THE EFFECT OF TWO DIFFERENT VEGETATIVE COVERS OF VARIOUS HEIGHTS ON THE STABILITY OF WATERWAY CHANNELS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDIX TABLES

LIST OF FIGURES

Figure Page

CHAPTER I

INTRODUCTION

There is a hazard of gully formation wherever surface runoff water is concentrated on sloping land. A protected waterway is needed when this gully erosion hazard exists.

Grass waterways are natural or manmade watercourses protected against erosion by a grass cover. These waterways serve as outlets for terraces, diversions, and surface drainage systems.

The construction of these grass waterways presents a major problem. The newly shaped waterways usually have no vegetation to protect them from erosion. The new channels have only bare soil exposed which offers little, if any, protection. Disposal of excess surface water by way of the newly constructed channel could ruin the channel before the grasses can be established.

The period from the completion of the new waterway until a permanent vegetative cover can be established is critical. For this reason it is best to establish the grass waterway before any water is turned into it. However, on many areas this is not possible because the newly constructed watercourse is located in a natural drainageway and is the only means of removing the excess water from the surrounding areas.

The perennial sod-forming grasses are usually considered the best for use in a grass waterway. These grasses give full protection to the channel bed. Bunch-type grasses generally have unprotected bare areas between the plants. Although these perennial sod-forming grasses provide the best protection to channels once they become established, they have limitations in that they can be established only during certain seasons of the year. In addition these grasses are slow as compared to many annual grasses in providing a dense, vigorous growth which will carry a flow of water without serious soil erosion.

Many of the annual grasses have more seedling vigor than the perennials. There are both warm and cool season types of annual grasses and a quick, temporary vegetative cover could be established with these in most cases after the waterways are completed.

The purpose of this study was to determine the amount of protection a temporary vegetative cover of either a warm season or a cool season grass at a given height and a minimum density of one plant per square inch would give to a waterway channel when subjected to water flows of various volumes.

CHAPTER II

LITERATURE REVIEW

Research in the use of vegetation for lining artificial waterways was reported by Ramser (9)[1] to have begun at Guthrie, Oklahoma in 1929 when a terrace outlet with a 2 1/2 percent slope was planted to bermudagrass. The bermudagrass was effective in preventing soil loss from the outlet. However, the effectiveness could not be determined by visual observation. This led to the establishment of outdoor hydraulic laboratories for studying the flow of water in channels lined with vegetation.

It was noted by Ree and Palmer (8) that the most important property of a vegetation for waterways was its ability to protect the waterway from scour. An earth channel for disposal of excess surface water was much more stable reported Hamilton (4) if it was lined with vegetation. Hamilton (4) noted the roots of the vegetation tended to bind the soil mass, and the plant cover protected the channel surface from the erosive action of flowing water and hindered movement of soil particles from the channel bed.

The "protective index" has been described by Cook and Campbell (1) as a convenient measure of the relative effectiveness of the vegetal lining.

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[1]Figures in parenthesis refer to Literature Cited

The "protective index" could be calculated when the linings were subjected to the same flow by the following expression:

$$\text{protective index} = \frac{\text{scour in bare channel} - \text{scour in lined channel}}{\text{scour in bare channel}}$$

This index had a value of 1 when the protection was perfect and a value of 0 when no protection was afforded by the lining.

Because the "protective index" was unsuited for practical application, the usual measure of the protective ability of a vegetation has been the maximum velocity of water to which the vegetation can be subjected and still protect the channel from serious erosion. Ree and Palmer (8) reported that this maximum velocity has been called "safe," "allowable," "noneroding," or "permissible".

The permissible velocity for a vegetative channel has been noted by Ree and Palmer (8) to depend on the texture of the soil and the quality of the vegetation in the channel. Channels lined with bermudagrass have proven to be highly satisfactory as a permanent lining for waterways (2,3,6,8,9). Velocities of water flow that were found by Ree and Palmer (8) to be permissible for Cecil sandy loam channels lined with bermudagrass in various conditions were:

Condition	Land slope (percent)	Permissible velocity (feet/second)
Green long	less than 10	8
Green long	10 to 20	7
Green short, kept cut	less than 10	9
Green short, cut before test	less than 10	6.5
Dormant long	less than 10	8
Dormant long	10 to 20	6
Dormant short	less than 10	6

Cox and Palmer (3), found the permissible velocities for Dougherty silt loam channels to be somewhat less than those reported by Ree and

Palmer (8) for Cecil sandy loam channels. The permissible velocity of short bermudagrass in waterways, with a slope of 10 percent or less was about 8 feet per second (hereafter designated feet/second), while long bermudagrass had a permissible velocity of about 7 feet/second. Buffalograss and blue grama, in the same study had a permissible velocity of 7 feet/second in waterways with a 10 percent slope.

Centipedegrass, a sod-forming grass in the southern United States, has also shown promise (8,9). The centipedegrass in a Cecil sandy loam channel of less than 10 percent slope was able to withstand a permissible velocity of 9 feet/second while in the green condition, and 8 feet/second in the dormant condition.

Channels lined with Kentucky bluegrass and a mixture of timothy and redtop have been tested by Smith (10) on Putnam silt loam channels. Thin stands of Kentucky bluegrass in the first year after establishment in waterways with a slope of 4 percent had a permissible velocity of 3 feet/second. After another year, however, the permissible velocity had increased to 7 feet/second. The mixture of timothy and redtop at the end of the first year was able to withstand a velocity of 7 feet/second.

Unmowed native grass mixtures and long weeping lovegrass have been noted by Cox and Palmer (3) to have a permissible velocity of 3.5 feet/second in Dougherty silt loam channels with a 5 percent slope. Ree and Palmer (8) found that vegetal mixtures of redtop, orchardgrass, common lespedeza, and Italian ryegrass in a Cecil sandy loam channel could withstand a velocity of 6.5 feet/second in the long, green-growing stage and in the short, green stage. A mixture of dallisgrass and crabgrass, in the same study, had a permissible velocity of 3.5 feet/second on a channel having a 6 percent slope.

It has been reported (9) that sericea lespedeza, a perennial legume, exposed to flows of moderate velocity tends to permit considerable scour. The permissible velocities of flow for channels lined with sericea lespedeza in various conditions were:

Condition	Land slope (percent)	Permissible velocity (feet/second)
Dormant uncut	6	2.5
Green uncut, woody	6	3
Green uncut, not woody	3	5.5
Dormant long or short	3	3
Green short	3	3.5

Ree (7) noted that kudzu, a prolific perennial vine that produces dense foliage, offered very little protection to a channel in Cecil sandy loam soil. The permissible velocities for kudzu lined channels on a 3 percent slope for the various conditions reported were:

Condition	Permissible velocity (feet/second)
Live, heavy growth	
uncut	4
cut	3
Dormant, heavy growth, uncut	2.5

In tests with other legumes, common lespedeza was noted by Ree and Palmer (8) to have promise as a vegetal lining for channels. Velocities of flow that were found permissible for channels lined with common lespedeza in various conditions were:

Condition	Land slope (percent)	Permissible velocity (feet/second)
Green		
uncut (spring)	3	5.5
long (summer)	6	5.5
short, cut before test	3	4.5
Dead, uncut stubble		
spring	3	1
fall	3	3.5

The protective value of the dead lespedeza stubble in the spring was reported by Ramser (9) to be no better than bare soil. Cox and Palmer (3) reported the permissible velocity of established stands of alfalfa to be 3 feet/second on slopes of less than 3 percent.

Sudangrass, a rapidly growing annual grass, has been noted by Ree and Palmer (8) to be adaptable for temporary lining in waterways where the flow of water could not be diverted and where a rapidly established cover was needed to protect the channel until a perennial grass could be established. Cook and Campbell (1) reported the permissible velocity of sudangrass to be 5 feet/second on a Cecil sandy loam channel with a 6 percent slope. Ree and Palmer (8) in their first analysis of sudangrass determined the permissible velocity to be 3 feet/second on long dead sudangrass and 4 feet/second on tall growing sudangrass. Later analysis (11) showed sudangrass to have a permissible velocity of 3.5 feet/second on erosion resistant soils and 2.5 feet/second on easily eroded soils in channels with less than a 5 percent slope.

Lake (5) stated that comparisons of sudangrass and wheat showed wheat to offer more protection against erosion than sudangrass of the same age. Sudangrass 2 inches tall compared to wheat 1 inch tall was noted to have 17 percent more erosion of 0.08 foot or more. In the same study, Lake reported sudangrass 45 days of age and 42 inches tall, gave good protection against soil erosion to waterways at flow rates of 7.76 cubic feet per second.

CHAPTER III

METHODS AND MATERIALS

A study to determine the protective ability of two vegetative covers of different heights and a minimum density of one plant per square inch in waterway channels was conducted in 1960 at the Stillwater Outdoor Hydraulic Laboratory located 6 miles west and 1 1/2 miles north of Stillwater, Oklahoma. The laboratory was located below the dam of Lake Carl Blackwell.

Water for the tests was discharged through a 12 inch pipe from the lake to the channels for the lower flows. The larger flows were discharged to the channels by a supply channel from the dam.

The channels used for this study consisted of 8 individual channels, 96 feet in length, 3 feet in width, with a 5 percent slope. The lower end of a few channels is shown in Figure 1. The individual channels were separated by concrete walls which were 12 inches wide and protruded 3 inches above the level of the channel beds. One foot wooden sideboards were placed on top of the concrete walls to permit use of larger water volumes in tests of the two tallest sudangrass covers used in this study.

Each channel was designated as a replication with four replications per treatment. Due to permanent channel construction and apparatus limitations, the four replications were located side by side.

Each channel had nine testing stations for determining the topography of the channel beds. These stations were located at 20, 25, 30, 50, 55,

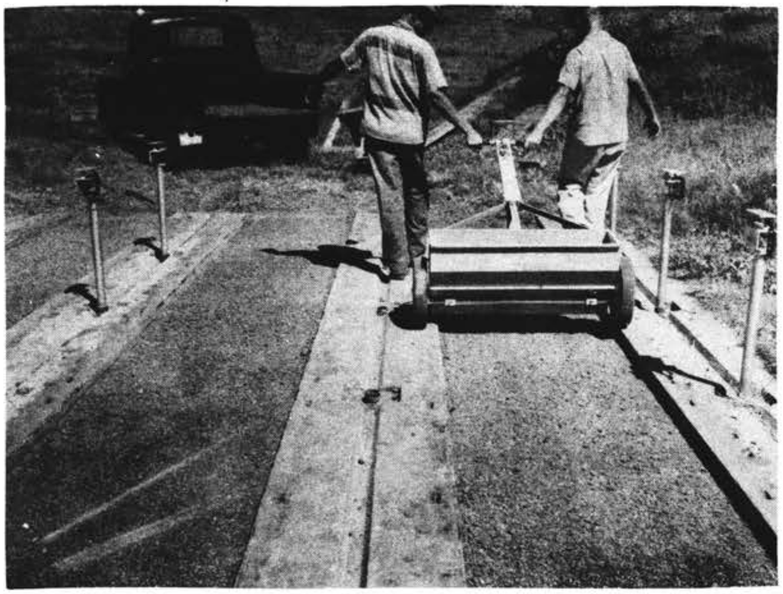

Figure 1. The Lawn Beauty spreader which was used to apply fertilizer and distribute the seed for the various vegetative covers.

