WATERSHEDS AND HOW TO CARE FOR THEM

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A watershed is a concave or trough-shaped land area in which the runoff from rain and snow drains toward a single channel. A watershed may cover less than an acre, or it may be a complex of many watersheds. Our entire land surface is made up of watershed units. On them we depend for our supply of water.

Never before has our interest been greater than now in water for irrigation, power, industry, navigation, domestic use, and recreation. Most of the water for those purposes has its source on the forest and range lands, which comprise two-thirds of the land area in the United States. Stream flow is a natural product of most of those lands, but the usefulness of the runoff from them hinges on their management.

Watershed management is a system of handling land resources within a drainage primarily to achieve usable runoff. This generally involves the same methods of husbandry that are employed in good forest and range management, but the objectives go beyond the attainment of sustained timber and forage production. Watershed management aims to keep the land in such condition that there will be maximum yields of high-quality water.

Because watersheds have been inexpertly handled, the water problems are critical in all parts of the country. In the past 100 years, while population increased from 17 million to 140 million, the demands for water increased manyfold. Industrial development and municipal expansion are now restricted in many places because of insufficient water. The extent of destructive floods is increasing. Sediment eroded from the land is filling reservoirs, stream channels, and harbors. Those problems will become more serious as our populations and business expand.

Through research on watersheds we are finding out how different types of land use affect runoff and water quality, how to avoid past mistakes, and how to restore and maintain our water resources in the future. Some 40 years ago two experimental watersheds near Wagon Wheel Gap in Colorado were equipped to measure the effect of clear cutting of timber on stream flow. A few years later, a pair of range watersheds near Ephraim, Utah, were similarly equipped to determine the effects of grazing herbaceous plant cover on summer storm flow and erosion. More recently, additional forest and range watershed laboratories have been established in the Rocky Mountains of Colorado and in the mountains of Idaho, Utah, Arizona, and California. The Forest Service has developed an outdoor hydrologic laboratory on the Coweeta Experimental Forest in western North Carolina. Research on runoff and erosion problems of farm lands also has expanded greatly.

Every acre of land in a drainage basin receives and disposes of precipitation and thus functions as an integral part of a whole watershed. On each acre, the plant cover and soil mantle control the reception and disposition of precipitation. The control varies from place to place, resulting in different degrees of balance between the destructive forces of the weather and the developmental processes of soil formation and plant succession.

Before man started to move soil around, the developmental processes of soil formation and plant succession were stronger than the forces of degradation on much of the forest and range lands. That is, soil had been formed on most of those lands faster than it had eroded. The naturally adjusted balances between land and weather that had been in the process of development for thousands of years, however, were disrupted by land clearing, devastation logging, overgrazing of livestock and game, and fire.

Changes took place at the ground surface that altered the manner in which precipitation entered the soil. The storage capacity of the soil was also altered. Those changes threw the original control of water and of soil stability out of balance. The result has been widespread accelerated erosion, sediment in the streams, erratic stream flow, and damaging floods. Nature's original controls were maintained by vegetation. Today, better land-management practices must be inaugurated to restore a more favorable plant cover and soil structure if we wish to maintain land and stream conditions to serve our present and future needs for usable water.

THE SOIL and the underlying rock mantle is the key to understanding the control of water on the land. Soil is capable of storing water. Some of this water is retained by the soil just as water is held behind a dam. But the soil also releases water when the mantle is filled to capacity.

Soils on forest and range lands can absorb and retain against the force of gravity from 1 to 3 inches of water per foot of mantle depth. Fine-textured soils with a high content of organic matter have a greater retention-storage capacity than coarse soils—a dry soil mantle 4 feet deep can absorb and hold from 4 to 12 inches of rain or water from melted snow without yielding a drop of runoff. This retention-storage function is the same as that performed by a dam. Removal of the soil by erosion, or otherwise, reduces the capacity of a site to retain water and so increases the chances for greater runoff and flood discharges in the same way as would the lowering of a dam.

