THE EFFECTS OF TWO DIFFERENT VEGETATIVE COVERS OF VARIOUS PHYSIOLOGICAL AGES ON THE HYDRAULICS OF CONSERVATION CHANNELS

By

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INTRODUCTION

Land surface treatment in such a manner as to obtain an orderly and economical disposal of runoff water from all sources is a major problem associated with waterway construction.

The period from completion of the waterway until a permanent vegetative cover is established is the most critical. Heavy rains on a newly constructed and planted waterway will probably result in damage from scouring. This scouring results in rills which are slow to cover, and eventually this leads to channel failure when floods occur.

Grass, particularly the sod-forming species, are among the best types of vegetation for the prevention of soil losses through erosion. The permanent vegetative covers are generally perennial in nature and somewhat slower in their initial rate of growth than annual species. Too, the time of completion of the waterway may not coincide with the optimum dates for planting the permanent species.

With the use of annual forage species, the possibility exists of providing a temporary vegetative cover prior to and during the period of establishment of the permanent vegetation for waterways. Among the annual grass species there are both warm and cool season types which afford an opportunity to select one for the particular period of the year when a temporary cover is needed.

The purpose of this study is to evaluate annual forage species which may be used as a temporary vegetative cover from the time a waterway is completed until a permanent vegetative cover can be established.

REVIEW OF LITERATURE

Ree (7)[1], in a study at Stillwater, Oklahoma, reported that the most important property of a cover of vegetation for vegetated waterways is to protect the waterway from erosion. The usual measure of the protective ability of a specific cover of vegetation is the maximum velocity to which the vegetative cover can be subjected and still protect the channel from serious damage. This maximum velocity is termed permissible velocity. Ree, in the same study reported that sod forming grasses had a higher permissible velocity tolerance than did the bunch type grasses, due to bare soil surrounding the bunch grasses. The slope of the channel also will affect the permissible velocity of a specific vegetation cover.

Sudangrass, a fast growing summer annual, was tested as a temporary cover for waterways from which flows could not be diverted while perennial plants were becoming established. Ramser (5) found that the permissible velocity of mature, green sudangrass lined waterways with a moderate slope was about 4 feet per second (hereafter designated feet/second) and waterways lined with dead sudangrass was about 3 feet/second. Cook and Campbell (2) found that dead sudangrass lined waterways with a six per cent slope had a permissible velocity of 5 feet/second. Ree (8) reported that two different soil types in waterways with a five per cent slope would influence the permissible velocity of green, mature sudan-

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[1] Figures in parenthesis refer to Literature Cited.

grass. He found the permissible velocity of sudangrass in waterways with an erosion resistant soil was about 3.5 feet/second, and 2.5 feet/second on an easily eroded soil.

Ramser (9) reported an objection to the use of sudangrass for waterways lining as it tended to crowd out all permanent vegetation which was seeded with it, and after the sudangrass was dead, the channel had very little protection.

Bermudagrass is used extensively in waterways in the south because it can tolerate high velocities of water. Ramser (5, 9) found that the permissible velocity of short bermudagrass in waterways, with a slope of 10 to 20 per cent, was reported to be about 7 to 8 feet/second, while uncut, green bermudagrass was about 7 feet/second. Dormant bermudagrass lined waterways with a 10 per cent or less slope was able to endure a velocity of 8 feet/second, and 6 feet/second on a six per cent slope, according to Cook and Campbell (1).

Ramser (9) reported a mixture of redtop, orchardgrass, common lespedeza and Italian ryegrass has a permissible velocity of 6.5 feet/second when used as a waterway lining. Cox and Palmer (2) found that a native grass mixture and weeping lovegrass could endure a velocity of 3.5 feet/second on a five per cent slope. Buffalograss and bluegrama, in the same study had a permissible velocity of 7 feet/second in waterways with a 10 per cent slope. A mixture of timothy and redtop had a permissible velocity of 7 feet/second in the first, second and third year after establishment in waterways on a Putman silt loam, according to Ramser (9). Smith (10) found that Kentucky bluegrass, in a thin stand condition, could only tolerate a velocity of 3 feet/second in waterways with a slope of four per cent in the first year after establishment, but after the second year of growth, the permissible velocity increased to 7 feet/second.

Ree and Palmer (8) found that centipede grass, a sod forming grass in the southern United States, showed a permissible velocity of 9 feet/second while in a green condition, and 8 feet/second in the dormant condition, with a slope less than 10 per cent.

Ree (6) reported that kudzu could withstand a velocity of 3 feet/second in the green condition and 2.5 feet/second in the dormant condition when used in waterways with a three per cent slope.

In tests with other legumes, Ramser (5) found that common lespedeza in the green, uncut condition had a permissible velocity of 5.5 feet/second, and in the green, cut condition, the permissible velocity was 7 feet/second. The lespedeza stubble in the fall of the year, endured less than 1 foot/second. Cox and Palmer (2) reported that alfalfa had a permissible velocity of 3 feet/second in waterways with a slope of three per cent.

Hamilton (3) recommended the use of quick establishing annuals such as small grains, sudangrass, domestic ryegrass, and similar crops which may be seeded in the spring to hold the soil effectively, and also produce a mulch in which to seed the permanent vegetation the following fall. Holmberg (4) reported that the use of a companion crop, such as oats and rye, when seeded with the permanent vegetation, would offer temporary erosion control and provide a mulch for the establishment of the permanent vegetation.

MATERIALS AND METHODS

A study to determine the effects of two different vegetative covers of various physiological ages on the hydraulics of conservation channels was conducted at the Stillwater Outdoor Hydraulic Laboratory located 5 miles west, 2 miles north, 1 mile west and 1/2 mile south of Stillwater, Oklahoma at Lake Carl Blackwell in 1959.

The field layout consisted of 8 unit channels, 96 feet in length, 3 feet in width, and with a five per cent slope. Each of the channels was separated by a concrete wall which extended approximately 3 inches above the soil surface. Each treatment was replicated four times, with each channel designated as a replication. Due to apparatus limitations which influenced the method of testing, the four replications were located side by side. The water for testing purposes was discharged through a 12 inch pipe from Lake Carl Blackwell. Flow-rates were measured by an orifice meter located in this line.

Each channel had 9 testing stations for determining the topography of the channel beds. These stations were located at 20, 25, 30, 50, 55, 60, 80, 85, and 90 feet from the head of the channel. Each testing station consisted of an angle iron crossmember which served as a support for the McIntyre point gauge. The McIntyre point gauge, which is calibrated in thousandths of a foot, was used to measure the soil surface topography of the channel bed. The soil surface topography readings were made at 15 locations across the width of the channel at all nine stations. These measuring points were located at 0.1, 0.3, 0.5, 0.7, 0.9, 1.1, 1.3, 1.5, 1.7, 1.9, 2.1, 2.3, 2.5, 2.7, and 2.9 feet from the north wall of the channel.

The vegetative covers selected for this study were sudangrass, Sorghum sudanense (Stapf) and Triumph wheat, Triticum vulgare (L.). To simulate field conditions, sudangrass was arbitrarily designated the crop to be seeded if the waterway construction was completed after April 15 and prior to October 1, whereas, wheat was to be used in the period from September 1 to May 15. A one month overlap was purposely included in the dates for use of these two crops to fit various climatic conditions in Oklahoma. The number of viable seed in a pound was determined for each of these crops. The seeding rate was arbitrarily designated to provide 1 plant per square inch. This was achieved through the determination of and planting on the basis of per cent pure live seed for each crop variety and seed lot.

The channel bed was prepared for planting with a Roto-Tiller, Model 3 implement which stirred the soil to a depth of 4 to 5 inches. The channel was leveled to a depth of 3 inches below the channel wall. The channel was then compacted twice with a water filled roller which weighed approximately 160 pounds.

The seed was distributed over the channel in 2 passes by using a 3 foot Gandy fertilizer spreader, calibrated to deliver the desired amount of seed per channel. The seed was then stirred into the upper 1/2 inch of the soil surface with leaf rakes. The channel was again compacted twice with the roller. In addition, 1/2 to 1 inch of soil was spread over the channel to cover the seed better. Immediately after planting, the newly seeded channels were irrigated with approximately 1/2 inch of water. Irrigation was used throughout the growing season as needed.

The intensity of erosion on bare soil, subjected to increasing water flow-rates, was determined prior to the evaluation of the vegetative covers of four calendar ages after emergence. The plant covers were subjected initially to the same flow-rate of water on or about 5, 10, 20, and 40 days after emergence. Hereafter, each age group of vegetative cover subjected to various flow-rates of water will be referred to as an experiment. Each flow-rate of water was evaluated as to its soil erosive action and was designated as a test.

Each experiment began with the low flow-rate of water. If this flow failed to destroy the channels, the flow was increased in successive tests until destruction occurred.

The soil surface topography readings were made with the McIntyre point gauge immediately before each test began. The changes in the topography of the channel beds were obtained by subtracting the topography readings after each flow from the measurements obtained at the respective locations prior to the start of the tests. The changes in topography were grouped in increments of 0.02 foot for frequency distribution counts. Water surface readings were made with the McIntyre point gauge 10 minutes after the test had begun. At the end of each test, which was 40 minutes in duration, soil surface topography readings were again taken.

The type of coverage, planting and testing dates, plant age and water flow-rates are shown in Table I.

