Interrelationship Between Watershed Condition and Health of Riparian Areas in Southwestern United States

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Abstract.—Sensitive hydrologic interrelationships exist between watershed condition and the health of associated riparian areas in the southwestern USA. The impact of extensive unmanaged livestock grazing, wildfires, and past forest clearing, coupled with numerous small linear perturbations such as travelways, low standard roads, and livestock trails, has dramatically illustrated the interrelationship between watershed condition and riparian health. Vegetation removal and soil compaction substantially increased surface runoff, produced sediment-laden flows, and increased erosive power to the channel system, upsetting the balance between riparian areas and the surrounding watershed. This led to the degradation, or in some cases complete destruction, of many riparian areas. A key factor in improving deteriorated riparian areas is understanding the balance that existed between watershed condition and riparian health in near pristine conditions. Under such conditions, watershed slopes and riparian channels were able to dissipate rainfall and concentrate flow energies produced during different precipitation events. This paper discusses the interdependency between hydrologic processes operating on upland slopes of a watershed and the channel processes affecting downstream riparian stability in the southwestern USA. A synthesis of this information is used to outline a method for assessing the capability of a watershed-riparian system to attain acceptable low-maintenance conditions in response to different rehabilitation treatments.

Riparian areas are closely interrelated with the surrounding watershed. For example, riparian communities stabilize stream channels (Riedl and Zachar 1984), provide repositories for sediment (Lowrance et al. 1986), serve as nutrient sinks for surrounding watersheds (Lowrance et al. 1984), and improve the quality of water leaving the watershed (Schlosser and Karr 1981). They also provide temperature control through shading, reduce flood peaks by providing resistance to flow, and serve as key recharge points for renewing ground water supplies (McGlothlin et al. 1988). However, riparian areas must be managed within the context of the entire watershed because all tributary effects cumulate to influence riparian health and stability. A delicate balance exists between riparian communities and the conditions of the watershed in which they reside. Upland watersheds in satisfactory condition absorb storm energies, provide regulation of stormflows through the soil mantle, and, as a result, provide stability to the entire watershed. This, in turn, provides sustained flows necessary for supporting healthy riparian ecosystems.

In contrast, watersheds receiving past abuse have developed channel systems throughout the watershed, including ephemeral gully networks, in response to increased surface flows which cause headcutting and gully formation. These gully networks cause rapid, concentrated, surface runoff which increases peak flows and produces large amounts of sediment. Past abuse and overuse of wildlands throughout the southwestern USA by grazing, trail and road construction, timber and fuelwood harvesting, mining, and other land uses have not only destroyed plant cover and increased soil erosion but also, in the process, reduced valuable riparian habitat.

A large body of information is available on watershed abuse and its effect on the condition of a watershed. Likewise, a considerable amount of information is emerging which describes the factors necessary for maintaining healthy riparian areas (e.g., streamflow duration, channel stability and configuration, grazing management, etc.). However, we are not aware of any publication which stresses the interdependency between the health of riparian areas and upstream watershed condition when developing rehabilitation strategies. Therefore, in this paper we (1) discuss the interdependency between watershed condition and riparian health, (2) identify specific hydrologic processes important for maintaining an acceptable balance between riparian areas and the surrounding watersheds, and (3) provide guidelines for developing rehabilitation strategies based on the balance between watershed condition and riparian health. Although this paper focuses mainly on rangelands in the southwestern USA, some of the general principles developed have application on forests and brushlands throughout the western USA.

Riparian Health and Watershed Condition

"Riparian health" refers to the stage of vegetative, geomorphic, and hydrologic development, along with the degree of structural integrity exhibited by a riparian ecosystem. As such, riparian health reflects an equilibrium condition between aggradation and degradation processes operating within the riparian area, which is dependent upon the condition of the surrounding watershed. The term "watershed condition" describes the state of a watershed. It effectively integrates a number of resource factors including vegetation cover, flow regime, sediment and nutrient output, and site productivity (Hanes et al. 1986). In essence, the riparian communities reflect both biotic and abiotic conditions of the watershed in which they reside. A major assumption underlying the discussions in this paper is that a healthy riparian community reflects a dynamic balance between the riparian ecosystem, including the associated channels, and the hydrologic and geomorphic processes operating in tributary watersheds. Furthermore, it is implicit in this assumption that healthy riparian areas require stable watershed conditions to maintain and perpetuate themselves. However, the converse is not necessarily true; that is, watersheds in satisfactory condition require a healthy riparian area. Concentrated activities in the riparian areas (e.g., grazing and placer mining activities) may severely disturb the riparian areas but not affect the surrounding watershed.

