Monitoring of restoration impact on geomorphology and hydraulics

Background & motivation:
Monitoring of restoration impacts on geomorphology (channel form) and hydraulics is carried out by Umeå University, led by a fluvial geomorphologist, Lina Polvi Sjöberg (PhD). The surficial geology and stream geomorphology in northern Sweden is strongly controlled by former continental glaciation in two ways: (1) glaciations have caused widespread glacial deposits (e.g., till, eskers, moraines) that contain a mix of sediment sizes including very coarse boulders; (2) land uplift has divided the landscape by the former highest-coastline (FHC; at ~250 m above sea level), above which there are only glacial deposits with mostly coarser sediment and below which land that has been underneath sea level and thus contains finer deltaic sediment. River systems extend above and below the FHC, all of which were subjected to timber-floating and were thus channelized, but rivers above and below the FHC may respond very differently to restoration of geomorphic complexity. In addition to the different sediment sizes, rivers respond differently to different flow magnitudes, which correspond to stream size or drainage area. Therefore, geomorphic monitoring of river restoration in northern Sweden needs to encompass a span of different river sizes both above and below the FHC. Furthermore, monitoring should ideally span several years post-restoration. Rivers are inherently and naturally dynamic, renewing habitat areas for a multitude of organisms. Because restoration may lead to increased dynamism it is important to monitor restored reaches twice after restoration to determine whether there has been natural geomorphic re-working of the channel.

Study design:
Geomorphic monitoring of restoration will be monitored within the Lögde River catchment along the mainstem river and its tributaries. The eight monitoring sites will be equally divided between the mainstem and tributaries and between above and below the FHC, so that there are two sites in each category (a see Table 1). The length of the study reach (a section of a river with approximately similar channel geometry characteristics throughout is length) will be approximately 10 times the channel width before restoration.

Site abbreviations	***Above FHC***	***Below FHC***
Lögde River		
Mainstem	LMA1 LMA2	LMB1 LMB2
Tributary	LTA1 LTA2	LTB1 LTB2

Table 1. Geomorphic monitoring sites: abbreviations

Timeline:
All sites will be surveyed before restoration and 1 year and 3 years after restoration (Table 2). Four sites along the Lögde River and its tributaries were surveyed during summer 2017 that were originally all planned to be restored in the late summer/autumn of 2017. However, due to high flows only LMB1 was restored in 2017 and the 1-year post-restoration survey will be conducted in 2018. The remaining three sites (LMA1, LTA1, LTB1) will have 1-year post-restoration surveys during 2018. This is not deemed to affect the results; in particular for the sites above the FHC and thus contain very coarse sediment (gravel, cobbles and boulders up to 1-2 m in diameter), there is very little sediment transport and thus geomorphic re-working of the channel.

Year	***Lögde River & tributaries***		***Restoration***
	Above FHC	*Below FHC*	
2017	Pre-restoration surveys: LMA1, LTA1	Pre-restoration surveys: LMB1, LTB1	LMB1
2018	Pre-restoration surveys: LMA2, LTA2	Pre-restoration survey: LMB2, LTB2 1-year post restoration: LMB1	LMA1, LMA2, LTA1, LTA2, LMB2, LTB1, LTB2
2019	1-year post restoration: LMA1, LMA2, LTA1, LTA2	1-year post restoration LMB2, LTB1, LTB2	
2020		3-years post restoration: LMB1	
2021	3-years post restoration: LMA1, LMA2, LTA1, LTA2	3-years post restoration: LMB2, LTB1, LTB2	

Table 2. Timeline of pre- and post-restoration surveys at monitoring sites.

Field methods:
The field methods are divided into two components: surveying the channel geometry and measuring flow velocities. As far as the channel geometry, we will survey ten cross-sections, the longitudinal profile of the thalweg (deepest part of the channel) and chanel edges (including potential islands). Measurements of flow velocity will be taken at multiple points along five transects. Depending on the size and location of the channel at each site, two different methods are used.

- *Main channel*: In the main channels of the Lögde River, which may be too deep or fast-flowing to wade, we will tow a small raft that is carrying an Acoustic Doppler Current Profiler (ADCP). An ADCP is a high-tech instrument that measures both the distance to the channel bed and the velocity along the depth profile across the entire cross-section using Doppler technology. Using this equipment, we will obtain an accurate measurement of the channel morphology and velocity (from the channel bed to the surface of the water) in the entire reach. From these data we can calculate all of the morphologic and hydraulic metrics mentioned above. To get additional measurements of the channel edge, we can either use an RTK-GPS, which takes GPS points at centimeter-scale accuracy, or a total station. A limiting factor of using the RTK-GPS is that there is both connections with satellites and mobile telephone towers, this can be difficult at some of the more remote sites and where there is a lot of forest cover.

