# RIPARIAN ROAD GUIDE

## Managing Roads to Enhance Riparian Areas



Produced by

**Terrene Institute**
Washington, D.C.

In cooperation with

**U.S. Environmental Protection Agency**
Region 6 Water Management Division
Water Quality Management Branch
Dallas, Texas

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Southwestern Region
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This guide is based on the experiences of field staff in the Apache-Sitgreaves, Carson, Cibola, Gila, and Prescott National Forests and documented in a paper entitled "Riparian Area Enhancement through Road Design and Maintenance" by Russell A. LaFayette, John R. Pruitt, and William D. Zeedyk of the USDA Forest Service. William Zeedyk deserves special credit. His vision and enthusiasm brought these ideas into application where it counts most: in the field.

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# Contents

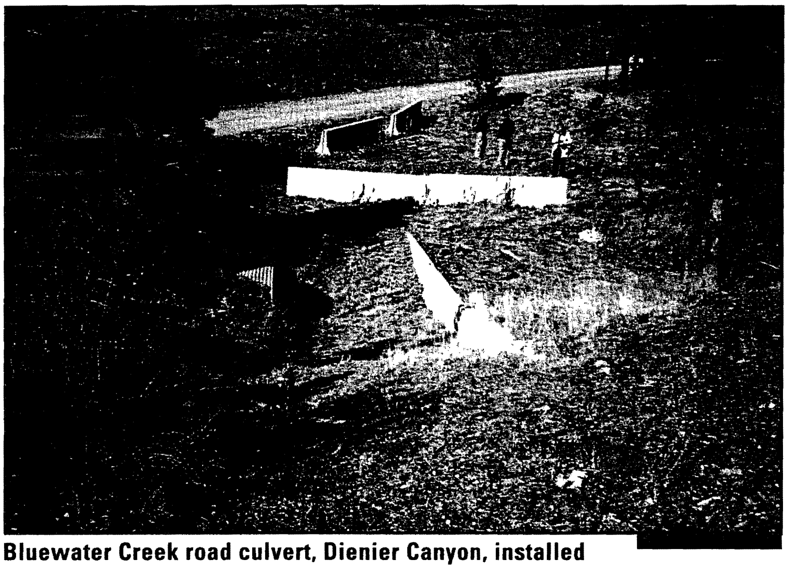
# Introduction

**IN THE PAST, A MAIN OBJECTIVE IN ROAD DESIGN AND** maintenance was to keep roads dry and safe to travel. Water was considered a liability and threat to road safety and stability, and extraordinary efforts were made to keep water off and away from roads.

Historically, roads were built following early paths and trails, frequently along streams, rivers, and lakes. Before locating roads next to waterbodies and through riparian areas—the moist vegetative lands related to or bordering on water—early road builders considered ease of travel, convenience, and safety. They did not, however, consider the environmental impact of the road on surrounding lands. As a result, traditional road design, construction, and maintenance have harmed important riparian areas and diminished water quality.

Traditional engineering practices fully drained roads and sometimes caused major undesirable changes in the environment:

- *Road building* has, in some instances, dramatically changed the water flow pattern across the landscape. Areas adjoining the roads that were formerly wet—riparian areas, wet meadows, small streams—have dried up. Where water continues to flow, its erosive force (its velocity and volume) has increased.
- *Traditional road building practices* have also changed the quality or cleanliness of the water. Previously clear waters are now muddy and turbid after rain storms.



**Bluewater Creek road culvert, Dienier Canyon, installed traffic barriers to restore stream level and to capture sediment. Unused barriers in the background show design setting.**

- *The landscapes that border road locations* have also changed. Plants and wildlife that once thrived in moist or wet environments can no longer survive.

Action can and should be taken to improve the management of water and riparian lands as natural resources and assets. We can restore or recreate former riparian and wet areas and modify road design and maintenance to disperse rather than channelize water, thus reducing erosion, sedimentation, and other pollution.

This booklet presents a number of cost-effective road construction practices that are easy to install and maintain. Their use can help local governments maintain clean water and safe roads while simultaneously enhancing and restoring the health and value of riparian areas. The solutions recommended in section 3 highlight inexpensive retrofits of roads that periodically wash out or erode during storms. Cost information, if available, is also included.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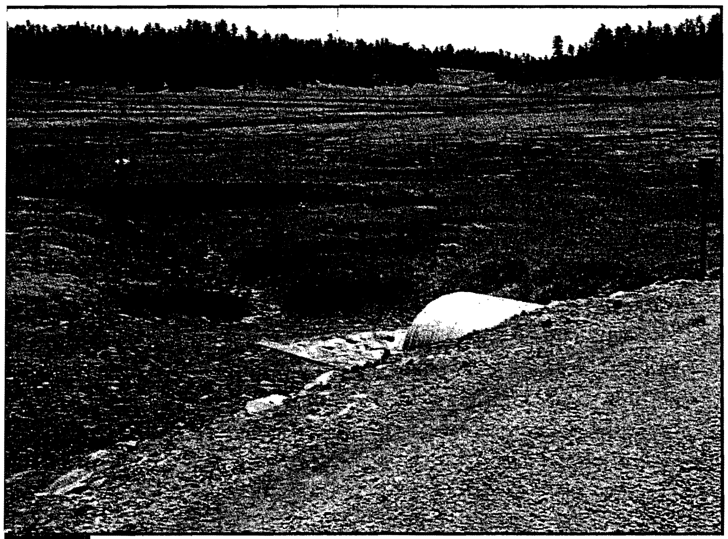
This guide was written primarily for local government personnel, elected officials, and road designers and contractors in the arid and semiarid southwestern United States. The general principles, however, are applicable in other regions of the country if techniques are modified accordingly. It is applicable to suburban and rural road systems, less applicable to roads in heavily urbanized areas. Urban environments present unique challenges to road construction and retrofit that have not been considered here.

This guide is divided into three sections, which

- review the history of road-related impacts on riparian areas and water quality,
- describe common road and riparian area conflicts and the benefits of using modified designs, and
- suggest ways to correct existing problems and simple techniques for avoiding these problems in the future.



