Gullies and Sediment Yield

Herbert B. Osborn and J. Roger Simanton

Gully erosion can be a major contributor to rangeland watershed sediment yield and stock pond or small reservoir sedimentation. There is considerable literature on qualitative gully development and growth, but little quantitative information on the extent of gully contribution to sediment yield and subsequent downstream sedimentation. The principles of gully erosion, as defined as early as 1939 for the Piedmont region of South Carolina, are also pertinent to southwestern rangelands.

In southwestern rangelands, accelerated gully erosion appears to be the result of road and trail development, cattle paths, overgrazing and climatic change (Cooke and Reeves 1976). Gullying has occurred in two ways on the Walnut Gulch Experimental Watershed in southeastern Arizona (Fig. 1). First, there has been downcutting in the major channels as headcuts have moved "upstream" from the San Pedro River. Second, there is evidence of localized (small watershed) gullying independent of the general downcutting on the watershed. The downcutting of the San Pedro River has been blamed primarily on overgrazing, climatic change, or a combination of the two factors. Localized gullying is probably due to a combination of overgrazing, concentration of flow on trails and stock paths, failure of man-made structures, and climatic change. This discussion is limited to localized gully downcutting on four small subwatersheds on Walnut Gulch. The gully contribution to watershed total sediment yield is estimated by proportioning measured sediment yield into upland, tributary, and gully sediment sources.

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Editor's Note: Readers may wish to see the following articles:
"Arroyo Formation, Juab County, Utah, 1983" by James L. Baer, *Rangelands* 7(6):245-248, 1988
"Gully Erosion" by Arthur Bettis III and Dean M. Thompson *Rangelands* 7(2):70-72, 1985
"Managing Rangeland Soil Resources: The Universal Soil Loss Equation" by K.G. Renard and G.R. Foster, *Rangelands* 7(3):118-122, 1985.

Study Area Description

The 58-mi² Walnut Gulch Experimental Watershed, in southeastern Arizona, is representative of millions of acres of brush and grass rangeland found throughout the semiarid Southwest, and is a transition zone between the Chihuahuan and Sonoran Deserts. Average annual precipitation on the watershed is about 12 inches, with 70%

