Suspended and substrate sediment sizes of the lower Rio Puerco, New Mexico

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Abstract. An understanding of the transport of sediment in any river requires an understanding of the sizes of the sediment in the substrate and the sizes of transported sediment. Data in USGS records for the Rio Puerco near Bernardo show that 50% of the suspended load samples have at least 90% fines (<0.062 mm) and 90% of the samples have at least 77% or more fines. Samples from the river at a location above the gage show the surface material of the Rio Puerco has a median size of 0.0022 mm - very fine material. This layer is a few centimeters thick. Below this layer is substrate with a median size of 0.085 mm. Samples from the flood plain profile had a median size range of 0.007-0.20 with median in the range of 0.06. The flood plain and substrate samples have more sand than the suspended sediment size measurements imply. Another concern is the actual size of the sediment in transport. Data for the suspended sediment show significant differences in the sizes of the sediment measured using a dispersent compared to sizes with native water. To simulate this in the laboratory, very fine sediment (the surface material on the stream bed) was measured with and without dispersent. The size of the sediment measured with dispersent was 0.0022 mm compared to without dispersent median size of 0.01 mm. A similar test was done for one of the courser samples; the 'with dispersent' median size was 0.044 mm compared to 'without dispersent' median size of 0.050 mm. The analytical technique used in the laboratory determination of the particle sizes of suspended sediment and of the substrate must be part of the information reported in any study using grain size analysis.

1. Introduction

An understanding of the transport of sediment in a river requires an understanding of the size of the sediment in the substrate of the river and the size of sediment being transported. This paper shows that selection of laboratory techniques for substrate (bed material) analysis may influence the results of studies of sediment transport or sedimentation in rivers. In some situations the differences in sediment size obtained from alternative laboratory procedures can be significant.

USGS data for the gaging station on the Rio Puerco near Barnardo, New Mexico (0835300) are used to show the differences in sizes of suspended sediment in the river and to show the range of sizes that are possible depending on the laboratory analysis. Data from a trench upstream of the

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gaging station are used to illustrate the impact of laboratory analysis procedures on the characteristics of the size distribution of the bed material and the median size of bed material.

There is nothing new in the idea that different techniques for grain size analysis will result in different estimates sizes of the sediment (Lambe, 1951). What this paper tries to contribute is an appreciation that 1) it is important in sedimentation and sediment transport studies to consider which technique gives the best results for the study at hand, and 2) the laboratory procedures used in grain size analysis must be part of any report using the results of the analysis.

2. Selected characteristics of the Rio Puerco near Bernardo.

A map showing the location of the Rio Puerco watershed is presented in Figure 1. The Rio Puerco is tributary to the Rio Grande south of Albuquerque, New Mexico. At the USGS gaging station near Bernardo (just above the junction with the Rio Grande) the watershed area is 7350 square miles. The USGS reports at least 1130 square miles does not contribute directly to surface runoff (Ortz et al, 2000).

The climate may have an impact on the results presented herein. The variation of the average monthly precipitation and temperature are presented in Figure 2. The information in Figure 2 is for the NOAA climate division that includes the lower watershed. The upper watershed includes mountains and bad land areas with lava flows. Figure 2 shows the region is arid; the rains are strongest in the summer (July - September). The temperatures are moderate.

Folklore associated with the Rio Puerco is that the river transports 'only' very fine sediment. The measured suspended load samples in the USGS records for which the fraction smaller than sand (0.063 mm) has been determined show that 50% of the suspended load samples have are at least 90% fines and 90% of the samples have at least 77% or more fines (see Figure 3).

The sediment data measured by USGS at the Bernardo gaging station includes the grain size distributions (% smaller than a specified size). A few of the measurements include the size distribution measured with distilled water and a dispersent along with measurements with 'native' water. One of the measurement pairs is presented in Figure 4. There is considerable difference between the size determined using distilled water compared to native water analysis for the smaller sizes (<0.016 mm). That difference is the reason for this paper. The next section show that the differences can be simulated in the laboratory using substrate samples and can be important.