The balance between watershed condition and riparian health represents a dynamic interrelationship between runoff and erosive forces where precipitation forces producing runoff are counteracted by vegetative, geomorphic, and structural resistance. When this natural system is in equilibrium, it maintains a level of stability tending to dissipate potential energies that would otherwise cause rapid changes. This resistance to change emanates from a combination of factors acting together throughout a watershed. Most important of these factors is vegetation. The relationship between vegetation cover and runoff and erosion has been extensively documented for wildland areas throughout the western USA by numerous investigators for several decades (Forsling 1931; Craddock and Pearse 1938; Woodward and Craddock 1945; Packer 1951, 1953; Dortignac and Love 1960; Rich and Reynolds 1963; Lusby 1970; Gifford 1976; Busby and Gifford 1981, Gifford 1985). Flows in excess of channel capacity overflow onto floodplains where vegetation and other debris provide a substantial resistance to flow and act as filters for sediment (Lowrance et al. 1984).

A watershed-riparian system in balance is also resilient. Most of the potential runoff produced by storms immediately infiltrates into the soil, and thus provides a more regulated flow according to the variable source area concept (Hewlett and Troendle 1975). Excess runoff reaching the channel increases flow volume and velocity, and this short-term increase in flow causes an oscillation in the balance between erosion and deposition. While the balance tips back and forth, it is quickly dampened by the channel characteristics. As a result, there is no permanent change in the central tendency toward maintaining an equilibrium between aggradation and degradation processes in the riparian area. The resilience, or elasticity, of the system is not violated, and little perceptible change in the apparent balance or erosional tendency occurs.

The balance between watershed condition and riparian health is well substantiated by recent reviews describing pristine riparian areas throughout the southwestern USA (Dobyns 1981; Minckley and Rinne 1985). These accounts portrayed these riparian areas as stable, aggrading stream networks containing substantial amounts of organic debris and supporting large beaver (*Castor canadensis*) populations. Under these conditions, headwater tributaries provided a continuous supply of small and large organic debris that formed log steps in smaller streams (Heede 1985), and large accumulations of logs and other organic debris along larger order, low-elevation mainstreams (Minckley and Rinne 1985). Naturally occurring floodplain and channel structures, along with living plants, dissipated energy, controlled sediment movement and deposition, and thereby provided a regulated sustained flow. These factors provided a hydrologically stable environment necessary for maintaining and perpetuating healthy riparian communities. The energy dissipation decreased flow velocities in stream channels and on floodplains, which improved percolation of water into subsurface storage. This delaying effect was likely enhanced because many stream channels were above fault-fracture zones that led to underground aquifers (McGlothlin et al. 1988). Water stored in these high-elevation aquifers was available and, when slowly released, supported late-season flows in downstream riparian areas. Sufficiently dense vegetation and ground cover were present throughout the watershed, which allowed most precipitation from storm events to infiltrate into the soil. Water passing slowly through the soil mantle sustained the dependable perennial streamflow necessary to maintain downslope riparian communities. It is important to note that under a pristine regime, where most storm events infiltrated into the soil, channel networks were less extensive (Carlston 1963). In particular, swales and slopes were generally free of incised channels and gullies. Flows also typically contained lower concentrations of sediment. Sustained flow provided a favorable environment for extensive riparian vegetation and supported beaver populations that constructed dams, which further regulated flows. The beaver were likely in balance with the food supply and predation and may have expanded the areas supporting riparian vegetation (Parker et al. 1985; Skinner 1986).

Past misuse of both watershed sideslopes and associated riparian communities throughout the western USA effectively disrupted the balance between watershed condition and riparian health. A common sequence of events leading to destruction of these upland riparian communities was as follows. Grazing and timber harvesting led to a loss of protective plant cover. When removal was severe, infiltration was reduced and overland flow increased (Leopold 1946; Ellison 1954; Elmore and Beschta 1987). Excessive overland flow delivered more water to the channels, where it exceeded their capacity and enlarged them. This produced expanded drainage networks which maintained rapid runoff that carried large amounts of sediment. When roads and trails were developed as part of this use, overland flow was further concentrated and water delivery to the channels increased. Incised channels drained existing water tables, many of which were close to the surface and supported healthy riparian communities. Lowered water tables led to dewatering, destruction of riparian communities, and an overall reduction in site productivity (Heede 1986). Therefore, the attributes of satisfactory and unsatisfactory watershed condition and riparian health were quite different (Table 1). Concurrently, misuse of lower elevation mainstreams by woodcutting, agricultural development, and urbanization, or more subtle impacts of desiccation from stream incision, impoundment, and channelization, also led to widespread destruction of riparian areas along the large lower elevation rivers throughout the southwestern USA (Conrad and Hutchinson 1985; Minckley and Rinne 1985).

