The East Fork River shows similar characteristics of lateral spatial variability; the bedload-trap section at the East Fork River is in a lesser bend, but has more of a central bar. For the same reasons of bed-shear distribution and secondary circulations, maximum transport rate and particle sizes occur atop the central bar; both maxima are skewed toward the inner (left) channel while faster velocities are skewed toward the outer (right) channel. As with the Snake River, as water discharge changes, there are subtle changes in the cross-channel distribution of bedload characteristics. Again, knowledge of the bedload distribution at one stage is no guarantee of knowledge of the distribution at another stage.

Reconnaissance of river channels, aided by aerial viewing from light aircraft, enhances our knowledge of spatial variability. Figure 6 is aerial views of the East Fork River near the bedload trap in Wyoming; light-colored depositional areas (point bars) appear on the inside of meanders bends as are alternating lateral bars associated with riffles in straight reaches of channel. The fact that the point bars have a spacing on the order of 5 to 7 channel widths, and the riffles (lateral bars) have a spacing of 5 to 7 channel widths suggests that the same processes operating in bends are operating in straight reaches. The bedload that forms these depositional bars alternates between channel sides every 5 to 7 channel widths and indicates a bedload direction corresponding to about the tangent of 1/6, or 0.167. This corresponds to an angle of about 9 to 10 degrees and suggests that even in straight channels, bedload motion is a zigzag course downstream. This general tendency was verified by bedload sampling at a number of sections on the East Fork River, Wyoming during 1979-1980 (for a list of references for the East Fork River studies, see Emmett, Leopold, and Myrick, 1983).

Figure 6. Spatial variations in bedload as indicated by locations of lateral bars and point bars. (a) Looking down valley at East Fork River near Pinedale, Wyoming; bedload trap is about 50 meters downstream of the road crossing. (b) Close-up of the meander loop in the foreground of part (a).

Dispersive Stress

Largely known from the research of Ralph Bagnold (see, for example, Bagnold, 1954), but observed in many painted-rock experiments (see for example, Leopold, Emmett, and Myrick, 1966) a dispersive stress normal to the direction of flow acts differentially on particles of different sizes; larger particles receive the greatest force such that large particles tend to migrate upward during motion. This is not only apparent when the largest particles in a debris flow appear at the surface, but in river flows, can occasionally give the appearance of coarse particles appearing to ‘float’ with only infrequent contact with the streambed. Subsequent to floods which barely submerge bridge crossings, cobbles and boulders frequently can be found littering the bridge surface, having been supported upward in the flow by dispersive stress. In painted-rock experiments, it is dispersive stress that enables coarse particles to be observed at the streambed surface even though the underlying smaller particles had earlier scoured to some depth.

Concluding Statement

Some observed behavioral characteristics of bedload suggest the relative greater importance of bedload at higher flows, that the bedload-transport process is characterized by spatial and temporal variability, neither of which can be ignored, and that adequate direct-sampling techniques exist to quantify characteristics of bedload in natural rivers. At present, measurement of bedload is a time-consuming and expensive undertaking. Technology surrogate to direct sampling of bedload is both developing and encouraging; these indirect methods of measurement must provide information relevant to real-world needs. The ability of indirect methods to conform to observations from direct measurement should be useful in the continued development of surrogate technology.

References Cited

Bagnold, R.A., 1954, Some flume experiments on large grains but little denser than the transporting fluid, and their implications: Institute of Civil Engineers Proceedings, Paper 6041, pp. 174-205.

Druffel, Leroy, Emmett, W. W., Schneider, V. R., and Skinner, J. V., 1976, Laboratory hydraulic calibration of the Helley-Smith bedload sampler: U. S. Geological Survey, Open-File Report 76-752, 63 p.

Edwards, T.K., and Glysson, G.D., 1998, Field methods for measurement of fluvial sediment: U. S. Geological Survey, Techniques of Water Resources Investigations, Book 3, Chapter C2, 80 p.

Emmett, W.W., 1975, The channels and waters of the upper Salmon River Area, Idaho: U. S. Geological Survey, Professional Paper 870-A, p. 1-116.