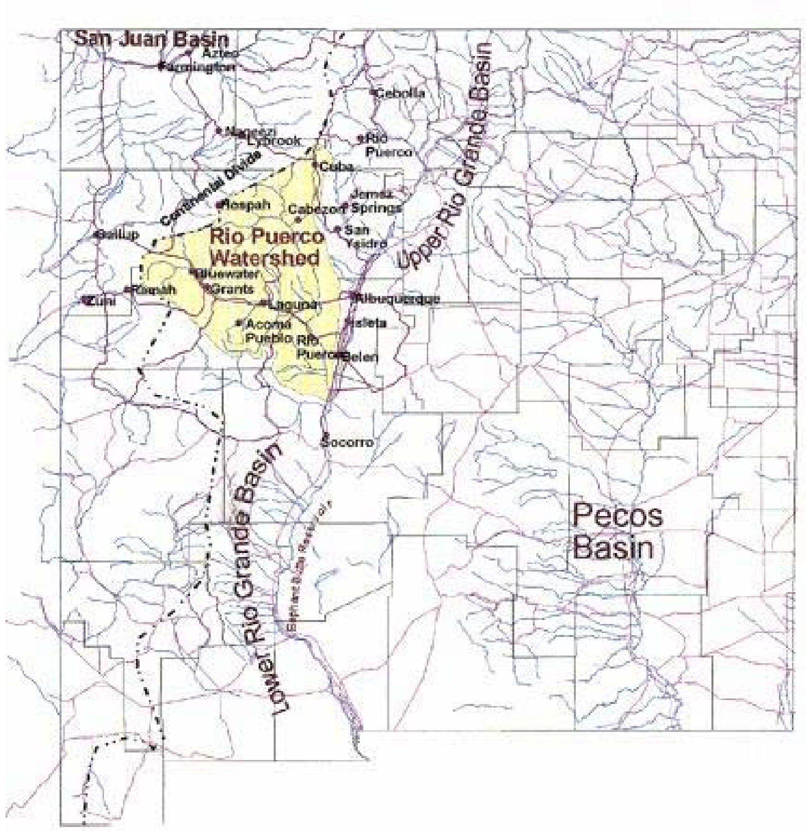

Figure 1. Map showing the location of the Rio Puerco watershed in New Mexico. Source: USGS climate change web site: (http://climchange.cr.usgs.gov/rio_puerco/puerco2/location_map.html.

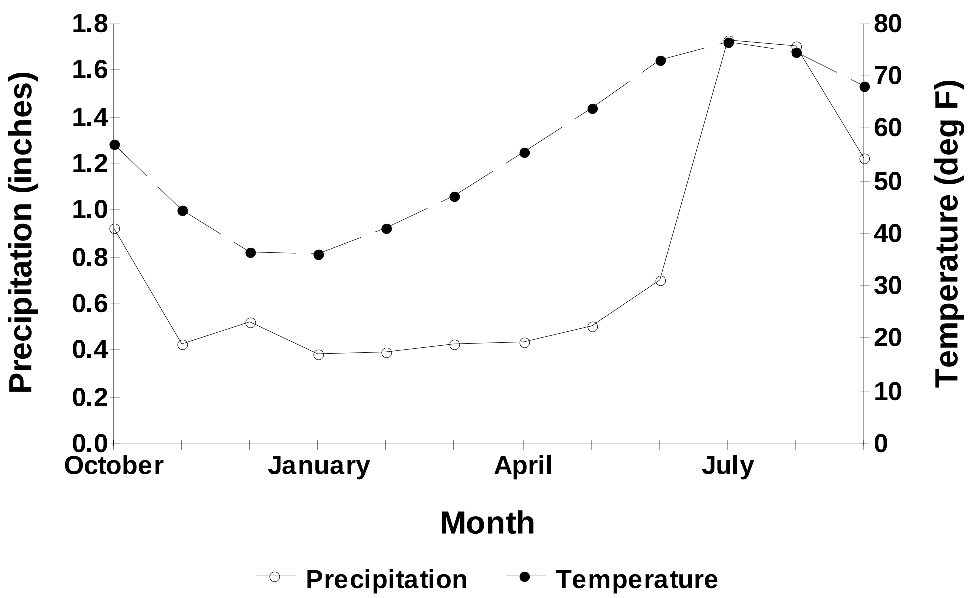

Figure 2. Average monthly temperature and precipitation for the New Mexico Central Valley climate division. The averages are for water years 1896 - 2003. Source of data: Western Regional Climate Center.

