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Water quality — Guidance standard on determining the degree of modification of lake hydromorphology

bsi.

National foreword

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Wasserbeschaffenheit - Anleitung zur Bestimmung der hydromorphologischen Eigenschaften von Seen

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European foreword

This document (EN 16870:2017) has been prepared by Technical Committee CEN/TC 230 “Water analysis”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2017, and conflicting national standards shall be withdrawn at the latest by August 2017.

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Introduction

This European Standard will enable broad comparisons to be made of the hydromorphological condition of lakes throughout Europe (e.g. for reporting by the European Environment Agency). In this document, the word 'lake' is used as a generic term for standing waters including natural lakes, reservoirs, excavated pits and other artificial water bodies.

The Guidance standard for assessing the hydromorphological features of lakes (EN 16039) describes a protocol for survey (field and remote sensing methods) and feature recording, whereas this standard gives guidance on assessing the condition of those features, and focuses especially on human pressures that affect lakes. This standard has applications for nature conservation, environmental impact assessment, lake management, and guiding lake restoration work.

The assessment of lake 'quality' in Europe has evolved over the past decades from its focus on chemical conditions to a more comprehensive ecological approach. The EC Water Framework Directive (WFD) has reinforced the need for this broader view of lake 'quality' through its requirement for determining 'ecological status' based on phytoplankton, phytobenthos, macrophytes, invertebrates and fish. The Directive also requires hydromorphological and physico-chemical conditions to be suitable for supporting biological communities. This standard, therefore, may be helpful for implementing the WFD when indicating the extent to which pressures might have caused a departure from natural hydromorphological conditions. In doing so it complements methods that have been developed within particular countries for assessment and reporting under the WFD. However, this standard makes no links between hydromorphology and biology, nor does it set any hydromorphological condition targets that should be achieved. Whereas decisions on management for individual lakes require expert local knowledge and vary according to lake type, this standard provides a framework to help those decisions to be made consistently.

1 Scope

This European Standard provides guidance on determining the degree of modification of lake hydromorphological features described in EN 16039. It enables consistent comparisons of hydromorphology between lakes within a country and between different countries in Europe, providing a method for broad based characterization across a wide spectrum of hydromorphological modification. Its primary aim is to assess 'departure from naturalness' for a given type of lake as a result of human pressures, and it suggests suitable sources of information that may contribute to characterizing the degree of modification of hydromorphological features. For wholly artificial lakes or reservoirs formed by damming rivers the aim is to assess the extent to which processes approximate to those in comparable natural water bodies. However, this standard does not replace methods that have been developed within particular countries for local assessment and reporting. Decisions on management for individual lakes require expert local knowledge and vary according to lake type. The assessment of the hydromorphological conditions as needed for the WFD (supporting the biological quality elements) remains in the competence of the individual Member States.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 15843:2010, *Water quality - Guidance standard on determining the degree of modification of river hydromorphology*

EN 16039:2011, *Water quality - Guidance standard on assessing the hydromorphological features of lakes*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
bank
physical edge of the lake shore, or of the island(s) within, generally defined by a wave-cut break in slope at or near the water's edge of the lake, but can also be defined as the line along which riparian (terrestrial or land) conditions change to littoral in-lake conditions

[SOURCE: EN 16039:2011, definition 3.3]

3.2
bar
discrete, natural, depositional feature with shallow slope into water composed of unconsolidated material

3.3
bathymetry
systematic survey of size, shape and water depth distribution in a lake

Note 1 to entry: Bathymetry is the basis of deriving morphometric parameters and to predict thermal stratification, residence time and sediment redistribution processes.

[SOURCE: EN 16039:2011, definition 3.5]

3.4
catchment
drainage basin contributing water and sediment into a lake (also recognized as drainage area)

[SOURCE: EN 16039:2011, definition 3.10]

3.5
connectivity
continuity
uninterrupted movement of water, sediment and organisms into, out of and within a lake system

[SOURCE: EN 16039:2011, definition 3.11]

3.6
drawdown
lowering of lake levels caused by deliberate water release

3.7
dune
underwater ridge formed by wave or current action on the lake bed

3.8
ecological status
expression of the quality of the structure and functioning of aquatic ecosystems, by comparing the prevailing conditions with reference conditions

Note 1 to entry: As classified in accordance with Annex V of the EC Water Framework Directive.

3.9
embeddedness
extent to which fine sediment infiltrates littoral gravels

3.10
gauging board
staff gauge
graduated scale, fixed to a lake outlet or inflow structure, or directly into the substrate, used to measure the water level in a lake

3.11
geotextile
permeable fabric often used to reinforce or protect banks

3.12
groundwater table
surface of a body of underground water below which the soil or rocks are permanently saturated with water

3.13
hard engineering
stabilization of the shoreline using 'hard' materials including concrete walls, gabion baskets and sheet piling

3.14
hydromorphology
physical and hydrological characteristics of lakes including the underlying physical processes from which they result

[SOURCE: EN 16039:2011, definition 3.22]

3.15
island
landform protruding from the surface of a lake

[SOURCE: EN 16039:2011, definition 3.26]

3.16
lake stratification
variations in water column structure with respect to temperature and density

[SOURCE: EN 16039:2011, definition 3.30]

3.17
littoral zone
habitat extending from the water's edge to the lakeward limit of rooted macrophytes or algae on the lake bed

[SOURCE: EN 16039:2011, definition 3.33]

3.18
pelagic zone
open water zone extending from the littoral zone towards the centre of a lake

[SOURCE: EN 16039:2011, definition 3.41]

3.19
planform
view of lake shape from above, e.g. elongate, circular, etc., and also relevant in relation to the shoreline development index which expresses the degree of irregularity of a lake compared with a circular form of the same area

[SOURCE: EN 16039:2011, definition 3.42]

3.20
profundal zone
deeper parts of the lake where light does not penetrate and there is no photosynthetic activity

3.21
ramping rate
rate of rise and fall of water levels often associated with hydropower generation

3.22
remote sensing
group of techniques for acquiring data on land forms and land cover (e.g. aerial photographs, satellite imagery, radar, sonar)

3.23
residence time
retention time
time for water in a lake to be replaced, which can be calculated in a range of ways (e.g. instantaneous, seasonal, annual) and may be applied to the entire lake, to individual lake basins or to strata within the lake

3.24
riparian zone
area of land adjoining the lake capable of directly influencing the condition of the aquatic ecosystem (e.g. by shading and leaf litter input)

[SOURCE: EN 16039:2011, definition 3.45]

3.25
scour hole
depression in the lake bed created by wave or current action

3.26
shore zone
comprises riparian, eulittoral and littoral zones around the perimeter of a lake

[SOURCE: EN 16039:2011, definition 3.48]

3.27
sidescan sonar
sonar scanning obliquely onto the lake bed used to characterize lake-bottom features

3.28
soft engineering
stabilization of the shoreline using 'soft' materials including basket-work, planted saplings and live willow, dumped natural debris (to re-nourish sediment supply) and degradable synthetic materials

Note 1 to entry: Also includes earth-moving where re-sectioning and re-profiling takes place

3.29
step
feature of erosion where a lake bank or an old depositional bar has been eroded to create distinct edges (steps) into water

Note 1 to entry: Several steps can develop down the shore to reflect different periods of erosion at times of different water level

3.30
substrate (substratum)
natural sediment or engineered surfaces comprising the shore and bed of a lake

Note 1 to entry: Natural sediments are generally characterized by texture and organic matter content, while artificial substrates are described by their construction materials

[SOURCE: EN 16039:2011, definition 3.49]

3.31
tracer experiment
one of a group of hydrogeological field techniques used to quantify groundwater flow

3.32
water balance
flow of water into and out of a lake (e.g. groundwater, rain water, evaporation)

3.33
wetland
transitional zone between permanently inundated, and generally dry, environments, e.g. marshes (wet ground without peat), fens (groundwater fed peats) and bogs (rain-fed peat systems)

[SOURCE: EN 16039:2011, definition 3.52]

3.34
willow spiling
method of soft engineering used to strengthen lake shores using retaining walls constructed of woven willow stems from which trees will sprout

4 Principle

A standard protocol is described for assessing the degree of modification of the hydromorphological features of different lake zones. Both this European Standard and EN 16039 focus attention on lake features as surrogates for lake processes. Those making assessments, therefore, do not need to be trained geomorphologists although some geomorphological input may be useful. To ensure consistency in approach, the main feature categories are in general the same as those in EN 16039. However, some minor adjustments have been made to the details to help facilitate scoring.