-------- 1976, Bedload transport in two large, gravel-bed rivers, Idaho and Washington: Proceedings, Third Federal Inter-Agency Sedimentation Conference, Denver, Colorado, March 22-26, 1976, pp. 4-101 to 4-114.

-------- 1980, A field calibration of the sediment-trapping characteristics of the Helley-Smith bedload sampler: U. S. Geological Survey, Professional Paper 1139, 44 p.

-------- 1981a, Measurement of bedload in rivers: Proceedings, International Symposium on the Measurement of Erosion and Sediment Transport, Florence, Italy, June 22-25, 1981, Publication no. 133, International Association of Hydrological Sciences, pp. 3-15.

-------- 1981b, Bedload sampling in rivers: Proceedings, International Symposium on River Sedimentation, Beijing, China, March 24-28, 1980, Guanghua Press, Peking, China, pp. 991-1014.

-------- 1984, Measurement of bedload in rivers, Chapter 5 in Erosion and Sediment Yield, R. F. Hadley and D. E. Walling (ed): Geo Books, Norwich, England, pp. 91-110.

-------- 1999, Quantification of channel-maintenance flows for gravel-bed rivers: in Wildland Hydrology, Proceedings, American Water Resources Association Symposium, Bozeman, Montana, June 30 – July 2, 1999, TPS-99-3, pp. 77-84.

Emmett, W. W., and Myrick, R. M., 1985, Field data describing the movement and storage of sediment in the East Fork River, Wyoming; Part V, Bed-material tracers, 1979 and 1980: U. S. Geological Survey, Open-File Report 85-169, 365 p.

Emmett, W. W., Leopold, L. B., and Myrick, R. M., 1983, Some characteristics of fluvial processes in rivers: Proceedings, Second International Symposium on River Sedimentation, Nanjing, China, October 11-16, 1983, Water Resources and Electric Power Press, pp. 730-754.

Emmett, W. W., and Wolman, M. G., 2001, Effective discharge and gravel-bed rivers: Earth Surface Processes and Landforms, v. 26, no. 13, pp. 1369-1380.

Gilbert, G. K. 1914, The transportation of debris by running water, based on experiments made with the assistance of E.C. Murphy: U. S. Geological Survey, Professional Paper 86, 263 p.

Helley, E.J., and Smith, Winchell, 1971, Development and calibration of a pressure-difference bedload sampler: U. S, Geological Survey, Open-File Report, 18 p.

Klingeman, P. C., and Emmett, W. W., 1982, Field progress in describing sediment transport, Chapter 7 in Gravel-bed Rivers, R. D. Hey, J. C. Bathurst, and C. R. Thorne (ed): John Wiley and Sons, Ltd., New York, New York, pp. 141-179.

Leopold, L. B., and Emmett, W. W., 1976, Bedload measurements, East Fork River, Wyoming: Proceedings, National Academy of Sciences, v. 73, no. 4, pp. 1000-1004.

Leopold, L. B., and Emmett, W. W., 1983, Bedload movement and its relation to scour: Proceedings, Rivers ‘83, American Society of Civil Engineers, Waterway, Port, Coastal, and Ocean Division Conference, New Orleans, Louisiana, October 24-26, 1983, pp. 640-649.

Leopold, L. B., and Emmett, W. W., 1997, River hydraulics and sediment transport: some inferences from the East Fork River, Wyoming: U. S. Geological Survey, Professional Paper 1583, 52 p.

Leopold, L. B., Emmett, W. W., and Myrick, R. M., 1966, Channel and hillslope processes in a semiarid area, New Mexico: U. S. Geological Survey, Professional Paper 352-G, pp.193-253.

Reid, Ian, Brayshaw, A.C., and Frostick, L.E., 1984, An electromagnetic device for the automatic detection of bedload motion and its field applications: Sedimentology, v. 31, p. 269-276.

Ryan, S. E., and Emmett W.W., 2002, The nature of flow and sediment movement in Little Granite Creek near Bondurant, Wyoming: U. S. Forest Service, General Technical Report RMRS-GTR-90, 48 p.