ASSESSMENT AND RECOMMENDATIONS FOR STREAM RESTORATION PLANS IN CLOVER SPRINGS VALLEY, ARIZONA

Taylor Joyal, Ron Griffiths, and Colin Ferguson*

Many stream morphologies exist along the Mogollon Rim of northern Arizona. Of these, wet meadows are unique and critical for the health of the area's stream ecosystems and ponderosa forests. Many of these meadow systems have been incised due to recent anthropogenic and natural activities. In some instances the cause of channelization remains unclear. It is possible that regional incision may have occurred primarily in response to climate change or extreme runoff events tied to high seasonal precipitation. Channel incision lowers the local water table, threatening the wet meadow riparian ecosystem. In addition, increased erosion reduces downstream water quality. One such degraded system in the Clover Spring Valley has already been incised up to 3 m. Anthropogenic activities, such as straightening of the stream channel, have severely impacted the morphology, hydrology, and biology of the stream system in this area. In an effort to restore the health of this system, an interdisciplinary group from Northern Arizona University, in conjunction with the National Forest Service, has developed a demonstrative plan that includes restoration of the stream's natural meanders and removal of a Forest Service road. Previous efforts to alleviate channelization in Clover Spring Valley that involved the construction of check dams have failed. Determination of the "correct" pre-disturbance morphology and the long-term stability of the restoration project has yet to be addressed. This review examines the efforts taken to determine the correct pre-disturbance morphology and evaluates the proposed techniques and strategies for restoration.

Introduction

Part of the headwaters to the Verde, Little Colorado, and Gila Rivers are upland wet meadows along the Mogollon Rim of central Arizona approximately 80 km south of Flagstaff. Many of these wet meadows have been degraded as a result of stream channel incision, sometimes to bedrock. The Verde River Headwaters Riparian Restoration Demonstration Project is designed to restore the wet meadow ecosystem along a reach of stream in the Clover Springs Valley. We outline and evaluate the strategy and methods proposed in the restoration project and make recommendations for a more sustainable, long-term restoration plan.

Regional Setting

The Mogollon Rim is part of an escarpment that bisects Arizona diagonally from the northwest corner to the central-eastern part of the state. This escarpment is approximately 500 km in length and forms the boundary between the Colorado Plateau to the north and the Transition Zone–Basin and Range provinces to the south. The escarpment is bounded on its western margin by the structurally controlled Grand Wash Cliffs and on the eastern margin by the White Mountains. The Mogollon Rim has local relief of up to 600 m (Peirce et al. 1979). The rim forms a drainage divide that separates the northward-flowing streams that feed the Little Colorado River from streams to the south that drain into the Verde and Salt Rivers.

Background

Quaternary deposits along the Mogollon Rim contain abundant proxies for interpreting the region's paleoenvironmental record, including sediment and midden deposits. Pollen, macrobotanical, and fossil remains derived from stratigraphic deposits in lakes, bogs, alluvium, and caves, as well as deposits of packrat middens and herbivore dung provide evidence for late Quaternary environments. Regional climatic oscillations can be deduced from these assemblages (Anderson et al. 2000). As a result, numerous studies have established an extensive 50,000 yr climate and

*Northern Arizona University, Flagstaff

paleoecological record for the Mogollon Rim region (Anderson 1993; Anderson et al. 2000; Hasbargen 1994; Whiteside 1965).

The southern Colorado Plateau contains the highest concentration of studied paleoenvironmental sites, and also contains the most complete paleoenvironmental records (Anderson et al. 2000). In compiling previous paleoenvironmental studies, Anderson et al. (2000) cited evidence for periods of wetter and colder climates during the middle and late Wisconsin. Anderson (1993) followed up a study by Whiteside (1965) on the paleoecological record beneath Potato Lake, which is located on the Colorado Plateau in central Arizona. Anderson's (1993) findings concurred with the interpretation of a wet and cool mid and late Wisconsin climate. Hasbargen's (1994) research on nearby Stoneman Lake sediments suggested a pattern of strong monsoons between 10,000 and 8,000 yr B.P. that subsequently tapered off to warmer, drier conditions. The Arizona monsoon season's sensitivity to glacial intervals (Anderson et al. 2000), coupled with the orographic rise of the Mogollon Rim, could have induced major geomorphic responses associated with these climate changes (Diana Anderson, personal communication). As a result, the deviations in climate should have triggered distinct fluvial geomorphic responses throughout the region.