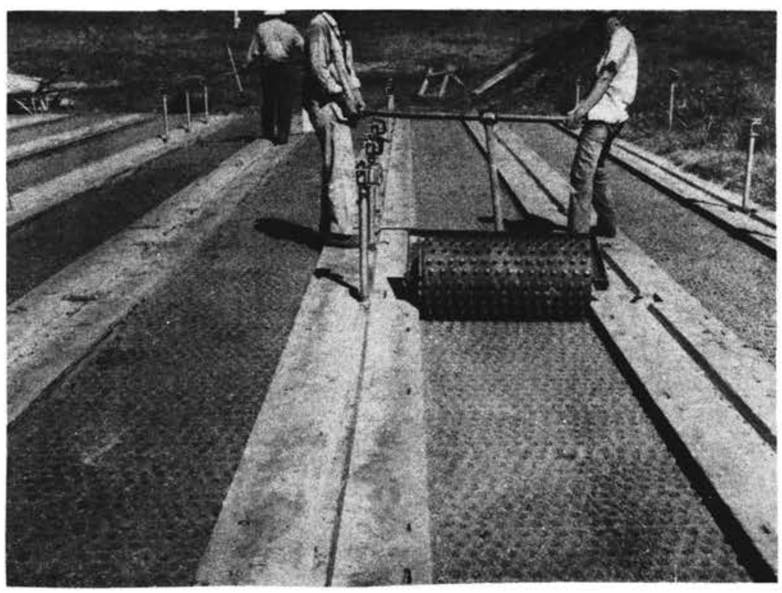

Figure 2. The "sheepsfoot" packer which was constructed and used on the last five experiments to prevent rows lengthwise of the channel and to provide good seed coverage.

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 a McIntyre point gauge. The uprights at the stations on which the angle iron crossmembers were clamped can be seen in Figures 1 and 2.

The vegetative covers selected for use in this study were common sudangrass, Sorghum sudanense (Staph) and Triumph wheat, Triticum vulgare (L.). Sudangrass was designated as the grass to be planted after April 15 and prior to October 1, whereas, wheat was to be used from September 1 to May 15. A one month overlap for use of the two grasses was included to adjust for variations in weather conditions in Oklahoma.

The number of viable seed in a pound was determined for each crop. The seeding rate was arbitrarily designated to be three pure live seed per square inch to insure a minimum density of one plant per square inch. This was achieved through the determination of and planting on the basis of percent pure live seed for each crop variety and seed lot.

The sudangrass planted May 14 and tested on June 6 when 5.68 inches tall (Table I) was not fertilized. Hereafter, each vegetative cover subjected to various flow-rates of water will be referred to as an experiment. The remainder of the experiments were fertilized with the equivalent of 80 pounds each of nitrogen, phosphorous, and potassium per acre. All experiments were irrigated immediately after planting and further irrigated throughout the growing season as needed.

Channel Preparation

The channels were sterilized with methyl bromide at the rate of one pound per 100 square feet of area before the start of the experiments.

TABLE I

TYPE OF COVERAGE, PLANTING DATE, HEIGHT AND AGE OF PLANT, AND FLOW VOLUMES USED IN STUDYING THE STABILITY OF CONSERVATION CHANNELS AT STILLWATER OUTDOOR HYDRAULIC LABORATORY, STILLWATER, OKLAHOMA, 1960

Exp. No.	Height* Inches	Type of Coverage	Planting Date	Plant Age**	Flow Number	Flow Rate***
1	5.68	Sudan	May 14	19	1	0.014
					2	0.039
					3	0.124
					4	0.302
2	2.57	Sudan	June 15	7	1	0.014
					2	0.040
					3	0.124
3	17.56	Sudan	June 15	22	1	0.039
					2	0.164
					3	0.540
					4	1.111
					5	3.249
4	4.38	Sudan	July 26	7	1	0.016
					2	0.039
					3	0.125
5	11.22	Sudan	July 26	15	1	0.039
					2	0.169
					3	0.561
					4	1.151
6	5.98	Wheat	Sept. 2	26	1	0.016
					2	0.036
					3	0.132
					4	0.299
7	-	Bare Soil	-	-	1	0.017
					2	0.039
8	3.25	Wheat	Oct. 11	9	1	0.014
					2	0.039
					3	0.138
					4	0.299

*Average of 360 plants.

**Determined from day of planting.

***The cubic feet of water discharged per second per foot of channel width. Average of the four channels in an experiment.

The soil used to fill and topdress the channels was also sterilized. To eliminate soil type as a variable, the channels were filled with a sandy loam soil (Appendix Table V) prior to each experiment.

The channel bed preparation was accomplished with a Roto-Tiller, model 3 implement, which stirred the soil to a depth of 4 to 5 inches. The channels were then raked with a garden rake to remove the clods. After the channels were stirred and raked smooth, they were filled to a graded height of 3 inches below the top of the channel walls with the soil sieved through a 1/2 inch mesh hardware cloth.

Planting Methods

Raking

The channels were first compacted twice with a water-filled roller (background Figure 2) which weighed approximately 160 pounds. Next, the sudangrass seed was distributed over the top of the channel in one pass with a three foot Lawn Beauty spreader (Figure 1), which was calibrated to deliver three live seed per square inch. The seeds were then stirred into the upper one inch of soil with a garden rake. One-half inch of soil was then placed over the seeds to insure adequate coverage. Only the first experiment was planted in this manner.

Cultipacker

The seeds were distributed over the channels for the second and third experiments the same as in the previous planting method. The seeds were then pressed into the soil from two passes with a cultipacker. The channel beds were then leveled and packed by four passes with the smooth roller.

"Sheepsfoot" Packer

After the seeds were distributed over the channel beds, the remaining experiments were established by pressing the seed into the soil by four passes with the "sheepsfoot" packer (Figure 2). Two passes were then made with the smooth roller to level and pack the channel bed.

Testing

When the vegetation reached the desired condition for study, as shown in Table 1, they were subjected to a measured flow of water for 40 minutes. The first flow discharged down the channels was of a low volume. If this low volume flow failed to damage the channels, a larger flow was discharged. Each flow-rate of water was evaluated as to its soil erosive action and was designated as a test. This procedure was continued until the channel failed or until the capacity of the channels was reached.

Measurements and Observations

Discharge

The lower flow-rates were measured by an orifice meter located in the 12 inch discharge pipe. Larger flows were measured by a H-flume located in the water supply channel.

Channel Bottom Topography

In all experiments, channel bottom measurements were made before and after each test flow. The McIntyre point gauge, which is calibrated in thousandths of a foot, was used to make these measurements. The soil surface topography readings were made at 15 locations (substations) across the width of the channel at the 9 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 channels.

Soil

The compaction of the soil in each experiment was determined from measurements of 12 soil bulk densities. The soil bulk density samples were taken prior to tests of each vegetative cover at 27.5, 57.5, and 87.5 feet from the head of the channels. These 12 samples were then averaged to give mean soil bulk density for each experiment.

The characteristic of the soil that was used to fill the channels was determined by a mechanical analysis and pH of the soil. These determinations were made from the pooled samples collected every 10 feet starting at the head of the channels.

Vegetation

Plant stand counts were taken at six locations in each channel before the tests began. These plant counts were taken across the channel at 10, 25, 40, 55, 70, and 85 feet from the head of the channel. Each location consisted of three, 1 by 1 foot, quadrats across the channel. Total plant height and diameter of culm were determined on 90 plants selected across the channel at 10, 40, and 70 feet from the head of the channel. The amount of roots in a given volume of soil for each experiment was determined by washing the soil from the roots in the soil bulk density samples. The major portion of the soil was removed from the roots by washing the soil through a 20 mesh screen. The roots were further washed and separated by placing them in a 50 ml. flask of water. The roots were then removed and oven dried. The 12 determinations were averaged and adjusted to give milligrams of roots per cubic inch of soil.

Methods of Computation

Scour Rate

The effect of each test flow on the channels was determined by the amount of erosion or deposition of the substations before and after the tests. The average rate of change in the channel depth which resulted from scour or deposition was computed in inches per hour. The scour rate for each flow was then plotted against the discharge rate per foot of channel width.

Channel Bed Topography

The changes in the topography of the channel beds were obtained by subtracting the 540 substation readings after each flow from the measurements obtained at the respective location prior to the start of the test. The changes in topography of the channel beds in the 4 replications were pooled for the last 2 flows in each experiment. These changes in topography were plotted against percentage of occurrence to give an accumulated frequency distribution curve for the last two test flows in each experiment.

The rilling effect of each flow on the channels was determined by the variance of the topographical measurements of the 15 substations per station before and after a 40 minute flow. These variances at the 36 stations (9 stations per channel) were pooled and divided by 36 to give an average variance for the 36 stations. The extraction of the square root of the variances gave the standard deviation before and after the flows for each experiment. The standard deviation for each rate of flow was then plotted against the discharge rate per foot of channel width to give an indication of the roughness of the cross-section of the channel beds.

CHAPTER IV

RESULTS AND DISCUSSION

The best method to determine when a channel has been destroyed by water has not been established. For this study the destruction was determined by visual observation. When the plants were washed out or a deep rill occurred, the channels were considered destroyed.

The first experiment (Table 1) received over an inch of rain (Appendix Table VIII) before the plants were up. This along with the planting method lead to a stand which was not uniform in plant density (Appendix Table III). As a result of the rains prior to the tests, some rills were noted in the second channel before the tests began. This lead to destruction of the one channel with the fourth water flow whereas the other three channels of this experiment were not destroyed. This experiment was concluded after the fourth flow because the capacity of the channels was reached.

Experiments 2 and 3 (Table 1) had uniform stands of sudangrass (Appendix Table III). The only objection to the stands was that the plants were distributed in rows parallel to the length of the channels. This was caused by using a cultipacker to press the seed into the soil. It was noted that there was the same number of rows in a channel as there were rollers on the cultipacker. This type of plant distribution allowed erosion which was localized between the rows.

The vegetative covers of experiments 4 and 5 (Table 1), which had the seed packed in with the "sheepsfoot" packer, were uniform in distribution and density in all channels (Appendix Table III). This tended to spread the flow of water uniformly over the entire channel and gave a uniform scour rate.

In experiment 6 (Table 1), wheat was planted by the same method as the sudangrass in experiments 4 and 5. Due to the hot weather during the first part of September, the wheat seed planted did not materialize into as high a density as for the other experiments (Appendix Table III). However, due to the tillering and prostrate growth of Triumph wheat in the fall, the stand resulted in a good vegetative cover. Because the capacity of the channels was reached, the experiment was concluded after the fourth water flow.

Experiment seven (Table 1) was conducted to determine how much protection bare earth would offer to the channels. Rills formed in the bare earth channels because the water flow concentrated in portions of the channel rather than remaining distributed over the entire channel bed.

