DESSIN

DEMONSTRATE ECOSYSTEM SERVICES ENABLING INNOVATION IN THE WATER SECTOR

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D31.2: Emscher Demonstration: Improving water quality in the strongly urbanised Emscher area

Final evaluation of the technological solution in terms of ESS and sustainability

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TITLE OF THE REPORT

D31.2: FINAL EVALUATION OF THE TECHNOLOGICAL SOLUTION IN TERMS OF ESS AND SUSTAINABILITY
Final evaluation of the technological solution in terms of ESS and sustainability, including governance/policy implications

SUMMARY

The DESSIN framework for evaluating changes in ecosystem services (ESS) and sustainability (D11.2) as a result of the implementation of new technical or management solutions has been applied to the five DESSIN demo cases. The evaluations have been conducted with the help of the specially developed ESS toolkit for the MIKE Info/Workbench software (D23.3). The present deliverable reports on the evaluation of the two innovative technologies demonstrated in the Emscher demo case study:

a) Decentralized water treatment via a cross-flow lamella settler (chapter 2)
b) Real Time Control of sewer network via the ADESBA algorithm (chapter 3)

Both technologies have the aim to improve water quality. The capabilities of both technologies, as investigated in the demo cases (D31.1) and the expected effects on water quality are described.
Based on this, the influence on ESS provision and use is discussed. The intermediate Regulation & Maintenance ESS "Self-purification" and "Biodiversity" as well as the final Cultural ESS "Aesthetic" and "Experiential use, Physical use, Educational use, Existence" were assessed qualitatively. All these ESS are expected to increase by trend due to an improvement in water quality. The final Cultural ESS are dependent both on the improvements in water quality and the improvement in the Regulation & Maintenance ESS. However, the improvements in ESS are expected to be only marginally and to depend on the spatial extent of the implementation (i.e. number of CSO facilities equipped with the technical solutions).

Additionally, sustainability metrics of all five dimensions (social, environmental, financial, assets, governance) are assessed for each of the technologies. All relevant sustainability criteria were evaluated for the two solutions. Part of the criteria could be assessed quantitatively, while the other part was described qualitatively. The effects on all criteria were classified into five categories ranging from very negative to very positive effects due to the measure. Finally, the result could be presented in a spider plot.

Finally, we describe a potential actual implementation processes in the local context. In this context, we refer to governance and policy implications as well as financial options relevant for the actual implementation process of the technologies.

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List of Acronyms and Abbreviations

ADESBA	Adaption und Entwicklung einer vorkonfektionierten Steuerungsbox zur Abflussteuerung von Kanalnetzen, basierend auf innovativen Kommunikationsmedien [German acronym and name of the RTC solution demonstrated in DESSIN]
COD	Chemical oxygen demand
CSO	Combined sewer overflow
EG	Emschergenossenschaft
ESS	Ecosystem services
FESS	Final ecosystem services
IESS	Intermediate ecosystem services
RTC	Real Time Control
SA	Sustainability assessment
SEGNO	Segno Industrie Automation
TOC	Total organic carbon
TSS	Total suspended solids
TSS fine	Fraction of TSS < 63 µm
UFT	Umwelt- und Fluid-Technik Dr. H. Brombach GmbH
UDE	University of Duisburg-Essen
WFD	European water framework directive
WWTP	Wastewater treatment plant

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General introduction

Water scarcity and quality issues are a concern in many regions in- and outside of Europe. New technologies may provide solutions for these issues. If the benefits of technical solutions are demonstrated and verified, the solutions are more likely to be implemented.

The European water research project DESSIN demonstrates and promotes innovative solutions for water scarcity and water quality related challenges & demonstrates a methodology for the evaluation of ecosystem services (ESS). Innovative solutions are tested at five demo sites across Europe.

Within the DESSIN project, a framework has been developed for the evaluation of changes in ecosystem services (ESS) and sustainability as a result of the implementation of new technical or management solutions (D11.2). This framework is applied on the five European demo cases. It is one of the first times that an evaluation framework has been applied on several international cases at once.

This document contains the ESS evaluation report of one of the demo cases. The evaluations have been conducted with the help of the specially developed ESS toolkit for the MIKE Workbench software (D23.3).

The objective of this report is to show how the technical solution(s) affect ecosystem services, and to perform an (economic) evaluation of the changes in ESS provision and use. Furthermore, the sustainability of the measure(s) is assessed and implications regarding governance and policy are discussed. After that, opportunities and challenges related to governance and policy are discussed, and novel financing mechanisms are proposed.

1. Emscher case introduction

The Emscher catchment in Northwestern Germany is one of the most densely populated regions in Europe. Formerly, coal mining and steel production was the main trigger for development and intense urbanization in the region. Now this has shifted to industry and service providing businesses. The Emscher River and its tributaries had been strongly modified to guarantee safe wastewater discharge and flood protection throughout the period of heavy industry in the last century. Now, however, the streams are being reconverted to a near-natural state.