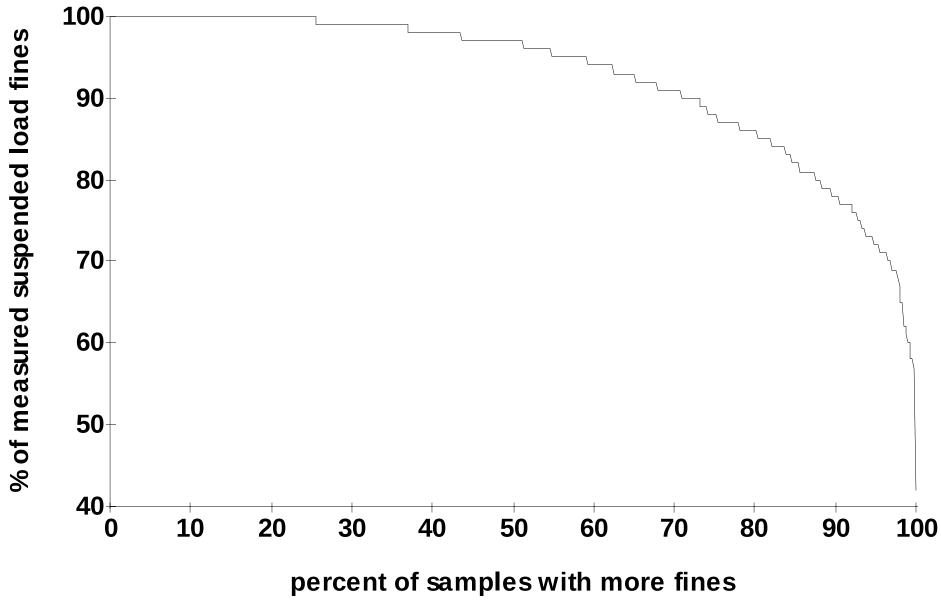

Figure 3. Exceedence diagram for the percent of measured suspended load files (<0.063 mm) at the USGS gage on the Rio Puerco near Bernardo, New Mexico (1948-2002).

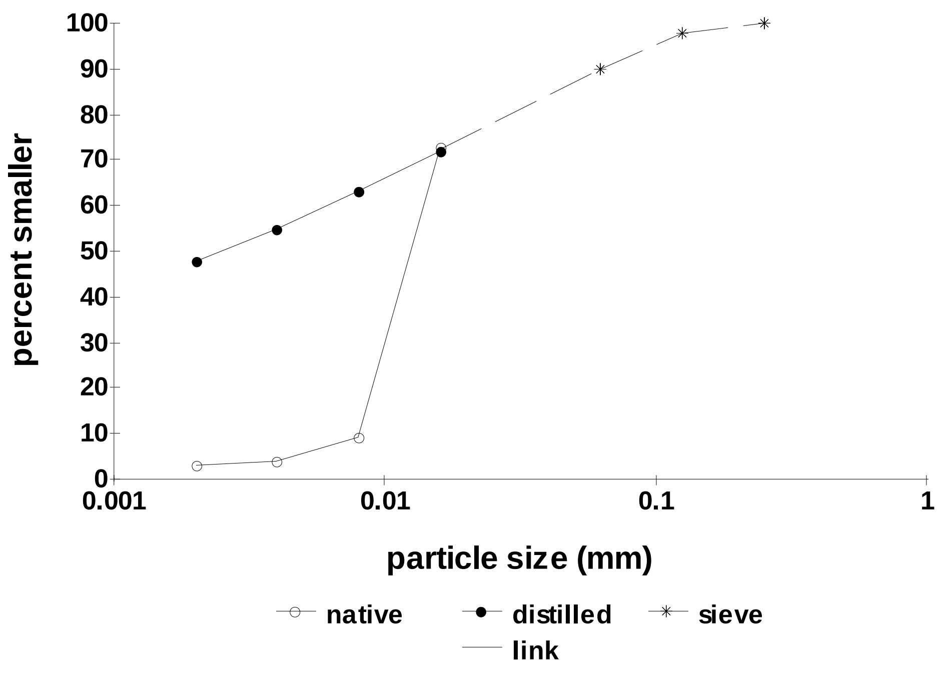

Figure 4. The measured size distribution for Rio Puerco suspended sediment transported on 21 August 1995 when the discharge was 5960 cfs and the measured suspended sediment concentration was 107 g/l. Link goes from last of the sieve measurements (0.062mm) to the average of the largest fall velocity measurements (0.016mm).

The percent of the measured suspended sediment with a size less than 0.008 mm are shown in Figure 5 for paired distilled and native water measurements. There are considerable differences. A similar diagram for 0.031 mm shows little differences.

