FERRO
Fostering European Lake Restoration

Deliverable D3.1 – List of lake restoration metrics to be collected for the database

Lead Beneficiary: UFZ

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2.0	Final	30/06/2025	Tallent Dadi, Annette Schmidt

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Summary

Deliverable 3.1 (D3.1) contributes to the development of a database of restored lakes, with a primary focus on FERRO consortium countries, but also including relevant cases from other EEA-38 and Horizon Europe countries, with a focus on mainland Europe. This work is part of Work Package 3 (WP3), which aims to support restoration planning by compiling and analyzing data from past restoration efforts.

The deliverable outlines the approach for identifying and collecting relevant data through a combination of desktop research and stakeholder engagement. Key data sources include scientific literature, environmental databases, reports, and responses to a targeted questionnaire. This approach ensures that both published and unpublished information is captured, enabling broad representation of restoration efforts across Europe.

Deliverable 3.1 also sets out a structured list of metrics to be collected for each lake, covering five thematic categories: lake and catchment characteristics, restoration interventions, monitoring data (pre- and post-restoration), remote sensing indicators, and socioeconomic aspects including stakeholder involvement and governance. These metrics were selected for their relevance for assessing restoration outcomes and enabling comparisons across lakes and restoration approaches.

1 Data Sources and Methods

This section outlines the sources and methods used to collect data for the restored lake database. It describes how a combination of desktop research and stakeholder engagement is being used to gather both published and unpublished information. This approach ensures broad geographic and contextual coverage of restoration cases across FERRO consortium countries as well as other relevant countries within the EEA-38 and Horizon Europe area, with a focus on mainland Europe.

1.1 Published Data Sources

Published data will be retrieved from:

i. Scientific literature, including peer-reviewed journal articles, reports, and case studies on lake restoration.
ii. European environmental databases, such as the European Environment Agency's Waterbase and WISE, which contain water quality, pressure, and policy-related data.
iii. Global and regional lake datasets, including the Global Lakes and Wetlands Database (GLWD) and the Global Lake Ecological Observatory Network (GLEON) and others.
iv. National databases and agency reports, provided by environmental ministries, water authorities, and research institutions within consortium countries.

1.2 Unpublished Data and Grey Literature

To complement published sources, a structured questionnaire has been developed to collect information directly from experts, institutions, and stakeholders involved in past lake restoration efforts. The questionnaire is designed to gather not only the core metrics listed in this

deliverable but also contextual insights that can help interpret restoration outcomes—such as implementation details, monitoring approaches, and enabling or limiting factors. It is provided in Annex 1 of this deliverable.

The questionnaire will be launched in Q3 2025 and remain open for approximately three months. It will be distributed via existing networks and through consortium partners. It is intended to capture:

i. Restoration cases not covered in the scientific literature;
ii. Project documentation, monitoring results, and implementation details held in local or institutional records.

This dual approach enables the database to include a wide range of restoration examples, including lesser-known or informal initiatives, and ensures that both quantitative data and qualitative insights are captured. Templates will be used to standardize data entry across all sources and to ensure consistent recording of key restoration metrics for integration into the central database.

2 Restoration Metrics

This section provides an overview of the metrics selected for inclusion in the restored lake database. The metrics are structured around five thematic categories—lake and catchment characteristics, restoration interventions, monitoring data (pre- and post-restoration), remote sensing indicators, and socioeconomic aspects including stakeholder involvement and governance. For each metric, a brief description is provided along with an indication of its data availability and its relevance to restoration assessment and cross-lake comparison. The table below summarizes the proposed metrics.

