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Erosion and Sedimentation in Utah: A Guide for Control

C. Earl Israelsen

Eugene K. Israelsen

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A Guide For Control

C. EARL ISRAELSEN
JOEL E. FLETCHER
FRANK W. HAWS
EUGENE K. ISRAELSEN

Utah Water Research Laboratory
College of Engineering
Utah State University
Logan, Utah 84322-8200

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INTRODUCTION

Description of Problem

Soil erosion from urbanizing areas may be 10 to 100 times greater than erosion on agricultural land of equal size, slope, and soil type. Each year vast acreages in Utah are converted from agricultural to urban use to become the sites for new houses, schools, churches, shopping centers, parks, and highways for a growing population. These changing acres are the source of much of the sediment that pollutes streams, fills lakes and reservoirs, clogs storm sewers, and muddies streets.

Much of the erosion occurs during construction because of inadequate protection of disturbed areas. Even after construction is completed, erosion may occur below the construction zone because of increased runoff from impervious paved and compacted areas. Stream channels below a construction zone become filled with sediment, and then flood when heavy storms occur, filling basements, eroding stream banks, and damaging valuable property. Even on construction sites themselves erosion undercuts roads and pavements, erodes embankments, fills storm sewers, and washes away top soil.

Sediment from construction sites lowers the quality of water for municipal and industrial uses, as well as for boating, fishing, swimming, and other water-based recreational activities. Sediment comes also from agricultural land, but amounts contributed by land undergoing development are generally much higher in proportion to the acreage.

Effective erosion control and reduction depend upon understanding the problems and taking the recommended necessary steps to control them. Most of the erosion and sedimentation problems created by urbanization can be solved or prevented with presently known methods.

Methods and Objectives

Authors of this handbook recently participated in the preparation of a national erosion control manual under the sponsorship of the Transportation Research Board, National Research Council, and the manual was published as National Cooperative Highway Research Project NCHRP Report 221, Erosion Control During Highway Construction--Manual on Principles and Practices. Information for the manual was gleaned from numerous state and federal agencies, universities, and first-hand experience, and photographs included herein were taken during visits to highway construction sites throughout the nation. Many of the methodologies, techniques, and measures employed for controlling erosion on highway construction sites apply equally well for controlling erosion in urban environments, and are included in this handbook. Information specific to urban erosion control problems, that did not appear in the highway manual, are included also.

The objective of the present study was to develop a handbook of nonagricultural erosion and sedimentation control for Utah, complete with updated rainfall and soils maps and instructions, with examples, for their use.

Handbook Contents

This handbook describes the factors influencing erosion and sedimentation, and presents a procedure for predicting sheet erosion. Several kinds of erosion are discussed, together with methods for their control, and essentials of erosion control planning are listed.

Appendix A lists and describes erosion control measures currently in use in the United States, and presents photographs of many of them. Appendix B contains a nomograph for solving the predictive water soil loss equation, as well as several examples of its use for solving practical field problems. Appendix C provides detailed examples of water erosion calculations and gives computational procedures for determining the topographic factor LS for single and multiple slopes, and the erosion control factor, VM. It describes also a rapid method of measuring rill erosion. Appendix D explains how to determine "R" values from rainfall intensity and duration data.

SOIL EROSION AND SEDIMENTATION

Factors Influencing Erosion and Sedimentation

Erosion is the loosening and transport of soil by the action of water, wind, and/or ice. Sedimentation is the settling out and accumulation of soil particles which are carried by water. The proper application of known conservation principles can control both erosion and sedimentation within reasonable limits. This manual will concentrate on erosion problems caused by water, but generally speaking, measures implemented for the control of erosion caused by water will protect also against that caused by wind.

Floods, landslides, debris flows, and mudflows are forms of erosion that are also addressed briefly in this discussion. Potential erosion of any particular site is the amount of erosion that would occur if no control measures were implemented, and is determined by four principal factors: its vegetative cover, the characteristics of its soil, its topography, and its climate. Of these, the climate and soil characteristics are inherent in the site, but the other two, topography and vegetation, may be manipulated to vary the amount of erosion that might occur.

Soil Loss Equation

Several different formulas have been developed for estimating potential erosion. The one used in this handbook is a modification of the universal soil loss equation developed by Wischmeier.

Soil Loss Rate A

The universal soil loss equation (USLE) was developed for agricultural lands east of the Rocky Mountains. A modified equation, based on the USLE, is used in this handbook for predicting soil loss due to water erosion in Utah, and for determining the effectiveness of various erosion control measures. Each of the parameters in the equation affects the amount of erosion that will occur on any given site, and its value and use must be understood by each decision-maker if he is to effectively control erosion. The modified universal soil loss equation is:

$$A = R \cdot K \cdot LS \cdot VM \qquad (1)$$

in which

A = computed amount of soil loss per unit area for the time interval represented by factor R, generally expressed as tons per acre per year

R = rainfall (precipitation) factor. R values for Utah presented in this handbook include erosion caused by snowmelt as well as that by rain.

K = soil erodibility factor in tons per acre per year per unit of R

LS = topographic factor (length and steepness of slope) (dimensionless)

VM = erosion control factor (vegetative, chemical, and mechanical measures) (dimensionless)

This equation does not account for rilling or gullying but only for sheet erosion caused by snowmelt and rainfall. Other forms of erosion cannot be predicted, but their quantities can be calculated after the fact. All of the material eroded, by whatever form, adds to the problem of sedimentation on adjacent property and in streams, lakes, and reservoirs.

Rainfall (Precipitation) Factor R

The rainfall factor is the number of erosion index units in a normal year's rain, and the erosion index is a measure of the erosive force of rainfall.

R is computed from precipitation and/or streamflow records summed over a given time interval to obtain the cumulative R value to be used in the soil-loss equation. R is derived from probability statistics and thus should not be considered as a precise estimator of soil loss. Its value lies in its use as a predictive tool and risk evaluator. Construction activities in areas with high values of "R" will require greater attention to erosion control practices than similar construction in areas of low "R" values. Erosion index distribution curves for Utah are shown in Figure 1. R values for periods of 1 year or less can be determined from these curves.

To illustrate the use of the iso-erodent (R) maps found in the map pocket, consider the following example of a site near Park City, east of Salt Lake City. From the Salt Lake City iso-erodent map, it is determined that R = 13. Using the map of erosion index distribution curves (Figure 1) one may determine the distribution of the erosive energy of storms throughout the year, shown in tabular form for Park City in Table 1. This distribution should be considered when estimating the amount of erosion control that will be needed during construction periods. One should remember also that this soil loss equation does not account for forms of erosion other than sheet erosion.

Soil Erodibility Factor K

The soil erodibility factor "K" has a value ranging from about 0.1 to 0.7 and is a numeric representation of the ability of the soil to resist the erosive energy of rain. Soils increase in erodibility as the value of K becomes larger. As calculated, the factor is independent of slope and dependent only upon particle size and distribution, structure, void space and pore size, and organic matter. Alterations to the soil (caused by such activities as blading and compacting), which change its structure and permeability and hence the K factor values, are accounted for in the soil loss equation by an appropriate VM factor, which will be discussed later. For a first approximation of the erodibility of soil in any given area of Utah, a soil erodibility map is provided in the map pocket. For a specific site a more accurate procedure is to perform laboratory analyses of samples of the soil in question and then to use these to determine its K value from Figure 2. If, for example, the soil from a construction site in Park City contains 65 percent silt and very fine sand, has 5 percent particles in the sand category, and contains 2.8 percent organic matter, the K value first approximation will be about 0.28 (follow dotted line in Figure 2 to first approximation of K) which corresponds with the erodibility map in the map pocket. If, in addition, the soil is found to have a structural value of 2 and a permeability of 4, the K value is 0.31 (in Figure 2, follow dotted line to final value of K).

NOTE: VALUES DETERMINED FROM THE SOIL ERODIBILITY MAP SHOULD BE USED ONLY WHEN SITE-SPECIFIC SOIL ANALYSES ARE NOT AVAILABLE, BECAUSE THEY ARE APPROXIMATIONS ONLY.

These maps were prepared from the latest information available from the Soil Conservation Service, but at best are only rough approximations of soil erodibility values of specific sites.

Topographic Factor LS

(See Appendix C for additional details.)

The only controllable parts of the soil loss equation are the topographic factor LS and the erosion control factor VM. The rainfall factor R and the soil erodibility factor K have both been fixed by nature and cannot be altered significantly by man's activities. The steepnesses and lengths of many of the slopes on construction sites, however, can be controlled as they are being built. It is obvious that flat slopes or short lengths will have less erosion than steep slopes or long lengths, but the amount of erosion expected for various combinations of length and steepness is not so obvious. The LS factor is therefore a numerical representation of the length-steepness combination to be used with the rainfall factor R and the soil erodibility factor K to estimate the erosion rate potential for a particular slope. Since the slope steepness and length can be controlled somewhat by the project designer, a knowledge of the LS factor will aid him in choosing proper combinations of slopes and lengths, and determining when to use berms, cross ditches, terraces or other control practices which effectively shorten a slope and reduce the LS factor. A convenient rule-of-thumb to remember is that shortening a slope length by one-half reduces total erosion by approximately one-third. Reasons for this are presented in detail in Appendix C.

To assist in determining the LS factor to use in the soil loss equation, Table 2 was developed.

Control Factor VM

This factor accounts for the effects of all erosion control measures that may be implemented. It is discussed more fully in the next section.

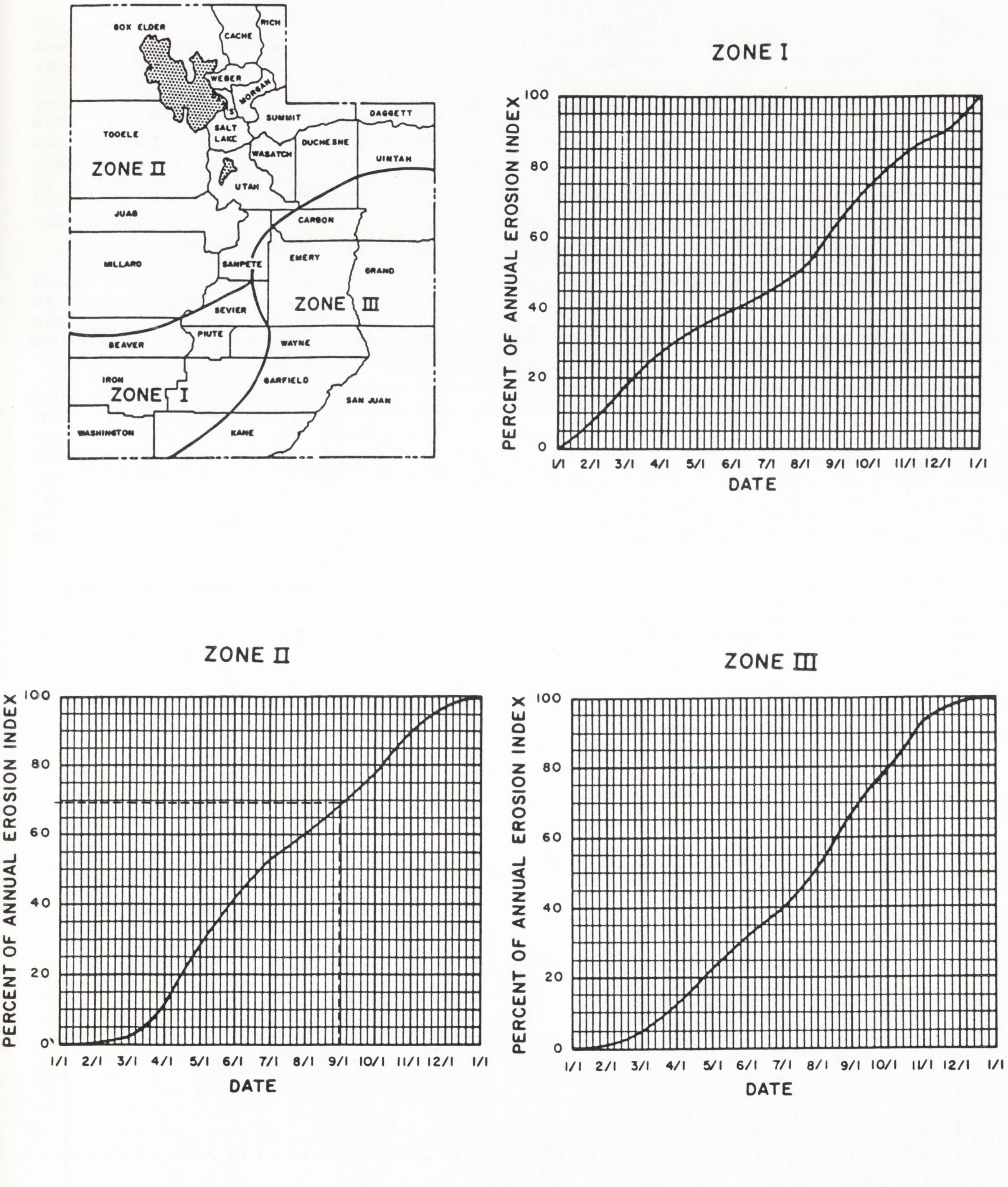


Figure 1. Erosion index distribution curves.

Table 1. Annual distribution^a of erosion index R near Park City, Utah.

Months	Percent		R-factor	
	Per Month	Cumulative	Per Month	Cumulative
January	1	1	0.13	0.13
February	1	2	0.13	0.26
March	10	12	1.30	1.56
April	16	28	2.08	3.64
May	14	42	1.82	5.46
June	11	53	1.43	6.89
July	7	60	0.91	7.80
August	8	68	1.04	8.84
September	9	77	1.17	10.01
October	13	90	1.69	11.70
November	7	97	0.91	12.61
December	3	100	0.39	13.00
	100		13.00	

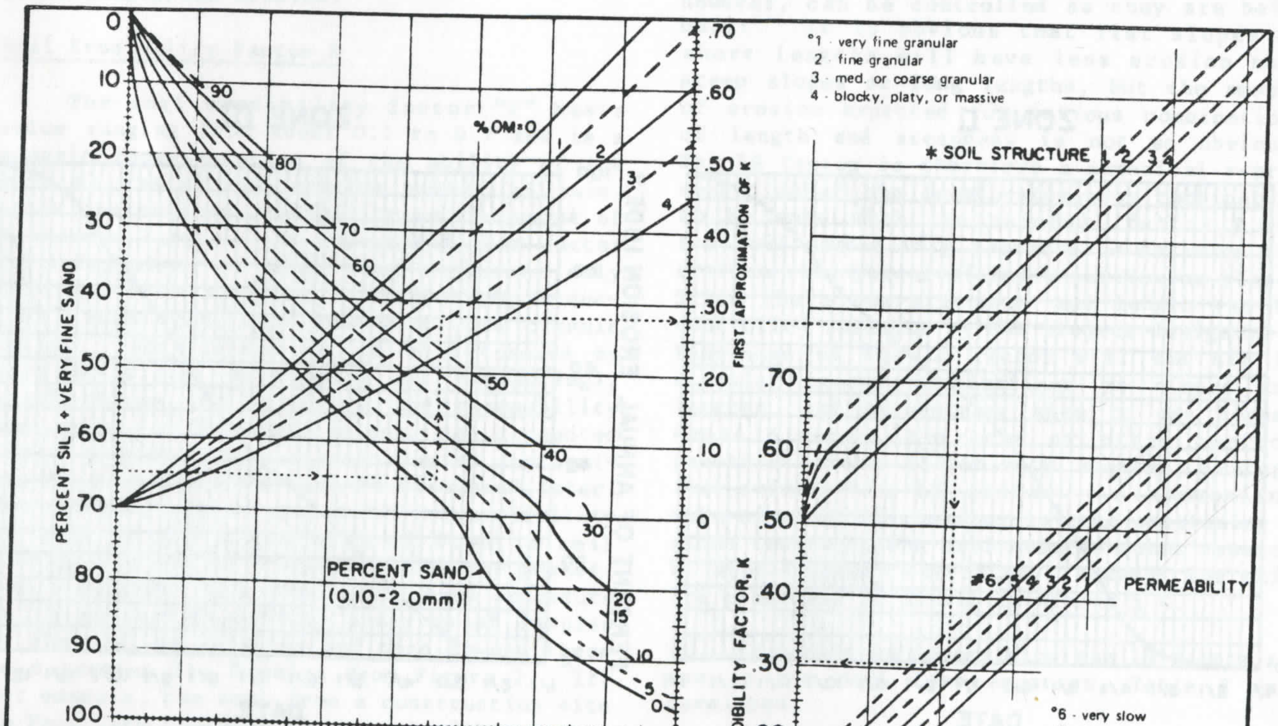
^{a}From distribution curve Zone II, Figure 1.

Limitations of the Equation

1. The equation is semi-empirical and does not necessarily express its several factors in their correct mathematical relationships. This limitation is overcome by the use of empirical coefficients. The physical data upon which the coefficients are based were previously limited to maximum uniform slopes of 20 percent and lengths of 300 feet. UWRL studies extended the slope steepnesses to 84 percent, and the coefficients still proved to be valid.

2. Gully erosion such as is caused by concentrated flows of water cannot be accounted for by the equation. Its use must be confined to sheet erosion, including that caused by snowmelt.

3. The equation was developed to predict soil loss on an average annual basis. Soil loss predictions on a storm-by-storm basis often result in error because of complicated interactions between forces governing soil-loss rates. On any given site these interactions tend to average out over a year's time so that their effect at any particular time is minimal.



PROCEDURE: With appropriate data, enter scale at left and proceed to points representing the soil's % sand (0.10-2.0 mm), % organic matter, structure, and permeability, in that sequence. Interpolate between plotted curves. The dotted line illustrates procedure for a soil having: sl+vfs 65%, sand 5%, OM 2.8%, structure 2, permeability 4. Solution: K = 0.31.

Figure 2. Nomograph for determining soil erodibility factor K.

Table 2. LS values.

Slope Ratio	Slope Gradient "s" (%)	Slope Length "ℓ" (ft.) (λ = summation of "ℓ" segments)																						
		10	20	30	40	50	60	70	80	90	100	150	200	250	300	350	400	450	500	600	700	800	900	1000
	0.5	0.06	0.07	0.07	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.10	0.11	0.11	0.12	0.12	0.13	0.13	0.13	0.14	0.14	0.14	0.15	0.15
100:1	1	0.08	0.09	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.14	0.14	0.15	0.16	0.16	0.16	0.17	0.17	0.18	0.18	0.19	0.19	0.20
	2	0.10	0.12	0.14	0.15	0.16	0.17	0.18	0.19	0.19	0.20	0.23	0.25	0.26	0.28	0.29	0.30	0.32	0.33	0.34	0.36	0.37	0.39	0.40
	3	0.14	0.18	0.20	0.22	0.23	0.25	0.26	0.27	0.28	0.29	0.32	0.35	0.38	0.40	0.42	0.43	0.45	0.46	0.49	0.51	0.54	0.55	0.57
	4	0.16	0.21	0.25	0.28	0.30	0.33	0.35	0.37	0.38	0.40	0.47	0.53	0.58	0.62	0.66	0.70	0.73	0.76	0.82	0.87	0.92	0.96	1.00
20:1	5	0.17	0.24	0.29	0.34	0.38	0.41	0.45	0.48	0.51	0.53	0.66	0.76	0.85	0.93	1.00	1.07	1.13	1.20	1.31	1.42	1.51	1.60	1.69
	6	0.21	0.30	0.37	0.43	0.48	0.52	0.56	0.60	0.64	0.67	0.82	0.95	1.06	1.16	1.26	1.34	1.43	1.50	1.65	1.78	1.90	2.02	2.13
	7	0.26	0.37	0.45	0.52	0.58	0.64	0.69	0.74	0.78	0.82	1.01	1.17	1.30	1.43	1.54	1.65	1.75	1.84	2.02	2.18	2.33	2.47	2.61
12½:1	8	0.31	0.44	0.54	0.63	0.70	0.77	0.83	0.89	0.94	0.99	1.21	1.40	1.57	1.72	1.85	1.98	2.10	2.22	2.43	2.62	2.80	2.97	3.13
	9	0.37	0.52	0.64	0.74	0.83	0.91	0.98	1.05	1.11	1.17	1.44	1.66	1.85	2.03	2.19	2.35	2.49	2.62	2.87	3.10	3.32	3.52	3.71
10:1	10	0.43	0.61	0.75	0.87	0.97	1.06	1.15	1.22	1.30	1.37	1.68	1.94	2.16	2.37	2.56	2.74	2.90	3.06	3.35	3.62	3.87	4.11	4.33
	11	0.50	0.71	0.86	1.00	1.12	1.22	1.32	1.41	1.50	1.58	1.93	2.23	2.50	2.74	2.95	3.16	3.35	3.53	3.87	4.18	4.47	4.74	4.99
8:1	12.5	0.61	0.86	1.05	1.22	1.36	1.49	1.61	1.72	1.82	1.92	2.35	2.72	3.04	3.33	3.59	3.84	4.08	4.30	4.71	5.08	5.43	5.76	6.08
	15	0.81	1.14	1.40	1.62	1.81	1.98	2.14	2.29	2.43	2.56	3.13	3.62	4.05	4.43	4.79	5.12	5.43	5.72	6.27	6.77	7.24	7.68	8.09
6:1	16.7	0.96	1.36	1.67	1.92	2.15	2.36	2.54	2.72	2.88	3.04	3.72	4.30	4.81	5.27	5.69	6.08	6.45	6.80	7.45	8.04	8.60	9.12	9.62
5:1	20	1.29	1.82	2.23	2.58	2.88	3.16	3.41	3.65	3.87	4.08	5.00	5.77	6.45	7.06	7.63	8.16	8.65	9.12	9.99	10.79	11.54	12.24	12.90
4½:1	22	1.51	2.13	2.61	3.02	3.37	3.69	3.99	4.27	4.53	4.77	5.84	6.75	7.54	8.26	8.92	9.54	10.12	10.67	11.68	12.62	13.49	14.31	15.08
4:1	25	1.86	2.63	3.23	3.73	4.16	4.56	4.93	5.27	5.59	5.89	7.21	8.33	9.31	10.20	11.02	11.78	12.49	13.17	14.43	15.58	16.66	17.67	18.63
	30	2.51	3.56	4.36	5.03	5.62	6.16	6.65	7.11	7.54	7.95	9.74	11.25	12.57	13.77	14.88	15.91	16.87	17.78	19.48	21.04	22.49	23.86	25.15
3:1	33.3	2.98	4.22	5.17	5.96	6.67	7.30	7.89	8.43	8.95	9.43	11.55	13.34	14.91	16.33	17.64	18.86	20.00	21.09	23.10	24.95	26.67	28.29	29.82
	35	3.23	4.57	5.60	6.46	7.23	7.92	8.55	9.14	9.70	10.22	12.52	14.46	16.16	17.70	19.12	20.44	21.68	22.86	25.04	27.04	28.91	30.67	32.32
2½:1	40	4.00	5.66	6.93	8.00	8.95	9.80	10.59	11.32	12.00	12.65	15.50	17.89	20.01	21.91	23.67	25.30	26.84	28.29	30.99	33.48	35.79	37.96	40.01
	45	4.81	6.80	8.33	9.61	10.75	11.77	12.72	13.60	14.42	15.20	18.62	21.50	24.03	26.33	28.44	30.40	32.24	33.99	37.23	40.22	42.99	45.60	48.07
2:1	50	5.64	7.97	9.76	11.27	12.60	13.81	14.91	15.94	16.91	17.82	21.83	25.21	28.18	30.87	33.34	35.65	37.81	39.85	43.66	47.16	50.41	53.47	56.36
	55	6.48	9.16	11.22	12.96	14.48	15.87	17.14	18.32	19.43	20.48	25.09	28.97	32.39	35.48	38.32	40.97	43.45	45.80	50.18	54.20	57.94	61.45	64.78
1¾:1	57	6.82	9.64	11.80	13.63	15.24	16.69	18.03	19.28	20.45	21.55	26.40	30.48	34.08	37.33	40.32	43.10	45.72	48.19	52.79	57.02	60.96	64.66	68.15
	60	7.32	10.35	12.68	14.64	16.37	17.93	19.37	20.71	21.96	23.15	28.35	32.74	36.60	40.10	43.31	46.30	49.11	51.77	56.71	61.25	65.48	69.45	73.21
1½:1	66.7	8.44	11.93	14.61	16.88	18.87	20.67	22.32	23.87	25.31	26.68	32.68	37.74	42.19	46.22	49.92	53.37	56.60	59.66	65.36	70.60	75.47	80.05	84.38
	70	8.98	12.70	15.55	17.96	20.08	21.99	23.75	25.39	26.93	28.39	34.77	40.15	44.89	49.17	53.11	56.78	60.23	63.48	69.54	75.12	80.30	85.17	89.78
	75	9.78	13.83	16.94	19.56	21.87	23.95	25.87	27.66	29.34	30.92	37.87	43.73	48.89	53.56	57.85	61.85	65.60	69.15	75.75	81.82	87.46	92.77	97.79
1¼:1	80	10.55	14.93	18.28	21.11	23.60	25.85	27.93	29.85	31.66	33.38	40.88	47.20	52.77	57.81	62.44	66.75	70.80	74.63	81.76	88.31	94.41	100.13	105.55
	85	11.30	15.98	19.58	22.61	25.27	27.69	29.90	31.97	33.91	35.74	43.78	50.55	56.51	61.91	66.87	71.48	75.82	79.92	87.55	94.57	101.09	107.23	113.03
	90	12.02	17.00	20.82	24.04	26.88	29.44	31.80	34.00	36.06	38.01	46.55	53.76	60.10	65.84	71.11	76.02	80.63	84.99	93.11	100.57	107.51	114.03	120.20
	95	12.71	17.97	22.01	25.41	28.41	31.12	33.62	35.94	38.12	40.18	49.21	56.82	63.53	69.59	75.17	80.36	85.23	89.84	98.42	106.30	113.64	120.54	127.06
1:1	100	13.36	18.89	23.14	26.72	29.87	32.72	35.34	37.78	40.08	42.24	51.74	59.74	66.79	73.17	79.03	84.49	89.61	94.46	103.48	111.77	119.48	126.73	133.59

METHODS OF CONTROLLING EROSION

Use of the modified universal soil loss equation described in this handbook enables one to determine the potential sheet erosion caused by raindrop impact, runoff, and snowmelt, at any particular construction site, and the degree of control needed to reduce that erosion to desired or tolerable limits.

Control Factor VM

(See Appendix C for additional details.)

The erosion control factor is applied in the equation as a single unit. It accounts for the effects of erosion control measures that may be implemented on any particular construction site, such as vegetation, mechanical manipulation of the soil surface, chemical treatments, etc. It does not include structures such as berms and ditches; these are part of the topographic factor, LS. For any site the soil loss equation may be solved with and without erosion control measures installed and the difference in the "A" values determined is an indication of the effectiveness of that particular control system.

Vegetative Controls

Vegetative controls include a variety of materials, both natural and synthetic, that differ widely in the amount of control they provide. All species of plants are included in this category and are employed in living form growing on the site, or as dead vegetative matter placed on the surface, or as a mulch incorporated into the soil. A variety of synthetic materials is now available, that may also be classed as vegetative controls.

Vegetative controls shield the soil surface from the impact of falling raindrops, they slow the velocity of runoff down the slope, they help maintain the soil's capacity to absorb water, and they help hold soil particles in place. In addition to their physical ability to assist in erosion control, vegetative mulches aid in the establishment of vegetative growth by helping in the retention of moisture, and by holding the seeds in place against the erosive action of water.

From research results reported in the literature, it was noted that mulches had apparent VM factor values commonly around 0.01 until R·K·LS factor values exceeded a certain critical level at which point the mulch partially failed. Thus for each set of R·K·LS values it is assumed that a certain quantity of mulch is required to maintain the VM factor value at a level near 1 percent. Figures 3, 4, 5, and 6 were developed using data gathered from both published and unpublished sources and show this relationship for straw or hay mulch not tacked, straw or hay mulch tacked or punched in across the slope, wood chip mulch, and stone mulch. To use the figures, one must enter the Y-axis at the R·K·LS value for the site, move horizontally to the right until the curve is intercepted, then drop vertically to the base scale and read the critical tonnage of mulch. This tonnage is the minimum needed to stabilize the site. Any quantity of mulch less than this amount would have a high failure risk and may thus be wasted. Of course, there is a gradual transition across the diagonal line on the graphs, and not an abrupt change as seems to be indicated.

In addition to its physical ability to aid in erosion control, an important value of hay or straw mulch is to aid in the establishment of vegetative growth. There is a limit to the amount of straw or hay that can be applied and still have seed germination and vegetation establishment. In revegetating disturbed areas, one should be aware of a limitation that may exist at each particular site and not prescribe amounts in excess of it.

