) Blowing soil effects on crops

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

1. Excessive wind erosion that removes planted seeds, tubers, or seedlings.
2. Exposure of plant root systems.
3. Burial of plants by drifting soil.
4. 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.

(b) Crop tolerance to blowing soil or wind (See Table 7, Crop Tolerances to Blowing Soil)

Many common crops have been categorized based on their tolerance to blowing soil. These categories of some typical crops are listed in Table 7. Crops may tolerate greater amounts of blowing soil than shown in Table 7, but yield and quality may be adversely affected.

(c) The effects of wind erosion on water quality

Some of the adverse effects of wind erosion on water quality include:

- Deposition of phosphorus (P) into surface water.
- Increased Biochemical Oxygen Demand (BOD) in surface water.
- Reduced stream conveyance capacity because of deposited sediment in streams and drainage canals.

Local water quality guidelines under Total Maximum Daily Loads (TDML) for nutrients may require that wind erosion losses be less than the soil loss tolerance (T) in order to achieve local phosphorus (P) or other pollutant reduction goals. For a phosphorus (P) entrapment estimation procedure, see the NRCS National Core 4 Manual, Chapter 3C, Cross Wind Trap Strips.

Procedure to Use the Wind Erosion Equation

The Wind Erosion Equation is expressed as: E = *f* (IKCLV) where:

E = estimated average annual soil loss in tons per acre per year
f = indicates relationships that are not straight-line mathematical calculations
I = soil erodibility index
K = soil surface roughness factor
C = climatic factor
L = the unsheltered distance
V = the vegetative cover factor

WEQ Procedural Steps:

Step 1: Determine the Soil "I" Value
Refer to the County Soils Data found in **Section II of the FOTG** to determine the "I" value or Michigan NRCS Electronic Technical Guide Section I, Erosion prediction-water Table 4. The "I" is adjusted for knoll erodibility from Table 3 if applicable. The adjusted "I" value applies only to that area affected by knoll erosion.

Step 2: Determine the Soil Roughness (Ridge) Value (Krd)
Factor K adjusts the "I" factor for tillage-induced oriented roughness, K (ridges). Refer to Table 5 to determine the "K" value. It is expressed as a decimal from 0.5 to 1.0.

Step 3: Determine the Climatic Factor
Factor C adjusts "I" and "K" for the local climatic factor.
See Table 2 for County Climatic Factors. C factors in Michigan range from 5 - 8. A Climatic factor of 8 is eight percent of the wind erosion that would occur at Garden City, Kansas, under the reference condition.

Step 4: Determine the "L" - Length of the Unsheltered Distance
Factor L adjusts "I," "K," and "C" for unsheltered distance.

"L" can be measured directly on a map or calculated using a wind erosion direction factor.

For uses of the Wind Erosion Equation involving a single annual calculation, L should be the measured distance across the area in the prevailing wind erosion direction from the stable upwind edge of the field to the downwind edge of the field. When the prevailing wind erosion direction is at an angle that is not perpendicular to the long side of the field, L can be determined by multiplying the width of the field by the appropriate conversion factor obtained from Table 4, Wind Erosion Direction Factors.

Multiply the width of the field by the "Adjustment Factor." This is the L for the field. If a barrier is on the upwind side of the field, reduce L by a distance equal to 10 times the height of the barrier.

Step 5: Determine the "V" Vegetative Factor (SGE) for each crop in the rotation
Factor V adjusts "I," "K," "C," and "L" for vegetative cover.
a. Determine the amount of residue cover, if any, at planting.
b. Use Table 1, Residue Conversion Procedure to Convert % Residue Cover to **SGe,** if appropriate.

Step 6: Determine "E" Estimated Annual Soil Loss by Wind Refer to the appropriate "E" Tables. See Table 6, E tables for Michigan C, K, and I values to determine the current soil loss. Work the E Tables backward to determine wind erosion alternatives to get T for soil loss or crop loss tolerance.

