# Updating of hydrographic features in topographic base information based on airborne laser scanning data

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## 1. Introduction

The limited validity of maps over time and the consequent need to periodically update topographic base information has long been recognized. As all the other features, also hydrographic features in topographic databases require updates because of changes in land surface conditions, but also due to possible changes in user requirements and improvement of sensor technology. Traditionally updating of hydrographic features has been carried out by the photogrammetric techniques, which are, however, considered of having quality deficiencies for channel extraction at a basin scale (Heine et al., 2004).

Many countries, including Finland (MMM, 2006), are collecting country-wide airborne laser scanning (ALS) data for various uses (Hyyppä, 2011). In recent times, ALS has proven to be useful technology in revisions of topographic data, including roads (Zhao et al., 2011), buildings (Matikainen et al., 2003) and even water bodies (James et al., 2006; James and Hunt, 2010; Poppenga et al., 2013). However, updating the features of a topographic databases is not a trivial task; it involves more than modifying an ageing database and sometimes, for example, the cartography-driven interpretations and classifications of the national mapping agencies (NMA) clashes with the needs of e.g. environmental modelling. When versatile use of ALS data is positioned within the National Spatial Data Infrastructure (NSDI) framework, it may be seen as an excellent source for producing high quality, up-to-date, comprehensive and interoperable spatial data (Rainio and Isotalo, 2011) corresponding to the requirements set by the NSDI initiatives and the INSPIRE directive.

The use of ALS has revolutionized the usefulness of terrain analysis (e.g. Kraus and Pfeifer, 1998; Briese and Pfeifer, 2001; Raber and Cannistra, 2005; Nelson et al., 2009; Hyyppä et al., 2009). Dense sampling of complex landscapes makes ALS-derived digital elevation models (DEM) suitable for large-scale risk assessment and mapping (e.g. Szwkely et al., 2008). Such a level of detail (Barber and Shortridge, 2005), in turn, is often problematic for hydrologic modelling, where pre-processing is required to remove unwanted sinks that impede the continuous flow and results in topologically inconsistent river network (e.g. Nelson et al., 2009). Furthermore, the fuzzy delimitation of channel heads (e.g. Montgomery and Dietrich, 1989) is a complex problem, where a univariate solution (e.g. setting a threshold for flow accumulation) is insufficient (James and Hunt, 2010).

This paper focuses on determining the suitability of country-wide ALS data for hydrographic feature extraction and its potential use as a support for representing the flow lines of the 1:10 000 Topographic database (TDB) by the National Land Survey of Finland (NLS). The TDB offers a range of possibilities for applications ranging from using it as a base map to land-use planning and environmental modelling (NLS, 2011).

## 2. Materials and methods

The study area consists of largely forested valleys, a number of lakes and swamp areas, various pastures and dwellings covering nearly 9 km² (Figure 1) close to Helsinki, Southern-Finland. The reference stream network used for completeness assessment was manually digitized from the relief shaded DEM created from the FGI´s ALS data (Table 1) and close-infra red orthophotos (0.2 ground resolution) both collected for establishment of the Nuuksio test environment (Sarjakoski et al, 2007). The FGI´s ALS data required pre-processing actions in order to extract the relevant bare earth data needed to generate the DEM. The ALS data was first calibrated in TerraMatch, where the Find Match tool (Soininen, 2011) resolved the misalignments detected between the laser scanner, IMU and the scanner mirror scale. Finally, the data was classified in TerraScan by an automated procedure which categorized points into bare ground, vegetation and building roof point classes. Correctness of the reference stream network was assessed by extensive field checking. In addition, a total number of 129 reference points representing channel centre lines and confluences were mapped during the field survey using Virtual Reference Station (VRS)-Global Positioning System (GPS). The reference points were collected for positional accuracy assessment purposes.

