The Geomorphic Process: Effects Of Base Level Lowering on Riparian Management

Linda S. Masters, J. Wayne Burkhardt and Robin Tausch

Recent emphasis in range management has centered on the maintenance and rehabilitation of riparian areas and associated meadows. These sites provide high forage values, critical wildlife and fisheries habitat, and important hydrological benefits. Many stream systems are downcutting or laterally eroding, causing concern over the stability of the riparian areas. This instability is believed by many land managers, biologists, and environmentalists to be the result of poor land uses. However, stream channel conditions are often the result of interactions between man's use of the land—such as urban development or range use—and natural, ongoing geomorphic processes. Common remedies attempting to arrest erosion include installing stream structures or altering domestic livestock grazing. Too often, these remedies are applied without first understanding the dynamics of the entire drainage system or the driving geomorphic processes. Streams are dynamic systems, constantly adjusting to changing conditions, and it is the natural state of streams to downcut and laterally erode. Whether a stream is downcutting or aggrading at any point along its channel depends on both upstream and downstream conditions.

This paper focuses on some of the physical and geomorphic processes of the Great Basin watersheds. The discussion is directed to the current impacts to stream channel morphology from the drying-up of the once massive ice age (Pleistocene) lakes.

The authors are, respectively, graduate student and associate professor, Department of Range, Wildlife and Forestry, University of Nevada, Reno, 1000 Valley Road, Reno 89512; and Project Leader, Intermountain Research Station, USDA-Forest Service, 920 Valley Road, Reno, Nevada 89512.

Stream Dynamics

Tectonic forces and climatic fluctuations in the last 25,000 years (Cronquist, et al. 1972) have not allowed steady state conditions to become established on most of the large watersheds in the Great Basin. Present day climatic conditions are conducive to occasional extreme precipitation events which produce high stream flows causing dramatic changes in stream channel morphology. Fol-low-ing these events, the streams once again undergo gradual changes leading toward a more balanced state. This process may take several hundred years depending on stream characteristics (e.g., steepness, channel material and confinement).

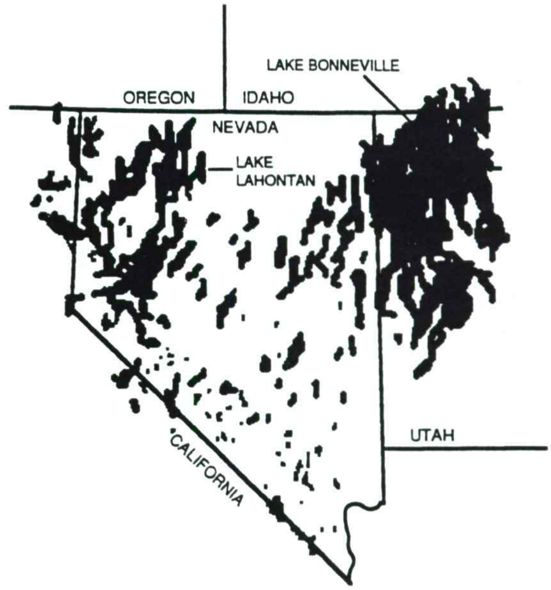

Fig. 1. *Pleistocene Lakes of the Great Basin.*

An important, but often overlooked physical process which always initiates readjustment in stream morphology is a change in base-level. The base-level of a stream is defined as the lowest level to which the stream can erode its channel or as the elevation of the stream's mouth where it enters the ocean, a lake, reservoir, or another stream (Hamblin 1982). A change in base-level always leads to some kind of readjustment in the stream bed gradient, width, depth and sinuosity (Lowe and Walker 1984).

Lowering of base-level creates a steepened gradient that induces accelerated flow and causes the formation of a headcut. The headcut migrates upstream with a corresponding downstream deposition of eroded material. This process continues throughout the watershed or until the advancing headcut encounters resistant bedrock. Other adjustments such as increase in channel width and decrease of bank angles will occur until a new steady state cross-section geometry is established. (Richards 1982).