Retention storage is only one of the storage functions of the watershed mantle. After a soil mantle is wet to its capacity to hold water against the force of gravity, it is not yet saturated. Air space still remains between the wet soil and rock particles. This additional storage space may be equivalent to as much as 2 inches a foot of mantle depth. Water that enters these spaces is not retained by the mantle but moves downward to the subsurface aquifers, where it may replenish the ground-water levels, or may emerge in channels or at springs to sustain stream flow.

The percolation of the free water through the soil and rock mantle of a watershed takes time—much longer than the escape of water over the spillway of a dam. The slowness of the percolation process is attested by the fact that streams continue to flow for periods as long as a year after free water disappears from the soil mantle.

The delayed yield of water is one of the most important and valuable functions of watershed lands. Communities and industries pay millions for a sustained yield of water and one of the major purposes of billions of dollars worth of dams is to catch spring floods and make them useful in the autumn droughts. The same functions are performed by the soil on many millions of acres of forest and range watershed lands. These natural and beneficial functions of the soil must be maintained through good management.

PLANTS—herbs and shrubs, as well as trees—are important in maintaining an efficient watershed mantle.

All who have sought shelter under a tree during a rainstorm do appreciate that vegetation intercepts precipitation in its descent to the earth. In a 40-inch rainfall belt, an old-growth hardwood forest will prevent 6 or 7 inches of rain from reaching the ground during the course of a year. This means that insofar as the soil under the forest is concerned there is really only about 34 inches of rain instead of 40. During individual storms the plant canopy may intercept up to 50 percent of the precipitation. The plant canopy, in other words, is an integral part of the watershed reservoir with the special function of intercepting and dissipating a part of the precipitation before it reaches the soil mantle.

Plants and the plant debris on the ground surface protect the soil from the direct impact of dashing raindrops. Big drops are broken into little drops that have less force. Tree trunks, the stems of shrubs and herbs, and dead twigs, leaves, and other trash on the ground keep surface water spread out and moving at low velocities, thus reducing the capacity to erode the soil and retarding movement toward channels. This favors infiltration of precipitation into the soil and rock mantle, and the subsequent yields of water as seepage, rather than overland runoff.

Roots of plants also help in the process. They provide channels for the percolation of water. They bind the surface soil against the scouring effect of storm runoff and anchor the soil mantle on steep slopes to the bedrock.

Vegetation lowers the air temperature near the ground surface and also reduces wind velocity. These influences are especially important in areas where runoff is derived mainly from snow, for they favor the accumulation of snow in deep drifts and slow snow-melting rates. It is not uncommon for snow in the shelter of conifer trees to remain a week or two longer than in the open. This delay in snow melting in turn means a slow and prolonged yield of water.

Also to be remembered is that plants, while they produce good storage conditions, use a great deal of water. An ordinary elm tree of medium size will get rid of 15,000 pounds of water on a clear, dry, hot day. Losses of water by evaporation and transpiration on well-drained forested slopes are generally not less than 15 inches a year and may be twice that much on sites where rainfall is plentiful during the growing season. Still greater volumes are lost by plants along streams where roots have continuous access to water.

The ability of plants to withdraw water from the soil may be bad or good, depending upon the local water problem. Where water is in high demand and the supply is limited, high losses from transpiration obviously accentuate problems of water shortage. But where flood control is important, the removal of water from the soil by transpiration maintains a greater opportunity for storing storm water.

An examination of the land, acre by acre, will show whether watershed conditions are satisfactory or unsatisfactory. Water that is not getting into the soil will accumulate and flow over the surface. Such storm runoff will leave its first traces in washed spots on the soil surface, in little rills, and small piles of leaves and debris. Later the signs are more conspicuous—severe sheet erosion and large gullies.

