January 1985

Evaluation of Miramat Under High Velocity Flows

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MIRAFI

Final Report

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TABLE OF CONTENTS

Introduction

Newly constructed earth channels and steep cut and fill slopes on construction projects need temporary protection from water erosion until a protective cover of vegetation can be grown. In some instances the temporary protective measures can be left in position to serve as part of the permanent system. Various kinds of vegetative and chemical mulches are available for use as temporary control measures, and other materials such as jute, fiberglass roving, and excelsior blanket are also in use. However, for large volumes of flow and for high velocities, more substantial materials are required. One class of such materials is referred to as ECRM, or Erosion Control and Revegetation Mats. These are designed primarily for use on steep slopes and in drainage channels where high velocities of flow are encountered, and where mulches are not effective.

Mirafi engineers, in cooperation with 3M Company, have developed an ECRM called Miramat, which is a flexible, three-dimensional web of bonded vinyl monofilaments. Since commercial introduction, it has gained rapid market acceptance, but more information was desired on its performance capabilities and limitations.

The objective of the present study was to conduct performance tests in the laboratory of two ECRMs, Miramat and Enkamat. One measure of the protective ability of such material is the flow velocity it can withstand before excessive erosion occurs. The determinaiton of this permissible velocity was one of the objectives of these tests.

Facilities and Procedures

Test Section Layout

The tests were conducted in an indoor concrete flume at the Utah Water Research Laboratory. The flume is 8 feet wide, 6 feet deep, and 570 feet in length, supplied with water from a nearby reservoir through a 3-foot diameter pipe. A spreader was constructed and installed at the outlet end of the pipe which distributed the water uniformly over the 8-foot width of the channel. A plywood partition and end gates in the flume provided two test sections each 4 feet wide and 50 feet long. The concrete and plywood sidewalls of the two test channels were covered with Miramat to provide a roughness comparable to that to be installed on the floors of the channels. Soil was compacted into the channels to a depth of 2 feet in preparation for the ECRM's for the tests.

Measurement Capabilities

A 4-wheeled measurement cart mounted on steel rails was provided over the test channels. Velocity measurements of the flows in the channels were made from this cart, using a Montedero-Whitney electromagnetic velocity probe, which has a range of 0-20 ft/sec with an accuracy of ± 1% full scale and a resolution of 0.01 ft/sec.

Contour measurements for determining erosion quantities from the test channels were also made from the measurement cart using a modified point gage mounted on an instrument carriage on rails. These measurements were made after every run at 1-foot intervals across the channels, and at 5-foot intervals along the channels.

Discharge measurements of flows in the channels were accomplished with a Nusonics Ultrasonic Flowmeter which has an advertised accuracy of ± 2% of reading for flows between 1 and 10 cfs, and of ± 1% of reading for flows over 10 cfs. Flow depths were determined with a wooden rod calibrated in inches.

Channel Preparation

Three different soils were utilized in the tests, a sand, a sandy loam, and a silt loam. Laboratory analyses of these soils are shown in Table 1. In preparing for each run, soil was added to each channel in 4 to 6 inch layers at a time, and each layer was compacted using a gasoline-driven hand-operated compactor to approximately 90% proctor as measured with a neutron probe.

The first few tests utilized the full 50-feet of channel length. It was noted, however, that excessive turbulence existed in the initial 20 feet of the channels which caused premature erosion to occur, so these portions were lined first with drainage fabric (which was too porous to provide the needed protection) and then with plywood, and the remainder of the tests were conducted in the resulting 28-ft long channels.

Installation of ECRMs

After the soil was compacted into the channels, ECR mats were installed according to manufacturers' recommendations. Figure 1 shows the placement and method of anchoring of the ECRM's and the side curtains in both channels. Side curtains for both ECRMs were Miramat. Figure 2 shows the stake-spacing details and the location of cross trenches. These configurations were used only for the 50-ft long test channels. When the channels were shortened to 28 feet, the stakes were spaced 3 ft apart throughout, and cross trenches were eliminated.

Table 1. Soil analyses.

	Hydrometer Analysis		
	% sand	% silt	% clay
Sandy loam	57	37	6
Silt loam	30	51	19

	Sieve Analysis (%)					
	Very Coarse	Coarse	Medium	Fine	Very Fine	Total
Sandy loam	0.1	0.7	3.3	24.3	28.5	56.9
Silt loam	0.2	0.2	0.4	7.5	15.8	24.1

	Compaction
Sandy loam	115.8 lbs/ft^3 @ 13.1% moisture
Silt loam	101.3 lbs/ft^3 @ 20.3% moisture

	Liquid Limit	Plastic Limit
Sandy loam	--	NP
Silt loam	34%	23%

	Sieve Analysis - Coarse and Wet Sieving			
	% material		Sieve size	
Sand	100.00%	<	4.750 mm	4 mesh
	100.00%	<	2.000 mm	10 mesh
	84.33%	<	0.589 mm	30 mesh
	32.31%	<	0.246 mm	60 mesh
	13.03%	<	0.147 mm	100 mesh
	4.39%	<	0.074 mm	200 mesh

	Organic Content and "K" values	
	% Organic Matter	K value (from Weischmeier)
Sandy loam	0.17	0.56
Silt loam	2.43	0.34
Sand	0.31	0.08

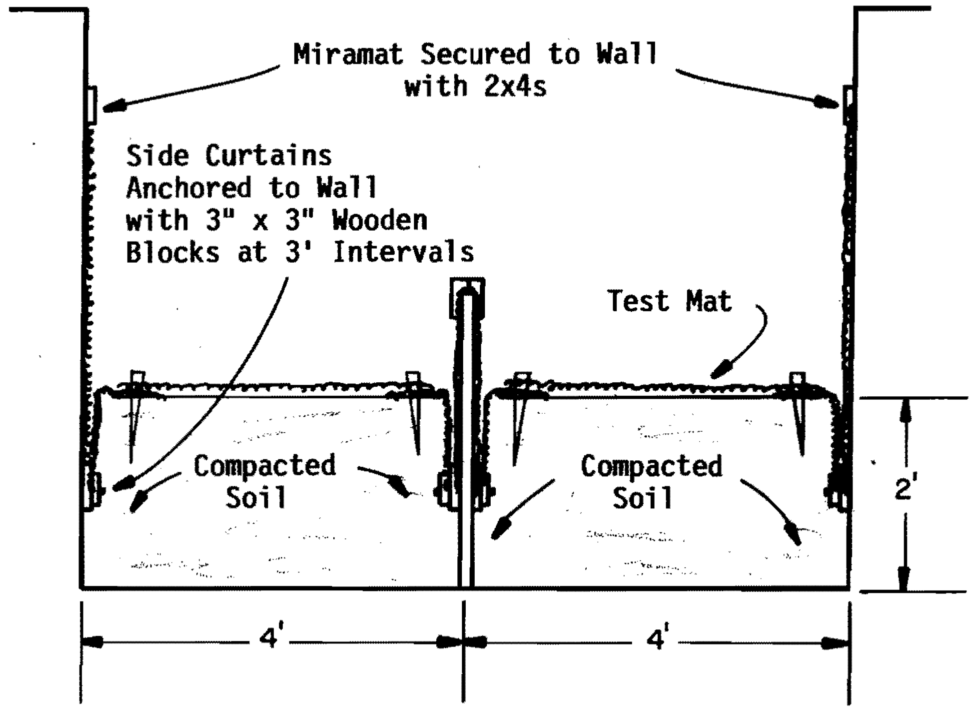


Fig. 1. Cross section of test channels showing placement of ECRMs.

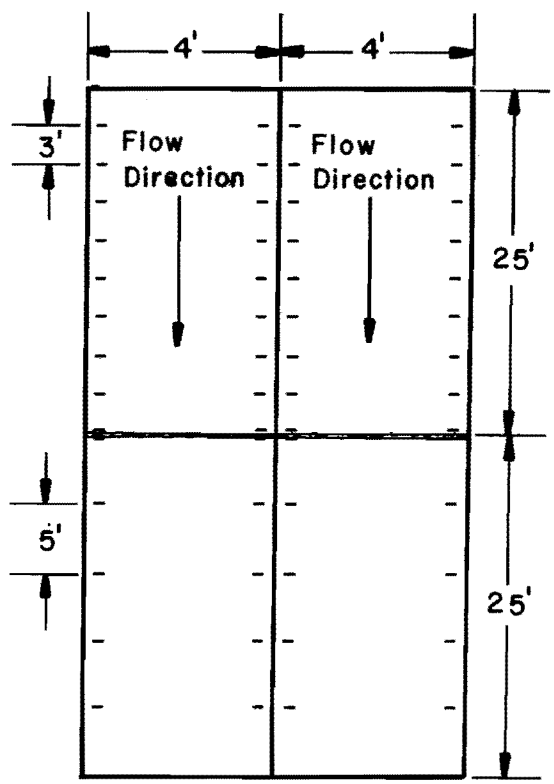


Fig. 2. Plan view of test channels showing cross ditch and stake spacing.

Anchoring of the ECRMs at the upstream ends of the channels was done according to the examples shown in Figure 3. Example B proved to be the most effective. Figure 4 shows methods of anchoring ECRMs in the cross trenches. Example A is the better of the two.

Testing, Observing, and Recording

Testing procedures included running each quantity of flow for 30 minutes, before advancing to the next one higher. Flow quantities used were 20, 32, 45, 60, and 75 cfs, divided equally between the two channels. During every run, velocity measurements were taken along the centerline of each channel at three different locations: the first near the head of the channel, the next at about the mid-point, and the last about 5 feet from the downstream end. All measurements were taken at a point beneath the water surface that was seven-tenths of the depth of flow from the channel bottom. After each 30-minute run, profile measurements were made at 1-foot intervals across the channels, and at 5-foot intervals along the channels.

Visual observations of such things as unusual turbulence, point of initiation of failure of the channel or the ECRM, and other items of interest, were recorded with the measured data.

Video tape recordings were made of each run, and will be submitted as part of the final report.