5 Determining the hydromorphological modifications of lakes

5.1 Feature categories

Assessments are made for the feature categories listed in EN 16039, with subdivisions into specific features where appropriate (Table 1).

Table 1 — Features to be assessed when determining the hydromorphological modifications of lakes

Feature category	Feature
1. Hydraulics	Water level variability Lake volume
2. Morphometry	Slope profile of shore zone Planform Depth distribution
3. Bedforms/Landforms and Substrate	Landform and substrate characteristics Bank structure and modifications Littoral substrate Lake bottom bedforms Extent of artificial material/imported natural substrate
4. Connectivity and Continuity	Natural exchange with groundwater Connectivity of lake with adjacent riparian wetlands Natural erosion/deposition patterns Natural exchange between groundwater and surface water Migratory movement Sediment transport
5. Aquatic Vegetation	Human disturbance or active management of aquatic vegetation (shore zone) Human disturbance or active management of aquatic vegetation (open water zone)
6. Land Cover	Land cover in riparian zone

5.2 Procedure for scoring

5.2.1 Users should note whether the lake being assessed is natural (N), heavily modified (H) or artificial (Ar). Annex A sets out guidance on how to allocate scores for each feature category. It contains two separate procedures for scoring – using score band A with quantitative data, or score band B with qualitative data. Score band A is a 5-point scale (1 = lowest degree of modification, 5 = highest degree of modification). Score band B is a 3-point scale (1, 3, 5; following the same general approach as for score band A). Quantitative data should always be used where available; where there are quantitative data for some of the features but not for all, a mix of quantitative and qualitative data may be used. Users should state which scores have been assigned based on quantitative data and which on qualitative descriptions, as this determines the degree of confidence in the assessment. This note should also be added to any maps produced that show the results of lake hydromorphological assessment.

5.2.2 Where the majority of scores have been derived from 5-band scales users may wish to retain the five bands. Where the majority have been derived from 3-band scales users may wish to change the 5-band scores to 3-band scores as follows, making clear in the results which scores have been changed in the way given in Table 2.

Table 2 — Conversion table

5-band score	3-band score
1	1
2	1
3	3
4	5
5	5

5.2.3 For those features where scoring 1 = 0 % to 5 % change, an asterisk should be added (i.e. 1*) where the recorded change is only 0 % to 1 %. This is to highlight lakes with extremely low levels of modification. A '☠'symbol should be added (i.e. 5☠) to indicate extreme levels of modification.

5.2.4 The importance of each of the features in Annex A for hydromorphological and ecological functioning will not be the same. However, at present there is insufficient scientific evidence to justify differential weighting of the scores allocated.

5.2.5 Three additional annexes are included in this standard. Annex B provides information to support interpretation of the scoring system for the 'water level variability' feature. Land cover in the wider catchment (Annex C) is included so that this information can be collated in order to provide context for the scored assessment of a lake. (This is undertaken as a separate assessment and does not form part of the hydromorphological assessment of the lake itself.) Annex D provides case studies to help in understanding and interpreting the overall scoring system. These examples include a description of the lake, a map, a summary of the scores with some interpretation, and a short conclusion.

6 Interpreting and reporting hydromorphological modifications

6.1 Modification scores

Scores should be reported as shown in Table 3. This process provides a range of options for different purposes, but shows clearly how each of the three combined scores (options 2, 3 and 4 in Table 3) has been derived.

Table 3 — Options, applications and procedures for reporting hydromorphological modification scores

Reporting option	Examples of applications	Procedure
1: Tabulate 16 scores separately	Providing maximum amount of information for lake management.	Score as in Annex A for all features; do not combine.
2: Create a 2-digit code	Reporting lake modification within the two main hydromorphological quality elements given in the WFD (hydrological regime, morphological conditions) but with no attempt to link hydromorphology with biology.	Combine the scores for category 1 to create a single mean score for hydrological regime (the first of the two digits). Scores should be rounded up or down to the nearest integer (rounding up any that end in 0,5). Combine the scores for categories 2–6 to create a single mean score for morphological conditions (the second of the two digits). Scores should be rounded up or down to the nearest integer (rounding up any that end in 0,5). [For example, a code of 1,1 would indicate a lake with near-natural hydrology and with the lowest degree of morphological modification.]
3: Group features according to zone	Reporting on the three main lake zones: open water pelagic/ profundal zone, shore zone, and riparian zone, as recommended in EN 16039.	Feature categories should be grouped and mean scores calculated for the three zones. Scores should be rounded up or down to the nearest integer (rounding up any that end in 0,5).
4: Produce a single score for the lake assessed	Reporting overall hydromorphological modification of a lake without the detail.	Take the mean of the 16 scores (see no. 1 in table). Round up or down to the nearest integer. Scores ending in '0,5' should be rounded up.

6.2 Assigning classification terms

6.2.1 Where five classes are used, the terms in Table 4 should be assigned to descriptions of hydromorphological modification, and represented (if required) on a map using the colour codings recommended in EN 16039.

Table 4 — Classification terms for 5 classes (Score band A)

Score	Class	Description	Map colour
1 to < 1,5	1	Near-natural	Blue
1,5 to < 2,5	2	Slightly modified	Green
2,5 to < 3,5	3	Moderately modified	Yellow
3,5 to < 4,5	4	Extensively modified	Orange
4,5 to 5,0	5	Severely modified	Red

6.2.2 Where three classes are used, the terms in Table 5 should be assigned to descriptions of hydromorphological modification, and represented (if required) on a map using the following colour codings:

Table 5 — Classification terms for 3 classes (Score band B)

Score	Class	Description	Map colour
1 to < 2,5	1	Near-natural to slightly modified	Blue
2,5 to < 3,5	3	Slightly to moderately modified	Yellow
3,5 to 5,0	5	Extensively to severely modified	Red

6.2.3 The names used to describe each class (e.g. 'near-natural') have been deliberately chosen to be different from terms used in the WFD (e.g. 'high', 'good') to emphasize that classifications using this standard are unrelated to classifications of ecological status for the WFD. Although the five colours listed in 6.2.1 for reporting hydromorphological modification are the same as those in the WFD, they are also used routinely for reporting other (non-WFD) aspects of environmental quality.

Annex A
(normative)

Characterization of lake modification based on hydromorphological features

When assessing artificial water bodies it may be possible to make a comparison with natural water bodies of a similar size and in a similar landscape setting, either in the same area or in areas remote from the artificial water body, but where a similar set of natural lake processes are operating. Alternatively, it may be possible to assess whether lake processes in the artificial water body have become naturalized by looking for evidence of historical water levels and depositional or erosional imbalances. Such evidence might also be obtained from modelling lake volumes, inflows and outflows, or by modelling lake landform evolution in response to the prevailing energy regime.

Land cover in the wider catchment should also be assessed, using the guidance in Annex C, in order to provide context for the scored assessment of a lake. This should be undertaken as a separate assessment and should not be part of the hydromorphological assessment of the water body itself.

Table A.1 — Characterization of lake modification based on hydromorphological features

		Features	Score band A – Quantitative	Score band B – Qualitative	Guidance	Examples of methods/ data use
1. HYDRAULICS	**Riparian zone**	N/A	N/A	N/A	N/A	N/A
	Shore zone	(see Annex B)	(see Annex B)	(see Annex B)	(see Annex B)	(see Annex B)
	Open water zone	Lake volume (includes residence time, stratification and mixing)	Feature not scored	1 = Near-natural. Very little or no change to lake volume 3 = Lake volume moderately altered 5 = Lake volume severely altered	This attribute captures changes in three related phenomena: i) water volumes and throughflow, e.g. change to residence times; ii) water volume and depth relations that influence stratification behaviour and stability of thermal or density layering; iii) mixing behaviour within the water column. If stratification or mixing is substantially different from a suitable natural analogue, a score of 5 should be allocated. If there is any abstraction or augmentation from the lake or the catchment (e.g. for hydropower production) a score of 1 cannot be assigned.	Water level time series; use of historical maps to show changes in planform, e.g. smaller equates to drawdown and reduced volume; modelling linked to catchment-scale water balance; Lake Habitat Survey (LHS) database; regular physico-chemical measurements at the deepest part of the lake; temperature and oxygen profiles; remote sensing data to indicate shoreline exposure; discussion with lake managers on whether there are water-mixing measures (e.g. aeration systems)
2. MORPHOMETRY	**Riparian zone**	N/A	N/A	N/A	N/A	N/A

Table A.1 (Continued)

