flows in the major river valleys. Such measures alleviate urban and agricultural damages caused by major floods lower down the main rivers.

This three-phase program is a coordinated approach to flood prevention and control—a program that protects the farmer or rancher of the uplands as well as of the lowlands, and the upstream bottomlands as well as the downstream cities.

ERWIN C. FORD *is an agricultural economist in the Watershed Planning Branch, Soil Conservation Service, Department of Agriculture.*

WOODY L. COWAN and H. N. HOLTAN *are hydrologists in the Central Technical Unit, Engineering Division, Soil Conservation Service, Department of Agriculture, Beltsville, Md.*

The Possibilities of Land Treatment in Flood Prevention

Howard O. Matson, William L. Heard, George E. Lamp, and David M. Ilch

In most tributary valleys, 75 to 90 percent or more of the total flood losses are caused by the comparatively small storms that occur on an average of once in 10 years or oftener.

If overflow in tributary valleys could be reduced to not more than once in 10 years, the risk of flood damage would be no greater, in general, than such other agricultural risks as drought, hail, early frost, lightning, and pests—risks that the farmer takes year in and year out. Often land treatment alone, but generally augmented by small waterflow-retarding structures and stream channel improvements, can provide enough flood protection in the headwater areas to reduce the risk to what the farmer faces against other natural forces.

A flood produced by a thunderstorm usually results when a center of intense rainfall develops at or near the center of a small watershed. Intense rainfall centers ordinarily move at about 15 to 25 miles an hour, and if the storm path follows down a watershed, the severity of flooding is greatly increased. Maximum rainfall during a thunderstorm is rarely more than 12 to 15 inches, although depths exceeding 30 inches in less than 24 hours have been reported.

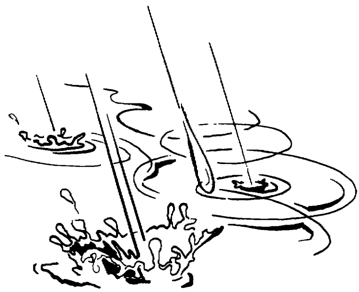
Floods of great magnitude on major rivers are produced only by general storms that persist for several days. When such storms occur in late spring, the flood volume may be increased by melting snow.

The frequency and severity of flooding are greatest in regions next to the Gulf of Mexico, where intensities of rainfall generally are higher than in other regions. Rainfall intensities decrease gradually northward from the Gulf and are higher over the eastern and central parts of the United States than in the territory between the Great Plains and the Sierra Nevada.

Other factors may be important, but the frequency of flooding generally is directly related to the frequency and characteristics of storms. Another factor is the relationship of the channel capacity of a stream to the size of its watershed area. In the Sandstone Creek watershed in western Oklahoma—typical of many small streams in that area—a runoff volume equivalent to one-fourth inch of rainfall from the watershed area was enough to cause flooding under average conditions. As a result, flooding occurred an average of more than nine times a year.

Rainfall occurring before a potential flood-producing storm affects the soil moisture and thereby the rate and volume of runoff that may result from the flood-producing storm that follows. Any effective antecedent rainfall—generally more than one-half inch in 24 hours within 10 days before a flood-producing storm—is usually significant in limiting the soil storage at the time of the storm. The amount of antecedent rainfall that might be

Let the Land and the People Rejoice



This is an account of a program to improve a pilot watershed in Ohio. It is an example, a guide, a lesson. The facts it brings out can be applied to watersheds all over our country.

The Upper Hocking watershed lies west and north of Lancaster, Ohio, the seat of Fairfield County. Its area of 31,418 acres (49 square miles) includes 27,700 acres of farmland, a part of Lancaster, and 3,202 acres of flood plain. The bottom land is intensively cultivated; about two-thirds is in grain each year. Some 44 wholesale, retail, and small manufacturing concerns are on the flood plain within the city.

In the past, any storm that produced 6 inches of runoff inundated the flood plain. Floods have been frequent along the Upper Hocking and Hunters Run, which joins the main channel in Lancaster. Damage caused by a flood in 1948 was set at 1 million dollars. Damages from floodwaters and sediment have averaged 100 thousand dollars a year—somewhat more than half to property in Lancaster and the rest to crops, pastures, farm improvements, and transportation. Gullies are common on the watershed. The slopes have lost up to half the topsoil through sheet erosion.

