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Evaluation of long term suspended sediment records for selected Canadian rivers

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Abstract Long term suspended sediment monitoring in Canadian rivers began in the 1950s for purposes which included documentation of geophysical processes and reservoir sedimentation. Many detailed (50–200 samples/year) data records with lengths of 10–30 years now exist. Presently both economic concerns and an awareness of different environmental applications have prompted a review of these records. Results indicate, for example, that mean characteristics are stable after about 10 years, and that a good range of conditions has been sampled. As a consequence of these reviews the emphasis of Canadian sediment monitoring activities is shifting towards shorter term programmes with reduced number of samples.

Evaluation des enregistrements de sédiments en suspension à long terme pour certains cours d'eau du Canada

Résumé La surveillance à long terme des sédiments en suspension dans les cours d'eau canadiens a débuté durant les années 1950 pour satisfaire divers besoins dont la documentation des processus géophysiques et de la sédimentation dans les réservoirs. Il existe maintenant de nombreux enregistrements détaillés de données (de 50 à 200 échantillons par an) effectués pour des périodes allant de 10 à 30 ans. Toutefois, des préoccupations d'ordre économique et une sensibilisation aux différentes applications environnementales des données ont incité le Ministère à examiner ces enregistrements. L'examen démontre par exemple que les caractéristiques moyennes sont stables aprés 10 ans environ et qu'on a échantillonné un choix assez vaste de conditions. A la suite de cet examen, le Canada a décidé de réorienter ses activités de surveillance des sédiments pour réaliser des programmes d'études à court terme où les prélèvements d'échantillons seraient en nombre réduit.

INTRODUCTION

The systematic documentation of suspended sediment transport (concentration and loads) in Canadian river systems commenced in the 1950s. Within a decade, year round sampling was initiated on many of the major river systems

particularly in central Canada. Today data are being collected at about 200 sites with further data existing for some 500 discontinued sites. Originally these sediment monitoring activities were initiated to document geophysical processes and to provide a data base for engineering applications (e.g. reservoir sedimentation and navigation). Now record lengths are substantial, ranging up to 30 years. This paper briefly describes the results of an ongoing systematic review of these data records.

USE OF SUSPENDED SEDIMENT DATA

As previously mentioned, these data were (traditionally) used for engineering applications. For studies of reservoir sedimentation, for navigation channel maintenance, for water intakes, etc., the data generally required are the mean and range of concentration, loadings and particle size. Usually, acceptable data can be obtained over a relatively short period of representative flows. How much is sufficient depends on the application, and how long monitoring must continue depends upon the character of the hydrology during the sampling period. In retrospect the focus of Canadian monitoring activities on long term detailed records was unnecessary, especially when the need for the required level of accuracy is appreciated. Documentation of large scale geophysical processes, another early focus for these activities is a somewhat different "application" and will be discussed separately later. Today it is recognized that there are many applications of suspended sediment data in environmental work, for example, biological studies (fish habitat and spawning beds) and water quality (nutrient and contaminant transport, as well as water supply). The role of sediment as an actor which works across the land-water interface is now well recognized. Its importance to the health of aquatic ecosystems is just becoming understood.

Environmental applications for these data, while obviously diverse, in common again require information of primarily the range and mean characteristics of suspended concentration (although loadings have applications), on cross-sectional distribution of concentration and particle size, and for short periods, on the time distribution of sediment concentrations and particle sizes. There is more of a site specific focus on these data needs. Monitoring activities to provide "environmental" data therefore need not extend over a long period. Again there is no standard period, but 5–10 years can prove adequate if the sampled conditions are reasonably representative of longer term conditions. Having to some extent already answered fundamental questions concerning requirements for data record length our choice was not to simply stop the long term stations. Rather we have initiated a process in which these long term data sets are systematically reviewed.

REVIEW PROCESS

The fundamental purpose of these long term monitoring activities is to provide a representative data base on the suspended sediment regime and

loadings. The central questions to be addressed in the data reviews are: what is the regime (here defined as the time distribution characteristics of concentration, load and particle size) and how well is it documented?; what flow ranges have been sampled (annual and seasonal series)?; and how representative of longer term conditions is the sampled period of record?

The procedures employed in the reviews are basic and commonly known and include frequency and duration analysis and sediment rating curves. Their application permits us to make decisions on the adequacy of sample coverage and on the range of flows sampled, to characterize the regime through plots and summary statistics, and to establish the quality of relationships between, for example, concentration and discharge. The reviews are producing quite similar results and are being documented in an internal report series.

