PALAEOHYDROLOGY

Introduction

Palaeohydrology is the study of ancient rivers and other hydrological features. Rivers undergo changes continuously, in varied scales, in response to both intra- as well as extrabasinal factors. Consequently interdependent variables like channel width (*W)*, depth (*d*), slope of the river channel (*S)*, channel sinuosity (ratio of channel length to valley length, *P)* and meander wave length (λ) also change. These parameters govern water discharge (mean) over a year, Q_w and type of sediment flux, Q_s, which, in turn, play pivotal roles in determining the nature and pattern of a river. Continuous alteration of the basic parameters, nevertheless, is manifested in wide variability of sedimentary attributes that we may target in ancient river deposits for deducing various palaeohydraulic properties. The empirical relationships between such sedimentary attributes with hydrology, as derived from modern rivers, their experimental analogues and numerical models, are the only means to deduce palaeohydrological details. These deductions are good for comparative studies and for germinating general ideas but have little worth for their absolute values. River channel width and depth, bedform height and lateral dimensions (width and length) are agreeable to direct measurement, but exposures are, more often than not, inadequate; one has to bank generally upon cross-set thicknesses for their well established relationship with hydraulic parameters.

Methodology

Interdependent channel dimensions are potent guides for river hydraulics. Palaeochannel dimensions are, nonetheless, rarely measurable and palaeohydraulic estimations are, in general, bound to be indirect. However, channel depth has the highest potential to be represented in rock record, especially when the channel-fills are covered by flood-plain deposits. Estimation of all hydrological parameters essentially depends on the correct measurements of channel depth, as many other parameters can easily be deduced from it using empirical equations. Correct measurements of channel depths, particularly from outcrops, are often hypothetical if not impossible. The general consent is that the bankfull channel depth approximates well with the decompacted thickness of complete, untruncated channel-bar or channel-fill sequences (Bridge and Tye, 2000). But such estimation is not always straightforward because complete channel-bar or channel-fill sequences are difficult to preserve and even if preserved, its completeness is hardly ever self-manifested. In addition, within a single channel belt, maximum channel depth and bar thickness can vary spatially by at least a factor of two (Bridge and Tye, 2000). Against this backdrop, thickness of medium-scale cross-sets provides a useful alternative (Bridge and Tye, 2000; Eriksson et al., 2006a). The set thickness empirically correlates with dune height and the latter, in turn, correlates with channel depth (Bridge, 1997;

Leclair et al., 1997). This method is applicable to homogeneous cosets of cross-strata, implying that the cross-strata were formed by migration of dunes with mean geometry not varying appreciably in time and space (Bridge and Tye, 2000). Based on this basic conception, starting with average cross-set thickness (h, in metres) many significant hydrological parameters can be estimated, as depicted below:

The **mean channel depth** is calculated following equation:

$$h = 0.086(d_m)^{1.19} \quad (1)$$

where, d_m = mean channel depth and h=mean set thickness in metres (Allen, 1968).

The **mean channel width** can be calculated from following equation:

$$w_m = 8.88d_m^{1.82} \quad (2)$$

where, d_m = mean channel depth and w_m = mean channel depth in metres (Bridge and Mackey, 1993a,b; Ito et al., 2006).

According to Williams (1984) and Ito et al. (2006)

$$Q_m = 0.06(w_m)^{1.66} \quad (3)$$

Where, Q_m is **mean annual discharge** in m^3/s

Osterkamp and Hedman (1982) further proposes an equation

$$Q_m = 0.027(w_b)^{1.71}$$

or

$$wb=\{(Qm)/0{:}027\}^{0{:}58} \quad (4)$$

Where, w_b is **bankfull channel width** in metres.

On the other hand, the **bankfull channel depth** (d_b) can be estimated by

$$w_b = 8.9d_b^{1.4} \quad \text{(Leeder, 1978)}$$

or

$$d_b=\{(w_b)/8{:}9\}^{0{:}71} \quad (5)$$

Where, d_b is bankfull channel depth in metres.

On the basis of above-mentioned variables the **paleoslope (*S*)** can be estimated from following equations proposed by Schumm (1972):

$$S = 30\{F^{0.95}/(w_m)^{0.98}\}/1000 \qquad (6)$$

Where S is paleoslope in m/m and F is channel width/depth ratio (Schumm, 1972).

$\{F = w_m/d_m$ (Schumm, 1968a)$\}$

According to Williams (1978) the **bankfull water discharge** is estimated by following equation:

$$Q_b = 4(A_b)^{1.21}(S)^{0.28} \qquad (7)$$

Where, Q_b is bankfull water discharge in m^3/s and A_b is the bank-full cross-sectional area represented by (w_b X d_b).

Based on the relationship between bankfull water discharge (Q_b) and the **drainage area** (A_d in km^2) is calculated by the following equation:

$(A_d)^{0.75} = Q_b$ (Leopold et al., 1964)

or

$$A_d = (Q_b)^{1.33} \qquad (8)$$

Finally, the **Principal Stream Length** is approximated from the following equation:

$$L = 1.4\,(A_d)^{0.6} \qquad (9)$$

Where, L is principal stream length inn km (Leopold et al., 1964).

The mean **Channel belt width** (*cbw* in m) has been calculated from its relationships with d_m expressed as following equation (Bridge and Tye, 2000; Ito et al., 2006):

$$cbw = 192(d_m)^{1.37} \qquad (10)$$

Importance and application of palaeohydrological study:

1. Paleohydrology has advanced our understanding of climate by uncovering the variability of the prehistoric water cycle. Various proxy records provide insight into aspects of the hydrologic cycle that occurred before the instrumental record and allow for paleoclimate reconstructions locally or over large regions. For example, geomorphologic methods can quantify megafloods; coral or sediment core methods create paleodischarge records; rodent middens archive changes in precipitation volume and temperature; closed-basin lake level fluctuations offer quantitative evidence of changes in water balance, and tree-rings provide a

high-resolution archive of precipitation or drought. Thus, paleohydrology enhances our understanding of climate variability. Hydrological fluctuations are linked to the factors causing them, and paleohydrological data can be used to validate climate models. On the orbital time scale, paleohydrological data reflects variations in the Earth's orbit and the cycle of glacial periods and interglacials.

2. Paleo-hydrology is an important study which simulates the historical hydrology at the lack of observed period, calibrated at the present period and predicted the future hydrological condition. The study of paleohydrology is to obtain the historical evidence for the present hydrology and improve the accuracy of the statistical analysis and the prediction modeling assessment. Paleo-inundation assessment is the study of historical inundation under flood events which occurred prior to direct measurement of hydrologic parameters using modern methods.
3. Precambrian fluvial systems would have lacked the binding, baffling and trapping of sediment by vegetation roots, and as a result, flashy surface runoff, lower bank. stability, broad channels with abundant bedload, and faster rates of channel migration would have been common, compared to younger vegetated areas. stability, broad channels with abundant bedload, and faster rates of channel migration would have been common, compared to younger vegetated areasThe hydraulics of Precambrian rivers are seldom addressed (Eriksson et al., 2006). The question, whether Precambrian rivers had hydraulic parameters comparable to those of modern and Phanerozoic rivers is, nonetheless, a loaded one. Since sedimentation framework underwent significant changes in post-Cambrian times, some significant differences in river-hydraulics should be expected.
4. Another application is in the quantification of erosion caused by rivers under differing climatological conditions.