Wind Erosion Worksheet -

Client:	**Field #**	**Date:**	**County:**

Step #1	**Determine the Soil "I" Value** - Refer to Section II of the FOTG			
	Soil Type #1	"I" Value #1	Soil Type #2	"I" Value #2

Step #2	**Determine the Soil Roughness (Ridge) Value (Krd)** - Refer to Tables 5*		
	🟨	**Tillage Type used for Krd**	**Krd Value**
	Present		
	Planned		

Step #3	**Determine the Climatic Factor (See Table 2)**
	Climatic Factor =

Step #4	**Determine the "L" - Length of the Unsheltered Distance**					
	🟨		**Or Calculated "L" (Table 4)**			
		Measured "L"	**Angle of Deviation**	**Adj. Factor**	**Field Width**	**"L"**
	Present					
	Planned					

Step #5	**Determine the "V" Vegetative Factor (SGE) for each crop in the rotation**					
	#	**Present Crop(s)**	**Type of Residue**	**% Residue Cover**	**Lbs. Of Residue Table 1**	**SGe Figures a1 through b6, Table 1**
	1					
	2					
	3					
	4					
	#	**Planned Crop(s)**	**Type of Residue**	**% Residue Cover**	**Lbs. Of Residue Table 1**	**SGe Figures a1 through b6 Table 1**
	1					
	2					
	3					
	4					

Step #6	**Determine "E" Estimated Annual Soil Loss by Wind Refer to the appropriate "E" Tables**				
	#	**Present Crop(s)**	**Present (E) Soil Loss**	**Planned Crop(s)**	**Planned (E) Soil Loss**
	1				
	2				
	3				
	4				
Comments					

* For soils with a I value of 134 or greater, always use a K factor of 1 (WEG 1 or 2) I =134, 160, 180, 220, 250, or 310.

Tables for WEQ - (Critical Period Method)

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2. **Residue Conversion Procedure to Convert % Residue Cover to SGe** - Table 1
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* NRCS National Agronomy Manual, 3rd Edition, Oct. 2002.

Exhibit 502-5 - Wind Erodibility Groups and Wind Erodibility Index

Soil Texture[1]	**Predominate Soil texture class of surface layer**	**Wind Erodibility Group (WEG)**[2]	**Soil Erodibility Index (I) (ton/ac/yr)**[3], [4]	**Soil Erodibility Index (I) for Irrigated soils (ton/ac/yr)**[3]
C	Very fine sand, fine sand, sand, or coarse sand	**1**	310 [3] 250 220 180 160	310 250 220 160 134
C	Loamy very fine sand, loamy fine sand, loamy sand, loamy coarse sand, sapric organic soil materials, and all horizons that meet andic [5] soil properties as per Criteria 2 in Soil Taxonomy, regardless of the fine earth texture	**2**	134	104
C	Very fine sandy loam, fine sandy loam, sandy loam, coarse sandy loam, and noncalcareous silt loam that has 25-50% very fine sand and 5-12% clay	**3**	86	56
F	Clay, silty clay, non-calcareous clay loam, or silty clay loam with more that 35% clay	**4**	86	56
M	Calcareous [6] loam and silt loam or calcareous clay loam and silty clay loam	**4L**	86	56
M	Non calcareous loam and silt loam with 12-20% clay (but does not meet WEG 3 criteria), noncalcareous sandy clay loam, sandy clay, and hemic soil materials	**5**	56	38
M	Non calcareous loam and silt loam with more than 20% clay, or non-calcareous clay loam with less than 35% clay or silty clay loam with less that 35% clay	**6**	48	21
M	Silt and fibric organic material	**7**	38	21
__	Soils not susceptible to wind erosion because of surface rock or rock fragments or wetness	**8**	__	__

1/ Soil texture: C = Coarse; M = Medium; F = Fine.
2/ For all WEGs except sand and loamy sand textures, if percent rock and pararock fragments (>2mm) by volume is 15-35, reduce **I** by one group with more favorable rating. If percent rock and pararock fragments by volume is 35-60, reduce **I** value by two favorable groups except for sands and loamy sand textures which are reduced by one group with more favorable rating. If percent rock and pararock fragments by volume is more than 60, use **I** value of zero for all textures except sands and loamy sand textures which are reduced by three groups with more favorable rating.
3/ The wind erodibility index is based on the relationship of dry soil aggregates greater than 0.84 millimeters to potential soil erosion. 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, Kansas.
4/ The **I** factor for WEG 1 vary from 160 for coarse sands to 310 for very fine sands. Use an **I** value of 220 as an average figure.
5/ Vitrandic, Vitritorrandic, and Vitrxerandic Subgroups with ashy textural modifiers move one group with less favorable rating.
6/ Calcareous is a strongly or violently effervescent reaction of the fine-earth fraction to cold dilute (IN) HCL.