**This meadow in Apache-Sitgreaves National Forest, Arizona, was restored by renovating a road crossing using a railroad tie and grout structure. Seventy acres were renovated for $700.**

Several technical terms are used throughout this report that may have different meanings in various contexts. These terms are included in a glossary at the end of the text. ■

**Emerald Glade in Chino Ranger District, Prescott National Forest, Arizona. Wetland renovation using small rock dam below a road to capture sediment and slow water. Note the obvious contrast between the riparian area and adjacent upland.**



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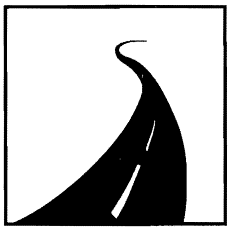
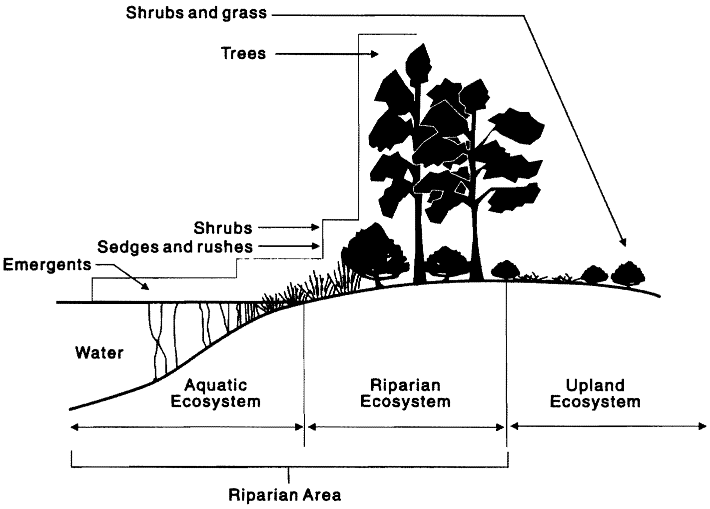


# Riparian Areas and Roads—A Short History

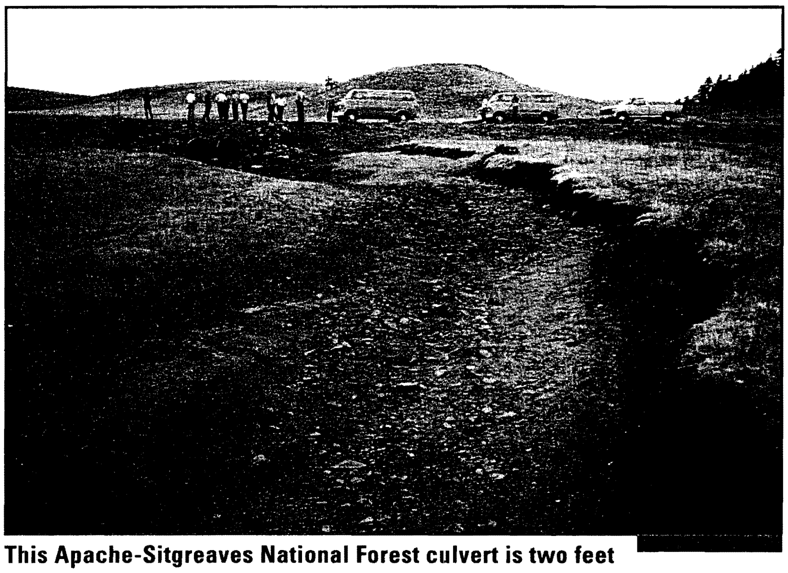
**RIPARIAN AREAS ARE A TRANSITIONAL, USUALLY LUSH,** zone between upland ecosystems and water or aquatic ecosystems (Fig. 1). They are lands bordering streambanks or surrounding bogs, wet meadows, lakes, and ponds. These areas and related wetlands and waterbodies normally occupy a small fraction of the total land area. In the Southwest, they occupy less than 2 percent of the total landscape; however, their small size is misleading because of their high value, productivity, and diverse uses.

**Figure 1.—Riparian area diagram**




**Source:** Cooperative Extension Services

Riparian areas contribute many values to the watershed and the people who live in it. Most important, they diminish the severity and impact of flood events and improve water quality. Historically, riparian areas have also been the focal point for human settlement and other commercial developments. Not surprisingly, roads have often been located adjacent to streams, rivers, and riparian areas to serve these various communities.



**This Apache-Sitgreaves National Forest culvert is two feet too low. A raised culvert would rewet the meadow and proper outfall would prevent gullying as well.**

## Riparian Degradation, a Serious Loss

Reports prepared by state and federal agencies in the Southwest indicate that approximately 50 percent of the area's original riparian acreage has been lost or significantly degraded, with corresponding changes in the quality of the rivers, streams, or lakes adjacent to these areas. Increased sedimentation and turbidity, increases in water temperature, and decreases in the dissolved oxygen content of the water have been observed and measured. In the arid Southwest, these losses of water quality and quantity are especially significant. The unique charac-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teristics that draw human beings to riparian areas, for example, deep moist soils, gentle terrain, large shade trees, clean and ample water, and abundant wildlife, disappeared as riparian areas were filled, paved, drained, mowed, channeled, or otherwise used by the increasing population.

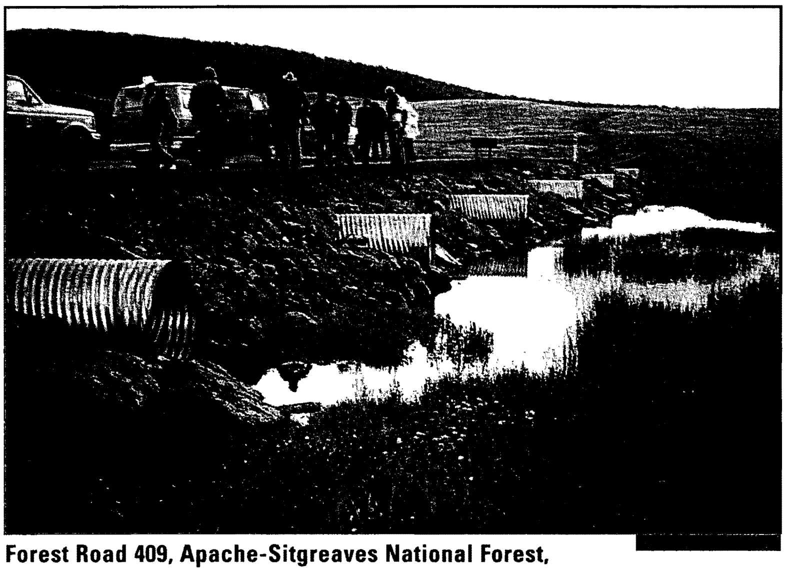
Many activities contributed to the degradation of riparian areas and the decline in water quality, including

- mining;
- diversions, such as dams, flood control, and channelization;
- irrigation;
- timber harvests;
- road construction and maintenance;
- domestic livestock grazing; and
- recreation.