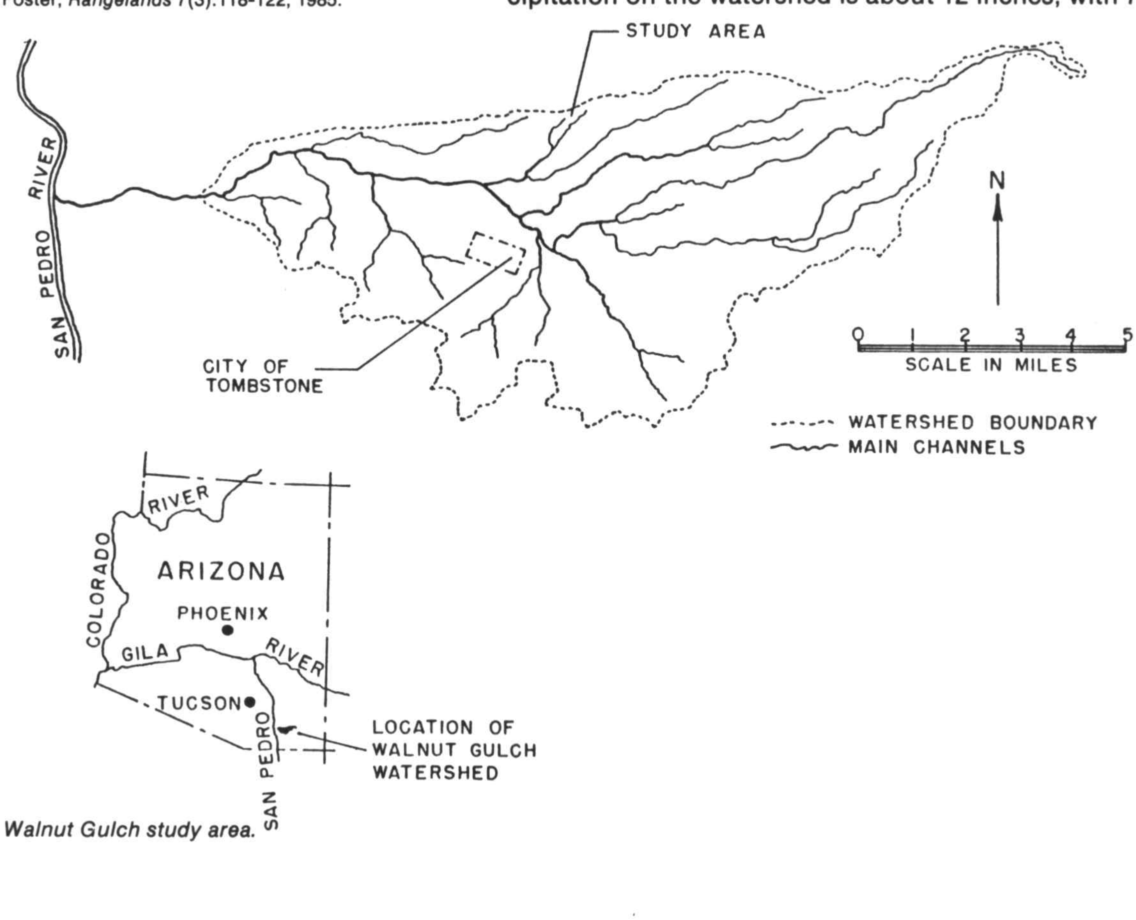

Fig. 1. *Location of Walnut Gulch study area.*

occurring during the summer thunderstorm season of July to mid-September. This is also the season when 99% of annual runoff occurs. Upland soils on the four small subwatersheds are generally well drained, calcareous, gravelly loams (Rillito Series) with large percentages (>50%) of rock and gravel on the soil surface. Soil in which gullies have formed is a sandy loam (Laveen Series) with up to 15% fine gravel on the surface. Watershed side slopes range from 3 to 15%, with about a 9% average. Cattle grazing was discontinued on the subwatersheds in 1962, and no revegetation or rangeland renovation treatments were made until 1980. Vegetation canopy cover is about 30%, and major species include: creosote bush, white-thorn, tarbush, snakeweed, burroweed, black grama, blue grama, sideoats grama, and bush muhly.

Instrumentation

In 1963, four small rangeland watersheds, within a 20-acre area on Walnut Gulch, were instrumented for hydrologic studies (Fig. 2). Three weighing-type recording raingages were established, and broadcasted V-notch weirs were constructed to measure runoff (Fig. 5). Watershed 101 is a tributary of 103, and 102 is a tributary of 104 (Fig. 2). Watershed 103 is drained by a relatively straight, incised gully, while watershed 104, adjacent to 103, is

