FIELD EXERCISE 2: EVOLUTION OF A MEANDER BEND

Field Trip Date: 22 April 2006

Report Due: 16 May 2006

The objective of this exercise is to analyze the evolution of a meander bend. Meander bends are a common feature of channels formed by flowing water; the fluvial processes in bends can be characterized generally when they are described relative to their downstream and cross-channel position in a bend. As a result, study of a single bend provides you with an analytical framework that can be applied widely. At this site, we also have the unique opportunity to track the recent development of channel form at this site, because water first entered this newly constructed channel in the summer of 2001. We also have a chance to investigate the role of channel design and alternative bank treatments on flow and erosion processes.

You will need to collect data and make observations that relate patterns in flow (water surface slope, direction, and velocity), shear stress, and bed material size to channel form. The basic approach will be to construct a base map that shows the plan form of the channel, record detailed observations on the map, and collect quantitative data on flow and bed material. Your field report will describe channel form, account for spatial variation in hydraulic and sedimentologic conditions based on their position in the bend, and describe past and likely future direction of channel evolution using your knowledge of fluvial processes.

Directions to the North Creek site:
Leave Johnson Hall parking lot @8:30 AM;
Drive north on 15th Ave NE;
Turn right (east) on Lake City Way NE;
Follow Lake City Way through Kenmore and into Bothell;
At the "big" intersection in Bothell, go straight up Main Street;
Pass through downtown, and continue on to the UW Bothell campus;
Turn right into campus and park in the first parking structure on the left.

Assemble on the viewing platform, out in the wetland, following the path down from the campus.

FIELD ACTIVITIES

We will work in groups for most of the day. **Each group must bring a compass, protractor, ruler, and calculator.** This exercise uses many of the same field techniques as the first exercise. If necessary, refer to the first handout for a detailed description of methods. This is not simply a repetition of the first exercise, however, so you are well advised to keep sight of the overall goals of this trip and to **read the instructions below!**

Each group will first complete the following initial tasks:

1. Draw a detailed tape-and-compass base map of "their" bend (note that more than one group may be working on the same bend, although at different cross sections);
2. Survey one cross-section of the channel and floodplain;
3. Characterize bed material texture at that cross section; and
4. Measure current velocity at that cross-section.

After each group completes the base map of channel form (#1), all members should copy it and annotate it individually. After you have completed all four listed activities, you are not done. Instead, continue to add detail to your map. You may want to do additional pebble counts, use tracers to examine 3dimensional flow structures and different levels and positions in the water column, and investigate the floodplain. Data that will be shared between all teams and class members will be the one cross-section survey and velocity measurement done at each cross section (tasks #2 and 4 above) and all pebble counts.

Task 1: Base map

Each group will construct a base map of their bend using a tape and compass. The map must include channel banks, water edge, cross-section location, the point bar, and any selected benchmarks identified in the field. The group should establish an "origin" for all measurements. Record the distance and compass bearing between the origin and features. Use these measurements to locate features on the map. Note that distances need to be scaled on the map. Report all bearings in terms of degrees east of north. While this is not intended to be a topographic map, you may report elevations of selected features. In particular, survey the point bar in sufficient detail to estimate sediment storage.

At each cross-section, use a level to measure the elevation of the left and right water edge, and also survey the left and right water's edge of your neighboring cross sections upstream and downstream. If you are the "first" or "last" cross section (or cannot sight an overly distant adjacent section), determine the location and bearing of another pair of water-edge measurements that will help characterize the water-surface slope through your section. Cross-sections should be perpendicular to flow, note any cross-channel variation in water surface elevation. MAKE SURE THAT THE LONGITUDINAL WATER SURFACE SLOPE IS NOT NEGATIVE AS YOU ARE SURVEYING (e.g., if you are working downstream, the mean elevation of the water surface should be progressively lower at each cross-section).

Task 2: Cross-section survey

Each group will survey one cross-section of the channel. Record the compass bearing of the survey so that the cross-section can be located on the map.

Task 3: Bed material texture

Perform at least one pebble count to characterize surface texture at the surveyed cross-sections. If there is textural variation across the channel, then sample material where you judge the movement of material to be most active. Sample uniformly across the channel only if you judge this to be the best representation of the material in active transport; this is not an exercise to characterize reach-averaged roughness (you've done that already).