Scour rates higher than 0.2 inch per hour have been termed by Ree and Palmer (8) to be definite destruction rates and that when scour rates exceed this, then the channel has been damaged. In this study the second and fourth flow of experiments 4 (sudangrass 4.38 inches tall) and 6 (wheat 5.98 inches tall) respectively caused soil loss greater than 0.2 inch per hour (Appendix Table VII), but visual observation at that time did not show the channels to be destroyed. For this reason the permissible scour rate was considered to be somewhat higher than 0.2 inch per hour for this study.

In this study the highest scour rate that was noted for an experiment where the channels were not considered destroyed was 0.245 inch of soil loss per hour (Appendix Table VII). The lowest scour rate that was noted in channels that were considered destroyed was 0.417 inch of soil loss per hour. This might suggest that for this study the permissible scour rate was about 0.3 inch per hour (a point approximately midway between the rate which was considered non-destructive and the rate which was considered destructive).

When the percentage of occurrence of erosion greater than 0.04 and 0.08 foot from the accumulative frequency distribution curves of the experiments (Figures 3,4,5,6,7,8,9, and 10) was plotted against scour rate for the last two flows (Appendix Table VII), there appeared to be a direct relationship between the scour rate and the percentage of occurrence for the two erosion rates (Figure 11). The point where the greater than 0.04 erosion line crossed the permissible scour rate of 0.3 inch per hour was at 21 percent. This suggests that the channels were destroyed anytime 0.04 foot and greater erosion occurred more than 21 percent of the time.

The resistance to water flow that a given vegetative cover can provide in a channel determines the stability of that channel. The forces of resistance in this study were the crop characteristics such as kind, height, population density, diameter of stems, and type of distribution.

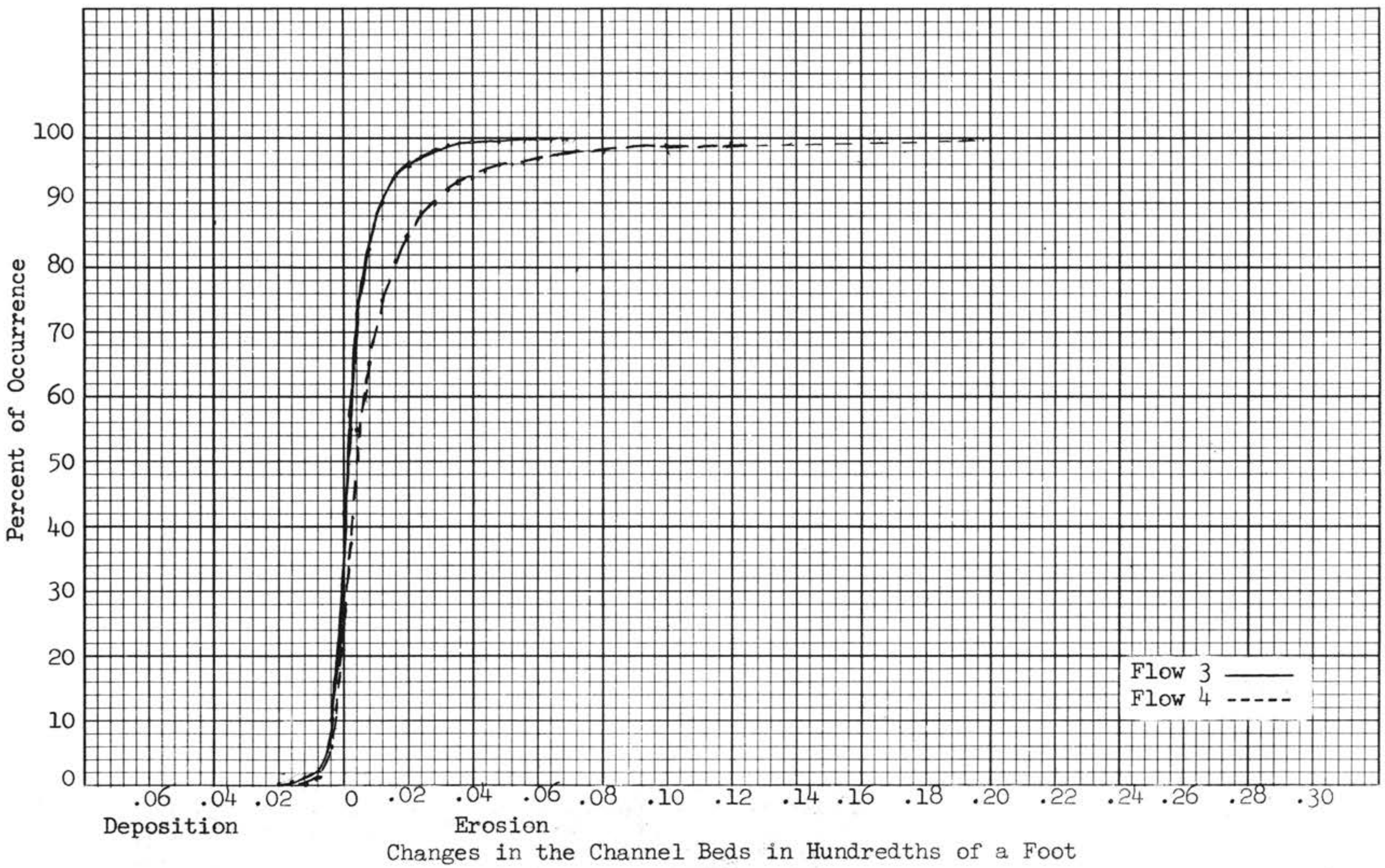

Figure 3. Accumulated frequency distribution curves of the changes in the channel beds of four replications, measured in hundredths of a foot, when protected by sudangrass 5.68 inches tall (Experiment 1) and subjected to a discharge rate of water of 0.124 and 0.302 cubic foot per second per foot of channel width.

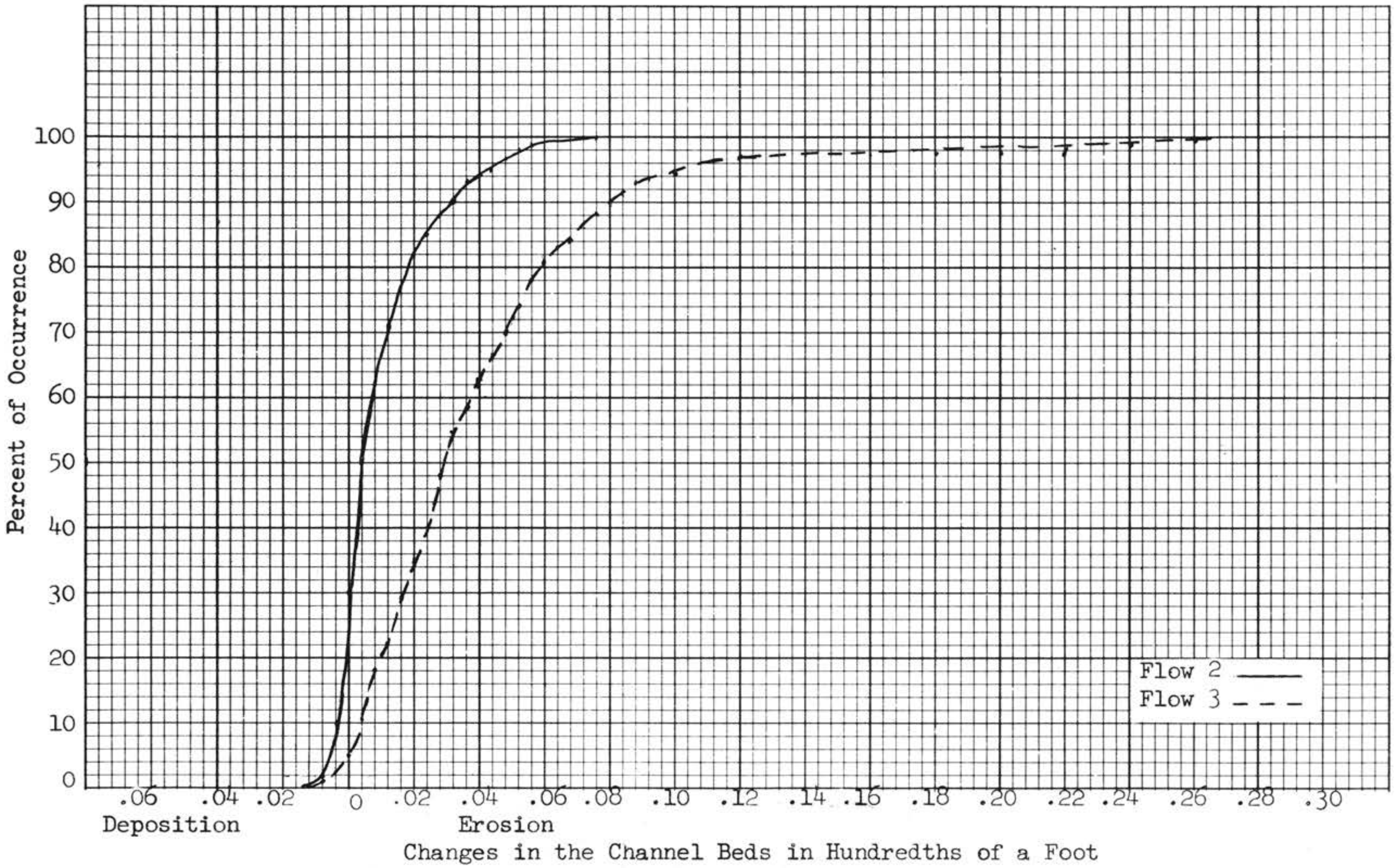

Figure 4. Accumulated frequency distribution curves of the changes in the channel beds of four replications, measured in hundredths of a foot, when protected by sudangrass 2.57 inches tall (Experiment 2) and subjected to a discharge rate of water of 0.040 and 0.124 cubic foot per second per foot of channel width.