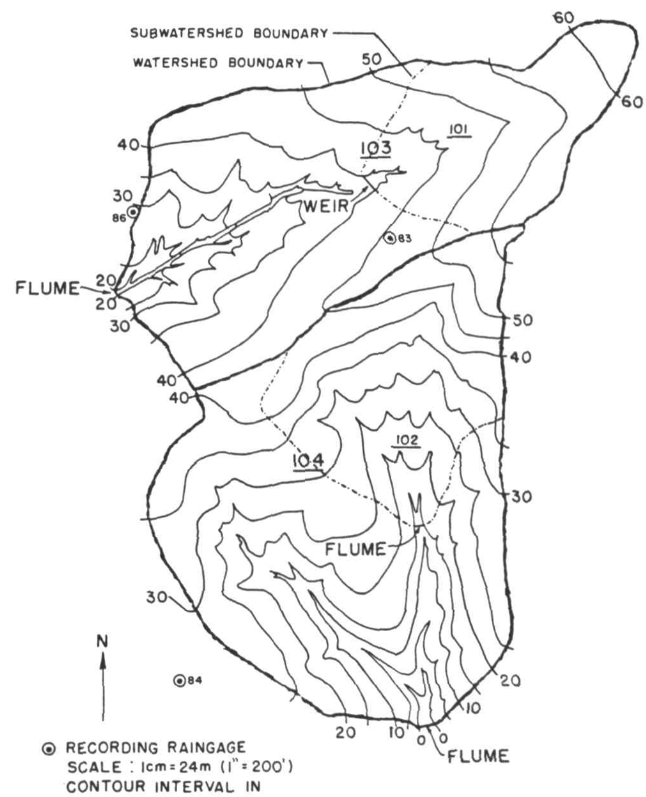

Fig. 2. *Subwatersheds 101, 102, 103, and 104, Walnut Gulch.*

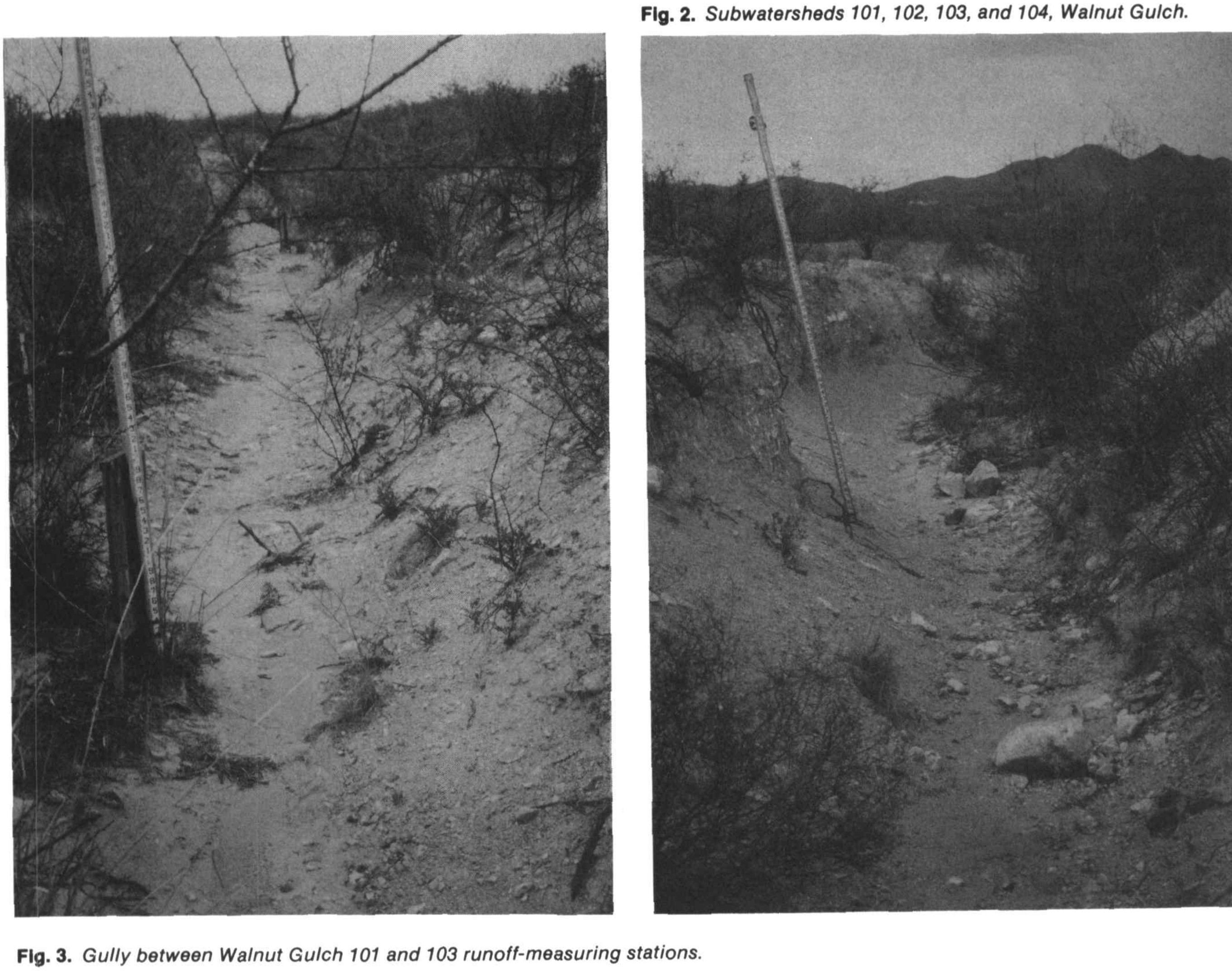

Fig. 3. *Gully between Walnut Gulch 101 and 103 runoff-measuring stations.*

drained by a meandering channel with more gently sloping banks. The V-notch weir for 101 was installed about 1.5 ft above the existing channel bottom. This silting basin above the weir allowed "clear water" discharge over the weir, which may have induced the active downcutting in the already incised gully between 101 and 103 (Fig. 3). A similar, but smaller, silting basin above 102 did not appreciably accelerate downcutting between 102 and 104 (Fig. 4).

Rainfall, runoff, and total sediment yield were available for 103 and 104 from 1973 through 1984. In the first few years, suspended sediment was sampled with pump samplers and bed load was measured as trapped sediment in the silting basins above the V-notch weirs (Fig. 5). Before the 1976 runoff season, the V-note weirs at 103 and 104 were replaced with more accurate supercritical flumes equipped with total load samplers (Fig. 6), and 13 permanent cross sections were