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# Data requirements for sediment, erosion and transport simulation

GEORGE FLEMING
*Department of Civil Engineering, University of Strathclyde, Glasgow G4 ONG, UK*
SERGIO FATTORELLI
*University of Padova, Italy*

ABSTRACT The computer simulation of sediment, erosion, transport and deposition processes has developed considerably, but limited discussion has taken place on the data requirements for the various models available. This paper starts with a review of the techniques available for assessing sediment processes. The main theme of the paper is the intercomparison of data requirements for each assessment technique. This comparison explores the relative reliability of the input information compared to the reliability and relevance of the output obtained from the assessment. For example, the accuracy of the input data to the universal soil loss equation and the relevance of the output to the real problem of soil loss tolerance assessment, is compared to the accuracy of the input to the Strathclyde sediment model and the relevance of its output to the same problem. Several methods are considered and recommendations made on future data needs.

Exigences de la simulation de l'érosion et du transport de sédiments relatives aux données d'observations

RESUME La simulation par ordinateur des processus de l'érosion, du transport ou du dépôt de sédiments a progressé considérablement mais il y a eu peu d'études sur les exigences relatives aux données pour les divers modèles possibles. Le thème principal de cette communication est l'intercomparaison des besoins en données pour chaque technique d'estimation. Cette comparaison étudie la validité relative des informations d'entrée par rapport à la validité et à l'exactitude des résultats obtenus par ces estimations. Par exemple l'exactitude des données d'entrée pour l'équation universelle des pertes en sol (universal soil loss equation) et la validité des résultats obtenus concernant la problème réel de la tolérance d'erreur sur les estimations de pertes en sol sont comparées à l'exactitude des entrées pour le modèle de sédimentation Strathclyde et à la validité des résultats obtenus pour résoudre le même problème. Plusieures méthodes ont été considérées et des recommandations sont faites sur les exigences futures concernant les données.

## DATA REQUIREMENTS AND ASSESSMENT TECHNIQUES

The data requirements for sediment, erosion and transport simulation depend on the model used, which in turn depends on the problem to be assessed. The same is true for all methods of hydrological and sediment process assessment. The major restriction on the choice of any assessment technique is the data limitation.

In the past, an inadequate data base coupled with weak computational tools led to the development of simple empirical analysis methods based on incomplete theory. These methods have been employed to solve increasingly complex water and sediment resource problems with undesirable consequences. With the more recent development of powerful computational tools, theoretical development in the fields of sediment, erosion and hydrology has been enhanced and the weakness of an inadequate data base exposed. A broader choice of assessment methods is now available for use in quantifying the water and sediment processes. The choice of the assessment technique depends on the problem to be solved and both depend on the balance between data requirements and data availability.

The whole subject of water and sediment resource assessment follows a learning curve where experience gained in making the initial assessment changes our understanding of the problem, the data requirements and the methods used to make the assessment. This is the basic strength of computer simulation methods.

The steps followed in applying a deterministic simulation model to a given problem are outlined in Fig. 1, proposed by Fleming (1979). The first step, i.e. "define the problem", is critical in relation to the choice of method and hence the data requirements. For example, if the problem is simply defined, then the assessment method may be equally simple. However, if the problem is defined in terms of the micro-factor contributing to the problem then the assessment technique must be able to account for micro-complexity between processes contributing to the problem. Two general situations can exist.

| I *Simple clearly defined problem* | II *Complex poorly defined problem* |
|---|---|
| Direct assessment of cause and effect | Indirect assessment of complex dynamic interaction of various processes |
| Decision making involving choice between single solutions | Decision making to establish an optimum solution from many alternatives subject to numerous constraints |

Examples of the two situations are as follows:

*Simple situation A*

Problem — A small unit of agricultural land with uniform soil type, and slope, in a temperate climate. Crop rotation required to control erosion rates within the soil loss tolerance.

