Ecological flow estimation in Latvian – Lithuanian Transboundary river basins (ECOFLOW) LLI-249

REVIEW

TRAINING COURSE REPORT

Abbreviations

BIOR	Institute of Food Safety, Animal Health and Environment
BQE	Biological quality element
E-Flow	Ecological flow
EU	European Union
GCP	Ground control point
GIS	Geographic Information System
GUS	Geomorphic unit
HMU	Hydromorphological unit
HPP	Hydropower plant
LEGMC	Latvian Environment, Geology and Meteorology Centre
LEI	Lithuanian Energy Institute
LiDAR	Laser Imaging, Detection and Ranging
LT	Lithuania
LV	Latvia
MQI	Morphological Quality Index
OECD	Organisation for Economic Co-operation and Development
PC	Personal computer
PDP	Partial Dependence Plot
QGIS	Quantum GIS
RBD	River basin district
REFORM	REstoring rivers FOR effective catchment Management
SD	Standard deviation
UCUT	Uniform continuous under threshold
WFD	Water Framework Directive (2000/60/EC)

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I. INTRODUCTION

The purpose of this Report is to assess effectiveness of the training events carried out under the Activity T2.1 "Training course of habitat modelling in meso-scale habitat simulation model (MesoHABSIM)". Training was organised for the 20 project experts, on the issue of assessment of HPP impact on ecological status of water bodies and on the estimation of ecological flows. It gives an essential input for the Activity T2.2 "First Habitat survey, modelling and E-Flow estimation of minimum E-Flow for regulated rivers within Venta RBD".

River basins being the subject of study within the ECOFLOW project are international ones, with the headwaters of Lielupe and Venta river catchments being located in Lithuania, and the downstream parts falling within the territory of Latvia. This poses obvious requirement for the assessment of ecological flows in these catchments, to be performed following a consistent approach between the neighbouring countries.

The concept of *mesohabitat* provides the necessary link between the amount of water flow and the living organisms in a river, which is crucial for the estimation of flow that is needed for the biological quality elements to be in good status. Training course on meso-scale habitat simulation model MesoHABSIM serves to increase the capacities of the respective national institutions to estimate the ecological flow through the survey of habitat changes due to flow regulations, and evaluation of the necessary ecological flow for regulated rivers. The course includes practical training in habitat mapping and in recognition of geomorphic units in rivers.

The training is performed by experts from Italy and Poland having sound experience in working with MesoHABSIM, including provision of best practice examples for the WFD Guidance Document No.31 on Ecological flows. The knowledge and skills gained by the project parties ensure unified approach to existing data compilation, equipment selection, field works, modelling, and interpretation of results, thus leading to common understanding of ecological flows to be achieved in Lielupe and Venta river catchments.

Report includes information about the training held, short description of presentations, and some input on actual learning acquired as a result of attending the training programme. Information and feedback on the amount of knowledge transfer that took place from the classroom to the workplace will be given in the First Survey Report.

Activity T2.1 did also include participation of one of the project experts in a joint workshop “Hydropower and Fish – Research and Innovation in the context of the European Policy Framework” (Brussels, Belgium 29-31 May 2017). Taking part in this workshop provided useful knowledge on hydropower production impact on fish fauna, thus ensuring better understanding of the forthcoming training course. Detailed information about this event is given in Annex IV.

ECOFLOW (Ecological flow estimation in Latvian – Lithuanian trans-boundary river basins) project is funded by the Interreg V-A Latvia – Lithuania programme 2014-2020. Project objective is to assess the impact of small hydroelectric power plants on river ecosystems in Latvian - Lithuanian cross-border river basins.

Main project outputs are the Methodology for E-Flow estimation and Recommendations for the amendment to national water legislations in order to ensure effective implementation of E-Flow, binding the strategic planning for water uses and the permitting process. The project is important for Latvian – Lithuanian cross-border cooperation. This will ensure a harmonized approach to water resource management in Latvian – Lithuanian border region.

ECOFLOW is implemented by three project partners: Latvian Environment, Geology and Meteorology Centre (LEGMC), Lithuanian Energy Institute (LEI) and Institute of Food Safety, Animal Health and Environment (BIOR).

This document has been produced with the financial assistance of the European Union. The contents of this document are the sole responsibility of LEGMC, LEI and BIOR, and can under no circumstances be regarded as reflecting the position of the European Union.

II. TRAINING COURSE OBJECTIVES

The main objective of the training course is capacity building of the involved project parties, through the acquisition of theoretical aspects needed for mesohabitat modelling, and also elaboration of practical skills necessary for conducting the field survey under Activity T2.2. The course is provided by external experts having solid experience in hydromorphology, habitat modelling and estimation of ecological flows, and is served not only as theoretical education, but also as practical demonstrations and learning-by-doing exercises.

Training course is organised from 3 – 21 July (three working weeks), during the summer low-flow period that constitutes an important season for aquatic habitat mapping. Each working week includes both theoretical courses and field works aimed at learning to correctly identify and map the survey units and mesohabitats using all the necessary equipment and software.

Field survey equipment owned by the project partners was not sufficient to meet the project needs, in terms of specific tasks to be accomplished, and also of the overall number of field workers. Lacking equipment has been purchased timely.

The course was held in Latvia, close to Saldus city, so as to provide possibility to visit several river stretches of particular interest within Venta river catchment (see Figure1). Short characteristics of the selected sites are given in Table 1.

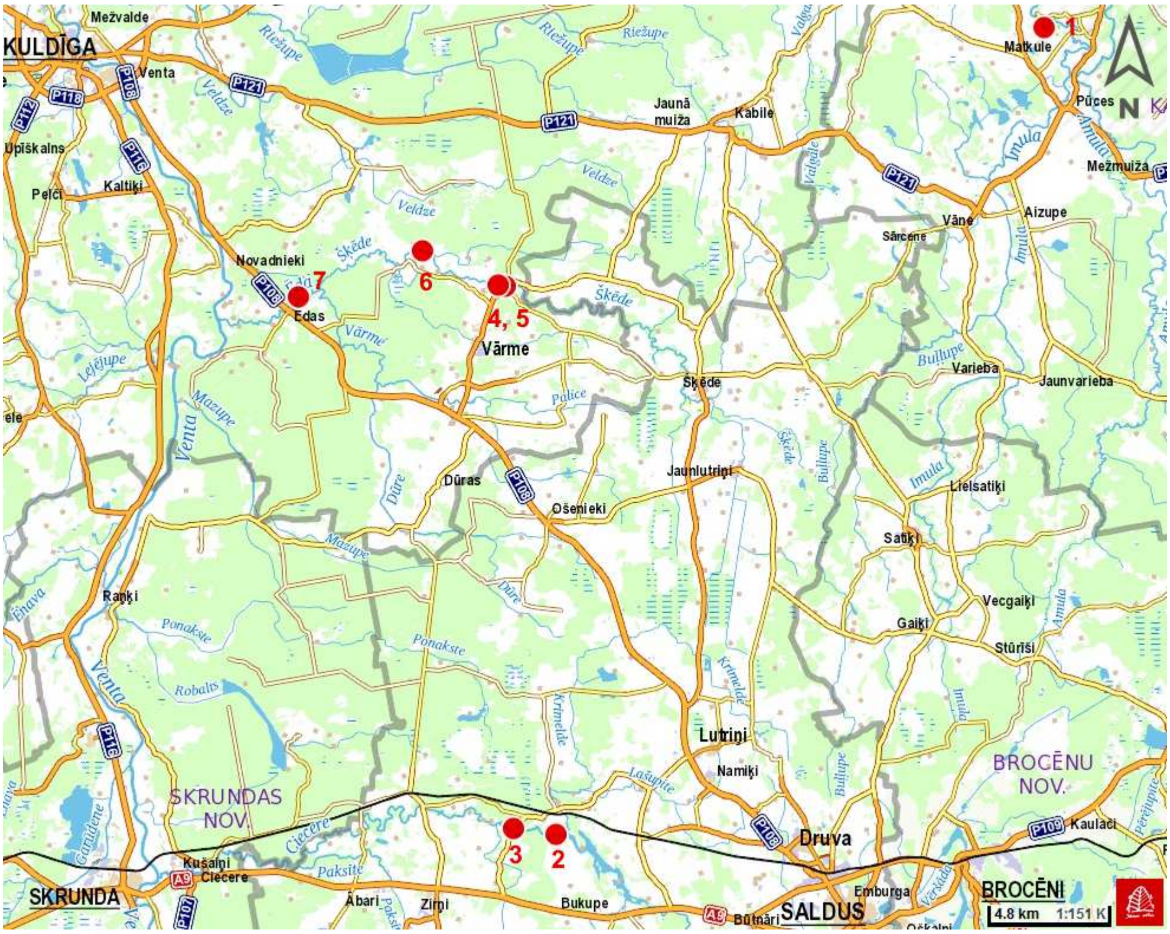

Figure 1. Locations of river stretches visited within Venta river catchment

1. Imula river, near mouth
2. Ciecere river, at Pakuļu HPP
3. Ciecere river stretch below Pakuļu HPP
4. Šķēde river, at Dzirnavu HPP
5. Šķēde river, below Dzirnavu HPP
6. Šķēde river, meandering stretch
7. Ēda river, upstream Varme river mouth

Table 1. Features of interest for the field visits during the training course

River name	Features of interest	Visits
Imula	River representing possible reference conditions in terms of hydromorphology (no HPP impact and straightening (near its mouth).	Week 1, one location (#1)
Ciecere	River flowing out of Ciecere lake (that has effect on the fish fauna of the river). Three HPP dams, first of which is located ca. 1.5 km from the lake and therefore problematic to establish reference conditions.	Week 1, two locations (#2, 3) Week 3, one location (#3) - habitat mapping
Ēda / Šķēde	Ēda river is formed by the confluence of rivers Vārme and Šķēde. Like other unregulated stretches in smaller streams, it is diverse in terms of hydromorphological units. Two HPP dams are built on the Šķēde river.	Week 2, four locations (#4 - 7)

Main topics within the scope of the training course are:

- Ecological flows in the legislative context;
- River hierarchical systems and habitat characteristics;
- Sediment transport, river meandering, effects of hydropeaking;
- Biological data collection;
- Field works and habitat modelling software;
- Drafting of possible methodologies for E-flow assessment in LV and LT.