Table 1: *Key Metrics for Lake Restoration Database*

No.	Metric	Description	Data availability	Relevance
	Lake and Catchment Metrics			
1.	Lake/Reservoir name	Official name of the lake	Common	Links all data to a specific water body.
2.	Country	Country where the lake is located	Common	Essential for regional context and policy relevance.
3.	GPS coordinates	Latitude & Longitude (decimal degrees)	Common	Enables geospatial analysis and integration with maps.
4.	Climate zone	EEA climate classification	Rare	Umbrella indicator summarizing temperature, precipitation, and hydrological conditions affecting lake function and restoration potential.
5.	Lake type	Natural / Reservoir / Artificial	Common	Influences restoration options and response.
6.	Lake use	Drinking water / Recreation / Fishing / etc.	Common	Relevant for ecosystem services and management goals. Links restoration to human uses.

No.	Metric	Description	Data availability	Relevance
7.	Lake surface area	Total surface area (km²)	Common	Important for understanding dilution capacity and productivity.
8.	Lake volume	Total volume of water in the lake, typically in cubic meters (m³) or cubic kilometers (km³).	Common	Needed to calculate residence time and assess the lake's capacity to dilute or retain nutrients.
9.	Maximum depth	Maximum lake depth (m)	Common	Helps infer stratification and internal loading potential.
10.	Mean depth	Average depth (m)	Common	Useful for water volume and stratification analysis.
11.	Water residence time	Average time water remains in the lake before being replaced.	Rare	Indicates water renewal and risk of nutrient accumulation.
12.	Number of inflows	Number of streams or rivers feeding into the lake	Common	Helps assess external nutrient loading and hydrological connectivity
13.	Number of outflows	Number of streams or rivers draining the lake	Common	Indicates potential for flushing and water residence time
14.	Groundwater interactions	Known groundwater inflow or outflow, including seepage zones	Rare	Crucial for understanding hidden nutrient pathways and internal-external fluxes
15.	Catchment area	Total catchment size (km²)	Rare	Relates to external nutrient loading potential.
16.	Dominant land use	% land cover types (agriculture, forest, etc.)	Rare	Determines external nutrient pressures.
17.	Presence of WWTPs	Location and number	Rare	Indicates point source nutrient load.
18.	Population density	Number of people per km² in the lake's catchment area, if known	Rare	Indicates potential human pressure and nutrient input from settlements
	Restoration Metrics			
19.	Restoration method	Type of intervention (biomanipulation, chemical precipitations, dredging, etc.)	Common	Crucial to categorize type of action taken.
20.	Targeted nutrient source	Internal / external loading, etc.	Common	Identifies main problem being addressed.
21.	Duration of restoration	Indicate the total duration of restoration activities. In case of multiple distinct restoration projects, provide details for each (e.g. years, duration, focus)	Rare	Necessary for evaluating before/after effects and understanding restoration timelines and complexity
22.	Restoration cost	Total investment, actual or estimated (€)	Rare	Important for cost-benefit assessment.
23.	Duration of pre-monitoring	Duration and start year of monitoring before restoration	Rare	Important for assessing the baseline and robustness of comparisons