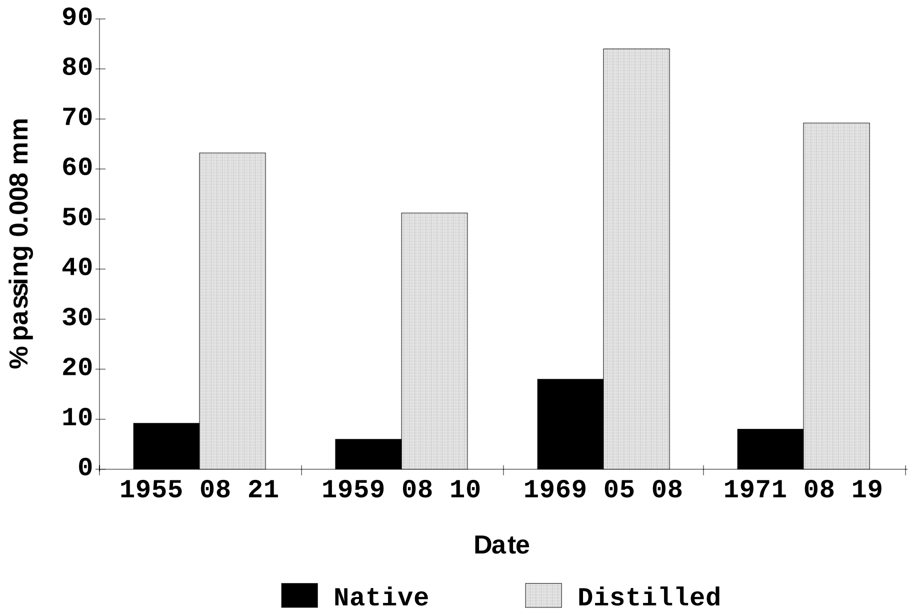

Figure 5. The percent of the suspended sediment with a maximum fall diameter of 0.008 mm (%<0.008 mm).

3. Alternative Measurements of Substrate Sediment Size

In the section above it was shown that suspended sediment measurements have different sizes depending on the water used in the laboratory analysis. In this section alternative laboratory measurements of bed and flood plain sediments are presented. By alternative laboratory procedures is meant the following:

- dry sieve analysis,
- wet sieve analysis,
- fall diameter analysis using distilled water and a dispersent, and
- fall diameter analysis using distilled water and no dispersent

Dry sieve analysis is where a sample is dried, and then sieved through a bank of sieves and the weight larger than each sieve determined, wet sieve means where the sample is dried, weighed, and washed through either a #200 (0.074) or a #230 (0.062 mm) screen. The fall diameter test follows closely the procedure in ASTM D422-63 (ASTM, 1990). An alternative wet sieve method (not used) is to wash a sample through a bank of sieves, dry the material retained on each individual screen and weigh.

The samples used in this presentation are from a trench dug in the flood plain for other purposes and from the river just upstream from the trench. The sediment on the surface of the stream bed is a cohesive layer of very fine sediment that forms a 'plate' cover about 1-2 cm thick over the stream bed. The plates crack when dry and are probably removed reasonably quickly on a rising hydrograph.

In Figure 6 are the alternative representations of the grain size for the very fine sediment on the surface of the stream bed. The sample labeled RPTA is for a standard hydrometer analysis with sieves used for the sediment retained on the #230 screen (0.062 mm). The laboratory analysis used distilled water and a dispersent. The curved labeled RPTAND was accomplished the same as for RPTA except a dispersent was not used - this is intended to match the 'native' water analysis. There is considerable similarity in the results shown in Figure 4 as compared to the results in Figure 6. The third test (RPTA2WKD) was made to determine if the sediment would disperse if allowed to soak in distilled water for a period of time and was made by allowing a sediment sample to set in distilled water for two weeks prior to the hydrometer measurements. There is not much difference in the results between RPTAND and RPTA2WKD. Dry sieve analysis can not be made on very cohesive sediments.

In wet sieve analysis the sample is dried and the total dry weight of the sample determined. The sample is then washed on a #230 (0.062 mm) screen and the fines removed. The samples are dried and dry sieved. The difference between a wet sieve and a hydrometer test without dispersent is that the sample is placed in a cylinder and the hydrometer measurements made prior to washing the sample through the #200 or #230 screen.