- *Tributaries*: To use the ADCP, the water depth must be at least 30 cm deep and without too many obstructions in the channel (e.g., wood, large boulders). Therefore, in the tributaries and in narrower/shallower sections of the mainstem, it may not be possible to use the ADCP. Since these channels should be wade-able, we will use a total station (that surveys to mm-scale accuracy with the use of lasers and no connection to satellites or mobile-phone towers are necessary) to survey the channel morphology and a velocimeter (which measures velocity at specific points in the water column, approximately five per cross-section) to measure velocities.
- *All channels*: At all sites, we will also survey the location, length and diameter of all instream wood that is found partially or completely within the channel.

Data analyses:

The data will be analyzed in three steps: (1) quantification of channel form and velocity at each site at each time period, by calculating average values of, for example, channel width and channel slope; (2) spatial analyses of channel form and velocity measurements at each site at each time period, by determining how geomorphically complex each site is. Geomorphic complexity is calculated as the variation around the mean values of, for example channel width and channel slope. If there is high variation in the channel width along the reach, then the channel is more complex than if the width is constant. Finally, (3) a temporal analysis will be conducted, evaluating how the average values, complexity and physical location of the channel changes with time before and after restoration (Figure 1).

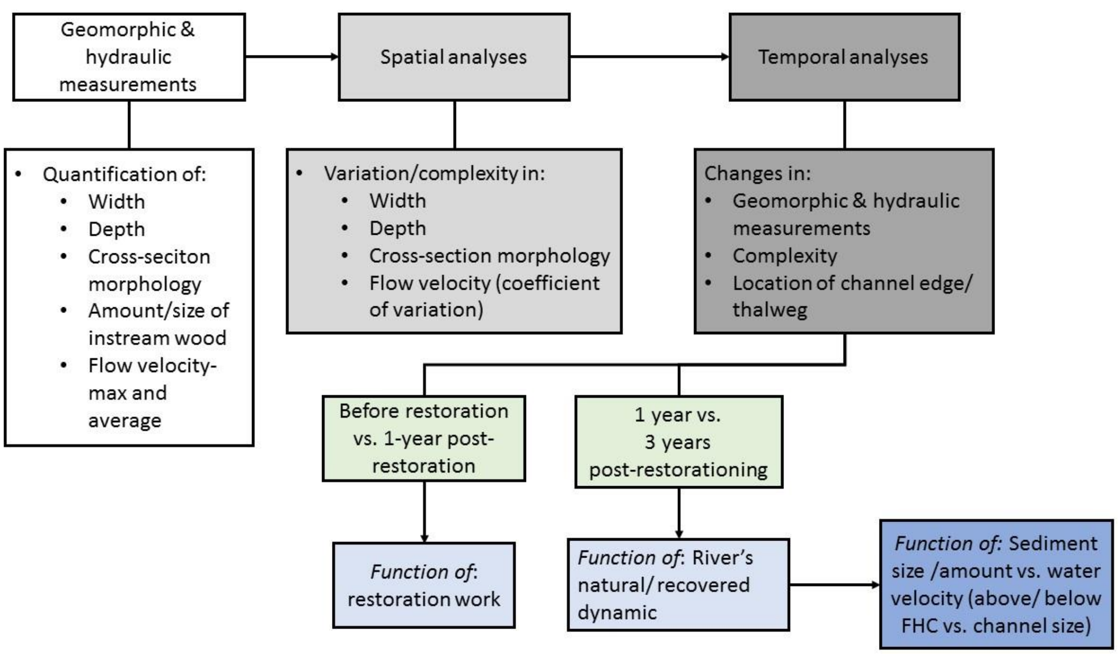
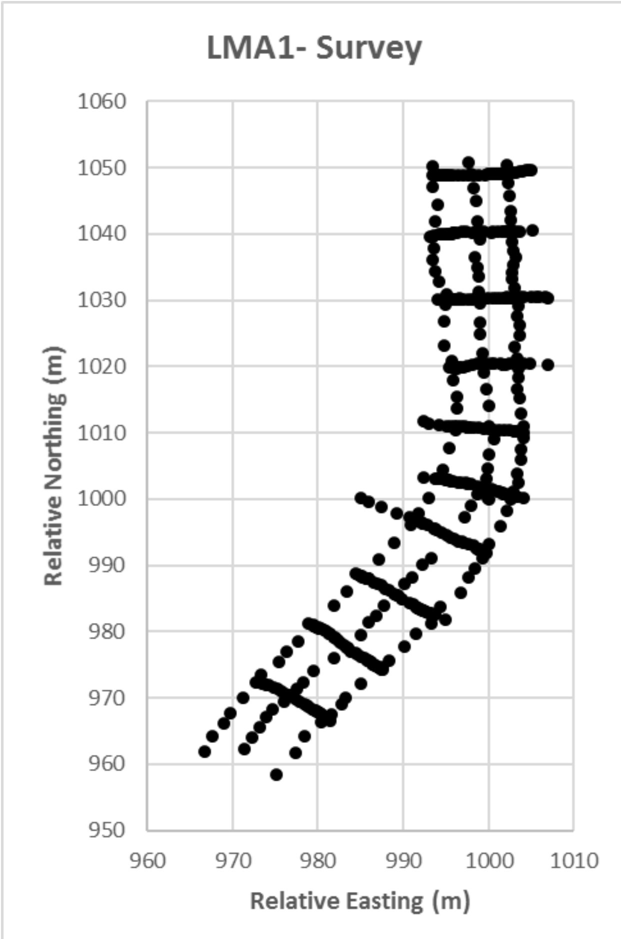