Pleistocene Lake History

During the Pleistocene ice-age, Lake Lahontan (Fig. 1) covered an area of about 45,000 square miles in northern and western Nevada, with small areas in the adjoining states of California and Oregon (Jones et al. 1925). One-hundred other valleys in the Great Basin also contained perennial lakes during that time (Williams 1983). These "pluvial" lakes were formed during a climatic regime in which there was greater net moisture available than is available in the same area today (Flint 1971). Lake Bonneville in Utah and Lake Lahontan in Nevada were the largest of these pluvial lakes. Base levels of the streams leading to the lakes have fluctuated as lake levels changed dramatically over time. This has created changing

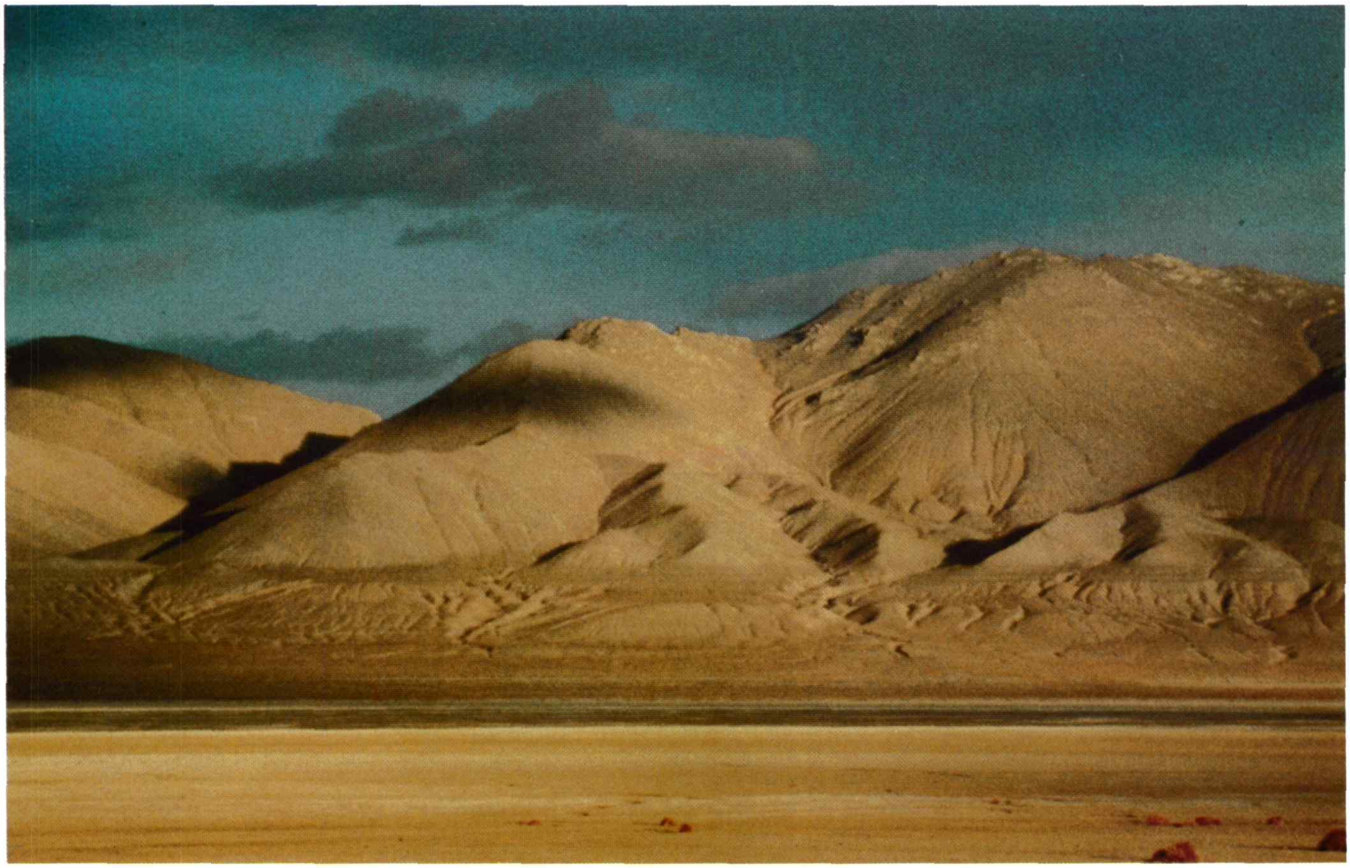

Fig. 2. *Channel entrenchment initiated by base-level lowering in small drainage basin adjacent to a remnant Pleistocene Lake (Winnemuca Lake).*

control points for erosional and depositional processes. Currently in Nevada, the dry playas and lakes within the closed basins represent the base-level for the surrounding drainage systems.