In addition, many well-intentioned laws provided incentives for people to modify riparian areas. The value of these areas has simply not been fully understood or appreciated. In the West, for example, water use laws known as prior appropriation laws require that water be diverted from the stream and put to a "beneficial" use for humans. But leaving the water undisturbed has not been considered a beneficial use in many western states. Until recently, the beneficial uses of water for fish and recreation were ignored, and water quality issues in ephemeral or intermittent streams were not addressed.

## Roads, a Major Contributor to Riparian Degradation

Road construction and maintenance activities have been major contributors to riparian area losses over the years. Early roads followed historical patterns of travel and commerce in the old West. Wagon routes often followed stream corridors because riparian areas had a gently rolling terrain, offered water and forage for horses and other



**Forest Road 409, Apache-Sitgreaves National Forest, Arizona, after the road retrofit. A series of culverts placed across a formerly degraded meadow now spreads water, slows velocity, captures sediment and promotes plant growth to enhance the riparian area.**



*Riparian Roa*

# Impacts of Road Building and the Benefits of Improved Design

**AFTER SEVERAL CENTURIES OF HABITATION AND LAND** development activities, including road building, riparian areas in poor condition and dewatered meadows with deep gullies have become a common sight. Most people accept these conditions and have no vision of what the land used to look like. Until recently, little thought or action was given to correcting the situation—in fact, few people recognized the problem.

## Environmental Awareness Increases

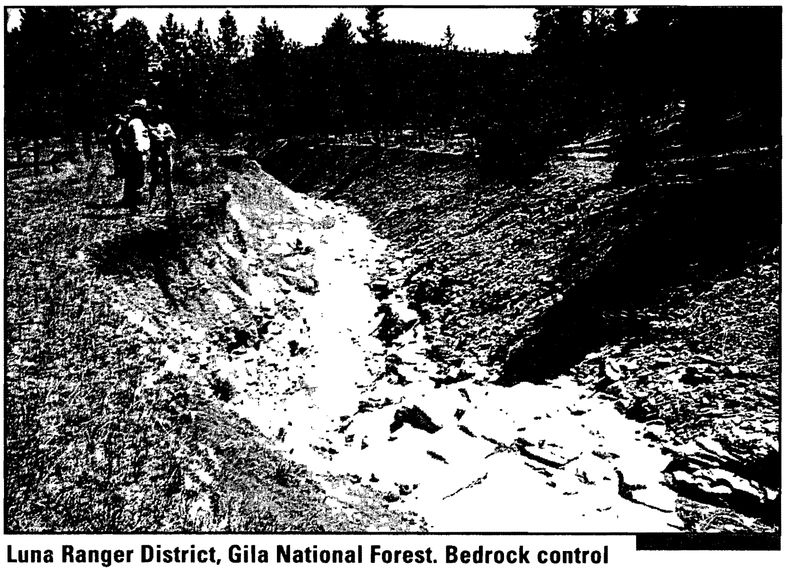
The nature and magnitude of riparian area losses related to road construction have recently been documented. Among them are the following:

- *Many acres of riparian land* are converted directly to road surface.
- *Concentrated flows* from traditional road building practices create deep gullies and dewater the riparian area.
- *Riparian plant species* yield to drier and less productive upland species, thereby decreasing plant and ecosystem diversity.
- *Accelerated runoff* (from impervious road surfaces), increased flood peaks, and abnormal flooding compromise the safety of land users and endanger adjacent facilities.

- *Streams* dry up earlier in the year or change from perennial to intermittent flow as a result of changes in the volume and duration of the base flow.
- *The loss of streambank vegetation* and the increased velocity of water flow accelerate erosion and increase downstream sedimentation.

Road construction in riparian areas can also lead to financial losses: improper road drainage contributes to higher road maintenance costs.

These effects were first recognized by wildlife and watershed managers and water quality agencies, but experienced road crews perfected the techniques discussed in this guide. To test these ideas, the U.S. Forest Service initiated demonstration projects to illustrate proper road rehabilitation techniques. The projects demonstrate practical methods to rehabilitate damaged riparian areas and reduce the environmental impacts of future roads. Section 3 of this guide summarizes information obtained from these projects, which were conducted in the national forests and grasslands of the Southwest: Arizona, New Mexico, and western Oklahoma and Texas.



**Luna Ranger District, Gila National Forest. Bedrock control site in Hardcastle Creek Gully before improvements.**

**Luna Ranger District, Gila National Forest. Bedrock control site in Hardcastle Creek Gully seven years later. Bank shaping, check dams, and road drainage management dramatically affected the channel.**

## A Changing Perspective

Viewing water as an asset rather than a liability helps road designers and managers work with, rather than against, the hydrology of a site. New and retrofitted road designs detain and slow the rate of water flow in or near riparian areas or wetland sites to prevent erosion and sedimentation. When water flow is dispersed throughout the area in natural patterns, a wide range of resources and users benefit, and cost savings are realized.

To use these ideas in road design and management, consider the following approaches:

- *Locate new roads* on dry sites in the watershed to avoid unwanted environmental impacts in riparian areas.
- *Reconstruct substandard roads* so that riparian areas are protected, recreated, or rewetted.
- *Retrofit other roads* during periodic maintenance to restore the function and health of associated riparian areas and to protect water quality.

## Improved Design and Maintenance

Managing roads to protect or enhance riparian areas yields a range of multiple benefits. Recreating former riparian areas by rewetting these landscapes helps restore the original watershed functions. A properly functioning watershed

- reduces flood peaks and related damages;
- prevents channel erosion and downstream sedimentation;
- traps sediments and soil nutrients;
- reduces evaporation in downstream reservoirs (by storing water in the upstream soil profile);
- increases wildlife and fisheries habitat quality, quantity, and diversity;
- increases forage production for livestock and wildlife; and
- increases recreational benefits and aesthetic values.