A similar series of tests were made for a sample of fine sandy sediment. A working assumption has been that dry sieve analysis will give satisfactory results for any material in a river that is obviously sand. The results are in Figure 7. This diagram clearly shows there are significant difference between dry and wet sieving but that for sandy sediment there is little difference between no-dispersent and dispersent tests. There is a difference between the wet methods and the dry method (sieve).

The differences between the median size (d50) from dry sieving compared to a hydrometer analysis with dispersent is shown in Figure 8 for eight samples, two from the river (A and B) and 6 from the trench in flood plain sediments. Sample B is the sediment in the river channel just below the surface sediment (Sample A). There are significant differences in the d50 from dry sieving and hydrometer analysis using dispersent. The samples without a value for the dry sieve analysis dry into clumps and can not be broken in to particles. It was obvious these samples would need to be analyzed using a wet technique (hydrometer or wet sieving). The percent less than 0.062 mm for the same samples is presented in Figure 9. The d50 for trench sample H using no-dispersent fall velocity analysis was 0.05 mm and the %<0.062 was 63%. The wet sieve analysis without hydrometer analysis is expected to give similar results.

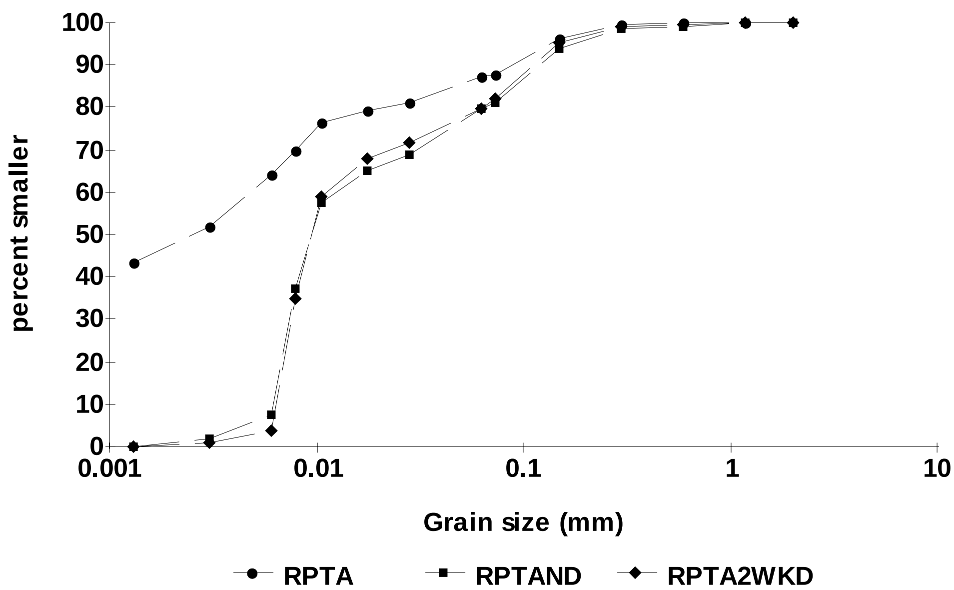

Figure 6. Particle size distribution data for the very fine sediment found on the surface of the Rio Puerco upstream of the Bernardo gage. The analyses use hydrometer techniques and distilled water, RPTA with a dispersent, RPTAND without a dispersent, and RPTA2WKD without a dispersent and after soaking in distilled water for two weeks.

4. Discussion

This paper shows that the type of laboratory analysis used in the determination of the particle sizes of sediment in a river bed can have a significant impact on the apparent size of the sediment available for transport. The results show there are differences between dry sieve and hydrometer (fall velocity) analysis – and between the results obtained using different waters in the hydrometer analysis. There are other tests besides the hydrometer test that can be used to measure the particle size distribution of substrate sediments using fall velocity (Guy, 1969). Laboratory analysis using any of these techniques would probably give results similar to the results from hydrometer analysis presented in this paper. Most available data for a river substrate with sand and fine sediment has been obtained using dry sieve analysis or using a dispersent. Much of the available size data is from laboratory analysis that use a dispersent for analysis of sizes less than 0.062 mm and a dry sieve analysis for sand sizes and larger. Sometimes fall velocity analysis with a dispersent was used for the sand sizes in the 1 mm to 0.062 range.