established in the gully between 101 and 103 (Fig. 7). Precise gully cross-section measurements were made at each of the 13 permanent cross sections before the beginning (late spring) and after the end (early fall) of each runoff season.

Analyses

Analyses were based on comparison of sediment yield estimates from the Universal Soil Loss Equation (USLE), the measured total sediment yield, and gully contributions based on measured changes at channel cross-sections (extrapolated to estimate volume changes between cross sections).

USLE

The USLE was developed to estimate the long-term average soil loss from agricultural fields (Wischmeier and Smith 1978). Although the USLE parameters have been developed primarily for cultivated agricultural areas, the physical conditions associated with the parameters, along with limited testing, have permitted extrapolation for use in the sparse vegetation conditions of western rangelands. The

Fig. 4. *Channel between Walnut Gulch 102 and 104 runoff-measuring stations.*

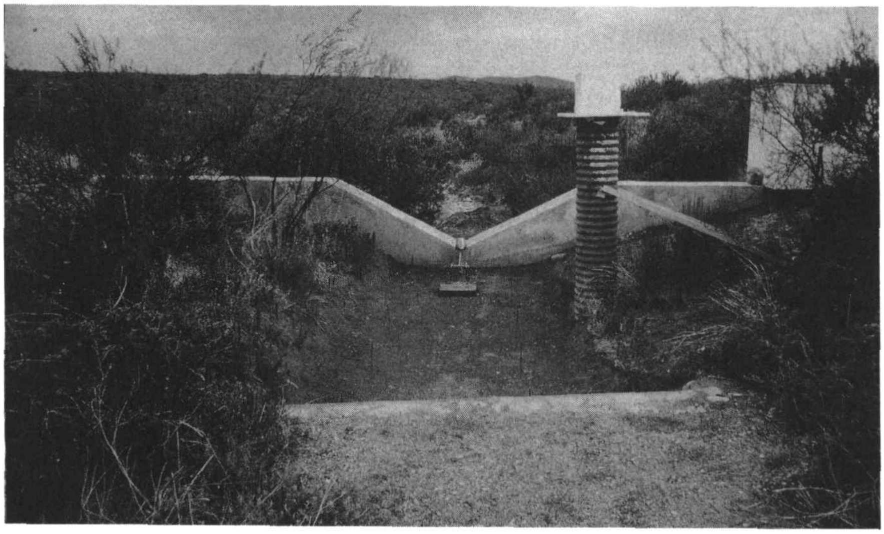

Fig. 5. *Sediment trap above Walnut Gulch runoff-measuring station 104 (looking downstream).*