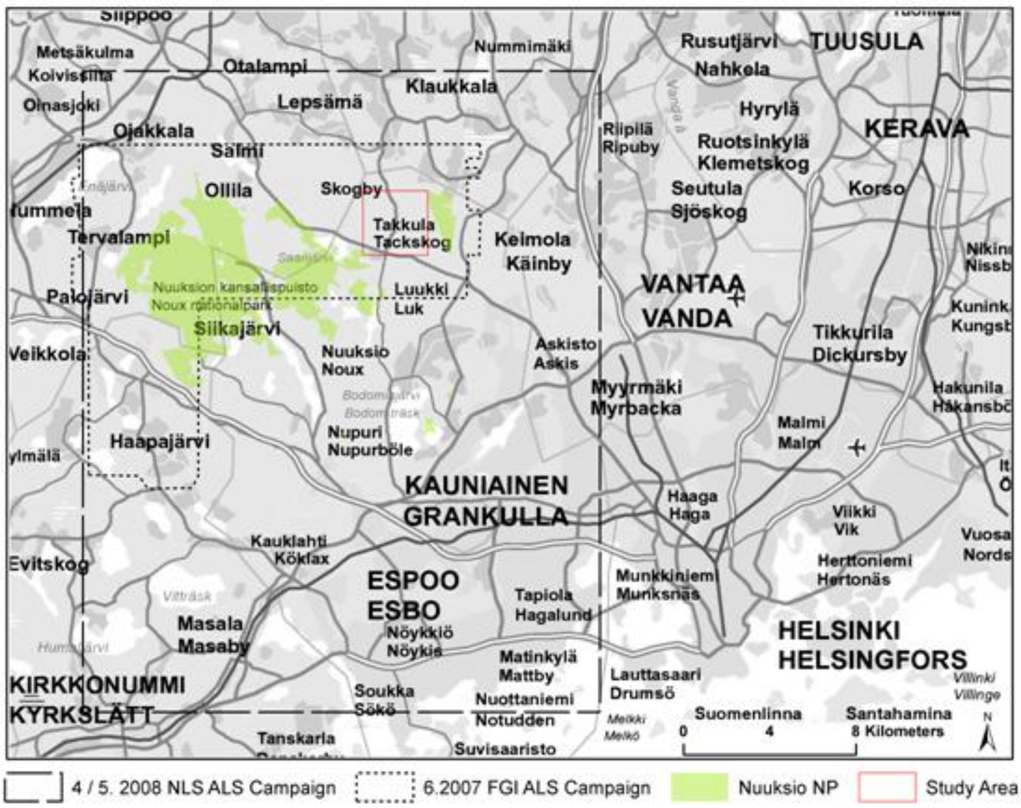


**Figure 1. Study area**

**Table 1.** ALS Data sets used in the study

| | Elevation datasets | |
|---|---|---|
| Data | NLS LIDAR point cloud | FGI LIDAR point cloud |
| Purpose | Automatic extraction of hydrographic network for updating the TDB | Manual extraction of hydrographic network to be used as the reference data |
| Producer | National Land Survey of Finland | Finnish Geodetic Institute |
| Scanning date | 2-4 April 2008 | June 2007 |
| Flying altitude | 1900 m | 1000 m |
| Average point density | 1.1 pnt/m$^2$ | 8.9 pnt/m$^2$ |

The stream network for updating the TDB was automatically extracted from the 1 m resolution DEM created from the NLS ALS point cloud (Table 1). The extraction of specific drainage threshold vector polylines was executed from D8-based (O'Callaghan and Mark, 1984) flow accumulation grids. By this approach, we were able to extract channels at different drainage density thresholds by adjusting the values according to the user's needs. Unlike the sink filling method (Jenson and Domingue, 1988), which may result in large artificial flat regions behind spurious barriers (Reuters et al., 2009), channelling (Wood, 2009) was used in this study. The latter method guarantees the flow connectivity even in the most troublesome spots by carving a descending path along the surrounding cells until a point of lower elevation is found.

For positional accuracy assessment purposes, the calculation of RMSE values was carried out in accordance with the ASPRS National Standard for Spatial Data Accuracy (ASPRS, 1998). According to the NLS's data specification, the positional accuracy of the water network centrelines has an RMSE of 5 m for all watercourse lines (NLS, 1995, 2006).