		Features	Score band A – Quantitative	Score band B – Qualitative	Guidance	Examples of methods/ data use
	Shore zone	Slope profile of shore zone	1 = 0 % to 5 % of lake with non-natural slope profile. 2 = > 5 % to 15 % of lake with non-natural slope profile 3 = > 15 % to 35 % of lake with non-natural slope profile 4 = > 35 % to 75 % of lake with non-natural slope profile 5 = > 75 % of lake with non-natural slope profile	1 = Near-natural slope profile. 3 = Slope profile near-natural throughout part of the lake. 5 = Slope profile non-natural in majority of lake; or lake completely or almost completely modified.	Assessment of the change in slope profile is very difficult to do accurately without repeat survey. There is some scope to estimate change by using a section of the shoreline that is unmodified. Alternatively, a change in slope profile might be indirectly inferred from: (i) imbalances in shore erosion or deposition; (ii) historical changes to water level elevation and planform (because the shore zone is located in a different section of the landscape); (iii) presence of hard bank engineering (because of increased reflection of waves and associated scour and deposition). In the case of artificially dug lakes the natural slope is taken to be that of similar-sized lakes, once geomorphological processes	If using LHS, the following sections of the survey form will help to infer changes: (i) 'Bank face erosion' and 'Signs of erosional or depositional imbalance' from section 2.2 – Hab-Plot Attributes, Exposed Shore. (Use the median value of the range, e.g. for a score of 2 (>10 %–40 %), assume 25 % of the bank length is eroding); (ii) 'Bank erosion' from section 3.1 – Whole Lake Assessment, Lake Perimeter Characteristics. (Use the median value of the range); (iii) 'Height water level raised or lowered' from section 4 – Hydrology; (iv) 'Predominant bank material', 'Bank face modification(s)'and 'Predominant shore forming material' from section 2.2 – Hab-Plot Attributes, Exposed Shore.

Table A.1 (Continued)

		Features	Score band A – Quantitative	Score band B – Qualitative	Guidance	Examples of methods/ data use
					have been formative.	Historical changes to water level elevation and planform may also be inferred from field evidence of historically higher lake levels or comparison of historical and contemporary maps or aerial photographs.
		Planform	1 = 0 % to 5 % of lake with non-natural planform. 2 = > 5 % to 15 % of lake with non-natural planform 3 = > 15 % to 35 % of lake with non-natural planform 4 = > 35 % to 75 % of lake with non-natural planform 5 = > 75 % of lake with non-natural planform	1 = Near-natural planform. 3 = Planform near-natural throughout part of the lake. 5 = Planform non-natural in majority of lake; or lake completely or almost completely modified.	The comparison of lake areas shall be based on a consistent datum, such as mean maximum water level within the historical observation period, or the mean minimum water level, combined with information on bathymetry. Potential data sources are listed in EN 16039:2011, 6.3.	

Table A.1 (Continued)

		Features	Score band A – Quantitative	Score band B – Qualitative	Guidance	Examples of methods/ data use
	Open water zone	Depth distribution	Feature not scored	1 = Depth distribution reflects near-natural condition. 3 = Depth distribution reflects moderate departure from near-natural condition. 5 = Depth distribution is artificial	Need information on the mean surface area of the lake and the depth per % of the area. Need information on mode of formation. Accurate assessment of the degree of modification of depth distribution is very difficult without repeat surveys of bathymetry. It is anticipated that assessments will become easier in future when new methods of measurement are developed. Alternatively, modifications might be indirectly inferred from historical changes to water level elevations and planform.	Direct assessments of change might be made using hydro-acoustic data, remote sensing, profile data, interpolation program, bathymetric data or GIS applications. Indirect assessments may be made using LHS data from section 4 – Hydrology, 'Height water level raised or lowered', or by comparison of historical and contemporary maps or aerial photographs.
	Riparian zone	N/A	N/A	N/A	N/A	N/A

Table A.1 (Continued)

		Features	Score band A – Quantitative	Score band B – Qualitative	Guidance	Examples of methods/ data use
3. BEDFORMS/ LANDFORMS AND SUBSTRATE	**Shore zone**	Landform and substrate characteristics (erosion/deposition character)	1 = 0 % to 5 % of lake with evidence of non-natural erosion or deposition 2 = > 5 % to 15 % of lake with evidence of non-natural erosion or deposition 3 = > 15 % to 35 % of lake with evidence of non-natural erosion or deposition 4 = > 35 % to 75 % of lake with evidence of non-natural erosion or deposition 5 = > 75 % of lake with evidence of non-natural erosion or deposition	1 = Erosion/deposition features reflect near-natural conditions 3 = Erosion/deposition features reflect moderate departure from near-natural conditions 5 = Erosion/deposition features conspicuously different from those expected under near-natural conditions	In-lake features comprise depositional features (e.g. steps, bars, islands), and erosional features (e.g. cliffs) and also features such as cushions of aquatic plants, large wood, etc. The significance of these features depends on the characteristics of the shoreline (e.g. slope, substrate, inflows). Where significant amounts of erosion and/or deposition are recorded it is important to distinguish one from the other, so that appropriate management can be put in place. Sediment core samples could be taken if further investigation is required to better understand the sedimentation regime. In some cases extensive non-natural deposition can cause embeddedness of substrate material.	Hydromorphological surveys; databases; aerial photos. When using LHS survey data recorded erosion on the whole lake survey section will give % of shoreline affected. This information can be checked using records in Hab-Plots section 2.2 – Shorezone; Bankface which has a line where any erosion is recorded. This is indicated on the form as 'ER' and can be used as an indicator of erosion.

Table A.1 (Continued)

		Features	Score band A – Quantitative	Score band B – Qualitative	Guidance	Examples of methods/ data use
		Bank structure and modifications – extent of artificial bank material (% of shore perimeter)	1 = Banks affected by 0 % to 5 % hard or 0 % to 10 % soft engineering. 2 = Banks affected by > 5 % to 15 % hard, or > 10 % to 30 % soft engineering. 3 = Banks affected by > 15 % to 25 % hard or > 30 % soft engineering. 4 = Banks affected by > 25 % to 50 % hard engineering. 5 = Banks affected by > 50 % hard engineering.	1 = Near-natural. No, or minimal, presence of artificial material 3 = Small to moderate presence of artificial material 5 = Extensive presence of artificial material	If modified bank materials are 'natural' (e.g. willow spiling) maximum score is 3. Assessment of extent of bank affected is based on predominant material present (may be a mix of two types)	Hydromorphological surveys (e.g. LHS); databases; aerial photos If using LHS, key Hab-Plot data include Section 2.2 – Bank Face: 'predominant bank material' and 'bank face modifications'; Beach: 'predominant shore forming material'

Table A.1 (Continued)

		Features	Score band A – Quantitative	Score band B – Qualitative	Guidance	Examples of methods/ data use
		Littoral substrate – extent of artificial material/ imported natural substrate	1 = 0 % to 1 % artificial material/imported natural substrate 2 = > 1 % to 5 % artificial material/imported natural substrate 3 = > 5 % to 15 % artificial material/imported natural substrate 4 = > 15 % to 30 % artificial material/imported natural substrate 5 = > 30 % artificial material/imported natural substrate	1 = Near-natural. No, or minimal, presence of artificial material 3 = Small to moderate presence of artificial material 5 = Extensive presence of artificial material	Artificial materials include brick-laid stone, concrete, geotextiles, etc. The percentage assessed is expressed as a proportion of the perimeter length and not as a proportion of the overall area of the littoral zone. Imported natural substrate refers to natural substrate types (e.g. gravel, sand, boulders) deliberately placed in areas of a lake where they would not naturally occur (e.g. large stone slabs positioned around the lake shore to prevent bank erosion). Record only natural substrates: mud, silt, sand, pebbles, gravel, stones, rocks, organic substrates. NOTE: The natural range of substrates is lake type- and site-specific.	Hydromorphological surveys (e.g. LHS); records made during biological sampling; databases; aerial photos If using LHS, key Hab-Plot data include Section 2.3 Littoral zone: 'predominant littoral substrate' and 'recent sedimentation over natural substrate'
	Open water zone	Lake bottom bedforms	Feature not scored	1 = Near-natural bedforms 3 = Bedform changes throughout part of the lake/basin 5 = Bedforms changed in majority of the lake/basin	This includes assemblage of natural bedform features (e.g. dunes, scour holes) and their associated properties (texture, structure). Activities such as dredging for navigation may be expected to influence bedforms. In lakes undergoing eutrophication increased	Bathymetric survey; sidescan sonar; grab samples, coring to provide information on changes to sedimentation rates; sedimentation traps; data from SCUBA surveys

Table A.1 (Continued)