Table 1 - Residue Conversion Procedure to Convert % Residue Cover to SGe 1/ 3/

Corn			**Soybeans**			**Small Grain - Alfalfa/Grass**		
% Cover 2/	Lbs. of Residue Per Acre	SGe	% Cover 2/	Lbs. of Residue Per Acre	SGe	% Cover 2/	Lbs. of Residue Per Acre	SGe
10	250	100	10	150	-	10	150	350
15	400	175	15	250	120	15	250	550
20	575	250	20	350	175	20	350	700
25	750	350	25	475	250	25	475	900
30	950	475	30	600	325	30	600	1100
35	1150	550	35	750	425	35	750	1300
40	1375	675	40	875	500	40	875	1400
45	1600	800	45	1025	600	45	1035	1600
50	1850	900	50	1200	700	50	1200	1800
55	2125	1100	55	1375	800	55	1375	2100
60	2400	1250	60	1600	1000	60	1550	2400
65	2900	1400	65	1750	1150	65	1875	2700
70	3425	1700	70	1950	1300	70	2175	2900
75	4000	2000	75	2175	1500	75	2550	3400
80	4650	2200	-	-	-	80	2990	3700
85	5325	2700	-	-	-	85	3400	4300
90	5325	3000	-	-	-	90	3850	4800
Other Crops and Residue SGe's								
Growing Small Grain 45 Days After Emergence - SGe = 1500								
Corn Silage Stubble and Sorghum Stubble - SGe = 350								

1/ Sources
RUSLE2 - Pounds of Residue at 30%, 60%, 90%.
NRCS Field Measurements of corn, soybean, and wheat residues in Michigan.

Examples of other Small Grain Equivalent Figures available in the NRCS National Agronomy Manual:

- A-1 Small grain residue (use for wheat, barley, rye, and oats) - Flat, Random Distribution
- A-2 Growing Small Grain - 45 Days After Emergence
- A-3 Corn residue - Flat random distribution 60% stalk, 40% fines
- A-4 Corn and grain sorghum silage stubble - 6.25 inches high 30" rows
- A-5 Growing corn and grain sorghum
- A-6 Growing corn and grain sorghum; days after emergence
- A-8 Grain sorghum and residue
- A-9 Sudan grass stubble and residue
- B-1 Alfalfa residue
- B-2 Dry bean, lentil, soybean, and winter pea residue - Random flat residue
- B-3 Growing soybeans
- B-15 Potato or sugar beet residue
- C-2 Manure

2/ % Cover refers to the % of the soil surface cover during critical erosion period.

3/ See National Agronomy Manual - Wind Erosion, Section 502, Flat Small Grain Equivalent Charts for crops not listed in the examples above.

Table 2 - Michigan County Climatic Factors
Source: National Agronomy Manual - Annual "C" Values of the Wind Erosion Equation

County	"C" Factor	County	"C" Factor	County	"C" Factor	County	"C" Factor
Alcona	5	Dickinson	6	Lake	7	Oceana	7
Alger	5	Eaton	7	Lapeer	8	Ogemaw	5
Allegan	8	Emmet	5	Leelanau	7	Ontonagon	5
Alpena	5	Genesee	8	Lenawee	7	Osceola	6
Antrim	7	Gladwin	6	Livingston	7	Oscoda	5
Arenac	6	Gogebic	5	Luce	5	Otsego	6
Baraga	5	Grand Traverse	7	Mackinac	5	Ottawa	8
Barry	7	Gratiot	8	Macomb	8	Presque Isle	5
Bay	8	Hillsdale	7	Manistee	7	Roscommon	5
Benzie	7	Houghton	5	Marquette	5	Saginaw	8
Berrien	8	Huron	8	Mason	7	Sanilac	8
Branch	7	Ingham	7	Mecosta	7	Schoolcraft	5
Calhoun	7	Ionia	7	Menominee	6	Shiawassee	8
Cass	7	Iosco	5	Midland	7	St. Clair	8
Charlevoix	6	Iron	5	Missaukee	6	St. Joseph	7
Cheyboygan	5	Isabella	7	Monroe	8	Tuscola	8
Chippewa	5	Jackson	7	Montcalm	7	Van Buren	8
Clare	6	Kalamazoo	7	Montmorency	5	Washtenaw	7
Clinton	7	Kalkaska	7	Muskegon	8	Wayne	8
Crawford	6	Kent	7	Newaygo	7	Wexford	7
Delta	6	Keweenaw	6	Oakland	8		

Table 3 (Adapted from National Agronomy Manual Table 502-1) -
Knoll Erodibility Adjustment Factor for "I" (I) X (Adjustment Factor) = Knoll Erosion based on slope

Percent slope change in the prevailing wind erosion direction	Increase at the crest area where erosion is most severe (Adjustment Factor)
3%	1.5
4%	1.9
5%	2.5
6%	3.2
8%	4.8
10% or Greater	6.8

Table 4 - Wind Erosion Direction Factors 1/ (Adapted from NAM Table 502-3)

Angle of Deviation 2/	Adjustment Factor
0^o	1.0
22.5^o	1.08
45^o	1.41
67.5^o	2.61
90^o	L = Length of the Field

1/ The adjustment factor is applicable when the preponderance is not considered. "L" cannot exceed the longest possible measured distance across the field.