List of training course participants, detailed agenda and most important training materials are provided, respectively, in Annex I, II, and III.

III. PRESENTATIONS AND TRAINING ACTIVITIES

3.1. ECOLOGICAL FLOWS IN THE CONTEXT OF EU LEGISLATION AND AT THE GLOBAL SCALE

The main objective of the Water Framework Directive (2000/60/EC) is to ensure good ecological and chemical status of surface water bodies (as well as good chemical and quantitative status of groundwater bodies) at EU scale. Ecological status of surface water bodies, in its turn, is a combination of biological, physico-chemical, and hydromorphological quality elements. The last comprises of components like hydrological regime, continuity, and morphological conditions.

Ecological status is defined as a degree of deviation from unaltered (reference) conditions. Good status is the state where there is only slight deviation from the reference. For heavily modified water bodies, the concept of good ecological potential is used instead.

It has to be taken into account that present hydromorphological conditions are a result of processes and changes that occurred in the past, and various development scenarios are possible in the future.

The Blueprint initiative of the European Commission (2012) aims at ensuring good quality water in sufficient quantity for all legitimate uses. It outlines actions for, among others, filling the knowledge gaps in particular as regards water quantity and efficiency. **Ecological flow** is defined in the Blueprint as “amount of water required for the aquatic ecosystem to continue to thrive and provide the services we rely upon”. Nevertheless, no common understanding of how E-flows should be estimated was available at EU level.

Working group on E-flows (2013-2015) was established to develop a common guidance on the estimation of E-flows. At the global scale, over 200 different definitions of E-flows can be found in literature; **in the context of implementation of the WFD** E-flow is defined as “the flow regime consistent with the achievement of good status of water bodies”.

Hydrological regime can be characterised in terms of:

- Magnitude of flow;

- Rate of change of flow;
- Timing, duration, and frequency of flow events.

All components of the flow regime play primary role in the structure and functioning of aquatic ecosystems. It has been recognised, in addition, that **sediment regime** is another important characteristics closely linked with flow amount and dynamics. A concept of Lane's balance is used to predict changes in ecosystem dependent on sediment size and stream slope (which is directly linked to current velocity). Lack of sediment in the river system (caused e.g. by dams or abstraction) leads to degradation processes.

The newest paradigm of river system available at present includes **flow, sediments and biota** (living organisms), taking into consideration that ecological processes are the outcome of both environmental drivers and biotic interactions.

The link between hydromorphological conditions, sediment transport processes and biota is the **habitat** that is formed by a combination of environmental conditions (incl. water depth, bed substrate, oxygenation conditions, etc.) and inhabited (and partially shaped by) aquatic organisms. According to newest scientific publication, fish are more sensitive to hydromorphological alterations than other BQE (macroinvertebrates, phytoplankton) and methods with the aim to assess hydrological degradation must be focused on fish communities as main indicator.

The WFD states that ecological status / potential of a water body is primarily measured by the status of biological elements. This approach has limitations with regard to hydromorphological alterations:

- Biological assessment methods, developed mostly to assess eutrophication as major pressure, are often not enough sensitive to the alterations in flow regime and morphology;
- Composition of biological community can be impacted by restocking of fish.

On the other hand, river flow regime controls the status of habitats and hence biota; and hydromorphological indicators measure the impact of hydromorphological pressures directly.

Therefore, it is recognised that **habitat modelling tools** can be used to design and monitor ecological flows, as well as evaluate the impact of both hydrological and morphological alterations on the aquatic and riparian ecosystem. These tools, however, require a solid knowledge base. Data on hydrological regime, morphology, sediment transport, biological communities and interactions, as well as information on socio-economic constraints are both needed to predict future scenarios at different scales.

On the global level, it is expected that water use extent will increase significantly in 2050, incl. water use for hydropower production (increase mainly expected outside OECD countries). Building of new dams is planned in a number of regions worldwide: Turkey, Balkans, China, Himalayas, India, South America. Many of these regions are also hotspots for biodiversity.

Most commonly used methods to estimate “safe” thresholds for water abstraction and use are based on hydrological calculations only. The so-called “hydraulic-habitat” and “holistic” approaches that consider river ecosystem requirements for water take more time, are more expensive, and hence are not so frequently used. It should be taken into account that methods based only on hydrology may lead to management decisions that do not ensure ecosystem stability in the long-term.

3.2. RIVER SYSTEMS AND HABITAT CHARACTERISTICS

Rivers are complex systems where abiotic and biotic components interact at different spatial and temporal scales. They can be viewed as a set of hierarchically organised subsystems, where smaller spatial and temporal levels nest within those of larger scales. Processes and forms occurring at larger scales dominate and determine processes and forms at smaller scales.

Hierarchy include eight levels: region; catchment; landscape unit; segment; reach; geomorphic unit; hydraulic unit; river element.

River is a dynamic system that transfers material and energy. It has a production zone where erosion processes are most active; transfer zone where sediment transport occurs, and deposition zone where sedimentation processes dominate. Important features for normal river functioning are its connectivity and longitudinal continuity, as well as lateral and vertical continuity (connection with the floodplain and groundwater).

Rivers respond to hydrological and morphological pressures by adapting their morphology and related functioning at the reach scale. Driving variables determining river channel morphology are water discharge and sediment discharge. Valley slope and topography, bed and bank sediments, as well as riparian vegetation can be seen as boundary conditions in river channel formation. The resulting channel form consists of three "dimensions": cross-section geometry, bed slope, and channel planform.

River system can develop in different scenarios, depending on the past and present conditions; e.g. bank erosion and river lateral mobility can be enhanced by hydropeaking.

To characterise the complexity of features composing a river system it is effective to implement a hierarchical framework where key spatial scales are adopted to describe specific properties of the system (see hierarchy above). This hierarchy has been developed within the REFORM project, and detailed descriptions can be found in project deliverables. WFD water bodies mainly correspond to the segment scale of the proposed hierarchy.

The basis for habitat modelling is the hierarchy level of river reaches. Subject for investigation are hydromorphological processes and habitats (formed by lower-level features, namely geomorphic units), and their changes. Vegetation has to be taken into account, as this is an important component of hydromorphological processes and forms. Controlling elements for the functioning of a river reach are found at higher hierarchy levels:

- Catchment and landscape level: water and sediment production (and its changes);
- Segment level: flow regime and extremes, as well as sediment regime and budget (and their changes).

These elements determine the characteristics of the river reach - namely, its hydromorphological functioning (and alteration); riparian corridor functioning (and alteration); as well as hydromorphological adjustment.

River reaches are defined as relatively homogeneous sections of the river where present morphological characteristics and boundary conditions are sufficiently uniform. Reaches are defined within segments of the river.

Within a landscape unit, a river is subdivided into segments, depending on factors like river channel confinement (i.e., isolation degree from the floodplain) and slope gradient, and major tributary confluences that significantly increase upstream catchment area and river discharge. Segments normally have a length of several kilometres (mountain areas) and up to tens of kilometres (lowland areas).

River segments are further subdivided based on changes in channel morphology (e.g. sinuosity, braiding, anabranching). Seven main morphological types of rivers can be identified by remote sensing and used, together with confinement, as a criterion for delineation of river reaches. Additional factors for reach delineation are: change in geomorphic units; bed slope; tributaries; dams and other artificial elements; change in size of the floodplain; change in (bankfull) channel width; change in sediment size. Further parameters important for the characterisation at reach scale are average bed slope of the reach, and sediment calibre.

Based on these criteria, survey units are identified, within which habitats are further investigated. “Rule of thumb” here is that the length of the survey unit has to be *at least* 10x river width; it can be extended up to 1 – 2 km.

To assess habitat availability for aquatic organisms (namely fish), small-scale hierarchy levels have to be investigated within a river reach of interest. Geomorphic units typically have a length of 10^0 – 10^2 m; hydraulic units: 10^{-1} – 10^1 m; river elements: 10^{-2} – 10^1 m. **Mesohabitat** (which is the basis for modelling with MesoHABSIM software) has spatial scale of 10^{-1} – 10^3 m and is typically found on the level of geomorphic units and hydraulic units.

Geomorphic unit survey and classification system is described in detail in REFORM project deliverables.

Habitat suitability for living organisms depends on: the type of corresponding geomorphic unit; hydrological characteristics (e.g. water depth, flow velocity) and water temperature; and the requirements of that particular group of organisms. Based on these criteria, it is possible to model habitat spatio-temporal variation and assess the *amount of flow* that is necessary for the particular habitat, to be optimally available for biota, and thus sustain good ecological status.

The **Morphological Quality Index (MQI)** is morphological assessment (diagnostic) tool based on a geomorphological approach. The MQI was initially developed to be specifically suitable for the Italian context, i.e. cover the full range of physical conditions, morphological types, degree of artificial alterations, and amount of channel adjustments. During the REFORM project, this method has been verified and expanded to cover the full range of physical conditions (physiographic units, hydrological, and climatic conditions, etc.) and the morphological types of rivers at European scale.