		Features	Score band A – Quantitative	Score band B – Qualitative	Guidance	Examples of methods/ data use
					sedimentation may also influence bedform structure.	
		Extent of artificial material/imported natural substrate	1 = 0 % to 1 % artificial material/imported natural substrate 2 = > 1 % to 5 % artificial material/imported natural substrate 3 = > 5 % to 15 % artificial material/imported natural substrate 4 = > 15 % to 30 % artificial material/imported natural substrate 5 = > 30 % artificial material/imported natural substrate	1 = Near-natural. No, or minimal, presence of artificial material 3 = Small to moderate presence of artificial material 5 = Extensive presence of artificial material	Artificial materials include brick-laid stone, concrete, geotextiles, etc. Imported natural substrate refers to natural substrate types (e.g. gravel, sand, boulders) deliberately placed in areas of a lake where they would not naturally occur (e.g. large stone slabs positioned around the lake shore to prevent bank erosion). Record only natural substrates: mud, silt, sand, pebbles, gravel, stones, rocks, organic substrates. NOTE: The natural range of substrates is lake type- and site-specific.	Grab sampling; remote sensing data; geophysical survey; LHS; SCUBA diving
	Riparian zone	Natural exchange with groundwater	Assessed as part of 'Land cover in riparian zone' (Section 6) and therefore not scored here		Attribute assessed: Proportion of shoreline length in natural state, i.e. extent of natural buffer zones	Field survey; maps; aerial photos

Table A.1 (Continued)

		Features	Score band A – Quantitative	Score band B – Qualitative	Guidance	Examples of methods/ data use
4. CONNECTIVITY AND CONTINUITY		Connectivity of lake with adjacent riparian wetlands. Connectivity of migratory movement between littoral and riparian zone	Assessed through alterations to mean annual water level range (Annex B)' and 'Bank structure and modifications' (Section 3) and therefore not scored here		Attribute assessed: Bank construction and reinforcement - proportion of shoreline length affected by hard engineering (e.g. impermeable concrete structure impeding groundwater exchange).	Connectivity of lake with adjacent riparian wetlands; Connectivity of migratory movement between littoral and riparian zone
	Shore zone	Natural erosion/deposition patterns	Assessed as part of 'Landform and substrate characteristics' (Section 3) and therefore not scored here		Conspicuous evidence of bank erosion, conspicuous evidence of unvegetated sediment deposits; non-natural grain size distribution in substrate	Field survey; maps; aerial photos; historical and contemporary records of surface area and bathymetry
	Open water zone	Natural exchange between groundwater and surface water	Feature not scored	1 = Near-natural exchanges between groundwater and surface water 3 = Moderate level of modification to exchanges between groundwater and surface water 5 = Conspicuous level of modification to exchanges between	Attributes assessed: Height of groundwater table and rate of flow; area of lake bottom sealed by construction; changes to sediment permeability; presence of barriers (e.g. causeways)	Field survey; tracer experiments; remote sensing; groundwater boreholes and piezometric measurements

Table A.1 (Continued)

		Features	Score band A – Quantitative	Score band B – Qualitative	Guidance	Examples of methods/ data use
				groundwater and surface water, especially in critical areas		
		Migratory movement	Feature not scored	1 = No structures or significant drawdown having any effect on migration 3 = Drawdown or structures present having moderate effects on migratory biota 5 = Structures that in general are barriers to all species	Attributes assessed: Presence of dams, weirs, water abstraction from lake; presence of impassable tributary reaches exposed by drawdown. Note that migration can be affected both from the lake downstream and upstream into tributaries. Timing of drawdown is critical, depending on species' requirements. Where there are barriers to migration on streams flowing into the lake, or in watercourses downstream, their effects should be assessed using the equivalent CEN standard for rivers (EN 15843) and actively incorporated into the lake assessment.	Field survey; remote sensing; maps; water abstraction records; water level records
	Open water zone	Sediment transport	Feature not scored	1 = No structures or significant drawdown having any effect on sediment transport 3 = Drawdown or	Attributes assessed: Presence of dams, weirs, water abstraction from lake.	Field survey; remote sensing; maps; water abstraction records; water level records

Table A.1 (Continued)

		Features	Score band A – Quantitative	Score band B – Qualitative	Guidance	Examples of methods/ data use
				structures present having moderate effects on sediment transport 5 = Structures that in general are barriers to sediment transport		
5. AQUATIC VEGETATION	Riparian zone	N/A	N/A	N/A	N/A	N/A
	Shore zone	Human disturbance or active management of aquatic vegetation	Feature not scored	1 = No or very little human disturbance or active management of aquatic vegetation 3 = Moderate levels of human disturbance or active management of aquatic vegetation 5 = High level of human disturbance or active management of aquatic vegetation	Various mechanical interventions, e.g. cutting, raking, pulling; also inadvertent damage by trampling, boats or boat wash. In some situations vegetation management or human disturbance may be considered beneficial in order to restore or maintain natural vegetation.	Local knowledge should be used

Table A.1 (Continued)

		Features	Score band A – Quantitative	Score band B – Qualitative	Guidance	Examples of methods/ data use
	Open water zone	Human disturbance or active management of aquatic vegetation	Feature not scored	1 = No or very little human disturbance or active management of aquatic vegetation 3 = Moderate levels of human disturbance or active management of aquatic vegetation 5 = High level of human disturbance or active management of aquatic vegetation	In some situations vegetation management or human disturbance may be considered beneficial in order to restore or maintain natural vegetation. In some countries grass carp (*Ctenopharyngodon idella*) is deliberately introduced as a vegetation management tool. Where this applies to an assessment of a lake made using this standard, a specific note should be made to this effect.	Local knowledge should be used
6. LAND COVER	**Riparian zone**	Land cover in riparian zone (including extensive stands of non-native species)	1 = 0 to 5 % non-natural land cover in riparian zone 2 = > 5 % to 15 % non-natural land cover in riparian zone 3 = > 15 % to 35 % non-natural land cover in riparian zone 4 = > 35 % to 75 % non-natural land cover in riparian zone 5 = > 75 % non-natural land cover in riparian zone	1 = only minimal areas of the riparian zone with non-natural land cover or extensive stands of non-native species 3 = Moderately large areas of the riparian zone with non-natural land cover or extensive stands of non-native species 5 = Riparian zone dominated by non-natural land cover or extensive stands of non-native species	This standard does not state any fixed width for the riparian zone, which should be defined based on the user's expertise and taking into account definition 3.24. If the user is still unsure what width to use, they should consider using a zone extending 15m landwards from the bank top, as described in the LHS protocol. Non-natural land cover includes orchards, agricultural land-cover such as crops, gardens, parkland, etc. It may also include extensive stands of certain non-native species that have	May combine reach-scale and site-based information from hydromorphological surveys (e.g. LHS); databases; aerial photos.

Table A.1 (Continued)

		Features	Score band A – Quantitative	Score band B – Qualitative	Guidance	Examples of methods/ data use
					major impacts on vegetation structure in the riparian zone (e.g. *Rhododendron,* Himalayan balsam, Japanese knotweed *(Fallopia japonica*). This list will vary with geographical location (every country shall have its own check-list).	
	Shore zone	N/A	N/A	N/A	N/A	N/A
	Open water zone	N/A	N/A	N/A	N/A	N/A

Annex B
(normative)

Alterations to mean annual water level range

NOTE The same caveats apply as for Annex A.

Table B.1 — Alterations to mean annual water level range

Features	Score band A – Quantitative	Score band B – Qualitative (but with some indicative figures to assist interpretation)	Guidance	Examples of methods/data use
Natural deep lake (mean depth > 3 m) without significant modification of lake outflow and minimal alteration of the catchment water balance (i.e. insignificant amounts of abstraction or augmentation from inter-basin water transfers)	1 = ≤ 1 m 2 = > 1 – 3 m 3 = > 3 – 5 m 4 = > 5 – 10 m 5 = > 10 m	1 = No, or minimal, alteration of the mean annual water level range: ≤ 1 m, when mean annual water level range < 1 m; < 50 % alteration of natural range, when mean annual water level range > 1 m 3 = Small to moderate alteration of the mean annual water level range: ≤ 5 m, when mean annual water level range < 2,5 m; 50 – ≤ 150 % alteration of natural range, when mean annual water level range > 2,5 m) 5 = Significant alteration of the mean annual water level range: > 5 m, when mean annual water level range < 2,5 m; > 150 % alteration of natural range, when mean annual water level range > 2,5 m	This measures the degree of alteration relative to the natural mean annual range of a given lake in a particular environmental setting. For example, a lake has a natural mean annual range of 2 m, which, if altered by engineering/abstraction to an annual range of 4 m, equates to a change of 2 m, which would be a 100 % deviation from the natural range. 'Equivalence' is an important principle here, so 'equivalent natural lake in a similar environmental setting' prompts comparison with natural lakes in similar climatic zones (defined by climate and altitude); similar lake–catchment relationships and similar physical morphology (size, shape, depth characteristics).	Water-level records Historical and contemporary records of surface area and bathymetry Geomorphological and ecological field observations indicative of historical or contemporary modifications to water-level regime, e.g. eroded shorelines, changes in vegetation community type Modelled water levels based on water balance