Figure 1. Flowchart showing the work flow for analysis of geomorphic and hydraulic measurements.

Preliminary results:

After one field season (summer 2017), data has been collected at four sites along the Lögde River and its tributaries. The ADCP could only be used at LMB1, which was the widest and deepest reach (Figure 2); an RTK-GPS surveyor was also used at LMB1 to obtain measurements of the channel edge (Figure 3). During surveys of the other reaches the water level was too low and the ADCP would not be able to move unobstructed and get good readings. Therefore, a total station and velocimeter was used to survey the remaining sites (Figures 3-4).

Figure 2. Photo of ADCP being towed across a cross-section at LMB1. Sea-fishing rods and reels were used to pull the ADCP on its raft back and forth across the channel.



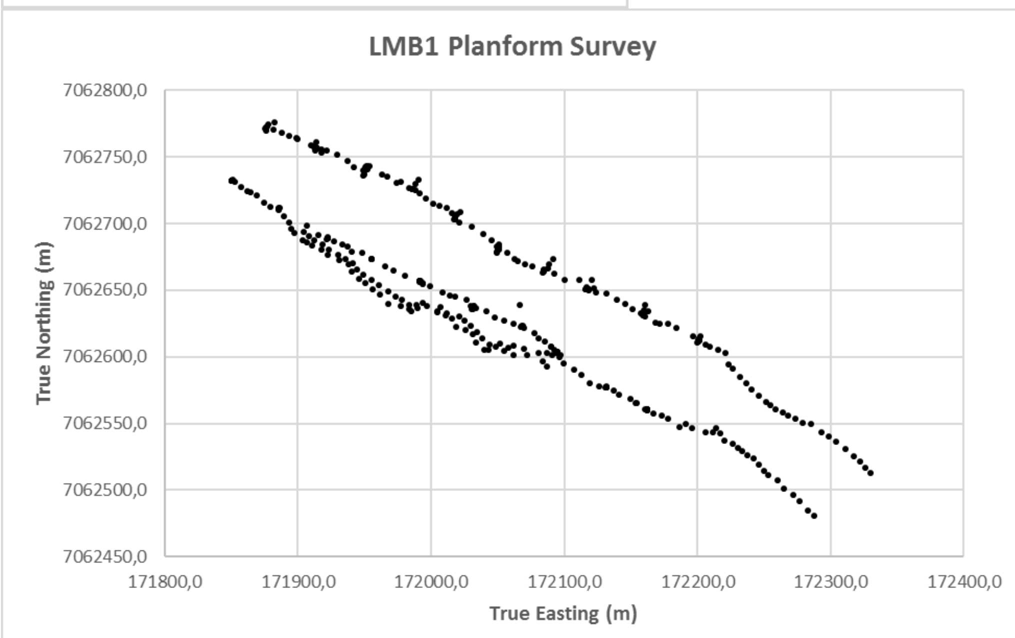


Figure 3. Surveys of the sites along the mainstem of the Lögde River. Transects are only shown on LMA1 as the ADCP survey was done on LMB1 and thus not included in the channel edge survey.