The ‘reach’ (i.e., a section of river along which present boundary conditions are sufficiently uniform, commonly a few kilometres in length) is the basic spatial unit for the application of the evaluation procedure. Whereas, concerning the temporal context, it is of great importance to consider a historical analysis of channel adjustments that provides insight into the causes and time of alterations and into future geomorphic changes.

General structure of MQI. The following aspects are considered for the assessment of the morphological quality of river reaches, and are consistent WFD requirements: (a) continuity of river processes, including longitudinal and lateral continuity; (b) channel morphological conditions, including channel pattern, cross section configuration, and bed substrate; (c) vegetation. These aspects are analyzed in terms of three components: (a) the geomorphological functionality of river processes and forms; (b) artificiality; and (c) channel adjustments.

Indicators of geomorphic **functionality** evaluate whether or not the processes and related forms responsible for the correct functioning of the river are prevented or altered by artificial elements or by channel adjustments. Indicators of **artificiality** assess the presence and frequency of artificial elements or interventions, independently of their effects on processes. Finally, indicators of **channel adjustments** are included in the evaluation. Adjustments caused by human disturbances can shift within a fluvial system in space and time.

Reference conditions are defined considering the previous three components. For functionality, they are given by the channel form and processes that are expected for the morphological type under examination. For artificiality, reference conditions are indicated by the absence or only slight presence of human intervention in terms of flow and sediment regulation, hydraulic structures, and river maintenance activities. If elements of artificiality exist, they should produce only small to negligible effects on the channel morphology and river processes. Finally, concerning channel adjustments in relation to reference conditions, the channel should be not going through major changes of channel morphology caused by human factors.

The **scoring system** was developed using the expert judgement. Scores and classes were defined and subsequently improved based on the results of a testing phase. Scores have remained unchanged in this extended version, in order to ensure data comparability when applied to different European countries. Three classes are generally defined for each indicator: (A) undisturbed conditions or negligible alterations; (B) intermediate alterations; (C) very altered conditions.

The sequence of working phases is summarised as follows:

1. Collection of existing material. This phase focuses on collecting data and information mainly at the reach scale, including: (i) the most recent remotely sensed images; (ii) historical aerial photographs (between about the 1930s and 1960s); (iii) a map layer of interventions (when available), including existing information on sediment and vegetation management by public agencies.

2. Preliminary remote sensing: GIS analysis. During this phase, the most recent remotely sensed images are analysed, and some preliminary GIS analysis is performed.

3. Field survey. It is important, if the results of the field survey are to be optimized, that it addresses and checks the critical aspects identified during the previous phase.

4. Concluding GIS analysis. Once the critical aspects of the evaluation have been resolved by means of the field survey, the GIS analysis and the measurement of quantitative parameters can be finalised.

According to the MQI, **four steps** can be used during the delineation. Step 1: physiographic setting is performed (division of the catchment into landscape units and of the rivers into segments). Step 2: lateral confinement is analyzed (division of segments based on confinement). Step 3: channel morphology is identified. Step 4: other elements for reach delineation are considered.

The MQI evaluation can be applied to any natural river water body. It is recommended to avoid periods of high flows and excessively low flows. The MQI assessment cannot be referred to a precise date (given that it is not a field sampling method), but it refers, rather, to an interval of time ranging from the date of the images used for the analysis and the date of the field survey.

The MQI assessment can be used as a basis for identifying problems and defining possible mitigation or restoration actions. Within REFORM project this assessment was applied to a series of case studies throughout Europe for river restoration interventions (such as removal of bank protections and channel widening).

Following the MQI, new hydromorphological assessment tools have been developed for different contexts and applications. The Morphological Quality Index for monitoring (MQIm) has been specifically designed to assess the environmental impact assessment of interventions, including both flood mitigation and restoration actions.

A river can be called “meandering river” when its sinuosity index exceeds 1.5. Morphometric properties of river meanders include wavelength, sinuosity, curvature, and regularity. Meander wavelength scales with channel width and radius of curvature.

In meandering rivers, four main channel processes can be distinguished: bed deformation in the channel bends; bank erosion (on one side); bank accretion (on the other side); and cutoffs. Main types of geomorphic units in such rivers are: meander pools, lateral bars, mid-channel bars, islands, different types of banks, abandoned meanders, and oxbow lakes. There is a multitude of mathematical formulas developed to calculate the mechanics of river meandering. The main tools for the analysis of meander dynamics are: extraction of meander properties from satellite / aerial images; analysis of topographic data (LiDAR, cross-section surveys); or meander mathematical modelling.

There is still very scarce information regarding the influence of small HPPs on river meandering. It is supposed that downstream HPP dams the erosion processes become more intensive, especially when hydropeaking occurs.

Hydropeaking means rapid flow and stage fluctuations in the receiving water bodies at a variety of sub-daily time scales which are caused by the release of water from HPP reservoirs. Sub-daily variations may induce heavy hydromorphological alterations in a watercourse. These short-time scale variations can result also from natural events such as rapid snowmelt and rainfall. But it has to be taken into account that the magnitude of natural events results in diurnal flow variations of about 10% of the daily mean flow, while anthropogenic water releases from HPP reservoirs can cause much more severe variations.

The occurrence of natural events is limited to a few days (precipitations) or weeks / months (snowmelt) during the year, while anthropogenic releases can repeat each day of the year. Hydropeaking has several known effects on the river biota: it causes alteration of abundance and species composition of fish, benthic and hyporheic communities; increases fish and invertebrate stranding; and reduces nearshore-riparian habitats.

Along with hydropeaking, there can also be found thermopeaking that can arise from the use of water for cooling by power plants, flow regulation, and wastewater from urbanized areas. The release of such water causes thermal regime alterations on a large spectrum of temporal scales - from intra decadal to seasonal and daily timescales.

On the longer scale, such alterations can cause selective disappearance of sensitive species from downstream reaches. Modified thermal patterns and daylength cues disrupt insect emergence patterns and reduce population success. Sub-daily river water temperature alterations are often related to hydropower production. In particular, the releases from HPPs (hydropeaking) fed by high elevation and stratified reservoirs are often characterised by a distinctly different temperature from that of the receiving water body. Beside impacts on river biota, thermal alterations affect also the dynamics of ice formation and breakup in cold regions, with potential related harmful consequences for people and civil infrastructure.

3.3. SEDIMENT TRANSPORT IN THE RIVER SYSTEMS

Sediment transport is one of the main driving forces in the river systems. It can be strongly affected by barriers on rivers, e.g. hydropower plant (HPP) dams and reservoirs.

Streams carry sediment material as dissolved load, suspended load and bedload. Dissolved load is composed of ions in solution that travel at the speed of the flow. Suspended load (typically silt and clay) is composed of material suspended by turbulence in the flow and moving at the speed of the flow. Bedload moves by rolling or sliding along channel bed and is typically composed of gravel and cobbles. Sand may travel as either suspended load or bedload, depending on the flow velocity.

In most unglaciated catchments, it is assumed that bedload comprises a small fraction (5-20%) of the total sediment yield. The dam changes proportion of suspended load and bedload. Downstream the dam the proportion of suspended load is higher and the turbidity of water increases. When there is a lack of sediment from the bedload (due to HPP dam), the river will "try" to get this amount back, by eroding the bed material below the dam, every time when the flow is greater than the critical value.

By calculations it is possible to determine how strong is the flow needed to mobilise the sediment particles, how much sediment can be transported by a given discharge, and how fast erosion/deposition proceeds at a certain river section. Analysis and estimation of motion thresholds can be based on different approaches – flow velocity, shear stress, unit discharge or unit stream power. Shear stress is force of the flowing water stream (moving the sediment particles along), it is proportional to flow velocity. In low-energy systems we can rely more on these standard equations. In mountain rivers, the equations don't work so well (example of an alpine stream where the curve explains only 50% of the amount of transported sediments in reality).

Bedload rating curves (function of the water discharge) can be highly season-dependent. Also, a big flood event can change the channel (remove vegetation, change the size of the dominant sediment particles) and therefore change the bedload rating curve graph for (at least several) following years.

Flow-sediment interactions in the sand-bed channels create different geomorphic units (GUS). Ripples are typical for environments with most slow flow, like those found in Latvia and Lithuania. Higher flow velocities create dunes, plane bed, antidunes (can often be seen on sea beaches). Froude number describes "slow" and "fast" environments, so there is an option to calculate which geomorphic units in sand-bed channels can be found.

Dead wood is a component of the shear stress, it impacts the "roughness" of the channel. Water is "pushing" wood and this energy is not used to move the sediment. Rooted vegetation also creates higher roughness, so the sediment transport becomes less efficient.

River morphology is highly linked to sediment transport. If the sediment regime is altered by dams or reservoirs, changes can be expected in channel morphology and habitat availability.

3.4. BIOLOGICAL MONITORING AND DATA COLLECTION

WFD states that hydromorphological conditions have to be "consistent with the achievement of the values specified for (the particular status class of) the biological quality elements. The reason for this is that hydromorphological processes form the physical environment for the living organisms.

In practice, status class for the biological quality elements often does not fit together with the hydromorphological status. A review by Poff & Zimmerman (2010) on ecological responses to changes in river flow found that:

- Macroinvertebrates show variable response with both reduced and increased density / diversity with changes in flow;
- Fish, in contrast, show a consistent negative response to both low and high flow (if there is an effect);
- In general, it is problematic to establish a consistent quantitative response between biota and river flow.