A watershed-protection program was developed jointly by the local people, the Fairfield Soil Conservation District, and the Soil Conservation Service. Its purpose is to prevent floods and to hold soil and water on the watershed.

The program includes nine drop-inlet dams, which are earth dams with small outlet conduits. They hold back floodwater from a 6-inch runoff long enough so that the water can flow through the conduits slowly, without damage. Structures to control sediment are being built. Stream channels are being improved. Critical sediment-producing areas are being stabilized.

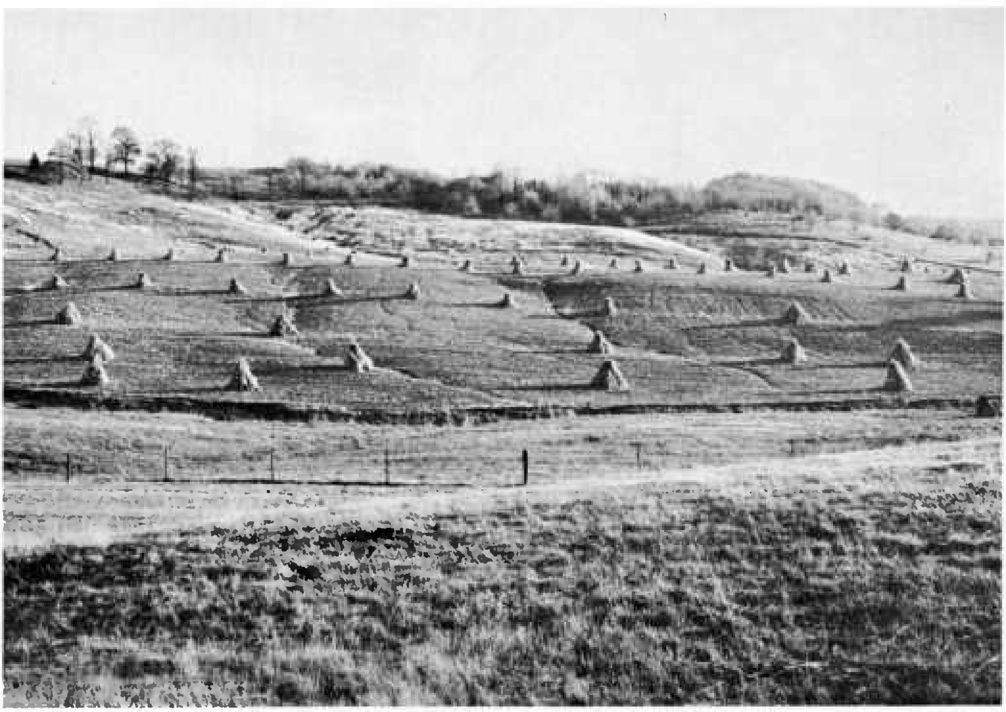
Conservation measures include adjustments in land use, stripcropping, terrace outlets, terraces, farm waterways, seeding of pastures, field diversions, and planting of trees. A fire-control program is being developed. Help in managing forests and woodlots is given landowners.

Residents expect the completed program to yield benefits worth 98 thousand dollars a year in watershed protection, a net increase in farm income of 84 thousand dollars, and a reduction of 87 percent in annual damage from floodwater.

The total cost of the flood-prevention and conservation measures has been estimated at 1.5 million dollars, shared nearly equally by the residents and the Federal Government.

The bottom lands and rolling uplands of the Upper Hocking watershed support general grain-livestock farming on 287 farms, whose average size is 150 acres. From Mt. Pleasant Park one can see a part of Lancaster, a city of 26,500 population. Hocking River and Hunters Run join in the lower part of Lancaster. Their floods have kept in jeopardy the homes and businesses on the flood plain there.

Large gullies may occur on unprotected land. Every heavy rain cuts them deeper. Soil carried from such gullies by floods to lowlands damage the flood plain and must be removed at great cost. Summer storms harm clean-cultivated crops, such as corn. Sheet erosion and incipient gullies may not appear serious at first, but before long they lower crop yields and productivity of soils.