2/ The angle of deviation of the prevailing erosive wind from a direction perpendicular to the long side of the field.

TABLE 4A - Prevailing Wind Erosion Direction and Preponderance of Wind Erosion Forces in the Prevailing Wind Erosion Direction

(“Direction” means degrees, measured in a clockwise direction from north, which is 0^o)

Location and Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ALPENA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	113	292	22	90	293	270	270	247	293	270	270	67
PREPONDERANCE	2.2	2.1	1.1	2.6	2.7	3.4	2.2	3.6	2.4	7.8	1.8	2.5
BATTLE CREEK	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	247	247	247	270	247	225	225	247	270	247	225	225
PREPONDERANCE	2.3	2.0	2.2	2.2	2.6	2.6	1.7	3.1	2.1	1.4	2.6	5.0
CADILLAC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	247	247	247	292	247	247	225	203	247	203	203	203
PREPONDERANCE	2.6	1.8	2.0	1.5	2.8	1.7	1.5	1.8	1.3	2.0	1.5	1.9
DETROIT/WAYNE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	270	270	270	247	270	225	270	247	292	247	247	270
PREPONDERANCE	2.7	2.0	1.7	2.0	2.0	1.8	1.3	1.4	1.5	1.4	1.7	2.1
FLINT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	270	270	247	247	247	247	270	270	270	247	247	270
PREPONDERANCE	2.5	2.3	1.7	2.0	2.1	1.6	2.1	1.6	1.9	1.3	1.8	1.8
GLADWIN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	247	247	247	225	247	247	203	225	247	225	203	203
PREPONDERANCE	2.4	2.4	2.4	1.6	6.3	2.2	2.0	1.7	2.5	1.8	2.6	3.2
GRAND MARAIS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	338	338	338	338	202	180	180	180	180	180	180	180
PREPONDERANCE	2.0	3.5	2.2	1.9	3.0	1.3	1.8	1.9	2.8	2.6	2.3	2.9
GRAND RAPIDS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	270	270	247	270	247	247	247	247	247	247	247	247
PREPONDERANCE	1.7	2.0	1.9	1.8	7.1	1.9	1.5	2.4	2.2	1.8	2.0	1.4
GREEN BAY WI	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	270	270	247	270	247	247	247	247	247	247	247	247
PREPONDERANCE	1.7	2.0	1.9	1.8	7.1	1.9	1.5	2.4	2.2	1.8	2.0	1.4
GROSSE ILE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	247	270	247	247	293	23	202	337	202	247	247	247
PREPONDERANCE	2.1	1.5	2.0	2.3	1.6	1.2	6.4	1.7	1.6	1.5	1.7	1.7
GWINN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	0	0	0	0	0	202	0	180	180	0	0	0
PREPONDERANCE	4.1	6.2	10.3	5.8	9.5	1.6	2.3	3.0	3.5	6.7	6.6	4.5
HOUGHTON LAKE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	270	247	270	90	270	270	270	270	270	270	270	270
PREPONDERANCE	2.3	1.7	1.9	2.2	3.1	2.3	8.5	2.5	6.3	5.1	5.4	3.9
JACKSON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	292	292	247	270	270	293	292	293	247	337	337	270
PREPONDERANCE	1.9	1.8	2.2	1.9	2.0	2.0	2.4	2.3	2.1	1.2	1.6	1.8
LANSING	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	270	247	247	270	270	247	247	248	247	270	270	270
PREPONDERANCE	2.3	1.9	2.0	2.0	2.5	1.7	2.7	1.7	1.7	1.9	2.8	2.1

TABLE 4A – Continued
Prevailing Wind Erosion Direction and Preponderance of Wind Erosion Forces in the Prevailing Wind Erosion Direction

(“Direction” means degrees, measured in a clockwise direction from north, which is 0^{o})