Analysis of links between hydromorphology and biota has been performed within the activity FP7 of the REFORM project (2013 – 2015). Species data, species traits and a number of biological metrics were analysed against measures of hydromorphological stress, water chemistry data, and land use data. No quantifiable links could be established for benthic diatoms and macrophytes. For benthic invertebrates, metrics like LIFE (Lotic-invertebrate Index for Flow Evaluation), DFI (Drought and flood index), MESH (Macroinvertebrates in Estonia: Score of Hydromorphology) showed quantifiable response, which could not be intercalibrated though. For fish, quantifiable response was partly established: it was shown that fish guild approach relates to overall hydromorphological conditions.

REFORM project also concluded that hydromorphological measurements are often performed at different spatial and temporal scale that biological observations; hydrological monitoring stations are less in number than biological ones, and often located not in the same place. This can be one of the reasons for the lack of convergence between status class estimation based on biological and hydromorphological data.

Fish appears to be the most sensitive BQE with regard to hydromorphology. There is also certain potential to use macrophytes (species traits) in lowland rivers. It is not possible to calculate species traits from routine macrophyte monitoring data. But with the current sampling strategies BQEs can primarily deliver information on the impact of other stressors (relevant in multiple stressor scenarios).

REFORM project recommended to use hydromorphology together with the data on chemistry and BQEs, for the estimation of all five status classes under the WFD (at present, hydromorphology is necessary to make the decision about high status class only). Alternative or new methods linking hydromorphology to BQEs should be developed up to 2019 WFD revision.

Other studies show that there are combined effects of discharge dynamics, channel plan form and substrate conditions on benthic invertebrates' fauna. Interactions between biota and hydromorphological conditions are complex, and include sediments as well. Stressors like organic pollution and pesticides also interact with the effects of low discharge, and often overrule them. It poses many difficulties for the assessment of consequences of the low flow.

It is recommended to: use species traits (habitat template theory); look at riparian organisms (amphibians, ground beetles); consider ecosystem functioning indicators (secondary production); and use sampling strategies that are representative of river behaviour. Habitat spatio-temporal alteration metrics can be of great use in assessing the impact of hydromorphological changes on aquatic organisms and hence the classification of ecological status. It is necessary to use hydromorphology and geomorphic unit based analysis to understand cross-scale mechanisms of geomorphic processes and habitat / biota response.

To estimate the impact of river hydromorphological characteristics on fish, species distribution models are used. These models describe the combinations of environmental variables that form the habitat necessary for the existence of a given fish species in different life stages. Another necessary component is the concept of reference fish community that is expected to be found in a given river type (on a reach scale), under undisturbed conditions. This requires sampling in reference sites (where hydrological, morphological and biological conditions are not subject to human pressure) and statistical analysis.

Random Forest models is a statistical technique based on automatic combination of decision trees. This technique shows good results in building predictive models for species distribution. Predictors are selected automatically from any number of environmental variables by calculating relative variable importance. The models is resistant to outliers and is able to handle data without processing (no need to rescale, transform, normalise the input data).

Modelling results are displayed graphically showing the probability of presence of a given fish species / life stage depending on the value of each environmental variable (e.g. water depth, current velocity, different types of substrate). Combinations of variables are not displayed because Random Forest models assign relative importance to each variable while all variables are analysed in a complex. Based on the modelling results, logical species distribution models (incl. species' presence models and abundance models) are developed (see Figure 2).

Barbus strumciae **ADULTS**

Presence test:

IF

[D15_30+D30_45+D45_60+D60_75+D75_90+D90_105] > 0.4

AND

[MICROLITHAL + AKAL + PSAMMAL] > 0.30

AND

[CV_15 + CV15_30 + CV30_45 + CV45_60 + CV60_75+CV75_90+CV90_105] > 0.3

AND

[ROOTS=1 OR SUBMER_VEG = 1 OR EMER_VEG=1 OR UNDERC_BAN=1 OR WOODY_DEBR =1]

Figure 2. Example of a species distribution model *(source: P. Vezza, presentation material)*

Model validation is performed using data obtained in another (comparable) region. Another possible way is to split the data into two blocks and develop the model using one block of data. After that, validation is performed on the data from the second block.

An alternative to Random Forest modelling is **conditional modelling**, based on logical formulas developed by expert judgement. This method is used when there is no appropriate data available to build spatially based model at HMU scale and there is no time to obtain it (collection of fish data at HMU scale sufficient for modelling is highly time consuming). Conditional modelling approach requires high level of knowledge on habitat preferences and natural hydromorphological limitations of distribution of different fish species.

3.5. DATA COLLECTION AND HABITAT MODELLING SOFTWARE

First habitat models have been established in 20th century. Since then, there have been created various habitat modelling tools, like PHABSIM, RHABSIM, RYHABSIM, EVHA, RSS, HABIOSIM/HYDREAU, CASIMIR, etc. First models were statistical; later they had been linked to habitats. Since the beginning, modelling purposes have changed from “flows for fish” to “flows for ecological quality, river restoration and understanding river mechanisms”. Main principle of habitat models is to combine physical conditions and biological requirements, to evaluate habitat availability and quality. We can speak about habitat only when there is a “user” (inhabitant) present. Habitat can be: unusable; usable; optimal. Models can only predict the *probability* that there will be a certain amount of fish.

Habitat modelling is composed of four parts. First, there is a need to obtain physical spatial measurements - hydraulic attributes (velocity, depth…), sediments, wood, boulders, etc. This can be done on a scale of river segment, reach, mesohabitat. Mesohabitats are linked with hydromorphological units: pools, glides, etc.

The second step is hydraulic modelling which can be either zero models (multiple measurements combined with interpolation), mechanistic models (1, 2 or 3-dimensional that need a lot of calculations), or statistical models (based on measurements in many rivers).

Third, biological measurements are needed (diver observations, electrofishing). Last step is establishment of biological models that define the relationship between fish distribution and physical environment. Time series analysis can be added to monitor habitat availability changes during different time periods.

MesoHABSIM model is based on the concept of hydromorphological units and target fish communities. Main idea is that hydromorphological units change with the flow. What is a pool today, may become a glide tomorrow. Form of the channel has an impact on the stability of habitat – example of a backwater where more water changes only wetted area, not the flow. Channel (river) may appear stable but the habitat within can be unstable. The model gives possibility to simulate abundance of fish under different circumstances. We cannot calculate ecological flow for heavily modified rivers (dams, trapezoid channels, etc.). A volume of water in a pipe still is not a usable habitat. First, we need to establish proper hydromorphology, then calculate ecological flow. For the biological part, first step is to define the bioperiod – spawning, growing etc., bioperiods for different fish species are associated with different amounts of water.

Affiliation index is used to compare fish community structure with the habitat composition structure.

SIM-STREAM software was developed to organize the collected data. It is useful in terms of analysis of graphs, etc. Web application is currently being developed.

Collecting hydromorphological data: at the mesoscale. Sensitivity of the MesoHABSIM model (to the input data) increases with decreasing number of geomorphic units. Good practice is to have >10 GUS in a surveyed river reach. This is a problem with homogeneous reaches.

Survey has to be representative in terms of annual hydrological variability. At least 4 discharges to be surveyed: minimum to low flow; low to median; median/mean; mean to high flow. From the biology point of view, most critical point is **low flow**, so it is needed to get more measurements during low flow.

Field instrumentation:

1) Rangefinder: in general, elevation (and azimuth) is not to be measured for objects farther than 80 metres. There is also some measurement error. To work with rangefinder, one needs to have compass for calibration; after that one can

measure angles, distances and map hydromorphological units along the river. Rangefinder communicates with tablet via MapStream (QGIS) or Arcpad (Esri) plugins. In parallel it is recommended to take ground control points (GCPs) to "calibrate" the points taken by the rangefinder, for example, station point displacement. During hydromorphological unit mapping, habitat description has to be done and vegetation should be recognized. Exposed roots not covered by water should not be considered as habitat. Dead wood in a large river should not be considered as cover. (In small rivers though, it can be.)

2) Flow meter can be electromagnetic or acoustic; do not recommend classic screw meters because of vegetation. Depth and velocity are measured in frequency classes (15 cm for water depth, 15 cm/s for velocity). Number of points in a given geomorphic unit should be >15, max 1 point per square metre. Cover the entire area of the GUS, choosing the points proportionally to GUS properties (e.g. changes of depth or velocity within GUS). If the GUS is small, number of points can be decreased to 7.
3) Field PC or tablet with software plugins MapStream (QGIS) or Arcpad (Esri), for data collection in field.

MesoHABSIM model runs through SimStream plugin for QGIS.

To enter the data in the model, use upload session. Enter *discharge* in the date of survey, in the sampled reach. If you have to asses HPP impact: sample under high flow or low flow, but not when the HPP is in the process of changing the flow speed.

Point measurements – can be uploaded from a txt file (if field measurements were written by hand). After upload, (one by one: .shp and .txt; surveys are numbered), the number of a given survey can be selected from the combo box above, to edit the properties of a particular survey. Name .shp and .txt files in the following way: river name + surveyed river stretch + date + discharge at that date. Then it is easy to select the necessary files for the analysis. It is best to upload the files in the order of increasing discharge. Date format: DD/MM/YYYY.

Next step is Time series analysis: reference flow time series and altered time series (can be more than one: e.g. current situation; and different scenarios, like new HPP with a certain regime). Use combo box to select "reference" or "altered" flow. After the upload of the reference flow time series, combo box status changes automatically to “altered”. Combo box also allows to select scenarios (if different scenarios have been uploaded).

Import biological data: by fish species and life stage. (Upload a separate model for each species and life stage.) A “Show PDP” button displays conditional models - partial dependence plots – if these models have been developed for local fish species. Combo box allows to switch between different fish species.