Further, riparian area planning reduces road maintenance cost and complies with local, state, and federal laws and regulations governing the management of floodplains and wetlands. ▮

# Solutions to Common Problems

**PROBLEMS RELATED TO ROAD DESIGN AND ITS EFFECTS** on riparian areas and water quality can be divided into three main categories:

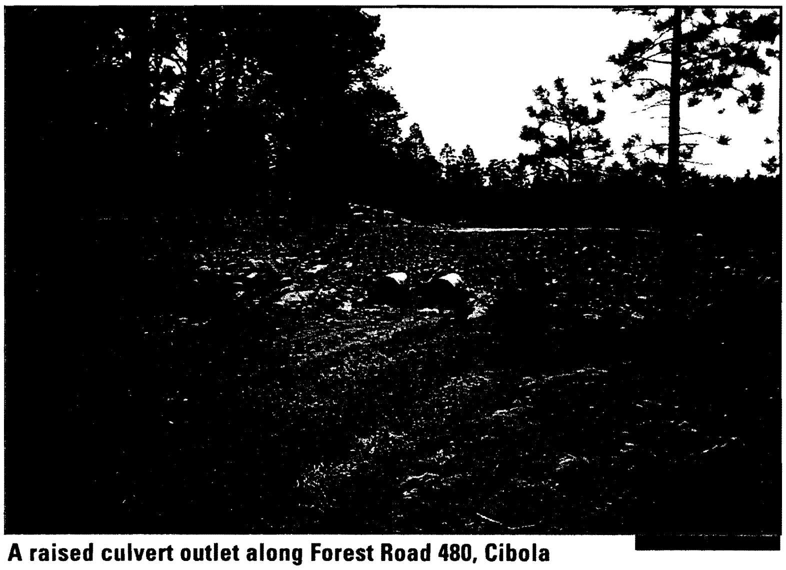
- stream crossings (culverts, fords, and bridges),
- wet meadow crossings, and
- road siting, alignment, and drainage.

This guide recommends several possible solutions to problems in these categories with particular attention to stream and wet meadow crossings because they present the greatest opportunities for improved water quality and enhanced riparian area function. Each of the following examples includes a problem statement, possible solutions, and specific recommendations, illustrated by simplified engineering diagrams.

Road designs to enhance or protect riparian areas are usually based on one of the following principles:

- *Multiple outlets.* Use multiple culverts placed over the width of the drainage in areas that do not have a single natural channel.
- *Proper alignment.* Align the structure with the stream direction and gradient; do not rely on artificially constructed channels because they tend to increase the gradient and accelerate the flow.

- *Proper elevation.* Place the bottom of the crossing at the level of the natural channel.
- *Drainage structures.* Avoid using supplemental ditches or drainage structures within the riparian zone.
- *Flow and infiltration.* Design the structure to pass the expected high flows and to allow appropriate infiltration.
- *Detain and retain.* Use techniques to detain water and retain sediment above the road, such as upstream dikes. Divert drainage waters into filter zones rather than directly into streams.
- *Proper location.* Avoid riparian areas entirely, if possible. Upland locations will have less impact on the environment.



**A raised culvert outlet along Forest Road 480, Cibola National Forest.**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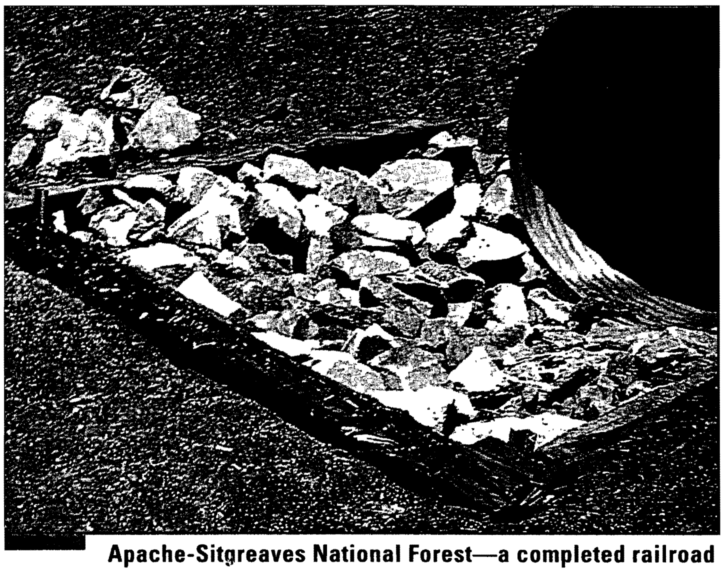
## Culverts for Stream Crossings

Culverts are the most frequently used stream crossing on smaller roads. They provide safe crossing for minimal initial investment; however, many culverts experience costly and repetitive maintenance problems after installation. Proper design, placement, and alignment of culvert crossings will avoid environmental problems and unnecessary maintenance costs. Chart 1 identifies common culvert problems and suggests cost-effective and environmentally beneficial solutions.

A premier example of these recommendations is the road drainage rehabilitation project in the Apache-Sitgreaves National Forests in Arizona. The retrofit involved raising the culvert's inlet using an upstream structure of railroad ties, rock, and grout. Volunteers installed the structure over a weekend. The structure captures sediment and slows runoff on an estimated 70 acres (28.3 hectares) of riparian area. Since the total cost of materials for the project was only $700, costs for the work were minimal: $10 per acre ($25 per hectare).



**Apache-Sitgreaves National Forest—a completed railroad tie and rock grout structure installed to raise culvert inlet 32 inches.**

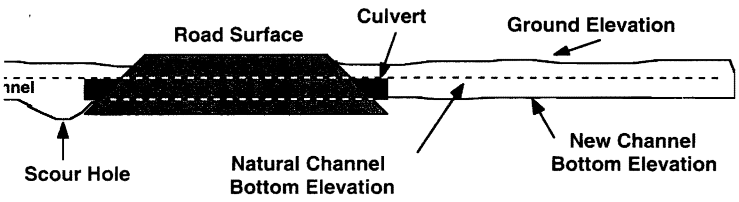
## CHART 1.—Retrofitting traditional culvert crossings.

| Common Mistake | Resulting Environmental Problem | Solutions |
|---|---|---|
| One or more large culverts are often installed to minimize installation effort and costs. | Directing all the flow through one or several openings concentrates energy, increases velocities, and accelerates erosion. | • **Determine the proper number, location, alignment, and elevation of inlets.**<br>When the streamflow is not naturally concentrated in a single wide channel, use multiple smaller culverts placed over the width of the affected area to spread the flow, decrease energy, and minimize erosion.<br><br>• **Construct an upstream dike.**<br>Where existing culverts cannot be changed, constructing an upstream dike will raise the water/sediment level, then drop the water safely to the existing culvert level. Materials that can be used for dikes include soil, rock, metal, concrete, or wood (Fig. 4). |
| Culverts seats are commonly excavated so that the culvert bottom rests on mineral soil below the natural grade of the stream bottom. | Excavated culverts keep the road dry and provide excellent bedding for the pipe; however, they also lead to upstream and downstream channel erosion. The culvert outfall is often unprotected and creates a scour hole, which lowers the channel and dries the surrounding riparian areas. In the upstream direction, side channel downcutting may occur, and upstream gullies may be formed. Further, the sediment lost by up- and downstream erosion will affect downstream water quality. | • **Place the bottom of the culvert at the natural level of the channel.**<br>If proper bedding is a problem, excavate and refill to the natural level of the channel (Fig. 2.)<br><br>• **Attach elbow at upstream dike.**<br>The upstream end of a culvert can be raised by attaching a 45 to 90 degree elbow with the elbow inlet at the desired stream bottom. Allow sufficient freeboard on the fill to avoid overtopping the road. Proceed cautiously, however, because culvert elbows also change the characteristics of how water enters the culvert and may reduce its capacity under high flow conditions (Fig. 3).<br><br>Water can sometimes flow along the exterior surface of the culvert, causing failure. |
| Culverts that are not properly aligned with the stream direction and gradient.<br><br>Culverts that are too long, too steep, or too high at the outfall. | Culverts may accumulate sediments inside, divert water into streambanks, and cause erosion or impede fish passage. | • **Align culverts with stream direction and gradient to ensure that sediment passes through the culvert and that water is not directed against the streambank.**<br>If fish passage is necessary, make sure the culvert openings allow passage, especially at outfalls. |