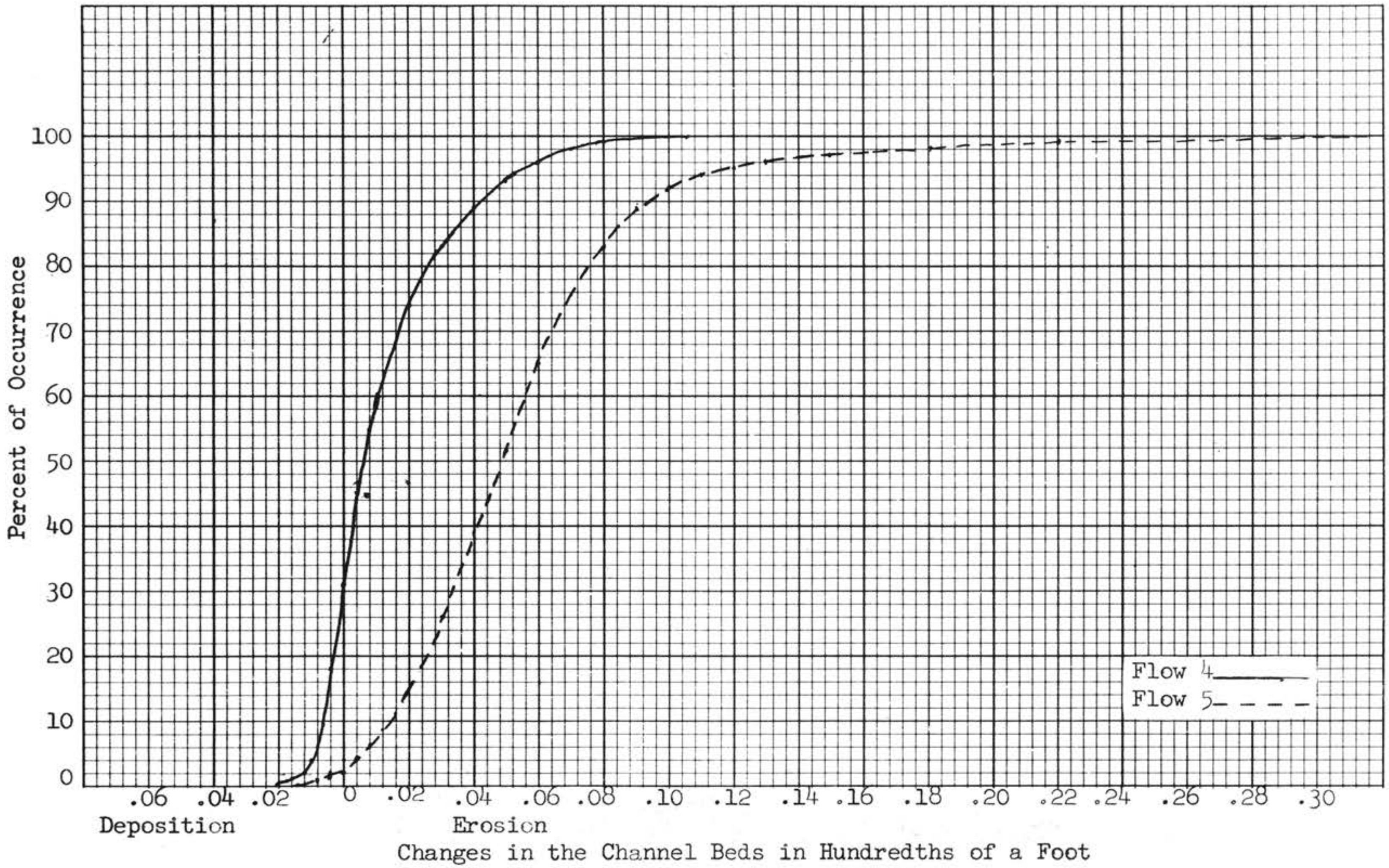

Figure 5. Accumulated frequency distribution curves of the changes in the channel beds of four replications, measured in hundredths of a foot, when protected by sudangrass 17.56 inches tall (Experiment 3) and subjected to a discharge rate of water of 1.111 and 3.249 cubic feet per second per foot of channel width.

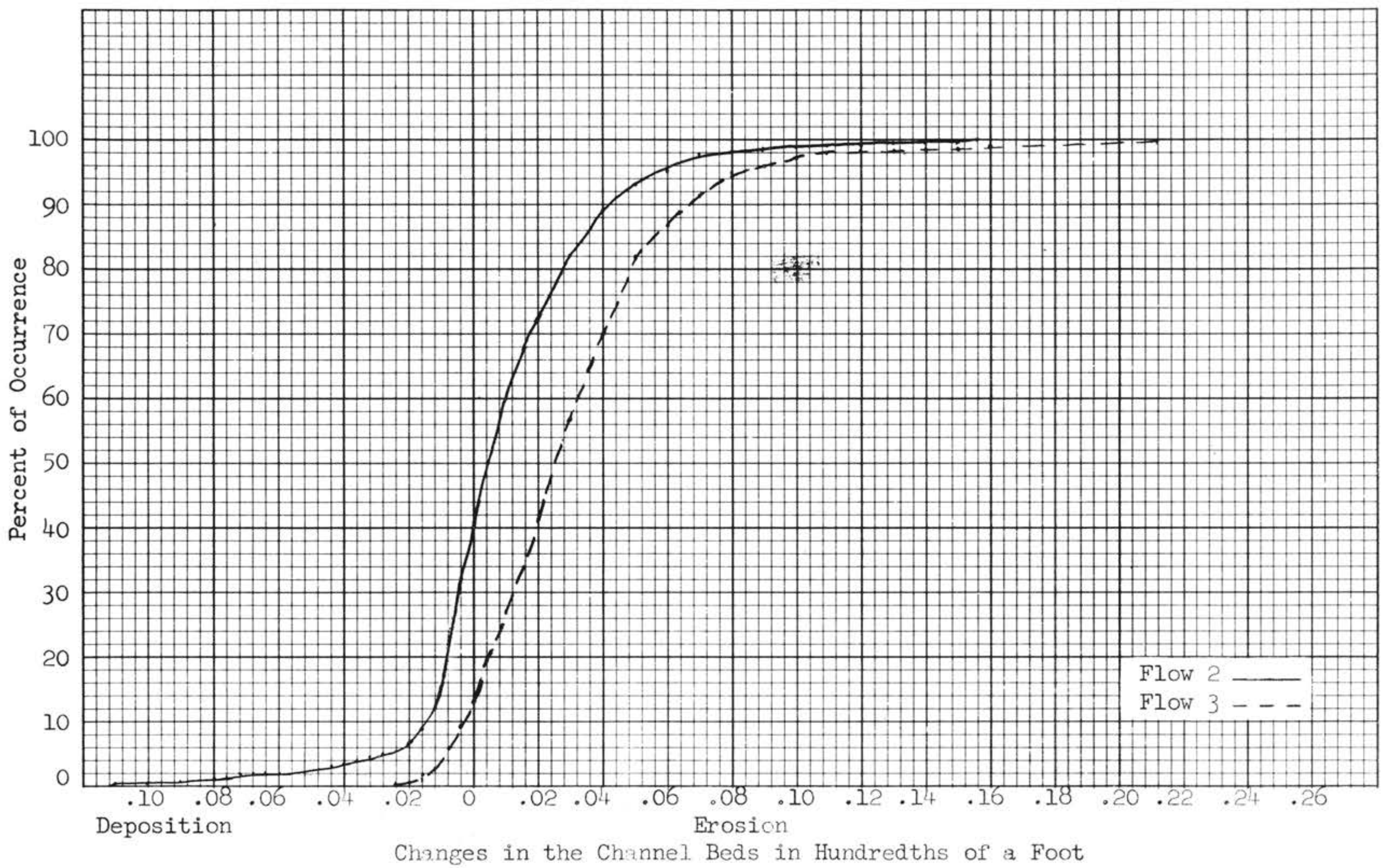

Figure 6. Accumulated frequency distribution curves of the changes in the channel beds of four replications, measured in hundredths of a foot, when protected by sudangrass 4.38 inches tall (Experiment 4) and subjected to a discharge rate of water of 0.039 and 0.125 cubic foot per second per foot of channel width.

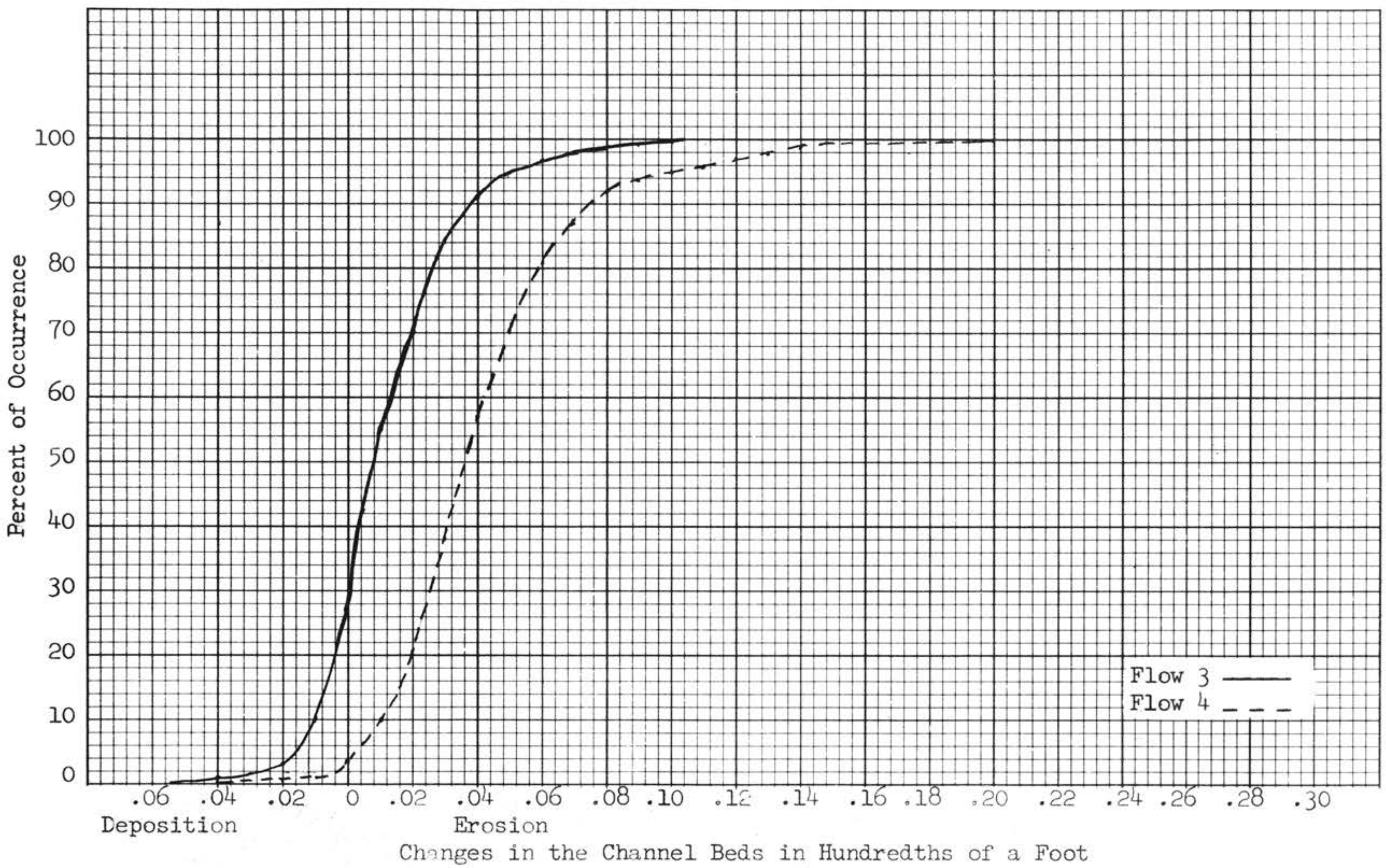

Figure 7. Accumulated frequency distribution curves of the changes in the channel beds of four replications, measured in hundredths of a foot, when protected by sudangrass 11.22 inches tall (Experiment 5) and subjected to a discharge rate of water of 0.561 and 1.151 cubic feet per second per foot of channel width.

