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Project Summary

Guidelines for the Monitoring of Urban Runoff Quality

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This study was undertaken to define adequate monitoring of urban runoff for various objectives and to develop a guidebook for those contemplating a program of measuring urban runoff in the field. Emphasis is placed on measuring urban runoff while it is still flowing on land and street surfaces rather than after it has been integrated with other waters in storm or combined sewers.

The study stresses the need to state the exact objective of any field monitoring program, since costs and requirements vary greatly depending on the purpose of the monitoring. Six possible objectives are identified for urban runoff monitoring programs (scientific research, problem identification, alternative solution monitoring, support of the final design, regulatory compliance monitoring, and operational performance monitoring).

The study also reviews current and recent monitoring programs, literature on monitoring program design, and monitoring strategies for receiving waters and best management practices. Monitoring and protocols are developed for satisfying various objectives, and a set of guidelines is developed to assist designers and planners of monitoring programs for urban runoff.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Storm and snowmelt runoff from urban lands contains constituents that can, under certain circumstances, occur at damaging, polluting levels. These circumstances and the phenomena and processes that produce the runoff quality levels are so poorly understood and so inherently random and variable that only field measurements can reliably characterize them.

Sometimes it is necessary or desirable to have extremely detailed information about the processes that cause deterioration in the quality of urban runoff. To get such information, an expensive, comprehensive field monitoring program must be launched. By contrast, a city planner or engineer, for example, may simply need information about the levels of one or more constituents in local storm runoff. Such a need can be met by a fairly cursory or modest monitoring program. This study defines what adequate monitoring is for specific objectives and develops a guidebook for those contemplating a field measurement program.

Historically, runoff has generally been sampled after it has entered storm or combined sewers and been integrated with waters from various sources. By contrast, this study emphasizes the quality of runoff still flowing on the land and street surfaces. Some discussion is also presented of flows and qualities of runoff in storm and combined sewers or at points of combined sewer overflows.

This study especially concentrates on statistical requirements and tests for sufficiency or significance of data sets, because these statistical considerations affect the success of each monitoring objective. Though insights to monitoring program design can be gained through the use of statistical inferences and hypotheses, considerable art is required in specifying sample numbers, levels of confidence, etc In particular, the investigator should be able to anticipate the general behavior of the phenomena being sampled, or considerable sampling effort, time, and money may be wasted. These concepts are developed in detail throughout the report.

Procedures

Developing Monitoring Objectives

Since the requirements and costs of monitoring urban runoff vary greatly depending on the purpose of the monitoring, this study stresses the need to state the exact objective of the field monitoring in each case. Six possible objectives were identified: (1) Scientific research, (2) problem identification, (3) alternative solution monitoring, (4) support of the final design, (5) regulatory compliance monitoring, and (6) operational performance monitoring.

Reviewing the Objectives and Successes of Current and Recent Monitoring Programs

Past monitoring programs reported in the literature were reviewed, and the results and conclusions were compared with the originally stated objectives.

Reviewing Literature on Monitoring Program Design

Past works on monitoring of urban runoff were reviewed to indicate the state-of-the-art in monitoring protocol design.

Reviewing and Developing Monitoring Strategies for Receiving Waters and Best Management Practices

Reviews were made of special-purpose monitoring for characterizing impacts of urban runoff on receiving waters and for planning or monitoring performance of certain runoff pollution control measures. Guidance is given where weaknesses are apparent.

Develop Monitoring Protocols for Satisfying Objectives

The study develops statistical inferences of reliable numbers of sampling sites and sample numbers for each of the six monitoring objectives selected.

Designing and Producing a Guidelines Report

A guidebook was developed to describe all the foregoing material for those contemplating a field measurement program. Minimum measurements were described for satisfying various objectives.

Summary Discussion

Storm and snowmelt runoff from urban lands contains quality constituents which under certain circumstances occur in damaging, polluting levels. These circumstances, the phenomena and processes making runoff quality levels what they are, remain so poorly understood and are so inherently random and variable that only field measurements can be relied upon to characterize their behavior.

Sometimes it is necessary or desirable to learn in great spatial and temporal detail what the processes are that cause deterioration in the quality of urban runoff. In these cases an expensive, comprehensive field monitoring program *must be launched to learn the required* information. By contrast there are other instances in which a planner or city engineer, for example, may wish to learn whether or not a particular constituent or several constituents in storm runoff attain potentially damaging levels in his or her community. In this case, a fairly cursory and modest monitoring program will suffice to satisfy this objective.

Statistical theory provides some guidance to the numbers of samples required for satisfying various objectives for monitoring. But a number of arbitrary variables, such as the degree of confidence or acceptable error must be specified by the monitoring program designer. Moreover, many statistical tests require that characteristics of *some* sampled data already be available, such as the sample standard deviation in the t-test, before they can be used to give guidance on the acceptability of sample numbers for still further monitoring.

