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HIGH-DENSITY AIRBORNE LiDAR POINT CLOUD FOR DIGITAL TERRAIN MODELS IN SMALL STREAM ASSESSMENT AND REHABILITATION

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Abstract

Accurate topographic data are essential for the assessment and planning of interventions along small streams and narrow valleys, where traditional survey methods are often constrained by limited access, dense vegetation, and complex terrain. Airborne LiDAR represents a reliable solution, producing high-density point clouds that capture topographic variations, channel geometry, old hydraulic works, and subtle landscape features often missed by conventional techniques. This study aims to demonstrate the workflow for UAV-LiDAR data acquisition and processing, including flight planning, PPK data processing, point cloud classification and filtering, and the generation of high-resolution Digital Terrain Models (DTMs). These results provide a basis for hydrological analysis, planning, and regulatory approvals, supporting engineers and hydrologists in intervention design planning.

Key words*: design planning, Digital Terrain Models, LiDAR, small streams, UAV.*

INTRODUCTION

Small streams represent essential components of fluvial systems, providing important ecological, hydrological, and socio-economic functions in fluvial landscapes. Despite their relatively small size, these watercourses contribute significantly to watershed connectivity, sediment transport, nutrient cycling, and ecosystem services, supporting both natural habitats and human activities (Ferreira et al., 2023). In many regions, small tributaries are particularly vulnerable to morphological alterations and channel instability, driven by both natural processes and anthropogenic pressures. These factors can increase flood susceptibility, accelerate bank erosion, and affect the performance of existing hydraulic infrastructure (Lin et al., 2020; Wang et al., 2021).

These processes are closely linked to the dynamic nature of fluvial environments, where erosion, sediment transport, and deposition continuously reshape channel and floodplain configuration. The interaction between natural processes and anthropogenic influences controls river corridor evolution and flow behaviour. Understanding these mechanisms allows a more accurate evaluation of channel stability and contributes to effective river management strategies (Sabou et al., 2025).

Accurate terrain representation is therefore required for the assessment, planning, and design of river engineering interventions, since topography governs flow direction, velocity, and water distribution. Digital Terrain Models (DTMs) are commonly used as input for hydraulic simulations, including flood modelling, channel morphology assessment, and hazard mapping (Muhadi et al., 2020). In small stream environments, where micro-topographic variations can significantly alter flow patterns, the quality and resolution of topographic data strongly influence modelling reliability (Li et al., 2021).

Conventional surveying methods, such as Global Navigation Satellite System (GNSS) receivers and total station measurements, face significant limitations in small stream environments, where restricted accessibility, dense vegetation, and steep terrain reduce data

coverage and increase acquisition time, often resulting in incomplete terrain representation (Sestras et al., 2025a). Traditional cross-sectional surveying approaches, although accurate, are time-consuming, costly, and may involve operational risks, while also failing to provide spatially continuous and sufficiently dense topographic representation of river environments (Gou et al., 2026). These constraints highlight the need for alternative approaches capable of capturing detailed topographic information in complex conditions.

LiDAR (Light Detection and Ranging) technology has proven to be an effective solution for acquiring high-resolution topographic data, as it generates dense three-dimensional point clouds that capture terrain morphology, channel geometry, and surrounding features (Marotta et al., 2021). Unlike photogrammetric methods, LiDAR data can be acquired under a wide range of conditions, including low-light or cloudy environments, while its capacity to penetrate vegetation enables the extraction of ground points in densely vegetated and urban areas, supporting the generation of reliable DTMs (Muhadi et al., 2020). At the same time, the integration of UAV photogrammetry and LiDAR enhances terrain modelling by leveraging the strengths of each method, enabling more accurate representation under varying surface and environmental conditions (Sestras et al., 2025b).

The development of unmanned aerial systems has further extended the use of LiDAR in environmental and engineering applications. UAV (Unmanned Aerial Vehicle) platforms enable flexible data acquisition at high spatial resolution, particularly in areas where existing elevation data are limited or insufficient in detail for accurate analysis (Trepekli et al., 2022). These systems are increasingly applied in flood modelling and terrain representation, especially in small basins where detailed topography is required for reliable simulations (Annis et al., 2020; Li et al., 2021). UAV-based LiDAR surveys can achieve centimetric accuracy, enabling the detection of topographic features such as small channels, roads, or surface irregularities that influence flow behaviour and flood propagation (Li et al., 2021).

High-density LiDAR datasets enable a detailed representation of terrain morphology, including channel features and floodplain topography, improving the accuracy of flood simulations. These datasets also support the identification of stream channels and tributary networks, as well as the extraction of morphological characteristics of river corridors (Grau et al., 2021). LiDAR-derived data have proven effective in generating Digital Elevation Models (DEMs) for hydraulic modelling and flood hazard assessment, particularly when integrated with simulation tools such as HEC-RAS (Mihu-Pintilie et al., 2019; Stoleriu et al., 2020).

The application of hydraulic models is often constrained by the need for large volumes of input data, including detailed stream geometry and flow characteristics, which are not always available in small or urban stream environments (Bolick et al., 2023). Most modelling studies also focus on larger river systems, while small streams are less frequently analysed, mainly due to the limited availability of consistent high-resolution topographic data, which increases uncertainty in hydrological and hydraulic analyses (Annis et al., 2020).

Beyond terrain modelling, LiDAR data support the analysis of geomorphological processes and terrain dynamics. Repeated acquisitions enable the detection of surface changes and the quantification of erosion and deposition through Digital Elevation Model of Difference (DoD) approaches (Li et al., 2024). The reliability of such analyses depends on factors such as point density and local terrain variability, which influence the accuracy of detected changes.

