Project „Water bodies without borders" (EstLat 66)

Economic analysis to support setting effective measures for reaching environmental targets of water bodies (T2.3)

TECHNICAL REPORT

Developed by K. Pakalniete and A. Krumiņa (AKTiiVS Ltd.), M. Simo (LindArt OÜ)
with contribution into the analysis by all project partners

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This document reflects the views of the authors. The managing authority of the programme is not liable for how this information may be used.

Contents

List of abbreviations

CEA	Cost-effectiveness analysis
CR	Cost recovery
CSB	Central Statistical Bureau
EC	Environmental costs
FC	Financial costs
GES	Good ecological status
HPP	Hydro-power plant
MCA	Multi-criteria analysis
NRT	Nature Resource Tax
PoM	Program of Measures
PPP	Polluters-pay-principle
RBD	River Basin District
RBMP	River Basin Management Plan
SWB	Surface water body
SWU	Significant water use
WB	Water body
WS	Water service
WFD	Water Framework Directive (2000/60/EC)

INTRODUCTION

This report has been prepared as part of the project of the INTERREG Estonian-Latvian programme "Water bodies without borders" (WBWB). The project includes activity (T2.3) on conducting economic analysis to provide relevant assessments for setting effective measures for the joint action plan.

The economic analysis aims to provide socioeconomic information and assessments relevant for planning and decision making on effective measures. It includes:

1. **Joint analysis of water use and users**, which aims to provide, as much as possible, quantitative and water-body scale socioeconomic data relevant for the next steps of the economic analysis to assess costs of the water use and socioeconomic impacts of measures.
2. **Joint assessment of the costs caused by water use and their recovery**, which analyses what are the costs of water use causing degradation of the water environment and who and to what extent is paying for these costs. This is analysed for significant water uses – those which create significant pressures causing failure of Good Ecological Status (GES) for water bodies (WBs) in the project area. The analysis serves basis for proposing the necessary policy actions to improve recovery of these costs according to the "cost recovery principle" and "polluter-pays-principle".
3. **Economic evaluation of the additional measures** for achieving environmental targets, which includes assessment of costs of the measures, their cost-effectiveness, analysis of other socioeconomic impacts of the measures. The results are used to provide recommendations on the most socioeconomically effective sets of supplementary measures to achieve environmental targets for the WBs failing GES.

The given report includes detailed results of the conducted economic analysis and it is seen as deliverable of T2.3 of the project.

The report has been prepared by the partners of the project responsible for the economic analysis in each country. But the work has been conducted in collaboration with all partners of the project, in particular the Latvian Environment, Geology and Meteorology Centre, the Estonian Ministry of Environment and the Environmental Board of Estonia.

1 ANALYSIS OF WATER USE AND USERS

The economic analysis of water use and users aims to provide relevant socioeconomic information to support assessing costs of water use and socioeconomic impacts of additional measures to achieve environmental targets of water bodies.

Such analysis is required by the WFD (Article 5) which prescribes that Member States shall ensure that *"an economic analysis of water use is undertaken"* and the Annex III further specifies that this analysis should *"contain enough information in sufficient detail (taking account of the costs associated with collection of the relevant data) in order (a) make the relevant calculations necessary for taking into account under Article 9 the principle of recovery of the costs of water services (..) and (b) make judgements about the most cost-effective combination of measures in respect of water uses to be included in the programme of measures under Article 11 (..)"*.

The content of this analysis was specified together with specialists involved in the river basin management planning of both countries to ensure that the results support work on the development of measures for achieving environmental targets of water bodies (WBs).

It was agreed that the analysis should include three elements:

1. general socioeconomic characterisation of the project area,
2. identification of significant water uses and users,
3. socioeconomic characterisation of the water users.

Results for each element are presented in next chapters.

1.1 General socioeconomic characterisation of the area

The general socioeconomic characterisation provides general socioeconomic information about the project area. The following quantitative socioeconomic indicators were discussed for the joint characterisation covering both countries: number of inhabitants, number of companies, number of employed persons and unemployment rate. Based on available statistical data, which are available according to administrative units, the first three of the proposed indicators are applied. Statistical data concerning unemployment rate are available in Latvia on the scale of statistical regions[1] only. Data on such scale are not appropriate to derive estimates for the project area with acceptable accuracy. Thus, this indicator was not applied.

For Latvia data of the Central Statistical Bureau (CSB) and the Office of Citizenship and Migration Affairs (OCMA) are used. The data from CSB are obtained based on a special data request to have data for the given indicators for the lowest administrative division (parishes and cities). In public databases of CSB the necessary data are available on more aggregated scale only.

For Estonia data of the Statistics Estonia is used, which are available in public databases.

Figure 1.1 shows map with water bodies (WBs) of the project area and administrative units (parishes and cities for Latvia, counties and cities for Estonia) from where the socioeconomic data are derived.

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[1] 6 regions in Latvia: Rīga, Pierīga, Vidzeme, Latgale, Zemgale, Kurzeme.

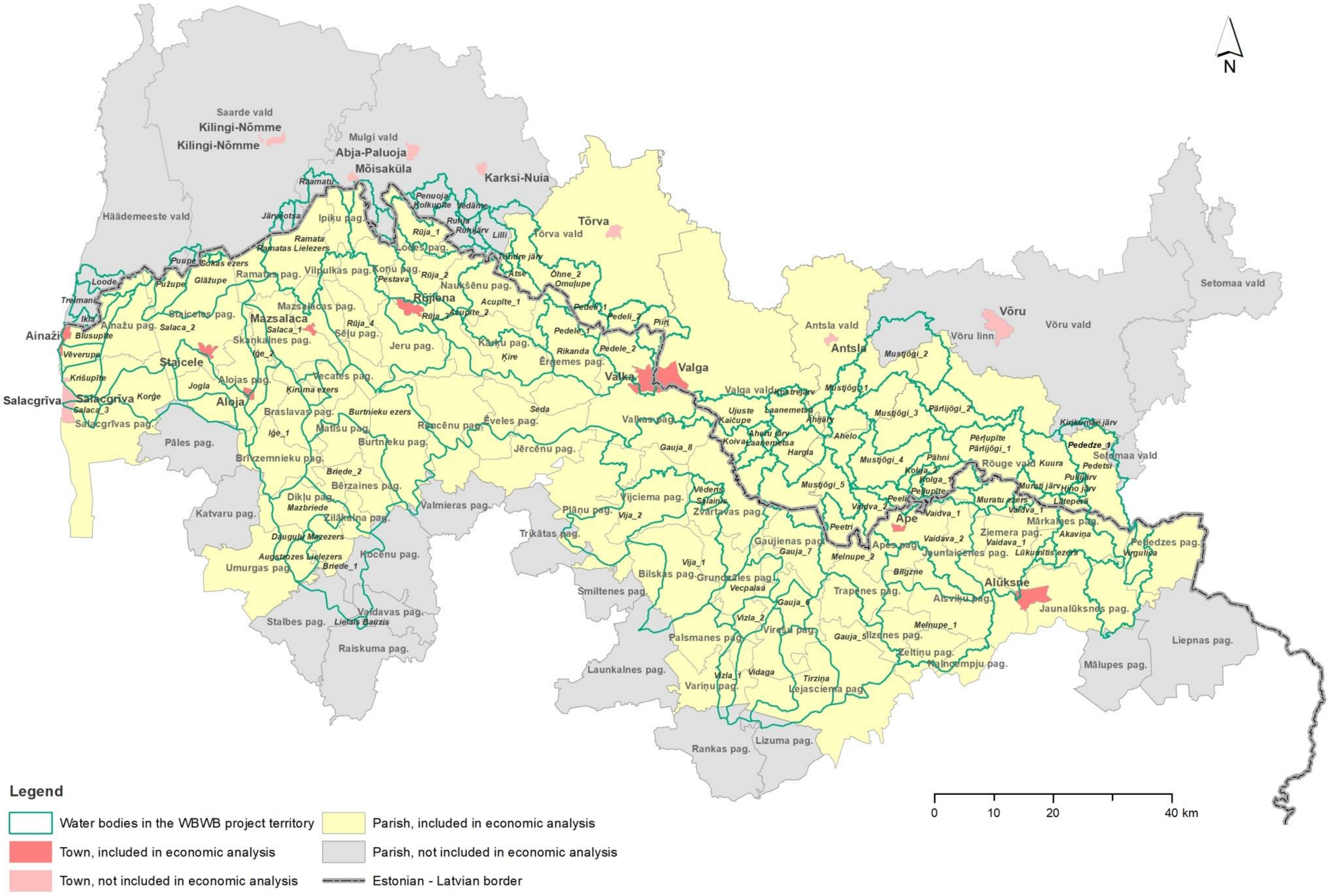

Figure 1.1. Map of water bodies and administrative units in the project area included in the economic analysis. *(Source: LEGMC.)*

NOTE. Yellow colour denotes the parishes and bright red colour denotes the cities that are included in the economic analysis (according to the approach described earlier). The parishes marked with grey and the cities marked with light red are excluded from the economic analysis.

Specific approach has been used to derive the socioeconomic estimates for the project area based on the data on administrative units. It is described below.

For Latvia the socioeconomic data are calculated for the project area based on proportion of territory of administrative units which belongs to the project area. The approach is described in details in Box 1. Such approach was used for all three applied socioeconomic indicators. The results show that 80 % of the total area of the included administrative units (marked with yellow and bright red in Figure 1.1) belongs to the project area. Based on the described approach 88 % of the total number of inhabitants of the included administrative units is estimated belonging to the project area. Overall 59 parishes and cities are included in the economic analysis (51 parishes and 8 cities) from 74 parishes and cities located at least partly in the project area.

For Estonia the number of inhabitants for the project area is estimated based on data of the Statistics Estonia (public databases, data for 2016) where GIS map layer is provided with distribution of inhabitants by their place of residence (number of people living in each 1 km^2). This GIS information is used to estimate number of inhabitants for the project area (accounting inhabitants located in the territories of WBs in the project area). For estimating the number of companies and employed persons in the project area similar approach was used as in Latvia (the approach is described in Box 2). There are 4 counties (Võru, Valga, Pärnu and Viljandi) located at least partly in the project area. Pärnu and Viljandi counties were not included because their territory in the project areas is very small. Hence two counties are considered in the analysis (Võru and Valga, including also the Valga city).

Box 1. The LATVIAN approach for deriving socioeconomic estimates for the project area based on data for administrative units (for the lowest administrative division in Latvia – parishes and cities).

The overall approach – socioeconomic data are calculated for the project area based on **proportion of territory** of administrative units which belongs to the project area.

Step 1: Selecting administrative units for the analysis. List of administrative units located in the project area and their territory (km^2) is provided by LEGMC. Administrative unit is included in the analysis if:

- more than 20 % of its territory belong to the project area,
- or less than 20 % of the territory belong to the project area but the administrative centre is located in the project area,
- or less than 20 % belong to the project area but wastewaters from centralised sewage systems are discharged in the project area (relevant for three cities – Alūksne, Ainaži and Salacgrīva, the latter is excluded because the wastewaters are discharged outside the project area although 22 % of its territory belong to the project area).

Based on this step, from 74 parishes and cities located at least partly in the project area 15 were excluded because they do not correspond to the criteria above. Thus, 59 parishes and cities are included (51 parishes and 8 cities).

Step 2: Calculating proportion (%) of territory of an administrative unit which belongs to the project area.

The proportion is calculated as [territory of an administrative unit which belongs to the project area, km^2] divided by [total territory of that administrative unit, km^2]. Both data are provided by LEGMC.

Step 3: Deriving coefficient for each administrative unit to be applied to the socioeconomic data based on the proportion of the territory. The coefficients are derived applying the following principles:

- if the proportion of territory in the project area is between 20 and 90 %, the calculated proportion is used as coefficient (e.g. coefficient 0.2 if the calculated proportion of territory is 20 %),
- if the proportion of territory in the project area is larger than 90 %, the coefficient 1 is used. Hence for 34 included administrative units 100 % of their socioeconomic data are accounted.

An exception is applied to the cities with the centralised wastewater discharges in the project area – Ainaži and Alūksne. 84 and 7 % of their territories respectively belong to the project area. But 100 % of the socioeconomic data for these cities are accounted. It is justified by the link of the socioeconomic analysis to the pressures' and status' analysis, which both aim to support planning of policy measures.

Box 2. The ESTONIAN approach for estimating number of companies and employed persons for the project area based on data for administrative units (for the lowest administrative division in Estonia – municipalities and counties).

The overall approach – the number of companies and employed persons are calculated for the project area based on **proportion of territory** of administrative units which belongs to the project area.

Step 1: Selecting administrative units for the analysis. List of administrative units located in the project area and their territory (km^2) is provided by Estonian Statistic. Administrative unit is included in the analysis if:

- more than 20 % of its territory belong to the project area,
- or less than 20 % of the territory belong to the project area but the administrative centre is located in the project area,

Based on this step, 2 counties (Võru, Valga) from 15 counties in Estonia overall are included in project area. There is also Valga City partly in the project area.

Step 2: Calculating proportion (%) of territory of an administrative unit which belongs to the project area.

The proportion is calculated as [territory of an administrative unit which belongs to the project area, km^2] divided by [total territory of that administrative unit, km^2]. Both data are provided by Estonian Statistics.

Step 3: Deriving coefficient for each administrative unit to be applied to the socioeconomic data based on the proportion of the territory. The coefficients are derived applying the following principle:

- the calculated proportion (%) of territory of an administrative unit which belongs to the project area is used as coefficient (e.g. coefficient 0.2 if the calculated proportion of territory in the project area is 20 %).

Results for the general socioeconomic characterisation are provided in Table 1.1.

Table 1.1. Estimated number of inhabitants, companies and employed persons in the project area. *(Source: Estimates developed as part of the project.)*

Indicators	**Estimates for the project area**			**Input data and estimation approach**
	For Latvia	**For Estonia**	**TOTAL**	
Number of inhabitants	50 897	12 442	**63 339**	For Latvia: Input data from the OCMA (data on 01.2019, for selected parishes and cities). Estimate for the project area based on the described approach. For Estonia: Input data from the Estonian Statistics (GIS map layer).
Number of companies	4 299	1029	**5 328**	For Latvia: Input data from CSB (data for 2017, for selected parishes and cities).* Estimate for the project area based on the described approach. For Estonia: Input data from Estonian Statistics 2018 for Võru and Valga county. Estimate for the project area based on the described approach.
Number of employed persons	14 921	5780	**20 701**	

* Note. There is uncertainty in the CSB data on number of employed persons since they are accounted according to location (administrative unit) of legal address of a company which can differ from administrative unit where employees are actually located. The actual number of employed persons in the administrative units of the project area could rather be larger than accounted in the statistical data.

The largest part of the project area is located in Latvia. Around 80 % of the estimated inhabitants and companies and around 70 % of the employed persons are located in the Latvian part of the project area.

1.2 Significant water uses and users in the project area

The identification of significant water uses aims to identify uses which need to be included in the economic analysis. The identification is done based on specified criteria.

Two types of water uses have been considered in the analysis in the countries' RBMPs:

- water uses that create significant pressures on the WBs,
- water uses that benefit from good water quality/quantity.

The uses of the first type are selected based on "significance" of their created pressures (as the criterion). Assessment of significance of the pressures comes from the pressures and impact analysis. Those pressures are considered as "significant" which cause failure of GES for (any of) WBs. These uses have been identified for the project area and included in the economic analysis.

Quantitative socioeconomic estimates for the water uses benefiting from good water state[2] are relevant for assessing benefits of implementing measures and achieving environmental targets. They are relevant also if exemptions to water quality objectives due to disproportionate costs need to be justified (where the costs of measures need to be compared with the benefits of their implementation). However, preparing such socioeconomic estimates requires special data collection on these uses. Such data have not been collected in the countries, and it was not feasible as part of the project. Moreover, the assessment of benefits or the economic analysis for justifying exemptions is out of the scope of the project. Hence, these water uses were not included in the economic analysis as part of the project.

The water uses causing significant pressures in WBs in the project area have been identified based on results of the pressures' analysis and WBs' status assessment prepared by the environmental partners (LEGMC and EAE). Summary on these results is provided in Annex 1. The water uses considered in the economic analysis are listed in Table 1.2.

For the Latvian part of the project area, water uses related to agriculture, forestry, small HPPs and dams/obstacles on rivers with other or no use impact several to large number of WBs. There are few other uses which cause failure of GES in 1 WB each. Thus, as part of further economic analysis the first group of uses and users is addressed in more details, while simplified analysis is sufficient for the second group (rather for single actors/users than for the uses overall).

For the Estonian part four water uses are significant however majority impacts only 1 WB each except the dams/obstacles on rivers with other or no use which impact 4 WBs.

Table 1.2. A list of significant water uses and users for the project area. *(Source: Based on analysis as part of the project.) * Information source: Pressures' and status' assessments from LEGMC and EAE.*

Water users	Water uses	Significant pressures due to the water use	Significance for LATVIA No of surface WBs failing GES*	Significance for ESTONIA No of surface WBs failing GES*
Agriculture	Pollution run-off from agricultural lands (mainly arable land and manure storage sites)	Diffuse pollution of nutrients	13 WBs	Do not cause significant pressures
	Drainage for agriculture (by polders, regulation of water regime, straightening of rivers, drainage ditches etc.)	Hydro-morphological pressure	7 WBs	Do not cause significant pressures

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[2] Such uses are: industrial fishing, swimming and near-water recreation, boating and other water sports, angling.

Water users	Water uses	Significant pressures due to the water use	Significance for LATVIA No of surface WBs failing GES*	Significance for ESTONIA No of surface WBs failing GES*
Forestry	Pollution run-off from clear-cutting and drained forest areas	Diffuse pollution of nutrients	5 WBs	Do not cause significant pressures
	Drainage of forest lands	Hydro-morphological pressure	4 WBs	Do not cause significant pressures
Various users (e.g. recreation, roads) or no users	Dams/obstacles on rivers with various uses or no use	Hydro-morphological pressure	3 WBs with 8 obstacles creating significant pressure	4 WB
Small hydro-power plants (HPPs)	Use of water flow for energy production (involving dam, turbine, water flow fluctuations, storage pond/reservoir, etc.)	Hydro-morphological pressure / Hydrological pressure (quantity, water flow regime)	3 WBs (due to operation of 5 HPPs).	1 WB (due to Vastse-Roosa dam)
Households, Industry, Other	Wastewater discharging from centralised sewage systems	Point source pollution of nutrients	1 WB (due to Alūksne city)	1 WB (due to Köstrejärv)
Industry	Wastewater discharging from individual sewage systems	Point source pollution of nutrients	1 WB (due to SIA "ALOJA-STARKELSEN").	Do not cause significant pressures
No user (historical)	Accumulated (past) pollution in WB	Nutrient pollution in sediments	1 WB, past pollution in sediments (Burtnieku lake).	1 WB, past pollution in sediments (Köstrejärv).

1.3 Socioeconomic characterisation of the water users

The socioeconomic characterisation is done for water **users** (e.g. economic sectors), which are linked to the significant water uses (identified using the approach as described in the previous chapter). This characterisation aims to show socioeconomic significance of the water use and users for the economy and welfare in the area.

For the Latvian part the following users are analysed for the whole project area since they impact large number of WBs – **agriculture, forestry, small HPPs and dams/obstacles on rivers with various or no use**. For the latter there is no data on their use, thus quantitative socioeconomic indicators could not be applied. In addition, **households** are included due to their relevance in light of the centralised "water services" for the cost recovery assessment (providing data for the whole project area as well as for the Aluksne city). For other significant water users, which impact single WBs, the socioeconomic data are not included here.

For the Estonian part the same users are included, but it should be noted that their impacts are rather local – their created pressures cause failure of GES in few WBs (as presented in the previous chapter).

For each user joint quantitative socioeconomic indicators have been agreed taking into account information needs for further economic assessments and availability of data for applying the indicators. Summary on the results covering both countries is provided in Table 1.3. Detailed results for each country are presented afterwards.

Table 1.3. Socioeconomic characterisation of water users in the project area. *(Source: Estimates developed as part of the project.)*

Water users (sectors/ activities)	**Applied socioeconomic indicators**	**Estimates for the project area**	
		for the LATVIAN part	**for the ESTONIAN part**
Agriculture	1. Number of companies 2. Number of employed persons 3. Turnover per year 4. Profit / Losses per year	1549 companies. 2703 employed persons. Turnover 38.4-38.7 milj EUR per year. Profit 5.35-5.38 milj EUR per year	437 companies together in agriculture and forestry sectors. 1270 employed persons together in agriculture and forestry sectors. Turnover 123.2 milj EUR per year together in agriculture and forestry sectors.
Forestry	1. Number of companies 2. Number of employed persons 3. Turnover per year 4. Profit / Losses per year	349 companies. 657 employed persons. Turnover 18.3-18.4 milj per year. Profit 0.58-0.59 milj per year.	
Users/ owners of dams/ obstacles (with various or no use)	1. Number of dams/obstacles causing failure of GES 2. Number of owners of these dams/ obstacles	8 dams/ obstacles causing significant pressure in 3 WBs (17 obstacles overall in these 3 WBs) 11 owners related to these 8 obstacles (28 owners related to all 17 obstacles)	11 dams causing failure of GES in 4 WBs.
Small hydro-power plants (HPPs)	1. Number of small HPPs in the project area 2. Their revenues from the produced energy	10 HHPs Revenues 0.69 milj EUR per year (average from 2016-2018 data).	1 HHP. Revenues 1735 EUR per year (average from 2016-2018 data).
Households	1. Number of inhabitants served with centralised water services 2. Mean disposal income of inhabitants per person per month	24 700 inhabitants in the project area, from those 5486 in the Aluksne city. Disposal income 361 EUR in the project area, 308 in the Aluksne county (489 EUR in Latvia on average).	10 300 inhabitants in the project area, from those 7250 in the Valga City. Disposal income 584 EUR in the project area (655 EUR in Estonia on average).

1.3.1. Detailed results for the Latvian part of the project area

Table 1.4 summarises results for the Latvian part of the project area. Estimates for the applied socioeconomic indicators and input data and estimation approaches are provided.

Table 1.4. Estimates for the Latvian part of the project area for the socioeconomic characterisation of water users. *(Source: Estimates developed as part of the project.)*

Water users (sectors/ activities)	Applied socioeconomic indicators	Input data and estimation approach	Estimates for the project area
Agriculture	1. Number of companies 2. Number of employed persons 3. Turnover per year 4. Profit / Losses per year	[1] and [2]: Statistical data from CSB for 2017 (special data request) and estimates for the project area (according to the approach described in Chapter 1.1). [3] and [4]: Statistical data from CSB for 2015-2017 and estimates on average turnover and profit/losses per year (milj EUR) for period 2015-2017. Estimated as range with various proportions assumed for the project area.[3]	1549 companies. 2703 employed persons. Turnover 38.4-38.7 milj EUR per year. Profit 5.35-5.38 milj EUR per year
Forestry	1. Number of companies 2. Number of employed persons 3. Turnover per year 4. Profit / Losses per year		349 companies. 657 employed persons. Turnover 18.3-18.4 milj per year. Profit 0.58-0.59 milj per year.
Users/ owners of dams/ obstacles (with various or no use)	1. Number of dams/obstacles causing failure of GES 2. Number of owners of the dams/ obstacles	Data on number of dams/ obstacles and significance of their pressures – data from LEGMC. Data for number of owners – data from State Land Service e-service portal www.kadastrs.lv.	8 dams/ obstacles causing significant pressure in 3 WBs (17 obstacles overall in these 3 WBs) 11 owners related to these 8 obstacles (28 owners related to all 17 obstacles)
Small hydro-power plants (HPPs)	1. Number of small HPPs in the project area 2. Revenues from their produced energy	For [1]: List of small HPPs from LEGMC. For [2]: Data from the Ministry of Economics for individual HPPs on the produced energy amounts and payments for subsidised renewable energy, average for 2016-2018.	10 HPPs. Revenues 0.69 milj EUR per year (average from 2016-2018 data).
Households (for the whole project area and in the Valka city)	1. Number of inhabitants served with centralised water services 2. Mean disposal income of inhabitants per person per month	For [1] Data from LEGMC (U-2 database). For [2]: Statistical data from CSB on mean households' disposal income per person per month on average in Latvia and net wages in counties of the project area (data for 2017); calculation to adjust these data and derive estimates for the project area and Valka city.	24 700 inhabitants in the project area, 5486 in the Aluksne city. Disposal income 361 EUR in the project area, 308 in the Aluksne county (489 EUR in Latvia on average).

Agriculture and Forestry

There are around 1550 agricultural companies in the project area, which employ around 2700 persons. Around 98 % of these companies are small size companies (with less than 10 employed persons). There are around 350 companies related to forestry in the project area employing around 660 persons. Also here 98 % are small size companies. These estimates have been derived based on

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[3] Estimates for the Project area are derived based on proportion of (i) number of companies and (ii) number of employed persons in each sector estimated for the project area from total in administrative units of the project area. The proportions are 0.851 and 0.845 respectively for agriculture and 0.834 and 0.83 for forestry. They form intervals of the turnover and profit estimates for the project area.

data from CSB (special data request) about number of companies and employed persons in the given sectors in each administrative unit of the project area. The proportion of these data for the project area is estimated with approach as for the general socioeconomic characterisation (described in Chapter 1.1).

The yearly turnover for the agriculture in the project area has been estimated in range of 38.5 milj EUR and the profit around 5.4 milj EUR per year. The yearly turnover for the forestry in the project area has been estimated in range of 18.35 milj EUR and the profit around 0.6 milj EUR per year. To account variability, an average from 3 year period is calculated (from data for the period 2015-2017). These estimates have been derived based on data from CSB (special data request) about turnover and profit/losses in the given sectors in all administrative units of the project area[4]. The proportion of these data for the project area is estimated based on proportion of number of companies and employed persons in each sector estimated for the project area.

Users/owners of dams/obstacles with various or no use

There are **3 WBs** failing GES in the project area due to dams/obstacles on rivers with various uses or no use. For most WBs there is more than 1 dam/obstacle (on the main river and tributaries). Overall **8 dams/obstacles** create significant pressures and cause failure of GES in these 3 WBs (from 17 dams/obstacles overall in these WBs).

Types of owners of these dams/obstacles were investigated based on data from the land cadastre (data from State Land Service e-service portal www.kadastrs.lv). In most cases owners are private persons, in rather few cases municipality or the state (for passages under roads) or legal person. In total **11 owners** are accounted for the 8 dams/obstacles causing failure of GES (28 owners related to all 17 obstacles).

Use of these (8) dams/obstacles will be investigated as part of work for economic evaluation of measures – by individual communications with local municipalities (e.g. to clarify if there is significant recreation above the dam).

Small HPPs

There are 10 small HPPs in the project area. Their estimated revenues (average for the period 2016-2018) compose 0.69 milj EUR on average per year (VAT is not included). Results for each HPP are provided in Table 1.5.

Table 1.5. Revenues of small HPPs in the project area. *(Source: Calculation based on data from the Ministry of Economics, available at: https://www.em.gov.lv/lv/nozares_politika/atjaunojama_energija_un_kogeneracija/informacija_par_izdotajiem_lemumiem_par_elektroenergijas_obligato_iepirkumu/.)*

Name of small HPP	Location – administrative unit (parish)	WB code	WB name	Installed capacity, MW	Operation starting date	Realised amount of energy, kWh	Revenues without VAT, EUR
						Average for 2016-2018	
Kārlīšu dzirnavu HES	Dikļu pagasts	G322	Briede_1	0.03	27.12.2002	54 142	**9 755**
Pedeles jeb Dzirnavnieku HES	Valkas pagasts	G317SP	Pedele_2	0.03	06.11.1998	53 983	**9 792**
Kalndzirnavas HES	Valkas pilsēta	G317SP	Pedele_2	0.08	09.01.2001	158 776	**26 980**
Rauskas HES	Ramatas pagasts	G307	Ramata	0.05	23.12.2002	49 624	**7 066**

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[4] Only totals for all administrative units in the project area were provided by CSB (due to data confidentially).

Name of small HPP	Location – administrative unit (parish)	WB code	WB name	Installed capacity, MW	Operation starting date	Realised amount of energy, kWh	Revenues without VAT, EUR
						Average for 2016-2018	
Ķoņu HES	Ķoņu pagasts	G313	Rūja_2	0.112	25.08.2000	235 605	**41 781**
Imantas dzirnavu HES	Jeru pagasts	G312	Rūja_3	0.1	23.12.1996	427 916	**74 408**
Karvas HES	Alsviķu pagasts	G235SP	Vaidava_2	0.48	12.10.2012	1 527 834	**242 956**
Grūbes HES	Apes pagasts	G235SP	Vaidava_2	0.39	05.02.1999	979 069	**153 956**
Skripstu HES	Plāņu pagasts	G228	Vija_2	0.03	01.12.1998	92 983	**16 940**
Vizlas HES	Grundzāles pagasts	G242	Vizla_2	0.32	04.04.2002	679 976	**108 988**
TOTAL for the project area						**4 259 907**	**692 623**

Households

24 700 inhabitants are served with the centralised water services in the project area (data for 2017), 5486 of those in the Aluksne city (data provided by LEGMC, based on data from “U-2” database). Share of inhabitants served with centralised water services compose only 49 % of the total number of inhabitants estimated for the project area.

The estimated mean households’ disposal income per person per month in the project area is 361 EUR, and 308 EUR in the Aluksne county. It is lower than on average in Latvia (489 EUR) by around 26 % in the project area and 37 % in the Aluksne county.

Since the statistical data on disposal income are available on the scale of statistical regions only, the disposal income for the project area was estimated. The lowest administrative scale data on inhabitants’ income, which are available by administrative units, is the data on net wages (available on the counties scale). The wages compose around 70 % of the inhabitants disposal income, thus these data were used as basis for the estimates. Deviation of the average wage in the project area and the Aluksne county from the average for Latvia was calculated (by 26 and 37 % lower than on average in Latvia). This deviation was applied to the national mean disposal income data to calculate the disposal income for the project area and the Aluksne county (estimate used for the Aluksne city). The estimates are provided in Table 1.6, which includes also calculated disposal income by quintiles (using the same approach).

Table 1.6 Mean disposal income of inhabitants in the project area and the Aluksne county (estimates for 2017). *(Source: Estimates developed as part of the project.)*

	For Latvia (CSB, data for 2017)	**For the project area** (calculated using the described approach)	**For the Aluksne city** (calculated using the described approach)
Average	**489**	**361**	**308**
1st quintile	162	120	102
2nd quintile	285	211	179
3rd quintile	401	296	252
4th quintile	572	423	360
5th quintile	1076	795	677

1.3.2. Detailed results for the Estonian part of the project area

Table 1.7 summarises results for the Estonian part of the project area. Estimates for the applied socioeconomic indicators and input data and estimation approaches are provided.

Table 1.7 Estimates for the Estonian part of the project area for the socioeconomic characterisation of water users. *(Source: Estimates developed as part of the project.)*

Water users (sectors/ activities)	Socioeconomic indicators	Input data and estimates	Estimates for the project area
Agriculture and Forestry	1. Number of companies 2. Number of employed persons 3. Turnover per year 4. Profit / Losses per year	Estonian Statistics, AS MAVES (private company), Environment Agency (KAUR), Environmental Board (KeA)	437 companies together in agriculture and forestry sectors. 1270 employed persons together in agriculture and forestry sectors. Turnover 123.2 milj EUR per year together in agriculture and forestry sectors.
Users/ owners of dams/ obstacles (with various or no use)	1. Number of dams/obstacles causing failure of GES 2. Number of owners of these dams/ obstacles	KAUR, KeA	11 dam2 causing failure of GES in 4 WBs.
Small hydro-power plants (HPPs)	1. Number of small HPPs in the project area 2. Revenues from their produced energy	For [1]: List of small HPPs. For [2]: Data from the State Aid (Ministry of Finance) for individual HPPs on the produced energy amounts and payments for subsidised renewable energy, average for 2016-2018.	1 HHP. Revenues 1735 EUR per year (average from 2016-2018 data).
Households	1. Number of inhabitants served with centralised water services 2. Mean disposal income of inhabitants per person per month	For [1] Data from AS MAVES. For [2]: Statistical data Võru and Valga County (2017)	10 300 inhabitants in the project area, 7250 in the Valga City. Disposal income 584 EUR in the project area (655 EUR in Estonia on average).

Users/owners of dams with various or no use

There are 11 dam in the project area which causes failure of GES for 4 WBs.

Small HPPs

There is 1 small HPP in the project area on Vaidva jõgi. The estimated revenues for the HPP in Vaidva jõgi were 1735 EUR on average per year (based on data for 2016-2018, VAT is not included) – see Table 1.8.

Table 1.8. Revenues of small HPPs in the project area. *(Source: Calculation based on data from the Ministry of Finance, available at: https://rar.fin.ee/rar/providedAidsByRecipientAndMeasureReviewPage.action?aidRecipientId=148110&name=MEELIS%20M%C3%95TTUS&regCode=36710286514&aidMeasureId=-1&procedureId=-1&aidProviderId=-1&aidProviderName=&aidTypeInstanceValues=&goalId=&aidFormId=-1&economicActivity=&aidRecipientTypeId=-1.)*

Name of small HPP	Location – administrative unit (parish)	WB code	WB name	Installed capacity, MW	Operation starting date	Realised amount of energy, kWh	Revenues without VAT, EUR
						Average for 2016-2018	
Vastse- Roosa	Rõuge Vald	1158000_1	Vaidva			5421	**1735**
TOTAL for the project area						5421	**1735**

Households

10 300 inhabitants are served with the centralised water services in the project area. The largest settlements are Valga City (7250 served inhabitants), Varstu (250), Mõniste (164), Misso (188), Rõuge (398). Share of inhabitants served with centralised water services compose 83 % of the total number of inhabitants estimated for the project area.

The mean households' disposal income per person per month was 584 EUR in the project area, while 655 EUR in Estonia on average.

2 ASSESSMENT OF COSTS CAUSED BY WATER USE AND THEIR RECOVERY

Aim of the assessment, commonly called as cost recovery assessment, is to support implementation of the following principles:

- Cost recovery principle to ensure that users of "water services" cover adequately costs of these "water services" (including, financial, environmental and resource costs).
- "Polluters-pay-principle" (PPP) which guides on how the costs of water use should be covered among water users, i.e. that the users provide adequate contribution into covering their created costs based on their role in causing these costs.

The cost recovery assessment needs to address range of methodological issues – from defining "water services" and other "significant water uses", assessment of recovery of their costs, analysis of the current pricing instruments via which the costs are recovered, assessing socioeconomic effects of the cost recovery of "water services" where relevant.

The cost recovery assessment is closely linked with the pressures and WBs status assessments, which provide basis for identifying "water services" and other "significant water uses" to be included in the assessment, as well indication on presence of the "environmental costs" due to water use. Summary on these assessments, which was used as basis for the economic analysis, is provided in Annex 1.

According to the WFD requirements the actions towards implementing the named principles shall be reported in the RBMPs and specific measures need to be included in the programs of measures.

2.1 Approach for the analysis

2.1.1. General elements of the analysis

The approach includes the following elements of the analysis:

1. defining and describing "water services" and (other) "significant water uses" for the assessment,
2. analysis of costs of water use and pricing instruments for their recovery, including concerning external "environmental costs",
3. assessment of cost recovery level (where qualitative assessment for each "water service" and "significant water use" was conducted).

2.1.2. Concept of "water services" and "significant water uses"

Two types of water uses are distinguished for the assessment – "water services" and (other) "significant water uses".

According to definitions in the WFD Article 2, the “water services” means all services which provide, for households, public institutions or any economic activity:

(a) abstraction, impoundment, storage, treatment and distribution of surface water or groundwater,

(b) wastewater collection and treatment facilities which subsequently discharge into surface water.

All water uses that correspond to the given definition of **“water services”** and taking place in the project area (related to surface waters, which is the focus of the project) have been defined as “water services”. The exception is the water use for hydro-energy production which is defined as “water service” in Latvia but not defined as such in Estonia. For Estonia it is considered in the assessment as “significant water use”.

Some water uses corresponding the definition of “water services” are not characteristic for the project area (not taking place at all or the amounts are negligible), thus are not included in the assessment.[5] The list of “water services” included in the assessment is provided in Chapter 2.2. According to the WFD requirements the users of “water services” must cover adequately costs of these “water services”, including, financial, environmental and resource costs[6].

Other water uses, if they cause failure of GES in WBs, are defined as **“significant water uses”**. The list of “significant water uses” in the project area is also provided in in Chapter 2.2. There is a need for policy instruments (i.e. additional measures for reducing pressures) to ensure that these uses give adequate contribution into reaching environmental targets in the affected WBs according to PPP.

2.1.3. Types of costs of the water use

Three types of the costs are distinguished overall – “financial costs”, “environmental costs” and “resource costs”. The latter are not significant in both countries, thus are not analysed.

For the “water services” relevant costs of water use include “financial costs” of using the service and “environmental costs” which capture negative impact from water use. For the “significant water uses” only the “environmental costs” are relevant.

The **“financial costs”** include all the costs of providing and administering the service. They include all operating and maintenance costs, as well as costs of capital and administrative costs. For centralised “water services” the “financial costs” are commonly analysed in details and the cost recovery level is assessed in quantitative terms. For individual “water services” the “financial costs” are not estimated but simple qualitative assessment of their recovery level is provided.

The **“environmental costs”** are the costs of damage caused by water uses to the water environment and ecosystems and those who are using them.

It is important to separate the past “environmental costs”, which are recovered (e.g. by implemented measures of the current RBMPs for reducing pressures), called also as internalised “environmental costs”, and the current (called also as external) “environmental costs”. Recovery of the past “environmental costs” is assessed by analysing “financial costs” recovery (to what extent the water users cover the “financial costs). In the context of the cost recovery assessment only the current (external) “environmental costs” are treated as “environmental costs”.

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[5] Such water uses concerning both countries are surface water use for centralised water supply, individual water supply by households and agriculture, individual water abstraction related to mining and individual water abstraction for irrigation. Concerning the Estonian part such uses include also individual excess water discharging related to mining and individual wastewater discharging by waste disposal sites, which both are taking place in the Latvian part thus are defined as “water services” for Latvia..

[6] Since there is sufficient water availability for all water uses in the project area, there are no “resource costs”. Thus, they are not included in the analysis.

The (external) “environmental costs” exist if there are WBs failing GES. Assessment of pressures shows which water uses create significant pressures causing the failure of GES. Hence the external “environmental costs” are linked to damage caused by concrete “water services”, water uses and users.

The “environmental costs” and their recovery is analysed based on number and characteristics of affected WBs, availability of pricing instruments and amount of the payments for covering these costs. Qualitative assessment of the “environmental cost” recovery is provided and recommendations on improving the cost recovery level are elaborated, which are considered when developing the program of measures.

2.2 The list of “water services” and “significant water uses” for the project area

The list of “water services” and “significant water uses” for the project area is provided in Table 2.1.

Table 2.1 The list of “water services” (WS) and “significant water uses” (SWU) for the project area. *(Source: Based on analysis as part of the project.)*

** No of WBs failing GES due to each water use is provided in parenthesis. Note that the same WB can be affected by multiple significant pressures.*
*** Since there are no WBs where the given “water service” creates significant pressure, it is assumed that there are no external (un-covered) “environmental costs”. Hence only “financial cost” recovery is analysed.*

Water uses	Their created significant pressures	LAT*	EST*
Centralised sewage services	Point source pollution of nutrients	WS (1)	WS (1)
Individual sewage discharge by households		WS (0)**	WS (0)**
Individual wastewater discharge by agriculture		WS (0)**	WS (0)**
Individual water (self) abstraction by industry		WS (0)**	WS (0)**
Individual (self) wastewater discharge by industry	point source pollution of nutrients	WS (1)	WS (0)**
Individual excess water discharging related to mining	pressure on surface water quality (suspended matters)	WS (0)**	Not relevant
Individual wastewater discharge by waste management (disposal) sites	point source pollution of hazardous substances	WS (0)**	Not relevant
Water use for energy production in small HPPs (involving water storage)	hydro-morphological pressures	WS (3)	SWU (1)
Dams/obstacles with various or no uses	hydro-morphological pressures	SWU (3)	SWU (4)
Pollution run-off from agricultural lands	diffuse nutrient pollution	SWU (13)	Not relevant
Pollution run-off from clear-cutting and drained forest areas	diffuse nutrient pollution	SWU (5)	Not relevant
Drainage for agriculture	hydro-morphological pressures	SWU (7)	Not relevant
Drainage for forestry	hydro-morphological pressures	SWU (4)	Not relevant
Accumulated (past) pollution in WB	nutrient pollution in sediments	SWU (1)	SWU (1)

2.3 Summary on the cost recovery assessment for the project area

Cost recovery level

Summary on qualitative assessment of the cost recovery level for the **“water services”** is presented in Table 2.2. It can be concluded concerning the “water services”:

- They cover their “financial costs” of water use, except the centralised “water services” where the cost recovery rate varies considerably depending on the settlement – it is in range of 78-101 % for Latvia (not assessed for all settlements), including 101 % for the Aluksne city, and 87 % for the largest settlement in the Estonian part (the Valga municipality).
- In the Estonian part only the “centralised water services” create (external) environmental costs (in 1 WB). NRT is paid for covering the environmental damage. Thus, the “environmental costs” are covered (at least) partly.
- In the Latvian part 3 out of the 8 “water services” create (external) “environmental costs” in single/few WBs. They pay NRT aimed to cover the environmental damage. Thus, the “environmental costs” are covered (at least) partly. However, the NRT payments are rather small and might not cover these costs.

Summary on qualitative assessment of the cost recovery level for the **“significant water uses”** is presented in Table 2.3. It can be concluded concerning all “significant water uses” that their created (external) “environmental costs” are not covered. In the Estonian part, three water uses cause “environmental costs” in single or several WBs[7] and there are no current pricing instruments for covering these costs. In the Latvian part, four water uses cause such costs in considerable number of WBs. There is the current pricing instrument only for compensating damage to fish resources. But no pricing instruments for covering other environmental damage costs.

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[7] Note that the water use for electricity production in small HPPs is considered as “water use”, not “water service” in Estonia, while it is considered as the “water service” in Latvia.

Table 2.2. Summary on the qualitative cost recovery assessment for the "water services" in the project area. *(Source: Based on analysis as part of the project.)*

Water services	**CR of Financial costs**		**(External) Environmental costs (EC)**		**Cost recovery level, incl. EC**	
	For LATVIAN part	**For ESTONIAN part**	**For LATVIAN part**	**For ESTONIAN part**	**For LATVIAN part**	**For ESTONIAN part**
Centralised water supply and sewage services	Financial CR 78-101 % (depending on settlement). 101 % for Aluksne city (SIA "Rūpe").	Financial CR 87 % for AS Valga Vesi	Cause EC in 1 WB – due to WW discharges of Aluksne city. NRT payment due to WW of Aluksne city is around 1200 EUR per year (in 2015-2017).	Cause external EC in 1 WB (due to WW discharges of the Köstrejärv) Paid NRT for pollution with WW 18 325 EUR in 2017.	**Financial CR 78-101 % (depending on settlement). EC (for 1 WB) are covered (at least) partly.**	**Financial CR 87 %. EC (for 1 WB) are covered (at least) partly.**
Individual sewage by households	Covered		No "environmental costs" due to this water use		Costs are fully covered.	
Individual water supply by industry	Covered		No "environmental costs" due to this water use		Costs are fully covered.	
Individual wastewater discharging by industry	Covered		Cause EC in 1 WB due to WW of a single company. NRT payment for this company is around 270 EUR per year (in 2015-2017)	No "environmental costs" due to this water use	**Financial costs are covered. EC are not covered in 1 WB.**	Costs are fully covered.
Individual wastewater discharging by agriculture	Covered (but possible use of subsidies)		No "environmental costs" due to this water use		Costs are fully covered.	
Individual excess water discharging by mining	Covered	*Not relevant for the Estonian part.*	No "environmental costs" due to this water use	*Not relevant for the Estonian part.*	Costs are fully covered.	*Not relevant for the Estonian part.*
Individual wastewater discharging by waste management (landfills)	Covered (but possible use of subsidies)	*Not relevant for the Estonian part.*	No "environmental costs" due to this water use	*Not relevant for the Estonian part.*	Costs are fully covered.	*Not relevant for the Estonian part.*
Water use for energy production in small HPPs	Covered (but public financial support is available which is covered by end users of electricity).	*Not defined as "waters service", analysed as "significant water use".*	Cause EC in 3 WBs. NRT paid by all (10) HPPs in the project area – around 25 000 EUR per year (around 50 % paid by 5 HPP creating significant pressures), can be in range of 400-7000 EUR per 1 HPP.	*Not defined as "waters service", analysed as "significant water use".*	**Financial costs are covered. EC are covered (at least) partly.**	*Not defined as "waters service", analysed as "significant water use".*

Table 2.3 Summary on the qualitative cost recovery assessment for "significant water uses" in the project area. *(Source: Based on analysis as part of the project.)*

"Significant water uses"	**Current policy and pricing instruments for "environmental cost" (EC) recovery**	**"Environmental cost" recovery description**		**Proposed instruments for improving EC recovery**
		For the LATVIAN part	**For the ESTONIAN part**	
Water use for energy production in small HPPs*	Policy instruments for covering the "past" EC (implementation of the measures and financing their costs according to mandatory requirements for environmental protection prescribed by the national regulations).	(Treated and assessed as the "water service" – see the previous table).	Creates "environmental costs" (in 1 WB). No current instruments for covering these costs. ⇨ **EC are not covered.**	Implementation of "additional" measures proposed in the program of measures to achieve environmental targets in the affected WBs.
Dams/ obstacles on rivers with various or no use	No current policy or pricing instruments are applicable to these users.	Creates "environmental costs" (in 3 WBs). No current instruments for covering these costs. ⇨ **EC are not covered.**	Creates "environmental costs" (in 4 WBs). No current instruments for covering these costs. ⇨ **EC are not covered.**	
Pollution run-off from agricultural lands, clear-cutting and drained forest areas	Policy instruments for covering the "past" EC (implementation of the measures and financing their costs according to mandatory requirements for environmental protection prescribed by the national regulations, although public financial support from the agricultural support mechanisms can be used to cover the costs of the measures).	Creates "environmental costs" (in 13 WBs due to agriculture and 5 WBs due to forestry). No current instruments for covering these costs. ⇨ **EC are not covered.**	Do not create "environmental costs".	**For Latvia:** Implementation of "additional" measures proposed in the program of measures to achieve environmental targets in the affected WBs.
Drainage for agriculture and forest lands	Policy instruments for covering the "past" EC (implementation of the measures and financing their costs according to mandatory requirements for environmental protection prescribed by the national regulations for drainage systems and hydro-technical constructions, for instance, measures to be included in the construction plan to compensate negative environmental impacts; although public financial support from the agricultural support mechanisms can be used to cover the costs of the measures). Current pricing instrument for covering the external "environmental costs" – payment for damage to fish resources.	Creates "environmental costs" (in 7 WBs due to agriculture and 4 WBs due to forestry). The current pricing instrument addresses only damage to fish resources. No data about the paid amounts. ⇨ **EC are not covered.**	Do not create "environmental costs".	
Accumulated (past) nutrient pollution in sediments	No current policy or pricing instruments are available for this water use.	Creates "environmental costs" (in 1 WB). No current instruments for covering these costs. ⇨ **EC are not covered.**	Creates "environmental costs" (in 1 WB). No current instruments for covering these costs. ⇨ **EC are not covered.**	Implementation of "additional" measures proposed in the program of measures to achieve environmental targets in the affected WBs.