Task 4: Current velocity

Make detailed current measurements at your cross-section for discharge and shear stress calculations. While your cross-section should be perpendicular to the channel, the current may not be aligned parallel to the channel. If so, orient the current meter to record maximum velocity (i.e. in the direction of the current). This can be determined by tying a piece of plastic tape to the current meter and pointing the current meter in that direction. Note that the direction of the current may change with depth and position across the channel. Record the compass bearing of the current for each velocity measurement. In addition, you should be able to make additional determinations of current direction (but not velocity) to show on your map (tie a piece of flagging on a stick and measure the orientation of the flow with a compass). Include two or more vertical profiles of the downstream velocity and as many current-direction vectors as you judge to be useful.

"Other" measurements

Once the group has completed a base map and completed these additional collective measurements, each person should copy the map onto their field notebook and begin to annotate it individually. Make observations that illustrate patterns in flow and geomorphic features relative to their position in the bend. Use tracers (e.g., small sticks or pieces of leaves) to help you observe flow through bend. Note the path of the swiftest current at different sections of the channel. Other observations could include surface and near-bed flow direction (using flagging tied to a wading rod), distinct textural patches of alluvium (i.e., bar, bed, and floodplain materials), vegetation, other roughness elements, bed forms (e.g., pools, bars/riffles, sand ripples), bank morphology (break points, slumps, height, materials), floodplain/terrace morphology. You are welcome to continue to collect information as a group, in pairs, or individually; some tasks will be more amenable to one style or another. Beyond the base-map information, however, everyone's data recording should reflect their own observations and handiwork

Your goal in making these (and other) measurements and observations is to characterize the interaction of flow and channel morphology in enough detail to describe how channel form is responding to, and influencing, the flow through the reach. Is there evidence of active erosion or deposition in this reach? Do vegetation patterns (e.g., exposed roots, stands of single-aged plants, distribution of aquatic vegetation) indicate recent changes in channel position and, consequently, active geomorphic processes? What dictates the location/direction of sediment transport? What is the distribution of coarse and fine sediments along the point bar and in the channel? What can you infer of the different types of sediment transport occurring in the bend? What accounts for sorting of sediment in the bend? Do coarse and fine grains move at the same time? Do they move along the same paths? Your observations should provide evidence for fluvial processes at work in the evolution of the bend and its potential migration across the floodplain.

DATA ANALYSIS

1. Channel geometry

The plan form of meanders is characterized by an amplitude, wave length, and sinuosity, channel width (w), radius of curvature (r_c). Other useful terminology for describing bends include the apex, where r_c is a minimum, and the point of inflection, which is the straight transition, often a riffle, between two bends. Leopold and Wolman (1957) observed that the wavelength of meanders (which spans two bends) is generally 7 to 12 channel widths. The planform of meanders has been found to vary with discharge such that low flows tend to make shorter radius bends and higher flows make longer radius bends (Friedkin 1945).

Provide estimates of these parameters at the field site. How would they change with discharge? What is the effect of meandering on the slope of the channel? Does the path of the swiftest current follow the centerline of the channel?

2. Hydraulic conditions

Energy losses (i.e., flow resistance) are associated with bends. If energy loss and flow resistance are increased at the bend, how do you expect the longitudinal water profile to deviate from that of uniform flow (i.e. in uniform flow, energy, water surface, and bed slopes are equal and depth is constant). Does the observed long profile concur with your theoretical prediction?

In severe bends, flow may separate from the channel. Extreme turbulence and large energy losses (and high flow resistance) are associated with flow separation. Flow separation can be observed where the direction of flow diverges away from the channel margin (e.g., at channel expansions). Leopold et al. (1960) found that flow resistance increases dramatically when r_c/w exceeds 2, which Bagnold (1960) attributed to flow separation. What is the value of the ratio at the observed discharge? at bankfull discharge? Do you observe flow separation at today's flow, and is it associated with the channel geometry or local obstructions?