No.	Metric	Description	Data availability	Relevance
24.	Duration of post-monitoring	Duration and start year of monitoring after restoration	Rare	Crucial for evaluating the effectiveness and long-term outcomes of restoration
25.	Success criteria	Specific restoration targets were defined at the start of the project. Examples: TP < 50 µg/L, Chl-a < 10 µg/L, preventing hypolimnetic anoxia, macrophyte re-establishment, improved water clarity etc.	Rare	Helps assess whether the restoration had measurable goals and supports evaluation of effectiveness
26.	Constraints faced	Political, social, technical	Rare	Useful for understanding implementation barriers.
27.	Lessons learned / recommendations	Summary of insights	Common	Supports knowledge transfer.
	Monitoring (Pre- and Post-Restoration) Metrics: growing season minimum, maximum and mean			
28.	Total phosphorus (TP)	TP concentration (mg/L)	Common	Key indicator of eutrophication.
29.	Soluble reactive phosphorus (SRP)	SRP concentration (µg/L)	Common	Key indicator of bioavailable phosphorus; directly linked to algal growth
30.	Total nitrogen (TN)	TN concentration (mg/L)	Common	Essential for nutrient limitation analysis.
31.	Nitrate (NO_3^-)	Nitrate concentration (mg/L)	Common	Important nitrogen source; helps assess nutrient limitation and inputs
32.	Ammonium (NH_4^+)	Ammonium concentration (mg/L)	Common	Reactive nitrogen form; linked to oxygen conditions and internal loading
33.	Dissolved organic carbon (DOC)	DOC concentration (mg/L)	Rare	Provides information on organic matter dynamics and potential oxygen demand
34.	Chlorophyll-a (Chl-a)	Chl-a concentration(µg/L)	Common	Proxy for algal biomass and response.
35.	Secchi depth	Water transparency (m)	Rare	Simple indicator of water clarity and algal impact.
36.	Turbidity	Turbidity (NTU)	Rare	Indicates water clarity; affected by sediment, algal blooms, or inflows
37.	Oxygen	Oxygen concentration (mg/L)	Common	Indicates potential for internal nutrient release.
38.	Temperature	Temperature (℃)	Common	Affects nutrient cycling and biological activity
39.	pH	Surface average	Common	Important for nutrient solubility and biotic conditions.
40.	Specific conductivity	Specific conductivity (µS/cm)	Common	General proxy for ion/nutrient content.
41.	Biological indicators	Macrophytes, fish, zooplankton	Rare	Reflect ecological structure and function.

No.	Metric	Description	Data availability	Relevance
	Remote Sensing (RS) Metrics			
42.	WP4 Lake	Yes / No	Common	Identifies lakes targeted for in-depth analysis.
43.	Land use classification	RS-derived catchment cover	Rare	Helps assess pressures using consistent data.
44.	Chlorophyll-a via RS	Satellite-derived estimates	Rare	Broad-scale, consistent algal indicator.
	Socioeconomic Metrics			
45.	Restoration driver(s)	Indicate what motivated the restoration (e.g. legal requirement, ecological concern, economic need)	Common	Contextualizes motivation, urgency, and external pressures
46.	Time from problem recognition to implementation	Estimate how long it took from the moment it became clear that restoration was needed to when it actually started	Rare	Helps gauge responsiveness and institutional or procedural delays in project implementation
47.	Funding source	Local, national, EU, private	Rare	Key to scale, priorities, and long-term security of a restoration project.
48.	Stakeholder involvement and governance	Indicate the governance level (local, regional, national) and list key stakeholders involved (e.g. authorities, NGOs, citizens, academia, SMEs). Describe their role (e.g. planning, implementation, citizen science, outreach).	Rare	Provides insight into institutional responsibility, stakeholder engagement, and public acceptance

3 Annex 1: Lake Restoration in Europe Questionnaire

Introduction

The Fostering European Lakes Restoration by Nutrient Removal, Recovery, and Reuse (FERRO) project is dedicated to promoting sustainable lake restoration across Europe. Our focus is on integrating innovative approaches, such as nutrient recovery and reuse, to help achieve good ecological status for European lakes while fostering a thriving circular economy.

Lakes are vital ecosystems, providing drinking water, supporting biodiversity, and enhancing quality of life, yet they face growing threats from eutrophication. Your participation in this survey helps address these challenges by sharing valuable insights into lake restoration efforts across Europe, including regional successes and challenges.

Why participate in this survey?

- **Collaboration:** Join a network of experts working together to tackle lake restoration challenges, combining knowledge from diverse regions and disciplines.
- **Influence:** Your input will shape the creation of a comprehensive, open-source lake restoration database, designed for interaction between lake restoration scientists, practitioners and inspire future projects.
- **Impact:** The insights you provide will directly contribute to enhancing lake restoration practices and help achieve sustainable management of European lakes.
- **Recognition:** All participants who complete the survey with substantial information will be considered for co-authorship in potential publications resulting from this work, provided they are willing to fulfill the responsibilities of a co-author. If you prefer not to be a co-author, indicate this at the end of the survey, and your contributions will instead be acknowledged.

