EAST MARICOPA FLOODWAY

REACHES 2 & 3 BANK PROTECTION

A121.609

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
PHOENIX, ARIZONA
PRELIMINARY
DESIGN REPORT

JANUARY, 1992

JOB: East Maricopa Floodway, Reaches 2 & 3 Bank Protection

PROJECT: East Maricopa Floodway

LOCATION: Pinal and Maricopa county

AUTHORITY: Public Law 566

PHASE: Preliminary Design

DESCRIPTION OF THE JOB

EMF Reaches 2 and 3 comprise approximately 9 miles of the 27 mile long East Maricopa Floodway. The earth lined portion of these channel reaches vary in depth from 10.5 feet to 13 feet, having a bottom width of 200 feet with side slopes of 3 to 1. Reach 2 was completed in 1983 and Reach 3 was completed in 1985.

During the design of Reaches 2 and 3, the decision was made to leave the channel slopes bare and monitor erosion for future determination of slope protection. Subsequent rainfall has caused jugging and rilling on the O&M roads and side slopes of the channel. In some cases, the rills are severe enough that the O&M road can not be used. Areas where the soil exhibits dispersive properties are also prevalent. During construction of Reaches 5 and 6, soils were specifically monitored for dispersion and appropriate measures applied.

The design limits for this project start at floodway station 743+00 (the beginning of Reach 3) through station 1189+00 (the downstream end of the concrete chute in Reach 2). The channel slopes from station 1189+00 to the outlet at the Gila River will be protected under a separate contract already designed.

The project consists of repairing the existing rills and protecting the channel banks and maintenance roads from erosion by applying a gravel cover. Gravel road surfacing will be compacted to approximately 4 inches thick. Rills and jug holes on the slopes will be filled with gravel and gravel cover placed on the slopes. It will be spread to a maximum thickness of approximately 2 to 2 1/2 inches and will be uncompacted.

DESIGN OBJECTIVE

The objective of the proposed work is to repair and to protect the banks from development of rills and jug holes caused by direct rainfall, and to reduce erosion caused by stream flow across side inlets. The cover for the O&M roads must be adequate to support maintenance traffic, and should match other similar covering already placed on these and other reaches of the EMF. The gravel cover for the slopes must be composed of gravel large enough to resist the tractive stress imposed by design channel flows. Some of the side inlets in Reach 2 need to be modified to reduce headcutting.

BASIS FOR DESIGN

1. Field Trial Report, EMF Reach - 3 Bank Erosion Study Sites November 30, 1990.

2. Chapter 6, Stability Design, TR-25, SCS, October 1977.

DISCUSSION - SLOPE PROTECTION

In 1989, a study was performed on the channel slopes of Reach 3, where various methods of slope protection against rilling were evaluated. Four different methods involved various applications of gravel, gravel and sand, or cobbles. All were effective against rilling. The most economical method involved filling existing rills with gravel and covering the slope with as thin a layer of gravel as could be constructed.

The application of gravel to the channel slopes to act as a protective cover also requires that the finished gravel surface be resistant to erosion from flow in the channel. Various gradations were analyzed for stability against tractive stress under design flow conditions.

Experience has also shown that a thin layer (less than 3-inches) of gravel cover act as an excellent mulch material. The gravel slows rainfall runoff and allows more time for percolation into the soil and retains the moisture in the soil longer. The gravel also collects fines which establishes an excellent seed bed for desirable plant growth.

The specification for road surfacing for O&M roads is similar to the one written for the repair of Reaches 1 & 2. The gradation for that material was based on the Maricopa Association of Governments (MAG) specifications for aggregate base. The same gradation and materials testing requirements were used herein under the SCS specification for gravel road surfacing.

The condition of the maintenance roads at present is that there are rills, jug holes and other rough features. Heavily loaded trucks carrying construction materials could damage the roads at these bumps. The specifications require that the gravel road surfacing materials be placed on the road before being used as a haul road for other materials, and that the contractor maintain all in good condition during the construction period.

Some of the side inlets located in Reach 2 have active headcuts working off of the right of way. This area is between floodway stations 1004+00 and 1066+00. The O&M road grade between inlets will be raised and the affected inlets will be modified to reduce headcutting.

The application rate of gravel cover is specified at 12 tons of cover per 1000 square feet of channel slope. The application rate includes filling the rills and spreading the remaining gravel uniformly over the slopes.

LOCATION AND LAYOUT

The location and layout are in accordance with the as-built drawings for Reach 2, Reach 3, and for the Reach 2 Side Inlets Reconstruction.

HYDRAULIC DESIGN

The major hydraulic parameters from the original channel design are as follows:

$Q =$ 8700 cfs

$n =$ 0.027

$s =$ 0.0003 Ft/Ft

$v =$ 4.2 ft/Sec (maximum)

A stability analysis, based on the tractive stress procedure in TR-25, was performed to determine how the gravel cover would resist erosion. Factors of safety were calculated for allowable tractive stress versus actual tractive stress on a range of gravel D75 values. A gravel mix was designed for a factor of safety of at least 2.5.

FOUNDATION AND/OR EMBANKMENT DESIGN

Grading of rills would result in loose material filling the bottom of the rills, creating uncompacted zones prone to settle and the formation of new rills. Therefore, the road and slopes will not be graded before placement of gravel road surfacing or gravel cover. The rills will be filled with gravel and the remaining required gravel will be spread evenly over the surface. Where gravel placement by equipment is allowed, vegetation which will interfere with placement shall be removed. Otherwise, gravel will be placed by hand to protect existing plants.

STRUCTURAL DESIGN

Structural designs were not necessary for this project. Cutoff walls at the side inlets were extended to reduce erosion. As these extensions are excavated into the earth, number 4 reinforcing bars were called for crack control.

ENVIRONMENTAL CONSIDERATIONS

The construction of gravel road surfacing and gravel cover on the slopes will have a positive impact on the visual aspects of the channel. Rilling that has occurred on the channel banks will be reduced. The gravel cover on the O&M roads will reduce dust produced by maintenance vehicles traveling on them.

Reach 2 was seeded during a contract issued in 1985. Plant growth was marginally successful on the channel slopes. There is, however, an area where the plants have done quite well, and hand placement of the gravel was specified for this area.

No impact on the conservation of biological or water resources is predicted. Water will be used to abate potential dust generated by construction activities.

CONSTRUCTION DRAWINGS

Original construction drawings for Reach 2 and Reach 3 were used to provide basic drafting information for the required drawings. The CADD system was used to produce and store the drawings using Versacad software, version 5.4.

SPECIFICATIONS

The construction specifications were prepared using the appropriate sections from NEH-20, and no special written specifications were required.

BID SCHEDULE

Water is considered a subsidiary item in this project because its main use is for dust abatement. The need for dust abatement is mostly a function of how the contractor conducts his work, and is less directly related to the materials being installed.

COST ESTIMATE

Most of the work involves the use of aggregate material which is available within about 5 miles, near the Gila River. The materials for construction are relatively simple, so little special preparation should be required to construct them. The project is of reasonable size so that little economy of scale is likely to result from an increase in the scope of work. No seasonal variation is expected.

CONSTRUCTION SCHEDULE

The construction period was based on an assumed production rate of 432 cubic yards (32 truck loads, or 16 truck loads per bank with a truck unloading every 30 minutes) per day of gravel placement. The preliminary estimate of performance time is four to five months.

OPERATION AND MAINTENANCE

In general, the new improvements are expected to reduce maintenance requirements in the channel.

CONSTRUCTION REVIEW

The most critical item to be carefully watched during construction will be the proper spreading of the gravel cover on the slopes. The objective is to get 100 percent coverage and uniform thickness of the gravel cover layer.

A preconstruction conference should be held to assure that the contractor understands the limits of construction and the proper application of the gravel layers.

by: William McFerrin, Civil Engineer

reviewed: John R. Harrington date: 3-18-92

State Design Engineer

approved: Ralph M. Unruh date: 3-31-92

State Conservation Engineer

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SOIL CONSERVATION SERVICE

STATE		PROJECT REACHES 2 & 3 BANK PROTECTION		
BY WAM	DATE 8/19/90	CHECKED BY JMH	DATE 3-18-92	JOB NO.
SUBJECT TRACTIVE STRESS ANALYSIS				SHEET 1 OF 1

SUMMARY OF RESULTS (See 1-9 of 9)

1. A tractive stress analysis of the native soil used for bank surface shows the actual tractive stress and the allowable tractive stress to be essentially equal. D_{50} was assumed to be 0.1 mm, or $D_{50} < 0.25$ inches.

2. A tractive stress analysis for $d_{75} = 0.25$ in ($D_{50} > 0.25$") showed very rounded aggregate to be inadequate for slope stability. Aggregate with $d_{75} = 0.50$ had a factor of safety of 1.37 (τ_s), $D_{75} = \frac{1}{2}$", $\frac{3}{4}$", 1", 1½", 2" were all analyzed with the largest providing a factor of safety = 4.22 for slopes and 4.00 for the bottom

The analyses indicate that any gravel with approx $D_{75} = 1$" should be satisfactory. The most convenient size needs to be selected for:

a. Readily available & economical.

b. Vehicles can traverse bank. size would need to be limited if this is to be a factor. Grader maintenance might require smaller rock.

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SUBJECT REVIEW TRACTIVE STRESS STABILITY				SHEET 1 OF 9

REACH 2 HYDRAULIC PARAMETERS (see HYDRAULICS section of Design Calculations)

$Q = 8700$ cfs
$n = 0.027$ (earth lining)
$s = 0.0003$
$b = 200$ ft Sta 975+00 to 1083+75 (less riprap sections)
$= 200 \rightarrow 250$ Sta 1083+75 to 1085+00
$= 250$ ft Sta 1085+00 to 1110+94
$d = 9.3$ ft (max) for 200' b (see attached summary)
8.7 ft (max) for 250' b (" " ")
$Z = 3$
$V = 4.2$ for $b = 200$
$V = 3.65$ for $b = 250$
$\gamma_w = 62.4$ pcf
$\nu = 1.2 \times 10^{-5}$ ft²/sec
$\rho = 1.94$ # sec²/ft⁴

- J H report
gravel material GW or GW-GM
max size 3"

- Corrin sheet
- reach 2-3 alignments
- cross sections

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SUBJECT REVIEW TRACTIVE STRESS STABILITY				SHEET 2 OF 9

1) For native soils, 200' wide channel
$D_{75} < 0.25''$
Assume: 0.1mm
$D_{50} = 0.1$ mm for allowable tractive stress
$D_{65} = 0.1$ mm for reference tractive stress (0.00033 ft)

REFERENCE TRACTIVE STRESS

$$V^3/gvS_e = (4.2)^3/32.2(1.2\times10^{-5})(0.0003) = 6.39\times10^8 \quad 8.6\times10^8$$

$$V/\sqrt{gRS_e} = 4.2/\sqrt{32.2(0.00033)(0.0003)} = 2{,}350$$

From Fig 6-10, TR-25, $V/\sqrt{\tau/\rho} = 28.7$ 29

$$\tau = V^2\rho/(V/\sqrt{\tau/\rho})^2 = \frac{(4.2)^2(1.94)}{(28.7)^2(29)^2} = 0.0415 \quad .041$$

$b/d = 200/9.3 = 21.5$

From Fig 6-12 & 6-13

$\tau_s/\tau \cong 1.1$ 1.15, $\tau_b/\tau \cong 1.2$ 1.3

Actual Tractive Stress $\tau_s = 0.0415(1.1) = 0.0456$ psf (1.15, 0.047)
$\tau_b = 0.0415(1.2) = 0.0498$ psf (1.3, 0.053)

Allowable TS, $D_{50} = 0.1$ mm, Table 6-14

Assume low content fine sediment

Allowable Tractive Force = 0.05 psf

Clay = 0.025

NOTE: Results indicate borderline stability for native material.