* The small HPPs in Latvia are not analysed here since their water use is defined as "water service" in Latvia. They pay NRT (as an instrument for covering the "environmental costs"). See the previous table on the "water services".

Recommendations for improving the cost recovery level

Recommendations concerning the "water services"

There is no full "financial costs" recovery for centralised "water services". The "financial costs" recovery can be improved by increasing tariffs for the "water services". According to international recommendations payments for the centralised "water services" should not exceed 3 % of households' disposal income. The estimated share of the payment for the centralised water supply and sewage services in households' disposal income is below 3 % on average in the project area. But it exceeds the 3 % threshold for lower households' income groups. It limits possibility for increasing the tariffs. At the same time, the share of the payment for the centralised "water services" differs across settlements, like also the "financial costs" recovery level. Hence, each settlements needs to be evaluated individually – whether there is full recovery of the "financial costs" and whether tariffs can be increased without exceeding the 3 % threshold, or there are any compensation mechanisms for low income households to make the tariffs affordable.

The individual "water services" cover fully their "financial costs" overall.

The "water services" create external "environmental costs" in 1 WB in the Estonian part and 5 WBs in the Latvian part of the project area (due to centralised "water services" of single settlements/cities in both countries, individual wastewater discharging by industry (an individual company) and water use for energy production in small HPPs (caused by 5 HPPs) in the Latvian part). These water users pay NRT, which is the current pricing instrument for compensating the "environmental costs". However, on the Latvian side, the estimated NRT payments are rather small to be seen covering the created "environmental costs". There are two policy instruments for covering these costs if new instruments are not introduced – increasing payments via the NRT (increasing NRT rates), and/or implementing additional measures (and financing their costs) for reducing the pressures. NRT is a national pricing instrument hence increasing the NRT rates would impact all respective water users nationally. Since the cost recovery problem is relevant in rather few WBs, local solutions could be preferred. Hence, the implementation of additional measures by the users for reducing their created pressures and allowing achievement of GES in the affected WBs is the recommended instrument for improving the "environmental costs" recovery level and implementing the PPP.

It should be noted concerning the centralised "water services" that the additional measures can include not only improving the wastewater treatment systems for reducing the nutrient pollution amounts discharged in the WBs. They can include also measures taken by the users of the centralised sewage services (e.g. households, industries, other companies and institutions) for reducing nutrient pollution amounts reaching their sewage.

Recommendations concerning the "significant water uses"

There are several WB in the Estonian part and considerable number of WBs in the Latvian part where the "significant water uses" create external "environmental costs". There are no current pricing instruments for covering these costs. The current policy instrument relates to implementation of measures by users and financing their costs according to the mandatory requirements for environmental protection prescribed by the national regulations. However, the failure of GES for range of WBs shows that these measures are not sufficient to be the external "environmental costs" covered. Introducing new pricing instruments would impact all respective water users nationally since the pricing instruments should be introduced nationally to secure equal conditions and requirements for water users. Also, establishing new pricing instruments for the most of the given water uses would be complex (and also costly) process. Local solutions (policy instruments) could be more appropriate. Hence, the implementation of additional measures by the users for reducing their created pressures and allowing achievement of GES in the affected WBs is the proposed instrument for improving the "environmental costs" recovery level according to the "polluters pay principle".

2.4 Detailed results for Latvia concerning "water services"

Centralised sewage services

Due to the focus of the project on surface waters, only centralised sewage services are relevant for the project area (since surface water is not used for the centralised water supply in the project area). However, the analysis covers both services (water supply and sewage) since relevant data and assessments cannot be separated for each service.

Organization of centralized water supply and sewage services

Main regulations governing provision of the services:

- Law on Local Governments (https://likumi.lv/ta/en/en/id/57255-on-local-governments);
- for pricing instruments (tariffs, taxes) Law "On Regulators of Public Utilities" (https://likumi.lv/ta/en/en/id/12483-on-regulators-of-public-utilities), "Natural Resources Tax Law" (https://likumi.lv/ta/en/en/id/124707-natural-resources-tax-law), municipal regulations;
- fulfilment of the requirements of the EU directives, mainly Council Directive 91/271 / EEC concerning urban waste-water treatment and Directive 98/83 / EC on the quality of drinking water.

The Law "On Local Governments" stipulates that municipalities have a duty to organize water supply and sewage services, waste water collection, treatment and disposal for the population. To ensure the fulfilment of their functions, municipalities establish companies and capital companies, many of them as non-profit organizations. In municipalities with small number of users, water supply and sewerage services are provided by municipal departments or institutions. In many cases, municipalities set up multidisciplinary public service companies that provide both water supply and sewage services, as well as heating, waste management and other services.

The provision of water supply and sewerage services as a commercial activity is regulated by the State in accordance with the Law on Regulators of Public Utilities. Public services, including centralized water supply and sewerage services, are regulated by the Public Utilities Commission (Regulator). The Regulator determines the methodology for calculating tariffs, licenses the provision of public services, monitors compliance of public services with certain quality and environmental requirements, technical regulations and other license conditions. In this case, the basic principle of cost recovery is already laid down by law, i.e. the tariffs for water supply and sewage services should be set at such a level that tariff charges cover economically justified costs of services and ensure the profitability of public services.

If the water supply and sewerage services are provided by the local government or local government agency, the tariffs are set by the municipality. The Regulator does not regulate the activities of such service providers.

The **pricing instruments** for cost recovery of the centralised "water services" include (i) tariffs paid by water users, (ii) NRT paid for amount of abstracted water and polluting substances discharged with wastewaters.

The **tariffs** are volumetric overall (EUR per m3, paid for actual consumed amounts according to water meters). In some cases fixed charge is applied (where water meters are not installed), however these are rather exceptions. Volumetric pricing provides incentive to consumers for efficient water use.

Both tariffs and fixed charge vary considerably among parishes and cities. In very rare cases service providers have applied different tariffs to different consumer groups. In general, the same tariffs are applied to all consumer groups. This ensures adequate contribution of various water service users to the recovery of the water service costs.

Information on the tariffs has been collected from homepages of water service providers and individual communications with water service companies in some cases. The tariffs in the project area range from 0.71 to 2.99 EUR per m^3 for sewage services and from 0.41 to 2.06 for water supply services. **The average (weighted) tariff for the project area is 1.66 EUR m^3 for sewage services and 1.20 EUR per m^3 for water supply services (2.87 EUR in total)** including VAT (21 %).

Tariffs for some water service providers in the project area are regulated by the "Regulator of Public Utilities" (RPU). The list of such service providers as well as their served administrative units is provided in Table 2.4.

NRT is estimated only for the Aluksne city since its wastewater discharges create external "environmental costs". Data on the paid NRT amounts are not public. The amount of paid NRT was estimated based on amounts of polluting substances discharged with wastewaters (reported in "U-2" database) multiplied by NRT rates for these substances. The estimated **NRT amount paid for the Aluksne city is around 1200 EUR on average per year** (based on data for the years 2015 – 2017).

The **cost-recovery of financial costs, including internalised "environmental costs"** was summarised for the water service providers regulated by the RPU, since such data are public. The results are provided in Table 2.4. They show that the cost-recovery level range from 78 % to 101 % depending on settlements. Data for other settlements are not available (special data collection would be necessary which was not possible as part of this project).

These estimates cover 25 administrative units from 59 in total included in the economic analysis covering around half of the provided centralised water services in the Latvian part of the project area (covering 50 % of all inhabitants of the project area, 48 % of inhabitants served with centralised water services, 57 % of wastewaters discharged by the centralised water services).

Table 2.4. Cost recovery level of financial costs for the water services' companies in the project area which are regulated by the Regulator of Public Utilities. *(Source: Homepage of the Regulator of Public Utilities, https://www.sprk.gov.lv/content/nozares-raditaji-0.)*

Name of water services' company	Served administrative territories	Cost recovery level (%) of financial costs, including internalised environmental costs (in 2017)
SIA "RŪPE"	**Alūksnes municipality:** Alūksnes City, Zeltiņu parish, Ilzenes parish, Alsviķu parish, Jaunlaicenes parish, Veclaicenes parish, Ziemera parish.	100.9
SIA "Smiltenes NKUP"	**Smiltenes municipality:** Bilskas parish, Grundzāles parish.	92.9
SIA "Salacgrīvas ūdens"	**Salacgrīvas municipality:** Ainažu city, Ainažu parish, Salacgrīvas parish.	86.9
SIA „BN KOMFORTS"	**Burtnieku municipality:** Ēveles parish, Vecates parish, Rencēnu parish, Burtnieku parish, Matīšu parish.	85
SIA "Rūjienas siltums"	**Rūjienas municipality**: Vilpulkas parish, Ipiķu parish, Jeru parish, Rūjienas city, Lodes parish.	84.5
SIA "Kocēnu komunālā saimniecība"	**Kocēnu municipality:** Zilākalna parish, Bērzaines parish, Dikļu parish.	77.7

Improving the cost recovery of the "financial costs" as well as the external "environmental costs" would require further increase in tariffs for the centralised "water services". According to the principle that equal tariffs should be applied to all user groups, increasing the tariffs might cause negative social impact on households, which is the most vulnerable group of users of these services. It is assumed that gradual increase in tariffs in line with the households' income would be affordable for other user groups. Thus, the potential socioeconomic impact on the households is analysed.

It is analysed by estimating **share of the payment for these services in households' disposal income**. The developed estimates for the project area and the Aluksne city are presented in Table 2.5 and 2.6. The estimates show that share of the payment for the centralised water supply and sewage services in households' disposal income was 2.3 % on average in the project area and 3.7 % in the Aluksne city (estimate for 2017). It ranges from 1 % for inhabitants with the highest income level (5th quintile) to 6.9 % for inhabitants with the lowest income level (1st quintile). The respective estimates for the Aluksne city are 1.7 % and 11.2 %. This share exceeds the commonly used threshold (3 %) for the two lowest income groups overall in the project area and the three lowest income groups in the Aluksne city.

However it should be noted that the estimates include uncertainty. The water consumption (m^3 per person per month) is estimated based on available data (reported discharged wastewater amounts and number of connected inhabitants in the "U-2" database, estimated share of services delivered to households from a survey of water service companies in 2014). Also, income of inhabitants is estimated based on available statistical data (available on rather high administrative aggregation) and assumptions. Secondly, the estimated share of the payment by quintiles is rather rough since it is based on the same average water consumption per person in all income groups (which might vary in reality across the groups). In addition, also water tariffs vary significantly across the settlements (the combined water supply and sewage tariff ranges from 1.2 to 4.4 per m^3 in the settlements of the project area). The conclusion that the share of payment in the inhabitants' income could be below the 3 % threshold on average but it exceeds the threshold for the lowest income group(s) is valid for the project area overall. But the situation can be different across concrete settlements.

Table 2.5. Share of the payment for centralised "water services" in households' disposal income for the Latvian part of the project area. *(Source: various data and calculation.*)

	Estimate for 2017	**Input data and estimation approach**
[1] Tariff for centralised water supply and sewage services (EUR/m3 incl VAT)	**2.87**	Average (weighted) tariff for the project area.
[2] Water consumption in households, m3/ person/ month	**2.9**	Calculated based on data on [yearly discharged WW amounts (1309 thous. m3, Ū-2 data, average from 2013-2017, LEGMC)] x [proportion of centralised sewage services to households (0.65, data for 2013, for Gauja RBD, based on survey in 2014)] / [number of connected inhabitants 24674 (Ū-2 data for 2017, LEGMC)].
[3] Payment for centralised water supply and sewage services EUR/ person/ month	**8.25**	Calculated [1] x [2].
[4] Households' disposal income EUR/ person/ month	**361**	Data from CSB on net wage by counties in the project area and mean disposal income for Latvia (data for 2017) and calculation to adjust the Latvian mean disposal income for the project area (approach described in Chapter 1.3). * Quintile – 1/5 of the total number of households, after ordering them in growing order by their disposal income for 1 household's member.
1st quintile	*120*	
2nd quintile	*211*	
3rd quintile	*296*	
4th quintile	*423*	
5th quintile	*795*	
Share (%) of the payment for the centralised water supply and sewage services in households' disposal income	**2.3**	Calculated [3] / [4] x 100.
1st quintile	*6.9*	
2nd quintile	*3.9*	
3rd quintile	*2.8*	
4th quintile	*2.0*	
5th quintile	*1.0*	

Table 2.6. Share of the payment for centralised "water services" in households' disposal income for the Aluksne city. *(Source: various data and calculation.*)

	Estimate for 2017	**Input data and estimation approach**
[1] Tariff for centralised water supply and sewage services in 2017 (EUR/m3 incl VAT)	**3.01**	Tariff for the Aluksne city.
[2] Water consumption in households, m3/ person/ month	**3.8**	Calculated based on data on [discharged WW amounts (385 thous. m3, Ū-2 data for 2017, LEGMC)] x [proportion of centralised sewage services to households (0.65, data for 2013, for Gauja RBD, based on survey in 2014)] / [number of connected inhabitants 5486 (Ū-2 data for 2017, LEGMC)].
[3] Payment for centralised water supply and sewage services EUR/ person/ month	**11.4**	Calculated [1] x [2].
[4] Households' disposal income EUR/ person/ month	**308**	Data from CSB on net wage in Aluksne county and mean disposal income for Latvia (data for 2017) and calculation to adjust the Latvian mean disposal income for the Aluksne city (approach described in Chapter 1.3). * Quintile – 1/5 of the total number of households, after ordering them in growing order by their disposal income for 1 household's member.
1st quintile	*102*	
2nd quintile	*179*	
3rd quintile	*252*	
4th quintile	*360*	
5th quintile	*677*	
Share (%) of the payment for the centralised water supply and sewage services in households' disposal income	**3.7**	Calculated [3] / [4] x 100.
1st quintile	*11.2*	
2nd quintile	*6.4*	
3rd quintile	*4.5*	
4th quintile	*3.2*	
5th quintile	*1.7*	

Water use for energy production in small HPPs

Small HPPs use water flow for energy production (involving dam, turbine, water flow fluctuations, storage pond/reservoir, etc.) creating hydro-morphological pressures (dam as obstacle for fish, pressure on water quantity and water flow regime).

They cover their "financial costs" of water use however subsidies are available for them which can be used for covering these costs. Small HPPs sell the produced energy under "mandatory procurement obligation" and are paid for this energy higher price than the market price. The costs of this higher price are covered by all electricity end-users in Latvia.

Small HPPs cause failure of GES for 3 WBs in the Latvian part of project area (due to operation of 5 HPPs). Thus, they **create (external) "environmental costs". Part of these costs is internalised via the current pricing instrument** – small HPPs pay Nature Resource Tax (according to the Nature Resources Tax Law). The tax rate is 0.00853 EUR per 100 m^3 of the water that has flown through the hydro-technical structure.

Data on the paid NRT amounts are not public (data for individual HPPs are confidential). Internal information from the State Environmental Board indicates that around 25 000 EUR per year are paid as NRT by all HPPs in the project area (around 50 % of this amount is paid by 5 small HPP creating significant pressure). The paid NRT amounts of individual HPPs can range from 400-7000 EUR per year. Hence, the small HPPs (at least) partly cover their created "environmental costs". The uncovered "environmental costs" need further assessment (planned as part of development of the program of measures).

Individual “water services” by households, agriculture, industry, mining and waste disposal

Relevant individual “water services” for the Latvian part of the project area include (i) individual sewage by households, (ii) individual wastewater discharge by agriculture, (iii) individual water abstraction by industry, (iv) individual wastewater discharge by industry, (v) individual excess water discharging related to mining and (vi) individual wastewater discharge by waste management (disposal) sites.

All these “water services” cover their “financial costs” of water use by financing own costs of individual sewage systems. It should be noted that there is public financial support for agriculture which can be used for covering the “financial costs”. Concerning the waste disposal, these costs are covered by final users (households, companies and other whose waste is disposed in a site) by tariffs for waste disposal in landfill. Individual households cover their costs of water use by financing operation of their individual sewage systems. There is national regulation[8] which requires ensuring till the end 2021 that all individual sewage systems are maintained in a way to avoid damage to human health and the environment and that owners of the individual sewage systems must cover the maintenance and operation costs.

An additional pricing instrument is NRT paid for abstracted water and emitted polluting substances with wastewaters. It is paid by companies which must have the water use permits according to the national regulations.

One “water service” – the individual wastewater discharge by industry creates significant pressure causing failure of GES for one WB due to point source pollution of nutrients. It is created by a single company (SIA “ALOJA-STARKELSEN”). Hence, this “water service” creates (external) “environmental costs”. There is pricing instrument for covering these costs since the NRT is paid for pollution emitted into surface waters. The information about paid NRT amounts is not public. The NRT amount paid the given company was estimated based on amounts of emitted polluting substances (reported in “U-2” database, data for period 2015-2017) and NRT tax rates for each substance. The estimate shows that around 270 EUR are paid per year (on average in the period 2015-2017). This is rather small amount to be seen compensating the damage. Hence, it can be concluded that the “environmental costs” are rather not covered. The uncovered “environmental costs” need further assessment (planned as part of development of the program of measures).

Qualitative assessment of recovery of the costs

Summary on qualitative assessment of the cost recovery level for “water services” is presented in Table 2.7). It can be concluded concerning the “water services”:

- They cover their “financial costs” of water use, except the centralised “water services” where the cost recovery rate varies depending on the settlement.
- For those, which create (external) “environmental costs” in few WBs, they pay NRT aimed to cover the environmental damage. Thus, the “environmental costs” are covered (at least) partly. However, the NRT payments are rather small and might not cover these costs.

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[8] Regulation of the Cabinet of Ministers No 384 (from 27.06.2017) "Noteikumi par decentralizēto kanalizācijas sistēmu apsaimniekošanu un reģistrēšanu".

Table 2.7. Summary on the qualitative cost recovery assessment for "water services" for the Latvian part of project area. *(Source: Based on analysis as part of the project.)*

Water services (WS)	WS providers and users	Pricing instruments for cost recovery	CR of Financial costs	(External) Environmental costs (EC)	Cost recovery level, incl. EC
Centralised services					
Water supply and sewage	Water services' companies. Users: households, industry, other.	NRT for water abstraction and pollution discharged with WW. Users – payment for water supply and sewage service.	Financial CR 78-101 % (depending on settlement). 101 % for Aluksne city (SIA "Rūpe").	Cause EC in 1 WB – due to WW discharges of Aluksne city. NRT payment due to WW of Aluksne is around 1200 EUR per year.	**Financial CR 78-101 % (depending on settlement). EC (for 1 WB) are covered (at least) partly.**
Individual "water services" by households					
Sewage	Households	Financing individual sewage solutions (individual WWTP, septic tanks etc.)	Covered	No "environmental costs" due to this water use	Costs are fully covered.
Individual "water services" by industry					
Water supply	Industrial companies	NRT for water abstraction.	Covered	No "environmental costs" due to this water use	Costs are fully covered.
Sewage	Industrial companies	NRT for pollution discharged with WW, financing costs of individual WWT.	Covered	Cause EC in 1 WB due to WW of a single company. NRT payment for this company is around 270 EUR per year (in 2015-2017)	**Financial costs are covered. EC are not covered in 1 WB.**
Individual "water services" by mining					
Excess water discharging	Industrial companies	NRT for pollution discharged with WW, financing costs of individual WWT.	Covered	No "environmental costs" due to this water use	Costs are fully covered.
Individual "water services" by agriculture					
Sewage	Agricultural companies/farms.	NRT for pollution discharged with WW, financing costs of individual WWT.	Covered (but possible use of subsidies)	No "environmental costs" due to this water use	Costs are fully covered.
Individual "water services" by waste management (landfills)					
Wastewater discharging	Operators of waste landfills. (Indirect) users – households and companies producing waste deposited in landfills.	NRT for pollution discharged with WW, financing costs of individual WWT. Payment for users for deposition of waste in landfills.	Covered (but possible use of subsidies)	No "environmental costs" due to this water use	Costs are fully covered.
Water use by small HPPs					
Water use for energy production in small HPPs	Commercial companies (operators of small HPPs). (Indirect) users – consumers of electricity.	NRT for used water amount (from 01.01.2014.). Payment for electricity for consumers.	Covered (but public financial support is available which is covered by end users of electricity).	Cause EC in 3 WBs. NRT paid by all (10) HPPs in the project area – around 25 000 EUR per year (around 50 % paid by 5 HPP creating significant pressures), can be in range of 400-7000 EUR per 1 HPP.	**Financial costs are covered. EC are covered partly.**

2.5 Detailed results for Latvia concerning "significant water uses"

Relevant "significant water uses" for the Latvian part of the project area include (i) diffuse nutrient pollution run-off from agricultural lands and clear-cutting and drained forest areas, (ii) drainage for agriculture and forestry causing hydro-morphological pressures and (iii) dams/obstacles on rivers with various or no uses causing morphological pressures. All these uses create significant pressures in the project area, thus cause (external) "environmental costs".

In addition, one WB fails GES in the Latvian part of the project area due to accumulated past nutrient pollution in sediments (the Burtnieku lake).

The **nutrient pollution run-off from agricultural lands and forestry** causes failure of GES in 13 and 5 WBs respectively in the Latvian part of the project area. There have been efforts to reduce the pressure by implementing the measures and financing their costs according to mandatory requirements for environmental protection prescribed by the national regulations, although public financial support from the agricultural support mechanisms can be used to cover the costs of the measures. However the WBs failing GES due to this pressure indicate that this water use creates "environmental costs". Since there are no current pricing instruments applicable to this water use **the "environmental costs" are not covered**.

The **drainage for agriculture and forestry** cause failure of GES in 7 and 4 WBs respectively. The only current pricing instrument is related to compensating damage to fish resources.[9] Other negative external environmental impacts are not compensated. Hence these water uses create **"environmental costs" which are not covered**.

Dams/obstacles on rivers with various or no uses cause failure of GES in 3 WBs. There are no applicable pricing instruments for such users. Hence, these water uses **do not cover their created "environmental costs"**.

The **accumulated past nutrient pollution in sediments** cause failure of GES in 1 WB, which means that there are (external) "environmental costs". There is no applicable pricing instrument for such water use hence **the "environmental costs" are not covered**.

The uncovered "environmental costs" need further assessment (planned as part of development of the program of measures).

Qualitative assessment of recovery of the costs

Summary on qualitative assessment of the cost recovery level for the "significant water uses" is presented in Table 2.8. It can be concluded concerning all "significant water uses" that their created (external) "environmental costs" are not covered currently. Implementation of additional measures for reducing their pressures to achieve environmental targets in the affected WBs is the proposed instrument for improving recovery of the created "environmental cost" according to the "polluters pay principle".

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[9] Regulation of the Cabinet of Ministers No 188 from 08.05.2001, last revisions in 01.01.2014, „Saimnieciskās darbības rezultātā zivju resursiem nodarītā zaudējuma noteikšanas un kompensācijas kārtība".

Table 2.8. Summary on the qualitative cost recovery assessment for "significant water uses" for the Latvian part of project area. *(Source: Based on analysis as part of the project.)*

"Significant water uses"	Current policy and pricing instruments for "environmental cost" (EC) recovery	"Environmental cost" recovery description	Proposed instruments for improving EC recovery
Pollution run-off from agricultural lands (mainly arable land and manure storage sites)	Policy instruments for covering the "past" EC (implementation of the measures and financing their costs according to mandatory requirements for environmental protection prescribed by the national regulations, although public financial support from the agricultural support mechanisms can be used to cover the costs of the measures).	Creates "environmental costs" (in 13 WBs). No current instruments for covering these costs. ⇨ **EC are not covered.**	Implementation of "additional" measures proposed in the program of measures to achieve environmental targets in the affected WBs.
Pollution run-off from clear-cutting and drained forest areas		Creates "environmental costs" (in 5 WBs). No current instruments for covering these costs. ⇨ **EC are not covered.**	
Drainage for agriculture (by polders, regulation of water regime, straightening of rivers, drainage ditches etc.)	Policy instruments for covering the "past" EC (implementation of the measures and financing their costs according to mandatory requirements for environmental protection prescribed by the national regulations for drainage systems and hydro-technical constructions, for instance, measures to be included in the construction plan to compensate negative environmental impacts including to compensate losses caused to biocenosis; although public financial support from the agricultural support mechanisms can be used to cover the costs of the measures). Current pricing instrument for covering the external "environmental costs" – payment for damage to fish resources.	Creates "environmental costs" (in 7 WBs). The current pricing instrument addresses only damage to fish resources. No data about the paid amounts. ⇨ **EC are not covered.**	
Drainage of forest lands		Creates "environmental costs" (in 4 WBs). The current pricing instrument addresses only damage to fish resources. No data about the paid amounts. ⇨ **EC are not covered.**	
Dams/obstacles on rivers with various or no use	No current policy or pricing instruments are applicable to these users.	Creates "environmental costs" (in 3 WBs). No current instruments for covering these costs. ⇨ **EC are not covered.**	
Accumulated (past) nutrient pollution in sediments	No current policy or pricing instruments are available for this water use.	Creates "environmental costs" (in 1 WB). No current instruments for covering these costs. ⇨ **EC are not covered.**	

2.6 Detailed results for Estonia concerning “water services”

Centralised sewage services

Due to the focus of the project on surface waters, only centralised sewage services are relevant for the project area (since surface water is not used for the centralised water supply in the project area). However, the analysis covers both services (water supply and sewage) since relevant data and assessments cannot be separated for each service.

Organization of centralized water supply and sewage services

Main regulations governing provision of the services:

- For organization of centralized water supply and sewerage services in Estonia “Public Water Supply and Sewerage Act” (https://www.riigiteataja.ee/en/eli/506072018002/consolide),
- for pricing instruments (tariffs, taxes) the law “Public Water Supply and Sewerage Act” (https://www.riigiteataja.ee/en/eli/506072018002/consolide), "Environmental charges act" (https://www.riigiteataja.ee/en/eli/ee/Riigikogu/act/521032019001/consolide), etc.),
- fulfilment of the requirements of the EU directives, mainly Council Directive 91/271 / EEC concerning urban waste-water treatment and Directive 98/83 / EC on the quality of drinking water.

The Law “Public water Supply and Sewerage” stipulates that municipalities have a duty to organize water supply and sewerage services, waste water collection, treatment and disposal for the population. To ensure the fulfilment of their functions, municipalities establish companies. In some cases, municipalities set up multidisciplinary public service companies that provide both water supply and sewerage services, as well as heating, waste management and other services.

The provision of water supply and sewerage services as a commercial activity is regulated by the State in accordance with the Public Water Supply and Sewerage Act. Public services, including centralized water supply and sewerage services, are regulated by the Estonian Competition Authority (Regulator). Estonian Competition Authority or the local government has the right, pursuant to their competence, to verify the size of connection charges and whether the connection charges are reasoned and comply with the methodology. The basic principle of cost recovery is already laid down by law, i.e. the tariffs for water supply and sewerage services should be set at such a level that tariff charges cover economically justified costs of services and ensure the profitability of public services.

If the licensed territory of a water service provider is situated in the wastewater collection area with pollution load of less than 2000 population equivalent or outside a waste water collection area, the water service provider shall co-ordinate the methodology with the local government. If the licensed territory of a water service provider is situated in the wastewater collection area with pollution load of 2000 population equivalent or more, the water undertaking shall co-ordinate the methodology with the Competition Authority. A water undertaking shall disclose the methodology for calculating connection charges after obtaining the approval.

The **pricing instruments** include (i) tariffs paid by water users, (ii) NRT paid for amount of polluting substances discharged with wastewaters.

The **tariffs** are volumetric overall (EUR per m^3, paid for actual consumed amounts according to water meters). Volumetric pricing provides incentive to consumers for efficient water use.

Tariffs vary considerably between different municipalities and parishes. In very rare cases, service providers have applied different tariffs to different consumer groups. In general, the same tariffs are applied to all consumer groups. This ensures adequate contribution of various water service users to the recovery of the water service costs.

Information on the tariffs has been collected from homepages of water service providers and individual communications with water service companies in some cases. The tariffs in the project area range from 1.9 to 2.7 EUR per m^3 for sewage services and from 1.2 to 1.7 for water supply services. **The weighted average tariff for the project area is 1.96 EUR m^3 for sewage services and 1.24 EUR per m^3 for water supply services (3.2 EUR in total) including VAT (20 %).**

Tariffs for AS Valga Vesi are regulated by the Estonian Competition Athority (Valga city over 2000 p.e). AS Valga Vesi is the biggest water company in the project area are (see Table 2.9).

The **cost-recovery of financial costs, including internalised "environmental costs"** was assessed for the biggest water service provider in the project area (Based on the companies' financial data available in saldo.fin.ee). The results are provided in Table 2.9. They show that the cost-recovery level on AS Valga Vesi is 87 %.

These estimates cover 2 administrative units from 15 in total included in the economic analysis, covering 20 % of all inhabitants of the project area and 83 % of wastewaters discharged by the centralised water services.

Table 2.9. Cost recovery level of financial costs for water services' AS Valga Vesi. *(Source https://saldo.fin.ee/saldo/reportManagement.longprofit.report.action?partnerId=2220&periodId=140&.)*

Name of water services' company	Served administrative territories	Cost recovery level (%) of financial costs, including internalised environmental costs (in 2017)
AS Valga Vesi	**Valga Municipality:** Valga City	87

Improving the cost recovery of the "financial costs" as well as the external "environmental costs" would require further increase in tariffs for the centralised "water services". According to the principle that equal tariffs should be applied to all user groups, increasing the tariffs might cause negative social impact on households, which is the most vulnerable group of users of these services. It is assumed that gradual increase in tariffs in line with the households' income would be affordable for other user groups. Thus the potential socioeconomic impact on the households is analysed.

It is analysed by estimating share of the payment for these services in households' disposal income. Quantitative estimate for the whole project area are presented in Table 2.10.

Table 2.10. Share of the payment for centralised "water services" in households' disposal income. *(Source: various data and calculation.)*

	2017	**Data and calculations**
[1] Tariff for centralised water supply and sewage services (EUR/m3 incl VAT)	3.20	Average (weighted) tariff for the project area.
[2] Water consumption in households m3/ person/ month	2.67	Valga Vesi AS, Rõuge Kommunaal OÜ
[3] Cots for centralised water supply and sewage services EUR/ person/ month	8.54	Calculated [1] x [2].
[4] Households' disposal income EUR/ person/ month	**584**	Source: http://pub.stat.ee/px-web.2001/Dialog/Saveshow.asp, http://pub.stat.ee/px-web.2001/Dialog/Saveshow.asp, Valga and Võru county average. * Quintile – 1/5 of the total number of households, after ordering them in growing order by their disposal income for 1 household's member.
1st quintile	*251*	
2nd quintile	*427*	
3rd quintile	*568*	
4th quintile	*785*	
5th quintile	*1245*	

	2017	Data and calculations
[5] Share (%) of the payment for the centralised water supply and sewage services in households' disposal income		Calculated [3] / [4] x 100.
Average	1.6 %	
1st quintile	3.7 %	
2nd quintile	2.2 %	
3rd quintile	1.6 %	
4th quintile	1.2 %	
5th quintile	0.8 %	

Individual "water services" by households, agriculture and industry

Relevant individual "water services" for the Estonian part of the project area include (i) individual sewage by households, (ii) individual wastewater discharge by agriculture, (iii) individual water abstraction by industry, (iv) individual wastewater discharge by industry.

All these "waters services" do not create significant pressures in the project area, thus do not cause "environmental costs". They cover their "financial costs" of water use by financing own costs of individual sewage systems. In addition, pollution tax is paid for emitted polluting substances with wastewaters by companies which must have the water use permits according to the national regulations. It should be noted that there is public financial support for agriculture which can be used for covering the "financial costs". Individual households cover their costs of water use by financing operation of their individual sewage systems.

Qualitative assessment of recovery of the costs

Summary on qualitative assessment of the cost recovery level for "water services" is presented in Table 2.11). It can be concluded concerning the "water services":

- They cover their "financial costs" of water use, except the centralised "water services" where the cost recovery rate is 87 % for Valga municipality.
- They do not create significant pressures, thus do not create "environmental costs".

Table 2.11. Summary on the qualitative cost recovery assessment for "water services" for the Estonian part of project area. *(Source: Based on analysis as part of the project.)*

Water services (WS)	WS providers and users	Pricing instruments for cost recovery	CR of Financial costs	(External) Environmental costs (EC)	Cost recovery level, incl. EC
Centralised					
Water supply and sewage	Water services' companies. Users: households, industry, other.	NRT for water abstraction and pollution discharged with WW. Users – payment for water supply and sewage services.	Financial CR 64 % for AS Valga Vesi	Cause external EC in 1 WB (due to WW discharges of the Köstrejärv) Paid NRT for pollution with WW 18 325 EUR in 2017.	**Financial CR 87 %** **EC (for 1 WB) are covered (at least) partly.**
Individual "water services" by households					
Sewage	Households	Financing individual sewage solutions (individual WWTP, septic tanks etc.)	Covered	No "environmental costs" due to this water use	Costs are fully covered.
Individual "water services" by industry					
Water supply	Industrial companies	NRT for water abstraction.	Covered	No "environmental costs" due to this water use	Costs are fully covered.
Sewage	Industrial companies	NRT for pollution discharged with WW, financing costs of individual WWT.	Covered	No "environmental costs" due to this water use	Costs are fully covered.
Individual "water services" by agriculture					
Sewage	Agricultural companies/farms.	NRT for pollution discharged with WW, financing costs of individual WWT.	Covered (but possible use of subsidies)	No "environmental costs" due to this water use	Costs are fully covered.

2.7 Detailed results for Estonia concerning "significant water uses"

Relevant "significant water uses" for the Estonian part of the project area include (i) water use for energy production in small HPPs, (ii) dams/obstacles on rivers with various or no uses causing morphological pressures and (iii) accumulated past nutrient pollution in sediments of a WB. All these uses create significant pressures in the project area (in single WBs), thus cause (external) "environmental costs".

Small HPPs use water flow for energy production (involving dam, turbine, water flow fluctuations, storage pond/reservoir, etc.) creating hydro-morphological pressures (dam as obstacle for fish, pressure on water quantity and water flow regime).

They cover their operation costs however subsidies are available for them which can be used for covering these costs. Small HPPs sell the produced energy under "mandatory procurement obligation" and are paid for this energy higher price than market price. The costs of this higher price are covered by all electricity end-users in Estonia. Small HPPs cause failure of GES for 1 WB in the Estonian part of the project area due to operation of 1 HPP. Thus, it **creates external "environmental costs**". There are no current pricing instruments which apply to this water use. **Hence the created "environmental costs" are not covered.** The uncovered "environmental costs" need further assessment (planned as part of development of the program of measures).

Dams/obstacles on rivers with various or no uses cause failure of GES in 4 WBs. There are no current pricing instruments which apply to this water use. **Hence the created "environmental costs" are not covered.**

The **accumulated past nutrient pollution in sediments** cause failure of GES in 1 WB, which means that there are (external) "environmental costs". There is no applicable pricing instrument for such water use hence **the "environmental costs" are not covered**.

Qualitative assessment of recovery of the costs

Summary on qualitative assessment of the cost recovery level for the "significant water uses" is presented in Table 2.12. It can be concluded concerning all "significant water uses" that their created (external) "environmental costs" are not covered currently. Implementation of additional measures for reducing their pressures to achieve environmental targets in the affected WBs is the proposed instrument for improving recovery of the created "environmental cost" according to the "polluters pay principle".

Table 2.12. Summary on the qualitative cost recovery assessment for "significant water uses" for the Estonian part of project area. *(Source: Based on analysis as part of the project.)*

"Significant water uses"	Current policy and pricing instruments for "environmental cost" (EC) recovery	"Environmental cost" recovery description	Proposed instruments for improving EC recovery
Water use for energy production in small HPPs	Policy instruments for covering the "past" EC (implementation of the measures and financing their costs according to mandatory requirements for environmental protection prescribed by the national regulations).	Creates "environmental costs" (in 1, 4 and 1 WB due to each water use respectively). No current instruments for covering these costs. ⇨ **EC are not covered.**	Implementation of "additional" measures proposed in the program of measures to achieve environmental targets in the affected WBs.
Dams/ obstacles on rivers with various or no use	No current policy or pricing instruments are applicable to these users.		
Accumulated (past) nutrient pollution in sediments	No current policy or pricing instruments are available for this water use.		

3 ECONOMIC EVALUATION OF ADDITIONAL MEASURES – AN OVERALL APPROACH

For the WBs failing GES additional measures need to be implemented to reduce significant pressures and ensure achievement of GES. Since various alternative measures are available for this purpose, the economic evaluation of possible additional measures aims to support their prioritisation and selection of the most socioeconomically efficient and acceptable measures.

The water uses and pressures creating significant pressures and failure of GES in both countries are described in chapter 1.2 of the report. Possible additional measures were identified to address the environmental problems in the project area – taking into account WBs failing GES and significant pressures and water uses causing this failure. The measures must be technically feasible and cost-effective, but also relevant socioeconomic impacts of their implementation should be considered. The evaluation approach should consider all these aspects to support effectively the planning of measures.

Possible approach for the evaluation of additional measures was discussed among the project partners who represent also relevant institutions in Latvia and Estonia involved in the River Basin Management Planning (RBMP). It was agreed that similar evaluation approach could be applied in both countries concerning common pressures and water uses which cause failure of GES of WBs in both countries (see chapter 1.2). Most relevant of such common pressures and water uses (causing failure of GES for the largest number of WBs) are hydro-morphological pressures from dams/obstacles in rivers with various uses (including small HPPs) or no use. There were no specific methodologies applied previously for the RBMP in the countries concerning the economic evaluation of additional measures for such pressures and uses. A **multi-criteria analysis (MCA) approach** was proposed since it was seen appropriate for the analysed pressures and measures and also practically applicable taking into account available information and resources. It was also seen relevant that the used approach and prepared assessments would be transferrable to other areas providing possibility to use them in the countries for the RBMP overall (not only concerning the trans-boundary WBs).

The multi-criteria analysis (MCA) approach allows simultaneous assessment of various relevant impacts in one methodological framework, where the applied criteria cover all relevant impacts.

The MCA approach was applied to the following cases of WBs (pressures and water uses):

1. dams used by small HPPs creating hydro-morphological pressures,
2. obstacles/impoundments with other/no use creating hydro-morphological pressure,
3. lakes with accumulated past nutrient pollution in sediments.

Possible additional measures were assessed with the MCA on general scale without connecting them to concrete WBs[10]. This assessment aims to support general prioritisation of the measures and to provide detailed information on relevant impacts and range of their magnitude. This information was used afterwards to guide selection of additional measures for concrete WBs (failing GES), but such WB scale analysis and selection is out of the scope of this assessment.

Range of WBs fails GES in the Latvian part of the project area due to nutrient pollution from agriculture and forestry and hydro-morphological pressures from drainage for these activities. Since

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[10] Except for lakes where the assessment partly addresses the WB failing GES – the Burtnieku lake in the Latvian part of the project area (which is particular lake due its size and specific environmental conditions) and the Köstrejärv lake in the Estonian part of the project area. The developed assessments can be attributed to similar lakes overall, however estimation of costs of the measures required taking into account specific characteristics of a lake. Detailed approaches and assessments, as well as their transferability are explained in respective chapters of the report.

there is large number of possible additional measures to reduce these pressures, the evaluation of such measures should focus primarily on assessing their effectiveness and costs and finding the most cost-effective measures for achieving the environmental targets. Therefore the **cost-effectiveness analysis of measures was conducted in Latvia** to support development of measures for these pressures. Due to limitations of the study, the analysis was conducted based on an example of a selected WB G308 Jogla, which fails GES due to elevated phosphorus (P) load coming as diffuse pollution from agriculture (arable land). The evaluation results can be used also for other WBs failing GES due to elevated P load. The costs assessments for the analysed measures can be used also for the cost-effectiveness analysis of these measures in light of nutrient pollution reduction.

The next two sections provide detailed results on the evaluation of possible additional measures conducted as part of the project.

4 MULTI-CRITERIA ASSESSMENT OF ADDITIONAL MEASURES FOR DAMS, IMPOUNDMENTS AND LAKES

4.1 Water bodies failing GES due to the analysed pressures and water uses

Table 4.1 summarises information on the WBs failing GES due to the pressures and water uses included in the MCA. The program of measures for these WBs should include additional measures for achieving GES, and the MCA results could support their selection.

Table 4.1. WBs failing GES due to the pressures and water uses included in the MCA. *(Source: Results of pressure and status assessment prepared as part of the project.)*

Water uses and pressures causing failure of GES	WBs failing GES due to these water uses and pressures	
	in the Latvian part	in the Estonian part
dams used by small HPPs creating hydro-morphological pressures	3 WBs affected by 5 small HPPs creating significant pressure (G235 Vaidava_2 – Karvas HPP, Grūbes HPP; G317 Pedele_2 – Dzirnavnieku HPP, Kalndzirnavu HPP; G322 Briede_1 – Kārlīšu dzirnavu HPP)	1 WB Vaidva_2 (Vastse-Roosa HPP)
obstacles/impoundments with other/no use creating hydro-morphological pressure	3 WBs with 8 dams/obstacles creating significant pressure (G301, G306, G322)	4 WBs: Pärlijõgi_1 (Saarlase and Pärlijõe dams), Pedeli_2 (Pedeli IV, Pedeli III, Pedeli II and Pedeli I); Pärlijõgi_2 (Sänna Alaveski, Sänna Mäeveski, Ala-Raudsepa dams), Õhne_2 (Holdre Vanaveski and Taagepera dams).
lakes with accumulated past nutrient pollution in sediments	1 WB E225 Burtnieku lake	1 WB Köstrejärv 2133700_1

4.2 Additional measures included in the evaluation

The additional measures included in the assessment are listed in Table 4.2.[11] They have been identified based on knowledge of the project's experts. The main principles for identifying possible measures were that they address the pressure causing failure of GES and are technically feasible. The technical feasibility was considered based on experience in the project's countries with implementing such measures, information from existing studies in the countries, as well as literature (e.g. some measures for the lakes). All the measures are technically feasible in principle. However their application for concrete WBs needs further analysis taking into account local conditions and selecting appropriate technical solutions (e.g. type of fish pass). This will be considered in the next step of developing the program of measures – when analysing and selecting measures on the WB scale (for each concrete WB failing GES).

It should be noted concerning the measures for dams used by small HPPs that the measures M2 and M3 have very limited applicability in Latvia since they can be implemented only in cases with an existing fish pass. But such cases are rare in Latvia (only 1 dam with a small HPP has an existing fish pass out of 5 such cases creating significant pressure in the project area). Hence, the measures M1 and M4-M8 were the main alternatives for the evaluation.

Similar note applies also to Estonia where the measure M4 for dams used by small HPPs and other obstacles/impoundments has limited applicability since this can be implemented only in case where there is an existing fish pass, hence the main alternatives for the evaluation are M1-M3.

Table 4.2. The additional measures included in the evaluation with the MCA approach.

Similar measures analysed in both countries are marked with light green colour.

Additional measures analysed for Latvia	Additional measures analysed for Estonia
Additional measures for dams used by small HPPs for energy production creating hydro-morphological pressures	
M1 Building of a fish pass	M1 Building of a fish pass
M2 Reconstruction or improvement of an existing fish pass	M2 Demolishing a dam
M3 Maintenance of an existing fish pass	M3 Environmentally friendly turbine
M4 Environmentally friendly turbine	*M4 Improvement of an existing fish pass*
M5 Implementation of ecological flow	
M6 Demolishing a dam	
M7 Permanently lowering a dam	
M8 Opening migration way during spawning period	
Additional measures for obstacles/impoundments with other/no use creating hydro-morphological pressure	
M1 Building of a fish pass	M1 Building of a fish pass
M2 Demolishing a dam	M2 Opening migration way during spawning period
M3 Opening migration way during spawning period (if a dam with sluice)	M3 Demolishing a dam
	M4 Improvement of an existing fish pass
Additional measures for lakes with accumulated past nutrient pollution in sediments*	
M1 Sediment dredging	M1 Sediment dredging

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[11] Detailed description of each measure is provided in the results chapters.

Additional measures analysed for Latvia	Additional measures analysed for Estonia
M2 Removal of macrophytes	M2 Removal of macrophytes
M3 Immobilization of phosphorus using chemical treatment	M3 Biomanipulation
M4 Artificial aeration and mixing	M4 Complex methods (sediment dredging and macrophytes removal)
M5 Biomanipulation	
M6 Hypolimnetic withdrawal	
M7 Artificial floating wetlands	

* Note for Estonia: For all restoration options concerning lakes with accumulated nutrient pollution in sediments, proper limnological investigations should be conducted, especially on external and internal loading, buffer capacity of a lake to that loading, inventory of biota, evaluation of the main factors influencing functioning efficiency of a lake.

As can be seen from the table, there are differences between the countries concerning measures included in the analysis. Some measures were not considered in Estonia – detailed explanation for not including these measures is provided in chapter 4.7.2.

4.3 Evaluation approach

4.3.1 Assessment criteria, categories and scores

With the MCA approach measures are assessed applying criteria, which aim to cover relevant impacts of the measures. Criteria identified as relevant for the evaluation and applied in the assessment are listed in Table 4.3. They were identified taking into account:

- relevant policy principles/requirements for developing additional measures (e.g. the measures must be cost-effective requiring assessment of their effectiveness and costs) and
- other impacts of measures which are relevant for the measures of the analysed pressures and water uses (e.g. negative adverse environmental impacts, constraints of implementation of a measure).

Initially also socioeconomic (welfare) benefits from the environmental improvements were discussed as potential criterion. However, it was decided not to include it since it overlaps with the effectiveness criterion, and including both would create accounting twice the same impact.[12]

The assessments for the criteria are prepared using assessment categories. Table 4.3 provides the used categories and related scores. Summary assessment is calculated for each measure by summing up scores from the individual criteria. The summary scores of measures can be compared, and they can be used for prioritisation of measures. In general, the larger is the summary score, the higher is the priority.

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[12] The effectiveness of measures reflects environmental improvements achieved by a measure in environmental terms. The welfare benefits from environmental improvements measure the same in socioeconomic terms.

Table 4.3. List of criteria, assessment categories and related scores applied in the MCA of the additional measures.

