US Army Corps
of Engineers
Omaha District

Determination of Location And Rate Of Growth Of Delta Formations

Prepared by
Omaha District
Corps of Engineers

November 1957

Missouri River Division
Corps of Engineers
U.S. Army

M.R.D. Sediment Memorandum No.6

DETERMINATION OF THE RATE OF GROWTH AND LOCATION OF DELTA FORMATIONS

Introduction

The general suspended sediment equation is $L = Q\bar{c}$, that is, the sediment load equals the water discharge times the average suspended sediment concentration (all terms in consistent units). This equation suggests that a simple ratio of the suspended sediment concentration at any point in the back-water reach to that of the open river, C_n/C_1, can be used to approximate the rate of growth, location, and volume of a delta formation in a reservoir.

An empirical evaluation of this concentration ratio from data obtained in the back-water reaches of four reservoirs indicated that it could be related, within reasonable limits, to the shear velocity, U_*. For three general classes of particle size (sand, silt, and clay), three equations were obtained of the form

$$\frac{C_n}{C_1} = KU_*^m$$

The changes in sediment concentration and the respective changes in sediment transport that occur through the back-water reach can be determined by using these simple equations. The change in sediment transport per unit time occurring through the back-water reach defines the rate of growth and location of the delta formation It does not, however, account for any redistribution of material by gravity flow that may occur after deposition, nor can it account for any redistribution of deposited material that may occur on exposure of the delta by a drawdown of the reservoir. This method is by no means considered a final solution to the problem; however, within the limits of present knowledge it offers a convenient tool.

The experimental plots from which the equations of the concentration ratio were empirically defined must be further amplified with data from reservoirs on rivers of differing characteristics to prove or disprove their adequacy for universal application.

As a sediment carrying river flows into a reservoir, a reduction in the sediment transporting power of the water occurs as a result of changing hydraulic characteristics. This reduction in transporting power causes the sediment to deposit in the reservoir in one of two characteristic fashions or combinations thereof: (a) in a delta deposit at the head of the reservoir or (b) in a general blanket over the entire reservoir bottom. The delta type of deposit generally contains the coarser material transported by the river but may also contain large quantities of silt and clay. The blanket type of deposit contains only the finer materials transported, primarily the clays. This type of deposit is normally of importance only in small reservoirs where the entire pool may at times contain material in suspension.

In some cases, where enough bottom slope is available, density currents may form and transport the finer material deeply into the reservoir. If the bed slope is steep enough, density currents may carry fine material to the dam and this fine material may even be discharged through the dam outlets. In some areas, massive deposits of fine material may initially form in the delta area only to move later as gravity flows deeper into the reservoir. This type of gravity flow has been noted in reservoirs where the inflowing sediment is composed of a high percent of active clays which may form thixotropic deposits. These density currents and gravity flows tend to follow the old channel (thalweg of the reservoir) on flowing deeper into the reservoir, filling the channel and forming, in low places, low density pools or blanket type deposits of fine sediment.

The section of the river profile of the hydraulic transition between the open river and the level pool is the back-water reach. In this reach the discharge remains constant but the depth increases while the velocity and transporting capacity decrease. Figure 1 shows a typical profile through a backwater reach.

Experience indicates that the inflowing river water tends to remain in a concentrated stream on the delta as it enters the reservoir even though the water depths on the delta are large and the water surface is valley wide. This concentrated stream flow tends to follow the old submerged channel filling it with sediment. After the old channel is filled with sediment, the concentrated flow continues to deposit more sediment, aggrading the channel and forming a relatively narrow ridge or dike. Deposits of fine material tend to form in the slack-water areas alongside of the concentrated flow. The channel will then shift to a series of locations in the head waters of the reservoir by a series of avulsions which occur when the aggrading bed is built up somewhat higher than the adjacent delta areas. This movement of the concentrated flow over the submerged flood plain by avulsions builds up wide areas of deposits.

In narrow to moderately wide valleys flooded by a reservoir, the delta generally occupies the full valley width. However, where the inflowing stream enters a wide flooded valley, the delta projects into the reservoir in a relativel narrow band which may be approximated by the average width of the meander pattern of the normal river.

As a part of the hydraulic characteristics the area of the concentrated flow should be used as the cross-sectional area of flow. The width of the band of concentrated flow may be approximated by the width of the old submerged channel excluding any submerged overbank. This same width should be used in the volumetric computations for the delta deposits until the delta profile rises above the overbank, then the width should be changed to the valley width for narrow valleys or to the normal river meander pattern width for wide valleys.

Analytical Relationships

The open river upstream from the back-water reach (Figure 1) has a water discharge Q (cubic feet per second) which transports a sediment load L_1 (tons per day). At some section in the reservoir pool, the water discharge Q moves through the increased area at such a low velocity that no sediment is transported (except for the possibility of a density current). Considering only the suspended sediment load, the load L_1 equals KQC_1 tons per day, where K is a constant and C_1 is the average suspended sediment concentration. At any point in the back-water reach where deposition is occurring, the suspended sediment load L_n equals KQC_n where C_n is the average suspended sediment concentration at section n. L_n may be written:

$$L_n = L_n \frac{L_1}{L_1} = L_1 \frac{KQC_n}{KQC_1} = L_1 \frac{C_n}{C_1} \qquad (1)$$

The amount of sediment deposited from suspension between sections 1 and n is A, the difference in loads or:

$$A_{1-n} = L_1 - L_n = L_1 \left(1 - \frac{C_n}{C_1}\right) \qquad (2)$$

Similarly, the amount of sediment deposited from suspension between any two successive sections n and n+1 is:

$$A_{n-(n+1)} = L_1 \left(\frac{C_n}{C_1} - \frac{C_{n+1}}{C_1}\right) \qquad (3)$$