The management plan for the entire watershed is based on the requirements of its independent parts. Some soils can erode so easily that even the slightest change in the natural vegetation results in disastrous erosion. On them, it is good land management to prevent any possible disturbance of natural conditions; if they already have been disturbed, it is good land management to try to restore as much plant cover as conditions will support and as soon as possible.

Failure to recognize watershed deterioration in its early stages and to start remedial action toward the control of abnormal runoff and accelerated erosion is almost certain to lead to still greater deterioration and a more difficult and costly restoration job. This has happened in northern Mississippi, where 60-foot gullies are almost impossible to fill or stop.

Examination of channels and stream deposits is another approach toward determining watershed condition. Unusual deposition, channel cutting, and high watermarks may constitute direct evidence of abnormal watershed conditions. An accurate interpretation of these downstream indicators is sometimes difficult because of complex geologic and climatic factors. Even under these circumstances, however, the signs of flood runoff and siltation are the best guide toward locating the problem areas on the watershed. By indicating the source of the storm runoff and sediment, they point to the areas that need better management.

The next requirement for effective watershed restoration is the selection of the best remedial measures. These fall into several categories, depending upon the degree of deterioration and the prospects for recovery.

The first of these are measures that will aid in the natural establishment and growth of local plants. Protection from fire is important. Regulated grazing is necessary. In many sections fencing out all livestock is imperative. Seed trees must be left when the timber is harvested. In some cases all such uses must be curtailed or prohibited. These measures are applicable on areas where there has been but slight deterioration and where it is reasonable to expect rapid improvement. Chief indicators of successful natural revegetation possibilities are an abundance of seed plants and a fertile soil.

On certain areas that have been overused or damaged by fire, plants will not come in of their own accord, because seed source is inadequate. Methods of planting and seeding will differ greatly for the different regions. Planted and seeded areas must be given intensified fire protection and at least temporary protection from grazing and trampling until the new vegetation becomes well established.

Mechanical controls such as contour trenches, water spreaders, gully plugs, water drops, retaining walls, impounding dams, and debris basins constitute a third category of watershed-restoration measures. They are essential where erosion is severe and active. Mechanical measures, in nearly all instances, should be considered as methods of site preparation so as to expedite vegetation establishment.

It is of utmost importance that the need for mechanical controls be recognized. A too-optimistic judgment as to the probable success of achieving effective restoration by natural and artificial revegetation will only lead to failure and a more difficult and costly job at some future date. It is far better to overdo the restoration work than to risk failure by underestimating needs.

The preservation of existing values on a watershed is obviously a sounder and cheaper course than restoration of any kind. The primary objective of maintenance is to preserve the water-controlling functions of the land. This means keeping storm-flow discharges and sediment loads to a minimum. Such an aim—since soil stability is the key to maintaining normal hydrologic behavior—can only be achieved when the plant cover and soil mantle are in condition to withstand damage from occasional unusually heavy storms. That is to say, a safety margin is necessary. In countless cases it is the "usual" storm that does the damage.

A high degree of fire control is the first requirement for maintaining satisfactory watershed conditions. The purpose of fire control in watershed management is to prevent a reduction in the density of the plant cover and litter and in the organic-matter content of the soil. Fires that bare the ground and lessen the water-holding capacity of the mantle almost invariably result in accelerated erosion and increased storm-flow discharges, even on the sites where vegetation grows quickly.

Fire-control standards vary for each drainage basin and for parts of drainage basins having different runoff and erosion potentials. Steep watersheds that are subject to rains of great volume or high intensity obviously require more protection from fire than areas on which there is a lesser risk of accelerated erosion and flood runoff.

Fire-control plans must give adequate consideration to the downstream values. The presence of reservoirs, harbors, canals, factories, farms, communities, and other developments so located downstream as to be susceptible of flood and sedimentation damage may require a higher degree of fire control than is needed for the protection of the timber, forage, or other resources on the watershed lands. In some places the downstream values may be so great as to warrant a fire-control program tight enough to prevent the occurrence of any man-made fire, with provision for the immediate suppression of naturally caused fires.