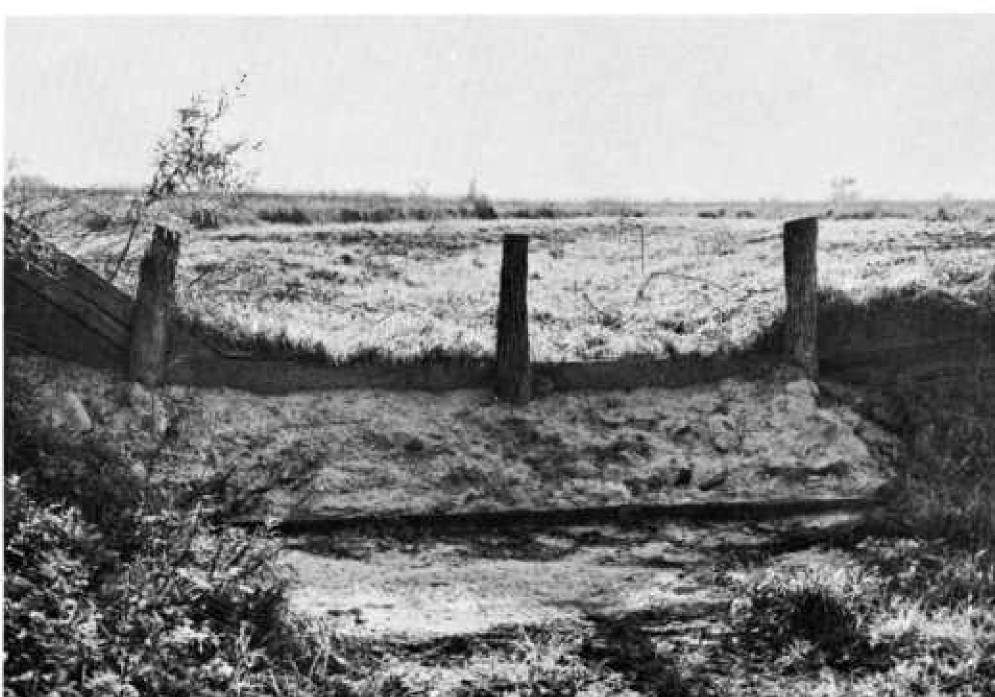


Lancaster suffered a serious flood on July 22, 1948. Small houses were washed from their foundations. Railroad property was damaged. The products of lumbering and other businesses floated away or were buried in the debris and sediment washed down from the uplands.

As the watershed-protection program of the Upper Hocking got underway, farmers and businessmen took an active interest in the work. Here a group is inspecting the concrete dissipator blocks used in the outlet of the first dam to be constructed. Crop inlets, of concrete, provide for a slow, uniform passage of runoff waters into the channel below. The concrete work is finished before the embankment or earth fill is constructed to form the dam.

Engineers of the Soil Conservation Service checked the contractors' work on the dams, nine of which were planned for the watershed, at a cost of about 900 thousand dollars. The surfaces of the completed dams are protected by seeding with grass to prevent erosion. Baled hay is spread as a mulch to help the grass get started.

Work to conserve soil and water on the farms in the watershed has been carried out simultaneously with flood-prevention measures. One practice was to make open drains to eliminate soggy meadows and increase production. Outlets provide safe methods of water disposal for the field waterways. Waterways were graded into former gullies and natural water courses. Grassed waterways are left as a permanent protection to the land and are not plowed during cultivation of fields.



Contour stripcropping protects fields where clean-cultivated and close-growing crops are raised in rotation. The force of water running across bare soil is broken when the water reaches the alternate grass strip. The grass holds some of the water and filters out dirt. Farmers in the Upper Hocking watershed plan to stripcrop about 5,000 acres. Trees planted on otherwise idle land also will help reduce erosion and runoff. Farm ponds are used for stock water, recreation, and other purposes. Ponds can produce up to 200 pounds of largemouthed bass and bluegills per surface acre of water.

considered effective, however, varies from place to place and from season to season. The occurrence of effective antecedent rainfall can be a significant factor in limiting the effectiveness of land treatment.

Generally, land treatment is most effective in reducing the runoff from long-continued rains of moderate intensity and have the least effect on the rates and volumes of runoff resulting from short, intense storms. For example, Ralph W. Baird, project supervisor at the Blacklands Experimental Watershed, near Waco, Tex., reported that conservation practices have reduced peak rates of runoff appreciably and that the reduction in peak rate is a relatively constant amount—about 0.5 inch an hour. This means that a peak rate of runoff of 1 inch an hour would be reduced to 0.5 inch, but a peak runoff rate of 3 inches an hour would be reduced only to 2.5 inches an hour.