Kennedy (1999) completed a geomorphic analysis of a stream system located at Clover Spring that underwent stress induced by anthropogenic and climatic effects. The studied reach is representative of streams and wet meadows found across the Mogollon Rim. The focus of the study was to determine the causes and timing of aggradation and erosion that occurred along a section of stream within the Cover Springs stream system. One goal was to determine the cause of a regional incision event that occurred during the 1880s, which was previously attributed to climate, overgrazing, and channel straightening. The depositional record of the stream extended 7,000 yr B.P., but the study focused primarily on the late nineteenth century incision event. Radiocarbon dating, dendrochronology, and historic photos were employed to determine the timing of preserved depositional events. Tree rings were examined to distinguish wet and dry periods, however the range of the tree rings was limited to slightly over 100 yr B.P (Kennedy 1999). Kennedy was able to correlate a wet period evident in tree rings to the regional incision event. In addition, grain size analysis of the stream deposits suggested that depositional environments were similar through the time period studied. Kennedy (1999) concluded that the coincidence of drought and grazing prior to a wet period during the 1880s contributed to the incision of the stream at Clover Spring.

Insight into the response of fluvial systems to climate change is an important contribution to our understanding of paleoenvironments. Additionally, this information can be valuable to restoration projects that require distinction between natural cyclic changes in fluvial systems and anthropogenic sources of change. For example, heavy grazing of a floodplain adjacent to a stream can produce a considerable decrease in vegetative cover, which can destabilize the stream and facilitate incision. Conversely, a period of incision could be attributed to an interval of high precipitation and consequential runoff following a dry period. As a result, the condition of the stream in question may be well within the natural cycle of the fluvial system.

Project Objectives

The primary goal of the Verde River Headwaters Riparian Restoration Demonstration Project is channel stabilization and re-establishment of riparian wet meadow function along an approximately 8300 m reach of Clover Springs wet meadow. To reach this ultimate goal, three main objectives were formulated: (1) designing and executing a plan to stabilize the channel and preserve the wet meadow in the Clover Springs reach; (2) interpreting the factors leading to incision and deciphering the timing of these events with the intention of creating a long-term mitigation plan; and (3) producing informational material to transmit activities of the project to the public.

To accomplish the goals of objective two, a geomorphic analysis was proposed to determine the mode of sediment deposition and erosion within wet meadow fluvial systems of the Mogollon Rim region. Particularly, the mechanism, timing, and effects of the local incisional events and subsequent depositional events will be evaluated. Supporting objectives are to (1) establish the nature of the system prior to incision; (2) identify various fluvial regimes, identify buried soils, and collect material suitable for ^{14}C dating; and (3) compare paleoclimate records to prehistoric geomorphology. In addition, historic climate records and land-use changes will be compared with the historic geomorphic section to determine how both climate and land-use changes have affected the erosional and depositional history of the area.

Proposed Site Resoration Methods

Active restoration techniques, including road removal, back-filling, and channel diversion, are the proposed methods for restoration. Use of these restoration techniques and determination of the correct channel morphology are based on quantitative measurements and comparisons to similar, non-degraded reference streams. Post-restoration changes will be monitored and compared to pre-restoration conditions.

Pre-Restoration Site Characterization

Pre-restoration site conditions were determined and documented by the production of a high-resolution topographic map in c. 1999. This map was constructed on a 1:3000 scale with the use of a Topcon 310 total station. Coordinates were collected for 2600 survey points and plotted using ArcView. This survey map provides a datum from which post-restoration changes can be measured.

Determination of Correct Channel Morphology

Correct channel morphology has been determined for the project area based on site information and comparisons to stable, non-degraded stream channels found with similar characteristics (reference sections). Site information includes stream profiles and cross sections, hydrologic analysis, and aerial photograph interpretation. This information was combined with observations from the reference sections to attain a stream channel design. Hydraulic analysis was then completed on the newly designed stream channel to further refine the design. Project design is restricted by the base level control imposed by culverts in the upper section of the project area and bedrock located in the lower section.

Restoration Work to Be Completed

Restoration work at the site will occur in two sections. Work on the upper section will include removal of a Forest Service road adjacent to the stream, which will increase the bottom width of the channel from 2.5 m to approximately 5 m. This will lower bank-full velocities and allow the stream channel to become more sinuous. Back-filling of material in the headcut locations will also be done to smooth the stream profile and reduce headward erosion. Other related work on this section will include cutting back the existing stream bank to a more stable profile and re-vegetation of newly exposed sections.