Natural shallow lake (mean depth < 3 m) as described above, but in case of shallow lakes key impact measures are concentrated on the extent of draw-down (water level reduction).	1 = ≤ 0,5 m 3 = > 0,5 – 1,5 m 5 = > 1,5 m	1 = Minimal alteration to mean annual water level range (<50 % alteration of natural range) 3 = Small to moderate alteration to mean annual water level range (50 – < 100 %) 5 = Highly significant alteration to mean annual water level range (>100 %)	Note that in shallow lakes the key impacts relate to draw-down, although increasing depth may also have important impacts (e.g. increased likelihood and duration of thermal stratification consequences for hypolimnion anoxia and bed sediment nutrient release).	As above
Deep reservoir or heavily modified natural lake (mean depth > 3m)	N/A	1 = Mean annual water level range broadly consistent with equivalent natural lake in a similar environmental setting 3 = Moderate difference in mean annual range and/or water level regime of the water body relative to an equivalent natural lake in a similar environmental setting 5 = Highly altered regime and/or annual range relative to an equivalent natural lake in a similar environmental setting	Reservoirs and impounded natural lakes frequently exhibit large variations in water level depending on use. Examples include, *inter alia*, hydro-power (large annual and/or significant daily water level fluctuations); flood control (drawn down during winter months to provide flood storage capacity and potentially higher in summer for recreation); temperate water supply (strong seasonal signature capturing winter runoff and systemic water level decline during summer months); Mediterranean and other dry-land environments often feature irrigation reservoirs designed to capture rare high magnitude storm flows from which controlled releases occur over several subsequent dry years. By contrast, other types of reservoir/ impoundment, such as amenity or flooded excavations, may have much more natural water level fluctuations.	Reservoir manager Water-level records Historical and contemporary records of surface area and bathymetry 'Equivalence' is an important principle here, so 'equivalent natural lake in a similar environmental setting' prompts comparison with natural lakes in similar climatic zones (defined by climate and altitude); similar lake–catchment relationships and similar physical morphology (size, shape, depth characteristics).

Annex C
(normative)

Land cover in the lake catchment

NOTE The same caveats apply as for Annex A

Table C.1 — Land cover in the lake catchment

Features	Score band A – Quantitative	Score band B – Qualitative (but with some indicative figures to assist interpretation)	Guidance	Examples of methods/data use
'Intensive land-use' (%) in catchment area	1 = 0 – 2 % cover 2 = > 2 – 10 % cover 3 = > 10 – 20 % cover 4 = > 20 – 40 % cover 5 = > 40 % cover	1 = No, or minimal, presence of intensive catchment land- use 3 = Small to moderate presence of intensive land- use 5 = Significant presence of intensive land-use classes within the catchment	Categories of intensive land- use include urban, arable, intensive grazing, and plantation forestry. If individual intensive land use types are especially influential on the lake catchment, make a note of them for possible further investigation – e.g. urban.	Data can be obtained from variety of sources including maps, databases and remote sensing images – or field-based observation
Catchment area covered by reservoirs (%)	1 = 0 – 2 % cover 2 = > 2 – 10 % cover 3 = > 10 – 20 % cover 4 = > 20 – 40 % cover 5 = > 40 % cover	1 = Minimal presence of impounded water bodies in upstream catchment 3 = Small to moderate presence of impounded water bodies in upstream catchment 5 = Catchment dominated by impounded water bodies in upstream catchment	The percentage bands refer to the reservoir catchment area as a proportion of the total lake catchment area. Reservoirs constructed on the channel network alter flow, sediment and migratory movement.	Data can be obtained from variety of sources including maps, databases and remote sensing images – or field-based observation. NOTE: any simple topographic analysis could be augmented by discussion with water managers to consider inter-basin transfers.

Annex D
(informative)

Case study examples

D.1 Lago Maggiore (Italy)

D.1.1 Summary description

Lago Maggiore (se Figure D.1) is a large deep lake lying on the south side of the Alps between Italy and Switzerland and shared between two Italian Regions, Piedmont and Lombardy. The catchment of Lago Maggiore (6599 km^2) comprises impermeable rocks and a dense hydrographic network, defined by surface rather than subterranean runoff. Most of the rocks are volcanic and metamorphic in origin (siliceous or crystalline). More than 6 % of the catchment lies above 2500 m a.s.l. The climate is characterized by heavy rainfall, with an annual average exceeding 1700 mm. The high rainfall has led to the construction of many dams and water withdrawals for hydroelectric power generation. The total capacity of all reservoirs is approximately $500 \cdot 10^6$ m^3 .

The high ratio of catchment area to lake area emphasizes the strong impact of the catchment on hydrology and lake chemistry. There are many protected areas (e.g. Special Protection Areas, Sites of Community Interest, National Park, Special Reserve). Nevertheless, the riparian zone and the coast have extensive urban development, with tourist, recreation and shipping infrastructure having a substantial impact on the biological communities and their habitats. The major changes in the ecological condition of the lake are the result of significant variation in nutrient loads, and the progressive eutrophication observed since the 1970s. By the end of the 1980s Lago Maggiore was meso-eutrophic but the remedial measures produced positive effects from the early 1990s so that it can now be considered oligotrophic.

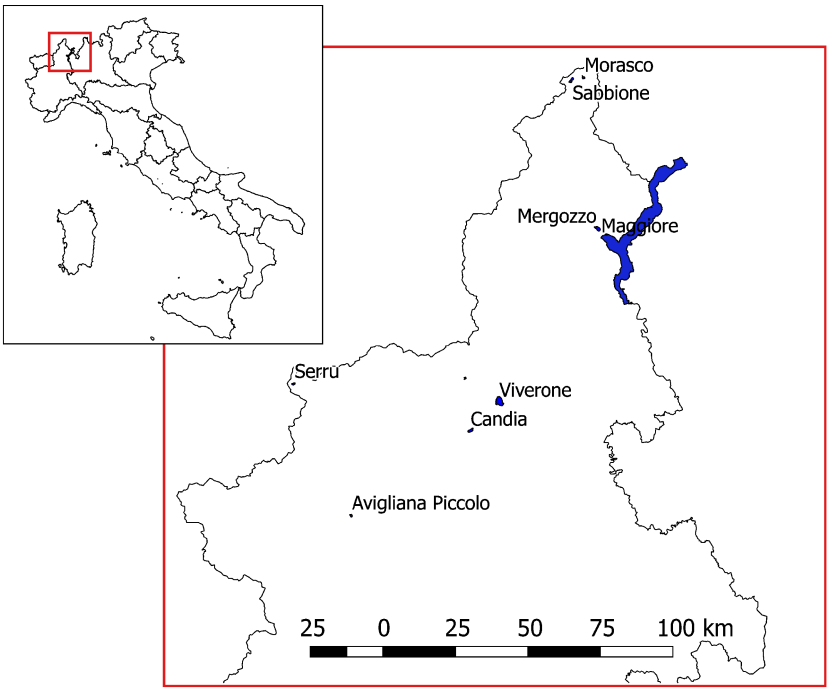

Figure D.1 — Location of Lago Maggiore

D.1.2 Morphometric characteristics

The main morphometric features are shown in Table D.1.

Table D.1 — Morphometric characteristics of Lago Maggiore

Surface area (ha)	21 250
Surface area at maximum volume (ha)	Not available
Volume (10^6 m^3)	37
Max. volume (10^6 m^3)	Not available
Mean depth (m)	177
Max. depth (m)	370
Mean lake altitude (m a.s.l.)	194
Maximum catchment altitude (m a.s.l.)	4.634
Max. length (m)	54 000
Max. width (m)	10 000
Shore length (m)	170 000
Catchment area (km^2)	6 599

D.1.3 Degree of modification using Annex A

Table D.2, based on data from LHS, summarizes the scores for lake modification using reporting option 1, in which attribute scores are presented individually. Table D.3 shows the scores for Lake Maggiore using reporting options 2, 3 and 4.