Numbers of samples for example programs specified for satisfaction of six different monitoring objectives ranged from 24 for a design objective to 54,000 for a comprehensive scientific, process-monitoring objective. Costs for monitoring varied proportionately, from about $11,000 to $9,300,000, for the two respective objectives.

Detailed sampling and laboratory analyses are expensive. Sometimes the expense of sampling and analysis will prove prohibitive. *The major point of this work, however, is that curtailment of monitoring for reasons of expense or for any other reason can mean that the original monitoring objective cannot be met.* If one sets out to elucidate runoff quality processes or to build and verify a model of these causative processes and finds that he can afford only $75,000 per year to do the indicated monitoring, then in fact he *cannot* adequately define processes or verify his model. The best he can hope for is to monitor operational performance, to gather information on what happened, what the effects were, and not what caused those effects to be realized. The information gained is likely *not* to be sufficient to allow prediction of what will happen in other places or under changed conditions.

Urban runoff quality in the early 1980's is not considered a high priority item of national environmental interest, except in those instances where urban runoff is conveyed and discharged through systems. Runoff quality control remains a new field of engineering endeavor. It is natural, therefore, that design criteria, discharge standards and receiving water criteria, and scientific knowledge about this field are still preliminary, incomplete, and rudimentary. For these same reasons, however, it is virtually axiomatic that mistakes may be made, monitoring and construction monies may occasionally be misspent on unnecessary or unsupported or inadequate facilities or monitoring programs. It is to be hoped that this guidebook will assist in keeping straight what is adequate monitoring for separate objectives and what is not.

Conclusions

1. Urban runoff may be sampled for a variety of reasons, i.e., to satisfy any of a number of objectives. The objective in each case should be stated explicitly and restated as necessary in concrete, numerical terms so a program of sampling can be devised that will clearly satisfy that objective.

2. Sampling in the field is expensive. Laboratory analyses are both expensive and relatively inexpensive, depending on which constituents are being analyzed. But economies of scale in laboratory analyses are available, and opportunities should be sought for learning more for the same total budget by having more analyses performed and sampling fewer events in the field.

3. Statistical theory that exists today is somewhat useful in guiding decisions about sampling program design. Certain concepts from statistics, such as the existence of Type I and Type II errors, should be appreciated since they are axiomatic and unavoidable. Statistical tests such as the t-test, the F-test, and the chi-square test are useful and instructive and worthy of consideration, but they do *not* function usefully in the absence of any prior sample information. That is very frustrating but inescapable. Statistical theory on the whole is not developed sufficiently to assist meaningfully in multiple-site, multiple-phenomena, multiple-constituent, stochastic-process sampling.
4. Mathematical models existing today for estimation of urban runoff quality loads do not have a solid scientific base. Some do not require or even give regard to the satisfaction of mass continuity. Directly as a result, they are either difficult or impossible to calibrate or they must be recalibrated with practically every use. Because they are so limited in transferability and even the most basic level of scientific rigor, they cannot be relied upon solely to replace or obviate the need for local quality sampling, regardless of the objective.
5. Research needs to be done to formulate the physics and chemistry of urban runoff behavior at several levels of sophistication and approximation. Just as it is not necessary to monitor each drop of rainfall, each clay particle, or each liter of runoff to design a detention basin, it is not necessary to model each of these things rigorously to design the basin without sample results. But design "theory" does need to be developed that is consistent with scientific principles, that allows for variability in behavior both chemically and physically, both quality-wise and hydraulically, and that approximates at least the continuity of mass and the processes of scour and deposition and chemical equilibria and rates of change of concentration with time and with changes in chemistry of the incoming and surrounding fluid. Current models in wide use are predicated on an assumed first-order decay or wash-off or first-flush phenomenon, which data from Denver and other places have clearly indicated does not always occur. Concentrations or masses of pollutants in runoff do *not* always decrease exponentially or at all with time after the onset of rainfall. Current theory on the behavior of urban runoff and its quality constituents is poor at best and misleading or even wrong at worst. Hydraulic behavior is much better understood, and it is approximated adequately at various levels of study detail, i.e., for use with varying scientific, planning, design, or monitoring objectives. Quality theory should be developed and advanced in a commensurate fashion.
6. There is no guarantee that water quality data, no matter how carefully collected, will be transferable to other areas and other circumstances. However, because data collection and interpretation is so expensive and time-consuming, EPA is encouraged to maintain a data base, such as that now started at the University of Florida, wherein runoff quality data from across the nation may be stored and accessed by subsequent users. But it is recommended that data so stored be characterized by the contributor as to their statistical properties (numbers of samples, variance, and the like) and as to the conditions and purposes under and for which they were collected.

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The complete report, entitled "Guidelines for the Monitoring of Urban Runoff Quality," (Order No. PB 84-122 902; Cost: $14.50, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
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