LiDAR-derived products also support advanced terrain analysis and feature extraction workflows. High-resolution Digital Elevation Models enable the identification of drainage patterns, small channels, and geomorphological structures through terrain analysis and machine learning techniques (Regmi et al., 2024; Busarello et al., 2025). These approaches support the analysis of channel morphology and geomorphological processes. LiDAR data also facilitate the monitoring of channel adjustments and bank erosion, providing insight into river dynamics over time (El-Khoury et al., 2025; Andualem et al., 2024).

The integration of Digital Surface Models (DSMs) and DEMs allows the selective incorporation of structural features such as embankments, bridges, and other built

structures, improving the representation of their hydraulic influence on flow behaviour and flood extent (Lee et al., 2025).

Despite these advantages, the use of high-resolution LiDAR point clouds also introduces practical limitations. Sub-meter resolution leads to large data volumes, often requiring simplification, such as subsampling, or scale adaptation for efficient use in hydrological applications, particularly over extended areas (Almeida et al., 2024). LiDAR systems are also limited in water-covered areas, as laser pulses are reflected by the water surface, preventing the acquisition of reliable information on channel bed morphology (Gou et al., 2026).

This study presents a complete UAV-LiDAR workflow for small stream assessment and rehabilitation, from data acquisition and point cloud processing to the generation of topographic products and hydraulic modelling inputs. The proposed methodology was applied to an urban stream sector requiring rehabilitation works and resulted in the generation of a classified point cloud, vectorized topographic features, a Digital Terrain Model and cross-sections used for hydraulic modelling. The generated datasets supported both the preparation of the topographic documentation submitted for technical acceptance by the Office of Cadastre and Real Estate Publicity (OCPI) and the evaluation of existing and proposed hydraulic conditions in HEC-RAS.

MATERIALS AND METHODS

Study area

The study area is located in north-western Romania, within Bihor County, in the built-up area of Peștiș village, administratively belonging to Aleșd town (Figure 1). The investigated watercourse is Valea Secătura, also known locally as Valea Șinteu, cadastral code III.1.44.19.2.0.0, situated within the Crișul Repede River basin. Figure 1 illustrates the geographical location of the study area at multiple spatial scales, including the position of Bihor County within Romania (Figure 1A), the location of Aleșd administrative territory within the county (Figure 1B), and the hydrographic context of Valea Secătura within the local drainage network (Figure 1C).

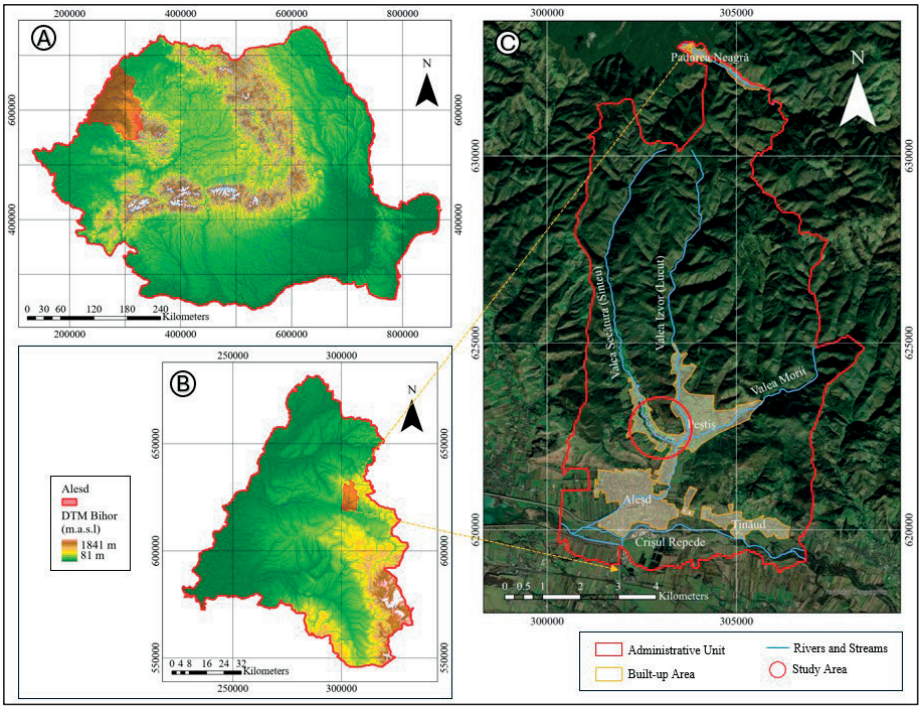


Figure 1. Geographic location of the study area and hydrographic context of Valea Secătura

According to the national hydrographic data and the technical documentation prepared for the rehabilitation project, Valea Secătura is a right-bank tributary of Valea Izvor (locally known as Valea Lucut), while Valea Izvor also collects the waters of Valea Morii (Valea Peștiș) in its upstream sector. Through this drainage network, the waters of Valea Secătura and Valea Morii are collected by Valea Izvor and ultimately discharge into the Crișul Repede River.

Based on cadastral records, Valea Secătura has a total length of approximately 9.6 km and drains a catchment area of about 14 km². The present study focuses on a 1.7 km sector of Valea Secătura situated within the built-up area of Peștiș village. The UAV-LiDAR survey covered the entire investigated sector, including the area targeted by the rehabilitation project entitled *"Amenajarea Valea Secătura (Șinteu)"*, for which engineering design and topographic documentation were required. The proposed rehabilitation works are concentrated on a channel sector of approximately 1 km located within the LiDAR survey corridor. In the built-up area of Peștiș village, the stream corridor is strongly influenced by anthropogenic activities and existing infrastructure, including local roads, residential properties, access crossings, bridges, retaining walls, and other hydraulic protection structures, as illustrated in Figure 2.