Desired type of output should be selected. After that, project data is uploaded to the server. Output is downloaded as a .zip file. (To do that, press Logout; select Yes when it is prompted that “all data will be lost” because the data are on the server already. Log in again and go to the Download section to get the results. From the combo box, select the .zip file, download and unzip.) All the calculated results and maps (polygons) have to be open in QGIS. Separate shapefile is produced for every fish species and life stage. If there are 10 fish species, 2 life stages and 4 discharges, the model output will be 80 shapefiles.

Results are provided in separate folders. Habitat integrity scenarios. Maps of habitat suitability (shapefiles with 7 files inside). Habitat flow rating curves (built for the entire surveyed reach). Hydromorphological unit data (reorganized for the statistical analysis – 0 and 1 only; including depth and substrate frequency classes for each single HMU, SD for velocity (the less SD = the steadier the flow), and Froude number (the steepness of the stream)). Streamflow-Habitat time series. UCUT curves. Habitat integrity index.txt – a file containing all calculated indices. Maps: for every species and life stage – optimal, suitable, not suitable habitats under different flows.

Habitat-flow rating curves: when interpreting, *look at the reference hydrograph*, too. What looks like optimal flow (from habitat availability point of view) can be a rare event in reference conditions – e.g. Q_{30} – and hence cannot be chosen as an ecological flow threshold.

If MapStream is used, shapefiles will be produced in the right format for work with SimStream. If another GIS software (ArcPad) is used, shapefile attribute tables will have to be adjusted. In the shapefile attribute tables, Z_MAX, Z_MIN can be left equal to 0 because slope (gradient) will not be critical for the fish in the case of LV and LT.

3.6. FIELD TRIPS

Week 1: During this field trip, first practical works on the recognition of geomorphic units were carried out on two different rivers. Primary study object within the frame of the project is Ciecere river, but identification of reference conditions is complicated there due to impact of Ciecere lake and of three small HPPs. Therefore, Imula river had been investigated to clarify whether it could provide comparable reference conditions for the river Ciecere. On Ciecere river itself, Pakuļu HPP and river stretch downstream this small HPP were investigated.

Week 2: Hydromorphological survey was conducted on the river Ēda (upstream part called river Šķēde) by three small teams. Several locations were visited, to allow for the assessment of pressure of the Dzirnavu HPP on the river system. Each team filled in a field survey protocol and performed the assessment of morphological quality elements by means of MQI (morphological quality index).

Figure 3. Field works on Ciecere river

Week 3: Full scale field works were carried out on the river Ciecere below Pakuļu HPP, in order to apply the actual knowledge acquired through the training course. Practical exercises included working with the field survey equipment and data collection software. Three small teams, each led by one of the instructors (Paolo Vezza, Guido Zolezzi, and Andrea Zanin) performed mesohabitat mapping within the selected river stretch, including mapping and characterisation of geomorphic units, as well as measuring water depth and current velocities, and determining bed substrate in a multitude of representatively selected points within each geomorphic unit (Figure 3).

3.7. DRAFTING OF POSSIBLE METHODOLOGIES FOR E-FLOW ASSESSMENT IN LV AND LT

Discussion and drafting of appropriate survey methodologies for Latvia and Lithuania took part both within the time frame foreseen in the training agenda, and during informal discussions and practical exercises in the field. Main topics included:

- Identification of river reaches, within the rivers previously selected by LT and LV experts to be the subject of study in the frame of the project. This included, among other subjects, a more detailed analysis of large-scale geomorphic features that form the basis for river reach delineation in LT and LV;
- Identification of appropriate river stretches for the in-depth survey;
- Discussion of GUS that are mainly present / are of particular interest in Latvian and Lithuanian rivers;
- Solving of questions with regard to field survey equipment and software;
- Selection of approaches for fish modelling. It has been decided to create one fish model for both LV and LT transboundary catchments. Migratory fish species can be absent simply due to inappropriate season, therefore the concept of bioperiods (e.g. migration or spawning time of salmonids) should be taken into account. It was also agreed to use conditional fish models. Italian experts will develop the necessary modelling algorithms, after the conditional models are constructed.

IV. CONCLUSIONS AND RECOMMENDATIONS

4.1. CONCLUSIONS

All local experts demonstrated the interest to the training course topics and knowledge in the technical issues of the assessment of hydromorphological pressures, namely HPP, as well as river habitat mapping and calculation of river morphological quality index MQI.

The theoretical part on hydromorphology and sediment transport, which had been given at a high academic level, became the basis for understanding of the hydromorphological processes in river systems.

Practical works delivered both in lectures and in the field have shown the capability of project experts to evaluate the E-flow using MesoHABSIM model.

Baltic lowland rivers, characterised by relatively low energy, soft substrate and small dimensions, differ from the rivers in other parts of Europe. Meso-scale assessment approach demonstrated during the training course has been tested in lowland rivers. Nevertheless, data used for habitat modelling and river characterisation must be carefully checked by local experts to avoid misunderstandings in interpretation of results (caused by typological differences).

4.2. RECOMMENDATIONS

The objectives of the learning event for project experts have been successfully met.

However, some questions remain opened, as E-flow evaluation on a scale of a country or river basin district, and policy integration in transboundary river basins. Those issues will require closer cooperation of national experts, and should be included in the area of discussion.

It is evident that MQI evaluation approach should be compared with the present hydromorphological assessment methods used in Latvia and Lithuania. Regional workshops for experts in hydromorphology will be very useful with respect to discussion on guidance documents, standards, and protocol adaptation in transboundary river basins.

The following recommendations should be taken into account in organising of similar training courses on hydromorphology and habitat modeling:

- The practical exercises on the model and field trips duration should be extended, but the theoretical aspects should be done topic by topic in between practical works;
- Field surveys should be carried out on river sites in both countries near the state border;
- More attention should be paid to the preparation of equipment and data for practical work (statistical, topographical, and hydrological).

ANNEX I

List of participants

Participant name	Institution
Tatjana Koļcova	LEGMC
Jolanta Jēkabsone	LEGMC
Marina Čičendajeva	LEGMC
Eduards Križickis	LEGMC
Maruta Vehi	LEGMC
Mārcis Tīrums	LEGMC
Alīna Kļaševa	LEGMC
Armands Bernaus	LEGMC
Linda Fībiga	LEGMC
Aiga Krauze	LEGMC
Jūratė Kriaučiūnienė	LEI
Diana Šarauskienė	LEI
Diana Meilutytė-Lukauskienė	LEI
Darius Jakimavičius	LEI
Aldona Jurgelėnaitė	LEI
Vytautas Akstinas	LEI
Vytautas Kesminas	LEI
Tomas Virbickas	LEI
Jānis Birzaks	BIOR
Kaspars Abersons	BIOR
Jānis Bajinskis	BIOR
Jānis Dumpis	BIOR
Martina Busettini	External expert
Paolo Vezza	External expert
Francesco Comiti	External expert
Barbara Belletti	External expert
Piotr Prasiewicz	External expert
Guido Zolezzi	External expert
Andrea Zanin	External expert

ANNEX II

Training course agenda

WEEK 1
Teachers: Paolo Vezza, Martina Bussettini

	03.07.2017.	**04.07.2017.**	**05.07.2017.**	**06.07.2017.**	**07.07.2017.**
9:00-11:00	*Arrival and registration 11:00*	River habitat, hydro-morphology and e-flows *– by Paolo Vezza*	Biological monitoring considering hydro-morphology – *by Martina Bussettini*	Field works	Field works
11:00-11:20	Coffee break	Coffee break	Coffee break	Coffee break	
11:20-13:00	Ecological flows in the context of EU directives and guidance – *by Martina Bussettini*	Continued *by Paolo Vezza*	Biological data suitable for species distribution models at the mesohabitat scale – *by Paolo Vezza*	Field works	
13:00-14:00	Lunch	Lunch	Lunch	Lunch	
14:00-15:30	E-flows assessment and available guidance at the global scale – *by Paolo Vezza*	Field trip to Ciecere river	Drafting a possible methodology for e-flows assessment in Latvia / Lithuania – *discussions, group work*	Field works	
15:30-15:50	Coffee break	Coffee break	Coffee break	Coffee break	
15:50-17:00	Hierarchical structure of river systems – *by Martina Bussettini*	Field trip to Ciecere river	Continues group work and discussions	Field works	

WEEK 2

Teachers: Francesco Comiti, Barbara Belletti

	10.07.2017.	**11.07.2017.**	**12.07.2017.**	**13.07.2017.**	**14.07.2017.**
9:00-11:00	Field works	Introduction to solid transport and river morphological dynamics - *by Francesco Comiti*	Quantitative assessment of solid transport – *by Francesco Comiti*	Field trip to Ciecere river	Field works
11:00-11:20		Coffee break	Coffee break	Coffee break	Coffee break
11:20-13:00		Continued *by Francesco Comiti*	Continued *by Francesco Comiti*	Field trip	Field works continued
13:00-14:00		Lunch	Lunch	Lunch	Lunch
14:00-15:30		Morphological characterization of river systems – *by Barbara Belletti*	Geomorphic unit and classification system (GUS),with some computer application – *by Barbara Belletti*	Field trip	Closing the training week 15:00
15:30-15:50		Coffee break	Coffee break	Coffee break	
15:50-17:00	Welcome Coffee	Morphological Quality Index (MQI) – *by Francesco Comiti*	Continued *by Barbara Belletti*	Field trip	
	Registration into guest house 18:00				