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SUBJECT REVIEW TRACTIVE STRESS STABILITY				SHEET 3 OF 9

$D_{75} > 0.25$

2) For small gravel, $D_{75} = 0.25$ in

$$n_t = \frac{D_{75}^{1/6}}{39} = 0.020$$

$$S_t = \left(\frac{n_t}{n}\right)^2 S_e = \left(\frac{0.020}{0.027}\right)^2 (0.0013) = 0.00016$$

$$\tau_o = \gamma_w d S_t = 62.4\,(9.3)(0.00016) = 0.0929$$

$$b/d = 200/9.3 = 21.5$$

$\tau_b/\tau_o = 1.0$, $\tau_s/\tau_o = 0.8$ (Fig 6-3 & 6-4)

ACTUAL $\tau_b = 0.093$ psf, $\tau_s = 0.074$ psf

Allowable $\phi_R = 20°$, $K = 0.38$ (Fig 6-8) (very rounded)

$\tau_{Lb} = 0.4\,D_{75} = 0.4\,(0.25) = 0.100$ (ok)

$\tau_{Ls} = 0.4\,K\,D_{75} = 0.4\,(0.38)(0.25) = 0.038$ (Too Low)

For moderately angular material, $K = 0.77$

$\tau_{Ls} = 0.4\,(0.77)(0.25) = 0.077$ (ok)

Factor of safety $= 0.038/0.074 = 0.51$ (rounded)

Note: Rounded aggregate is unsatisfactory. Material placed on slopes would have to be at least moderately angular to have adequate allowable tractive stress.

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SUBJECT CHECK TRACTIVE STRESS STABILITY				SHEET 4 OF 9

3) Check stability with $D_{75} = 0.5''$

$$n_t = \frac{D_{75}^{1/6}}{39} = 0.0228$$

$$S_t = \left(\frac{n_t}{n}\right)^2 S_e = \left(\frac{0.0228}{0.027}\right)^2 (0.0003) = 0.000214$$

$$\tau_o = \gamma_w d S_t$$

$$= 62.4\,(9.3)\,(0.000214) = 0.124$$

$$b/d = 21.5$$

$\tau_b/\tau_o = 1.0$, $\tau_s/\tau_o = 0.8$ (Fig 6-3 & 6-4)

Actual $\tau_b = \underline{0.124}$, $\tau_s = \underline{0.099}$

Allowable

$\phi_R = 26°$ (very rounded), $K = 0.68$ (Fig 6-8)

$\tau_{Lb} = 0.4\,D_{75} = 0.4\,(0.5) = \underline{0.2}$ psf

$\tau_{Ls} = 0.4\,K\,D_{75} = 0.4\,(0.68)(0.5) = \underline{0.136}$ psf

Factor of Safety for slopes $= \dfrac{0.136}{0.099} = 1.37$ psf

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SUBJECT CHECK TRACTIVE STRESS STABILITY				SHEET 5 OF 9

4) Check stability with $D_{75} = 1''$

$$n_t = \frac{D_{75}^{1/6}}{39} = \frac{1}{39} = 0.0256$$

$$S_t = \left(\frac{n_t}{n}\right)^2 S_e = \left(\frac{0.0256}{0.027}\right)^2 (0.0003) = 0.00027$$

$$\tau_o = \gamma_w d S_t = 62.4(9.3)(0.00027) = 0.157$$

$$b/d = 21.5$$

$$\tau_b/\tau_o = 1.0, \quad \tau_s/\tau_b = 0.8 \quad \text{(Fig 6-3 \& 6-4)}$$

ACTUAL $\tau_b = \underline{0.157}$ psf, $\tau_s = \underline{0.126}$ psf

Allowable

$\phi_R = 31.7$ (very rounded), $K = 0.79$ (Fig 6-8)

$\tau_{Lb} = 0.4 D_{75} = \underline{0.4}$ psf

$\tau_{sb} = 0.4(0.79)(D_{75}) = 0.4(0.79)(1) = \underline{0.316}$ psf

Factor of safety for slopes $= \frac{0.316}{0.126} = 2.51$ psf

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5) Check stability with $D_{75} = 1.5''$

$$n_t = \frac{D_{75}^{1/6}}{39} = \frac{1.07}{39} = 0.027$$

$$S_t = \left(\frac{n_t}{n}\right)^2 S_e = \left(\frac{0.027}{0.027}\right)^2 0.0003 = 0.0003$$

$$\tau_o = \gamma_w d S_t = 62.4(9.3)(0.0003) = 0.174$$

$$b/d = 21.5$$

$$\tau_b/\tau_o = 1.0 \quad , \quad \tau_s/\tau_o = 0.8 \quad (\text{Fig } 6\text{-}3 \text{ \& } 6\text{-}4)$$

Actual $\tau_b = 0.174$ psf , $\tau_s = 0.139$ psf

Allowable

$$\phi_R \cong 34.5^\circ \ (\text{Fig } 6\text{-}7), \quad K = 0.83 \ (\text{Fig } 6\text{-}8)$$

$$\tau_{Lb} = 0.4\, D_{75} = 0.60 \text{ psf}$$

$$\tau_{Ls} = 0.4\, K\, D_{75} = 0.4(0.83)(1.5) = 0.498 \text{ psf}$$

Factor of safety for banks $= \dfrac{0.498}{0.139} = 3.6$ psf

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6) Check stability with $D_{75} = 0.75$

$$n_t = \frac{D_{75}^{1/6}}{39} = \frac{0.953}{39} = 0.0244$$

$$S_t = \left(\frac{n_t}{n}\right)^2 S_e = \left(\frac{0.0244}{0.027}\right)^2 (0.0003) = 0.000245$$

$$\tau_o = \gamma_w d S_t = 62.4(9.3)(0.000245) = 0.142 \text{ psf}$$

$b/d = 21.5$

$\tau_b/\tau_o = 1.0$, $\tau_s/\tau_o = 0.8$ (Fig 6-3 & 6-4)

Actual $\tau_b = 0.142$ psf, $\tau_s = 0.114$ psf

Allowable

$\phi_R = 29.4°$ (Fig 6-7), $K = 0.77$ (Fig 6-8)

$\tau_{Lb} = 0.4\, D_{75} = 0.30$ psf

$\tau_{Ls} = 0.4\, K\, D_{75} = 0.4(0.77)(0.75) = 0.231$ psf

Factor of safety for slopes $= \dfrac{0.231}{0.114} = 2.03$ psf

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7) Check Stability with $D_{75} = 2.0''$

$$n_t = \frac{D_{75}^{1/6}}{39} = \frac{1.122}{39} = 0.029$$

$$S_t = \left(\frac{n_t}{n}\right)^2 S_e = \left(\frac{0.029}{0.027}\right)^2 (0.0003) = 0.000346$$

$$\tau_o = \gamma_w d\, S_t = 62.4\,(9.3)(0.000346) = 0.201$$

$$b/d = 21.5$$

$\tau_b/\tau_o = 1.0$ (Fig 6-3), $\tau_s/\tau_o = 0.8$ (Fig 6-4)

Actual $\tau_b = 0.201$ psf, $\tau_s = 0.161$ psf

Allowable $\phi_R = 36.4°$ (very rounded) (Fig 6-7), $K = 0.85$ (Fig 6-8)

$$\tau_{Lb} = 0.4\, D_{75} = 0.80 \text{ psf}$$

$$\tau_{Ls} = 0.4\, K\, D_{75} = 0.4\,(0.85)(2) = 0.680 \text{ psf}$$

$$\text{Factor of safety for slopes} = \frac{0.680}{0.161} = 4.22$$

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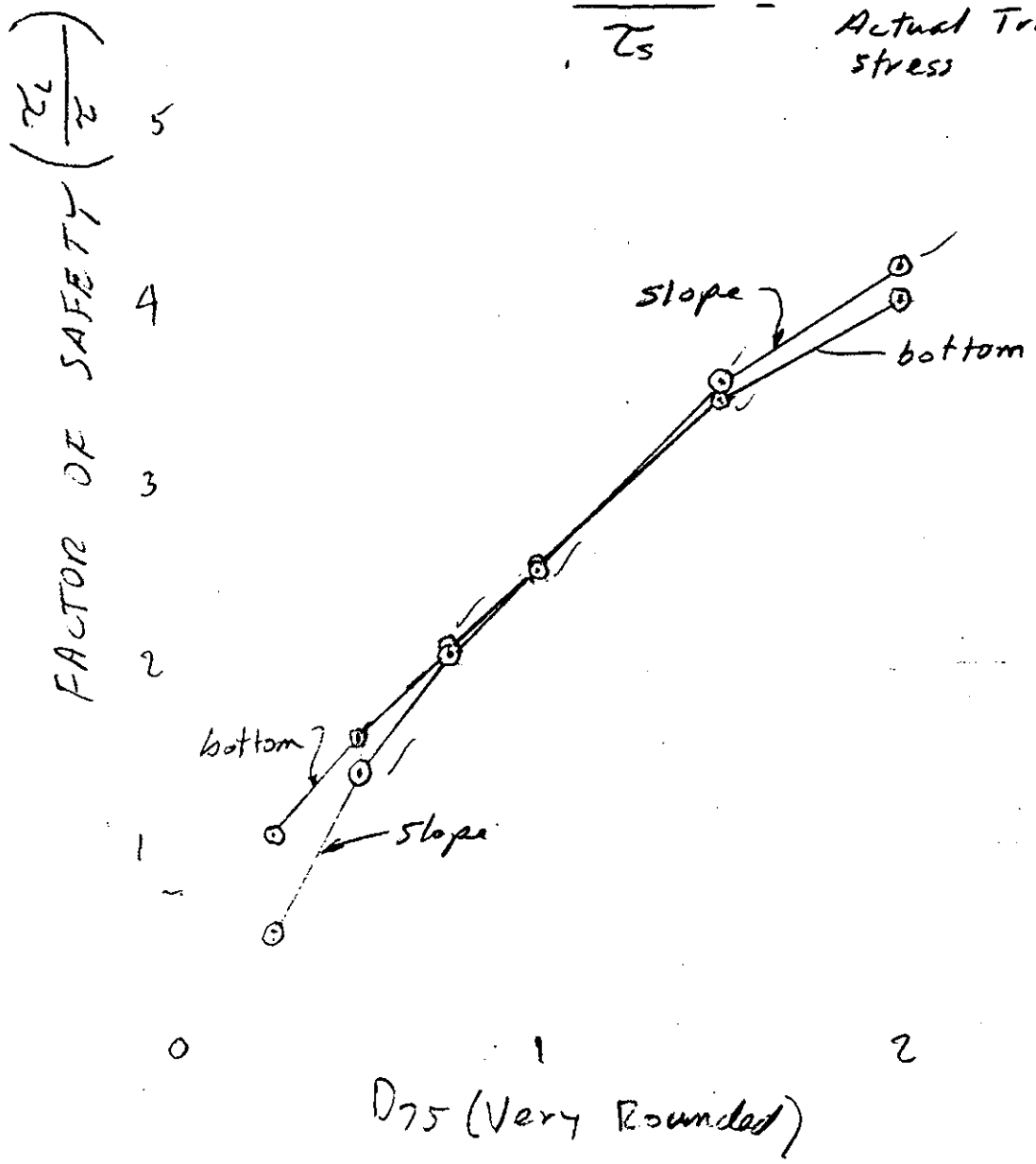
$$\frac{\tau_{LS}}{\tau_S} = \frac{\text{Allowable Tractive stress}}{\text{Actual Tractive stress}}$$