The mechanics of flow through a bend can be generalized for a cross-section by considering downstream and cross-stream components of forces acting on the water. Water must change its direction toward the center of the bend as it flows downstream. The change in direction can be described at a cross-section in terms of centripetal acceleration (i.e., toward the center of curvature). Assuming no downstream change in velocity, the centripetal acceleration is equal to u^2/r.

Acceleration of water requires an energy gradient. For centripetal acceleration, the water at the outside of the bend must have more energy than the water at the inside of the bend. The cross-stream energy gradient may be expressed by "superelevation" where the water at the outside of the bend is higher the water at the inside of the bend. If downstream velocity and radii of curvature are constant across the channel, the cross-stream energy gradient per unit weight is given by:

$$Dh/w = u^2/(r_c\ g) \qquad (1a)$$

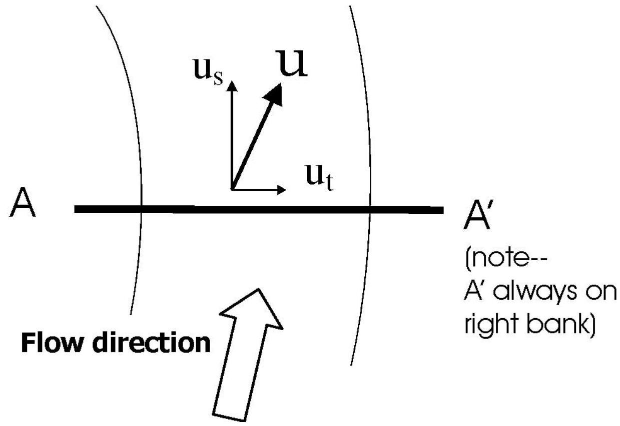
and so the superelevation can be calculated as:

$$Dh = u^2 w/(r_c\ g) \qquad (1b)$$

where u is downstream velocity and w is channel width (Chow 1959).

If velocity is constant and pressure is hydrostatic across the channel, what field observations would indicate a cross-stream energy gradient (consider the Bernoulli equation across the channel)? Is there evidence of a cross-stream energy gradient at any of the cross-sections?

Flow through a bend is helical or spiral so that water flows laterally across the stream and vertically between the bed and the surface as it travels downstream. Cross-stream currents are referred to as "secondary" currents or circulation (e.g., Richards 1982). Measured current velocity (u) at a point in a section (A-A') can be resolved into downstream (u_s) and cross-stream (u_t) components, where $u_s = u \cos(a)$ and $u_t = u \sin(a)$ and "a" is the angular deviation of velocity from the downstream direction:



Is the observed current direction always perpendicular to the cross-section where it is measured? Where is secondary flow (i.e., u_t) the strongest? Does current direction vary with depth? Do you find evidence of vertical flow? Illustrate patterns of secondary flow at a cross-section and through the bend.

3. Sediment transport

General patterns of erosion and deposition can be identified in meander bends. These patterns can account for the direction that a channel migrates across the floodplain and sorting of alluvium on bed, bars, and floodplains. Dietrich et al. (1979) and Dietrich and Smith (1984) provide a detailed description of shear stress fields, bed topography and sediment transport in a meander. In particular, they focus on how bed topography and shear stress interact to sort bed material across the channel. Their observations may provide you with some guidance about general patterns of sediment transport.

Describe patterns in shear stress and bed topography you observed in the bend. How does shear stress vary across and along the bend? How might patterns change at higher discharges? Describe trends in grain texture between different parts (e.g., from the top of the bar to thalweg, from the entrance to the apex of the bend). How might shear stress/bed topography patterns account for the distribution of alluvium in the channel? What types of sediment transport are active in this reach? Are there spatial patterns to sediment transport? Do coarse and fine bed load material follow the same paths? What can you infer from field observations about the direction of channel migration and bar/floodplain development?

Equilibrium has also been viewed as a balance between inflow and outflow of a system such that there is no net change in storage in the system. Can you determine if there has been a net change in sediment storage at this bend (consider in-channel, bar, and floodplain deposits)? Estimate rates of erosion and deposition. Is there evidence that the elevation of the channel has been stable, aggrading or incising over time? What can you infer about the history of this river from field observations, even after such a short period of time since its creation?

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