Streams, floods, and sediment transport: a field exercise at Little Fountain Creek[1]

Background

The second week of September 2013 brought 24 inches of rain in 48 to 72 hours to the Colorado Front Range (Gochis and others, 2015)[2]. The intense rainfall resulted in flooding across the Front Range corridor including along Little Fountain Creek at the LSU Charles Barney Geology Field Camp (Field Camp) (Figure 1 and Photo below; note the washed out bridge and that the road bed has been scoured to bedrock).

Figure 1. Photograph of bridge, stream, and scoured bedrock.

Once conditions were deemed safe, the Wicks research group (funded by the National Science Foundation) mobilized to Field Camp to measure and photo-document sediment bedload at twelve stations along Little Fountain Creek. In addition, the Wicks group documented the infilling of the reservoir (Figure 2). After that initial sampling effort, members of Dr. Kory Konsoer's research group and Fluvial Geomorphology class have analyzed the initial dataset, assessed shear stress and bedload transport, and produced an initial numerical study that predicted what the discharge through Little Fountain Creek might have been during the extreme rain and flood event.

As part of the field camp experience, this project is based on you applying your geological knowledge while learning new written and visual communication skills (LSU CxC

[1] As part of the field camp course, this project is includes elements of the written and visual communication skills that are part of the CxC requirements.
[2] Gochis and other, (2015), the great Colorado flood of September 2013, American Meteorological Society, September 2015 issue p. 1461-1487

course). You should expect to spend 1.5 days in the field gathering data and 1.5 days with writing and drafting figures and table, editing, and proofreading your report.

Figure 2. Aerial photograph showing the sediment in the reservoir.

Project Outline and Objectives[3]

you will be conducting a fluvial sediment transport study in Little Fountain Creek basin. The overall goal is to compare the size of clasts in the streambed material to the size of clasts that can be transported by various flood events. Your objectives are to:

1. characterize the size, shape, and composition of the streambed sediment and interpret changes in the downstream direction
2. assess the size of the sediment that might be transported for a flood with a 2-yr, a 10-yr, and a 100-yr recurrence interval by
    a. generating a synthetic rating curve
    b. generating a recurrence interval plot using historical discharge data from the US Geological Survey for Little Fountain Creek
    c. calculating the discharge associated with a flood event that has a 2-yr, a 10-yr, and a 100-yr recurrence interval
    d. determining the maximum depth of water for events
    e. and calculating the threshold grain (clast) size using the equation of the Shield's diagram at high discharge
3. estimate the recurrence interval of the 2013 flood and the size of sediment that event might have transported
4. integrate knowledge gained in a written report with appropriate visual elements.

[3] You may very well find that you will be spending more time working with the data and writing the report than you will spend collecting data. This project is focused on interpretation and written and visual communication skills. Do not underestimate the time necessary to prepare an effective report.

The locations

Downstream reach is accessed by walking to the flagpoles and wandering down the four-wheeler path to the stream. Midstream reach is near the student dorms and is accessed by scrambling down the path to the stream. Upstream reach is near the bridge into Upper Camp and is accessed by walking up to the Bridge and scrambling into the stream on the downstream side of the Bridge. As your group might pick slightly different upstream and downstream locations along the three reaches, you must provide the GPS coordinate of the upstream and downstream ends of your selected reach.

1. Methods for objective one
    1.1. Shape, size, and composition are the fundamental properties of particles. The size and shape are related to processes of transport and deposition. Composition is related to source of the material. At each of the three locations, you will measure particles of the streambed sediment and calculate the overall size and sphericity and determine the composition. You will then interpret how your results change in the downstream direction.
    1.2. Read the short paper by Manley[4].
    1.3. At each location, measure the orthogonal longest (D_l), intermediate (D_i), and shortest (D_s) axes of 60 to 100 clasts, enter the data into a spreadsheet, calculate the values of the shape parameters, and make needed and useful graphs. Follow the Wolman count method, where you walk heel-to-toe and measure each and every clast at your toe. If a clast is less than 2mm in length, record sand (and yes, that counts within your 60 to 100 clasts). For convenience, use a staff to isolate which clast is at the end of your toe. Start at one end of your reach and move systematically along the reach. Gently place measured clasts back in the stream and be careful with placement so that you do not inadvertently remeasure a clast.
    1.4. You also need to determine the composition of each clast using the following categories: granite, gneiss, sandstone, limestone, and human artifact. If the clast is sand (less than 2 mm), please enter “sand” as both size and composition. (A small error is introduced by using “sand” as the composition; however, the interpretation of your findings will not change due to that error.)
    1.5. For each location and based on data from all of the clasts measured at the location, determine values for the basic descriptive statistics, such as mean, mode, median, and plot a histogram.

[4] Manley, P., Shape of gravel particles: what does it mean? Middlebury College, Middlebury Vermont.

1.6. For each location, determine the value of sphericity for each clast using Sneed and Folk (1958)[5] equation:

$$\psi_p = \left(\frac{D_S^2}{D_L D_i}\right)^{1/3} \text{(eq. 2)}$$

1.7. For each location, construct a classic Zingg diagram. Plot $\{D_i/D_L\}$ as the y variable and $\{D_s/D_L\}$ as the x variable. Divide the diagram in four regions by adding a horizontal line where $\{D_i/D_L\}$ = 0.66 and a vertical line where $\{D_s/D_L\}$ = 0.66. Label the regions, “bladed” in the lower left corner, “prolate” in the lower right corner, “oblate” in the upper left corner, and “equate” in the upper right corner.

1.8. Interpret changes in size, sphericity, shape, and composition in the downstream direction. You can use relative downstream distances (upstream, midstream, and downstream) OR you can use the distance between the three reaches that you would calculate from maps.

