Rural Storm Water Management: Water Quality, Flood Avoidance, and System Integrity*

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Introduction

Total maximum daily loads (TMDLs) are the regulatory tool applied to nonpoint source pollutants in rural areas. TMDLs are controversial because the science is complex and the methods used to apportion load discharges seemingly arbitrary and capricious. Environmental regulators (the EPA, Tribes, and states) use inappropriate data and none has fully implemented the 2001 recommendations from the National Research Council's Water Science Technology Board. When the regulated public, regulators, and environmental policy makers better understand the environmental science of rural storm water management more effective decisions can be made. This document explains the shortcomings of the current approaches and offers suggestions on achieving more technically sound and legally defensible nonpoint source pollutants control. The need for better control of nonpoint source pollutants has become more important with climate warming and more frequent and intense extreme weather events, particularly in the drought-stricken western US.

Water quality in rural areas is regulated by apportioning a Total Maximum Daily Load (TMDL) for a specific water quality constituent among all storm water dischargers in the designated basin. Storm water dischargers are operations, such as farms, grazing areas, surface and underground mines, server farms, and other human activities where storm water surface flows enter receiving waters over diffuse areas.

Calculating the TMDL for a large stream or river reach, sub-basin, or the entire river basin requires much more data than are available to regulators. Apportioning that value among all anthropogenic activities in the defined area needs to be based on hydrology, hydraulics, topology, vegetation, and biota which all vary temporally and spatially in the regulated area. That sufficient data and appropriate methods are commonly unavailable to decision–makers results in contention, challenges, and lawsuits as well as tension between regulators and the regulated public. This does not need to be the case.

This document focuses on the management of precipitation runoff to comply with the federal Clean Water Act (CWA) requirement to address nonpoint pollutants using Total Maximum Daily Loads (TMDLs).

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Storm waters

There are two components of storm waters of concern to regulators and the public: water quality and river network integrity. The former is the focus of most urban/suburban storm water management regulations as most states require commercial and industrial operators to have discharge permits and Storm Water Pollution Prevention (or Control) Plans. Rural storm water management has water quantity of equal or greater concern because of the industries and residences dependent on sufficient potable water supplies. In rural areas storm water quality is becoming more important as water resources are limited by drought.

River network integrity is the second storm water component of concern. In urban/suburban areas (smaller drainage basins) channel scour, blocked culverts, and flooding can result from storm water discharge from point sources. In rural areas proposed projects might be required to re-route streams and storm drainage channels around the project area. In these cases it is necessary to ensure that the bypass channel be designed and constructed to emulate the energy dissipation and sediment transport capabilities of the reach it replaces. Failure to implement fluvial geomorphic factors will result in the failure of the bypass with flooding damage along its length as well as harmful alteration to downstream reaches.

Management approaches

Equations describing water flow in open channels (hydraulics) were developed by civil and environmental engineers and are the basis for storm water analyses. This approach works well in urban areas with the high percentage of impermeable surfaces and most commercial and industrial discharges from point source outfalls. The engineering-based management processes for urban and suburban areas (such as the SCS TR-55 Unit Hydrograph and the Santa Barbara Urban Hydrograph) produce working results. However, applying this engineering approach to storm water management in rural areas, or to entire river basins, leads to flooding and other undesired results.

Effective rural and basin-wide storm water management actions are based on established principles of geomorphology, hydrology, and ecology so control of excess precipitation (runoff) works with the receiving stream's (or river's) energetics rather than against it. The engineering concepts of time of concentration, peak flow, and hydrographs of different storm intensities continue to be useful inputs but much more data are needed. Rural drainage basins have many ungauged streams and non-uniform spatial precipitation patterns and weather station locations; for example, Figure 1.

Understanding watersheds and the river networks that drain them helps manage storm waters in rural areas so that industrial activities do not adversely impact the system downstream. This knowledge of river channel morphology, basin shape, hydrology, hydraulics, and sediment transport dynamics are also the foundation for restoring rivers and fish populations (from Lahonton cutthroat and Bull trout to Pacific salmon). With climate warming, extreme weather patterns and water resources becoming more unpredictable while competing demands keep increasing an ecological/fluvial geomorphological basis for making operational, policy, and regulatory decisions becomes more important.

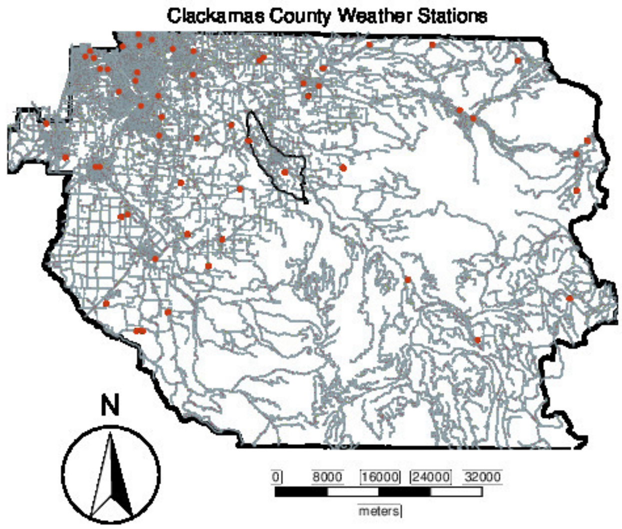

Figure 1: Weather stations in Clackamas County, Oregon (red dots; roads are in grey) One small drainage basin is outlined in black. There's only one weather station within the basin, and another immediately outside it..

