US Army Corps
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Analysis of Multi-Channel Bed Profiles Missouri River, Near Omaha July 27, 1982

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VIII. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A study has been made to measure bedload in the Missouri River. It is based on detailed sequential bed profiling in a 384 ft wide strip of the river channel between RM 615.2 and 615.8, carried out on July 27, 1982. The field data, especially collected for this purpose, comprise: four sequential runs at an average interval of about 2.8 hours; point velocity, point-integrated suspended sediment concentration and surface bed material samples at 18 verticals spread through the reach; water discharge; periodic gage height and water temperature measurements at frequent intervals. In addition, the gradient in this part of the river has already been determined in an earlier study. This chapter provides a summary of the procedures and important conclusions from this study. A set of recommendations for the future is, also, developed at the end of this chapter.

Summary and Conclusions

1. The bed profile data has been digitally recorded on 11 of 16 transducers mounted on the multi-channel bed profiler, at a frequency of 1Hz. The location and time data have been recorded on the profiles at 10 second intervals. The study reach has been divided into three segments, so that a total of 528 bed profiles with an aggregate length of 105 miles of record have been obtained. The hydraulic data consists of two discharge measurements on July 26 and 29, 1982 and 18 velocity profiles. The sediment data comprise 108 point-integrated suspended sediment concentration samples, which have been analyzed for spatial concentration and particle size distribution along with the particle size distribution at 18 locations.

2. The preparation of bed profile data for analysis, consists of two major steps. One, the removal of spurious soundings, which originate in the machine noise and the other, correction for the deviation of boat from the prescribed trackline. A two-scan filter has been designed and used to remove spurious soundings and the actual courseline has been vectorially projected onto the trackline to make length correction. The equispaced interpolated series have been obtained at an interval of 2 ft. Care has been taken to fix the starting location of all of the equispaced profiles at the respective reference axes, which are drawn normal to the trackline and pass through the zero point. The actual courseline of the boat has been plotted. It shows that in different runs, the maximum deviation from the trackline is less than 20 ft. This is acceptable, in view of the two-dimensional nature of the bedforms (See Para 7 below). For the velocity and sediment data, no special preparation is needed. These data are keypunched as per the standard formats in vogue in the District and have been analyzed by the sediment transport computer program package - ODSET.

3. Interpolated bed profile series have been extensively analyzed. The objective is to study the homogeneity of bedform regime in various parts of the cross section and among various runs. This opportunity has been used to investigate four different methods of analyzing bedform dimensions. This investigation is relevant to future automated analysis of digital sonic profiles for bedform dimensions. It is concluded that the method of zero-crossing provides a direct approach, which is computationally efficient; provides dimensions of individually identified bedforms and handles underlying bed level trends without resorting to digital filtering. Experience

presented herein shows that this method has the potential of being adapted for automated analysis of bedform dimensions. It has been shown that the computed parameters converge to stable values when the correct meanline is fitted (Figure 4.4).

4. A new technique of Maxima-Minima analysis, to identify, well-defined bedforms has been tried, with the purpose of studying bedform shapes and to investigate if the bedforms are in a state of maturity or otherwise. It is concluded that about 64 percent of the bedforms are in a theoretical state of growth; about 13 percent are mature and the remaining 23 percent are decaying. This is a relatively new idea in the genesis and evolution of bedforms and full implications of the distribution are not clear at this time (1983). The results, however, provide a reference datum and further interpretation must await additional studies on the Missouri and other sand bed field channels.

5. The analysis of bedform dimensions show that the bedforms do vary across the channel width. The bedforms close to the banks are generally smaller and increase in size towards the mid-stream. (Figures 4.5 and 4.6). The average bedform dimensions between various runs shows small variations, which are entirely related to unfiltered noise in the original data. No time-trend has been noted in the bedform size for the duration of study.

6. The measurement of bedform width has been attempted for the first time on a field channel. Two methods have been tried to determine bedform width from adjacent bed profiles. A graphical method, which measures the length of troughlines from pseudo-three-dimensional plots (Figures 4.23 through 4.26 and Appendix U) and cross spectral analysis. It is reasoned that the

cross spectral amplitude will show a minima where the bedform has changed to a different dimension. (Figures 4.28 through 4.39). The study shows that the cross spectral method yields about 25 percent larger widths. Pending additional experience with these techniques, the bedform widths may be taken as 80 percent of the width defined by the minima-points of cross spectral analysis.

7. The average bedform width in the study reach is about 2.5 times its length (Table 4-5). This means, that the bedforms are significantly two-dimensional, and that theoretical analysis based on two-dimensional flows are realistic. The two-dimensional nature of bedforms can, also, be used in the future to economize the extent of bedform data collection and analysis.

8. The velocity profiles measured in the study reach follow the semi-logarithmic distribution (Eq.(5.1)) although the values of von Karman's κ show large variation from one vertical to another.