Restoring The Watershed-Riparian Balance

The interrelationship between watershed condition and riparian health is delicately balanced and, consequently, responds readily to both natural processes and human activities (Forsling 1931). Watershed specialists recognized early the need for action programs aimed at rehabilitating these misused and deteriorated watersheds (Forsling 1931; Leopold 1946). This awareness led to widespread implementation of watershed rehabilitation programs throughout the western USA. The objectives of these early projects were to improve plant cover and reduce runoff and erosion by using either revegetation techniques or engineering structures, or both. Implementation of these treatment measures generally reversed the processes

Table 1.—Attributes of satisfactory and unsatisfactory levels of watershed condition and riparian health.

	Satisfactory level		Unsatisfactory level
		Watershed condition	
A	Vegetation and litter cover capable of absorbing precipitation energy, increasing infiltration, and extending release of flow to channels.	A'	Storm energies detach soil, seal soil pores, and create rapid sediment-laden runoff, resulting in ephemeral flows.
B	Minimum drainage density channel network is necessary for conveying runoff from watershed.	B'	Expanding drainage density and channels to accommodate increased surface flow.
C	Maximum temporary storage of water in the watershed system.	C'	Rapid conveyance of water from watershed with minimum retention of water for later release.
D	Limited sediment available in and adjacent to the channel.	D'	Sediment supplied from a variety of upland sources, including sheet erosion and mass erosion from gullies.
		Riparian health	
A	Efficient channel shape with narrow width that conveys all flows less than that of the mean annual peak flow event (2.33 year recurrence) with minimum bank and channel erosion.	A'	Inefficient channel shape often braided or shallow and widely fluctuating. Most events confined in channel. Maximum bank and channel erosion and expanding width.
B	Stream power $<$ critical power.	B'	Stream power $>$ critical power
C	Expanded channel length having lower hydraulic energy gradient and higher sinuosity.	C'	Shortened channel length having higher hydraulic energy gradient and low sinuosity.
D	Narrow, deep, stable channels.	D'	Shallow, wide, unstable channels.
E	Flows above mean annual peak spread over floodplain in low-energy flow: dissipating energy, filtering sediment, and capturing sediment.	E'	Flows contained in channel. Higher velocities associated with flows exceeding mean annual peak. Limited energy dissipation. Full conveyance of sediment and nutrients downstream.
F	Constant log step formation in confined channels. Well-developed meanders in nonconfined channel.	F'	Limited step formation by organic material. Gravel bars or rock structures are primary controls.
G	Channel generally stable with aggrading floodplain.	G'	Channel degrading with infrequent floodplain deposits. Floodplains undermined and eroded.

responsible for originally destroying the balance between riparian areas and the condition of the surrounding watershed. As a result, these treatments provided a new balance in the riparian-watershed system so it could respond to a wider range of storm and streamflow events (oscillations) without producing drastic or permanent changes in the relative balance.

A variety of land treatments and revegetation measures can be applied to deteriorated watersheds to improve hydrologic conditions on watersheds so that riparian communities are stabilized or new ones created. However, proper identification of the causes for degradation and stage of channel evolution is required before different rehabilitation strategies can be developed (Van Haveren and Jackson 1986). General approaches for providing a more stable interrelationship between riparian areas and their surrounding watersheds are based on two general types of actions: (1) improving watershed condition on the sideslopes; and (2) stabilizing channels to reduce erosion. These actions provide the basis for defining and implementing a series of treatments ranging from simple changes in grazing management or revegetation activities to more complex measures involving constructing channel structures that establish base-level controls. A careful analysis of the above treatment alternatives within the framework of cause-and-effect relationships is needed before a rehabilitation program can be implemented (DeBano and Hansen 1989). Problem identification must also include evaluating both land and channel systems as they relate to land-use practices.

