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A sediment monitoring program for North America

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ABSTRACT Sediment monitoring in North America has provided an extensive, but problem-specific data base, largely limited to physical characteristics such as suspended sediment and its movement. Environmental concerns, however, are increasing awareness of fluvial sediment as a transport medium for contaminants and as a possible indicator of global change. A sediment-monitoring program is proposed to complement hydrologic-data programs in Canada, the United States, and Mexico, and to provide information to meet objectives of a sediment network for North America. The program consists of: (a) sediment monitoring at selected hydrometric and water-quality stations, (b) supplementary sediment monitoring at stations having specific or unique objectives, and (c) use of existing data to enhance the sediment-monitoring effort. As an initial attempt to develop a North American sediment-monitoring program, 145 sites have been selected from streams of Canada, the United States, and Mexico for a coordinated sampling effort.

INTRODUCTION

This paper advocates the establishment of a North American strategy for a data base defining the physical characteristics and transport of fluvial sediment. In the past, engineering and economic considerations such as agriculture, municipal and industrial water supplies, and hydraulic structures have dominated demand for sediment information. These needs for sediment data have resulted from local and regional concerns, and therefore little pressure for a large-scale coordinated sediment program has developed. Now, however, environmental concerns, including those of human health, rival the physical factors of sediment for public and governmental awareness. Fluvial sediment is now recognized as possibly the continent's most important contaminant and the medium by which large amounts of toxic substances are transported and stored.

Local and regional needs for sediment data can no longer be isolated from the need for a large-scale, international program of sediment monitoring. Rivers and the contaminants they carry cross and form political boundaries; many drainage basins are shared by countries; those lakes and estuaries that form national boundaries have economic importance in common to the countries separated. Additionally, a unified approach to sedimet monitoring in North America is essential to achieve (a) easy access to data of common interest to two or more

countries, (b) compatible strategies for data collection and analysis, and (c) systematic management procedures to assure an orderly data-collection program. Only a cooperative approach by North American nations seems adequate to provide a sediment data base appropriate for present concerns.

Hydrologic monitoring involves repeated observation through time at a site, generally to facilitate the regulation or control of those operations for which the time-series data, including fluvial-sediment data, are collected. In contrast, hydrologic networks define areal variability of the movement of water and its loads; the determination of temporal variations, or trends, is also an objective of networks. Ideally, hydrologic networks are a systematic linking of component sampling sites, through common methods and objectives, into a description of the types, amounts, processes, and treads of water and sediment movement. The program proposed here does not conform fully to these criteria of a network, but is designed to determine large-scale areal and temporal variations in sediment-discharge characteristics.

BACKGROUND

Systematic collection of suspended-sediment data began in North America over a century ago when the U.S. Geological Survey (USGS) established sampling sites on the Rio Grande at Embudo, New Mexico, and El Paso, Texas (see various Annual Reports of the USGS, 1891-1898). During the century since these initial sampling efforts, considerable progress has been made on sampler development and sampling technique, and a large amount of fluvial-sediment data has accumulated. The purpose of many sampling sites was to predict sedimentation rates in large reservoirs that were constructed following World War II. Other purposes of sediment data have included an understanding of erosion on agricultural lands, stream-channel dynamics, and the effects of surface mining. In the last 10 to 20 years, USGS has received increasing responsibility to monitor and characterize the quality of the United States' water resources, and ancillary suspended-sediment data have been collected in support of these programs. At present, there is no systematic collection of bedload or bed-material data.

A national sediment-monitoring program began in Canada about 30 years ago as an addition to the Water Survey of Canada's hydrometric data-collection program (Day, 1991). Procedures and equipment used in this program continue to be based on those of the USGS. Although some of the sampling is designed for long-term trend analyses, most sediment data are collected for specific projects, primarily engineering. Currently, Environment Canada operates about 250 suspended-sediment sampling sites and stores data from 600 other discontinued sites. Few bedload and bed-material data are available.

Most sediment samples in Mexico are collected at gage sites on streams draining basins larger than 1,000 square kilometers. An extensive hydrometric data program is conducted in Mexico, and at many of the gage sites water-quality and sediment data are also collected. Many of the sediment stations are related to population centers and engineering projects.

MEETING CHANGING PROGRAM DESIGNS

During the last 100 years the costs associated with the collection of

sediment data have increased more rapidly than the perceived benefits of these data. Especially in Canada and the United States, available data were often adequate to identify the transport, physical characteristics, and yields of fluvial sediment to satisfy site-specific information needs, particularly for engineering design and navigation. Sampling design was pragmatic, and sampling strategies focused on long-term detailed records, in many cases producing more than sufficient engineering data. Although basin-and regional-scale data sets were developed, rarely were they managed to provide information commensurate to those scales. The program focus was, and in many cases continues to be, local.