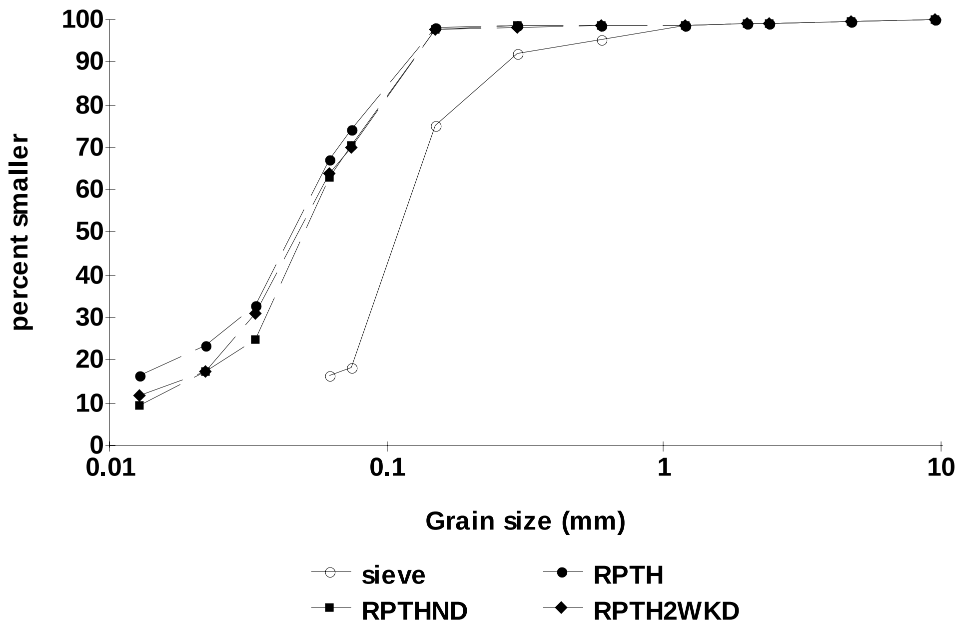

Figure 7. Particle size distribution data for sandy sediment from flood plain sediments of the Rio Puerco upstream of the Bernardo gage. Three samples were analyzed using hydrometer techniques and distilled water, RPTH with a dispersent, RPTHND without a dispersent, and RPTH2WKD without dispersent after a two week soaking. The fourth analysis, sieve, was a dry sieve analysis.

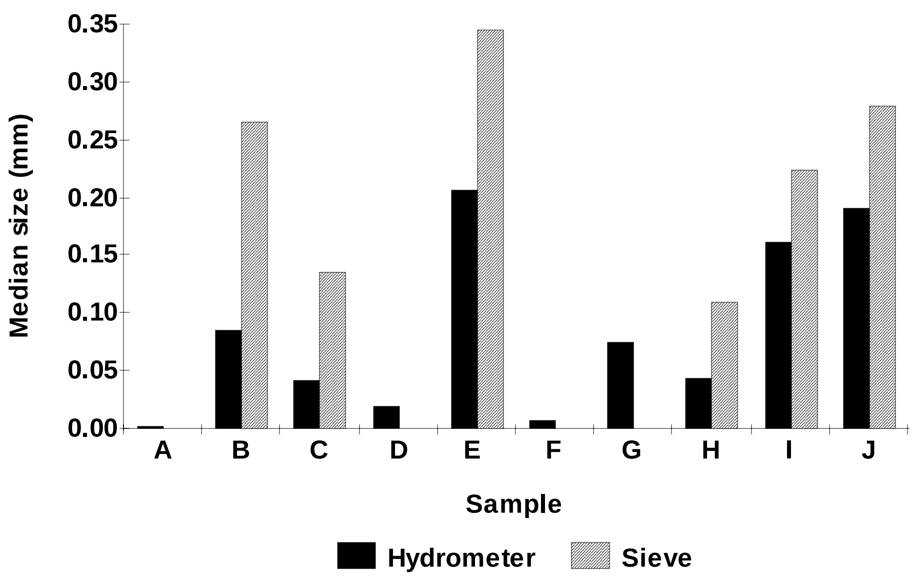

Figure 8. Comparison of the median size (d50) of river and flood plain sediment from the Rio Puerco as determined from hydrometer analysis using a dispersent and from dry sieving.