WEEK 3

Teachers: Paolo Vezza, Andrea Zanin, Piotr Parasiewicz, Guido Zolezzi

	17.07.2017.	**18.07.2017.**	**19.07.2017.**	**20.07.2017.**	**21.07.2017.**
9:00-11:00	*Arrival and registration 11:00*	Species distribution and habitat suitability models at the meso-scale – *by Paolo Vezza, Guido Zolezzi*	Data analysis with SimStream Software application – *by Andrea Zanin*	Field works	Field works
11:00-11:20	Coffee break	Coffee break	Coffee break	Coffee break	
11:20-13:00	Overview of habitat models (from micro-to meso-scale) and example of applications at the global scale – *by Piotr Parasiewicz*	Continued *by Paolo Vezza, Guido Zolezzi*	Continued *by Andrea Zanin*	Field works	Closing the training week 12:00
13:00-14:00	Lunch	Lunch	Lunch	Lunch	
14:00-15:30	Collecting hydro-morphological data at the meso-scale, with field surveys and the MapStream software – *by Paolo Vezza*	Field trip (hydro-morphological data collection) – *all team*	Open questions, discussions	Field works	
15:30-15:50	Coffee break	Coffee break	Coffee break	Coffee break	
15:50-17:00	Continued *by Paolo Vezza*	Field trip – *all team*	Continued discussions and closure of the course	Field works	
19:00 -			Official dinner		

Training materials

Examples of GUS in selected case study rivers in Latvia

	Vegetated mid-channel bar with side channel
	Glide with sand ripples
	Small riffle and side bar (cobble)

	Glide, interrupted by old beaver dam and woody debris
	Slow flowing glide covered by vegetation (*Sparganium emersum*)
	Vegetated and partly eroded bench

Habitat survey datasheet *(source: REFORM project deliverable 6.4)*

Habitat survey datasheet

Date:_______ Time:______ Discharge:_______

Reach name/location:____

Habitat #:_____

Habitat type: pothole; cascade; rapid; riffle; step; pool; glide; backwater; aquatic vegetation; secondary channel; floodplain lake; artificial element

Choriotop categories: Check those that exist around the measurement point:

- Megalithal (>40cm, big boulders)
- Macrolithal (20-40cm, hand to head)
- Mesolithal (6-20cm, fist to hand)
- Microlithal (2-6cm, bird egg to sm fist)
- Akal (gravel)
- Psammal (sand)
- Pelal (silt, loam, sludge, clay)
- Detritus (organic matter)
- Xylal (tree trunks, branches, roots)
- Sapropel (sludge)
- Phytal (submerged plants, floating mats)

Depth [cm]:	**Velocity** [m/s]:	**Substrate:**
1:_________	1:_________	1:_________
2:_________	2:_________	2:_________
3:_________	3:_________	3:_________
4:_________	4:_________	4:_________
5:_________	5:_________	5:_________
6:_________	6:_________	6:_________
7:_________	7:_________	7:_________
8:_________	8:_________	8:_________
9:_________	9:_________	9:_________
10:________	10:________	10:________
11:________	11:________	11:________
12:________	12:________	12:________
13:________	13:________	13:________
14:________	14:________	14:________
15:________	15:________	15:________
16:________	16:________	16:________

Geomorphic units and macro-units list *(source: REFORM project deliverable 6.4)*

Spatial setting	Macro-unit	Macro-unit type	Macro-unit sub-type
Bankfull channel ('submerged' units)	Baseflow or submerged channels (C/S)	Baseflow channel or main channel (C)	
		Secondary channel (within bankfull) (S)	Chute cut-off Two-way connected branch One-way connected branch Pond

Spatial setting	Macro-unit	Unit (type)	Unit sub-type
Bankfull channel ('submerged' units)	Baseflow or submerged channels (C/S)	Pothole (CH)	
		Cascade (CC)	
		Rapid (CR)	
		Riffle (CF)	Forced riffle
		Step (CT)	Rock step Waterfall Boulder step Log step
		Glide (CG)	Rock glide
		Pool (CP)	Forced pool Scour pool Plunge pool Dammed pool Meander pool
		Dune system (CD)	
Bankfull channel ('emergent' units)	Emergent sediment units (E)	Bank-attached bar (EA)	Side bar Point bar Counterpoint bar Junction bar Forced bank-attached bar
		Mid-channel bar (EC)	Longitudinal bar Transverse bar Diagonal bar Medial bar Bedrock core bar Forced mid-channel bar
		Bank attached high-bar (EAh)	
		Mid-channel high-bar (ECh)	
		Bank-attached boulder berm (EB)	
		Mid-channel boulder berm (EM)	
		Dry channel (ED)	
		Bedrock outcrop (EO)	
		Unvegetated bank (EK)	
	In-channel vegetation (V)	Island (VI)	Grassy island Young woody island Established/Adult woody island Mature woody island Complex woody island

	In-channel vegetation (V)	Large wood jam (VJ)	Meander jam Bench jam Bar apex jam Bar top jam Dam jam Bank input jam Flow deflection jam Landslide jam Vegetation-trapped jam
		Aquatic vegetation (VA)	Floating leaves Submerged leaves Emergent leaves
		Bench (VB)	Submerged shelf Berm Bench (sensu stricto) Ledge Point bench Concave bank bench Shelf Slump bench Ice abrasion and ice
		Vegetated bank (VK)	
Floodplain	Riparian zone (F)/ Human dominated areas (H)	Modern floodplain (FF/HF)	
		Recent terrace (FT/HT)	
		Scarp (FS/HS)	
		Levee (FL/HL)	
		Overbank deposits (FD/HD)	Crevasse splay Sand wedge Sand sheet
		Ridges and swales (FR/HR)	
		Floodplain island (FI/HI)	
		Terrace island (FN/HN)	
		Secondary channel (FC/HC)	Flood channel Abandoned channel Abandoned meander
	Floodplain aquatic zones (W/H)	Floodplain lake (WO/HO)	Oxbow lake
		Wetland (WW/HW)	Swamp Floodplain ponds

Spatial setting	**"Macro-units"**	Feature types
Floodplain	Human dominated areas (H)	Agriculture (HAg) Plantation (HPl) Urban (HUr)
All	Artificial features (A)	Dam (AA) Check-dam (AB) Weir A(C) Retention basin (AD) Diversion or spillway (AE) Culvert (AF) Ford (AG) Bridge (AH) Bed revetment (AI) Bed sill (AJ) Ramp (AK) Bank protection (AL) Artificial levee or embankment (AM) Mining sites / Sediment removal (AN)

Morphological Quality Index (MQI) evaluation form *(1 of 5)*

(source: REFORM project deliverable 6.4)

Morphological Quality Index (MQI)

EVALUATION FORMS FOR PARTLY CONFINED AND UNCONFINED CHANNELS

Version 1 - October 2015

GENERALITY

Date ______________ Operators ______________
Catchment ______________ Stream/river ______________
Upstream limit ______________ Downstream limit ______________
Segment code ________ Reach Code ________ Reach length (m) ________

DELINEATION OF SPATIAL UNITS

1. Physiographic setting

Physiographic context ____ *M*=Mountains, *H*=Hills, *P*=Plain Landscape unit ______________

2. Confinement

Confinement degree (%) ________ >90, 10-90, ≤10
Confinement index ________ 1-1.5, 1.5-*n*, >*n* *(n=5 single-thread or anabranching; n=2 braided or wandering)*
Confinement class ________ *PC*=Partly confined, *U*=Unconfined

3. Channel morphology

Aerial photo or satellite image ______________ (name, year)
Sinuosity index ________ 1-1.05, 1.05-1.5, >1.5
Braiding index ________ 1-1.5, >1.5 Anabranching index ________ 1-1.5, >1.5
Typology ________ *ST*=Straight, *S*=Sinuous, *M*=Meandering, *W*= Wandering, *B*= Braided, *A*= Anabranching
Bed configuration ________ *BR*=bedrock, *C*=Cascade, *SP*=Step Pool, *PB*=Plane bed, *RP*=Riffle Pool, *DR*=Dune ripple
(only for single-thread channels) *A*= Artificial, *NC*= not classified (high depth or strong alteration)
Mean bed slope, *S* ________ Mean channel width, *W* (m) ________
Bed sediment (dominant) ____ *C*=Clay, *Si*=Silt, *Sa*=Sand, *G*=Gravel, *C*=Cobbles, *B*=Boulders

4. Other elements for reach delineation

Upstream ______________ Downstream ______________
change in geomorphic units, bed slope discontinuity, tributary, dam, artificial elements, change in confinement and/or size of the floodplain, changes in grain size, other (specify) ______________

Additional available data / information

Drainage area (at the downstream limit) (km^2) ________
Sediment size, D_{50} (mm) ________ Unit ________ *Be*=Bed, *Ba*=Bar (*SU*=surface layer, *SUB*=sublayer)
Discharges ________ *M*=measured, E=estimated, *NA*=not available
Gauging station (if *M*) ________ Mean annual discharge (m^3/s) ________ $Q_{1.5}$ or Q_2 (m^3/s) ________
Maximum discharges (indicate year and *Q* when known) ______________

GEOMORPHOLOGICAL FUNCTIONALITY

Continuity

		part.	prog.	conf.
F1	**Longitudinal continuity in sediment and wood flux**			
A	Absence of alteration in the continuity of sediment and wood	0		
B	Slight alteration (obstacles to the flux but with no interception)	3		
C	Strong alteration (discontinuity of channel forms and interception of sediment and wood)	5		

		part.	prog.	conf.
F2	**Presence of a modern floodplain**			
A	Presence of a continuous (>66% of the reach) and wide modern floodplain	0		
B1	Presence of a discontinuous (10÷66%) but wide modern floodplain or >66% but narrow	2		
B2	Presence of a discontinuous (10÷66%) and narrow modern floodplain	3		
C	Absence of a modern floodplain or negligible presence (≤10% of any width)	5		

