Final Report: Implementation of the Innovative Training Unit on Remote Sensing for Construction Impact Assessment

1. Executive Summary

This report summarizes the implementation and outcomes of the project “Innovative Training Unit for Civil Engineers on Remote Sensing for Construction Impact Assessment.” The project aimed to integrate advanced remote sensing workflows into civil engineering education through a hands-on research-based case study—the Kakhovka Reservoir collapse (Ukraine, 2023)—serving as a real-world scenario for the application of geospatial and remote sensing technologies in construction impact and environmental monitoring.

The developed educational module achieved all targeted objectives by combining remote sensing data processing, machine learning classification, NDVI analysis, and change detection into a structured training framework for civil engineers.

2. Alignment with Project Objectives

The project’s implementation strictly followed the conceptual and structural framework outlined in the proposal. Each objective defined in the proposal was translated into a tangible educational or research activity. The Kakhovka Reservoir case study served as a unifying scenario where all project components—data acquisition, remote sensing analysis, environmental interpretation, and educational material development—were interconnected within a single workflow. The alignment analysis presented below demonstrates how the planned objectives evolved into measurable educational and scientific outcomes. This section shows not only that each objective was fulfilled but also that the project went beyond its initial scope by incorporating advanced data processing, open-access dissemination, and integration of disaster-related environmental modeling into civil engineering curricula. Table 1 below summarizes the correspondence between the proposal’s original objectives and the achieved implementation results, including new directions developed during project execution.

Table 1

Alignment with Project Objectives

Proposal Objective	Implementation and Results
Development of multimedia training content covering remote sensing for construction impact estimation	The Kakhovka dam collapse study formed the core of the module. Sentinel-2 imagery was used to demonstrate change detection, classification, and NDVI-based monitoring. Multimedia lecture materials were created explaining each processing stage, from data acquisition in Google Earth Engine (GEE) to classification evaluation.
Creation of practical lab content based on in-room and field data acquisition	The field studies allowed for creating a database of test images and spectral signatures. Unfortunately, due to the crisis situation in Ukraine, the field studies were subjected to severe restrictions. Students analyzed Sentinel-2 mosaics before and after the dam collapse (May 2023 vs August 2023). Laboratory exercises guided learners through supervised classification (SVM, RF, Naïve Bayes), water area computation, and NDVI trend visualization. Accuracy assessment tables and confusion matrices were integrated into the lab manual.
Establishing an outreach and dissemination strategy	The training module was deployed through a web-based environment compatible with open-source software GEE. The case study and datasets were presented at ISPRS-affiliated workshops (ISPRS TC V Mid-term Symposium, 2024 Insight to Foresight via Geospatial Technologies, Manila, Philippines; APRSEI - PHEDCS 2025, Tashkent, ISPRS WG V/6 Workshop: „Applied Photogrammetry and Remote Sensing for Environmental and Industry) and within university graduate programs, ensuring accessibility for institutions with limited computational resources.

3. Methodological Workflow

3.1 Data Selection and Preparation

In accordance with the project's Task 1 and Task 2, Sentinel-2 MSI imagery (10 m resolution) from 2020 to 2025 was used to monitor pre- and post-collapse environmental changes. Two mosaics (before and after June 6, 2023) were prepared in GEE, following the open-data principles outlined in the project proposal. Field studies for testing and data calibration were accomplished.

3.2 Data Processing and Algorithms

Following Task 3 and Task 5, classification algorithms such as Support Vector Machine (SVM), Random Forest, and Naïve Bayes were tested. SVM achieved the highest accuracy (0.934 pre-collapse, 0.879 post-collapse). Water surface reduction was estimated at –1793.7 km^2, with an area accuracy of near 1:1000.

3.3 NDVI Analysis and Change Detection

NDVI-based temporal trend analysis demonstrated vegetation transformation after the dam collapse. Greening vs Browning analysis (2020–2023) indicated 8262 km^2 greening vs 5516 km^2 browning, while post-collapse (2023–2025) showed 14233 km^2 browning, confirming widespread ecosystem stress.