Fig. 6. *Flume and total load sampler at runoff measuring station 103, Walnut Gulch.*

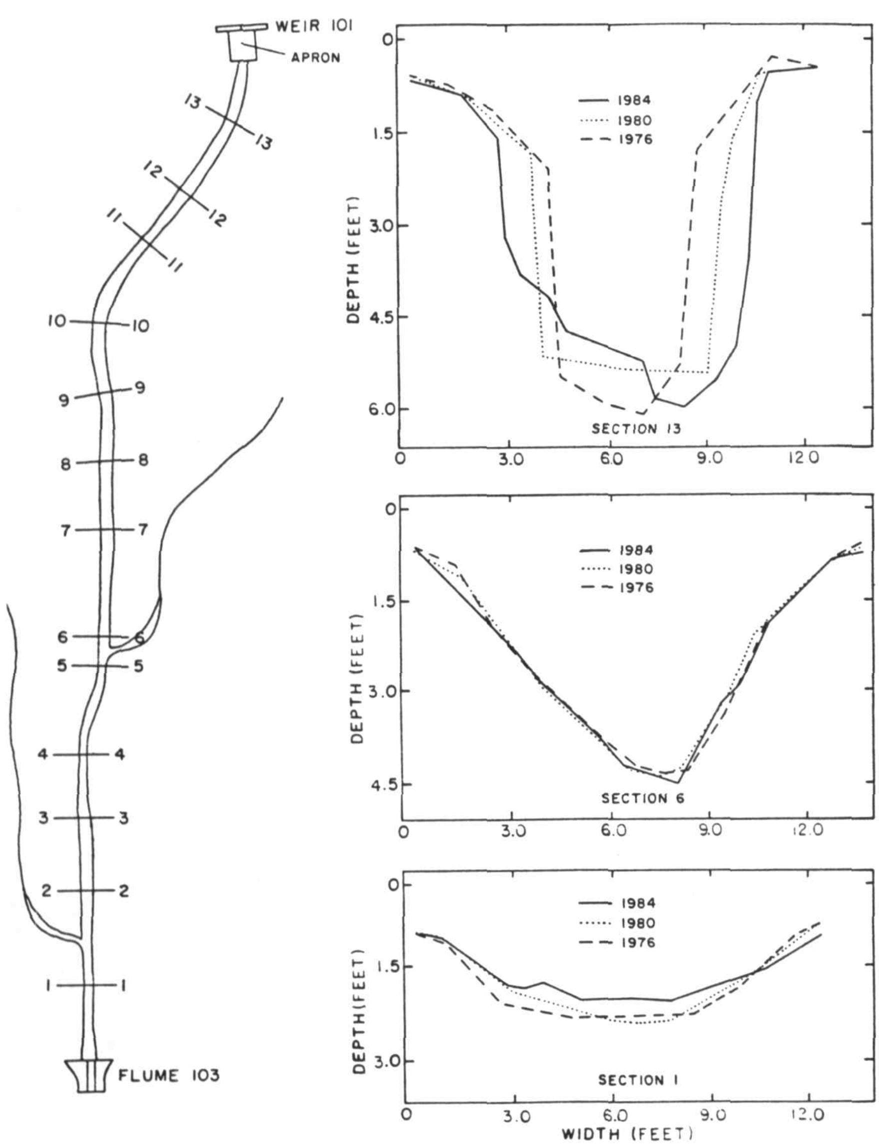

Fig. 7. *Location of cross sections and selected cross sections above flume 103.*

equation is:

$$A = RKLSCP$$

where A = estimated soil loss (tons/acre/year),
R = rainfall erosivity factor (EI units/year),
K = soil erodibility factor (tons/acre/EI unit),
LS = slope-length gradient factor,
C = cover and management factor, and
P = erosion control practice factor.