Not evaluated in the case of mountain streams along steep (>3%) alluvial fans

part.: partial scores (to circle) *prog.*: progressive scores *confidence level between A and B*
*conf.*confidence level in the answer, with *M*=Medium, *L*=Low *(High is omitted)* *confidence level between B and C*

Morphological Quality Index (MQI) evaluation form *(2 of 5)*

Morphological Quality Index (MQI)

F4	Processes of bank retreat		
A	Bank erosion occurs for >10% and is distributed along >33% of the reach	0	
B	Bank erosion occurs for ≤10%, or for >10% but is concentrated along ≤33% of the reach or significant presence (>25%) of eroding banks by mass failures	2	
C	Complete absence (≤2%) or widespread presence (>50%) of eroding banks by mass failures	3	

Not evaluated in the case of low energy straight, sinuous and anabranching channels and groundwater-fed streams

F5	Presence of a potentially erodible corridor		
A	Presence of a wide potentially erodible corridor (EC) for a length >66% of the reach	0	
B	Presence of a narrow potentially EC for >66%, or wide but for 33-66% of the reach	2	
C	Presence of a potentially EC of any width but for ≤33% of the reach	3	

Morphology

Morphological pattern

F7	Planform pattern		
A	Absence (<5%) of alteration of the natural heterogeneity of geomorphic units and channel width	0	
B	Alterations for a limited portion of the reach (≤33%)	3	
C	Consistent alterations for a significant portion of the reach (>33%)	5	

F8	Presence of typical fluvial landforms in the floodplain		
A	Presence of floodplain landforms (oxbow lakes, secondary channels, etc.)	0	
B	Presence of traces of landforms (abandoned during the last decades) but with possible reactivation	2	
C	Complete absence of floodplain landforms	3	

Evaluated only in the case of meandering rivers (now or in the past) excluding groundwater-fed streams

Cross-section configuration

F9	Variability of the cross-section		
A	Absence (≤5%) of alteration of the cross-section natural heterogeneity (channel depth)	0	
B	Presence of alteration (cross-section homogeneity) for a limited portion of the reach (≤33%)	3	
C	Presence of alteration (cross-section homogeneity) for a significant portion of the reach (>33%)	5	

Not evaluated in the case of low energy straight, sinuous, meandering or anabranching channels with natural absence of bars (lowland rivers, low gradients and/or low bedload) and groundwater-fed streams (natural cross-section homogeneity)

Bed structure and substrate

F10	Structure of the channel bed		
A	Natural heterogeneity of bed sediments and no significant armouring and/or clogging	0	
B	Evident armouring or clogging for ≤50% of the reach	2	
C1	Evident armouring or clogging for >50% of the reach or occasional substrate outcrops (≤33% of the reach) related to recent bed-incision of the alluvial substrate	5	
C2	Widespread alteration of substrate due to bed revetment or substrate outcrops (>33% of the reach)	6	

Not evaluated for sand-bed rivers, and for deep rivers when it is not possible to observe the channel bed

F11	Presence of in-channel large wood		
A	Significant presence of large wood along the whole reach (or "wood transport" reach)	0	
B	Negligible presence of large wood for ≤50% of the reach	2	
C	Negligible presence of large wood for >50% of the reach	3	

Not evaluated above the tree-line and in streams with natural absence of riparian vegetation (e.g. north-European tundra)

Morphological Quality Index (MQI) evaluation form *(3 of 5)*

Morphological Quality Index (MQI)

Vegetation in the fluvial corridor

F12	Width of functional vegetation	
A	High width of functional vegetation	0
B	Medium width of functional vegetation	2
C	Low width of functional vegetation	3

Not evaluated above the tree-line and in streams with natural absence of riparian vegetation (e.g. north-European tundra)

F13	Linear extension of functional vegetation and presence of emergent aquatic macrophytes	
A	Riparian vegetation >90% of maximum length, or riparian vegetation>33% and significant presence of emergent aquatic vegetation (low-energy channels)	0
B	Riparian vegetation 33÷90%, or riparian vegetation >90% but very limited presence of aquatic vegetation, or riparian vegetation ≤33% but significant presence of aquatic vegetation	3
C	Riparian vegetation ≤33%, or <90% but very limited presence of aquatic vegetation	5

Riparian vegetation not evaluated above the tree-line and in streams with natural absence (e.g. north-European tundra)
Aquatic vegetation evaluated only in low-energy straight, sinuous, meandering or anabranching channels

ARTIFICIALITY

Upstream alteration of longitudinal continuity — *part. | prog. | conf.*

A1	Upstream alteration of flows	
A	No significant alteration (≤10%) of channel-forming discharges and with return interval>10 years	0
B	Significant alteration (>10%) of discharges with return interval>10 years or release of increased low flows downstream dams during dry seasons	3
C	Significant alteration (>10%) of channel-forming discharges	6

A2	Upstream alteration of sediment discharges	
A	Absence or negligible presence of structures for the interception of sediment fluxes (dams for drainage area ≤5% and/or check dams/abstraction weirs for drainage area ≤33%)	0
B1	Dams (area 5-33%) and/or check dams/weirs with total bedload interception (area 33-66%) and/or check dams/weirs with partial or no interception (area>66%)	3
B2	Dams (area 33-66%) and/or check dams/weirs with total bedload interception (area>66%)	6
C1	Dams for drainage area >66%	9
C2	Dam at the upstream boundary of the reach	12

Alteration of longitudinal continuity in the reach

A3	Alteration of flows in the reach	
A	No significant alteration (≤10%) of channel-forming discharges and with return interval>10 years	0
B	Significant alteration (>10%) of discharges with return interval>10 years	3
C	Significant alteration (>10%) of channel-forming discharges	6

A4	Alteration of sediment discharge in the reach	
A	Absence of structures for the interception of sediment fluxes (dams, check dams, abstraction weirs)	0
B	*Channels with S≤1%:* consolidation check dams and/or abstraction weirs ≤1 every 1000 m *Steep channels (S>1%):* consolidation check dams ≤1 every 200 m and/or open check dams	4
C	*Channels with S≤1%:* consolidation check dams and/or abstraction weirs >1 every 1000 m *Steep channels (S>1%):* consolidation check dams >1 every 200 m and/or retention check dams or presence of a dam or artificial reservoir at the downstream boundary (*any bed slope*)	6
	In case of density of interception structures, including bed sills and ramps (see A9), is >1 every d1, add	6
	In case of density of interception structures, including bed sills and ramps (see A9), is >1 every d2, add	12

where d1=150 m and d2=100 m in steep channels, or d1=750 m and d2=500 m in channels with S≤1%

Morphological Quality Index (MQI) evaluation form *(4 of 5)*

Morphological Quality Index (MQI)

A5	Crossing structures	
A	Absence of crossing structures (bridges, fords, culverts)	0
B	Presence of some crossing structure (≤1 every 1000 m in average in the reach)	2
C	Presence of many crossing structure (>1 every 1000 m in average in the reach)	3

Alteration of lateral continuity

A6	Bank protections	
A	Absence or localized presence of bank protections (≤5% total length of the banks)	0
B	Presence of protections for ≤33% total length of the banks (sum of both banks)	3
C	Presence of protections for >33% total length of the banks (sum of both banks)	6
	In case of high density of bank protection (>50%) add	6
	In case of extremely high density of bank protection (>80%) add	12

A7	Artificial levées	
A	Absent or set-back levées, or presence of close and/or bank-edge levées ≤10% bank length	0
B	Bank-edge levées ≤50%, or ≤33% in case of total of close and/or bank edge>90%	3
C	Bank-edge levées >50%, or >33% in case of total of close and/or bank edge>90%	6
	In case of high density of bank-edge levées (>66%) add	6
	In case of extremely high density of bank-edge levées (>80%) add	12

Alteration of channel morphology and/or substrate

A8	Artificial changes of river course	
A	Absence of artificial changes of river course in the past (meanders cut-off, channel diversions, etc.)	0
B	Presence of changes of river course for ≤10% of the reach length	2
C	Presence of changes of river course for >10% of the reach length	3

A9	Other bed stabilization structures	
A	Absence of structures (bed sills/ramps) and revetments absent or localised (≤5%)	0
B	Sills or ramps (≤1 every *d*) and/or revetments ≤25% permeable and/or ≤15% impermeable	3
C1	Sills or ramps (>1 every *d*) and/or revetments ≤50% permeable and/or ≤33% impermeable	6
C2	Revetments >50% permeable and/or >33% impermeable	8
	In case of high density of bed revetment (impermeable >50% or permeable >80%) add	6
	In case of extremely high density of bed revetment (impermeable >80%) add	12

d=200 m in steep channels (S>1%); d= 1000 m in channels with S≤1%

Intervention of maintenance and removal

A10	Sediment removal	
A	Absence of recent (last 20 years) and past (last 100 years) significant sediment removal activities	0
B1	Sediment removal activity in the past (last 100 years) but absent during last 20 years	3
B2	Recent sediment removal activity (last 20 years) but absent in the past (last 100 years)	4
C	Sediment removal activity either in the past (last 100 years) and during last 20 years	6

A11	Wood removal	
A	Absence of removal of woody material at least during the last 20 years	0
B	Partial removal of woody material during the last 20 years	2
C	Total removal of woody material during the last 20 years	5

Not evaluated above the tree-line and in streams with natural absence of riparian vegetation (e.g. north-European tundra)

Morphological Quality Index (MQI) evaluation form *(5 of 5)*

Morphological Quality Index (MQI)

A12	Vegetation management		
A	No cutting interventions on riparian (last 20 years) and aquatic vegetation (last 5 years)	0	
B	Selective cuts and/or clear cuts of riparian vegetation ≤50% of the reach and partial or no cutting of aquatic vegetation, or no cutting of riparian but partial or total cutting of aquatic vegetation	2	
C	Clear cuts of riparian vegetation >50% of the reach, or selective cuts and/or clear cuts of riparian vegetation ≤50% of the reach but total cutting of aquatic vegetation	5	

Riparian vegetation not evaluated above the tree-line and in streams with natural absence (e.g. north-European tundra)
Aquatic vegetation evaluated only in low-energy straight, sinuous, meandering or anabranching channels

CHANNEL ADJUSTMENTS

part. prog. conf.