Table D.2 — Modification scores for Lago Maggiore, using reporting option 1

		Features assessed	**Score**	**Quantitative/ qualitative Assessment**
Hydraulics	Shore zone	Water level variability	0	Quantitative
	Open water zone	Lake volume	3	Qualitative
Morphometry	Shore zone	Slope profile of shore zone	4	Quantitative
		Planform	4	Quantitative
	Open water zone	Depth distribution	1	Qualitative
Bedforms/landforms and substrate	Shore zone	Landform and substrate characteristics	1	Quantitative
		Bank structure and modifications	4	Quantitative
		Littoral substrate	1	Qualitative
	Open water zone	Lake bottom bedforms	1	Qualitative
		Extent of artificial material/imported natural substrate	1	Quantitative

		Features assessed	Score	Quantitative/ qualitative Assessment
Connectivity and continuity	Open water zone	Natural exchange between groundwater and surface water	1	Qualitative
		Migratory movement	3	Qualitative
		Sediment transport	3	Qualitative
Aquatic vegetation	Shore zone	Human disturbance or active management	1	Qualitative
	Open water zone	Human disturbance or active management	n/a (no vegetation)	-
Land cover	Riparian zone	Land cover in riparian zone (including extensive stands of non-native species)	4	Quantitative
Annex C				
Land cover in the lake catchment	Intensive land-use (%) in upstream catchment area		3	Qualitative
	Upstream catchment area covered by reservoirs (%)		4	Quantitative

Table D.3 — Modification scores for Lago Maggiore using reporting options 2, 3 and 4

Reporting option			
2	**3**		**4**
2-digit code	Open water pelagic/ profundal zone	Shore zone (riparian/ littoral) and adjacent area	Single score
2, 3	1	2	2

D.1.4 Conclusions

Evaluating the morphological conditions of the lake shores using the different options is relatively straightforward using data derived from LHS. The hydrological conditions are more difficult to assess, because they depend upon direct measurements and information that is often not available. The results of the different reporting options for Lago Maggiore seem to represent well the present lake condition, although a greater level of modification was expected. The low value is probably the result of relying on qualitative rather than quantitative data for obtaining some of the scores. The score (from Annex C) on the percentage of area covered by reservoirs highlights the impact these have on lake volume. It was not possible to score the other aspect in Annex C – intensive land-use in the catchment – using quantitative data owing to a lack of information on land use in the Swiss part of the catchment.

D.2 Lago Bidighinzu (Italy)

D.2.1 Summary description

Lago Bidighinzu (Figure D.2) is a reservoir located in central-western Sardinia, built between 1952 and 1959 for drinking water supply. The climate is Mediterranean, with mild temperatures and low precipitation (annual mean = 700 mm). A concrete gravity dam, with a height of 43 m, is situated at the outflow of the reservoir.

The catchment of Lago Bidighinzu (50 km^2) is characterized by hills, composed of calcareous, carbonaceous, dolomitic rocks. Land use in the catchment consists mainly of woods (46 %) and farmland (48 %); other land uses include olive groves (<1 %), vineyards (<1 %), and artificial areas (according to CORINE land-cover mapping) (3 %). Within the catchment, livestock (cattle, sheep, horses and pigs) contribute low loads of nitrogen (~6 t yr^{-1}) and phosphorus (~1 t yr^{-1}). Nitrogen and phosphorus from agricultural activities are ~55 t yr^{-1} and ~3 t yr^{-1}, respectively. Bidighinzu is a warm monomictic lake, with a mixing period in winter and a stratification period in summer. It is hyper-eutrophic, characterized by high nutrient concentrations and periodic algal blooms of potentially toxic cyanobacteria.

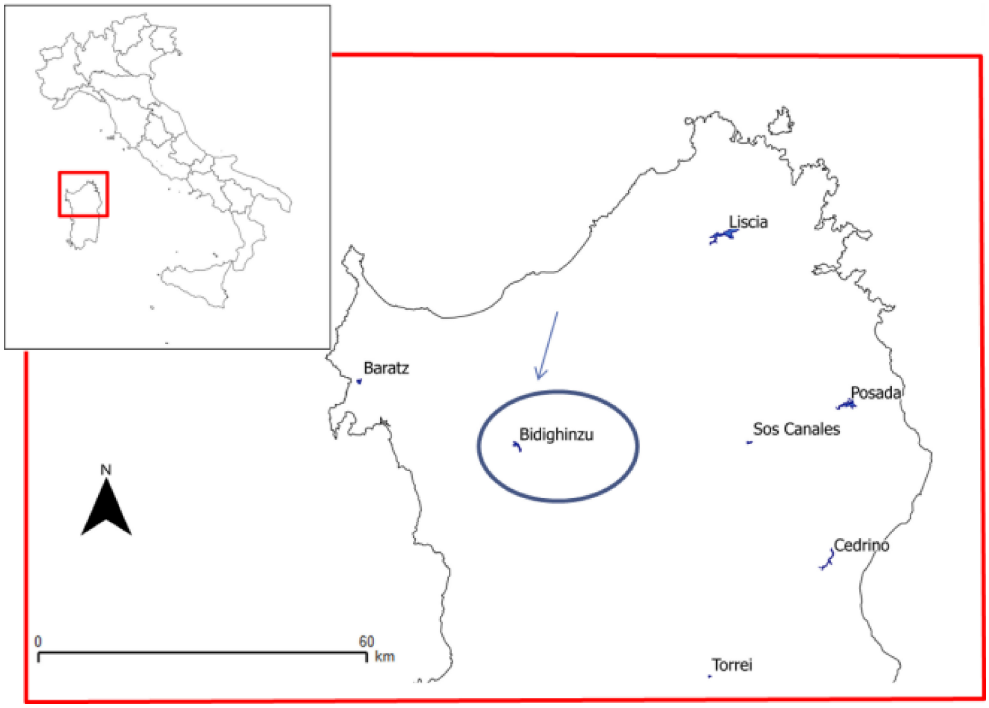

Figure D.2 — Location of Lago Bidighinzu

D.2.2 Morphometric characteristics

The main morphometric features are shown in Table D.4.

Table D.4 — Morphometric characteristics of Lago Bidighinzu

Surface area (ha)	150
Surface area at maximum volume (ha)	225
Volume (10^6 m^3)	11
Max. volume (10^6 m^3)	18
Mean depth (m)	8
Max. depth (m)	34
Mean lake altitude (m a.s.l.)	330
Maximum catchment altitude (m a.s.l.)	730
Max length (m)	3 100
Max. width (m)	930
Shore length (m)	11 600
Catchment area (km^2)	50

D.2.3 Degree of modification using Annex A

Table D.5, based on data from LHS, summarizes the scores for lake modification using reporting option 1, in which attribute scores are presented individually. Table D.6 shows the scores for Lake Bidighinzu using reporting options 2, 3 and 4.

Table D.5 — Modification scores for Lago Bidighinzu, using reporting option 1

		Features assessed	**Score**	**Quantitative / qualitative Assessment**
Hydraulics	Shore zone	Water level variability	3	Quantitative
	Open water zone	Lake volume	5	Qualitative
Morphometry	Shore zone	Slope profile of shore zone	1	Quantitative
		Planform	1	Quantitative
	Open water zone	Depth distribution	-	-
Bedforms/ Landforms and substrate	Shore zone	Landform and substrate characteristics	1	Qualitative
		Bank structure and modifications	1	Quantitative
		Littoral substrate	1	Qualitative
	Open water zone	Lake bottom bedforms	1	Qualitative
		Extent of artificial material/ imported natural substrate	1	Quantitative

		Features assessed	Score	Quantitative / qualitative Assessment
Connectivity and continuity	Open water zone	Natural exchange between groundwater and surface water	1	Qualitative
		Migratory movement	5	Qualitative
		Sediment transport	5	Qualitative
Aquatic vegetation	Shore zone	Human disturbance or active management	n/a (no vegetation)	-
	Open water zone	Human disturbance or active management	n/a (no vegetation)	-
Land cover	Riparian zone	Land cover in riparian zone (including extensive stands of non-native species)	1	Quantitative
Annex C				
Land cover in the lake catchment	Intensive land-use (%) in upstream catchment area		4	Quantitative
	Upstream catchment area covered by reservoirs (%)		1	Quantitative

Table D.6 — Modification scores for Lago Bidighinzu using reporting options 2, 3 and 4

Reporting option			
2	**3**		**4**
2-digit code	Open water pelagic/ profundal zone	Shore zone (riparian/ littoral) and adjacent area	Single score
4, 1	3	1	1

D.2.4 Conclusions

The results of the different reporting options for Lago Bidighinzu provide an accurate representation of the minor alterations to the morphological features in lake shore and littoral areas, apart from migratory movement and sediment transport. However, although evaluating the morphological conditions of the lake shores using data derived from LHS is straightforward, hydrological features are more difficult to assess because they depend on direct measurements and information, often not available. Despite these difficulties, the assessment for open water areas does reflect accurately the impact that water abstraction has on the high degree of lake level fluctuation. Scores using Annex C ('Land cover in the lake catchment') show that hydrological impacts are exclusively due to abstraction from the lake rather than reservoirs in the catchment upstream; in contrast, Annex C scores for intensive land-use explain the high level of eutrophication in Lake Bidighinzu.