These factors reflect the major variables which influence erosion by rainfall and resultant overland flow. The equation is based on plot data collected mainly in the eastern United States. Because equation factor relationships vary in different climatic areas, special considerations are required to extend the USLE to the western United States (Simanton et al. 1980).

We used the USLE to estimate the sediment contributed from the uplands. We assumed measurements of transported sediment at the flumes equaled total sediment yield from the watersheds. We also assumed that P = 1 for ungrazed, untreated rangeland, that C included rock fragments as part of ground cover, and that the soil erodibility nomograph developed for the USLE gave representative values for K. Values for each of the factors were estimated using field data and Agricultural Handbook No. 537 procedures and tables. The R factor was calculated using the nearest recording raingage record.

Although data were available from 1973 through 1984, a portion of watershed 104 was renovated (converted from brush to grass) in a separate study, before the 1981 runoff season. There was good correlation between the paired watersheds of annual measured sediment yields between 103 and 104 from 1973 through 1980 (Table 1 and Fig. 8). Comparisons of sediment yield before and after renovation suggested an increase in sediment after treatment on 104 (Fig. 8).

Gully Erosion

Analyses of gully cross-section data of 103 indicated only minor changes in the gully bottom gradient between 1976 and 1979. However, increases in gully cross-sectional areas indicated that gully banks were being lost and contributing to watershed sediment yield. From 1980 through 1984, the more steeply banked cross sections on 103 continued to contribute to sediment yield by banking sloughing, while the shallower sloped banks on the lower cross sections were becoming more stable, and gullies were aggrading (Fig. 7).

The greatest gully bank soil losses between 101 and 103, from 1976 through 1984, were from the uppermost reaches of the gully (Table 2). From 1976 through 1979, channel cross-section surveys indicated the lower reach of the gully contributed very little to watershed sediment yield. From 1980 through 1984, channel aggradation in the lower reach actually exceeded the channel bank contribution. On the upper reach, gully bank contributions per unit runoff were approximately constant over the 9 years of record. The

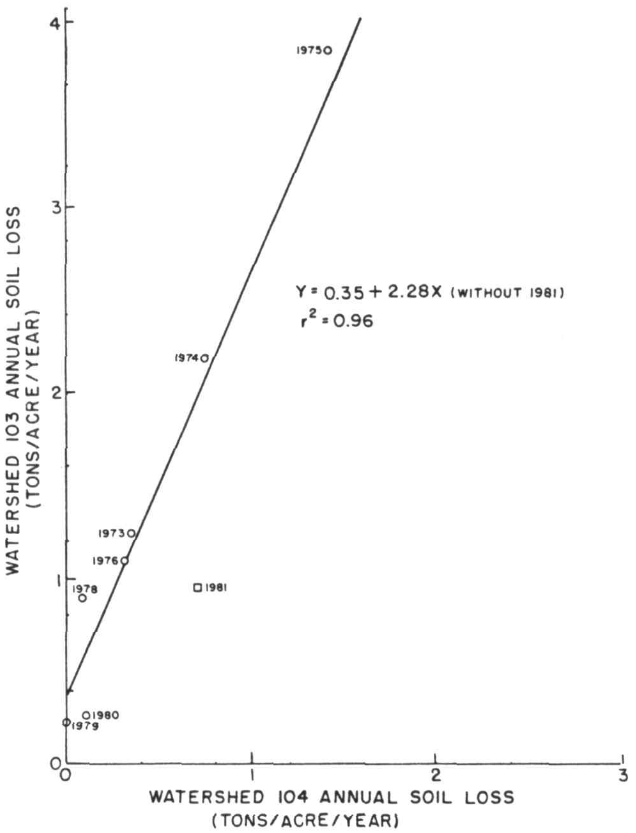

Fig. 8. *Correlation between annual sediment yields for watersheds 103 and 104, Walnut Gulch.*

uppermost cross section contributed an average of slightly over 3 tons per year, for a total of 28 tons, or about one-half of the total main gully contribution.