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	Tractive Stress on bottom (psf)		Factor of safety	Tractive stress on slope (psf)		Factor of safety
D_{75} (inches)	τ_b	τ_{cb}	τ_{cb}/τ_b	τ_s	τ_{cs}	τ_{cs}/τ_s
0.25	0.093	0.100	1.08	0.074	0.038	0.51
0.50	0.124	0.200	1.61	0.099	0.136	1.37
0.75	0.142	0.300	2.11	0.114	0.231	2.03
1.00	0.157	0.400	2.55	0.126	0.316	2.51
1.50	0.174	0.600	3.45	0.139	0.498	3.58
2.00	0.201	0.800	4.00	0.161	0.680	4.22

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STATE		PROJECT REACHES 2 & 3		
BY WAM	DATE 6/20/91	CHECKED BY [illegible]	DATE 3-18-92	JOB NO.
SUBJECT TRACTIVE STRESS STABILITY				SHEET 1 OF

1) Check tractive stress analysis assuming $D_{50} = 0.2$ mm & $D_{65} = 0.3$ mm (see 6/19 calcs p.1 & 2 for D_{75} < 0.25") (reference tractive stress method)

$$K_s = \frac{0.3}{25.4 \times 12} = 0.00098 \text{ ft}$$

4.2 $\quad V^3/g\,\nu\,S_e = 6.39 \times 10^8$ .0003

1.2×10⁻⁵

$$V/\sqrt{g K_s S_e} = \frac{4.2}{\sqrt{32.2 \times 0.00098 \times 0.0003}} = 1365$$

From Fig 6-10, TR-25

$$V/\sqrt{\tau/\rho} = \cancel{24.4}\ \cancel{25.6}\ 26.8$$

$$\tau = \frac{V^2 \rho}{\left(V/\sqrt{\tau/\rho}\right)^2} = \frac{(4.2)^2(1.94)}{\left(\frac{\cancel{24.4}}{25.6}\right)^2} = \cancel{0.059}\ \ 0.052 \text{ psf}$$

0.048

$b/d = 21.5$

From Fig 6-12 & 13

$$\tau_s/\tau = 1.12 \qquad \tau_b/\tau = 1.3$$

ACTUAL TRACT. STRESS $\quad \tau_s = (1.12)(\cancel{0.059}\ 0.052) = \cancel{0.066}\ 0.058$, $\tau_b = (1.3)\,0.059 = \cancel{0.077}\ 0.068$ psf

.048 .054 .062

ALLOWABLE TRACT STRESS $\quad D_{50} = 0.2$ mm, Table 6-14

$\tau_{cb} = 0.025$ for clear water
0.05 for low content fine sediment } unstable
0.078 " high " " " marginally stable

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SUBJECT				SHEET 2 OF

2) Check Tractive Stress for
$D_{50} = 1.0$ mm, $D_{65} = 1.5$ mm

$$K_s = \frac{1.5}{25.4 \times 12} = 0.0049$$

$$V^3/g\nu S_e = 6.39 \times 10^8$$

$$V/\sqrt{gK_s S_e} = \frac{4.2}{\sqrt{32.2(0.0049)(0.0003)}} = 610$$

From Fig 6-10:

$$V/\sqrt{\tau/\rho} = 22.9$$

$$\tau = \frac{V^2\rho}{\left(V/\sqrt{\tau/\rho}\right)^2} = \frac{(4.2)^2(1.94)}{(22.9)^2} = 0.065$$

$b/d = 21.5$, From Fig 6-12 & 13

$$\tau_s/\tau = 1.12, \quad \tau_b/\tau = 1.3$$

<u>ACTUAL</u> $\tau_s = 0.0073$, $\tau_b = 0.085$

<u>ALLOWABLE</u>

τ_{cb}	= 0.04	- clear	unstable
	= 0.062	- low content fines	marginal
	= 0.09	- high content fines	stable

Arizona
C.E.G.
Soil Test Data
12-17-79

RWCD Floodway Reach 2

Station	Correlation Number	Lab Sample Number	Group	Depth feet	Unified Soil Class	d_{75} mm	PI	Unconfined Compression ~~Shear~~ Strength $q_u/2$
985+00	14	—	C	7.8	CH	0.06	41	—
987+00	14	790192	C	6	ML	0.2	3	720
987+00	14	790161	C	4	CL	0.24	13	790
999+00	14	—	C	9	SM	1.0	non-plastic	—
1009+00	14	—	~~C~~ G	10	SM	1.0	non-plastic	—
1020+00	14	730525	C	8-9	CL-ML	.25	5	208
1028+00	14	730515	C	3-5	CL-1	.22	9	129
1028+00	14	730518	C	2-6	SM-2	.7	non-plastic	280
1028+00	14	—	~~C~~ G	11-13	CL-1	.2		~~58~~
1050+00	14	740042	C	3-3.7	SM-1	.55	non-plastic	122
1050+00	14	—	C	12.0-12.7	SM-1	.35	9	—
1074+00	14	—	C	5	SM	0.9	non-plastic	—
1089+00	14	—	C	7.5	SM	1.3	non-plastic	—
1099+00	14	—	C	10	SM	3.0	non-plastic	—
1117+21	14	730514	C	13-15	SM-2	1.0	10	331

1294 of 285

RWCD Floodway Reach 2

Arizona
C.E.G. 12-17-79
Soil Test Data

Station	Correlation Number	Lab Sample Number	Group	Depth	Unified Soil Class	d_{75} mm	PI	Shear Strength
1165+00	2	—	B	0	SM	0.25	3	—
1180+00	2 or 12	—	B	8.5	CH	0.03	31	—
1185+00	2 or 12	79018	B	8.3	CH	0.09	51	840
1190+00	2 or 12	—	B	5.5	SM-SC	9.00	10	—
1197+50	2 or 12	790158	B	6	CL	0.18	12	1660
1200+00	2	—	B	7	SM	0.24	non-plastic	—
1205+00	11	—	?	5	SM	7.50	non-plastic	—

ARIZONA RIVER REACH III

D. Thackston 4/18/83

CHANNEL STABILITY ANALYSES

SHEET 1 8

PROBLEM: MAKE A PRELIMINARY CHECK OF CHANNEL STABILITY USING TRACTIVE STRESS PROCEDURES.

ANALYSIS: 1. USE Q = 8700 CFS (, 8100 & 6900)

2. USE B = 200; Z = 3; S = 0.0003

3. COMPUTE MAX. TRACTIVE POWER USING TR-25.

4. COMPUTE ALLOWABLE TRACTIVE POWER (S-LINE VALUES) USING FIG 6-15, P 6-32, TR-25 FOR THE SOIL TEST VALUES (UNCONFINED COMPRESSIVE STRENGTH) OBTAINED FOR REACH III. CHECK ALSO FOR WORK DONE ON REACHES I & II.

5. CORRELATE TEST VALUES AND ALLOWABLE TRACTIVE POWER TO THE STRATIGRAPHIC UNITS IDENTIFIED IN THE REACH III GEOL. REPORT.

ARIZONA RWCO REACH 3

D. Thackeray 4/21/83

CHANNEL STABILITY ANALYSIS

2 8

PROBLEM: NEED TO COMPUTE EST. TRACTIVE STRESS. ($D_{75} < 1/4$)

ANALYSIS: 1. EQUATIONS:

(P. 6-18, EQ. 6-9) $\tau = \gamma_w R_t S_e$

2. PROCEDURE:

(P. 6-28)

a. Determine S_e & V

b. Find ρ & ν, given temp (Fig. 6-11)

c. Compute $V^3/g\nu S_e$

d. Compute $V/(gR_s S_e)^{1/2}$

e. Find $V/\sqrt{\tau/\rho}$, given values from ⓒ & ⓓ

f. Find τ, given $V/\sqrt{\tau/\rho}$, ν and ρ

$$\tau = \frac{V^2\rho}{(V/\sqrt{\tau/\rho})^2}$$

g. USING FIG 6-12 AND FIG 6-13 DETERMINE τ_B AND τ_S GIVEN b/d.

P 6-24

$k_s = d_{65}$ ft.

$\gamma = 62.4$

$\rho = 1.94$

$S_e = 0.00030$

$V = 3.86$

$k_s = D_{65}$ in feet $= 0.000328$

$\nu = 1.4 \times 10^{-5}$

$$\frac{V^3}{g\nu S_e} = \frac{3.86^3}{32.2(1.4 \times 10^{-5})(0.0003)} = \frac{57.5}{0.01352 \times 10^{-3}} = 4.252 \times 10^{7}$$

STATE ARIZONA PROJECT RWCD REACH 3
D. Thackeray 5/4/83 CHECKED BY DATE JOB NO.