EXAMPLES

Thorough reviews have been made on a number of data sets including the six listed in Table 1. These six present typical cases. All are located in central Canada, in the provinces of Alberta, Saskatchewan and Manitoba. In each case large numbers of data exist. With the detailed sampling strategies (flow-weighted) suspended sediment regime is very well documented for every year of the record. It is possible to clearly visualize and summarize annual and seasonal variations in concentration, loadings and to a lesser extent particle size. Also, in each case the historic annual flow range is well sampled, although peak flow coverage has not always occurred.

Table 1 Summary of monitoring programme for six typical sediment stations

Station	Basin Area (km^2)	Record Length Flow	Record Length Sediment	No. of Samples Taken	Flow Range Maximum/ Sampled ($m^3 s^{-1}$)	Loadings	Flow Trends
Oldman River, Alberta (05AA024; Day and Spitzer, 1986a)	4 400	1966-1987	1966-1986* (20 yrs)	1570	1220/1220	250 000 t **	Decreasing mean and max. seasonal flows
Highwood River, Alberta (05BL024; Day and Spitzer, 1986b)	3 990	1970-1987	1970-1980 (10 yrs)	587	331/331	1.5 Mt **	Decreasing mean and max. seasonal flows
Red Deer River, Alberta (05CK004; Hydrocon Engineering, 1987)	44 700	1960-1987	1975-1984 (10 yrs)	2473	878/206	1.6 Mt	None
North Saskatchewan River, Saskatchewan (05GG001; Ashmore, 1987)	131 000	1912-1987	1962-1985* (24 yrs)	2109	5300/3880	2.1 Mt **	None
Saskatchewan River, Manitoba (05KJ001, Northwest Hydraulics, 1986)	347 000	1954-1987	1963-1984 (22 yrs)	3197	3000/2310	2.2 Mt	Regulated
Pembina River, Manitoba (05OB007, Hydrocon Engineering, 1987a)	7 500	1962-1987	1963-1984 (22 yrs)	2185	317/27.6	97 200 t	None

* Latest year of completed data record, stations still in operation up to 1988
** Seasonal (open water) loadings, otherwise annual (12 month values).

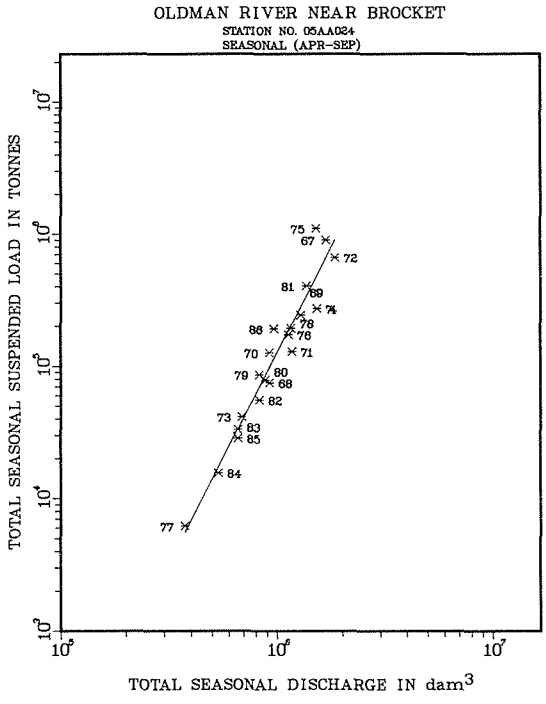

Fig. 1 Rating relationship for seasonal flows and loads 1967–1986 Oldman River, Alberta.

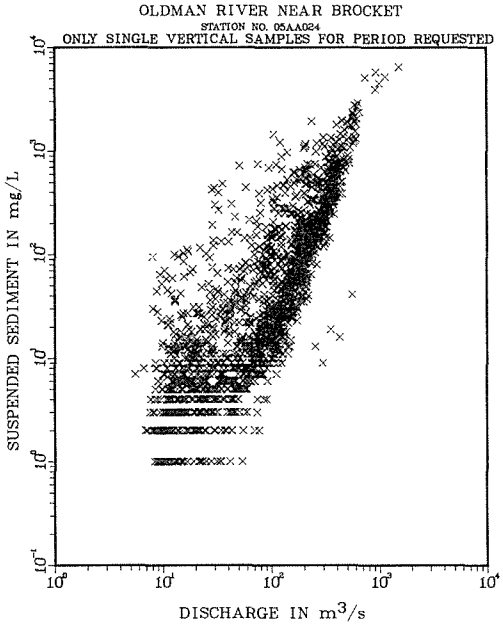

Fig 2 Rating plot of discharge vs. concentration showing large density of data resulting from long term monitoring Oldman River, Alberta.