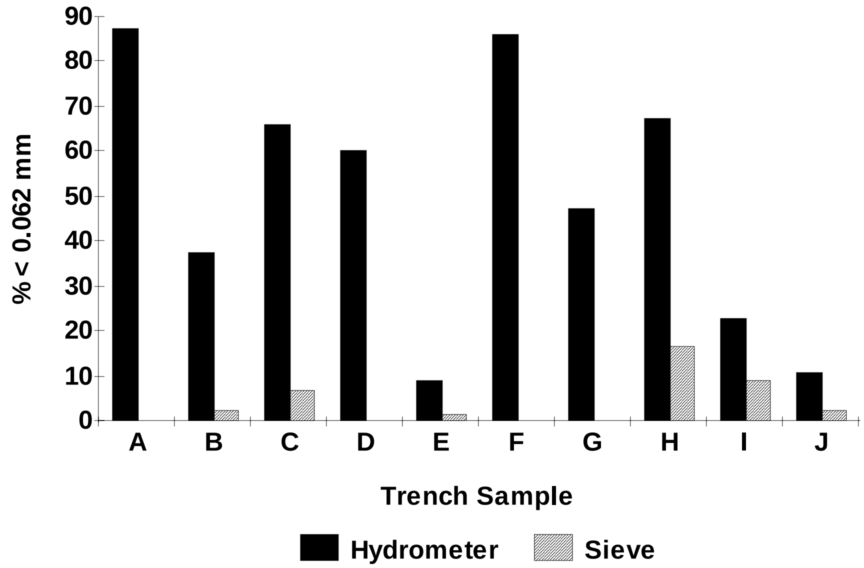

Figure 9. Comparison of the percent of the sample smaller than 0.062 mm for the ten trench samples determined from hydrometer analysis using a dispersent to the values from dry sieving.

A natural river has 'native' water without a dispersent - it would appear to be reasonable to assume the sizes of the sediment actually transported by the river are similar to the USGS native water measurements in Figure 6. The results presented above suggest both dry sieving and hydrometer analysis may give misleading results for the actual sizes of the sediment transported if the actual size is similar to the native water results. Using distilled water without dispersent to simulate native water in a grain size analysis using fall velocity may be useful for situations where the substrate is fine sediment.

For sandy sediment it may be useful to do either a hydrometer analysis of the substrate material without a dispersent or a wet sieve analysis. The information in Figure 9 suggests dry sieve analysis will underestimate the fines in the substrate.

Field observations of the Rio Puerco substrate quickly establish that cohesive fines are part of the substrate of the river. An overall recommendation from the analysis herein is that if cohesive fines are found proceed directly to wet techniques for size analysis. This recommendation is based on the information in Figures 8 and 9 that show dry sieve analysis completely underestimates the d50 size and of the percent of the substrate less than 0.062 as compared to wet techniques. Therefore, as stated in the recommendation, if the sample to be analyzed is from a river with some cohesive samples all of the samples should be analyzed using wet techniques. The cohesive samples (trench sample A as an example) should be analyzed using fall velocity techniques. Samples that appear to be granular (trench sample H for example) could be analyzed using wet sieve techniques.

It is very clear the analytical technique used in the laboratory determination of the particle sizes of suspended sediment and of the substrate must be part of the information reported in any study using grain size analysis. The laboratory techniques must match how the results are to be used in analysis.

The reason the temperature and precipitation data was present in Figure 3 was to show that the Rio Puerco watershed is semi-arid. It is probably not wise to assume the preliminary results herein apply to all rivers.

The results presented in this paper are preliminary and descriptive. Additional work will need to be done before hard conclusions can be drawn.

5. Acknowledgments

The trench samples were obtained from a trench dug to link stratigraphy and vegetation as part of a joint USGS Biological Resources Division and Water Resources Division project with Jonathan Friedman as the overall project lead.

6. References

ASTM. 1990. Standard Test for Particle-Size Analysis of Soils. Annual Book of ASTM Standards, Vol 04.08. Designation: D 422-63 (Reapproved 1990).

Guy, H.P. 1969. Laboratory Theory and Methods for Sediment Analysis. USGS-TWRI book 5, Chapter C1. 58 pages. U.S. Geological Survey.

Lambe, T. William. 1951. Soil testing for engineers. John Wiley and Sons. New York, NY 165 p.

Ortz, D., K. Lange, and L. Beal. 2000. Water Resources Data. New Mexico. Water Year 1999. Volume 1. The Rio Grande Basin, the Mimbres River Basin, and the Tularoas Valley Basin. Water-Data Report NM-99-1. U.S. Geological Survey. Albuquerque, NM.