River Characteristics by Sediment Transport

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1. Introduction

Ground-water recharge from river channels, seepage from ground-water to the river, and tributary inflow sometimes, and in some places, considerably influence flow characteristics of rivers and, consequently, affect river sediment regimes. The change in sediment regimes will result in the alteration of river characteristics, including bed and water surface slopes, width, and depth of flow.

The purpose of this study is aimed at investigating the change in some river characteristics from the effects of ground-water inflow and outflow and tributary inflow, using a simplified mathematical computer model. The study provides some ideas and a better understanding of how ground-water recharge from the stream, ground-water inflow to the stream channel, and tributary inflow affect and alter river characteristics. It also will be a guide for detailed or further studies relating to the problem.

2. Theoretical basis and conceptual approach

Two important criteria taken into consideration in computing sediment transport in rivers or reservoirs are the water surface profile and the bed profile, both of which will change due to deposition of sediment or the scouring process. Usually, the basic equations and relationships, including the equations of conservation of momentum of waterflows, continuity of waterflows, and continuity of sediment transport; relationships for sediment transport; and a flow resistance formula are applied for solving such a problem.

A non-uniform flow, with non-uniform discharge resulting from adding and diminishing water along the reach of flow, is more complicated than flow with constant discharge. The added or diminished water will cause variation in the

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energy or momentum content of the flow. In addition, flow with increasing discharge is somewhat different in hydraulic behavior from the flow with discharge decreasing.

Water-flow with increasing or decreasing discharge

The equation of conservation of momentum for steady flow is applied for this type of flow where mixing of added water and water flowing in the channel results in an appreciable portion of the energy loss.

$$\Delta y = -\frac{Q_1(V_1+V_2)}{g(Q_1+Q_2)}(\Delta V + \frac{V_2}{Q_1}\Delta Q) + (s_0 - \overline{s_f})\Delta x$$

Continuity equation for sediment flow

$$\Delta z_i = \frac{\Delta q_{si}}{\Delta x_i}\Delta t$$

where $\Delta q_{si} = q_{si} - q_{s(i-1)}$

A water course with uniform flow and a constant discharge has a certain sediment transport capacity. If the flow is decreasing or increasing in the downstream direction, the flow and the sediment transport will change reach by reach. The differences between inflowing and outflowing sediment in each reach must be deposited or eroded in the reach.

Equation for total sediment load of streams

The following equations developed by Laursen(1958) are used in the calculation of total sediment load in rivers.

$$\overline{c} = \Sigma p(\frac{d}{y_0})^{7/6}(\frac{\tau_o'}{\tau_c} - 1)f(\frac{\sqrt{\tau_0/\rho}}{w})$$

3. Development of a river sediment routing model

Attempts to develop two and three dimensional river and sediment flow models have been made by some authors in recent years. Even though two and three dimensional models should describe the phenomena involved better, they are very complex, require much more computer time, and have not been completely satisfactory. Fortunately, one dimensional models often provide satisfactory answers to simple situations. Most of the work on river and reservoir sedimentation modeling has used a one dimensional approximation.

Some of the popular one dimensional models currently used for predicting scour and deposition of sediment in rivers and reservoirs are HEC-6, CSU-Model, and GOGREAH Model (Nakato, 1981). However, most of these model require detailed data and involve large amount of d tailed work; they are too detailed for a preliminary study.

As most existing river sediment-routing models are too detailed for this study and are concerned primarily with constant discharge, a simplified sediment model was developed for the investigation. The model was developed for a specific case of study, but may be used for other similar cases. The model can handle flow with varying discharge resulting from flow increasing or decreasing.