Figure 2. Aerial view of the investigated sector of Valea Secătura within the built-up area of Peștiș village

As a result, the channel is highly constrained and its morphology is largely controlled by previous engineering interventions. The technical documentation describes the watercourse as being bordered by roads and adjacent properties throughout the regulated sector. Existing hydraulic structures and the current channel configuration are presented in Figure 3.



Figure 3. Existing hydraulic infrastructure and anthropogenic constraints

Many of the existing hydraulic structures were originally constructed as part of the *"Regularizare Valea Izvor și afluenți"* project in 1987. Subsequent technical inspections revealed substantial deterioration of the hydraulic infrastructure, including damage to retaining walls, erosion of the channel bed and banks, discontinuities within existing protection works, sediment accumulation within the channel, and local reductions in flow capacity caused by bridges, footbridges, and access crossings. Combined with recurrent flood events, these processes progressively reduced the functionality of the existing works and highlighted the need for rehabilitation measures.

The rehabilitation project developed for the investigated sector proposes the demolition of approximately 1,819 m of existing retaining walls, reprofiling of 1,028 m of channel, and the construction of 2,056 m of new bank protection structures. Additional measures include the rehabilitation of existing crossings and the reconstruction of channel stabilization works designed to improve flow capacity and enhance the long-term stability of the channel.

Given the complexity of the site, the presence of ageing hydraulic infrastructure, and the need for detailed geometric information to support engineering design, the study area provides an appropriate framework for demonstrating the applicability of high-density UAV-LiDAR surveys in stream rehabilitation projects. The generated topographic datasets support the creation of high-resolution Digital Terrain Models, the extraction of engineering features, and the preparation of hydraulic modelling inputs required for stream assessment and rehabilitation works.

UAV-LiDAR data acquisition and processing workflow

The methodological framework adopted in this study integrates UAV-LiDAR data acquisition, GNSS-supported trajectory correction, LiDAR data processing, and the generation of topographic products required for hydraulic modelling and rehabilitation design. The complete workflow adopted in this study is presented in Figure 4.

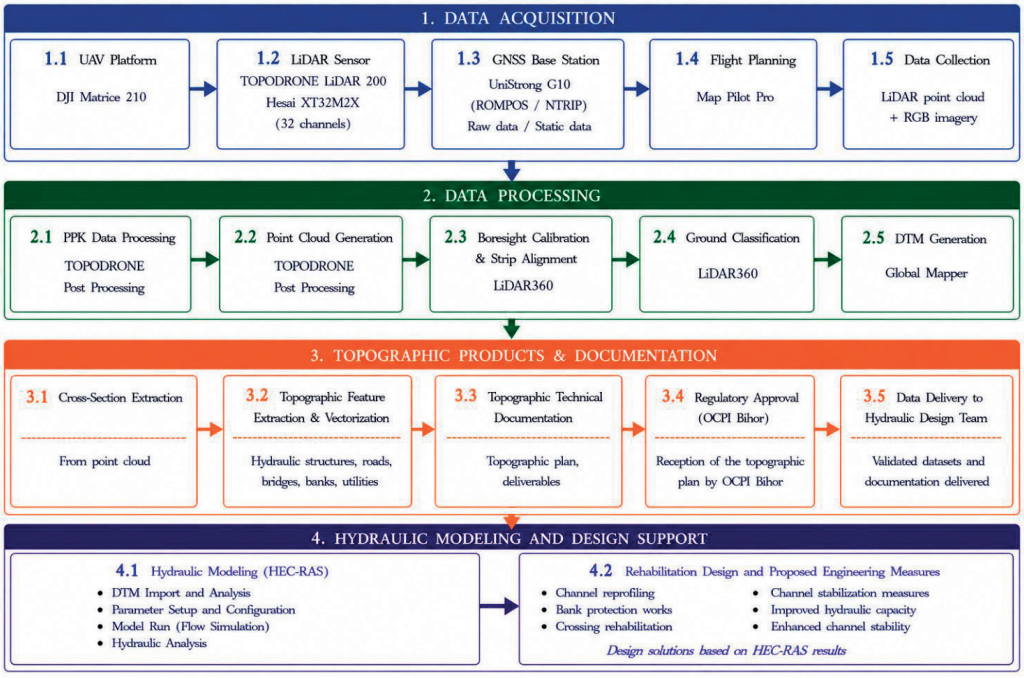


Figure 4. UAV-LiDAR data acquisition and processing workflow

The UAV-LiDAR survey was designed to acquire high-density airborne LiDAR data suitable for the generation of detailed topographic products required for stream assessment, hydraulic analysis, and rehabilitation planning along Valea Secătura. Attention was given to ensuring complete coverage of the stream corridor and adjacent infrastructure, including retaining structures, bridges, access crossings, roads, and neighbouring properties, while maintaining a consistent point density throughout the surveyed area.

Data acquisition was carried out using a DJI Matrice 210 unmanned aerial platform equipped with a TOPODRONE LiDAR 200 system integrating a Hesai XT32M2X laser scanner. The sensor incorporates 32 laser channels and a maximum acquisition rate of up to 640,000 points per second, enabling the collection of high-density point clouds suitable for detailed terrain modelling and the representation of both natural and engineered features within the investigated stream corridor. Simultaneously, RGB imagery was acquired using the onboard Zenmuse X4S camera. Although the primary objective of the survey was the acquisition of LiDAR data, the imagery was subsequently used for orthophoto generation and RGB colorization of the LiDAR point cloud.