Standing vegetation exerts its influence on the VM factor in proportion to its aerial density and type of root system. Apparently all grasses that are suitable for erosion control and adapted to the site can be grouped together as can all forbs such as legumes, weeds, etc. Figure 7 shows the relation between grass density and VM factor, and Figure 8 shows the same relationship for the forbs. Data for these plots were assembled from the literature. The VM values for the most common combinations of vegetal matter can be covered by the figures given, but those for bare soils and chemicals may be of a nearly

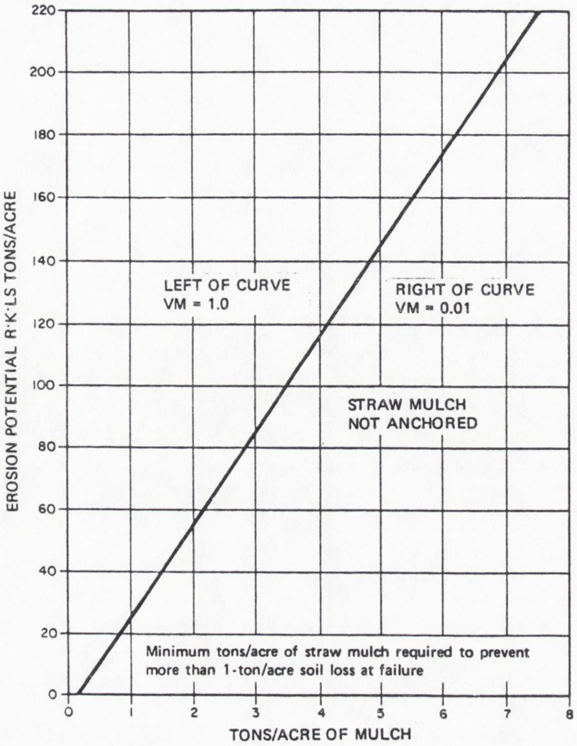


Figure 3. Straw mulch not anchored vs. R·K·LS.

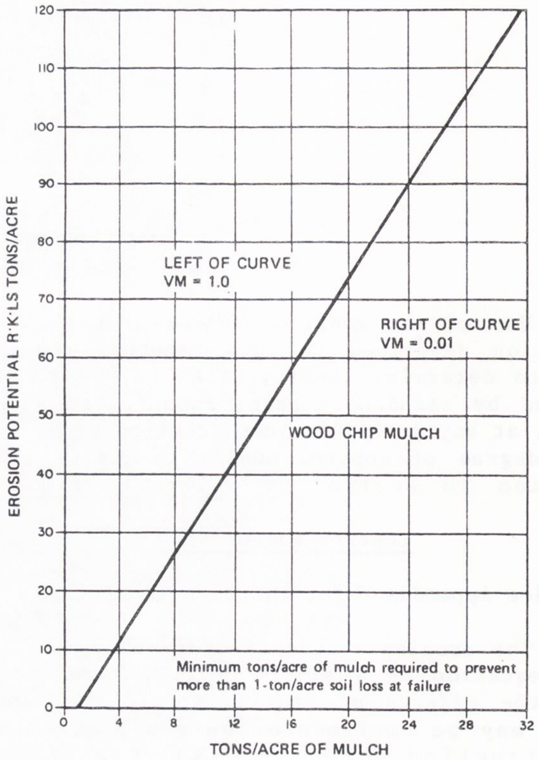


Figure 5. Wood chip mulch vs. R·K·LS.

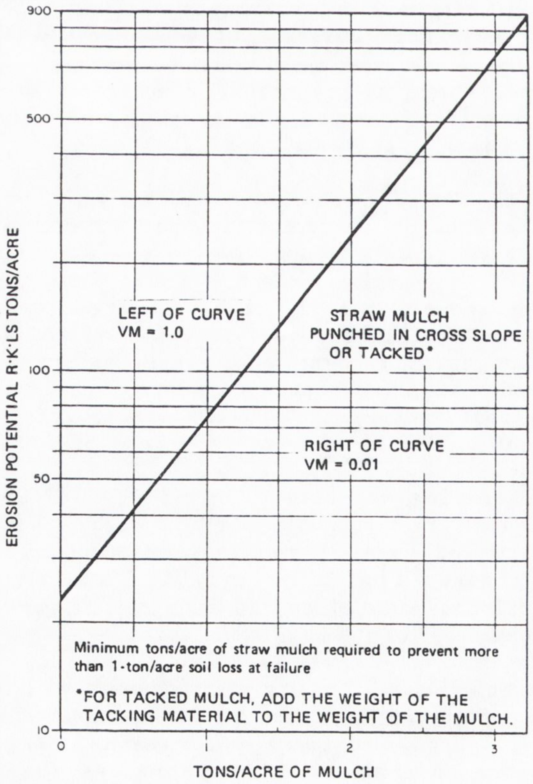


Figure 4. Straw mulch anchored vs. R·K·LS.

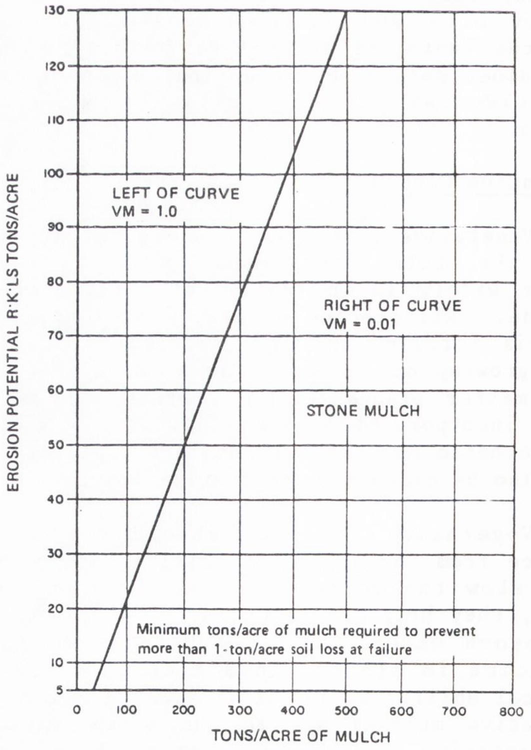


Figure 6. Stone mulch vs. R·K·LS.

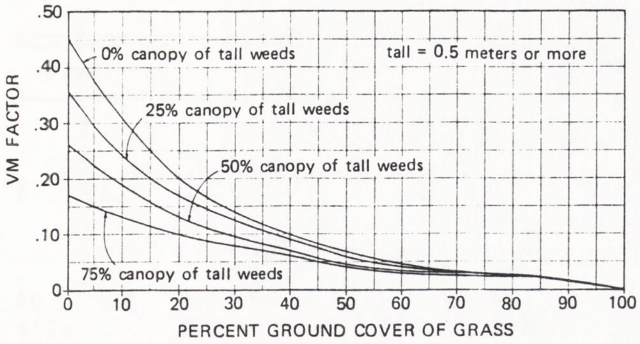


Figure 7. Relationship between grass density and VM factor.

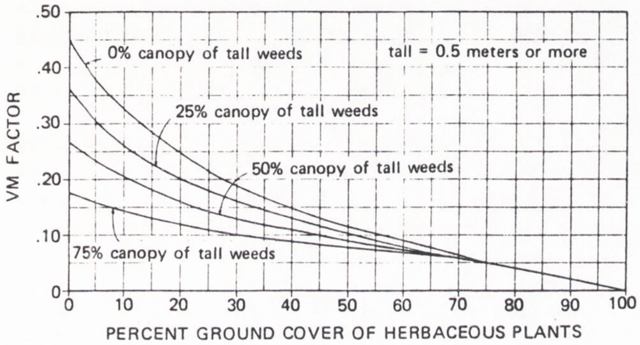


Figure 8. Relationship between forb density and VM factor.

infinite variety. Some of the commonly encountered conditions and possible treatments with their corresponding VM values that have been gleaned from the literature are tabulated in Table 3.

Mechanical Controls

Mechanical manipulation of the soil surface such as scarifying, disking, or tracking also provides a degree of erosion control by permitting more water to infiltrate and less to flow over the surface. Some mechanical measures reduce erosion by modifying the LS factor in the soil loss equation, such as shortening slopes by the use of berms, ditches and benches, or flattening slopes through the installation of retaining walls.

Other measures such as down drains, energy dissipators, and diversion structures all serve to decrease erosion by keeping water off erodible areas, confining runoff to controlled and protected areas, and reducing flow velocities to nonerosive levels. In some instances it may be desirable to pave erodible slopes with asphalt or concrete to eliminate erosion altogether. VM values for selected mechanical controls are given in Table 3.

Chemical Controls

Numerous chemical stabilizers have been developed for use in controlling erosion, both for applying directly to the soil surface and for use as tackifiers applied to mulches. Some of these are applied separately to the soil surface and others are mixed with water, seed, fertilizer, and mulch and applied through a hydromulcher. As with most commercial mulches, insufficient comparative testing of these products has been done to develop reliable performance information. A few VM values for chemical controls are shown in Table 3.

Timing of Implementation as a Method of Control

The time at which erosion control measures are implemented is as important, and sometimes more so, than the kind of measure implemented, because the amount of rainfall and runoff during different periods of the year influences erosion vulnerability. If the construction period will be short, and can be completed during the dry season of the year, then few if any erosion control measures will be required. On the other hand, extreme care must be exercised in planning and implementing control measures in areas that will be exposed during a rainy season if satisfactory results are to be obtained.

The season during which stabilizing vegetative cover can best be established should also be considered in construction scheduling. Temperature, as well as precipitation, influences seed germination, and generally, the cool, moist periods of early spring and fall are the most favorable for the establishment of stabilizing vegetative cover. In some cases it is recommended that stabilizing vegetation be established in critical areas, such as drainageways and stream banks, before major clearing and grading begin on the rest of the site. By properly scheduling the various phases of construction operations, both the exposed surface area and the duration of exposure can be minimized.

If construction is scheduled so that a vegetated area is used as a buffer above or below control areas such as slopes, stream banks, and surface drainageways under construction, the amount of runoff that can reach

Table 3. Typical VM factor values reported in the literature.[a]

Condition	VM Factor
1. Bare soil conditions	
freshly disked to 6-8 inches	1.00
after one rain	0.89
loose to 12 inches smooth	0.90
loose to 12 inches rough	0.80
compacted bulldozer scraped up and down	1.30
same except root raked	1.20
compacted bulldozer scraped across slope	1.20
same except root raked across	0.90
rough irregular tracked all directions	0.90
seed and fertilizer, fresh	0.64
same after six months	0.54
seed, fertilizer, and 12 months chemical	0.38
not tilled algae crusted	0.01
tilled algae crusted	0.02
compacted fill	1.24-1.71
undisturbed except scraped	0.66-1.30
scarified only	0.76-1.31
sawdust 2 inches deep, disked in	0.61
2. Asphalt emulsion on bare soil	
1250 gallons/acre	0.02
1210 gallons/acre	0.01-0.019
605 gallons/acre	0.14-0.57
302 gallons/acre	0.28-0.60
151 gallons/acre	0.65-0.70
3. Dust binder	
605 gallons/ac Fiber Glass Roving	1.05
1210 gallons/acre	0.29-0.78
4. Other Chemicals	
1000 lb. Fiber Glass Roving with 60-150 gallons asphalt emulsion/acre	0.01-0.05
Aquatain	0.68
Aerospray 70, 10 percent cover	0.94
Curasol AE	0.30-0.48
Petroset SB	0.40-0.66
PVA	0.71-0.90
Terra Tack	0.66
Wood fiber slurry,[b] 1000 lb/acre fresh	0.05-0.73
Wood fiber slurry,[b] 1400 lb/acre fresh	0.01-0.36
Wood fiber slurry,[b] 3500 lb/acre fresh	0.009-0.10
Portland Cement and Latex	
1000 lbs/ac + 8 gal/ac	0.13
1500 lbs/ac + 12 gal/ac	0.006
5. Seedings	
temporary, 0 to 60 days	0.40
temporary, after 60 days	0.05
permanent, 0 to 60 days	0.04
permanent, 2 to 12 months	0.05
permanent, after 12 months	0.01
6. Brush	0.35
7. Excelsior blanket with plastic net	0.04-0.10
8. Mulch (see Figures 3, 4, 5, 6)	

[a] Note the variation in values of VM factors reported by different researchers for the same measures.

[b] This material is commonly referred to as hydromulch.

the critical exposed area will be reduced. A construction operation scheduled in phases is especially valuable in dealing with long slopes, because stabilizing the upper portion of the slope will protect the lower area.

For each phase of construction, control measures which will serve to protect exposed areas and adjacent property, such as sediment traps, basins or ponds, and diversion ditches, should be installed before clearing and grading begin. Structures such as these do not decrease erosion but serve to catch the sediment after it has left the source area. Design drawings for such structures are readily available from local offices of the Soil Conservation Service and from other sources and are not included in this handbook. Even though much research remains to be done in order to determine the true efficiencies and optimum designs of sediment basins and traps, existing designs may be used effectively to prevent sediment from leaving rights-of-way and entering streams, lakes, or adjacent properties. The amount of sediment captured in such structures can be measured or calculated and subtracted from the total soil loss, determined by the equation, to estimate actual loss. Where areas are to be left for long periods of time, temporary measures such as vegetation, berms, down drains, and mulch covers should be installed to protect and stabilize the exposed soil surface, and then permanent control measures should be implemented as soon as is practical.

Much can be done to minimize erosion and sedimentation if problems are anticipated and provided for before development begins, and if control measures are implemented in a timely manner.

METHODS OF CONTROLLING SEDIMENT

Stopping sediment before it has had an opportunity to leave its source is the most effective means of erosion control, but one that is rarely practiced. It costs much less to maintain sediment at or near its place of origin than to replace it after it has moved downslope. Numerous small sediment traps, each no larger than a few cubic yards in volume, strategically placed at critical areas on the construction site have proven to be an effective means of controlling sediment. These prevent sediment from moving more than a few hundred feet from its source, but require regular maintenance throughout the period of construction to remain effective. It is necessary to clean them after every storm, but this is generally less expensive than having to restore sediment that has traveled long distances, entered waterways, or has left the construction site.

At times it may be advantageous to construct a single large sediment basin or detention pond to catch all the runoff coming from a construction site. Detention time should be long enough to allow sediment to settle out before the water is allowed to leave the basin and enter a stream or a drain. Straw bales, vegetation, or gravel may be used to filter sediment from water before it leaves the site. Filter cloth laid over a gravel berm is effective in removing fine sediment from runoff, but must be frequently cleaned with a shovel or brush. The most effective sediment control measures are those that are properly cleaned and maintained throughout the life of the project.

ARCHITECTURAL CONSIDERATIONS

Oftentimes on building construction sites the most serious erosion occurs as a result of runoff from paved or impervious areas, for which inadequate considerations were given in the design. The architect should anticipate and provide for control of runoff from parking areas, rain gutters, sidewalks, play grounds, and other areas responsible for concentrating flows of water that could cause erosion.

Excavating the toe of a slope will cause the slope to become unstable, and sliding or sloughing may result unless an adequately designed retaining wall is installed. Downspouts from rain gutters may require splash blocks, or other protection to prevent serious erosion from this source, especially on sloping terrain. Drainageways may require bed and bank protection to carry the occasional flood flows that may flow through them. Home construction on hillslopes may require installation of subsurface drains to prevent downslope movement of the completed structures. Shoulders of paved roadways and sidewalks must be protected to prevent undermining of the pavement. Energy of high-velocity flows down street gutters must be dissipated in some manner before being discharged into an open ditch. Bridge culverts, storm sewer outlets, and accumulated water flow from city streets can cause serious erosion and/or flooding unless adequate precautions are taken. Architects should design for these and numerous other similar situations to minimize damages that may result in subdivisions and other building areas from runoff, mudslides, and erosion. Many innovative and effective designs have been developed, and photos of some of these are included in Appendix A.

OTHER FORMS OF EROSION

The universal soil loss equation is used to estimate losses of soil from sheet erosion only, and therefore erosion such as rills and gullies must be calculated separately. Erosion amounts from other than sheet erosion cannot be predicted, but rather can be measured after the fact and added to calculations of amounts of sheet erosion to determine total erosion for a particular area.

Rill and Gully Erosion

These two forms of erosion occur in the same way, and differ only in the amount of soil they produce. If soil losses are less than about 100 tons per acre the mechanism causing the losses is referred to as rilling, and if in excess of 100 tons per acre it is known as gullying. Both forms are caused by running concentrated flows of water for long periods of time over erodible soil. First, rills are formed, and then if left unchecked or unrepaired they continue to grow and eventually become gullies. The amount of soil eroded in this manner can be determined by measuring and calculating the volumes of the rills and gullies formed.

If adequate protection is provided to control sheet erosion, then rills and gullies will never form from rainfall. However, under certain conditions and at particular sites, this may not be possible and gullying results. Gullies may form also from concentrated flows of surface water from streets, parking lots, etc., flowing uncontrolled down a slope.

Gullies, if not too large, can sometimes be repaired by regrading the slopes on which they occur. In some instances it may be necessary to replace the eroded soil either by reclaiming that which has left the slope, or by importing soil from other sources, in order to restore the slope to a predetermined grade. Provisions should be made also for diverting the water above the gully, either partially or totally, so that the same problem doesn't reoccur.

In locations where it is not necessary to fill the gullies, they may be stabilized and landscaped so they do not grow larger, by the appropriate placement of rock or gravel rip-rap, brush, or other similar type bulky materials, and planting appropriate grasses, vines, and shrubs.

Appendix C describes a method often used for calculating rill erosion, known as the Alutin Rill Erosion Method. It measures erosion in tons per acre and is fairly accurate up to losses of about 100 tons per acre.

Stream and Channel Erosion

As much as possible, natural stabilized drainage ways existing on a site should be utilized during and after construction. As the volume and velocity of runoff increase because of changes in surface and soil conditions brought about by construction, erosion of the stream channel banks and bottom may occur. These may be stabilized with the appropriate placement of rip-rap, erosion control mats, revetments, gabions, or other such materials. Where the capacity of the natural channel is exceeded, additional capacity, stabilizing vegetation, and/or structural measures may be needed. Formulas and techniques for designing channel cross sections, slopes, stabilizing covers, and design velocities may be obtained from Soil Conservation District Offices. The following are characteristics of a stable channel:

1. It neither aggrades or degrades beyond tolerable limits (at the mean annual runoff peak).

2. The channel banks do not erode to the extent that the channel cross section is changed appreciably.

3. Excessive sediment bars do not develop.

4. Excessive erosion does not occur around culverts and bridges or elsewhere.

5. Gullies do not form or enlarge due to the entry of uncontrolled surface flow to the channel.

Landslides, Mudflows, Debris Flows and Piping

During periods when average annual precipitation increases, and during shorter periods of unusually high rainfall, there is often an increase also in the number of landslides or mudflows that occur. It is generally not possible to predict accurately where and when the next ones will be, or to mitigate them once they have begun, but there are measures that can be taken to avoid their devastating effects.

Landslides, mudflows, debris flows, and piping are all caused by the same set of conditions which are summarized as follows:

1. There must be a source of water.

2. The soil must be more permeable at the surface than it is at some horizon or interface at depth.

3. There must be a slope or gradient.

4. The soil above the impermeable layer must be erodible.

5. There must be an outlet.

All five of these parameters must be present before slides, mudflows, debis flows or piping can occur.

In addition, one may induce sliding on an otherwise stable slope by removing the toe of the slope or excavating a roadway or building site into the hillside, and not adequately stabilizing it afterwards. Methods exist for preventing or controlling slides, but they are all fairly expensive. The best policy, generally, is to try to avoid them.

Procedure for prevention or control.

1. Inspect the area to ascertain if old slide or pipe (karst) scars are observable. If none exist and no excavations or impoundments are to be made, no further studies are necessary.

2. If scars are present, decide which of the five above-listed parameters is least expensive to remove or modify. The most common is to provide physical reinforcement of the slope to prevent further movement of the soil, and to allow water to be released under control. This may be done with retaining walls of such materials as concrete, reinforced earth, sheet piling, gabions, etc.

3. If excavations or impoundments are to be made, a study of the earth profile should be conducted to determine whether these will create inlets or outlets for water, or paths for lateral flow. Such a phenomenon will not occur every year, but only in those years that extra water is available (such as from above-normal rainfall or hilltop development).

4. Developers would do well to avoid, whenever possible, construction on floodplains and in areas known to be prone to slides and piping, because sooner or later these devastating events will occur again. When avoidance is not possible or desirable, precautions should be taken to prevent or remove one or more of the problem-causing conditions listed above.

EROSION CONTROL PLANNING

Erosion control measures should be carefully considered during the planning and design phases of any project, as well as during its construction and use phases. This procedure will enable many potential problems to be averted or ameliorated that might otherwise arise either during or following the construction period. Many temporary measures that are effective in controlling erosion during construction may serve permanently during the operational period if they are kept properly cleaned or otherwise maintained. The following steps should be included in every erosion control plan:

1. During the project planning stage, gather information about erosion-sensitive zones and adjacent areas wherein sediment, even in small amounts, might become a problem. These would include such places as streams, ponds, lakes, inhabited areas, neighbors lawns, and other high-value concerns.

2. Identify the locations which may produce acute erosion problems such as steep slopes, and deep cuts and fills, sandy zones, springs, high water tables, erodible soils, and natural drainages and floodplains.

3. Determine the values of the parameters in the modified soil loss equation, A = R·K·LS·VM, for each segment of the project delineated on the basis of similarity of erosion characteristics, and determine the sheet erosion potential for each, using the step-by-step procedures outlined in the handbook. The required data may be obtained from appropriate maps, charts, tables, soil samples, and job specifications for each site.

4. Investigate the possibility of other types of hazards such as can come from building on a floodplain, near or on slopes having piping or sliding potential, on top of a known fault, or where concentrated flows of water from higher elevations could cause rilling, gullying, mudflows, slides or flooding, and avoid these areas.

5. For each segment of the project having an erosion potential in excess of that deemed appropriate for its location, designate erosion control measures for reducing the anticipated soil loss to acceptable levels. Step-by-step procedures for accomplishing this are presented in this handbook.

6. Include sufficient information regarding the erosion control plan in the design drawings, including necessary graphics and working details, so that there will be no misunderstanding by construction and/or landscaping personnel as to what is required. Supplemental instructions and explanations may be necessary.

7. Provide adequate means of enforcing frequent review and implementation of the erosion control specifications. An effective means of encouraging compliance is to foster proper attitudes among contractors by including erosion control measures as bid items in the contract, and by providing appropriate training sessions for selected construction personnel. Conduct a preconstruction meeting and on-site inspection where the contractor is informed of the importance of erosion control measures and where site specific conditions are discussed prior to the start of construction.

8. Leave those measures in place that can continue to assist in controlling erosion after the construction phase is completed, provided there is no safety hazard created thereby, and they are not aesthetically objectionable. Adequate provisions should be made in the maintenance schedule and budget for cleaning and otherwise maintaining these measures.

STEP-BY-STEP PROCEDURE FOR DETERMINING EROSION

The following step-by-step procedures will lead one through the proper use of appropriate tables, figures, maps, and graphs in this handbook for determining sheet erosion.

1. Determine as precisely as is practicable the latitude and longitude of the construction site in question.

Example: A construction site near Park City. From an appropriate map, the location is determined to be 40°38'52"N, 111°30'53"W.

2. Using the location information from 1, enter the appropriate iso-erodent map and determine the annual R value for the site. (Remember that these R values for Utah include snowmelt as well as rainfall.)

Example: From Salt Lake City iso-erodent (R) values map (in map pocket) the R value is determined to be 13.

3. Estimate as nearly as possible the length of time the site will be exposed to erosive forces.

Example: The site will be exposed for approximately 8 months, beginning in January.

4. With the information from number 3, enter Figure 1 and read the percentage of annual R for each month or fraction thereof that the site will be exposed. These individual percentages are added together to give a percentage for the total time period. This total percentage is then multiplied by the annual R value from number 2 to obtain the proper value of R to use in the soil loss equation.

Example: From Figure 1, Zone II distribution graph (and Table 1), the cumulative percentage of R for 8 months is 68 percent. (Enter the bottom of the distribution graph at the end of the 8th month [follow dotted line], move vertically until graph is intercepted, then horizontally to the left and read 68 percent on the percentage scale.) Therefore, the proper value of R to use in the equation is

$$0.68 \times 13 = 8.84$$

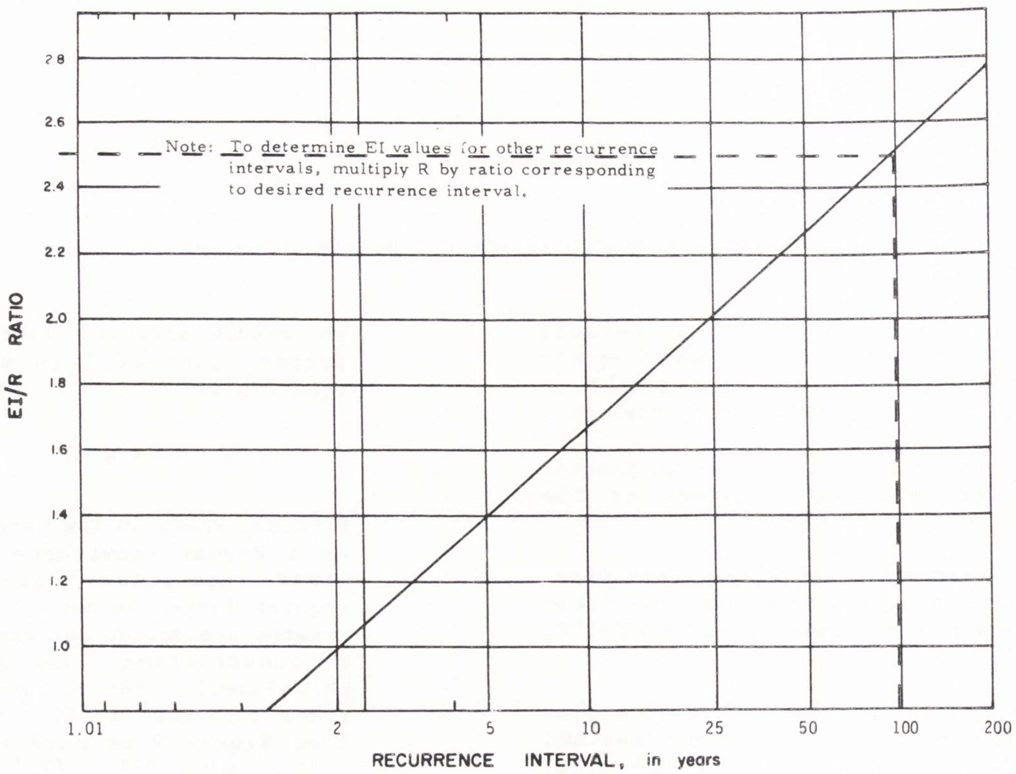
R values shown on the maps are based on a 2-year recurrence interval. Other recurrence intervals will require larger values of R and thus greater protection for exposed areas of construction. For purpose of this example, let us use a recurrence interval of 100 years. Then from Figure 9 we read a ratio of EI/R of about 2.51. (Follow the 100 year recurrence interval line vertically until it intercepts the diagonal, then move horizontally and read the appropriate EI/R value.) The R value to use in the equation then is 2.51 x 8.84 = 22.19.

5. With the location information from number 1, enter an appropriate soil survey map and determine the soil erodibility factor K for the site in question. A better way than using a soil survey map is to take appropriate samples at the site and analyze them for particle size, percent organic matter, soil structural class, and relative permeability. With this information, use the nomograph in Figure 2 to determine the K factor.

In the absence of both of these, enter the soil erodibility map in the map pocket and determine the approximate value for K.

Example: From the colored soil erodibility index map in the map pocket, the K factor is near the boundary between yellow and green (value range 0.21 to 0.40). Soil samples were collected at the site and analyzed. Then using Figure 2 the actual value of K was determined to be 0.31.

6. Determine slope steepness as percent gradient. (For example, 2.5:1 slope equals a gradient of 40 percent.)



Note: To determine EI values for other recurrence intervals, multiply R by ratio corresponding to desired recurrence interval.

Figure 9. The relationship between the EI/R ratio and recurrence interval.

Example: The slope at the site is 2 to 1 or 50 percent.

7. Determine the slope length in feet.

Example: The measured length of the slope is 350 ft.

8. Using data from numbers 6 and 7 enter Table 2 and determine the topographic factor, LS. (For multiple slopes, follow the procedure detailed in Appendix C.)

Example: The LS value from Table 2 for a 50 percent slope, 350 feet long, is 33.34.

9. The product of values determined in 4, 5, and 8 is the R·K·LS value, or potential erosion.

Example: A = R·K·LS = 22.19 x 0.31 x 33.34

= 229.34 t/ac/yr

10. The amount of mulch required to reduce the potential erosion to the amount of 1 ton/acre can be determined from Figures 3 through 6. Other control measures are listed in Table 3 together with their approximate VM values. The VM value of any particular control measure, multiplied by the R·K·LS value determined in number 9, will give an indication of the effectiveness of that particular measure in controlling erosion.