Test Set No. 1 (Silt Loam)

This run was made in 50-ft long channels on black, silt loam soil. Mirimat was installed in both channels with the only difference in the two configurations being that the south channel had a cross trench at the 25 ft. mark, and the north channel had none. Runs were made at 20, 45, 60, and 75 cfs. Failure occurred in the south channel about 5-minutes

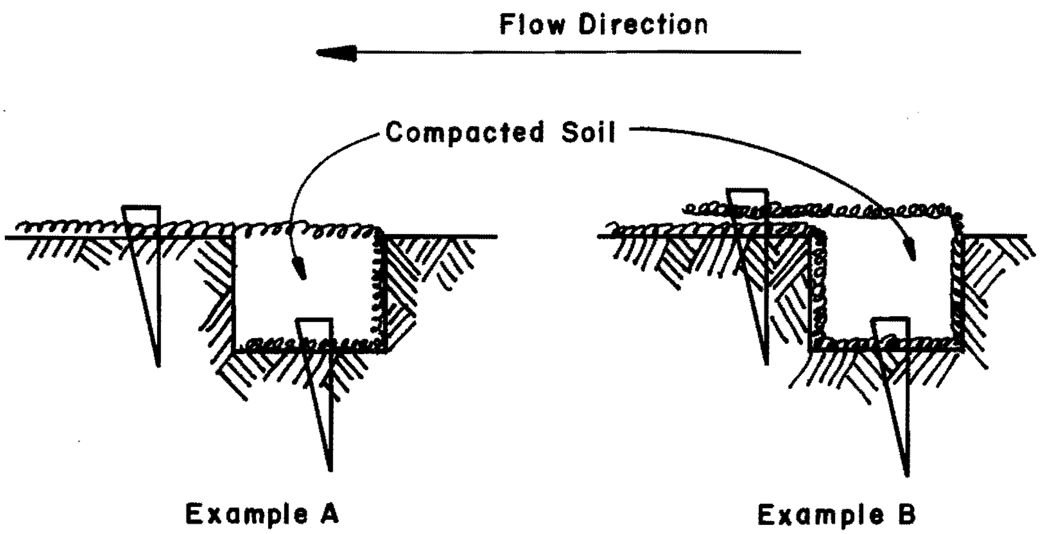


Fig. 3. Anchoring ECRM at upstream end of channel.

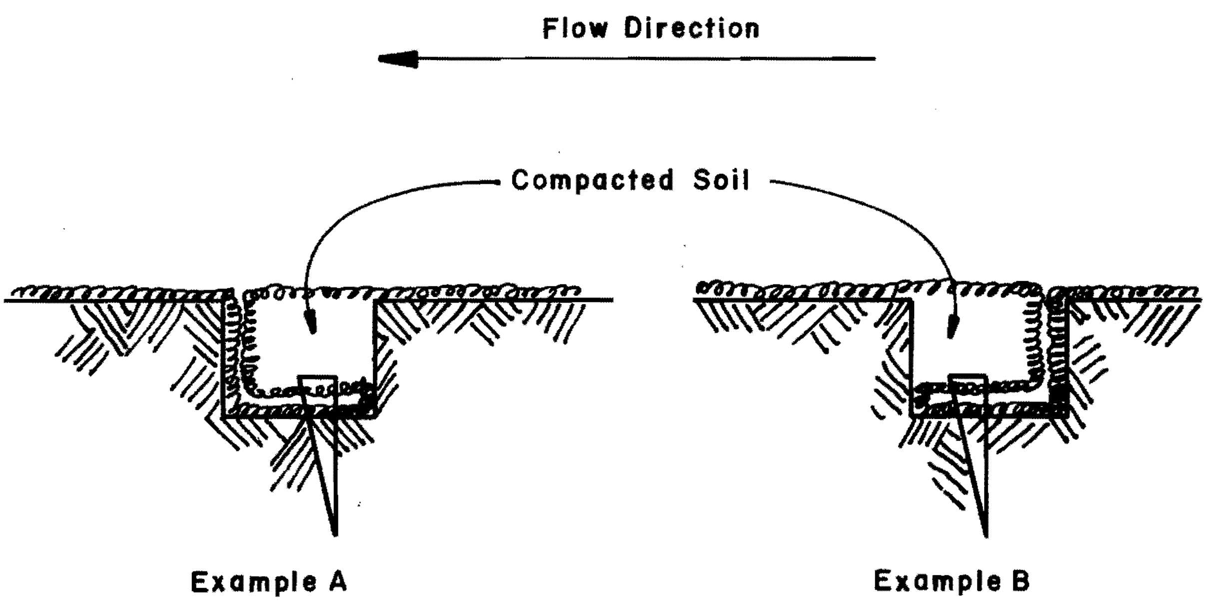


Fig. 4. Anchoring ECRM in cross ditches.

into the 75 cfs runs so the flow was shut down. The north channel was run for a full 30 minutes. Profile measurements were then made of both channels.

Test Set No. 2 (Silt Loam)

This was a comparison test of the two ECRMs, with Miramat in the south channel and Enkamat in the north. Channels for this run were shortened to 28 feet. Both mats were spliced between stations 35 and 40. Runs were made at 20, 32, 45, 60 and 75 cfs.

Test Set No. 3 (Sandy Loam)

Miramat was installed in the north channel and Enkamat in the south. Test channels were 28 feet in length. After 5 runs at 30 minutes each, the south channel had eroded noticeably more than the north one.

Test Set No. 4 (Sandy Loam)

Run 4 was identical to Run 3 except that the mat locations were switched, Miramat being in the south channel and Enkamat in the north. Again the south channel eroded noticeably more than did the north one. All five runs were made.

Test Set No. 5 (Sand)

Sand utilized in the study was brown, washed and graded plaster sand. This run was made in 50-ft. long channels, and had cross ditches in both channels at the 25-ft. mark. Miramat was in the south channel and Enkamat in the north. Runs were made at 20 and 45 cfs. At the end of the second run failure of both channels was noted from station 5 to about station 20 where sand was eroded from beneath the mats and wooden stakes were left hanging from the fabric, above the sand. Comparatively small amounts eroded between stations 20 and 50.

Test Set No. 6 (Sand)

Both channels were shortened to 28 feet in length for these runs, with Miramat in the north channel and Enkamat in the south. Runs were made at flows of 20, 32, 45 and 60 cfs. Eighteen-inch-long metal rods with 1 1/4"-diameter washers were used instead of wooden stakes.

Test Set No. 7 (Sand)

Channels were 50 feet in length, but the first 22 feet were covered with a drainage fabric to protect against excessive erosion in the initial parts of the channels. Miramat was installed in the north channel and Enkamat in the south. The drainage fabric and both ECRMs were anchored with 18" metal rods. The drainage fabric was too porous to provide adequate protection, so only one run of 20 cfs was made. Excessive erosion occurred beneath the drainage fabric, but only a small amount in the downstream reaches.

Test Set No. 8 (Sand)

A flow of 30 to 35 cfs was run continuously for a period of 72 hours, and profile measurements were made at the end of each 24 hours. Velocity in the channels changed with time as sand eroded and the channel profiles changed, so the flow had to be reduced periodically to compensate. Flow started at 35 cfs but early in the run had to be reduced to 30 cfs to maintain approximately the same flow conditions.

Results and Discussion

Results

Results of the erosion control tests are summarized in Tables 2 through 9, and Table 10 shows the total amount of soil eroded during each run in each channel. However, the overall performance of the ECRMs as well as the configuration of the test channels can best be understood by viewing the video tape which accompanies this report. Highlights of the series of tests appear separately on a narrated, edited version of the detailed video tapes.

Results of the testing are summarized also in the computer printouts appearing in the Appendix. Data from north and south channels are presented separately. Runs 1 through 5 represent the various quantities of flow that were put through each test channel; 10, 16, 22.5, 30, and 37.5 cfs. Velocities were measured for each different discharge, at three locations in each channel. Incremental erosion per run is the total volume of sediment leaving the channel during the 30-minute duration of each particular discharge.

Values shown on the printouts, beneath the various runs, are the calculated quantities of sediment leaving each 5-ft long section of the channel during the run. The density of the redeposited material is less than the compacted original, but was not considered in calculating the new volumes. Positive numbers indicate quantities of soil eroded and negative ones are quantities deposited. During each run some sediment left the channel, but other sediment was just moved from one location to another within the channel. Tables 2 through 9 indicate this movement, and these data were used to plot the graphs in Figures 5 through 12.

Table 2. Test Set 1 - Black Silt Loam, 2-19-85

South Channel (Miramat)

Station	Flow in Cubic Feet per Second: 10			16			22.5			30			37.5		
	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps
5-20	0.05	0.05	3.8				2.5	2.5	11.6	2.8	2.8	16.1	36.2	36.2	18.9
20-40	-0.04	0.01	3.5				1.3	3.8	6.4	6.5	9.3	13.5	-11.4	24.8	-
40-50	-0.20	-.19	4.2				0.9	4.7	-	1.4	10.7	7.9	-2.7	22.1	9.5

North Channel (Miramat)

Station	Flow in Cubic Feet per Second: 10			16			22.5			30			37.5		
	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps
5-20	0.5	0.5	3.3				2.5	2.5	11.5	2.9	2.9	16.1	41.0	41.0	19.8
20-40	0.1	0.6	3.5				3.0	5.5	7.1	2.5	5.4	13.9	44.0	85.0	17.7
40-50	0.2	0.8	3.9				1.2	6.7	-	0.7	6.1	9.5	4.9	89.9	14.2

Table 3. Test Set 2

South Channel

Station	Flow in Cubic Feet per Second: 10			16			22.5			30			37.5		
	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps
5-20	0.5	0.5	3.6	0.3	0.3	4.0	5.0	5.0	10.0	3.9	3.9	13.3	5.4	5.4	10.8
20-40	0.7	1.2	3.7	0.2	0.5	4.6	5.8	10.8	8.5	1.7	5.6	11.2	7.0	12.4	14.5
40-50	2.5	3.7	5.1	1.9	2.4	6.3	6.3	17.1	8.0	-1.3	4.3	8.9	3.4	15.8	10.7

North Channel

Station	Flow in Cubic Feet per Second: 10			16			22.5			30			37.5		
	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps
5-20	0.1	0.1	3.2	0.7	0.7	4.3	4.4	4.4	10.2	4.0	4.0	14.9	13.0	13.0	19.7
20-40	0.1	0.2	3.5	2.2	2.9	4.7	7.4	11.8	8.9	1.9	5.9	12.3	5.9	18.9	16.7
40-50	6.1	6.3	5.7	3.1	6.0	6.7	6.6	18.4	7.7	-1.5	4.4	8.7	2.5	21.4	12.6