Today the challenge for sediment-monitoring agencies is to consider strategic problems, to address the major environmental concerns such as toxics transport. These concerns bring new information demands and therefore require new data sets. The role of sediment in source, transfer, fate and effects of contaminants, and other aquatic concerns, is compelling renewed attention to the properties, physical and chemical, and fluxes of fluvial sediment. Commonly the information contained in existing data sets is inadequate or too imprecise to answer questions pertaining to solute and organic-carbon transport, toxicity to wildlife and domestic water supplies, wildlife habitat, and numerous other environmental concerns. Ordinary sampling programs may not (a) provide data on the needed time scale of relevance (events), (b) involve downstream sampling along a river to provide suitable transfer and fate information, (c) be designed for pertinent transport and routing models, (d) be linked to upstream land-use practices, nor (e) be coordinated with and integrated into water-quality monitoring activities. Generally too little attention has been given to what information these data provide about how a river system and its drainage basin relate, or to how fluvial sediment influences the quality and integrity of aquatic systems.

To answer these questions it is necessary to obtain data from relatively large basins of complex land-use patterns on the source pathways of movement, and fates of sediment and its sorbed contaminants. From smaller, event-dominated basins, data are needed to characterize hydrologic and sediment-discharge processes pertinent to numerous environmental problems including long-term trends such as possible global climate change. Increases in erosion and sedimentation rates with land uses such as agriculture, urbanization, and climate change have been acknowledged by hydrologists, but only by compiling long-term data sets can these observations be confirmed and lead to remedial action.

STRATEGIES AND OBJECTIVES FOR A CONTINENTAL APPROACH

The strategies for implementing a continental approach to the collection of sediment data must be based on the development of (a) a monitoring design appropriate to the needs and resources of the participating countries, (b) integrated planning and assessments (interpretation) to assure sufficient data of adequate quality to meet program needs, (c) compatible standards for equipment, equipment use, and procedures for sampling, analysis, and data reduction, and (d) a systematic, or coordinated management approach among the various countries.

The first two of these strategies consider the information generated by a monitoring program, and are based on the objectives of identifying generalized continental-scale sediment yields, fluxes of

sorbed chemical contaminants, and trends in sediment discharge due to induced and natural changes in watershed processes. Sampling and data strategies must ensure that consistent methods are used to obtain and compile sediment information in the various countries of North America, and that the information is readily accessible to all potential users. The goal of a coordinated management strategy is to guarantee a unified and continuing data-collection program that maintains long-term continental-scale objectives but has the flexibility to respond to smaller-scale problems.

These strategies are not new, but there is considerable challenge for their implementation among nations. Data-collection agencies of the nations must continue to meet demands for traditional hydrologic-flux information, but must also respond to data needs pertinent to environmental issues.

DESIGN OF A NORTH AMERICAN MONITORING PROGRAM

The successful development of a North American sediment-monitoring program depends on data bases from active and discontinued stations. It depends also on a systematic approach to data reduction. The sediment-monitoring program proposed here is based on primary sampling sites, supplementary sampling sites, and archived or available data sets (Osterkamp & Parker, 1991). Selection of primary and supplementary sampling sites is influenced by the amounts and geographic sources of validated archived data.

One hundred forty-five primary sites, chosen from active and discontinued streamflow gages, are proposed as the principal component of a North American sediment-monitoring program (Fig. 1). These sites are selected to be consistent with the stated objectives of the program, to enhance the utility and credibility of ongoing hydrometric and water-quality monitoring, and to provide geographic, physiographic, and basin-size representativeness. Sampling frequency and types of samples (suspended, bed load, etc.) collected at primary sites will be dependent on location and specific purposes for the data. All primary sampling sites are intended for extended operation, but each will be subject to review at no less than 5-year intervals to ensure that data collection and frequency of sampling at the sites generate the information required by program objectives. The continuing interpretation of data is essential for site reviews and success of the monitoring program.

Supplementary sampling sites are to be operated for short to intermediate periods with sampling frequencies dependent on data needs. Supplementary sites will be in support of primary monitoring to provide increased sensitivity of the monitoring program where specific objectives require a better understanding of the source, transfer, and fate of sediment through the river system. The establishment and duration of secondary sites will be governed partly by the amount and quality of archived data. Supplementary sampling sites will be subject to review at no greater than two-year periods.