The geographical scope of this survey is EEA38 plus Horizon Europe (Mainland Europe). See details below

Category	**Countries**
EU Member States (27)	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France (continental), Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden
Non-EU EFTA Countries (4)	Iceland, Norway, Liechtenstein, Switzerland
Candidate and Potential Candidate Countries (7)	Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, Serbia, Turkey
Other Horizon Europe Associated Countries (2)	UK, Ukraine

We sincerely appreciate your participation and look forward to collaborating with you to enhance the ecological health of Europe's lakes. Thank you for joining this effort!

Tip: *We recommend that you first read through the PDF version of the survey and prepare your data before starting. You can also fill in the survey partially, save your progress, and return to complete it later. Once you're finished, don't forget to save and submit your responses.*

Section 1: Participant Background

1. What is your primary scientific discipline? (Select all that apply)

- Environmental science
- Ecology
- Hydrology
- Biology
- Engineering
- Geology
- Chemistry
- Other (please specify)

2. What type of organization do you work for? (Select all that apply)

- University or academic institution
- Government agency
- Research institution
- Industry (company, start-up, consultancy)
- Non-governmental organization (NGO)
- Other (please specify)

3. Which country are you based in? (Open-ended input field)

4. How many years have you been involved in lake restoration projects?

- 0–5 years
- 5–10 years
- 10+ years

5. How many lake restoration projects have you been involved in?

- 1 lake
- 2–5 lakes
- More than 5 lakes

Note: If you have worked on more than one lake, please complete Sections 2 and 3 separately for each lake. Submit one full set of responses for each lake you wish to include in the database.

Section 2: Lake Restoration Data

Lake and Catchment Information

6. For each lake, please provide:

- Lake/Reservoir name
- Country
- GPS coordinates (decimal degrees, Latitude, Longitude e.g. 47.3769, 8.5417)
- Lake Type (Natural / Reservoir / Artificial). We distinguish between: **natural lakes** (formed by natural processes), **reservoirs** (used for water storage, typically dammed), and **artificial lakes** (human-made, such as gravel excavation lakes, mining pits, or urban ponds).
- Lake use (Drinking water / Recreation / Fishing /Irrigation etc.)
- Lake surface area (km^2)
- Lake volume (km^3)
- Maximum depth (m)
- Mean depth (m)
- Water residence time (years)

- Number of inflows (streams or rivers feeding into the lake)
- Number of outflows (streams or rivers draining the lake)
- Groundwater interactions (e.g. known inflow or outflow through groundwater, seepage zones)
- Catchment area (km^2)
- Dominant land use types (e.g., agriculture, forest, urban)
- Presence of WWTPs (number, location, and size — if known, specify in population equivalent [PE] or flow rate [m^3/day])
- Population density (number of people per km^2, if known)

Restoration Metrics

7. What was the main nutrient source targeted by the restoration intervention? [Select one option only]

- Internal loading (e.g. release of phosphorus from sediments)
- External loading (e.g. agricultural runoff, point sources such as wastewater, or urban/stormwater inputs)
- Both internal and external loading
- Unknown / not specified

Optional: Please provide additional details if available:

8. What are the primary goals of the lake restoration projects? (Select all that apply):

- Improving water quality (e.g., TP, TN, Chlorophyll-a)
- Restoring aquatic habitats for biodiversity
- Enhancing recreational value
- Achieving ecological targets (e.g., Good Ecological Status under EU WFD)
- Other (please specify)

9. What methods were used? *Select all applicable in case of combined methods*

- Biological treatments (e.g., biomanipulation, macrophyte removal)
- Chemical treatments (e.g., alum, iron, calcium treatment)
- Mechanical removal (e.g., dredging)
- Oxygenation
- Construction of wetlands
- Shoreline stabilization
- Watershed management (e.g., agricultural runoff reduction, buffer strips, point source reduction at wastewater treatment plants)
- Public engagement/education (e.g., awareness campaigns)
- Other (please specify)

10. What was the rationale for choosing this/these method(s)? Please describe how the decision was made — for example, was a preliminary system analysis conducted, were there stakeholder consultations, or was the choice based on previous experience or guidance?