Assessment — Direct assessment would involve establishing the

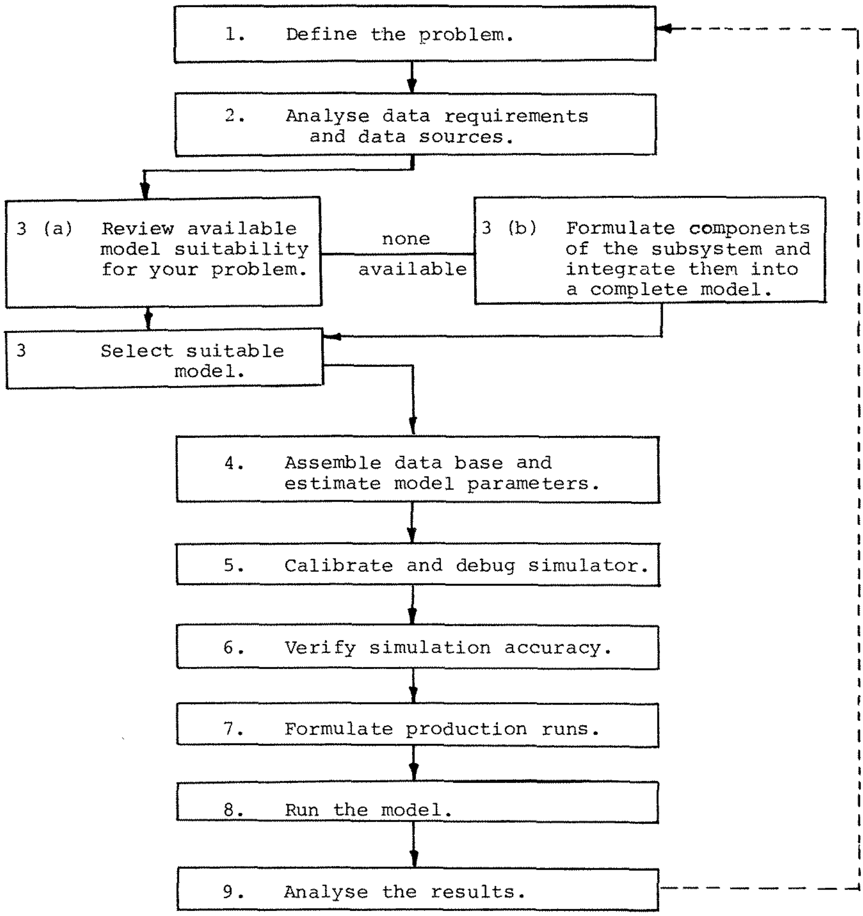


**Fig. 1** Steps in applying a deterministic model to a hydrological problem.

erosion rates for the various crops (e.g. grass, cereals, vegetables, etc.) which yield the best economic returns for the soil type, slope and climate. Assessment could be by measurement or the use of published data.

Decision making — Decision making would involve selecting desirable crop rotations and with necessary conservation practice which established erosion rates, within the tolerable soil loss.

*Complex situation B*

Problem — Total river basin with variable topography, vegetation, land use, soil type and meteorological inputs. Existing dams, cities and irrigation schemes present. Overall plan required to improve the efficiency of the existing industrial, agricultural and forestry water requirements and to develop a plan for future development and conservation of water and sediment resources

| | |
|---|---|
| Assessment | Indirect assessment of total river basin using existing data base on input and output response in order to extend this information and relate it to the existing physical characteristics of the drainage basin and the land and water uses, then to predict the drainage basin response under future development conditions to establish water and sediment response alternatives. |
| Decision making | Systems approach to decision making to establish the optimal water and sediment resource utilization under present and future land use conditions. |

Once the problem has been defined the next step is to examine the data sources and requirements. Table 1 shows a list of data sources ranging from simple to complex. Data requirements depend on step 3, the choice of assessment method. A comprehensive review of the methods of assessment for hydrology and sediment processes has been published by Fleming (1975, 1977 and 1979).