Table 4. Test Set 3

South Channel

Station	Flow in Cubic Feet per Second														
	10			16			22.5			30			37.5		
	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps
22-30	0	0	3.3	0.1	0.1	4.6	1.8	1.8	9.8	8.3	8.3	14.2	21.5	21.5	19.2
30-40	0.5	0.5	3.7	0.5	0.6	4.9	1.0	2.8	9.1	3.6	11.9	12.3	27.6	49.1	-
40-50	1.2	1.7	5.2	3.5	4.1	6.9	3.1	5.9	8.0	1.6	13.5	9.1	20.5	69.6	8.4

North Channel

Station	Flow in Cubic Feet per Second														
	10			16			22.5			30			37.5		
	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps
22-30	0.4	0.4	4.1	0.2	0.2	4.5	2.8	2.8	10.7	10.1	10.1	15.2	7.5	7.5	19.4
30-40	0.4	0.8	4.2	0.4	0.6	5.0	2.8	5.6	9.8	5.7	15.8	12.4	15.0	22.5	-
40-50	0.6	1.4	5.1	0.2	0.8	5.9	2.5	8.1	8.2	2.1	17.9	9.1	4.5	27.0	8.2

Table 5. Test Set 4

South Channel

Station	Flow in Cubic Feet per Second: 10 Eros. ft3	10 Cum. ft3	10 Vel. fps	16 Eros. ft3	16 Cum. ft3	16 Vel. fps	22.5 Eros. ft3	22.5 Cum. ft3	22.5 Vel. fps	30 Eros. ft3	30 Cum. ft3	30 Vel. fps	37.5 Eros. ft3	37.5 Cum. ft3	37.5 Vel. fps
22-30	1.0	1.0	4.0	0.2	0.2	4.5	5.6	5.6	10.2	7.5	7.5	13.8	23.0	23.0	17.9
30-40	1.5	2.5	3.8	1.3	1.5	4.7	1.6	7.2	8.6	3.9	11.4	10.8	40.2	63.2	-
40-50	4.0	6.5	5.6	2.5	4.0	6.5	2.7	9.9	8.5	1.6	13.0	9.9	14.9	78.1	8.3

North Channel

Station	Flow in Cubic Feet per Second: 10 Eros. ft3	10 Cum. ft3	10 Vel. fps	16 Eros. ft3	16 Cum. ft3	16 Vel. fps	22.5 Eros. ft3	22.5 Cum. ft3	22.5 Vel. fps	30 Eros. ft3	30 Cum. ft3	30 Vel. fps	37.5 Eros. ft3	37.5 Cum. ft3	37.5 Vel. fps
22-30	0.6	0.6	3.3	0.6	0.6	4.5	6.5	6.5	10.6	8.2	8.2	14.9	16.0	16.0	19.6
30-40	0.9	1.5	3.6	1.1	1.7	4.6	1.8	8.3	8.4	8.9	17.1	10.2	4.3	20.3	-
40-50	3.4	4.9	5.3	2.6	4.3	6.2	2.8	11.1	7.9	1.1	18.2	8.9	2.9	23.2	8.5

Table 6. Test Set 5

South Channel

Station	Flow in Cubic Feet per Second: 10			16			22.5			30			37.5		
	Eros. ft3	Cum. ft3	Vel. fps	Eros. ft3	Cum. ft3	Vel. fps	Eros. ft3	Cum. ft3	Vel. fps	Eros. ft3	Cum. ft3	Vel. fps	Eros. ft3	Cum. ft3	Vel. fps
5-20	4.6	4.6	3.7				18.8	18.8	8.5						
20-40	4.1	8.7	4.3				-2.0	16.8	6.9						
40-50	2.7	11.4	5.4				3.2	20.0	6.5						

North Channel

Station	Flow in Cubic Feet per Second: 10			16			22.5			30			37.5		
	Eros. ft3	Cum. ft3	Vel. fps	Eros. ft3	Cum. ft3	Vel. fps	Eros. ft3	Cum. ft3	Vel. fps	Eros. ft3	Cum. ft3	Vel. fps	Eros. ft3	Cum. ft3	Vel. fps
5-20	5.6	5.6	3.5				15.4	15.4	8.3						
20-40	9.2	14.8	4.0				-7.9	7.5	6.8						
40-50	6.5	21.3	5.6				-5.3	2.2	7.0						

Table 7. Test Set 6

North Channel

Station	Flow in Cubic Feet per Second: 10			16			22.5			30			37.5		
	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps
22-30	-0.7	-0.7	4.0	4.4	4.4	7.8	4.7	4.7	11.1	14.7	14.7	14.7			
30-40	0.4	-0.3	4.3	4.8	9.2	6.2	3.3	8.0	8.2	14.6	29.3	7.0			
40-50	2.4	2.1	5.2	3.0	12.2	6.6	3.4	11.4	7.4	7.2	36.5	7.2			

South Channel

Station	Flow in Cubic Feet per Second: 10			16			22.5			30			37.5		
	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps
22-30	0.3	0.3	3.7	2.6	2.6	6.7	10.6	10.6	10.9	13.4	13.4	14.6			
30-40	0.5	0.8	4.3	3.6	6.2	6.1	4.3	14.9	8.3	31.0	44.4				
40-50	4.9	5.7	5.6	3.8	10.0	6.7	3.4	18.3	6.8	9.0	53.4				

Table 8. Test Set 7

South Channel

Station	Flow in Cubic Feet per Second														
	10			16			22.5			30			37.5		
	Eros. ft3	Cum. ft3	Vel. fps	Eros. ft3	Cum. ft3	Vel. fps	Eros. ft3	Cum. ft3	Vel. fps	Eros. ft3	Cum. ft3	Vel. fps	Eros. ft3	Cum. ft3	Vel. fps
22-30	3.6	3.6	3.3												
30-40	3.3	6.9	4.1												
40-50	4.6	11.5	5.4												

North Channel

Station	Flow in Cubic Feet per Second														
	10			16			22.5			30			37.5		
	Eros. ft3	Cum. ft3	Vel. fps	Eros. ft3	Cum. ft3	Vel. fps	Eros. ft3	Cum. ft3	Vel. fps	Eros. ft3	Cum. ft3	Vel. fps	Eros. ft3	Cum. ft3	Vel. fps
22-30	2.4	2.4	4.5												
30-40	4.4	6.8	4.6												
40-50	6.0	12.8	5.5												

Table 9. Test Set 8

South Channel

	Flow in Cubic Feet per Second														
	10			16			22.5			30			37.5		
Station	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps
22-30	20.2	20.2	6.2	2.9	2.9		-3.3	-3.3							
30-40	31.5	51.7	5.0	10.2	13.1		-0.4	-3.7							
40-50	33.7	85.4	5.3	5.0	18.1		-2.1	-5.8							

North Channel

	Flow in Cubic Feet per Second														
	10			16			22.5			30			37.5		
Station	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps	Eros. ft^3	Cum. ft^3	Vel. fps
22-30	18.6	18.6	5.5	5.3	5.3		-0.6	-0.6							
30-40	33.0	51.6	4.6	7.2	12.5		-0.7	-1.3							
40-50	37.6	89.2	5.0	5.9	18.4		-6.2	-7.5							

Table 10. Erosion summaries.

	Quantities Eroded (ft^3)
Test Set 1 (Black Silt Loam) four runs*	
South Channel (Miramat)	= 37.20
North Channel (Miramat)	= 103.60
Test Set 2 (Black Silt Loam) five runs	
South Channel (Miramat)	= 43.34
North Channel (Enkamat)	= 56.35
Test Set 3 (Yellow Sandy Loam) five runs	
South Channel (Enkamat)	= 94.58
North Channel (Miramat)	= 55.27
Test Set 4 (Yellow Sandy Loam) five runs	
South Channel (Miramat)	= 111.76
North Channel (Enkamat)	= 61.84
Test Set 5 (Sand) two runs	
South Channel (Miramat)	= 31.31
North Channel (Enkamat)	= 23.34
Test Set 6 (Sand) four runs	
South Channel (Enkamat)	= 87.55
North Channel (Miramat)	= 62.34
Test Set 7 (Sand) one run	
South Channel (Enkamat)	= 11.53
North Channel (Miramat)	= 12.80
Test Set 8 (Sand) 72 hour test	
South Channel (Miramat)	= 97.91
North Channel (Enkamat)	= 99.93

*Note: A run consists of a fixed quantity of water flowing through the test channels for a 30-minute time period. Flow quantities varied from 20 to 75 cfs.