Example: Control measures: One may select from several alternatives, such as the following.

A = R·K·LS·VM

If R·K·LS = 229.34 and we wish to reduce it to say <10 tons/acre/yr the VM required = 10/229.34 = 0.04. Any one of several treatments having appropriate VM values can be selected from Table 3. For example:

1000 lb fiber glass roving with asphalt emulsion = 0.01 to *0.05
1400 lb/ac hydromulch = 0.01 to *0.36
Permanent seedings 0 - 60 days = 0.04
Excelsior blanket with plastic net = 0.04 to *0.10
and from Figure 4, 2.5 tons/ac straw (punched in) = 0.01

*Range of values reflects variations in the literature reported by different researchers.

11. Place more mulch at the lower end of the slope than at the top to compensate for the higher rate of erosion in this area.

Example: Review detailed example in Appendix C of the distribution of erosion on a slope.

12. NOTE LIMITATIONS LISTED PREVIOUSLY OF THE SOIL LOSS EQUATION.

Example:
1. Erosion determined is on an average annual basis.
2. Valid only for sheet erosion.
3. Equation is semi-empirical and thus is limited by data upon which coefficients are based.

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APPENDIX A

EROSION CONTROL MEASURES, USES, AND PHOTOGRAPHS

1. A listing of erosion control measures and their characteristics, and examples of their use locations.
2. Photographs of erosion control measures.

EROSION CONTROL MEASURE	CHARACTERISTICS OF MEASURE	EXAMPLES OF USE LOCATIONS													
		Figure Number of Picture	Adjacent Properties	Adjacent Water Bodies	Borrow and Stockpile Areas	Enclosed Drainage (Inlet and Outlet Control)	Large Flat Surface Areas	Medians	Residential Areas	Rights of Way--Roadways	Shoulders	Slopes (Cuts and Fills)	Streams amd Waterways	Drainageways	Parks and Recreation Areas
Aggregate Cover	Stabilizes soil surface. Used on seeps. Permits construction traffic in adverse weather. May be used as part of permanent base construction. Made by placing gravel on soil surface.	A-1				X	X	X	X		X	X	X	X	X
Barrier, Temporary Brush Fence Hay or Straw Bales	Impedes surface runoff and stops the movement of sediment, mulch or other surface protectors. Brush and hay bales used on medium slopes or at the toes of steep slopes. Fence used on slopes. Made by piling or staking on or near a contour along the surface to be protected. Also serves as filter on berm.	A-2	X			X		X	X			X	X	X	X
Benches (Terraces)	Reduce slope lengths. Made by constructing wide (say 10'-20') horizontal, level or slightly reverse sloping steps in intervals (say 50'-100') down the slope, on or near contours. Reduce water velocities and increase infiltration. Require provision for runoff disposal.	A-3			X					X		X			
Berms Berm and Ditch Burlap Sand Sausage Diversion Slope	To control or divert the flow of surface runoff. Made by piling a soil windrow or other obstruction along the shoulders of the roadbed or top of cut to prevent surface runoff from eroding slopes. Require adequate downdrains to dispose of water. The burlap sand sausage is made by filling a burlap tube with sand or piling sand on a long piece of burlap and sewing the burlap into a tube.	A-4	X	X	X			X	X		X	X		X	X
Cellular Concrete Block Revetment (Gobi Blocks)	Excellent for surface protection on slopes and especially against wave action. These blocks are constructed of dense concrete and are installed on top of a plastic filter cloth. After installation topsoil is spread loosely over the revetment to partially fill the cell openings, and the revetment is then fertilized and seeded.	A-5		X		X						X	X	X	
Channels Asphalt Bare Burlap Concrete Concrete Block Excelsior Fiber Glass Roving Gabions Jute Plastic (Nylon) Mat Plastic Sheeting Rock or Riprap Sod Vegetation	Used to convey runoff from points of concentration across, through, along, and around highway rights of way, or other areas to be protected. Channels steeper than approximately three percent need protection to prevent erosion. Allowable slope of bare channels depends on the type of soil.	A-6	X	X	X	X	X	X	X	X	X	X	X	X	X
Check Dams Graded Stone Log Log and Hay Rock and Fence Sheet Piling Staked Bales Straw Bales & Fence	Prevent channel erosion and allow settling of suspended solids. They reduce water velocities, lengthen detention times and increase stream cross-sections. Constructed by placing the selected material across the channel normal to the flow. Dam height is dictated by flow amount and channel slope. Check dams should be kept clean and free from obstructions.	A-7	X	X	X	X		X	X		X		X	X	X
Chemical Stabilization Aerospray 52 Aerospray 70 Aquatain Arzan Asphalt Emulsion	Used to reduce the movement of soil and other soil protectors. Applied by spraying the liquid chemical onto the soil surface or over other protectors. Some will inhibit plant growth and some will foster it--inquire of the seller.	A-8			X		X	X	X	X	X	X		X	X

		EXAMPLES OF USE LOCATIONS												
EROSION CONTROL MEASURE	CHARACTERISTICS OF MEASURE	Figure Number of Picture	Adjacent Properties	Adjacent Water Bodies	Borrow and Stockpile Areas	Enclosed Drainage (Inlet and Outlet Control)	Large Flat Surface Areas	Medians	Residential Areas	Rights of Way--Roadways	Shoulders	Slopes (Cuts and Fills)	Streams and Waterways	Drainageways	Parks and Recreation Areas
Chemical Stabilization (Continued) Coherex Conwed Fiber Curasol Dust Binder Ecology Control Erode-X Fiber Glass Roving, Tacked Glenkote Petroset PVA Soil Bond Soil-Lok Soil Master Soil Seal Surfaseal Terra-Krete Verdyol (Super) Wood Fiber Slurry (Others)															
Chutes Asphalt Bare Burlap Concrete Concrete Block Excelsior Fiber Glass Roving Grass Jute Plastic (Nylon) Mat Plastic Sheeting Rock or Riprap Sod	Used to convey water down slopes and can be either temporary or permanent. Chutes generally require energy dissipators at the downstream ends. (See also down drains.)	A-9			X				X	X		X		X	X
Cofferdam Concrete Earth Steel Supported Plastic Sheet Wood Other	Diverts water from structures or stream bank segments during construction to prevent sediment from entering adjacent streams.	A-10		X									X		
Compaction	Proper compaction of fill embankments will reduce the erosion rate, especially at lower water velocities. It should be done in proper increments at the optimum soil moisture content.	A-11								X		X			
Construction Dam	Similar to a cofferdam except it usually leaves the structure accessible to the bank rather than surrounding it.	A-12		X									X		
Construction Fabrics	Uses include ground stabilization, subsurface drainage, road construction and maintenance, sediment control, and others.	A-13				X	X		X	X				X	X
Diaper (see Floating Sediment Barrier)															
Ditch Blocks and Dams	Similar to check dams but are applied to smaller water ways. Therefore less rigid materials can be used such as loose straw or hay, some mulching materials, small gravel, etc.	A-14	X	X	X	X	X	X	X	X	X	X	X	X	X

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		EXAMPLES OF USE LOCATIONS													
Diversion Ditch, Cut Slope	Constructed at the upper edges of cut slopes to collect water from adjacent properties and divert it around the cut. Materials used to construct these ditches are determined by the slope of the ditch but include sod, gravel, stone, asphalt, and concrete. Ditches may be temporary or permanent.	A-15							X			X			X
Drain, Down Asphalt Burlap Concrete Excelsior Mat Fiber Glass Roving Flexible Pipe Gravel, Rock or Rubble Jute Mesh Plastic Sheeting Rigid Pipe Sod Subsurface Pipe	Used to conduct runoff down a slope. May be open channel or closed conduit, temporary or permanent. (See also Chutes.)	A-16	X	X	X	X		X	X	X	X	X	X	X	X
Drain, Horizontal	Used to dewater slopes and embankments. May also be drilled on an incline rather than horizontal.	A-17										X			
Drain, Slope (See also Interceptor Drains)	Placed horizontally at vertical intervals on long slopes to reduce the effective slope length. These drains can be of any open channel cross section and must be lined. Usually function both as temporary and permanent structures.	A-18			X				X			X			X
Drop Box Culvert (See also Inlets)	Consists of a culvert inlet-box with vertical sides. Acts as an energy dissipator and reduces the velocity in the culvert. This type of structure is usually permanent except in temporary sediment basins, and is constructed of steel, wood, or concrete.	A-19	X	X	X	X			X	X		X	X	X	X
Drop Structure	Effectively reduces velocity of flow in inclined channel to prevent scour. Serves also as energy dissipator. May be constructed of any rigid material, and may be temporary or permanent.	A-20				X		X	X	X			X	X	X
Energy Dissipators Boulders Concrete Concrete Blocks Gabions Riprap Rock Sausages USBR Water Pool	Convert high-velocity flows from paved channels and/or conduits to lower velocity flows. Materials used are frequently gabions, concrete or large boulders.	A-21				X			X				X	X	X
Erosion Stops	Similar to check dams but need not be restricted to a water channel. Controls overland flow-erosion on mild slopes. Materials of construction include hay bales, brush, gravel, snow fence and straw, etc.	A-22	X	X	X	X	X	X	X			X	X	X	X
Fertilization	Applied according to soil vegetation needs as determined by testing. Stimulates growth which increases erosion resistance.	A-23			X		X	X	X		X	X		X	X
Filter Berm Brush Baled Hay or Straw Nylon Cloth Rock or Gravel Sediment Basin Outlet Sediment Trap	Filters remove sediment from flowing water. They are used around drain inlets, along toes of slopes, on small slopes, on sediment basin dams, between water bodies and next to down-hill adjacent properties. Filters can be constructed from any porous material that can be stabilized in rows, banks, or mounds. They must be kept clean.	A-24	X	X	X	X	X	X	X	X	X	X	X	X	X

EROSION CONTROL MEASURE	CHARACTERISTICS OF MEASURE	EXAMPLES OF USE LOCATIONS													
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Floating Sediment Barrier or Diaper	Retains suspended sediment within the disturbed area of a lake, pond, or stream. The diaper is a plastic barrier mounted on posts driven into the lake bed. The floating barrier is a plastic or other impermeable barrier suspended from floats tied together with a rope and anchored at each end to the shore. Both barriers extend from the water surface to within a few inches of the lake bed.	A-25		X									X		X
Floodways (or Waterways)	Natural channels or other areas through which intermittent flood flows may be directed with minimum damage. May include grassed areas through parks, natural channels maintained free of construction, designated streets and roadways, or temporary channels formed with sandbags, soil, or debris.	A-26	X			X			X	X			X	X	X
Gabions	Used as energy dissipators, channel liners, steep-slope protectors, and retaining walls. Construction of gabions is accomplished by placing wire-mesh baskets at the desired location, filling them with gravel and tying them together. The size of basket and diameter of gravel are determined by the amount of protection required.	A-27	X			X						X	X	X	
Grubbing Omitted	When grubbing is omitted the surface algae as well as vegetation grow and stabilize the soil. Established root systems also are left to hinder erosion. New sprouts occur more rapidly. Fertilization may not be needed.								X	X					
Gunnite	Wire mesh is anchored to vertical rock embankments with steel pins. Concrete is then blown onto the mesh to prevent the bank from sloughing. Weep-holes are provided at intervals to relieve hydrostatic pressure.	A-28										X			
Gutters	Gutters are protected channels for the collection and transport of surface runoff from highways. They may also be associated with curbs. Though gutters are generally thought of as permanent structures, timely installation will permit their use during part of the construction period as well. They are made from concrete, asphalt, stone, brick, etc.	A-29						X	X	X	X	X			X
Impoundments	Catchment areas for collecting floodwaters or streamflow, which can be released over time at a controlled rate to prevent downstream flooding.	A-30	X				X	X	X	X			X	X	X
Inlets Box Drop Down Drain Hooded Pipe Drop	Provide smooth efficient transitions between overland or channel flow and pipe flow. They may serve both temporary and permanent functions. Temporary inlets are constructed of rock and earth, hay bales, wood and other available materials. The more permanent types are usually constructed of concrete.	A-31	X	X		X		X	X		X	X	X	X	X
Interceptor Dike	Directs overland flow to a desired collection or runoff point. Constructed with any material that will withstand the anticipated flows.		X		X	X	X	X	X	X		X		X	X
Interceptor Ditch or Drain (See also Slope Drains)	Ditches and drains, like the dike, change the course of flow of surface runoff and direct it to a desirable collection or runoff point. Construction of ditches and drains is similar to that of most water channels and they must be protected to withstand the flow velocities anticipated.	A-32	X		X		X	X	X	X		X		X	X
Irrigation	For the purpose of establishing and maintaining vegetation. The water is generally most efficiently applied by sprinkler or drip irrigation.	A-33			X		X	X	X	X	X	X			X
Jetties Brush Logs Pile Riprap Other	Used to deflect water currents away from selected sections of a stream bank or shore.	A-34											X	X	

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Level Spreader	A level spreader converts channel or pipe flow to sheet flow, thereby reducing velocity and increasing infiltration. Level spreader surfaces may need sod or other material to protect them from erosion.		X		X					X		X		X	X
Matting Excelsior Jute Plastic	Matting is used as a surface and channel protector. In most cases it requires staking to the ground. It is usually used in conjunction with seeding and protects the surface until vegetation becomes established.	A-35	X			X	X	X	X		X	X		X	X
Mulch Cellulose Dairy Waste Gravel Hay Hydromulch Rice Hulls Sawdust Shredded Paper Straw Vegetative Fodder Wood Chips Wood Fibers Other	Used to increase infiltration, decrease runoff, protect soil surface from erosive action of raindrops and to enhance seedbed for vegetative growth. Mulch is applied with machinery or by hand using either water or air as the carrying agent. Proper application rates are important.	A-36	X		X		X	X	X	X	X	X			X
Mulch Anchoring Asphalt Tacking Matting Netting Punching	Anchoring increases the effectiveness of mulch against surface erosion by water and wind. It is accomplished by spraying (asphaltic materials), covering and stapling (paper, plastic, nylon, jute, wire netting, etc.) and discing (incorporating mulch materials into the soil surface).	A-37	X		X		X	X	X	X	X	X			X
Pavement	Materials such as concrete, asphalt, cobble rocks, or brick are placed on the ground to produce a hard surface. Used for walkways, parking areas, etc.	A-38					X	X	X	X				X	X
Outlet Protection	Pipe outlets require a section of protected channel for completing the transition from pipe to channel flow. The needed protection can be provided by energy dissipators, channel protection, or combinations of the two.	A-39	X			X			X				X	X	X
Plastic Film	Used as a temporary protection for bare soil surfaces including channels, chutes, downdrains, etc.	A-40	X	X	X	X	X	X	X		X	X	X	X	X
Poured in Place Concrete or Precast Slabs	Concrete can serve for both temporary and permanent erosion control. It is used for surface and channel protection and for numerous kinds of structures.	A-41	X	X		X	X	X	X	X	X	X	X	X	X
Reinforced Earth Retaining Wall	Modular concrete blocks to whose flat sides are attached long thin metal strips, are stacked on edge to form a wall. The metal strips are laid horizontally and compacted into the backfilled soil on the uphill side of the wall. Friction of the soil on the strips holds the stacked concrete blocks in place, providing a sturdy, pervious retaining wall. Particularly useful on slopes that are steeper than the angle of repose of the soil, and where horizontal distances are limited.	A-42	X									X	X		
Retaining Wall	Used for stabilizing steep slopes and to prevent earth slides. They can serve as either permanent or temporary structures and are commonly constructed of reinforced concrete, gabions, wood, steel, rocks or concrete blocks.	A-43	X						X			X	X		X

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Retention Pond (see Sediment Basin)															
Revetment (see Cellular Concrete Block)	Revetments are often used as bank protectors in streams. However, other applications may be considered. They are constructed of brush mats, rock, concrete rubble, log jacks, car bodies, etc. and are normally quite large.	A-5		X		X						X	X	X	
Riprap, Rubble	These materials are used for surface protectors, channel protectors, and energy dissipators.	A-44	X	X		X	X	X	X		X	X	X	X	X
Roughened Surface	An unsmoothed fill surface or a surface that has been ripped, ploughed or disked is called a roughened surface. It increases infiltration and decreases runoff.	A-45	X		X		X	X		X	X	X			
Sand Bags	Bags filled with sand are used to direct floodwaters away from property to be protected. They are small, easy to handle, and can be stacked to form barriers that are almost water tight.	A-46	X			X		X	X	X			X	X	X
Sausages Gravel Rock Sand	Sausages generally consist of rocks or sand bound together with a plastic, wire, or burlap mesh. They may vary both in diameter and length from a few inches to several feet, depending on where they are to be used. Loose rocks are not recommended when the longitudinal slope of a stream is greater than 10%. Rock sausages can be used on slopes as great as 50%.	A-47	X	X		X		X		X	X		X	X	
Sediment Basin	Sediment basins control or stop sediment after it has eroded. Basins are quite large, as compared to traps, and receive runoff from large areas. Each consists of a dam, an outlet structure, and water storage space. Most sediment in flowing water will settle out in a sediment basin if the detention time is long enough. They must be cleaned regularly, so maintenance access should be provided.	A-48	X	X					X	X			X		X
Sediment Traps Board Dam at Inlet Catch Basin Culvert Excavated Inlet	Sediment traps are small sediment basins. They are constructed as simply as possible and should be used extensively during construction. They are made by digging holes in medians and other drainage ways and by building small dams of wood, stone, bales, etc. across channels, culvert inlets, and other low areas. They must be cleaned regularly, so maintenance access should be provided.	A-49	X	X	X	X	X	X	X	X	X	X	X	X	X
Seeding Aerial (Chopper or fixed wing) Broadcasting Drilling Hydroseeding with Mulch or/and Matting	Seeding is done to establish vegetative erosion control. Stage seeding, both temporary and permanent, is generally very effective in controlling erosion on construction sites.	A-50	X		X		X	X	X	X	X	X	X	X	X
Seepage Control	Seepage control from cut banks is accomplished by covering the surface with a gravel blanket or inserting pipes horizontally into the bank to draw off the water. Either method stabilizes the cut surface and prevents sloughing.	A-51			X				X	X	X	X			
Selective Grading and Shaping	Involves nonstandard grading and shaping of slopes in critical areas where erosion potential is high.	A-52			X					X		X		X	
Serrated Slopes	Increase infiltration and reduce water velocities down cut slopes. They also provide a better seedbed for establishing vegetation and help to retain moisture. Horizontal steps are constructed with a grader as the cut is made.	A-53										X			

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Sheet Piling	Excellent for constructing check dams, cofferdams, sediment traps, and other erosion control devices.	A-54	X	X		X		X			X		X	X	
Shoreline Protection	Shoreline protection is used where highways run parallel to or cross water bodies and must be protected from wave action. Rock, concrete, gobi blocks, and other large surface protectors are used.	A-55		X									X		
Silt Fence	Consists of filter cloth backed by wire net fence mounted on posts. Very effective for retaining sediment on right-of-way. If first fence fills with sediment, another can be built behind it.	A-56	X	X			X			X			X	X	X
Slope Grooming	Final smoothing of a sloped area, usually involving hand labor, in preparation for seeding, sodding or paving.	A-57							X	X	X	X			X
Sodding	Used for surface and channel protection. Sod may be hand laid over the entire surface or in narrow strips along the contours of a slope. On steep slopes it may need to be staked to prevent slippage. Another effective use of sod in areas of high rainfall is a 15" wide strip laid along the edges of the pavement of highways, to prevent the shoulders from eroding.	A-58	X			X		X	X		X	X	X	X	X
Spillways Box Inlet Drop Chute Drop Pipe Pipe Drop Straight Drop	Used in conjunction with dams to bypass overflows with minimum erosion.	A-68							X				X	X	X
Splash Basins	Catchment basin which receives water running from tops of buildings, and bleeds it slowly into drains, or infiltrates it into soil.	A-59							X						
Splash Blocks	Concrete or wooden blocks, or rocks which dissipate energy of water falling from roof drains to prevent it from eroding.	A-60							X						
Sprigging	Sprigging consists of planting shoots or sprouts as opposed to seeds. It is done to achieve more rapid growth of larger vegetation.	A-61	X		X		X	X			X	X	X	X	
Spur Dikes Concrete Bags Gobi Blocks Rocks	Spur dikes provide funnels and expansion sections for streams flowing beneath bridges. They are similar to jetties and must have substantial surface protection to the high water line.	A-62											X		
Stabilized System	All erosion control measures are in place and functioning so that no erosion or sedimentation exists throughout the area.	A-63	X	X	X	X	X	X	X	X	X	X	X	X	X
Stacked Concrete Bags	Stacked concrete bags may be used for slope protectors at highway overpasses and for channel protectors at pipe outlets. Consist of bags of wet concrete stacked and allowed to dry.	A-64				X			X			X	X	X	
Storm Sewers	Collect rainfall or snowmelt runoff and transport it to a disposal point. Storm sewers are usually permanent and constructed from durable materials, but may be utilized during the construction phase as well.	A-65	X	X		X		X	X	X		X	X		X
Stream Bank Protection	This protection requires large material masses or smaller anchored structures such as large boulders, brush mats, log jacks, concrete rubble or special concrete and/or steel structures.	A-66		X					X				X		X

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		EXAMPLES OF USE LOCATIONS													
Stream Channel Change	May be a temporary bypass to permit construction of a bridge or other structure on the main channel, or a permanent change to allow a more desirable alignment of a highway. In either case, the new channel must be protected against erosion with such things as riprap, concrete, and large vegetation.	A-67											X		X
Stabilizing with Rock	Large rocks or boulders are placed by hand or machine on ground slopes to control erosion of soil surface. It is usually necessary to fill in voids with smaller rocks and/or vegetation.	A-69				X			X			X	X	X	X
Surface Area Exposure	The smaller the area exposed to the elements at a time with no protection, the less will be the erosion from that particular site. Good management will ensure the cleared areas have erosion control measures installed before additional areas are bared.	A-70	X		X		X	X	X	X	X	X			
Temporary Crossing	Culverts in the stream or a bridge spanning it provides a temporary means of crossing without muddying the water.	A-71											X		
Timing of Control Implementation	An excellent erosion control measure is of no value until it is implemented. Therefore erosion control measures should be implemented at the proper time and place to be of maximum benefit.		X	X	X	X	X	X	X	X	X	X	X	X	X
Toe Drain Ditch	A toe drain ditch is used to collect seepage and runoff from a slope and transport it to a channel. They should be lined with rock riprap or other protective material as needs dictate.	A-72										X			
Topsoiling	Stockpiling and subsequent spreading of topsoil on cut and fill slopes aid greatly in the establishment of vegetation. Fertilizer may not be required if topsoiling is done. Topsoil may also be brought from an outside area depending on cost.	A-73			X		X	X	X		X	X			X
Tubelings	A dry land planting technique which eliminates the need for irrigation during plant establishment and is conducive to mechanization. Plants are grown in 2 1/2" by 24" paper tubes reinforced by plastic mesh sleeves. These "tubelings" are planted in holes drilled into the ground with a power auger.	A-74	X					X			X	X			X
Vegetative Buffer Strip	A strip of dense vegetation is used to prevent sedimentation or erosion at critical areas. It is often used along boundaries to prevent deposition of sediment on adjacent property, but can also be used at other locations such as stream banks.	A-75	X	X	X		X	X	X		X	X	X	X	X
Vegetative Stabilization Forbs Grasses Legumes Shrubbery Trees	Vegetative stabilization is accomplished by planting imported or native vegetation on cut and fill slopes and other areas needing erosion protection. It is used both during and after construction.	A-76	X	X	X		X	X	X	X	X	X	X	X	X
Wattles Brush Straw	Early method used for stabilizing fill slopes. Hand labor required. Leafy brush, straw or both are packed into a "cable" about 12" wide and 10" thick and laid in trenches dug into the slope face along the contours. 1" x 2" x 24" stakes are driven in on 2' centers below the wattles to hold them in place. Live cuttings are planted between the wattles rows and the entire area is seeded.											X			

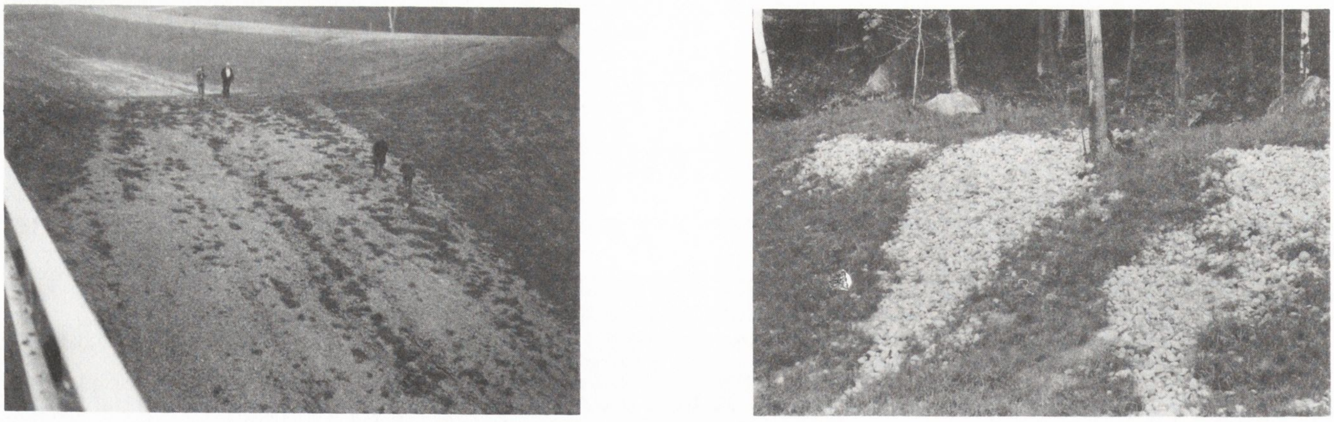


Figure A-1. Aggregate Cover

Straw Bales

Fences

Figure A-2. Barriers

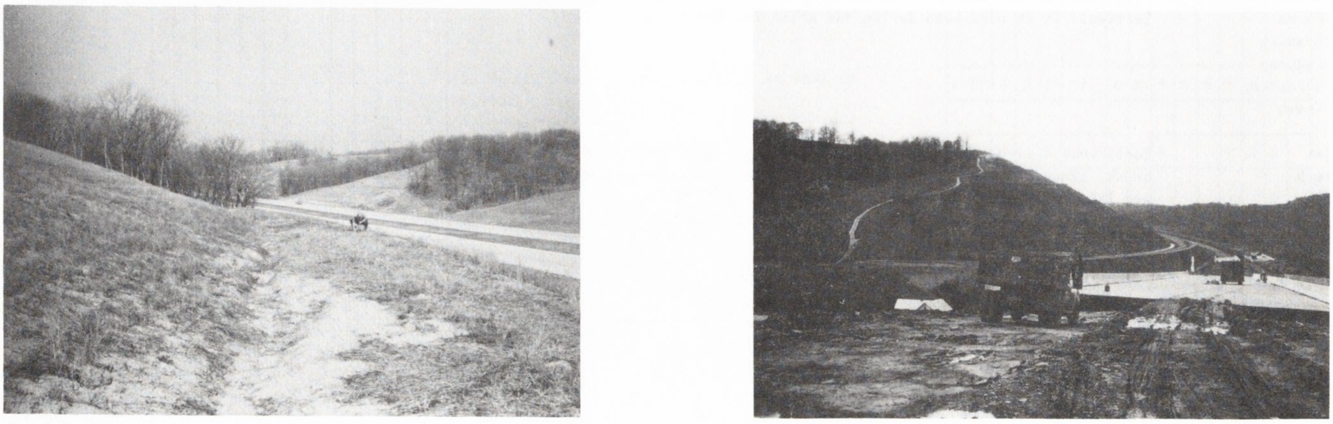


Figure A-3. Benches (Terraces)