Criteria	Assessment categories	Scores
1. Effectiveness of a measure	No effect	0
	Low effect	1
	Moderate effect	2
	High effect	3
2. Certainty of the Effectiveness assessment	-	0
	Low certainty	1
	Moderate certainty	2
	High certainty	3
3. Negative adverse environmental impacts from implementing a measure	High impact	0
	Moderate impact	1
	Low impacts	2
	No impact	3
4. Costs of a measure	-	0
	High costs	1
	Moderate costs	2
	Low costs	3
5. Constraints/obstacles of implementation of a measure (institutional, legal, financial)	High constraints	0
	Moderate constraints	1
	Low constraints	2
	No constraints	3

It is possible to assign different weights for each criterion. The larger the weight, the higher importance is attached to a particular criterion, and it changes the calculated summary scores for individual measures, hence, the prioritisation of the measures[13]. It was decided not to apply the weights since all the included criteria are seen of similar importance in the context of the measures for the analysed pressures and water uses. The exception is the effectiveness criterion which is assessed using specific approach (described in chapter 4.3.3), and the effectiveness score can be estimated in a way giving larger weight for this criterion when calculating the summary score. Impact of this estimation approach is tested as part of "sensitivity analysis" of the evaluation results, e.g. whether it impacts the prioritisation of the measures.

4.3.2 Assessment of effectiveness of the measures

Three criteria are included covering relevant environmental impacts of the measures: C1 Effectiveness of a measure, C2 Certainty of the Effectiveness assessment and C3 Negative adverse environmental impacts.

The effectiveness assessment (Criterion 1) evaluates whether and to what extent a measure improves the state and reduces the gap to GES (concerning each used state parameter). The used qualitative assessment categories and scores: 0 no effect, 1 Low, 2 Moderate, 3 High effectiveness.

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[13] Giving higher summary score (and priority) for the measures with better assessments for the criteria having larger weights.

The certainty of the effectiveness assessment (Criterion 2) shows confidence of the effectiveness assessment (that a measure would deliver the expected effect). The used qualitative assessment categories and scores: 1 Low, 2 Moderate, 3 High certainty of the effectiveness assessment.

The negative adverse environmental impacts (Criterion 3) cover any negative environmental side impacts on the WB or wider environment from implementing a measure. The used qualitative assessment categories and scores: 0 High, 1 Moderate, 2 Low or 3 No negative impact.

The assessments of measures for these criteria are developed based on expert opinion of the environmental experts of the project for each country.

4.3.3 Environmental state parameters used for assessing effectiveness of the measures

Even if the effectiveness is assessed qualitatively (with qualitative categories), it is important to define clear approach for its assessment. The effectiveness of the measures is assessed evaluating their capacity to deliver achievement of GES. Hence the same environmental state parameters that are used for the status assessment of WBs are relevant for measuring the effectiveness. The environmental state parameters that are used for assessing the effectiveness of the measures are provided in Table 4.4.

Table 4.4. Environmental state parameters used for assessing the effectiveness of the additional measures.

** Detailed information on applying these parameters for Estonian is provided in respective results chapter.*

Water uses and pressures causing failure of GES	Environmental state parameters used for assessing effectiveness of the measures	
	for Latvia	**for Estonia***
dams used by small HPPs for energy production creating hydro-morphological pressures	P1 Obstacle for fish migration, disruption of river continuity (as indicator under WFD). • Presence of obstacle for fish migrating (Yes/No). • Length (Km) of river or area (km2) of river catchment opened for fish migration. P2 Rapid Habitat areas (riverbed). Size of habitat areas (ha or m2, or m) with suitable (rapid) conditions (hydro-morphological conditions of the habitats). P3 Ecological flow (enough water in a river during different fish bio-periods).	P1 Obstacle for fish migration, disruption of river continuity (as indicator under WFD). Presence of obstacle for fish migrating (Yes/No). P2 Hydro-morphological quality of river. P3 Improvement of fish index. P4 Objectives of Habitats directive. Whether it improves the status or not.
obstacles/impoundments with other/no use creating hydro-morphological pressure	P1 Obstacle for fish migration, disruption of river continuity (as indicator under WFD). • Presence of obstacle for fish (Yes/No). • Improvement of fish index. • Length (Km) of river or area (km2) of river catchment opened for fish migration. P2 Habitat areas (riverbed). Size of habitat areas (ha or m2) with suitable conditions (hydro-morphological conditions of the habitats).	P1 Obstacle for fish migration, disruption of river continuity (as indicator under WFD). Presence of obstacle for fish (Yes/No). P2 Hydro-morphological quality of river. P3 Improvement of fish index. P4 Objectives of Habitats directive. Whether it improves the status or not.

Water uses and pressures causing failure of GES	Environmental state parameters used for assessing effectiveness of the measures	
	for Latvia	**for Estonia***
lakes with accumulated past nutrient pollution in sediments	P1 Phosphorus amount (concentration) in water	P1 Macrophytes. Improvement in macrophytes status. P2 Macroinvertebrates. Improvement in macroinvertebrates status. P3 Fish. Improvement in fish status.

There are some differences regarding these parameters used for the assessment in Latvia and Estonia. Concerning the dams used by small HPPs, in Estonia "Fish index" is used instead of "P3 Ecological flow" which is used in Latvia. In Latvia the calculated "Fish index" does not fully assess hydro-morphological alterations, but it is seen indicating eutrophication impact. Hence not used as parameter here. In Estonia the River Fish Index is calculated based on monitoring results, showing the status of fish fauna.

Another difference is that P4 related to objectives of the EU Habitat directive is considered in Estonia as a parameter for rivers. Objectives of WFD and Habitats directive are closely related. In Koiva river basin most of dams, where fish passage is needed, situate in rivers designated also as Natura 2000 areas. Therefore in Koiva river basin achieving objectives of the Habitats directive is also one parameter of the gap.

Different parameters are used for lake measures. Phosphorus amount is used in Latvia, while 3 parameters related to biotic elements are used in Estonia. More detailed explanation of the parameters used in Estonian are provided in respective results chapter.

The effectiveness assessment (assigning the category and score) is prepared for each state parameter separately. Where more than one parameter is used, the summary effectiveness score can be calculated in two ways – as an average score of all parameters' scores, or as a summary score by summing up individual scores of each parameter. The latter approach gives larger score for the effectiveness criterion increasing its importance when calculating the summary score of a measure. Illustration on the two approaches is provided in Table 4.5.

Table 4.5. Illustration on the effectiveness (Criterion 1) assessment and approaches for calculating the summary effectiveness score *(illustration for two measures applied in Latvia to dams used by small HPPs). (Source: Assessment by LEGMC.)*

The used qualitative assessment categories and scores: 0 no effect, 1 Low, 2 Moderate, 3 High effectiveness.

M1 Building of a fish pass	
C1 Effectiveness of a measure for …	Comments in relation to the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstacle for fish migration, disruption of river continuity	Yes for P1 - increases fish migration. Effectiveness is variable among different types of fish passes, it can range from low to high. *Assessment category and score:* ***moderate (2).***
P2 Habitat areas	Yes for P2 – increases accessible habitat areas. To increase the effect on rivers with multiple HPPs, construction of fish passes should start downstream. *Assessment category and score:* ***moderate (2).***
P3 Ecological flow	No / Partly for P3, depending on technical solution. A fish pass could be used to guarantee ecological flow, if e-flow is directed through the fish pass.

	Assessment category and score: ***no effect-low (0.5).***
Summary score	*Average score:* ***1.5*** *[(2+2+0.5)/3]* *Summary score:* ***4.5*** *[2+2+0.5]*
M6 Demolishing a dam	
C1 Effectiveness of a measure for …	Comments in relation to the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstacle for fish migration, disruption of river continuity	Yes for P1 - removes the obstacle, fully restores migration possibilities for fish. *Assessment category and score:* ***high (3)***
P2 Habitat areas	Yes for P2 - increases habitat areas by restoring natural river flow and continuity upstream and downstream. *Assessment category and score:* ***high (3)***
P3 Ecological flow	Yes for P3 – fully restores natural flow of river. *Assessment category and score:* ***high (3)***
Summary score	*Average score:* ***3*** *[(3+3+3)/3]* *Summary score:* ***9*** *[3+3+3]*

4.3.4 Assessment of costs of the measures

A measure can involve the following categories of the costs:

1. Direct financial costs of a measure (investment costs, yearly operation and maintenance costs, other direct costs),
2. "opportunity costs" (foregone/lost revenues) for an actor who implements a measure,
3. "induced costs" – costs due to implementing a measure to other actors than the one who implements the measure.

Assessment of the costs for each measure includes the following steps:

- identifying and describing relevant types of the costs (related to the categories above),
- developing quantitative estimates for each type of the costs,
- calculating total costs of a measure (as annualised costs per year),
- estimating financing need for the planning period 6 years (2022-2027) for implementing a measure,
- estimating costs as a share of a implementers' revenues/budget (%),
- performing sensitivity analysis of the calculated costs to incorporate variation and uncertainty in the costs' estimate,
- assigning the qualitative assessment category (high, moderate, low costs) based on the share of the costs in revenues/budget.

Total costs for each measure are estimated quantitatively[14]. To incorporate variation and uncertainty in the costs a "sensitivity analysis" is performed. Relevant input parameters (the ones impacting the calculated total costs most significantly) are identified and cost interval is calculated (with the range of values for the relevant input parameters).

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[14] The described approach is applied to additional measures for dams/obstacles. Concerning measures for lakes, the quantitative estimates were developed for part of measures only.

For the measures applied to small HPPs, the costs are estimated as a share of yearly revenues of a HPP. It should be noted that the small HPPs differ significantly in terms of produced electrical energy amounts and, thus, their revenues.

For Latvia, three cases are used for this assessment – a HPP with the lowest and highest energy production/revenues and an "average" HPP (average revenues calculated from all 5 HPPs in the project area creating significant pressures).[15] Hence these three cases can be seen representing variety of the cases of the HPPs.

For Estonia, the only HPP Vastse-Roosa which is in the project area hasn´t been working lately due to dam reconstruction issues and therefore there are no data on production. Hence a hypothetical HPP with the same size and other parameters is used to show how much energy could be produced in ideal conditions (max flow rate, no technical problems). On average small HPP is earning 22500 EUR revenues per year.

For other measures, different approaches are used in the countries. In Latvia the costs are estimated as a share of yearly municipal budget16. It should be noted that counties differ significantly in terms of budget size. Three cases are used for this assessment – a county with the lowest and largest yearly budget, as well as calculated average budget (an average from all counties) in the project area. Hence these three cases can be seen representing variety of the cases of the counties. In Estonia the costs are estimated as a share of an average yearly budget of the Environmental Investments Centre's (EIC) water management programme (total budget for 2016-2019 was 57.51 million EUR, yearly average 19.17 million EUR).

The costs are classified as low/moderate/high costs according to an approach as presented in the Tables 4.6 and 4.7. In this way the costs are linked to financial capacity of actors to implement a measure (called also as "affordability" of the costs).

The percentage thresholds for "high" costs were set based on expert opinion of the project's experts, taking into account also practice in other EU countries[17] and similar national assessments to support implementation of the marine protection policy in Latvia.

Table 4.6. Interpretation of the qualitative costs' categories (and scores) for measures applied to small HPPs.

Costs' category	Interpretation of the category	Costs as a share (%) of yearly HPP revenues
Low (3)	The costs are affordable, an actor could cover the costs with own funding.	< 1 % of revenues
Moderate (2)	The costs are hardly affordable, some public financial support would be recommended to facilitate implementation of a measure.	1-1.5 % of revenues
High (1)	The costs are not affordable, public funding would be needed for financing implementation of a measure.	> 1.5 % of revenues

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[15] Data on revenues of small HPPs in the project area are presented in chapter 1.3.1 of the report. 5 HPPs create significant pressures in the Latvian part of the project area (out of 10 small HPPs in total). Data for these HPPs are used for this assessment.

[16] County scale data are used including all counties in the Latvian part of the project area. Also budget of the Burtnieku county is used for the lake measures.

[17] European Commission (2014) *"Addressing affordability concerns in WFD implementation. Resource document for the WG Economics."* Version from October 2014.

Table 4.7. Interpretation of the qualitative costs' categories (and scores) for other measures.

* For Latvia: the costs as a share of a yearly municipal budget. For Estonia: the costs as a share of a yearly EIC budget of water programme.

Costs' category	Interpretation of the category	Costs as a share (%) of yearly budget*
Low (3)	The costs are affordable, an actor could cover the costs with own funding.	< 0.5 % of a budget
Moderate (2)	The costs are hardly affordable, some public financial support would be recommended to facilitate implementation of a measure.	0.5-1 % of a budget
High (1)	The costs are not affordable, public funding would be needed for financing implementation of a measure.	> 1 % of a budget

Direct financial costs

The direct financial costs can include the following types of the costs:

- Investment costs – discounted over lifetime to calculate the yearly costs.
- One-off costs (technical feasibility studies) – either discounted together with related investment costs or divided by 6 years (planning cycle) to calculate the costs per year.
- Yearly operation and maintenance costs, personnel costs (e.g. for HPPs M8).
- Other direct costs (monitoring costs) – total costs are divided by 6 years (planning cycle) to calculate the costs per year.

"Opportunity costs"

The "opportunity costs" are foregone revenues of lost future opportunities if implementation of a measure creates such impact (for an actor who implements the measure).

For the analysed measures they are relevant for some measures applied to small HPPs – when implementation of a measure reduces amount of electrical energy that is produced in a HPP creating lost revenues in the future.

Table 4.8 and 4.9 presents the assessments of lost production due to implementing the analysed measures for Latvia and Estonia respectively. These assessments are taken into account when estimating the costs of the measures.

For Latvia, the data on yearly revenues of the HPPs[18] creating significant pressures in the project area are used to calculate the "opportunity costs" of each measure (applying the percentage shares of lost production provided in the last column of Table 4.8). The intervals of the percentage share of lost production are used to estimate range of the "opportunity costs" (considered latter in the "sensitivity analysis"). A specific approach is used to estimate the "opportunity costs" for the measure *M6 Demolishing a dam*. Using a "minimum approach" the opportunity costs are calculated assuming compensation for value of private properties based on the official cadastral value.[19] Using a "maximum approach" the opportunity costs are calculated assuming compensation for foregone

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[18] Data on the yearly revenues are presented in chapter 1.3.1 of the report. Average revenues per HPP from all 5 HPPs creating significant pressures were calculated (around 90 000 EUR on average per one HPP per year). In addition, data for the energy production and revenues by months (from the same data source and for the same HPPs) were used to calculate the revenues in the fish spawning period (relevant for M1, M8).

[19] Data on the cadastral value of the properties related to the dams/impoundments creating significant pressures are used for the cost estimates.

revenues for 10 years of possible economic activity (electrical energy production in a small HPP is assumed as possible activity).[20]

For Estonia the “opportunity costs” are estimated using data for the hypothetical HPP, and calculating yearly foregone revenues according to the share of lost production (presented in the last column of Table 4.9). For the measure *M2 Demolishing a dam* the “opportunity costs” are calculated accounting revenues of a one year (as the foregone revenues).

Table 4.8. Assessment for LATVIA on foregone (lost) production for HPPs due to reduced electrical energy production from implementing the analysed measures. *(Source: Assessment of the project’s experts, taking into account also available information from literature.)*

Possible additional measures included in the analysis	**Whether the measure cause reduction in the electrical energy production** (Yes/No; for what period)	**Share (%) of lost production** (assumed also for lost revenues)
M1 Building of a fish pass	YES, in the fish spawning period (spring, autumn – 6 months)	5 %
M2 Reconstruction or improvement of an existing fish pass	NO	-
M3 Maintenance of an existing fish pass	NO	-
M4 Environmentally friendly turbine	NO (although efficiency of such turbines is lower, but they can be operated longer time during a year for production of energy, also in lower water periods)	0 %
M5 Implementation of ecological flow	YES, for a whole year, if old turbines are used which can produce energy with certain water flow rate only. NO for modern turbines which can produce energy with varying water flow rate.	5-10 % 0 %
M6 Demolishing a dam	YES, production is lost fully.	100 %
M7 Permanently lowering a dam	YES, for a whole year	10-15 % (or even more)
M8 Opening migration way during spawning period	YES, in the fish spawning period (spring, autumn – 6 months)	5-10 % (or even more)

Table 4.9. Assessment for ESTONIA on foregone (lost) production for HPPs due to reduced electrical energy production from implementing the analysed measures. *(Source: Assessment of the Estonia project’s experts.)*

Possible additional measures included in the analysis	**Whether the measure cause reduction in the electrical energy production** (Yes/No; for what period)	**Share (%) of lost production** (assumed also for lost revenues)
M1 Building of a fish pass	Yes, for whole year	10 %
M2 Demolishing a dam	Yes	100 %
M3 Changing turbines for environmentally friendly turbines	No	0 %
M4 Improvement of an existing fish pass	No	-

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[20] Data on revenues of the small HPPs creating significant pressures are used (the lowest revenues 9800, the highest revenues 243 000 EUR per year).

“Induced costs”

“Induced costs” result from negative impacts due to implementing a measure to other actors than the one who implements the measure.

The analysed measures for dams/obstacles may create negative impacts on up-stream/down-stream uses, hence create the “induced costs” for these users. The potential impacts due to these measures are characterised in Tables 4.10 and 4.11 for Latvia and Estonia respectively.

For Latvia the impacts were identified based on analysing such users in the 5 WBs failing GES due to dams/obstacles[21] and expert opinion (of the Latvian project experts) on how these users can potentially be impacted. The analysis shows that the “induced costs” could be created due to some analysed measures for the dams (see the measures M6-M8 in Table 4.10). Due to limitations of the study quantitative information could not be collected, thus the “induced costs” were not estimated. They are considered in a qualitative way when analysing total costs of the measures.

Table 4.10. Assessment for LATVIA on potential negative impacts on up/down-stream users due to implementing the analysed measures for dams. *(Source: Assessment by the Latvian project experts, based on analysis of information about such users in the WBs failing GES due to dams/obstacles in the Latvian part of the project area.)*

Note. The assessment is provided concerning the analysed measures applicable to small HPPs. The same applies also for the analysed measures for other obstacles (see the Latvian measures M1-M3 in chapter 4.1).

Up/down-stream users **Measures**	**Fish farming***	**Recreational angling**	**Water related recreation (e.g. swimming)**	**Road over a dam**
M1 Building of a fish pass	(No impact)	(No impact)	(No impact)	(No impact)
M2 Reconstruction or improvement of an existing fish pass	(No impact)	(No impact)	(No impact)	(No impact)
M3 Maintenance of an existing fish pass	(No impact)	(No impact)	(No impact)	(No impact)
M4 Environmentally friendly turbine	(No impact)	(No impact)	(No impact)	(No impact)
M5 Implementation of ecological flow	(No impact)	(No impact)	(No impact)	(No impact)
M6 Demolishing a dam	X (due to eliminating impoundment)	X (due to eliminating impoundment)	X (due to eliminating impoundment)	X (costs for strengthening construction of the road or building a bridge
M7 Permanently lowering the dam	(No impact)	X (due to decreasing impoundment)	X (due to decreasing impoundment)	(No impact)
M8 Opening migration way during spawning period	(No impact)	X (due to decreasing impoundment)	(No impact**)	(No impact)

* Fish farming commonly takes place below a dam (not using the impoundment). ** Swimming is not assumed in the spawning period (spring, autumn).

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[21] Available information from public sources was collected for each WB on the potentially affected users, including: the users deriving benefits from use of a dam; the users up/down-stream a dam, related to impoundment above a dam or in close vicinity; whether there are officially registered real estates related to a dam/impoundment or its use, their official cadastral value; whether there are roads above/close which could be impacted (e.g. in case of demolishing a dam).

Table 4.11. Assessment for ESTONIA on potential negative impacts on up/down-stream users due to implementing the analysed measures for dams. *(Source: Assessment by the Estonia project experts.)*

Note. The assessment is provided concerning the analysed measures applicable to small HPPs. Impact is almost the same for other obstacles' measures.

Up/down-stream users **Measures**	**Fish farming***	**Recreational angling**	**Water related recreation (e.g. swimming)**	**Road over dam**
M1 Building of a fish pass	X (due to water abstraction for fish farming)	(No impact)	(No impact)	X (fish pass needs to cross the road, costs for building a small tunnel)
M2 Demolishing a dam	X (due to eliminating impoundment)	(No impact)	X (due to eliminating impoundment)	X (costs for strengthening construction of the road or building a bridge)**
M3 Environmentally friendly turbines	(No impact)	(No impact)	(No impact)	(No impact)
M4 Improvement of an existing fish pass	(No impact)	(No impact)	(No impact)	(No impact)

* Fish farming in Estonia commonly takes place upstream the dam using self-flowing water from the impoundment. When fish pass is built, there will be an issue of how to ensure enough water to fish farm and fish pass in low water level periods.

** If a dam is regularly opened and closed or demolished, there may be a need to strengthen the road constructions or to build a bridge.

For Latvia, the "induced costs" may result also from the analysed measures for lakes, but it depends on use of a lake (e.g. whether there is commercial fishing and recreational angling in a lake). Two measures (*M2 Removal of macrophytes* and *M7 Artificial floating wetlands*) are not expected to create such costs. If there is commercial fisheries and recreational angling in a lake (like it is important in the Burtnieku lake) the measure *M5 Biomanipulation* may create "induced costs" in the short-run due to restriction for fishing predatory fish species, which commonly make the largest part of catch[22]. However, in the long run these costs could decrease or be minimised if fishermen switch to fishing other species and markets are created for using "less valuable" fish species. Moreover, economic benefits could accrue in the long-run from improved state and productivity of a lake. Also other measures for lakes may create some negative impacts and "induced costs" (depending on whether there are users) due to their negative adverse environmental impacts on a lake ecosystem, although these negative impacts are assumed to be temporal. Due to limitations of the study the "induced costs" related to the analysed measures for lakes could not be estimated, but are considered only in a qualitative way when analysing total costs of the measures.

4.3.5 Assessment of constraints/obstacles of implementation of the measures

The following types of the constraints/obstacles of implementation were identified as potentially relevant for the analysed measures:

- Institutional, for instance, acceptance by actors who should implement a measure, by other affected society groups; complexity/procedures for coordination of the implementation.

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[22] Creating, for instance, foregone revenues for commercial fisheries, lost welfare from recreational angling, lost income from fishing licenses.

- Legal, for instance, impact on an official cultural heritage site or Natura 2000 site[23]; impact on private properties requiring financial compensation of the damage; mandatory regulatory procedures (e.g. permit, Environmental Impact Assessment); lack of mandatory regulatory requirements (as incentives) for implementing a measure.
- Financial, for instance, lack of public financial support instruments (if necessary due to high costs of a measure).

Relevant types of the constraints/obstacles were identified for each analysed measure and the assessments using the qualitative categories (and scores) were prepared based on expert opinion of the project's experts.

4.3.6 "Sensitivity analysis" of the evaluation results

The "sensitivity analysis" aims to incorporate uncertainties in an assessment results. It can be applied to indicate whether the relevant "output" (e.g. scores of measures, their prioritisation) changes significantly when accounting uncertainty in the input assumptions, estimates and assessments.

There are two main reasons for the uncertainties in the given results:

1. methodological uncertainties,
2. assessment uncertainties.

The methodological uncertainty is related to the MCA approach and the included criteria (e.g. what criteria are included, what scoring system is used). This uncertainty is addressed by calculating summary scores of the measures when (I) excluding/including separate criteria (e.g. certainty of the effectiveness assessment, adverse environmental impacts, constraints); (II) calculating Average versus Sum score of the state parameters for the effectiveness assessments. All the assessment results are described in details ensuring transparency and possibility to use and develop this background information further when analysing and selecting measures for concrete WBs.

The assessment uncertainties are particularly relevant for the effectiveness and cost assessments. The effectiveness assessment rely on an expert judgement however it was based on best available knowledge from existing studies, literature and experience with implementing measures in the project countries. The cost estimates incorporates the uncertainty by developing cost intervals (instead of point estimates) covering possible variations and uncertainties in the costs. Cases where the costs are close to the "high" cost threshold are carefully analysed and indicated in the results.

4.4 Detailed results for Latvia on the evaluation of the measures for dams used by small HPPs creating hydro-morphological pressures

4.4.1 Environmental impacts of the measures (Criterion 1-3)

Table 4.12 summarises the assessments concerning the environmental impacts of the measures covered by the Criteria 1-3. Detailed results on the assessments for the Criteria 1 and 3 are provided in chapter 4.4.5.

Since the effectiveness is assessed against three state parameters the summary effectiveness score can be calculated as an average or sum of the parameters' scores. Both estimates are provided in the table (see the columns "Average" and "Sum").

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[23] There are no such sites in the WBs failing GES due to dams/obstacles in the Latvian part of the project area.

Table 4.12. The prepared assessments for the environmental impacts (Criteria 1-3) of the analysed additional measures for dams used by small HPPs creating hydro-morphological pressures. *(Source: An assessment by the project's experts (LEGMC).)*

The used assessment categories and corresponding scores:

C1 Effectiveness of a measure: 0 no effect, 1 Low, 2 Moderate, 3 High effectiveness.

C2 Certainty of the Effectiveness assessment: 1 Low, 2 Moderate, 3 High certainty.

C3 Negative adverse environmental impacts from implementing a measure: 0 High, 1 Moderate, 2 Low, 3 No negative impact.

State parameters for the Effectiveness assessment: P1 Obstacle for fish migration, disruption of river continuity; P2 Habitat areas; P3 Ecological flow.

The analysed additional measures	**C1 Effectiveness of a measure**					**C2 Certainty**	**C3 Negative impact**
	P1	**P2**	**P3**	**Average**	**Sum**		
M1 Building of a fish pass	2	2	0.5	**1.5**	**4.5**	Moderate (2)	Moderate (1)
M2 Reconstruction or improvement of an existing fish pass	*2*	*2*	*0.5*	***1.5***	***4.5***	*Moderate (2)*	*Moderate (1)*
M3 Maintenance of an existing fish pass	*2*	*2*	*0.5*	***1.5***	***4.5***	*Moderate (2)*	*No impact (3)*
M4 Environmentally friendly turbine	1	0	0.5	**0.5**	**1.5**	Moderate-High (2.5)	No impact (3)
M5 Implementation of ecological flow	1	2	3	**2**	**6**	Moderate (2)	No impact (3)
M6 Demolishing a dam	3	3	3	**3**	**9**	High (3)	Moderate-High (0.5)
M7 Permanently lowering a dam	1	0.5	0.5	**0.67**	**2**	Low-Moderate (1.5)	Low-Moderate (1.5)
M8 Opening migration way during spawning period	1.5	1	0.5	**1**	**3**	Low-Moderate (1.5)	Moderate (1)

The highest effectiveness assessment is for the measure *M6 Demolishing a dam*. It is rather low for the measures M4, M7 and M8. An operational fish pass would provide *Low* to *Moderate* effect.

High certainty of the effectiveness assessment is for the *M6 Demolishing a dam*, quite high also for *M4 Environmentally friendly turbine*. Certainty is assessed *Moderate* for all measures related to fish passes (M1-M3). It is rather low for the measures M7 and M8.

Concerning the possible negative environmental impacts, they are expected rather high from demolishing a dam, however such impacts would be temporal. No negative adverse impact is assessed for environmentally friendly turbines and ecological flow implementation.

Applicability of the measures M2 and M3 is limited to dams with existing fish passes hence in most cases they would not provide solution for achieving GES. The only measure which fully eliminates the problem for all state parameters is the measures *M6 Demolishing a dam*, it has also high certainty of the effectiveness assessment, and the negative environmental effect is expected to be temporal. Other measures give positive effect concerning part of state parameters only. If all state parameters are relevant for WBs failing GES, a set of the measures would be necessary to ensure achievement of GES (for instance, a fish pass and ecological flow implementation).

4.4.2 Costs of the measures

Table 4.13 summarises the assessments concerning the costs of the measures (Criterion 4). The costs were estimated quantitatively for each measure, and they were compared to yearly revenues of small HPPs to assign the qualitative assessment category and score (according to the approach described in chapter 4.3.4). Detailed results on the quantitative cost estimates are provided in chapter 4.4.5. The costs are considered as "high" if they exceed 1.5 % of yearly revenues of a HPP. Only for the measure *M6 Demolishing a dam* the costs are compared to a yearly municipal budget, and they are "high" if they exceed 1 % of the budget.

To account possible variations in the costs and uncertainty, the cost estimates are developed as intervals (see the second column in the table). The lower and upper bounds of the intervals are calculated based on possible cost range for input estimates (for instance, possible range of the investment costs, opportunity costs). Hence also the qualitative assessment categories can form intervals (see the third column in the table). Another reason for the intervals of the categories is related to differences in size of HPP yearly production and revenues – they differ considerably and can create different assessment categories for "low", "average" and "high" revenue HPPs.[24] For instance, the same costs can be "low" for a HPP with the largest revenues and "high" for a HPP with the lowest revenues. The same applies also to the yearly municipal budgets – they differ considerably.[25]

Table 4.13. The prepared assessments for the costs (Criterion 4) of the analysed additional measures for dams used by small HPPs creating hydro-morphological pressures. *(Source: Estimates prepared as part of the project.)*

The used assessment categories and corresponding scores: High 1, Moderate 2, Low 3 costs.

The analysed additional measures	Annualised costs per year	Assessment categories and scores
M1 Building of a fish pass	**10 000 – 30 000 EUR/y**	**High (1)**
M2 Reconstruction or improvement of an existing fish pass	***5000 – 13 500 EUR/y***	***High (1)*** *(Moderate (2) only for Highest production (revenue) HPP when excluding (public) monitoring costs.)*
M3 Maintenance of an existing fish pass	***3000-3500 EUR/y***	***Moderate-High (1.5)*** *(Low-High (2) when excluding (public) monitoring costs depending on revenue size of a HPP.)*
M4 Environmentally friendly turbine	**3000 – 15 000 EUR/y**	**High (1)** (Moderate-High (1.5) when excluding (public) monitoring costs depending on production (revenue) size of a HPP.)
M5 Implementation of ecological flow	**2500 – 11 500 EUR/y**	**Moderate-High (1.5)** (Low-High (2) when excluding (public) monitoring costs and whether there are the opportunity costs depending on production (revenue) size of a HPP.)
M6 Demolishing a dam	**MIN Opportunity costs: 4 500 – 25 000 EUR/y** **MAX Opportunity costs: 8 000 – 155 000 EUR/y**	**Low-High (2)** Based on MIN Opportunity costs (compensating cadastral value) – **Low costs (3)** for all cases, except for Lowest budget county with Upper bound of the costs. Based on MAX Opportunity costs (compensating

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[24] Data on yearly revenues for 5 HPPs creating significant pressures in the project area are used. The revenues range from 10 000 to 240 000 EUR per year. The "average" production (revenues) is calculated as an average from these 5 HPPs.

[25] Data on yearly budgets of all counties in the project area are used. The budgets range from 2.5 to 31 million EUR per year.

		foregone revenues from energy production) – **Low-High costs (2)** depending on size of the opportunity costs. Note. The costs are discounted over 50-100 years; Induced costs are not estimated.
M7 Permanently lowering a dam	**13 000 – 25 000 EUR/y**	**High (1)** (The same category for all size HPPs also when excluding public (monitoring) costs.)
M8 Opening migration way during spawning period	**7000-9000 EUR/y**	**High (1)** (The same category for all size HPPs also when excluding public (monitoring) costs.)

M6 Demolishing a dam is the only measures which could have "low" costs. If the opportunity costs are estimated based on compensating cadastral value of properties, the costs are "low" practically for all size counties (even with the upper bound of the financial costs). If the opportunity costs are estimated based on compensating foregone revenues from energy production, the costs are "low" for all size counties with the lower bound of the costs (assuming low revenue HPP). But they could be "high" in most cases with the upper bound of the costs (assuming high revenue HPP). But it should be noted that the costs are spread over 100 years (assumed lifetime of the effect of the measure[26]), and that the costs estimate do not include induced costs.

Concerning the measures applicable to HPPs, the results show that most measures have "high" costs for all sizes of the HPPs (M1, M4, M7, M8).

For the lowest revenue HPP none of the measures is affordable, costs exceed the "high" cost threshold considerably.

For the highest revenue HPP the costs are "moderate" for *M4 Environmentally friendly turbine* with the lower bound of the costs, and they become "low" when excluding (public) monitoring costs. With the upper bound of the costs they are "high" also when the monitoring costs are excluded. Quite similar situation can be seen concerning *M5 Implementation of ecological flow* – the costs are "moderate" with the lower bound of the costs, and they become "low" when excluding (public) monitoring costs. With the upper bound of the costs they are "high" also when the monitoring costs are excluded. Overall, these two measures could be affordable for high revenue HPPs depending on actual size of the costs (needs to be estimated for each concrete case).

The measures M2 and M3 can be applied only in cases with an existing fish pass (there is only one such case in the project area in the WBs failing GES due to operation of HPPs). These measures could be affordable for high revenue HPP. For M2 the same conclusion as for M4 and M5 applies. Concerning *M3 Maintenance of an existing fish pass* – it has "moderate" costs for high revenue HPP (high costs for other). When (public) monitoring costs are excluded the costs are "low" for highest revenue HPP and "high" for the lowest revenue HPP.

It can be concluded overall:

- For small size HPP public financial support would be needed for implementing any of the measures. Or it could be more cost-effective to stop operation of such HPP and to demolish a dam.
- Demolishing a dam could be low cost option if the opportunity costs need to be compensated based on cadastral value of properties. It could still be affordable if compensating foregone revenues from electrical energy production assuming low-moderate compensation. The costs become high if large production value would need to be compensated (e.g. if there is a small HPP with large production).

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[26] The cost estimates do not change significantly also if 50 year lifetime is used.

- For moderate size and, in particular, large size small HPPs affordability of the costs depends on actual costs of the measures and size of HPP (production and revenues) in each concrete case. Results of this assessment can be used to develop estimates for each concrete case when elaborating the program of measures on WB scale.

4.4.3 Constraints/obstacles of implementation

Table 4.14 summarises the assessments concerning the constraints/obstacles of implementation of the measures (Criterion 5). The constraints are assessed as "high" for the measures M1, M6-M8. "Moderate" assessment category is assigned to the measure M4, Low-Moderate for M5.

Table 4.14. The prepared assessments for the constraints/obstacles of implementation (Criterion 5) of the analysed additional measures for dams used by small HPPs creating hydro-morphological pressures. *(Source: An assessment by the project's experts.)*

The used assessment categories and corresponding scores: High 0, Moderate 1, Low 2, No 3 constraints/obstacles.

The analysed additional measures	Description of possible constraints/obstacles and assessment categories and scores
M1 Building of a fish pass	Institutional: Acceptability from HPP owners. Procedures for inclusion of the measure in permit. Legal: No specific constraints. Lack of legal incentives (requirements) for implementing the measure. Financial: Lack of public support financing instruments (in light of high costs). **High (0)**
M2 Reconstruction or improvement of an existing fish pass	*Institutional: Acceptability from HPP owners. Procedures for inclusion of the measure in permit.* *Legal: No specific constraints. Lack of legal incentives (requirements) for implementing the measure.* *Financial: Lack of public support financing instruments (in light of considerable costs).* ***Moderate (1)***
M3 Maintenance of an existing fish pass	*Institutional: Acceptability from HPP owners (when not included in the permit).* *Legal: No specific constraints.* *Financial: No considerable constraints.* ***Low/No (2.5)***
M4 Environmentally friendly turbine	Institutional: Acceptability from HPP owners. Procedures for inclusion of the measure in permit. Legal: No specific constraints. Financial: Lack of public support financing instruments (in light of considerable costs). **Moderate (1)**
M5 Implementation of ecological flow	Institutional: Acceptability from HPP owners. Estimation of ecological flow, changes in permits. Legal: No specific constraints. Lack of legal incentives (requirements) for implementing the measure. Financial: Lack of financing for e-flow estimation. **Low-Moderate (1.5)**
M6 Demolishing a dam	Institutional: Acceptability from HPP owners, other users. Legal: Compensating private properties. Financial: Lack of public financing instruments (in light of costs and possible need for compensations). **High (0)**
M7 Permanently lowering a dam	Institutional: Acceptability from HPP owners, other (up-stream) users. Procedures for inclusion of the measure in permit. Legal: No specific constraints Financial: Lack of public support financing instruments (in light of considerable costs).

	High (0)
M8 Opening migration way during spawning period	Institutional: Acceptability from HPP owners, other users. Legal: No specific constraints. Lack of legal incentives (requirements) for implementing the measure. Financial: Lack of public support financing instruments (in light of considerable costs). **High (0)**

4.4.4 Summary assessment

Table 4.15 provides summary assessment for the analysed measures for dams used by small HPPs creating hydro-morphological pressures. Table 4.16 provides the summary assessment when considering only the effectiveness and costs (cost-effectiveness assessment) and excluding other criteria.

The measures M2 and M3 are treated separately because of the limited applicability (limited such cases in Latvia) hence in most cases they would not provide solution for achieving GES. Other measures are ordered in the tables starting with the measure with the highest summary score. However this ordering should not be taken as strict ranking because the assessment approach is rather rough to be used for strict ranking.

Table 4.15. Summary assessments for the analysed additional measures for dams used by small HPPs creating hydro-morphological pressures. *(Source: Assessments prepared as part of the project.)*

[1] Using Average of all parameters' scores for the Effectiveness assessment. [2] Using Sum of all parameters' scores for the Effectiveness assessment.

The analysed additional measures	C1 Effect AVER[1]	C1 Effect SUM[2]	C2 Certainty	C3 Negative impact	C4 Costs	C5 Constraints	Total (AverEffec) [1]	Total (SumEffec) [2]
M5 Implementation of ecological flow	2	6	Moderate (2)	No impact (3)	Moderate-High (1.5)	Low-Moderate (1.5)	**10.0**	**14.0**
M6 Demolishing a dam	3	9	High (3)	Moderate-High (0.5)	Low-High (2)	High (0)	**8.5**	**14.5**
M4 Environmentally friendly turbine	0.5	1.5	Moderate-High (2.5)	No impact (3)	High (1)	Moderate (1)	**8.0**	**9.0**
M1 Building of a fish pass	1.5	4.5	Moderate (2)	Moderate (1)	High (1)	High (0)	**5.5**	**8.5**
M7 Permanently lowering a dam	0.67	2	Low-Moderate (1.5)	Low-Moderate (1.5)	High (1)	High (0)	**4.7**	**6.0**
M8 Opening migration way during spawning period	1	3	Low-Moderate (1.5)	Moderate (1)	High (1)	High (0)	**4.5**	**6.5**
M3 Maintenance of an existing fish pass	*1.5*	*4.5*	*Moderate (2)*	*No impact (3)*	*Moderate-High (1.5)*	*Low/No (2.5)*	**10.5**	**13.5**
M2 Reconstruction or improvement of an existing fish pass	*1.5*	*4.5*	*Moderate (2)*	*Moderate (1)*	*High (1)*	*Moderate (1)*	**6.5**	**9.5**

Table 4.16. Summary assessment of the analysed measures when considering only the effectiveness and costs (cost-effectiveness analysis) and excluding other criteria.

[1] Using Average of all parameters' scores for the Effectiveness assessment. [2] Using Sum of all parameters' scores for the Effectiveness assessment.

The analysed additional measures	Total (AverEffec) [1]	Total (SumEffec) [2]
M6 Demolishing a dam	**5.0**	**11.0**
M5 Implementation of ecological flow	**3.5**	**7.5**
M1 Building of a fish pass	**2.5**	**5.5**
M8 Opening migration way during spawning period	**2.0**	**4.0**
M7 Permanently lowering a dam	**1.7**	**3.0**
M4 Environmentally friendly turbine	**1.5**	**2.5**
M3 Maintenance of an existing fish pass	**3.0**	**6.0**
M2 Reconstruction or improvement of an existing fish pass	**2.5**	**5.5**

The measures M7 and M8 are not proposed further as options due to their low effectiveness, uncertainty in the effectiveness assessment and high costs. Possible options include the measures M1, M4, M5, M6.

When using Sum versus Average of all parameters' scores for the Effectiveness assessment, it does not change the prioritisation overall. It gives higher score only for the measure *M6 Demolishing a dam*, since this measure ensures "high" effect for all state parameters.

The summary assessment and prioritisation change when considering only the effectiveness and costs (cost-effectiveness assessment) and excluding other criteria. It gives the highest priority for *M6 Demolishing a dam*, since the cost-effectiveness assessment does not consider adverse environmental impacts and constraints (which are high for this measure). The cost-effectiveness assessment reduces substantially the priority for *M4 Environmentally friendly turbine* due to its very low effectiveness.

The only measure which fully eliminates the problem for all state parameters is the measures *M6 Demolishing a dam*, it has also high certainty of the effectiveness assessment, and the negative environmental effect is expected to be temporal. Other measures give positive effect concerning part of state parameters only. If all state parameters are relevant for WBs failing GES and a dam removal is not a suitable option, a set of the measures would be necessary to ensure achievement of GES (for instance, a fish pass and ecological flow implementation). This would increase the costs, hence public financial support could be necessary even for small HPP with relatively large production.

For small size (revenue) HPP public financial support would be needed for implementing any of the measures. Hence it would be more sustainable to stop the operation of such HPP and to demolish a dam. Demolishing a dam could be low cost option if the opportunity costs need to be compensated based on cadastral value of properties. It could still be affordable if compensating foregone revenues from electrical energy production assuming low-moderate compensation. The costs become high if large production value would need to be compensated (e.g. if there is a small HPP with large production).

It can be concluded overall that removing a dam is the highest priority option where it is suitable and no large energy production is involved/possible. Where it is the case other measures must be considered, but a set of measures could be needed to ensure achievement of GES.

For moderate and large size small HPPs affordability of the costs depends on actual costs of the measures and size of a HPP (production and revenues) in each concrete case. Estimates for each concrete case should be developed when elaborating the program of measures on WB scale.

All the collected information and detailed assessments can be used and developed further when analysing and selecting measures for concrete WBs.

4.4.5 Detailed results for each measure

In this chapter detailed results are included concerning (I) descriptions of the measures; (II) assessments of the effectiveness and negative adverse environmental impacts (Criteria 1 and 3) and (III) quantitative cost estimates.

Descriptions of the measures

1. **Building of a fish pass**: Technical measure with an aim to construct an alternative way for migration of fish on rivers affected by dams or other obstacles. Case specific requirements for each fish pass should be established, depending on fish species of concern and specifics of river, as well as local specifics – availability of space, geology, etc. There are two main types of fish passes - natural type and technical type. Natural type fish passes require more space, as they mimic the river (artificial river bed is created). Technical type fish passes can require less space.

   Natural-type fish passes:

   1) rapid or ritral bypass channels and fish passes in the river channel with low slope (≤2%);
   2) pond type fish passes (pond cascades) with low slope (≤3,5%);
   3) rapid and pond cascades with higher slope (≤5%).
   Technical type fish passes:

   4) vertical slot fish passes;
   5) pool type fish ladders with surface and bottom openings;
   6) pool type fish ladders with bottom openings;
   7) pool type fish ladders with surface openings;
   8) denil fish passes (baffle fish ways);
   9) pool type fish ladders without openings;
   Problems can be present with both upstream and downstream migration of fish, in that case construction of two fish passes could be necessary to resolve both problems. Best available technological solutions must be applied based on scientific studies about fish pass efficiency rate. The measure also includes further maintenance of the fish pass in good working conditions (see the option 3).

2. **Reconstruction or improvement of an existing fish pass**: Technical measure with the aim to ensure the existing fish pass is in working conditions. The measure includes evaluation of fish pass suitability for the specifics of river, reconstruction or repair of fish pass using best available technological solutions. It includes also further maintenance of the fish pass in good working conditions (see the option 3).

3. **Maintenance of an existing fish pass**: Technical measure which aims to prevent obstruction of fish pass and ensure maintenance of all its parts in good working condition. It includes also on-going evaluation of fish pass efficiency (fish monitoring every year for 3 years period). For natural types of fish passes, to ensure sufficient water discharge and water depth (river specific) as well as prevention of effects of eutrophication, the measure includes clearing away excess vegetation, as well as in case of necessity – addition of substrate (e.g. stones).

   Note that this measure is needed for all fish passes (both new and reconstructed).

4. **Environmentally friendly turbine:** Technical measure that includes changing existing HPP turbines to Archimedes screw type of turbines, in order to reduce mortality of fish that pass through them when migrating downstream. This option does not solve other hydro-morphological issues caused by the HPP dam.
5. **Implementation of ecological flow (assessment and implementation):** Measure addresses need for higher water level/discharge in river. Can be implemented by technical modification of sluice for storing less water above the dam and allowing the water flow. The measure requires a study to assess the ecological flow regime, as well as hydrological monitoring of the flow regime every year for a three year period.
6. **Demolishing a dam:** Technical measure that includes complete removal of the dam and its structures. It aims restoring fully natural continuity of river and removing all adverse effects of HPP operation and dam on ecological status of river. There are various approaches used in dam removal. (1) *Notch and release approach* include slow removal of the dam by making notches in the dam wall and slowly draining the reservoir through them. (2) *Rapid release approach* includes fast removal of dam by creating a large hole in the dam wall and releasing water and sediments quickly. (3) *Dig and dewater approach* entails emptying the entire reservoir, allowing the sediment to dry, and then removing it. (4) *Retained sediment approach* includes leaving the impoundment lake as it is without removal of sediment and rerouting river around the dam site (making a new river bed). Choosing the right method depends on many factors - size and type of the dam, the amount of sediment behind the dam, the aquatic environment below the dam etc.
7. **Permanently lowering the dam:** Technical measure that includes permanently removing or opening upper part of the dam (depending on technical specifics of dam). The aim of the measure is to either (I) lower the dam to make it easier to build a fish pass or, (II) reduce harmful effects of reservoir, or (III) if dam is lowered sufficiently - to give access to upstream habitats for fish. Possibility to implement the measure depends on type of a dam.
8. **Opening migration way during spawning period:** Technical measure that would ensure access to upstream habitats for fish during spawning period. The measure is suitable for HPP dams where the water level difference in upstream and downstream is not very high – if dams are low, with small water reservoirs, easily removable gates and no constructions that would obstruct the fish passage after the gates are removed. Measure would require employment of a person who would operate the gates - opening the migration way and keeping it open for the essential periods of fish migration – twice a year, in spring and autumn. It is essential not to lower the water level faster than 0,2 m (absolute maximum 0,3 m) per day to avoid hydropeaking, so it could take a lot of days to operate the gates. The periods of migration way opening would be determined by migration periods of fish species of interest.