The size and shape of watersheds are permanent characteristics that influence mainly the concentration or time distribution of runoff from a watershed. The size and shape of the watersheds greatly affect collection and discharge of streamflow. Surface runoff in some watersheds is quickly assembled and discharged. In some others, the surface drainage is longer delayed and the discharge released more slowly. Part of this influence is due to the soil characteristics. As watersheds increase in size, they become more complex with regard to slope, topography, soil, and the vegetative cover conditions. Many streamflow characteristics are related either directly or indirectly to topographic features which cannot be modified greatly by land treatment.

Steep slopes generally have limited surface soil storage; therefore discharge is usually rapid. This is particularly true of short, steep slopes. The runoff from a long slope is usually slower but lasts longer after the rainfall ceases. The effect of slope will vary with the rate and duration of the rainfall. During periods of prolonged, intense rainfall, when runoff usually becomes a constant, the effect of slope is less pronounced; the converse is usually the case during storms of short duration. Steepness of slope is frequently a limiting factor in the application of land treatment measures which would be most effective in reducing runoff.

Return of all the land to its original pristine condition in order to attain the optimum natural control of water is neither practical nor desirable. The land must be considered as it is today—as it is now used—and in this setting we must try to maintain or improve its productive capacity as well as to improve its hydrologic functions in flood prevention. Because it must continue to be used, and because it is made up of a complex number of elements, there will be distinct limitations in accomplishing the maximum that the land is capable of in reducing runoff and erosion.

Various means have been devised to protect the cultivated soil while continuing to grow crops. Steep, cultivated lands have been terraced instead of simply growing crops on the natural slopes. Contour cultivation is now accepted as distinctly better than cultivation up and down the slope. Stubble mulching, working crop residues into the soil, and various other ways of adding plant material to the soil surface are now recognized practices which stabilize the soil and keep it absorptive of water. Periodically changing from clean-cultivated crops to close growing plant covers is effective in reducing the eroding effect of heavy rains. Breaking the length of clean-tilled slopes with strips of sod is also useful in reducing the soil losses. Listing, strip cropping, green manures, cover crops, and similar practices are used to prepare the soil to absorb water better at the same time it is being used to produce food crops.

Conclusions drawn from rotation studies conducted in various parts of the country indicate that surface runoff and erosion are generally reduced, often as much as 50 percent, by rotations that include one or more years in

325862°—55——13

close-growing vegetation when compared with land continuously row cropped and that the greater reductions occur when the rotation is in hay or pasture crops. In some cases row crops grown in rotation released as much surface runoff and erosion as when they were grown continuously.

Strip cropping appears to have less effect in reducing surface runoff than rotation cropping, but generally it reduces erosion markedly. Strips of close-growing vegetation filter the soil from runoff water entering them from above and protect the soil in the strips from erosion. Strip cropping seems to be a better practice than rotation cropping for erosion control. For adequate surface runoff control, strip cropping should be supplemented with other control measures.

Contour cultivation has reduced the runoff from rains of low and medium intensity as much as 80 percent when compared to the surface runoff from similar fields plowed up and down the slope.

Changes in the composition and the density of the forage cover are due only in part to the consumption of the forage by the livestock. Equally important is the effect of soil trampling by animals. Trampling has a direct effect upon the infiltration capacity of soil, because the animals' hoofs compact the soil, making it less receptive to water. Heavy use is generally more conducive to severe soil disturbance than is light use. In either instance, the effects of use are modified markedly by the texture and moisture content of the soil. Dry, sandy soils are little affected by trampling since they can be compacted only slightly. As soil texture becomes finer and the soil moisture increases, the compacting effect of animal hoofs becomes more pronounced.

Treatment of the range and pasture to reduce surface runoff and erosion and to maintain forage plant cover for livestock use can be accomplished in several ways. In some areas the quality and density of forage can be improved by reducing the number of grazing animals or by excluding all animals for varying periods of time. Forage conditions often are improved by seeding, which provides additional protective cover for the soil. Cultivation and soil fertilization in the East have been effective in rehabilitating depleted range and pasture, with attendant reduction in runoff and erosion.