Improving Watershed Condition

A first step in restoring an acceptable balance between riparian health and watershed condition is to improve the latter. Riparian rehabilitation should not be attempted in stream systems where watershed condition is unsatisfactory or in a declining trend (Heede 1977; Van Haveren and Jackson 1986). Rehabilitation treatments may be aimed at both improving the vegetation cover on sideslopes and controlling gully erosion in small headwater streams of a watershed. Often, improved management restores plant cover, but the expanded channel network continues to rapidly transmit unfavorable flows and erosion. This demonstrates the importance of rehabilitating the geomorphic slope and surface conditions (i.e., channel shaping) along with improving vegetation cover.

The simplest way of improving watershed condition is to provide plants an opportunity to regain vigor and establish a denser ground cover. Increasing plant cover allows more water to infiltrate into the soil mantle, where it slowly moves downslope into channels. Proper grazing management is the key to improving plant vigor. Where plant cover cannot be improved by grazing management alone, grass seeding and temporary mechanical treatments to retain water and aid in vegetation establishment are viable alternatives. However, these treatments will require several years of rest from grazing so that plants can become well established (root-firm) before grazing is resumed.

Contour trenching has been used with variable success. When properly designed and applied, trenches have been used successfully to improve badly deteriorated high-elevation watersheds in Utah (Bailey et al. 1947; Copeland 1960). In contrast, when rehabilitating steep chaparral watersheds in southern California after a wildfire, trenches could not be designed properly and were found totally ineffective (Rice et al. 1965). In Utah, contour trenches not only reduced peak flows (DeByle 1970a; Doty 1971) but also increased soil moisture storage immediately beneath the treatment depressions (Gifford et al. 1978); however, infiltration rates into trenches varied considerably, depending upon the soil parent material used for constructing the trenches (DeByle 1970b). Reseeding contour trenches with a variety of native and introduced perennial grasses has been found to be an effective means of stabilizing trenches and improving their uptake of water. The best seeding responses are usually obtained in terrace bottoms (Hull 1973). Implementing upstream treatments on watersheds may not necessarily lead to perennial streamflow, but it does provide a method for reducing surface runoff and improving sideslope moisture conditions, which, in turn, contributes to improved watershed condition.

The Role of Channel Treatments in Rehabilitation

Riparian communities in the southwestern USA have been particularly sensitive to overuse because they exist in a semiarid climate and are subjected to wide variations in annual precipitation (Leopold 1946). Perennial surface streamflow frequently does not occur in many smaller drainages throughout the southwestern USA. Marginal streamflow conditions make watersheds and associated riparian areas extremely sensitive to overuse. Any rehabilitation of deteriorated riparian areas is often complex and difficult. In many cases where extensive long-term abuse has occurred, exclusion from grazing and revegetation measures alone may not be sufficient to fully restore former riparian communities. Therefore, additional supplementary measures may be needed, such as the construction of gully structures in upland watersheds (Heede 1968b, 1977). These are often costly and complex but effective means of providing a more stable environment for riparian recovery (Heede and DeBano 1984; Hansen and Kiser 1988; DeBano and Hansen 1989).

An important consideration when designing rehabilitation treatments for upland areas is to be aware of their effect on channel dynamics and to include provisions for maintaining these structures under different channel equilibrium conditions (DeBano and Heede 1987). This is particularly important when riparian restoration depends upon expensive and complex treatments, such as tributary channel structures. Spillway stability and integrity of structures should be checked regularly and appropriate repairs made immediately to weakened or damaged structures. Applying good range management principles in conjunction with channel structures is a prerequisite to long-term success. This requires applying livestock management methods and stocking levels compatible with watershed and riparian improvement objectives as a whole. These approaches have proven vital to the health and success of created riparian communities.

Guidelines for Improving Watershed Condition and Riparian Health

The principles relating to watershed condition an riparian health presented above provide a basis for formu lating general management approaches and specifi treatment plans necessary for successfully addressin riparian area rehabilitation. This section summarizes th background information presented above within the cor text of a close interrelationship between riparian healt and watershed condition. This synthesis is then used as th basis for developing guidelines to (1) diagnose the cause for disrupting the balance between riparian health an watershed condition; (2) define the objectives for alterna tive treatments; and (3) specify treatments necessary fc restoring an acceptable balance between watershed cond tion and riparian health.

Various factors, including land uses and misuses, ca affect the balance between watershed condition and ripa ian health by creating (1) excessive runoff, (2) increase frequency and magnitude of peak streamflow, (3) steepe stream slope, (4) excess tributary sediment, and (5) accele ated bank erosion. Substantial misuse of the watershe can destroy the balance between watershed condition an riparian health. Loss of this balance causes a series c adjustments in erosional and depositional processes t occur in the riparian area until a new balance is estal lished. Once achieved, a new balance is maintained unt additional changes exceeding the elastic limit of the sy tem occur, setting the process of adjustment in motio again.