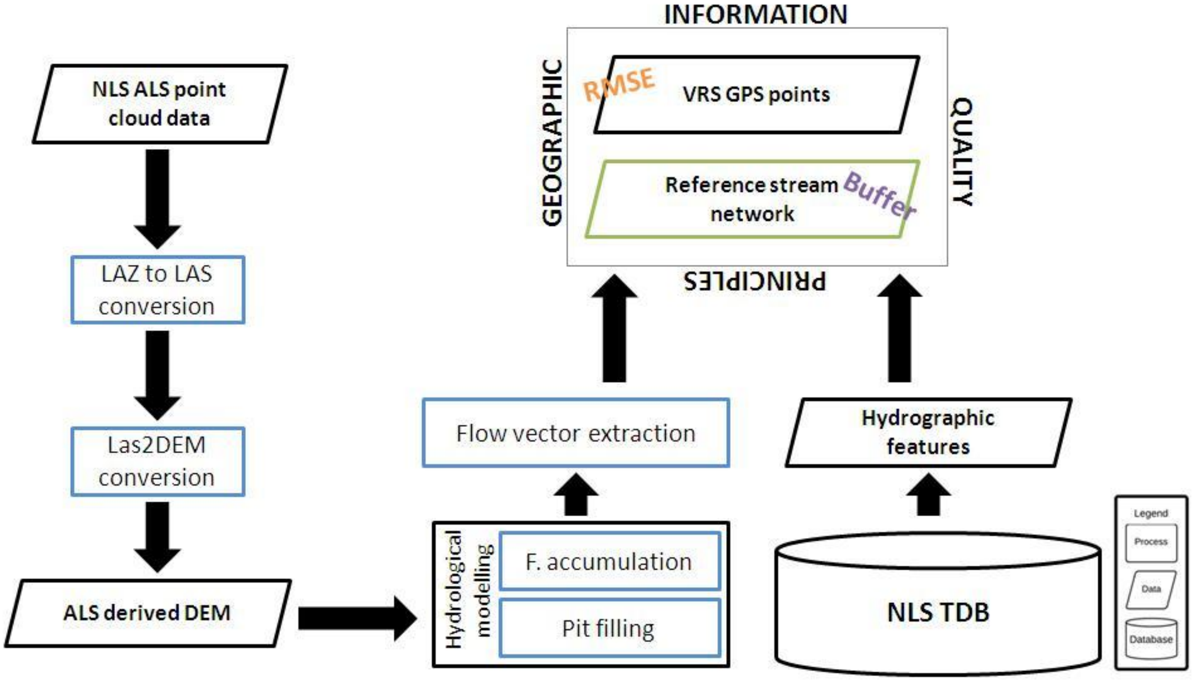


**Figure 2. ALS-based DEM stream delineation diagram**

## 3. Results

According to the preliminary results, the quality of the stream network extracted automatically from the NLS ALS data looks promising and laser scanning appears to be superior in finding streams under quite dense canopy. In this respect, the analysis has revealed the existence of errors of omission in the current TDB. The study also shows that in identified streams, the RMSE values of the current TDB (4,6 m) meet the requirements of the production specification. In the case of ALS, RMSE values may drop up to 1.8 m. Despite the general improvement in performance, gentle topographies (Figure 3) and human-impacted areas (Figure 4) remain the greatest challenges for automatic feature extraction methods from ALS. In these instances RMSE values increase accordingly.

These results are consistent with the ones presented by Colson et al. (2006), who stressed the challenge of mapping low-relief areas with ALS. The adoption of different drainage thresholds counteracts in some measure similar matters in the headwaters with a realistic approximation to the observations in the field. In this regard, it is of importance to mention that no other errors of omission than those caused by the terrain complexity capturing were identified in the ALS-derived vector flow lines. Such errors are in some cases substantial in NLS TDB vector streams.