Flight planning was performed in Map Pilot Pro using terrain-following functionality based on the Copernicus DEM. The mission was conducted at an average altitude of 100 m above ground level, allowing the UAV to maintain a nearly constant distance from the terrain surface throughout the survey. This approach reduced variations in point density associated with terrain elevation changes and improved the geometric consistency of the acquired dataset. The survey covered the entire 1.7 km study corridor along Valea Secătura, extending

beyond the proposed rehabilitation sector in order to capture the surrounding terrain and infrastructure necessary for the preparation of topographic documentation and hydraulic analyses. The main UAV-LiDAR mission parameters are presented in Table 1.

Table 1. UAV-LiDAR mission parameters

Parameter	Value
Flight mission	Linear mission
Survey area	30.22 ha
Survey corridor length	3.45 km
Flight altitude (AGL)	100 m
Flight speed	6.0 m/s
Flight duration	11 min 15 s
Number of flight lines (passes)	2
Forward/Side overlap	75% / 75%

The flight configuration consisted of two parallel flight lines following the longitudinal axis of the watercourse, ensuring complete coverage of the investigated corridor and sufficient overlap between the LiDAR strips.
The flight plan and survey coverage area are presented in Figure 5.

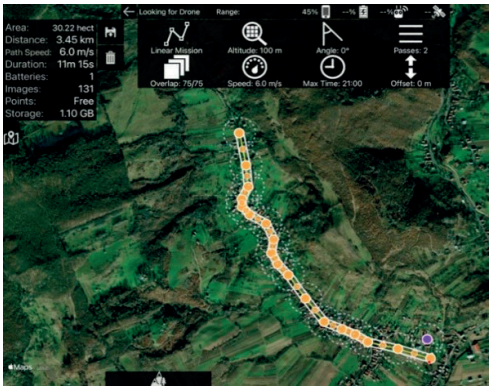


Figure 5. UAV-LiDAR mission planning

A dual-frequency UniStrong G10 GNSS receiver was installed at a location providing favourable satellite visibility and connected to the Romanian Positioning System (ROMPOS) through the Networked Transport of RTCM via Internet Protocol (NTRIP) service. The coordinates of the receiver position were initially determined using Real-Time Kinematic (RTK) positioning, after which the receiver was switched to static mode and continuously recorded raw GNSS observations during the survey. Following the initialization of the GNSS base station, the UAV-LiDAR survey was conducted while both the ground receiver and the onboard GNSS receiver (Helix antenna) simultaneously recorded raw satellite observations.
Data acquisition was conducted under favourable meteorological conditions, characterized by low wind speeds and the absence of precipitation. These conditions reduced vegetation movement during scanning and improved the quality of the acquired LiDAR data, supporting subsequent point cloud processing and ground classification.
Raw GNSS observations recorded by both the reference station and the onboard UAV receiver were processed using Post-Processed Kinematic (PPK) techniques to refine the flight trajectory and improve the positional accuracy of the LiDAR dataset. The TOPODRONE LiDAR Post Processing interface and the main processing parameters are presented in Figure 6.

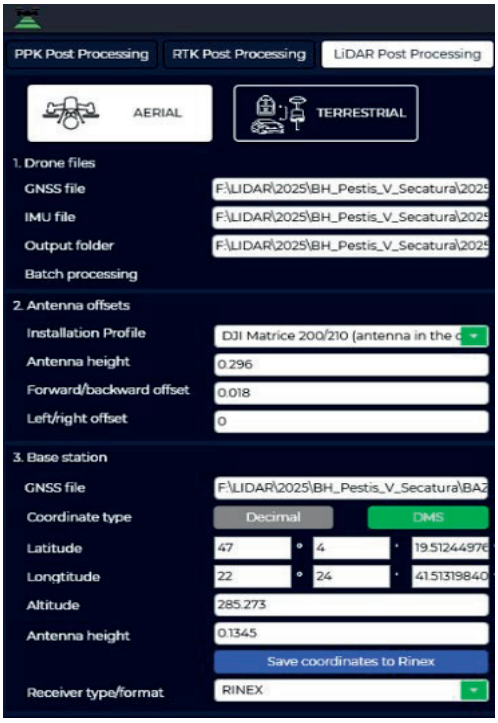


Figure 6. TOPODRONE LiDAR Post Processing interface and configuration parameters

The observations collected by the UniStrong G10 reference station were exported and converted to Receiver Independent Exchange Format (RINEX) files before being imported

into TOPODRONE Post Processing software together with the GNSS and Inertial Measurement Unit (IMU) data recorded by the UAV platform. The processing procedure incorporated UAV data files, antenna offsets, reference station coordinates, and the corresponding RINEX file to compute a corrected trajectory. The resulting solution enabled accurate reconstruction of the UAV trajectory and precise positioning of the LiDAR observations throughout the survey.

Following trajectory refinement, the LiDAR observations stored in PCAP format and the corresponding POS trajectory file were imported into TOPODRONE software for point cloud generation. This procedure integrated the corrected trajectory with the LiDAR measurements, enabling the calculation of the spatial coordinates of individual laser returns and the generation of the point cloud, as illustrated in Figure 7.

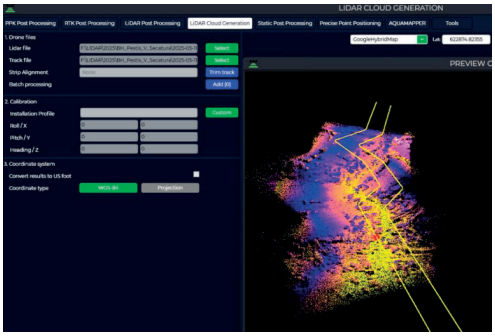


Figure 7. Point cloud generation in TOPODRONE software

The generated point cloud was processed in LiDAR360. Point cloud segments affected by increased positional uncertainty during UAV manoeuvres at flight-line transitions were excluded from further processing. These areas are typically associated with larger roll and pitch variations, which may introduce geometric distortions and reduce local accuracy. Boresight calibration was then performed to compensate for residual angular offsets between the GNSS receiver, IMU, and LiDAR sensor. Strip alignment procedures were subsequently applied to minimize positional discrepancies between overlapping flight strips. The aligned point cloud and a cross-sectional view of the dataset are presented in Figure 8.