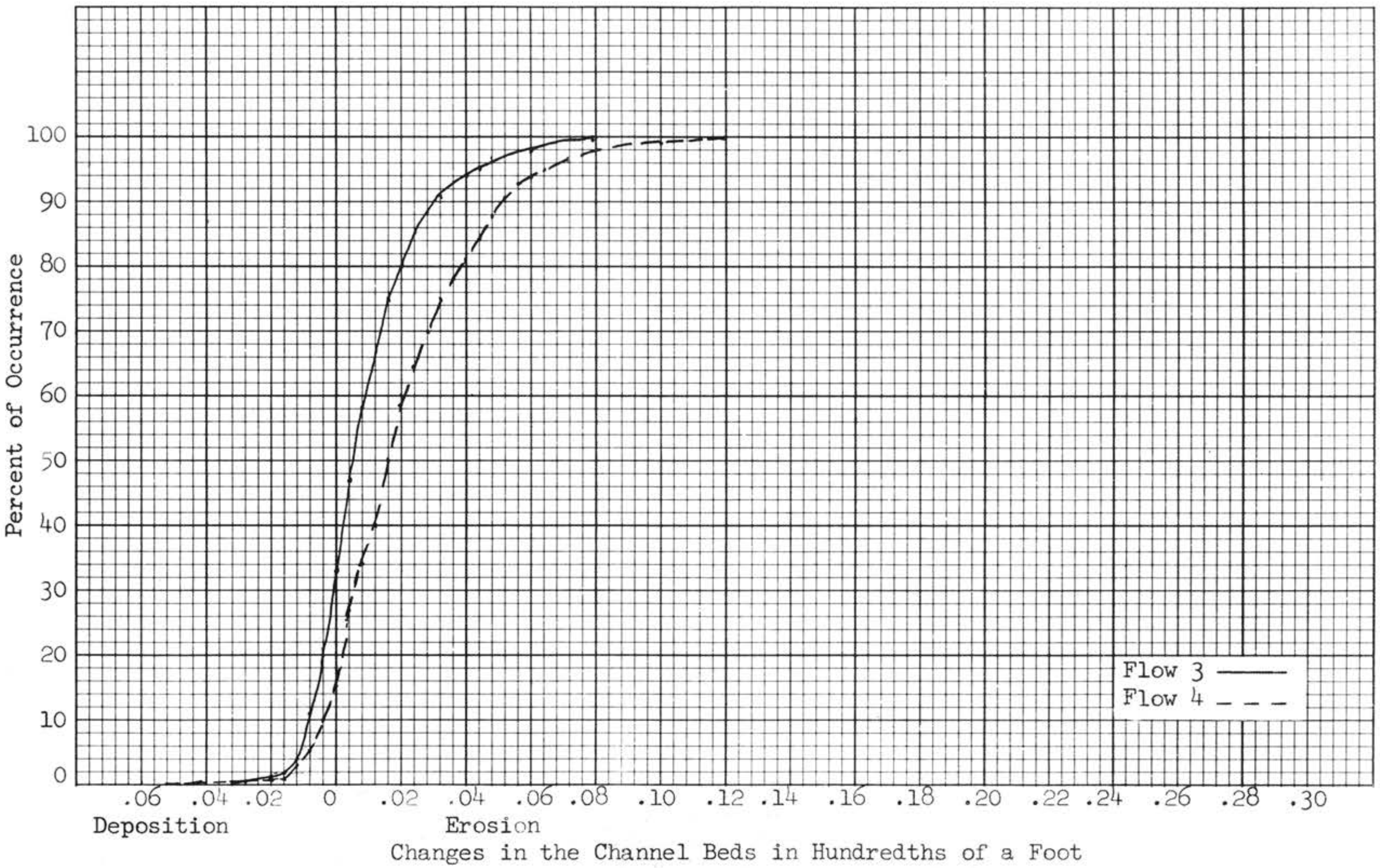

Figure 8. Accumulated frequency distribution curves of the changes in the channel beds of four replications, measured in hundredths of a foot, when protected by wheat 5.98 inches tall (Experiment 6) and subjected to a discharge rate of water of 0.132 and 0.299 cubic foot per second per foot of channel width.

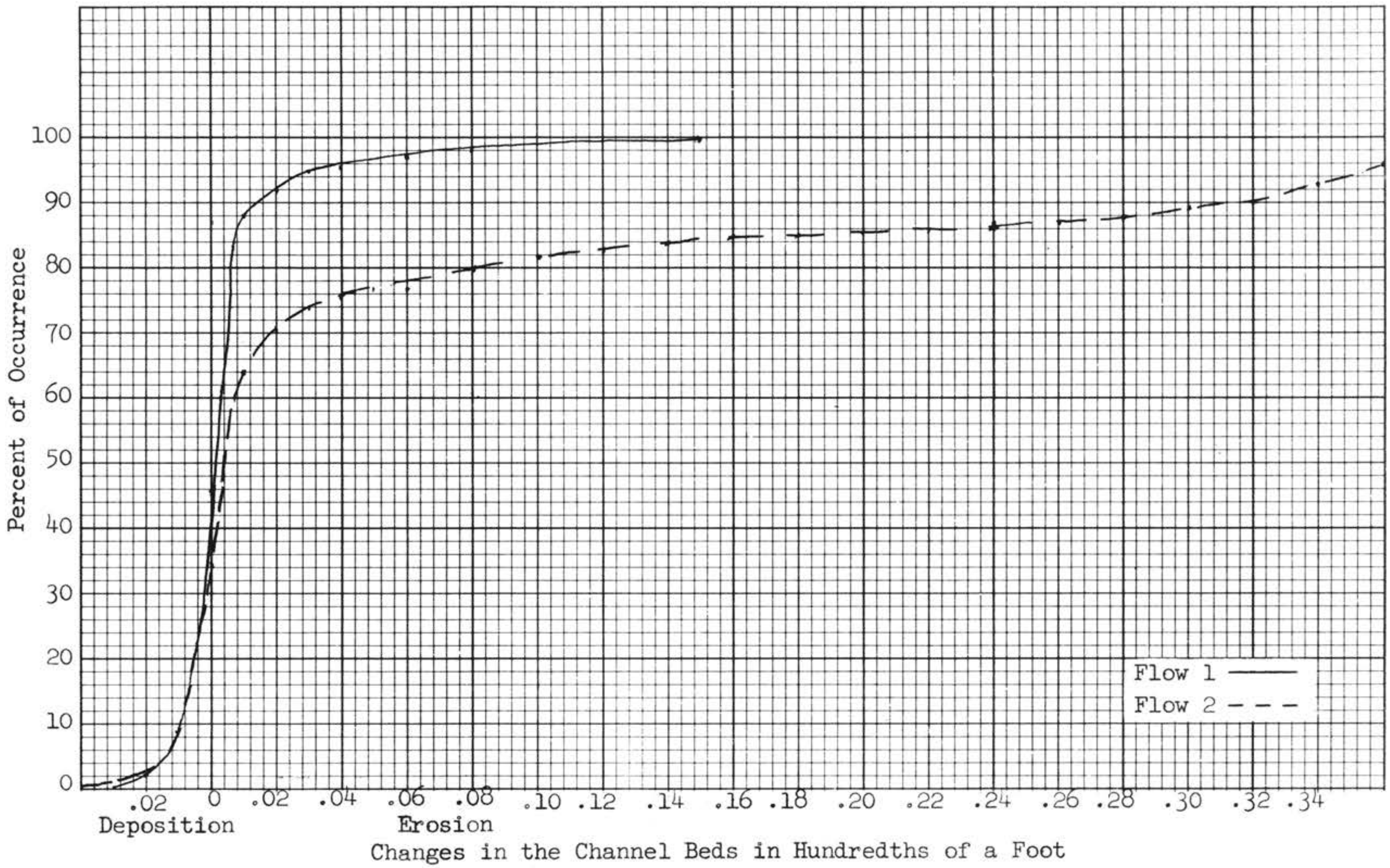

Figure 9. Accumulated frequency distribution curves of the changes in the channel beds of four replications, measured in hundredths of a foot, when protected by no vegetative cover (Experiment 7) and subjected to a discharge rate of water of 0.017 and 0.039 cubic foot per second per foot of channel width.

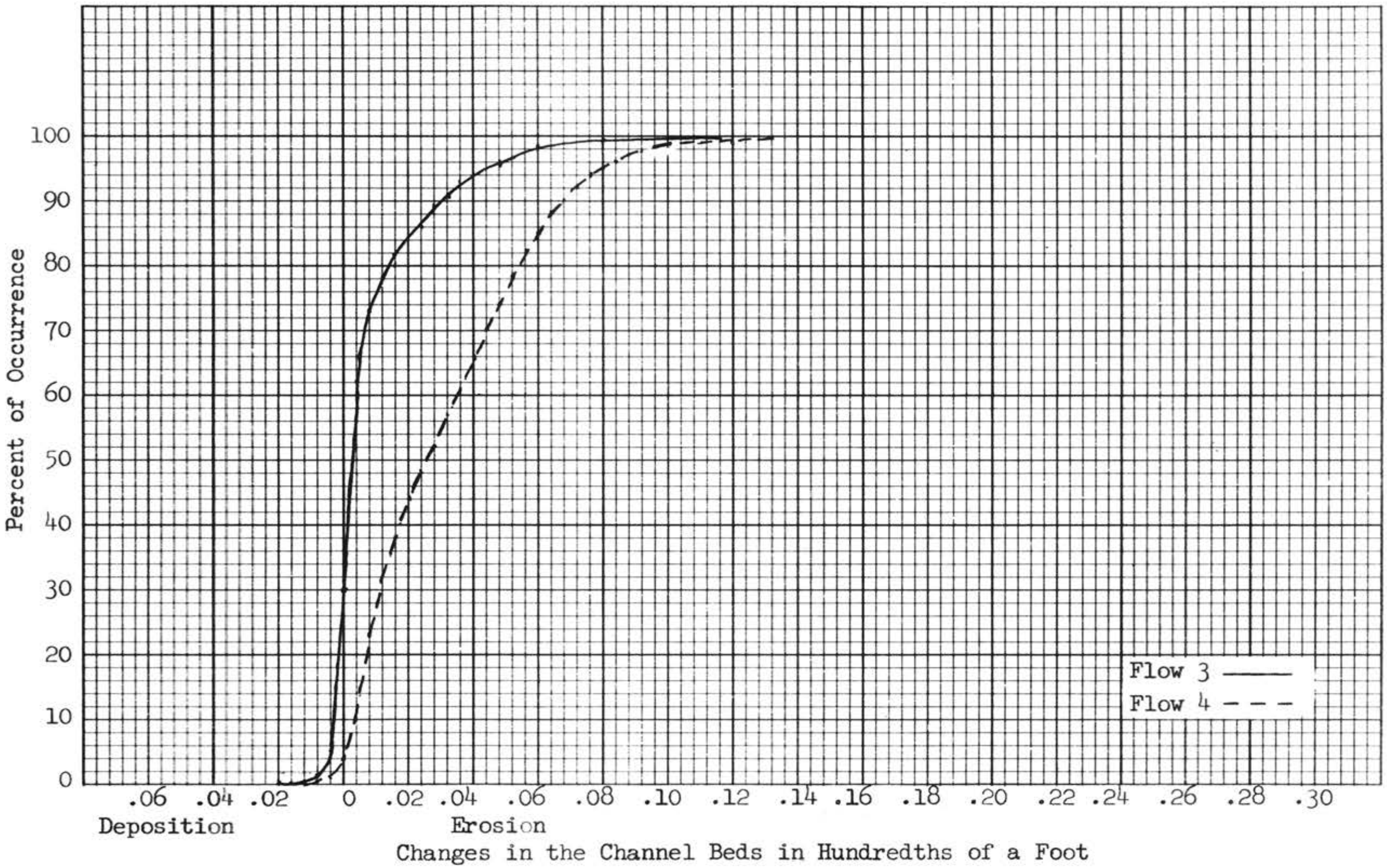

Figure 10. Accumulated frequency distribution curves of the changes in the channel beds of four replications, measured in hundredths of a foot, when protected by wheat 3.25 inches tall (Experiment 8) and subjected to a discharge rate of water of 0.138 and 0.299 cubic foot per second per foot of channel width.