**Table 1** Basic data for assessing hydrological and sediment processes

| Simple | | Complex |
|---|---|---|
| *Hydrology* | | |
| Flow rating curve<br>Continuous monthly/daily rainfall | Continuous hourly flow<br>Continuous autographic precipitation<br>Monthly evaporation<br>Soil moisture deficit | Telemetered flow and precipitation<br>Daily evaporation<br>radiation<br>temperature<br>humidity, wind speed,<br>groundwater levels |
| Coefficients of runoff | Time delay histograms<br>Unit hydrographs<br>Regional flood frequency curves<br>Envelopes of specific floods<br>Envelopes of extreme rainfalls<br>Mass curves of drought sequences | Land use classification<br>Vegetation cover parameters<br>Geological maps<br>Topographical maps<br>Channel network geometry<br>Urban network characteristics<br>Reservoir characteristics<br>Operational rules<br>Hydrological parameters<br>e.g. infiltration, interception, interflow, percolation, overload flow, recessions, snow process parameters |
| *Sediment* | | |
| Sediment rating curve<br>Annual sediment load based on flow duration curves<br>Annual erosion plot data | Daily sediment loads (bed/suspended)<br>Continuous erosion plot data | Continuous sediment load data<br>Semi-monthly vegetation canopy, area and stalk density |
| Soil classification maps | Particle size distribution of land and river channel sediment<br>Organic content of soil types<br>Relationships between particle size/critical tractive force<br>Design curves for sediment, erosion/discharge<br>Erosion potential of rainfall<br>Soil erodibility data<br>Erosion control indices | Sediment parameters<br>e.g. threshold sizes for detachment coefficients for detachment, rill erosion parameter, topsoil disturbance |

*For the simple situation A* The universal soil loss equation proposed by Wischmeir & Smith (1960) could be used in assessment. The equation has the general form:

$$E = R\ K\ L\ S\ C\ P$$

where the output is: E = the average annual soil loss in tons per acre for a specific field; inputs are: R = erosion potential of average annual rainfall, K = soil erodibility factor, L = length of overland flow factor, S = land slope factor; and parameters are: C = cropping management factor, P = conservation planning factor.

The basic inputs to the universal soil loss equation (i.e. R, K, L and S) are obtained from regional maps of the area which are based on measurements of erosion processes undertaken on experimental plots. The parameters C and P are allowed to vary for different land use plans and the resulting erosion potential assessed. This erosion potential is then compared to assigned soil loss tolerance standards and the suitable land use plan yielding maximum benefit is implemented.

*For the complex situation B* The Strathclyde sediment model I proposed by Walker & Fleming (1979) could be used in the assessment. This model has a structure shown in Fig. 2. The data base required to use the model is as follows:

I *Land watershed module*
Two years of daily precipitation record, semi-monthly or daily evapotranspiration
Daily streamflow (already available)
Topographic scale maps:
basin area > 150 $km^2$ 1:50 000 contours at 15 m interval
basin area < 150 $km^2$ 1:25 000 contours at 10 m interval
Vegetation details

II *Land erosion model*
Particle size details
Initial storage
Organic content of the soil horizon
Semi-monthly values of:
1. Stalk density
2. Canopy density
3. Area of vegetation
4. Height of vegetation

Disturbance factor (agricultural practice, etc.)

III *Channel module*
Channel length details for each reach
Slope for each reach
Manning's roughness inbank and bankfull
Particle sizes and composition of each reach
Channel cross section details for each reach: one section for one reach
Sediment record (already available)

The model inputs are used to calibrate the model response to that of the river basin. Once satisfactory calibration and verification of the model is achieved then the model can be used to check the existing data base, to extend it and to test proposed land use practices by changing the input parameters of the model.

The two methods are complimentary rather than exclusive. Each is designed to assess a specific range of problems within the limitations of the data base and required accuracy. Both methods