Assessments on effectiveness and negative adverse environmental impacts

M1 Building of a fish pass	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstacle for fish migration, disruption of river continuity	Yes for P1 - increases fish migration. Effectiveness for fish migration is variable among different types of fish passes, it can range from low to high. Does not eliminate disruption of river continuity. *Score:* **moderate, 2.**
P2 Habitat areas	Yes for P2 – increases accessible habitat areas. To increase the effect on rivers with multiple HPPs, construction of fish passes should start downstream. *Score:* **moderate, 2.**
P3 Ecological flow	No / Partly for P3, depending on technical solution. A fish pass could be used to guarantee ecological flow, if e-flow is directed through the fish pass. *Score:* **no effect-low, 0.5.**
Summary score	*Average score:* **1.5** *Summary score:* **4.5**
C3 Negative / adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	Yes, temporary (2-5 years) negative impact on water quality during building process. *Score:* **moderate, 1**

M2 Reconstruction of an existing fish pass	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstacle for fish migration, disruption of river continuity	Yes for P1 - increases fish migration. Effectiveness is variable among different types of fish passes, it can range from low to high. *Score:* **moderate, 2.**
P2 Habitat areas	Yes for P2 – increase in accessible habitat areas *Score:* **moderate, 2**.
P3 Ecological flow	No / Partly for P3, depending on technical solution. A fish pass could help to maintain ecological flow[1] *Score:* **no effect-low, 0.5.**
Summary score	*Average score:* **1.5** *Summary score:* **4.5**
C3 Negative / adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	Yes, temporary (2-5 years). Temporary negative impact on water quality during reconstruction process. *Score:* **moderate, 1**

M3 Maintenance of an existing fish pass	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstacle for fish migration, disruption of river continuity	Yes for P1 - helps to preserve the positive effect of Option 1 on migration *Score:* **moderate, 2**
P2 Habitat areas	Yes for P2 – maintains access to available habitat areas *Score:* **moderate, 2**
P3 Ecological flow	No / Partly for P3 depending on technical solution- a fish pass can be used to maintain ecological flow. *Score:* **no effect-low, 0.5**
Summary score	*Average score:* **1.5** *Summary score:* **4.5**
C3 Negative / adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	No impacts. *Score:* **3**

M4 Environmentally friendly turbines	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstacle for fish migration, disruption of river continuity	Partly for P1 - reduced number of killed or injured migratory fish (for downstream migration), no other effect on disruption of river continuity. *Score:* **low, 1**
P2 Habitat areas	No effect for P2 – accessibility to or availability of areas not changing. *Score:* **no effect, 0**
P3 Ecological flow	No effect / partly for P3 – depends on type of turbines (some turbines can additionally help to stabilise flow, reduce hydropeaking) *Score:* **no-low, 0.5**
Summary score	*Average score:* **0.5** *Summary score:* **1.5**
C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	No impacts. *Score:* **3**

M5 Ecological flow implementation	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstacle for fish migration, disruption of river continuity	Effect for fish migration – reduces harmful effects of hydropeaking on fish migration. *Score:* **low, 1**

P2 Habitat areas	Yes for P2 - expands habitat areas downstream HPP by providing sufficient flow *Score:* **moderate, 2**
P3 Ecological flow	Yes for P3, ensures at least minimal necessary flow to achieve GES *Score:* **high, 3**
Summary score	*Average score:* **2** *Summary score:* **6**
C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	No impacts. *Score:* **3**

M6 Demolishing the HPP and dam	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstacle for fish migration, disruption of river continuity	Yes for P1 - removes the obstacle, fully restores migration possibilities for fish *Score:* **high, 3**
P2 Habitat areas	Yes for P2 - increases habitat areas by restoring natural river flow and continuity upstream and downstream *Score:* **high, 3**
P3 Ecological flow	Yes for P3, fully restores natural flow of river *Score:* **high, 3**
Summary score	*Average score:* **3** *Summary score:* **9**
C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	Temporary negative impact on water quality during and few years after demolishing works (sediments from impoundment flushed downstream and covering spawning areas, effect for 2-3 years). *Score:* **moderate – high, 0.5**

M7 Permanently lowering the dam	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstacle for fish migration, disruption of river continuity	Partly for P1 - if dam is lowered enough for some fish species to overcome the obstacle, depends on technical specifics of dam. *Score:* **low, 1**
P2 Habitat areas	No / partly for P2 as there is no guarantee to increase habitat areas. Habitat areas could be increased, if lowering the dam would help to implement ecological flow. *Score:* **no-low, 0.5**
P3 Ecological flow	No / partly for P3 - only if lowered sufficiently to achieve ecological flow, depends on water levels and technical specifics of dam

	Score: **no-low, 0.5**
Summary score	*Average score:* **0.67** *Summary score:* **2**
C3 Negative adverse environmental impacts	**Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)**
Assessment and summary score	No / partly – a temporary negative impact on water quality possible, if accumulated sediments may become dislodged and move downstream. *Score:* **low-moderate, 1.5**

M8 Opening the migration way during spawning period	
C1 Effectiveness of a measure for …	**Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)**
P1 Obstacle for fish migration, disruption of river continuity	Yes for P1 - increases fish migration options during spawning period. No effect for the rest of the year. *Score:* **low-moderate, 1.5**
P2 Habitat areas	Yes for P2 – increases accessible habitat areas during spawning period, however measure would have no effect on accessibility to habitats of fish for most of the year. *Score:* **low, 1**
P3 Ecological flow	No effect/minimal effect for P3 - by opening the migration way ecological flow might be achieved during spawning period, but not permanently. *Score:* **no effect-low, 0.5**
Summary score	*Average score:* **1** *Summary score:* **3**
C3 Negative adverse environmental impacts	**Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)**
Assessment and summary score	Disturbs flow regime, causes fluctuations of flow and hydropeaking that are harmful for riverine biota. *Score:* **moderate, 1**

Quantitative cost estimates

M1 Building of a fish pass

Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	The used range of the costs: **80 000 - 300 000 EUR** (Source: data from built fish passes in Estonia.) The costs are annualised to calculate costs per year using: - discount rate 5.5 % (4-5.5 % for sensitivity analysis); - lifetime 30 years (20 years for sensitivity analysis) (Source: Recommendation from Estonian experience). *Comments: The investment costs of fish passes can be very different depending on fish pass type and local conditions. In Estonia the costs of fish passes have varied from 30 000 EUR to 8 500 000 EUR. The most commonly costs have been between 80 000 and 300 000 EUR.* *Latvian example – project for Aģe – 250 000 EUR. The costs include 50 000 EUR for technical feasibility study (incl. construction plan).*
Financial: One-off costs	Costs of technical feasibility study (incl. construction plan) – included in the investment costs.

<table>
<tr><td>Financial: Yearly maintenance and operation (O&M) costs</td><td>Yearly O&M costs: 800 – 1500 EUR per year. (Source: Based on data from Estonian experience and Aviekste HPP in Latvia.)</td></tr>
<tr><td>Financial: Other costs</td><td>Monitoring costs: 4000 EUR/y, for 3 years (12 000 EUR in total). (Source: Recommendation from Estonian experience).</td></tr>
<tr><td>Opportunity costs (lost revenues)</td><td>5 % of revenues of a HPP in fish spawning period (spring and autumn). (Source: Expert judgement, information from literature). Calculated based on data for HPPs creating failure of GES in the project area (5 HPPs) – their electrical energy production in the spawning period (specified for each HPP in water use permit), multiplied by 0.05.
2200 EUR per year on average for 1 HPP (150 – 5500 EUR for HPP with the lowest or highest production respectively).</td></tr>
<tr><td>Induced costs (to other actors)</td><td>No such costs.</td></tr>
<tr><td>Significant input parameters, which create variability in the costs</td><td>1. Investment costs (the used range is 80 000 – 300 000 EUR).
2. Yearly revenues of HPPs for the opportunity costs (the used data: Average revenues 88 700 EUR; but they range from Lowest revenues 9 800 to, Highest revenues 243 000 EUR per year).
3. Life time (20-30 years), discount rate (4-5.5 %) for calculating annualised investment costs.</td></tr>
<tr><td>Total annualized costs per year, EUR:</td><td>9 000 – 30 000 EUR per year (the Lower and Upper bound of the costs).
Note. There can be situations where 2 fish passes are needed for a dam for upstream and downstream migration of fish. Thus, the estimated costs would be even much higher.</td></tr>
<tr><td>Total estimated financing need for planning period 6 years (2022-2027):</td><td>110 000 – 335 000 EUR (taking into account the Lower and Upper bound of the costs).</td></tr>
<tr><td>Costs as share of HPP revenues, %</td><td>
<table>
<tr><th>Revenues[1] / Costs</th><th>Lower bound</th><th>Upper bound</th></tr>
<tr><td>Highest revenues</td><td>4</td><td>13</td></tr>
<tr><td>Average revenues</td><td>11</td><td>35</td></tr>
<tr><td>Lowest revenues</td><td>100</td><td>315</td></tr>
</table>
If not accounting the lost revenues and (public) monitoring costs and when assuming lower bound of investment costs, the total costs become affordable for the highest revenue HPP (2 % of the revenues, Moderate category).
[1] Used data on yearly revenues of HPPs: Lowest 9 800, Average 88 700, Highest 243 000 EUR per year.</td></tr>
<tr><td>Assessment category
(1 High, 2 Moderate, 3 Low costs)</td><td>High (1)
The same category also if (public) monitoring costs are excluded, and opportunity costs are not considered (high even for a HPP with the highest revenues also when considering lower bound of the investment costs).</td></tr>
</table>

M2 Reconstruction or improvement of a fish pass

Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	The used range of the costs: **20 000 - 100 000 EUR** (Source: expert judgement) The costs are annualised to calculate costs per year using: - discount rate 5.5 % (4-5.5 % for sensitivity analysis); - lifetime 30 years (20 years for sensitivity analysis) (The same as for M1)
Financial: One-off costs	Costs of technical feasibility study (incl. construction plan): **15 000 – 20 000 EUR**.
Financial: Yearly maintenance and operation (O&M) costs	**Yearly O&M costs: 800 – 1500 EUR per year**. (Source: Based on data from Estonian experience and Aviekste HPP in Latvia.)
Financial: Other costs	**Monitoring costs: 4000 EUR/y, for 3 years** (12 000 EUR in total). (Source: Recommendation from Estonian experience).
Opportunity costs (lost revenues)	No such costs (existing fish pass, do not change water regime).

<table>
<tr><td>Induced costs (to other actors)</td><td>No such costs.</td></tr>
<tr><td>Significant input parameters, which create variability in the costs</td><td>1. Investment costs (the used range is 20 000 – 100 000 EUR).</td></tr>
<tr><td>Total annualized costs per year, EUR:</td><td>5 000 – 13 500 EUR per year (the Lower and Upper bound of the costs).</td></tr>
<tr><td>Total estimated financing need for planning period 6 years (2022-2027):</td><td>52 000 – 140 000 EUR (taking into account the Lower and Upper bound of the costs).</td></tr>
<tr><td>Costs as share of HPP revenues, %</td><td>
<table>
<tr><th>Revenues[1] / Costs</th><th>Lower bound</th><th>Upper bound</th></tr>
<tr><td>Highest revenues</td><td>2*</td><td>6</td></tr>
<tr><td>Average revenues</td><td>5</td><td>15</td></tr>
<tr><td>Lowest revenues</td><td>50</td><td>140</td></tr>
</table>
* 1 % (Moderate) if (public) monitoring costs are excluded.
[1] Used data on yearly revenues of HPPs: Lowest 9 800, Average 88 700, Highest 243 000 EUR per year.</td></tr>
<tr><td>Assessment category
(1 High, 2 Moderate, 3 Low costs)</td><td>High (1)
When (public) monitoring costs are excluded, the category changes only for Highest revenue HPP from High to Moderate.</td></tr>
</table>

M3 Maintenance of an existing fish pass

<table>
<tr><th>Types of the costs</th><th>Explanations and quantitative estimates</th></tr>
<tr><td>Financial: Investment costs</td><td>No such costs.</td></tr>
<tr><td>Financial: One-off costs</td><td>No such costs.</td></tr>
<tr><td>Financial: Yearly maintenance and operation (O&M) costs</td><td>Yearly O&M costs: 800 – 1500 EUR per year. (Source: Based on data from Estonian experience and Aviekste HPP in Latvia.)</td></tr>
<tr><td>Financial: Other costs</td><td>Monitoring costs: 4000 EUR/y, for 3 years (12 000 EUR in total). (Source: Recommendation from Estonian experience).</td></tr>
<tr><td>Opportunity costs (lost revenues)</td><td>No such costs (existing fish pass, do not change water regime).</td></tr>
<tr><td>Induced costs (to other actors)</td><td>No such costs.</td></tr>
<tr><td>Significant input parameters, which create variability in the costs</td><td></td></tr>
<tr><td>Total annualized costs per year, EUR:</td><td>2 800 – 3 500 EUR per year (the Lower and Upper bound of the costs).</td></tr>
<tr><td>Total estimated financing need for planning period 6 years (2022-2027):</td><td>17 000 – 21 000 EUR (taking into account the Lower and Upper bound of the costs).</td></tr>
<tr><td>Costs as share of HPP revenues, %</td><td>
<table>
<tr><th>Revenues[1] / Costs</th><th>Lower bound</th><th>Upper bound</th></tr>
<tr><td>Highest revenues</td><td>1.2*</td><td>1.4*</td></tr>
<tr><td>Average revenues</td><td>3.2*</td><td>3.9</td></tr>
<tr><td>Lowest revenues</td><td>29</td><td>36</td></tr>
</table>
* < 1 % (Low) if (public) monitoring costs are excluded.
[1] Used data on yearly revenues of HPPs: Lowest 9 800, Average 88 700, Highest 243 000 EUR per year.</td></tr>
<tr><td>Assessment category
(1 High, 2 Moderate, 3 Low costs)</td><td>Moderate-High (1.5)
Low-High (2) when excluding (public) monitoring costs depending on production (revenue) size of a HPP.</td></tr>
</table>

M4 Environment friendly turbine

<table>
<tr><th>Types of the costs</th><th>Explanations and quantitative estimates</th></tr>
<tr><td>Financial: Investment costs</td><td>The used range of the costs: 25 000 - 150 000 EUR (Source: Expert judgement)
The costs are annualised to calculate costs per year using:
- discount rate 5.5 % (4-5.5 % for sensitivity analysis);
- lifetime 30 years (20 years for sensitivity analysis). (Source: Recommendation from Estonian experience).</td></tr>
<tr><td>Financial: One-off costs</td><td>Costs of technical feasibility study (incl. construction plan) – included in the investment costs.</td></tr>
<tr><td>Financial: Yearly maintenance and operation (O&M) costs</td><td>Yearly O&M costs: 1 % of the total investment costs per year. (Source: Expert judgement.) It is 250-1500 EUR per year for the given investment costs range.</td></tr>
<tr><td>Financial: Other costs</td><td>Monitoring costs: 4000 EUR/y, for 2 years (8 000 EUR in total).</td></tr>
<tr><td>Opportunity costs (lost revenues)</td><td>No lost production (revenues) assumed.</td></tr>
<tr><td>Induced costs (to other actors)</td><td>No such costs.</td></tr>
<tr><td>Significant input parameters, which create variability in the costs</td><td>Investment costs (the used range is 25 000 - 150 000 EUR).</td></tr>
<tr><td>Total annualized costs per year, EUR:</td><td>3 000 – 15 000 EUR per year (the Lower and Upper bound of the costs).</td></tr>
<tr><td>Total estimated financing need for planning period 6 years (2022-2027):</td><td>35 000 – 165 000 EUR (taking into account the Lower and Upper bound of the costs).</td></tr>
<tr><td>Costs as share of HPP revenues, %</td><td>
<table>
<tr><th>Revenues[1] / Costs</th><th>Lower bound</th><th>Upper bound</th></tr>
<tr><td>Highest revenues</td><td>1.2*</td><td>6</td></tr>
<tr><td>Average revenues</td><td>3.4</td><td>17</td></tr>
<tr><td>Lowest revenues</td><td>30</td><td>150</td></tr>
</table>
* < 1% (Moderate) if excluding (public) monitoring costs.
[1] Used data on yearly revenues of HPPs: Lowest 9 800, Average 88 700, Highest 243 000 EUR per year.</td></tr>
<tr><td>Assessment category
(1 High, 2 Moderate, 3 Low costs)</td><td>High (1)
Moderate-High (1.5) when excluding (public) monitoring costs depending on production (revenue) size of a HPP.</td></tr>
</table>

M5 Implementation of ecological flow

Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	Investment costs of modifying sluice: **10 000 EUR** (Source: expert judgement, project experts) The costs are annualised to calculate costs per year using: - discount rate 5.5 % (4-5.5 % for sensitivity analysis); - lifetime 30 years (20 years for sensitivity analysis). (Source: assumption – the same as for fish pass).
Financial: One-off costs	**2000 EUR** investment costs of monitoring equipment, **5000 EUR** for ecological flow assessment. Divided by 6 years to calculate costs per year.
Financial: Yearly maintenance and operation (O&M) costs	No such additional costs.
Financial: Other costs	Monitoring costs: **1500 EUR/y, for 3 years** (4 500 EUR in total).
Opportunity costs (lost revenues)	**0 %** if modern turbines which can produce energy with varying water flow rate. **5-10 %** if old turbines are used which can produce energy with certain water flow rate only. Calculated based on data for HPPs creating failure of GES in the project area (5 HPPs), yearly

<table>
<tr><td></td><td>revenues multiplied by 0-0.1. 0-9000 EUR per year on average for 1 HPP.</td></tr>
<tr><td>Induced costs (to other actors)</td><td>No such costs.</td></tr>
<tr><td>Significant input parameters, which create variability in the costs</td><td>1. Range of lost revenues (assumption 0-10 %).
2. Yearly revenues of HPPs for the opportunity costs (the used data: Average revenues 88 700 EUR; but they range from Lowest revenues 9 800 to, Highest revenues 243 000 EUR per year).</td></tr>
<tr><td>Total annualized costs per year, EUR:</td><td>2 500 – 12 000 EUR per year (the Lower and Upper bound of the costs).</td></tr>
<tr><td>Total estimated financing need for planning period 6 years (2022-2027):</td><td>21 500 – 75 000 EUR (taking into account the Lower and Upper bound of the costs).</td></tr>
<tr><td>Costs as share of HPP revenues, %</td><td>
<table>
<tr><th>Revenues[1] / Costs</th><th>Lower bound</th><th>Upper bound</th></tr>
<tr><td>Highest revenues</td><td>1*</td><td>4.8</td></tr>
<tr><td>Average revenues</td><td>2.8</td><td>13</td></tr>
<tr><td>Lowest revenues</td><td>25</td><td>120</td></tr>
</table>
* < 1 % (Low) if excluding (public) monitoring costs and if there are no the opportunity costs. High if there are the opportunity costs
[1] Used data on yearly revenues of HPPs: Lowest 9 800, Average 88 700, Highest 243 000 EUR per year.</td></tr>
<tr><td>Assessment category
(1 High, 2 Moderate, 3 Low costs)</td><td>Moderate-High (1.5).
Low-High (2) when excluding (public) monitoring costs and whether there are the opportunity costs depending on production (revenue) size of a HPP</td></tr>
</table>

M6 Demolishing a dam used for energy production

Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	Technical costs for demolishing a dam: the used range **40 000 – 300 000 EUR**. (Source: based on experience in Estonia.) *According to Estonian experience it may cost 20 000 – 4 000 000 EUR, commonly the costs are 1/2 – 2/3 of the cost of fish pass.* The costs are annualised to calculate costs per year using: - discount rate 5.5 % (4-5.5 % for sensitivity analysis); - lifetime of a measure 100 years (50 years for sensitivity analysis).
Financial: One-off costs	Costs of technical feasibility study (incl. construction plan, permit): **15 000 – 50 000 EUR**. Annualised over 100 lifetime.
Financial: Yearly maintenance and operation (O&M) costs	No such costs
Financial: Other costs	Monitoring costs: **4000 EUR/y, for 3 years** (12 000 EUR in total). (Source: LEGMC)
Opportunity costs – compensation for expropriation of private property	Foregone revenues (lost future opportunities), estimated with two approaches: 1) **MIN** – compensating value of private property(ies) based on official cadastral value. All buildings of 5 HPPs are registered in official cadastre (value 2000-10000 EUR), but not the dams. Staicele dam is registered with 44 000 EUR cadastral value (no energy production on this dam). **2) MAX** – compensating foregone revenues for 10 years of possible economic activity (electrical energy production is assumed as possible activity). Input data on yearly revenues of HPPs: Lowest revenues 9800, Highest revenues 243 000 EUR per year.
Induced costs (to other actors)	Lost welfare for up-stream uses, costs for strengthening construction of the road (over dam) or building a bridge. Costs are not estimated.
Significant input parameters, which create variability in the costs	1. Compensation for foregone revenues (large range of foregone revenues). 2. Range of financial costs (investment and study costs).
Total annualized costs per	**With MIN Opportunity costs approach: 4 500 – 25 000 EUR per year (the Lower and Upper**

<table>
<tr><td>year, EUR:</td><td>bound of the costs).
With MAX Opportunity costs approach: 8 000 – 155 000 EUR per year (the Lower and Upper bound of the costs).
Note. Induced costs are not estimated.</td></tr>
<tr><td>Total estimated financing need for planning period 6 years (2022-2027):</td><td>With MIN Opportunity costs approach: 69 000 – 400 000 EUR (taking into account the Lower and Upper bound of the costs).
With MAX Opportunity costs approach: 165 000 – 2 840 000 EUR (taking into account the Lower and Upper bound of the costs).
Note. Induced costs are not estimated.</td></tr>
<tr><td>Costs as share of county yearly budget, %</td><td>MIN option (with MIN opportunity costs):
<table>
<tr><th>Budget[1] / Costs</th><th>Lower bound</th><th>Upper bound</th></tr>
<tr><td>Largest budget</td><td>0.01</td><td>0.08</td></tr>
<tr><td>Moderate budget</td><td>0.04</td><td>0.22</td></tr>
<tr><td>Lowest budget</td><td>0.18</td><td>1.04</td></tr>
<tr><td><i>Alojas county (Staicele dam)</i></td><td><i>0.12</i></td><td><i>0.52</i></td></tr>
</table>
MAX option (with MAX opportunity costs):
<table>
<tr><th>Budget[1] / Costs</th><th>Lower bound</th><th>Upper bound</th></tr>
<tr><td>Largest budget</td><td>0.03</td><td>0.5</td></tr>
<tr><td>Moderate budget</td><td>0.07</td><td>1.4</td></tr>
<tr><td>Lowest budget</td><td>0.34</td><td>6.5</td></tr>
<tr><td><i>Alojas county (Staicele dam)</i></td><td><i>0.17</i></td><td><i>3.2</i></td></tr>
</table>
Note. Induced costs are not estimated (foregone benefits for up-stream uses, costs for roads).
[1] Used data on yearly county budget: Lowest 2.4 mil, Average 11.5, Highest 31 mil EUR per year, 4.87 mil EUR for Alojas county.</td></tr>
<tr><td>Assessment category
(1 High, 2 Moderate, 3 Low costs)</td><td>Low-High (2)
Based on MIN Opportunity costs (compensating cadastral value) – Low costs (3) for all cases, except for Lowest budget county with Upper bound of the costs.
Based on MAX Opportunity costs (compensating foregone revenues from energy production) – Low-High costs (2) depending on size of Opportunity costs.
Note. Induced costs are not estimated.</td></tr>
</table>

M7 Permanently lowering a dam

Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	The used range of the costs: **20 000 - 100 000 EUR** (Source: Expert judgement.) The costs are annualised to calculate costs per year using: - discount rate 5.5 % (4-5.5 % for sensitivity analysis); - lifetime 30 years (20 years for sensitivity analysis) (Source: assumption – the same as for fish passes.)
Financial: One-off costs	Costs of technical feasibility study (incl. construction plan): **15 000 – 20 000 EUR**.
Financial: Yearly maintenance and operation (O&M) costs	No such costs.
Financial: Other costs	**Monitoring costs: 4000 EUR/y, for 3 years** (12 000 EUR in total). (Source: Recommendation from Estonian experience).
Opportunity costs (lost revenues)	**10-15 % of yearly production-revenues of a HPP**. (Source: Expert judgement, information from literature). Calculated based on data for HPPs creating failure of GES in the project area (5 HPPs) – their yearly revenues, multiplied by 0.1-0.15. **2200 EUR per year on average for 1 HPP** (150 – 5500 EUR for HPP with the lowest or highest

<table>
<tr><td></td><td>production respectively).</td></tr>
<tr><td>Induced costs (to other actors)</td><td>Lost welfare for recreational angling and water related recreation up-stream due to decreasing impoundment.
Costs are not estimated.</td></tr>
<tr><td>Significant input parameters, which create variability in the costs</td><td>1. Investment costs (the used range is 20 000 – 100 000 EUR).
2. Yearly revenues of HPPs for the opportunity costs (the used data: Average revenues 88 700 EUR; but they range from Lowest revenues 9 800 to, Highest revenues 243 000 EUR per year).
3. Life time (20-30 years), discount rate (4-5.5 %) for calculating annualised investment costs.</td></tr>
<tr><td>Total annualized costs per year, EUR:</td><td>13 000 – 25 000 EUR per year (the Lower and Upper bound of the costs).
Note. Induced costs are not estimated.</td></tr>
<tr><td>Total estimated financing need for planning period 6 years (2022-2027):</td><td>100 000 – 125 000 EUR (taking into account the Lower and Upper bound of the costs).
Note. Induced costs are not estimated.</td></tr>
<tr><td>Costs as share of HPP revenues, %</td><td>
<table>
<tr><th>Revenues[1] / Costs</th><th>Lower bound</th><th>Upper bound</th></tr>
<tr><td>Highest revenues</td><td>5*</td><td>10</td></tr>
<tr><td>Average revenues</td><td>15</td><td>29</td></tr>
<tr><td>Lowest revenues</td><td>132</td><td>260</td></tr>
</table>
* High costs also when (public) monitoring costs excluded. If the opportunity costs are not accounted, the costs are Moderate only with the Lower bound of the costs, still High with the Upper bound, and High for other size HPPs.
[1] Used data on yearly revenues of HPPs: Lowest 9 800, Average 88 700, Highest 243 000 EUR per year.</td></tr>
<tr><td>Assessment category
(1 High, 2 Moderate, 3 Low costs)</td><td>High (1)
The same category also if (public) monitoring costs are excluded.</td></tr>
</table>

M8 Opening migration way during spawning period

Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	Investment costs of modifying sluice: **15 000 EUR** (Source: Expert judgement.) The costs are annualised to calculate costs per year using: - discount rate 5.5 % (4-5.5 % for sensitivity analysis); - lifetime 30 years (20 years for sensitivity analysis). (Source: assumption – the same as for fish passes.)
Financial: One-off costs	No such costs.
Financial: Yearly maintenance and operation (O&M) costs	Costs of personnel for operating sluice: **1700 EUR per year**. Average personnel costs in Latvia (wage data from CSB) 1400 EUR/month x 6 month (spawning period) x 0.2 workload.
Financial: Other costs	Monitoring costs: **4000 EUR/y, for 3 years** (12 000 EUR in total).
Opportunity costs (lost revenues)	**Lost revenues: 5-10 % of revenues of a HPP in fish spawning period** (spring and autumn). (Source: Expert judgement). Calculated based on data for HPPs creating failure of GES in the project area (5 HPPs) – their energy production in the spawning period (specified for each HPP in water use permit), multiplied by 0.05-0.1. **2200-4400 EUR per year on average for 1 HPP** (150-300 and 5500-11000 EUR for HPP with the lowest or highest energy production respectively).
Induced costs (to other actors)	Lost welfare for recreational angling due to decreasing impoundment in spawning period. Assumed no negative impact on other uses (e.g. near water recreation, fish farming). Costs are not estimated.
Significant input parameters, which create variability in the	1. Range of lost revenues. 2. Yearly revenues of HPPs for the opportunity costs (the used data: Average revenues 88 700

costs	EUR; but they range from Lowest revenues 9 800 to, Highest revenues 243 000 EUR per year).
Total annualized costs per year, EUR:	**7 000 – 9 500 EUR per year (the Lower and Upper bound of the costs).** Note. Induced costs are not estimated.
Total estimated financing need for planning period 6 years (2022-2027):	**90 500 – 104 000 EUR (taking into account the Lower and Upper bound of the costs).** Note. Induced costs are not estimated.
Costs as share of HPP revenues, %	see table below
Assessment category **(1 High, 2 Moderate, 3 Low costs)**	**High (1)** The same category for all size HPPs also when excluding public (monitoring) costs.

Revenues[1] / Costs	Lower bound	Upper bound
Highest revenues	3*	4*
Average revenues	8	11
Lowest revenues	70	100

* High costs also when excluding (public) monitoring costs. Low-Moderate if the opportunity costs were not considered.

[1] Used data on yearly revenues of HPPs: Lowest 9 800, Average 88 700, Highest 243 000 EUR per year.

4.5 Detailed results for Latvia on the evaluation of the measures for obstacles/impoundments with other/no use creating hydro-morphological pressures

4.5.1 Environmental impacts of the measures (Criterion 1-3)

Table 4.17 summarises the assessments concerning the environmental impacts of the measures covered by the Criteria 1-3. Detailed results on the assessments for the Criteria 1 and 3 are provided in chapter 4.5.5.

Since the effectiveness is assessed against two state parameters the summary effectiveness score can be calculated as an average or sum of the parameters' scores. Both estimates are provided in the table (see the columns "Average" and "Sum").

Table 4.17. The prepared assessments for the environmental impacts (Criteria 1-3) of the analysed additional measures for obstacles/impoundments creating hydro-morphological pressures. *(Source: An assessment by the project's experts (LEGMC).)*

The used assessment categories and corresponding scores:

C1 Effectiveness of a measure: 0 no effect, 1 Low, 2 Moderate, 3 High effectiveness.

C2 Certainty of the Effectiveness assessment: 1 Low, 2 Moderate, 3 High certainty.

C3 Negative adverse environmental impacts from implementing a measure: 0 High, 1 Moderate, 2 Low, 3 No negative impact.

State parameters for the Effectiveness assessment: P1 Obstacle for fish migration, disruption of river continuity; P2 Habitat areas.

The analysed additional measures	C1 Effectiveness of a measure				C2 Certainty	C3 Negative impact
	P1	P2	Average	Sum		
M1 Building of a fish pass	2	2	**2**	**4**	Moderate (2)	Moderate (1)
M2 Demolishing a dam	3	3	**3**	**6**	High (3)	Moderate (1)
M3 Opening migration way during spawning period	2	1.5	**1.75**	**3.5**	Low-Moderate (1.5)	Moderate (1)

The highest effectiveness assessment is for the measure *M6 Demolishing a dam*. It is “moderate” for other two measures. *M6 Demolishing a dam* has also “high” certainty of the effectiveness assessment. It is “low” to “moderate” for other two measures.

Concerning the possible negative environmental impacts, they are expected “moderate” for all the analysed measures, but they would be temporal for M1 and M2 while permanent for M3.

The only measure which fully eliminates the problem for both relevant state parameters is the measures *M6 Demolishing a dam*, it has also high certainty of the effectiveness assessment, and the negative environmental effect is expected to be temporal. Other measures give only partial achievement of GES concerning both relevant state parameters.

4.5.2 Costs of the measures

Table 4.18 summarises the assessments concerning the costs of the measures (Criterion 4). The costs were estimated quantitatively for each measure, and they were compared to yearly municipal budgets of counties in the project area to assign the qualitative assessment category and score (according to the approach described in chapter 4.3.4). Detailed results on the quantitative cost estimates are provided in chapter 4.5.5. The costs are considered as “high” if they exceed 1 % of a yearly municipal budget.

To account possible variations in the costs and uncertainty, the cost estimates are developed as intervals (see the second column in the table). The lower and upper bounds of the intervals are calculated based on possible cost range for input estimates (for instance, possible range of the investment costs). Hence also the qualitative assessment categories can form intervals (see the third column in the table). Another reason for the intervals of the categories is related to differences in size of municipal budgets.[27]

Table 4.18. The prepared assessments for the costs (Criterion 4) of the analysed additional measures for obstacles/impoundments creating hydro-morphological pressures. *(Source: Estimates prepared as part of the project.)*

The used assessment categories and corresponding scores: High 1, Moderate 2, Low 3 costs.

The analysed additional measures	Annualised costs per year	Assessment categories and scores
M1 Building of a fish pass	**7 500 – 28 500 EUR/y**	**Low-Moderate (2.5)** (Moderate only for Lowest budget county with Upper bound of the costs, also when (public) monitoring costs are excluded.)
M2 Demolishing a dam	**MIN Opportunity costs: 4 500 – 25 000 EUR/y** **MAX Opportunity costs: 8 000 – 155 000 EUR/y**	**Low-High (2)** Based on MIN Opportunity costs (compensating cadastral value) – **Low costs (3)** for all cases, except for Lowest budget county with Upper bound of the costs. Based on MAX Opportunity costs (compensating foregone revenues from energy production) – **Low-High costs (2)** depending on size of the opportunity costs. Note. The costs are discounted over 50-100 years; Induced costs are not estimated.
M3 Opening migration way during spawning period	**4 500 – 5 000 EUR/y**	**Low (3)** Note. Induced costs are not estimated.

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[27] Data on yearly municipal budgets of all counties in the project area are used. The budgets range from 2.5 to 31 million EUR per year. The “average” budget is calculated as an average from all counties.

The measure *M3 Opening migration way during spawning period* has the lowest costs. The costs are "low" also for the measure *M1 Building of a fish pass*, except for the lowest budget county with the upper bound of the costs.

M6 Demolishing a dam has large variability of the costs ranging from "low" to "high". If the opportunity costs are estimated based on compensating cadastral value of properties, the costs are "low" practically for all size counties (even with the upper bound of the financial costs). If the opportunity costs are estimated based on compensating foregone revenues from energy production, the costs are "low" for all size counties with the lower bound of the costs (assuming low revenue HPP). But they could be "high" in most cases with the upper bound of the costs (assuming high revenue HPP). But it should be noted that the costs are spread over 100 years (assumed lifetime of the effect of the measure[28]), and that the costs estimate do not include induced costs.

It can be concluded overall:

- The costs of all measures could be affordable overall even for small budget counties.
- Demolishing a dam could be low cost option if the opportunity costs need to be compensated based on cadastral value of properties. It could still be affordable if compensating foregone revenues from electrical energy production assuming low-moderate compensation. The costs become high if large foregone production value would need to be compensated (e.g. if there was a small HPP with large production).

4.5.3 Constraints/obstacles of implementation

Table 4.19 summarises the assessments concerning the constraints/obstacles of implementation of the measures (Criterion 5). The constraints are assessed as "high" for the measure M2 and "moderate" for M1 and M3.

Table 4.19. The prepared assessments for the constraints/obstacles of implementation (Criterion 5) of the analysed additional measures for obstacles/impoundments creating hydro-morphological pressures. *(Source: An assessment by the project's experts.)*

The used assessment categories and corresponding scores: High 0, Moderate 1, Low 2, No 3 constraints/obstacles.

The analysed additional measures	Description of possible constraints/obstacles and assessment categories and scores
M1 Building of a fish pass	Institutional: Acceptability from owners. Procedures for legal approval/coordination. Legal: No specific constraints. Lack of legal incentives (requirements) for implementing the measure. Financial: No considerable constraints. **Moderate (1)**
M2 Demolishing a dam	Institutional: Acceptability from land owners, other users (incl. can be locally important site). Legal approval/coordination. Legal: Compensating private properties. Financial: Lack of public financing instruments (in light of costs and possible need for compensations). **High (0)**
M3 Opening migration way during spawning period	Institutional: Acceptability from owners. Legal: No specific constraints. Lack of legal incentives (requirements) for implementing the measure. Financial: No considerable constraints. **Moderate (1)**

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[28] The cost estimates do not change significantly also if 50 year lifetime is used.

4.5.4 Summary assessment

Table 4.20 provides summary assessment for the analysed measures for obstacles/impoundments creating hydro-morphological pressures. Table 4.21 provides the summary assessment when considering only the effectiveness and costs (cost-effectiveness assessment) and excluding other criteria.

The measures are ordered in the tables starting with the measure with the highest summary score. However this ordering should not be taken as strict ranking because the assessment approach is rather rough to be used for strict ranking.

Table 4.20. Summary assessments for the analysed additional measures for obstacles/impoundments creating hydro-morphological pressures. *(Source: Assessments prepared as part of the project.)*

[1] Using Average of all parameters' scores for the Effectiveness assessment. [2] Using Sum of all parameters' scores for the Effectiveness assessment.

The analysed additional measures	C1 Effect AVER[1]	C1 Effect SUM[2]	C2 Certainty	C3 Negative impact	C4 Costs	C5 Constraints	Total (AverEffec) [1]	Total (SumEffec) [2]
M2 Demolishing a dam	3	6	High (3)	Moderate (1)	Low-High (2)	High (0)	**9.0**	**12.0**
M1 Building of a fish pass	2	4	Moderate (2)	Moderate (1)	Low-Moderate (2.5)	Moderate (1)	**8.5**	**10.5**
M3 Opening migration way during spawning period	1.75	3.5	Low-Moderate (1.5)	Moderate (1)	Low (3)	Moderate (1)	**8.3**	**10.0**

Table 4.21. Summary assessment of the analysed measures when considering only the effectiveness and costs (cost-effectiveness analysis) and excluding other criteria.

[1] Using Average of all parameters' scores for the Effectiveness assessment. [2] Using Sum of all parameters' scores for the Effectiveness assessment.

The analysed additional measures	Total (AverEffec) [1]	Total (SumEffec) [2]
M2 Demolishing a dam	**5.0**	**8.0**
M3 Opening migration way during spawning period	**4.8**	**6.5**
M1 Building of a fish pass	**4.5**	**6.5**

When using Sum versus Average of all parameters' scores for the Effectiveness assessment, it does not change the prioritisation. The summary assessment and prioritisation change slightly considering only the effectiveness and costs (cost-effectiveness assessment) and excluding other criteria. It gives slightly higher score for M3 comparing to M1 since the M3 has lower costs. However the scores are rather similar with such rough assessment approach.

The only measure which fully eliminates the problem for both relevant state parameters is the measure *M6 Demolishing a dam*, it has also high certainty of the effectiveness assessment, and the negative environmental effect is expected to be temporal. Other measures give only partial achievement of GES concerning both relevant state parameters.

The costs of all measures could be affordable overall even for small budget counties. Demolishing a dam could be low cost option if the opportunity costs need to be compensated based on cadastral value of properties or assuming low to moderate compensation of the foregone revenues.

It can be concluded overall that removing a dam is the highest priority option and should be applied where technically suitable. Where it is not the case other measures must be considered but possibility of achievement of GES needs to be evaluated carefully.

All the collected information and detailed assessments can be used and developed further when analysing and selecting measures for concrete WBs.

4.5.5 Detailed results for each measure

In this chapter detailed results are included concerning (i) descriptions of the measures; (ii) assessments of the effectiveness and negative adverse environmental impacts (Criteria 1 and 3) and (iii) quantitative cost estimates.

Descriptions of the measures

1. **Building of a fish pass**: Technical measure with an aim to construct an alternative way for migration of fish on rivers affected by dams or other obstacles. Case specific requirements for each fish pass should be established, depending on fish species of concern and specifics of river, as well as local specifics – availability of space, geology, etc. There are two main types of fish passes - natural type and technical type. Natural type fish passes require more space, as they mimic the river (new river bed is created). Technical type fish are special constructions built from various materials, such as concrete, metal, they can require less space than natural type.

   Natural-type fish passes:

   1) rapid or ritral bypass channels and fish passes in the river channel with low slope (≤2%);
   2) pond type fish passes (pond cascades) with low slope (≤3,5%);
   3) rapid and pond cascades with higher slope (≤5%).
   Technical type fish passes:

   4) vertical slot fish passes;
   5) pool type fish ladders with surface and bottom openings;
   6) pool type fish ladders with bottom openings;
   7) screw fish elevators and turbines;
   8) pool type fish ladders with surface openings;
   9) denil fish passes (baffle fish ways);
   10) pool type fish ladders without openings;
   11) fish locks and lifts.
   Problems can be present with both upstream and downstream migration of fish, in that case construction of two fish passes could be necessary to resolve both problems. Best available technological solutions must be applied based on scientific studies about fish pass efficiency rate. The measure also includes further maintenance of the fish pass in good working conditions.

2. **Demolishing a dam / obstacle:** Technical measure that includes complete removal of the dam or obstacle and its structures. It aims to restore fully natural continuity of river and remove all adverse effects of the obstacle on ecological status of river. There are various approaches used in demolishing and removal, depending on the dam / obstacle type. If there is an impoundment lake present, there are four most common approaches to removal. (1) *Notch and release approach* includes slow removal of the dam by making a notches in the dam wall and slowly draining the reservoir through them. (2) *Rapid release approach*

includes fast removal of dam by creating a large hole in the dam wall and releasing water quickly. (3) *Dig and dewater approach* entails emptying the entire reservoir, allowing the sediment to dry, and then removing it. (4) *Retained sediment approach* includes leaving the impoundment lake as it is without removal of sediment and rerouting river around the dam site (making a new river bed). Choosing the right method depends on many factors - size and type of the dam, the amount of sediment behind the dam, the aquatic environment below, etc. If there is no impoundment lake, removal of the dam / obstacle means dislodging and removing its structures.

3. **Opening migration way during spawning period:** Technical measure that would ensure access to upstream habitats for fish during spawning period. The measure is suitable for dams where the water level difference in upstream and downstream is not very high – if dams are low, with small water reservoirs, easily removable gates and no constructions that would obstruct the fish passage after the gates are removed. Measure would require employment of a person who would operate the gates - opening the migration way and keeping it open for the essential periods of fish migration – twice a year, in spring and autumn. It is essential not to lower the water level faster than 0,2 m (absolute maximum 0,3 m) per day to avoid hydropeaking, so it could take a lot of days to operate the gates. The periods of migration way opening would be determined by migration periods of fish species of interest.

Assessments on effectiveness and negative adverse environmental impacts

M1 Building of a fish pass	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstacle for fish migration, disruption of river continuity	Yes for P1 - increases fish migration. Effectiveness depends on the type of fish pass and can range from negligible to high. Usually one fish pass can be suitable only for certain fish species, while not suitable for others. *Score:* **moderate, 2.**
P2 Habitat areas	Yes for P2 – increase in accessible habitat areas. To increase the effect on rivers with multiple HPPs, construction of fish passes should start downstream. *Score:* **moderate, 2.**
Summary score	*Average score:* **2** *Summary score:* **4**
C3 Negative / adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	Yes, temporary (2-5 years) negative impact on water quality during building process. *Score:* **moderate, 1**

M2 Demolishing a dam	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstacle for fish migration, disruption of	Yes for P1 - removes the obstacle, fully restores migration possibilities for fish

river continuity	*Score:* **high, 3**
P2 Habitat areas	Yes for P2 - increases habitat areas by restoring natural river flow and continuity *Score:* **high, 3**
Summary score	*Average score:* **3** *Summary score:* **6**
C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	Temporary negative impact on water quality during and few years after demolishing works (sediments from impoundment flushed downstream and covering spawning areas, effect for 2-3 years). *Score:* **moderate, 1**

M3 Opening the migration way during spawning period	
C1 Effectiveness of a measure for …	**Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)**
P1 Obstacle for fish migration, disruption of river continuity	Yes for P1 - increases fish migration options during spawning period. No effect for the rest of the year. *Score:* **moderate, 2**
P2 Habitat areas	Yes for P2 – increases accessible habitat areas during spawning period, however measure would have no effect on accessibility to habitats of fish for most of the year. *Score:* **low-moderate, 1.5**
Summary score	*Average score:* **1.75** *Summary score:* **3.5**
C3 Negative adverse environmental impacts	**Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)**
Assessment and summary score	Disturbs flow regime, causes fluctuations of flow and hydropeaking that are harmful for riverine biota. *Score:* **moderate, 1**

Quantitative cost estimates

M1 Building of a fish pass

Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	The used range of the costs: **80 000 - 300 000 EUR** (Source: data from built fish passes in Estonia.) The costs are annualised to calculate costs per year using: - discount rate 5.5 % (4-5.5 % for sensitivity analysis); - lifetime 30 years (20 years for sensitivity analysis) (Source: Recommendation from Estonian experience). *Comments: The investment costs of fish passes can be very different depending on fish pass type and local conditions. In Estonia the costs of fish passes have varied from 30 000 EUR to 8 500 000 EUR. The most commonly costs have been between 80 000 and 300 000 EUR.* *Latvian example – project for Aģe – 250 000 EUR. The costs include 50 000 EUR for technical feasibility study (incl. construction plan).*

<table>
<tr><td>Financial: One-off costs</td><td>Costs of technical feasibility study (incl. construction plan) – included in the investment costs.</td></tr>
<tr><td>Financial: Yearly maintenance and operation (O&M) costs</td><td>Yearly O&M costs: 800 – 1500 EUR per year. (Source: Based on data from Estonian experience and Aviekste HPP in Latvia.)</td></tr>
<tr><td>Financial: Other costs</td><td>Monitoring costs: 4000 EUR/y, for 3 years (12 000 EUR in total). (Source: Recommendation from Estonian experience).</td></tr>
<tr><td>Opportunity costs (lost revenues)</td><td>No such costs.</td></tr>
<tr><td>Induced costs (to other actors)</td><td>No such costs.</td></tr>
<tr><td>Significant input parameters, which create variability in the costs</td><td>1. Investment costs (the used range is 80 000 – 300 000 EUR).
2. Life time (20-30 years), discount rate (4-5.5 %) for calculating annualised investment costs.</td></tr>
<tr><td>Total annualized costs per year, EUR:</td><td>7 500 – 28 500 EUR per year (the Lower and Upper bound of the costs).
Note. There can be situations where 2 fish passes are needed for a dam for upstream and downstream migration of fish. Thus, the estimated costs would be even much higher.</td></tr>
<tr><td>Total estimated financing need for planning period 6 years (2022-2027):</td><td>97 000 – 320 000 EUR (taking into account the Lower and Upper bound of the costs).</td></tr>
<tr><td>Costs as share of county yearly budget, %</td><td>
<table>
<tr><th>Budget[1] / Costs</th><th>Lower bound</th><th>Upper bound</th></tr>
<tr><td>Largest budget</td><td>0.02</td><td>0.09</td></tr>
<tr><td>Moderate budget</td><td>0.06</td><td>0.25</td></tr>
<tr><td>Lowest budget</td><td>0.31</td><td>1.19</td></tr>
</table>
[1] Used data on yearly county budget: Lowest 2.4 mil, Average 11.5, Highest 31 mil EUR per year.</td></tr>
<tr><td>Assessment category
(1 High, 2 Moderate, 3 Low costs)</td><td>Low-Moderate (2.5)</td></tr>
</table>

M2 Demolishing a dam used for energy production

Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	Technical costs for demolishing a dam: the used range **40 000 – 300 000 EUR**. (Source: based on experience in Estonia.) *According to Estonian experience it may cost 20 000 – 4 000 000 EUR, commonly the costs are 1/2 – 2/3 of the cost of fish pass.* The costs are annualised to calculate costs per year using: - discount rate 5.5 % (4-5.5 % for sensitivity analysis); - lifetime of a measure 100 years (50 years for sensitivity analysis).
Financial: One-off costs	Costs of technical feasibility study (incl. construction plan, permit): **15 000 – 50 000 EUR**. Annualised over 100 lifetime.
Financial: Yearly maintenance and operation (O&M) costs	No such costs
Financial: Other costs	Monitoring costs: **4000 EUR/y, for 3 years** (12 000 EUR in total). (Source: LEGMC)
Opportunity costs – compensation for expropriation of private property	Foregone revenues (lost future opportunities), estimated with two approaches: 1) **MIN** – compensating value of private property(ies) based on official cadastral value. All buildings of 5 HPPs are registered in official cadastre (value 2000-10000 EUR), but not the dams. Staicele dam is registered with 44 000 EUR cadastral value (no energy production on this dam). **2) MAX** – compensating foregone revenues for 10 years of possible economic activity (electrical energy production is assumed as possible activity). Input data on yearly revenues of HPPs: Lowest revenues 9800, Highest revenues 243 000 EUR per year.