11. Were specific success criteria or restoration targets defined at the start of the project? [Select one]

- Yes
- No
- Unknown

If yes: *Please indicate the criteria or targets (e.g. TP < 50 µg/L, Chl-a < 10 µg/L, preventing hypolimnetic anoxia, macrophyte re-establishment, improved water clarity etc.)*

12. For each restoration project, please provide:

- Year of restoration (list all years if there were multiple interventions)
- Duration of each restoration phase (months/years)
- Actual or estimated cost (€) for each phase (please indicate if the cost is actual or estimated)

13. Has the lake been restored more than once?

- Yes
- No
- Not sure

Follow-up (if yes): Why was repeated intervention necessary? (Open-ended)

14. Time interval between restorations:

- Less than 5 years
- 5-10 years
- 10-20 years
- Over 20 years

Monitoring Metrics

Pre-Restoration Monitoring

15. Was pre-restoration monitoring conducted?

- Yes
- No

If "Yes," proceed to questions 14 and 15.

16. Was the monitoring detailed enough to identify the key stressors and determine the extent to which external and/or internal nutrient loading needed to be reduced?

- Yes
- Partially
- No
- Don't know

If yes or partially, please describe how this was assessed (e.g., type of monitoring, indicators used, duration).

17. How many years of pre-restoration monitoring were conducted?

- [Enter the number of years]

18. Indicate the mean, minimum and maximum **growing season (May–October)** concentrations of the following parameters (leave blank if unavailable): *Note: Indicate the mean, minimum, and maximum growing season (May–October) concentrations of the following parameters. For unstratified lakes, provide surface values. For stratified lakes, provide both surface and hypolimnetic values (if available). Leave blank if data is unavailable.*

- Total phosphorus (TP, mg/L)
- Soluble reactive phosphorus (SRP, µg/L)
- Total nitrogen (TN, mg/L)
- Nitrate (NO_3^-, mg/L)
- Ammonium (NH_4^+, mg/L)
- Dissolve organic carbon (DOC, mg/L)
- Chlorophyll-a (µg/L)
- Secchi depth (m)

- Turbidity (NTU)
- Oxygen (mg/L and %)
- Temperature (℃)
- pH
- Specific Conductivity (µS/cm)
- Biological indicators (describe what was monitored — e.g. macrophytes, fish, zooplankton — and any observed changes over time)

Post-Restoration Monitoring

19. Was post-restoration monitoring conducted?

- Yes
- No

If "Yes," proceed to questions 17 and 18.

20. If yes, how many years of post-restoration monitoring were conducted?

- [Enter the number of years]

21. Indicate the mean, minimum and maximum growing season (May–October) concentrations of the following parameters (leave blank if unavailable): *Note: Indicate the mean, minimum, and maximum growing season (May–October) concentrations of the following parameters. For unstratified lakes, provide surface values. For stratified lakes, provide both surface and hypolimnetic values (if available). Leave blank if data is unavailable.*

- Total phosphorus (TP, mg/L)
- Soluble reactive phosphorus (SRP, µg/L)
- Total nitrogen (TN, mg/L)
- Nitrate (NO_3^-, mg/L)
- Ammonium (NH_4^+, mg/L)
- Dissolve organic carbon (DOC, mg/L)
- Chlorophyll-a (µg/L)
- Secchi depth (m)
- Turbidity (NTU)
- Oxygen (mg/L and %)
- Temperature (℃)
- pH
- Specific conductivity (µS/cm)
- Biological indicators (describe what was monitored — e.g. macrophytes, fish, zooplankton — and any observed changes over time)

Circular Economy-Based Restoration and Remote Sensing

22. Were nutrient recovery or reuse practices (e.g., phosphorus or nitrogen recovery) incorporated into the restoration efforts of the lakes or catchments you worked on?