The primary sampling sites proposed in Figure 1 are tentative. All of the sites have streamflow data, and most have sediment and water-quality data. Emphasis has been placed on rivers transporting large sediment and chemical loads from the continent, and on river systems judged most vulnerable to contamination and land-use damage. Changes in site selections for Mexico are especially likely after representatives of the Mexican government have reviewed the proposed sites. A list with locations of the proposed sampling sites is available from the authors.

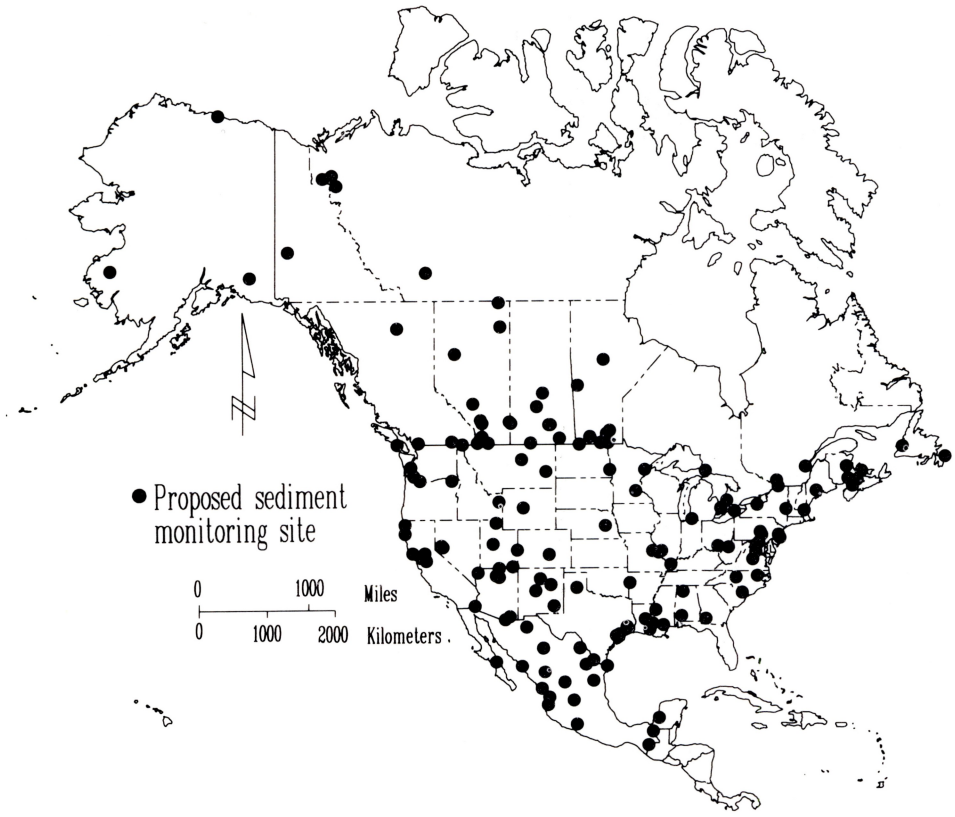

FIG. 1 Map of North America showing primary sampling sites, North American sediment monitoring program.

IMPLEMENTATION AND MANAGEMENT

Regardless of the perceived urgency for a coordinated continental program, organizational commitment to its implementation and management will be impeded due to limited resources, the higher profile and better understanding by managers of chemical and biological concerns in rivers and lakes, and the organizational changes required for the acceptance of new perspectives and technical procedures. The successful implementation of a North American monitoring program depends on organizational recognition that fluvial sediment is basic to ecosystem health, and that the continental concerns for this health require a unified approach to ensure that:

(a) a core of complementary monitoring sites remains active to provide basic information on sediment transport, fate, and effects.
(b) that at the regional level, integration of data-collection programs for the determination of sediment quantity and quality is maintained, and that on an issue basis these data are used for the resolution of environmental problems.
(c) a systematic planning and management approach is promoted in North America for the purposes of guaranteeing that (i) monitoring sites and their data are coordinated, (ii) management decisions for individual sampling sites are consistent with the continental

program design, (iii) interpretive expertise is focussed on generating the information required to guide program decisions, (iv) information is used in the resolution of environmental concerns and for reporting the state of the environment, and (v) cooperative opportunities for scientific and technical activities are maintained and encouraged.

The best procedure to develop a coordinated North American monitoring program is to build on the strengths of present national networks and monitoring programs. The greatest technical challenges may be in setting standards, information generation, interpretation of the role of sediment in aquatic health, and designing sampling strategies and procedures to document contaminant transport through time and within the river cross section.

REFERENCES

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