D.3 Lake Lidzbarskie (Poland)

D.3.1 Summary description

Lake Lidzbarskie (Figure D.3) is the last reservoir in a series of flow-through lakes of the lowland Wel River. The catchment of the lake is predominantly agricultural, although there are also many human settlements, including the largest town of Lidzbarskie, situated close to the lake. The area of the catchment surrounding the reservoir is dominated by forest along almost all of its shoreline (with the exception of the eastern shore adjacent to the urban development of Lidzbarskie) and extending to the south of the reservoir. Approximately 30 % of the catchment in the immediate vicinity of Lake Lidzbarskie comprises agricultural land. The lake, which is mainly used for recreation, is relatively deep and thermally stratified during the summer. The lake is eutrophic and does not meet good ecological status under the EC Water Framework Directive.

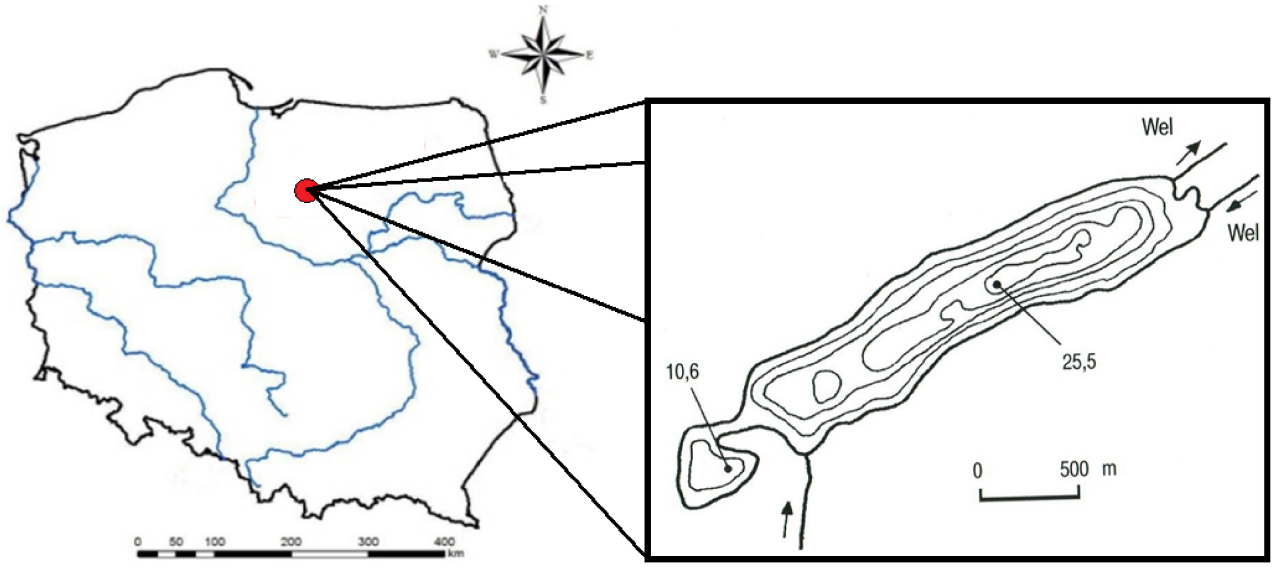

Figure D.3 — Location of Lake Lidzbarskie and a map of its bathymetry

D.3.2 Morphometric characteristics

The main morphometric features are shown in Table D.7.

Table D.7 — Morphometric characteristics of Lake Lidzbarskie

Surface area (ha)	122
Surface area at maximum volume (ha)	Not available
Volume (10^6 m^3)	12
Max. volume (10^6 m^3)	Not available
Mean depth (m)	10
Max. depth (m)	26
Mean lake altitude (m a.s.l.)	128
Maximum catchment altitude (m a.s.l.)	312
Max length (m)	3 050
Max. width (m)	500
Shore length (m)	7 550
Catchment area (km^2)	534

D.3.3 Degree of modification using Annex A

Table D.8, based on data from LHS, summarizes the scores for lake modification using reporting option 1, in which attribute scores are presented individually. Table D.9 shows the scores for Lake Lidzbarskie using reporting options 2, 3 and 4.

Table D.8 — Modification scores for Lake Lidzbarskie, using reporting option 1

		Features assessed	**Score**	**Quantitative/ qualitative Assessment**
Hydraulics	Shore zone	Water level variability	1	Qualitative
	Open water zone	Lake volume	1	Qualitative
Morphometry	Shore zone	Slope profile of shore zone	1	Quantitative
		Planform	1	Quantitative
	Open water zone	Depth distribution	1	Qualitative
Bedforms/landforms and substrate	Shore zone	Landform and substrate characteristics	1	Quantitative
		Bank structure and modifications	1	Quantitative
		Littoral substrate	1	Quantitative
	Open water zone	Lake bottom bedforms	1	Qualitative
		Extent of artificial material/imported natural substrate	1	Quantitative

		Features assessed	Score	Quantitative/ qualitative Assessment
Connectivity and continuity	Open water zone	Natural exchange between groundwater and surface water	1	Qualitative
		Migratory movement	3	Qualitative
		Sediment transport	3	Qualitative
Aquatic vegetation	Shore zone	Human disturbance or active management	1	Qualitative
	Open water zone	Human disturbance or active management	1	Qualitative
Land cover	Riparian zone	Land cover in riparian zone (including extensive stands of non-native species)	2	Quantitative
Annex C				
Land cover in the lake catchment	Intensive land-use (%) in upstream catchment area		5	Quantitative
	Upstream catchment area covered by reservoirs (%)		1	Quantitative

Table D.9 — Modification scores for Lake Lidzbarskie using reporting options 2, 3 and 4

Reporting option			
2	**3**		**4**
2-digit code	Open water pelagic/ profundal zone	Shore zone (riparian/ littoral) and adjacent area	Single score
1, 1	1	1	1

D.3.4 Conclusions

The assessment using the CEN scoring system shows only minor hydromorphological modification in Lake Lidzbarskie, comparable with most natural lakes in Poland. Only three features were scored higher than 1. The highest score (5) was attributed to intensive agricultural land-use in the lake catchment. In the riparian zone of the lake forests prevail, but the proportion of non-natural land cover is the reason why this feature has been given a score of 2. A small weir on the inflow to the lake, not equipped with a fish ladder, interrupts migratory movement and sediment transport, leading to the higher score of 3.

D.4 Lake Velenje (Slovenia)

D.4.1 Summary description

Lake Velenje (Figure D.4) is an artificial lake formed as a consequence of sub-surface coal mining after the Second World War. The lake is situated in a partly rural/ partly industrial area in the hilly landscape of the Saleška valley. A small river that retains its natural state flows into the lake, and the outflow is regulated by a small dam.