Construction improvements, such as roads, trails, airfields, and the like, are potentially hazardous from the standpoint of runoff and erosion because they uncover extensive land areas. The construction of such projects calls for special precautions.

First, roads, trails, and other clearings should be located and designed so as to cause the least possible soil disturbance. Provision should be made for the immediate stabilization of cut and fill slopes. Because such projects invariably produce some runoff, experience shows that adequate provision is needed for safely passing the drainage water to the natural channels, or for storing the runoff in the adjacent mantle by contour trenching or terracing the land. Provision for regular maintenance and prompt repair of cut and fill slope stabilization works and of drainage facilities is essential. Where it is not feasible—physically or economically—to meet these requirements of satisfactory watershed maintenance, the improvements should not be built.

The construction of water facilities, such as dams, canals, and transmountain diversions, present other problems. These require consideration of all possible adverse effects as well as beneficial effects on watershed conditions. All, of course, must be designed against failure. Adequate provision should be made in the design and operation of impounding dams for maintaining an effective habitat for fish and other aquatic life. Transmountain diversions should be constructed and operated so as not to cause the scouring of channels and consequent sedimentation in the areas to which water is diverted. Full advantage should be taken of opportunities to spread the store water underground.

Harvest cuttings, timber-stand improvement, thinnings, and the other cultural treatments of the forest and range cover offer possibilities of improving the usefulness of stream flow in two ways. Some types of treatment will result in increased, or more timely, yields of water; others, in less runoff.

Removal of trees and shrubs from along stream banks and on valley bottoms where the plant roots have continuous access to free water in the channels or valley fill is an effective means of reducing transpiration losses and thus increasing stream flow during the growing season. Conversion of a forest type to a plant cover that requires less water for growth offers another possibility of increasing water yields. It may be desirable on some western watersheds, for example, to suppress the deep-rooted aspen, which consumes up to about 20 inches of water in a growing season, and encourage a plant cover of more shallow-rooted grasses and herbs that require several inches less water for growth.

In other areas, where most of the stream flow is derived from winter snow, harvest cuttings of the conifers, which create openings for deeper accumulation of snow and decrease interception losses, offer another chance of obtaining a greater or a more prolonged yield of stream flow. Studies in Utah indicate the use of snowdrift fences may accomplish similar results on high-elevation and windswept snow fields. All such measures should be undertaken, however, only when they can be accomplished without causing accelerated erosion or a serious increase of flood discharges.

In many parts of the country the flood hazard is high because of prolonged, copious rainfall, or very high rates of rainfall and of snow melt. Flood control in such areas generally requires the maximum possible cover of vegetation and litter. Here harvest operations should be aimed at maintaining a canopy that will intercept and evaporate the greatest possible amount of precipitation before it reaches the ground. There should be a minimum of disturbance to the litter or the soil surface, so as to maintain maximum possible rates of infiltration of water into the mantle. Harvesting methods should also provide for the encouragement of the species that are capable of transpiring large quantities of water and thus maintain the greatest storage capacity in the mantle.

Logging operations can and often do cause serious watershed impairment, even though they leave the stand in satisfactory condition for natural regeneration. The chief injury is that brought about by the clearing and compaction of the soil along skid trails and haul roads. Compaction and consequent abnormally rapid surface runoff is known to persist for many years even though the land is quickly revegetated. Skid trails and similar disturbances to the soil should be held to a minimum. There should be adequate provision for the immediate stabilization of loosened soil, for the safe handling of drainage, and for the reestablishment of plant cover so as to prevent excessive runoff and accelerated erosion. Where these watershed maintenance requirements cannot be met, there should be no logging.