After the factors responsible for disrupting the balanc between watershed condition and riparian health hav been identified, their causes can be used as guiding princ ples for rehabilitation. These principles can be used fc formulating specific treatment objectives and remedie necessary to restore the balance between satisfactor watershed condition and riparian health (Table 2). Th large array of possible treatment alternatives discusse above can be classified into two general types, those use for (1) improving vegetation cover and reducing surfac runoff and erosion from sidelopes; and (2) stabilizin channel networks. Four broad alternative courses of actio arise from these two general approaches. The first alterna tive is to neither improve sideslope cover nor stabilize th channel. This alternative would usually not be acceptabl where riparian-watershed systems are completely out c balance.

The remaining three alternatives require different le els of action programs. A second alternative may involv only managing sideslopes. Sideslope treatment would b feasible on those watersheds where naturally occurrin (e.g., bedrock) control sections are present. Natural cor trols may have been exposed by channel erosion and b currently limiting future downcutting. Under this alterna tive, if rilling has not occurred, then grazing managemer alone may allow a dense vegetative cover to become estal lished. Where surface rilling is severe, channel bank sha ing, contour trenching, and revegetation may all b required. Techniques for stabilizing channel bank by sha ing and revegetation, including use of burlap strips, ar described by Heede (1968a, 1975). The primary objective c these treatments is to enhance the natural healing pro esses, revegetate channel banks, and reduce sediment cor tributions from bank erosion. It is unlikely riparian con munities would be established in response to this treatmer alternative.

Table 2.—Conditions threatening riparian areas and possible remedies for achieving different treatment objectives.

Condition	Cause	Remedy	Treatment objective
Excess runoff	Major flood events on pristine watersheds.	None on watershed. If riparian areas have been damaged, then some structures, bank stabilization, and revegetation may be necessary.	Rehabilitate changes.
	Areas with depleted cover lacking infiltration capacity and resistance to surface runoff.	Improve livestock, game, or fire management. Revegetate and manage for increased vegetation and litter cover.	Increased resistance to surface flow. Greater infiltration capacity. Eliminate sheet runoff.
Increased frequency and magnitude of flow events.	Rilled and gullied slopes resulting from depleted cover or soil compaction.	Reduce drainage density by constructing contour furrows or trenches and manage for increased ground cover. Restoration of vegetation.	Increased retention of storm flow on-site until infiltrated. Eliminate concentrated flow. Regulation of runoff through soil mantle. Increase of vegetation cover and improve infiltration.
	Roads and travelways that intercept, collect, and concentrate flows.	Intercept flow paths with waterbars and divert flows to areas with greater infiltration capacity. Rip and reseed compacted surfaces where travelways have been abandoned. Improve forest filter by adding log flow obstructions or detention basins. Eliminate traffic.	Shorten slope length. Infiltrate excess flow into forest floor. Restore on-site infiltration of flow and protect soil. Regulate flows through soil mantle.
Excess discharge	Transbasin diversion that produces the effect of greater drainage area and increased flow.	Provide reservoir storage to regulate transferred flows. Avoid inchannel transport of increased flows. Convey increased flows during low-stage seasons.	Maintain flows within the limits of critical stream power.
	Forest harvest effects on water yield that produce greater runoff.	Schedule harvests in time and space over the watershed to maintain increased runoff within the range of channel capacity and critical power. Consider effects of various silviculture techniques on snow retention and water yield. Minimize road density and drainage of lower slopes by roads.	Maintain flows within critical power threshold. Dissipate peak flows through soil mantle.
Excess stream slope	Channelization of riparian areas by roads, trails, and travelways.	Avoid roads, trails, and travelways in riparian areas. Eliminate old travelways and relocate where necessary. Take special precautions and measures to avoid channelized flow where facilities must be in riparian areas.	Maintain slope, channel length, and configuration that supports dynamic equilibrium. Avoid actions that concentrate flows, produce higher velocities, or change energy configuration of channels or meadows.
	Historic channelized riparian caused by arroyos, gullies, and travelways.	Reestablish and construct channel configuration and slope that watershed conditions can sustain (Heede 1968a) or use check dams to control grade while channel adjusts to new equilibrium. Where conditions allow, consider introducing beaver.	Develop slope channel length and configuration that support a new dynamic equilibrium. Correct conditions that generate unfavorable flows.