TABLE I

TYPE OF COVERAGE, PLANTING AND TESTING DATES, AGE OF PLANTS, AND FLOW VOLUMES USED IN STUDYING THE HYDRAULICS OF CONSERVATION CHANNELS AT STILLWATER OUTDOOR HYDRAULIC LABORATORY, STILLWATER, OKLAHOMA, 1959

Type of Coverage	Planting Date	Testing Date	Plant* Age	Flow Number	Flow Rate** Cu. Ft./Sec.
Bare Soil	-	April 20-21	-	1	0.04313
				2	0.1110***
Wheat	April 10	April 23-24	5	1	0.04541
				2	0.1172
Sudan	May 20	May 28-29	5	1	0.04125
				2	0.1350
Sudan	May 23	June 9-11	16	1	0.04806
				2	0.1180
				3	0.3685
				4	0.9037
Sudan	June 27	July 20-22	21	1	0.04114
				2	0.1170
Sudan	June 15	August 3-8	45	1	0.1186
				2	0.3706
				3	0.8813
				4	1.8241
				5	3.64715
				6	7.7625

* Determined from day of emergence.

** Average of the four channels.

*** Average of two channels, first flow destroyed two of the channels.

Plant stand counts and plant height were taken at 15 random locations throughout the channel before the tests began. Soil bulk density samples were also taken at this time.

Due to an infestation of nutgrass, Cyperus spp. (L.), which occurred after the first two experiments, the channels were sterilized with methyl bromide on May 10, 1959.

RESULTS AND DISCUSSION

In this study, the frequency distribution counts of the changes in topography of the channel beds (soil deposition or erosion) in the four replications were pooled by flows. It was felt that the 135 observations in each channel would not be an adequate sample to determine frequency distribution of the changes in the channel bed. Therefore, the 135 observations in each of the four replications were pooled to give 540 measurements of topography variations after each flow and treatment. The changes in the channel beds were plotted as an accumulated frequency distribution curve. Each experiment was plotted by the accumulated frequency distribution of changes in the channel bed obtained from the flow just preceding destruction of the channels and the last flow which destroyed the channels. In addition, frequency distribution counts were made on the changes in the channel bed at the first 3 stations as a group, the second 3 stations as a group and the third 3 stations as a group. These frequency counts were determined specifically to localize the area within the four replications where the greatest amount of erosion or deposition occurred.

Based on these data, which are only preliminary and probably inadequate, a prediction can be made of the probability of various degrees of erosion or deposition which will occur in the topography of a channel with a five per cent slope when subjected to a given flow-rate of water. For an example, the accumulated frequency distribution curve in Figure 9 indicates that a channel with a five per cent slope covered with a good stand of sudangrass, 16 to 20 days old and 8-10 inches tall will erode .08 of a foot or less 96 per cent of the time when subjected to a flow-rate of 0.3685 cubic feet/second. To arrive at this predicted value project a vertical line from the point of .08 foot erosion shown on the abscissa to the frequency distribution curve then to the ordinate at a right angle and read the per cent of occurrence on the ordinate scale.

A variation of plant stand was noted throughout the study as shown in Appendix Table I. Perhaps a reason for this variation is that the seed tended to collect along the sides and lower end of the channel especially if a rain occurred before germination. The predicted stand count based on pure live seed determinations did not materialize in the field. The plant height at various ages is shown in Appendix Table I.

The soil which was used in this study is a fine sandy clay with an average density reading of 1.28 grams/cubic centimeter. This density measurement indicates the soil is rather light and is probably easily eroded.

Two of the four replications in the experiment with no vegetative cover were destroyed by the first flow as shown in Figure 1. The remaining two replications had an infestation of nutgrass, Cyperus spp. of approximately 20 plants per square foot which perhaps is the reason these replications were not destroyed by the first flow, as shown in Figure 2. It should be noted that the first flow which destroyed the first 2 replications did not damage the channels as severely as did the flow which destroyed the second two replications. Figures 3 and 4 indicate the locations of the changes within the channels. The first three stations as a group eroded more than did the second or third group of three stations.

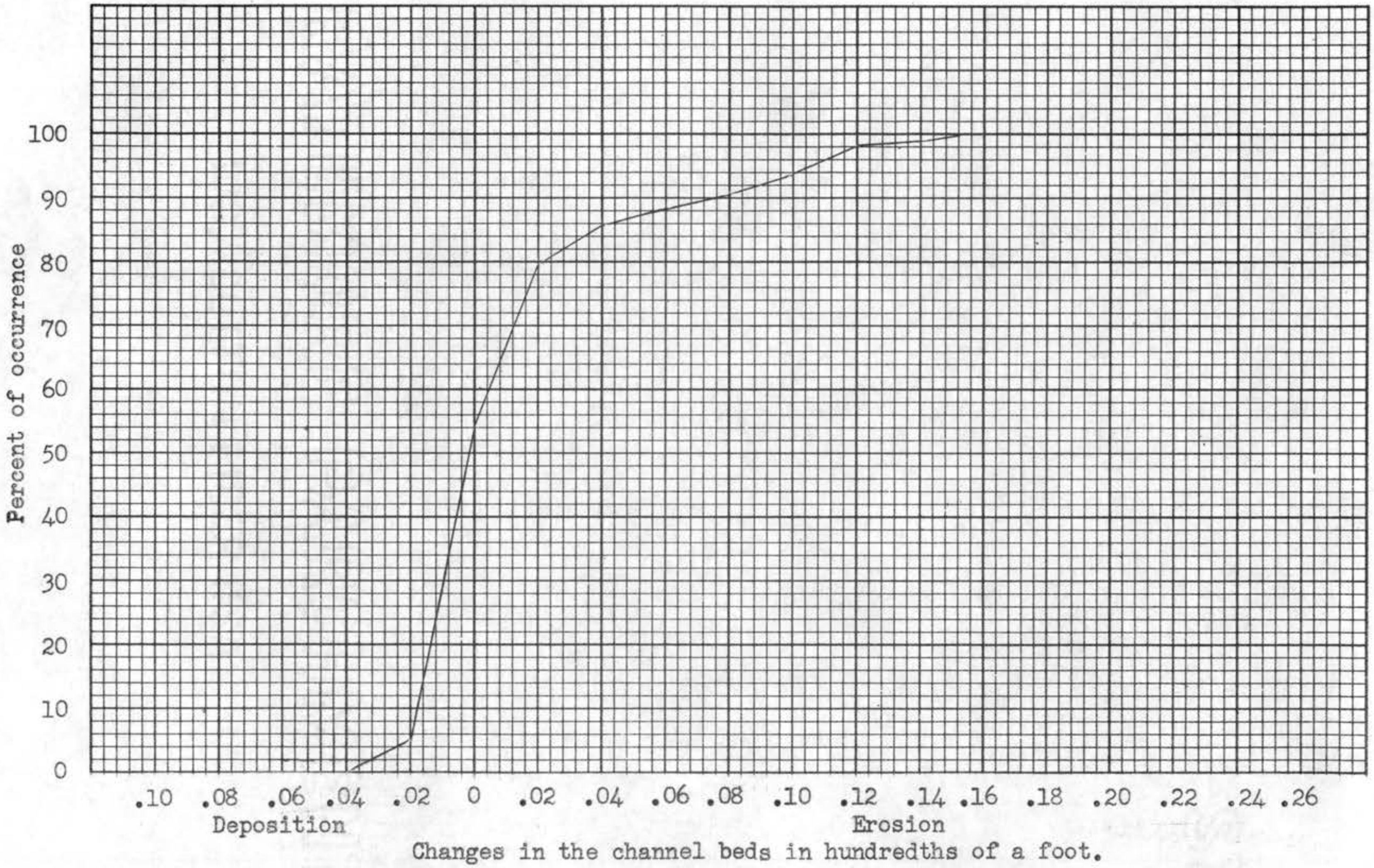

Figure 1. Accumulated frequency distribution curve of the changes in the channel beds of two replications, measured in hundredths of a foot, when protected by no vegetative cover and subjected to 0.04313 cubic feet/second of water flow.