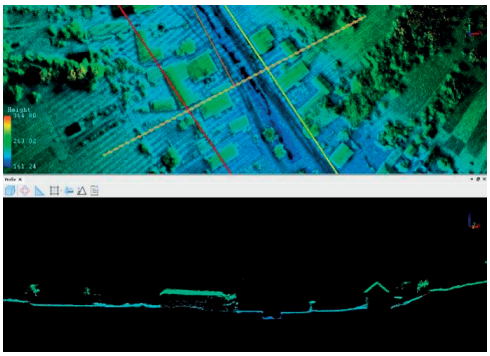


Figure 8. Strip alignment results and cross-sectional view of the LiDAR point cloud

The effectiveness of the calibration and strip alignment procedures was evaluated using the alignment statistics generated in LiDAR360. Boresight corrections involving roll, pitch, and heading adjustments were applied during the calibration process. The adjustment process reduced the maximum alignment error from 2.073 m to 0.079 m and the RMSE from 0.820 m to 0.029 m. The calibration report and alignment statistics are shown in Figure 9.

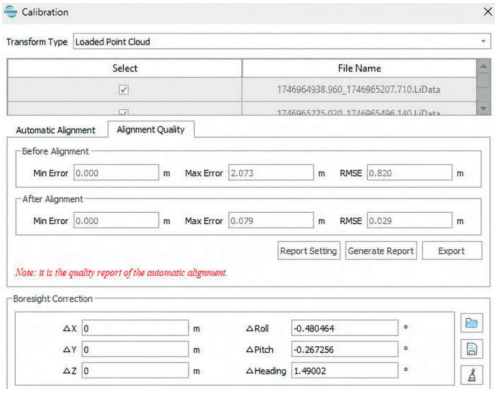


Figure 9. Calibration report and alignment statistics obtained in LiDAR360

The calibrated point cloud was further classified in LiDAR360 using the ground filtering algorithm to separate ground points from vegetation and other non-terrain features. Accurate ground classification is particularly important in stream environments, where riparian vegetation may significantly influence terrain representation and obscure the underlying terrain surface. Non-ground points were subsequently removed and the ground

class was extracted to generate a filtered dataset representing the bare-earth surface.

The extraction of the ground class represents a necessary stage in the LiDAR processing workflow, as the accuracy of the Digital Terrain Model depends on the correct identification of terrain points. Inaccurate classification may result in the inclusion of vegetation or other non-terrain features within the terrain model, potentially introducing local distortions in channel geometry and bank morphology. Particular attention was therefore given to the inspection of the classified dataset to ensure a continuous representation of the terrain throughout the surveyed corridor, including areas characterized by dense riparian vegetation. The resulting ground-filtered point cloud is presented in Figure 10.

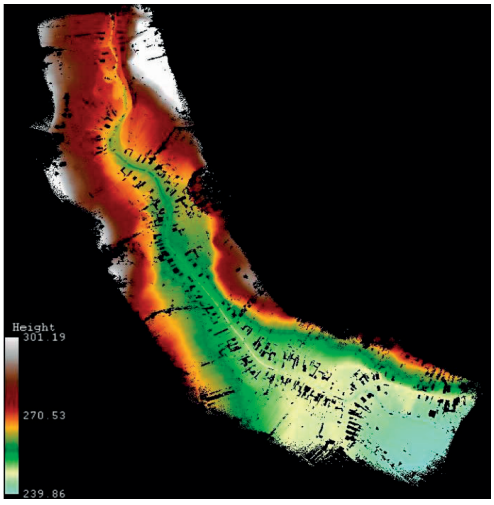


Figure 10. Ground-classified LiDAR point cloud

The ground-classified point cloud was processed in Global Mapper to generate the DTM. The terrain model captured the geometry of the stream channel, bank morphology, adjacent infrastructure, and surrounding terrain, providing spatial information for topographic and hydraulic applications. The density of the UAV-LiDAR dataset allowed the preservation of fine-scale terrain characteristics that are often difficult to identify using conventional surveying methods. The DTM generated for the investigated sector together with an example cross-section extracted from the terrain model are shown in Figure 11.

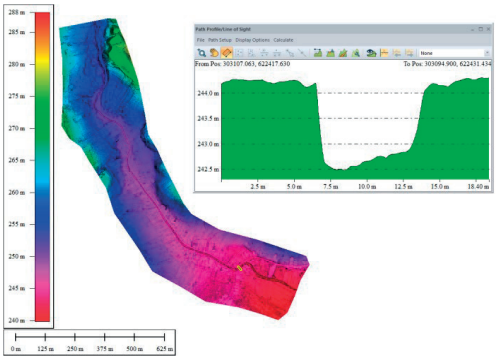


Figure 11. Digital Terrain Model and sample cross-section derived from the terrain model

Classified ground point cloud was used to derive the topographic information required to satisfy the beneficiary's requirements. Using the longitudinal axis of the watercourse as a reference, a total of 52 cross-sections were automatically generated in 3Dsurvey software and manually reviewed to identify and remove potential geometric irregularities resulting from the extraction process. Vector features required for topographic mapping, including points, breaklines, and other terrain elements, were extracted from the classified point cloud. The extracted datasets were used for the preparation of the topographic documentation submitted for technical acceptance by the Office of Cadastre and Real Estate Publicity (OCPI). Following acceptance, the approved topographic plan, together with the DTM and extracted cross-sections, was delivered to the beneficiary and subsequently used by the design team as input data for hydraulic analyses and the development of rehabilitation solutions for the investigated sector. The resulting products and their applications are presented in the following section.