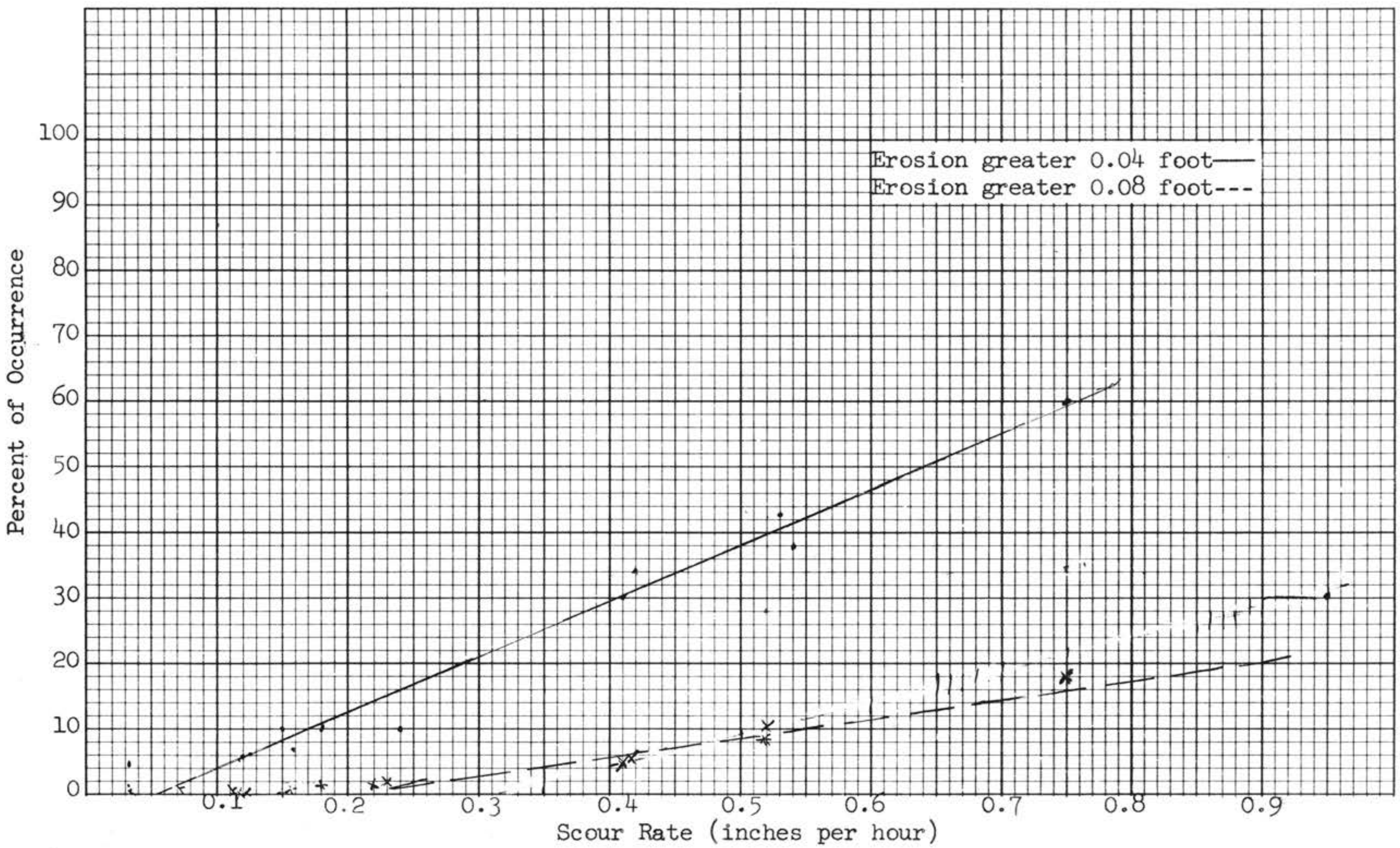

Figure 11. Frequency of occurrence, in percent, of erosion greater than 0.04 and 0.08 foot for the last 2 flows of the experiments plotted against scour rate in inches per hour.

Height Effect

As the height of the vegetative cover used in this study increased, the stability of the channels increased. Channels lined with sudangrass 4.38 inches tall were only able to withstand a discharge rate of 0.05 cubic foot of water per second per foot of channel width (Figure 12) at the 0.3 inch per hour scour rate. A tripling of the sudangrass height allowed a discharge rate of 0.8 cubic foot per second per foot of channel width. Sudangrass eighteen inches in height was able to withstand a flow-rate of 1.80 cubic feet per second per foot of channel width at the 0.3 inch per hour scour rate.

Results of the wheat lined channels were similar to those obtained with sudangrass. The taller cover of wheat provided the best stability to the channels. At the same flow rate, 0.299 cubic foot per second per foot of channel width, channels lined with wheat 5.98 inches tall had a soil loss of 0.23 inch per hour while channels lined with wheat 3.25 inches tall had a soil loss of 0.41 inch per hour (Figure 13). This represented approximately twice as much soil loss in the channels lined with wheat 3.25 inches tall as in those channels lined with wheat 5.98 inches tall.

Population Density Effect

In this study uniform population densities between 132 and 342 plants per square foot seemed to differ very little in their effect on channel stability. Wheat lined channels of different populations subjected to 0.299 cubic foot of water per second per foot of channel width resulted

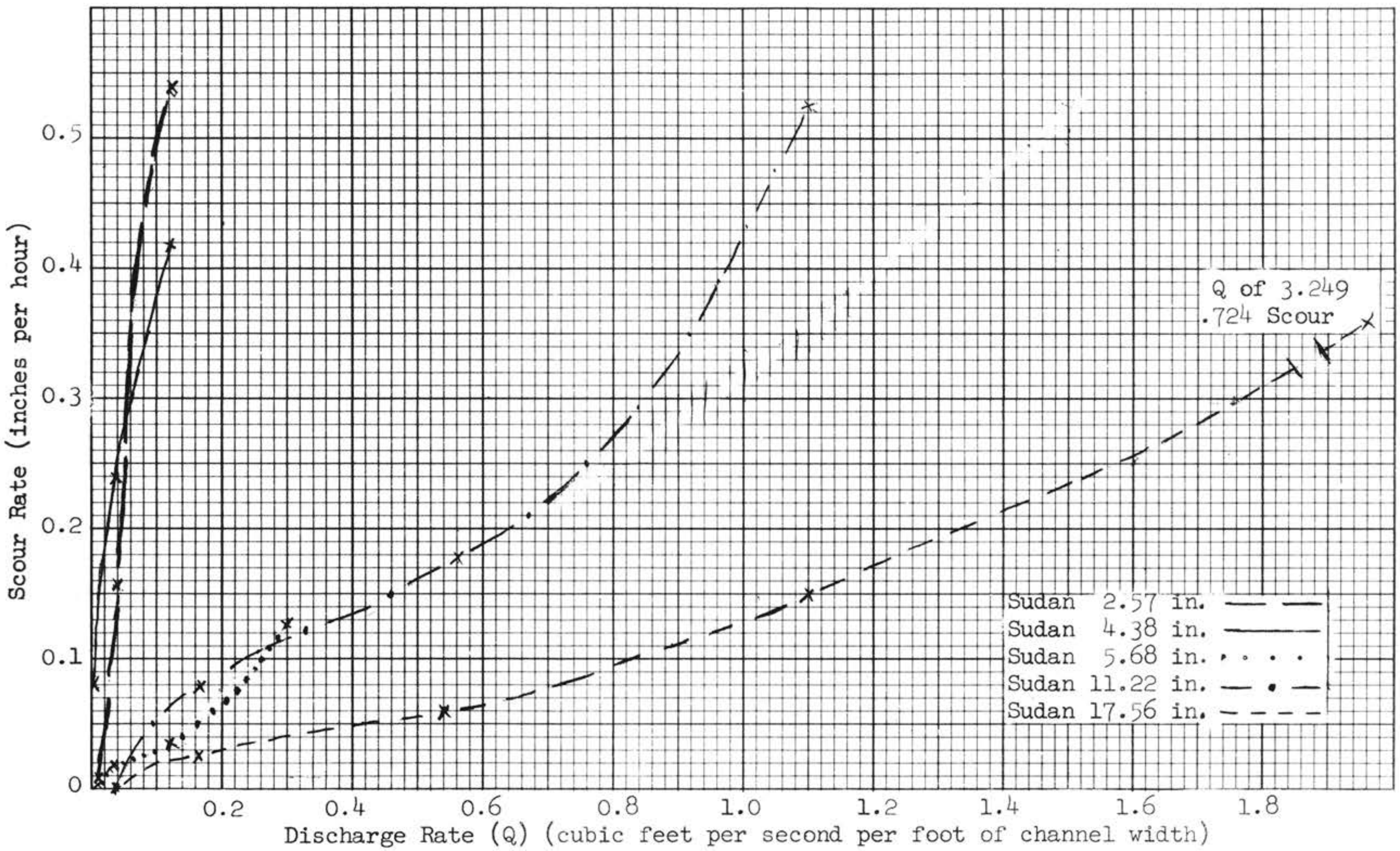

Figure 12. Scour rate in relation to velocity of flow for channels lined with sudangrass.