**Figure 2.—Raise culvert elevation to the natural level of the stream channel.**

## *Before*

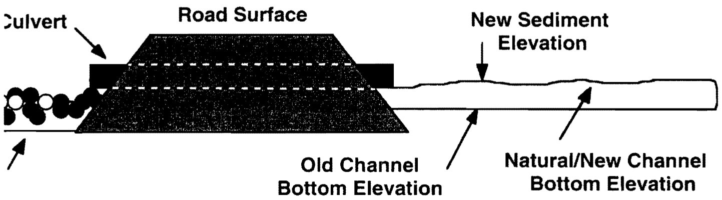
**culvert placement, with culvert bottom below natural bottom, degrades channel both above and below road.**



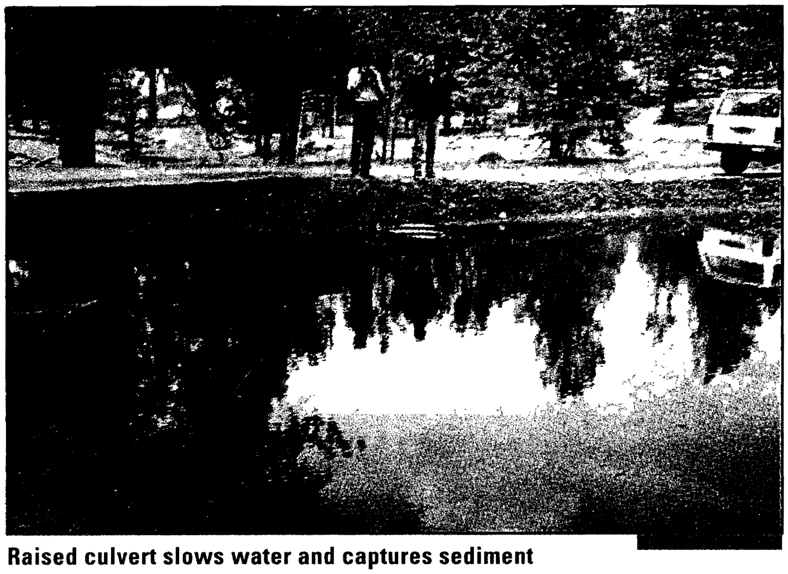

**ack of outfall protection commonly results in cour hole and further channel erosion.**

## *After*

**ad bed and culvert to natural channel elevations, retards ing sediment deposition and channel aggradation above nus recreating wetland area. Road acts as a dam, ediment, slowing water runoff, and promoting infiltra-**

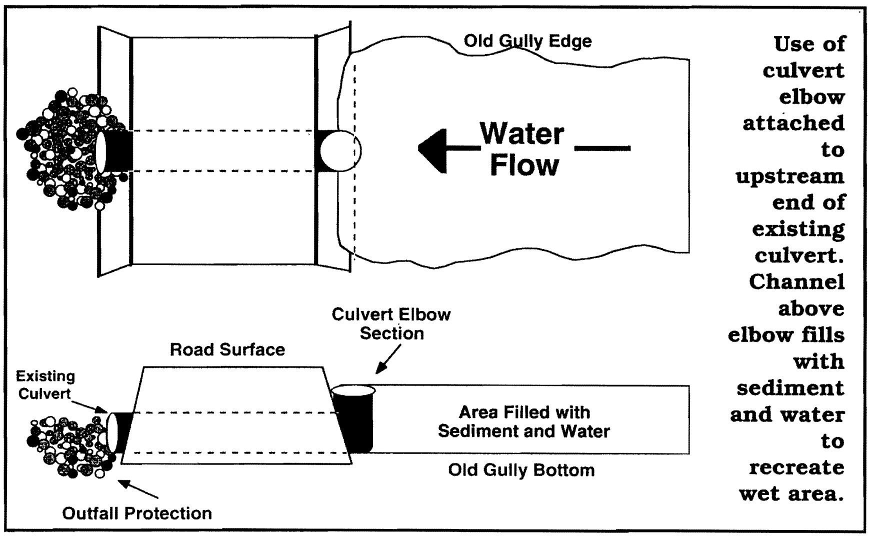


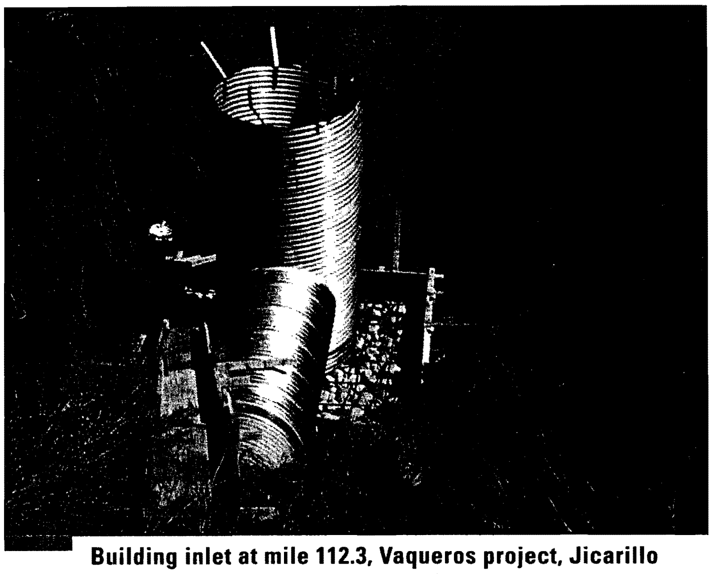

**Protecting culvert outfall preserves channel bottom, preventing erosion of channel.**



Raised culvert slows water and captures sediment following spring runoff June 14, 1991, on F.R. 480, Zuni Mountains, Mt. Taylor Ranger District, Cibola National Forest.