CHANNEL STABILITY ANALYSIS SHEET 3 8

REFERENCE TRACTIVE FORCE: $D_{65} = 0.1\,mm$ (SIRES)
$= 0.0039\,in$
$= 0.000328\,ft$

USE SAME PARAM. AS ABOVE:

$$\frac{V^2}{gRS_0} = 5.97\times10^8 \quad (4.25\times10^8)$$

$$\frac{V}{\sqrt{gR_s S_0}} = \frac{3.86}{\sqrt{32.16(0.000328)(0.0002)}} = 2170$$

$$V/\sqrt{\tau/\rho} = 24 \quad (28)$$

$$\tau = \frac{V^2\rho}{(V/\sqrt{\tau/\rho})^2} = \frac{3.86^2(1.935)}{24^2} = \underline{0.050\ psf}$$

b/d — $b/y = 200/9.2 \approx 22$, beyond the range of fig. 6-13 and 6-12 of TR-25.

— use values for max b/d (≈ 8); $z = 3$:

$\tau_b/\tau = 1.15$, $\underline{\tau_b = 0.058\ psf}$

$\tau_b/\tau = 1.3$, $\underline{\tau_b = 0.065\ psf}$

TRACTIVE POWER

$$\tau_b V = 0.065(3.86) = 0.25\ lb/ft\cdot sec^2$$

= Actual Tractive Power

CHECK ALLOWABLE TRACTIVE STRESS FOR THE COARSE GRAINED SOILS:

THESE ARE GROUP K (UNIT 20, 22, 23):

TEST VALUES:

STA	UNIT	D_{25}	D_{25}
889+25	22	15 mm	0.59 in
827+00	23	16 mm	0.63 in

ALLOWABLE TRACTIVE STRESS PER P.6-18, TR-25:

USE $D_{25} = 0.5$ in

$\tau_{LB} = 0.4(D_{25}) = 0.4(0.5) = \underline{0.20 \text{ psf}}$

$\tau_{LG} = 0.4 K D_{25} = 0.4(0.78)(0.5) = \underline{0.16 \text{ psf}}$

(Fig 6-8, $\phi_{RT} = 30°$, $K = 0.78$)

TR25 P 6-12

APPROXIMATE ACTUAL TRACTIVE STRESS

FOR: $D_{75} = 0.75$ in $d = 9.2$ ft

$n = 0.027$

$S_e = 0.0003$

FIND $n_t = \dfrac{D_{75}^{1/6}}{39} = \dfrac{(0.75)^{1/6}}{39} = 0.95$ (0.0244)

$S_t = \left(\dfrac{n_t}{n}\right)^2 S_e = \left(\dfrac{0.95}{0.027}\right)^2 (0.0003) = 0.37$ (0.100)

$\tau_{oo} = \gamma_w d S_t = 62.4(9.2)(0.37) = 212$ psf (0.141)

FIG 6-3, 6-4

$\tau_b/\tau_{oo} \simeq 1.0$; $\tau_s/\tau_{oo} \simeq 0.8$

$\underline{\tau_b = 212 \text{ psf} ; \tau_s = 170 \text{ psf}}$ (0.113) $\gg \tau_{cal}$

ACTUAL TRACTIVE STRESS:

AS A PRELIMINARY ESTIMATE DETERMINE ACTUAL TRACTIVE STRESS FOR:

$T = 75°F$ USE $k_s = 0.02$ in

$b = 200$

$z = 3$

$Q = 8100$

$S_e = S = 0.0003$

$n = 0.027$

By Manning's EQN: $d_n = 9.2$ FT, $V = 3.86$ ft/s; $b/d = 21.7$; $A = 1094$; $P = 258$; $R = 8.11$

Fig 6-11, p 6-24: $\nu = 1.0 \times 10^{-5}$ ft/sec; $\rho = 1.935$ slugs/ft³

$$\frac{V^3}{g\nu S_e} = \frac{3.86^3}{32.16(1.0\times10^{-5})(0.0003)} = 5.97\times10^{8}$$

$$\frac{V}{\sqrt{g k_s S_e}} = \frac{3.86}{\sqrt{32.16(0.02/12)(0.0003)}} = 962.60$$

FIG 6-9, p 6-22:

$V/\sqrt{\tau/\rho} = 25.2$

$$\tau = \frac{V^2\rho}{(V/\sqrt{\tau/\rho})^2} = \frac{3.86^2(1.935)}{(25.2)^2} = \underline{\underline{0.045}}$$

ARIZONA RWCD FLOODWAY

D. Thackeray 5/3/83

CHANNEL STABILITY ANALYSIS

CHECK RESULTS:

EQN 6-10 $$\frac{V}{\sqrt{g R_t S_e}} = 5.75 \log\left(12.27 \frac{R_t x}{R_s}\right)$$

$$R_t = \frac{\tau}{\gamma_w S_e} = \frac{0.045}{62.4(0.0003)} = 2.4$$

$$\frac{V}{\sqrt{g R_t S_e}} = \frac{3.86}{\sqrt{62.4(2.4)(0.0003)}} = 18.21$$

$$\sigma = \frac{11.6 \nu}{\sqrt{g R_t S_e}} = \frac{11.6(10^{-5})}{\sqrt{32.16(2.4)(0.0003)}} = 7.623 \times 10^{-4}$$

$$R_s/\sigma = \frac{0.02/12}{7.623 \times 10^{-4}} = 2.186$$

FIG 4 TP1026

FIND $x = 1.4$

$$5.75 \log\left(12.27 \frac{R_t(x)}{R_s}\right) = 5.75 \log\left(\frac{12.27(2.4)(1.4)}{0.02/12}\right)$$

$$= 25.2$$

COMPUTATION SHEET

ENG-523A Rev. 6-69

U.S. DEPARTMENT ... SOIL CONSERVATION SERVICE

STATE ARIZONA | PROJECT ROAD REACH 3 | JOB NO

D. Medaney | CHECKED BY | DATE 5/6/83 | SHEET 7 8

ALLOWABLE TRACTIVE STRESS

CHECK ALLOWABLE TRACTIVE STRESS FOR $D_{50} = 0.1$ MM

- (THIS CONSERVATIVELY INCLUDES ALL FINE GRAINED SOILS FOUND IN THE INVESTIGATION)

FOR LOW CONTENT FINE SED (1000-2000 PPM)

FIND $\tau_o = 0.05$ PSF.

COMPUTATION SHEET
SCS-ENG-323A Rev 9-69

U.S. DEPARTMENT OF AGR
SOIL CONSERVATION SERVICE

STATE ARIZONA
D. Thadeny

PROJECT RUCO REACH 3
CHECKED BY
DATE 4/27/83
JOB NO.
SHEET 8 8

CHANNEL STABILITY

1962 HYDRAULICS SEMINAR, PORTLAND
"BOREL PRACTICE", R.H. BOITE.

— RULE OF THUMB TRACTIVE FORCE WDS = 0.7 PSF STEAM FLOW ON DRY BED CH. FINE GR. SOIL
— WDS = 0.18 PSF SMALL CONTINUOUS FLOW OCC. LGE FLOW
— WDS = 0.075 PSF FOR CONTINUOUSLY WET CHANNELS SUCH AS IRRIGATION CANALS.

CHOW, "OPEN CHANNEL HYDRAULICS"

— USER DATA RELATING VOIDS RATIO TO ALLOWABLE TRACTIVE STRESS FOR COHESIVE SOILS P. 174 FIG 7-11

— PI MAY BE USED AS A ROUGH INDEX OF SCOUR RESISTANCE WITH PI = 7 BEING TAKEN AS A CRITICAL VALUE, WITH SCOUR OCCURING FOR MODERATE STRESSES BELOW THIS VALUE.

STABLE EARTH CHANNELS, COURSE REF., SCS 1979

— $\tau_c = 0.0024(PI)^{0.84}$ [SHERRON & BEASLEY FIG 15a, p III-27]

— SEE FIG 12 p III-22

EMF REACHES 2 & 3 SLOPE PROTECTION

WAM 9/9/91 Gantt 3-18-92

AGGREGATE GRADATIONS / /

ROCK MULCH FOR SLOPE PROTECTION (CRUSHED ROCK)

Screen	% Passing
2"	100
1 1/2"	75-100
~~1"~~	~~45-75~~
3/4"	30-60
~~1/2"~~	~~25-55~~
#4	10-40
#200	0-10

MAX PI = 5

ABC FOR O & M ROADS (MAG)

Screen	% Passing
1 1/8	100
#4	38-65
#8	25-60
#30	10-40
#200	3-12

MAX PI = 5

A2 EMF REACHES 2&3 SLOPE PROTECTION
WAM 9/6/91 JMH 3-18-92
DESIGN OF ROCK MULCH 1 11

The purpose of this design is to determine what type of rock cover can be placed on the slopes of Reaches 1 & 2 to protect against rilling. The rilling is caused by rainfall on the maintenance roads and slopes.

Some maintenance roads have been graded so they no longer drain onto the slopes. However, protection is still required because rilling occurs on slopes from direct rainfall.

The application of rock to the channel slopes to act as a protective mulch also requires that the finished rock surface be resistant to erosion from flow in the channel. The design was therefore based on two assumptions:

1. PRACTICAL APPLICATION. A study was performed on the channel slopes of reach 3 where various methods of slope protection against rilling were evaluated. Four different methods involved application of gravel, gravel and sand, or cobbles. All were effective against rilling, including Study Site 4 which involved filling existing rills with gravel and leaving the non-rilled portion of slope with as thin a layer of gravel as could be constructed. The Study Site 4 remedy was easy to construct; a 3-inch layer of gravel was moderately hard to construct, a 6-inch gravel/sand layer was difficult to construct and a 6-inch layer of cobbles was difficult to construct. (See Attachment A)

2. STABILITY. The factors of safety for different gradations of gravel were analyzed for stability against tractive stress along the slope under maximum flow conditions. See the attached table and plots.