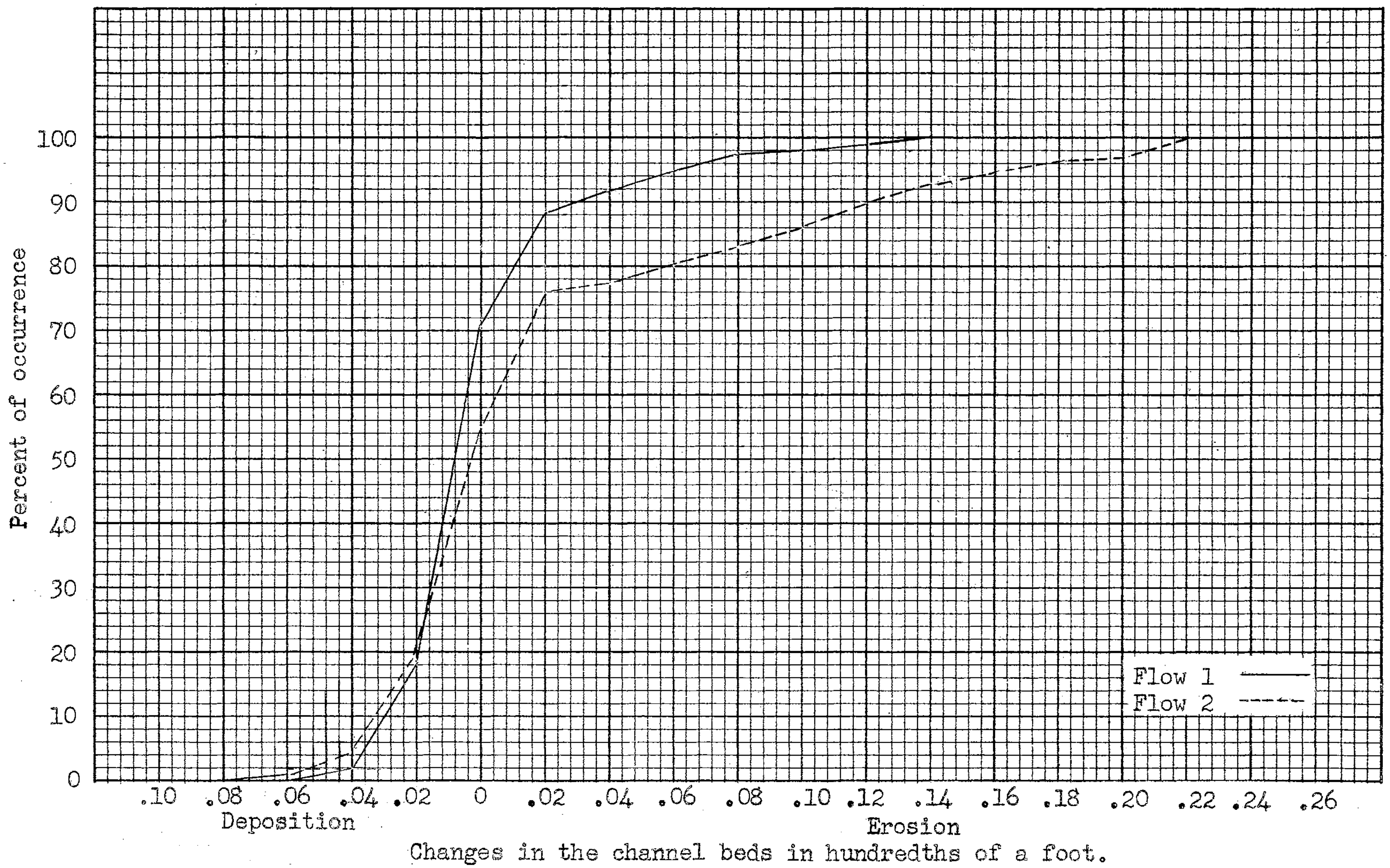

Figure 2. Accumulated frequency distribution curves of the changes in the channel beds of two replications, measured in hundredths of a foot, when protected by no vegetative cover and subjected to 0.04313 and 0.110 cubic feet/second of water flow.

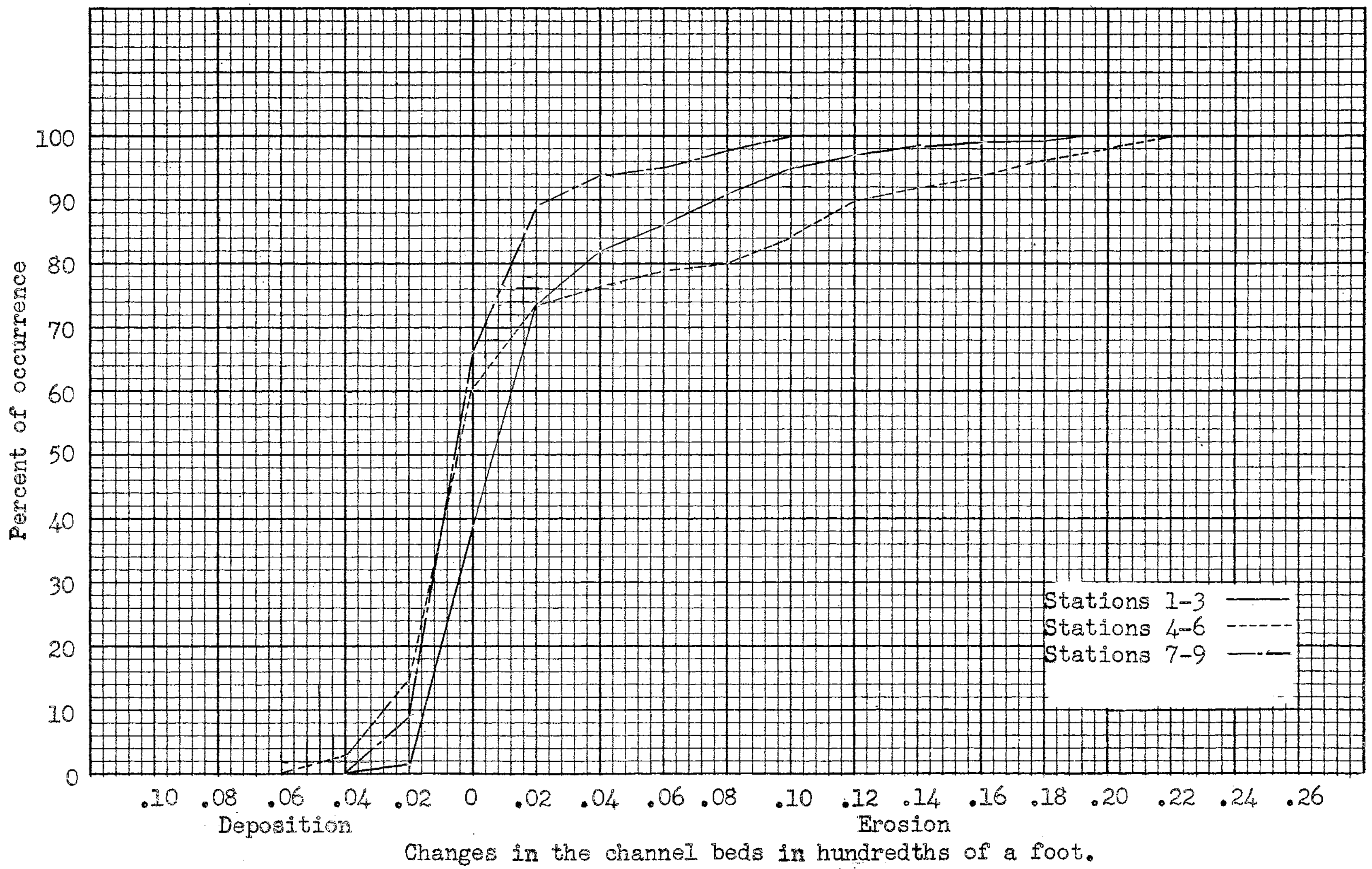

Figure 3. Accumulated frequency distribution curves of the changes in the channel beds of two replications of three groups of three stations each, measured in hundredths of a foot, when protected by no vegetative cover and subjected to 0.04313 cubic feet/second of water flow.