3.1 Simplification of the Model

The simplified river sediment model developed in this study for investigating the alteration of some river characteristics that depend on sediment transport utilizes the digital computer in simulating the physical behavior of the river process. In order to keep the model simple, the following assumptions have been mad in developing the model:

- The water and sediment flows are steady over a period of time.
- The water and sediment flows are one dimensional and unidirectional.
- River reaches are of rectangular and uniform section.
- The same inflow water hydrograph is used for all years.
- The rates of ground-water inflow and outflow are constant over the river reach.
- The Manning formula is used to evaluate the friction loss, and the Manning coefficient n varies with water discharge.
- The inflow from a tributary contributes the same sediment concentration as the main stream.
- Sediment properties and characteristics are assumed the same along the river.

3.2 Model structure and components

The computer model consists of three major parts. The first part mainly concerns computation of the water surface profile for any time period. The second part deals with calculation of the sediment transport capacity of the river at each cross-section. The third portion was developed for evaluating and estimating the deposited or scoured volume of sediment between two river cross-sections and the change of flow depth and bed elevation due to deposition or scouring.

3.3 Input and output of the model

As the model is composed of three major parts and the first and second parts can be used independently, inputs are separated into tow sets. The first set, for the first portion of the model, contains data describing initial channel characteristics, including starting bed elevation, channel bottom width, channel side slope, and the inflow water hydrograph. The initial input for the second set concerns sediment characteristics, including sediment size distribution (sediment size and percent finer by weight of each sediment class), water and sediment properties (including water temperature, water density and specific weight, specific weight of sediment, and critical shear force coefficient).

The output from the first part of the model will be the flow parameters at each cross-section, including discharge, depth of flow, average flow velocity, and water surface elevation. The output from this part together with the initial input for the second part, is used to calculate total sediment load at each river cross-section. Thus, the output of the second part is the total sediment load at each cross-section.

4. Data used for study

General input data, including, inflow hydrograph, bed material size distribution, and relationships of Manning's roughness "n" and water discharge are based on the available field data for the Red River near Alexandria, Louisiana.

The initial geometry of the model channel is represented by uniform rectangular sections having a constant width of 800 feet. The initial bed slope is specified as a uniform slope of 0.55 feet per mile. The roughness of the channel is specified by Manning's "n" values; and it varies as a function of water discharge. The relation of the Manning coefficient and water discharge is expressed by the equation, $n = 0.03136 * EXP(-5.629*10^{-6} * Q)$ which will yield approximate "n" values of 0.03, 0.025, and 0.020 for water discharges of 8,000 cfs, 40,000 cfs, and 80,000 cfs, respectively.

A channel length of 120 miles, with 4-mile reach intervals was selected for the study.

5. Conclusions

It can be concluded that ground-water inflow contributes to degradation of a river bed by reason of lessening the sediment concentration of the main stream. By decreasing sediment concentration of the stream, the required flow velocity and the energy slope decrease. Therefore, the river bed profile has a tendency to be concave up in order to adjust itself to the new lower concentration. On the other hand, when ground-water seeps from a river reach, slopes of both bed and water surface profiles have a tendency to become concave down as a result of higher aggradation of the river bed over the affected reach.

The seeping of water from a reach of the main stream results in a decreased sediment concentration. Consequently, higher flow velocity and slope are required for transporting the higher sediment concentration.

In the case of tributary inflow, flow entering from a tributary with the same concentration of sediment as the main stream affects the main stream by increasing water discharge of the main stream. Increasing flow in the main stream results in greater flow depth and velocity. Since the sediment concentration remains unchanged, but the flow depth and velocity increase, the capability for transporting sediment (or in the other words total sediment load) of the main stream increases downstream. Higher sediment load of stream sections downstream of the confluence than that supplied at the confluence leads to imbalance in sediment load between two sections. Consequently, degradation of the bed stream occurs in the reach. The degradation will progress downstream and upstream but is concentrated in the confluence region. Finally, the river will adjust itself to a new equilibrium corresponding to the new sediment regime.

