Understanding Erosion

with the

Revised Universal Soil Loss Equation

Towards a Better Understanding of the

What, Why & How

Erosion is a process of detachment and transport of soil particles by erosive forces. Erosive forces include raindrop impact and surface runoff from rainfall.

Types of Erosion

- Impact Erosion- Physical detachment of soil particles as a result of raindrop impact.
- Sheet erosion- Thin, uniform wearing away of the uppermost surface layers in the soil profile. Seldom the detaching agent, but just merely transporting soil particles detached by raindrop impact.
- Rill erosion- Follows sheet erosion. As the amount and velocity of water increases water is now able to both detach and transport soil particles.
- Gully erosion- As rills deepen and widen, gullies form.

  Simple definition: gullies are rills that are too large to be repaired with conventional tillage equipment.
- Channel erosion- Erosion as a result of concentrating and confining the erosive forces of water. Includes both manmade and natural channels.
- Mass Wasting- Large failures usually as a result of gravitational forces. Landslides, pot-slides, slumps, debris torrents.

Revised Universal Soil Loss Equation (RUSLE)

- original purpose was for agricultural activities as a result of the dust bowl era
- certain other adjustments made for construction activities
- used to estimate average annual soil loss
- only considers sheet and rill erosion
- does not consider gully erosion, stream bank erosion, mass wasting (landslides)
- a simplified approach that assumes static conditions
- does not consider the unpredictable human element
- its primary use is as a predictive tool to evaluate land use options
- a linear formula so its EZ to work with, and also somewhat EZ to remember

$$A = R\ K\ L\ S\ C\ P$$

Rickleskip

Revised Universal Soil Loss Equation (RUSLE)

A= R K L S C P

A= average annual soil loss

R= rainfall-runoff erosivity factor

K= soil erodibility factor

LS= slope length and steepness factor

C= cover management factor

P= support practice factor

NO, you are not expected to remember this formula, its an understanding of the basic concepts that is important.

A Average Annual Soil Loss [tons per acre per year]

- estimates average erosion in tons per acre per year
- an annual average loss over a site where losses at various parts of the site may differ greatly from one area to another
- this is what you want to reduce by working with the other variables
- in order to evaluate options you need to work with the other variables in consideration of the underlying assumptions and limitations

Those other variables are?

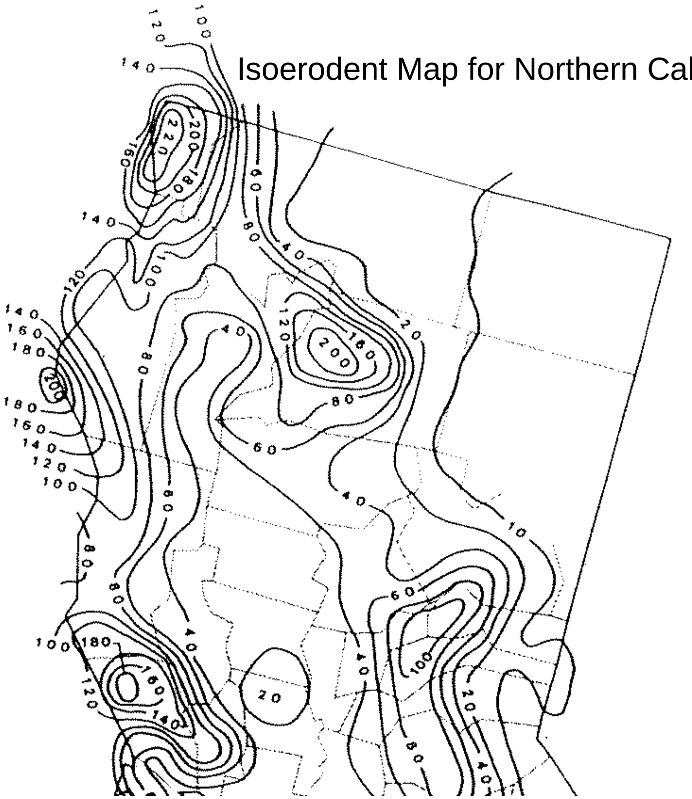
R Rainfall-Runoff Erosivity Factor

- a measure of the erosive force and intensity of rain in a normal year
- values of R have been computed from rainfall records and probability statistics across the United States, so should not be considered as a precise factor for any given time or location
- need to make adjustments for runoff from snow melt and freeze-thaw conditions
- its principal value, and that of the soil loss equation itself, is as a predictive tool and risk evaluator

R Rainfall-Runoff Erosivity Factor

May be determined from isoerodent maps depicting yearly average values, or tables and charts that can break it down to a percent by month basis.