Table 2 (continued).—Conditions threatening riparian areas and possible remedies for achieving different treatment objectives.

Condition	Cause	Remedy	Treatment objective
	Absence of large organic debris to provide steps and energy dissipation in confined mountain channels.	Add logs or rock structures to regain stability. Manage adjacent areas to provide a desired rate of logs to the system.	Reduce streamslope with log steps or other structures. Slow velocities, reduce flood peaks, and increase channel uptake. Stabilize sediments.
Excess tributary sediment	Sheet and rill erosion from denuded areas.	Apply techniques similar to those used for controlling excess runoff.	Reduce exposure to erosion. Eliminate concentrated flow on slopes. Provide vegetation protection.
Excess bank sediment	Incised, confined channels that cut high banks.	Improve watershed condition. Reduce bank heights by installing check dams. Use flow separation techniques to deposit materials to buttress banks and provide a media for riparian vegetation establishment. Use techniques outlined for excess slope.	Reduce availability of sediment. Restore channel equilibrium that can be sustained.

A third, more complex, alternative would involve only channel stabilization. This alternative should only be attempted where watersheds are healing naturally, as a result of improvements in watershed condition, but require assistance in stabilizing base control sections. The objective of this treatment could be to stabilize or stop downcutting, reduce erosion, and revegetate channel banks. Channel structures such as check dams or gully plugs would be constructed to control base levels. Dam spacing and effective spillway heights would be designed only to store enough sediment to stabilize the channel. Approaches to gully treatment (Heede 1980), computer procedures for gully control (Heede and Mufich 1974), methods of construction (Heede 1960, 1970), and strategies for determining treatment priorities (Heede 1982) are all available. Water storage and ground water recharge would occur if sufficient annual precipitation were present, and as a result, enhancement of riparian communities would be expected.

Finally, the fourth and most comprehensive treatment alternative would involve both channel stabilization and comprehensive watershed rehabilitation (Heede 1968b, 1977). The objective of this level of treatment would be to stabilize and aggrade channels and provide adequate channel and ground water storage to enhance riparian establishment. Increases in channel deposition and ground water recharge would be accomplished by increasing dam spacing and effective spillway heights. The resulting channel aggradation would provide water storage behind each structure and enhance soil moisture and channel flow. Riparian establishment could occur naturally or be enhanced by the planting of riparian species adapted to the area.

Any combination of the last three levels of action plans described above may be implemented within a single watershed, but it remains critical to establish treatment objectives before implementation. Through the use of comprehensive evaluation and treatment techniques, it is possible to enhance or rehabilitate potential riparian sites throughout the southwestern USA, although the general approach has much wider application. It is important to be aware of the necessity of including continual management and maintenance as an integral part of these rehabilitation plans in order to assure the continued effectiveness of the initial treatments.

Summary and Conclusions

Management of riparian areas is a critical issue throughout the USA. In the southwestern USA, riparian areas are recognized as unique and valuable habitats whose welfare is strongly interrelated with the surrounding watershed. Large-scale misuse of watersheds and associated riparian communities in the 19th century, coupled with emphasis on water yield augmentation in the twentieth century, has led to the degradation of many naturally occurring riparian communities. However, land managers are now recognizing the importance of these valuable upland and riparian ecosystems, and current management philosophy is based on maintaining a viable interrelationship between watershed condition and riparian health.

Land managers are currently implementing a variety of watershed treatments that are, or have the potential for, improving riparian communities. In some cases, these treatments were initiated for reasons other than improving riparian areas but, after being applied, have created a more stable environment and provided favorable hydrologic regimes that allowed riparian communities to become reestablished. The most obvious practices benefiting riparian communities are upstream treatments aimed at improving watershed condition, lengthening duration of streamflow, and stabilizing channels to reduce erosion. Improving watershed condition involves improved livestock management, which is sometimes supplemented by cultural treatments, to gain better livestock distribution and control. In addition, strategically applied mechanical stabilization of channels may become a necessary part of restoration treatment when significant gullying and erosion has occurred in upland tributaries.

Successful treatment programs require a clear picture of the desired riparian and watershed condition. Understanding departures from this desired condition enables managers to select the best combination of improved management and treatments needed to regain riparian health. The basic knowledge for improving watershed and riparian areas is generally available. However, the key to successful rehabilitation lies in wise and timely application of management principles and technology necessary to restore former riparian areas and realize their benefits.

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