<table>
<tr><td>Induced costs (to other actors)</td><td>Lost welfare for up-stream uses, costs for strengthening construction of the road (over dam) or building a bridge. Costs are not estimated.</td></tr>
<tr><td>Significant input parameters, which create variability in the costs</td><td>3. Compensation for foregone revenues (large range of foregone revenues).
4. Range of financial costs (investment and study costs).</td></tr>
<tr><td>Total annualized costs per year, EUR:</td><td>With MIN Opportunity costs approach: 4 500 – 25 000 EUR per year (the Lower and Upper bound of the costs).
With MAX Opportunity costs approach: 8 000 – 155 000 EUR per year (the Lower and Upper bound of the costs).
Note. Induced costs are not estimated.</td></tr>
<tr><td>Total estimated financing need for planning period 6 years (2022-2027):</td><td>With MIN Opportunity costs approach: 69 000 – 400 000 EUR (taking into account the Lower and Upper bound of the costs).
With MAX Opportunity costs approach: 165 000 – 2 840 000 EUR (taking into account the Lower and Upper bound of the costs).
Note. Induced costs are not estimated.</td></tr>
<tr><td>Costs as share of county yearly budget, %</td><td>MIN option (with MIN opportunity costs):
<table>
<tr><th>Budget[1] / Costs</th><th>Lower bound</th><th>Upper bound</th></tr>
<tr><td>Largest budget</td><td>0.01</td><td>0.08</td></tr>
<tr><td>Moderate budget</td><td>0.04</td><td>0.22</td></tr>
<tr><td>Lowest budget</td><td>0.18</td><td>1.04</td></tr>
<tr><td><i>Alojas county (Staicele dam)</i></td><td><i>0.12</i></td><td><i>0.52</i></td></tr>
</table>
MAX option (with MAX opportunity costs):
<table>
<tr><th>Budget[1] / Costs</th><th>Lower bound</th><th>Upper bound</th></tr>
<tr><td>Largest budget</td><td>0.03</td><td>0.5</td></tr>
<tr><td>Moderate budget</td><td>0.07</td><td>1.4</td></tr>
<tr><td>Lowest budget</td><td>0.34</td><td>6.5</td></tr>
<tr><td><i>Alojas county (Staicele dam)</i></td><td><i>0.17</i></td><td><i>3.2</i></td></tr>
</table>
Note. Induced costs are not estimated (foregone benefits for up-stream uses, costs for roads).
[1] Used data on yearly county budget: Lowest 2.4 mil, Average 11.5, Highest 31 mil EUR per year, 4.87 mil EUR for Alojas county.</td></tr>
<tr><td>Assessment category
(1 High, 2 Moderate, 3 Low costs)</td><td>Low-High (2)
Based on MIN Opportunity costs (compensating cadastral value) – Low costs (3) for all cases, except for Lowest budget county with Upper bound of the costs.
Based on MAX Opportunity costs (compensating foregone revenues from energy production) – Low-High costs (2) depending on size of Opportunity costs.
Note. Induced costs are not estimated.</td></tr>
</table>

M3 Opening migration way during spawning period

Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	Investment costs of modifying sluice: **15 000 EUR** (Source: Expert judgement.) The costs are annualised to calculate costs per year using: - discount rate 5.5 % (4-5.5 % for sensitivity analysis); - lifetime 30 years (20 years for sensitivity analysis). (Source: assumption – the same as for fish passes.)
Financial: One-off costs	No such costs.
Financial: Yearly maintenance and operation (O&M) costs	Costs of personnel for operating sluice: **1700 EUR per year**. Average personnel costs in Latvia (wage data from CSB) 1400 EUR/month x 6 month (spawning

<table>
<tr><td></td><td>period) x 0.2 workload.</td></tr>
<tr><td>Financial: Other costs</td><td>Monitoring costs: 4000 EUR/y, for 3 years (12 000 EUR in total).</td></tr>
<tr><td>Opportunity costs (lost revenues)</td><td>No such costs.</td></tr>
<tr><td>Induced costs (to other actors)</td><td>Lost welfare for recreational angling due to decreasing impoundment in spawning period. Assumed no negative impact on other uses (e.g. near water recreation, fish farming).
Costs are not estimated.</td></tr>
<tr><td>Significant input parameters, which create variability in the costs</td><td></td></tr>
<tr><td>Total annualized costs per year, EUR:</td><td>4 500 – 5 000 EUR per year (the Lower and Upper bound of the costs).
Note. Induced costs are not estimated.</td></tr>
<tr><td>Total estimated financing need for planning period 6 years (2022-2027):</td><td>37 000 EUR (taking into account the Lower and Upper bound of the costs).
Note. Induced costs are not estimated.</td></tr>
<tr><td>Costs as share of county yearly budget, %</td><td>
<table>
<tr><th>Budget[1] / Costs</th><th>Lower bound</th><th>Upper bound</th></tr>
<tr><td>Largest budget</td><td>0.01</td><td>0.02</td></tr>
<tr><td>Moderate budget</td><td>0.04</td><td>0.04</td></tr>
<tr><td>Lowest budget</td><td>0.19</td><td>0.20</td></tr>
</table>
[1] Used data on yearly county budget: Lowest 2.4 mil, Average 11.5, Highest 31 mil EUR per year.</td></tr>
<tr><td>Assessment category
(1 High, 2 Moderate, 3 Low costs)</td><td>Low (3)
Note. Induced costs are not estimated.</td></tr>
</table>

4.6 Detailed results for Latvia on the evaluation of the measures for lakes with accumulated nutrient pollution in sediments

4.6.1 Environmental impacts of the measures (Criterion 1-3)

Table 4.22 summarises the assessments concerning the environmental impacts of the measures covered by the Criteria 1-3. Detailed results on the assessments for the Criteria 1 and 3 are provided in chapter 4.6.5.

Table 4.22. The prepared assessments for the environmental impacts (Criteria 1-3) of the analysed additional measures for lakes with accumulated nutrient pollution. *(Source: An assessment by the project's experts (LEGMC).)*

The used assessment categories and corresponding scores:

C1 Effectiveness of a measure: 0 no effect, 1 Low, 2 Moderate, 3 High effectiveness.

C2 Certainty of the Effectiveness assessment: 1 Low, 2 Moderate, 3 High certainty.

C3 Negative adverse environmental impacts from implementing a measure: 0 High, 1 Moderate, 2 Low, 3 No negative impact.

The analysed additional measures	C1 Effectiveness	C2 Certainty	C3 Negative impact
M1 Sediment dredging	High (3)	High (3)	Moderate (1)
M2 Removal of macrophytes	Low (1)	High (3)	Low (2)
M3 Immobilization of phosphorus using chemical treatment	Moderate-High (2.5)	Moderate (2)	Moderate (1)
M4 Artificial aeration and mixing	Low-Moderate (1.5)	Low-Moderate (1.5)	Moderate (1)

The analysed additional measures	C1 Effectiveness	C2 Certainty	C3 Negative impact
M5 Biomanipulation	Moderate (2)	Moderate-High (2.5)	Low-Moderate (1.5)
M6 Hypolimnetic withdrawal	Moderate (2)	Moderate (2)	Moderate (1)
M7 Artificial floating wetlands	Low (1)	Moderate (2)	No impact (3)

The effectiveness is assessed as “high” only for the measure *M1 Sediment dredging*. It has also “high” certainty of the effectiveness assessment, and “moderate” negative environmental impact (temporal). The effectiveness is also quite high for *M3 Immobilization of phosphorus using chemical treatment* with “moderate” certainty of this assessment and “moderate” negative environmental impact. The measures M5-M6 have “moderate” effectiveness with various certainties of this assessment and low to moderate negative environmental impacts. The effectiveness of M7 was assessed with caution as “low” due to limitations in information for assessing the actual expected effect, hence also the certainty of this assessment is “moderate”. Effectiveness is assessed as “low” also for the measure M2 with “high” certainty of this assessment.

The lowest certainty of the effectiveness assessment is indicated for M3, M4, M6 and M7 – these measures need targeted, lake-specific scientific studies for improving knowledge about the expected effectiveness before proposing their implementation.

Concerning the possible negative environmental impacts, they are expected considerable for most measures, except M7 with no such impact, M2 with “low” and M5 with “low” to “moderate” negative impact.

Based on the effectiveness assessment it can be concluded that only M1 could ensure achievement of GES (besides with high certainty). All other measures might bring partial achievement of GES. The next best measure is M5 with “moderate” effectiveness and quite high certainty of this assessment, besides rather low negative adverse impacts. The measure M2 on it’s own cannot be considered as realistic option for achieving GES due to its low effectiveness. A combination of the measures M1, M2 and M5 could be proposed for the Burtnieku lake after more detailed scientific studies for the lake to determine specific lake areas where each measure would have the highest effect.

4.6.2 Costs of the measures

Table 4.23 summarises the assessments concerning the costs of the measures (Criterion 4). The costs were estimated quantitatively for the measures M1, M2 and M5, and they were compared to yearly municipal budgets to assign the qualitative assessment category and score (according to the approach described in chapter 4.3.4). Detailed results on the quantitative cost estimates are provided in chapter 4.6.5. The costs are considered as “high” if they exceed 1 % of yearly municipal budget.

Costs for other measures were assessed with the qualitative categories based on expert judgement which was based on review of literature, analysis of relevant cost types and comparing this information with the measures with the quantitative cost estimates (M1, M2, M5).

For the quantitative cost estimates, to account possible variations in the costs and uncertainty, the cost estimates are developed as intervals (see the second column in the table). The lower and upper bounds of the intervals are calculated based on possible cost range for input estimates for the financial costs. Hence also the qualitative assessment categories can form intervals (see the third column in the table). Another reason for the intervals of the categories is related to differences in size of municipal budgets.[29]

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[29] Data on yearly municipal budgets of all counties in the project area are used. The budgets range from 2.5 to 31 million EUR per year. The “average” budget is calculated as an average from all counties. Also, budget for the Burtnieku county is used for the analysis (8.5 million EUR).

It should be stressed that the magnitude of the costs depends highly on size of a lake. The quantitative estimates are calculated assuming relevant characteristics of the Burtnieku lake (including its size), which is the fourth largest lake in Latvia. [30] The costs would be lower for smaller lakes. But also size of counties in terms of yearly municipal budgets, against which the costs are compared, vary considerably.[31]

Table 4.23. The prepared assessments for the costs (Criterion 4) of the analysed additional measures for lakes with accumulated nutrient pollution. *(Source: Estimates prepared as part of the project.)*

The used assessment categories and corresponding scores: High 1, Moderate 2, Low 3 costs.

* The quantitative cost estimates are developed for the Burtnieku lake. The costs would be lower for smaller lakes.

** The cost estimate do not included "induced costs"

The analysed additional measures	Annualised costs per year*	Assessment categories and scores
M1 Sediment dredging	**1 – 2.8 mil EUR/y****	**High (1)**
M2 Removal of macrophytes	**5 000 – 16 000 EUR/y**	**Low (3)**
M3 Immobilization of phosphorus using chemical treatment	Not estimated	**High (1)**
M4 Artificial aeration and mixing	Not estimated	**High (1)**
M5 Biomanipulation	**85 000 – 155 000 EUR/y****	**Moderate-High (1.5)** Low for large budget county, High for small budget county, Moderate-High for Burtnieku county (depending on actual size of the financial costs).
M6 Hypolimnetic withdrawal	Not estimated	**High (1)**
M7 Artificial floating wetlands	Not estimated	**High (1)**

The costs are "high" and they exceed the "high" cost threshold considerably for all analysed measures except M2 and M5. The measure *M2 Removal of macrophytes* has "low" costs. But costs should be considered together with effectiveness of a measure (which is also "low" for M2).

The measure *M5 Biomanipulation* has "moderate-high" costs. The cost estimate is prepared considering the Burtnieku lake, for smaller lakes the costs could be lower. And the estimate is compared with various yearly municipal budgets. If such a large lake was located in a small county, the costs are "high", but they are "low" for a large budget county. Assuming budget of the Burtnieku county the costs are below "high" costs threshold (1 % of the yearly municipal budget) only with lower bound of the costs. Since "induced" costs are not estimated and included, it is likely that the costs exceed the "high" cost threshold.

It can be concluded overall:

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[30] The only lake in the project area failing GES due to the given environmental problem (accumulated P in sediments).

[31] The costs are compared with the budgets of counties with Highest and Lowest yearly budgets in the project area, as well as the budget of the Burtnieku county.

- There is limited number of measures available for addressing the environmental problem with affordable cost level.
- From the analysed measures *M2 Removal of macrophytes* has low costs, but at the same time it does not provide solution for the environmental problem.
- Costs of *M5 Biomanipulation*, if assuming the Burtnieku lake and size of the Burtnieku county budget, could be affordable with some financial support.
- Affordability of the costs depends on characteristics of a lake (including its size) and budget size of a county where it is located. These relevant parameters need to be considered when using these results for other WBs.

4.6.3 Constraints/obstacles of implementation

Table 4.24 summarises the assessments concerning the constraints/obstacles of implementation of the measures (Criterion 5). The constraints are assessed as "high" for the measures M1, M3, M4 and M6. They could be seen as "moderate" for M5, "low" to "moderate" for M7 and negligible for M2.

Table 4.24. The prepared assessments for the constraints/obstacles of implementation (Criterion 5) of the analysed additional measures for lakes with accumulated nutrient pollution. *(Source: An assessment by the project's experts.)*

The used assessment categories and corresponding scores: High 0, Moderate 1, Low 2, No 3 constraints/obstacles.

The analysed additional measures	Description of possible constraints/obstacles and assessment categories and scores
M1 Sediment dredging	Institutional: Acceptability of stakeholders, users of a lake. Legal: Legal procedures and approval (EIA procedure). Financial: Lack of financial support instruments (in light of high costs). **High (0)**
M2 Removal of macrophytes	Institutional: No specific constraints. Legal: No specific constraints. Financial: Possible limitations in financial support instruments (although, the costs are relatively low). **No-Low (2.5)**
M3 Immobilization of phosphorus using chemical treatment	Institutional: Acceptability of stakeholders, users of a lake. Legal: Legal procedures and approval (EIA procedure). Financial: Lack of financial support instruments (in light of high costs). **High (0)**
M4 Artificial aeration and mixing	Institutional: Acceptability of stakeholders, users of a lake. Legal: Legal procedures and approval (EIA procedure). Financial: Lack of financial support instruments (in light of high costs). **High (0)**
M5 Biomanipulation	Institutional: Acceptability of stakeholders, users of a lake. Legal: Legal procedures and approval (EIA procedure). Financial: Lack of financial support instruments (in light of considerable costs). **Moderate (1)**

The analysed additional measures	Description of possible constraints/obstacles and assessment categories and scores
M6 Hypolimnetic withdrawal	Institutional: Acceptability of stakeholders, users of a lake. Legal: Legal procedures and approval (EIA procedure). Financial: Lack of financial support instruments (in light of high costs). **High (0)**
M7 Floating treatment wetlands	Institutional: No specific constraints. Legal: Legal procedures and approval (EIA procedure). Financial: Lack of financial support instruments (in light of high costs). **Low-Moderate (1.5)**

4.6.4 Summary assessment

Table 4.25 provides summary assessment for the analysed measures for lakes with accumulated nutrient pollution in sediments. Table 4.26 provides the summary assessment when considering only the effectiveness and costs (cost-effectiveness assessment) and excluding other criteria.

The measures are ordered in the tables starting with the measure with the highest summary score. However this ordering should not be taken as strict ranking because the assessment approach is rather rough to be used for strict ranking.

Table 4.25. Summary assessments for the analysed additional measures for lakes with accumulated nutrient pollution. *(Source: Assessments prepared as part of the project.)*

The analysed additional measures	C1 Effectiveness	C2 Certainty	C3 Negative impact	C4 Costs	C5 Constraints	Summary score
M2 Removal of macrophytes	Low (1)	High (3)	Low (2)	Low (3)	No-Low (2.5)	**11.5**
M5 Biomanipulation	Moderate (2)	Moderate-High (2.5)	Low-Moderate (1.5)	Moderate-High (1.5)	Moderate (1)	**8.5**
M7 Artificial floating wetlands	Low (1)	Moderate (2)	No impact (3)	High (1)	Low-Moderate (1.5)	**8.5**
M1 Sediment dredging	High (3)	High (3)	Moderate (1)	High (1)	High (0)	**8**
M3 Immobilization of phosphorus using chemical treatment	Moderate-High (2.5)	Moderate (2)	Moderate (1)	High (1)	High (0)	**6.5**
M6 Hypolimnetic withdrawal	Moderate (2)	Moderate (2)	Moderate (1)	High (1)	High (0)	**6**
M4 Artificial aeration and mixing	Low-Moderate (1.5)	Low-Moderate (1.5)	Moderate (1)	High (1)	High (0)	**5**

Table 4.26. Summary assessment of the analysed measures when considering only the effectiveness and costs (cost-effectiveness analysis) and excluding other criteria.

The analysed additional measures	Summary score
M1 Sediment dredging	**4**
M2 Removal of macrophytes	**4**
M5 Biomanipulation	**3.5**
M3 Immobilization of phosphorus using chemical treatment	**3.5**
M6 Hypolimnetic withdrawal	**3**
M4 Artificial aeration and mixing	**2.5**
M7 Artificial floating wetlands	**2**

The measures M3, M4, M6 and M7 are not proposed further as options due to their limited effectiveness in combination with uncertainty in the effectiveness assessment and high costs. M1 Sediment dredging also could not be seen as realistic option due to too high costs (in particular, if considering such a large lake as the Burtnieku lake). Hence possible options include the measures M2 and M5.

Based on the effectiveness assessment it can be concluded that only M1 could ensure achievement of GES (besides with high certainty). All other measures might bring partial achievement of GES. The next best measure is M5 and with "moderate" effectiveness and quite high certainty of this assessment, besides rather low negative adverse impacts. The measure M2 cannot be considered as realistic option for achieving GES due to its low effectiveness.

The summary assessment and prioritisation change when considering only the effectiveness and costs (cost-effectiveness assessment) and excluding other criteria. It gives considerably higher priority for M1 (although the costs are "high", also the effectiveness is the highest). At the same time the measures M7 gets lower priority because of the "low" effectiveness achieved with "high" costs.

It can be concluded overall that there is a very limited number of measures available for addressing the given environmental problem with affordable cost level. From the analysed measures *M2 Removal of macrophytes* has low costs, but at the same time it does not provide solution for the environmental problem. Costs of *M5 Biomanipulation*, if assuming the Burtnieku lake and size of the Burtnieku county budget, could be affordable with some financial support. Affordability of the costs depends on characteristics of a lake (including its size) and budget size of a county where it is located.

It can be concluded that the measures, which should be investigated further, are *M5 Biomanipulation*, *M1 Sediment dredging* and *M2 Macrophyte removal* in combination, as there is no single measure that would provide achievement of GES with affordable costs. Assuming the Burtnieku lake with its large size, the costs for the highly effective measure M1 would be too high. The measure M5 could be to some extent affordable but there is uncertainty whether it alone would provide achievement of GES. The measure M2 can be considered due to its low costs but the achieved state improvement would be very limited. The main criteria which need further investigation is the effectiveness – whether the measures would ensure achievement of GES, and costs since the prepared assessments are rather rough. Further investigations are needed to assess possible combined effect of measures. The costs are expected to be high, in particular for such large lake as the Burtnieku lake, and financial support would be needed for implementing measures. Hence, also further studies could be suggested to look for additional (not considered in this study) possible measures for addressing the given environmental problem.

4.6.5 Detailed results for each measure

In this chapter detailed results are included concerning (i) descriptions of the measures; (ii) assessments of the effectiveness and negative adverse environmental impacts (Criteria 1 and 3) and (iii) quantitative cost estimates.

Descriptions of the measures

1. **Sediment dredging:** Measure includes mechanical removal of sediments from the lake bed. Near the coast it is possible to remove the sediments using dredger (excavator), but for most of the lake area cutter and suction dredger would need to be used – appliances designed to dislodge sediments by cutting them, remove by suction through pipes and dispose in collection containers. A ship/ boat could be needed to carry out the works. Correct disposal of removed sediments needs to be arranged.
2. **Removal of macrophytes:** Measure includes cutting and removing macrophytes from lake. It can be done by using aquatic mowers and collection containers attached to boats or by using specially designed aquatic weed harvesters. Macrophytes use available nutrients to grow, cutting them and removing from lake removes secondary useable nutrients (nutrients remaining in lake from decomposing plant matter).
3. **Immobilization of phosphorus using chemical treatment:** Technical measure that includes addition of certain chemical compounds to the lake water, to facilitate sorption of phosphorus, leading to a reduction of biologically available phosphorus. Aims to create non-soluble phosphorus compounds on the ground of lake bed. Various chemicals possess the capacity to reduce bioavailability of phosphorus, such as iron, aluminium, calcium and specially developed composite materials, such as *Phoslock*. Measure also includes scientific case-studies, careful evaluation and ongoing monitoring to avoid adverse effects. Addition of aluminium as alum - concentrated liquid alum is added to lake water from boats. Addition of calcium - calcite or lime dispersed over the lake in powdered form, can be dispersed from air (from a plane or helicopter). Addition of Phoslock - Phoslocsk^{TM} is a brand of phosphorus binding chemicals, made of lanthanum modified bentonite clay powder. Dispersed in water from boats.
4. **Artificial aeration and mixing:** Artificial aeration is a technical measure to increase oxygen concentration in hypolimnion, to prevent deep water anoxia and the consequent accelerated internal loading of phosphorus during stratification. Artificial aeration could also lead to improvements in redox potential and immobilisation of phosphorus by sorption on iron, as well as enhance the distribution of fish and invertebrates. Carried out as either injection of oxygen or atmospheric air into the hypolimnion or with use of full-lift aerators, bringing oxygenated water from surface to hypolimnion. [2] Measure would require monitoring of oxygen consumption and possibly gradual increase in aeration.
5. **Biomanipulation:** The measure aims to change dominating fish species in lake to decrease amount of cyprinid fish species, e.g. roach (rauda – latv., *Rutilus rutilus*), bream (plaudis – latv., *Abramis brama*) etc., and increase species of predatory fish (pike (līdaka – latv., *Esox Lucius L.*), pike-perch (zandarts – latv., *Stizostedion lucioperca (L.)* etc.). Cyprinid fish that eat zoobenthos loosen up sediments in the process, causing phosphorus to leach from sediments into water column. Also population of large zooplankton (e.g. *Daphnia)* can be enhanced by eliminating planktivorous fish (fish that feed on planktonic food, including zooplankton or phytoplankton) through physical removal (fishing) or increased piscivory (introduction of fish eating species). Measure can include both increased targeted fishing of cyprinid fish and increase of piscivory fish populations. In order to increase predatory fish populations restrictions on predatory fish fishing can be set, also - predatory fish populations can be increased artificially.

6. **Hypolimnetic withdrawal:** Lakes tend to stratify or form layers based on temperature, density and other characteristics. The lowest layer that comes into contact with the sediment, or the hypolimnion, often contains higher phosphorus concentrations when the lake is stratified. This remediation technique involves selectively removing the nutrient-enriched layers of water from the lake through siphoning, pumping or selective discharge. Hypolimnetic withdrawal shortens nutrient retention time, decreases the chance for anaerobic conditions to develop, accelerates phosphorus export, reduces surface phosphorus concentration, and improves hypolimnetic oxygen content.
7. **Floating treatment wetlands:** Wetlands rely on natural processes to biologically filter water as it passes through areas of dense aquatic vegetation and permeable bottom soils. Floating treatment wetlands are composed of an artificial platform that serves as a growing base for macrophytes. The primary mechanisms for nutrient removal are microbial transformation and uptake, macrophyte nutrient assimilation, absorption into organic and inorganic substrate materials and volatilization. Additional effect can be achieved if macrophytes are removed (cut) once or twice per vegetation season.

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[1] Kuha, J., Palomäki, A. H., Keskinen, T., & Karjalainen, J. (2016). Negligible effect ofhypolimnetic oxygenation on the trophic state of Lake Jyväsjärvi, Finland.Limnologica, 58, 1-6. doi:10.1016/j.limno.2016.02.001

[2] M.R., Davy A.J. (eds.), 2002. Handbook of ecological restoration. ISBN 0521791286 (461s)

[3] Kimberly Lewtas, Dimple Roy, Michael Paterson, 20016. Manitoba Prairie Lakes: In-lake remediation treatment summary. International Institute for sustainable development.

Assessments on effectiveness and negative adverse environmental impacts

A1 Sediment dredging	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Decreasing of Phosphorus amount	Measure highly effective, as it aims to completely remove the accumulated pollution and has the potential to restore GES, failing due to nutrient pollution. Long lasting effects if incoming nutrient pollution is prevented. *Score:* **high, 3**
C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	Mechanical damage to habitats, fauna and flora – temporarily lowering biological quality of lake. Removal of benthic organisms together with sediments. It is essential to isolate the area of sediment dredging, otherwise some temporary negative effects could be present, such as higher concentrations of nutrients, organic and particulate matter in water during the removal of sediments. *Score:* **moderate, 1**

A2 Removal of macrophytes	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Decreasing of Phosphorus amount	It is essential to not cut and remove too much, as it could have a reverse effect – during the growth plants use up nutrients that are available. It may take very long time to show results if accumulated pollution is extensive

	– measure is not highly effective. According to a survey during 3 years conducted in Sweden, results showed average mean reductions of 0.5 g N m^{-2} d^{-1} and 0.04 g P m^{-2} d^{-1}. Harvested biomass contained approximately 10% of removed nitrogen and 20% of removed phosphorus [1] For more effectiveness this measure can be combined with other measures. *Score:* **low, 1**
C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	Some fish, invertebrates, bird nests and other fauna might be removed from lake when removing macrophytes, however this adverse effect might be insignificant, as macrophyte removal could increase the area of suitable habitats for both aquatic fauna and birds. *Score:* **low, 2**

[1] Ecological Engineering Volume 2, Issue 1, March 1993, Pages 49-6 (https://www.sciencedirect.com/science/article/abs/pii/092585749390026C)

A3 Chemical treatment	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Decreasing of Phosphorus amount	**Addition of aluminium as liquid alum -** effects can last up to 20 years. Effective in a small range of pH values (7-8). **Addition of calcium –** more effective if added as lime, less effective if added as as calcite. Not suitable for lakes with high pH level (above 8) **Addition of Phoslock** - suitable lake conditions for effective application: Lake size: 0.9–64 hectares, mean depth: 1.6–8.8 m, max depth: 2.5–34 m. Suitable in wide range of pH conditions. *Score:* **moderate - high, 2.5**
C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	Depending on choice of chemical immobilisation of phosphorus and lake specific conditions various adverse effects may occur, including increased eutrophication and toxicity. To avoid adverse effects, scientific case-studies, careful evaluation and ongoing monitoring are important for this measure. **Addition of aluminium as alum -** depending on the dosage, alum treatment may elevate sulphate levels, reversing the lake back to eutrophic state. Aluminium toxicity risk, if lake pH falls below 6. **Addition of calcium -** calcium changes the pH level of lake and changes can have negative implications for biota. Hard-water lakes may be able to withstand calcium addition better, but measure may not be suitable for soft-water lakes - pH can raise above 11 in soft-water lakes. **Addition of Phoslock** – negative effects currently not known yet – not studied. *Score:* **moderate, 1.**

A4 Artificial aeration and mixing	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Decreasing of	Long-term studies suggest that aeration may not bring sufficient results in

Phosphorus amount	nutrient loading reduction due to oxygenation eventually not being sufficient to provide enough oxygen to hypolimnion. Oxygen consumption with aeration tends to increase over the time due to complex system of physical and biological processes [1]. More effective in presence of iron (see A.3. Chemical treatment) that can bind to phosphorus. *Score:* **low – moderate, 1.5.**
C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	Full-lift aerators and mixing of water column could lead to an increase in water temperatures in hypolimnion in summer and it could lead to lower temperatures and increase the extent of freezing in the lake in winter. Bringing nutrient rich water from hypolimnion to the surface could increase eutrophication. Ecosystem changes due to artificial aeration can't become self-sustaining, ecosystem becomes reliant on artificial oxygen inflow. Use of oxygen in hypolimnion may gradually increase. *Score:* **moderate, 1.**

[1] Gächter R., Wehrli B., Ten Years of Artificial Mixing and Oxygenation: No Effect on the Internal Phosphorus Loading of Two Eutrophic Lakes.

A5 Biomanipulation	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Decreasing of Phosphorus amount	According to surveys the effect of effective biomanipulation can lead to decrease of phosphorus per 20-30%, decrease of phytoplankton biomass per 30-50% [1]. To maintain the effect, biomanipulation needs to be done every year (projects with duration 10 – 20 years). Low survival of introduced fish can diminish effectiveness, as well as poor timing of fish stocking, insufficient number of fish removed, inedible algae species in lake (cyanobacteria). Lake parameters that impact effectiveness: - Lake size: In theory, there is no restriction on lake size, although lakes smaller than 25 hectares have had the highest percentage of success. Successful implementation in the literature ranged from 1.5–240 hectares. Very effective biomanipulation carried out in Lake Mendota (USA), area - 4,000 hectares. - Lake depth: Greatest probability to reduce algal biomass occurs in lakes less than 3 metres deep. Successful implementation from the literature review: 1.5–2.6 metres. - Phosphorus load: 1.0–14 kg hectare^{-1} year^{-1}. - Lakes with external P loadings below 0.6 g P m-2yr^{-1} have a higher probability for biomanipulation to reduce algal densities. - Total Phosphorus: Successful implementation in the literature range from 0.05–1.4 mg L^{-1}. - The recommended lake total phosphorus concentration is less than 100 µg L^{-1}. - Chlorophyll-*a*: 21–300 µg L^{-1}. - Successful implementation in the literature ranged from 80–116 µg L^{-1}. - Secchi depth: 0.9–2.9 metres. - Cyanobacteria – measure may not be effective when cyanobacteria

	present [2] *Score:* **moderate, 2**
C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	Changes in natural fish population, zoobenthos and phytobenthos populations. Long-term unsustainability of the fish populations, overstocking of piscivorous fish. *Score:* **low-moderate, 1.5**

A6 Hypolimnetic withdrawal	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Decreasing of Phosphorus amount	Effective in a wide range of conditions (Lake size: 1.5–400 hectares. Depth (mean): 3.0–48 metres. Depth (max.): 6.8–56 metres. Residence time: 0.26–9.0 years.). Most effective for deeper, stratified lakes with considerable internal loading or phosphorus release from sediments at the bottom of the lake. Withdrawal followed by treatment and discharge back to the lake is inefficient in removing phosphorus compared to in-lake treatment. *Score:* **Moderate, 2.**
C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	Potential warming of the lake as bottom waters are exposed to surface temperatures. Destabilization of the thermocline (distinct layer of water in which temperature changes rapidly with depth) and enable nutrients from the hypolimnion to become available for phytoplankton growth in the epilimnion (upper layer of water in a stratified lake). *Score:* **Moderate, 1.**

A7 7. Floating treatment wetlands	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Decreasing of Phosphorus amount	The size of the system is an indicator of effectiveness, where platform characteristics (design, size, macrophyte species) and specific lake characteristics (temperature, pH, phosphorus and nitrogen content, Chlorophyll-a) will determine nutrient reduction. Longevity: With relatively low maintenance and secured placement, FTWs will continuously sequester nutrient in the plant material. Harvesting material increases nutrient removal and longevity. *Score:* **Low, 1.**
C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and	Little to no adverse effects on lake quality mentioned in the literature.

summary score	*Score:* **No impact, 3.**

[1] Vides risinājumu institūts, 2015. *Burtnieka ezerā veiktā hidrobioloģiskā izpēte un ekosistēmas pieejā balstīts ezera praktiskas apsaimniekošanas plāns*. Vides risinājumu institūts.

[2] Kimberly Lewtas, Dimple Roy, Michael Paterson, 20016. *Manitoba Prairie Lakes: In-lake remediation treatment summary*. International Institute for sustainable development.

Quantitative cost estimates

M1 Sediment dredging

Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	Financial costs **7 EUR/m^3** (Source: estimate provided by EST experts). Amount of sediments (m^3) to be extracted: **3.2-4.8 milj m^3** (Source: Estimate for the Burtnieku lake) Surface area of lake 4000 ha multiplied by thickness of sediment layer to be extracted 0.2 m; assuming 40-60 % of the lake area with sediments to be extracted (based on available information and consultations with LU). **Note. This is estimate for the Burtnieku lake** (among the largest lakes in Latvia) The costs are annualised to calculate costs per year using: - discount rate 5.5 % (4-5.5 % for sensitivity analysis); - lifetime 50 years (20-50 years for sensitivity analysis) (Source: Expert judgement).
Financial: One-off costs	30 000 EUR costs of a technical feasibility (incl. sediment) study.
Financial: Yearly maintenance and operation (O&M) costs	No such costs.
Financial: Other costs	Costs of depositing sediments (if polluting substances' concentrations in sediments exceed standards, sediments must be deposited and NRT as for waste landfilling must be paid). It is not analysed whether this could be necessary. The costs are not estimated.
Opportunity costs (lost revenues)	No such costs.
Induced costs (to other actors)	Foregone income for commercial fisheries; lost welfare from recreational activities (angling, recreation); lost income for municipality – fishing licenses. For around 5 years. The costs are not estimated.
Significant input parameters, which create variability in the costs	1. Sediment amount m^3 to be extracted (the given estimate is for the Burtnieku lake, which is among the largest lakes in Latvia; uncertainty in the amount of m^3 the measure should be applied).
Total annualized costs per year, EUR:	**1 – 2.8 milj EUR per year (the Lower and Upper bound of the costs).** Estimate for the Burtnieku lake (the costs would be lower for smaller lakes). Without induced costs and financial costs of depositing (contaminated?) sediments.
Total estimated financing need for planning period 6 years (2022-2027):	**22.4 – 33.6 milj EUR (taking into account the Lower and Upper bound of the costs).** Estimate for the Burtnieku lake (the needed financing would be lower for smaller lakes). Without induced costs and financial costs of depositing (contaminated?) sediments.
Costs as share of county yearly budget, %	see below

Budget[1] / Costs	**Lower bound**	**Upper bound**
Highest budget	3.4	9.1
Burtnieku county budget	12	33
Lowest budget	43	117

Without induced costs and financial costs of depositing (contaminated?) sediments.

[1] Used data on yearly county budget: Lowest 2.4 mil, Highest 31 mil EUR per year; the Burtnieku county

	8.5 mil EUR.
Assessment category **(1 High, 2 Moderate, 3 Low costs)**	**High (1)**

M2 Removal of macrophytes

<table>
<tr><th>Types of the costs</th><th>Explanations and quantitative estimates</th></tr>
<tr><td>Financial: Investment costs</td><td>100 EUR per ha multiplied by number of ha (50-160 ha for Burtnieku lake). 5000 – 16 000 EUR per year.
Original cost estimate from WNF (has implemented the measure for Papes and Engures lakes) – 400 EUR for 4 ha per day. Renting the equipment (together with personnel), from non-profit organisation.
For the number of ha (50-160 ha) – assumption/estimate for Burtnieku lake (source: earlier studies for Burtnieku lake, literature).</td></tr>
<tr><td>Financial: One-off costs</td><td>No such costs.</td></tr>
<tr><td>Financial: Yearly maintenance and operation (O&M) costs</td><td>No such costs (renting of the existing equipment is assumed, the costs per ha include all the financial costs).</td></tr>
<tr><td>Financial: Other costs</td><td>No such costs.</td></tr>
<tr><td>Opportunity costs (lost revenues)</td><td>No such costs.</td></tr>
<tr><td>Induced costs (to other actors)</td><td>No such costs.</td></tr>
<tr><td>Significant input parameters, which create variability in the costs</td><td>1. No of ha for a concrete lake for the financial costs (the given estimate is for the Burtnieku lake, which is among the largest lakes in Latvia; large interval comes from uncertainty to how many ha the measure should actually be applied).</td></tr>
<tr><td>Total annualized costs per year, EUR:</td><td>5 000 – 16 000 EUR per year (the Lower and Upper bound of the costs).
Estimate for the Burtnieku lake (the costs would be lower for smaller lakes).</td></tr>
<tr><td>Total estimated financing need for planning period 6 years (2022-2027):</td><td>30 000 – 96 000 EUR (taking into account the Lower and Upper bound of the costs).
Estimate for the Burtnieku lake (the needed financing would be lower for smaller lakes).</td></tr>
<tr><td>Costs as share of county yearly budget, %</td><td>
<table>
<tr><th>Budget[1] / Costs</th><th>Lower bound</th><th>Upper bound</th></tr>
<tr><td>Highest budget</td><td>0.02</td><td>0.1</td></tr>
<tr><td>Burtnieku county budget</td><td>0.1</td><td>0.2</td></tr>
<tr><td>Lowest budget</td><td>0.2</td><td>0.7</td></tr>
</table>
[1] Used data on yearly county budget: Lowest 2.4 mil, Highest 31 mil EUR per year; the Burtnieku county 8.5 mil EUR.</td></tr>
<tr><td>Assessment category
(1 High, 2 Moderate, 3 Low costs)</td><td>Low (3)</td></tr>
</table>

M5 Biomanipulation

Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	No such costs.
Financial: One-off costs	**10 000 EUR** costs of a technical feasibility study (divided by 6 years – policy cycle for estimating costs per year). (Source: Expert judgement.)
Financial: Yearly maintenance and operation (O&M) costs	Financial costs of implementing the measure, including costs for targeted fishing of certain (predator) fish species. **80 000 – 150 000 EUR per year**. The measure needs to be implemented continuously. (Source: Expert judgement, based on information from studies/literature.)
Financial: Other costs	Monitoring costs: **4000 EUR per year, for 5 years** (20 000 EUR in total)
Opportunity costs (lost	No such costs.

revenues)	
Induced costs (to other actors)	Foregone income/welfare loss due to limiting fishing of predatory fish: foregone revenues for commercial fisheries; lost welfare from recreational angling; lost income from fishing licenses. The measures may create the “induced costs” in the short-run due to restriction for fishing predatory fish species, which commonly make the largest part of catch. However, in the long run these costs could decrease or be minimised if fishermen switch to fishing other species and markets are created for using “less valuable” fish species. Moreover, economic benefits could accrue in the long-run from improved state and productivity of a lake. The costs are not estimated.
Significant input parameters, which create variability in the costs	Magnitude of the financial costs (range).
Total annualized costs per year, EUR:	**85 000 – 155 000 EUR per year (the Lower and Upper bound of the costs).** Note. Induced costs are not estimated.
Total estimated financing need for planning period 6 years (2022-2027):	**510 000 – 930 000 EUR (taking into account the Lower and Upper bound of the costs).** Note. Induced costs are not estimated.
Costs as share of county yearly budget, %	see table below Note. Induced costs are not estimated. [1] Used data on yearly county budget: Lowest 2.4 mil, Highest 31 mil EUR per year; the Burtnieku county 8.5 mil EUR.
Assessment category **(1 High, 2 Moderate, 3 Low costs)**	**Moderate-High (1.5)** Low for large budget county, High for small budget county, Moderate-High for Burtnieku county. Note. Induced costs are not estimated.

Budget[1] / Costs	**Lower bound**	**Upper bound**
Highest budget	0.3	0.5
Burtnieku county budget	1.0	1.8
Lowest budget	3.5	6.4

4.7 Results for Estonia on the evaluation of the measures for dams, impoundments and lakes

4.7.1 Environmental state parameters used for assessing effectiveness of measures

Table 4.27. Environmental state parameters used for assessing the effectiveness of the additional measures for Estonia.

Water uses and pressures causing failure of GES	Environmental state parameters used for assessing effectiveness of the measures
dams used by small HPPs for energy production creating hydro-morphological pressures	**P1 Obstacle for fish migration, disruption of river continuity** (as indicator under WFD). Presence of obstacle for fish migrating (Yes/No). Gap scale: a) free fish passage guaranteed, b) good and safe conditions for both up- and downstream migration, c) up- or downstream migration partly obstructed, d) fish passage up- or downstream obstructed (not possible) **P2 Hydro-morphological quality of river** a) remarkable improvement of hydro-morphological quality, b) moderate improvement of hydro-morphological quality, c) minor improvement of hydro-morphological quality,

	d) no improvement of hydro-morphological quality. **P3 Improvement of fish index** a) remarkable improvement of River Fish Index, b) moderate improvement of River Fish Index, c) minor improvement of River Fish Index, d) no improvement of River Fish Index. **P4 Objectives of Habitats directive.** Whether it improves the status or not. a) remarkable improvement of current conservation status, b) moderate improvement of current conservation status, c) minor improvement of current conservation status, d) no improvement of current conservation status.
obstacles/impoundments with other/no use creating hydro-morphological pressure	**P1 Obstacle for fish migration, disruption of river continuity** (as indicator under WFD). Presence of obstacle for fish (Yes/No). **P2 Hydro-morphological quality of river** **P3 Improvement of fish index** **P4 Objectives of Habitats directive.** Whether it improves the status or not.
lakes with accumulated past nutrient pollution in sediments	**P1 Macrophytes.** Improvement in macrophytes status. **P2 Macroinvertebrates.** Improvement in macroinvertebrates status. **P3 Fish.** Improvement in fish status.

In Estonia an inventory of dams was carried out in 2012-2013 to determine importance of each obstructed WB for fish migrations. Based on this inventory we know where we have to open dams for fish migration, where it is not necessary and where there is no good solution for opening the dam. Since then we have better knowledge about dams and fish passes and today there are over 100 dams/obstacles in Estonian rivers where we have made already a fish pass or demolished the dam. The list of additional measures builds on this experience.

There are some differences regarding “gap” parameters used in Latvia and in Estonia. In Estonia River Fish Index is used instead of ecological flow which is used in Latvia. In Latvia the calculated fish index doesn’t fully assess hydro-morphological alterations, instead it indicates eutrophication impact. Ecological flow is not used in Estonia. In Estonia River Fish Index is calculated based on monitoring results, showing the status of fish fauna.

In Estonia we don´t calculate the river length opened for fish migration as a parameter for GES, but it is a factor that influences whether a fish pass is needed or not for a certain dam. In Estonia, overall dam inventory was conducted in 2012-2013. Totally about 1000 dams were involved. During the inventory, importance of fish passage and technical possibilities of building a fish passage were analysed for each dam. Optimal solutions were proposed to ensure fish migration in dams where fish passage is needed.

Objectives of WFD and Habitats directive are closely related. Improving the ecological status of a river favours also the achieving favourable conservation status of protected habitats and species. In Koiva river basin most of dams, where fish passage is needed, situate in rivers designated also as Natura 2000 areas. Therefore in Koiva river basin achieving objectives of Habitats directive is also one parameter of the gap. In protected salmonid rivers and Natura Rivers the disturbing of the natural water flow is also prohibited by law.

In Estonia, for estimating the ecological status, we use a principle (harmonized in EU), where all used parameters have equal weight. Phosphorus is used as one parameter in quality element of abiotic water properties, but phosphorus is just one characteristic and it does not play decisive role. In fact, the content of phosphorus in our selected lakes is not a problematic quality parameter. Status of these lakes is based on results of biotic elements.

4.7.2 Additional measures included in the evaluation

The additional measures included in the assessment are listed in Table 4.28.

It should be noted concerning the measures for dams used by small HPPs and other obstacles/impoundments that the measure M4 has limited applicability since this can be implemented only in case there is an existing fish pass. The main alternatives for the evaluation are M1-M3.

As prerequisite for all options of restoration concerning lakes with accumulated nutrient pollution in sediments, proper limnological investigations should be proceeded, especially external and internal loading, buffer capacity of a lake to that loading, inventory of biota, evaluation on of main factors influencing functioning efficiency of a lake.

Table 4.28. Identified additional measures evaluated by the MCA approach.

Measures for dams used by small HPPs for energy production creating hydro-morphological pressures
M1 Building of a fish pass
M2 Demolishing a dam
M3 Environmentally friendly turbine
M4 Improvement of an existing fish pass
Measures for obstacles/impoundments with other/no use creating morphological pressure
M1 Building of a fish pass
M2 Opening migration way during spawning period
M3 Demolishing a dam
M4 Improvement of an existing fish pass
Measures for lakes with accumulated past nutrient pollution in sediments
M1 Sediment dredging
M2 Removal of macrophytes
M3 Biomanipulation
M4 Complex methods (sediment dredging and macrophytes removal)

Some measures included in the evaluation for Latvia are not analysed for Estonia. The differences are explained below.

In Estonian side the measure *reconstruction or improvement of an existing fish pass* is a measure that essentially means *improvement of an existing fish pass*. This measure includes smaller improvements made to the fish pass. It doesn´t include reconstruction which means more likely changing the main structures. Also the costs are very different for improvement and reconstruction works.

Maintenance of an existing fish pass is a measure that is essentially the same as the measure *building of a fish pass* and therefore isn´t needed separately in this evaluation for Estonian side.

Since ecological flow is not used in Estonia, the measure of implementation of ecological flow was not evaluated.

Permanently lowering a dam is a measure that has very little effect on fish status in Estonia. Since the WBs in the Estonian side are mostly salmonid rivers and Natura 2000 habitats, which are protected by law, then this measure will not help to achieve any objectives. This option will be helpful when first step would be to lower the dam permanently (if possible) and secondly to build a fish pass. But just lowering the dam permanently will not open the free fish passage. It also does not help to achieve good ecological status and will not improve gap parameters. On the other hand, lowering the dam is also unacceptable for HPP owner, because it practically excludes hydroelectricity production.

Opening migration way during spawning period is a technical measure that basically could ensure fish passage both up- and downstream. This option can be used when it´s technically possible to open the dam all the way down (commonly it is not the case). Technical feasibility depends on dam's water levels, size of the impounded lake and water use conditions related to the dam. It must be considered, that large impounded lakes take very long time to be lowered and later also raised. If the dam has to be lowered twice a year (spring and autumn migration time), it may happen that the dam will be mostly down. There must be a person responsible for water level regulations during several weeks every year. Risk of flood and over-reduction of water flow are high. Sediments must be removed from the water reservoir before first opening of the dam. So for many cases this measure usually cannot be used. Since this measure practically excludes possibilities for electroenergy production (share of lost revenues ~50%) because the dam should be down while there are the best conditions in rivers for hydroelectricity production. So it´s not analysed and the measure is not assessed further for Estonian WBs for hydromorphological pressures caused by small HPPs.

Theoretically GES restoration measures for lakes with nutrient pollution can be also chemical treatment (e.g. PhosLock) or oxidation (RIPLOX). So far chemicals are not allowed to be used in Estonia and RIPLOX method is very fragile and complicated, therefore we do not include these possibilities.

M3 Immobilization of phosphorus using chemical treatment (PHOSLOCK) is a measure that is extremely expensive and is therefore excluded from Estonian additional measures. Also, there was said in the two last lakes remediation conferences, that an alternative for this method is needed.

M4 may suit for the shallow lakes. Since we have little knowledge on these lakes in the Estonian project area it is very hard to predict effectiveness, certainty or negative impact. M6 can also be used for lakes with hypolimnion, but we have no such lakes in the Estonian project area. M7 is not known in Estonia and therefore it is not analysed.