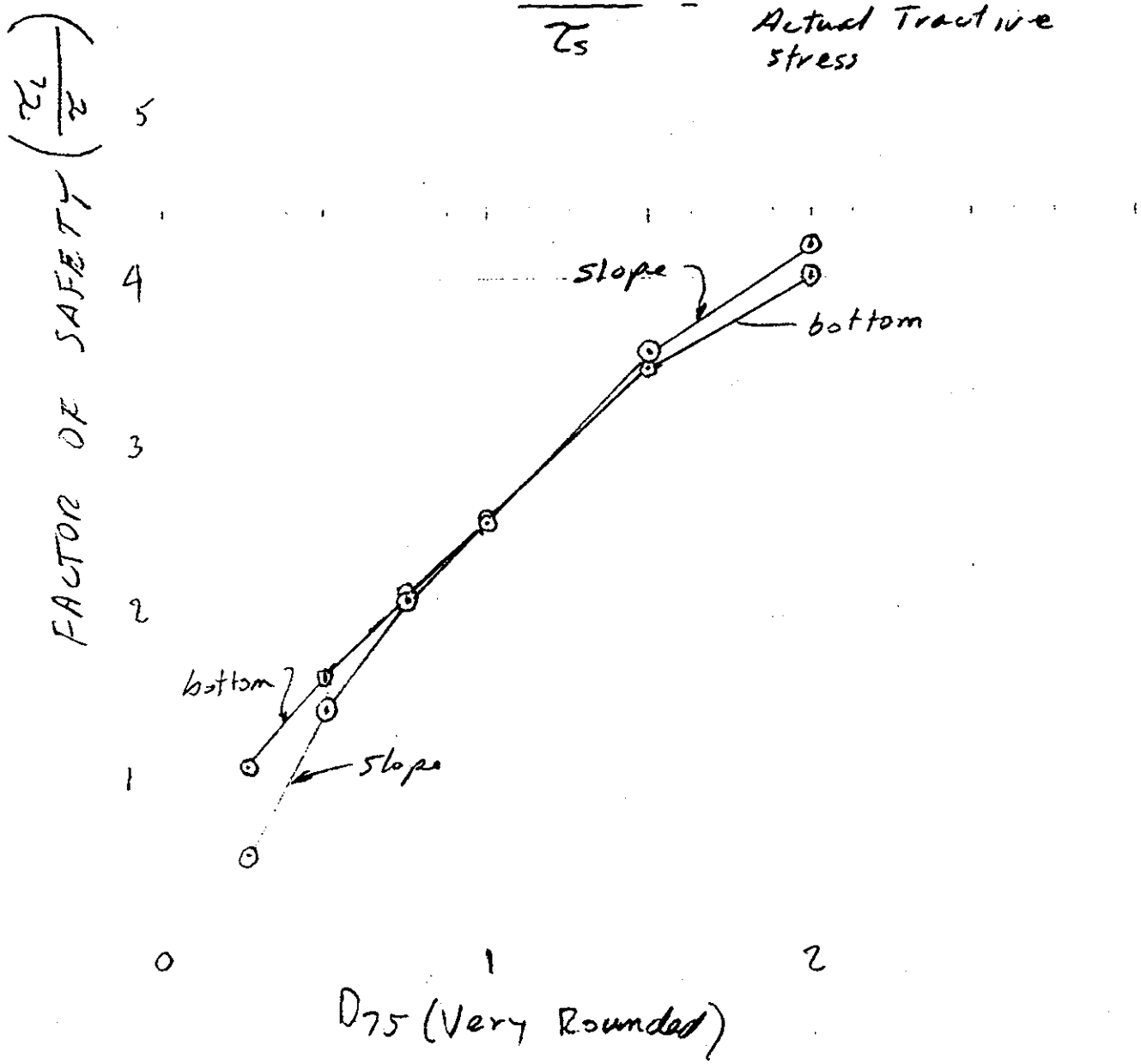
Further discussion on the use of rock for a mulch is provided in Attachment B. A cover of 100 % is assumed herein to be desireable because of greater surface protection. Furthermore, the channel slope study showed that desert plants will grow in slopes with 100 % cover.

COMPUTATION SHEET
SCS–ENG–522 REV. 3–69

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

STATE		PROJECT		
BY WAM	DATE 6/19/91	CHECKED BY Jmlt	DATE 3-18-92	JOB NO.
SUBJECT				SHEET ~~9~~ 2 OF ~~9~~ 11

$$\frac{\tau_{LS}}{\tau_S} = \frac{\text{Allowable Tractive stress}}{\text{Actual Tractive stress}}$$



COMPUTATION SHEET
SCS-ENG-522 REV. 3-69

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

STATE		PROJECT		
BY WAM	DATE 6/24/91	CHECKED BY JMH	DATE 3-18-92	JOB NO. 3
SUBJECT				SHEET 9A OF 9 11

D_{75} (inches)	Tractive Stress on bottom (psf) τ_b	τ_{cb}	Factor of safety τ_{cb}/τ_b	Tractive stress on slope (psf) τ_s	τ_{cs}	Factor of Safety τ_{cs}/τ_s
0.25 ✓	0.093	0.100 ✓	1.08	0.074	0.038 ✓	0.51
0.50	0.124	0.200	1.61	0.099	0.136	1.37
0.75	0.142	0.300	2.11	0.114	0.231	2.03
1.00	0.157	0.400	2.55	0.126	0.316	2.51
1.50	0.174	0.600	3.45	0.139	0.498	3.58
2.00	0.201	0.800	4.00	0.161	0.680	4.22

Check by JMH $D_{75} = 0.25''$

$\tau_\infty = \gamma_w d S_t$

$S_t = \left(\frac{n_t}{n}\right)^2 S_e$

$n_t = \frac{D_{75}^{1/6}}{39}$

$= \frac{(.25)^{1/6}}{39} = 0.02035$

$S_t = \left(\frac{.02035}{.027}\right)^2 (.0003)$

$S_t = 0.00017$

$d = 9.3$

$\tau_\infty = 62.4(9.3)\ .00017$

$\tau_\infty = 0.0989$

$b/d = \frac{200}{9.3} = 21.5 \Rightarrow$ Fig 6-4 $\tau_s/\tau_\infty = 0.8$

$\tau_s = 0.0989 \times 0.8 = 0.07912$

WAm 9/6/91

DESIGN OF ROCK MULCH

Based on the practical application and stability analysis the following assumptions were made:

- A gravel layer, 2" thick over filling of rills, would be placed on the slope. According to the previous tests this would be between easy and moderately difficult to construct.
- Crushed gravel would be used. Previous studies and analyses were based on very rounded material. Therefore, construction would be easier and stability would be higher than indicated by stability analysis.

The following mix designs were considered

- MIX A (100 % Pass the 1½")
- MIX B (100 % Pass the 2")
- MAG TYPE B

Other requirements:

GW requirements

$C_u > 4$ Coef. of Uniformity

C_x between 1 & 3 Coef. of Curvature

$PI \leq 5$

U.S. Department of Agriculture
Soil Conservation Service

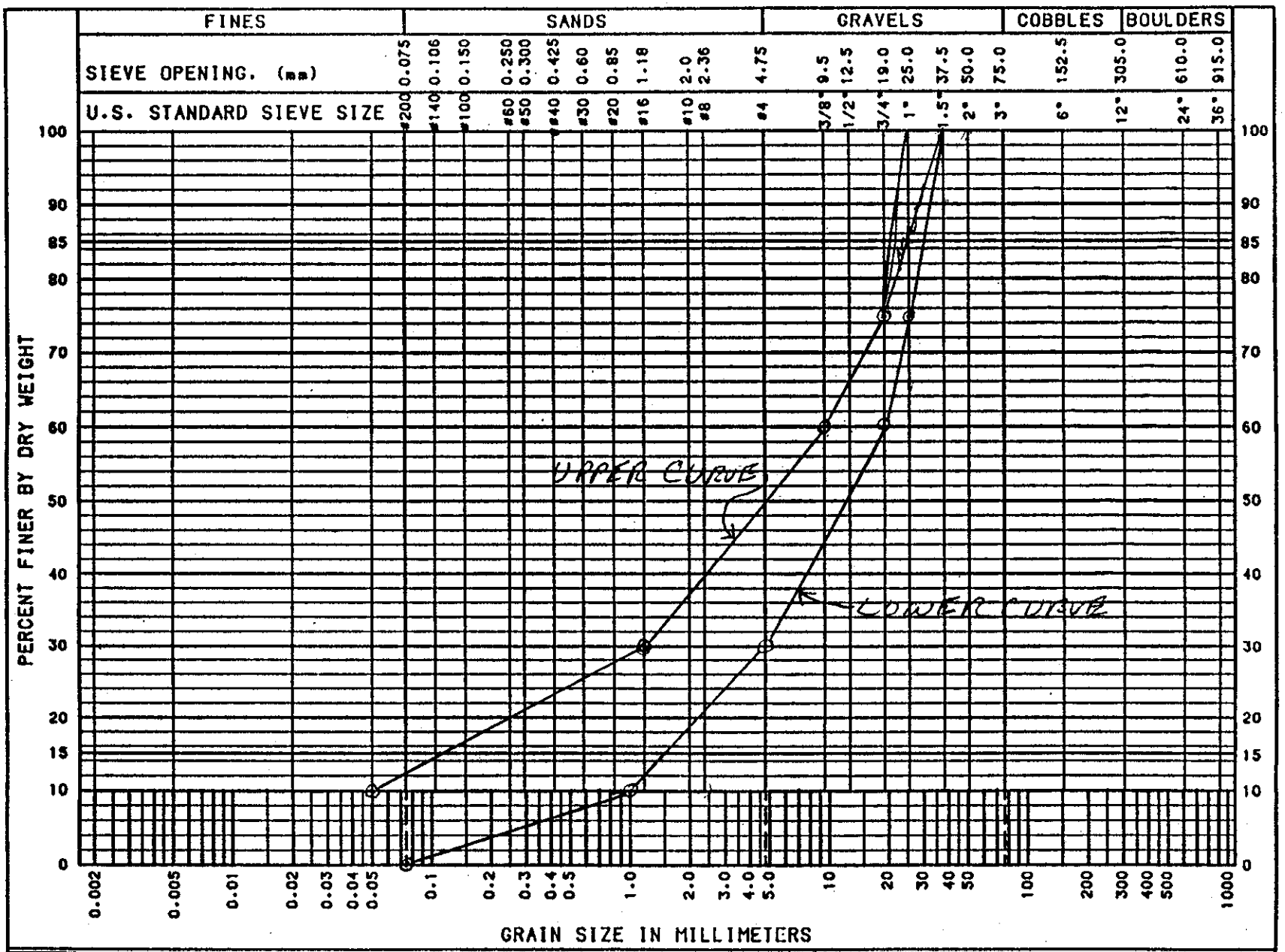
SCS-ENG-130
2-85

GRAIN SIZE ANALYSIS FOR

CRUSHED ROCK FOR SLOPE - MIX-A
(Specify)

Project and state EMF REACHES 2 & 3 SLOPE PROTECTION AGAINST BILLS

Designed at PHOENIX By WAM Date 9/6/91



REMARKS

wm 9/6/91 Jan H 3-18-92

DESIGN OF ROCK MULCH 6 11

MIX-A, UPPER CURVE

$D_{10} = 0.05$ mm

$D_{30} = 1.18$ mm

$D_{60} = 9.5$ mm

$C_u = \frac{D_{60}}{D_{10}} = \frac{9.5}{0.05} = 190$ (>4)

$C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}} = \frac{(1.18)^2}{0.05 \times 9.5} = 2.93$ (>1<3)

LOWER CURVE

$D_{10} = 1.0$ mm

$D_{30} = 5.0$

$D_{60} = 19.0$

$C_u = \frac{19}{1.0} = 19$ (>4)

$C_z = \frac{(5)^2}{1.0 \times 19.0} = 1.32$ (between 1 & 3)