Figure A-4. Berms

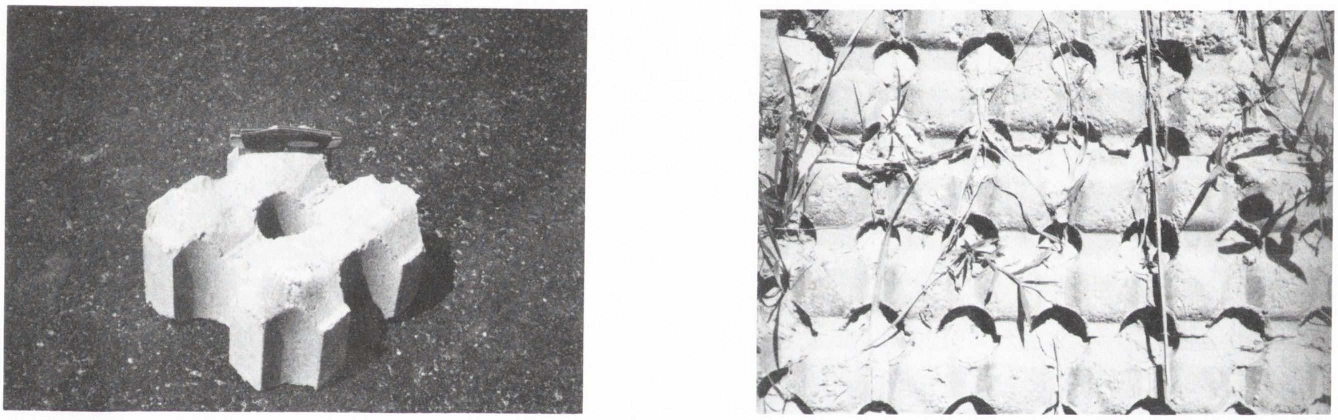
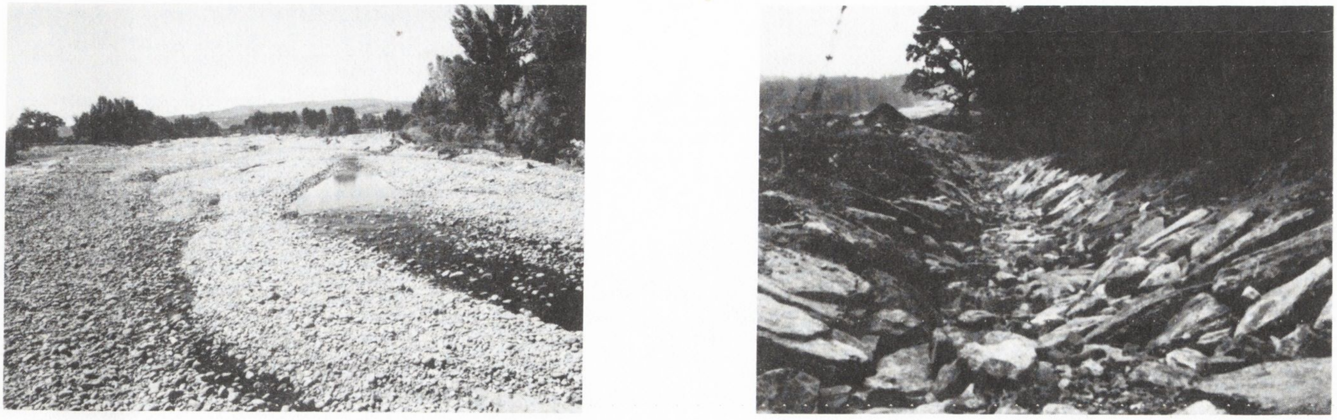


Figure A-5. Cellular Concrete Blocks



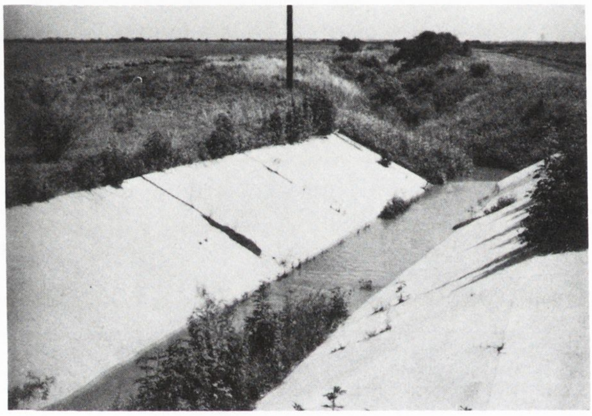
Gravel

Rock

Figure A-6. Channels

Gabions

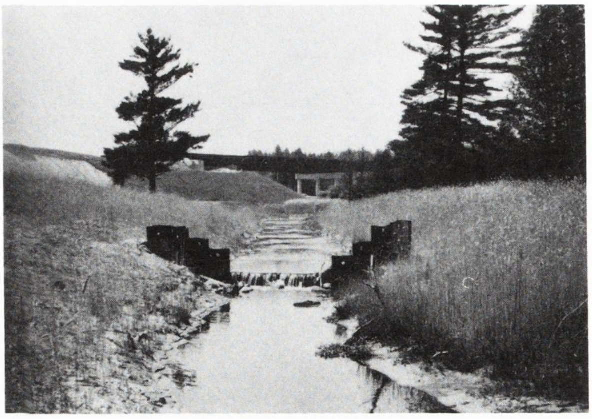
Jute



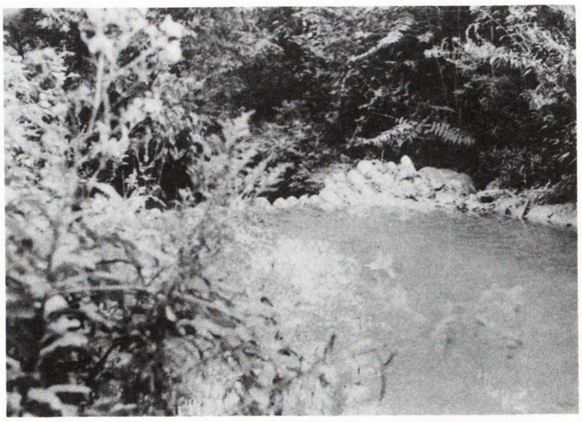
Concrete

Fiberglass roving

Figure A-6. Channels (continued)

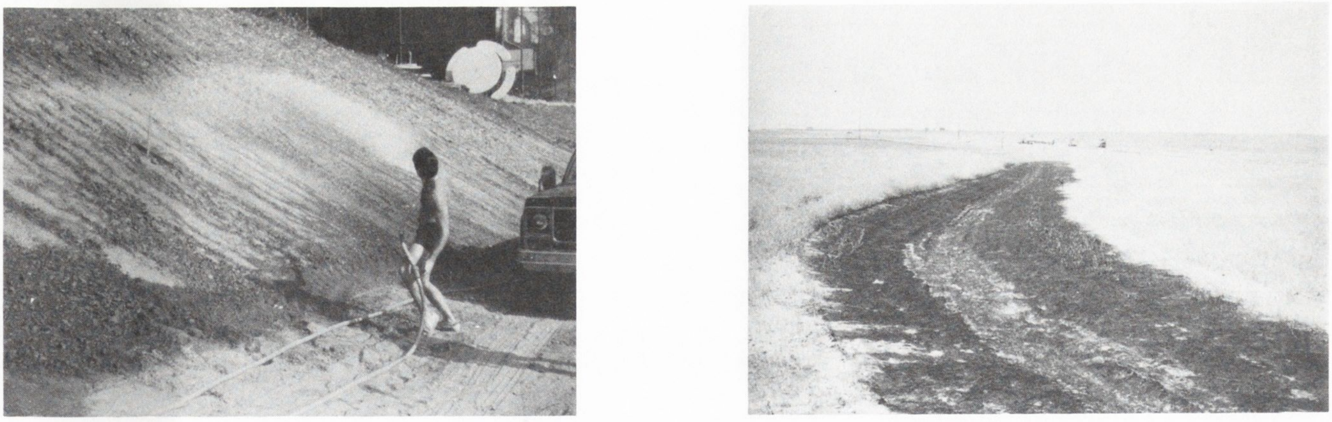


Sheetpilings



Logs

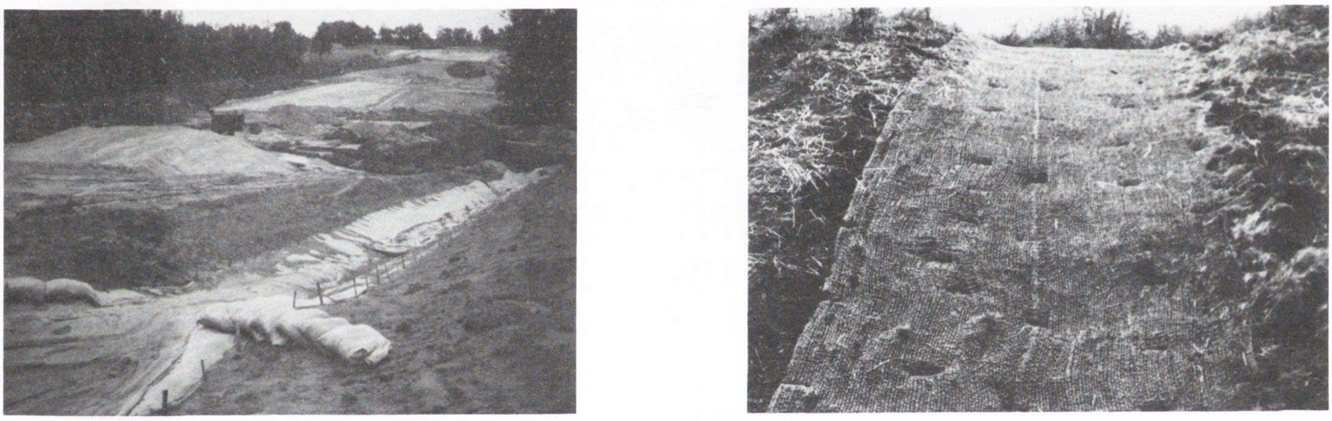
Figure A-7. Checkdams



Soil Seal (Photo courtesy Soil Seal Corp.)

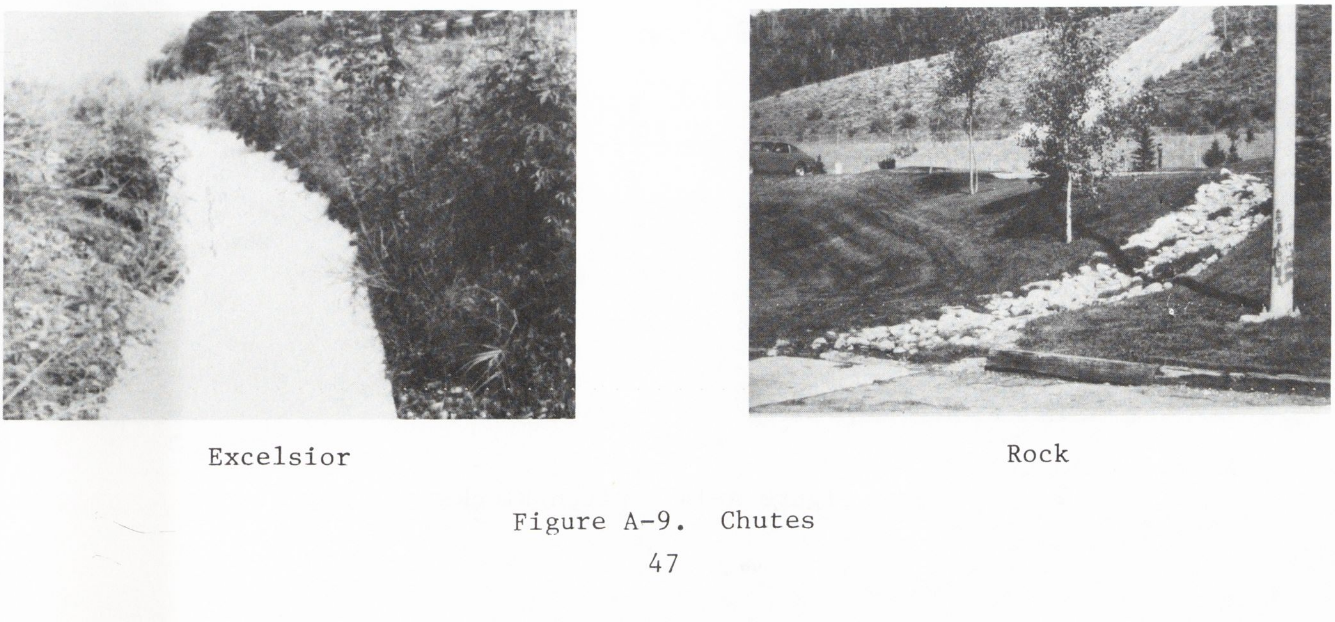
Fiberglass roving

Figure A-8. Chemical Stabilization



Plastic

Jute



Excelsior

Rock

Figure A-9. Chutes

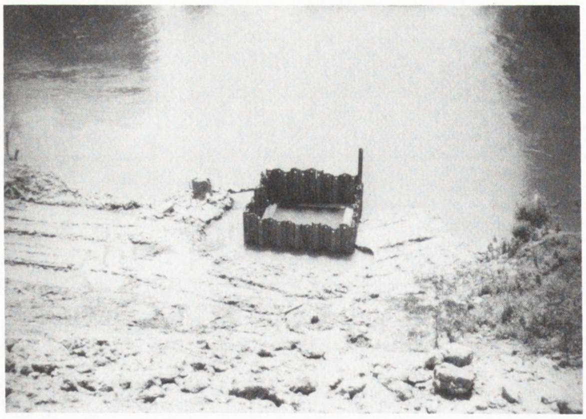


Figure A-10. Cofferdam

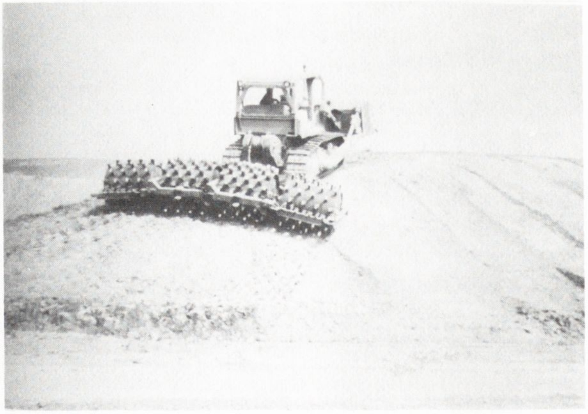


Figure A-11. Compaction

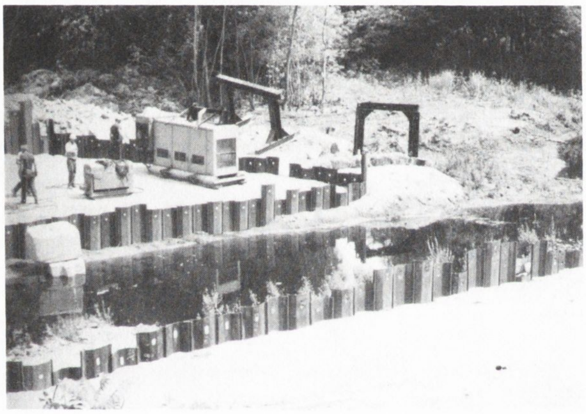


Figure A-12. Construction Dam

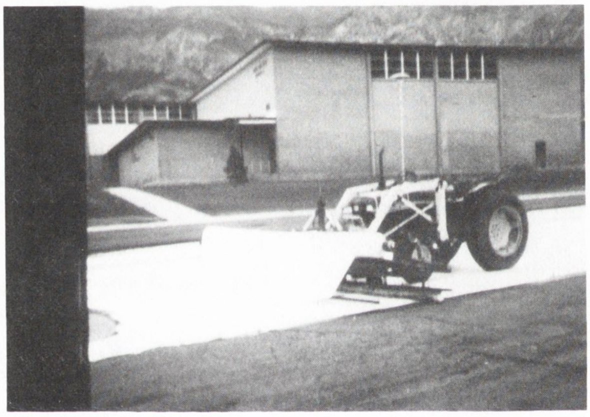


Figure A-13. Construction Fabric

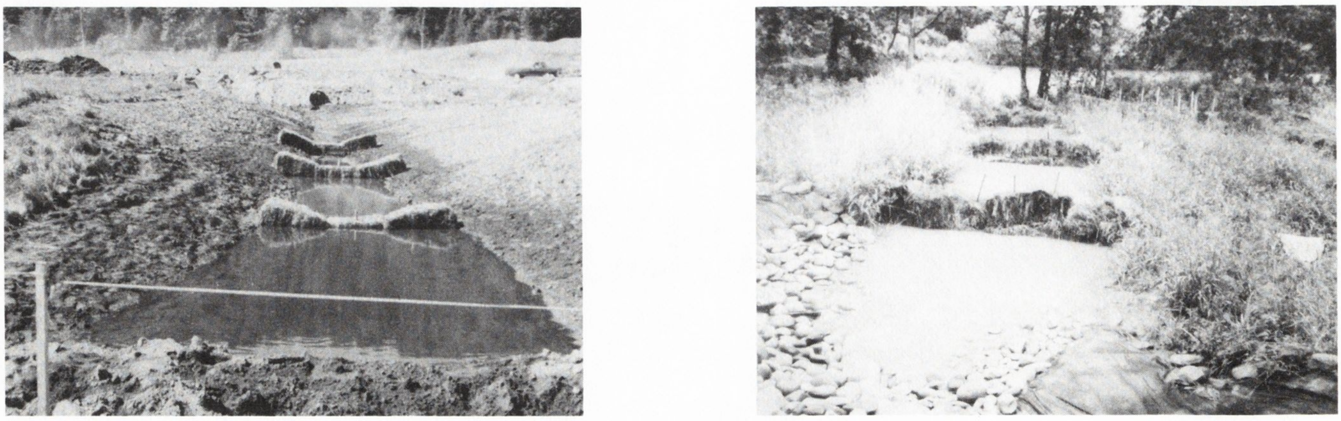


Figure A-14. Ditch Blocks

Seeded & Mulched

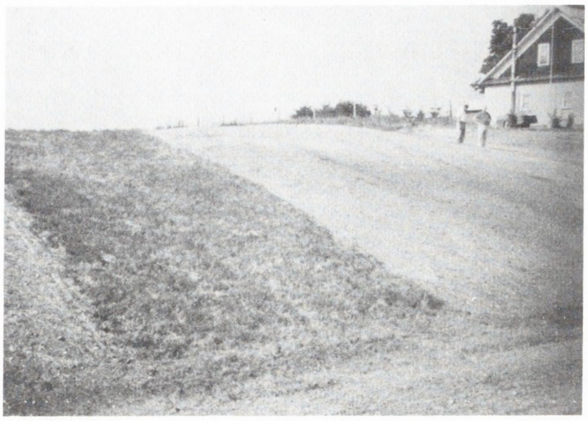
Concrete

Figure A-15. Diversion Ditch

Flexible Pipe

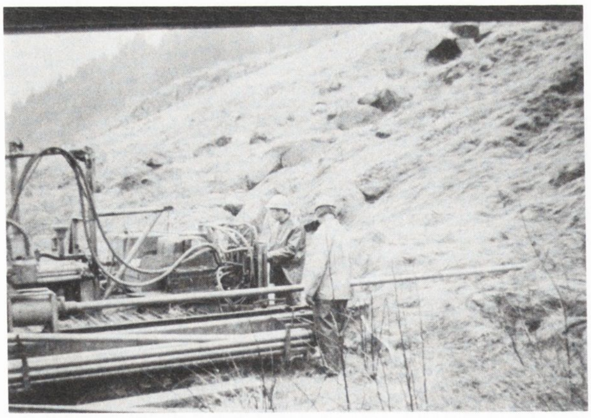
Rigid Pipe

Cemented Rock



Sod

Figure A-16. Down Drains



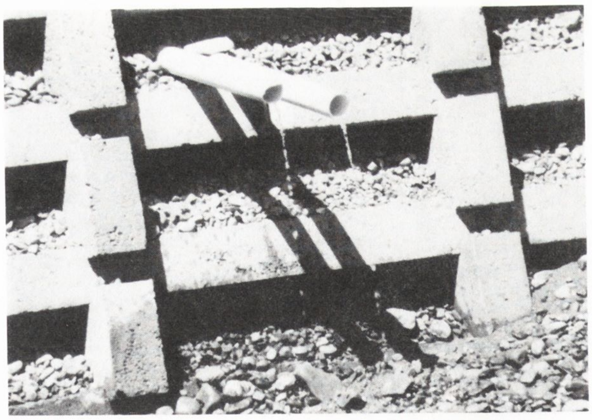
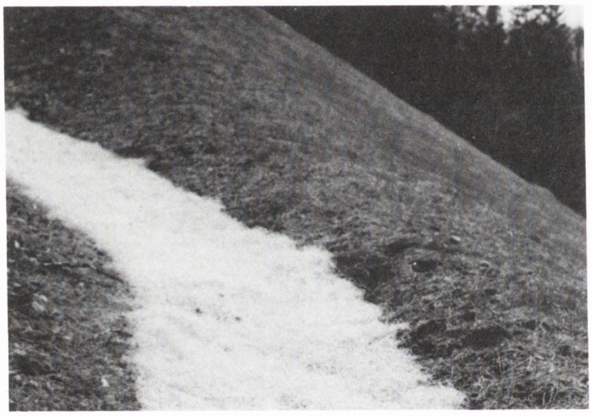


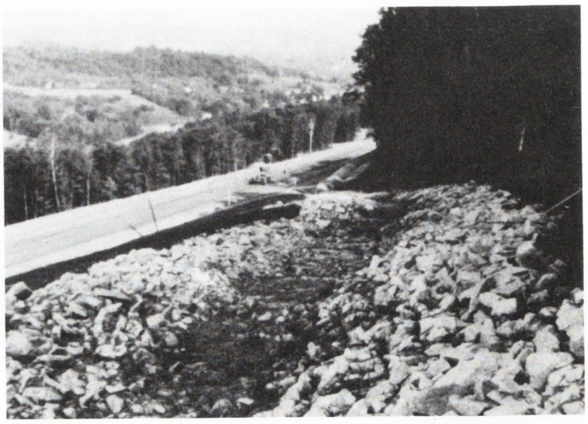
Figure A-17. Horizontal Drains



Excelsior

Concrete

Gravel



Rock

Figure A-18. Slope Drains

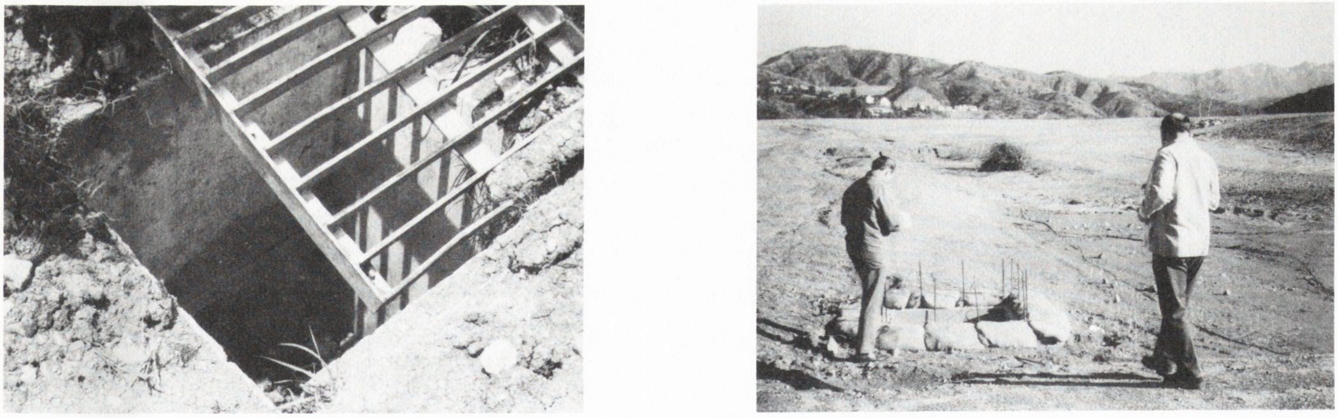


Figure A-19. Drop Box Culvert

Figure A-20. Drop Structures

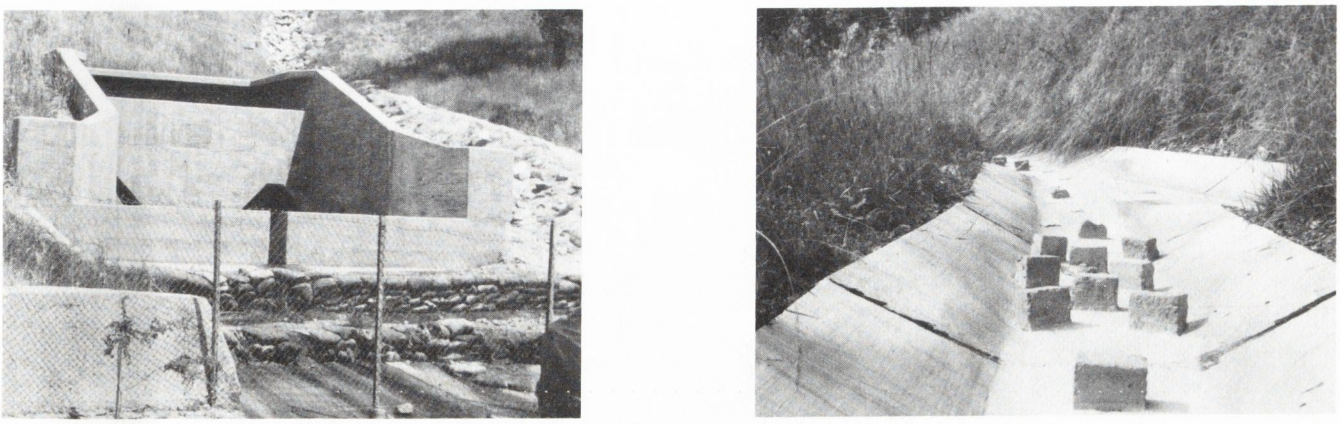


Figure A-21. Energy Dissipators

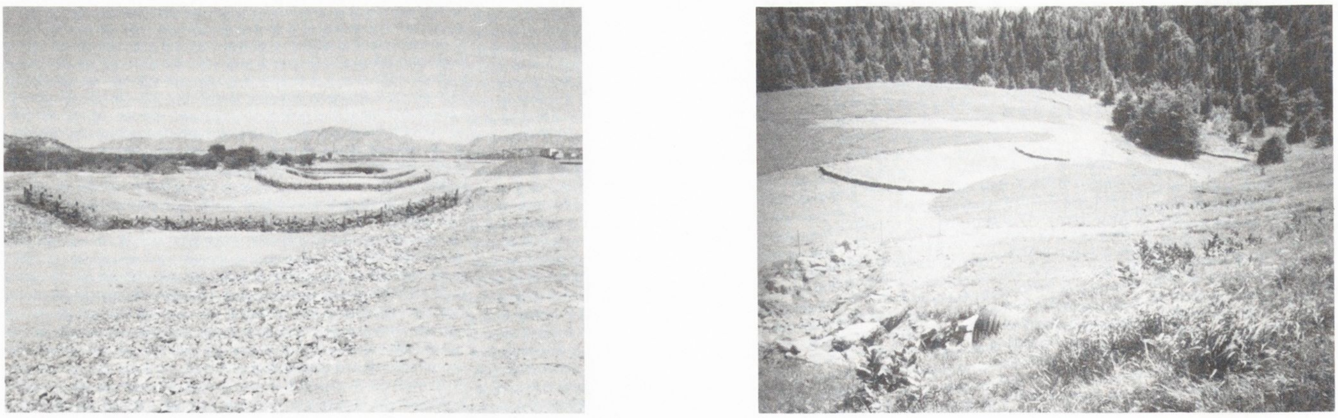


Figure A-22. Erosion Stops

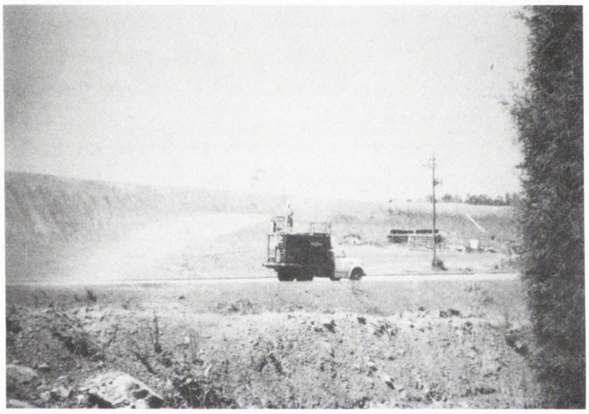
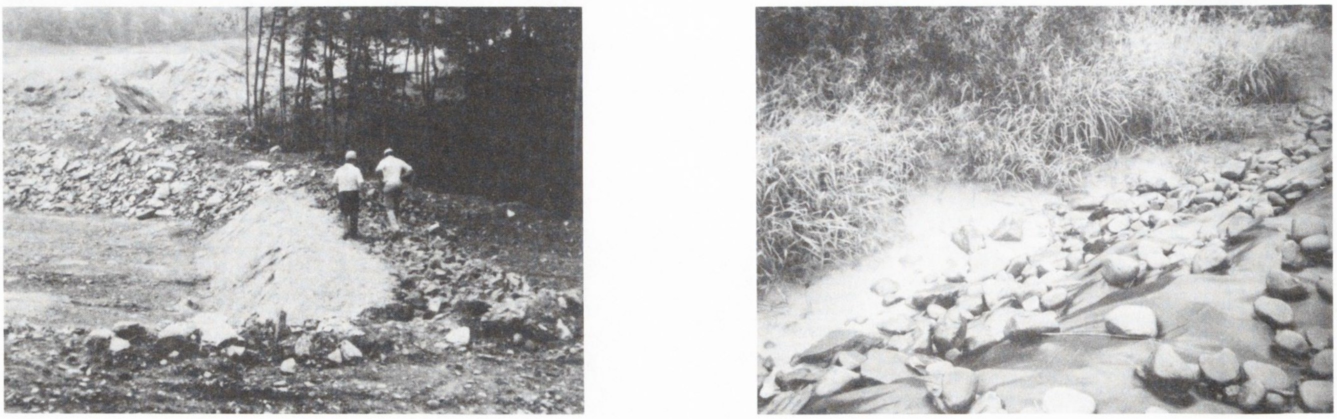