9. The dominant particle size fraction in the bed and the suspended (bed) material) load is 0.074 - 0.420 mm with a geometric mean size of 0.176 mm. The concentration profiles for this fraction follow the Rouse Equation (Eq.(5.3)). The observed value of exponent z is, however, close to the theoretical value based on the local shear velocity, U_* (Eq.(5.5)) rather than on U_*' (Eq.(5.4)).

10. An attempt has been made to compute bedload from the distribution of velocity and suspended bed material concentration in the verticals. It is noticed that due to uncertainties in the origin of velocity profiles and large gradients of concentration profiles near the bed, this is not a viable

approach of measurement. In the present data, extrapolation of fitted velocity profiles (Eq. (5.1)) to the bed layer, yields negative velocities at the outer edge of laminar sub-layer (Eqs. (5.8) and (5.9)) have been used. The results are shown in Table 5-2.

11. Two numerical methods have been used to compute the bedload from sequential profiles - the cross spectral and downcrossing. In the cross spectral method, two constants are needed to relate the volume and height of bed-form to the variance associated with different frequencies. Experiments have been made with synthetic profiles to evaluate these constants. Computed values of bedload by the two methods are summarized in Table 6-1. Evaluation of cross spectral and downcrossing methods is made to conclude that the latter is preferable and is adopted for analysis of bedload.

12. A study of the space-variation of bedload shows that the bedload is smaller near the channel banks and increases towards the mid-stream, but the maximum rate of bedload is, generally, located off-center. The ratio of the maximum to average value of bedload in a cross section is around 2.5 and the distribution across the channel width is related to planform channel geometry. Average cross sections in the three segments (Figure 4.8) show that, although the study reach has a mild left-handed curve, a crossing has developed in the middle segment. The maximum bedload rate in the upstream segment no: 3 is towards the right of mid-channel, due to the effect of channel bend preceding the study reach. The maximum bedload rate in the downstream segment no: 1, is towards the left of mid-channel, as a result of the crossing in the middle segment 2.

13. The distribution of bedload rate in the three segments shows an oscillation in time (Figures 6.16 through 6.18). This is an interesting result and may be symptomatic of the behavior of bedload in straight or mildly curving sand bed channels. On the other hand, the oscillation may be present due to the existing channel being too wide (36 percent) compared to regime dimensions.

14. Six sediment transport functions have been used to compute the bedload, both in the measurement verticals and in the channel cross section in the three segments. It is reasoned that due to the time variation of bedload, it is not possible to make a comparison betweeen the measured and predicted values. The cross section average value of bedload in various runs and segments varies from 18 to 35 ppm (Table 6-3) with an average for the study reach of 28 ppm. Einstein Bedload Function (12), gives a predicted value of 23 to 39 ppm with an average of 33 ppm. It is concluded that Einstein Bedload Function yields closest agreement to the measured bedload. All other transport functions yield an underestimation of bedload.

15. The measured hydraulic resistance in the study reach is Manning n = 0.027 and Darcy-Weisbach f = 0.036 (Tables 7-1 and 7-2). The coefficient of variation for n measured at different verticals is 12 percent and that for f is 22.4 percent.

16. Values of form friction factor, f" have been calculated from a recent analytical method (15), based on bedform dimensions. The use of average, median and full array values of bedform dimensions has been investigated. It is concluded that the average bedform dimensions in a reach shoud be preferred.

17. In the method of zero crossing, the mean bed line is computed as the spline curve passing through the average bed level points in non-overlapping segments of equal length, $\Delta\bar{x}$ (Chapter IV). The effect of $\Delta\bar{x}$ on the computed friction factor from bedforms has been studied. It is seen that if $\Delta\bar{x}$ is increased from 52 ft, used in the preceding analysis, to 80 ft, the computed friction factor is not changed. It is concluded that the friction factor computed from the bedform dimensions given by the friction zero crossing method are not sensitive to the adopted value of Δx, provided the limits of $1.5\ L < \Delta\bar{x} < 2.5\ L$; L = average bedform length are observed.

Recommendations for Future Work

Bedforms are the most important feature of alluvial channel. To further the analytical developments in dynamics of alluvial channels, it is imperative that quantitative data on the bedform dimensions are obtained under a wide range of conditions. This will certainly entail digital acquisition of bed profile data, as done in the present study. Computer analysis of bed profiles, however, has not been developed to a stage of automation, so that, a considerable lag time exists between the acquisition and analysis of data. Experience gained in this study, indicates that it is possible to develop an on-line method of analysis by digital computers, so that, quantitative bedform data can be routinely collected along with other measurements in alluvial channels.

A successful use of sequential profiles to measure bedload in field channels has been demonstrated in the present study. The results obtained herein, have also brought out space and time variation patterns that were unknown in the past. It is important that similar studies are carried out in the future, in straight