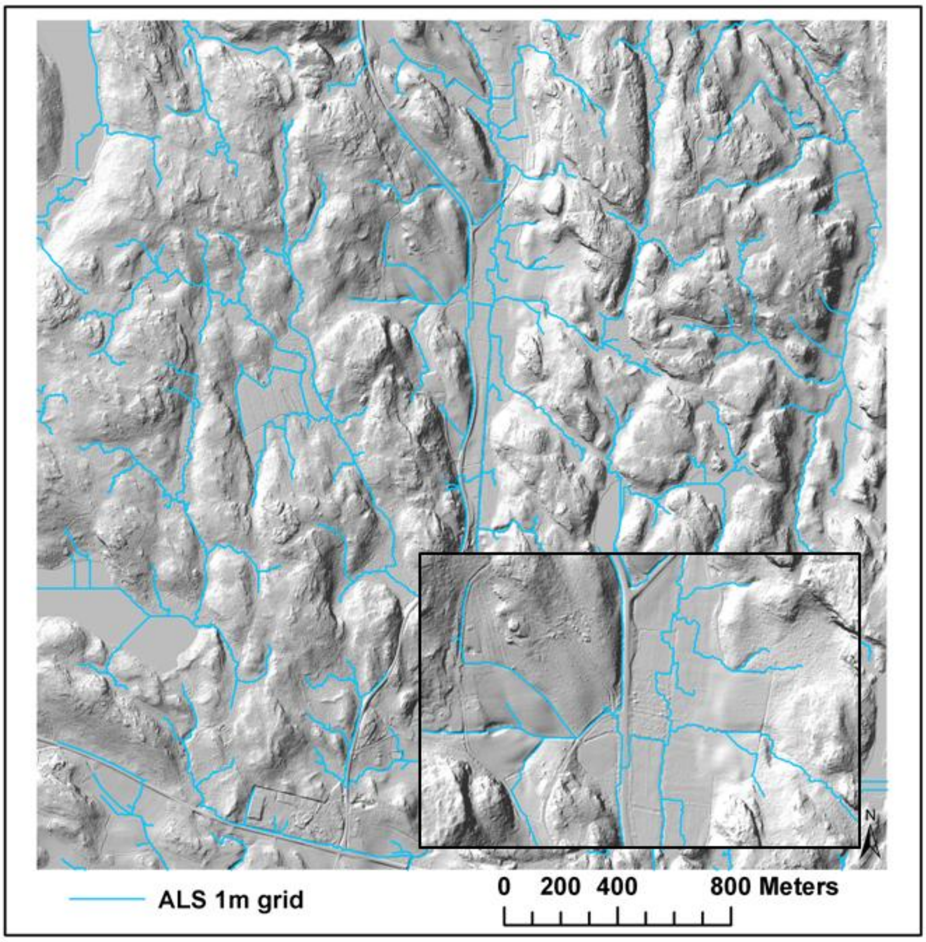


**Figure 3. ALS-based automatic streams extraction in the central plain of the study area positioned on a hillshaded DEM**

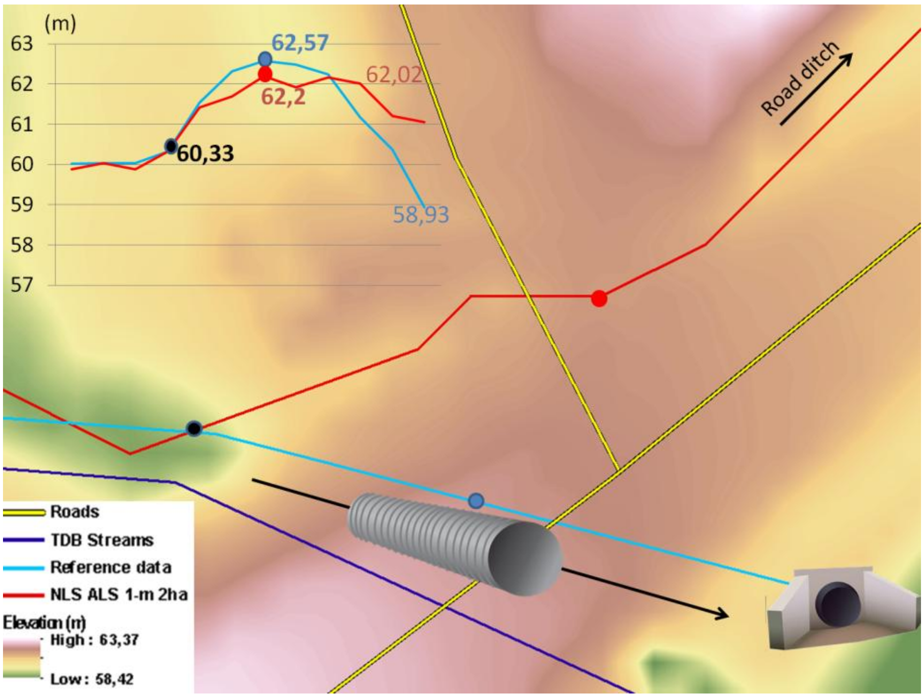


**Figure 4. ALS-based flow route deviation in an engineered landscape.**

## 4. Conclusions and future work

The study focused on usefulness of ALS data for capturing automatically hydrographic features at a basin scale and find appropriate answers to the various major challenges entailed by its use. Furthermore the use of ALS as a source of a potential update for NLS 1:10 000 TDB was explored. Digital map databases need to be updated, either because land surface conditions suffer numerous variations or because traditionally employed techniques have proven to be inadequate for large-scale mapping.

When these findings are further elaborated and validated the findings of the study may have a number of important implications on the usefulness of future topographic maps. Above all, ALS could make new, large-scale mapping generation possible (James and Hunt, 2010) and its efficiency would be proven by both, highly detailed capturing and greatly accurate positioning. The use of ALS as a support for conventional means of capturing hydrographic features could lead, as a consequence, to a more complete understanding of landscape patterns (Campbell, 2002).

## 5. Acknowledgements

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