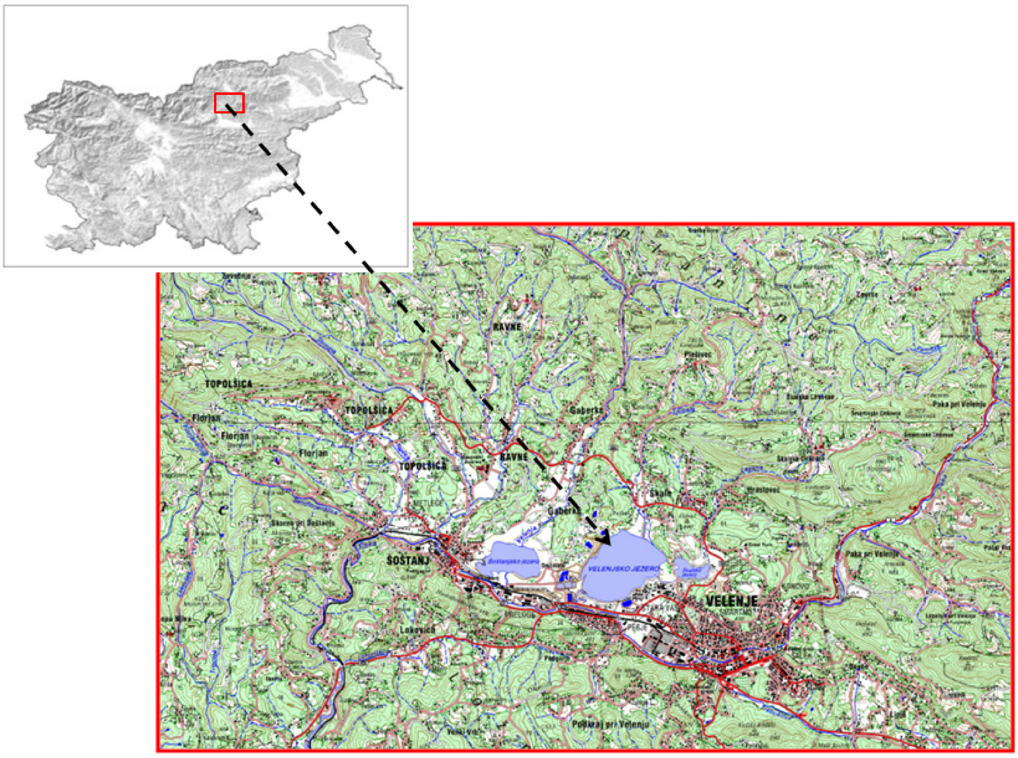

Figure D.4 — Location of Lake Velenje

D.4.2 Morphometric characteristics

The main morphometric features are shown in Table D.10.

Table D.10 — Morphometric characteristics of Lake Velenje

Surface area (ha)	142
Surface area at maximum volume (ha)	144
Volume (10^6 m^3)	25
Max. volume (10^6 m^3)	32
Mean depth (m)	23
Max. depth (m)	56
Mean lake altitude (m a.s.l.)	367
Maximum catchment altitude (m a.s.l.)	923
Max. length (m)	1 400
Max. width (m)	1 300
Shore length (m)	5 080
Catchment area (km^2)	21

D.4.3 Degree of modification using Annex A

Table D.11, based on data from LHS, summarizes the scores for lake modification using reporting option 1, in which attribute scores are presented individually. Table D.12 shows the scores for Lake Velenje using reporting options 2, 3 and 4.

Table D.11 — Modification scores for Lake Velenje, using reporting option 1

		Features assessed	Score	Quantitative/ qualitative Assessment
Hydraulics	Shore zone	Water level variability	1	Qualitative
	Open water zone	Lake volume	1	Qualitative
Morphometry	Shore zone	Slope profile of shore zone	4	Quantitative
		Planform	3	Qualitative
	Open water zone	Depth distribution	1	Qualitative
Bedforms\landforms and substrate	Shore zone	Landform and substrate characteristics	3	Qualitative
		Bank structure and modifications	3	Quantitative
		Littoral substrate	4	Quantitative
	Open water zone	Lake bottom bedforms	1	Qualitative
		Extent of artificial material/imported natural substrate	1	Qualitative
Connectivity and continuity	Open water zone	Natural exchange between groundwater and surface water	1	Qualitative
		Migratory movement	3	Qualitative
		Sediment transport	3	Qualitative
Aquatic vegetation	Shore zone	Human disturbance or active management	1	Qualitative
	Open water zone	Human disturbance or active management	1	Qualitative
Land cover	Riparian zone	Land cover in riparian zone (including extensive stands of non-native species)	4	Quantitative
Annex B				
Alterations to mean annual water level range	Reservoir or heavily modified natural lake		1	Quantitative
Annex C				
Land cover in the lake catchment	Intensive land-use' (%) in upstream catchment area		4	Quantitative
	Upstream catchment area covered by reservoirs (%)		1	Quantitative

Table D.12 — Modification scores for Lake Velenje using reporting options 2, 3 and 4

Reporting option			
2	**3**		**4**
2-digit code	Open water pelagic/ profundal zone	Shore zone (riparian/ littoral) and adjacent area	Single score
1, 2	2	3	2

D.4.4 Conclusions

It is crucial when using the scoring system for artificial lakes to decide what the 'guiding image' (the 'baseline') should look like. For Lake Velenje the scores assess the level of departure from natural conditions compared with the baseline on the assumption that the water body is an artificial lake very similar to a natural lake. The results show that the lake has near-natural water level variability and residence time as well as most features related to the open water zone. However, the slope profile of the shore zone is extensively modified, leading to modification of the planform as well as erosion and deposition processes. The banks are affected by soft engineering (up to 50 %), while 25 % of the littoral substrate is composed of artificial material.

D.5 Arkanj Lake (Serbia)

D.5.1 Summary description

Arkanj is a natural, lowland (75 m altitude), high alkalinity (total alkalinity 201 µeq L^{-1} $CaCO_3$), eutrophic lake (total organic carbon 5,35 mg L^{-1}, dissolved oxygen 2,3 mg L^{-1}, PVI 5), with dimictic stratification and an eroded shore zone.

It originated from an oxbow (surface area 0,68 km^2, maximum length 1 800 m, maximum width 120 m), situated in the Middle Danube Basin (total catchment area 817,000 km^2), in the Koviljski rit wetland area. This comprises about 15 000 ha proposed as a Ramsar site and designated as a National Nature Reserve. The lake is subject to moderate recreation pressure.

The riparian zone is dominated by broadleaf near-natural woodlands, wetlands and broadleaf plantations, which are affected by invasive species such as *Amorpha fruticosa*, *Acer negundo*, *Elodea nuttalii*. Water level variability and water level balance are greatly influenced by the Danube flooding regime. The lake substrate is composed of mud, while shore materials are predominantly sand and earth.

D.5.2 Morphometric characteristics

The main morphometric features are shown in Table D.13.

Table D.13 — Morphometric characteristics of Arkanj Lake

Surface area (ha)	68
Surface area at maximum volume (ha)	106
Volume (10^6 m^3)	2,04
Max. volume (10^6 m^3)	5,3
Mean depth (m)	3
Max. depth (m)	7
Mean lake altitude (m a.s.l.)	75
Maximum catchment altitude (m a.s.l.)	3 400
Max length (m)	1 800
Max. width (m)	120
Shore length (m)	4 300
Catchment area (km^2)	817 000

D.5.3 Degree of modification using Annex A

Table D.14, based on data from LHS, summarizes the scores for lake modification using reporting option 1, in which attribute scores are presented individually. Table D.15 shows the scores for Arkanj Lake using reporting options 2, 3 and 4.

Table D.14 — Modification scores for Arkanj Lake, using reporting option 1

		Features assessed	Score	Quantitative/ qualitative Assessment
Hydraulics	Shore zone	Water level variability	1	Qualitative
	Open water zone	Lake volume	1	Qualitative
Morphometry	Shore zone	Slope profile of shore zone	2	Quantitative
		Planform	1	Qualitative
	Open water zone	Depth distribution	1	Qualitative
Bedforms/landforms and substrate	Shore zone	Landform and substrate characteristics	3	Quantitative
		Bank structure and modifications	3	Quantitative
		Littoral substrate	1	Quantitative
	Open water zone	Lake bottom bedforms	1	Qualitative
		Extent of artificial material/imported natural substrate	1	Quantitative
Connectivity and continuity	Open water zone	Natural exchange between groundwater and surface water	-	-
		Migratory movement	1	Qualitative
		Sediment transport	1	Qualitative
Aquatic vegetation	Shore zone	Human disturbance or active management	1	Qualitative
	Open water zone	Human disturbance or active management	1	Qualitative
Land cover	Riparian zone	Land cover in riparian zone (including extensive stands of non-native species)	4	Quantitative
Annex C				
Land cover in the lake catchment	Intensive land-use (%) in upstream catchment area		4	Qualitative
	Upstream catchment area covered by reservoirs (%)		1	Qualitative

Table D.15 — Modification scores for Arkanj Lake, using reporting options 2, 3 and 4

Reporting option			
2	**3**		**4**
2-digit code	Open water pelagic/ profundal zone	Shore zone (riparian/ littoral) and adjacent area	Single score
1, 2	1	2	2

D.5.4 Conclusions

Water level variability, water level balance, connectivity and continuity of the lake are greatly influenced by the Danube flooding regime and could be characterized as near-natural. Moderate recreation pressure contributes directly to the shore modification, resulting in soil poaching and bank erosion influencing substrate characteristics, and changing the slope profile. Although the riparian zone (15 m from the bank edge) is dominated by natural and near-natural land-cover types, the presence of extensive stands of invasive species affects the final score. Furthermore the upstream catchment area includes a significant proportion of intensive land-use classes, such as arable and urban.

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