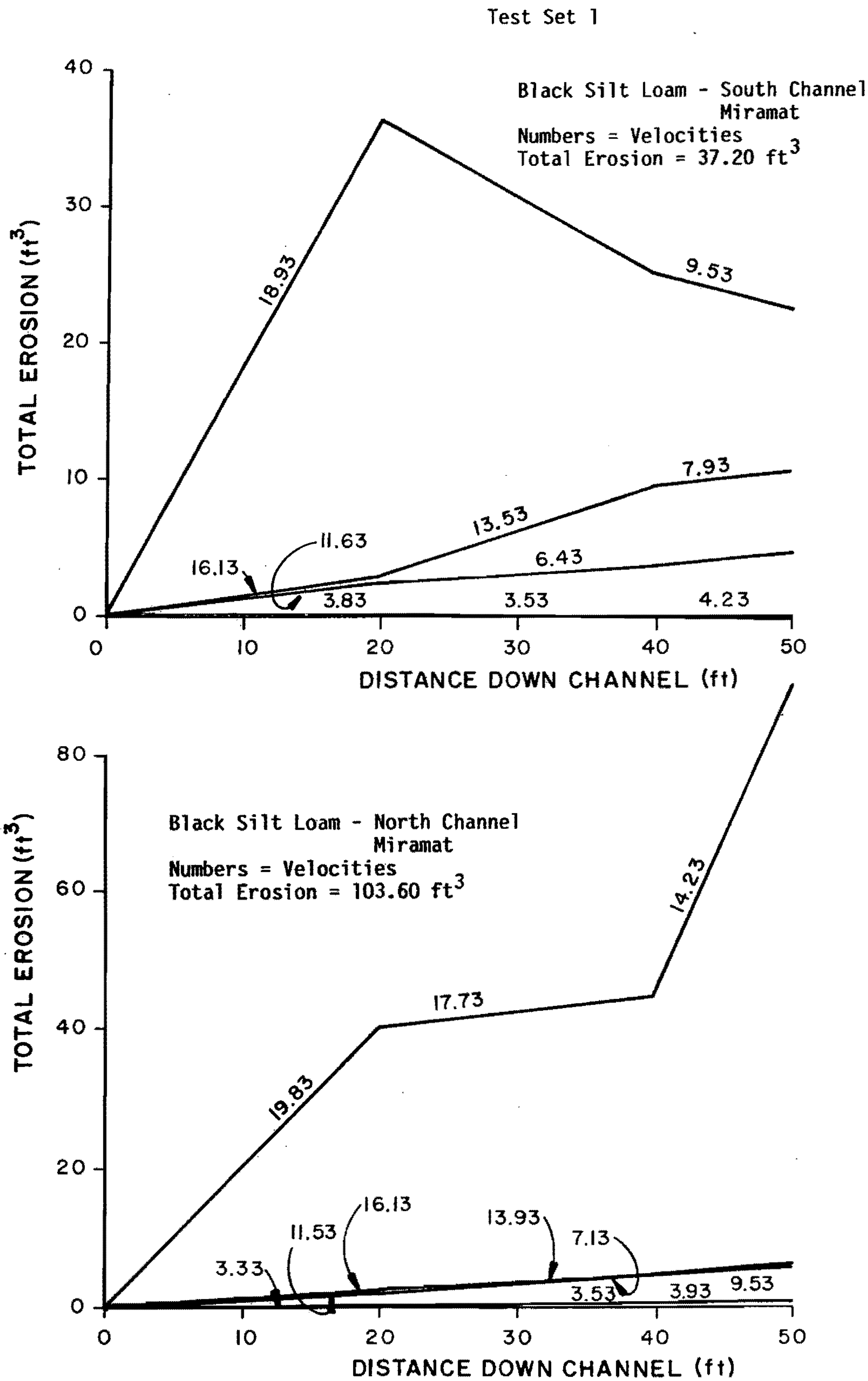


Fig. 5. Test set no. 1.

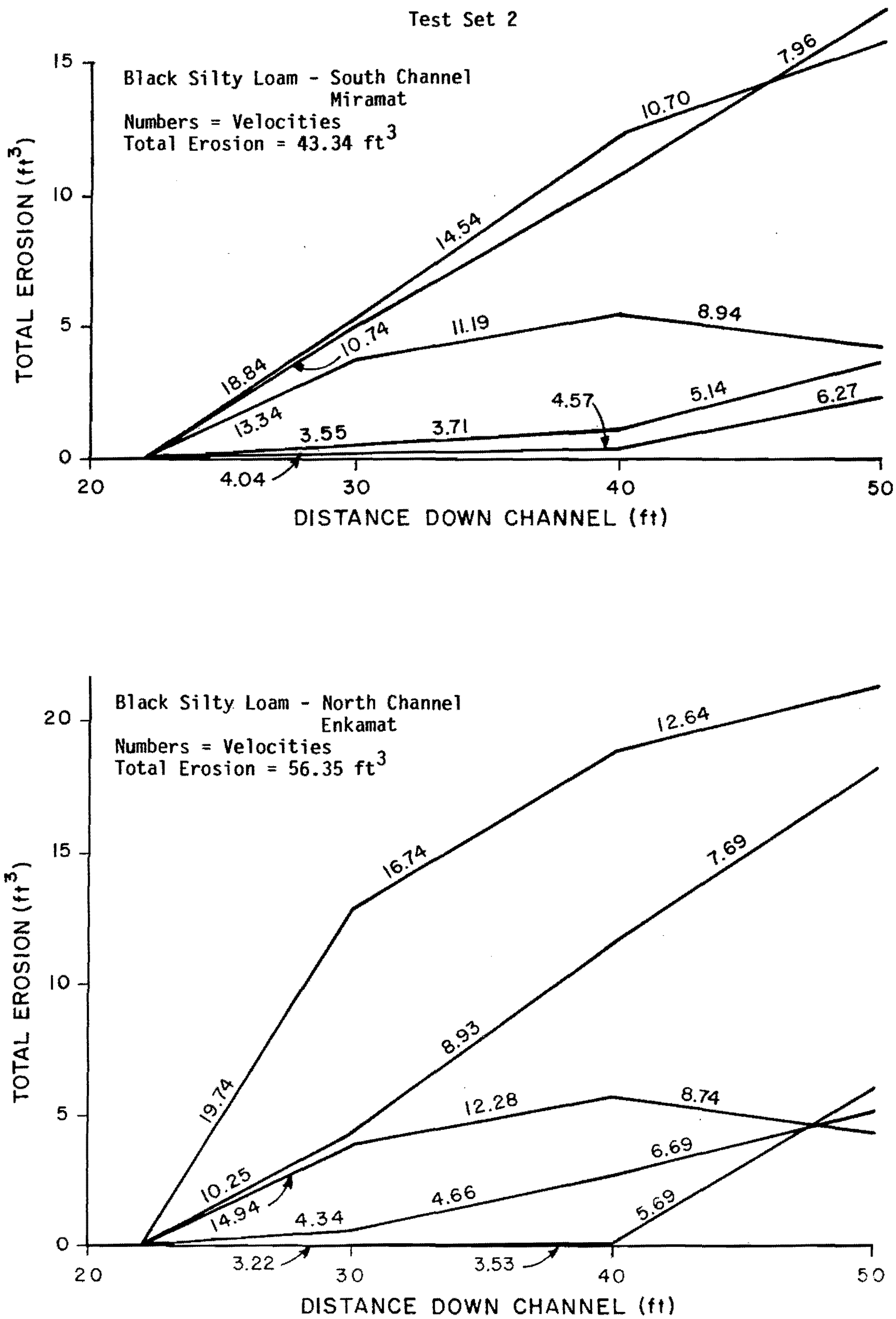
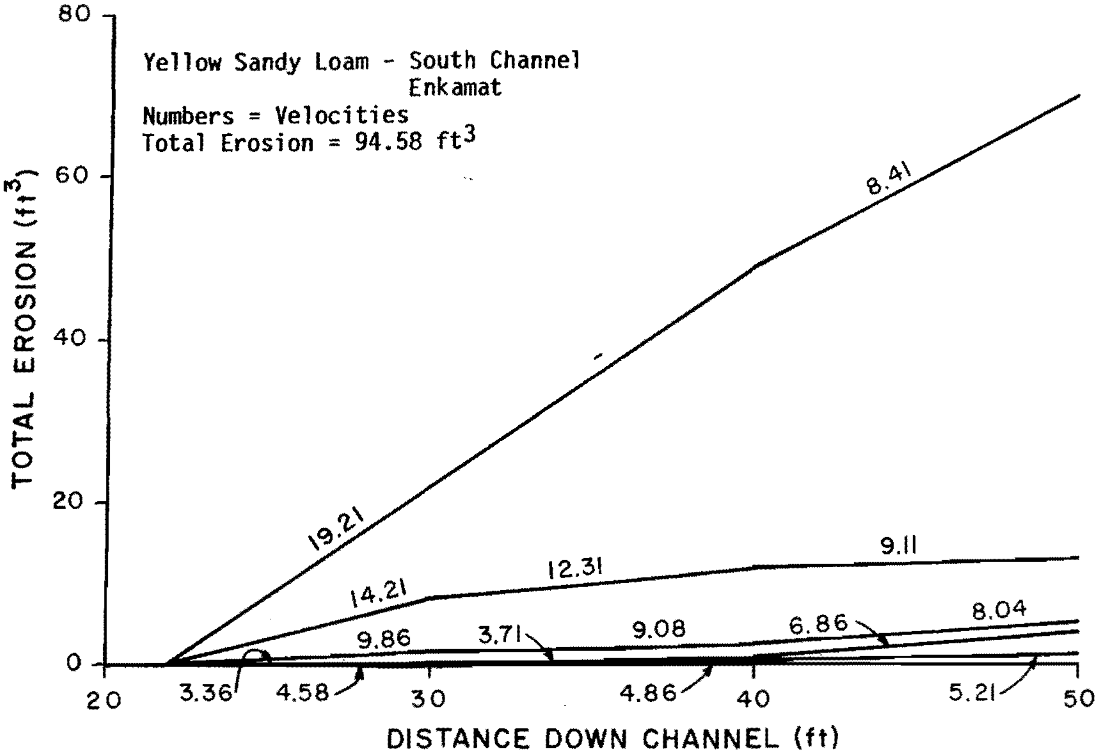


Fig. 6. Test set no. 2.