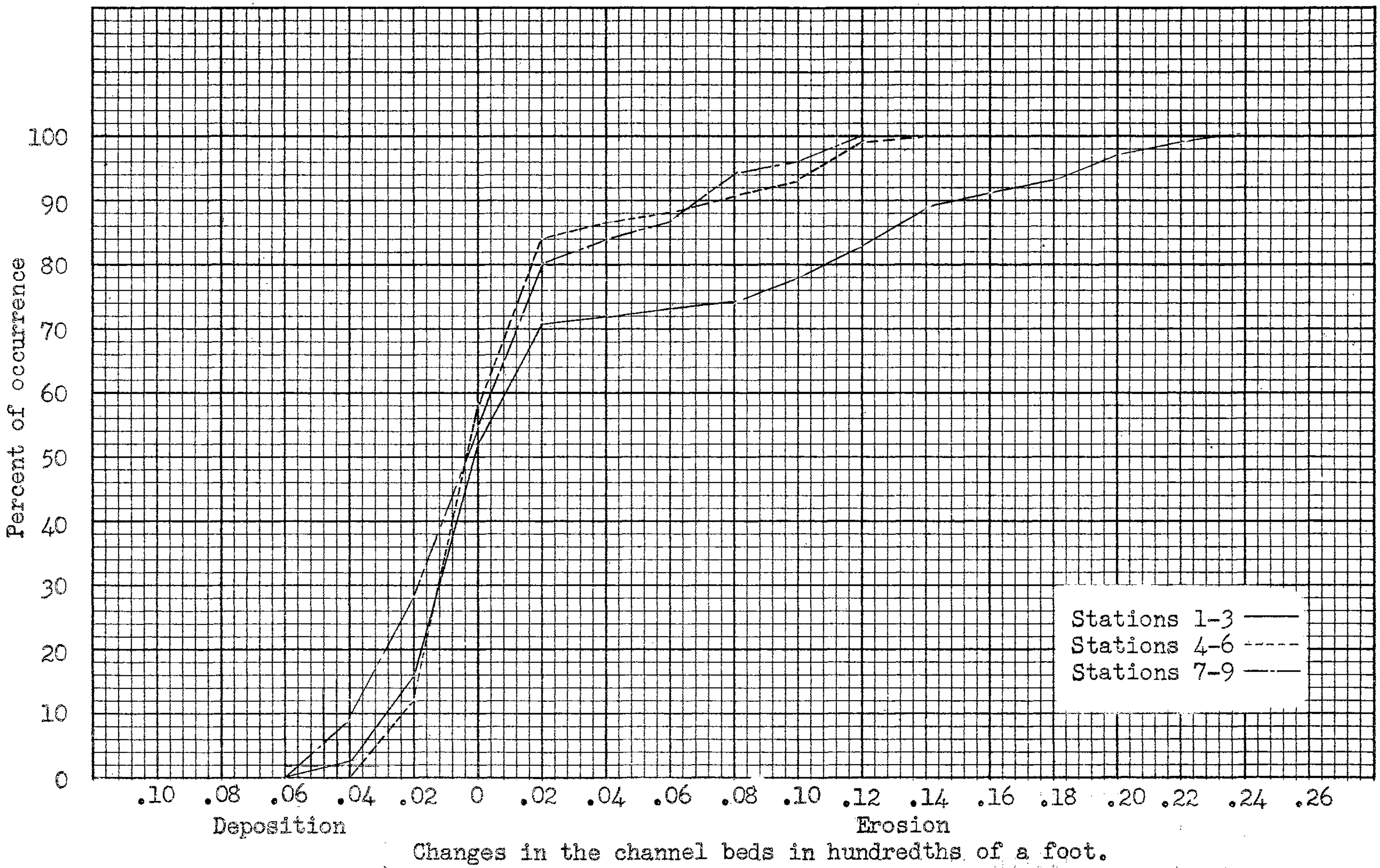

Figure 4. Accumulated frequency distribution curves of the changes in the channel beds of two replications of three groups of three stations each, measured in hundredths of a foot, when protected by no vegetative cover and subjected to 0.04313 and 0.110 cubic feet/second of water flow.

When comparing wheat at 5 days of age and 1 inch tall (Figure 5) with sudangrass 5 days of age and 2 inches tall (Figure 6) the channels with the wheat had less severe erosion than did the sudangrass lined channels. The sudangrass lined channels had 17 per cent more measurements of .08 foot or more (approximately 1 inch) than did the wheat. Figure 7 shows that the first group of stations had the greatest amount of erosion in the channels lined with wheat 5 days of age. Figure 8 shows that the first group of stations had more erosion than did the second or third group of stations, but the third group of stations eroded more than did the second.

The channels lined with sudangrass 16 days of age and 8 inches in height withstood 3 flow-rates of water before they were destroyed. All of the erosion by the first and second flow was .08 of a foot or less. The greatest amount of erosion occurred at the first group of stations, but the difference between the groups of stations was not as great as in the previous experiments as shown in Figure 10.

The channels covered with sudangrass 21 days of age and 10 inches in height were destroyed by 2 flows as shown in Figure 11. The early destruction was probably due to small rills present in the channel beds before the testing started. The prior damage was caused by heavy rains (Appendix Table II) which occurred soon after the channels were planted. The plant stand was very poor in this experiment which may account for some of the early erosion. Figure 12 shows that the second and third group of stations were almost identical in the amount of erosion, but again there was more erosion at the first group of stations than the others.

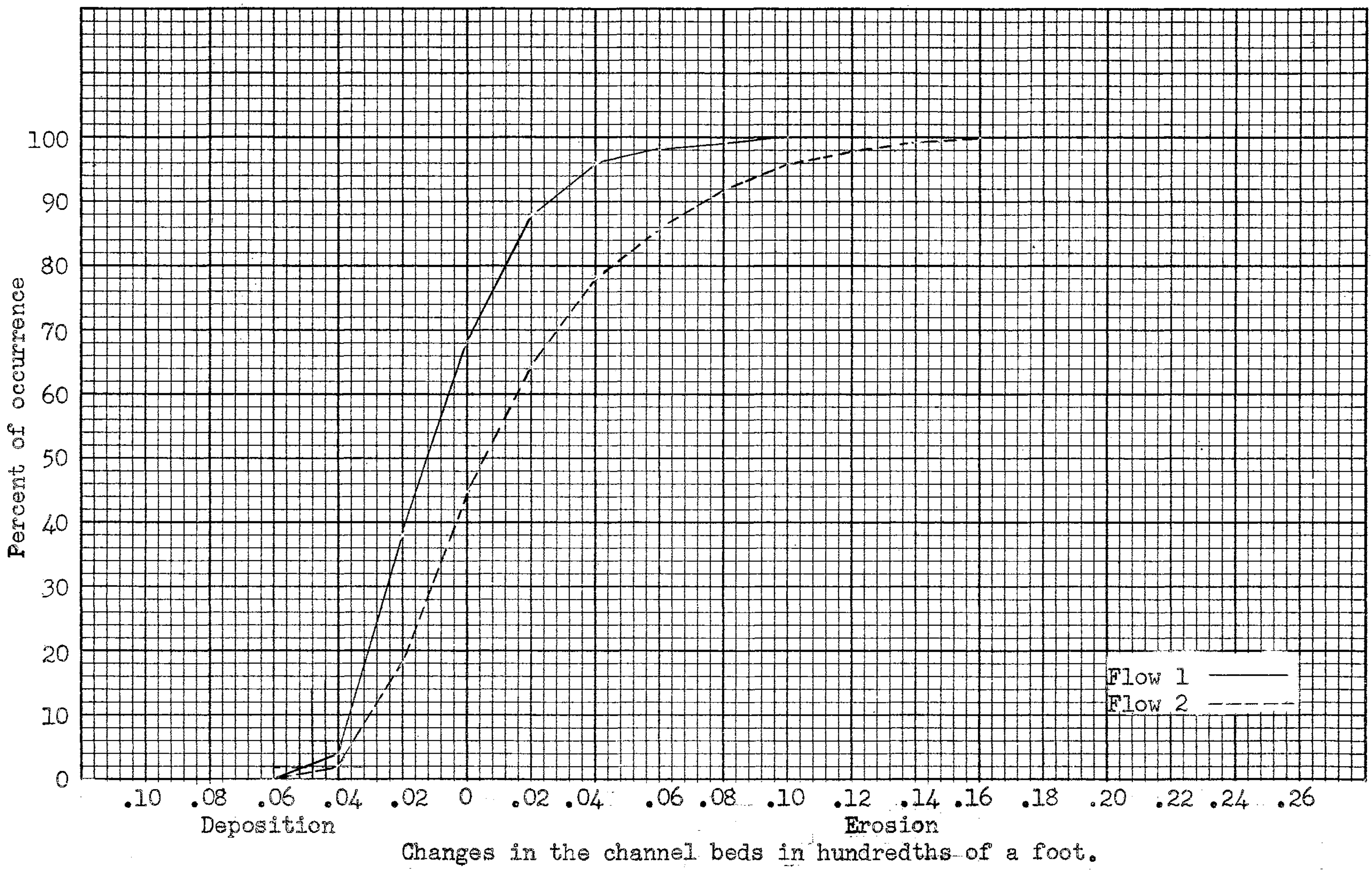

Figure 5. Accumulated frequency distribution curves of the changes in the channel beds of four replications, measured in hundredths of a foot, when protected by wheat at five days old and subjected to 0.04541 and 0.1172 cubic feet/second of water flow.