RESULTS AND DISCUSSIONS

Topographic products

The generated topographic products provided the geometric information required for both engineering documentation and hydraulic modelling. These products included the classified point cloud, DTM, cross-sections, and the topographic plan submitted for technical acceptance by OCPI. A portion of the generated topographic plan is shown in Figure 12.

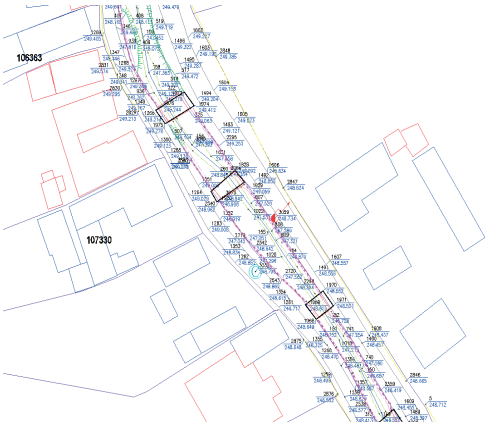


Figure 12. Topographic plan derived from the UAV-LiDAR survey.

The level of detail provided by the generated products enabled the identification of channel banks, hydraulic structures, road crossings, and other natural and anthropogenic features required for hydraulic modelling. The resulting DTM preserved subtle terrain variations along the stream corridor, allowing local morphological features to be represented with a level of detail that is difficult to achieve using conventional surveying methods. Similar findings have highlighted the importance of accurate ground point classification for generating reliable DTM suitable for engineering applications (Oniga et al., 2024).
The adopted workflow and the obtained results demonstrate that UAV-LiDAR surveys provide the topographic information required for engineering projects developed along narrow stream corridors. Comparable findings have been reported for the use of high-density LiDAR datasets in detailed terrain characterization supporting hydraulic analyses and river management applications (Stoleriu et al., 2020; Li et al., 2021).

Hydraulic assessment of existing conditions

The topographic products derived from the UAV-LiDAR survey constituted the basis for hydraulic modelling of the investigated sector.
The DTM, extracted cross-sections, and vectorized infrastructure elements were integrated into the HEC-RAS modelling environment to simulate hydraulic conditions corresponding to the climate change-adjusted design discharge with a 1% exceedance probability (Q1% = 47.70 m³/s). Two hydraulic modelling scenarios were analysed: the existing channel conditions at the time of the UAV-LiDAR survey and the proposed engineering solution developed for the investigated sector.
The hydraulic modelling results for the existing channel conditions and the proposed engineering solution are presented in Figures 13 and 14, respectively.

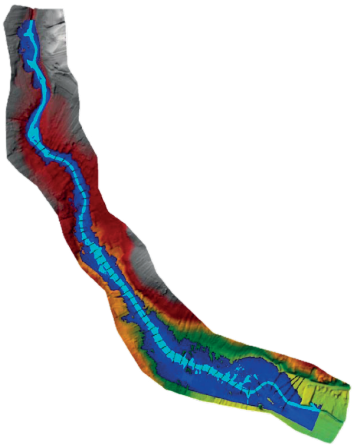


Figure 13. HEC-RAS hydraulic model of the investigated sector under existing conditions

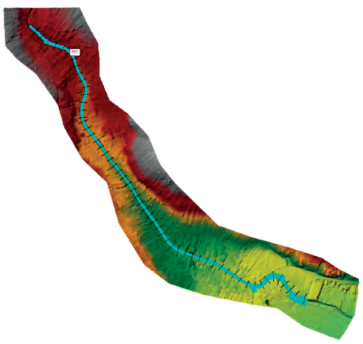


Figure 14. HEC-RAS hydraulic model of the proposed engineering solution

The comparison of these scenarios enabled the evaluation of the expected hydraulic performance of the proposed rehabilitation measures under identical hydrological conditions.
Simulation of the existing channel conditions revealed the influence of local geometric constraints associated with ageing hydraulic structures, channel degradation, sediment accumulation, and the consequent reduction in

flow conveyance capacity within several sections of the investigated corridor.

The reliability of hydraulic simulations is strongly dependent on the quality of the DTM and the geometric datasets used to construct the hydraulic model, including extracted cross-sections and vectorized infrastructure elements. Previous studies have demonstrated that high-resolution UAV-derived topographic datasets improve terrain representation and provide a reliable geometric basis for hydraulic modelling, flood hazard assessment, and the evaluation of engineering solutions (Mihu-Pintilie et al., 2019; Bilașco et al., 2021). The results obtained in the present study are consistent with these findings, demonstrating that the generated DTM and extracted cross-sections provided the geometric detail required for a realistic representation of hydraulic conditions within the investigated stream corridor.

Rehabilitation design and hydraulic performance

Based on the hydraulic assessment, a rehabilitation solution was proposed for the investigated sector of Valea Secătura. The proposed design comprised channel reprofiling over approximately 1 km, reconstruction of bank protection structures with a total length of approximately 2 km, replacement of deteriorated retaining walls, and additional stabilization measures intended to improve hydraulic performance and channel stability.

The main hydraulic parameters for the representative cross-section (P20) under existing and proposed conditions are compared in Table 2. Both simulations were performed using the same climate change-adjusted design discharge (Q1% = 47.70 m³/s), allowing the differences in the hydraulic response to be attributed exclusively to the proposed channel geometry.