The second, lower section of restoration will include abandonment of the existing incised stream channel and the construction of a new channel. This technique will promote the conversion of an F or G type channel to a more optimal C or E channel configuration, following Rosgen's classification scheme (Rosgen 1996). The new channel will be constructed on the existing floodplain where it should evolve from a sinuous, low entrenchment, gravel-dominated C-5 stream type to a stable, low to moderately sinuous, E-5 stream with gentle to moderately steep channel gradients and low width to depth ratios.

Monitoring Plan

Site conditions will be monitored after the restoration work has been completed to assess the stability of the redesigned channel. Monitoring will include two sets of measurements taken annually for the duration of the project funding and at least once every 3 years thereafter. The two sets of measurements to be taken include a longitudinal stream profile and cross-sectional profiles that will be taken after the stream's annual peak discharge. Other parameters to be monitored include shallow groundwater, vegetation, and surface water flow, as well as repeat photographs of the stream and floodplain. These measurements will allow assessment of stream stability and document any changes in the system, which will allow for a better future understanding of how streams respond to this type of restoration work.

Evaluation of Restoration Strategy and Methods

Proposed as a riparian restoration effort, in contrast to a more extensive watershed restoration, the Verde River Headwaters Restoration Demonstration Project will attempt to restore the function of a wet meadow. An active restoration plan was therefore devised; however, after reviewing the plan, two major suggestions are apparent. First, the initial proposal identified a need for regional geomorphic survey of similar wet meadow–stream systems. Correlation of the geomorphic stratigraphy with existing paleoclimatic research would reveal what responses to climate and environmental change these systems have achieved during the Holocene. With this knowledge, a more comprehensive understanding of the dynamics of these systems along the Mogollon Rim would be gained. Unfortunately, this regional assessment was not completed prior to the conception of the active restoration plan.

A second suggestion is to assess the watershed as a whole. The small stretch of the stream system to be restored during this project is bound by artificial base levels. Culverts create the base level upstream of the project, and upon completion of the restoration project, a weir will create the downstream base level. These controls will preserve the restored section for the short term, but the long-term stability of the reach depends on a broader watershed-based approach to stream restoration.

Many controls contribute to the channel morphologies found within a watershed. These controls include channel gradient, drainage discharge, and sediment input. Sediment input can vary dramatically in response to factors such as fire suppression, road construction, natural grazing variation, vegetation change, soil formation, and climatic changes resulting in altered stream morphologies. For example, fire suppression will increase forest density, affecting runoff and reducing sediment supply, ultimately leading to incision. Changes in the migration patterns of herbivores can affect vegetation density as well. Additionally, climate changes can produce precipitation variation that results in runoff fluctuations and changes in vegetation patterns.

To gain a full understanding of the natural dynamics and limits of a system in resilient quasi-equilibrium, a more complete survey of the regional geomorphic response to climatic and anthropogenic variables should be considered. As a result, alternative efforts at restoration, including passive restoration techniques, can then be considered.

References Cited

Anderson, R. S. 1993. A 35,000 year vegetation and climate history from Potato Lake, Mogollon Rim, Arizona. Quaternary Research 40:351–359.

Anderson, R. S., J. L. Betancourt, J. I. Mead, R. H. Hevly, and D. P. Adam. 2000. Middle- and late-Wisconsin paleobotanic and paleoclimatic records from the southern Colorado Plateau, USA. Paleogeography, Paleoclimatology, Paleoecology 155:31–57.

Hasbargen, J. 1994. A Holocene paleoclimatic and environmental record from Stoneman Lake, Arizona. Quaternary Research 42:188–196.

Kennedy, J. 1999. Channel incision and straightening on the southern Colorado Plateau at Clover Spring, Arizona. Senior thesis, Northern Arizona University.

Peirce, H. W., P. E. Damon, and M. Shafiqullah. 1979. An Oligocene (?) Colorado Plateau edge in Arizona. Techtonophysics 61:1–24.

Rosgen, D. L. 1996. Applied river morphology. Wildland Hydrology, Pagosa Springs, Colorado.

Whiteside, M. C. 1965. Paleoecological studies of Potato Lake and its environs. Ecology 46:807–816.