Monitoring Series No. 3

California Rangelands Research and Information Center

Nonpoint Source Pollution Monitoring

Kenneth W. Tate, Department of Agronomy & Range Science, University of California, Davis, CA

There is significant interest in "water quality monitoring" within California's rangeland community. This interest reflects an awareness of nonpoint source pollution (NPS) related water quality issues on the part of ranchers and rangeland managers. The purpose of this document is to familiarize ranchers and range managers with some basic concepts and the reality of water quality monitoring. It is ***not*** to encourage ranchers to conduct water quality monitoring or to hire "experts" to conduct it for them. In most cases, water quality monitoring is beyond the financial, labor, and technical scope of individual ranchers. It is also in most cases beyond the monitoring needs of the individual rancher. However, ranchers should understand the basics of developing a meaningful water quality monitoring program. The reader is referred to Rangeland Monitoring No. 1 for a definition of monitoring and explanation of types of monitoring.

Basics

Definitions

Water quality reflects the composition of water as affected by natural causes and man's activities, expressed in terms of measurable amounts and related to intended use of the water.

Water quality monitoring is the measurement of water quality variables such as suspended sediments, temperature, nutrients, and pathogens in a stream over time.

Pollutant concentration is the mass of pollutant per volume water often expressed as milligrams per liter (mg/L). Concentration can also be reported as parts pollutant per million parts water (ppm). For most purposes it can be assumed that 1mg/L = 1 ppm.

Pollutant load is the mass of pollutant passing a point along a stream over a specific unit of time often expressed as total storm load or annual load (tons). Load is calculated as concentration (mg/L) per unit time multiplied by flow volume (L) for the same unit time.

Important Concepts to Remember

Nonpoint source pollution is driven by meteorological and hydrological events and is due to natural processes which can be altered by human activity. The occurrence and magnitude of nonpoint source pollution are directly linked to the hydrologic cycle. These facts lead to some basic concepts which must be considered when developing or evaluating an existing NPS monitoring program.

1. The watershed is the basic land unit of the hydrologic cycle and thus of nonpoint source pollution generation and transport. Water quality at any point along a stream reflects all pollutant contributions from all sources in the watershed above that point (grazed uplands, roads, housing developments, channel erosion, wildlife activities, campers, etc.).

2. Nonpoint source pollution from rangelands is storm flow dependent. The majority of nonpoint source pollution will be generated and transported during high-flow storm events which represent a short period (hours to days) of stream flow. In general, concentrations of nonpoint source pollutants

such as suspended sediment, nitrogen, phosphorus, and pathogens increase as stormflow increases. The exception are those pollutants which are controlled by ground water discharge to streams (Ca, Mg, pH, etc.). In this case, concentrations can decrease during storm flows.

3. Because nonpoint source pollution generation and transport is driven by meteorology and is dependent upon individual watershed characteristics, nonpoint source pollution has a strong random (unpredictable) component. There is a high level of inherent variability in NPS generation and transport due to interacting climatic, hydrologic, geologic and soil, ecological, and land use factors.

4. Because nutrient cycling and erosion are natural processes, there is some level of "background" or natural nonpoint source "pollution" for each watershed. Background levels vary from watershed to watershed based upon unique climatic, hydrologic, geologic and soil, and ecological factors and are almost always unknown. The potential does exist for background levels to exceed water quality standards during rare stormflow events (10-, 25-, 100-year, etc. storms).

Relationship of NPS to Stormflow

It is important to consider the relationship of nonpoint source pollution transport to streamflow when considering the timing and frequency of sample collection. Figure 1 illustrates the general relationship between suspended sediment concentration, the major NPS pollutant on rangelands, and streamflow during a single storm event on a headwaters stream. Suspended sediment is simply used as an example, most other nonpoint source pollutants on rangelands have a similar if not more complex relationship with flow.

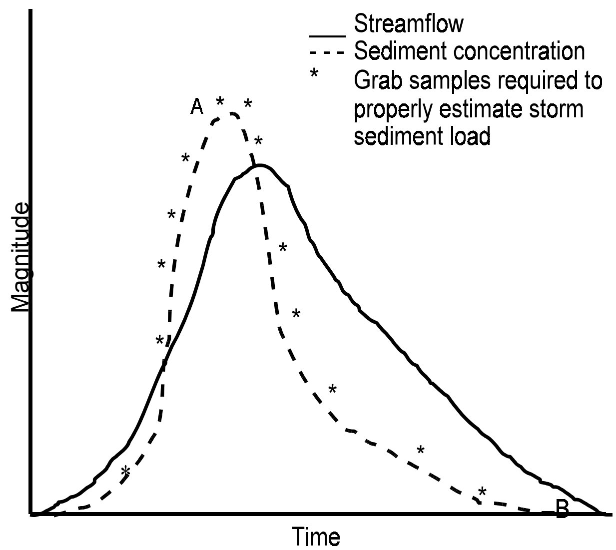

Figure 1. General relationship between streamflow and suspended sediment concentrations during a stormflow event.

In headwater streams, where most ranches are located, suspended sediment concentration increases rapidly with stream flow and typically peaks before streamflow (Figure 1). Erosion is usually highest at the start of a runoff event when sediments are readily available for transport via overland flow to the stream channel. Sediment concentrations drop rapidly as the supply of readily eroded sediment is diminished. Note the timing and frequency of grab samples required to adequately estimate total storm sediment load.