Table 2. Comparative hydraulic indicators for representative cross-section P20

Hydraulic parameter	Existing	Proposed
Design discharge (m³/s)	47.7	47.7
Channel bed elevation (m)	244.45	243.37
Wetted area (m²)	22.44	14.42
Wetted perimeter (m)	26.33	10.49
Hydraulic radius (m)	0.85	1.37
Roughness coefficient (left bank)	0.04	0.02
Roughness coefficient (channel)	0.04	0.03
Roughness coefficient (right bank)	0.04	0.02
Mean flow velocity (m/s)	2.13	3.31
Maximum water level (m)	246.65	245.69

Figure 15 presents the representative cross-section (P20), showing the existing ground profile together with the proposed engineering solution. The trapezoidal channel geometry was designed to provide adequate flow capacity while accommodating the local topographic and infrastructural constraints. The proposed design also accounted for existing crossings, adjacent properties, and the demolition and reconstruction of deteriorated hydraulic structures as part of the planned rehabilitation works.

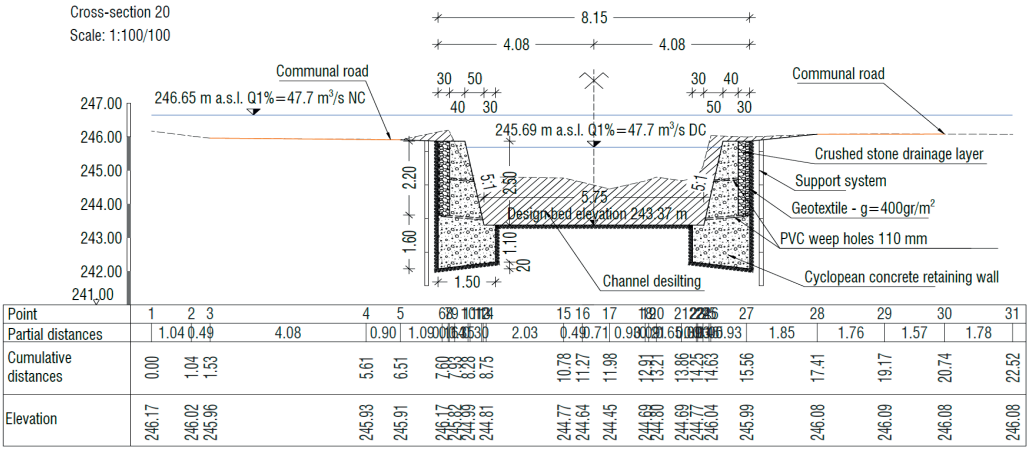


Figure 15. Designed cross-section (P20)

The comparison between the existing and proposed channel conditions demonstrated the importance of detailed topographic information for evaluating the hydraulic response of the investigated sector prior to implementation. High-resolution UAV-LiDAR datasets enabled the realistic representation of channel geometry and surrounding infrastructure, providing the basis required for hydraulic modelling and engineering design. Similar integrated approaches combining detailed terrain models, GIS analyses, and hydraulic simulations have been shown to support the evaluation and optimization of river rehabilitation solutions (Bilașco et al., 2021).

CONCLUSIONS

This study demonstrated the applicability of UAV-LiDAR technology for acquiring high-resolution topographic data to support small stream assessment and rehabilitation planning. The proposed workflow, integrating PPK trajectory correction, LiDAR point cloud generation and calibration, ground classification, and terrain modelling, produced high-resolution topographic datasets suitable for cadastral documentation and hydraulic modelling.

The adopted methodology generated a DTM, a classified ground point cloud, vectorized topographic features required for the preparation of the topographic plan, and 52 cross-sections along the investigated sector of Valea Secătura. The resulting topographic plan was submitted for technical acceptance by the OCPI. Following technical approval, the approved topographic plan, together with the DTM, classified point cloud, and extracted cross-sections, was delivered to the design team.

Integration of these topographic datasets into the HEC-RAS modelling environment enabled the evaluation of existing hydraulic conditions and the assessment of the proposed engineering solution under the climate change-adjusted design discharge. The resulting analyses supported the identification of channel deficiencies and the design of channel reprofiling, bank protection structures, retaining walls, and additional stabilization measures adapted to the characteristics of the investigated sector.

The obtained results confirm that UAV-LiDAR surveys provide an efficient alternative to conventional topographic surveying methods for engineering projects involving small watercourses. The high density of the acquired point cloud enabled detailed representation of channel geometry, surrounding infrastructure, and terrain morphology.

At the time of manuscript preparation, the rehabilitation solution developed using the generated topographic and hydraulic datasets is under implementation within the investigated sector. This demonstrates the practical applicability of the proposed workflow and highlights the value of integrating UAV-LiDAR technology with hydraulic modelling to support real-world small stream rehabilitation projects.

REFERENCES

Almeida, A. A. R. D., Mendonça, R. L., Silva, N. M. M., & da Paz, A. R. (2024). Evaluation of LiDAR-derived river networks coarsening with spatial patterns preservation. *Computers & Geosciences*, *189*, 105639.

Andualem, T. G., Peters, S., Hewa, G. A., Myers, B. R., Boland, J., & Pezzaniti, D. (2024). Channel morphological change monitoring using high-resolution LiDAR-derived DEM and multi-temporal imageries. *Science of the Total Environment*, *921*, 171104.

Annis, A., Nardi, F., Petroselli, A., Apollonio, C., Arcangeletti, E., Tauro, F., Belli, C., Bianconi, R., & Grimaldi, S. (2020). UAV-DEMs for small-scale flood hazard mapping. *Water*, *12*(6), 1717.

Bilașco, Ș., Roșca, S., Vescan, I., Fodorean, I., Dohotar, V., & Sestras, P. (2021). A GIS-based spatial analysis model approach for identification of optimal hydrotechnical solutions for gully erosion stabilization. Case Study. *Applied Sciences*, *11*(11), 4847.