Good rating relationships can be established for any time scale (Fig. 1), many showing hysterisis characteristics. An example of the density of the data is given in Fig. 2.

Mean characteristics of seasonal (open water) and annual loads and concentrations are equally well defined. For example, in Fig. 3 the standard error of estimate of the mean seasonal load is plotted against record length. The curve is a normal distribution fitted through the last mean value. The lower half of the plot shows the per cent gain in standard error for each additional year of record. Clearly, in this case little improvement is gained after about 10 years of record. While each data set has specific characteristics, generally after 10 years there is little to be gained if definition of mean values is required.

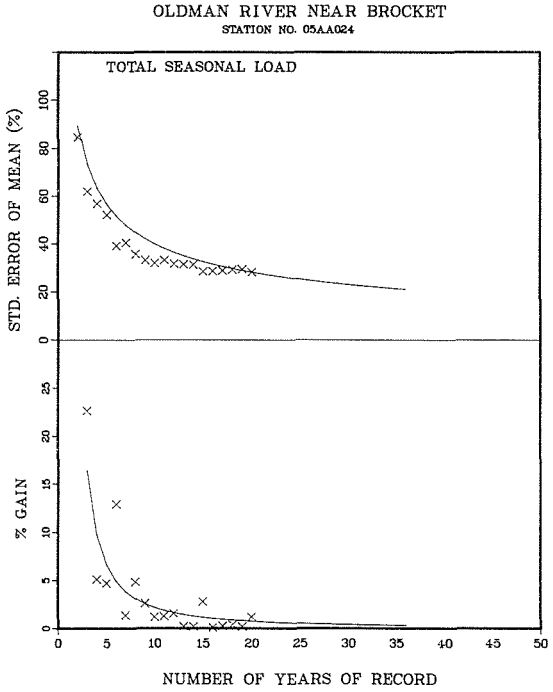

Fig. 3 Standard error of mean seasonal load versus period of record, Oldman River, Alberta. Per cent gain for each additional year of record is shown in the lower diagram.

In many cases such summary statistical efforts are compromised by the existence of flow trends (see Table 1). For the Oldman and Highwood rivers there has been a decreasing trend in both mean and maximum annual or seasonal flow. Hence, any of our standard efforts to characterize the regime and provide summary information on loads are negated to some extent. While we are starting to pursue studies to remove trends from the data sets, in a practical sense any decisions to stop data collection are still correct, there simply being a great wealth of data for any perceived

engineering or environmental application.

GEOPHYSICAL PROCESS DOCUMENTATION

An objective of most physical or chemical monitoring in aquatic systems is to provide a data base for trend analysis. Such was an early objective in the Canadian sediment programme. Many of the long term stations were established to provide data which could be interrogated to seek effects of upstream land use programmes and water resource construction activities. However, in retrospect our success has been limited. Certainly in large basins such as the Saskatchewan system in central Canada, the location of stations and the standard period of operation are not ideal, so it is difficult to directly compare records across the basin at critical sites. Also, with many major flow alterations occurring across the basin it has proved difficult to separate cause and effect (Northwest Hydraulic Consultants Ltd, 1986; Ashmore, 1986). Furthermore, in large basins where most of the major long terms records exist, little documentation on large scale land use or natural cause effects exists. The possible overlapping of effects and their downstream pace and attenuation also complicates data interpretation. Only the downstream effects of reservoir construction are clearly noticeable.

Even in smaller basins such as the Oldman, little data on basin state are available to relate to the 20 years of suspended sediment record. Also as basin size decreases the natural variability in the records increases thereby adding a further complication.

CONCLUSION

(a) Long term records of suspended sediment transport are of limited use in documenting geophysical processes due to the limited sensitivity of basin response and to the complication of natural and man induced changes.

(b) Long term records provide in a sense too much data for any standard environmental and engineering application. Consequently, monitoring activities are shifting towards shorter less detailed records.

(c) Adequate characterization of transport as required for standard environmental and engineering application, can be achieved in 5–10 years for most streams and rivers, depending upon the specific monitoring objectives and the representativity of the period of record.

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