Final examination River Morphodynamics Kleinhans GEO3-4305 2008

This exam consists of three assignments. Be concise and sharp: extensive answers with some good remarks hidden in a flood of words will not earn you as many points as just good answers. Hint: if you do not know an answer, you could also provide two possible answers or directions or scenarios and work out both (or skip and go to the next question). Ask Kleinhans if you find a question unclear.

1. Rivers and floodplains

Imagine a river, much larger than the Rhine, in a wide floodplain, very far away from mountains. The supply of fines (wash load: clay and silt) to the river is as large as the supply of bed material (sand). The climate is such that there is almost no precipitation in winter and much precipitation in summer. The average day temperature in winter is about -20°C (253 K; remember that water melts at 273 K) for at least 6 months and in summer is about +20°C (293 K). The vegetation on the floodplains consists of shrubs, herbs and grass.

a) What river pattern do you expect? What bedforms and bars do you expect? Why? What are typical values for Shields number and Froude number and width-depth ratio for such rivers? Why this width-depth ratio?

b) What flow regime do you expect in this river? (When) do you expect floods? Why?

Imagine a sudden climate change, such that the vegetation on the floodplains changes to a thick forest.

c) Describe and explain the short-term (after a few decades) effects on river hydrodynamics.

d) Describe and explain the long-term effects on river and floodplain morphology.

Now imagine a sudden climate change, such that the vegetation does *not* change but the winter temperature is on average no longer below the freezing point.

e) Describe and explain the long-term effects on river and floodplain morphology.

Two researchers want to estimate the annual bed sediment load of this river and want to collect enough accurate hydrodynamic parameters to be able to calibrate an appropriate sediment transport predictor. Measurements are expensive so it is essential to focus on the methods that are most accurate and allow derivation of other non-measured parameters.

f) Which parameters must be measured? In what conditions? Which method (for each parameter) do you advise?

2. Living on an alluvial fan

Where the Waiho river flows out of the mountains, it forms an alluvial fan. Artificial levees have been built decades ago along the river, and a village, Franz Josef, is located on the fan next to the river. The Waiho river is located on the west coast of the South Island of New Zealand, where the annual precipitation is about 10 m (compare to Netherlands where it is less than 1 m). The river derives its flow and sediment, coarse gravel, from the Franz Josef glacier and from a catchment next to, and hydrologically isolated from, the glacier.
There is a sharp transition from mountain range to alluvial fan, and this transition coincides with a major fault system that produces heavy earthquakes. The catchment is connected to the river through a narrow gorge through the last mountain. (If you saw the Lord of the Rings movie after Tolkiens books: the flood that washed away the Black Riders in pursuit of the Hobbits was filmed at exactly this location.)

a) What river pattern do you expect? What bedforms and bars do you expect? Why? What are typical values for Shields number and Froude number and width-depth ratio for such rivers? Why this width-depth ratio (refer to question 1a in a concise answer)?

b) Describe the general evolution of this river that you expect; will it remain stable, erode or aggrade in the coming decades? Why?

Imagine the following (realistical!) scenario. A large earthquake causes very large landslides on the slopes of the gorge, which then block the gorge by forming a natural dam of loose sediment just upstream of the river and 1 km from the village. According to the laws of Murphy, this event will coincide with heavy rain storms so that a lake forms behind the dam. Then a flow starts to seep through the dam...

c) What will happen? Will the dam erode gradually or will it fail catastrophically? Why? (Remember the flume experiments but also consider possible differences between your experiments and this situation.)

d) Imagine a catastrophical failure of the dam that will also cause the artificial levees to fail. How can it be calculated (by simple means) how much time the villagers have to flee for this flood wave? Do you expect survivors?

e) Describe long-term (=decades) effects of this rare event on the fan evolution.

3. River bifurcations

I. Consider the following problem. 300 years ago, politicians decided that the discharge division over the Dutch Rhine branches should be fixed at 2/3 through the Waal, 1/3 through the Pannerdensch Kanaal (at the first bifurcation), of which 1/3 should go through the IJssel and 2/3 through the Nederrijn (at the second bifurcation which has the Pannerdensch Kanaal as its upstream branch).
For low flow and moderate floods, the bank protection works at the bifurcations have been modified such that the ratios are about correct. However, for the design flood (i.e. the hypothetical flood that might occur every 250 years and during which the levees should not fail) the division differs: more flow goes through the Pannerdensch Kanaal.
Note that the Pannerdensch Kanaal has a strong armour layer. Also note that bank protection works in all Rhine branches are founded on subsoil sediment such that common floods will not undercut these works.

a) Describe potential hazards during the flood and on the long term associated to increased flow through the Pannerdensch Kanaal, and in which branch these hazards may occur.

II. Consider an anastomosing river. This is a river with several parallel branches with cohesive and vegetated floodplains in between. These branches are connected at river bifurcations (and confluences of course). During most flow conditions, even below bankfull, all channels are filled with water along their entire length.

Saskatchewan River, Cumberland Marshes, Canada. Courtesy Norm Smith.

There is one controversial theory by Huang and Nanson that explains the existence of anastomosing rivers. This theory demonstrates that the sediment transport capacity of several parallel branches in a river is slightly larger than in a single channel that conveys the same discharge as the multiple channels together. In other words, multiple parallel channels are more efficient in transporting sediment than a single channel.

b) Can this theory explain the existence of multiple channels? Why (not)?