Bolick, M. M., Post, C. J., Naser, M. Z., Forghanparast, F., & Mikhailova, E. A. (2023). Evaluating urban stream flooding with machine learning, LiDAR, and 3D modeling. *Water*, *15*(14), 2581.

Busarello, M. D. S. T., Ågren, A. M., Westphal, F., & Lidberg, W. (2025). Automatic detection of ditches and natural streams from digital elevation models using deep learning. *Computers & Geosciences*, *196*, 105875.

El-Khoury, L., Kurki-Fox, J., & Doll, B. (2025). Quantifying streambank erosion: A comparison of physical surveys, aerial imagery and UAS LiDAR surveys. *Earth Surface Processes and Landforms*, *50*(6), e70039.

Ferreira, V., Albariño, R., Larrañaga, A., LeRoy, C. J., Masese, F. O., & Moretti, M. S. (2023). Ecosystem services provided by small streams: an overview. *Hydrobiologia*, *850*(12), 2501-2535.

Gou, J., Lee, H., Park, J., Jang, S., Lee, N., & Song, I. (2026). Development of a stream DTM generation methodology using UAV-based SfM and LiDAR point cloud. *Scientific Reports*, *16.* 5178.

Grau, J., Liang, K., Ogilvie, J., Arp, P., Li, S., Robertson, B., & Meng, F. R. (2021). Using unmanned aerial vehicle and lidar-derived DEMs to estimate channels of small tributary streams. *Remote Sensing*, *13*(17), 3380.

Lee, S. J., Han, Y. S., Kim, J. S., & Yun, H. S. (2025). High-Resolution Flood Risk Assessment in Small Streams Using DSM–DEM Integration and Airborne LiDAR Data. *Sustainability*, *17*(21), 9616.

Li, B., Hou, J., Li, D., Yang, D., Han, H., Bi, X., Wang, CX., Hinkelmann, R., & Xia, J. (2021). Application of LiDAR UAV for high-resolution flood modelling. *Water Resources Management*, *35*(5), 1433-1447.

Li, P., Li, D., Hu, J., Fassnacht, F. E., Latifi, H., Yao, W., Gao, J., Chan, F.K., Dang, T., & Tang, F. (2024). Improving the application of UAV-LiDAR for erosion monitoring through accounting for uncertainty in DEM of difference. *Catena*, *234*, 107534.

Lin, L., Li, M., Chen, H., Lai, X., Zhu, H., & Wang, H. (2020). Integrating landscape planning and stream quality management in mountainous watersheds: A targeted ecological planning approach for the characteristic landscapes. *Ecological Indicators*, *117*, 106557.

Marotta, F., Teruggi, S., Achille, C., Vassena, G. P. M., & Fassi, F. (2021). Integrated laser scanner techniques to produce high-resolution DTM of vegetated territory. *Remote Sensing*, *13*(13), 2504.

Mihu-Pintilie, A., Cîmpianu, C. I., Stoleriu, C. C., Pérez, M. N., & Paveluc, L. E. (2019). Using high-density LiDAR data and 2D streamflow hydraulic modeling to improve urban flood hazard maps: A HEC-RAS multi-scenario approach. *Water*, *11*(9), 1832.

Muhadi, N. A., Abdullah, A. F., Bejo, S. K., Mahadi, M. R., & Mijic, A. (2020). The use of LiDAR-derived DEM in flood applications: A review. *Remote Sensing*, *12*(14), 2308.

Oniga, V. E., Loghin, A. M., Macovei, M., Lazar, A. A., Boroianu, B., & Sestras, P. (2024). Enhancing LiDAR-UAS derived digital terrain models with hierarchic robust and volume-based filtering approaches for precision topographic mapping. *Remote Sensing*, *16*(1), 78.

Regmi, N. R., Webb, N. D., Walter, J. I., Heo, J., & Hayman, N. W. (2024). Mapping landforms of a hilly landscape using machine learning and high-resolution LiDAR topographic data. *Applied Computing and Geosciences*, *24*, 100203.

Sabou, C. S., Bruma, S., Ioana, P. O. P., Matei, F., Sestras, P., Deak, J., ... & Salagean, T. River corridor change detection using satellite imagery and LiDAR data: a case study of the Siret river near Corbu Vechi village. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. XIV*, 985-993

Sestras, P., Badea, G., Badea, A. C., Salagean, T., Roșca, S., Kader, S., & Remondino, F. (2025a). Land surveying with UAV photogrammetry and LiDAR for optimal building planning. *Automation in Construction*, *173*, 106092.

Sestras, P., Badea, G., Badea, A. C., Salagean, T., Oniga, V. E., Roșca, S., ... & Nedevschi, S. (2025b). A novel method for landslide deformation monitoring by fusing UAV photogrammetry and LiDAR data based on each sensor's mapping advantage in regards to terrain feature. *Engineering Geology*, *346*, 107890.

Stoleriu, C. C., Urzica, A., & Mihu-Pintilie, A. (2020). Improving flood risk map accuracy using high-density LiDAR data and the HEC-RAS river analysis system: A case study from north-eastern Romania. *Journal of flood risk management*, *13*, e12572.

Trepekli, K., Balstrøm, T., Friborg, T., Fog, B., Allotey, A. N., Kofie, R. Y., & Møller-Jensen, L. (2022). UAV-borne, LiDAR-based elevation modelling: A method for improving local-scale urban flood risk assessment. *Natural Hazards*, *113*(1), 423-451.

Wang, R., Kim, J. H., & Li, M. H. (2021). Predicting stream water quality under different urban development pattern scenarios with an interpretable machine learning approach. *Science of the Total Environment*, *761*, 144057.