Figure A-23. Fertilization
(with hydromulch)

Straw Bales

Figure A-24. Filter



Sand and Rocks

Nylon Cloth

Figure A-24. Filters (continued)

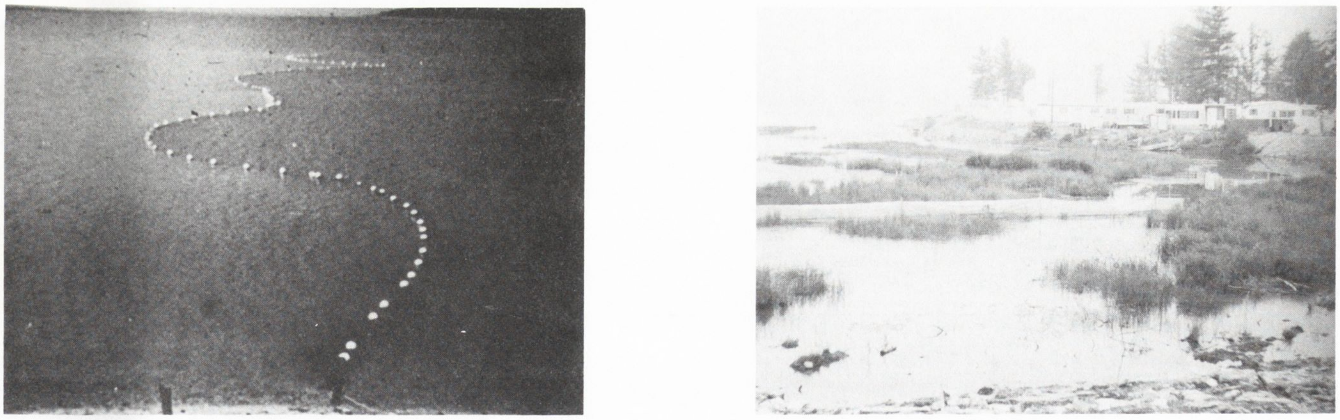
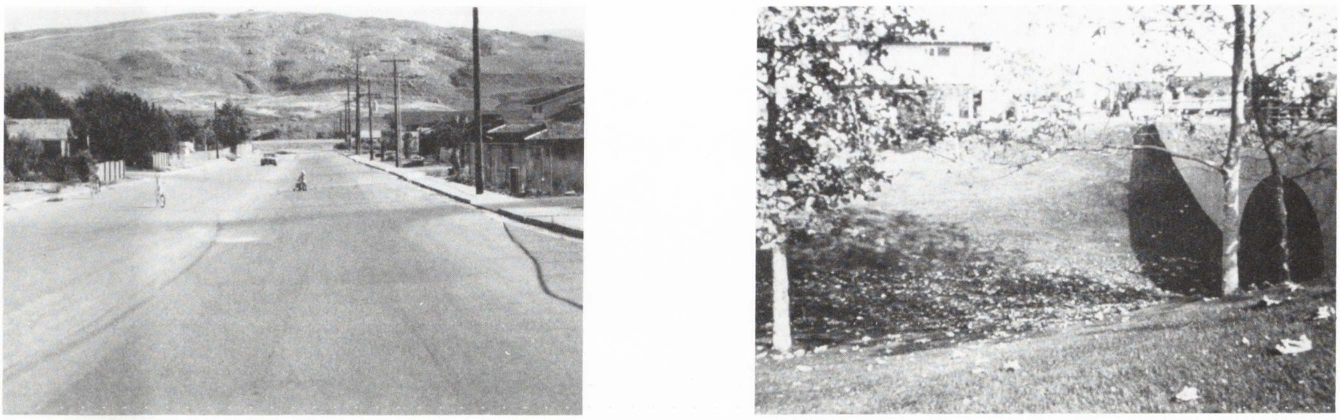


Figure A-25. Floating Sediment Barriers

Modified Natural Channel

Enlarged Drainage Ditch



Designated Street

Public Park

Figure A-26. Floodways (waterways)

Residential Park Temporary Measure

Figure A-26. Floodways (waterways)

Figure A-27. Gabions

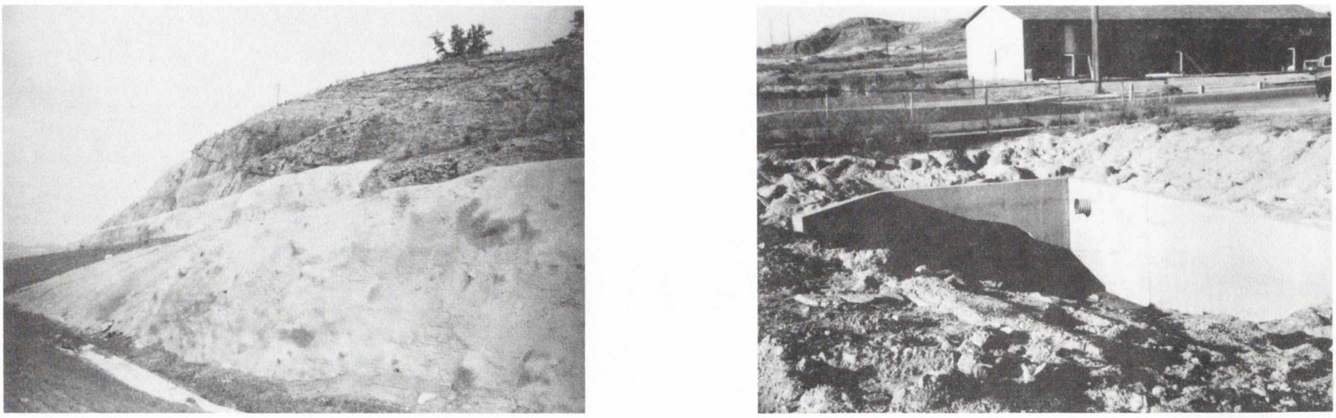
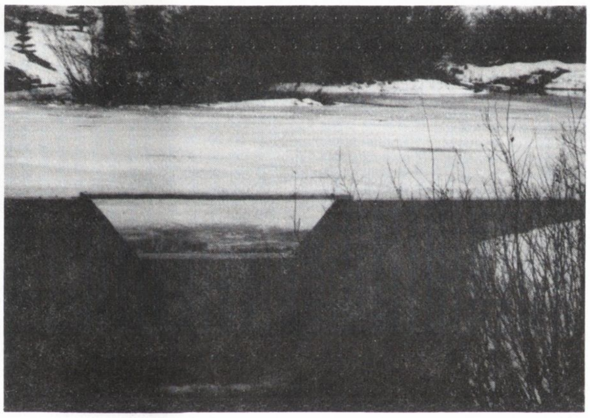
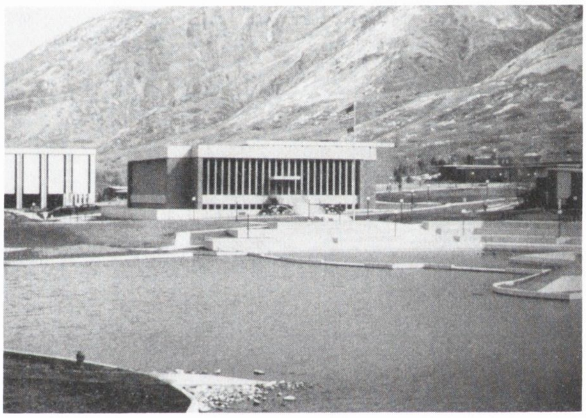


Figure A-28. Gunnite

Figure A-29. Gutters

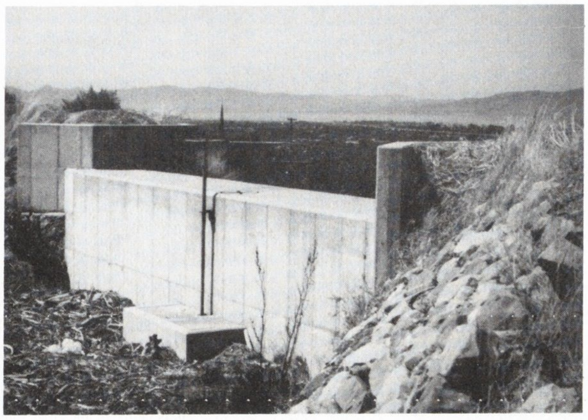


At Park City



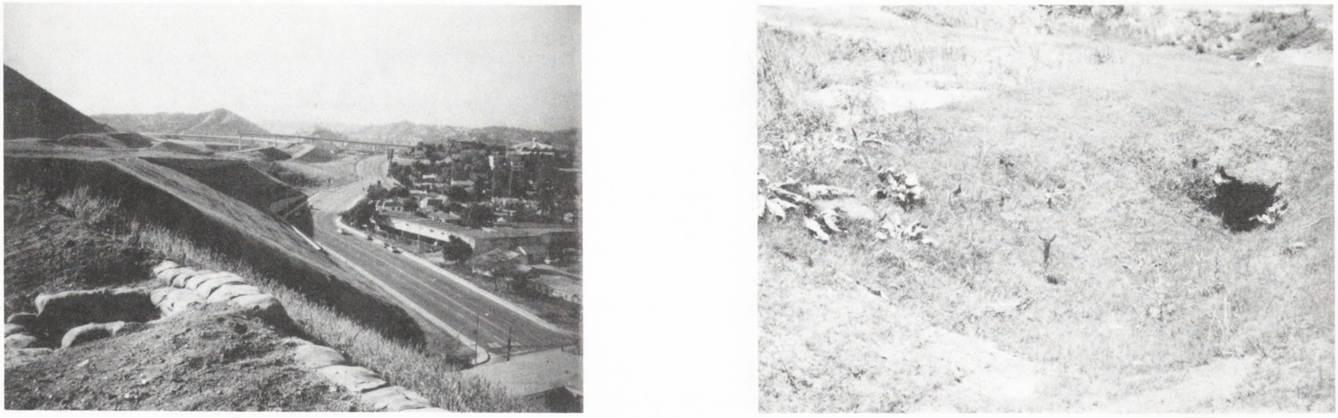
At Weber State College

Above Cedar City



Above Provo

Figure A-30. Impoundments



Sandbagged

Grassed

Figure A-31. Inlets

Figure A-32. Interceptor Ditches

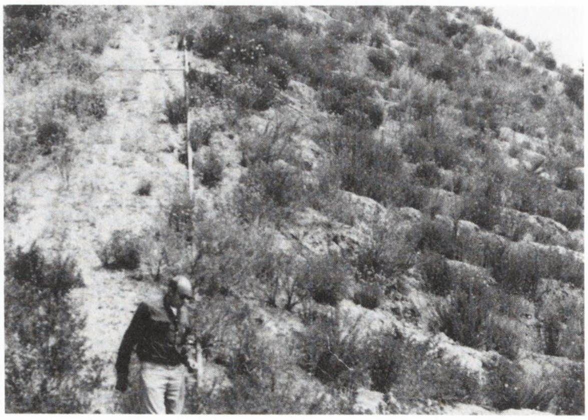


Figure A-33. Irrigation

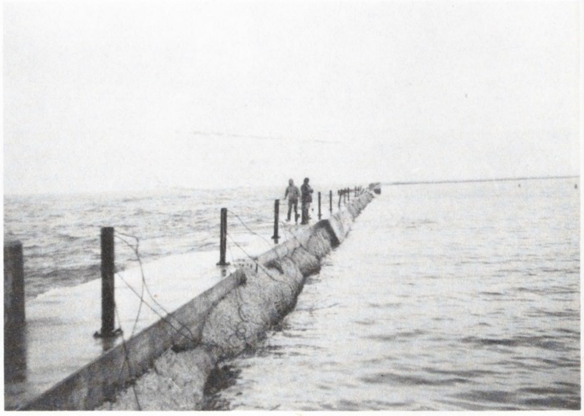
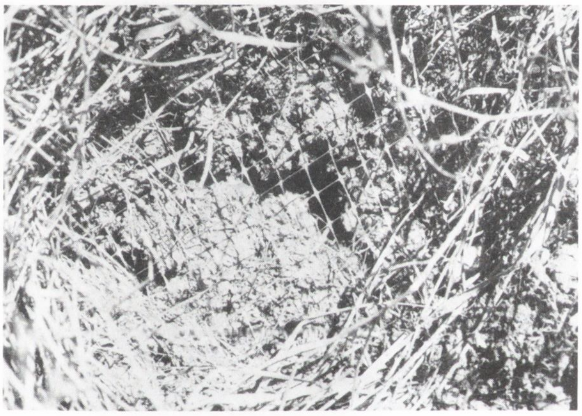


Figure A-34. Jetty

Jute

Excelsior



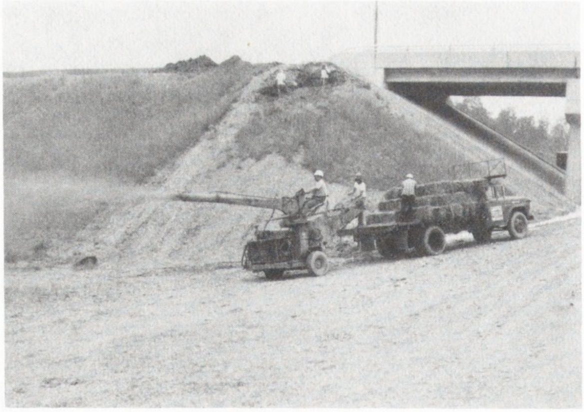
Plastic Net

Fiberglass Roving

Jute and Sod

Plastic

Figure A-35. Matting

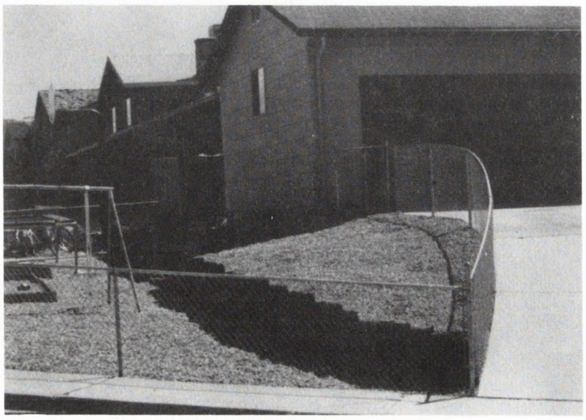


Straw Mulcher

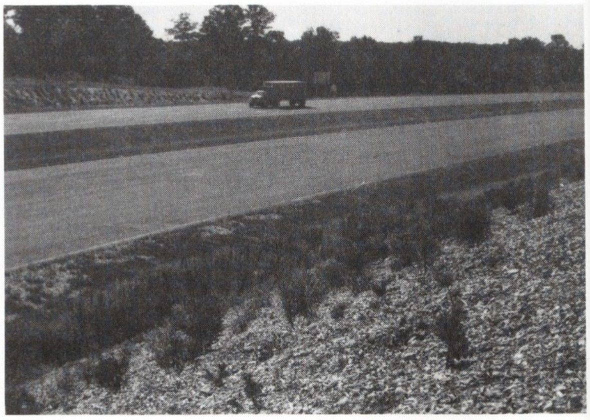
Straw Mulch

Hydromulcher

Hydro Mulch

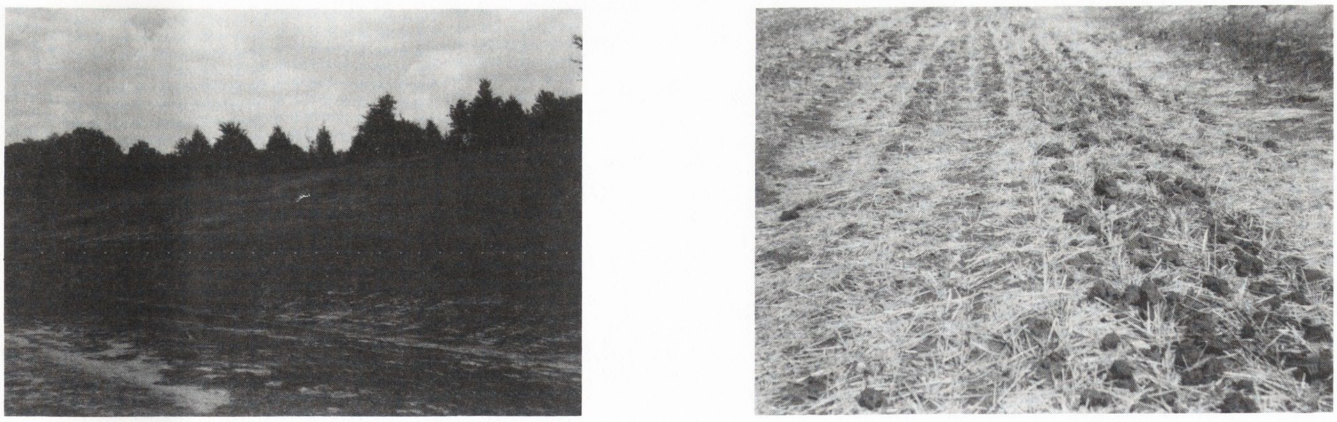


Gravel



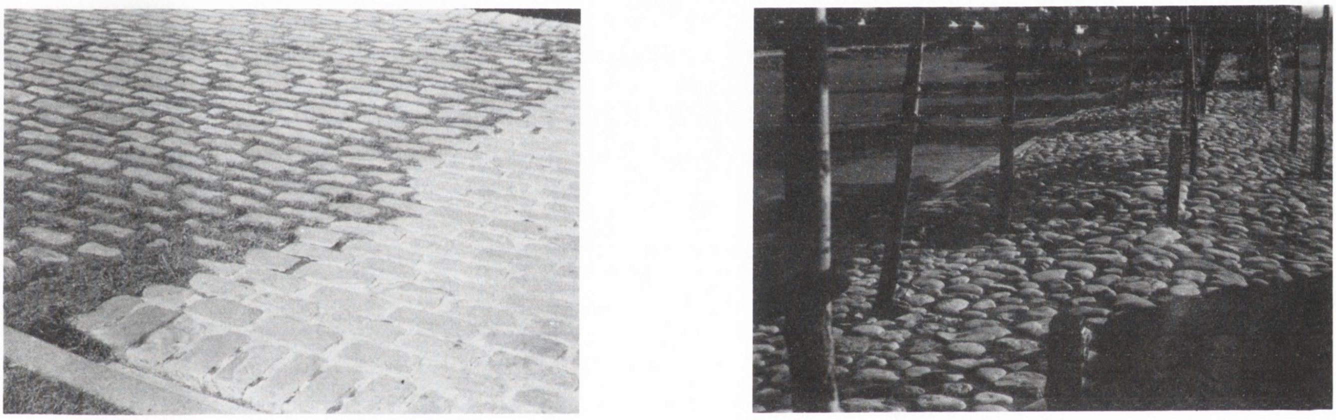
Woodchips

Figure A-36. Mulch



Straw with Tackifier Straw Punched In

Figure A-37. Mulch Anchoring

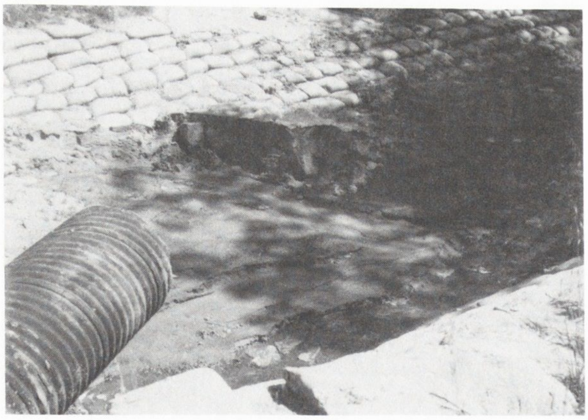


Brick Cobbles

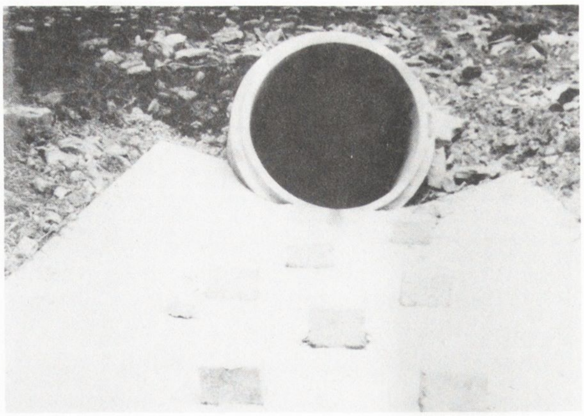
Figure A-38. Pavement

Plastic Mat Rocks

Figure A-39. Outlet Protection

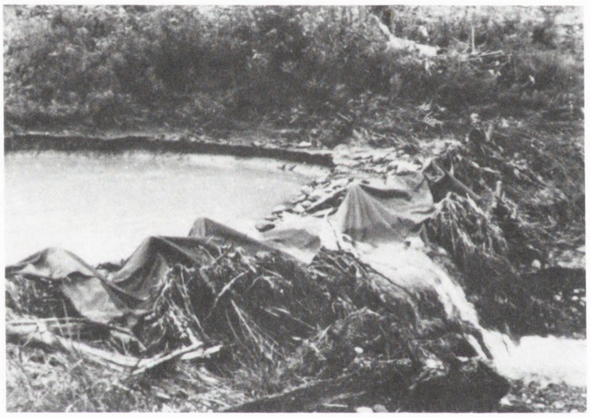


Stacked Concrete Bags



Concrete Slabs

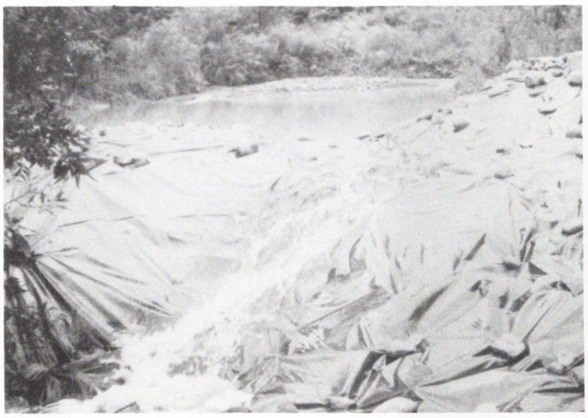
Figure A-39. Outlet Protection (continued)



Checkdam

Dam

Downdrain



Spillway

Figure A-40. Plastic Film

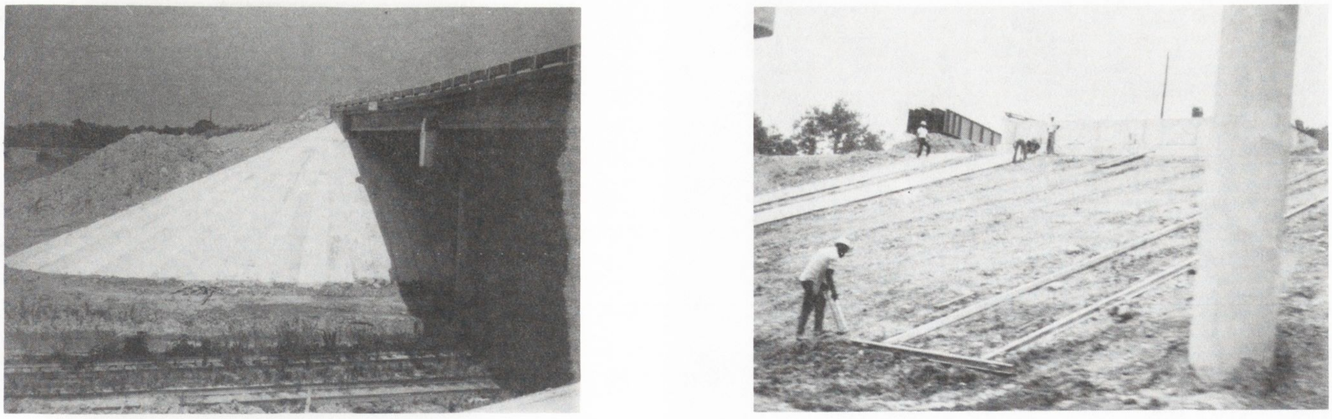


Figure A-41. Poured in Place Concrete or Precast Slabs

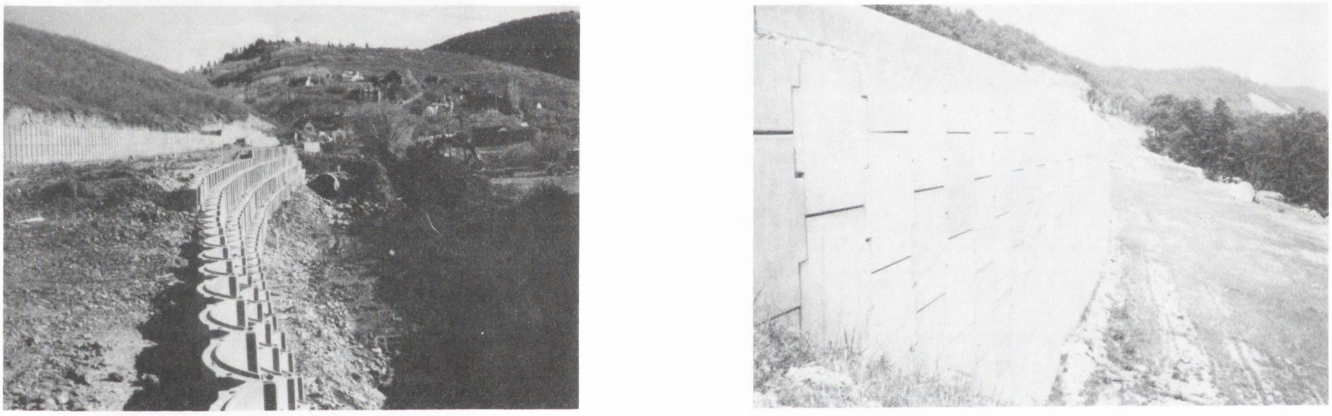
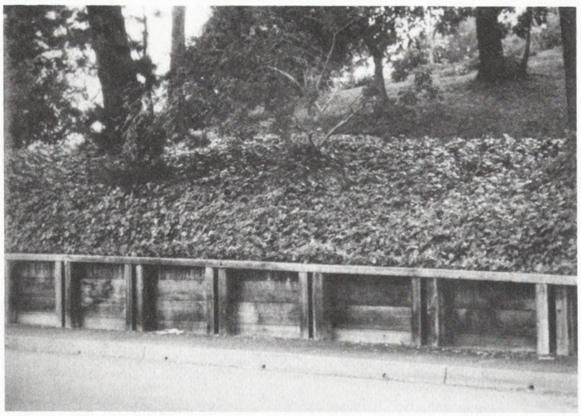


Figure A-42. Reinforced Earth Retaining Walls

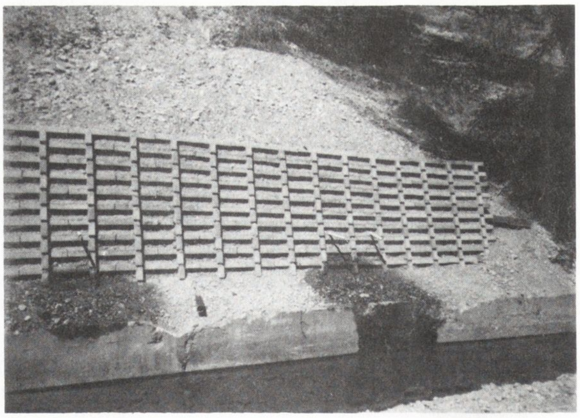
Stacked Rock

Decorative Block

Figure A-43. Retaining Walls

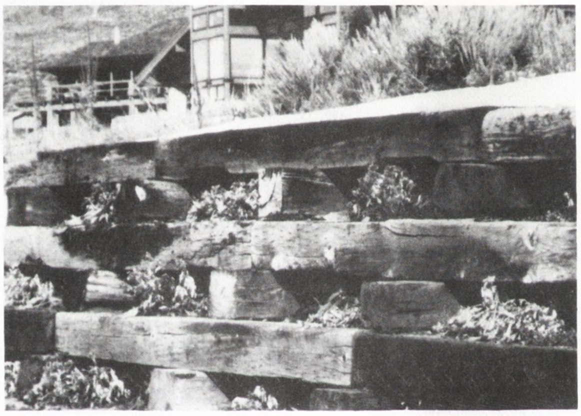


Timber



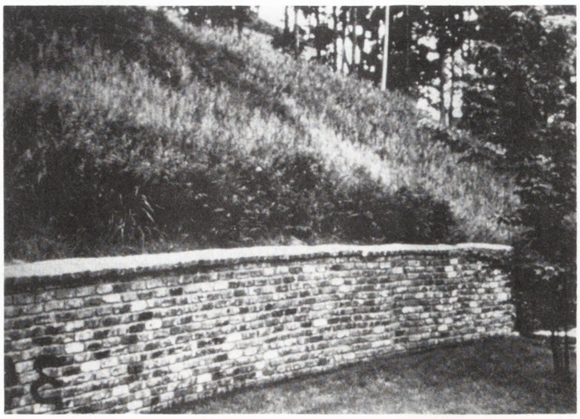
Concrete Cribbing

Cemented Rock



Railroad Ties

Gabions



Brick

Figure A-43. Retaining Walls (continued)