SCREEN SIZE	% PASSING
1 1/2"	100
1"	75 - ~~85~~ 100
3/4"	60 - 75
1/2"	50 - ~~64~~ 66
#4	30 - 50
#200	0 - 12

PI ≤ 5

U.S. Department of Agriculture
Soil Conservation Service

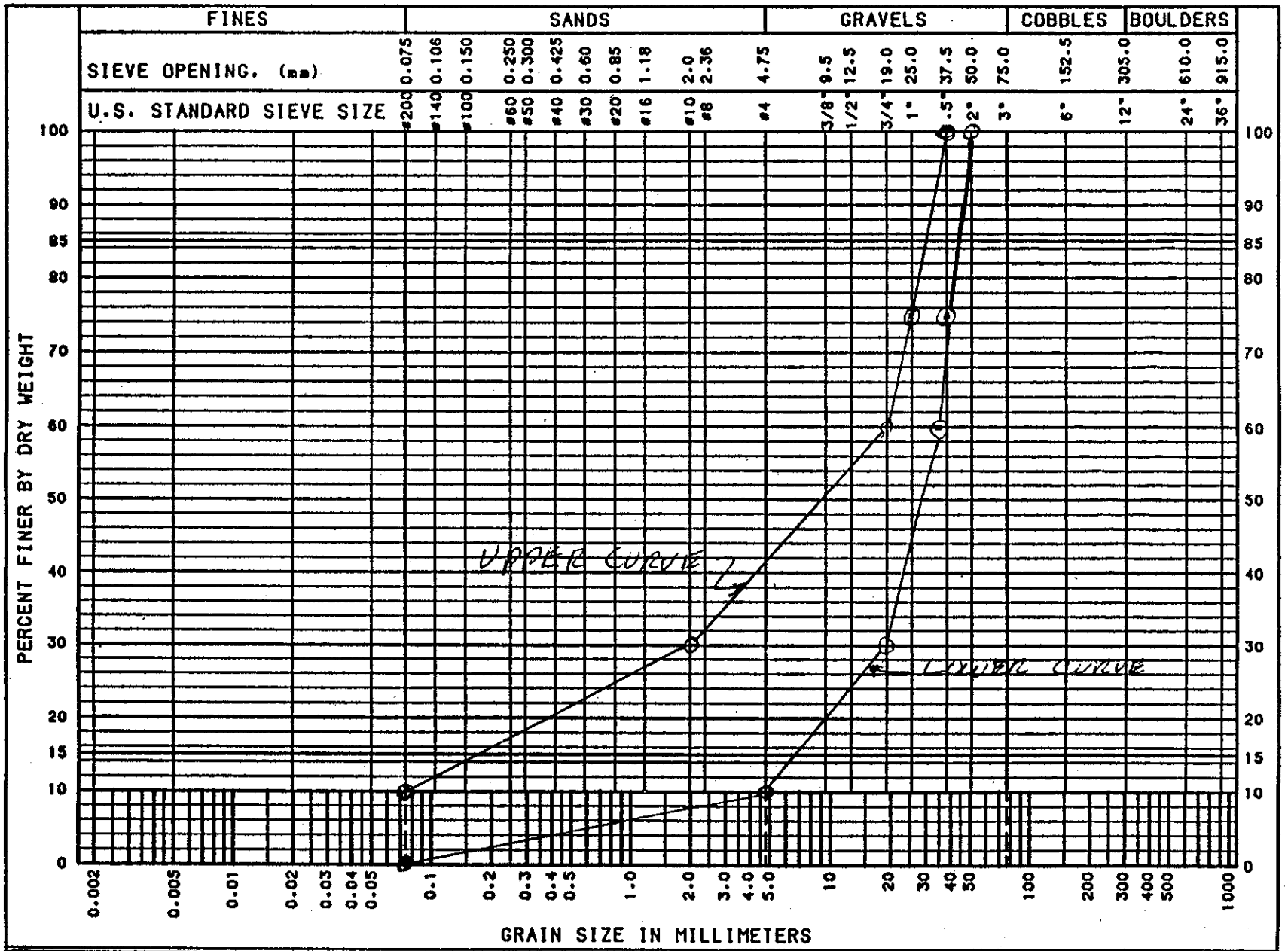
SCS-ENG-130
2-85

GRAIN SIZE ANALYSIS FOR

CRUSHED ROCK FOR SLOPE - MIX B
(Specify)

Project and state _____

Designed at _____ By WAM Date 8/6/81



REMARKS

7 of 11

WAM 9/6/91 Jmt 3-18-92

DESIGN OF ROCK MULCH - MIX B 8 11

MIX-B

UPPER CURVE	LOWER CURVE
$D_{10} = 0.075$	$D_{10} = 4.75$
$D_{30} = 2.0$	$D_{30} = 19.0$
$D_{60} = 19.0$	$D_{60} = 35$
$C_u = \frac{D_{60}}{D_{10}} = \frac{19}{0.075} = 253$	$C_u = \frac{35}{4.75} = 7.37$
$C_x = \frac{(D_{30})^2}{D_{10} \times D_{60}} = \frac{(2.0)^2}{0.075 \times 19} = 2.8$	$C_x = \frac{(19)^2}{4.75 \times 35} = 2.17$

SCREEN SIZE	% PASSING
2"	100
1 1/2"	75 - 100
1"	45 - 75
3/4"	30 - 60
1/2"	25 - 55
#4	10 - 40
#200	0 - 10

$PI \leq 5$

U.S. Department of Agriculture
Soil Conservation Service

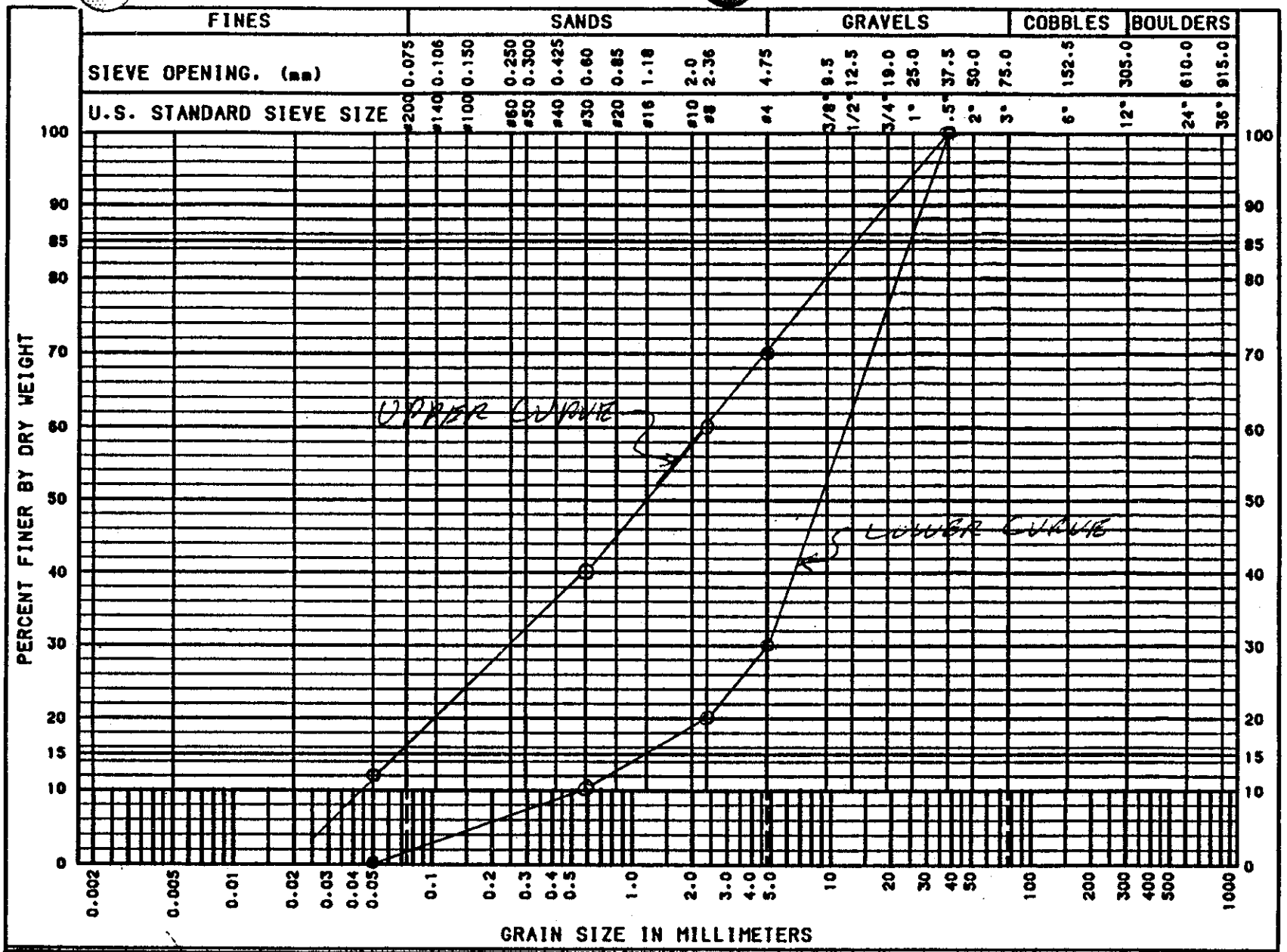
SCS-ENG-130
2-85

GRAIN SIZE ANALYSIS FOR

MAG TYPE B
(Specify)

Project and state _____

Designed at _____ By _____ Date _____



REMARKS

W Ann 9/6

DESIGN OF ROCK MULCH

MAG MIX TYPE B

SCREEN	% PASSING
1½"	100%
#4	30-70
#8	20-60
#30	10-40
#200	0-12

PI Max = 5

UPPER CURVE

$D_{10} = 0.045$

$D_{30} = 0.250$

$D_{60} = 2.36$

$C_u = \frac{2.36}{0.045} = 52$

$C_x = \frac{(0.250)^2}{0.045 \times 2.36} = 0.6$

LOWER CURVE

$D_{10} = 0.60$

$D_{30} = 4.75$

$D_{60} = 11.5$

$C_u = \frac{11.5}{0.60} = 19$

$C_x = \frac{(4.75)^2}{0.60 \times 11.5} = 3.3$

SHOULD BE BETWEEN 1 & 3

$D_{75} \cong 1/4''$, upper curve

$D_{75} \cong 3/4''$, lower curve

WAm 9/9/91 JMH 3-10-92

DESIGN OF ROCK MULCH " "

SUMMARY OF D_{75}

	UPPER CURVE	LOWER CURVE
MIX A	3/4"	1"
MIX B	1"	1.5"
MAG TYPE B	1/4"	3/4"

MIX A	- 100% Pass 1 1/2"
MIX B	100% Pass 2"
MAG TYPE B	100% Pass 1 1/2"

CONCLUSIONS

- MIX B is more conservative than MIX A, with Factor of Safety from 2.5 to 3.6 versus 2.0 to 2.5.
- MAG TYPE B has insufficient D_{75}

- **USE MIX B**

SCREEN	% PASSING
2"	100
1 1/2"	75 - 100
1"	45 - 75
3/4"	30 - 60
1/2"	25 - 55
#4	10 - 40
#200	0 - 10

SUGGEST SPEC

2"	100%
1.5"	75-100%
3/4	30-60%
#4	10-40%
#200	0-10%

WAM 1/23/92

O&M ROAD COVER 1 3

The following MAG specifications provide the best gradation for road cover. The Aggregate Base (Aggregate Base Course - ABC) is the same as that specified for the Reach 1 & 2 Repair project. It is easily spread and compacted and will provide good protection of road surfaces against rilling / gugging.