4.8 Detailed results for Estonia on the evaluation of the measures for dams used by small HPPs creating hydro-morphological pressures

In Estonia small HPP-s creating hydro-morphological pressures are HPP-s that are on the average size rivers (catchment area 300-1000 km²) on dams with water level difference 2-4 m. Average size rivers are all important for fish life. HPPs in such rivers cause following negative impacts for fish fauna:

- Obstruction of fish migrations
- Loss of valuable rapids and rithral spawning grounds (flooded by water reservoir)
- Risk of sediment pollution and habitat degradation below the dam
- Hydropeaking and disturbing the natural flow regime of a river below the dam
- Fish injuries and mortality in turbines

4.8.1 Environmental impacts of the measures (Criterion 1-3)

Table 4.29 summarises the assessments concerning the environmental impacts of the measures covered by the Criteria 1-3. Detailed results on the assessments for the Criteria 1 and 3 are provided in chapter 4.8.5.

Since the effectiveness is assessed against three state parameters the summary effectiveness score can be calculated as an average or sum of the parameters' scores. Both estimates are provided in the table (see the columns "Average" and "Sum").

Table 4.29. The prepared assessments for the environmental impacts (Criteria 1-3) of the analysed additional measures for dams used by small HPPs creating hydro-morphological pressures. *(Source: An assessment by the project's experts).*

The used assessment categories and corresponding scores:

C1 Effectiveness of a measure: 0 no effect, 1 Low, 2 Moderate, 3 High effectiveness.

C2 Certainty of the Effectiveness assessment: 1 Low, 2 Moderate, 3 High certainty.

C3 Negative adverse environmental impacts from implementing a measure: 0 High, 1 Moderate, 2 Low, 3 No negative impact.

State parameters for the Effectiveness assessment: P1 Obstacle for fish migration, disruption of river continuity; P2 Hydro-morphological river quality; P3 River Fish index; P4 Objectives of Habitat Directive.

Analysed additional measures	**C1 Effectiveness of a measure**						**C2 Certainty**	**C3 Negative impact**
	P1	**P2**	**P3**	**P4**	**Average**	**Sum**		
M1 Building a fish pass	1	1	2.5	2	2	8	Moderate (2)	Low (2)
M2 Demolishing a dam	3	3	3	2.5	2.9	11.5	High (3)	Low (2)
M3 Environmentally friendly turbine	1.5	2	1	1	1.4	5.5	Moderate (2)	Low (2)
M4 Improvement of an existing fish pass	2.5	0	2.5	2	1.75	7	Moderate (2)	Low (2)

The measure *Demolishing a dam* has the highest effectiveness. The effectiveness is rather low for the measure *environmentally friendly turbine* since the obstacle for fish migration upstream remains. An operational fish pass would provide moderate effect. Measure M4 is applicable only in case of existing fish passes.

High certainty of the effectiveness assessment is for the *demolishing a dam*, other measures have moderate certainty.

Negative adverse impact for all measures is assessed low, also such impacts would be mainly temporary.

4.8.2 Costs of the measures

Table 4.30 summarises the assessments concerning the costs of the measures (Criterion 4). The costs were estimated quantitatively for each measure, and they were compared to yearly revenues of small HPPs to assign the qualitative assessment category and score (according to the approach described in chapter 4.3.4). Detailed results on the quantitative cost estimates are provided in chapter 4.8.5. The costs are considered high if they exceed 1.5 % of yearly revenues of a HPP. As it seems, all the measures have high costs compared to revenues.

Table 4.30. The prepared assessments for the costs (Criterion 4) of the analysed additional measures for dams used by small HPPs creating hydro-morphological pressures. *(Source: Estimates prepared as part of the project.)*

The used assessment categories and corresponding scores: High 1, Moderate 2, Low 3 costs.

Analysed additional measures	Annualised costs per year	Assessment categories and scores
M1 Building a fish pass	8000 – 15 700 €/year	High (1)
M2 Demolishing a dam	5 500 – 7 100 €/year	High (1)
M3 Environmentally friendly turbine	8500 – 13 650 €/year	High (1)
M4 Improvement of an existing fish pass	1400 – 2100 €/year	High (1)

4.8.3 Constraints/obstacles of implementation

Table 4.31 summarises the assessments concerning the constraints/obstacles of implementation of the measures (Criterion 5). The constraints are assessed as high-moderate for the measure M2. Moderate assessment category is assigned for the measure M1 and M3, low for the measure M4.

Table 4.31. The prepared assessments for the constraints/obstacles of implementation (Criterion 5) of the analysed additional measures for dams used by small HPPs creating hydro-morphological pressures. (Source: An assessment by the project's experts.)

The used assessment categories and corresponding scores: High 0, Moderate 1, Low 2, No 3 constraints/obstacles.

Code	Short name	Categories and scores
M1	Building of a fish pass	Institutional: Acceptability from HPP owners. Permission from landowners. Legal: Natura 2000 habitats and species. Water permit is needed for building a fish pass. Financial: Possible financing from Environmental Investments Centre but may be expensive work. Moderate (1)
M2	Demolishing a dam	Institutional: Acceptability from HPP owners, other users. Legal: Natura 2000 habitats and species. Water permit is needed for this kind of water use. Financial: Possible financing from Environmental Investments Centre but may be expensive work. Moderate-High (0.5)
M3	Environmentally friendly turbines	Institutional: Acceptability from HPP owners. Legal: Possible EIA procedure. Financial: No public support financing instruments. Moderate (1)
M4	Improvement of an existing fish pass	Institutional: Acceptability from HPP owners. Permission from landowners. Legal: No. Financial: No. Low (2)

4.8.4 Summary assessment

Table 4.32 provides summary assessment for analysed measures for dams used by small HPPs creating hydro-morphological pressures. Table 4.33 provides summary assessment when considering only the effectiveness and costs (cost-effectiveness assessment) and excluding other criteria.

Measures are ordered in the tables starting with the measure with the highest summary score. However this ordering should not be taken as strict ranking because the assessment approach is rather rough to be used for strict ranking.

Table 4.32. Summary assessments for the analysed additional measures for dams used by small HPPs creating hydro-morphological pressures. *(Source: Assessments prepared as part of the project.)*

[1] Using Average of all parameters' scores for the Effectiveness assessment. [2] Using Sum of all parameters' scores for the Effectiveness assessment.

	C1 Effect Average	**C1 Effect Sum**	**C2 Certainty**	**C3 Negative impact**	**C4 Costs**	**C5 Constraints**	**Total (Aver Effec)** [1]	**Total (SumEffec)** [2]
M2 Demolishing a dam	2.9	11.5	High (3)	Low (2)	High (1)	Moderate-High (0.5)	**9.4**	**18**
M4 Improvement of an existing fish pass	1.8	7	Moderate (2)	Low (2)	High (1)	Low (2)	**8.8**	**14**
M1 Building of a fish pass	2	8	Moderate (2)	Low (2)	High (1)	Moderate (1)	**8**	**14**
M3 Environmentally friendly turbines	1.4	5.5	Moderate (2)	Low (2)	High (1)	Moderate (1)	**7.4**	**11.5**

Table 4.33. Summary assessment of the analysed measures when considering only the effectiveness and costs (cost-effectiveness analysis) and excluding other criteria.

[1] Using Average of all parameters' scores for the Effectiveness assessment. [2] Using Sum of all parameters' scores for the Effectiveness assessment.

The analysed additional measures	**Total (AverEffec)** [1]	**Total (SumEffec)** [2]
M6 Demolishing a dam	3.9	12.5
M1 Building of a fish pass	3	9
M2 Improvement of an existing fish pass	2.8	8
M4 Environmentally friendly turbine	2.4	6.5

Demolishing a dam and giving up electricity production is always the most effective measure to open fish migration route and to protect aquatic biota. Also it is usually cheaper than to construct a fish pass. That is why this measure should be treated as preferred measure. Only when demolishing a dam is not feasible considering socio-economic reasons, the construction of fish pass is reasonable. The installation of a fish-friendly turbine instead of a non-friendly turbine is an extra measure to protect fish when continuing electricity generation at a dam is indispensable.

4.8.5 Detailed results for each measure

In this chapter detailed results are included concerning (i) descriptions of the measures; (ii) assessments of the effectiveness and negative adverse environmental impacts (Criteria 1 and 3) and (iii) quantitative cost estimates.

Descriptions of the measures

1. Building of a fish pass

Fish pass is a construction built for fish to pass the obstacle. In Estonia for protected salmonid rivers (125 rivers and river sections named by Ministry of Environment regulation) it is obligatory to find a solution for fish passage on all dams. For other rivers it´s a decision for the Environmental Board based on environmental impact assessment or other expert judgement.

Best available technological solutions must be applied based on scientific studies, applied research projects and monitoring experiences about fish pass efficiency rate.

During the last decade many different types of fish passes have been built in Estonia: these are mostly different nature-like fish passes (rapids, pond cascades) both as bypass channels and constructions in the river bed, but also some technical fish passes (vertical slot fish passes, pool type fish ladders and also one fish lift). All mentioned types of fish passes have been also involved in fish pass efficiency monitoring project.

Building of fish pass is technically feasible in most of dams, but there are some cases, when building of effective fish pass is either impossible or it has no point. Very large water reservoirs are serious migration obstacles by itself. Environmental objectives may remain unattainable regardless of building a fish pass. There may be also some high dams with no space nearby for designing an efficient fish pass. Building a good fish pass may be also unreasonably expensive. In these cases the only measure fulfilling the environmental objectives is demolishing the dam. Another option is to accept, that fish passage is not technically feasible and it is impossible to achieve GES of a water body. Then the principal decision must be made by Environmental Board or Estonian Government.

Fish pass type depends on height of the dam, availability of space around dam, ownership, land use conditions, water use, hydrological conditions, owner´s desires etc.

Different types of fish passes may be considered and evaluated for each site to find suitable technical solution.

After completion every fish pass needs more or less regular maintenance and sometimes also repairing. Rapid fish passes with low slope commonly need the least every-day maintenance, same time as pond type cascades and technical fish passes need regular cleaning. Wooden debris and water plants carried downstream by water flow may easily clog a narrow pool or pond outlet, because of that the fish pass cannot function any more.

The fish pass' resistance to high water and ice deformations depends largely on building quality, but sometimes every fish pass needs repairing. Nature-like pond cascades in main river channel are most vulnerable to natural forces.

In Estonia maintenance of fish pass is the owner's obligation.

Main technical solutions of fish passes:

Natural-like fish passes

1) Natural-like rapid or rithral bypass channels and fish passes in the river channel with low slope (≤2%);

2) Natural-like pond type fish passes (pond cascades) with low slope (≤3.5%);

3) Natural-like rapids and pond cascades with higher slope (≤5%);

Technical fish passes

4) Vertical slot fish passes

5) Pool type fish ladders with surface and bottom openings

6) Pool type fish ladders with bottom openings

7) Screw fish elevators

8) Pool type fish ladders with surface openings

9) Denil fish passes (baffle fish ways)

10) Pool type fish ladders without openings

11) Fish locks and lifts

Effectiveness of fish passes depends on many factors (fish pass type, length, slope, height of dam, positioning of fish pass, water use and other hydraulic conditions, etc.). Nevertheless one of key factors is always the type of fish pass. According to Estonian experiences and based on general knowledge of fish demands and behaviour, the following effectiveness is commonly expected:

Type 1 and 2	good
Type 3 and 4	moderate
Type 5, 6 and 7	moderate to low
Type 8 and 9	low (=meaningless)
Type 10 and 11	very low (=meaningless)

In most cases fish pass types 1 and 2 must be preferred. Only in very specific cases types 3 and 4 may come into consideration. Types 5 to 11 most probably do not help to achieve the environmental objectives and should be avoided.

There is possibility to apply for subsidies for building fish pass.

2. Demolishing a dam

Technical measure with the aim to remove the dam and guarantee fish migration both up- and downstream. It doesn´t always mean that all the dam structures should be demolished. For example if a dam is a part of a bridge, then the bridge stays. If the dam is a cultural heritage monument, then some parts of it may be kept in a way that won´t disturb fish migration. It must be keep in mind, that removing a dam is always the best option to ensure fish migration both up- and downstream. It is also the only measure, which almost always guarantees fish passage with 100% efficiency for all type specific biota groups. Demolishing a dam is one-time project and mostly maintenance free later. Therefore this measure must always be considered as a priority one. Only if this measure is not feasible, other measures (e.g. building of fish pass) can be considered.

Technically demolishing a dam is always feasible. But dam owners, water users and some groups of interest may confront. In some cases constraints may rise, if the dam is protected as a cultural heritage object. If a compromise can be accomplished, then the dam can be demolished (completely or partly). Sediments must be removed when demolishing the dam.

There is possibility to apply for subsidies for demolishing a dam.

3. Environmentally friendly turbine

Technical measure that aims to kill less fish that go through turbines and allows to use hydro energy with variable flow rates. This measure means that the turbines used (e.g. Francis, Kaplan) will be changed to environmentally better turbines – screw turbines. It helps fish to migrate safely downstream through turbines, but an obstacle for upstream migration stays. Screw turbines meant for electroenergy production don´t help fish migrate upstream.

4. Improvement of an existing fish pass

A technical measure for improving a fish pass when it has some problems. If fish pass is built, but it is not working, then it has to be improved, reconstructed or a new one has to be built. This measure here includes smaller improvements to the fish pass. It doesn´t include reconstruction which means more likely changing the main structures. Also the costs are very different for improvement and reconstruction works. The measure includes evaluation of fish pass suitability for fish passage and improving of fish pass using best available technological solutions.

Assessments on effectiveness and negative adverse environmental impacts

M1 Building of a fish pass	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstruction of fish migration	In Estonia for protected salmonid rivers (MoE regulation) it is obligatory to find a solution for fish passage. Other rivers it´s a decision for the Environmental Board based on environmental impact assessment or other expert judgement. This option should secure fish passage over the dam. Different types on fish passes have different expected effectiveness. In Koiva WB natural-like fish passes with low slope (≤2%) must be preferred. Only in very specific cases natural-like fish passes with higher slope (≤3.5%) or vertical slot fish passes with low slope (≤5%) may be alternatives. Score: 2.5
P2 Hydro-morphological quality of river	Nature-like fish passes are valuable habitats for rithral fish and macroinvertebrates, sometimes there are also spawning grounds for rithral fish species. May improve hydromorphological quality of river. Score: 1
P3 River Fish Index	This option will improve River Fish Index. Score: 2.5
P4 Objectives of Habitats directive	Protected fish species can perform their spawning, feeding and wintering migrations. Improves conservation status of Natura fish and macro-invertebrate species. Score: 2
Summary score	*Average score: 2* *Summary score: 8*

C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	May be some temporary negative impacts during construction time and shortly after it. Score: 3

M2 Demolishing a dam	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstruction of fish migration	Always the most effective measure for opening of fish migration way. Only measure which guarantees free fish passage 100%. Score: 3
P2 Hydro-morphological quality of river	Improves hydromorphological quality of river. Additional valuable rithral habitats and spawning grounds for fish arise, risk of water flow regulation and hydropeaking disappears. Score: 3
P3 River Fish Index	Status of fish fauna improves. River Fish Index will show higher ecological quality. Score: 3
P4 Objectives of Habitats directive	Free fish passage is crucial for some Natura fish species (river lamprey, salmon) and important for all others (asp, grayling, brook lamprey, bullhead, spined loach, mud loach). Improving of fish fauna means better living conditions for some Natura macro-invertebrates depending on fish as intermediate hosts (fresh water pearl mussel, creek mussel) or depending on rithral habitats. Dam removing turns river more natural-like and thus the status of river as a Natura habitat type improves. Score: 2.5
Summary score	*Average score: 2.875* *Summary score: 11.5*

C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	In Estonia it is not allowed to let sediments downstream from water reservoir. Some temporary negative influences may appear during the demolishing process (redirection of water flow, additional sediment load) Score: 2

M3 Environmentally friendly turbine	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstruction of fish migration	Screw turbine doesn´t remove the obstacle for upstream migration. Fish have better survival rate when migrating downstream through turbines. Score: 1.5
P2 Hydro-morphological quality of river	Screw turbines can work with variable water flows, the risk of hydropeaking decreases. Score: 2
P3 River Fish Index	Better conditions for downstream migration (lower injury and mortality rates when passing turbines) ensure higher value of River Fish Index. Score: 1
P4 Objectives of Habitats directive	Lower hydropeaking risk and better conditions for downstream migration ensure better conservation status of protected species. Score: 1
Summary score	*Average score: 1.375*

	Summary score: 5.5

C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	No negative impacts. Score: 3

M4 Improvement of an existing fish pass	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstruction of fish migration	Improvement of existing (problematic) fish pass ensures better fish passage. Score: 2.5
P2 Hydro-morphological quality of river	Commonly no impact. Score: 0
P3 River Fish Index	Better fish passage will improve status of fish fauna which reflects in higher River Fish Index. Score: 2,5
P4 Objectives of Habitats directive	Better fish passage will ensure better protection status of Natura fish species and Natura macro-invertebrates depending on fish. Effect depends on species of concern. Score: 2
Summary score	*Average score: 1.75* *Summary score: 7*

C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	No negative impact if all is done according to instructions/project. If this requirement is filled then this option has low/no negative impact. Score: 3

Quantitative cost estimates

M1 Building of a fish pass	
Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	Costs of fish passes will vary commonly from 200 000 to 400 000 € (dam height 2-4 m).
Financial: One-off costs	-
Financial: Yearly maintenance and operation costs	800-1600 € (0.4% of investment costs)
Financial: Other costs	Construction supervision by owner/authority (3%)
Opportunity costs (foregone/lost revenues)	-10% from energy production. 2500€ per year
Induced costs (to other than implementers)	Monitoring costs 0-12 000 € (3 years monitoring program includes trapping, fish marking and electrofishing during fish migration periods). Only these fish passes should be monitored, in case of which we cannot be sure, that they

	work (ichthyological expert opinion). If monitoring needed, then done by public authority, not owner.
Significant input parameters, which create variability in the costs	Investment costs depends on fish pass type, dams height, natural, land and water use conditions, but also on indirect costs (reconstruction and repairing of dam, different restoration works, etc). Commonly the building of nature-like fish passes costs about 100 000 € for every meter of dam height (e.g. designing of fish pass). Depending on site-specific issues, sometimes separate fish pass for downstream migration is also needed. The costs for this kind of fisf pass may be around +10% of investment costs. These are here not included. Sometimes it´s needed to remove sediments from impounded lakes also. Since the amount depends on certain cases, it can be very different and is therefore not estimated here.
Total annualized costs per year, EUR:	Life-time is the same that life-time of the dam and HPP. Expected life-time for calculations 30 years. Annual costs for 30 years: 8000 – 15 700 €/year
Total annualized costs for the planning period 6 years (2021-2027), EUR:	257 100 - 452 700 €
Total estimated financing need for the planning period 6 years (2021-2027):	223 000 – 435000 €
Costs as share of HPP revenues, % - MIN:	35%
Costs as share of HPPrevenues, % - MAX:	69%
Costs as share of HPP revenues, % - on AVERAGE:	52%
Assessment category **(1 High, 2 Moderate, 3 Low costs)**	1 (High)

M2 Demolishing a dam	
Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	Costs of dam removal commonly vary from 150 000 to 200 000 € (dam height 2-4 m).
Financial: One-off costs	Investment costs are one-off costs.
Financial: Yearly maintenance and operation costs	No maintenance costs.
Financial: Other costs	Demolishing the dam lowers the upper water level and it may lower water level in wells situating near the river bank (drinking water). New source of drinking water might be needed. Estimated cost 0-2 well, average cost 7 500 € per well. In total 0 – 15 000 €.
Opportunity costs (foregone/lost revenues)	-100%
Induced costs (to other than implementers)	Monitoring is not needed. We can assume that removing the dam always ensures free fish passage.

Significant input parameters, which create variability in the costs	Investment costs depend on dam height, natural, land and water use conditions, water reservoir area, but also on compensation measures (building of new wells, etc.). Sometimes it´s needed to remove sediments from impounded lakes also. Since the amount depends on certain cases, it can be very different and is therefore not estimated here.
Total annualized costs per year, EUR:	**Life-time is unlimited. Theoretical life-time for calculations 30 years.** **Annual costs for 30 years: 5 500 – 7 100 €/year**
Total annualized costs for the planning period 6 years (2021-2027), EUR:	165 000-215 000 €
Total estimated financing need for the planning period 6 years (2021-2027):	165 000-215 000 €
Costs as share of HPP revenues, % - MIN:	24%
Costs as share of HPP revenues, % - MAX:	32%
Costs as share of HPP revenues, % - on AVERAGE:	28%
Assessment category **(1 High, 2 Moderate, 3 Low costs)**	1 (High)

M3 Changing turbines for environmentally friendly turbines	
Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	120 000 – 200 000 € Expected cost of screw turbines 120 000 € (head 3 m, installed flow 1 m^3/s, power 20 kw, cost of full installation). Expected cost of screw turbines 200 000 € (head 3 m, installed flow 2 m^3/s, power 40 kw, cost of full installation).
Financial: One-off costs	Environmental impact assessment is mandatory if HPP is reconstructed and turbines changed. 15000 €
Financial: Yearly maintenance and operation costs	3 600 - 6 000 € (3% of investment cost)
Financial: Other costs	-
Opportunity costs (foregone/lost revenues)	0%
Induced costs (to other than implementers)	Monitoring costs (if needed) are 0-12 000 € (3 years monitoring program includes trapping, experimental tests, fish marking and electrofishing during fish migration periods). Monitoring must be done by public authority, not by owner.
Significant input parameters, which create variability in the costs	Investment costs may vary depending on the height of the dam, installed flow and reconstruction works needed.
Total annualized costs per year, EUR:	**Expected life-time for calculations 30 years.** **Annual costs for 30 years: 8500 – 13 650 €/year**

Total annualized costs for the planning period 6 years (2021-2027), EUR:	174700-271 500€
Total estimated financing need for the planning period 6 years (2021-2027):	149 500-229 500€
Costs as share of HPP revenues, % - MIN:	37%
Costs as share of HPP revenues, % - MAX:	60%
Costs as share of HPP revenues, % - on AVERAGE:	48%
Assessment category **(1 High, 2 Moderate, 3 Low costs)**	1 (High)

M4 Improvement of an existing fish pass	
Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	Expected cost of improvements is 10 000 – 20 000 €.
Financial: One-off costs	-
Financial: Yearly maintenance and operation costs	800-1200 €
Financial: Other costs	Technical design of improvement is needed in advance. It costs ~2 500 € per fish pass.
Opportunity costs (foregone/lost revenues)	-
Induced costs (to other than implementers)	Monitoring is needed also after the improvement. Monitoring costs are 0-9 000 € for fish pass (3 years monitoring program includes trapping, fish marking and electrofishing during fish migration periods). Monitoring must be done by public authority, not by owner.
Significant input parameters, which create variability in the costs	Problems of fish passes are different. Investment costs may vary depending on construction and improvements needed.
Total annualized costs per year, EUR:	**Life-time of improvements is the same that life-time of fish pass. Expected life-time for calculations 30 years.** **Annual costs for 30 years: 1400 – 2100 €/year**
Total annualized costs for the planning period 6 years (2021-2027), EUR:	24 600-37 400 €
Total estimated financing need for the planning period 6 years (2021-2027):	19000-29000 €
Costs as share of HPP revenues, % - MIN:	6.3%
Costs as share of HPP revenues, % - MAX:	9.4%
Costs as share of HPP revenues, % - on AVERAGE:	7.8%
Assessment category **(1 High, 2 Moderate, 3 Low costs)**	1 (High)

4.9 Detailed results for Estonia on the evaluation of the measures for obstacles/impoundments with other/no use creating hydro-morphological pressures

4.9.1 Environmental impacts of the measures (Criterion 1-3)

Table 4.34 summarises the assessments concerning the environmental impacts of the measures covered by the Criteria 1-3. Detailed results on the assessments for the Criteria 1 and 3 are provided in chapter 4.9.5.

Since the effectiveness is assessed against two state parameters the summary effectiveness score can be calculated as an average or sum of the parameters' scores. Both estimates are provided in the table (see the columns "Average" and "Sum").

The highest effectiveness assessment is for the measure *demolishing a dam*, closely second is *building a fish pass.* M6 has also high certainty of the effectiveness assessment. It is low for M2 opening migration way during spawning period.

Concerning the possible negative environmental impacts, they are expected to be high for M2 and low and temporary for M1 and M4.

The only measure which fully eliminates the problem for all relevant state parameters is the measure M6, it has also high certainty of the effectiveness assessment, and the negative environmental effect is expected to be temporary.

Table 4.34. The prepared assessments for the environmental impacts (Criteria 1-3) of the analysed additional measures for obstacles/impoundments creating hydro-morphological pressures. *(Source: An assessment by the project's experts.)*

The used assessment categories and corresponding scores:

C1 Effectiveness of a measure: 0 no effect, 1 Low, 2 Moderate, 3 High effectiveness.

C2 Certainty of the Effectiveness assessment: 1 Low, 2 Moderate, 3 High certainty.

C3 Negative adverse environmental impacts from implementing a measure: 0 High, 1 Moderate, 2 Low, 3 No negative impact.

State parameters for the Effectiveness assessment: P1 Obstacle for fish migration, disruption of river continuity; P2 Hydromorphological river quality; P3 River Fish index; P4 Objectives of Habitat Directive.

Analysed additional measures	**C1 Effectiveness of a measure**						**C2 Certainty**	**C3 Negative impact**
	P1	**P2**	**P3**	**P4**	**Average**	**Sum**		
M1 Building a fish pass	2.5	1	2.5	2	2	8	Moderate (2)	Low (2)
M2 Opening migration way during spawning period	1.5	0	1.5	1.5	1.125	4.5	Low (1)	High (0)
M3 Demolishing a dam	3	1.5	2.5	2	2.25	9	High (3)	Low (2)
M4 Improvement of an existing fish pass	2.5	0	2.5	2	1.75	7	Moderate (2)	Low (2)

4.9.2 Costs of the measures

Table 4.35 summarises the assessments concerning the costs of the measures (Criterion 4). The costs were estimated quantitatively and they were compared to the EIC yearly water programme budget to assign the qualitative assessment category and score (according to the approach described in chapter 4.3.4). Detailed results on the quantitative cost estimates are provided in chapter 4.9.5. The costs are considered high if they exceed 1 % of the yearly budget.

Table 4.35. The prepared assessments for the costs (Criterion 4) of the analysed additional measures for obstacles/impoundments creating hydro-morphological pressures. *(Source: Estimates prepared as part of the project.)*

The used assessment categories and corresponding scores: High 1, Moderate 2, Low 3 costs.

The analysed additional measures	**Annualised costs per year**	**Assessment categories and scores**
M1 Building of a fish pass	8 000 – 12 000 €/year	High (1)
M2 Opening migration way during spawning period	2 000 – 3800 €/year	Low (3)
M3 Demolishing a dam	5 000 – 7 000 €/year	High (1)
M4 Improvement of an existing fish pass	1 500 – 2 300 €/year	Low (3)

The construction of a fish pass is usually the most costly solution to open fish migration route. This should be taken into account when deciding to maintain the dam. Also there will remain costs related to dam and fish pass maintenance and improvement (if needed).

The regular opening of a dam is significantly cheaper, but it involves a number of risks, is applicable to only a few of all dams and it might not be sustainable – there might not be a human present to operate the dam. If there is a need to do repair work in the fish pass, it is relatively cheap and when problems occur, it is essential. Otherwise there is no use of big investment.

4.9.3 Constraints/obstacles of implementation

Table 4.36 summarises the assessments concerning the constraints/obstacles of implementation of the measures (Criterion 5). The constraints are assessed mainly as moderate. Slightly higher constraints are related to M3 demolishing a dam.

Table 4.36. The prepared assessments for the constraints/obstacles of implementation (Criterion 5) of the analysed additional measures for obstacles/impoundments creating morphological pressures. *(Source: An assessment by the project's experts.)*

The used assessment categories and corresponding scores: High 0, Moderate 1, Low 2, No 3 constraints/obstacles.

Code	**Short name**	**Categories and scores**
M1	Building of a fish pass	Institutional: Acceptability from owners. Permission from landowners. Legal: Natura 2000 habitats and species. Water permit is needed for building a fish pass. Financial: Possible financing from Environmental Investments Centre but may be expensive work. **Moderate (1)**
M2	Opening migration way during spawning period	Institutional: Acceptability from owners, other users. Legal: Natura 2000 habitats and species. Water permit is needed for this kind of water use. Financial: Acceptability from owners. **Moderate (1)**
M3	Demolishing a dam	Institutional: Acceptability from owners, other users. Legal: Natura 2000 habitats and species. Water permit is needed for

		this kind of water use. Financial: Possible financing from Environmental Investments Centre but may be expensive work. **Moderate-High (0.5)**
M4	Improvement of an existing fish pass	Institutional: Acceptability from owners. Permission from landowners. Legal: No. Financial: No. **Low (2)**

4.9.4 Summary assessment

Table 4.37 provides summary assessment for the analysed measures for obstacles/impoundments creating hydro-morphological pressures. Table 4.38 provides the summary assessment when considering only the effectiveness and costs (cost-effectiveness assessment) and excluding other criteria.

Table 4.37. Summary assessments for the analysed additional measures for obstacles/impoundments creating hydro-morphological pressures. *(Source: Assessments prepared as part of the project.)*

[1] Using Average of all parameters' scores for the Effectiveness assessment. [2] Using Sum of all parameters' scores for the Effectiveness assessment.

	C1 Effect AVER[1]	**C1 Effect SUM[2]**	**C2 Certainty**	**C3 Negative impact**	**C4 Costs**	**C5 Constraints**	**Total (Aver Effec) [1]**	**Total (Sum Effec) [2]**
M3 Demolishing a dam	2.3	9	High (3)	Low (2)	High (1)	Moderate-High (0.5)	**8.8**	**15.5**
M4 Improvement of an existing fish pass	1.8	7	Moderate (2)	Low (2)	Low (3)	Moderate (1)	**9.8**	**15**
M1 Building of a fish pass	2	8	Moderate (2)	Low (2)	High (1)	Moderate (1)	**8**	**14**
M2 Opening migration way during spawning period	1.125	4.5	Low (1)	High (0)	Low (3)	Moderate (1)	**6.13**	**9.5**

Table 4.38. Summary assessment of the analysed measures when considering only the effectiveness and costs (cost-effectiveness analysis) and excluding other criteria.

[1] Using Average of all parameters' scores for the Effectiveness assessment. [2] Using Sum of all parameters' scores for the Effectiveness assessment.

The analysed additional measures	**Total (AverEffec) [1]**	**Total (SumEffec) [2]**
M3 Demolishing a dam	3.3	10
M4 Improvement of an existing fish pass	4.2	10
M1 Building of a fish pass	3	9
M2 Opening migration way during spawning period	4.13	7.5

Comparing only the effectiveness and the cost, then with using average effectiveness the best measure would be M2. At the same time, with implementing measure M2, the probability of achieving targets is low. Considering the sum of effectiveness, the best option would be to demolish the dam. If possible, the dam should always be demolished. If it's not possible considering socio-economic reasons or legal reasons, then there should be constructed effectively working fish pass. If the fish pass is already constructed, but for some reason it doesn't work effectively, then if possible, the problem should be eliminated. Opening the regulator of the dam can be a solution only in exceptional cases and probably it is not sustainable for long.

4.9.5 Detailed results for each measure

In this chapter detailed results are included considering (i) descriptions of the measures; (ii) assessments of the effectiveness and negative adverse environmental impacts (Criteria 1 and 3) and (iii) quantitative cost estimates.

Descriptions of the measures

1. Building of a fish pass

Fish pass is a construction built for fish to pass the obstacle. In Estonia for protected salmonid rivers (125 rivers and river sections named by Ministry of Environment regulation) it is obligatory to find a solution for fish passage in all dams. For other rivers it´s a decision for the Environmental Board based on environmental impact assessment or other expert judgement.

Best available technological solutions must be applied based on scientific studies, applied research projects and monitoring experiences about fish pass efficiency rate.

During the last decade many different types of fish passes have been built in Estonia: these are mostly different nature-like fish passes (rapids, pond cascades) both as bypass channels and constructions in the river bed, but also some technical fish passes: vertical slot fish passes, pool type fish ladders and also one fish lift. All mentioned types of fish passes have been also involved in fish pass efficiency monitoring project.

Building of fish pass is technically feasible in most of dams, but there are some cases, when building of effective fish pass is either impossible or it has no point. Very large water reservoirs are serious migration obstacles by itself. Environmental objectives may remain unattainable regardless of building a fish pass. There may be also some high dams with no room nearby for designing an efficient fish pass. Building a good fish pass may be also unreasonably expensive. In these cases the only measure fulfilling the environmental objectives is demolishing the dam. Another option is to accept, that fish passage is not technically feasible and it is impossible to achieve GES of a water body. Then the principal decision must be made by Environmental Board or Estonian Government.

Fish pass type depends on height of the dam, availability of space around dam, ownership, land use conditions, water use, hydrological conditions, owner´s desires etc.

Different types of fish passes may be considered and evaluated for each site to find suitable technical solution.

After completion every fish pass needs more or less regular maintenance and sometimes also repairing. Rapid fish passes with low slope commonly need the least every-day maintenance, same time as pond type cascades and technical fish passes need regular cleaning. Wooden debris and water plants carried downstream by water flow may easily clog a narrow pool or pond outlet, because of that the fish pass cannot function any more.

The fish pass’ resistance to high water and ice deformations depends largely on building quality, but sometimes every fish pass needs repairing. Nature-like pond cascades in main river channel are most vulnerable to natural forces.

In Estonia maintenance of fish pass is the owner’s obligation.

Main technical solutions of fish passes:

Natural-like fish passes

1) Natural-like rapid or rithral bypass channels and fish passes in the river channel with low slope (≤2%);

2) Natural-like pond type fish passes (pond cascades) with low slope (≤3.5%);

3) Natural-like rapids and pond cascades with higher slope (≤5%);

Technical fish passes

4) Vertical slot fish passes

5) Pool type fish ladders with surface and bottom openings

6) Pool type fish ladders with bottom openings

7) Screw fish elevators

8) Pool type fish ladders with surface openings

9) Denil fish passes (baffle fish ways)

10) Pool type fish ladders without openings

11) Fish locks and lifts

Effectiveness of fish passes depends on many factors (fish pass type, length, slope, height of dam, positioning of fish pass, water use and other hydraulic conditions, etc.). Nevertheless one of key factors is always the type of fish pass. According to Estonian experiences and based on general knowledge of fish demands and behaviour, the following effectiveness is commonly expected:

Type 1 and 2	good
Type 3 and 4	moderate
Type 5, 6 and 7	moderate to low
Type 8 and 9	low (=meaningless)
Type 10 and 11	very low (=meaningless)

In project area fish pass types 1 and 2 must be preferred. Only in very specific cases types 3 and 4 may come into consideration. Types 5 to 11 most probably do not help to achieve the environmental objectives and should be avoided.

There is possibility to apply for subsidies for building fish pass.

2. Opening migration way during spawning period

Technical measure that basically could ensure fish passage both up- and downstream. This option can be used when it´s technically possible to open the dam all way down (commonly it´s not the case). Technical feasibility depends on dam’s water levels, size of the impounded lake and water use conditions related to the dam. It must be considered, that large impounded lakes take very long time to be lowered and later also raised. If the dam has to be down twice a year (spring and autumn migration time) it may occur that the dam will be mostly down. There must be a person responsible for water level regulations during several weeks every year. Risk of flood and over-reduction of water flow are high. Sediments must be removed from the water reservoir before first opening of the dam.

So for many cases this measure usually cannot be used.

3. Demolishing a dam

Technical measure with the aim to remove the dam and guarantee fish migration both up- and downstream. It doesn´t always mean that all the dam structures should be demolished. For example if a dam is a part of a bridge, then the bridge stays. If the dam is a cutural heritage monument, then some parts of it may be kept in a way that won´t disturb fish migration. It must be kept in mind that removing a dam is always the best option to ensure fish migration both up- and downstream. It is also the only measure, which almost always guarantees fish passage with 100% efficiency for all type specific biota groups. Demolishing a dam is one-time project and mostly maintenance free later. Therefore this measure must always be considered as a priority one. Only if this measure is not feasible, other measures (e.g. building of fish pass) can be considered.

Technically demolishing a dam is always feasible. But dam owners, water users and some groups of interest may confront. In some cases constraints may rise, if the dam is protected as a cultural heritage object. If a compromise can be accomplished, then the dam can be demolished (completely or partly). Sediments must be removed when demolishing the dam.

There is possibility to apply for subsidies for demolishing a dam.

4. Improvement of an existing fish pass

A technical measure for improving a fish pass when it has some problems. If a fish pass is built, but it´s not working, then it has to be improved, reconstructed or a new one has to be built. This measure here includes smaller improvements to the fish pass. It doesn´t include reconstruction which means more likely changing the main structures. Also the costs are very different for improvement and reconstruction works. The measure includes evaluation of fish pass suitability for fish passage and improving of fish pass using best available technological solutions.

In project area there exists 3 fish passes in Pärlijõgi River. Two of them are more or less problematic and may need improvements. None of these fish passes have been monitored (until now there has been only expert opinions).

Assessments on effectiveness and negative adverse environmental impacts

M1 Building of a fish pass	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstruction of fish migration	In Estonia for protected salmonid rivers it is obligatory to find a solution for fish passage. Other rivers it´s a decision for the Environmental Board based on environmental impact assessment or other expert judgement. This option should secure fish passage over the dam. Different types on fish passes have different expected effectiveness. In project area natural-like fish passes with low slope (≤2%) must be preferred. Only in very specific cases natural-like fish passes with higher slope (≤3.5%) or vertical slot fish passes with low slope (≤5%) may be alternatives. Score: 2.5
P2 Hydro-morphological quality of river	Nature-like fish passes are valuable habitats for rithral fish and macroinvertebrates, sometimes there are also spawning grounds for rithral fish species. May improve hydromorphological quality of river.

	Score: 1
P3 River Fish Index	This option will improve River Fish Index. Score: 2.5
P4 Objectives of Habitats directive	Protected fish species can perform their spawning, feeding and wintering migrations. Score: 2
Summary score	*Average score: 2* *Summary score: 8*

C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	May be some temporary negative impacts during construction time and shortly after it. Score: 3

M2 Opening migration way during spawning period	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstruction of fish migration	This option will remove temporarily the obstacle. There are risks that the timing of opening is not correct, water flow regulations may cause over-reduction of water flow and flood, risk of sediment pollution and different other risks related to "human factor". Score: 1.5
P2 Hydro-morphological quality of river	No positive effect to hydromorphological quality of river. Score: 0
P3 River Fish Index	May improve River Fish Index if opening is properly managed and negative effects avoided. Score: 1.5
P4 Objectives of Habitats directive	May help protected fish species to perform their spawning, feeding and wintering migrations. Score: 1.5
Summary score	*Average score: 1.125* *Summary score: 4.5*

C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	Sediments need to be removed before starting the lowering water levels periodically. There are high risks related to human factor - water flow regulations may cause over-reduction of water flow and flood below the dam, risk of sediment pollution. Normal living conditions for biota in water reservoir may be absent. Score: 1

M3 Demolishing a dam	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstruction of fish migration	Always the most effective measure for opening of fish migration way. Only measure which guarantees free fish passage 100%. Score: 3
P2 Hydro-morphological quality of river	Improves hydro-morphological quality of river. Additional valuable rithral habitats and spawning grounds for fish arise, risk of water flow regulation disappears. Score: 1.5
P3 River Fish Index	Status of fish fauna improves. River Fish Index will show higher ecological quality. Score: 2.5
P4 Objectives of Habitats directive	Free fish passage is crucial for some Natura fish species (river lamprey, salmon) and important for all others (asp, grayling, brook lamprey, bullhead, spined loach, mud loach). Improving of fish fauna means better living conditions for some Natura macro-invertebrates depending on fish as intermediate hosts (fresh water pearl mussel, creek mussel) or depending on rithral habitats. Dam removing turns river more natural-like and thus the status of river as a Natura habitat type improves. Score: 2
Summary score	*Average score: 2.25* *Summary score: 9*

C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	In Estonia it is not allowed to let sediments downstream from water reservoir. Some temporary negative influences may appear during the demolishing process (redirection of water flow, additional sediment load) Score: 2

M4 Improvement of an existing fish pass	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Obstruction of fish migration	Improvement of existing (problematic) fish pass ensures better fish passage. Score: 2.5
P2 Hydro-morphological quality of river	Commonly no impact. Score: 0
P3 River Fish Index	Better fish passage will improve status of fish fauna which reflects in higher River Fish Index. Score: 2.5
P4 Objectives of Habitats directive	Better fish passage will ensure better protection status of Natura fish species and Natura macro-invertebrates depending on fish. Effect depends on species of concern. Score: 2
Summary score	*Average score: 1.75*

	Summary score: 7

C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	May be some temporary negative impacts during construction time. Score: 3

Quantitative cost estimates

M1 Building of a fish pass	
Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	In project area costs of fish passes will vary commonly from 200 000 to 300 000 € (dam height 2-3m).
Financial: One-off costs	Investment costs are one-off costs.
Financial: Yearly maintenance and operation costs	800-1200 € (0,4% of investment costs)
Financial: Other costs	Construction supervision by owner/authority (3%)
Opportunity costs (foregone/lost revenues)	-
Induced costs (to other than implementers)	Monitoring costs 0-9 000 € (3 years monitoring program includes trapping, fish marking and electrofishing during fish migration periods). Only these fish passes should be monitored, in case of which we cannot be sure, that they work (ichthyological expert opinion). If monitoring needed, then done by public authority, not owner.
Significant input parameters, which create variability in the costs	Investment costs depends on fish pass type, dams height, natural, land and water use conditions, but also on indirect costs (reconstruction and repairing of dam, different restoration works, etc). Commonly the building of nature-like fish passes costs about 100 000 € for every meter of dam height (e.g. designing of fish pass). Sometimes it´s needed to remove sediments from impounded lakes also. Since the amount depends on certain cases, it can be very different and is therefore not estimated here.
Total annualized costs per year, EUR:	**Life-time is the same that life-time of the dam. Expected life-time for calculations 30 years.** **Annual costs for 30 years: 8 000 – 12 000 €/year**
Total annualized costs for the planning period 6 years (2021-2027), EUR:	211600 - 326 400€
Total estimated financing need for the planning period 6 years (2021-2027):	Average cost 300 000 €. For 3 fish passes in Õhne river Koorküla, Holdre, Taagepera, the total cost is 900 000€.
Costs as share of EIC yearly water programme budget, %	3.1%
Assessment category **(1 High, 2 Moderate, 3 Low costs)**	1 (High)

M2 Opening migration way during spawning period	
Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	Most often some dam specific construction works are needed. Probable costs 5 000 – 15 000 €.
Financial: One-off costs	Investment costs are one-off costs.
Financial: Yearly maintenance and operation costs	2 000 – 3 000 € (1 month man labour costs + other expenditures)
Financial: Other costs	-
Opportunity costs (foregone/lost revenues)	-
Induced costs (to other than implementers)	Monitoring costs 0-9 000 € (3 years monitoring program includes trapping, fish marking and electrofishing during fish migration periods). Only these dams should be monitored, in case of which we cannot be sure, that fish passage is guaranteed (ichthyological expert opinion). If monitoring needed, then done by public authority, not owner.
Significant input parameters, which create variability in the costs	Different dams may need very different efforts to open and close the gates. Most of dams need modification or reconstruction works in advance. Sometimes it´s needed to remove sediments from impounded lakes also. Since the amount depends on certain cases, it can be very different and is therefore not estimated here.
Total annualized costs per year, EUR:	**Life-time is unlimited. Theoretical life-time for calculations 30 years.** **Annual costs for 30 years: 2000 – 3800 €/year**
Total annualized costs for the planning period 6 years (2021-2027), EUR:	19 150 €-45 000€
Total estimated financing need for the planning period 6 years (2021-2027):	19 150 €-45 000€
Costs as share of EIC yearly water programme budget, %	0.1%-0.2%
Assessment category **(1 High, 2 Moderate, 3 Low costs)**	3 (Low)

M3 Demolishing a dam	
Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	In project area costs of dam removal will vary probably from 150 000 to 200 000 €.
Financial: One-off costs	Investment costs are one-off costs.
Financial: Yearly maintenance and operation costs	No maintenance costs.
Financial: Other costs	Demolishing the dam lowers the upper water level and it may lower water level in wells situating near the river bank (drinking water). New source of drinking water might be needed. Estimated cost 0-2 well, average cost 7 500

	€ per well. In total 0 – 15 000 €.
Opportunity costs (foregone/lost revenues)	-
Induced costs (to other than implementers)	Monitoring is not needed. We can assume that removing the dam always ensures free fish passage.
Significant input parameters, which create variability in the costs	Investment costs depends on dams height, natural, land and water use conditions, water reservoir area, but also on compensation measures (building of new wells, etc.). Sometimes it´s needed to remove sediments from impounded lakes also. Since the amount depends on certain cases, it can be very different and is therefore not estimated here.
Total annualized costs per year, EUR:	**Life-time is unlimited. Theoretical life-time for calculations 30 years.** **Annual costs for 30 years: 5 000 – 7 000 €/year**
Total annualized costs for the planning period 6 years (2021-2027), EUR:	165 000€-215000€
Total estimated financing need for the planning period 6 years (2021-2027):	Average cost for one demolition is 180 000 €. For 2 dams in Pärlijõgi river (Saarlase, Pärlijõe) the total cost is 360 000€.
Costs as share of EIC yearly water programme budget, %	1.3%
Assessment category **(1 High, 2 Moderate, 3 Low costs)**	1 (High)

M4 Improvement of an existing fish pass	
Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	In project area 2 fish passes may need improvement (Pärlijõgi river: Sänna Mäeveski and Ala-Raudsepa fish passes). Expected cost of improvements is 10 000 – 20 000 € for two fish passes.
Financial: One-off costs	Technical design of improvement is needed in advance. It costs ~2 500 € per fish pass.
Financial: Yearly maintenance and operation costs	800-1200 €
Financial: Other costs	-
Opportunity costs (foregone/lost revenues)	-
Induced costs (to other than implementers)	Monitoring is needed also after the improvement. Monitoring costs are 0-9 000 € for fish pass (3 years monitoring program includes trapping, fish marking and electrofishing during fish migration periods). Monitoring must be done by public authority, not by owner.
Significant input parameters, which create variability in the costs	Problems of fish passes are different. Investment costs may vary depending on construction and improvements needed.
Total annualized costs per	**Life-time of improvements is the same that life-time of fish pass.**

year, EUR:	**Expected life-time for calculations 30 years.** **Annual costs for 30 years: 1 500 – 2 300 €/year**
Total annualized costs for the planning period 6 years (2021-2027), EUR:	27100-39900 €
Total estimated financing need for the planning period 6 years (2021-2027):	In project area 2 fish passes may need improvement. Total cost: 33 000 €.
Costs as share of EIC yearly water programme budget, %	0.2%
Assessment category **(1 High, 2 Moderate, 3 Low costs)**	3 (Low)

4.10 Detailed results for Estonia on the evaluation of the measures for lakes with accumulated nutrient pollution in sediments

4.10.1 Environmental impacts of the measures (Criterion 1-3)

Table 4.39 summarises the assessments concerning the environmental impacts of the measures covered by the Criteria 1-3. Detailed results on the assessments for the Criteria 1 and 3 are provided in chapter 4.10.5.