3.4 Similarity and Correlation Studies

Advanced labs included NDVI profile analysis across cross-sections with Pearson correlation, cosine similarity, and RMSE calculations. The results showed distinct separation between 2020–2023 and 2024–2025 datasets, emphasizing the method's power for environmental impact analysis.

4. Educational Outcomes

To connect the remote sensing and geospatial analytics training unit with the core competencies of civil engineering, the course was developed to balance engineering relevance, data-science rigor, and environmental interpretation. Below is a developed semester-long course, optimized for civil engineering students and aligned with the project's educational framework and a case study. The course was integrated and launched in the Spring semester for civil engineering students at the **Kyiv National University of Construction and Architecture, Kyiv, Ukraine.**

4.1 Course Objectives

By the end of the course, students will:

1. Understand the role of geospatial and remote sensing data in civil engineering planning, construction, and maintenance.
2. Develop skills in data acquisition, preprocessing, and interpretation using open-access satellite imagery (Sentinel-2, Landsat).
3. Apply machine learning and spectral analysis to assess construction and environmental impact.
4. Integrate remote sensing outputs into GIS and CAD environments for engineering decision support.
5. Conduct a capstone project analyzing a real or simulated case (e.g., dam collapse, reservoir sedimentation, urban expansion).

4.2 Course Structure

In Table 2, one may see the structure of the implemented course "***Remote Sensing for Civil and Environmental Engineering Applications***"

Table 2

Course Structure (15 weeks / 5 modules)

Module	Focus Area	Civil Engineering Context	Key Tools & Methods	Practical Output / Assessment
Module 1. Fundamentals of Remote Sensing for Engineers	Principles of remote sensing, sensors, spectral signatures, etc.	Building materials reflectance, thermal mapping of structures, water–soil interactions	Sentinel-2 MSI, Landsat 8/9, Google Earth Engine (GEE)	Quiz + short report on interpreting construction materials in multispectral imagery
Module 2. Data Acquisition and Preprocessing	Data collection, geometric correction, cloud masking	Remote sensing and UAV imaging of construction sites, topographic mapping, change monitoring	GEE, Agisoft, Pix4D	Lab: preprocess and orthorectify UAV and Sentinel data
Module 3. Classification and Change Detection	Supervised/unsupervised classification; SVM, RF, NDVI	Land-use change near civil infrastructure, flood impact on roads/reservoirs	Python (scikit-learn), GEE	Lab: classify pre- and post-event reservoir imagery (Kakhovka case)
Module 4. Environmental and Structural Monitoring	NDVI, NDWI, NDMI, change vectors, and correlation	Vegetation recovery, dam leakage, slope stability, urban heat islands	GEE, QGIS, MATLAB	Group project: NDVI/NDWI time-series of a construction site
Module 5. Engineering Decision Support and Capstone Project	Integration into GIS/CAD and digital twin concepts	Construction impact simulation, structural health monitoring	QGIS, AutoCAD Civil 3D, MATLAB	Capstone report and presentation: Environmental and structural assessment case study

The following labs were integrated with learning modules (Table 3):

Table 3

Laboratory Sessions (Integrated with Modules)

Lab	Title	Learning Outcome
1	Spectral Signature of Construction Materials	Identify building materials (concrete, asphalt, vegetation, water) from spectral reflectance
2	Hydrotechnical object mapping	Derive reservoir area using Sentinel-2 and compute geometric uncertainty
3	NDVI Trend Analysis	Assess vegetation dynamics near construction zones or reservoirs
4	SVM and RF Classification	Apply and compare ML classifiers for post-construction land-use mapping
5	Change Detection Workflow	Detect impact zones and visualize in GIS
6	Web-Based Dissemination	Create interactive maps and dashboards (e.g., GEE Apps or Leaflet)

5. Research and Societal Outcomes

The study created a benchmark dataset for water surface and vegetation recovery modeling. Future modules will extend this with NDMI, EVI, and PDI indices. The module's open-data approach ensures accessibility for developing countries and integration into ISPRS summer schools.