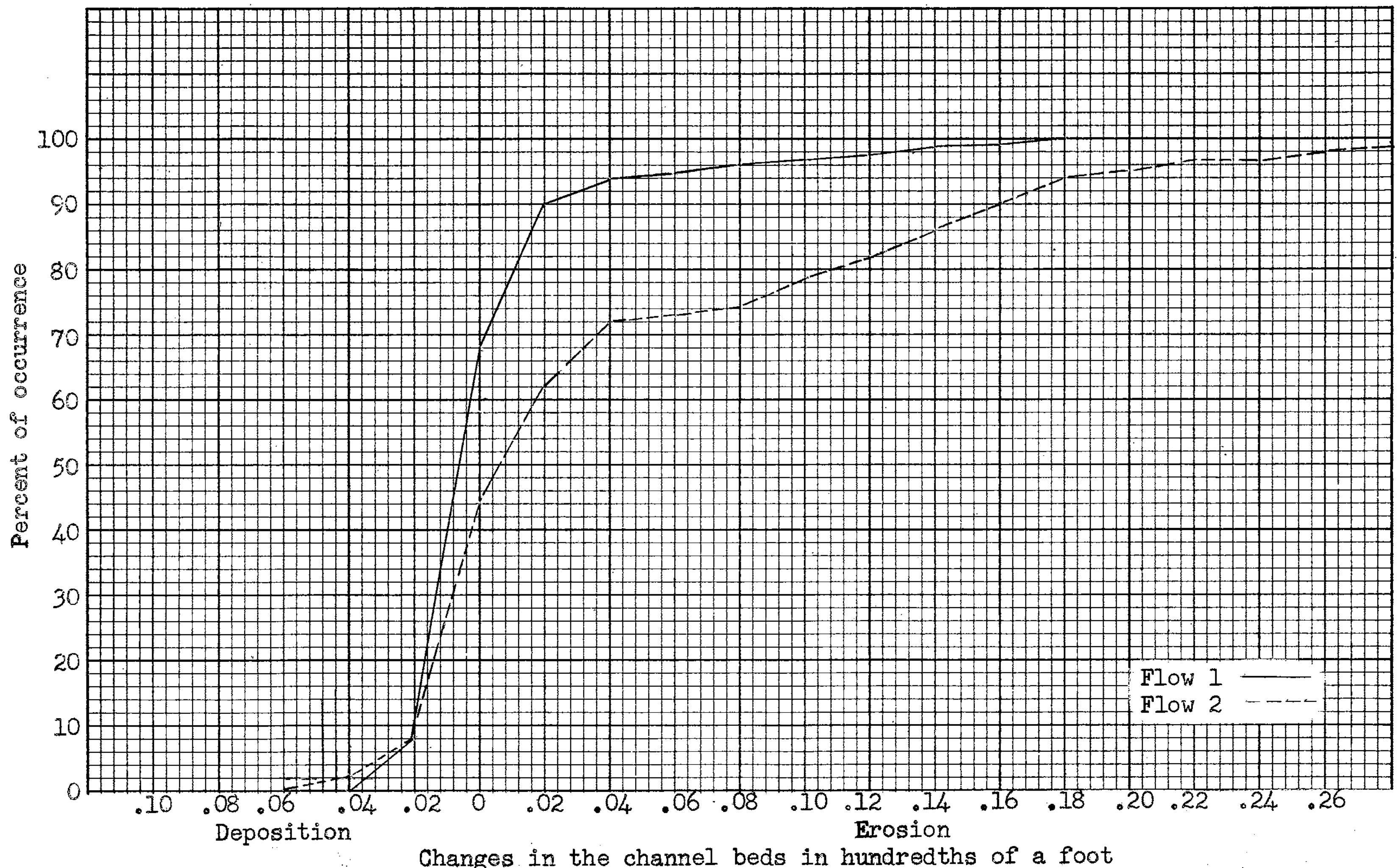

Figure 6. Accumulated frequency distribution curves of the changes in the channel beds of four replications, measured in hundredths of a foot, when protected by sudan at five days old and subjected to 0.04125 and 0.1350 cubic feet/second of water flow.

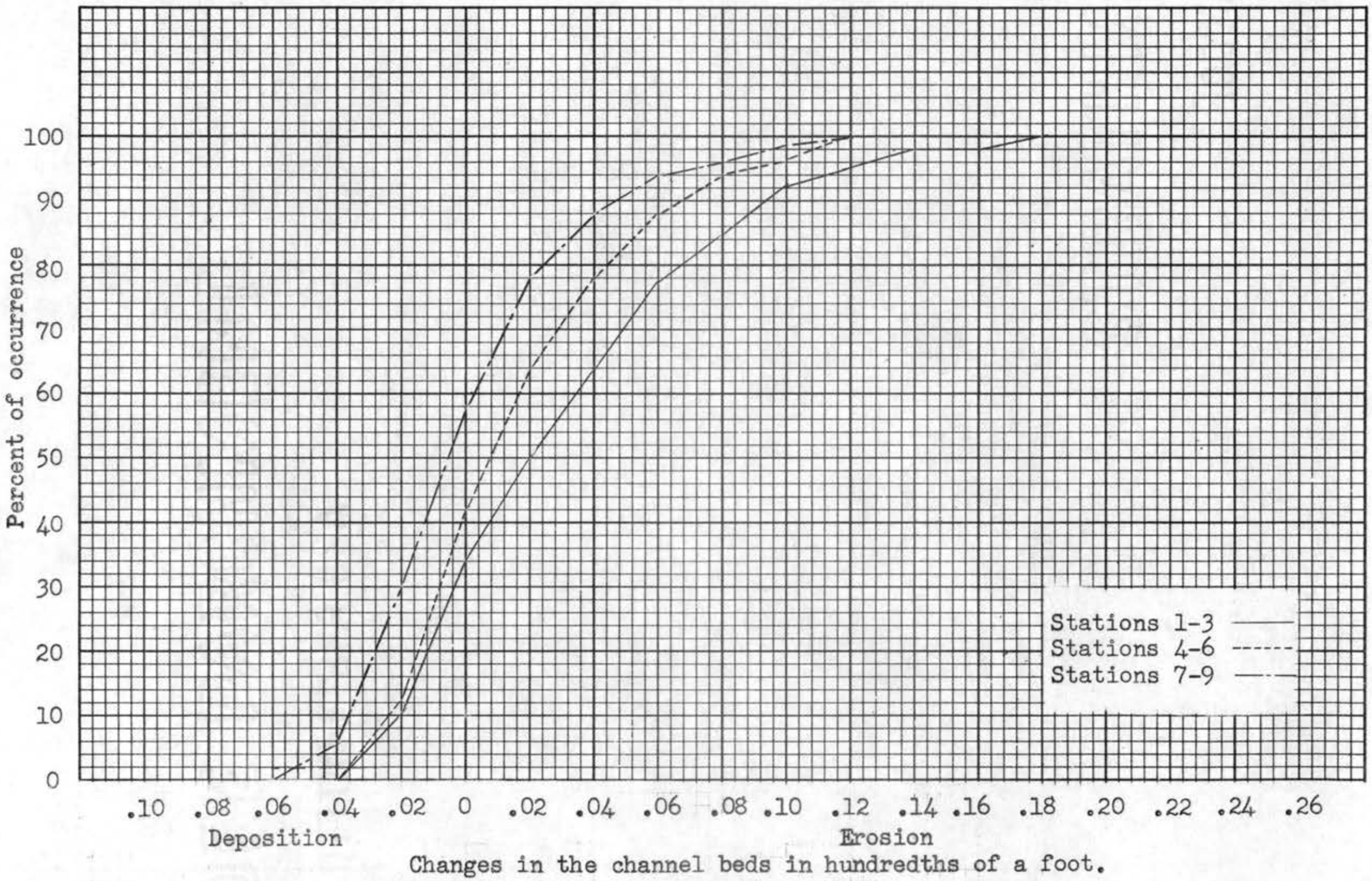

Figure 7. Accumulated frequency distribution curves of the changes in the channel beds of four replications of three groups of three stations each, measured in hundredths of a foot, when protected by wheat at five days old and subjected to 0.1172 cubic feet/second of water flow.

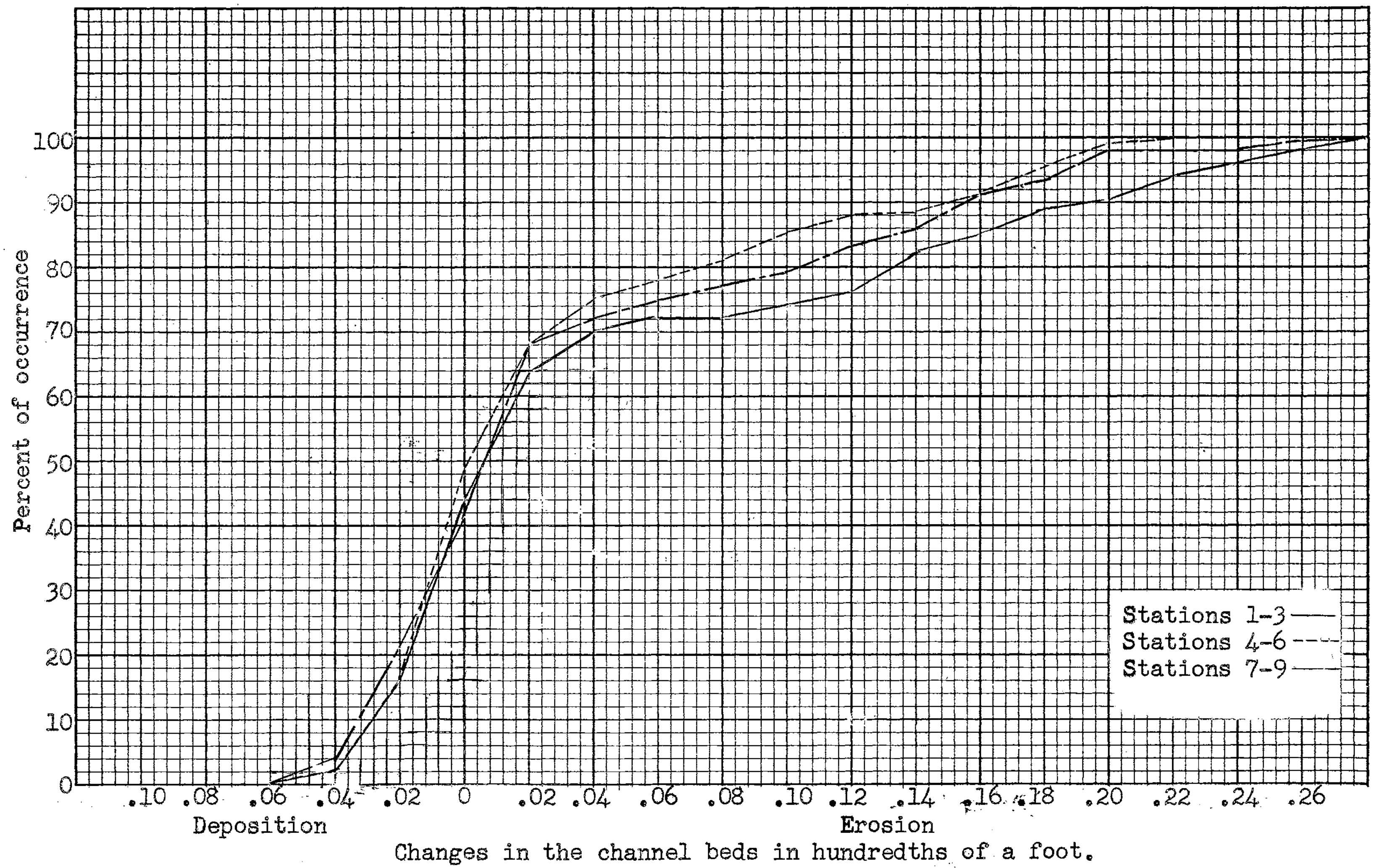

Figure 8. Accumulated frequency distribution curves of the changes in the channel beds of four replications of three groups of three stations each, measured in hundredths of a foot when protected by sudan at five days old and subjected to 0.1350 cubic feet/ second of water flow.