Discussion

Several steps led to the conclusions in this study. First, we assumed that the USLE gave us a good estimate of upland soil loss. Second, we assumed that the precise measurements at 13 cross sections were representative of the entire gully length, and that changes in the product of cross sectional areas and intermediate lengths provided volumetric estimates of sediment yield. We assumed that the estimates based on sediment samples were sufficient to accurately estimate the total watershed sediment yield. Finally, we assumed that the differences between the total sediment yield at the runoff-measuring station and the combined upland and main gully contribution could be attributed to tributary gullies on the remainder of the watershed (Table 3).

In a parallel hypothesis, we considered the possibility that the USLE did not give us an accurate estimate of upland erosion for rangeland watersheds. If the channel between 102 and 104 was eroding, it was much less obvious than for the channel between 101 and 103; yet upland erosion, using the USLE, was underestimated for both 103 and 104. If, in fact, sediment yields at flume 104 were a better indication of upland erosion than the USLE, then upland erosion on watershed 103 could have been as

Table 1. Annual sediment yield (tons/acre) for two small watersheds, 103 and 104, on the Walnut Gulch Experimental Watershed.

	103 (9.2 acres)		104 (11.1 acres)	
Year	Est.*	Meas.	Est.*	Meas.
1973	0.29	1.24	0.25	0.35
1974	.36	2.17	.30	.75
1975	.85	3.83	.72	1.42
1976	.14	1.08	.12	.31
1977	.37	3.04	.32	1.33
1978	.21	.89	.17	.08
1979	.11	.21	.10	0
1980	.12	.25	.10	.10
Average	0.31	1.59	0.26	0.54

*From USLE

Table 2. Cross sectional estimates of gully contribution to sediment yield between weir 101 and flume 103, Walnut Gulch.

Cross Section	1976 X sectional area	Dist. between sections	1976-1979 Δ vol	1980-1984 Δ vol	1976 1984 Δ vol
	(ft^2)	(ft)	(ft^3)	(ft^3)	(ft^3)
Flume 103					
1	24.79	37	+ 50.4	+106.9	+157.3
2	29.07	46	- 3.1	+ 86.7	+ 83.6
3	21.41	37	- 17.2	+ 56.2	+ 39.0
4	28.81	32	+ 8.5	+ 55.4	+ 63.9
5	30.51	45	- 14.2	- 27.4	- 41.6
6	38.71	12	+ 5.4	- 29.5	- 24.1
7	47.56	55	- 99.4	-180.0	-279.4
8	M	34	--	--	--
9	64.88	33	-103.6	-197.6	-301.2
10	M	35	--	--	--
11	43.81	46	-146.7	-145.2	-291.9
12	M	29	--	--	--
13	36.63	42	-290.0	-387.5	-677.5
Weir 101		27			
			(-610)	(-662)	(-1272)
Totals	(@ 0.0425 tons / ft^3)		26 tons	28 tons	54 tons

M = missing; + = aggradation; – = degradation.

Table 3. Breakdown of total measured sediment yield for Watershed 103 (1976-1984) with upland erosion estimated from the USLE and 104.

	Est. from USLE		Est. from 104	
	Amount (tons)	*Percent*	*Amount* (tons	*Percent*
Measured (total)	105	100	104	100
Main gully erosion	54	51	54	51
Upland erosion	20	19	41	40
Other (tributary gullies)	31	30	10	9

much as 41 tons from 1976 through 1984, and the tributary channels as little as 10 tons (Table 3). In comparison, Piest, et al. (1975) reported that, on an average, about one-fifth of the total sediment yield from Iowa croplands resulted from gully erosion, with gully contribution approaching 50% of the observed sediment yield in individual cases.