Isoerodent Map for Northern California



Adjustment factor for estimating monthly and periodic portions of annual soil loss. Ukiah (R=59)

Month	Percent
January	11
February	16
March	11
April	6
May	3
June	5
July	4
August	3
September	4
October	5
November	15
December	17
TOTAL	100

**Source: Internet- USEPA Rainfall Erosivity Factor Calculator

R Rainfall-Runoff Erosivity Factor

You can not do much about the weather except work around it and schedule your activities appropriately, and try to use it to your advantage.

•schedule grading activities in the drier portions of the year, yet while trying to take advantage of soil moisture conditions

• schedule accordingly when transplanting or seeding to increase chances of success

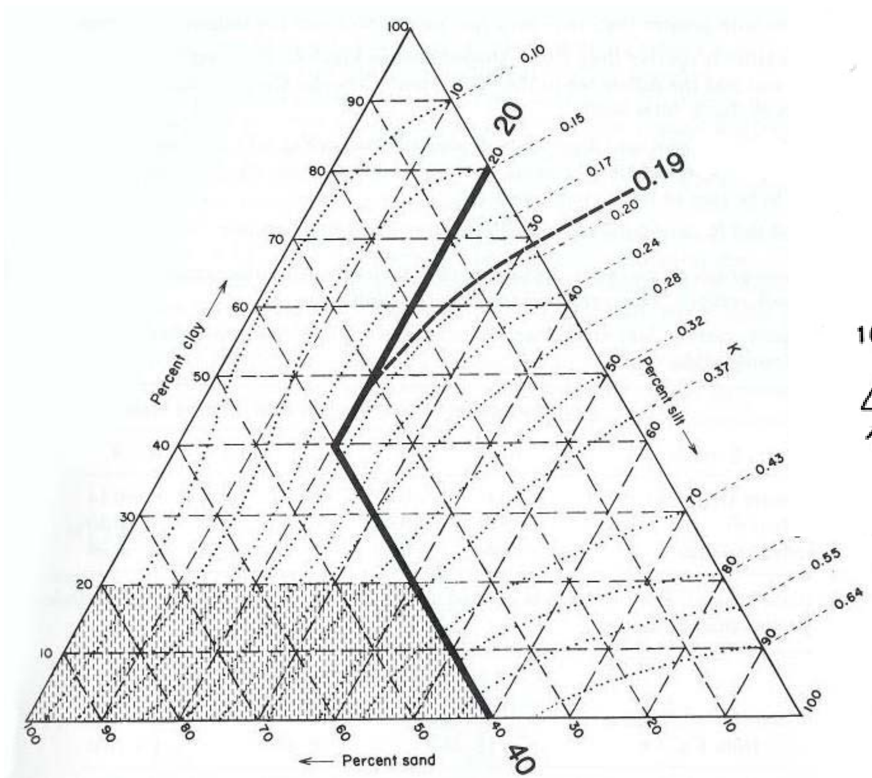
Just remember when gambling with the weather, “ being this is a 44 % chance storm event that could just blow your project clean off, you've got to ask yourself one question:
'Do I feel lucky?'
Well, Do you punk…!!!”