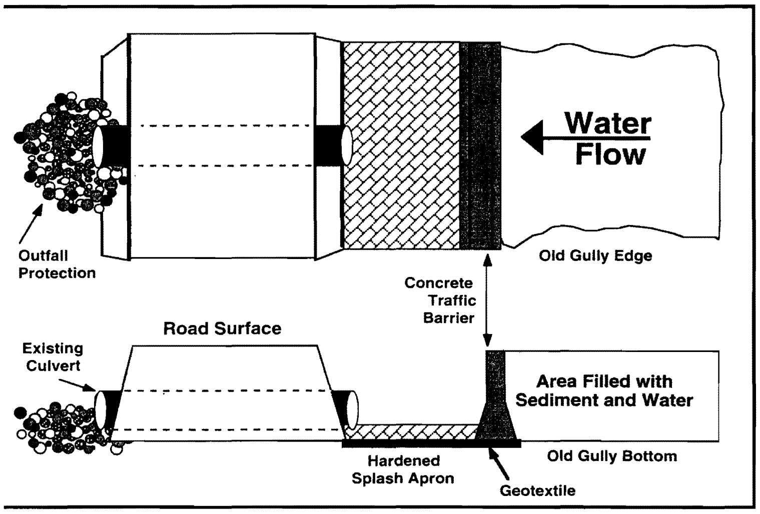
Figure 3.—Attach elbow to the upstream end of an existing culvert.



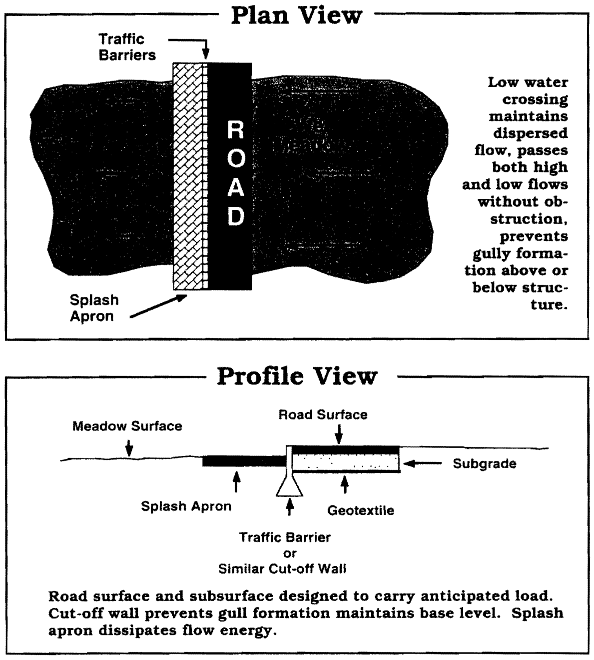


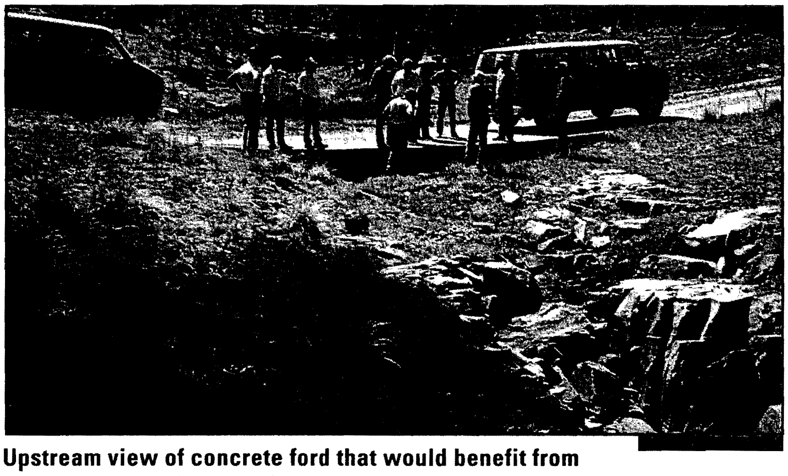
Building inlet at mile 112.3, Vaqueros project, Jicarillo Ranger District, Carson National Forest.

**Figure 4.—Construct an upstream dike using a concrete traffic barrier.**



## Figure 5.—Design details for using fords across roads.

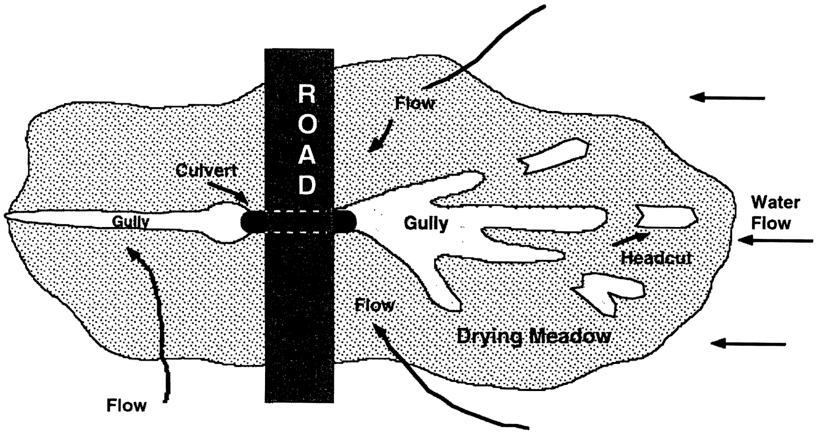


**Upstream view of concrete ford that would benefit from increased elevation, cutoff wall, and splash apron.**

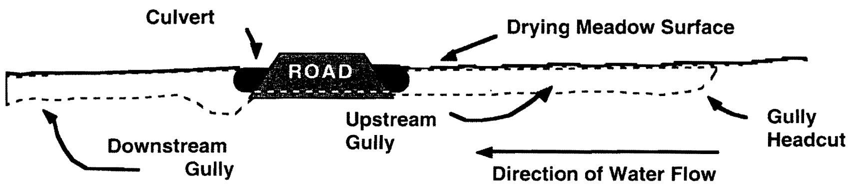
**Figure 6.—View of an improperly designed wet meadow crossing.**

## Plan View




**Crossing meadow with one culvert with pipe bottom below the original meadow surface, frequently with supplemental lead-in ditches. Gully network forms upstream of road and downstream too.**