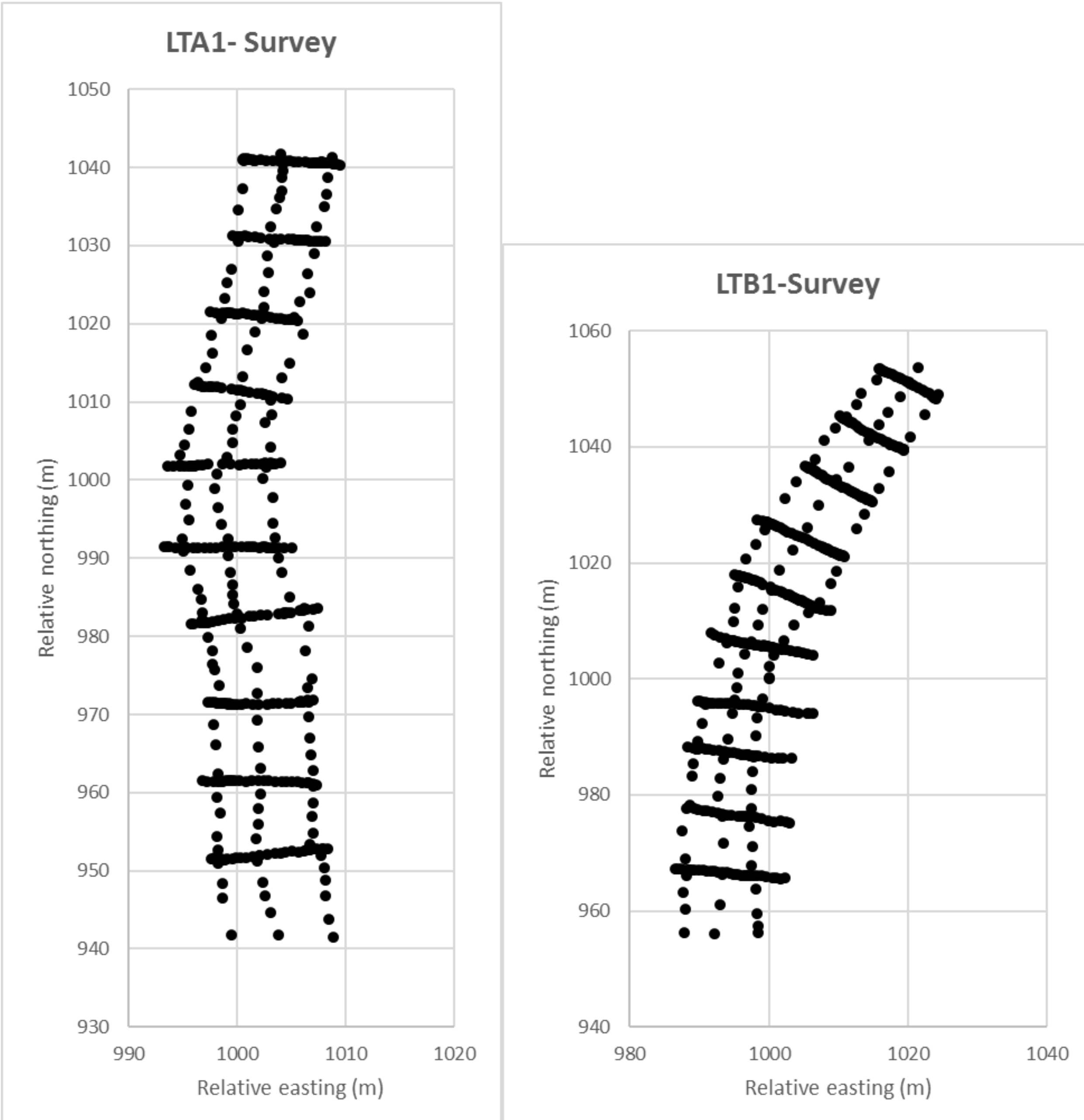


Figure 4. Examples of survey data obtained from the tributaries to the Lögde River (LTA1 and LTB1) pre-restoration. Flow direction is from top to bottom. The channel edges (where the water would overtop the bank) as well as thalweg (the deepest/fastest part of the channel) are shown in addition to 10 transects.

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