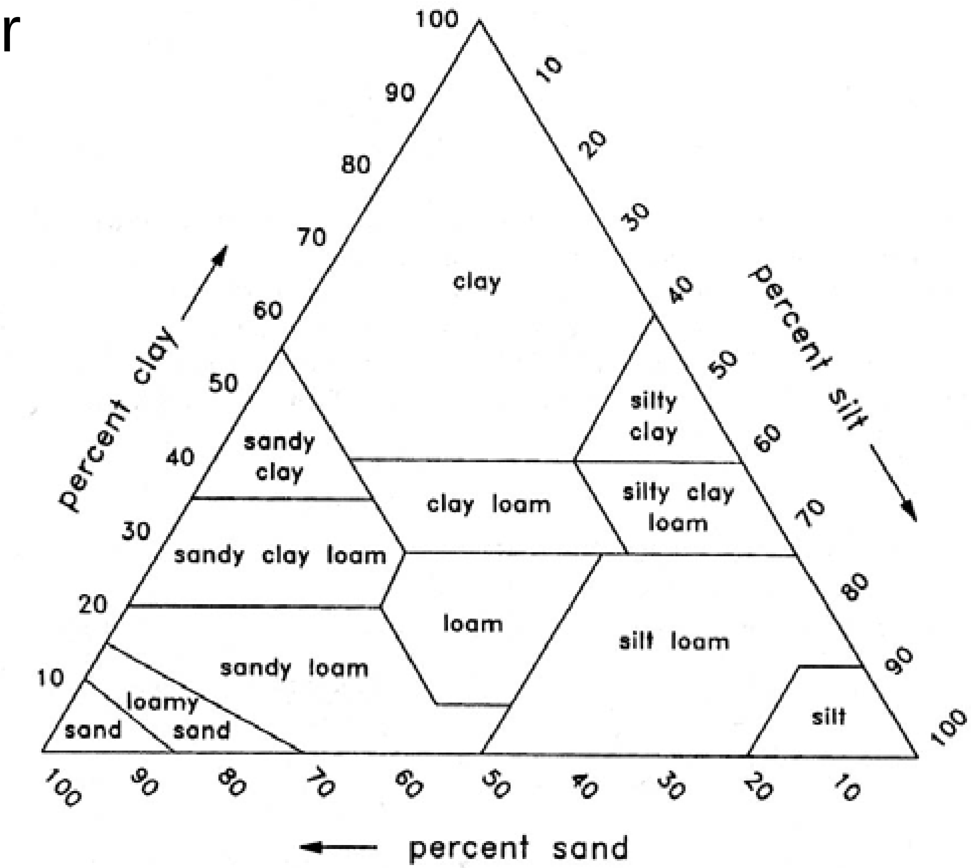
K Soil Erodibility Factor

- a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff
- Soil texture is the principle factor affecting K, but soil structure, organic matter and permeability also contribute
- Soil texture- sand, silt and clay with 12 variations
- Soil structure- how individual soil granules clump or bind together, and therefore, the arrangement of soil pores between them
- determined from NRCS soil survey data, or by particle analysis, (ASTM D-422 hydromoter analysis)

K   Soil Erodibility Factor

Soil K Value Nomograph





Soil Texture Nomograph

K Soil Erodibility Factor

Generalized Soil Characteristic	K	
High clay content	0.05 – 0.15	resistance to detachment decreases erodibility
Course textured sandy soils	0.05 – 0.2	even though these soils are easily detached they produce low runoff
Medium textured silt loam soils	0.25 – 0.4	moderately susceptible to detachment and produce moderate runoff
High silt content	> 0.4	most erodible of all soils because they are easily detached; tend to crust and produce high rates of runoff

K values range from 0.02 to 0.69

K Soil Erodibility Factor

- There is not much you can do about the material you are working with. But, a small understanding of the basic principles used to determine the soil erodibility factor can be used to your advantage
- nomograph assumes 15% rock (size > 2mm), 15 – 35% reduces K by 50 – 58%
- nomograph assumes 2% organic matter, 4% reduces K by 30 - 35%
- compact soils increase K because of reduced permeability
- high pH (alkaline) increases K (BMP - dispose of concrete waste water properly)

→ Focus of RUSLE is on erosion not structural integrity ←

- on roads we want compaction / less compact soils are good in off shoulder areas
- higher rock contents are good everywhere
- Organic matter reduces erodibility because it reduces the susceptibility of the soil to detachment, and it increases infiltration, which reduce runoff and thus erosion. Its also beneficial for establishing vegetation. (BMP- stockpile the top soil layer separately for broadcast application prior to final erosion control.)