Table 4.39. The prepared assessments for the environmental impacts (Criteria 1-3) of the analysed additional measures for lakes with accumulated nutrient pollution. *(Source: An assessment by the project's experts.)*

The used assessment categories and corresponding scores:

C1 Effectiveness of a measure: 0 no effect, 1 Low, 2 Moderate, 3 High effectiveness.

C2 Certainty of the Effectiveness assessment: 1 Low, 2 Moderate, 3 High certainty.

C3 Negative adverse environmental impacts from implementing a measure: 0 High, 1 Moderate, 2 Low, 3 No negative impact.

The analysed additional measures	**C1 Effectiveness**					**C2 Certainty**	**C3 Negative impact**
	P1	**P2**	**P3**	**Average**	**Sum**		
M1 Sediment dredging	2	3	3	2.7	8	High (3)	Low (2)
M2 Removal of macrophytes	2	2	2	2	6	Low (1)	Low (2)
M3 Biomanipulation	1	1	3	1.7	5	Low (1)	Low (2)
M4 Complex methods	3	3	3	3	9	High (3)	Low (2)

The effectiveness is assessed high for the measure M1 and M4. Both have also high certainty of the effectiveness assessment and low negative environmental impact (temporary).

4.10.2 Costs of the measures

Table 4.40 summarises the assessments concerning the costs of the measures (Criterion 4). The costs were estimated quantitatively and they were compared to the EIC yearly water programme budget to assign the qualitative assessment category and score (according to the approach described in chapter 4.3.4). Detailed results on the quantitative cost estimates are provided in chapter 4.10.5. The costs are considered high if they exceed 1 % of yearly budget.

It should be stressed that the magnitude of the costs depends highly on size of a lake. The quantitative estimates are calculated assuming relevant characteristics of the Köstrejärv (including its size), which is rather small. The costs would be bigger for larger lakes.

Table 4.40. The prepared assessments for the costs (Criterion 4) of the analysed additional measures for lakes with accumulated nutrient pollution. *(Source: Estimates prepared as part of the project.)*

The used assessment categories and corresponding scores: High 1, Moderate 2, Low 3 costs.

** The quantitative cost estimates are developed for the lake Köstrejärv. The costs would be higher for larger lakes.*

The analysed additional measures	Annualised costs per year*	Assessment categories and scores
M1 Sediment dredging	128300 – 378300 € per year	High-Moderate (1.5)
M2 Removal of macrophytes	13 000 € per year	Low (3)
M3 Biomanipulation	2250 € per year	Low (3)
M4 Complex methods	135 300 – 385 300 EUR per year	High-Moderate (1.5)

It can be concluded overall:

- There is limited number of measures available for addressing the environmental problem with affordable cost level.
- From the analysed measures *M2 Removal of macrophytes* has low costs, but at the same time it does not provide solution for the environmental problem.
- Affordability of the costs depends on characteristics of a lake (including its size).These relevant parameters need to be considered when using these results for other WBs.

4.10.3 Constraints/obstacles of implementation

Table 4.41 summarises the assessments concerning the constraints/obstacles of implementation of the measures (Criterion 5). The constraints are assessed moderate for the measures M1 and M4. Constraints for M2 and M3 are low.

Table 4.41. The prepared assessments for the constraints/obstacles of implementation (Criterion 5) of the analysed additional measures for lakes with accumulated nutrient pollution*. (Source: An assessment by the project's experts.)*

The used assessment categories and corresponding scores: High 0, Moderate 1, Low 2, No 3 constraints/obstacles.

Code	Short name	Categories and scores
M1	Sediment dredging	Institutional: Permission from landowners. Legal: Environmental Impact Assessment procedure. Natura 2000 habitats and species. Environmental permit for water use is needed. Financial: Possible financing from Environmental Investments Centre but high costs. **Moderate (1)**
M2	Removal of macrophytes	Institutional: Permission from landowners. Legal: Natura 2000 habitats and species. Financial: no.

		Low (2)
M3	Biomanipulation	Institutional: Permission from landowners. Legal: Natura 2000 habitats and species. Permits from Estonian Environmental Board Veterinary and Food Board. Financial: no. **Low (2)**
M4	Complex methods	Institutional: Permission from landowners. Legal: Environmental Impact Assessment procedure. Natura 2000 habitats and species. Financial: Possible financing from Environmental Investments Centre but high costs. **Moderate (1)**

4.10.4 Summary assessment

Table 4.42 provides summary assessment for the analysed measures for lakes with accumulated nutrient pollution in sediments. Table 4.43 provides the summary assessment when considering only the effectiveness and costs (cost-effectiveness assessment) and excluding other criteria.

The measures are ordered in the tables starting with the measure with the highest summary score. However this ordering should not be taken as strict ranking because the assessment approach is rather rough to be used for strict ranking.

Table 4.42. Summary assessments for the analysed additional measures for lakes with accumulated nutrient pollution*. (Source: Assessments prepared as part of the project.)*

[1] Using Average of all parameters' scores for the Effectiveness assessment. [2] Using Sum of all parameters' scores for the Effectiveness assessment.

	C1 Effect Aver	**C1 Effect Sum**	**C2 Certainty**	**C3 Negative impact**	**C4 Costs**	**C5 Constraints**	**Total (Aver Effec) [1]**	**Total (Sum Effec) [2]**
M4 Complex method	**3**	9	High (3)	Low (2)	High-Moderate (1.5)	Moderate (1)	**10.5**	**16.5**
M1 Sediment dredging	2.7	8	High (3)	Low (2)	High-Moderate (1.5)	Moderate (1)	**10.2**	**15.5**
M2 Removal of macrophytes	2	6	Low (1)	Low (2)	Low (3)	Low (2)	**10**	**14**
M3 Biomanipulation	1.7	5	Low (1)	Low (2)	Low (3)	Low (2)	**9.7**	**13**

Table 4.43. Summary assessment of the analysed measures when considering only the effectiveness and costs (cost-effectiveness analysis) and excluding other criteria.

The analysed additional measures	**Total (Aver Effec) [1]**	**Total (Sum Effec) [2]**
M4 Complex method	**4.5**	**10.5**
M1 Sediment dredging	**4.2**	**9.5**
M2 Removal of macrophytes	**5**	**9**
M3 Biomanipulation	**4.7**	**8**

Comparing only the effectiveness to the cost, then with using medium effectiveness the best measure would be M5. At the same time, with implementing measure M5, the probability of achieving targets is low. Considering the sum of effectiveness, the best option would be measure M4.

Since all measures are very much dependent on certain cases (m^3 of sediments to be removed or ha of macrophytes to be cut), the cost can vary a lot. Variable costs can make a big difference in case specific assessments.

4.10.5 Detailed results for each measure

In this chapter detailed results are included considering (i) descriptions of the measures; (ii) assessments of the effectiveness and negative adverse environmental impacts (Criteria 1 and 3) and (iii) quantitative cost estimates.

Descriptions of the measures

Last time Lake Köstrejärv was assessed, was in 2018. Final ecological status assessment score was moderate. Good status for lakes is evaluated by water abiotioc properties, phytobenthos and phytoplankton. Moderate or worse status for Köstrejärv was given by macrophytes (bad status), macroinvertebrates and fish.

According to historical data from at least in 1960s Lake Köstrejärv had well-balanced ecosystem with open water area and shoreline covered by macrophytes. On last decades open water (pelagial) is practically absent – lake grows over rapidly. Last time lake was monitored, was in 2018. Besides mentioned quality elements, zooplankton status was even worse, but this living group is not included officially in directive. In comparison state of macrophytes was bad on the basis of all used parameters. The reasons – domination of species preferring high eutrophic state, the lack of pelagial zone, domination of floating plants (e.g. *Lemna* sp.) and macroscopic filamentous algae. Small percentage of benthic fauna and domination of one species (*Asellus aquaticus*) was the reason, why status was estimated as moderate. Number of fish species was small and high domination of cyprinidae is the reason why conditions for fish are not good. Sometimes it has been noticed also anoxic conditions in late winter, killing fish. Lake Köstrejärv needs complex restoration. Dealing with status of some elements won’t have positive results. In Lake Köstrejärv it has been proceeded state monitoring, but also sediment analyses. The latter includes investigation of possible phosphorus release to euphotic water zone. Missing information includes thickness, elementary content and distribution of sediments. Also there is a need to estimate external load.

1. Sediment dredging: Information about distribution of sediments, density of sediments, elementary analysis, characterization (the quality structure), content of nutrients, information about phosphorus fractions and leakage from the sediments into the water, proportion of organic matters are needed before actions. Is undoubtedly very effective measure if external load is diminished to the certain limit.
2. Removal of macrophytes: Calculations on the bases of existing macrophyte communities – what is the amount of nutrients in macrophytes. Important is to predict concentration of nutrients after restoration. Macrophyte cutting and removal is more or less method improving esthetical value of lakes and less affecting GES. It is very hard to achieve lower pressure selecting this method.
3. Biomanipulation: Efficiency of biomanipulation depends on many items including nutrient mobility and content in sediments. This method is so far effective for small and shallow lakes. On the other hand the result depends very much on amount of phosphorus and the source of phosphorus. Since sediments are rich in phosphorus and resuspension is relatively

intensive, this method is not the best for Lake Köstrejärv. Biomanipulation is probably very cheap method for restoration, but has only short-term effects.

4. Complex methods: These include sediment removal, macrophyte cutting and removal. Information about sediments (see option 1) is crucial and not so important about macrophytes. Sediment removal with macrophyte treatment succeeds in the environment where there is well-balanced habitat conditions as well as water properties. There will be high quality habitats for species living in profundal, littoral and sublittoral. Effect is good only in cases when external load has stopped. This can be considered as the most effective measure for Lake Köstrejärv.

Assessments on effectiveness and negative adverse environmental impacts

M1 Sediment dredging	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Macrophytes	If sediments will be removed from profundal, macrophytes will benefit. Lake depth in profundal areas should be achieved appr. 3 m. In this case there will be good balance between emergent floating leaved and submerged plants. Score: 2
P2 Macroinvertebrates	Community in profundal has low diversity. If after restoration the structure, light and aeration terms will improve, these biotic groups will benefit. Score: 3
P3 Fish	In all means fish will benefit (see P1 and P2). Proportions of fish groups will change towards predatory fish. There will be less bottom- feeding fish and other cyprinids. Score : 3
Summary score	*Average score: 2.7* *Summary score: 8*

C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	There may temporarily be some negative impacts during construction time and some years after. In previous periods in many cases the area of work was not isolated. Nowadays it is a requirement to separate treatment area from the other parts. Negative effect that may occur in the lake and biota is short-term. Important is to evaluate the littoral habitats and not to disturb biota during restoration procedures. Score: 3

M2 Removal of macrophytes	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Macrophytes	There is always a question, how large should be the treated area to get the improvement of ecological status. One should remember that phytoplankton and macrophytes are competitors for light and nutrients. If macrophytes disappear, phytoplankton may start to prevail bringing negative effects – water blooming, turbid water etc. Score: 2
P2 Macroinvertebrates	Cutting macrophytes can temporarily destroy benthic fauna, later species may be

	substituted. Score: 2
P3 Fish	See P1. There should be found good balance between open-water and macrophyte areas. Score: 2
Summary score	*Average score: 2* *Summary score: 6*

C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	There may temporarily be some negative impacts during construction time and some years after. Score: 2

M3 Biomanipulation	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Macrophytes	Effect to macrophytes is minimal. Score: 1
P2 Macroinvertebrates	Diversity of macoinvertebrates will improve. Score: 1
P3 Fish	Proportion of predatory/non-predatory fish will improve a lot. The value of commercial fish will improve. Score: 3
Summary score	*Average score: 1.7* *Summary score: 5*

C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	In many cases there have been described negative side-effects. Some examples from the literature, where were negative effects, are: some species increased abundance, affecting negatively ecosystem services. Score: 2

M4 Complex methods	
C1 Effectiveness of a measure for …	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
P1 Macrophytes	If there is the information about the right size of treated area, macrophytes would benefit from restoration. Score: 3
P2 Macroinvertebrates	In long-term perspective status will be improved Score: 3
P3 Fish	See option 1, P3. Score: 3
Summary score	*Average score: 3*

	Summary score: 9

C3 Negative adverse environmental impacts	Comments in relation to effect, explanations on the effectiveness assessment and the qualitative assessment categories (scores)
Assessment and summary score	There may temporarily be some negative impacts during construction time and some years after. Score: 3

Quantitative cost estimates

M1 Sediment dredging	
Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	Financial costs 15 €/m^3 Amount of sediments (m^3) to be extracted: 50 000-150 000 m^3
Financial: One-off costs	20 000 € costs of a technical feasibility (incl. sediment) study with environmental impact assessment.
Financial: Yearly maintenance and operation (O&M) costs	
Financial: Other costs	Costs of depositing sediments (if polluting substances' concentrations in sediments exceed standards, sediments must be deposited and nature resource tax as for waste landfilling must be paid). It is not analysed whether this could be necessary. The costs are not estimated.
Opportunity costs (lost revenues)	-
Induced costs (to other actors)	The costs are not known and not estimated.
Significant input parameters, which create variability in the costs	Variable parameter is the amount of sediments that has to be removed (large interval comes from uncertainty to how many m^3 the measure should be applied).
Total annualized costs per year, EUR:	**128300 – 378300 € per year (the Lower and Upper bound of the costs).**
Total estimated financing need for planning period 6 years (2021-2027):	0.75 – 2.25 mln € (taking into account the Lower and Upper bound of the costs).
Costs as share of EIC yearly water programme budget, %	0.7%-2%
Assessment category (1 High, 2 Moderate, 3 Low costs)	1.5 (High-Moderate)

M2 Macrophyte cutting and removal	
Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	-
Financial: One-off costs	1000€ for expert opinion on macrophyte cutting and removal.
Financial: Yearly maintenance and operation (O&M) costs	Area of 5-10 ha for cutting, 3000€ per year; cutting is needed after every other year.
Financial: Other costs	No such costs.
Opportunity costs (lost revenues)	No such costs.

Induced costs (to other actors)	No such costs.
Significant input parameters, which create variability in the costs	Hectares for cutting macrophytes in specific lake - large variability comes from uncertainty of how many hectares the measure should be applied.
Total annualized costs per year, EUR:	**7000 -14 000 € per year (the Lower and Upper bound of the costs).**
Total estimated financing need for planning period 6 years (2021-2027):	46000-91000 € (taking into account the Lower and Upper bound of the costs).
Costs as share of EIC yearly water programme, %	0.04-0.07%
Assessment category (1 High, 2 Moderate, 3 Low costs)	3 (Low)

M3 Biomanipulation	
Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	No such costs.
Financial: One-off costs	
Financial: Yearly maintenance and operation (O&M) costs	Financial costs of implementing the measure, including costs for targeted fishing of certain (cyprinid) fish species and artificial growing and release of certain (predator) fish species. 49 500 €
Financial: Other costs	Monitoring costs: 18 000 €
Opportunity costs (lost revenues)	No such costs.
Induced costs (to other actors)	The costs are not known and not estimated.
Significant input parameters, which create variability in the costs	
Total annualized costs per year, EUR:	**2250 € per year (the Lower and Upper bound of the costs).**
Total estimated financing need for planning period 6 years (2021-2027):	67 500 € (taking into account the Lower and Upper bound of the costs).
Costs as share of EIC yearly water programme budget, %	0.05%
Assessment category (1 High, 2 Moderate, 3 Low costs)	3 (Low)

M4 Complex methods: Sediment removal, macrophyte cutting and removal	
Types of the costs	**Explanations and quantitative estimates**
Financial: Investment costs	Financial costs 15 €/m^3 Amount of sediments (m^3) to be extracted: 50 000-150 000 m^3
Financial: One-off costs	20 000 € costs of a technical feasibility (incl. sediment) study with environmental impact assessment.
Financial: Yearly maintenance and operation (O&M) costs	Area of 5-10 ha for cutting, 3000 € per year; cutting is needed after every other year
Financial: Other costs	Costs of depositing sediments (if polluting substances’ concentrations in sediments exceed

	standards, sediments must be deposited and NRT as for waste landfilling must be paid). It is not analysed whether this could be necessary. The costs are not estimated.
Opportunity costs (lost revenues)	-
Induced costs (to other actors)	The costs are not known and not estimated.
Significant input parameters, which create variability in the costs	Variable parameter is the amount of sediments to be removed and macrophytes to be cut (large interval comes from uncertainty to how many m^3 and ha the measure should be applied).
Total annualized costs per year, EUR:	**39 600 – 82 600 EUR per year (the Lower and Upper bound of the costs).**
Total estimated financing need for planning period 6 years (2021-2027):	0.860– 2.315 mln EUR (taking into account the Lower and Upper bound of the costs).
Costs as share of EIC yearly water programme budget, %	0.7%-2%
Assessment category (1 High, 2 Moderate, 3 Low costs)	1.5 (High-Moderate)

5 COST-EFFECTIVENESS ANALYSIS OF ADDITIONAL MEASURES FOR AGRICULRE (FOR LATVIA)

5.1 Scope and general approach of the analysis

Range of WBs fails GES in the Latvian part of the project area due to nutrient pollution from agriculture and forestry and hydro-morphological pressures from drainage for these activities. The largest number of these WBs fails GES due to **diffuse nutrient pollution from agriculture** (from crop farming). Due to limitation of the study the analysis was focused on evaluating possible additional measures for this pressure and source/activity.

There is large number of possible additional measures to reduce diffuse nutrient pollution from agriculture. The evaluation should support identifying and selecting the most cost-effective measures for achieving nutrient load reduction targets. Hence, the **cost-effectiveness analysis (CEA)** is the most appropriate tool to support the prioritisation and selection of the measures. The CEA involves assessing effectiveness and costs of the measures and estimating cost-effectiveness of each measure. The measures with higher effectiveness and lower costs are more cost-effective. The CEA can help finding the least cost way for achieving the environmental objectives.

To serve the given purpose quantitative analysis would be preferable. The more quantitative CEA is aimed, the more detailed and quantitative information is needed about the current nutrient pollution load, applicability, effect and costs of the measures. Due to limited information for the project area and limitations of the study, the analysis was conducted **based on an example of a selected WB failing GES due to the given pressure – G308 Jogla.**

Although the assessment was conducted on the basis of a selected WB, it aims to provide generalised assessment of cost-effectiveness of the measures, which could be applicable to other WBs also and support the RBMP. Running similar analysis for few other selected WBs could allow verifying outcome of the given assessment to provide general prioritisation of the measures (based on their cost-effectiveness). This information could be used afterwards to guide selection of additional measures for concrete WBs (failing GES) when planning the program of measures.

The developed methodology can be used also for evaluating measures concerning other pressures from agriculture and forestry.

5.2 Additional measures included in the evaluation

The additional measures included in the assessment are listed below. They have been identified based on knowledge of the project's experts. The main principles for identifying possible measures were that they address the pressure causing failure of GES and are technically feasible. The technical feasibility was considered based on experience in the project's countries with implementing such measures, information from existing studies in the countries, as well as literature. All the measures are technically feasible in principle. However their application for concrete WBs needs further analysis taking into account local conditions. This can be considered in the next step of developing the program of measures – when analysing and selecting measures on the WB scale (for each concrete WB failing GES).

Possible additional measures for reducing diffuse nutrient pollution from agriculture (crop farming), which were initially identified for the analysis:

M1 Artificial (constructed) wetlands (groundwater)
M2 Artificial (constructed) wetlands (surface)
M3 Controlled drainage
M4 Buffer bars
M5 Using of nitrogen stabilizers when applying nitrogen
M6 Post-crops sowing after harvest / middle crops sowing (intermediate crops), catch crops
M7 Sedimentation basins / traps
M8 Crop rotation in arable land
M9 Spreading of fertilizers at certain distances from waters
M10 Winter green areas (stubble fields)
M11 Agricultural liming
M12 Energy crops
M13 Straw application in the field before winter sowing
M14 Preparation of fertiliser management plans or improving of basic fertiliser management plans.

5.3 Effectiveness of the measures

5.3.1 Assessment approach

The assessment approach has been developed (in 2014) and applied (in 2016) for the CEA of marine protection measures in Latvia, also has been applied for the second RBMPs in Estonia.

Effectiveness assessment consists of **3 elements, which are combined** for estimating the total effectiveness of a measure.

<u>1) Effect of a measure in terms of load reduction</u> from the source. Such assessment is done for each measure. It is not WB-specific but general assessment for a measure as such.

The used assessment scale and categories:

1 – “low” effect, a measure gives < 5% reduction of load from the source,

2 – “moderate” effect, a measure gives 5-15 % reduction of load from the source,

3 – “high” effect, a measure gives 15-30 % reduction of load from the source,

4 – “very high” effect, a measure gives > 30 % reduction of load from the source.

2) Relative significance of the activities’ created pressure, which, in general, shows relative contribution of each activity causing the particular pressure into the total pressure on all WBs failing GES due to this pressure. In the given analysis, which is based on a selected WB, the total nutrient load on the selected WB is taken as the total pressure. The used assessment categories are presented in Table 5.1.

3) Significance of scale of the activities’ created pressure, which characterises extent of impact of the activities’ created pressure in terms of number of WBs failing GES due to the given pressure. The used assessment categories are presented in Table 5.1.

The assessments for the elements 2 and 3 are not measure specific, they are developed for the analysed pressure and relevant activities contributing into this pressure. Hence they are the same for all measures addressing the same pressure and activity (e.g. contribution of the agriculture into the total nutrient load).

Assessments with the categories can be derived based on expert judgement. In our case, nutrient modelling data are used for the element 2 (for the selected WB) and pressure and status assessment results (on WBs failing GES due to various pressures in the project area) are used for the element 3.

Table 5.1. Description of the assessment scale for assessing the significance of activities’ caused pressures. *(Source: LHEI, AKTiiVS (2014).[32])*

** In the given analysis total nutrient load on the analysed WB (G308 Jogla) is taken as the total pressure.*

Scale	Categories	Description of the categories for SIGNIFICANCE OF PRESSURE (Effectiveness element 2)	Description of the categories for SIGNIFICANCE OF SCALE of pressure (Effectiveness element 3)
1	**Low significance**	Activity makes **< 20 %** of the total pressure on all WBs failing GES*	Pressure from activity impacts **< 5 %** of the WBs failing GES due to given pressure
2	**Moderate significance**	Activity makes **20-30 %** of the total pressure on all WBs failing GES*	Pressure from activity impacts **5 -20 %** of the WBs failing GES due to given pressure
3	**High significance**	Activity makes **30-50 %** of the total pressure on all WBs failing GES*	Pressure from activity impacts **20-60 %** of the WBs failing GES due to given pressure
4	**Very high significance**	Activity makes **> 50 %** of the total pressure on all WBs failing GES*	Pressure from activity impacts **> 60 %** of the WBs failing GES due to given pressure

Summary effectiveness assessment for each measure is calculated by multiplying scores of each element, and interpreting the summary points according to the following categories, where the effectiveness is:

1 – “very low” = if total points range from 1 to 5,

2 – “low” = if total points range from 6 to 10,

3 – “moderate” = if total points range from 11 to 20,

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[32] LHEI, AKTiiVS (2014) Report for a project financed by the Latvian Environment Protection Fund “Feasibility study for developing program of measures for achieving GES”. Available in Latvian (at http://www.lhei.lv/attachments/article/133/Projekti-Prieksizpete_JSD_PP_Nosleguma%20atskaite_20141222_gala.pdf).

4 – “high” = if total points range from 21 to 30,

5 – “very high” = if total points range above 30.

5.3.2 Assessment for load reduction from the source (Effectiveness element 1)

Table 5.2 provides assessment of effect of the measures as nutrient load reduction from the source (Effectiveness element 1). It was assessed based on expert knowledge (LEGMC) using also information from national studies and literature. Also certainty of this effectiveness assessment is provided. It was assessed applying the following categories:

1 “very low” – a measure is not clearly defined / specified that the effectiveness can be properly estimated.

2 “low” – effectiveness of a measure is highly dependent on set of activities for each case (site / WB) and therefore it is very case specific.

3 “moderate” – there are factors that introduce considerable variations in the effectiveness (e.g. site specific characteristics, way of implementing a measure). Thus the actual effect can be lower / higher in some cases. The definition of a measure doesn’t account fully these factors. No national data / studies are available on the effectiveness of a measure.

4 “high” – there are factors that can introduce certain variations in the effectiveness (for instance, effectiveness can change during operation if no specific actions are taken, e.g. cleaning of a sedimentation pond). No national data / studies are available on the effectiveness of a measure.

5 “very high” – there are no factors introducing significant variations in the effectiveness. The estimate is based on national experience (data, studies).

NI means that there is no direct impact on reducing pressure / improving state.

Table 5.2. Assessment on effect of the measures as load reduction from the source. *(Source: Assessment prepared by LEGMC based on expert knowledge and literature.)*

[1] Assessment category for the “targeted effect” – nutrient load reduction (from the source).

[2] Multiple effects – a measure gives also positive effect on other quality parameters (+ if reducing suspended solids, + if positive impact on hydrological regime and morphology).

	Effect as load reduction from source (Effectiveness element 1)		**Certainty of the Effectiveness assessment**
Assessed additional measures	**Nutrients[1]**	**Multiple[2]**	
M1 Artificial (constructed) wetlands (groundwater)	4	++	4 (high)
M2 Artificial (constructed) wetlands (surface)	4	+	4 (high)
M3 Controlled drainage	4	+	4 (high)
M7 Sedimentation basins / traps	3	++	4 (high)
M4 Buffer bars	3	+	4 (high)
M6 Post-crops sowing after harvest / middle crops sowing (intermediate crops), catch crops	3		4 (high)
M8 Crop rotation in arable land	3		4 (high)
M10 Winter green areas (stubble fields)	2		4 (high)
M5 Using of nitrogen stabilizers when applying nitrogen	2		3 (moderate)
M9 Spreading of fertilizers at certain distances from waters	2		3 (moderate)
M12 Energy crops	2		3 (moderate)

Assessed additional measures	Effect as load reduction from source (Effectiveness element 1)		Certainty of the Effectiveness assessment
	Nutrients[1]	Multiple[2]	
M11 Agricultural liming	2		2 (low)
M13 Straw application in the field before winter sowing	1		3 (moderate)
M14 Preparation of fertiliser management plans or improving of basic fertiliser management plans.	NA		NI

Multiple effects are not accounted in the total score directly, but can be taken in addition when prioritising the measures. For instance, M4 and M7 have the same effect category (score), but M7 has larger multiple effects, thus, it has higher effectiveness than M4. If a WB is impacted also by hydro-morphological pressures (e.g. due to drainage), the measures with positive multiple impact on hydro-morphology have higher effectiveness and priority. Also the certainty assessment can be considered as additional factor when prioritising the measures.

The measures are ordered in the table starting with the one with the highest effectiveness, including when taking into account the multiple effect and certainty. The ordering demonstrates impact on prioritisation when multiple effect and certainty is also considered for the effect. Initially the measures were ordered starting from the highest effect. Now some measures have changed position in the list after considering the multiple effect and certainty. For instance, the measure *M7 Sedimentation basins / traps* has gotten higher priority due to its multiple effect (and high certainty of the effect).

Note that some measures have identical effectiveness assessment which is not reflected in the ordering (e.g. the measures with identical score, multiple effect and certainty, like M2 and M3, M6 and M8, M5-M12).

The selected WB G308 fails GES due to phosphorus (P) load. Hence, the effect of measures was assessed as P load reduction from the source (presented in Table 5.3). This assessment was used in further analysis when estimating the costs and cost-effectiveness.

Table 5.3. Assessment on effect of the measures as phosphorus (P) load reduction from the source. *(Source: Assessment prepared by LEGMC based on expert knowledge and literature.)*

[1] Assessment category for the "targeted effect" – P load reduction (from the source).

[2] Multiple effects – a measure gives also positive effect on other quality parameters (+ if reducing suspended solids, + if positive impact on hydrological regime and morphology).

The used assessment scale and categories:

1 – "low" effect, a measure gives < 5% reduction of load from the source,
2 – "moderate" effect, a measure gives 5-15 % reduction of load from the source,
3 – "high" effect, a measure gives 15-30 % reduction of load from the source,
4 – "very high" effect, a measure gives > 30 % reduction of load from the source.

Assessed additional measures	Effect as load reduction from source (Effectiveness element 1)		Certainty of the Effectiveness assessment
	Phosphorus[1]	Multiple[2]	
M1 Artificial (constructed) wetlands (groundwater)	4	++	4 (high)
M2 Artificial (constructed) wetlands (surface)	4	+	4 (high)
M3 Controlled drainage	4	+	4 (high)
M7 Sedimentation basins / traps	3	++	4 (high)

Assessed additional measures	Effect as load reduction from source (Effectiveness element 1)		Certainty of the Effectiveness assessment
	Phosphorus[1]	Multiple[2]	
M4 Buffer bars	3	+	4 (high)
M11 Agricultural liming	3		2 (low)
M8 Crop rotation in arable land	2		3 (moderate)
M9 Spreading of fertilizers at certain distances from waters	2		3 (moderate)
M10 Winter green areas (stubble fields)	2		3 (moderate)
M12 Energy crops	1		3 (moderate)
M5 Using of nitrogen stabilizers when applying nitrogen	No effect for P load reduction		NI
M6 Post-crops sowing after harvest / middle crops sowing (intermediate crops), catch crops	No effect for P load reduction		NI
M13 Straw application in the field before winter sowing	No effect for P load reduction		NI
M14 Preparation of fertiliser management plans or improving of basic fertiliser management plans.	NA		NI

Some from the initially included measures has effect on N but do not have effect on P (e.g. M5, M6). They were not included in further analysis for the selected WB.

Quantitative estimates of the effect that were used for the analysis are presented in Table 5.4.

Table 5.4. Phosphorus (P) load reduction from the source (crop farming) used in the analysis. *(Source: Assessment prepared by LEGMC based on expert knowledge and literature.)*

** Middle of the interval of the effect assessment (presented in the previous table).*

Assessed additional measures	P load reduction, %
M1 Artificial (constructed) wetlands (groundwater)	80
M2 Artificial (constructed) wetlands (surface)	60
M3 Controlled drainage	50
M7 Sedimentation basins / traps	30
M4 Buffer bars	30
M11 Agricultural liming	22.5*
M8 Crop rotation in arable land	10*
M9 Spreading of fertilizers at certain distances from waters	10*
M10 Winter green areas (stubble fields)	10*
M12 Energy crops	2.5*

5.3.3 Assessment for significance of pressure from the source/activity (Effectiveness element 2)

Table 5.5 presents the assessment of significance of pressure from relevant sources/activities contributing into the total pressure (nutrient pollution emissions).

For full scale analysis such assessment would show contribution of each relevant activity into the total pressure on all WBs failing GES due to nutrient pollution. It would require calculating nutrient load to all WBs failing GES due to nutrients and contribution of each activity into this total load. Since such data were not available, our analysis was limited to a selected WB, and the assessment shows contribution of each activity into the total nutrient load for that WB (G308 Jogla). Only anthropogenic load is taken into account in this assessment, and contribution of activities into this load.

The assessment was prepared by LEGMC experts based on results of nutrient load modelling. It shows that diffuse pollution from agriculture (crop farming) makes more than 50 % of the total anthropogenic nutrient load on the given WB. Hence it has score 4 for this effectiveness element, which is applied to all analysed measures (since they address nutrient pollution from this activity).

***Table 5.5. Assessment on significance of pressure from the sources/activities for G308 Jogla**. (Source: Assessment by LEGMC, based on modelling of nutrient pollution loads.)*

[1] Note that the assessment shows contribution of an activity into the total nutrient load for the WB G308 Jogla. Only anthropogenic part of the total load is considered in the assessment.

"-" means that pressure from this activity is not significant in the analysed WB.

Pressure	**Activities causing significant pressure**	**Assessment of significance of pressure from the activity**	
		Category	**Description of the category**
Emission of nutrients	Agriculture – crop farming	**4**	Activity makes **> 50 %** of the total pressure on the WB[1]
	Forestry – clear cutting	**-**	
	Centralised sewage systems	**-**	
	Industrial individual sewage systems	**1**	Activity makes <**20 %** of the total pressure on the WB[1]

5.3.4 Assessment for significance of scale of the pressure (Effectiveness element 3)

Table 5.6 presents the assessment of significance of scale of pressure from relevant activities (Effectiveness element 3). All WBs failing GES due to the nutrient pollution (from all sources/activities) are listed in the table.

Number of WBs failing GES due to each source/activity is calculated as percentage from (i) all WBs failing GES due to nutrient pollution (16 WBs in total) and (ii) all WBs failing GES due to all pressures in the project area (24 WBs in total).

If the aim is to obtain effectiveness assessment that is comparable across all pressures causing failure of GES, the assessment [2] (at the end of the table) needs to be used for the Effectiveness element 3. Such effectiveness assessment would allow comparing and prioritising additional measures for all pressures causing failure of GES. But, at the same time, it would reduce the total effectiveness assessment for all measures. The assessment [1] aims comparing and prioritising measures for nutrient pollution pressure only allowing comparison of measures from relevant nutrient sources/activities.

Table 5.6. Assessment on significance of scale of the nutrient pressure from various activities. *(Source: Pressures and status assessment prepared as part of the project by LEGMC.)*

WBs failing GES due to nutrient pollution in the Latvian part of the project area	**due to nutrient pollution from**			
	agriculture	**forestry**	**centralised sewage**	**industrial sewage**
Salainis E203		X		
Lūkumīša ezers E204		X		
Burtnieku ezers E225	X			
Lielais Bauzis E228	X			
Vija_1 G229	X	X		
Melnupe_2 G233	X			
Melnupe_1 G234	X			
Vaidava_2 G235	X			
Gauja_6 G241	X	X		
Salaca_2 G301	X	X		
Salaca_3 G303SP	X			
Iģe_1 G304	X			
Jogla G308	X			X
Briede_1 G322	X			
Blusupīte G325	X			
Vaidava_1 G334			X	
No of WBs failing GES due to pressure from this source/activity	13	5	1	1
Proportion (%) from all WBs failing GES due to the nutrient pressure (**16 WBs**)	81 %	31 %	6 %	6 %
Assessment category for SIGNIFICNACE OF SCALE OF PRESSURE [assessment 1]	**4**	**3**	**2**	**2**
Proportion (%) from all WBs failing GES in the LAT project area due to all pressures (**24 WBs**)	54 %	20.8 %	4 %	4 %
Assessment category for SIGNIFICNACE OF SCALE OF PRESSURE [assessment 2]	**3**	**2-3**	**1**	**1**

For additional measures related to agriculture as nutrient source the assessment for Effectiveness element 3 is "4" or "3" depending on the scope of the analysis. It is based on the assessment categories presented earlier (the nutrient pressure from agriculture impacts *"more than 60 % of the WBs failing GES due to nutrient pollution"* or *"20-60 % of the WBs failing GES due to all pressures"*).

In the given analysis we aim to find cost-effective measures for nutrient pollution pressure, hence we used the assessment 1 (category 4 for the agricultural measures). It is applied to all analysed measures (since they address nutrient pollution from this activity).

5.3.5 Effectiveness of the measures

Table 5.7 provides summary on the effectiveness assessment. The total effectiveness (score) is calculated according to the approach described in chapter 5.3.1 (by multiplying scores of the three elements). Multiple effects are not accounted in the total score directly, but can be taken in addition when prioritising the measures. For instance, M4 and M7 have the same total score and category, but M7 has larger multiple effects, thus, it has higher effectiveness than M4.

The assessment category (last column) is primarily based on the total effectiveness score. But in case where the total score is close to a threshold between two categories, the assessment category is corrected taking into account certainty of the effectiveness assessment (e.g. decreasing category for M8-M10 due to moderate certainty).

The measures are ordered in the table starting with the one with the highest effectiveness for P reduction, including when taking into account the multiple effect and certainty.

Table 5.7. Assessment of effectiveness of additional measures for reducing phosphorus (P) pollution from agriculture (crop farming). *(Source: Assessment compiled based on results of the analysis.)*

Assessment categories are explained in chapter 5.3.1.

[1] Assessment category for the "targeted effect" – phosphorus load reduction (from the source).

[2] Multiple effects – a measure gives also positive effect on other quality parameters (+ if reducing suspended solids, + if positive impact on hydrological regime and morphology).

[3] Certainty of the effectiveness assessment (for the "targeted effect").

[4] The category is primarily based on the Total effectiveness score. But in case where the Total score is close to a threshold between two categories, the assessment category is corrected taking into account certainty of the effectiveness assessment (e.g. decreasing category for M8-M10). Multiple effect is not accounted in the category directly but can be considered for prioritisation.

Assessed additional measures	**Effect1**			**Effect2**	**Effect3**	**Total**	**Category[4]**
	Phosphorus[1]	**Multiple[2]**	**Certainty[3]**				
M1 Artificial (constructed) wetlands (groundwater)	4	++	4 (high)	4	4	**64**	**Very High (5)**
M2 Artificial (constructed) wetlands (surface)	4	+	4 (high)	4	4	**64**	**Very High (5)**
M3 Controlled drainage	4	+	4 (high)	4	4	**64**	**Very High (5)**
M7 Sedimentation basins / traps	3	++	4 (high)	4	4	**48**	**Very High (5)**
M4 Buffer bars	3	+	4 (high)	4	4	**48**	**Very High (5)**
M11 Agricultural liming	3		2 (low)	4	4	**48**	**Very High (5)**
M8 Crop rotation in arable land	2		3 (moderate)	4	4	**32**	**High (4)**
M9 Spreading of fertilizers at certain distances from waters	2		3 (moderate)	4	4	**32**	**High (4)**
M10 Winter green areas (stubble fields)	2		3 (moderate)	4	4	**32**	**High (4)**
M12 Energy crops	1		3 (moderate)	4	4	**16**	**Moderate (3)**

The results show that all the measures except M12 are highly effective. Their effect in terms of load reduction from the source is different, but they all address the activity which gives the largest contribution into the total nutrient load on the WBs (the WB G308 Jogla in the given analysis) and which impacts large proportion of all WBs failing GES due to nutrient pollution in the project area.

5.4 Costs of the measures

5.4.1 Assessment approach

A measure can involve the following categories of the costs:

1. direct financial costs of a measure (investment, e.g. construction, costs; yearly operation and maintenance costs; other direct costs e.g. costs of a construction project and permit);
2. "opportunity costs" (foregone/lost revenues) for an actor who implements a measure and for the local economy – some measures create such costs due to lost production (e.g. in the measures application area for wetlands and buffer bars) or due to reduced yield in the measure application area (e.g. for M9);[33]
3. administrative costs (e.g. for controlling implementation of a measure) – might be relevant for some of the measures, but could not be estimated quantitatively, hence are not included.

The measures can give also economic gains (e.g. due to improving soil fertility, increasing yield), but also these could not be estimated qualitatively, therefore are not included. The exception is the measure *M12 Energy crops* where the revenues from selling the harvest are estimated and the costs of this measure are calculated as net costs (revenues minus costs).

It was concluded overall that the main cost types are covered by the developed quantitative estimates, and the provided estimates could be seen reliable for the cost-effectiveness analysis and prioritisation of the measures.

Assessment of the costs for each measure included the following steps:

- identifying and describing relevant types of the costs (related to the categories above),
- developing quantitative estimates for each type of the costs,
- calculating total costs of a measure (as annualised costs per year),
- estimating costs as a share of a implementers' revenues (%),
- performing a sensitivity analysis of the calculated costs to incorporate variation and uncertainty in the costs' estimate,
- assigning the qualitative assessment category (from "very high" to "very low" costs) based on the share of the costs in the revenues.

Total costs for each measure are estimated quantitatively. To incorporate variation and uncertainty in the costs a "sensitivity analysis" was performed. Relevant input parameters (the ones impacting the calculated total costs most significantly) are identified and cost interval is calculated (with the range of values for the relevant input parameters).

The quantitative costs are calculated as a share of yearly turnover of the crop farming in the project area (since the analysed measures address diffuse nutrient pollution load from arable land). Various CSB data are used to estimate the turnover of the crop farming in the project area and in the analysed WB G308 Jogla.

The costs are classified as low/moderate/high costs according to an approach as presented in Table 5.8. In this way the costs are linked to financial capacity of actors to implement a measure (called also as "affordability" of the costs). The applied affordability threshold (for high costs) is 1.5 % of turnover. This threshold was set based on expert opinion of the project's experts, taking into account also practice in other EU countries[34] and similar national assessments for the marine protection policy in Latvia.

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[33] The „opportunity costs" are estimated based on the data about turnover and profit of crop farming (using CSB data and calculations) and application area of a measure.

[34] European Commission (2014) *"Addressing affordability concerns in WFD implementation. Resource document for the WG Economics."* Version from October 2014.

Table 5.8. Interpretation of the qualitative costs' categories (and scores).

Costs' category	Interpretation of the category	Costs as a share (%) of yearly turnover
Very low (5)	The costs are affordable, an actor could cover the costs with own funding.	< 0.5 % of turnover
Low (4)		0.5-1 % of turnover
Moderate (3)	The costs are hardly affordable, some public financial support would be recommended to facilitate implementation of a measure.	1-1.5 % of turnover
High (2)	The costs are not affordable, public funding would be needed for financing implementation of a measure.	**1.5**-2 % of turnover
Very high (1)		> 2 % of turnover

5.4.2 Assessment result

Results of the cost estimation are provided in Table 5.9. Only those measures are included with an effect on P load reduction.

The costs are estimated assuming required **application** of a measure for 100 ha of arable land area (presented in the column 1). The same reference arable land area needs to be considered in order to obtain comparable cost estimates across measures that they could be compared for the cost-effectiveness analysis and prioritisation. To simplify the calculation and make it more transparent 100 ha arable land area is used. The costs can be estimated in the same way also for the whole arable land area of the analysed WB (1269.20 ha). Some measures are applied outside the arable land, and the optimal application extent is calculated as proportion of the "served" arable land area (e.g. M1, M2, M3, M4, M7 and M9). For instance, it is suggested that the surface constructed wetland (M2) should make 0.5-4 % of the "served" catchment area, and the "served" catchment area should not be larger than 100 ha for 1 such wetland. The application for this measures is estimated assuming 0.5 % of the wetland from the catchment (arable land) area and 1 wetland for every 80 ha (giving for 100 ha of arable land 0.5 ha of total wetland area and 1.25 wetland). Other measures (M8, M10, M11, M12) are applied on the arable land hence their costs are estimated with the assumed application for the whole area (100 ha).

The column 2 provides the estimated **costs for the given application extent (100 ha of arable land area).** The costs are estimated as annualised costs per year. The cost estimates are based on input data from national studies, literature and expert assumptions. Hence the lower and upper bound of the costs are calculated accounting range of the input data (in particular, for the construction costs and operation and maintenance costs; in case of M9 with different assumptions on lost yield due to limiting use of fertilisers).

Some cost types could not be estimated quantitatively, like administrative costs of controlling implementation of a measure (might be relevant for some of the measures, but could not be estimated quantitatively). Also some measures would give economic gains (e.g. due to improving soil fertility, increasing yield), but also these could not be estimated qualitatively. At the same time, it can be concluded that the main costs are covered by the estimates, and the provided estimates are reliable enough for the cost effectiveness analysis and prioritisation of the measures.

The costs of *M12 Energy crops* are estimated to be 0 EUR. Although there are considerable costs of implementing the measure, the harvest can be sold for energy production providing revenues. Thus, the costs of this measure are calculated as "net costs" (revenues minus implementation costs). The estimated revenues exceed considerably the estimated costs, hence the (net) costs of the measure are assumed to be zero.

The column 3 provides the estimated **yearly costs per 1 ha of arable land area**. These estimates can be used for calculating total costs of a measure for any WB according the required application of the measures to achieve nutrient load reduction target. Such estimate for the WB G308 Jogla is provided in Table 5.11. But **these unit costs (EUR/1 ha of arable land area) can be used also for other WBs where P or N load related to diffuse pollution needs to reduced**.

The highest costs are estimated for *M1 Artificial (constructed) wetlands (groundwater).* This measure requires large number of objects per catchment area, and it increases the construction costs considerably due to construction project and permit needed for each such object. It also involves relatively larger "opportunity costs". The next measure with the highest costs is *M8 Crop rotation in arable land*. Its costs include primarily the "opportunity costs" – due to leaving the land as fallow as part of crop rotation the lost yield creates the foregone revenues (a conservative assumption is used that the yield is lost once per every 5 years). Relatively high costs are created also by the measures M2, M3, M10 and M11. The largest cost positions for M2 are construction costs and yearly operation and maintenance costs, although the measure involves also some "opportunity costs" (due to allocating productive agricultural land for the wetland). For M3 the largest part is created by the construction costs, including costs of a construction project and permit. The estimated costs of M12 include only yearly operation costs, where the lower bound of the cost interval is based on estimate from Lithuanian experience and the upper bound of the cost interval is based on the compensation payment for this measure as part of the Rural Development Plan assuming to cover all the costs. For M11 the cost estimates include only operation costs of applying lime (once in every 5-6 years).

The lowest costs are estimated for *M9 Spreading of fertilizers at certain distances from waters*, which involves only "opportunity costs" due to lost productivity in the agricultural land with no fertilisation allowed (the cost interval is based on an assumption of 50 and 100 % lost yield in the measure's application area for the lower and upper bound of the costs). The next lowest costs are estimated for the *M7 Sedimentation basins / traps*, which is assumed to create only construction and maintenance costs. Also *M4 Buffer bars* has relatively lower costs, here the largest cost position is "opportunity costs" due to lost production area, although the estimate includes also yearly maintenance costs and also some arrangement costs (they are relatively small since discounted over 10-20 years assumed lifetime of the measure).

The column 4 of the table provides the **assessment of the costs as percentage share of the crop farming turnover** in the WB 308 Jogla.[35] The column 5 provides for each measure the **qualitative cost assessment category** (according to the approach explained in chapter 5.4.1). The results show "very high" costs for majority of the measures. Exceptions are M7, M9 and M12 – the costs are "high-very high" for M7, "moderate-high" for M9 and there are not (net) costs for M12. However the M9 and M12 alone could not provide achievement of the required P load reduction. The same needs to be noted concerning M8 and M10.

It can be concluded overall that the costs are not **affordably** for majority of the measures, but this conclusion is linked to the applied threshold of "high costs" (1.5 % of the yearly turnover). This threshold was set based on opinion of project experts and also previous experience in Latvia applying similar costs' assessment approach in the context of marine protection policy. If increasing the threshold, the costs could become "low" for M9, "moderate" for *M7 Sedimentation basins / traps*, "high" or even "moderate" for the *M4 Buffer bars* depending on the used threshold. Hence, the results must be interpreted and used together with the given threshold of the "high" costs.

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[35] The estimated yearly turnover of crop farming in the whole WB area (1269.2 ha of arable land area) is 239 200 EUR per year, or 18 850 EUR per year for 100 ha of arable land area, which is used in the cost calculation. The estimated turnover of agriculture for the project area (based on CSB data) is provided in chapter 1.3 of this report. Based on CSB data, proportion for the crop farming was estimated, as well as proportion for the WB 308 Jogla was estimated (based on the share of arable land of the WB into the total arable land in the project territory – 1.3 %).