It is generally agreed that there were one or more peaks in lake level from 25,000 to 15,000 years before the present (B.P.) and one or more very brief high lake levels in some basins about 12,000 years B.P. (Mifflin and Wheat 1979). During the last major pluvial stage, Lake Lahontan raised in elevation from 3,800 feet to 4,200 feet (Hawley 1968) and had a maximum depth of about 700 feet at Pyramid Lake and about 500 feet at Carson Sink (Morrison 1965). As the Pleistocene ended, Lake Lahontan was full and surrounding streams had aggraded (Davis and Elston 1972). Drainages formed during this time terminated at the upper shoreline of the lake and stream energy dynamics were controlled by high lake levels.

About 10,000 years before the present, the Great Basin climate shifted toward warmer and dryer conditions (Harper and Alder 1972) and recent studies suggest that lakes dropped rapidly to low levels by 9,000 years B.P. (Lajoie 1983). From about 3,500 to 1,400 years B.P., the climate was again cool and moist enough for episodic lakes to form in such basins as the Black Rock Desert, a playa remnant of Lake Lahontan (Davis and Elston 1972). Since that period minor cyclic climatic changes have occurred. Within the last few hundred years, drying and warming trends have again caused the evaporation of Pleistocene lake remnants and most lake basins in Nevada are now dry playas. However, exceptional snowfall during the early 1980's produced a twenty-five foot rise in Pyramid Lake and historic lake level rises in other basins such as Salt Lake and Malhuer. Cycles of stream channel entrenchment and deposition caused by these numerous lake fluctuations have created a series of headcuts which continue to successively sweep through the drainage networks in an upstream direction (Schumm and Hadley 1957).

Drainage Response and Management Concerns

As Lake Lahontan receded, the base level for all rivers entering the basin was lowered and cutting of the present river channels was initiated (Davis and Elston 1972). The lowering of the base level increased the erosional energy of the rivers. As a result, expanded drainage systems are currently forming through the readjustment processes of downcutting, headward erosion, slope retreat and extension of drainages downslope. In small, steep drainages adjacent to remnants of Pleistocene lakes the effects of these processes are clearly demonstrated (Fig. 2). Downcutting and slope retreat occurs in all segments of the streams; headward erosion is extending the drainage network upslope in the moun-

Fig. 3. *Channel entrenchment in a large drainage basin (Long Valley Creek) initiated by base-level lowering at Honey Lake.*

tains above the old shoreline and downcutting is extending the drainage system downslope into old lake sediments.

In larger drainage systems, the effects of these processes are not as easily perceived. They are, however, still occurring. In the Long Valley drainage which empties into the Honey Lake basin northwest of Reno, downcutting through old Pleistocene lake deposits is apparent between Herlong and Doyle (Fig. 3). In this case, readjustment results in a different geomorphological expression of the downcutting processes than that seen in small steep drainages. Here the entrenchment is much broader and flatter, reflecting the surrounding basin characteristics. In this watershed, headward erosion has, so far, extended 50 miles up the drainage to a point just west of Bordertown on the California and Nevada border. The existing headcut in this portion of Long Valley marks the upstream extension of the erosion processes initiated several thousand years ago by the drying up of the Honey Lake arm of pluvial Lake Lahontan (Fig. 4). The headcuts are still slowly moving upstream degrading conditions in the remaining meadows irrespective of current, past, or future land use in the valley.

The downcutting of the main channel of Long Valley Creek has also affected tributaries entering the stream. As the headcut in the mainstream moves past a tributary, the local base-level of that drainage is drastically lowered, thereby initiating erosional adjustments in the tributary (Fig. 5). Erosion in tributaries can mean the loss of valuable meadows and riparian areas as headcuts move up through valley bottoms. In addition, reduction of base-level not only lowers the drainage outlet of all tributaries, but it also profoundly affects the ground water levels in the basin. Lowering of a water table can result in encroachment of woody shrubs into a previously productive meadow. It is important to recognize the underlying physical processes taking place in this area so that management or rehabilitation programs are aimed at the appropriate target. Man induced perturbations to the Long Valley watershed have obviously affectd this drainage, but the dominant cause of channel erosion and water table lowering is base-level lowering and the subsequent headward progression of the stream channel readjustments.