LS Slope Length Steepness Factor

- quantifies the combined effect of slope length and slope steepness
- based upon experimental data - the ratio of soil loss per unit area on a site to the corresponding loss from a 72.6 foot long experimental plot with a 9 percent slope
- reducing slope gradient and effective slope length will reduce the LS factor
- LS factors for different slope angles and slope lengths are conveniently summarized in tables

LS Slope Length Steepness factor

	Slope length in feet																
Slope	<3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
%																	
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
0.5	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.12	0.12	0.13
1.0	0.09	0.09	0.09	0.09	0.09	0.10	0.13	0.14	0.15	0.17	0.18	0.19	0.20	0.22	0.24	0.26	0.27
2.0	0.13	0.13	0.13	0.13	0.13	0.16	0.21	0.25	0.28	0.33	0.37	0.40	0.43	0.48	0.56	0.63	0.69
3.0	0.17	0.17	0.17	0.17	0.17	0.21	0.30	0.36	0.41	0.50	0.57	0.64	0.69	0.80	0.96	1.10	1.23
4.0	0.20	0.20	0.20	0.20	0.20	0.26	0.38	0.47	0.55	0.68	0.79	0.89	0.98	1.14	1.42	1.65	1.86
5.0	0.23	0.23	0.23	0.23	0.23	0.31	0.46	0.58	0.68	0.86	1.02	1.16	1.28	1.51	1.91	2.25	2.55
6.0	0.26	0.26	0.26	0.26	0.26	0.36	0.54	0.69	0.82	1.05	1.25	1.43	1.60	1.90	2.43	2.89	3.30
8.0	0.32	0.32	0.32	0.32	0.32	0.45	0.70	0.91	1.10	1.43	1.72	1.99	2.24	2.70	3.52	4.24	4.91
10.0	0.35	0.37	0.38	0.39	0.40	0.57	0.91	1.20	1.46	1.92	2.34	2.72	3.09	3.75	4.95	6.03	7.02
12.0	0.36	0.41	0.45	0.47	0.49	0.71	1.15	1.54	1.88	2.51	3.07	3.60	4.09	5.01	6.67	8.17	9.57
14.0	0.38	0.45	0.51	0.55	0.58	0.85	1.40	1.87	2.31	3.09	3.81	4.48	5.11	6.30	8.45	10.40	12.23
16.0	0.39	0.49	0.56	0.62	0.67	0.98	1.64	2.21	2.73	3.68	4.56	5.37	6.15	7.60	10.26	12.69	14.96
20.0	0.41	0.56	0.67	0.76	0.84	1.24	2.10	2.86	3.57	4.85	6.04	7.16	8.23	10.24	13.94	17.35	20.57
25.0	0.45	0.64	0.80	0.93	1.04	1.56	2.67	3.67	4.59	6.30	7.88	9.38	10.81	13.53	18.57	23.24	27.66
30.0	0.48	0.72	0.91	1.08	1.24	1.86	3.22	4.44	5.58	7.70	9.67	11.55	13.35	16.77	23.14	29.07	34.71
40.0	0.53	0.85	1.13	1.37	1.59	2.41	4.24	5.89	7.44	10.35	13.07	15.67	18.17	22.95	31.89	40.29	48.29
50.0	0.58	0.97	1.31	1.62	1.91	2.91	5.16	7.20	9.13	12.75	16.16	19.42	22.57	28.60	39.95	50.63	60.84
60.0	0.63	1.07	1.47	1.84	2.19	3.36	5.97	8.37	10.63	14.89	18.92	22.78	26.51	33.67	47.18	59.93	72.15

NRCS Unit Plot, LS=1

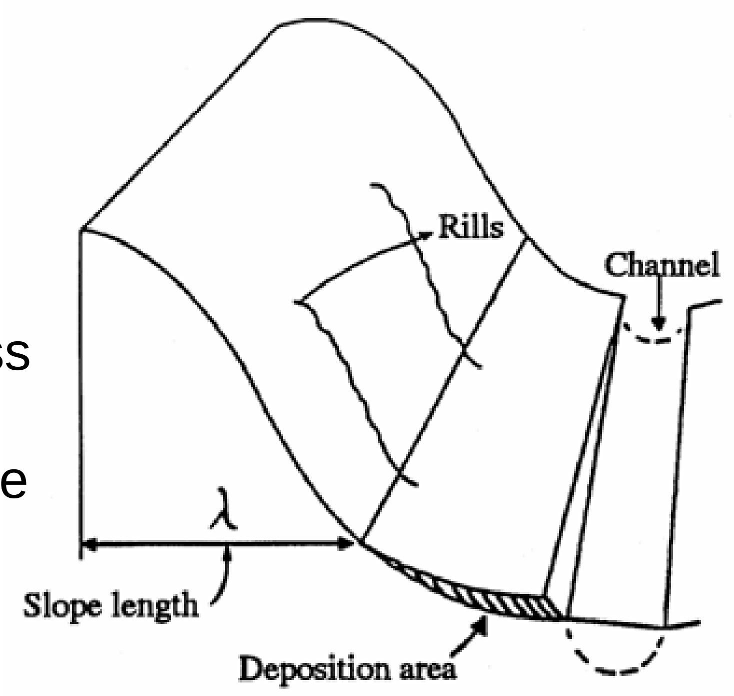
LS Values for Freshly Prepared Construction and other Highly Disturbed Soil, with Little, or no Cover (Renard, *et al.* 1987)