Table 5.9. Costs of the measures for phosphorus (P) load reduction for WB G308 Jogla. *(Source: Estimates developed as part of the project.)*

Assessed additional measures	**Necessary application for 100 ha of arable land**	**Total yearly costs (EUR) for 100 ha of arable land**		**Yearly costs EUR per 1 ha of arable land**		**Share (%) from turnover**		**Costs' category**	**Comments**
		Lower	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**		
	[1]	[2]		[3]		[4]		**[5]**	[6]
M1 Artificial (constructed) wetlands (groundwater)	106 wetlands; 1.7 ha of total wetland area	8 431	26 465	84.3	264.6	45	140	**Very high (1)**	Very high costs due to small size of an individual wetland and large No of such objects needed for achieving load reduction.
M2 Artificial (constructed) wetlands (surface)	1.25 wetlands; 0.5 ha of total wetland area	964	2 623	9.6	26.2	5	14	**Very High (1)**	
M3 Controlled drainage	17 controlling wells	850	2 493	8.5	24.9	4.5	13	**Very high (1)**	
M4 Buffer bars	2 ha of buffer bar area (2 % of arable land)	484	613	4.8	6.1	2.6	3.3	**Very high (1)**	Cost estimates are sensitive to the assumption on required buffer bar area as % of "served" catchment area (2% of arable land are assumed; for instance, the costs would be "Low" with 1%).
M7 Sedimentation basins / traps	1.3 basins; 0.3 ha of total basin area	288	401	2.9	4.0	1.5	2.1	**High-Very high (1.5)**	The costs category is sensitive to number of required basins (which depends on required application for achieving load reduction target). With 10 basins the category becomes "Moderate"
M8 Crop rotation in arable land	100 ha	3 769	3 769	38	38	20	20	**Very high (1)**	Not enough area in the WB for required application to achieve the load reduction target. It is due to low effect of M. on P load reduction, which requires large area of application to achieve the target. **Achieving the objective with this M. only is not possible.**
M9 Spreading of fertilizers at certain distances from waters	2 ha of no fertilisation area (2 % of arable land)	188	377	1.9	3.8	1	2	**Moderate-High (2.5)**	
M10 Winter green areas (stubble fields)	100 ha	1 500	8 700	15.0	87.0	8	46	**Very high (1)**	
M11 Agricultural liming	100 ha	1 667	2 000	16.7	20.0	9	11	**Very high (1)**	
M12 Energy crops	100 ha	0	0	0	0	0	0	**No costs (5)**	Revenues from harvested crops cover the costs. But not enough area in the WB for required application to achieve the load reduction target. **Achieving the objective with this M. only is not possible.**

Table 5.10 presents the estimated load reduction which can be achieved by each measures **with maximal application of each measure in the WB G308 Jogla (1269.2 ha).** It should be taken into account that theoretical maximal application of each measure is used (with the total available arable land in the WB). Real application is not analysed – it needs to be done when selecting measures on WB scale for developing program of measures (it is out of the scope of this general evaluation), including taking into account local conditions and current application of the measures. As can be seen, for the M8, M9, M10 and M12 the required load reduction is not achieved even with maximum possible application of the measure.

Table 5.10. Estimates on required P load reduction for the WB 308 Jogla and possible load reduction with maximal application of each measure. *(Source: Estimates developed as part of the study.)*

[1] Nutrient modelling results (LEGMC).

[2] The required load reduction is not achieved even with maximum possible application of the measure.

NOTE. *Theoretical maximal application of each measure with the available arable land (1269.2 ha) is used. Real application is not analysed – it needs to be done when selecting measures on WB scale for developing program of measures (out of the scope of this general evaluation), including taking into account local conditions and current application of the measures.*

Current P load on the WB, kg/year[1]	245 kg
Allowed P load to comply with objectives, kg /year[1]	199.2 kg
Required P load reduction kg/year[1]	**45.8 kg**
Possible P load reduction (kg/year) assuming maximal implementation of a measure in the WB G308 Jogla (1269.2 ha arable land)	
M1 Artificial (constructed) wetlands (groundwater)	196 kg
M2 Artificial (constructed) wetlands (surface)	147 kg
M3 Controlled drainage	122.5 kg
M4 Buffer bars	73.5 kg
M7 Sedimentation basins / traps	73.5 kg
M8 Crop rotation in arable land	25 kg[2]
M9 Spreading of fertilizers at certain distances from waters	25 kg[2]
M10 Winter green areas (stubble fields)	24.5 kg[2]
M11 Agricultural liming	55 kg
M12 Energy crops	6 kg[2]

Table 5.11. Total yearly costs of the measures for achieving required P load reduction in the WB G308 Jogla (45.8 kg /year). *(source: Estimates prepared as part of the study.)*

** Maximum possible application in the WB is assumed (taking into account available arable land area in the WB – 1269.2 ha). But it does not provide the required P load reduction to comply with the target.*

NOTE. Theoretical necessary/maximal application of each measure with the available arable land (1269.2 ha) is used. Real application is not analysed – it needs to be done when selecting measures on WB scale for developing program of measures (out of the scope of this general evaluation). Including taking into account local conditions and current application of the measures.

	Total yearly costs for the necessary P load reduction for G308 Jogla (45.8 kg /year) (EUR/year)		**Comments**
	Lower	**Upper**	
M1 Artificial (constructed) wetlands (groundwater)	25 004	78 489	

	Total yearly costs for the necessary P load reduction for G308 Jogla (45.8 kg /year) (EUR/year)		Comments
	Lower	**Upper**	
M2 Artificial (constructed) wetlands (surface)	3 812	10 374	
M3 Controlled drainage	4 032	11 830	
M4 Buffer bars	3 830	4 850	
M7 Sedimentation basins / traps	2 277	3 172	
M8 Crop rotation in arable land	89 420*	89 420*	Maximum possible application in the WB is assumed. Only around 50 % of the required load reduction can be achieved with such application.
M9 Spreading of fertilizers at certain distances from waters	4 471*	8 942*	
M10 Winter green areas (stubble fields)	35 589*	206 41*9	
M11 Agricultural liming	17 575	21 090	
M12 Energy crops	0*	0*	Only 13 % of the required load reduction can be achieved with the maximum application of the measure.

5.5 Cost-Effectiveness of the measures

5.5.1 Assessment approach

The cost-effectiveness of measures allows comparing measures and selecting the most cost-effective ones for achieving the environmental objectives (for the required P load reduction in the analysed case). The cost-effectiveness of each measure is assessed combing the assessments on their effectiveness and costs according to the approach as presented in Table 5.12. The cost-effectiveness is also assessed in the scale from 1 "very low" (red cells in the table) to 5 "very high" (dark green cells in the table). The given approach has been developed and applied in Latvia for evaluating the marine protection measures. Also has been applied for the 2nd RBMPs in Estonia.

Table 5.12. Approach for estimating cost-effectiveness of additional measures based on the assessed effectiveness and costs. *(Source: AKTiiVS, LHEI (2016) „Sociālekonomiskais novērtējums papildus pasākumiem laba jūras vides stāvokļa panākšanai", LVAF finansēta projekta atskaite.)*

Cost categories	Effectiveness categories				
	5 very high	4 high	3 moderate	2 low	1 very low
1 very high	3	3	2	1	1
2 high	3	3	3	2	1
3 moderate	4	4	3	2	2
4 low	5	4	3	3	3
5 very low	5	5	4	3	3

In addition a **cost-effectiveness coefficient** is calculated for each measure based on the effectiveness and costs' categories (scores). It is calculated diving the costs' score by the effectiveness' score, where the costs scores are changed from 1 being "very low" costs to 5 being "very high" costs. It can take value from 0.2 to 5 – the lower is the coefficient, the better is the cost-effectiveness.

5.5.2 Assessment result

Table 5.13 provides the assessment result on the cost-effectiveness of the analysed measures. The assessment with the qualitative cost-effectiveness categories is provided as the first. It is assessed combining the effectiveness and costs' assessment (according to the approach described in the previous chapter). It shows that most measures has “moderate” cost-effectiveness, except *M12 Energy crops* with “high” cost-effectiveness due to zero (net) costs and *M9 Spreading of fertilizers at certain distances from waters* with “moderate-high” cost-effectiveness due to relatively good effectiveness and low costs. But both measures have rather limited capacity for achieving the required load reduction, like it is also for the measures M8 and M12.

The table includes also the calculated CE coefficient (the costs assessment score divided by the effectiveness assessment score). It allows slightly more differentiated assessment supporting better prioritisation of the measures based on their cost-effectiveness. As can be seen, the coefficient varies for all the measures with the same “moderate” cost-effectiveness category (from 0.9 for M7 till 1.25 for M8 and M10).

Due to the low cost-effectiveness the measures M1, M8 and M10 are not proposed as potential options. Also M12 and M9 could be seen as “second best” options (or not considered at all) – they have rather low effectiveness giving limited capacity to provide achievement of the required load reduction.

The last columns of the table include fully quantitative cost-effectiveness assessment, which shows the estimated costs per 1 unit of the reduced P load (EUR/1 P kg). The measures are ranked in the table according to this result – starting with the most cost-effective measure (with the least costs per 1 reduced P kg, using the mid of the interval).

Table 5.13. Assessment on the cost-effectiveness of additional measures for P load reduction. *(Source: Estimates developed as part of the project.)*

[1] Assessment according to the approach in chapter 5.5.1.

[2] Calculated dividing the costs category (score) by the effectiveness category (score), where the costs score is changed from 1 being “very low” costs to 5 being “very high” costs. The coefficient can take value from 0.2 to 5. The lower it is, the better is the cost-effectiveness of a measure.

[3] Calculated dividing the estimated costs (EUR) by the delivered P load reduction (kg/year).

** These measures have limited capacity to provide achievement of the required load reduction (due to their relatively low effectiveness). Hence they are not proposed as options for the WB scale analysis. 3 of them have also the worst cost-effectiveness for P load reduction.*

	Cost-effectiveness assessment		**Yearly costs EUR per 1 kg of P reduction[3]**		
	Category[1]	**CE coefficient[2]**	**Lower**	**Upper**	**Middle**
M7 Sedimentation basins / traps	Moderate (3)	**0.90**	50	69	**59**
M4 Buffer bars	Moderate (3)	**1**	84	106	**95**
M2 Artificial (constructed) wetlands (surface)	Moderate (3)	**1**	83	227	**155**
M3 Controlled drainage	Moderate (3)	**1**	88	258	**173**
M11 Agricultural liming	Moderate (3)	**1**	384	460	**422**
*M12 Energy crops**	*High (4)*	***0.3***	*0*	*0*	***0***
*M9 Spreading of fertilizers at certain distances from waters**	*Moderate-High (3.5)*	***0.88***	*98*	*195*	***146***
M1 Artificial (constructed) wetlands (groundwater)	*Moderate (3)*	***1***	*546*	*1714*	***1130***
*M8 Crop rotation in arable land**	*Moderate (3)*	***1.25***	*1952*	*1952*	***1952***
*M10 Winter green areas (stubble fields)**	*Moderate (3)*	***1.25***	*777*	*4507*	***2642***

The results clearly demonstrate that the more quantitative is the cost-effectiveness assessment, the better results serve prioritisation of measures for selecting the most cost-effective set of additional measures for WBs failing GES.

The given results can be used for WBs failing GES due to phosphorus pollution (they cannot be used concerning nitrogen since the measures' effectiveness and, hence, the cost-effectiveness differs for nitrogen). The prioritised list of the measures can be applied for selecting measures on WB scale when developing the program of measures – for the analysed WB G308 Jogla, but also for other WBs in the project area where the P load from agriculture (diffuse pollution from crop farming) needs to be reduced for achieving GES. When working on the WB scale, the primary issue to be analysed in possible application of the measures taking into account local conditions and also current application of a measures (which reduces applicability). The overall principle to guide the selection is to start with the most cost-effective measures and apply them as much as possible to achieve the required load reduction.

Such theoretical set of additional measures for G308 Jogla is provided in Table 5.14. But note that real applicability of each measure for the given WB is not analysed. Hence this result is just for illustrating the approach. The analysed measures with the lowest cost-effectiveness are not included in the list (M1, M8, M10). Also the measure *M12 Energy crops* is not proposed – although it has very good cost-effectiveness ratio, it has very limited capacity to provide load reduction.

For the given WB, even the first measure *M7 Sedimentation basins* could be sufficient for achieving the required P load reduction. If there are limitations in technical applicability of this measure in reality, also *M4 Buffer bars* can be considered in addition. Most likely there would be no need for other additional measures.

Table 5.14. Illustration on selecting additional measures for the program of measures for WB G308 Jogla.

[1] Nutrient modelling results (LEGMC).

[2] Assuming maximal (theoretical) application of the measures (real applicability is not analysed).

Required P load reduction for G308 Jogla, kg/year[1]	**45.8 kg**	
The proposed additional measures – RANKED starting with the most cost-effective measure	**The achieved P load reduction by each single measure (kg/year)[2]**	**Comments in relation to measures' selection for the program of measures**
M7 Sedimentation basins / traps	73.5	Top 1 measure. Also positive multiple effect (on suspended solids reduction, hydro-morphological quality elements)
M4 Buffer bars	73.5	Top 2 measures. Also positive multiple effect (on suspended solids reduction).
M9 Spreading of fertilizers at certain distances from waters	-	*Not proposed since it overlaps with the M4 Buffer bars, but implemented alone would not allow achieving the load reduction target.*
M2 Artificial (constructed) wetlands (surface)	147	No need for these measures since the required load reduction most likely could be achievable with the first measures in the list.
M3 Controlled drainage	122.5	
M11 Agricultural liming	55	

ANNEX 1: Summary on water uses and pressures in the project area (used as basis for the economic analysis)

Source of pressure		PRESSURES	No of WBs failing GES		Comments in relation to significance of pressures		Division between water services and other water uses	
Water USERS (economic sectors, activities)	**Water USES**		**in LAT**	**in EST**	**For LATVIAN part of the project area**	**For ESTONIAN part of project area**	**LAT**	EST
Households, Industry, Other	Water abstraction for **centralised** water supply	Pressure on surface water quantity	-	-	*Surface water is not used for the centralised water supply.*	*Surface water is not used for the centralised water supply.*	(-) Reference to the Art.9.4.	(-) Reference to the Art.9.4.
	Wastewater discharging from **centralised** sewage systems	Point source pollution of nutrients	1	1	G334 municipal WWTP (Alūksne city, SIA "Rūpe").	WBs at risk due to centralised WW discharges. 2133700_1 Köstrejärv	WS	WS
		Point source pollution of hazardous substances	0	0	Pressure is not significant.	Pressure is not significant.		
Households	Individual water **(self)** abstraction	Pressure on surface water quantity	-	-	*Surface water is not used for water supply.*	*Surface water is not used for water supply.*	(-) Reference to the Art.9.4.	(-) Reference to the Art.9.4.
	Pollution from **individual** sewage	Diffuse pollution of nutrients	0	0	Pressure is not significant.	Pressure is not significant.	WS	WS
		Diffuse pollution of hazardous substances	0	0	Pressure is not significant.	Pressure is not significant.		
Industry	Individual water **(self)** abstraction	Pressure on surface water quantity	0	0	Pressure is not significant.	Pressure is not significant.	WS	WS
	Wastewater discharging from **individual** sewage systems	Point source pollution of nutrients	1	0	G308 Jogla (SIA "ALOJA-STARKELSEN") - risks (ļoti būtiska slodze)	Pressure is not significant.	WS	WS
		Point source pollution of hazardous substances	0	0	Pressure is not significant.	Pressure is not significant.		
Mining	Water **(self)** abstraction related to mining	Pressure on surface water quantity	-	-	*Water use is not relevant in Latvia.*	*Water use is not relevant in Estonia.*	(-) Reference to the Art.9.4.	(-) Reference to the Art.9.4.
	Individual excess water discharging related to mining	Pressure on surface water quality	0	-	Pressure is not significant.	*Water use is not relevant in Estonia.*	WS	(-) Reference to the Art.9.4.
Waste management (disposal)	Wastewater discharging from individual systems	Point source pollution of hazardous substances	0	-	Pressure is not significant.	*Water use is not relevant in Estonia.*	WS	(-) Reference to the Art.9.4.
	Pollution run-off from **historical** contaminated sites – waste landfills	Diffuse pollution of hazardous substances	0	-	Pressure is not significant.	*Water use is not relevant in Estonia.*	-	-
Forestry	Pollution run-off from clear-cutting and drained forest areas	Diffuse pollution of nutrients	5	0	Taking into account land use, drainage and clear-cut level, in 5 WBs pressure is significant (E203, E204, G229, G241, G301).	Pressure is not significant.	SWU	-
	Drainage of forest lands	Hydro-morphological pressure	4	-	In 4 WBs pressure is significant (G229, G304, G310, G325).	*Water use is not relevant in Estonia.*	SWU	-

Source of pressure		PRESSURES	No of WBs failing GES		Comments in relation to significance of pressures (incl., if there are HMWS - how many).		Division between water services and other water uses	
Water USERS (economic sectors, activities)	**Water USES**		**in LAT**	**in EST**	**For LATVIAN part of the project area**	**For ESTONIAN part of project area**	**LV**	EST
Agriculture	Individual water **(self)** abstraction	Pressure on surface water quantity	-	-	*Surface water is not used for water supply.*	*Surface water is not used for water supply.*	(-) Reference to the Art.9.4.	(-) Reference to the Art.9.4.
	Individual water abstraction for **irrigation**	Pressure on SW quantity	-	-	*Water use is not relevant (the abstracted amounts are negligible).*	*Water use is not relevant (the abstracted amounts are negligible).*	(-) Reference to the Art.9.4.	(-) Reference to the Art.9.4.
	Wastewater discharging from **individual** sewage systems	Point source pollution of nutrients, hazardous substances	0	0	Pressure is not significant.	Pressure is not significant.	WS	WS
	Pollution run-off from agricultural lands (mainly arable land and manure storage sites)	Diffuse pollution of nutrients	13	0	Often the pressure is in combination with other pressure (drainage, for example).	Pressure is not significant.	SWU	-
		Diffuse pollution of hazardous substances	0	0	Pressure is not significant.	Pressure is not significant.	-	-
	Pollution run-off from **historical** contaminated sites	Diffuse/Point source pollution of hazardous substances	0	-	Pressure is not significant.	*Water use is not relevant in Estonia.*	-	-
	Drainage for agriculture (by polders, regulation of water regime, straightening of rivers, drainage ditches etc.)	Hydro-morphological pressure	7	0	7 WBs "at risk" of failing GES.	Pressure is not significant.	SWU	-
	Beaver created dams on rivers due to destroying beaver habitats by anthropogenic, e.g. agricultural, land use	Hydro-morphological pressure	-	0	*Water use is not relevant in Latvia.*	Pressure is not significant.	-	-
No user (historical)	Accumulated (past) pollution in WB	Nutrient pollution in sediments	1	1	1 WB E225 Burtnieku lake with accumulated nutrients in sediments.	1 WB at risk due past pollution in sediments - 2133700_1 Köstrejärv	SWU (past)	SWU (past)
Small hydro-power plants (HPPs)	Use of water flow for energy production (involving dam, turbine, water flow fluctuations, storage pond/reservoir, etc.)	Hydro-morphological pressure / Hydrological pressure (quantity, water flow regime)	3	1	No of WBs - 3 under significant risk **due to 5 HPPs** (G235 - significant pressure from **Grūbes** and **Karvas** HES, G322 - significant pressure from **Kārlīšu** HPP; G317 - significant pressure from **Dzirnavnieku** and **Kalndzirnavu HPPs**).	Small HPP. 1158000_1; Vaidva, Vastse-Roosa dam	WS	SWU
Various users (incl. recreation, roads), no users	Dams/obstacles on rivers with various or no use (include also other obstacles e.g. "bottlenecks" under roads)	Morphological pressure	3	4	3 WBs with 8 dams/ obstacles creating significant pressure (G301, G306, G322)	Pärlijõgi_1 (Saarlase and Pärlijõe dams), Pedeli_2 (Pedeli IV, Pedeli III, Pedeli II and Pedeli I); Pärlijõgi_2 (Sänna Alaveski, Sänna Mäeveski, Ala-Raudsepa dams), Õhne_2 (Holdre Vanaveski and Taagepera dams).	SWU	SWU

ANNEX 2: Input data for the economic analysis

A2.1: Summary on the current pricing instruments in Latvia for covering the costs of water use

The pricing instruments internalise costs of water use that they are paid by water users according to the "polluters pay principle" (PPP).

There is pricing instrument for covering "financial costs" of the centralised water services – the payment for the services paid by users. Concerning the "environmental cost" recovery the applicable current pricing instruments include the NRT for water pollution, waste deposition and water use for hydro-energy production (according to the Law on NRT) and the compensation for damage to fish resources (according to the national Regulation No 188 from 08.05.2001). Where failure of GES for WBs indicate presence of (external) "environmental costs" the amounts paid via these instruments are compared to estimated "environmental costs" to assess if they are covered.

Nature Resource Tax (NRT)

The Law on NRT (adopted in 2005, the current version for 01.07.2019 – 31.12.2020) prescribes the activities which are asked to pay the tax and the tax rates. In light of significant water uses in the project area NRT is paid for pollution discharged with wastewaters, disposal of waste and water use for hydro-energy production. The tax rates for the former two are presented in Tables 1 and 2. The tax rate for water use for hydro-energy production is 0.00853 euros per 100 m3 of the water that has flown through the hydro-technical structure (source https://www.vid.gov.lv/lv/dabas-resursa-nodokla-likmes; https://likumi.lv/ta/en/en/id/124707).

NRT forms the current pricing instrument for covering the (external) "environmental costs" and, hence implementing the PPP. It is paid by all "water services" except the individual sewage by households. However the estimated amounts of the paid NRT are rather small to cover the created (external) "environmental costs" (see Chapter 2.2 for more information).

Table 1 NRT tax rates for pollution discharged with wastewaters. *(Source: Natural Resources Tax Law.)*

Note: Classification of polluting substances by their hazardousness corresponding to the tax rate groups is set in the Regulation of the Cabinet of Ministers No 404 (from 19.06.2007, last revision in 06.07.2018) „Dabas resursu nodokļa aprēķināšanas un maksāšanas kārtība un kārtība, kādā izsniedz dabas resursu lietošanas atļauju" , Annex 4.

Classification of polluting substances according to the category of hazardousness	**Tax rate EUR per ton**
Non-hazardous substances	5.50
Suspended matters (non-hazardous)	14.23
Moderately-hazardous substances, except total phosphorus (P kop)	42.69
Hazardous substances	11 382.97
Particularly hazardous substances	71 143.59
Total phosphorus (P kop)	270.00

Table 2. NRT rates for disposal of waste from 01.01.2017 *(for Municipal waste and production waste which are not seen as hazardous waste in accordance with the laws and regulations regarding waste classification and characteristics making waste hazardous). (Source: Natural Resources Tax Law.)*

Rate from 01.01.2017 to 31.12.2017 (EUR per ton)	Rate from 01.01. 2018 to 31.12.2018 (EUR per ton)	Rate from 01.01.2019 to 31.12.2019 (EUR per ton)	Rate from 01.01.2020 (EUR per ton)
25.00	35.00	43.00	50.00

Payment to compensate damage to fish resources

Damage to fish resources due to economic activities must be compensated according to the national regulation (Regulation of the Cabinet of Ministers No 188 from 08.05.2001, last revisions in 01.01.2014, *„Saimnieciskās darbības rezultātā zivju resursiem nodarītā zaudējuma noteikšanas un kompensācijas kārtība”*). The requirement applies to all economic activities which cause damage to fish resources, including inter alia to construction and operation of hydro-technical infrastructures, cleaning and regulation of water bodies (rivers, lakes, ponds). It is not applied to HPPs which pay NRT. But it applies to other water uses creating hydro-morphological pressures in the project area if they cause damage to fish resources.

According to the Regulation the damage to fish resources include direct losses of fish resources and indirect losses which are created due to damage to fish feeding and spawning grounds, including losses due to reduced fishing productivity of a water body. The Regulation prescribes how the damage (losses) needs to be estimated.

This payment forms the current pricing instrument for covering the (external) “environmental costs” and, hence implementing the PPP, as far as it concerns the negative impact on fish resources.

A2.1: Input data for the analysis for the Latvian part of the project area

List of administrative units (parishes and cities) included in the economic analysis, coefficients for each unit applied for the socioeconomic estimates (for the general socioeconomic characterisation), estimated number of inhabitants, number of companies and number of employed persons in the project area (by the administrative units) in 2017

	Administrative unit (municipalities and cities)	Area in Project territory, %	COEFFICIENT for socioeconomic estimates	Number of INHABITANTS in Project area	Number of COMPANIES in Project area	Number of EMPLOYED PERSONS in Project area
TOTAL for the project area:		**80%**		**50897**	**4299**	**14921**
1	**Ainaži**	84	1.00	752	53	176
2	Ainažu pagasts	84	0.84	390	30	55
3	**Aloja**	100	1.00	1171	84	250
4	Alojas pagasts	99	1.00	818	87	363
5	Alsviķu pagasts	80	0.80	1108	106	149
6	**Alūksne**	7	*1.00*	7451	593	3323
7	**Ape**	100	1.00	900	65	448
8	Apes pagasts	99	1.00	471	61	266
9	Bērzaines pagasts	98	1.00	537	40	104
10	Bilskas pagasts	73	0.73	862	84	184
11	Braslavas pagasts	100	1.00	590	69	154
12	Brīvzemnieku pagasts	88	0.88	799	62	89
13	Burtnieku pagasts	96	1.00	1335	112	517
14	Dikļu pagasts	91	1.00	1044	109	203
15	Ērģemes pagasts	100	1.00	818	90	162
16	Ēveles pagasts	67	0.67	313	34	37
17	Gaujienas pagasts	87	0.87	766	66	177
18	Grundzāles pagasts	100	1.00	852	93	188
19	Ilzenes pagasts	100	1.00	339	28	33
20	Ipiķu pagasts	89	0.89	192	25	25
21	Jaunalūksnes pagasts	38	0.38	423	32	70
22	Jaunlaicenes pagasts	100	1.00	442	42	143
23	Jeru pagasts	100	1.00	1265	74	611
24	Jērcēnu pagasts	31	0.31	125	13	30

25	Kalncempju pagasts	36	0.36	66	6	6
26	Kārķu pagasts	100	1.00	613	79	130
27	Ķoņu pagasts	100	1.00	635	79	236
28	Lejasciema pagasts	65	0.65	982	59	186
29	Lodes pagasts	89	0.89	273	28	44
30	Matīšu pagasts	100	1.00	814	70	141
31	**Mazsalaca**	100	1.00	1224	109	499
32	Mazsalacas pagasts	100	1.00	584	46	112
33	Mārkalnes pagasts	89	0.89	311	18	77
34	Naukšēnu pagasts	99	1.00	1202	110	446
35	Palsmanes pagasts	30	0.30	264	22	68
36	Pededzes pagasts	34	0.34	223	21	27
37	Plāņu pagasts	36	0.36	193	16	40
38	Ramatas pagasts	99	1.00	417	66	99
39	Rencēnu pagasts	72	0.72	1007	109	189
40	**Rūjiena**	100	1.00	2873	179	959
41	Salacgrīvas pagasts	48	0.48	972	95	220
42	Sēļu pagasts	100	1.00	357	42	57
43	Skaņkalnes pagasts	100	1.00	612	64	128
44	**Staicele**	100	1.00	929	60	89
45	Staiceles pagasts	97	1.00	552	83	205
46	Trapenes pagasts	99	1.00	698	43	101
47	Umurgas pagasts	25	0.25	268	23	48
48	**Valka**	97	1.00	5173	312	1762
49	Valkas pagasts	90	0.90	1037	75	215
50	Variņu pagasts	37	0.37	280	18	51
51	Vecates pagasts	100	1.00	408	49	107
52	Veclaicenes pagasts	80	0.80	280	25	29
53	Vijciema pagasts	96	1.00	657	67	131
54	Vilpulkas pagasts	100	1.00	486	49	65
55	Virešu pagasts	100	1.00	607	63	109
56	Zeltiņu pagasts	76	0.76	259	27	75
57	Ziemera pagasts	97	1.00	749	65	226
58	Zilākalna pagasts	100	1.00	751	38	240
59	Zvārtavas pagasts	98	1.00	380	30	49

Calculated number of companies and number of employed persons in Agriculture and Forestry in the project area (by the administrative units) in 2017

	Administrative unit (municipalities and cities)	No of companies in Agriculture in Project area	No of employed persons in Agriculture in Project area	No of companies in Forestry in Project area	No of employed persons in Forestry in Project area
TOTALS for the project area:		**1549**	**2703**	**349**	**657**
1	**Ainaži**	6	6	1	1
2	Ainažu pagasts	10	15	3	9
3	**Aloja**	14	14	8	11
4	Alojas pagasts	51	110	3	3
5	Alsviķu pagasts	37	43	4	10
6	**Alūksne**	20	30	33	86
7	**Ape**	8	8	10	16
8	Apes pagasts	22	31	7	17
9	Bērzaines pagasts	24	79	0	0
10	Bilskas pagasts	40	76	15	21
11	Braslavas pagasts	44	77	5	5
12	Brīvzemnieku pagasts	30	39	5	14
13	Burtnieku pagasts	54	165	4	4

14	Dikļu pagasts	51	62	5	9
15	Ērģemes pagasts	53	78	11	18
16	Ēveles pagasts	20	22	1	1
17	Gaujienas pagasts	21	51	17	24
18	Grundzāles pagasts	68	83	5	10
19	Ilzenes pagasts	19	26	1	1
20	Ipiķu pagasts	20	20	2	1
21	Jaunalūksnes pagasts	12	17	3	8
22	Jaunlaicenes pagasts	19	25	2	4
23	Jeru pagasts	48	147	2	3
24	Jērcēnu pagasts	8	17	2	2
25	Kalncempju pagasts	4	4	0	0
26	Kārķu pagasts	42	66	15	36
27	Ķoņu pagasts	49	100	5	11
28	Lejasciema pagasts	22	58	5	28
29	Lodes pagasts	20	33	1	1
30	Matīšu pagasts	30	61	3	9
31	**Mazsalaca**	16	18	11	19
32	Mazsalacas pagasts	30	90	0	0
33	Mārkalnes pagasts	9	11	1	6
34	Naukšēnu pagasts	50	160	7	8
35	Palsmanes pagasts	9	26	5	7
36	Pededzes pagasts	13	15	2	4
37	Plāņu pagasts	7	21	2	5
38	Ramatas pagasts	46	47	6	17
39	Rencēnu pagasts	50	68	4	6
40	**Rūjiena**	13	14	17	15
41	Salacgrīvas pagasts	31	41	7	12
42	Sēļu pagasts	24	37	4	3
43	Skaņkalnes pagasts	24	30	5	21
44	**Staicele**	18	19	8	20
45	Staiceles pagasts	58	75	10	16
46	Trapenes pagasts	20	46	10	11
47	Umurgas pagasts	10	19	3	6
48	**Valka**	8	21	19	40
49	Valkas pagasts	31	35	7	14
50	Variņu pagasts	7	28	4	7
51	Vecates pagasts	35	34	0	0
52	Veclaicenes pagasts	11	12	3	3
53	Vijciema pagasts	33	71	6	10
54	Vilpulkas pagasts	31	39	6	6
55	Virešu pagasts	29	53	8	15
56	Zeltiņu pagasts	17	20	2	4
57	Ziemera pagasts	32	52	2	9
58	Zilākalna pagasts	0	0	2	1
59	Zvārtavas pagasts	20	40	9	8

No of inhabitants served with the centralised water supply and sewage services in the project area* (by WBs and administrative units).

** Accounting those with wastewater discharges in the WBs of project area.*

WB code	WB name	Administrative unit (parishes and cities)	Number of connected inhabitants	Yearly discharged wastewater amounts, thous m3 (2017)	Yearly supplied water amounts, thous m3 (2017)
TOTAL for the project area			**24 674**	**1 465.5**	**1 101.6**

G301	Salaca_2	Staiceles pagasts	46	1.9	2.0
G301	Salaca_2	Staiceles pilsēta	330	9.5	18.7
G304	Iģe_1	Brīvzemnieku pagasts	153	8.2	12.6
G304	Iģe_1	Braslavas pagasts	122	2.9	3.9
G305	Iģe_2	Alojas pagasts	928	66.4	29.0
G308	Jogla	Alojas pagasts	249	5.6	0.0
G321	Briede_2	Brīvzemnieku pagasts	231	5.5	6.1
G234	Melnupe_1	Zeltiņu pagasts	63	4.8	3.1
G234	Melnupe_1	Ilzenes pagasts	83	6.7	11.1
G234	Melnupe_1	Alsviķu pagasts	180	5.6	6.8
G235	Vaidava_2	Jaunlaicenes pagasts	152	10.1	7.3
G237	Pērļupīte	Veclaicenes pagasts	71	5.2	3.0
G334	Vaidava_1	Alūksnes pilsēta	5486	384.9	210.1
G334	Vaidava_1	Alsviķu pagasts	328	14.9	9.8
G334	Vaidava_1	Ziemera pagasts	270	5.8	13.2
G231	Gauja_7	Virešu pagasts	14	1.8	0.0
G231	Gauja_7	Gaujienas pagasts	621	13.3	21.0
G233	Melnupe_2	Trapenes pagasts	412	16.9	18.4
G235	Vaidava_2	Apes pilsēta	460	9.4	13.2
G232	Strenčupīte	Ēveles pagasts	170	2.8	7.1
G306	Salaca_1	Vecates pagasts	145	24.7	10.7
G316	Seda	Rencēnu pagasts	198	6.7	7.8
G316	Seda	Rencēnu pagasts	330	7.9	15.1
G321	Briede_2	Burtnieku pagasts	400	108.2	17.0
G321	Briede_2	Matīšu pagasts	350	34.6	13.2
G244	Tirziņa	Lejasciema pagasts	830	6.2	17.4
G321	Briede_2	Zilākalna pagasts	850	23.4	20.0
G323	Mazbriede	Bērzaines pagasts	150	7.1	9.1
G323	Mazbriede	Dikļu pagasts	300	14.1	12.2
G306	Salaca_1	Skaņkalnes pagasts	280	5.2	8.4
G306	Salaca_1	Mazsalacas pagasts	1599	34.6	23.0
G307SP	Ramata	Ramatas pagasts	190	2.9	11.7
G310	Rūja_4	Sēļu pagasts	103	1.5	7.6
G311	Pestava	Ķoņu pagasts	43	1.2	8.0
G312	Rūja_3	Naukšēnu pagasts	470	55.1	28.3
G313	Rūja_2	Ķoņu pagasts	35	0.1	3.4
G311	Pestava	Vilpulkas pagasts	90	2.8	4.8
G311	Pestava	Ipiķu pagasts	62	1.3	1.4
G312	Rūja_3	Jeru pagasts	90	9.8	12.9
G312	Rūja_3	Rūjienas pilsēta	1050	88.6	56.0
G314	Rūja_1	Lodes pagasts	100	4.3	7.2
G301	Salaca_2	Ainažu pagasts	46	0.5	0.4
G302	Korģe	Salacgrīvas pagasts	150	4.6	6.6
G303SP	Salaca_3	Salacgrīvas pagasts	110	5.5	6.5
G325	Blusupīte	Ainažu pilsēta	430	22.2	22.9

G229	Vija_1	Bilskas pagasts	55	7.5	7.6
G239	Vecpalsa	Grundzāles pagasts	250	17.7	7.4
G228	Vija_2	Plāņu pagasts	132	3.0	3.6
G232	Strenčupīte	Jērcēnu pagasts	154	4.3	7.8
G228	Vija_2	Vijciema pagasts	310	11.6	10.8
G315SP	Ķire	Kārķu pagasts	330	3.7	8.9
G316	Seda	Valkas pilsēta	4348	353.9	316.9
G316	Seda	Valkas pagasts	325	8.9	11.1

Average net wages EUR per person per month in the counties of the project area

Counties in the project area	**Average NET wage, EUR (CSB data for 2017)**
Alojas novads	528
Alūksnes novads	450
Apes novads	439
Burtnieku novads	538
Gulbenes novads	565
Kocēnu novads	592
Limbažu novads	522
Mazsalacas novads	452
Naukšēnu novads	565
Rūjienas novads	536
Salacgrīvas novads	569
Smiltenes novads	552
Strenču novads	504
Valkas novads	504
On average in Latvia:	**715**

Provided service amounts and tariffs for the centralised “water services” in the administrative units of the project area

WB code	**WB name**	**Administrative units**	**No of connected inhabitants**	**Discharged WW, thous.m3 (2017)**	**Abstracted water, thous.m3 (2017)**	**TARIFF for collection and treatment of sewage (EUR/m3, incl. VAT)**	**TARIFF for water supply (EUR/m3, incl. VAT)**	**Total TARIFF (EUR/m3, incl. VAT)**
G301	Salaca_2	Staiceles pagasts	46	1.9	2.0	2.99	1.13	**4.11**
G301	Salaca_2	Staiceles pilsēta	330	9.5	18.7	2.99	1.13	**4.11**
G304	Iģe_1	Brīvzemnieku pagasts	153	8.2	12.6	1.83	1.60	**3.42**
G304	Iģe_1	Braslavas pagasts	122	2.9	3.9	2.17	0.83	**3.00**
G305	Iģe_2	Alojas pagasts	928	66.4	29.0	2.64	1.21	**3.85**
G308	Jogla	Alojas pagasts	249	5.6	0.0	2.75	1.55	**4.30**
G321	Briede_2	Brīvzemnieku pagasts	231	5.5	6.1	2.03	1.17	**3.21**
G234	Melnupe_1	Zeltiņu pagasts	63	4.8	3.1	1.72	1.29	**3.01**
G234	Melnupe_1	Ilzenes pagasts	83	6.7	11.1	1.72	1.29	**3.01**
G234	Melnupe_1	Alsviķu pagasts	180	5.6	6.8	1.72	1.29	**3.01**

G235	Vaidava_2	Jaunlaicenes pagasts	152	10.1	7.3	1.72	1.29	**3.01**
G237	Pērļupīte	Veclaicenes pagasts	71	5.2	3.0	1.72	1.29	**3.01**
G334	Vaidava_1	Alūksnes pilsēta	5486	384.9	210.1	1.72	1.29	**3.01**
G334	Vaidava_1	Alsviķu pagasts	328	14.9	9.8	1.72	1.29	**3.01**
G334	Vaidava_1	Ziemera pagasts	270	5.8	13.2	1.72	1.29	**3.01**
G231	Gauja_7	Virešu pagasts	14	1.8	0.0			
G231	Gauja_7	Gaujienas pagasts	621	13.3	21.0	1.00	0.79	**1.79**
G233	Melnupe_2	Trapenes pagasts	412	16.9	18.4	0.71	0.48	**1.20**
G235	Vaidava_2	Apes pilsēta	460	9.4	13.2	1.00	0.76	**1.77**
G232	Strenčupīte	Ēveles pagasts	170	2.8	7.1	2.02	1.09	**3.11**
G306	Salaca_1	Vecates pagasts	145	24.7	10.7	2.02	1.09	**3.11**
G316	Seda	Rencēnu pagasts	198	6.7	7.8	2.02	1.09	**3.11**
G316	Seda	Rencēnu pagasts	330	7.9	15.1	2.02	1.09	**3.11**
G321	Briede_2	Burtnieku pagasts	400	108.2	17.0	2.02	1.09	**3.11**
G321	Briede_2	Matīšu pagasts	350	34.6	13.2	2.02	1.09	**3.11**
G244	Tirziņa	Lejasciema pagasts	830	6.2	17.4	1.54	1.77	**3.30**
G321	Briede_2	Zilākalna pagasts	850	23.4	20.0	1.50	1.08	**2.58**
G323	Mazbriede	Bērzaines pagasts	150	7.1	9.1	1.50	1.08	**2.58**
G323	Mazbriede	Dikļu pagasts	300	14.1	12.2	1.50	1.08	**2.58**
G306	Salaca_1	Skaņkalnes pagasts	280	5.2	8.4	2.30	2.06	**4.36**
G306	Salaca_1	Mazsalacas pagasts	1599	34.6	23.0	2.30	2.06	**4.36**
G307SP	Ramata	Ramatas pagasts	190	2.9	11.7	1.03	1.84	**2.87**
G310	Rūja_4	Sēļu pagasts	103	1.5	7.6	1.03	1.84	**2.87**
G311	Pestava	Ķoņu pagasts	43	1.2	8.0	0.86	0.61	**2.18**
G312	Rūja_3	Naukšēnu pagasts	470	55.1	28.3	0.86	0.61	**2.18**
G313	Rūja_2	Ķoņu pagasts	35	0.1	3.4	0.86	0.61	**2.18**
G311	Pestava	Vilpulkas pagasts	90	2.8	4.8	1.78	0.98	**2.76**
G311	Pestava	Ipiķu pagasts	62	1.3	1.4	1.78	0.98	**2.76**
G312	Rūja_3	Jeru pagasts	90	9.8	12.9	1.78	0.98	**2.76**
G312	Rūja_3	Rūjienas pilsēta	1050	88.6	56.0	1.78	0.98	**2.76**
G314	Rūja_1	Lodes pagasts	100	4.3	7.2	1.78	0.98	**2.76**
G301	Salaca_2	Ainažu pagasts	46	0.5	0.4	1.83	1.13	**2.95**
G302	Korģe	Salacgrīvas pagasts	150	4.6	6.6	1.83	1.13	**2.95**
G303SP	Salaca_3	Salacgrīvas pagasts	110	5.5	6.5	1.83	1.13	**2.95**
G325	Blusupīte	Ainažu pilsēta	430	22.2	22.9	1.83	1.13	**2.95**
G229	Vija_1	Bilskas pagasts	55	7.5	7.6	1.51	1.31	**2.82**
G239	Vecpalsa	Grundzāles pagasts	250	17.7	7.4	1.51	1.31	**2.82**
G228	Vija_2	Plāņu pagasts	132	3.0	3.6	1.55	1.02	**2.57**
G232	Strenčupīte	Jērcēnu pagasts	154	4.3	7.8	2.31	1.38	**3.69**
G228	Vija_2	Vijciema pagasts	310	11.6	10.8	0.76	0.41	**1.17**
G315SP	Ķire	Kārķu pagasts	330	3.7	8.9	0.88	0.59	**1.47**
G316	Seda	Valkas pilsēta	4348	353.9	316.9	1.48	0.94	**2.42**
G316	Seda	Valkas pagasts	325	8.9	11.1	1.00	0.79	**1.79**
TOTAL for the project area:			**24674**	**1465.5**	**1101.6**			

Nature Resource Tax rates for estimating the paid NRT amounts from individual wastewater discharging (Source: SRS and NRT Law, Annex 5, https://www.vid.gov.lv/lv/dabas-resursa-nodokla-likmes)

Substance	NRT rate (EUR per ton)
BOD-5 Bioķīmiskais skābekļa patēriņš (BSP-5)	5.50
CD Kadmijs (Cd)	71 143.59
COD Ķīmiskais skābekļa patēriņš (ĶSP)	42.69
CR Hroms (Cr)	11 382.97
CU Varš (Cu)	11 382.97
HG Dzīvsudrabs (Hg)	71 143.59
HIND Naftas produkti	11 382.97
N02N Nitrītu slāpeklis (N/NO2)	5.50
N03N Nitrātu slāpeklis (N/NO3)	5.50
NH4N Amonija slāpeklis (N/NH4)	5.50
NI Niķelis (Ni)	11 382.97
NTOT Kopējais slāpeklis (Nkop)	42.69
PB Svins (Pb)	71 143.59
PO4P Fosfātu fosfors (P/PO4)	5.50
PTOT Kopējais fosfors (Pkop)	270.00
P_IND Fenoli	11 382.97
SS Suspendētās vielas	14.23
SURFAC Sintētiskās virsmas aktīvās vielas (SVAVkop)	5.50
ZN Cinks (Zn)	11 382.97
NH4- Amonija joni	5.5
SO4 Sulfāti	5.5
CL Hlorīdi	5.5
Mn mangāns	5.5
B bors	5.5
Co kobalts	5.5
SNE sausne	5.5
NH4- Amonija joni	5.5

A2.3: Input data for the analysis for the Estonian part of the project area

Households' disposal income EUR/ person/ month

EUR	Average	*Lowest quintile*	*Second quintile*	*Third quintile*	*Fourth quintile*	*Highest quintile*
Estonia	665	*264*	*427*	*566*	*790*	*1278*
Harju county	760	*258*	*428*	*571*	*793*	*1288*
..Tallinn	768	*260*	*428*	*572*	*792*	*1304*
Hiiu county	635	*271*	*432*	*555*	*787*	*1239*
Ida-Viru county	512	*259*	*428*	*566*	*776*	*1195*
Jõgeva county	549	*285*	*433*	*570*	*774*	*1190*
Järva county	595	*280*	*421*	*562*	*786*	*1291*

Lääne county	572	*241*	*427*	*562*	*767*	*1204*
Lääne-Viru county	600	*278*	*420*	*567*	*789*	*1266*
Põlva county	513	*276*	*423*	*579*	*783*	*1254*
Pärnu county	584	*268*	*425*	*566*	*784*	*1284*
Rapla countyd	649	*275*	*427*	*556*	*818*	*1260*
Saare county	645	*261*	*432*	*562*	*779*	*1257*
Tartu county	659	*272*	*429*	*555*	*798*	*1294*
Valga county	508	*254*	*422*	*553*	*773*	*1205*
Viljandi county	627	*292*	*428*	*570*	*793*	*1235*
Võru county	540	*210*	*426*	*565*	*777*	*1254*

Environmental Charges Act

Scope of application of Act (adopted 07.12.2005)

Environmental Charges Act provides the grounds for determining the natural resource charges, the rates of the pollution charge, the procedure for calculation and payment thereof, and the grounds and specific purposes for using state budget revenue obtained from environmental use.

In light of significant water uses in the project area pollution charge is paid for pollution discharged with wastewaters.

Pollution charge forms the current pricing instrument for covering the (external) "environmental costs" and, hence implementing the PPP. It is paid by all "water services" except the individual sewage by households. However the estimated amounts of the paid pollution charges are rather small to cover the created (external) "environmental costs".

§ 14. Grounds for imposing pollution charge

The pollution charge is imposed in the event of emission of pollutants into the ambient air, groundwater or soil, and upon waste disposal.

The pollution charge is not imposed where pollutants are emitted into the ambient air, groundwater or soil, or waste is disposed in quantities and manners for which a permit is not required as well as in the events specified in subsection 6 of § 5 of this Act and other events provided by law.

Pollution charge rates in 2018 based on act

Classification of polluting substances according to the category of hazardousness	**Tax rate EUR per ton**
organic matter (BOD7)	1435
phosphorous compounds (Ptot)	12 014
nitrogen oxides (Ntot)	2826
suspended solids	552.89
monophenols	24 326
oil, oil products, mineral oil	4582
other hazardous waste	21 056