The most difficult of all watershed-management jobs is to maintain satisfactory watershed conditions on an area heavily grazed by livestock and big game. Many have considered this solely a western problem. But that is erroneous, for serious grazing-watershed problems exist in the Central States, in the South, and in the East.

The chief thing to avoid is overgrazing. When the livestock overcrop the herbaceous and shrubby forage, the ground surface is bared to the direct impact of the rain. This condition opens the canopy, permitting the sun's rays to hasten the disintegration of litter on the ground. Consumption of the forage, though it puts pounds on the grazing animals, robs the soil surface of its normal annual accumulation of dead grass stalks and leaves. Continued over the years, this further exposes the soil surface. In addition, the hoofs of the grazing animals compact the soil or push it down hill. All these effects lower the capacity of the land to soak up and store water and therefore favor destructive overland flow, accelerated erosion, and greater sediment loads in the streams.

Overgrazing results in progressively serious stages of watershed deterioration. With each decrease in the capacity of a site to take up and store water, less precipitation is required to cause overland flow and accelerated erosion. Once the processes of deterioration get under way, there is less and less control of runoff and more and more soil loss. Thus, without any change of climate, watershed impairment results in more and larger storm flows and greater sediment loads.

The maintenance of satisfactory watershed conditions under grazing requires extreme care in the handling of stock on the range and in the location and use of driveways, water developments, salt grounds, bed-grounds, and similar stock-control devices so as to give a minimum of soil disturbance and depletion of the plant cover. Grazing use should be avoided when the soil is wet, particularly on sites that are susceptible to compaction. In some places satisfactory conditions can be maintained by postponing grazing until after the season of high-intensity storms. Great care is needed to make certain that safely grazeable portions of a range can be used without causing impairment to adjacent lands.

Finally, there is need for adequate and frequent inspections. They should be made by men who can determine accurately the effect of grazing on the condition and trend of the range. They must not be limited solely to consideration of the forage plants but must also give adequate consideration to the soil and its litter surface. Inspections must be followed by prompt remedial action.

The achievement of effective watershed management is a big task, but it is not hopeless. We have learned much by observing the effects of unplanned exploitation of our forest and range lands. Research in different parts of the country is now beginning to specify effective management procedures. Experience and research show that efficient watershed management is usually the best possible forest and range management. Good forests, good range, good soil, good water go together.

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TO HELP CONTROL FLOODS

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Many of our serious water problems have their roots in the misuse of land. The same human activities that aggravate water-shortage difficulties also contribute to uncontrolled water surpluses and all the misery and destruction they bring in their wake. Basically, the flood-control program of the Department of Agriculture aims at more than the repair of damaged watersheds. Even more important, it seeks to help those who now hold the land in trust to pass it on unimpaired so that the national health and strength will be maintained.

Large acreages of our finest bottom lands lie increasingly exposed to the threat of recurrent floods. Many farms are ruined beyond repair by the relentless cutting away of fertile fields that border on streams. The safety and productivity of the extensive industrial, community, water-supply, and other developments are seriously endangered by the murky flows that so often originate on the improperly handled crop, forest, or range lands.

Much more damage is caused annually on the average by the more frequent floods on the smaller tributaries than by the large, spectacular floods on the main streams. Flood and sedimentation damages alone now amount to well over 300 million dollars each year throughout the United States. More than 100 million dollars in losses occur on the Mississippi River system alone—damages that are mostly above and beyond the growing losses in the storage capacities of reservoirs due to filling with material carried down from eroding watersheds.

Progress has been made in the building of works on our major waterways to reduce the flood losses. Comparable progress will have to be made in treating watersheds to reduce the greater aggregate damages we find on the smaller streams and to slow down the rate at which sediment is ruining reservoirs.

Engineering developments cannot by themselves overcome the problems of floods, because they operate only after the floodwaters have concentrated in the main channels.

We must begin where the floods begin. We must retard the runoff and reduce or prevent the loss of soil from the watershed lands themselves, be-

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