Figure A-44. Riprap, Rubble

Figure A-45. Roughened Surface

Figure A-46. Sand Bags

Figure A-47. Sausage

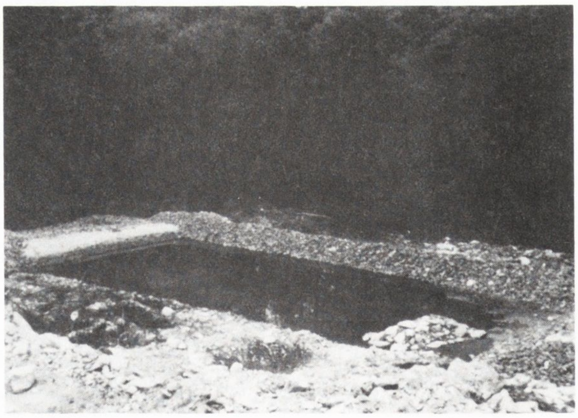


Figure A-48. Sediment Basin

In Toe Drain

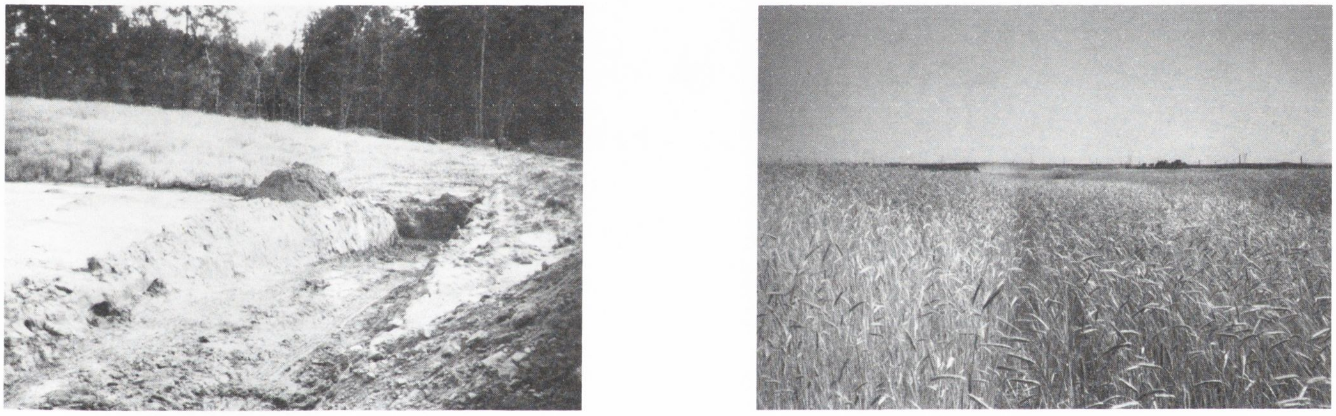
Ready for Cleaning

Multiple Traps

At Entrance to Culvert

Figure A-49. Sediment Traps

Figure A-49. Sediment Traps (continued)



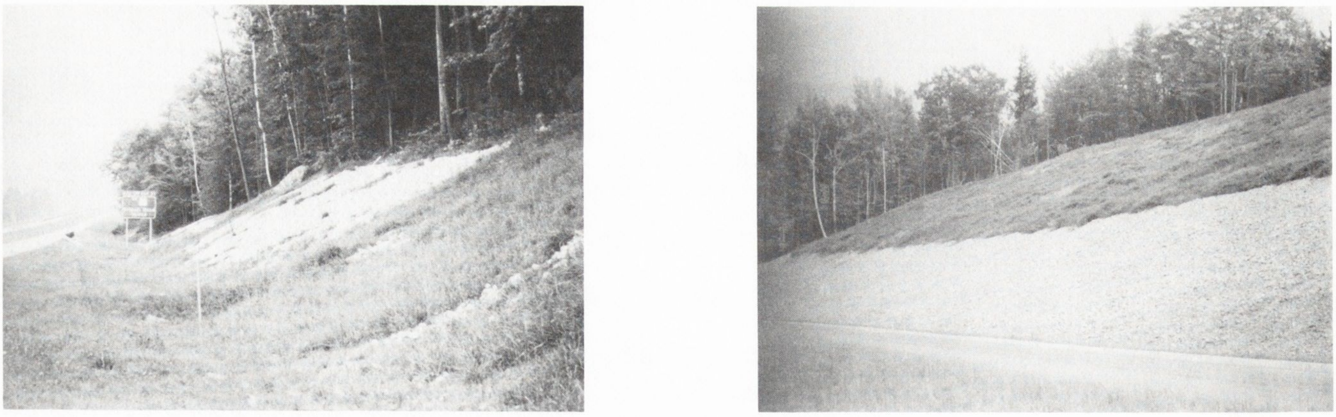
Temporary Grass in Construction Area

Temporary Rye along Roadside

Permanent-Newly Planted

Permanent on Completed Slope

Figure A-50. Seeding



Gravel Filter

Gravel Filter

Figure A-51. Seepage Control

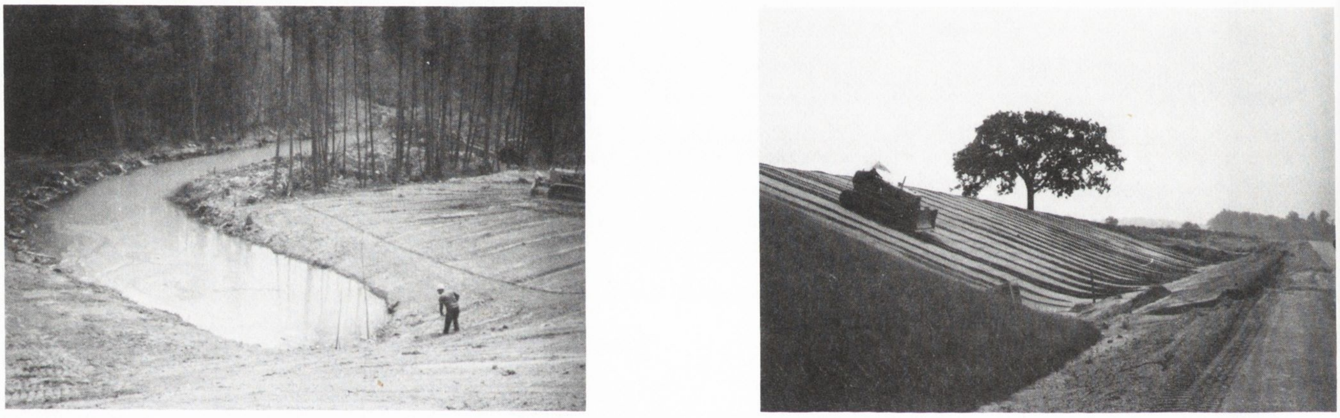
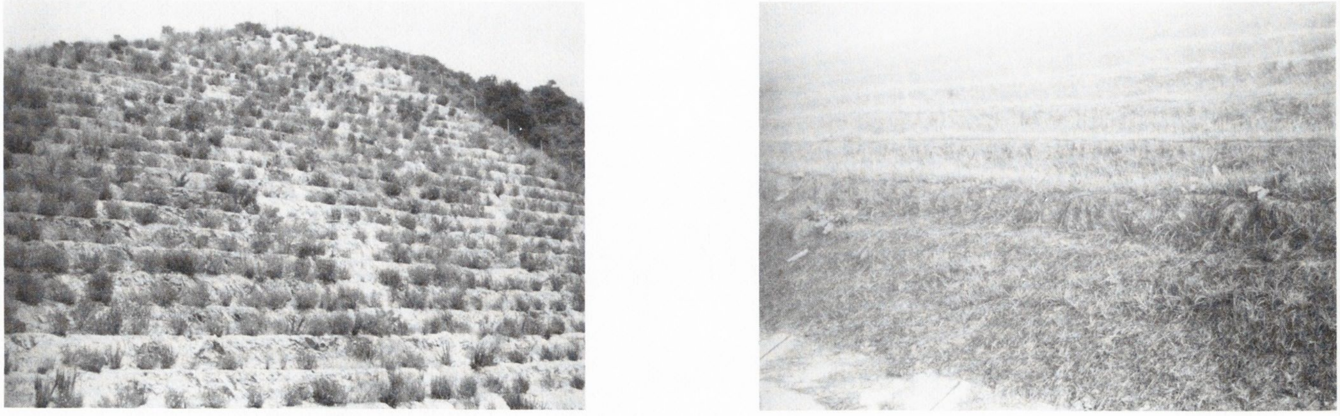


Figure A-52. Selective Grading & Shaping



In Semi-Arid Climate

In Humid Climate

Figure A-53. Serrated Slopes

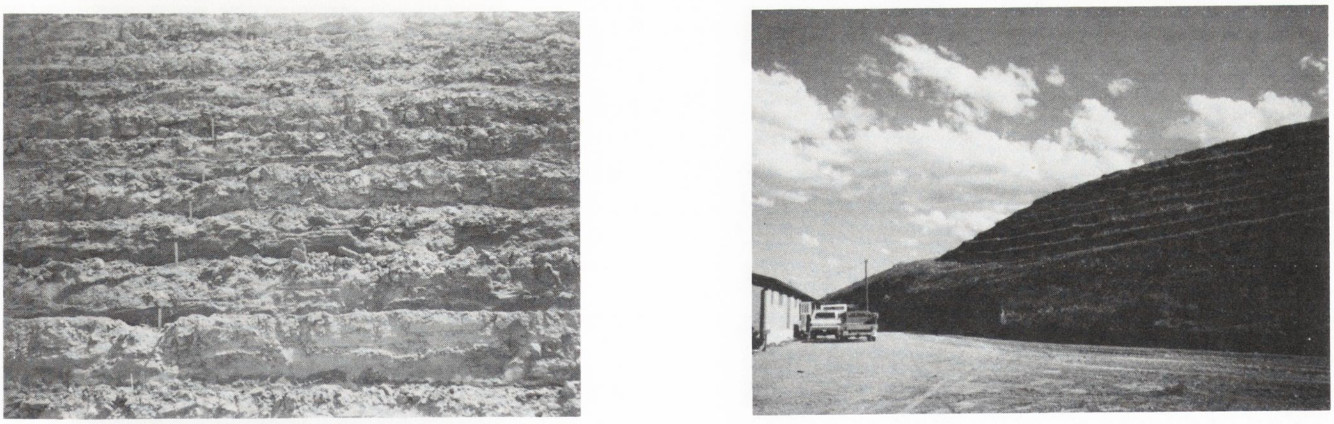


Figure A-53. Serrated Slopes (continued)

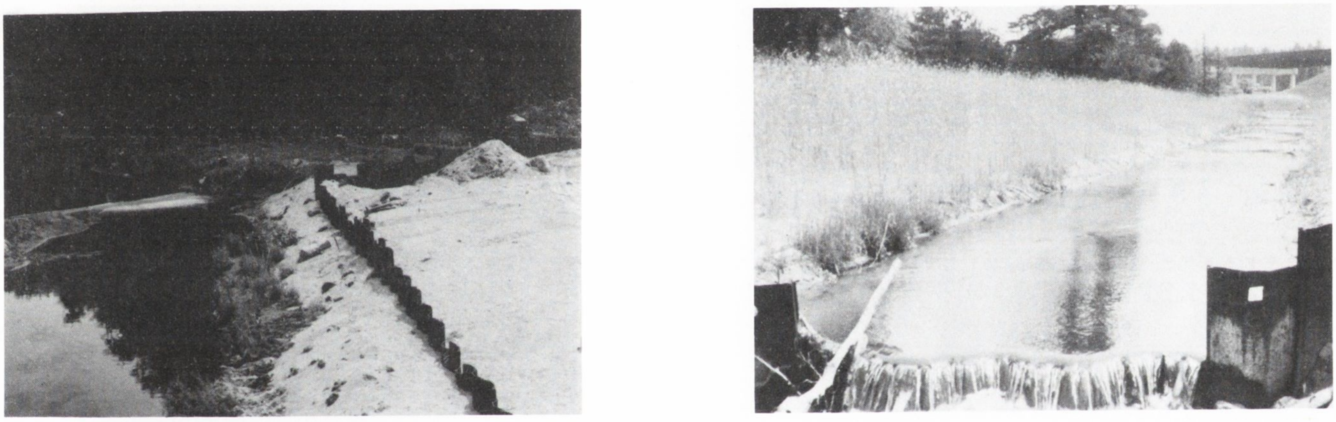
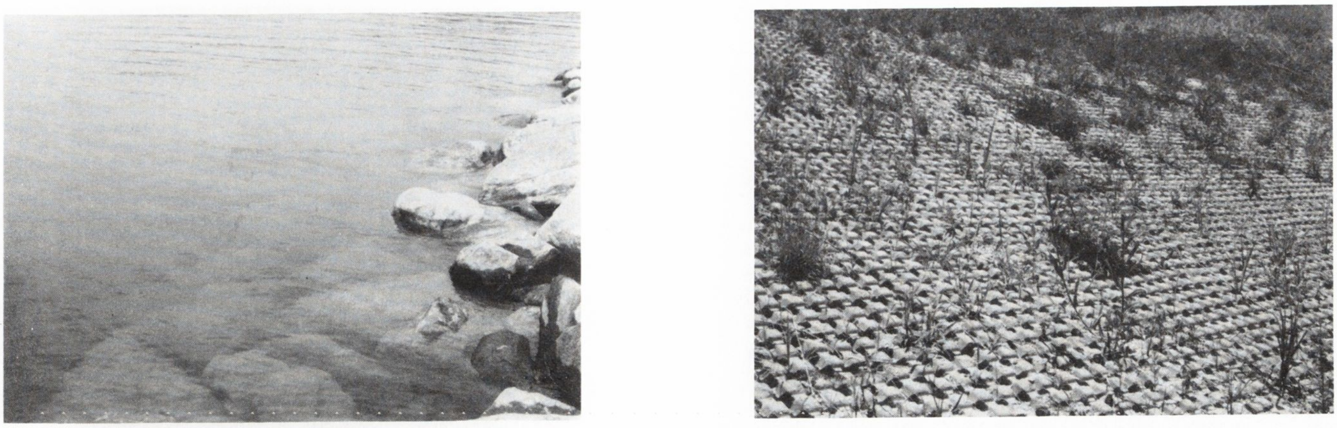


Figure A-54. Sheet Piling



Rocks

Modular Concrete Blocks

Figure A-55. Shoreline Protection

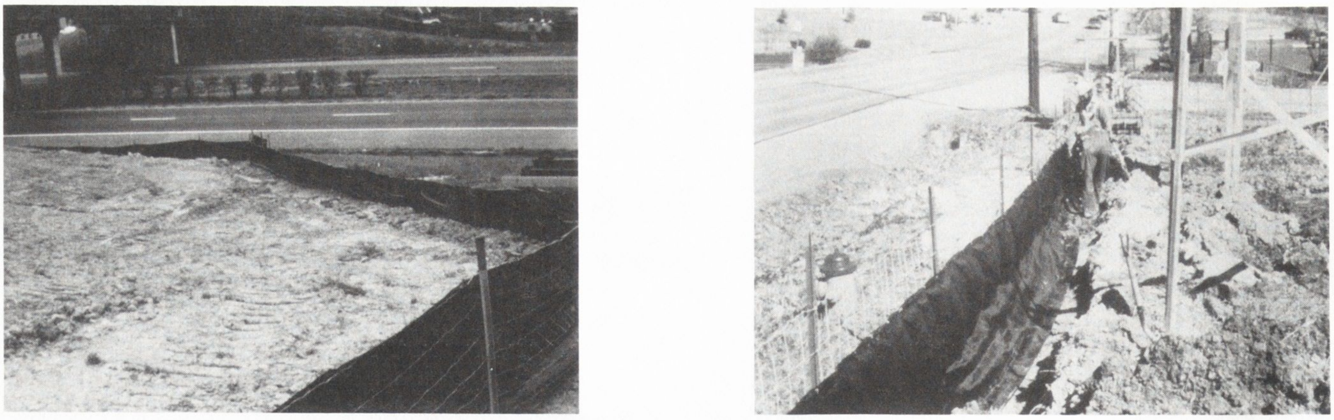


Figure A-56. Silt Fences
(Photos courtesy Apex Building Specialties, Inc.)

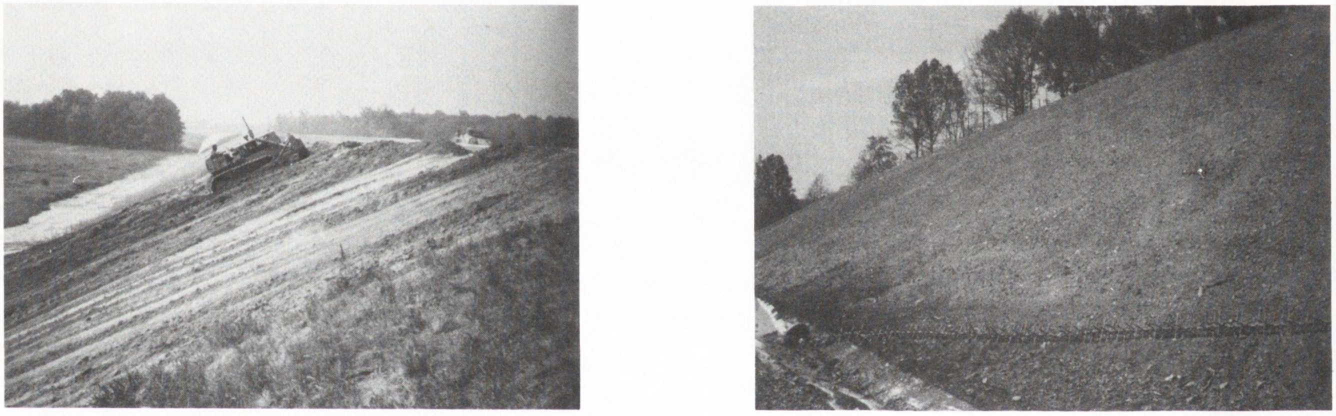
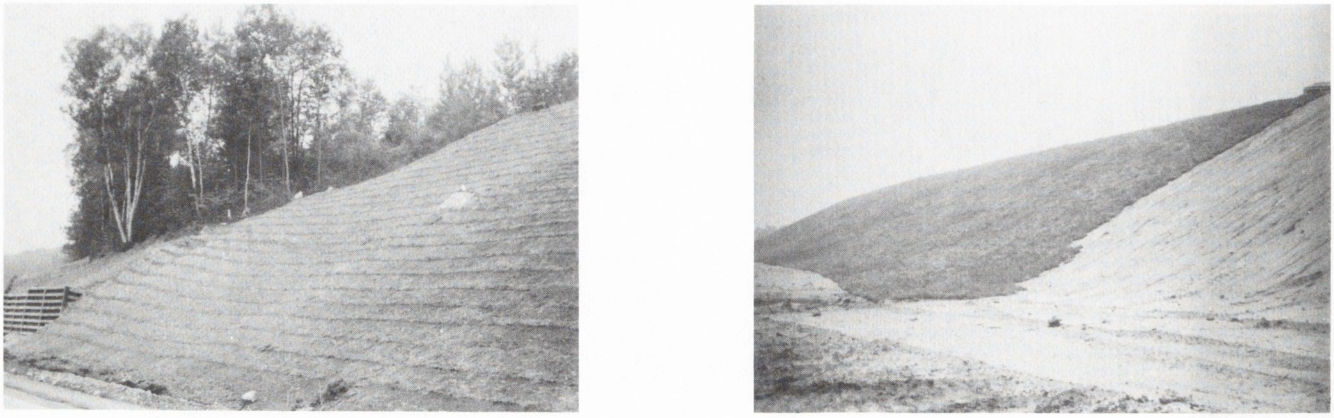


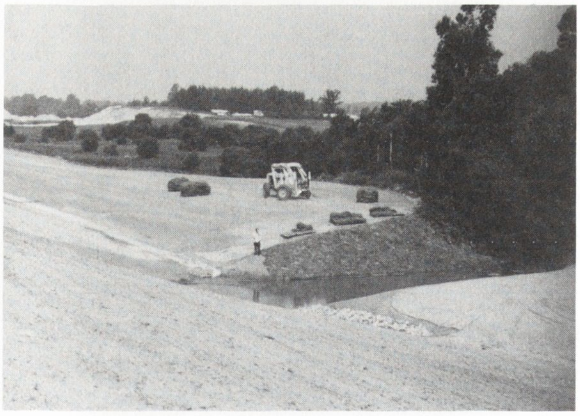
Figure A-57. Slope Grooming



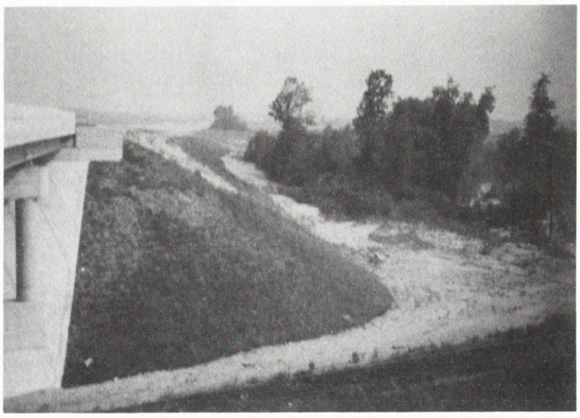
Stripping along Contours

Complete Coverage

Figure A-58. Sodding



Stream Protection



On Bridge Abutment

Figure A-58. Sodding (continued)

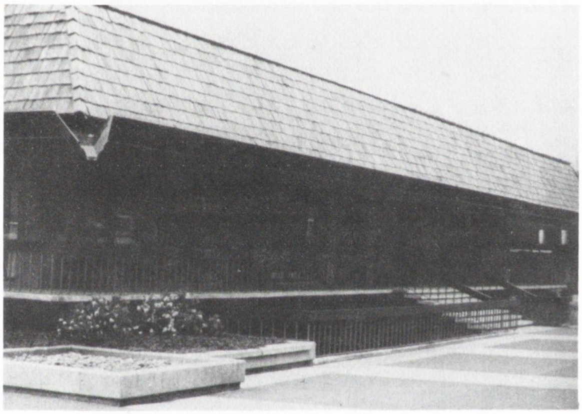


Figure A-59. Splash Basin

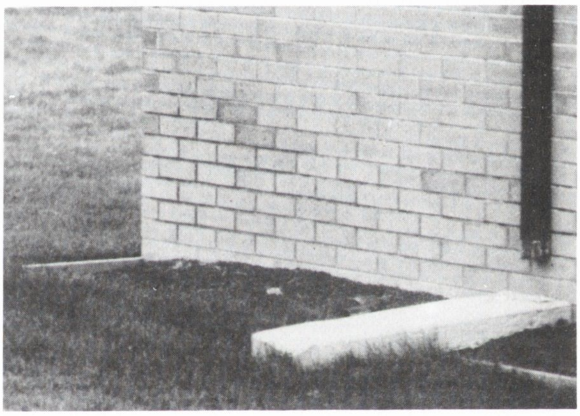
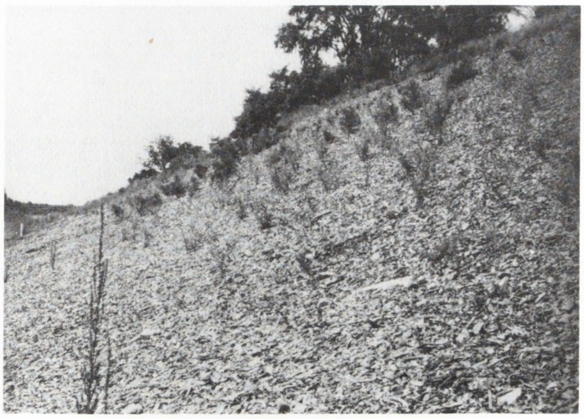
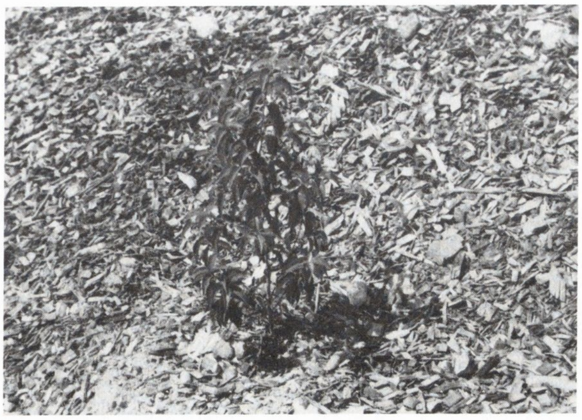


Figure A-60. Splash Block



On Mulched Slope



On Mulched Slope

Figure A-61. Sprigging

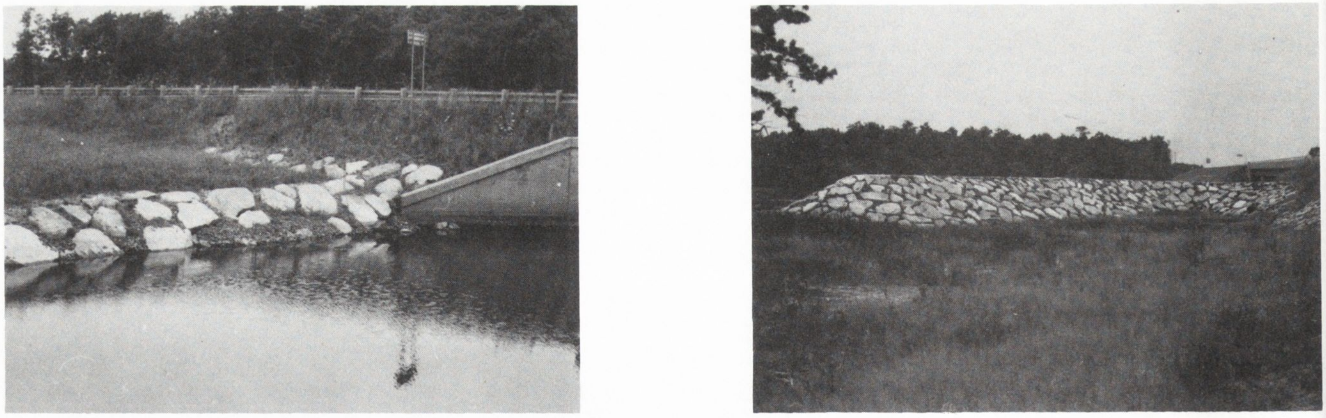
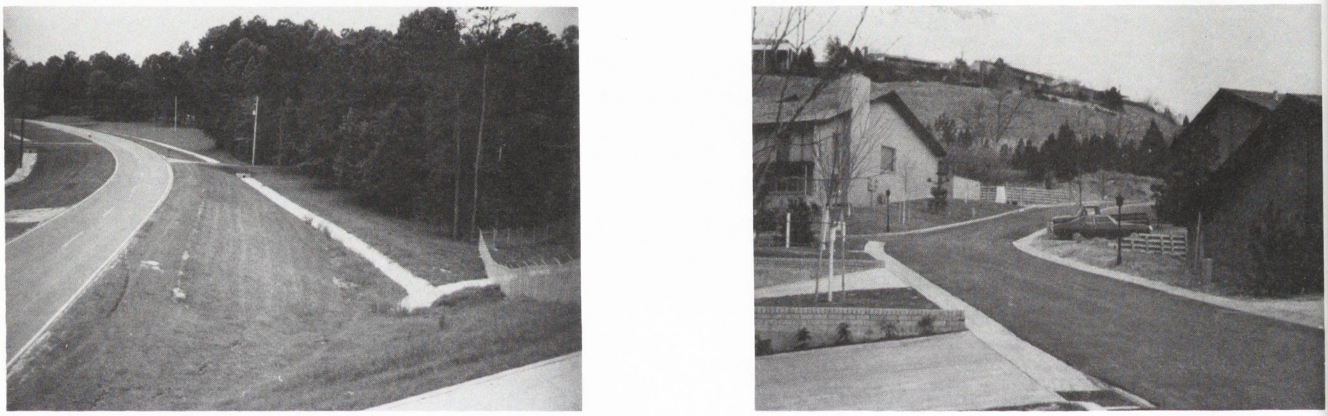