MAG FOR O&M ROAD COVER

MATERIALS

SECTION 701

ROCK, GRAVEL, AND SAND

701.1 GENERAL:

The following specifications set forth the requirements for crushed rock, gravel, sand, and quarry stone. Samplings and sieve analysis shall be performed in accordance with ASTM D-75 and ASTM C-136. Sand equivalents shall be determined in accordance with AASHTO T-176. The liquid limit and plasticity index shall be determined in accordance with AASHTO T-89 and T-90.

701.2 CRUSHED ROCK AND GRAVEL:

Rock and gravel shall be clean, hard, sound, durable, uniform in quality, and free of any detrimental quantity of soft, friable, thin, elongated, or laminated pieces, disintegrated material, organic matter, oil, alkali, or other deleterious substance.

The loss by abrasion in the Los Angeles abrasion machine, determined as prescribed in ASTM C-131, Grading A, shall not exceed 10 percent, by weight, after 100 revolutions nor 40 percent after 500 revolutions.

701.2.1 Crushed Rock: Crushed rock shall consist of the product obtained by crushing rock, stone, or gravel so that at least 50 percent by weight of aggregate retained on the No. 4 sieve for ¾ inch or larger maximum sizes, and 50 percent retained on the No. 8 sieve for maximum sizes less than ¾ inch shall consist of particles which have at least one rough, angular surface produced by crushing. All material that will pass a grizzly with bars spaced 15 inches apart, clear opening, shall be crushed when producing from the Contracting Agency's source.

The gradation of crushed rock shall comply with ASTM D-448.

701.2.2 Gravel: Material designated herein as gravel shall be composed entirely of particles that are either fully or partially rounded and water-worn. Crushed rock obtained by crushing rock which exceeds ASTM D-448 maximum gradation sizes may be combined provided it is uniformly distributed throughout and blended with the gravel. The quality and gradation requirements shall be as stated in this specification.

701.3 SAND:

Sand shall be fine granular material produced by the crushing of rock or gravel or naturally produced by disintegration of rock and shall be sufficiently free of organic material, mica, loam, clay, and other deleterious substances to be thoroughly suitable for the purpose for which it is intended.

701.3.1 Sand for Asphalt Concrete Pavement: Sand for asphalt concrete pavement shall comply with AASHTO M-29 except that grading requirements shall be deleted and have a minimum sand equivalent of not less than 50 and shall be non-plastic when tested in accordance with AASHTO T-89 and T-90.

701.3.2 Sand for Portland Cement Concrete, Mortar and Plaster: It shall be thoroughly and uniformly washed and shall be entirely free from oil and deleterious substances.

The average value of sand equivalent determined on 3 successive samples shall not be less than 70. No individual sample shall have a sand equivalent less than 65.

SHT 2 OF 3

MAG FOR O&M ROAD COVER

702.2.1 Soundness: The percentage of wear of crushed aggregate to be used as base will be determined as in Section 701, except that Grading B of ASTM C-131 shall be used. The percentage of wear of the material shall not exceed 40 after 500 revolutions.

702.2.2 Grading: The aggregate shall be well graded when tested in accordance with ASTM C-136 and C-117. The percentage composition by weight shall be within the following limits.

TABLE 702

Sieve Sizes (Square Openings)	Percentage by Weight Passing Sieve		
	Select Material		Aggregate Base
	Type A	Type B	
3"	100		
1½"		100	
1⅛"			100
No. 4	30-75	30-70	38-65
No. 8	20-60	20-60	25-60
No. 30	10-40	10-40	10-40
No. 200	0-12	0-12	*3-12
P.I. MAX.	5	5	*5

*Except as required in Section 312.5 for inverted section and does not apply to Processed Steel Slag.

702.3 PROCESSED NATURAL MATERIAL:

702.3.1 General: Processed natural material shall consist of hard, durable fragments of stone or gravel and a filler of sand or other finely divided mineral matter. It shall be free from an excess of soft or disintegrated pieces, alkali, adobe, vegetable matter, loam, or other deleterious substances.

702.3.2 Physical Requirements: When sampled and tested in accordance with standard test methods, the aggregate shall meet the following requirements:

(A) Percentage of Wear: When tested in accordance with ASTM C-131, the percentage of wear shall not exceed 40 percent after 500 revolutions.

(B) Plasticity Index: When tested in accordance with AASHTO T-90, the plasticity index shall no be more than 5.

(C) Liquid Limit: When tested in accordance with AASHTO T-89, the liquid limit shall not be more than 25 percent.

702.3.3 Crushed Material: Crushed material is not required, but may be incorporated in the finished product.

702.3.4 Grading: The aggregate shall conform to the sieve analysis in this specfication except that the least dimension of the maximum particle size shall not exceed ⅔ of the compacted thickness of the specified lift being placed.

SHT 3 OF 3

ATTACHMENT A

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ARIZONA STATE OFFICE
ENGINEERING STAFF
PHOENIX, ARIZONA
November 30, 1990

FIELD TRIAL REPORT

Job: Williams-Chandler WPP
Project: EMF Reach-3 Bank Erosion Study Sites
Location: Maricopa and Pinal Counties, Arizona
Evaluation: Bank Erosion Study

BACKGROUND

The East Maricopa Floodway located approximately 20 miles southeast of Phoenix, Arizona has a capacity of 8,700 CFS and discharges into the Gila River. The floodway is roughly 27 miles long, of which approximately 24 miles is earth lined. The floodway depth varies from 8 to 11 feet and is 200 feet wide through the lower reaches. It was constructed in 6 reaches. Reach 1 construction began in 1981 and Reach 6 was completed in 1989.

Rainfall and local runoff have caused jugging and rilling of the 3:1 side slopes along portions of the floodway. The severity of the bank erosion varies with the amount of time since construction, diversity of the existing soils, the design parameters used, and the impacts of the local drainage areas.

During the construction of Reach 3, a number of rain showers occurred which clearly indicated the need to address the rilling on the slopes. The rills initially are an eye sore. They progressively degrade, in some cases making the O&M road undrivable. A modification was written during the Reach 3 construction to prevent local runoff from getting onto the side slopes. Subsequent designs for Reaches 4, 5 and 6 specified cross slopes on the O&M roads to direct runoff away from the channel banks into an O&M side ditch for collection. Pipe drop inlets were provided to allow the runoff collected in the side ditch to enter the floodway. These design changes have decreased the rate of erosion occurring on Reaches 4, 5, and 6 by isolating the slopes to only direct rainfall.

Jugging and rilling continues to be a problem as the soils are fine grained, generally classified as SM and CL, and some are dispersive. In 1989, the Arizona design section with technical assistance from the WNTC designed and installed six different slope protective measures to evaluate their effectiveness in reducing or eliminating rill erosion.

The six measures were installed during October 1989, and a periodic monitoring program initiated. The purpose of this report is to evaluate the effectiveness of each after they have been exposed to the elements for one year.

DESCRIPTION OF APPLIED MEASURES

STUDY SITE NO. 1: Sta. 789+00 to 791+00, Left Bank.

The slope was ripped to approximately 6 inches deep and the loose material bladed to the toe of the slope for processing. Approximately 19,000 gallons of water was applied to the material while being removed, for processing in the stockpile and during replacement on the slope. A seed mixture consisting of Mediterranean ricegrass, bermuda grass, purple three awn, and bufflegrass was sprayed on the slope using a hydro-mulcher machine. An erosion control blanket fabricated from straw and coconut fibers was placed over the seeded slope and anchored with 6-inch staples and keyed into the ground 6 to 12 inches on all four edges.

STUDY SITE NO. 2: Sta. 826+00 to 828+00, Right Bank.

This study site was used as a control section. The earth slope was restored using similar methods as was used for Site No. 1, except no further treatment or seeding was done after finish grading of the slope. This section was compared to the six measures applied at study Sites No. 1 and No. 3 through No. 7.

STUDY SITE NO. 3: Sta. 828+00 to 830+00, Right Bank.

The earth slope for this site was also restored similar to those methods described above for Study Site No. 1. The seed was mixed in the hydro-mulcher with a soil stabilizing compound and applied to the finished slope.

STUDY SITE NO. 4: Sta. 830+00 to 832+00, Right Bank.

Gravel material, specified in the contract to be a GW or GW-GM, was placed by blading onto the undisturbed slope as thin as possible so as to just fill the rills. The contractor removed all large shrubbery, primarily tumbleweed growth, by hand prior to blading the gravel onto the slope.

STUDY SITE NO. 5: Sta. 911+00 to 913+00, Left Bank.

This site was treated similar to site No. 4 except the site was seeded and then the specified GW material was placed approximately 3-inches thick on the slope.

STUDY SITE NO. 6: Sta. 929+00 to 931+00, Right Bank.

A sand filter (C-33 sand) 3-inches thick and filling the rills was placed on the slope. The filter was then covered with a 3-inch layer of GW material which had a maximum size of 2-inches.

STUDY SITE NO. 7: Sta. 964+00 to 966+00, Right Bank.

The specifications required a "well graded sand, gravel, and cobble mixture with a maximum size of six inches". This site was cleared and seeded prior to placing a 6-inch layer of the 6-inch minus cobbles and gravel on the slope.

CONSTRUCTION OBSERVATIONS

Sites 1, 2, and 3 required considerable effort by the contractor to restore the slopes to a freshly cut condition.

Site 4 was the easiest to construct. The blade was able to travel across the slope without sliding down.

Site 5 was more difficult than Site 4. It required two or three times more effort to place the gravel because of the greater thickness. It was a difficult task for the contractor to keep the blade from sliding down the slope while spreading the gravel cover material.

Site 6 was the most difficult to complete of the three sites designated for gravel cover. The clean filter material (C-33 sand) could not be spread on the slope by the blade. The contractor resorted to stock piling the sand at the top of the slope and using a loader to back drag the material down the slope. Uniformity of the sand layer was difficult to achieve, as numerous passes by the loader were required to spread the sand evenly. The gravel cover was even more difficult to place than the sand layer. The blade was again unsuccessful so the loader was used in a similar manner as was used to place the sand. Hand labor was used as a final step to dress the slope.