- Yes
- No
- Not sure

23. If nutrient recovery or reuse (aligned with circular economy principles) was integrated, what specific applications were implemented? (*For example: reuse of nutrients in agriculture, bioenergy generation from harvested biomass such as macrophytes or fish, recycling of materials used in restoration efforts.)*

- [Open-ended response]

24. *Was remote sensing used to support monitoring during or after the restoration project?* [Select one]

- Yes
- No
- Unknown

If yes: *Please indicate the type of remote sensing used (e.g. satellite imagery, drone surveys, aerial photography) and what it was used for (e.g. water quality, vegetation cover, land use):*

Socioeconomic Metrics

25. What were the main drivers or motivations for initiating the lake restoration project? [Select all that apply]

- Legal or regulatory requirement
- Ecological concern (e.g. biodiversity loss, eutrophication)
- Economic need (e.g. tourism, fisheries, property value)
- Environmental catastrophe (e.g. fish kill, algal bloom, flooding)
- Public or community pressure
- Scientific recommendation
- Other (please specify): _____

26. Approximately how long was the time between the recognition of the lake's degradation and the start of restoration implementation? [Select one]

- Less than 2 years
- 2–5 years
- 5–10 years
- More than 10 years
- Unknown

Optional: Please describe any known reasons for delays (if applicable):

27. What were the main sources of funding for the restoration project? [Select all that apply]

- Local (e.g. municipal budgets)
- National (e.g. government ministries or agencies)
- EU (e.g. LIFE, Horizon, Interreg)
- Private (e.g. companies, foundations, landowners)
- Other (please specify): _____
- Unknown

28. At which governance level(s) was the restoration planned and managed? [Select all that apply]

- Local
- Regional
- National
- Transboundary or international
- Unknown

29. Which stakeholders were involved in the restoration process? Please indicate their role(s) (e.g. planning, implementation, citizen science, communication): [Select all that apply and describe roles briefly]

- Government authorities (e.g. environment ministry, water agencies)
- NGOs or civil society organizations
- Local citizens or community groups
- Academic or research institutions
- Private sector (e.g. consultancies, SMEs)
- Other (please specify): _____

Brief description of stakeholder roles:

Restoration outcome

30. Was the restoration considered successful in addressing the main problems or achieving defined targets? *(Select one)*

- Yes – it addressed the problem and met the defined targets
- Partially – some objectives were met
- No – main targets or problems were not fully addressed
- Unknown / not evaluated

If yes or partially go to Q32, if no go to Q33

31. If restoration was successful or partially successful, what were the key benefits of the restoration? *(Select all that apply)*

- Improved water quality (e.g. reduced nutrient concentrations, increased Secchi depth, reduced algal blooms)
- Increased biodiversity
- Enhanced recreational opportunities
- Improved aesthetic value
- Other (please specify): _____

Note: Please briefly elaborate on the selected benefits (e.g. type of improvement observed, timeframe, magnitude):

32. If restoration was not successful, please explain why the restoration was not successful and what lessons were learned:
(Open-ended – e.g. technical limitations, lack of long-term maintenance, funding issues, governance challenges)

33. Was the restoration documented or published? *(Select one)*

- Yes, in peer-reviewed journals
- Yes, in grey literature
- Yes, in both
- No
- Not sure

If yes: *Please provide references or URLs:*

Section 3: Contributor Information and Final Remarks

34. Would you like to be considered for co-authorship?

- Yes (*I am willing to fulfill the responsibilities of a co-author*)
- No (*I prefer to be acknowledged for my contributions*)

35. Please provide your contact details for future communications:

- Full Name [Open-ended response]
- Email [Open-ended response]

36. If there is any other information you would like to share or convey related to this survey or the restoration efforts, please provide it here:

- [Open-ended response]

Closing Statement

Your participation is highly valued and greatly appreciated. All respondents will be kept updated on the status of the survey and any further developments at the end of the survey period.