Figure A-62. Spur Dikes



Along Highways

In Sub-division

Figure A-63. Stabilized Systems

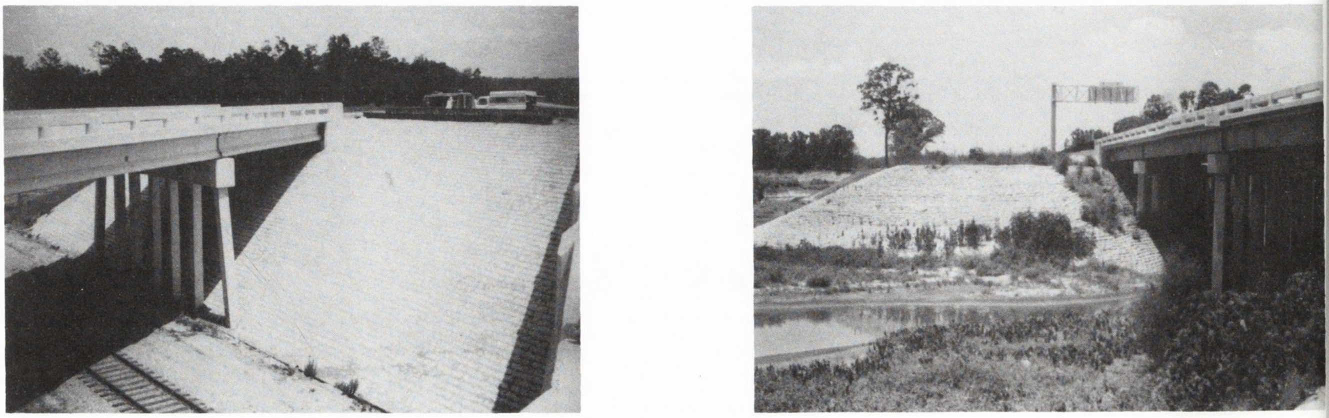
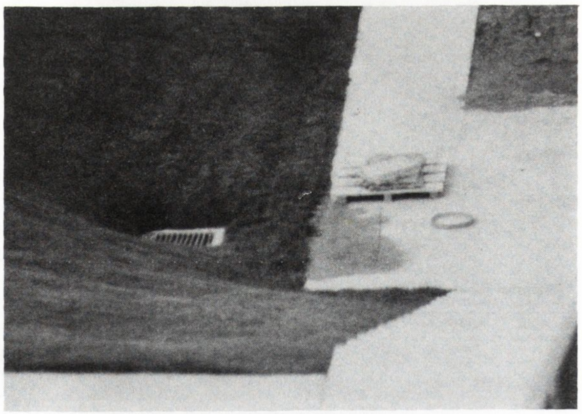
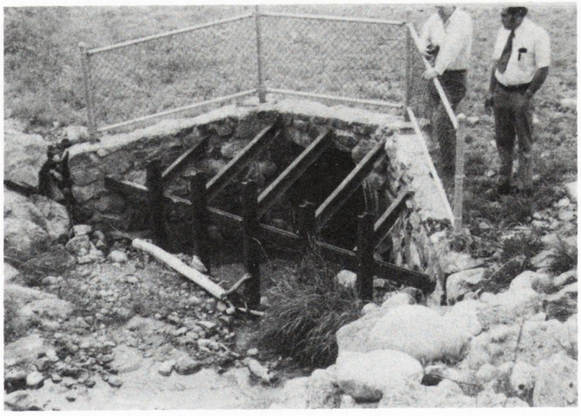


Figure A-64. Stacked Concrete Bags



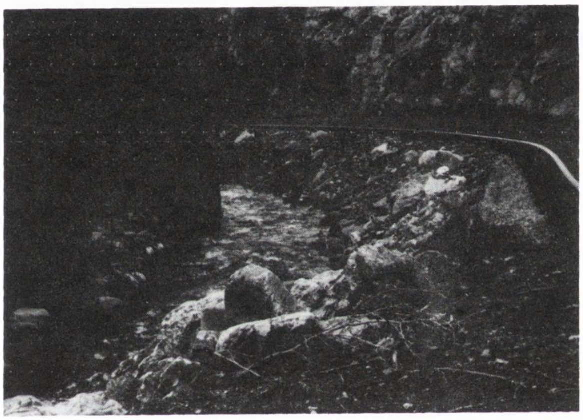
In Sub-division



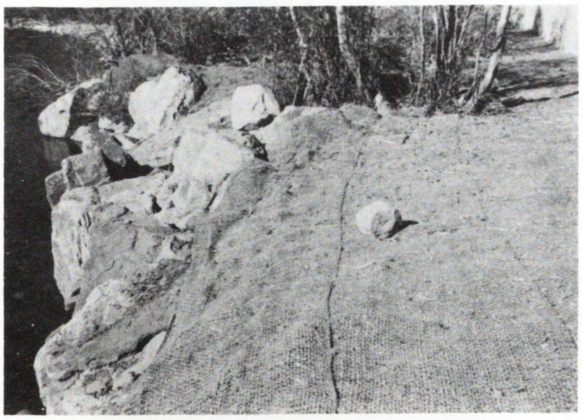
In Highway System

Figure A-65. Storm Sewers

Vegetation



Rocks



Jute and Rocks

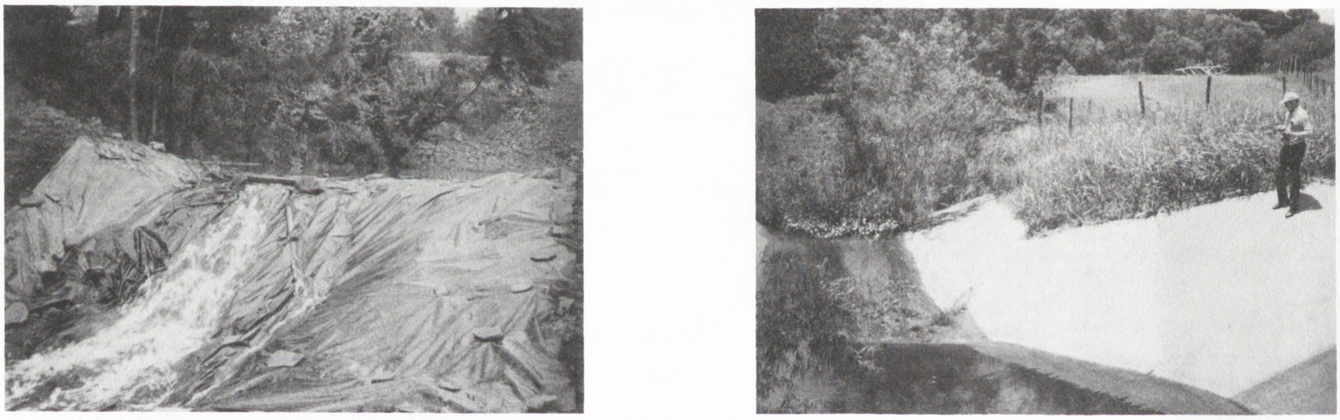
Rocks

Figure A-66. Streambank Protection

Man-made Stream Channel

Temporary By-pass Channel

Figure A-67. Stream Channel Change



Temporary-Plastic

Permanent-Concrete

Figure A-68. Spillways

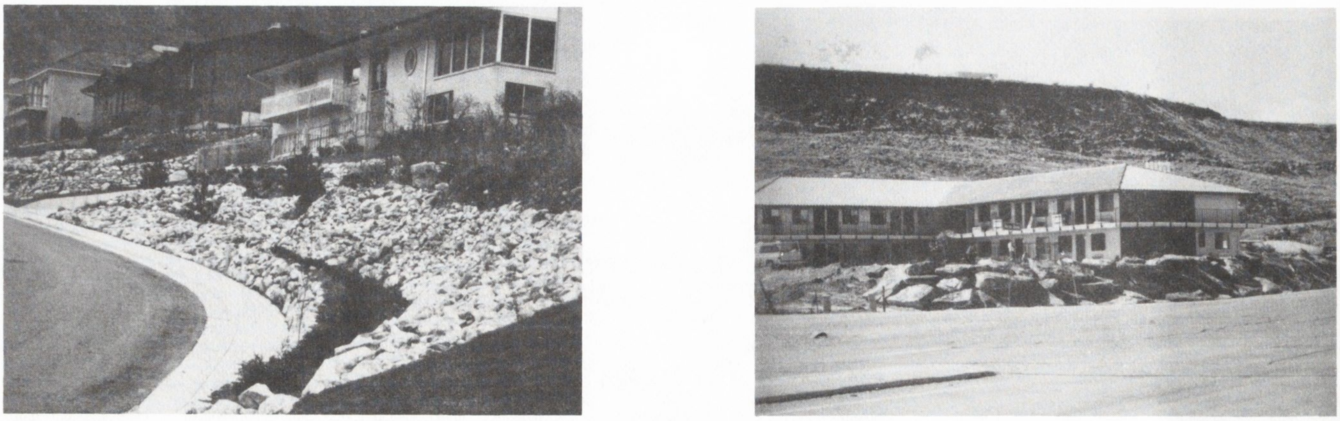


Figure A-69. Stabilizing With Rock

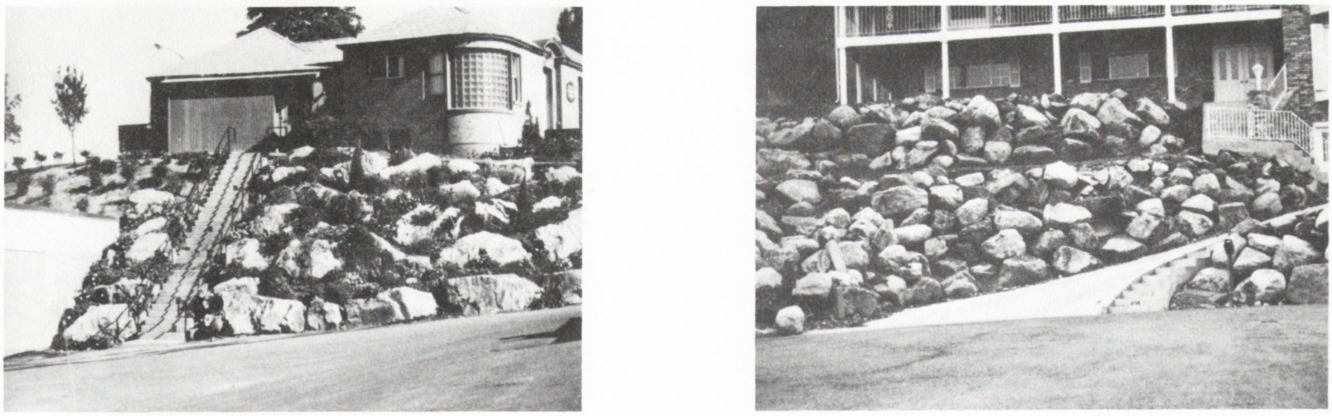


Figure A-69. Stabilizing With Rock (continued)

Building Construction

Highway

Figure A-70. Surface Area Exposure

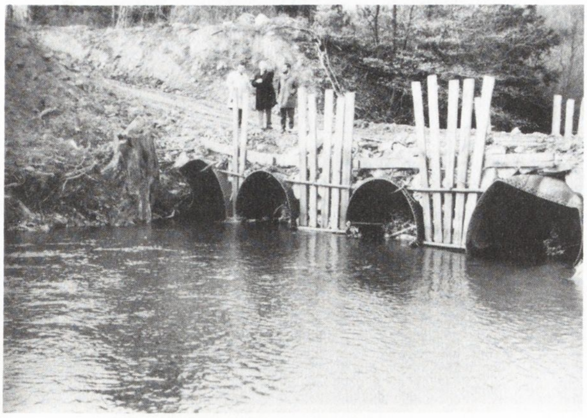


Figure A-71. Temporary Crossing

Figure A-72. Toe Drain Ditch

Figure A-72. Toe Drain Ditch (continued)

Respreading

Stockpiling

Figure A-73. Topsoiling

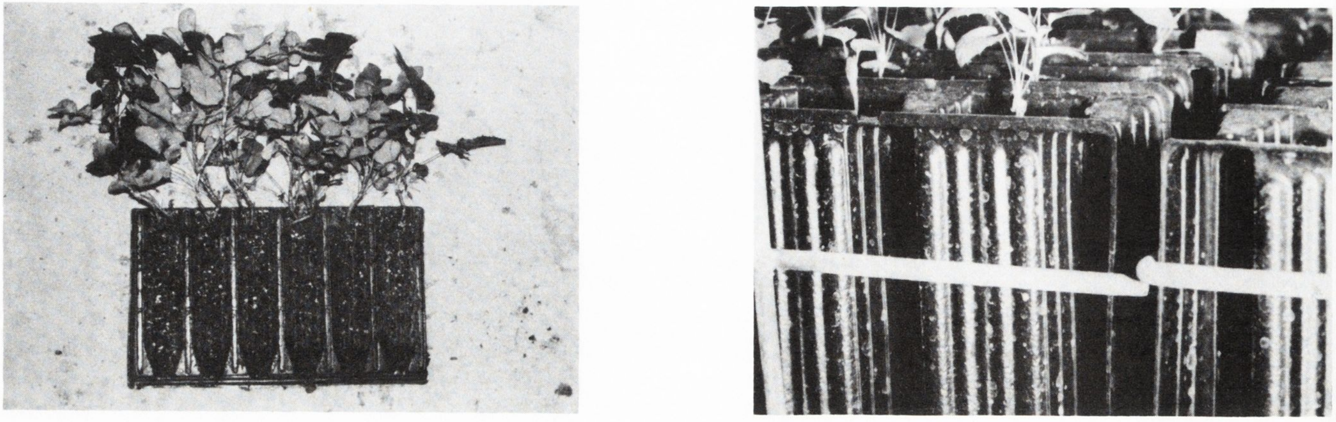
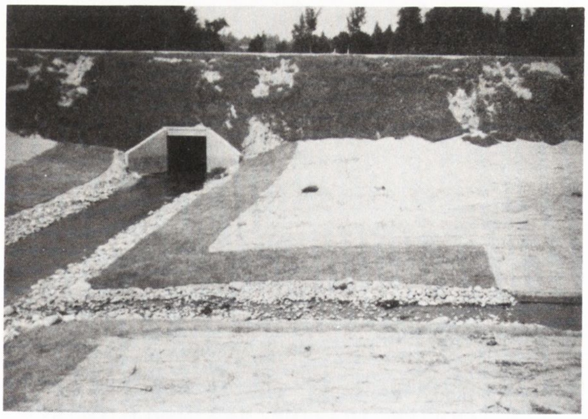
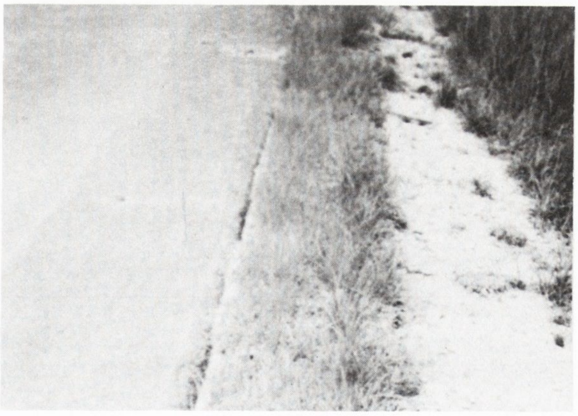


Figure A-74. Tubelings (Photos courtesy Native Plants, Inc.)

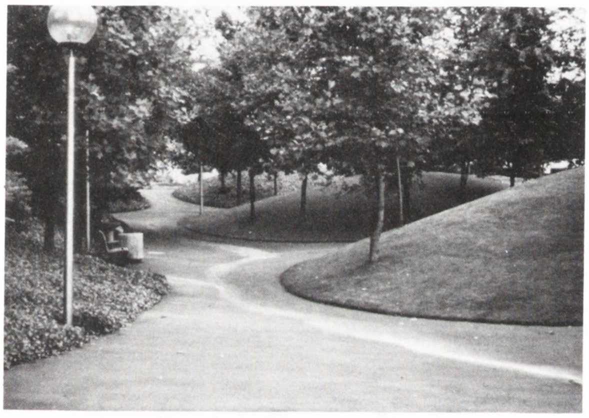


Along Stream Banks



Along Highway Pavement

Figure A-75. Vegetative Buffer Strips



Public Park

University Campus

Seeded with Straw Mulch

Highway Fill

Figure A-76. Vegetative Stabilization

APPENDIX B

GRAPHICAL SOLUTION OF THE SOIL LOSS EQUATION

The nomograph, or alignment chart, is a useful tool for solving mechanically many functions of three or more variables. Although the alignment charts can be used to solve any of the problems which can be solved by a slide rule, they cannot give exact solutions for the problems covered. Nevertheless, nomographs present solutions of an accuracy which does not suffer by comparison with slide rule computation. Nomographs are very useful and time saving in repetitive solutions of mathematical formulas. Moreover, they are most helpful in showing the interrelationships among the variables.

The parallel-scale nomograph (Figure B-1) is designed to provide quick graphical solution to the modified soil loss equation, with the aid of a straightedge. The nomograph can also be used to advantage as a guide in erosion control design during construction. It is used in the following manner:

1. The annual rainfall factor R and the soil erodibility factor K for the area under consideration are determined from the Utah R-factor map and soils map.

2. A line connecting R and K values on the parallel-scale nomograph identifies a point X on the turning axis. This point is used in determining the maximum allowable LS or the erosion potential A.

3. If the slope length and steepness are given, the LS factor is determined from Table C-1 and the value is entered on the parallel-scale nomograph, Figure B-1. A straight line is drawn connecting the LS value and point X, determined previously. Potential erosion is read at the intersection of the straight line and the potential erosion scale.

4. If an allowable* erosion potential is given, the maximum allowable LS factor value is found by extending the line connecting the point X on the turning axis and the allowable erosion potential value to its intersection with the LS scale.

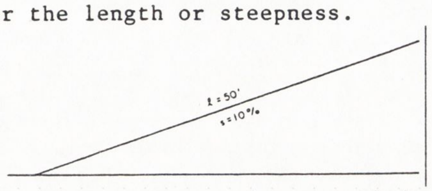
Suppose that an architect is faced with the problem of designing slopes of a particular hillside subdivision for effective control of erosion during the construction period. While the absolute erosion potential at the site may not be known to him, he can certainly influence the amount of erosion that occurs by manipulating the topographic factor, LS and/or the erosion control factor, VM. Then he can determine the amount of control needed by a judicious use of the nomograph.

For purposes of illustration, assume that the site location is in Park City, east of Salt Lake City. From the Utah R-factor map the average annual R value is determined to be 13. The soils map indicates that the K value for this area varies from 0.11 to 0.30. Data from soil samples from the particular site in question show the actual K value to be 0.30 (this is the value that should be used in preference to the approximate value from the map).

On Figure B-1, extend a line between R = 13 and K = 0.30 and locate the point X on the turning axis. Now consider the following slope configurations with different sets of conditions.

Configuration 1

Assume maximum allowable* soil loss A = 10 T/acre, and that other design considerations require that no tolerance be permitted in either the length or steepness.



Because of the very stringent limitations given, nothing can be done about the manipulation of the topographic factor, LS. Necessary VM can, however, be provided if needed. Since

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*Allowable erosion at any given site may be specified by state regulations, or by elected officials of local municipalities or agencies or of other interests.

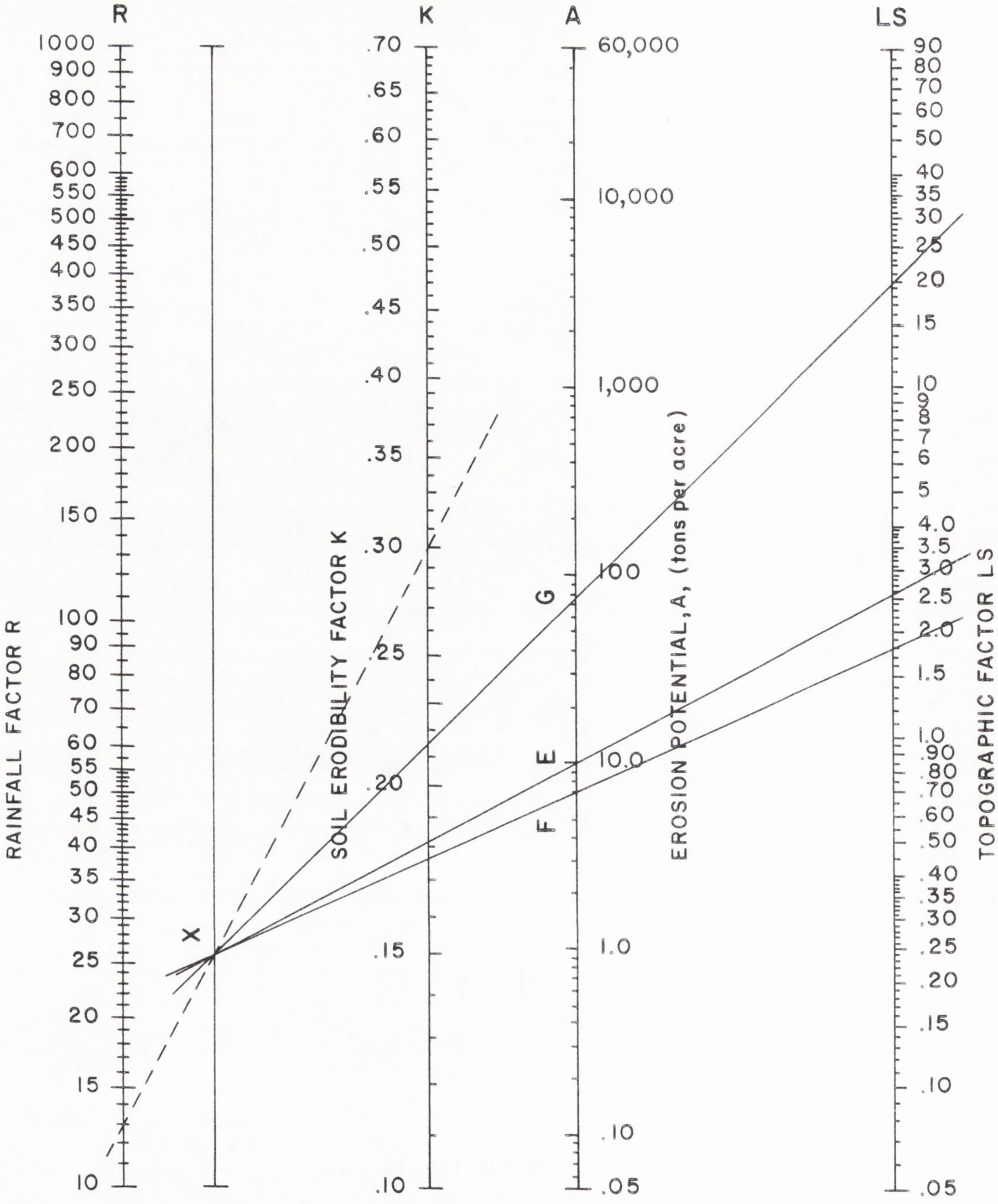


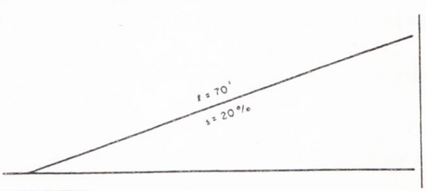
Figure B-1. Parallel scale nomograph for solving soil loss equation A = R·K·LS.

an allowable soil loss value is given (A = 10 T/acre) enter this value as point E on the erosion potential scale of Figure B-1. Extending a line from X through E gives a maximum allowable LS value of 2.60.

Now check for adequacy of the LS values on the graph for a 50 foot slope length and 10 percent slope angle in Table C-1. LS for this case = 0.97. As the LS available (0.97) is less than that allowable (2.6), the slope configuration itself will provide adequate erosion control. If LS were not adequate, VM would have been required.

Configuration 2

Assume maximum allowable* soil loss, A = 7 T/acre.



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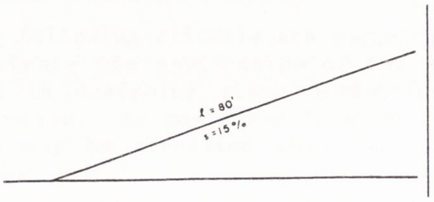
*Allowable erosion at any given site may be specified by state regulations, or by elected officials of local municipalities or agencies or of other interests.

A line drawn from point X through potential erosion value A = 7 (point F on Figure B-1) and extended to the LS scale defines a maximum allowable LS value of 1.8. Suppose, in this configuration, that a 15 percent flexibility is possible in the length-slope parameter. The actual LS value (determined from Table C-1) is found to be 3.41 which is higher than the maximum allowable value determined from Figure B-1 (LS = 1.8). Taking advantage of the flexibility allowed, the configuration is changed to ℓ = 80 and s = 15 percent which (from Table C-1) gives a new value of LS = 2.29.

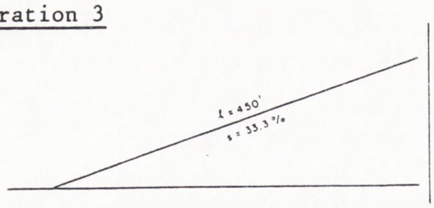


This configuration change decreases the erosion potential but still does not meet the allowable value determined from Figure B-1 of LS = 1.80. Therefore, erosion control measures (VM) will be required. Using the water soil loss equation, the necessary amount of VM can be calculated.

$$VM = \frac{A}{R \cdot K \cdot LS} = \frac{7}{(13 \times 0.30 \times 2.29)} = 0.78$$

One or more measures from the table of VM values can be selected to supply the necessary additional protection.

Configuration 3



The slope length and steepness values are given and the erosion potential value is desired. The value of LS is determined from Table C-1 to be 20.0. This value is entered on the parallel scale nomograph, Figure B-1, and a straight line is drawn from this value to point X. Point G on this line indicates the potential erosion to be approximately 78 T/acre/year. If this amount is more than can be tolerated, the LS and/or VM factors must be manipulated to decrease it to the desired level, as explained previously.

Note 1: The above examples are intended only to illustrate the use of nomographs. Economic and other considerations have not been included.

APPENDIX C

EXAMPLES OF EROSION CALCULATIONS

Erosion Control Design Criteria

The following criteria are suggested only to illustrate the application of the erosion equation in designing slope protection from sheet erosion. At any given location, design criteria may be specified which will differ from these.

1. The erosion rate, A, from finished, protected slopes shall not exceed:

   a. 1.0 tons/acre for high priced residential or commercial areas or where zero pollution to streams is mandated.

   b. 5.0 tons/acre for urban areas not adjacent to streams or other drainage ways.

   c. 50.0 tons/acre for rural areas remote from streams.

In order for a designer/contractor to be able to design erosion control measures to meet these criteria it is necessary that he know:

1. How to calculate "LS" values for single and compound slopes.

2. How to manipulate "LS" and how to apply "VM" values to attain the design erosion rate, A.

3. How to evaluate the risk of erosion occurring during short time periods when slopes are bare and exposed.

Determination of LS

Single Slopes

The length of a slope and its steepness are both factors which affect the rate at which sediment will move. For convenience both factors have been combined into a single value which can be determined for single slopes by solving the equation;

$$LS = \left(\frac{65.41\ s^2}{s^2+10,000} + \frac{4.56\ s}{\sqrt{s^2+10,000}} + 0.065 \right) \left(\frac{\ell}{72.6} \right)^m \qquad \text{(C-1)}$$

in which

LS = topographic factor

s = slope gradient in percent

ℓ = slope length in feet

$$m = \begin{cases} 0.2 \text{ for slope gradients of 0 to 1 percent} \\ 0.3 \text{ for slope gradients of 1 to 3 percent} \\ 0.4 \text{ for slope gradients of 3.5 to 4.5 percent} \\ 0.5 \text{ for slope gradients greater than 5 percent} \end{cases}$$

Table C-1 presents solutions to Equation C-1 for various values of ℓ and s.