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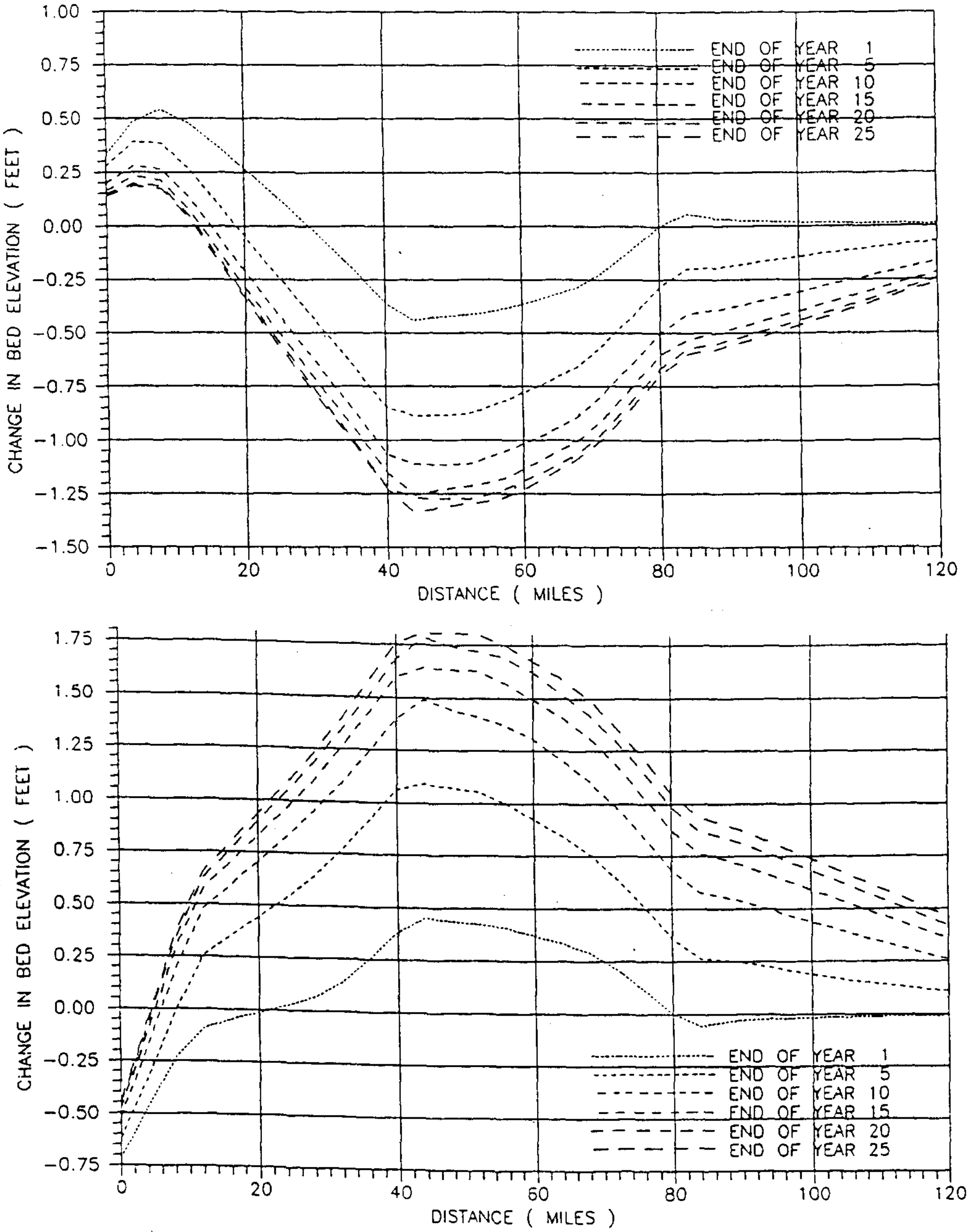

Figure. Total change in bed elevations at the end of years 1,5,10,15,20, and 25(with ground-water inflow and outflow of 150 CFS/MILE between miles 40 and 80)