6. Project Evaluation and Dissemination

All milestones were completed within the one-year timeline. Budget allocation followed the initial plan.

7. Conclusions

The implementation of the *Innovative Training Unit for Civil Engineers on Remote Sensing for Construction Impact Assessment* represents a significant milestone in integrating geospatial technologies with modern civil engineering education. The project has successfully demonstrated how remote sensing data, machine learning, and geospatial analysis can be systematically embedded in the training of civil and environmental engineers to enhance their decision-making capacity in the context of sustainable infrastructure and environmental resilience.

The Kakhovka Reservoir collapse case study proved to be a powerful educational and research catalyst. It provided a real-world example that linked environmental monitoring with civil infrastructure risk assessment — enabling students and researchers to witness, model, and quantify the consequences of hydrotechnical failure through open satellite data. This approach established an authentic learning environment where theoretical geospatial concepts were directly translated into practical analytical workflows using *Sentinel-2* imagery, *Google Earth Engine (GEE)*, and open-source tools such as *QGIS* and *MATLAB*.

A major technological deliverable of the project is the web-based interactive application developed to host the training unit, analytical tools, and database of reference imagery. Built using open frameworks (JavaScript, Leaflet, and GEE integration), the platform provides:

An online educational portal containing lecture materials, lab manuals, and interactive quizzes.

A visualization dashboard for real-time access to Sentinel-2 imagery, NDVI maps, and classification layers of the Kakhovka region.

User interaction modules allowing students to perform basic image classification, NDVI calculations, and change-detection tasks directly in the browser—without the need for local software installation.

Database integration, storing spectral signatures and pre-processed mosaics of hydrotechnical and urban areas for reuse in classroom and research projects.

This application ensures long-term accessibility of the educational content, supports blended and distance learning, and promotes data sharing among universities. Its modular architecture allows expansion toward other study areas or additional analytical functions such as machine-learning classification or time-series analysis. The platform is designed to be hosted both locally and on cloud-based servers, supporting deployment under limited internet connectivity—a crucial feature for developing regions and conflict-affected zones.

From a pedagogical perspective, the project succeeded in:

- bridging the long-standing gap between geospatial sciences and traditional civil engineering curricula;
- producing a structured and reproducible training sequence consisting of lectures, labs, and capstone projects;
- validating the feasibility of using entirely open-access datasets and free software platforms for engineering education, even in resource-constrained environments.

The educational outcomes have exceeded expectations. Students were able to not only process satellite imagery and compute indices such as NDVI, NDWI, and NDMI but also critically interpret the results within engineering contexts — including dam safety, erosion, and vegetation recovery. This indicates a fundamental shift from passive learning to analytical reasoning and system thinking — a direction that aligns with global trends in engineering education emphasizing digital transformation, sustainability, and environmental accountability.

The societal dimension of the project is equally important. By designing the unit around open data and open-source tools, the project ensures inclusivity and scalability. The educational materials can be implemented in developing countries or conflict-affected regions where access to commercial software and field data is limited. The first approbation of the course at the ***Kyiv National University of Construction and Architecture*** demonstrates that even under challenging conditions, international collaboration and digital education can continue to advance.

Looking forward, the training unit provides a foundation for a long-term educational ecosystem that will:

1. Evolve into a complete specialization or minor in ***Geospatial Technologies for Civil Engineering***;
2. Support international academic exchange through ISPRS-sponsored workshops and Erasmus+ partnerships;
3. Expand toward digital-twin applications, integrating UAV photogrammetry, LiDAR, and structural monitoring sensors into the same analytical framework.

In summary, the project has delivered far more than a teaching module — it has created a prototype of the future civil engineering curriculum, one in which data-driven environmental analysis and infrastructure management coexist within a single interdisciplinary domain. The successful fusion of education, research, and open innovation exemplifies how the civil engineering profession can adapt to the rapidly evolving technological and ecological challenges of the 21st century.