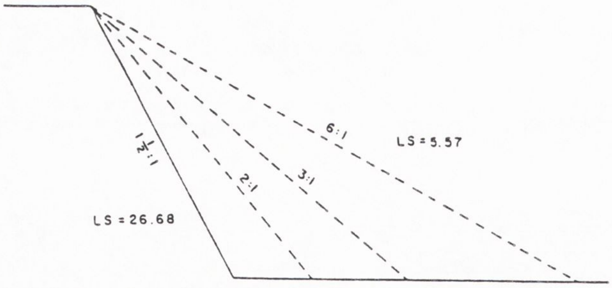
Sensitivity of LS of Single Slopes to Changes in Slope and Length

Sensitivity of LS to changes in slope and length may be demonstrated by the following example using Table C-1. If the site calls for a fill slope 100 feet long at a steepness of 1-1/2:1 (67 percent) the LS factor value is 26.68. Reducing the slope to 2:1 (50 percent) would increase the length to 124 feet (increasing the exposed area by 24 percent), and the new LS factor value becomes 19.86. The erosion rate potential has thus been reduced to 74 percent of the original and the erosion amount to 92 percent. Further reducing the slope to 3:1 (33 percent) the LS factor value

Table C-1. LS values.

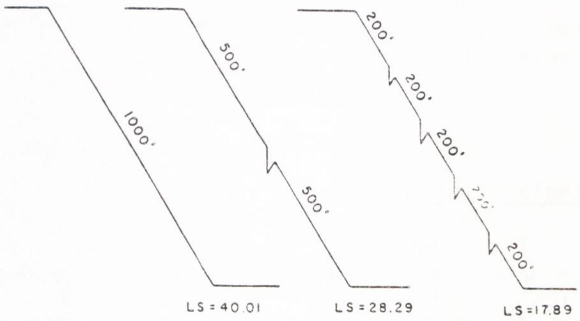
Slope Ratio	Slope Gradient "s" (%)	Slope Length "ℓ" (ft.) (λ = summation of "ℓ" segments)																						
		10	20	30	40	50	60	70	80	90	100	150	200	250	300	350	400	450	500	600	700	800	900	1000
	0.5	0.06	0.07	0.07	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.10	0.11	0.11	0.12	0.12	0.13	0.13	0.13	0.14	0.14	0.14	0.15	0.15
100:1	1	0.08	0.09	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.14	0.14	0.15	0.16	0.16	0.16	0.17	0.17	0.18	0.18	0.19	0.19	0.20
	2	0.10	0.12	0.14	0.15	0.16	0.17	0.18	0.19	0.19	0.20	0.23	0.25	0.26	0.28	0.29	0.30	0.32	0.33	0.34	0.36	0.37	0.39	0.40
	3	0.14	0.18	0.20	0.22	0.23	0.25	0.26	0.27	0.28	0.29	0.32	0.35	0.38	0.40	0.42	0.43	0.45	0.46	0.49	0.51	0.54	0.55	0.57
	4	0.16	0.21	0.25	0.28	0.30	0.33	0.35	0.37	0.38	0.40	0.47	0.53	0.58	0.62	0.66	0.70	0.73	0.76	0.82	0.87	0.92	0.96	1.00
20:1	5	0.17	0.24	0.29	0.34	0.38	0.41	0.45	0.48	0.51	0.53	0.66	0.76	0.85	0.93	1.00	1.07	1.13	1.20	1.31	1.42	1.51	1.60	1.69
	6	0.21	0.30	0.37	0.43	0.48	0.52	0.56	0.60	0.64	0.67	0.82	0.95	1.06	1.16	1.26	1.34	1.43	1.50	1.65	1.78	1.90	2.02	2.13
	7	0.26	0.37	0.45	0.52	0.58	0.64	0.69	0.74	0.78	0.82	1.01	1.17	1.30	1.43	1.54	1.65	1.75	1.84	2.02	2.18	2.33	2.47	2.61
12½:1	8	0.31	0.44	0.54	0.63	0.70	0.77	0.83	0.89	0.94	0.99	1.21	1.40	1.57	1.72	1.85	1.98	2.10	2.22	2.43	2.62	2.80	2.97	3.13
	9	0.37	0.52	0.64	0.74	0.83	0.91	0.98	1.05	1.11	1.17	1.44	1.66	1.85	2.03	2.19	2.35	2.49	2.62	2.87	3.10	3.32	3.52	3.71
10:1	10	0.43	0.61	0.75	0.87	0.97	1.06	1.15	1.22	1.30	1.37	1.68	1.94	2.16	2.37	2.56	2.74	2.90	3.06	3.35	3.62	3.87	4.11	4.33
	11	0.50	0.71	0.86	1.00	1.12	1.22	1.32	1.41	1.50	1.58	1.93	2.23	2.50	2.74	2.95	3.16	3.35	3.53	3.87	4.18	4.47	4.74	4.99
8:1	12.5	0.61	0.86	1.05	1.22	1.36	1.49	1.61	1.72	1.82	1.92	2.35	2.72	3.04	3.33	3.59	3.84	4.08	4.30	4.71	5.08	5.43	5.76	6.08
	15	0.81	1.14	1.40	1.62	1.81	1.98	2.14	2.29	2.43	2.56	3.13	3.62	4.05	4.43	4.79	5.12	5.43	5.72	6.27	6.77	7.24	7.68	8.09
6:1	16.7	0.96	1.36	1.67	1.92	2.15	2.36	2.54	2.72	2.88	3.04	3.72	4.30	4.81	5.27	5.69	6.08	6.45	6.80	7.45	8.04	8.60	9.12	9.62
5:1	20	1.29	1.82	2.23	2.58	2.88	3.16	3.41	3.65	3.87	4.08	5.00	5.77	6.45	7.06	7.63	8.16	8.65	9.12	9.99	10.79	11.54	12.24	12.90
4½:1	22	1.51	2.13	2.61	3.02	3.37	3.69	3.99	4.27	4.53	4.77	5.84	6.75	7.54	8.26	8.92	9.54	10.12	10.67	11.68	12.62	13.49	14.31	15.08
4:1	25	1.86	2.63	3.23	3.73	4.16	4.56	4.93	5.27	5.59	5.89	7.21	8.33	9.31	10.20	11.02	11.78	12.49	13.17	14.43	15.58	16.66	17.67	18.63
	30	2.51	3.56	4.36	5.03	5.62	6.16	6.65	7.11	7.54	7.95	9.74	11.25	12.57	13.77	14.88	15.91	16.87	17.78	19.48	21.04	22.49	23.86	25.15
3:1	33.3	2.98	4.22	5.17	5.96	6.67	7.30	7.89	8.43	8.95	9.43	11.55	13.34	14.91	16.33	17.64	18.86	20.00	21.09	23.10	24.95	26.67	28.29	29.82
	35	3.23	4.57	5.60	6.46	7.23	7.92	8.55	9.14	9.70	10.22	12.52	14.46	16.16	17.70	19.12	20.44	21.68	22.86	25.04	27.04	28.91	30.67	32.32
2½:1	40	4.00	5.66	6.93	8.00	8.95	9.80	10.59	11.32	12.00	12.65	15.50	17.89	20.01	21.91	23.67	25.30	26.84	28.29	30.99	33.48	35.79	37.96	40.01
	45	4.81	6.80	8.33	9.61	10.75	11.77	12.72	13.60	14.42	15.20	18.62	21.50	24.03	26.33	28.44	30.40	32.24	33.99	37.23	40.22	42.99	45.60	48.07
2:1	50	5.64	7.97	9.76	11.27	12.60	13.81	14.91	15.94	16.91	17.82	21.83	25.21	28.18	30.87	33.34	35.65	37.81	39.85	43.66	47.16	50.41	53.47	56.36
	55	6.48	9.16	11.22	12.96	14.48	15.87	17.14	18.32	19.43	20.48	25.09	28.97	32.39	35.48	38.32	40.97	43.45	45.80	50.18	54.20	57.94	61.45	64.78
1¾:1	57	6.82	9.64	11.80	13.63	15.24	16.69	18.03	19.28	20.45	21.55	26.40	30.48	34.08	37.33	40.32	43.10	45.72	48.19	52.79	57.02	60.96	64.66	68.15
	60	7.32	10.35	12.68	14.64	16.37	17.93	19.37	20.71	21.96	23.15	28.35	32.74	36.60	40.10	43.31	46.30	49.11	51.77	56.71	61.25	65.48	69.45	73.21
1½:1	66.7	8.44	11.93	14.61	16.88	18.87	20.67	22.32	23.87	25.31	26.68	32.68	37.74	42.19	46.22	49.92	53.37	56.60	59.66	65.36	70.60	75.47	80.05	84.38
	70	8.98	12.70	15.55	17.96	20.08	21.99	23.75	25.39	26.93	28.39	34.77	40.15	44.89	49.17	53.11	56.78	60.23	63.48	69.54	75.12	80.30	85.17	89.78
	75	9.78	13.83	16.94	19.56	21.87	23.95	25.87	27.66	29.34	30.92	37.87	43.73	48.89	53.56	57.85	61.85	65.60	69.15	75.75	81.82	87.46	92.77	97.79
1¼:1	80	10.55	14.93	18.28	21.11	23.60	25.85	27.93	29.85	31.66	33.38	40.88	47.20	52.77	57.81	62.44	66.75	70.80	74.63	81.76	88.31	94.41	100.13	105.55
	85	11.30	15.98	19.58	22.61	25.27	27.69	29.90	31.97	33.91	35.74	43.78	50.55	56.51	61.91	66.87	71.48	75.82	79.92	87.55	94.57	101.09	107.23	113.03
	90	12.02	17.00	20.82	24.04	26.88	29.44	31.80	34.00	36.06	38.01	46.55	53.76	60.10	65.84	71.11	76.02	80.63	84.99	93.11	100.57	107.51	114.03	120.20
	95	12.71	17.97	22.01	25.41	28.41	31.12	33.62	35.94	38.12	40.18	49.21	56.82	63.53	69.59	75.17	80.36	85.23	89.84	98.42	106.30	113.64	120.54	127.06
1:1	100	13.36	18.89	23.14	26.72	29.87	32.72	35.34	37.78	40.08	42.24	51.74	59.74	66.79	73.17	79.03	84.49	89.61	94.46	103.48	111.77	119.48	126.73	133.59

becomes 12.50 or 47 percent of the original. A 6:1 slope would reduce the LS value to 5.57 or nearly 21 percent of the first design, but the slope length has now more than tripled to 337 feet and the total amount of erosion has reduced to only 72 percent of the original.



Slope	Length	LS	LS Value (Percent of Original)	Erosion Amount (Percent of Original)
1-1/2:1	100	26.68	100	100
2:1	124	19.86	74	92
3:1	173	12.50	47	82
6:1	337	5.57	21	72

The sensitivity of LS factors to shortening of slope lengths on a fill slope while keeping the slope steepness constant is illustrated with the following example wherein the original total slope length is 1000 feet and the slope steepness is 2-1/2:1 (40 percent). Slope segments are created by installing interceptor ditches across the slope as shown in the illustration below and their LS values may be obtained from Table C-1.



When a slope is shortened by means of intercept ditches, the LS values for the new slope segments created can be determined also by multiplying the LS for the individual slope by $1/\sqrt{\text{no. of segments}}$. For example, the original LS value for the 1000 ft slope in the example above is 40.01. Dividing the slope into 5 equal segments decreases the LS to $40.01/\sqrt{5} = 17.89$.

Cutting the slope length in half cuts the erosion amount on the total slope by approximately one-third or to 70 percent of the original amount.

The reader should remember that erosion potential, or the R·K·LS value, is a rate and must be multiplied by an area to determine total erosion amount.

Multiple Slopes

The soil loss equation is based on the assumption that the sediment load carried by the runoff is limited only by the amount of material detached and not by the capacity of the water to carry the detached material. Under this assumption the sediment load increases as the water moves downslope and the runoff from the upper slope adds to the rainfall on the lower slope and thus increases the erosion rate on the lower slope. To obtain an LS factor for a segment of a multiple slope which takes into account the runoff from the upper slope, the following formula can be used:

$$(LS)_n = \frac{(L_{\lambda_n} S_{s_n})\,\lambda_n - (L_{\lambda_{n-1}} S_{s_n})\,\lambda_{n-1}}{ln} \qquad \text{(C-2)}$$

in which

$(LS)_n$ = topographic factor for slope segment n

ln = length of slope segment n

s_n = slope gradient in percent of segment n

λ_n = the sum of the slope segment length from the top of the slope to the bottom of slope segment n

S_n = slope factor for slope segment n

L_n = length factor for slope segment n

To illustrate its use, consider the multiple slope shown in Figure C-1.

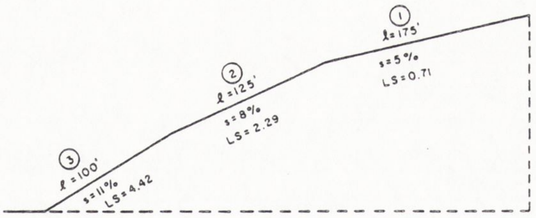


Figure C-1.

The parts can be tabulated thus:

$\lambda_0 = 0$

$\ell_1 = 175 \quad \lambda_1 = 175 \quad S_1 = 5\%$

$\ell_2 = 125 \quad \lambda_2 = 300 \quad S_2 = 8\%$

$\ell_3 = 100 \quad \lambda_3 = 400 \quad S_3 = 11\%$

Using Table C-1, the above values of ℓ, λ, and s, and Equation C-2, LS values for the three slope segments, as influenced by the slopes above them, can be determined

LS for λ_1 S_1 = 0.71
LS for λ_0 S_1 = 0
LS for λ_2 S_2 = 1.72
LS for λ_1 S_2 = 1.31
LS for λ_3 S_3 = 3.16
LS for λ_2 S_3 = 2.74

Segment 1 would have an LS value equal to:

$$LS_1 = \frac{(0.71)(175) - (0)(0)}{175} = 0.71$$

Segment 2 would have:

$$LS_2 = \frac{(1.72)(300) - (1.31)(175)}{125} = 2.29$$

and segment 3 would have:

$$LS_3 = \frac{(3.16)(400) - (2.74)(300)}{100} = 4.42$$

Potential erosion rates will now be calculated using the soil loss equation for a hypothetical site at Park City, Utah, where R = 13 and k = 0.30.

A = R·K·LS

segment 1, A = 13 (0.30)(0.71) = 2.77 T/A

segment 2, A = 13 (0.30)(2.29) = 8.93 T/A

segment 3, A = 13 (0.30)(4.22) = 16.46 T/A

The VM values needed to reduce the potential on each slope segment to 1.0 T/A are calculated from:

VM = 1/A

for segment 1 VM = 0.36

for segment 2 VM = 0.11

for segment 3 VM = 0.06

The designer may select from a variety of treatments to meet these conditions. (See Figures 3, 4, 5, 6, and Table 3.)

Distribution of Erosion on a Slope

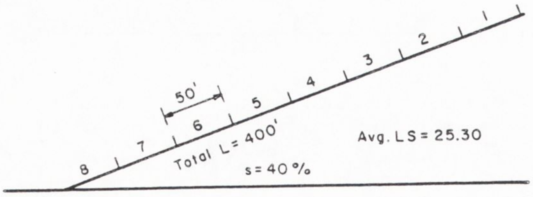
The overall LS for the compound slope in Figure C-1 is 2.13. This value is used in the erosion equation to calculate the rate of erosion from the entire slope in tons per acre per year. However, if this value were used to determine the amount of protection (VM) required to reduce the overall erosion rate to a particular amount, it would overdesign for the top of the slope and underdesign for the lower part because it is an average LS for the entire slope, as shown here.

A = 13 (0.30) 2.13 = 8.31 tons/acre, and

VM = 1/A = 1/8.31 = 0.12

The bottom portion of the slope experiences the greatest amount of erosion due to the extra flow of water from the slopes above. The following example shows the magnitude of the increase of erosion in a downhill direction.

Assume a single slope 400 feet long and having a steepness of 40 percent. Divide it into eight segments of equal length and analyze them as if they were a multiple slope, using Equation C-2 and Table C-1. The calculations can be shown in tabular form as follows.



n	$(L\lambda_n\ S_{s_n})$ λ_n	- $(L\lambda_{n-1}\ S_{s_n})$	λ_{n-1}	/ln		=(LS)n
1	8.95	50	0	0	50	8.95
2	12.65	100	8.95	50	50	16.35
3	15.50	150	12.65	100	50	21.20
4	17.89	200	15.50	150	50	25.06
5	20.01	250	17.89	200	50	28.49
6	21.91	300	20.01	250	50	31.41
7	23.67	350	21.91	300	50	34.23
8	25.30	400	23.67	350	50	36.71

Average LS = 25.30

The erosion rates and VM values to meet the 1.0 T/A criterion, using Park City, Utah, data are as follow, using A = R·K·LS and VM = 1/A:

Segment	A	VM
1	34.9	0.029
2	63.8	0.016
3	82.7	0.012
4	97.7	0.010
5	111.1	0.009
6	122.5	0.008
7	133.5	0.0075
8	143.2	0.007

These data show that the erosion rate at the lower end of the slope is about 145 percent as much as that near the center, or the average. However, the erosion rate at the upper end of the slope is only one-third of the average. These facts should be kept in mind when applying mulches or other erosion control measures to the slope, the middle third of the slope should be covered at the calculated rate, the top third at a lesser rate, and the bottom third at a greater rate, in order to get the most protection.

Controlling Erosion at a Specific Site

Site Conditions

The following example (see Table C-3) will illustrate the use of the erosion equation for determining potential erosion, and for selecting control measures that will decrease erosion to acceptable rates. The selected site for the example is in Park City where the R factor determined from the map in the pocket is 13.0, and the K factor from Figure 2 is 0.30. The compound slope selected (see Figure C-2) extends 140 feet up to a

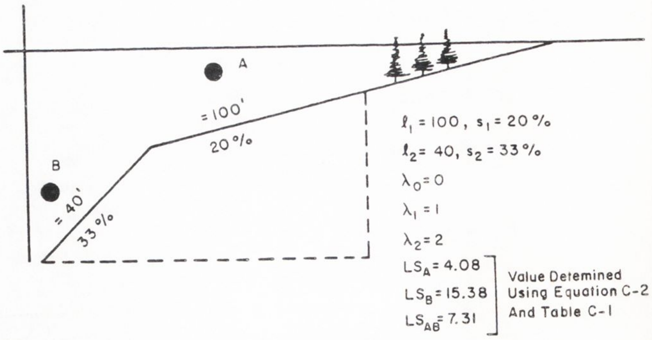


Figure C-2. Profile of hypothetical slopes selected for example in Park City Utah.

stand of native evergreens and brush, from which no runoff is expected. Both slopes were completely bared during early stages of the construction period. The time from grubbing and clearing to final shaping was 3 months (September, October, and November). The bare soil condition at the end of final shaping is described as "bulldozer compacted and scraped across the slope." As soon as final grading was completed both A and B slope segments were covered with topsoil, and seed and fertilizer were applied. The seeded area was also covered with straw mulch, punched in across the slope. No growth of grass is expected for 4 months (because of late fall seeding), and an established, permanent grass cover is expected to take an additional 3 months (7 months from date of seeding).

The two parameters in the erosion equation that vary with time are the rainfall factor, R, and the erosion control factor, VM. The R factor in Park City given on the map is an average annual value, and its distribution throughout the year is shown in Table C-2. VM values may be different for each erosion control measure, and for vegetation, varies with time from seeding until plants are mature. Selected VM values are presented in Table 3 and in Figures 3 through 8.

Table C-3 shows conditions existing on each slope for each month of the year. Note that for 9 of the 12 months the treatments specified decreased the erosion rate to less than 1 ton per acre per year. During the 3 months that the slopes were bare, slope A eroded at the average rate of 5.5 tons/acre/year, and slope B at 21 tons/acre/year. If both slopes had been left bare all year, slope A would have eroded at the average annual rate of 15.91 tons/acre/year, and slope B at 60.37 tons/acre/year.

Table C-2. Annual distribution[a] of erosion index R near Park City, Utah.

Months	Percent		R-factor	
	Per Month	Cumulative	Per Month	Cumulative
January	1	1	0.13	0.13
February	1	2	0.13	0.26
March	10	12	1.30	1.56
April	16	28	2.08	3.64
May	14	42	1.82	5.46
June	11	53	1.43	6.89
July	7	60	0.91	7.80
August	8	68	1.04	8.84
September	9	77	1.17	10.01
October	13	90	1.69	11.70
November	7	97	0.91	12.61
December	3	100	0.39	13.00
	100		13.00	

[a] From distribution curve Zone II, Figure 1.

Summary

The effectiveness of the erosion control measures employed in the previous example can be determined from the following equation:

$$E = \frac{\text{RKLS} - \text{RKLS VM}}{\text{RKLS}} \times 100 \qquad \text{(C-3)}$$

Inserting the values from the above example

$$\text{Slope A} = \frac{15.91 - 6.28}{15.91} \times 100 = 60.5\%$$

$$\text{Slope B} = \frac{60.37 - 21.76}{60.37} \times 100 = 64\%$$

This means that the erosion control measures described above are expected to be 60.5 percent and 64 percent effective, respectively, on slopes A and B in controlling erosion. In other words, the control measures selected will stop 60.5 percent and 64 percent, respectively, of the erosion that would have occurred on slopes A and B had no controls been used.

Measuring Rill Erosion

A rapid method of measuring rill erosion that is fairly accurate up to 100 tons per acre is known as the Alutin Rill Erosion method. The formula for this method is:

> Tons/acre soil loss = sum of cross section of rills in square inches along a measured lineal distance of 12.5 feet across the slope.

The following procedure can be used for estimating rill erosion in the field:

Step 1 - Pace off or measure a lineal distance of 37.5 or 75 feet across the slope. Choose a representative strip across the slope at right angles to the general direction of the rills.

Step 2 - Measure in inches the average width and depth of each rill along the chosen distance.

Table C-3. Erosion at a hypothetical construction site, Slope AB (Figure C-2), at Park City, Utah.

1	2	3	4	5	6	7	8
	LS	R	K	A_1*	VM	A_2	
Time Period	Equation C-2 and Table C-1	From map. in pocket and Table C-2	From Fig. 2 or maps in pocket	R·K·LS Tons Per Year Per Acre Col. (2) x Col. (3) x Col. (4) x 12	From Table 3 if Figs. 3, 4, 5, and 6	RKLSVM Col. (5) x Col. (6) T/A/year	Notes
				Slope A			
Sept.	4.08	1.17	0.30	17.18	1.20	20.6	Bare soil--bulldozer slope compacted across slope
Oct.	"	1.69	0.30	24.82	1.20	29.8	
Nov.	"	0.91	0.30	13.37	1.20	16.0	
Dec.	"	0.39	0.30	5.73		<1	Straw mulch applied--punched in across slope--2.5 tons per acre
Jan.	"	0.13	0.30	1.91	0.01	<1	
Feb.	"	0.13	0.30	1.91	0.01	<1	
Mar.	"	1.30	0.30	19.10	0.01	<1	
Apr.	"	2.08	0.30	30.55	0.01	<1	Early grass growth
May	"	1.82	0.30	26.73	0.01	<1	
June	"	1.43	0.30	21.00	0.01	<1	Established grass
July	"	0.91	0.30	13.37	0.01	<1	
Aug.	"	1.04	0.30	15.28	0.01	<1	
Annual	"	13.00	0.30	15.91			
				Slope B			
Sept.	15.38	1.17	0.30	64.78	1.20	77.7	Bare soil--bulldozer compacted scraped across slope
Oct.	"	1.69	0.30	93.57	1.20	112.3	
Nov.	"	0.91	0.30	50.38	1.20	60.5	
Dec.	"	0.39	0.30	21.59	0.0025	<1	Straw mulch applied--punched in across slope--2.5 tons per acre
Jan.	"	0.13	0.30	7.20	0.0025	<1	
Feb.	"	0.13	0.30	7.20	0.0025	<1	
Mar.	"	1.30	0.30	71.98	0.0025	<1	
Apr.	"	2.08	0.30	115.17	0.0025	<1	Early grass growth
May	"	1.82	0.30	100.77	0.0025	<1	
June	"	1.43	0.30	79.18	0.0025	<1	Established grass
July	"	0.91	0.30	50.38	0.0025	<1	
Aug.	"	1.04	0.30	57.58	0.0025	<1	
Annual	"	13.00	0.30	59.98			

*These are expressed as average annual erosion rates for purpose of comparison. Monthly values may be obtained by dividing each value by 12.

Step 3 - Multiply each average width and depth reading to obtain a cross sectional area of each rill in square inches.

Step 4 - Add together the cross sectional areas of all rills within the measured distance.

Step 5 - Divide this sum by 3 if a 37.5 foot distance was selected, and by 6 if 75 feet was chosen. The result is tons of soil loss per acre.

Sample calculation--Width (in.) x depth (in.) = area in square inches (assuming rectangular cross sections) (divide by 2 if cross sections are triangular)

Rill	Avg. Width (in.)	x	Depth (in.)	=	Area in Square Inches
1st	3		3		9
2nd	2		3		6
3rd	3		6		18
4th	4		6		24
5th	3		5		15
6th	5		6		30
					102 sq. inches

For a chosen distance of 37.5 feet the soil loss = 102/3 = 34 tons/acre. Judgment in selecting representative sites for measurement is essential in making good estimates. In practice it is well to average measurements taken at the top, middle, and bottom of a slope to obtain a more accurate estimate of soil loss from the entire area.

APPENDIX D

DETERMINATION OF "R" FROM RAINFALL INTENSITY AND DURATION DATA

FOR A SINGLE STORM

$$E = \Sigma_1^m \left(\frac{916 + 331 \log x_1}{100}\right) y_1 \quad . \quad . \ (E\text{-}1)$$

wherein

x_1 = rainfall intensity for period 1 (inches/hr)
y_1 = rainfall depth for period 1 (inches)
m = number of periods in a storm

If I_{30} is the maximum 30 minute intensity for the m periods then the storm EI is E times I_{30}. This would be in the same units as R or EI/100.

ANNUAL EI

The Equation D-1 is repeated on all storms in each year of record. The annual maximum 30-minute intensity is multiplied by the sum of each year's E for the same year for each year of record. These years of EI values are plotted on log normal paper and the two-year EI determined. This value is the R value for the site.

SAMPLE CALCULATION

Single Storm EI

The following data pertain to a storm which occurred at the Great Basin Experimenal Area on August 13, 1965. The storm was divided into intervals according to time periods of fairly uniform intensities, as shown.

Storm	Time	Time Increments	Accumulated Depth of Precipitation	Depth for Interval	Intensity	Energy
Began	19:00		0.0			0.0
	19:17	17 min	0.70	0.700	2.471	7.32
	19:30	13 min	0.80	0.100	0.462	0.80
Ended	20:30	60 min	0.83	0.030	0.03	0.12
				0.83	E = total	8.24
				ft.	tons/acre	inch

The 30 minute maximum intensity is calculated as follows:

17 minutes at 2.471 in/hr.
13 minutes at 0.462 in/hr.
17 + 13 = 30 minutes
Total depth of rain in this period = 0.70 + 0.10 = 0.80 in. 0.80 inches in 30 minutes is 1.60 inches per hour. Total storm energy = 8.24 ft. tons/acre inch. Total storm EI = 8.24 x 1.600 = 13.184 ft tons/acre in/hr/100.

Annual EI

Repeat the process described above to obtain E values for each storm of the year. Storms at the Great Basin Experimental Area station during 1965 yielded values of E as follows: 0.31, 0.31, 0.40, 7.99, 0.16, 1.01, 0.26, 1.09, 0.77, 0.02, 2.62, 1.08, 0.04, 1.08, 0.49, 0.30, 0.26, 0.16, 4.05, 0.04, 1.14, 3.31, 2.49, 0.07, 0.32, 0.26, 2.19, 0.12, 0.36, 0.16, 0.05, 1.08, 8.24, 0.04, 0.76, 0.24, 2.78, 1.81, 0.03, 0.94, 0.03, 0.65, 0.73, 1.11, 0.17, 0.09, 0.28, 0.31, 0.04, 0.26, 0.15, 0.21, 0.20, 0.44, 0.15, 0.13, 0.46, and 1.05 = 98.85. (Note that these values have already been divided by 100).

The maximum 30 minute intensity during this year was 1.60 inches per hour and the annual EI is 98.85 x 1.60 = 158.16 ft tons/acre in/hr/100.

EI values for other years of record at this same station are the following:

26.44 x 0.568 = 15.02
13.39 x 0.364 = 4.87
98.85 x 1.600 = 158.16
10.47 x 0.360 = 3.77
22.95 x 0.464 = 10.65
4.13 x 0.300 = 4.43
62.18 x 0.702 = 43.55
15.54 x 0.286 = 4.44
21.94 x 0.480 = 10.53
16.62 x 0.548 = 9.11
15.77 x 0.473 = 7.46
17.10 x 0.407 = 6.96

To obtain the R value these EI values are ranked and plotted on log normal paper using 100m/n+1 as the plotting position. The 2 year return is considered to be the mean annual value which by definition is the R value. This is read as 8.3 for the values given.

Monthly or Seasonal EI

As the Equation D-1 is used to compute the energy for individual storms, all storm energies for each month can be ranked for each year and plotted as for the annual values on log probability paper after the multiplication by the respective 30 minute intensities and each mean annual January, February, March, etc. value read off.