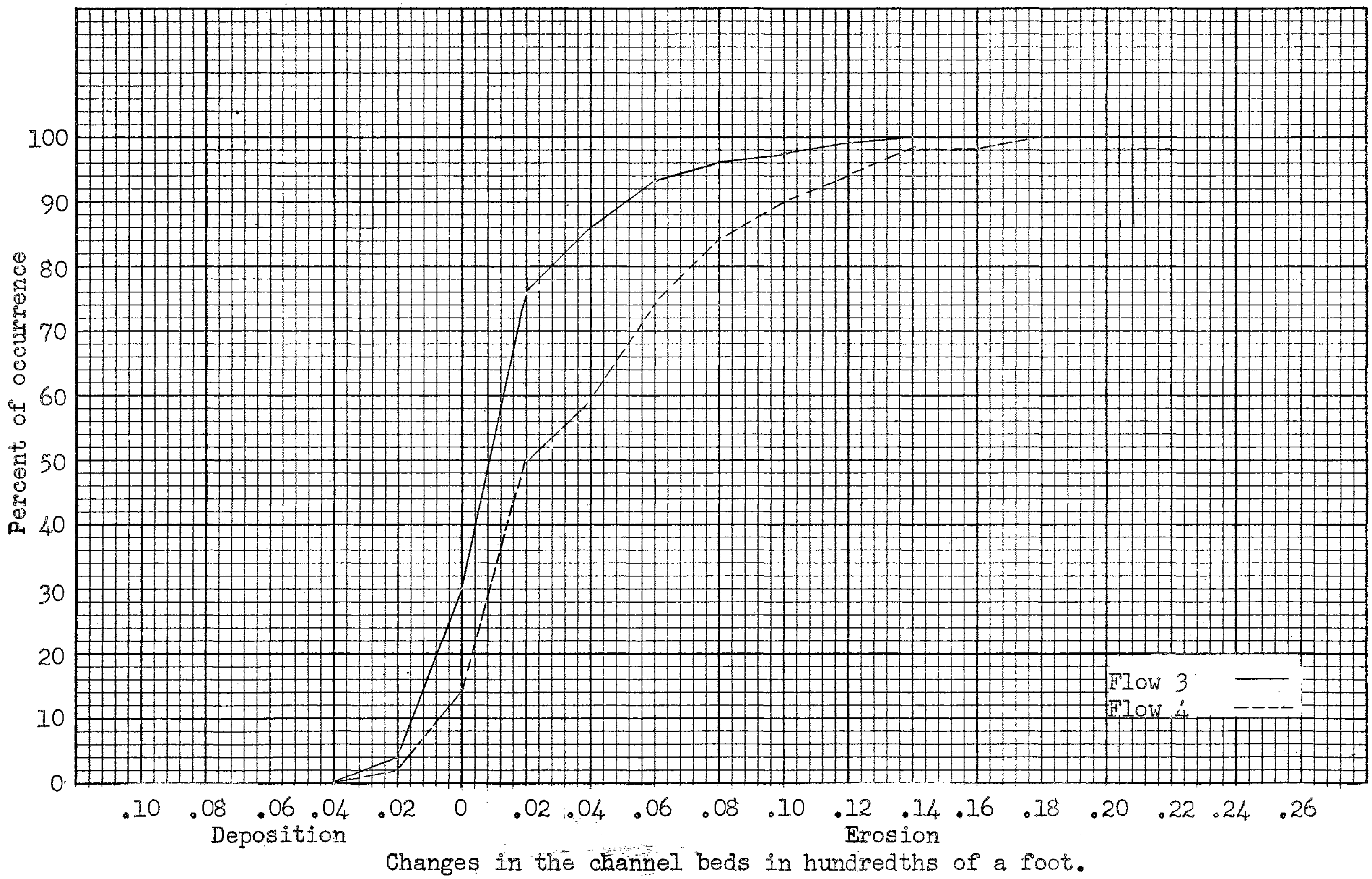

Figure 9. Accumulated frequency distribution curves of the changes in the channel beds of four replications, measured in hundredths of a foot, when protected by sudan at 16 days old and subjected to 0.3685 and 0.9037 cubic feet/second of water flow.

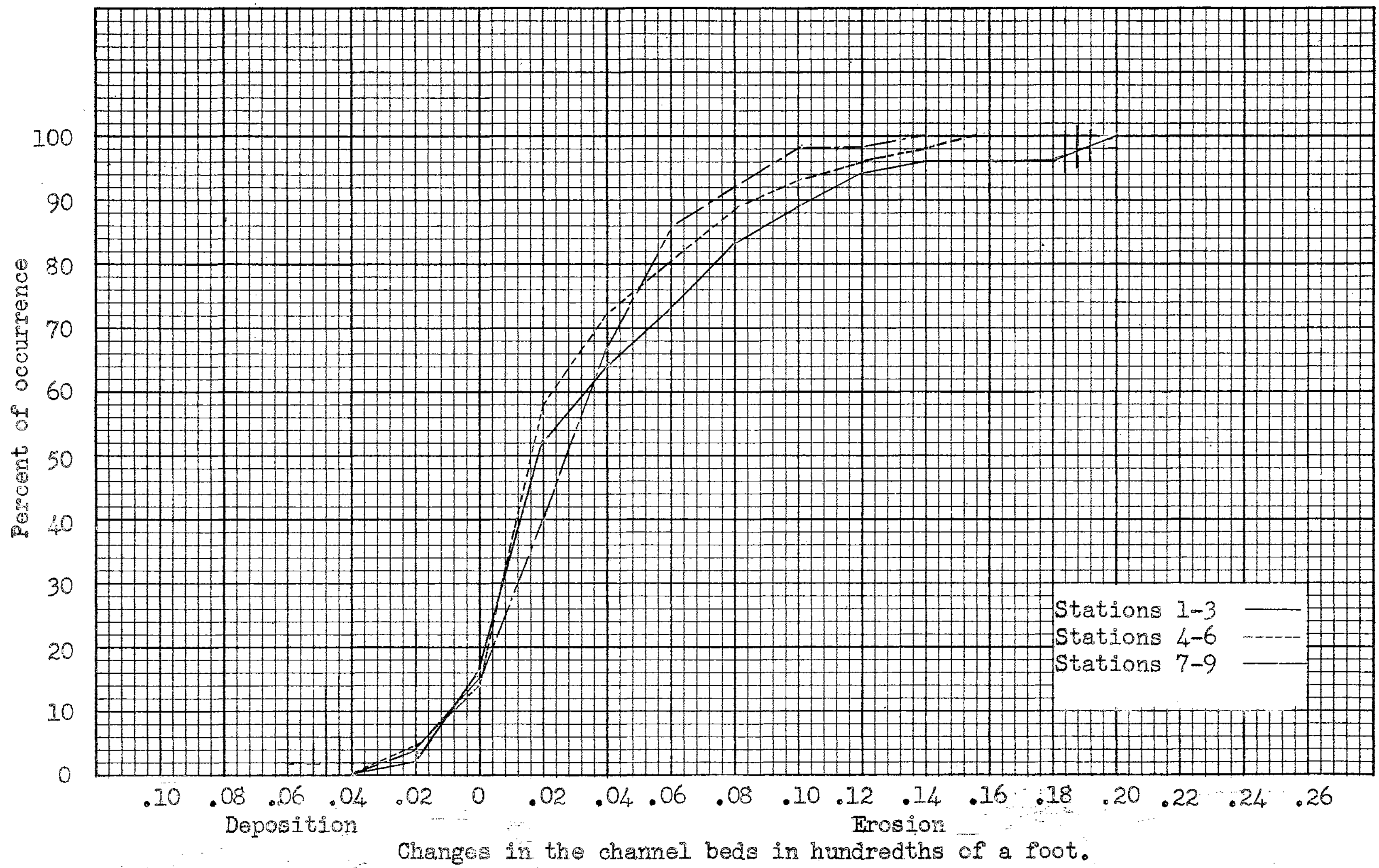

Figure 10. Accumulated frequency distribution curves of the changes in the channel beds of four replications of three groups of three stations each, measured in hundredths of a foot, when protected by sudan at 16 days old and subjected to 0.9037 cubic feet/second of water flow.