At Site 7 a loader was used to place the material. This type of equipment is not well suited for placing this kind of material on the slopes. Uniformity and neatness ~~was~~ were difficult for the contractor to achieve. In retrospect a gradall would have performed the work more efficiently.

SITE MONITORING PROGRAM

To monitor the effectiveness of the measures installed, five site visits were made to photograph and record their condition for a one year period after construction. Photographs were also made for preconstruction and as-built conditions at each site.

RESULTS AT EACH SITE

STUDY SITE NO. 1: SEEDING AND EROSION CONTROL BLANKET.

Prior to construction, the site had rills spaced approximately every 10 feet with depths that varied from 0.2 feet to 1.3 feet. At the end of the monitoring period, there were no obvious rills under the erosion control matts. The netting that holds the matts together was substantially weaker because of its exposure to sunlight during the year. There was no evidence that any of the seeds in the mixture planted had germinated. There was a uniform growth of tumbleweeds on the slope and it appears from studying the before and after photos there are approximately twice as many plants than before construction. The floodway had flow depths of 1 to 2 feet several times during the year. The matts remained in their anchored position and did not show any signs of distress from these flows.

STUDY SITE NO. 2: CONTROL SECTION-RESTORED SLOPE.

The rill spacing on the slope before restoration was 3 to 4 feet apart and their depths ranged from 0.5 to 1.8 feet. At the end of the monitoring period the rill spacing was similar to those before construction and the depths varied from 0.2 to 0.7 feet. The condition of this site indicates that sufficient rainfall occurred during the monitoring period to test the applied measures.

STUDY SITE NO. 3: SEEDING AND TACKIFIER.

The rill spacing before restoration was approximately 8 feet and the depths ranged from 0.6 to 3.3 feet. At the end of the study period there were no continuous rills from the top to the toe of the slope. Erosion had started, generally beginning at the middle of the slope with rills 4 to 6 feet long and 0.2 feet deep. There was no indication of any seed germination at the site. The tumbleweed growth is approximately twice as dense as the adjacent site No. 2. The tackifier sprayed on the slope is still visible, but is discontinuous due to rills and other irregularities in the slope. Additional wear of the tackifier on the surface could be seen at the toe of the slope where the occasional flows reached a depth of 1 to 2 feet.

STUDY SITE NO. 4: EXISTING RILLS FILLED WITH GRAVEL

The prestudy slope at this site had rills spaced at approximately 5 feet intervals, with depths varying from 0.3 to 1.1 feet. During the monitoring period no rills have developed. There are a couple of jug holes in the O&M road. The tumbleweed growth is substantially denser than at the adjacent sites. The cover material remained stable during the low flows and has a thin layer of sediment build up at the toe of the slope.

STUDY SITE NO. 5: SEEDING AND GRAVEL 3-INCHES DEEP.

The prestudy slope had rills spaced at approximately 6 feet intervals with depths varying from 0.3 to 2.6 feet. The slope did have an area of significant erosion having a rounded "bad lands" appearance. After the monitoring period, there is no rilling on the slope. There is a sparse stand of dormant grass that may be the Mediterranean Rice Grass in the seed mixture that was seeded at sites 1, 3, 5, and 7. The site has at least eight different species of plants growing, but only one of the eight comes from the four types in the seed mix. The toe of the slope is in good condition, no displacement of cover material is evident.

STUDY SITE NO. 6: 3-INCH SAND FILTER AND 3-INCH GRAVEL COVER.

Rill spacing prior to construction was 2 to 3 feet with depths varying from 0.3 to 2.2 feet. There was very little tumbleweed growth on the slope prior to construction. There is an increase in tumbleweeds after the first year and a few short rills less than 0.1 feet deep have developed. There is gopher activity prevalent along the toe of the slope at this site. There is no evidence of material displacement along the toe due to the minor channel flows.

STUDY SITE NO. 7: SEEDING AND 6-INCH LAYER OF COBBLES.

The rill spacing prior to construction was approximately 2 feet having depths that varied from 0.3 to 3 feet. There is a significant increase of native plant growth through the cobbles. Buffelgrass, one of the four species seeded, was growing at the site. The rock at the toe of the slope is fairly well silted in from the channel flows.

SUMMARY OF SITES

A table rating the sites relative to each other is shown below. In general, sites 4 and 5 are considered the best solution for correcting the existing rills and controlling future rilling action. The other sites were considered less desirable for the following reasons.

The Site No. 1 treatment is expensive and relies upon vegetation to eventually control erosion. Vegetation that is dense enough to control erosion on the slopes would require irrigation to survive.

The Site No. 3 treatment requires substantial earthwork to repair the slopes prior to the application of a tackifier. The tackifier has a limited life and rilling was recurring before the treatment was one year old.

The Site No. 6 treatment was the most expensive to install. There may be some advantages from the sand filter that are not yet evident, especially when placed on dispersive soils. This treatment would be difficult to maintain if slope problems developed. Heavy maintenance equipment such as a blade can not be driven across the slope because of displacing and mixing of the layered material.

Site No. 7 was also expensive to construct. Maintenance is a potential problem as vehicles can not traverse the material.

STUDY SITE	EST COST PER MILE	RILLING CONTROLLED	RELATIVE CONSTRUCTABILITY	MAINTENANCE	MODIFIABLE AT LATER DATE
1	$190,000	PARTIAL	*	*	*
3	$110,000	NO	*	*	*
4	$ 85,000	YES	EASY	EASY	EASY
5	$170,000	YES	MODERATE	MODERATE	MODERATE
6	$230,000	YES	DIFFICULT	DIFFICULT	DIFFICULT
7	$230,000	YES	DIFFICULT	DIFFICULT	DIFFICULT

* Sites 1 and 3 not evaluated further because rilling not controlled.

CONCLUSION

The study indicates Sites No. 4 and 5 were the most successful of the six treatments applied. The major difference between Site No. 4 and Site No. 5 is that Site No. 5 has approximately three times more gravel material than No. 4. This difference in the quantity of material required was due to the greater rill erosion and thicker finished layer required at Site No. 5. The treatment at Site No. 4 could be applied to both sides of the channel for less than $100,000 per mile of floodway. Severely eroded areas could receive a heavier treatment and/or can be easily added to by a maintenance program at a later date. The thin gravel layers also act as a durable mulch material improving vegetation on the slopes. Past experience using pitrun sand and gravel mixtures at other locations of the floodway has also produced excellent results for controlling rill erosion. The intent of the gravel is to protect the slope from direct rainfall, not concentrated flows. It is important that accumulated surface waters be entered into the floodway by suitable side inlets.

The result of this limited study is that a thin gravel layer bladed over the existing slope is an economical and practical solution to correct existing rills and to control future rilling on the floodway slopes.

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CONSERVATION PLANNING TECHNICAL NOTE

NUMBER 8

GUIDE FOR PLANNING MULCHING

by

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November 1990

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Albuquerque, New Mexico

GUIDE FOR PLANNING MULCHING

by
William W. Fuller

One of the best mulches to control erosion and to insure vegetative establishment is rock, of any size (preferably at least 0.5 inches in diameter and as long as it is not applied so thickly that no seed or light can get to the ground). It should be remembered, that in New Mexico many areas receive inadequate rainfall to insure sufficient vegetation to control erosion. A rock mulch, with approximately 80-100% ground cover, will reduce erosion to insignificant amounts, provide excellent protection for germinating seedlings, and is often cost comparable to vegetative mulching which requires tucking or tacking. The rock will also last indefinitely with total erosion control while vegetative mulches soon deteriorate.

The standard method for determining 80% ground cover is to use a tape. At several random locations, stretch it out and check at the foot marks. If at least 8 out of 10 points falls on a rock, then 80% ground cover has been achieved. If less than 8 out of 10 points falls on a rock, additional amounts should be added until the minimum required is reached.

The choice of mulch material should be determined by the site characteristics, the availability of mulch material, the planned use of the site after vegetation establishment, cost, and effectiveness. Generally grass hay or straw is very effective for **short-term** protection and is cost competitive. It is important when using grass or straw which is to be tucked, to insure that the soil is loosened to at least a four inch depth. The hay should be anchored into the soil at least two inches. As the slope steepens, the ability of grass or hay mulch to prevent water erosion decreases, particularly on longer slopes. Chemical soil binders have not been effective in New Mexico, either in preventing erosion or in successfully establishing stands of vegetation.

Wood chips have been effective. However bark, which is normally much lighter than the wood chips, has a tendency to blow off of an exposed site, or if the area is subject to

overland flow, they float readily. Excelsior blankets or jute netting are effective but they are costly. The excelsior blankets also can cause a problem where there are large numbers of Russian thistles. As the dead weeds roll across the matting, they catch in the excelsior, which is strong enough to hold them fast. If the installation also happens to be in an area with considerable blowing dust, the thistles catch the dust and the entire installation can be buried several inches deep in the dust deposits. This effectively negates any seeding which has been done since the seed are buried too deeply to emerge. Other mulches may also catch windblown dust but not to the extent of the thistles. In urban areas where esthetics are a consideration, the mass of accumulated thistles is also unsightly as well as being a fire hazard.

Farm by-products such as cotton burs, aged manure, and corn or sorghum stalks are all satisfactory mulches when adequate amounts are applied.

There are presently several types of plastic mulches on the market. Most are satisfactory, if they are properly installed. The plastic mulches normally degrade very slowly. Most are used along the edges or in the bottom of channels where fast flowing water could cause scouring rather than as simple "ground covers".

Enkamat[1], an extruded nylon mesh which resembles a kitchen scouring pad, needs to be covered with soil to the depth of the mat to function properly. When left exposed on the surface, its stiffness allows water erosion to form rills beneath the mat, and stiff-stalked weeds will lift the mat off of the ground. Rilling beneath the mat can also be a problem with the excelsior matting if it is not properly stapled down.

Nearly any material which protects the soil surface from the effects of wind and water erosion is generally beneficial for seedling establishment. However, placement of seed at the proper depth, and providing a good soil-seed contact, followed by mulching is nearly always more successful than using methods which mix the seed and the mulch (hydromulching). When the seed is mixed with the mulch, it often ends up suspended above the soil surface and upon germinating the rootlet fails to reach soil before it dries out and dies. Also, small showers may moisten the mulch material sufficiently for the seed to germinate and yet the soil does not have adequate moisture available to sustain the newly germinated seedling. It is much preferred to hydroseed first, and then apply the hydromulch. When only water and seed are used initially, soil-seed contact is more likely to occur, and then the mulch ends up on top of the seed to

provide the needed protection. If the area is subject to overland water flow, some hydromulches also have a tendency to float away from the site.

1/ The use of product names in this publication does not constitute an endorsement.