Managing nonpoint source storm waters

Introduction

Natural ecosystems have several characteristics that constrain how data are analyzed so that policies and regulations produce desired results from regulated operations . Some of these characteristics are that:

- Environmental data collection is not based on experiments but on observations.
- All physical, chemical, and biological observation or measurement have a specific location and time associated with it that needs to be recorded.
- Restoration and maintenance of water quality, reduction of flooding potential, river network integrity, and fisheries are inter-related and based on the same two principles:
  - Understanding the environmental context of the area or project of interest.
  - Accepting that streams and rivers act to dissipate kinetic energy by minimizing the flows needed to transport sediments from headwaters to the basin outlet (Rosgen 1996).

Current approach

In 2001 Congress directed the Water Science and Technology Board of the National Research Council (NRC) to produce the report, "Assessing the TMDL Approach to Water Quality Management". The Board prefaced their report by writing

> The Total Maximum Daily Load (TMDL) program, initiated in the 1972 Clean Water Act, recently emerged as a foundation for the nation's efforts to meet state water quality

standards. A 'TMDL' refers to the total maximum daily load of a pollutant that achieves compliance with a water quality standard; the TMDL process refers to the plan to develop and implement the TMDL

Given the reduction in pollutant loading from point sources such as sewage treatment plants over the last 30 years, the successful implementation of most TMDLs will require controlling nonpoint source pollution.

The difficult challenges facing EPA and the states in the implementation of the TMDL program were immediately apparent to the committee. Because the committee faced a congressionally mandated deadline, a number of issues important to some stakeholders were not addressed comprehensively.

The NRC report noted that "[s]cientific uncertainty is a reality within all water quality programs, including the TMDL program, that cannot be entirely eliminated." This is a critical point that will be discussed in the natural ecosystem approach section on on this page. The report also discusses in detail the need for TMDLs (and storm water management systems) to be based on ambient water quality (also discussed in detail).

Natural ecosystem approach

Natural ecosystems are complex and trying to understand them is filled with uncertainties. Aquatic ecosystems, in particular, are highly variable and their response to precipitation events dependent on geomorphic, geologic, hydrologic, hydraulic, and biologic factors. Regulation of water quality at river basin (or river reach) scales is difficult and uneven because of insufficient data for characterizing and understanding the spatial and temporal dynamics of these systems. Financial and other realistic constraints limit data availability. Data tend to be clustered around urban areas and other specific reaches and the time period for data collection is usually quite limited. Research agencies such as the US Geological Survey tend to have longer periods of data at gauge stations (not present on all sub-basins) and there might be limited chemical concentration data for some constituents. These conditions mean that applying mathematical differential equation models with fixed ecosystem functions fail to provide needed outcomes (Shepard 2016).

Replacing the fixed model approach to rural storm water management with one that works with the terrestrial and aquatic ecosystems and the human activities that occur on them is based on two broad concepts:

1. Use only available data and analyze those data using spatio-temporal statistical models that accommodate the uncertainties and variabilities of these data.
2. Analyze whole watersheds, or sub-basins, and work with the streams and rivers rather than against them.

Three major objectives for the analyses of environmental data (including storm water management, TMDLs, flood reduction or avoidance, and river/fisheries restoration) are forecasting (including concentrations in non-sampled locations), predicting change, and measuring inherent natural variability. Understanding these objectives allows discharge permit holders, regulators, and policy makers make better informed decisions and can quantify the efficacy of regulatory actions.

Water quality

Too often rural water quality concerns focus on a single location and do not consider the watershed in which it is located. High nutrient levels in a stream adjacent to a farm or dairy are commonly assumed to be related to farm or dairy operations, but this assumption takes the measurements out of their environmental context. Before penalizing the operator for violating a maximum concentration limit regulators should consider all factors affecting water chemistry in that stream reach.

Among the factors affecting the measured concentration of a chemical constituent at a stream location are the season, flow velocity, riparian cover, soil composition and chemistry, upstream concentrations, and the beneficial uses of surface waters currently in that reach. Relevant factors include the adjacent agricultural operation obtaining potable water from wells, potentially affected aquatic organisms not present, downstream distance to a surface water use, and rate of dilution all contribute to an assessment of adverse affects.

Sediments from roads, aggregate material mines, slopes denuded of their normal vegetation by wildland fires, and construction sites are frequent concerns to regulators and the public. Whether the sediments actually adversely impact beneficial uses for that reach (commonly fish) is usually not considered by regulators, and fish species of concern may not occur in that reach. Looking at the watershed context when evaluating water quality greatly improves operational and regulatory decisions.

Conclusions

As the climate continues to change it alters patterns of drought, wildland fires, and storms. Water resources are more limited and uncertain, particularly in semi-arid and arid environments. The concerns of operators, regulators, and society include: competing demands for limited water resources; toxic chemicals in potable water supplies, irrigation waters, and fish; and flooding of suburban residential developments, town and city centers, farmlands, and flood plain industrial activities. Past storm water management activities contributed to many of these problems. We must accept that the approach to storm water management needs to change to reduce the economic, environmental, and societal costs of harmful water quality, flooding, and smaller fish populations.

The tools have existed for a long time and there are only benefits to be gained by applying them. The environmental approach to storm water management, particularly in rural areas, uses proven fluvial geomorphological and ecological principles to allow streams and rivers improve themselves.

References

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