Heavy grazing on many western rangelands has increased surface runoff and erosion, often causing more frequent flash floods, increased damage to lowlands, and rapid sedimentation of reservoirs. The effects have been shown clearly by comparisons among similar lands grazed heavily and lightly or not at all. Total exclusion of livestock for definite periods is effective in improving both forage and hydrologic conditions in certain western areas.

Pasturing of woodlots in the East is not compatible with good control over surface runoff and erosion, especially on hilly land. Trampling compacts the soil, reducing the rate at which water can enter; browsing destroys the soil-protective cover provided by small and young growth, increasing the susceptibility of the soil to erosion. The sod grasses and legumes that make up most of the forage in the humid sections protect the soil well against erosion, if grazing is not too heavy.

Studies on the Coweeta Experimental Forest in North Carolina show the following effects of logging disturbances in steep mountain watersheds: ". . . Over a 4-year period, 2.3 miles of road lost 6,850 cubic yards of soil. During storms, the stream turbidity on the logged area reached a maximum of 7,000 parts per million as compared with 80 p. p. m. for the check (unlogged) area. . . . Flash runoff from the roads has also doubled flood peaks. Although the logged area is still forest-covered and will produce another crop of timber, its water quality and sediment production are more typical of hillside cornfields than of forest."

Land treatment in forest and woodland areas can be aimed at minimizing the harmful effects resulting from the operations of harvesting the wood crop. Practical methods are now known by which forest lands can be used for timber production and yet contribute substantially to waterflow retardation and erosion prevention. It is possible to improve the hydrologic functions of many of the existing tracts of forest and woodland and to reestablish a protective forest growth on many acres of deteriorated cultivated crop and pasture land no longer usable for that purpose.

To ACCOMPLISH EFFECTIVE land treatment for flood prevention is not simply a question of money—limitless funds would not produce the results without the complete and willing cooperation of the landowner and the operator. The cooperation can be achieved once the land user realizes that erosion and water control on the land will also mean better crops, easier management for him, and a reduction in floods and sediment downstream.

HOWARD O. MATSON *heads the Engineering and Watershed Planning Unit, Soil Conservation Service, Fort Worth, Tex. He has been with the Soil Conservation Service since its creation in 1935. He has degrees in agricultural engineering from the University of Nebraska and the University of California.*

WILLIAM L. HEARD *entered Federal service in 1932. He has been with the Soil Conservation Service since 1935. He is assistant State conservationist for the Soil Conservation Service in Mississippi.*

GEORGE E. LAMP *is area conservationist, Soil Conservation Service, Sioux City, Iowa. A graduate in civil engineering of Iowa State College, he has had varied engineering experience with the Rock Island Railroad and Iowa Highway Commission before he joined the Soil Conservation Service in 1935.*

DAVID M. ILCH *is assistant division chief of Flood Prevention and River Basin Programs, Forest Service, Washington. A graduate forester from Iowa State College, he has had more than 24 years of experience with the Forest Service in watershed management research and flood prevention surveys.*

Frozen Soil and Spring and Winter Floods

Herbert C. Storey

Along with heavy rains and rapidly melting snow as the causes of floods in winter and in early spring, one should consider frozen soil.

Consider first, though, some mistaken beliefs about the occurrence, characteristics, and the effects of frozen soil. Many persons think that if subfreezing temperatures persist for some time, the soil will freeze uniformly over large areas or that once soil is frozen it becomes impermeable and stays frozen until the spring thaw. Some element of truth resides in those ideas: It is true that if temperatures remain below freezing for a time, some soils start to freeze. It is also true that some frozen soils prevent infiltration. It is also true that some soils have remained frozen throughout the winter.

Soil freezing is an important hydrologic factor in the part of the United States where low winter temperatures prevail and the snow cover is light. Its southern boundary is a line extending from the vicinity of New York City southwesterly across New Jersey and Pennsylvania, and west across southern Ohio, Indiana, and Illinois, through the upper part of Missouri and Kansas, then southwest to the Rocky Mountains in the lower part of Colorado, north along the eastern edge of the Rockies into southern Wyoming, westerly to the northeast part of Utah and the southeast part of Idaho, then east and north again along the east front of the Rockies through Wyoming and Montana. Another zone, separated from the main area by the northern Rockies, includes the eastern one-fourth of Washington and a small part of northeastern Oregon.

Soil freezing does occur south of that line, but it is largely intermittent (freezing at night, thawing during the