## Profile View



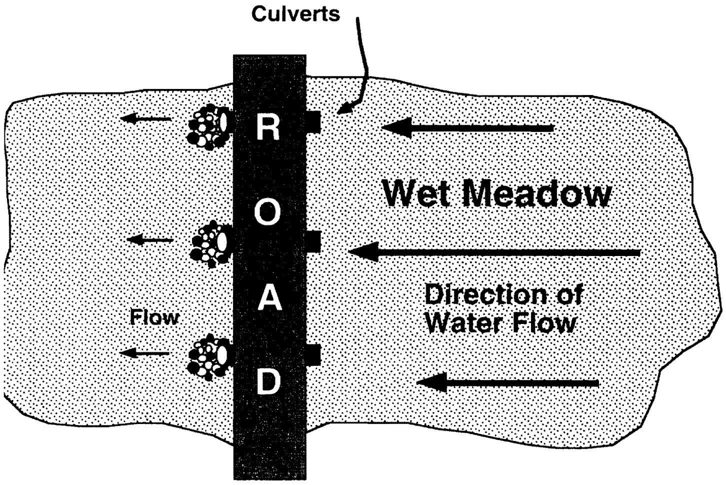

**Concentration of formerly dispersed flow causes downstream gully. Gully formation above road due to culvert bottom below original meadow surface drains wet meadow as headcut migrates upstream.**

**Avoid crossing wet meadow if at all possible If this is not avoidab use multiple culverts with bottom edges se at origi meadow level, n below.**

**Setting prevent outfall i**

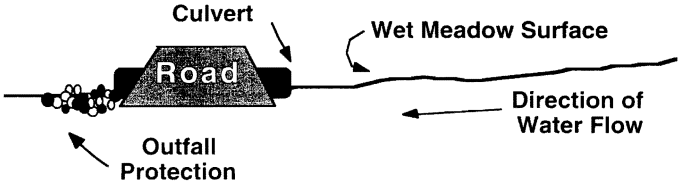
**Figure 7.—A properly designed wet meadow crossing.**

## Plan View




**Multiple culverts across a meadow maintains dispersed flow rather than concentrating flow.**

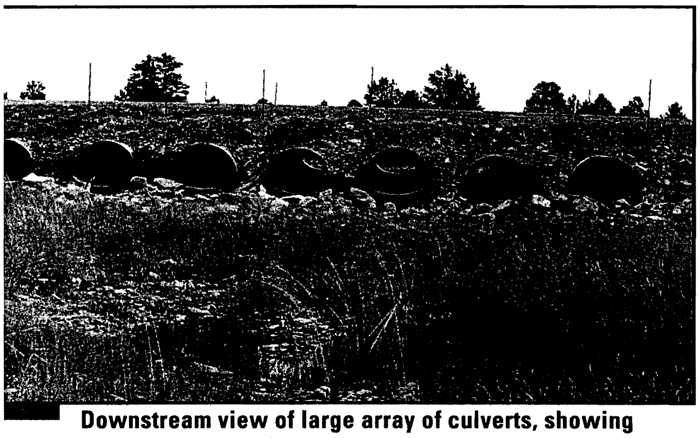
## Profile View




**vert bottoms at level of original wet meadow surface
:ad cutting and dewatering of soil profile. Always protect
ı erosion.**

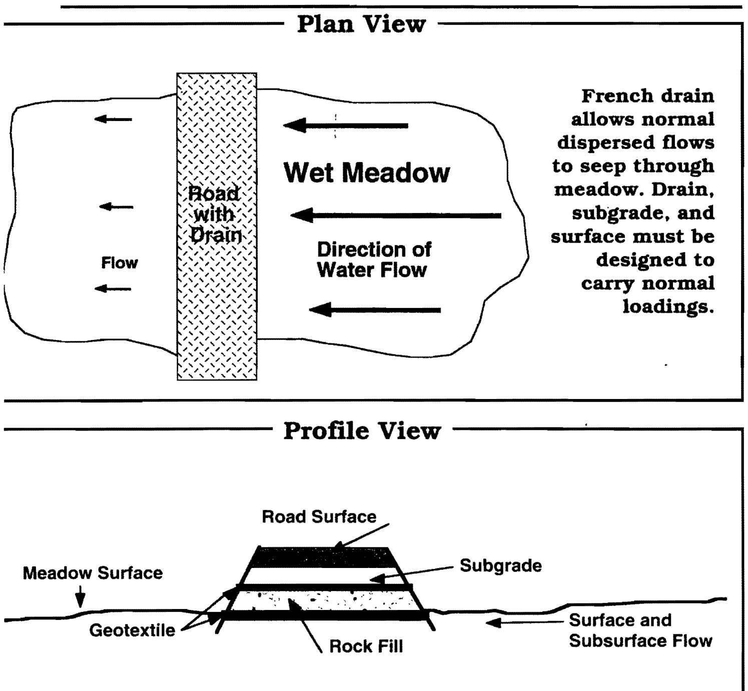
## CHART 4.—Retrofitting wet meadow crossings.

| Common Mistake | Resulting Environmental Problem | Solutions |
|---|---|---|
| Wet meadows are usually watered by surface and subsurface flows that are slow and dispersed. A road and its drainage structures tend to cut off dispersed water flows or to concentrate them and increase their velocities through one large culvert. | When the subsurface flow is removed, the rate of infiltration is reduced, the water table is lowered, and riparian vegetation is replaced by upland species or bare soil. | • **Select alternative routes at higher elevations.**<br>The best solution to the adverse effects of roads on wet meadows is to avoid them altogether.<br><br>• **Design crossings in concert with the environment.**<br>If it is not possible to avoid crossing the meadow, use construction methods that have minimum effect on the area. Cross below or above the meadow instead of through it. Take advantage of local geologic features by crossing at natural pinch points, at grade, or at right angles to the flow (compare Figs. 6 and 7). |
| Drainage structures are commonly excavated to set on mineral soil, that is, below the natural grade of the meadow. This placement causes gullies to form above and below the width of the meadow. | The gullying gradually dries out the meadow as the channel deepens. The permanent water table is lost; and upland plant species begin to encroach on the formerly wet meadow, changing the vegetation composition, diversity, and productivity. | • **Disperse the flow rather than concentrate it.**<br>Instead of one large culvert, locate several smaller culverts across the width of the meadow (See Fig. 7 and the photograph on p. 29).<br><br>• **Use permeable fill.**<br>Sometimes it is advantageous to use permeable fill or french drains. This technique consists of rock sandwiched between layers of geotextile. A french drain allows water to pass under the road and at the same time keeps the road surface dry. It may be used alone or in conjunction with a culvert designed to carry flood flows (Fig. 8). |



**Downstream view of large array of culverts, showing outfall protection (rock rip and rap) and initial rewetting of lower meadow.**

**Figure 8.—Use of permeable fill to cross a wet meadow.**




**French drain allows normal dispersed flows to seep through meadow. Drain, subgrade, and surface must be designed to carry normal loadings.**

**French drain uses rock or other permeable fill material sandwiched between layers of geotextile. Road built atop this drainage device allows dispersed flow to pass normally yet allowing traffic to pass.**

## Road Alignment and Drainage

Chart 5 illustrates problems that often exist in traditional designs for road alignment and drainage.