Location and Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MOUNT CLEMENS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	225	247	225	225	225	203	225	180	202	203	203	225
PREPONDERANCE	2.6	1.4	1.5	1.7	1.3	1.8	1.7	2.0	1.4	1.6	1.7	1.6
MUSKEGON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	293	180	180	203	202	202	202	180	180	180	293	225
PREPONDERANCE	1.1	1.3	1.3	1.3	2.4	2.6	2.2	2.8	1.7	1.4	1.2	1.2
OSCODA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	247	247	247	225	247	247	270	270	270	247	247	45
PREPONDERANCE	2.6	1.4	2.1	1.6	2.0	2.4	1.4	1.3	2.6	1.7	3.5	2.0
SAGINAW	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	247	247	247	247	247	247	247	225	247	247	225	225
PREPONDERANCE	4.6	2.9	2.3	2.2	8.0	2.5	2.8	1.9	1.9	2.1	1.7	2.1
SAULT STE MAR.	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	292	293	293	293	293	293	293	293	293	293	293	293
PREPONDERANCE	2.4	2.6	2.6	3.7	2.9	3.0	3.6	2.2	2.4	3.1	3.0	4.0
TRAVERSE CITY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	0	203	0	203	225	225	247	225	225	203	0	0
PREPONDERANCE	2.7	1.5	1.7	2.1	2.0	2.5	1.9	1.7	1.9	1.6	5.3	1.7
YPSILANTI	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PREV WIND EROS DIR	270	270	270	270	270	270	270	270	270	270	270	247
PREPONDERANCE	2.1	2.5	3.0	3.1	1.9	3.0	1.8	1.8	2.1	2.2	2.2	1.9

- Prevailing Wind Erosion Direction - Direction of winds over 12 mph one foot above ground surface.
- Preponderance - Change of wind coming from a certain direction. A preponderance of 1.5 means that there is a 1.5-1.0 or 60% chance that the wind can come from the prevailing wind erosion direction.

TABLE 4B - Angle of Deviation
(The angle between the prevailing wind erosion direction and a line perpendicular to row direction when determining effect of wind direction on the ridge roughness factor.)

Prevailing Wind Erosion Direction in Degrees	East/West	North/South
0-360	0	90
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
337.5	22.5	67.5
360-0	0	90

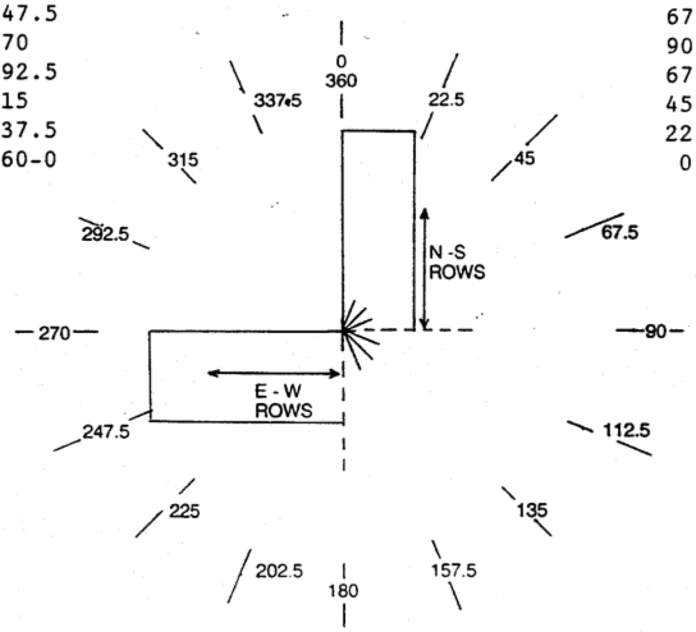

Table 5 - Soil Roughness (Ridge) Values (Krd) - Adapted from NAM Tables 502-5A through 502-5T	
Tillage / Planting System	**"K" Roughness / Ridge Factor***
Disk, Field Cultivate, Smooth	K = 1.0
Disk, Field Cultivate, 1-2 inch ridges by 12-18 inches wide	K = 0.9
Disk, Field Cultivate, 2-3 inch ridges by 12-18 inches wide	K = 0.8
Chisel Plow, 3-4 inch ridges by 18 inches wide	K = 0.7
Chisel Plow, 5-6 inch ridges by 18 inches wide	K = 0.6
Ridge Tillage, 4-6 inch ridges by 30 inches wide	K = 0.5
Tomato Bed, 4-6 feet wide, with furrow	K = 0.9
No Till Planting	K = 1.0

- For soils with a I value of 134 or greater, always use a K factor of 1 (WEG 1 or 2) I =134,160, 180, 220, 250, or 310.