CA1	Adjustments in channel pattern		
A	Absence of changes of channel pattern from 1930s - 1960s	0	
B	Change to a similar channel pattern from 1930s - 1960s	3	
C	Change to a different channel pattern from 1930s - 1960s	6	

Not evaluated in the case of small streams where resolution of aerial photos is insufficient

CA2	Adjustments in channel width		
A	Absent or limited changes (≤15%) from 1930s - 1960s	0	
B	Moderate changes (15÷35%) from 1930s - 1960s	3	
C	Intense changes (>35%) from 1930s - 1960s	6	

Not evaluated in the case of small streams where resolution of aerial photos is insufficient

CA3	Bed-level adjustments		
A	Negligible bed-level changes (≤0.5 m)	0	
B	Limited to moderate bed-level changes (0.5÷3 m)	4	
C1	Intense bed-level changes (>3 m)	8	
C2	Very intense bed-level changes (>6 m)	12	

Not evaluated in the case of absolute lack of data, information and field evidence

Total deviation:	*Stot =*	
Maximum deviation:	*Smax =* 142 - *Sna=*	

where Sna = sum of maximum scores for indicators that have not been applied

Morphological Alteration Index:	*MAI = Stot / Smax =*	

if Stot>Smax, MAI is assumed =1

Morphological Quality Index:	*MQI=1-MAI =*	
Quality class of the reach		

0≤*MQI*<0.3: Very Poor or Bad; 0.3≤*MQI*<0.5: Poor; 0.5≤*MQI*<0.7: Moderate;
0.7≤*MQI*<0.85: Good; 0.85≤*MQI*≤1.0: Very Good or High

ANNEX IV

Workshop agenda and materials

Hydropower and Fish
Research and Innovation in the context of the European Policy Framework

Joint Workshop
IEA Hydropower TCP– European Commission DG RTD

29-30 May 2017
Brussels, Place Madou 1
31 May 2017
Field visit to the Ham Hydropower Plant at the Albert Canal

DRAFT AGENDA

Monday 29th of May – 14:00

Welcome introduction

- András Siegler, European Commission, Director DG RTD G
- Torodd Jensen, International Energy Agency, Chair of Executive Committee, Hydropower TCP
- Thomas Schleker, European Commission, Policy Officer DG RTD G.3;
  Hans-Petter Fjeldstad, Operating Agent IEA Hydropower TCP Annex XIII:
  Introduction to the workshop

Session 1 - The EU Water Framework Directive- the Legislative Context

- Raimund Mair, European Commission, Policy Officer, DG ENV: *Environmental requirements for fish in regulated rivers in the context of the WFD*
- Christina Pantazi, European Commission, Policy Officer, DG ENV: *Natura 2000 in relation to hydropower*
- Jonathan Bonadio, European Commission, Policy Officer, DG ENER: *Hydropower in the context of the Energy and Climate Package and the Renewable Energy Directive (tbc)*

Coffee break

Session 2 - The EU Water Framework Directive -National legislations and implementation

- Veronika Koller-Kreimel, Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management, Deputy Head of Department : *Strategic planning approach for new hydropower development in Austria*
- Jukka Muotka, Fortum/IEA Senior Adviser: *Implementation of the EU WFD in Finland*
- Steffen Schweizer, KWO, Head of Department: *Implementation of the Swiss regulatory context from an operator perspective*
- Roy Langåker, Norwegian Environment Agency: *The implementation of the WFD in Norway*
- Andrea Casolaro, ENEL, Head of Unit: *Implementation of the EU WFD in Italy*

Session 3 - Hydropower and Fish in the context of Research and Innovation

- Piotr Tulej, European Commission, Head of Unit DG RTD G.3: The *Horizon 2020 Energy Work Programme on Hydropower in the context of Energy Union, SET-Plan and ACEI*
- Hans-Petter Fjeldstad, Operating Agent IEA Hydropower TCP Annex XIII Hydropower and Fish: *Hydropower and Fish*
- Panagiotis Balabanis, European Commission, Deputy Head of Unit DG RTD I2: *Research on Hydropower and Fish in the WP on Climate action, environment, resource efficiency and raw materials*
- Angelo Salsi, European Commission, Head of Unit, EASME: *Research on Hydropower and Fish in the LIFE programme (tbc)*

Networking event around 18:30

Tuesday 30th of May – 08:30

Session 4 - Hydropower, Fish Technology

- Peter Rutschmann, Technical University of Munich, Professor: *Hydropower and Fish in the project FITHydro (Horizon 2020)*
- Matthias Schneider, SJE, Executive Director: *Monitoring fish passes with new tools (lateral line probe), assessment of the location of fish pass entrances via modelling approaches (CASiMiR migration, attraction flow) and new ideas for using the approach also for downstream migration.*
- François Avellan, EPFL-LMH, Professor: *Fish-friendly turbines and The Hyperbole Project (Horizon 2020)*
- Harald Rosenthal, World Sturgeon Conservation Society, President: *Title tbc*
- Franz Greimel, BOKU, University of Vienna: *Mitigation of hydropower impacts on fish(tbc)*

Coffee break

Session 5 - Fish habitat in regulated rivers

- Gerd Frik, VERBUND Hydro Power GmbH: *Existing hydropower facilities: Strategic planning for ecological restoration*
- Detlef Fisher, Association of the Bavarian Energy and Water Industry (VBEW: *integrative approach to combine connectivity, river restoration, sediment management, spawning grounds, fish habitats and the interaction of river and oxbows.*
- Christian Haas, IAmHydro: *Unmanned Aerial Systems (UAS) - New opportunities for measuring, mapping and modelling rivers and lakes*
- Jörg Freyhof, IGB-Berlin: *The BioFresh project: Critical sites for freshwater biodiversity in Europe*

Lunch

Session 6 – Migration and River connectivity

- Willem Schreurs, International Meuse Commission, Secretary General: *Master plan for Migratory Fish in the Meuse basin*
- Piotr Parasiewicz, Rushing Rivers Institute, Director: *Migration and river connectivity*
- Martin Wilkes, Coventry University: *FISH-Net: Prior probabilities to support sustainable hydropower planning, design and monitoring*
- Hans-Petter Fjeldstad, SINTEF: *The Mandal Project - Efficient two-way fish migration past hydropower plants in Norway.*
- Wouter Van de Bund, European Commission, Scientific/Technical Project Manager, JRC: *Innovative approaches to Adaptive Barrier Management - Hydropower and Fish in the Horizon 2020 project AMBER*

Coffee break

Session 7 - Energy and ecology

- Atle Harby, SINTEF Energy: *Environmental design of hydropower to meet requirements in the EU Water Framework Directive*
- Martina Bussettini, ISPRA - Italian National Institute for Environmental Protection and Research: *A process-based hydromorphological assessment approach to support river management*
- Isabel Boavida, CERIS - Civil Engineering Research and Innovation for Sustainability University of Lisbon: *Structural mitigation measures for hydro peaking downstream hydropower dams*
- Peter Matt, Engineering Services Vorarlberger Illwerke AG: *Implemented Measures of Austrian Hydropower*

- Agnar Aas, Statkraft: *Implementation of the WFD – long term operation of our flexible hydro power; balancing between environmental improvements and the need for more renewable energy, flexible operations and flood control*

Panel Discussion

Open questions to Research and Innovation in the context of implementation of the WFD

- Veronika Koller-Kreimel, Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management, Deputy Head of Department
- Willem Schreurs, International Meuse Commission, Secretary General
- Jukka Moutka, EURELECTRIC/Fortum
- Harald Rosenthal, World Sturgeon Conservation Society, President
- Isabel Boavida, CERIS - Civil Engineering Research and Innovation for Sustainability University of Lisbon (tbc)
- Further participants (tbc)

Wrap-up and conclusions
- Hans-Petter Fjeldstad, Operating Agent IEA Hydro Annex XIII

Foreseen end: 18:30

Wednesday 31st of May 09:00-14:00

Field visit tour to Ham HPP on the Albert canal

09:00	Departure from Brussels by bus.
10:15	Arrival at HPP Ham - coffee
10:30	Presentation of the HPP and pumping station of Ham in the Albert canal - Werner Dirckx (De Vlaamse Waterweg)
11:00	Effect of the HPP and pumping station of Ham on the fish populations in the Albert canal - Johan Coeck (INBO)
11:30	Archimedes screws in hydropower production - Stefan Schmutz (BOKU)
12:00	Guided visit to the HPP Ham - Werner Dirckx (De Vlaamse Waterweg)
13:00	End of the visit and return to Brussels

Registration via: RTD-IEA-HYDRO-2017@ec.europa.eu

All the presentations and pictures of the event are available on the IEA Hydropower TCP website (link is given below):
http://www.ieahydro.org/publications/hydropower-and-fish-workshop