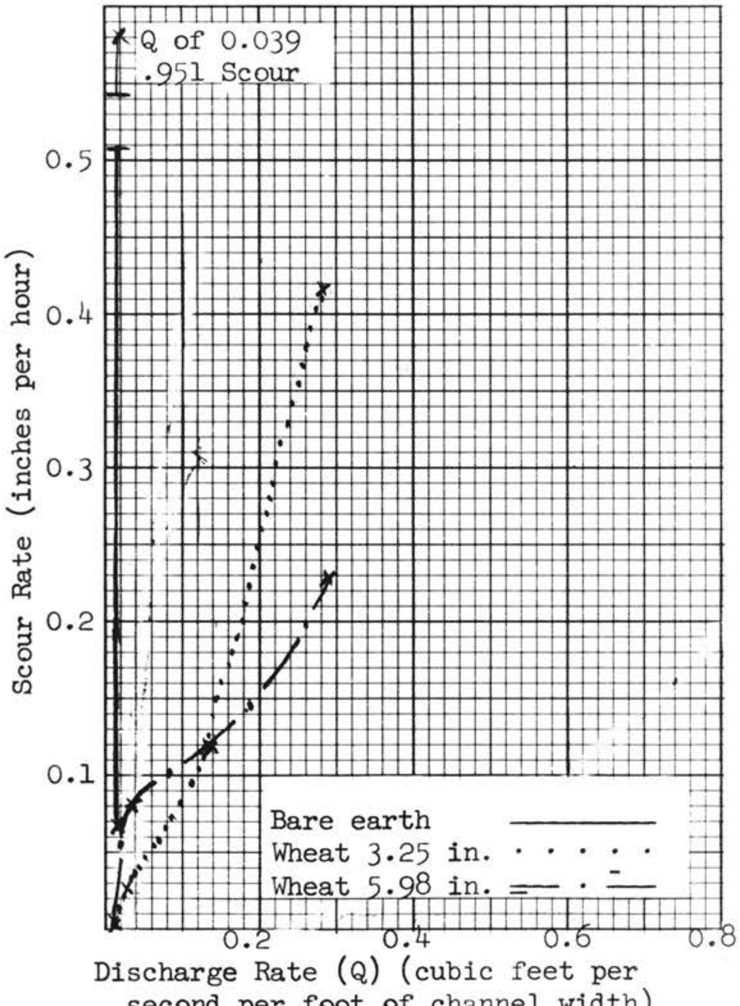

Figure 13. Scour rate in relation to velocity of flow for bare earth and wheat lined channels.

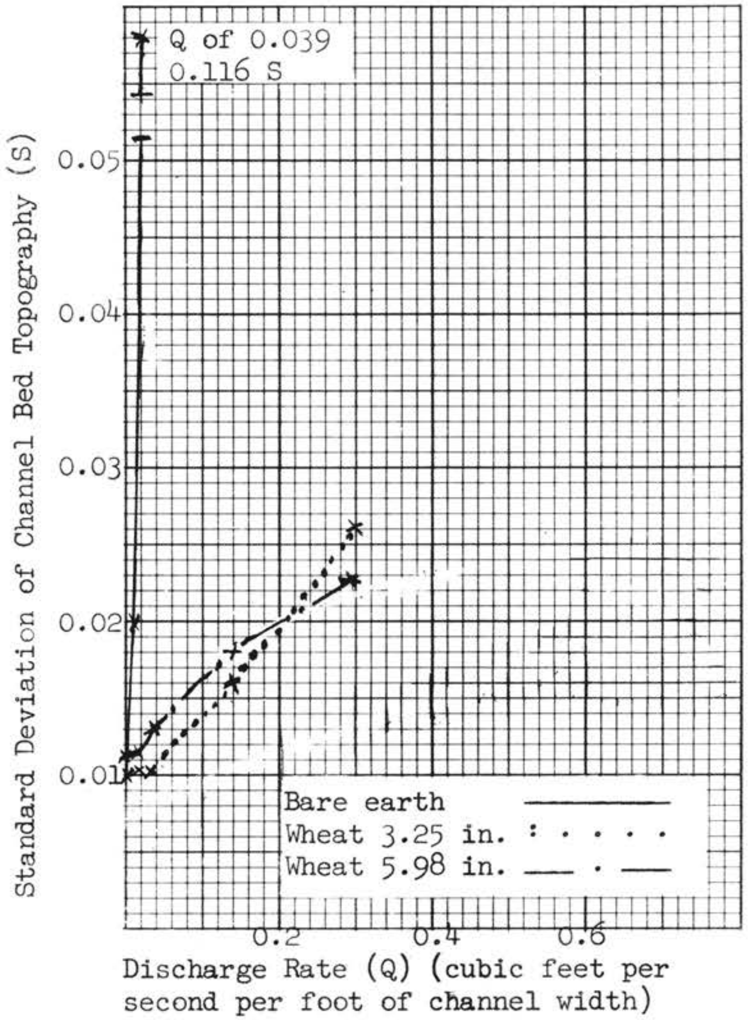

Figure 14. Standard deviation in relation to velocity of flow, for bare earth and wheat lined channels.

in different scour rates (Figure 13) which can be explained perhaps by the plant height effect. Because vegetation of similar height and different densities were not included in this study, the small effect on erosion that differences in population at these high densities (132 to 342 plants) might have can not be shown.

Row Direction Effect

The row direction did not seem to have much effect on the amount of soil removed at the flow rates used in this study (Figure 12). However, the row direction did have an effect on the topography of the cross-section of the channels. Sudangrass 2.57 inches tall (Experiment 2), which had rows parallel to the length of the channel, was eroded between the rows while sudangrass 4.38 inches tall (Experiment 4), which had rows perpendicular to the length of the channel, had more uniform erosion over the entire channel bed. After a discharge rate of 0.124 cubic foot of water per second per foot of channel width, the standard deviation of channel topography (indication of channel roughness from a cross-section) for rows parallel to the channel length (sudangrass 2.57 inches tall) was about 0.06 (Figure 15). The channels with rows perpendicular to the channel length (sudangrass 4.38 inches tall) showed a standard deviation of only 0.024.

Wheat Versus Sudangrass

Triumph wheat seemed to offer more stability to a channel than common sudangrass of a similar size when compared at less than five inches in height. Wheat 3.25 inches in height had a scour rate of only 0.12 inch per hour at a discharge rate of 0.124 cubic foot per second per foot of

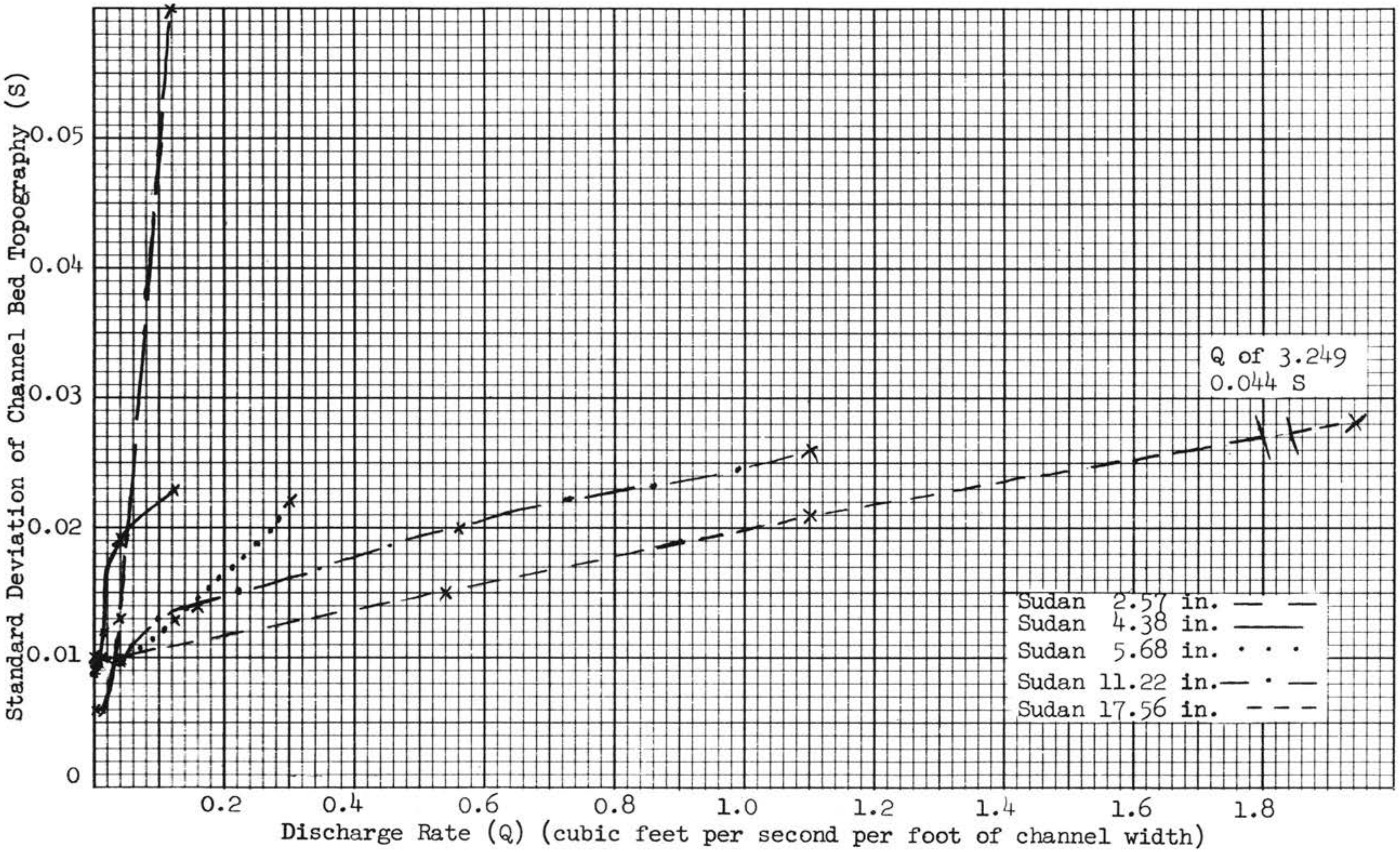

Figure 15. **Standard deviation in relation to velocity of flow per foot of channel width for channels lined with sudangrass.**

channel width (Figure 13) while sudangrass 4.38 inches in height had a scour rate of 0.42 inch per hour when subjected to the same flow (Figure 12). From the results of this study, no comparison can be made between wheat and sudan when greater than 5 inches in height as protective covers for waterway channels because these experiments were not carried to destruction.

Bare Earth Compared to Vegetation

Bare earth channels allowed the water-flow to concentrate in portions of the channel bed whereas vegetation kept the water-flow distributed over the entire channel bed. This concentration of water-flow on a portion of the channels caused soil loss in the form of rills rather than an overall removal of the soil. The comparisons of roughness of channel bed topography for bare earth and vegetative channels are shown in Figures 14 and 15.

This rilling in bare earth channels permitted a discharge rate of only 0.02 cubic foot of water per second per foot of channel width before scour rate was excessive (Figure 13). A vegetative cover of sudangrass 7 days after planting, 2.57 inches in height, allowed three times as much discharge before the rate of scour exceeded 0.3 inch per hour (Figure 12). A vegetative cover of the same type and age but 4.38 inches in height, allowed a discharge rate of 0.07 cubic foot per hour per foot of channel width before the rate of scour exceeded 0.3 inch per hour. Wheat 3.25 inches in height, 9 days after planting, was able to withstand 11 times the discharge rate as bare earth before the scour rate exceeded 0.3 inch per hour (Figure 13). Sudangrass 11.22 inches in height 15 days after planting was able to withstand a flow rate 40 times greater than the bare earth channels at the 0.3 inch per hour scour rate (Figure 12). An increase in height of sudangrass to 17.56 inches and 22 days old, allowed a discharge rate 88 times larger than for the bare earth at the scour rate of 0.3 inch per hour.