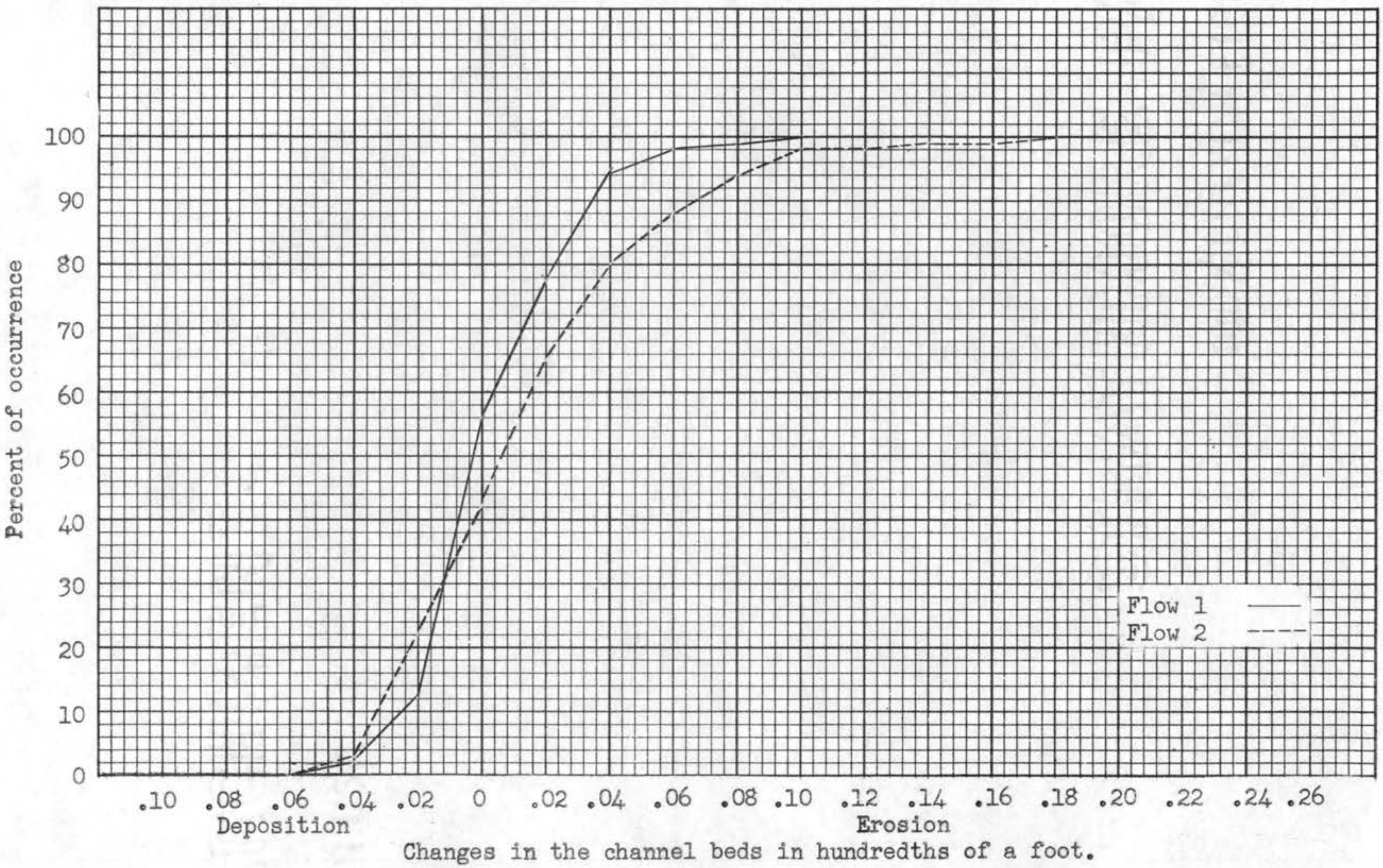

Figure 11. Accumulated frequency distribution curves of the changes in the channel beds of four replications, measured in hundredths of a foot, when protected by sudan at 21 days old and subjected to 0.04114 and 0.1170 cubic feet/second of water flow.

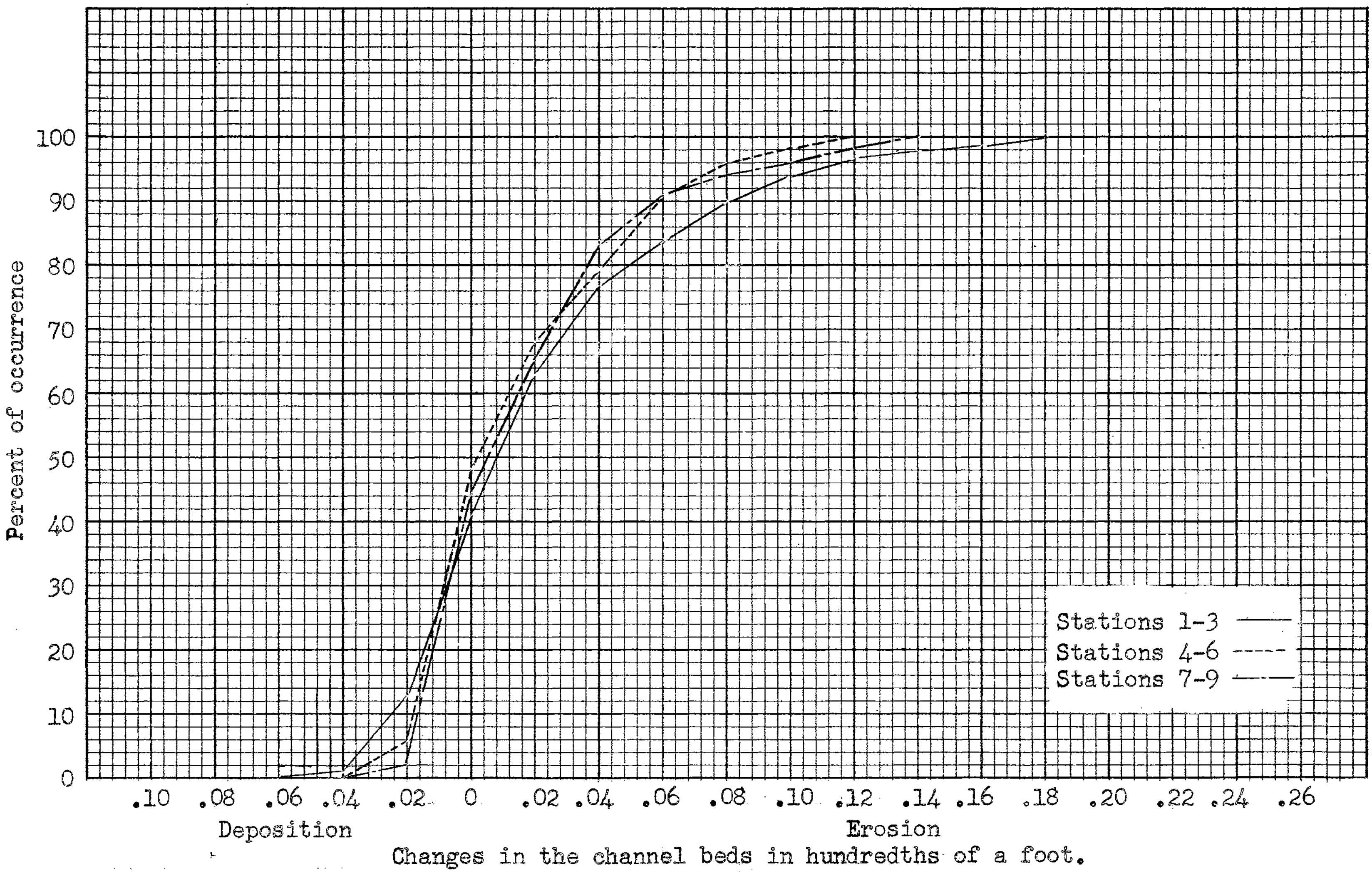

Figure 12. Accumulated frequency distribution curves of the changes in the channel beds of four replications of three groups of three stations each, measured in hundredths of a foot, when protected by sudan at 21 days old and subjected to 0.1170 cubic feet/second of water flow.

As shown in Figure 13, the channels lined with sudangrass 45 days of age and 42 inches tall withstood 5 flow-rates of water before they were destroyed. All of the changes in the channels due to the first, second, third, and fourth flow were .06 foot or less. The first group of stations had more erosion than did the second or third group as shown in Figure 14.