LS Slope Length Steepness Factor

• LS is the slope length from the ridge to the point where deposition starts to occur near the bottom of the slope

• assumes uniform slope
• convex slopes tend to increase soil loss,
• concave slopes tend to decrease soil loss

• as a general rule soil loss increases more with slope steepness than it does with slope length



C Cover Management Factor

- the ratio of soil loss from land under specified crop or mulch conditions to the corresponding soil loss from tilled, bare soil
- the C factor reduces the soil loss estimate according to the effectiveness of vegetation and mulch at preventing detachment and transport of soil particles (erosion control)
- lots of *'bang for the buck'* by working with the cover management factor

C Cover Management Factor

Cover Management Factors for Construction Sites		
Vegetative Cover	**C factor**	**Percent Reduction of soil loss**
None (fallow ground)	1.0	0
Native vegetation (undisturbed)	0.01	99
Temporary Ryegrass, 90% (perennial)	0.05	95
Temporary Ryegrass, 90% (annuals)	0.1	90
Permanent Seedlings (90%)	0.01	99
Sod (laid immediately)	0.01	99
Mulching (for slopes 2:1 or less)		
Hay (0.5 tons/acre)	0.25	75
Hay (1.0 tons/acre)	0.13	87
Hay (1.5 tons/acre)	0.07	93
Hay (2.0 tons/acre)	0.02	98
Wood chips (6 tons/acre)	0.06	94
Wood cellulose (1.75 tons per acre)	0.10	90
Other		
Competent gravel layer	0.05	95
Rolled erosion control fabrics	(for slopes greater than 2:1)	variable C value by type

P Support Practice Factor

- the ratio of soil loss with a given surface condition to soil loss with up-and-down hill plowing
- in agriculture, used to describe plowing and tillage practices
- for construction sites, reflects the roughening of the soil surface by tractor treads, rough grading, raking or disking
- practices that reduce the velocity of runoff and the tendency of runoff to flow directly down-slope reduce the P factor
- rough and irregular helps trap sediment (sediment control)
- does not consider the unpredictable human element (disturbance)

P Support Practice Factor

Support Practice Factor for Construction Sites	
Surface Condition with No Cover	**P factor**
Loose as a disked plow layer (control condition)	1.0
Compacted and smooth	1.3
Track-walked along contour	1.2
Track-walked up and down slope	0.9
Punched straw	0.9
Rough, irregular surface, equipment tracks in all directions	0.9
Loose with smooth surface greater than 12 inches depth	0.9
Loose with rough surface greater than 12 inches depth	0.8

- roughened soils greatly increase plant establishment and thus also reduces the C factor once they become established.
- vegetation, mulch, slope length and gradient are your best bet to reduce soil loss.
- we do not want loose soils on roads

Putting the Basic Principals to Work

Example 1 - Generic Project in Ukiah

Freshly disturbed nearly flat ¼ acre square (~100 ft per side) with smooth compacted surface

R- value from tables is 59 for Ukiah

K- from Soil Survey is 0.32 (well drained loamy terrace deposits)

LS- 0.05 from tables

C- since its freshly graded assume no cover C = 1

P- value from table for stated condition is 1.3

A= R K (L S) C P = (59)(0.32)(0.05)(1)(1.3) = 1.2 tons/acre/year

But we have a quarter acre so we have a quarter of that for this site.

HOMEWORK- What if this is an active stockpile area with loose unconsolidated materials going in and out and the site is under constant disturbance.