CHAPTER V

SUMMARY AND CONCLUSION

A study to determine the protective ability of two vegetative covers of different heights and a minimum density of one plant per square inch in waterway channels was conducted in 1960 at the Stillwater, Outdoor Hydraulic Laboratory located west of Stillwater, Oklahoma.

The channels used for the study consisted of 8 individual channels with a 5 percent slope, 96 feet in length and 3 feet in width. Each channel had nine test stations for determination of the channel bed topography.

The stability that a given cover would offer to a channel was determined by the scour rate (inches of soil removed per hour). The scour which took place in the channels was characterized by an accumulative frequency distribution curve of the 540 measurements for the last 2 flow-rates in each experiment. The roughness of topography of the channel beds was also shown by the standard deviation of the bed readings after each flow.

The permissible scour rate was determined to be about 0.3 inch per hour for this study. Higher scour rates than this resulted in what appeared to be definite damage in the form of rills and overall removal of soil from the channels. For a channel to remain undamaged and within the permissible scour rate of 0.3 inch of soil loss per hour, erosion greater than 0.04 foot must not occur more frequently than 21 percent of the time.

Bare earth channels were able to withstand only 0.02 cubic foot of water flow per second per foot of channel width before the scour rate was excessive (greater than 0.3 inch per hour). Seven days after planting, a vegetative cover of sudangrass was able to withstand three times this flow rate of water before the scour rate was excessive. As the age and height of the plants increased, the protection offered to the channels increased. Sudangrass 22 days old and 17.56 inches in height was able to withstand a flow rate of 1.76 cubic feet per second per foot of channel width before scour rate was excessive. This represents an increase of flow capacity of 88 times over the bare earth channels.

Wheat 3.25 inches in height and 9 days old offered more protection to the channels than did sudangrass 4.38 inches in height and 7 days old. Channels lined with wheat 3.25 inches tall had no erosion greater than 0.13 foot, while sudangrass, 4.38 inches tall, subjected to a flow-rate of 1/3 of that for the wheat had 1.5 percent of its erosion occurrence greater than 0.13 foot.

LITERATURE CITED

1. Cook, H. L. and F. B. Campbell. Characteristics of some meadow strip vegetations. Agr. Eng. 20: 345-359. 1939.

2. Cox, M. B. Tests on vegetated waterways. Oklahoma Agr. Exp. Sta. Tech. Bul. T-15. 1942.

3. _________ and V. J. Palmer. Results of tests of vegetated waterways and methods of field application. Oklahoma Agr. Exp. Sta. Misc. Pub. MP-12. 1948.

4. Hamilton, C. L. Terrace outlets and farm drainageways. U.S.D.A. Farmers' Bul. 1814. 1939.

5. Lake, B. H. "The effects of two different vegetative covers of various physiological ages on the hydraulics of conservation channels". (Unpub. M.S. Thesis, Oklahoma State University, 1960).

6. Ramser, C. E. Grassed waterways for handling runoff in agricultural areas. Agr. Eng. 24: 412-415. 1943.

7. Ree, W. O. Hydraulics tests of kudzu as a conservation channel lining. Agr. Eng. 22: 27-29. 1941.

8. _________ and V. J. Palmer. Flow of water protected by vegetative linings. U.S.D.A. Tech. Bul. 967. 1949.

9. Science in Farming. U.S.D.A. Yearbook Agr. 541-546. 1947.

10. Smith, D. E. Bluegrass terrace channel outlet. Agr. Eng. 24: 333-336. 1943.

11. U.S.D.A. SCS Handbook of channel design for soil and water conservation. TP-61. 1954.

APPENDIX

TABLE I

PLANT HEIGHT COUNT

Type of Coverage	Average Plant Height* in Inches				Ave. for Experiment
	Rep. I	Rep. II	Rep. III	Rep. IV	
Sudan 2.57 inches	2.02	2.48	2.82	2.96	2.57
Sudan 4.38 inches	3.59	3.90	5.08	4.95	4.38
Sudan 5.68 inches	5.42	4.92	6.23	6.17	5.68
Sudan 11.22 inches	11.90	10.66	11.20	11.11	11.22
Sudan 17.56 inches	16.80	18.31	17.80	17.33	17.56
Wheat 3.25 inches	3.08	3.41	3.17	3.36	3.25
Wheat 5.98 inches	6.12	5.78	5.90	6.14	5.98

*The plant height is an average of 90 plants.

TABLE II

PLANT DIAMETER COUNT

Type of Coverage	Average Plant Diameter* in Inches				Ave. for Experiment
	Rep. I	Rep. II	Rep. III	Rep. IV	
Sudan 2.57 inches	0.040	0.043	0.043	0.043	0.042
Sudan 4.38 inches	0.039	0.039	0.047	0.049	0.044
Sudan 5.68 inches	0.059	0.059	0.059	0.057	0.058
Sudan 11.22 inches	0.080	0.078	0.082	0.078	0.080
Sudan 17.56 inches	0.092	0.093	0.099	0.096	0.095
Wheat 3.25 inches	0.048	0.052	0.045	0.042	0.047
Wheat 5.98 inches	0.071	0.063	0.069	0.079	0.070

*The plant diameter is an average of 90 plants.

TABLE III

PLANT STAND COUNT

Type of Coverage	Average Plant Stand*/sq. ft. Rep. I	Rep. II	Rep. III	Rep. IV	Ave. for Experiment
Sudan 2.57 inches	282	267	226	239	254
Sudan 4.38 inches	294	283	261	308	286
Sudan 5.68 inches	284	196	222	205	227
Sudan 11.22 inches	250	252	236	259	249
Sudan 17.56 inches	253	274	267	222	254
Wheat 3.25 inches	324	362	426	357	342
Wheat 5.98 inches	126	150	144	110	132

*The plant stand is an average of 18 square feet.

TABLE IV

SOIL BULK DENSITY AND AMOUNT OF ROOTS

Type of Coverage	Bulk Density* gm./cu. cm.	mg. roots per cu. in. soil**
Sudan 2.57 inches	1.24	8.8
Sudan 4.38 inches	1.35	5.8
Sudan 5.68 inches	1.31	11.3
Sudan 11.22 inches	1.31	12.2
Sudan 17.56 inches	1.36	9.5
Wheat 3.25 inches	1.31	5.1
Wheat 5.98 inches	1.28	3.1

*Bulk density is an average of 12 samples.

**Amounts of roots is an average of 12 determinations.

TABLE V

MECHANICAL ANALYSIS AND SOIL pH*

Percent Clay (less than 2 μ)	Percent Silt (50 μ to 2 μ)	Percent Sand (greater than 50 μ)	Soil pH
11.33	27.23	61.44	6.5

*Mechanical analysis and pH determinations are an average of 3 samples, each being composed of 24 subsamples.

TABLE VI

STANDARD DEVIATION OF CHANNEL TOPOGRAPHY READINGS

Type of Coverage	When Topography Readings Taken	Standard* Deviation
Bare soil	Before first flow	0.0105
	After first flow	0.0227
	After second flow	0.1163
Sudan 2.57 inches	Before first flow	0.0062
	After first flow	0.0067
	After second flow	0.0133
	After third flow	0.0613
Sudan 4.38 inches	Before first flow	0.0092
	After first flow	0.0121
	After second flow	0.0194
	After third flow	0.0239
Sudan 5.68 inches	Before first flow	0.0092
	After first flow	0.0101
	After second flow	0.0107
	After third flow	0.0133
	After fourth flow	0.0228
Sedan 11.22 inches	Before first flow	0.0100
	After first flow	0.0098
	After second flow	0.0144
	After third flow	0.0198
	After fourth flow	0.0265
Sudan 17.56 inches	Before first flow	0.0107
	After first flow	0.0099
	After second flow	0.0105
	After third flow	0.0150
	After fourth flow	0.0210
	After fifth flow	0.0441
Wheat 3.25 inches	Before first flow	0.0106
	After first flow	0.0108
	After second flow	0.0107
	After third flow	0.0162
	After fourth flow	0.0268
Wheat 5.98 inches	Before first flow	0.0113
	After first flow	0.0113
	After second flow	0.0130
	After third flow	0.0180
	After fourth flow	0.0228

*Determined by extracting the square root of the pooled variance of the 36 stations in an experiment.

TABLE VII

SCOUR RATE

Type of Coverage	Flow Number	Flow* Rate	Scour** Rate
Bare soil	1	0.017	0.071
	2	0.039	0.952***
Sudan 2.57 inches	1	0.014	0.010
	2	0.040	0.156
	3	0.124	0.544***
Sudan 4.38 inches	1	0.016	0.081
	2	0.039	0.245
	3	0.125	0.419***
Sudan 5.68 inches	1	0.014	0.007
	2	0.039	0.019
	3	0.124	0.035
	4	0.302	0.127
Sudan 11.22 inches	1	0.039	-0.050
	2	0.169	0.083
	3	0.561	0.188
	4	1.151	0.526***
Sudan 17.56 inches	1	0.039	-0.016
	2	0.164	0.027
	3	0.540	0.061
	4	1.111	0.159
	5	3.249	0.760***
Wheat 3.25 inches	1	0.014	0.007
	2	0.039	0.024
	3	0.138	0.117
	4	0.299	0.417***
Wheat 5.98 inches	1	0.016	-0.064
	2	0.036	0.086
	3	0.132	0.120
	4	0.299	0.231

*The cubic feet of water discharged per second per foot of channel width. Average of the four channels in an experiment.

**Scour rate is inches of soil removed in one hour. Plus quantities indicate scour; minus quantities, deposition. Scour rate per hour was determined by determining the difference in the 540 substation readings after subjected to 40 minutes of testing and adjusting this to an hour.

***Considered destroyed by visual observation.

TABLE VIII

DAILY RAINFALL AT THE OUTDOOR HYDRAULIC LABORATORY, STILLWATER, OKLAHOMA FROM MAY 1 TO DECEMBER 1, 1960

Day	Month					
	May	June	July	August	September	October
1		0.08				
2						
3			0.30			
4	0.34		2.35			
5						
6	1.01	1.33				
7		0.10	0.12			
8	0.13					
9				T*		
10						
11						
12		T				0.03
13			0.27			0.09
14						
15						
16						
17			1.34			
18	0.43			0.98		2.60
19						
20	0.59	0.23			0.09	
21			0.91			
22			0.07			
23					0.19	
24		0.23		0.98		
25	0.88					0.25
26				0.40	T	
27	0.20					
28	1.22					0.18
29			0.06			1.92
30						0.31
31						
Totals	5.66	2.10	5.42	2.36	0.28	5.38

*Trace

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