Test Set 3



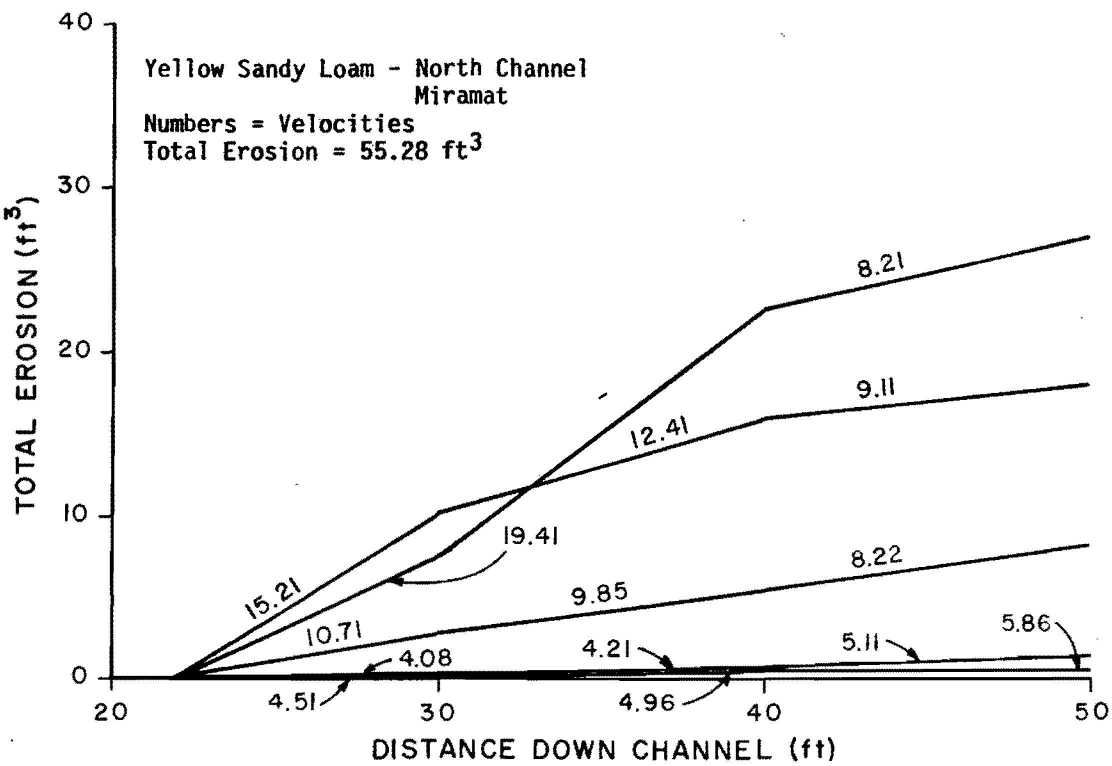
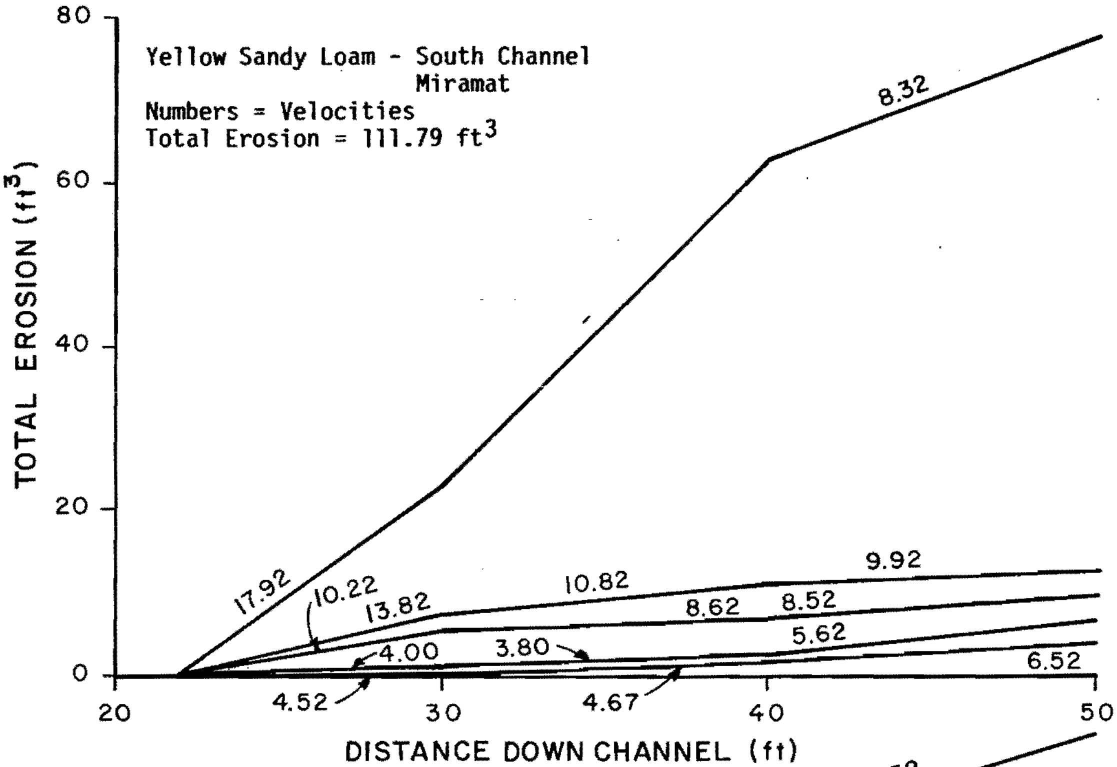


Fig. 7. Test set no. 3.

Test Set 4



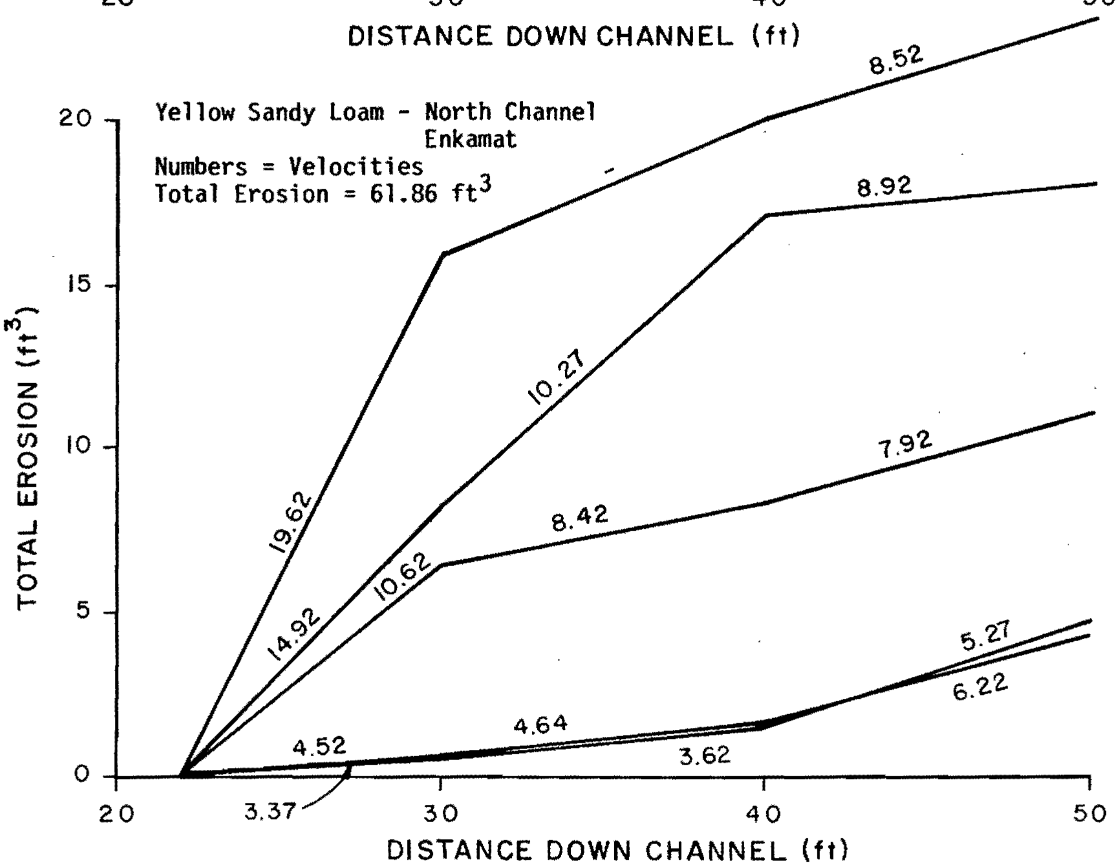


Fig. 8. Test set no. 4.

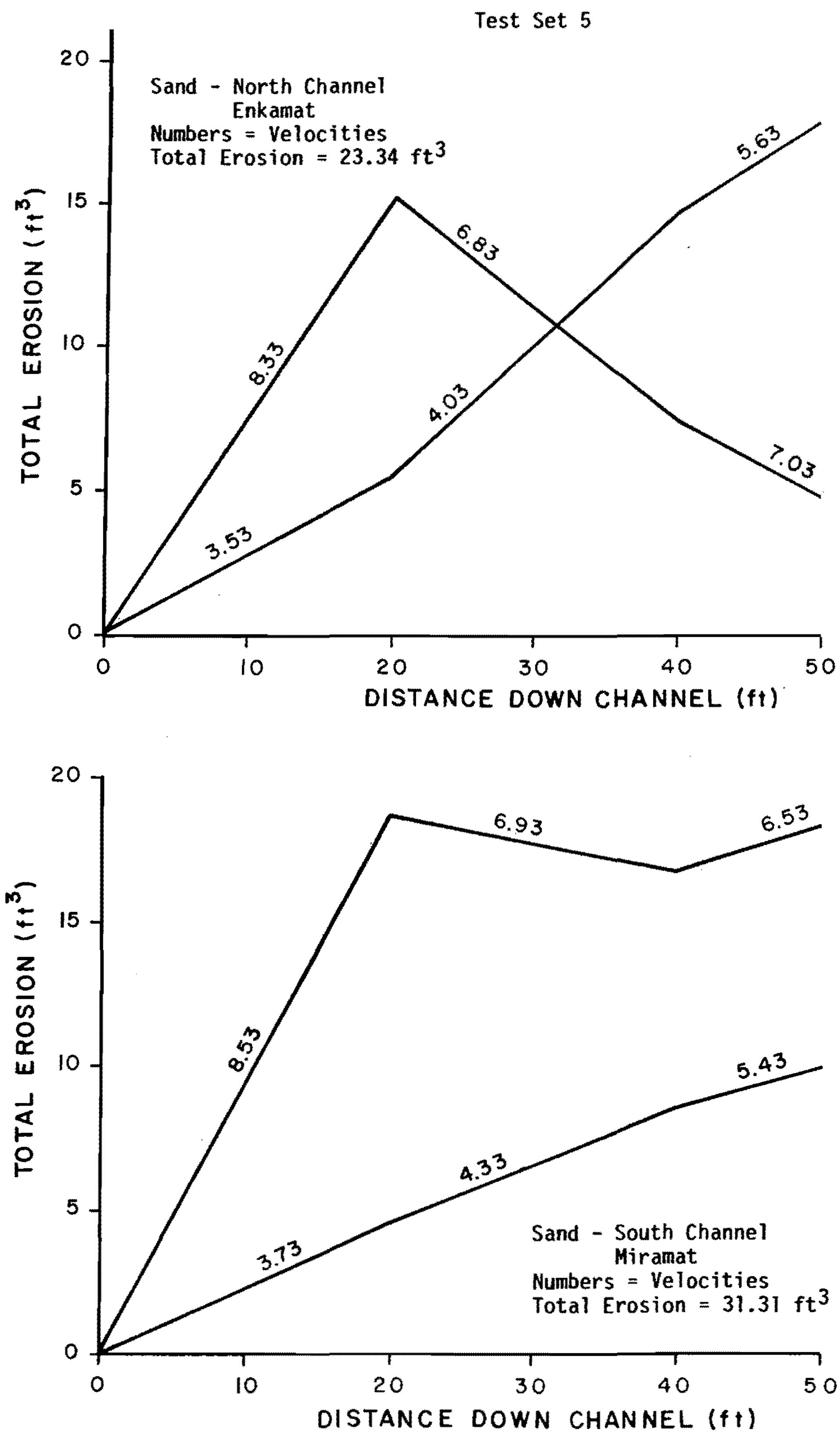


Fig. 9. Test set no. 5.