The relationship in Figure 1 will repeat itself through out a wet season as storms come and go and streamflow rises and falls. There will be very brief periods of sediment transport activity separated by relatively long periods of low sediment transport. To develop an estimate of annual sediment load, each storm event would have to be sampled with a timing and frequency similar to that illustrated in Figure 1. These storm events often occur at inopportune times such as late at night or when other activities are simply more pressing.

A grab sample is representative of nonpoint source pollution transport only at the time of sampling. For proper interpretation, each water sample should be accompanied by a streamflow measurement and an indication of whether the sample represents rising, peak, or falling flow. The reader is referred to Rangeland Monitoring No. 9 for an explanation of streamflow monitoring.

Developing a Monitoring Program

Important Questions

There are several basic questions which if specifically addressed will help guide the development of a meaningful nonpoint source pollution monitoring program. *Why* is it necessary to monitor water quality?
Who will conduct the monitoring, and what is their level of understanding of water quality monitoring and data interpretation? *What* water quality variables will be monitored, and what relation do the variables have to the monitoring objective? *Where* will water quality be monitored, and what relation do the locations have to the monitoring objective? *When* in terms of time of year and with regard to streamflow will water quality be monitored, and what relation does sampling time have to the monitoring objective? *How long* will the program last and how will you know when it is time to stop?

Objectives are the Key

The most important step in developing a meaningful nonpoint source pollution monitoring plan is to establish clear, explicit, and realistic objectives. A meaningful nonpoint source pollution monitoring program is developed to address a specific set of clear, well thought out questions. EXACTLY why do you need to monitor water quality? EXACTLY what do you intend to do with the information you obtain from this monitoring, and HOW will you do it? EXACTLY how confident do you need to be in the accuracy of this information? Vague or unrealistic objectives are likely to result in monitoring that collects unnecessary data and ultimately is unable to answer the pertinent management questions.

Once the monitoring objectives have been established, the who, what, where, when, and for how long questions can be systematically answered. The "best" monitoring program for each watershed and monitoring objective is unique.

Realistic Expectations

Ranchers, as well as technical specialists, often over estimate the importance and capabilities of water quality monitoring to address complex questions which are in actuality research hypotheses. Do not expect monitoring to answer cause and effect questions. Extremely well planned and conducted monitoring might be able to identify cause and effect. In most cases, monitoring simply describes the dynamics of a variable through time. Without the inclusion of valid experimental design and statistical principles early in the development process, it is difficult to identify the driving forces behind these dynamics.

Even with the use of the "best" techniques and designs, detecting changes in nonpoint source pollution related water quality is difficult. Spooner et al. (1987) evaluated the sensitivity of grab sample-based NPS monitoring programs and determined that a 30 to 60% change in average pollutant concentration over a 5 year period is required to document a significant trend in water quality as a result of management.

Cause and Effect Monitoring/Research Designs

There are three basic designs for documenting causes of water quality problems or changes in water quality due to changes in management (Spooner et al. 1985, USEPA 1993). The key to each of these designs is adequate baseline or control information. Each of these methods requires an understanding and application of experimental design and statistical principles. If you do not understand these basic principles, you may not want to jump into cause and effect monitoring. But it is a good idea to at least have an awareness that these methods exist.

The ***before and after*** design involves monitoring water quality before and after some land management change to determine if water quality changes over time as a result. Without associate long term monitoring of water quality, weather and streamflow this method will provide little insight. Of the three, this method is the least useful for determining cause and effect.

The ***above and below*** design involves sampling water quality over time above and below a potential source of nonpoint source pollution. The primary advantage of this design over the before and after design is that it allows for separation of NPS contributed up-stream of the area of interest.

The ***paired watersheds*** design involves monitoring water quality on two or more watersheds through time. The watersheds are initially under the same management, after a sufficient pre-treatment time period (several years at a minimum), one watershed is selected as a control and the others are treated. The control watershed allows for control of year-to-year and seasonal climatic variation. This design is the most useful of the three for establishing cause and effect relationships. It is also the most technical and expensive. Employing this design to answer a question represents water quality research.

Why should I Care about all this Technical Stuff?

Each of the designs mentioned above represents an effort to identify land use driven changes (improvements or degradation) in water quality by controlling for the "masking" influence of meteorologic and hydrologic variables. For instance the question might be: Does fencing the riparian zone on Ranch X reduce suspended sediment concentrations in the stream? Recall that we have established that suspended sediment concentration is dependent upon streamflow. Say that one of two things happen:

1. The stream is fenced and for the next four years rainfall and thus stream flow and sediment concentration is below normal. Was the reduction in sediment concentrations due to the fence or the low rainfall?

2. The stream is fenced and for the next four years rainfall and thus streamflow and sediment concentration is above normal. Was the fence an ineffective method of reducing sediment concentration, or was the increased sediment concentration due to the large storm events?

Without some method of controlling for the "masking" effect of natural weather and streamflow variation we have no way of determining the effectiveness of the fencing practice on Ranch X.

Conclusion

Again, the purpose of this document is to familiarize ranchers and range managers with some basic concepts and the reality associated with water quality monitoring. Monitoring for nonpoint source pollution related water quality can be a very important and valuable venture, if there is a clear need. Unless a water quality program is specifically needed and is designed to address specific objectives, a lot of money and time can be spent with very little return to the investment. ***As a manager, what does water quality monitoring do for you that a high quality photo monitoring program illustrating your proper management does not?***

References

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