Conclusions

Estimates of total sediment load, over a 9-yr period for a small gullied watershed, were partitioned to account for main gully contribution, tributary gully contribution, and upland erosion. These estimates were based on precise measurements of gully cross sections, comparisons of sediment yields of small gullied and ungullied watersheds, and USLE soil loss estimates. The main gully contributed about 50% of the total sediment yield. Estimates of upland erosion ranged from about 20% of the total based on the USLE to 40% based on comparison with an adjacent ungullied watershed. The remainder (10% to 30%) was attributed to contribution from tributary gullies.

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A Riparian Zone—One Story

Carl E. Bezanson and Lee E. Hughes

Riverbanks, streamsides, and wet meadows—riparian zones—have come to the attention of congressmen, public land managers, ecologists, ranchers, and conservationists. Proposed legislation dealing with the grazing fees on public land for 1988 addressed riparian areas for management emphasis. The pressure for government action is building to protect and manage riparian zones as very special areas, which indeed they are.

The Arizona Strip District (The Strip) of the Bureau of Land Management (BLM), that area found north of the Colorado River in northwestern Arizona, is not known for riparian areas. The Strip has relatively few springs and only three streams which pass through its bounds. The riparian areas comprise less than 1% of the Strip's 3 million acres. But the riparian areas and their water are immensely important on the ever-thirsty Strip.

A Brief Description

One important riparian area is the Paria River, which starts in southern Utah's plateau country and drains southward across the northeast corner of the Strip and barely flows into the Colorado River at Lees Ferry.

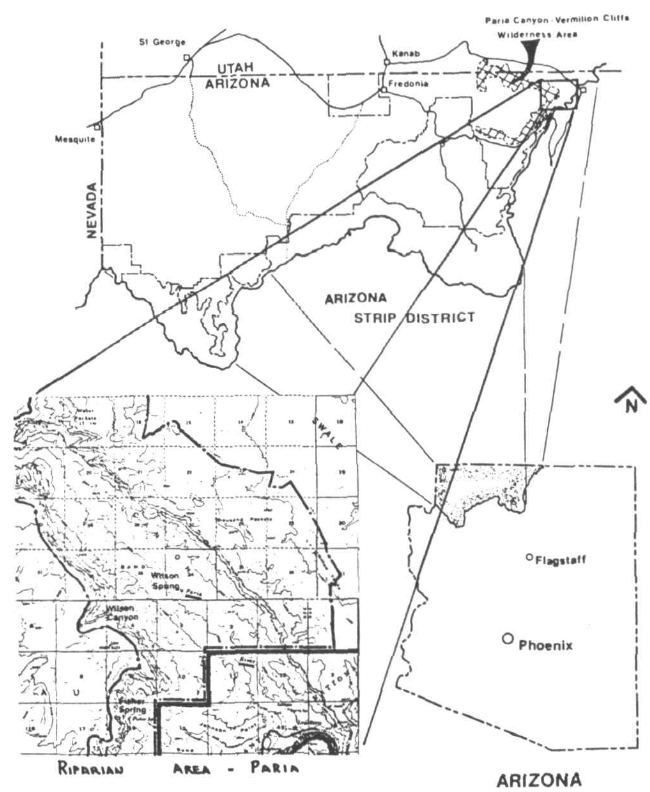
Ten miles above Lees Ferry the very narrow Paria Canyon significantly widens until its confluence with the Colorado River. This wide portion of the canyon has sandy slopes covered with desert grasses and browse such as Indian ricegrass and four-wing saltbush. The slopes all drain toward the Paria River, where water, feed, and shade from cottonwoods and willows exist.

In 1976 the 850-acre riparian zone along the Paria looked desolate: it was well trampled and heavily utilized by livestock. Outdoor enthusiasts, while hiking the slickrock Paria Canyon, objected to this condition of the riparian zone.

A Change

In 1979 The Strip evaluated its grazing program through an environmental impact statement. Following this effort, management changes were put in effect in the early 1980s through an all allotment management plan.

The objective of the allotment management plan and its



LOCATION MAP

Carl E. Bezanson was formerly range conservationist on the Arizona Strip District and now holds the same position on the Carson City District in Nevada. Lee E. Hughes is the district range conservationist for the Arizona Strip District.