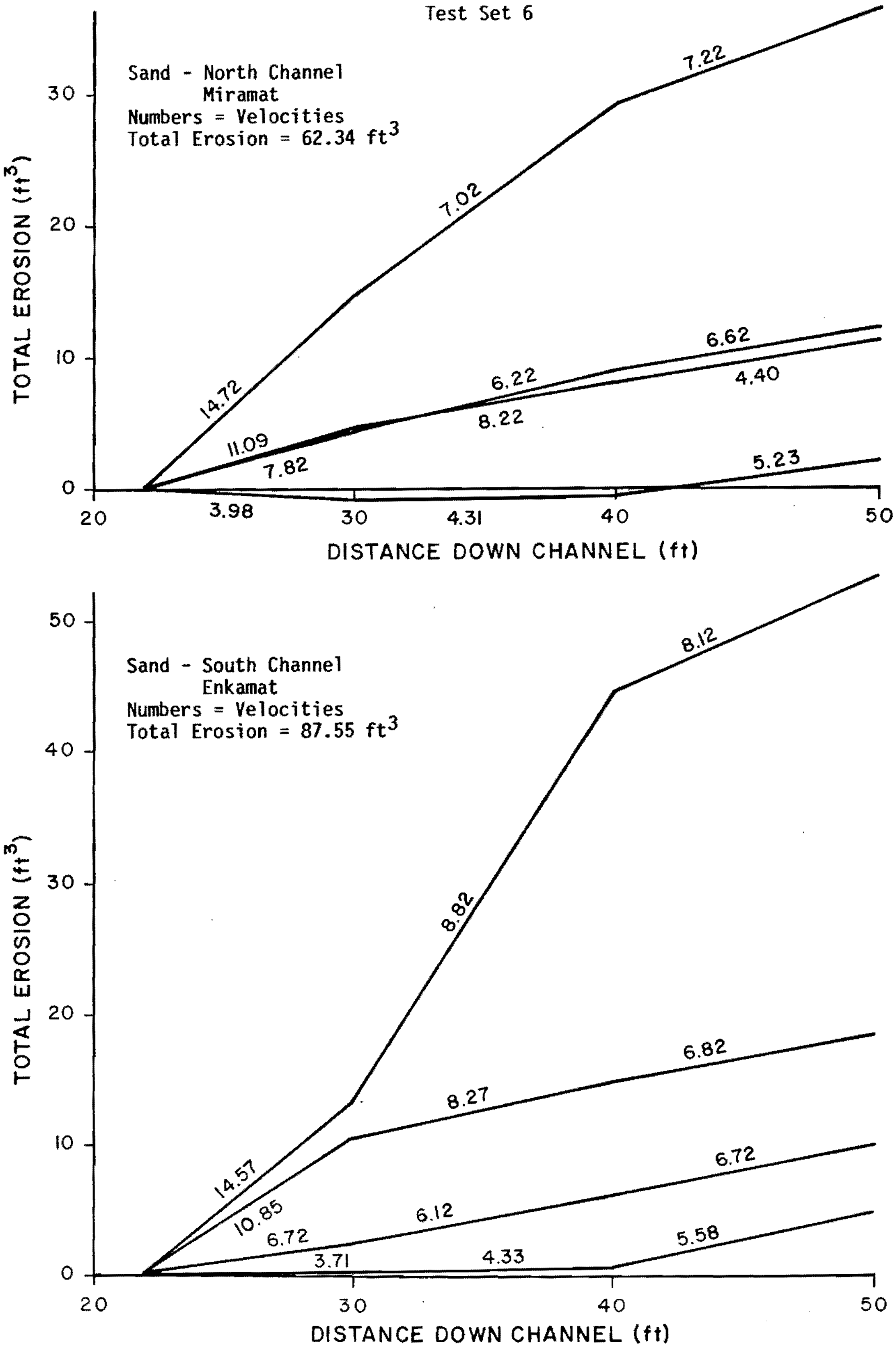


Fig. 10. Test set no. 6.

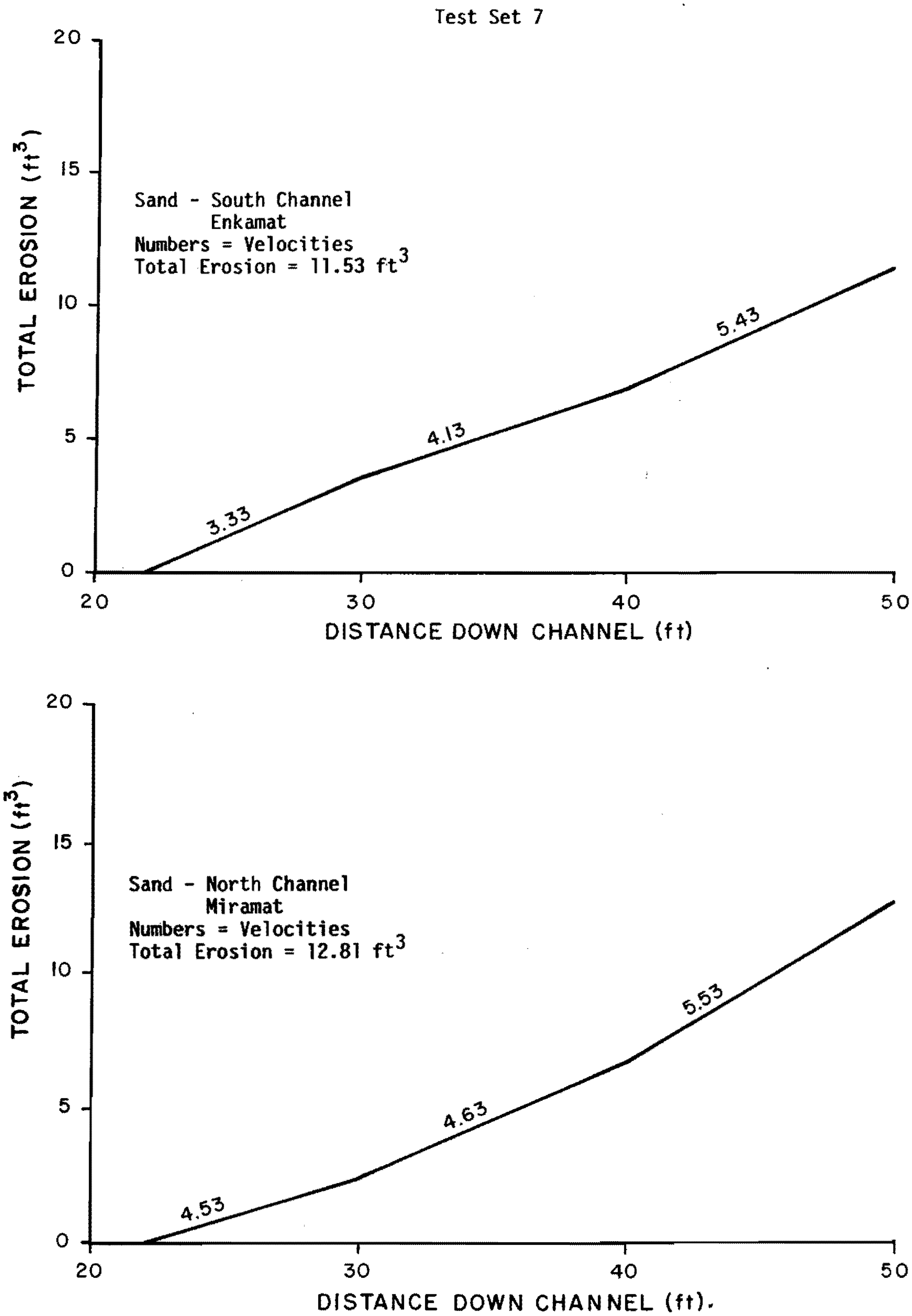
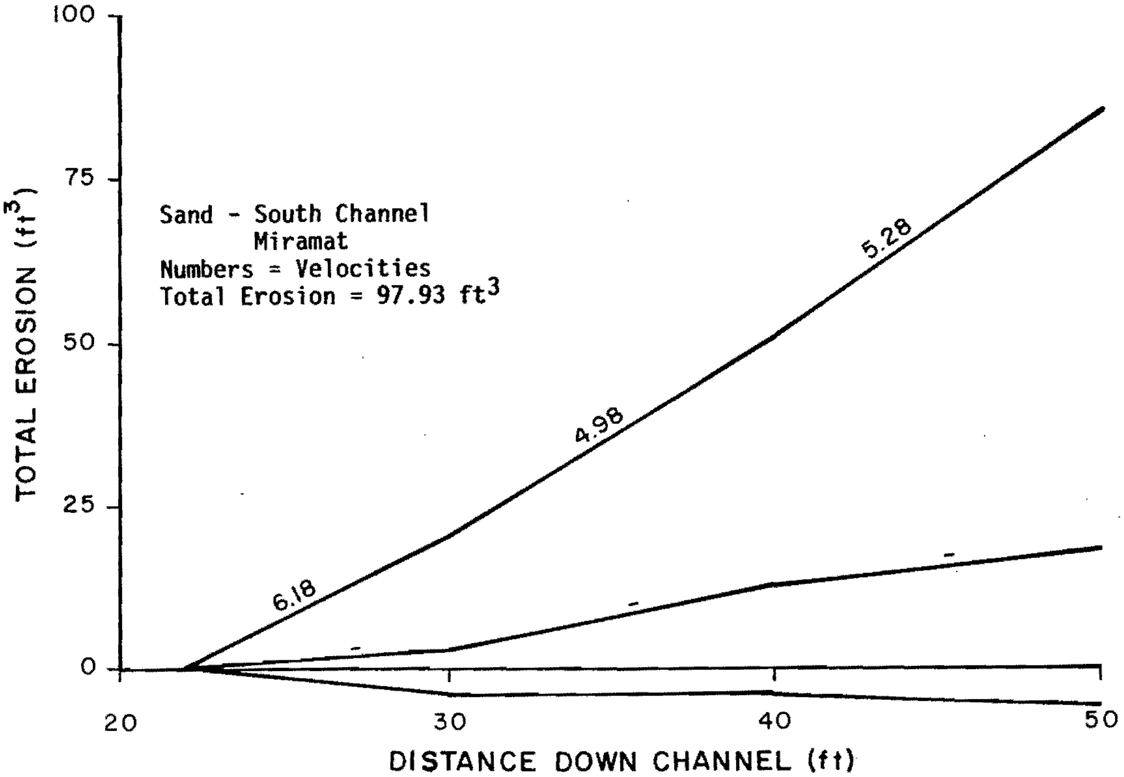


Fig. 11. Test set no. 7.