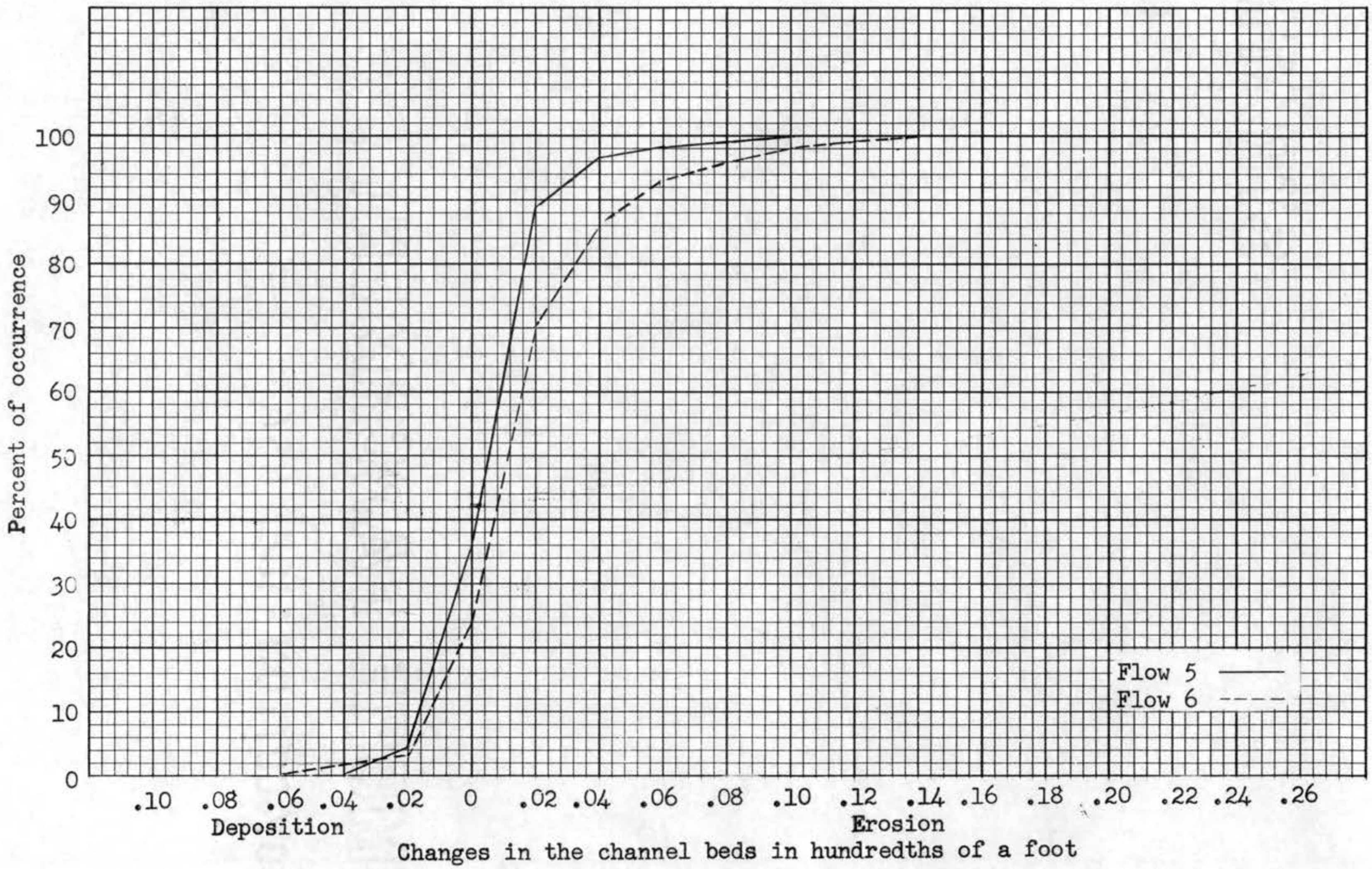

Figure 13. Accumulated frequency distribution curves of the changes in the channel beds of four replications, measured in hundredths of a foot, when protected by sudan at 45 days old and subjected to 3.6471 and 7.76 cubic feet/second of water flow.

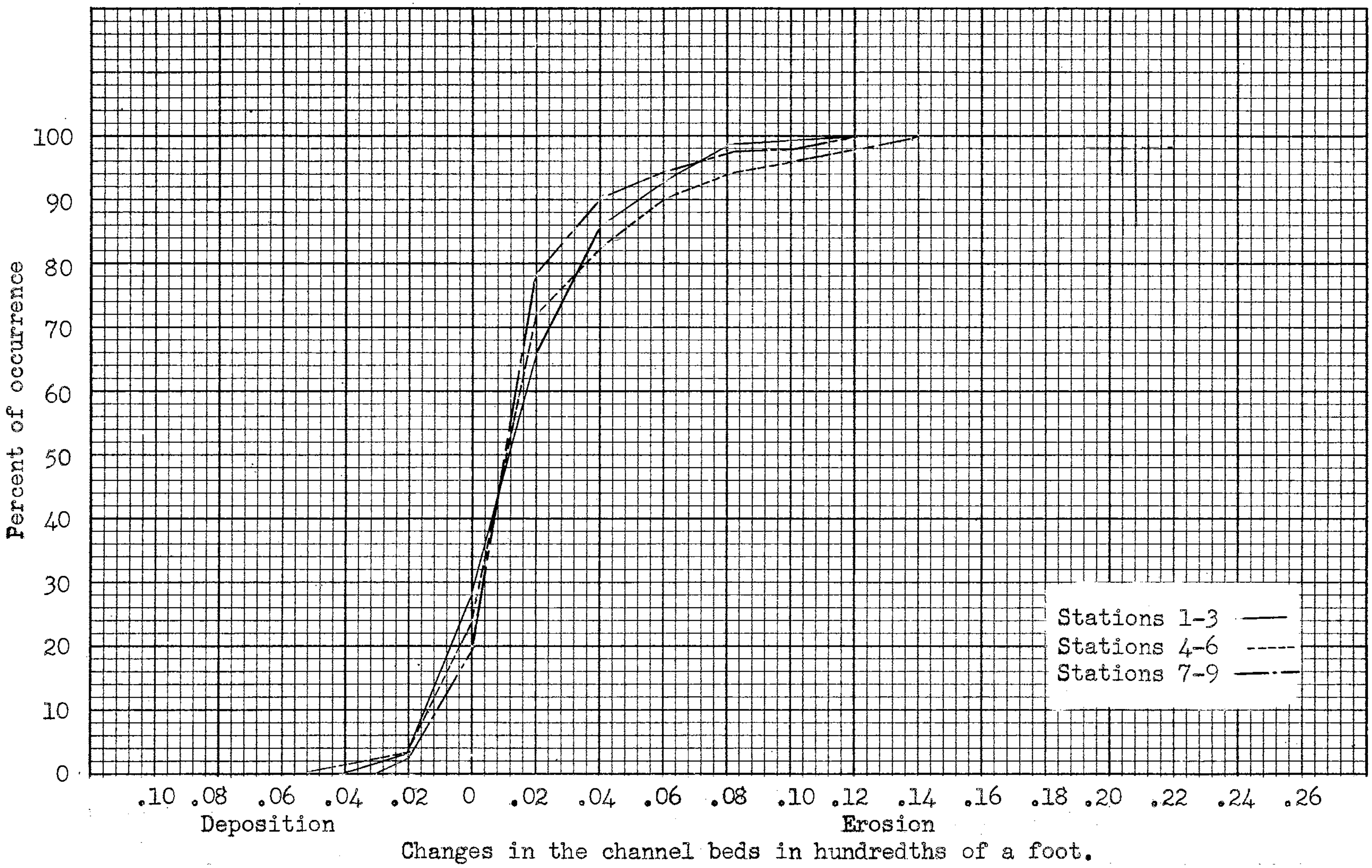

Figure 14. Accumulated frequency distribution curves of the changes in the channel beds of four replications of three groups of three stations each, measured in hundredths of a foot, when protected by sudan at 45 days old and subjected to 7.76 cubic feet/second of water flow.

SUMMARY AND CONCLUSIONS

A study to determine the effects of two different vegetative covers of various physiological ages on the hydraulics of conservation channels was conducted at the Stillwater Outdoor Hydraulic Laboratory located near Stillwater, Oklahoma in 1959.

The field layout consisted of 8 unit channels, 96 feet in length, 3 feet in width, and with a 5 per cent slope. Each channel had nine testing stations located 20, 25, 30, 50, 55, 60, 80, 85, and 90 feet from the channel head. The testing stations were used for determining the topography of the soil surface of the channel bed.

The changes in the channel beds were plotted by flows as an accumulated frequency distribution curve. It is possible to predict, based on the data collected, that a channel with a 5 per cent slope covered with a good stand of sudangrass, 16-20 days of age and 8-10 inches tall will erode .08 of a foot or less 96 per cent of the time when subjected to a flow rate of 0.3685 cubic feet/second.

The wheat at 5 days of age, 1 inch tall offered more protection against erosion than did sudangrass of the same age. The sudangrass 16 days of age and 8 inches tall offered more protection than did sudangrass 21 days of age and 10 inches tall, which was contrary to expected results. This perhaps can be explained by the fact that heavy rains occurred soon after planting which caused some rilling before the test period began. The sudangrass 45 days of age and 42 inches tall offered the most protection to waterways against erosion.

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APPENDIX

TABLE I

AVERAGE PLANT STAND COUNT PER SQUARE FOOT, AND HEIGHT IN INCHES OF VEGETATION USED IN THE CONSERVATION CHANNELS AT THE OUTDOOR HYDRAULIC LABORATORY, STILLWATER, OKLAHOMA IN 1959

Type of Coverage	Average Height Inches	Average Plant Stand Count/Square Foot			
		Rep. I	Rep. II	Rep. III	Rep. IV
Wheat 5 day	1	72	73	84	72
Sudan 5 day	2	76	80	59	68
Sudan 16 day	10	54	45	45	39
Sudan 21 day	12	49	41	27	30
Sudan 45 day	42	63	74	68	78

TABLE II

DAILY RAINFALL IN INCHES AT THE OUTDOOR HYDRAULIC LABORATORY, STILLWATER, OKLAHOMA FROM APRIL 1 TO SEPTEMBER 1, 1959

Day	April	May	June	July	August
1			.06	1.10	
2					
3					
4			1.71		
5		.60			
6					3.55
7					
8	1.15	.24		.28	
9					
10		1.99			
11			.32		
12					
13				.67	
14				2.69	
15					
16		.05		.36	
17	.38				
18	1.19		.10		
19					
20					
21				1.31	.22
22				.07	
23		T			
24					
25					
26		1.29	1.05		
27				4.34	
28					
29					
30					
31					
Totals	2.72	4.17	3.24	10.82	3.77

VITA

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