2. Methods for objective two

2.1. In order to assess the size of clasts that could be transported in a 2-yr, 10-yr, and 100-yr event, you need to have a relation between depth of water and discharge called a “rating curve”. In many cases, a rating curve is generated by measuring the discharge of the stream and calculating the average water depth at the same time and in the same location. This process is repeated many times and over a wide range of discharges and thus depths, then you can simply plot those data. However, you do not have time to measure discharge and depth over a wide range of discharge conditions, so you will need to construct a synthetic rating curve that is still a relation between discharge (x axis) and depth of water (y axis). A synthetic rating curve is based on an empirical relation, called the Manning equation and is not based on specific field actual data. The Manning equation has been calibrated over thousands of streams and is a valid empirical approach to generating a rating curve in absence of field data. [These are steps 4 and 5 and Figure 3 in Tharp (1983).] You need to complete this objective at ONLY ONE of the locations.

2.2. Read the article by Tharp (1983)[6]

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[5] Sneed, E.D. and Folk, R.L., 1958, Pebbles in the lower Colorado River, Texas, a study in particle morphogenesis, The journal of Geology, 66:114-150.

[6] Modified based on Tharp, T.M., 1983, A field exercise in fluvial sediment transport, Journal of Geological Education, 31:375-378.

2.3. In order to use the Manning equation, you must know the relation between channel depth and channel width so that you can calculate wetted perimeter and the areas available for flow for a range of depths. You need to measure the channel width for a range of distances above the streambed and make a detailed cross-sectional map of the shape of the channel and where distance above the streambed is the channel depth and distance from one bank to the other is the channel width. (Note: the channel depth is not the depth of the water.)

2.3.1. Draw a detailed diagram of the cross section of the stream channel (changes in the channel width as a function of distance above the streambed).

2.3.1.1. Assume that the cross section is rectangular a constant width.

2.3.1.2. The wetted perimeter (P) is that part of the perimeter where there is contact between water and the solid boundary (stream banks and bed).

2.3.1.3. Area available for flow in a rectangle is the width multiplied by the water depth.

2.3.2. Measure the slope of the reach using the provided hand levels.

2.4. Generate a synthetic rating curve from your data by calculating discharge (Q) for a variety of distances above the streambed using equation 3 and using the value of 0.035 for the roughness factor, n.

$$Q = \left(\frac{1}{n}\right) A_c R^{0.67} S^{0.5} \; (eq. 3)$$

2.4.1. Plot the rating curve by plotting depth (m) on the y-axis and discharge (m3s-1) on the x-axis.

2.5. Generating a recurrence interval graph by using the data below, calculate the recurrence interval using the following formula: (n + 1)/ m where *n* number of years on record and *m* is the number of recorded occurrences of the event being considered.

2.6. Calculate the threshold grain size (D_t; Tharp 1983) that could be transported by a 2-yr, a 10-yr, and a 100-yr event by applying equations 4 and 5.

Table 1. Maximum discharge and gage height for several years of record. Data from the U.S. Geological Survey for site 07105928.

Water Year	Date	Discharge (cfs)	Gage height (ft)
1989	16-May-89	2.42	5.4
1988	Aug. 05, 1988	2.61	8.5
1986	Aug. 08, 1986	2.75	13
1996	8-May-96	2.85	22
1983	Jun. 10, 1983	3.05	37
1979	Jun. 09, 1979	3.2	35
1984	Aug. 26, 1984	3.4	53
1987	Jun. 09, 1987	3.47	53
1981	Jun. 03, 1981	3.61	70
1998	5-May-98	3.62	27
1982	Aug. 21, 1982	3.77	85
1980	8-May-80	4.46	157
1985	Oct. 04, 1984	5.04	224
1997	Jun. 10, 1997	7.29	914

$$D_t = \frac{0.05 * (\rho_s - \rho)\, g}{\rho V^2} \quad (eq. 4)$$

$$V = \sqrt{(ghS)} \quad (eq. 5)$$

3. Methods for objective three

3.1. Given the estimated discharge of 2810 cubic feet per second for 2013 flood, what was the recurrence interval? (Check units!). Given the depth of water, what is the largest clast that would have been moved? Given that typical size of clast that might have been transported, what percentage of the streambed sediment at each location your studied might have been transported during the flood of 2013? Given the discharge of 2810 cubic feet per second and using your synthetic rating curve, what would have been the depth of water at your location? How tall are you?

4. Objective four: Project Write-up

4.1. Introduction – focus on what we know already and clearly state your objectives

4.2. Geologic Setting

4.3. Materials and methods

4.3.2. For Objective one

4.3.3. For Objective two

4.3.4. For Objective Three

4.3.5. For Objective Four

4.4. Results

4.4.2. For Objective one

4.4.3. For Objective Two

4.4.4. For objective Three

4.4.5. For Objective Four

4.5. Discussion

4.6. Appendix – field notebook

Remember to be specific.

Display your results using effective graphics and discuss your results particularly any changes you note as (relative) distance downstream increases.

I should be able to walk to the locations where you collected your data based on your description of the location (coordinates, sketches, etc).

I should be able to repeat your measurements based on what you tell me in the Methods subsections.

You need to be specific about how you analyzed the raw and produced final figures.

Remember to use callouts for all tables and figures that you add.

The discussion should address assumptions that you had to make, errors, significance of the results, and importantly, you need to link the discussion back to the Introduction (what have we learned compared to what we knew before?)

You also have to send me your field notebook. I need to see ALL field data, location, team mates, etc. Your field notes have to be clear. If your field notes are not clear, then how can you write up your report?