Test Set 8



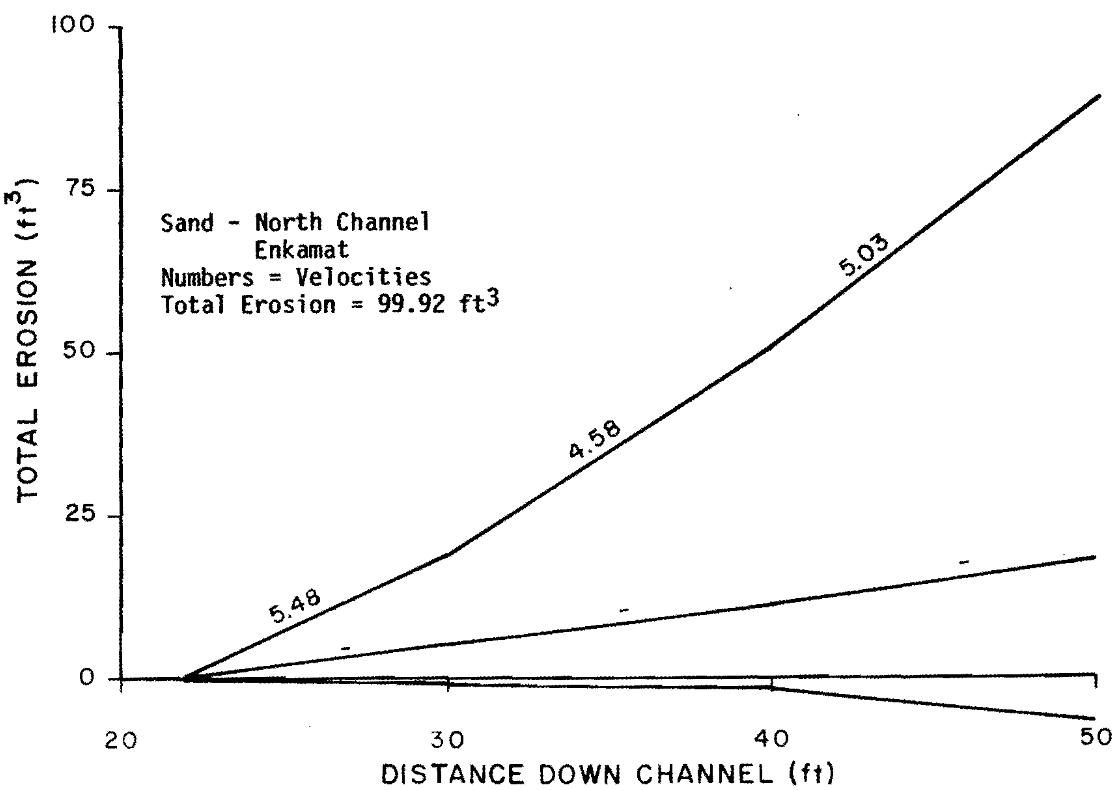


Fig. 12. Test set no. 8.

For purposes of plotting, the channels were divided into three sections. Soil eroded from an upstream section was either carried across or deposited in the downstream sections, in addition to the soil that was eroded from those sections themselves.

Retardance Coefficient

Using the Manning formula shown below, values for the retardance coefficient, or roughness, n, were calculated for some of the test runs, and are shown in Table 11.

$$n = \frac{1.486}{Q} A\ R^{2/3}\ S^{1/2}$$

in which

n = roughness or retardance coefficient

A = cross sectional area of the channel

S = slope of the water surface

Q = quantity of flow

R = hydraulic radius in feet = A/P

wherein

A = cross sectional area of channel

P = wetted perimeter of channel

The area (A) was an average of the cross sectional areas of the channel at the upstream and downstream locations where velocity was measured. The hydraulic radius (R) was computed using the average area and average wetted perimeter. The slope (S) was computed using velocity heads and water depths at either end of the channel. Q was measured directly with a sonic meter in the supply line to the channel.

Table 11. Roughness (retardance) coefficient.

ECRM	Soil	Discharge (cfs)	Manning Coefficient n
Miramat	Silt Loam	10	0.0036
Miramat	Silt Loam	16	0.0408
Miramat	Silt Loam	22.5	0.0318
Miramat	Silt Loam	30	0.0366
Miramat	Silt Loam	37.5	0.0374
Average			0.03004
Enkamat	Silt Loam	10	0.0042
Enkamat	Silt Loam	16	0.0398
Enkamat	Silt Loam	22.5	0.0350
Enkamat	Silt Loam	30	0.0428
Enkamat	Silt Loam	37.5	0.0628
Average			0.03692

Discussion

The planned procedure to determine the permissible velocity was to increase the discharge rate for each successive test to obtain higher velocities. These velocities were to be compared with the rate of erosion of the channel bed to see if a relation existed. Also sought was the velocity that marked the beginning of excessive erosion, and this velocity then would be the maximum allowable, the safe or permissible velocity. However, there could not be found a consistent relation between velocity of flow and rate of erosion, although in general the quantity of soil moved increased as velocity increased. Therefore, it was not possible to establish a permissible velocity based on the velocity-erosion relation.

The graphs of quantity of erosion versus distance along the channel (Figures 5 through 12) all have generally similar shapes (with the exception of a few anomalies). Initially, as the velocities are low, there is very little erosion taking place. As velocity increases the quantity of soil eroded also generally increases, and is either moved completely through the channel, or is deposited at some downstream location, or both. The velocity at which initial movement takes place is strongly dependent on the type of soil and on its degree of compaction.

In all of the runs involving sand there appeared to be erosion occurring on a continuous basis, increasing as the velocity increased. The same was true to a lesser extent on the fine silty soil. Of the tests run on this project the silt loam appeared to be the most stable. If ECRMs are to be used on sand, or on soil containing a lot of sand, there first should be some type of filter-fabric placed beneath the matting to prevent the fine particles from filtering through the ECRMs.

Velocity in a channel is dependent upon two major parameters, the slope and the hydraulic radius, as indicated by the following equation:

$$v = \frac{1.486}{n} r^{2/3} S^{1/2}$$

The hydraulic radius is determined by the cross-sectional area of the channel, and the wetted perimeter, or that amount of channel surface that is in contact with the water, r = A/P. On any given site, where a particular ECRM is to be used, the values for n and S will be fixed. Then the anticipated velocity can be controlled within limits, by varying the shape of the channel, which determines the value for r. In some instances it may be possible to vary the slope as well, which would also directly affect velocity.

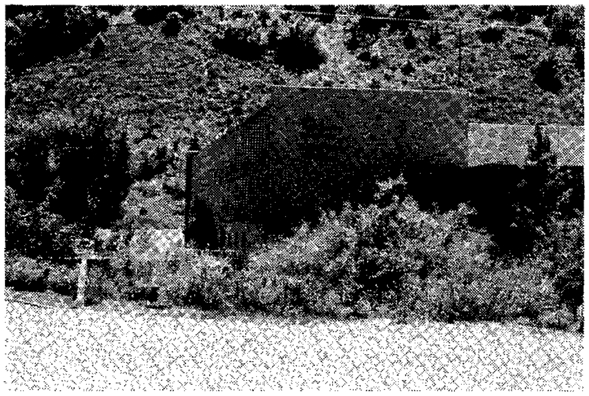


Fig. 13. Utah Water Research Laboratory, Logan, UT.

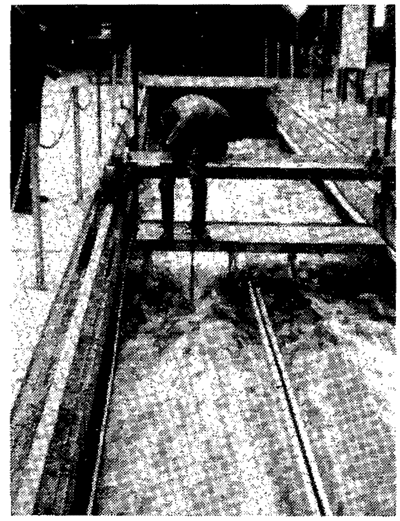


Fig. 14. Making flow velocity measurements using an electromagnetic probe.

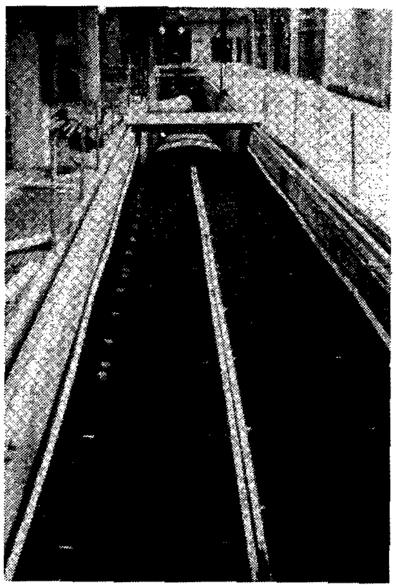


Fig. 15. Miramat staked in place ready for test run.

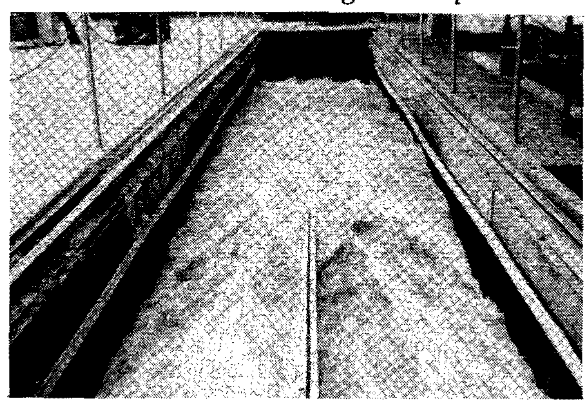


Fig. 16. A view downstream in high-velocity flow.