The extent to which resource managers need to be concerned with these large scale processes becomes apparent when a watershed the size of the Humboldt drainage is considered (Fig. 6). The present day Humboldt river is about 400 miles long and flows in a westerly direction

Fig. 4. *The current location of the Long Valley headcut, which was initiated by the drying-up of Honey Lake several thousand years ago.*

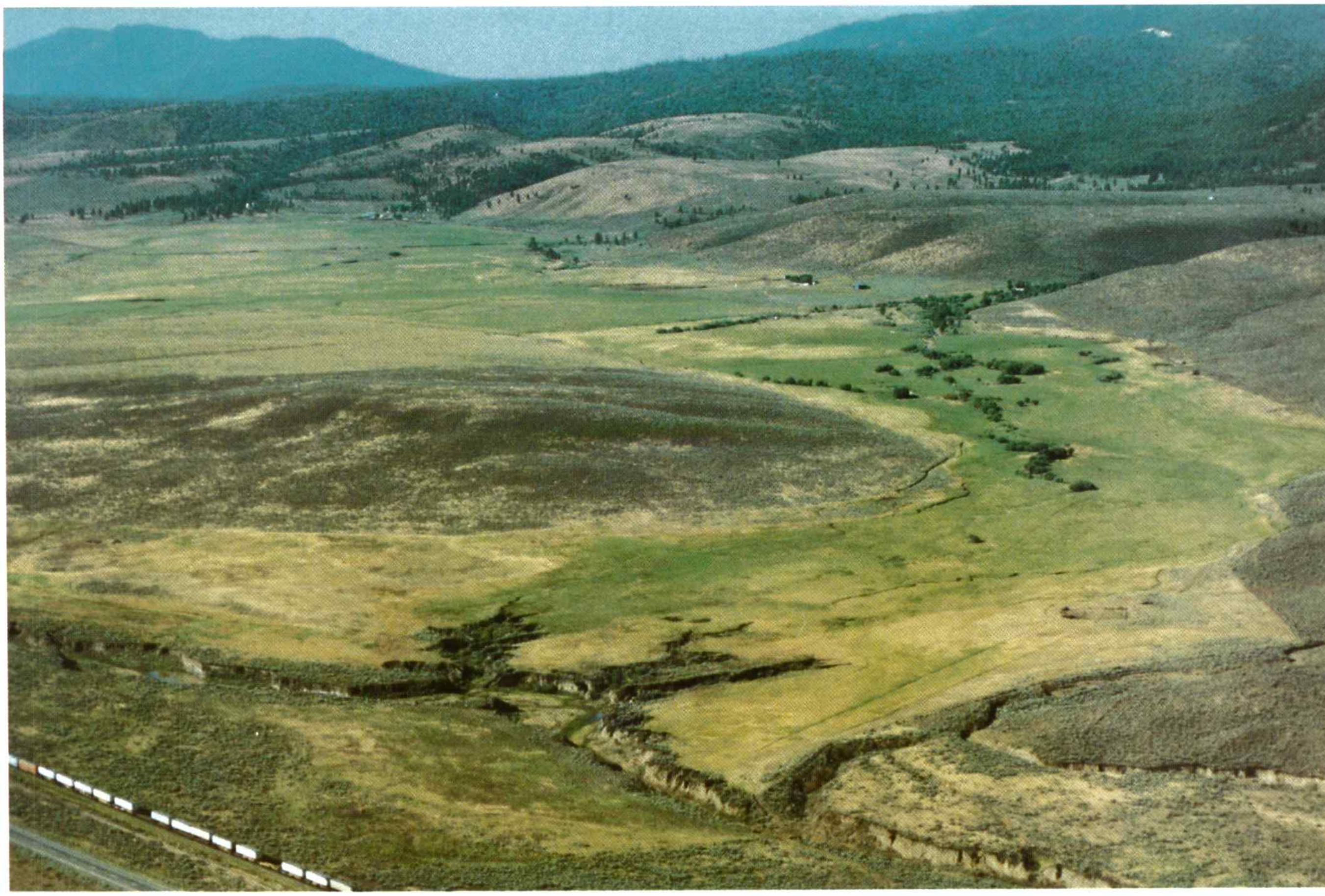

Fig. 5. *Initiation of erosional adjustments in a tributary subsequent to main channel entrenchment of Long Valley Creek.*

from headwaters in the Ruby Mountains (south fork) and the Independence Range (north fork) terminating in Humboldt Lake in west central Nevada. During the period of maximum depth of Lake Lahontan, the Humboldt River emptied into the lake northeast of Winnemucca. Today the terminus of the river at Humboldt sinks, south of Lovelock, has standing water only in wet years. The 500′ drop in base level this represents is still dramatically affecting the entire drainage system across northern Nevada.