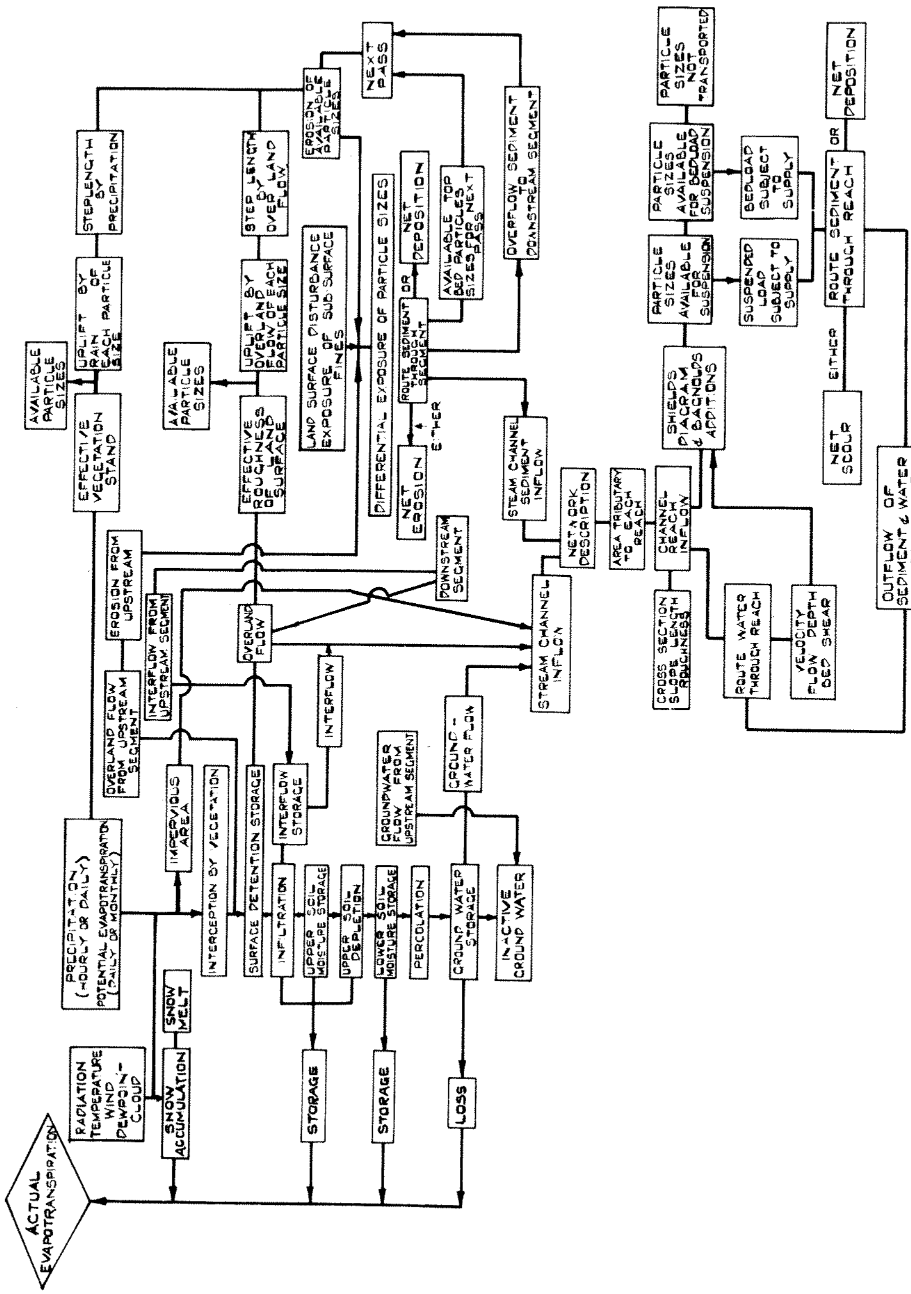


**Fig. 2** Flow diagram of the Strathclyde sediment model.

require a considerable effort in obtaining the input data required to support the method. For example, the original data for the universal soil loss equation for the eastern USA are based on more than 10 000 plot-years of experiment, which must be repeated if the method is used in other parts of the world.

Both methods would benefit from an expanded international data collection programme of the variables shown in Table 1.

The current (1981) state of the art in assessing sediment and hydrology processes shows considerable advances in both the theory and computational aids. The third corner of the triangle of knowledge, namely the data base from which to further develop theory and assessment, is now inadequate and needs the collaboration of the politician and the practitioner to improve the quality and coverage of data collection in the field of sediment erosion, transport and deposition. This is vital for the proper planting and conservation of our global water and soil resources.

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