Fig. 17. Making channel profile measurements using a calibrated depth gage.

Fig. 18. A 36" diameter supply line provides water to the test channels.

Recommendations

The following recommendations were developed from observing the behavior and performance of the ECRM "MIRAMAT" installed on different kinds of compacted bare soils, and subjected to high-velocity flows of water.

1. Miramat is recommended for use on bare soil on steep slopes and in channels where concentrated flows of water having velocities of up to about 15 feet per second may be expected.

2. Shapes or channels on which Miramat is to be used should be smoothed, compacted, and cleared of large rocks and other debris so the mat will be in close contact with the soil. The greater the compaction of the soil, and the closer the matting is to it, the better the performance of the mat.

3. Eighteen-inch long smooth metal rods with 1 1/4" washers worked at least as well as 12"-long wooden stakes for anchoring the mat to the soil, and are more aesthetically pleasing as well. Corrugated metal rods worked even better because they adhered more firmly to the soil.

4. It is extremely important that the upstream end of the Miramat be properly anchored (according to manufacturer's recommendation) to prevent water from getting beneath the mat and causing premature failure.

5. Apparently the main value of anchoring Miramat mats in cross-ditchs at intervals is to prevent the material from stretching excessively between anchor points during high-velocity flows.

6. Metal rods or wooden stakes installed at 1-foot intervals across the matting every 25 feet along the length of the channel serve almost equally as well as cross-ditches for anchoring the matting in high velocity flows.

7. Performance of Miramat in protecting slopes and channels during high-velocity flows would be greatly enhanced with established vegetation growing through it. Placement of the mat over bare soil should be regarded as a temporary measure only until vegetation is in place.

8. Tests similar to those performed in this study should be performed on ECRMs with vegetation in place. Only in this manner can true protective values of the mats, over long periods of time, be determined.

APPENDIX

BLACK SOIL; 4 RUNS 19/2/85

TOTAL EROSION

SOUTH CHANNEL NORTH CHANNEL

37.025 103.6

INCREMENTAL EROSION PER RUN

-.1875012	.7999991
4.687502	6.775
10.4625	6.062498
22.0625	89.96

RUN #1		RUN #3		RUN #4		RUN #5	
0.0375	0.1375	0.3375	0.2250	0.4375	0.4875	4.3000	0.8750
-0.0250	0.2125	0.5375	0.8000	0.9500	0.8125	11.1375	8.0500
-0.0125	0.1250	0.8750	0.8500	0.6375	0.6875	13.5250	14.4375
0.0500	0.0500	0.7375	0.6375	0.7750	0.9125	7.2375	~~17.6625~~
0.1875	-0.0375	0.2875	0.8000	2.2875	0.9000	-0.6625	17.6500
0.2125	0.0000	0.3500	0.8125	2.3500	0.7500	-4.7500	14.2875
-0.2000	0.1250	0.4000	0.7000	1.0875	0.4875	-4.4875	9.0500
-0.2375	0.0250	0.3000	0.7000	0.5750	0.3500	-1.5000	3.0000
-0.2125	0.0375	0.1125	0.6125	0.3875	0.6375	-1.6375	1.9125
0.0125	0.1250	0.7500	0.6375	0.9750	0.0375	-1.1000	3.0250

BLACK SOIL; 5 RUNS 13/5/85

TOTAL EROSION

SOUTH CHANNEL NORTH CHANNEL

43.3375 56.35

INCREMENTAL EROSION PER RUN

3.7025	6.175
2.487499	6.032501
17.0875	18.3625
4.237501	4.380001
15.8225	21.4

RUN #1		RUN #2		RUN #3		RUN #4		RUN #5	
0.0900	0.0000	0.1875	0.3450	1.2000	2.0625	1.3125	1.4925	1.7850	4.4250
0.3750	0.0500	0.1625	0.3750	3.8375	2.3375	2.5375	2.4875	3.6000	8.5625
0.3375	-0.0500	0.0625	0.8125	3.6250	2.3750	1.3000	1.9500	4.1500	4.9375
0.3625	0.1250	0.1500	1.4000	2.1625	5.0125	0.4000	-0.0750	2.8625	1.0125
0.6375	1.5375	0.6750	2.1750	3.0250	3.6625	-0.3000	-0.5875	1.8500	0.8125
1.9000	4.5125	1.2500	0.9250	3.2375	2.9125	-1.0125	-0.8875	1.5750	1.6500

YELLOW CLAY; 5 RUNS 15/4/85

TOTAL EROSION

SOUTH CHANNEL	NORTH CHANNEL
94.58	55.27

INCREMENTAL EROSION PER RUN

1.622499	1.4575
4.02	.7499991
5.88	8.127501
13.53	17.98
69.5275	26.955

RUN #1		RUN #2		RUN #3		RUN #4		RUN #5	
-0.0150	0.1200	0.0825	0.0750	0.9675	1.3650	2.8050	3.1425	5.8275	0.8550
-0.0250	0.3125	0.0375	0.1250	0.8750	1.4750	5.5375	7.0000	15.6375	6.6375
0.1125	0.1750	0.1375	0.2125	0.4750	1.1125	1.7875	3.4750	15.8125	9.2375
0.3250	0.2250	0.3000	0.1875	0.5000	1.7250	1.7750	2.2375	11.7375	5.7500
0.4625	0.1875	1.2250	0.0500	1.6000	1.6250	1.1000	1.1375	11.9250	2.0875
0.7625	0.4375	2.2375	0.1000	1.4625	0.8250	0.5250	0.9875	8.5875	2.3875

YELLOW CLAY; 5 RUNS 22/5/85

TOTAL EROSION

SOUTH CHANNEL	NORTH CHANNEL
111.76	61.84251

INCREMENTAL EROSION PER RUN

6.577501	4.9275
4.084999	4.3525
9.975001	11.18
13.01	18.2
78.1125	23.1825

RUN #1		RUN #2		RUN #3		RUN #4		RUN #5	
0.3900	0.0900	0.0225	0.4275	2.5500	2.2425	3.2475	3.4500	5.7375	9.2325
0.6625	0.5000	0.2125	0.1750	3.0875	4.3000	4.2125	4.8000	17.2500	6.7250
0.6250	0.7500	0.5875	0.1250	0.6375	0.8375	2.7625	5.7000	20.9375	1.8500
0.9125	0.1500	0.7375	1.0250	1.0000	0.9750	1.1375	3.1750	19.2625	2.4500
1.2000	0.9375	1.2000	1.2750	1.1750	1.3250	1.0000	1.1625	11.0500	1.2125
2.7875	2.5000	1.3250	1.3250	1.5250	1.5000	0.6500	-0.0875	3.8750	1.7125

SAND; 2 RUNS 19/3/85

TOTAL EROSION

SOUTH CHANNEL NORTH CHANNEL

31.3125 23.3375

INCREMENTAL EROSION PER RUN

11.3625 21.2
19.95 2.137499

RUN #1		RUN #2		RUN #3		RUN #4		RUN #5	
1.9625	1.5750	-0.2875	-0.3125	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.9750	2.5375	9.7625	5.6000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.1875	1.0375	10.4000	8.3000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.5125	0.4125	-1.1125	1.7625	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.6625	2.2500	-1.7375	-1.2875	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.8375	2.5250	-0.5625	-1.5000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.1500	1.9375	-0.2375	-2.4125	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.4125	2.4625	0.5500	-2.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.7125	2.2250	1.2000	-2.2750	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.9500	4.2375	1.9750	-3.0375	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

SAND; 4 RUNS 1/4/85

TOTAL EROSION

SOUTH CHANNEL NORTH CHANNEL

87.5475 62.34001

INCREMENTAL EROSION PER RUN

5.75 2.135
10.035 12.24
18.325 11.4275
53.4375 36.5375

RUN #1		RUN #2		RUN #3		RUN #4		RUN #5	
0.1125	-0.3900	0.8850	1.4025	3.7125	0.9900	2.7750	6.0750	0.0000	0.0000
0.1625	-0.2750	1.7250	3.0125	6.8625	3.7375	10.6375	8.6375	0.0000	0.0000
-0.0125	-0.0500	1.7750	2.5250	2.9750	2.1500	17.8125	8.3625	0.0000	0.0000
0.5500	0.4500	1.8375	2.2625	1.3250	1.1500	13.1625	6.2250	0.0000	0.0000
1.9875	1.1000	1.8375	1.8875	1.1500	1.2500	6.7375	4.0125	0.0000	0.0000
2.9500	1.3000	1.9750	1.1500	2.3000	2.1500	2.3125	3.2250	0.0000	0.0000

SAND; 1 RUN 25/3/85

TOTAL EROSION

SOUTH CHANNEL NORTH CHANNEL

11.5225 12.8025

INCREMENTAL EROSION PER RUN

11.5225 12.8025

RUN #1		RUN #2		RUN #3		RUN #4		RUN #5	
1.8975	0.6150	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.7125	1.8000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.7500	2.4125	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.5750	1.9625	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.0750	2.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.5125	3.3125	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LONG RUN SAND; 3 RUNS 29/4/85

TOTAL EROSION

SOUTH CHANNEL NORTH CHANNEL

97.91001 99.92999

INCREMENTAL EROSION PER RUN

85.45751 89.14499
18.13 18.385
-5.6775 -7.600001

RUN #1		RUN #2		RUN #3		RUN #4		RUN #5	
5.3700	4.8450	1.4925	0.9975	-1.1025	-0.4125	0.0000	0.0000	0.0000	0.0000
14.8250	13.7375	1.4125	4.2875	-2.1625	-0.2250	0.0000	0.0000	0.0000	0.0000
16.2125	15.5125	3.9500	4.8750	-0.1000	0.4375	0.0000	0.0000	0.0000	0.0000
15.3250	17.4500	6.2250	2.3125	-0.2500	-1.1625	0.0000	0.0000	0.0000	0.0000
16.9875	19.0875	2.9500	2.2000	-1.0125	-2.7750	0.0000	0.0000	0.0000	0.0000
16.7375	18.5125	2.1000	3.7125	-1.0500	-3.4625	0.0000	0.0000	0.0000	0.0000