Major drainages into the Humboldt River include: Grass Valley and Paradise Valley (Little Humboldt River) in the Winnemucca area, the Reese River Valley near Battle Mountain, Pine Creek and Susie Creek valleys near Carlin, and the South Fork and the North Fork of the Humboldt River near Elko (Fig. 6). All of these tributaries show various stages of downcutting, headward erosion, lateral erosion and aggradation in response to changes in the base level of the main fork of the Humboldt River. It must also be recognized that smaller drainages emptying into the above-mentioned tributaries are also being affected as headward erosion continues to proceed throughout the entire network of streams in the system. This natural process is on-going irrespective of past, present, or future land use.

Conclusions and Discussion

The drying of the Pleistocene Lakes has resulted in widespread downcutting and headward erosion that is continuing throughout watersheds in the Great Basin. However, this knowledge has largely been ignored or overlooked by many biologists, land managers, and environmentalists.

It is very easy to recognize the effects of lowered base-levels resulting from the drying-up of the Pleistocene lake systems on a small scale such as those visible at the Winnemucca Lake playa (Fig. 2). It is much more difficult for a resource manager to visualize these same impacts on a large scale when the closest playa is a hundred miles or more away.

It is important to recognize and understand these relationships so that responsible management decisions can be made. Removing or reducing domestic livestock from a meadow will not prevent the loss of that valuable land if the more dominant erosion processes associated with base-level adjustments are driving current stream channel changes.

Channel erosion and deposition in response to base level changes is a natural geomorphic process. Climatically driven Pleistocene Lake level changes, crustal tectonics such as the Stillwater Mountains faulting, or man-made channel alterations such as road crossings or reservoir con-

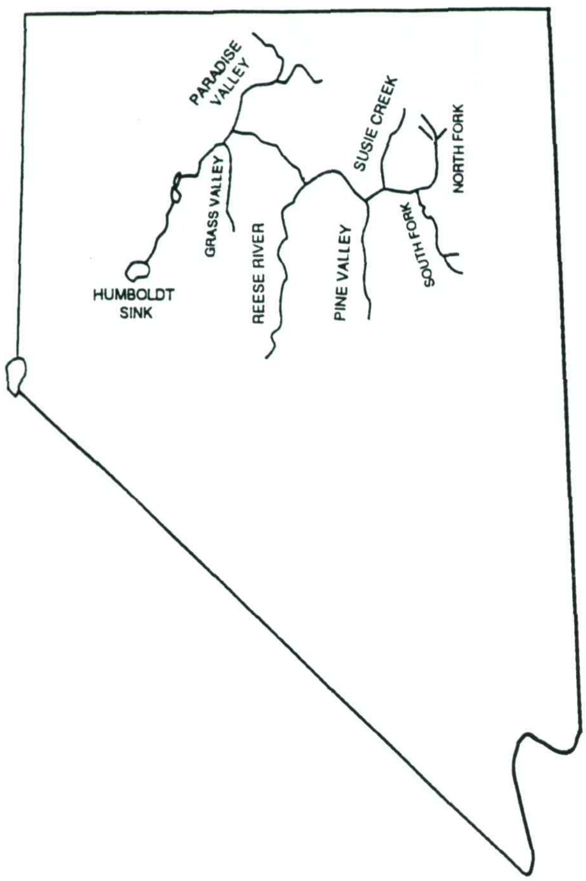

Fig. 6. *Humboldt River drainage and major tributaries.*

struction all produce similar results. Road construction, bridge and culvert installation, reservoirs and water diversions, channelizing, and revetment projects can all affect local stream base levels and initiate subsequent upstream and downstream channel adjustments.

The land manager, when confronted by current stream entrenchment and active head cuts should look well beyond just land use in the immediate locale. The entire stream drainage should be evaluated. Physical and geomorphic processes, more so than biotic impacts, are often the driving forces behind ongoing stream dynamics. Proper management and rehabilitation recommendations for stream systems require an evaluation of these processes as well as land use.

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