Lets go to the Coast with some different conditions

Example 2 - Generic Project on the South Coast

Freshly disturbed ¼ acre square on 10% slope with smooth compacted surface

R- value from Isoerodent map for Point Arena area is 100

K- from Soil Survey is 0.24 (poorly drained loamy sand)

LS- 1.46 from tables

C- since its freshly graded assume no cover C = 1

P- value from table for stated condition is 1.3

A= R K (L S) C P = (100)(0.24)(1.46)(1)(1.3) = 46 tons/acre/year

But we have a quarter acre so we have a quarter of that for this site.

What can we do to reduce the average annual soil loss?

Example 2 - Generic Project on the South Coast

Freshly disturbed ¼ acre square on 10% slope with smooth compacted surface

$$A = R\ K\ (L\ S)\ C\ P = (100)(0.24)(1.46)(1)(1.3) = 46 \text{ tons/acre/year}$$

Lets throw on some straw mulch at a rate of 2 ton/acre   C = 0.02

$$A = R\ K\ (L\ S)\ C\ P = (100)(0.24)(1.46)(0.02)(1.3) = 0.9 \text{ tons/acre/year}$$

Lets just use seed   C = 0.05

$$A = R\ K\ (L\ S)\ C\ P = (100)(0.24)(1.46)(0.05)(1.3) = 2 \text{ tons/acre/year}$$

(No you can not be cheep and just use seed or straw mulch. Mulch is short term cover to protect the soil till the seed becomes established.)

How about if we don't compact and grade it smooth but, track walk it up and down slope (P = 0.9)and just use wattles to reduce the slope length to 15 feet (LS = 0.4).

$$A = R\ K\ (L\ S)\ C\ P = (100)(0.24)(0.4)(1)(0.9) = 9 \text{ tons/acre/year}$$

Seed and mulch - 98% reduction in soil loss.

Track walking and wattles – 80% reduction in soil loss.

Use both and that's a 99% reduction in soil loss….at least according to basic theory.

Example 3 - Way Out There Dirt Road in Usal

Since it takes along time to get way out there and it sees a lot of rain, lets look at some typical road maintenance practices.

Project description: Way out there native surface 12 foot wide road at 8% grade with mud bog holes and few drainage facilities that are silted in, road rilling is up to 600 feet long in many areas. R = 120 K = 0.32 LS=3.52 C = 1 P = 1.3

$$A = R\ K\ (LS)\ C\ P = (120)(0.32)(3.52)(1)(1.3) = 176 \text{ tons/acre/year}$$

Lets get a handle on the drainage by draining the road at 100 foot intervals, LS = 1.1

$$A = R\ K\ (LS)\ C\ P = (120)(0.32)(1.10)(1)(1.3) = 55 \text{ tons/acre/year}$$

Lets work with the cover management factor by also rocking, C = 0.05

$$A = R\ K\ (LS)\ C\ P = (120)(0.32)(1.10)(0.05)(1.3) = 3 \text{ tons/acre/year}$$

That does not consider the unpredictable human element that tears things up.

- What does that 176 tons/acre/year represent? --- 23 CY/year for this road segment which represents about 1 inch of material loss on average.
- Even with improve drainage spacing at 100 feet that's about 7 yards of material per drainage structure.

………. At least according to the basic theory……….

Conclusion

A = RK(LS)CP *Rickleskip*

R Rainfall Runoff Erosivity Factor - You can not do much about the weather so plan accordingly.

K Soil Erodibility Factor - looks at it from a surface erosion perspective

- you are pretty much stuck with the material you have to work with
- that top layer of material that is generally no good for structural fills is great for broadcasting before final erosion control because of its organic matter content, soil micro organisms and seed bank for long term native revegetation that reduces the C factor.

LS Slope Length Steepness Factor - very important and applies everywhere.

C Cover Management Factor - very important and applies everywhere.

P Support Practice Factor – good for agriculture and construction sites on mild terrain and does not consider the unpredictable human element (vehicles) so it does not work all that great for roads ---- stick with compaction.

Conclusion

C Cover Management Factor

The use of Rye grass is discouraged

Use the following mix of California natives (Mendocino County)

Common Name	**Pounds per Acre**	**Percent**
Native Meadow Barley	20	31%
Native California Brome	20	30%
Native Molate Red Fescue	15	23%
Three Weeks Fescue	5	8%
Yellow Lupine	5	8%
TOTALS	65	100%

?