**CHART 5.—Road alignment and drainage.**

| Common Mistake | Resulting Environmental Problem | Solutions |
|---|---|---|
| Road Alignment | Many roads follow and cross streams and riparian areas.<br><br>These roads take up a significant portion of the total riparian area, replace natural vegetation with an impermeable surface, and increase runoff and flood peaks, which allow increased pollutant loads to reach the stream. These roads cut off or shorten stream meanders and steepen the stream gradient, thereby increasing its power and causing erosion and downstream sedimentation. | • **Do not build in riparian areas.**<br>Although initial construction costs may be higher for roads built on ridges or sideslopes, long-term maintenance costs and riparian damage will be less.<br><br>• **Align roads in concert with the environment.**<br>Minimize the number of stream and riparian crossings. Where crossings are unavoidable, construct them at right angles. Maintain naturally occurring stream meanders to keep a natural gradient with the stream. Design and construct roads to detain or delay water and sediment above the road to reduce flow velocity, increase infiltration, and prolong base flows below the road. |
| Road Drainage | Drainage from roads, especially from ditch lines, can affect nearby riparian areas. Infrequent drainage allows water to travel for long distances in ditches, gaining velocity and sediment loads and simultaneously reducing flow to meadows. Drainage outlets too close to channels can direct pollutant-laden water directly into the stream. Wing ditches and berms along roads frequently disrupt natural flow lines and concentration.<br><br>Drainage outlets on fill materials commonly cause significant erosion, and unprotected culvert outlets cause scour and additional sedimentation. Too much maintenance can remove erosion-resistant vegetation or rock armor, undermine stable banks, and increase erosion and sedimentation. | • **Design road drainage system in concert with the environment.**<br>Design outsloped roads and rolling dips and avoid inside ditches. Drain the road frequently to avoid concentrating water in ditches or at any single culvert. Protect drainage outlets against erosion by placing the outlet at the gradient of the channel bottom and installing energy dissipaters at the outfall. Avoid placing outlets on fill material. Avoid directing accumulated ditch waters and sediment into streams. Direct ditch waters to areas that allow the water to infiltrate and sediments to be deposited before they reach the stream. Sedimentation basins may be needed. Avoid intercepting subsurface flow with ditch.<br><br>• **Avoid excessive maintenance.**<br>Vegetation in the ditch can help stabilize the ditch and cut slope, which prevents erosion in both areas. ▮ |


Riparian Road

# Conclusion

**MANY OF THE TECHNIQUES RECOMMENDED IN THIS GUIDE** are relatively simple and low in costs. In most cases, the benefits of adjusting these designs easily outweigh the costs. Further, these practices can be initiated with little research and development. Awareness is the key to successful road management in riparian areas.

## Help is Available

Working with other agencies and officials involved with, or responsible for, road maintenance and environmental protection is a good way to avoid problems. Share your ideas and experience. Consult the following agencies and groups before undertaking road work in riparian areas.

- *State Water Quality Agencies.* Under Section 401 of the Clean Water Act, these agencies are responsible for issuing special water quality certification for any work to be done in a riparian or wet area. Special conditions or procedures may be applicable in certain situations. Some coastal states may have new road construction requirements and guidelines stemming from the Coastal Zone Act Reauthorization Amendments. Roads located in urban areas may be subject to federal stormwater runoff permit requirements.
- *U.S. Army Corps of Engineers.* Section 404 of the Clean Water Act charges the Corps to protect wetlands through a permit system. A special permit is needed if work is to be done in a river

or wetland area and results in placing dredged or fill material in the river or wetland.

- *U.S. Department of Agriculture, Forest Service, and Soil Conservation Service.* Watershed and engineering personnel may be able to help you translate ideas from this guide into workable designs for your specific local needs.
- *State Highway Administrations or Transportation Bureaus.* Transportation agencies may apply technical guidelines for road construction if the local road receives state or federal cost-share funding.
- *Local service organizations and environmental groups.* Groups, nonprofit organizations, or ad hoc associations, such as nature or bike trail organizations, wildlife clubs, citizen groups, and service clubs may volunteer labor or other resources for special projects to enhance riparian systems. ■

**High Clark Meadow, Luna Ranger District, Gila National Forest. Highly productive riparian area following placement of small structures, seeding, and proper grazing management. This photograph was taken 20 years after the restoration was accomplished.**

# GLOSSARY

**Aquatic Ecosystem:** the stream channel, lake, or estuary bed; water, fish, insects, and aquatic plant communities; and their habitats (rocks, pools, riffles, and the bottom substrate of sand or gravel).

**Culvert:** pipe placed under roads for carrying water. Culverts are often round, but may be other shapes as well.

**Cutoff Wall:** normally a concrete wall installed downstream of culverts to keep water and materials in place.

**Downcutting:** Water erosion that deepens an existing channel or forms a new channel where one did not previously exist. Downcutting distinguishes between downward and lateral erosion.

**Freeboard:** the height above the recorded high-water mark of a structure associated with water.

**Fords:** low water crossings over roads. Often used where flow is rarely high enough to prevent vehicles from crossing through the water.

**Inlet:** the upstream end of a culvert, sometimes called an invert.

**Outfall:** the downstream end of a drain or culvert; in general, the outlet of a body of water.

**Permeable Fill:** rock placed between layers of fiber material to allow water to pass through underground; sometimes called a french drain.

**Riparian Areas:** transitional land and water areas composed of, and located between, two ecosystems: upland ecosystems and aquatic ecosystems.

**Riparian Ecosystem:** the land-based or terrestrial community characterized by hydric (moist) soils and plant species dependent on the water table (saturated zone) or its capillary fringe.

**Splash Apron:** typically a concrete or rock structure placed at the outlet of a culvert, drop structure, channel, or ford to intercept the force of the water by slowing velocity and preventing scour holes.

**Wet Meadows:** meadows characterized by wet soils and slow surface and subsurface flows. Channels are typically poorly defined or nonexistent. Vegetation is dominated by riparian-dependent species.