This re-conversion can only be successful with a functioning sewer network and wastewater treatment. The sewer network transports combined sewage to four centralized wastewater treatment plants (WWTPs). During rain events, the sewage in the channels is mixed with rain water. Large underground storage basins are, thus, needed to retain the larger water volumes, as the sewers and WWTPs have limited hydraulic capacities. If the rain exceeds the available storage volume, the excess combined sewage is discharged into nearby rivers - this is called combined sewage overflow (CSO) (Figure 1). Despite a certain degree of pre-treatment in the storage basins through sedimentation, the overflowing water still contains sediment as well as particle-bound and dissolved organic matter, nutrients and contaminants.

The two demonstration case studies in the Emscher catchment tested novel technological solutions to improve the sedimentation of the combined sewage in storage basins and to reduce the frequency and duration of overflow events (D31.1). As an innovative technology for decentralized treatment of CSO discharge, a demonstration setup of a novel cross-flow lamella settler was tested. In the same time period, the Real Time Control (RTC) system ADESBA was testwise implemented in a section of the sewer system.

Deliverable D31.1 reports on the outcome of the demonstration studies. It has been shown that both technologies have the potential to reduce loads of suspended solids and organic carbon by enhancing sedimentation efficiency in the CSO facilities (with lamella settlers) or by reducing overflow volumes (with the RTC). Thus, they are able to reduce the pressures on the receiving waters and are, thereby, expected to enhance water quality. This can have positive effects on aquatic ecosystems. These effects are discussed in the present report. Depending on their status and functioning, those ecosystems can provide valuable services to human society.

The objective of this report is to show how the technical solutions affect ecosystem services (ESS) and to perform an evaluation of the changes in ESS provision and use. Furthermore, the sustainability of the two measures is assessed, opportunities and challenges related to governance and policy are discussed and novel financing mechanisms are proposed.

Figure 1 CSO facility next to the Emscher headwaters (photo: Daniel Horst).

1.1 Description of Task

T31.3 Evaluation of solutions (M1-M42, EG, ECOL, DHI, ADELPHI, IWW)

- Perform an (economic) valuation of changes in ESS provision resulting from the measures implemented as part of the final designed solutions proposed in Work Package (WP) 21 using the DSS Module developed in WP23 and the application of the valuation toolkit, included as part of the Evaluation Framework to measure changes in ESS provision developed in Work Area (WA) 1.

- Assess the sustainability, governance/policy implications and novel financing mechanisms of the chosen technical solutions demonstrated with respect to the actual implementation processes in the local context, using the Evaluation Framework and the Manual for Practitioners and Policymakers developed in WA 1.

1.2 Complementary application of the two solutions

Lamella modules can be implemented complementary to an implementation of a RTC in the sewer network. The two technologies are not directly competing with each other. For this reason, they are also not compared with each other in this report. Both have different fields of application, as discussed in the capabilities section (chapter 2.1.4.).

The aim of the lamella settler is to improve the decentral treatment at CSO facilities, and thus, to lower the pollutant concentration in the CSO discharge. This will also reduce the load on the receiving streams and, consequently, reduce physicochemical stress in the streams. The lamella settler can be refitted into existing CSO facilities if this CSO facility undersized or the influent combined sewage concentrations are too high.

The RTC, on the other hand, aims at reducing overflow frequency and volume. A RTC system can be implemented in a sewer system consisting of several CSO facilities if the utilization of the storage volume is not equally distributed over these facilities and if some facilities have unused storage volume, and thus, storage potential. As RTC aims at reducing overflow frequency and volume, it does not affect the concentration of overflowing water but it reduces the overflowing volume and can even avoid overflows - if the rain events are not too strong. In this sense, it also provides the capability to reduce the load discharged into receiving streams - similar to the lamella settler. A CSO facility equipped with lamellae, of course, can also store a defined volume of water, avoiding its discharge into recipient streams. The refitting with lamella, however, does not lead to a reduction of the discharged volume. Therefore, despite reducing physicochemical stress, a RTC also reduces hydraulic stress in the stream.

The implementation of a RTC thus reduces both physicochemical and hydraulic stress, while a refitting with lamellae only reduces physicochemical stress. The RTC, however, cannot in all cases prevent an overflow from happening. If the rain event is strong and the entire storage volume is used, an overflow occurs. Consequently, it would, be ideal to implement both technologies in a combined manner. This way, an overflow, if it occurs, would be treated additionally.

2. Decentralized water treatment

An innovative solution for decentralized water treatment at CSO facilities was tested in the Emscher region. Figure 2 shows the container solution for the demonstration of a cross-flow lamella settler. The container was located at a CSO facility in Castrop-Rauxel. Detailed information on the outcome of the testing can be obtained from deliverable D31.1.

Figure 2 Container in action, located at CSO facility at Ohmstraße in Castrop-Rauxel.

2.1. Application of the DESSIN ESS Evaluation Framework

2.1.1. Overview

An overview of the ESS and sustainability assessment (SA) conducted for the cross-flow lamella settler solution is shown in Figure 3.

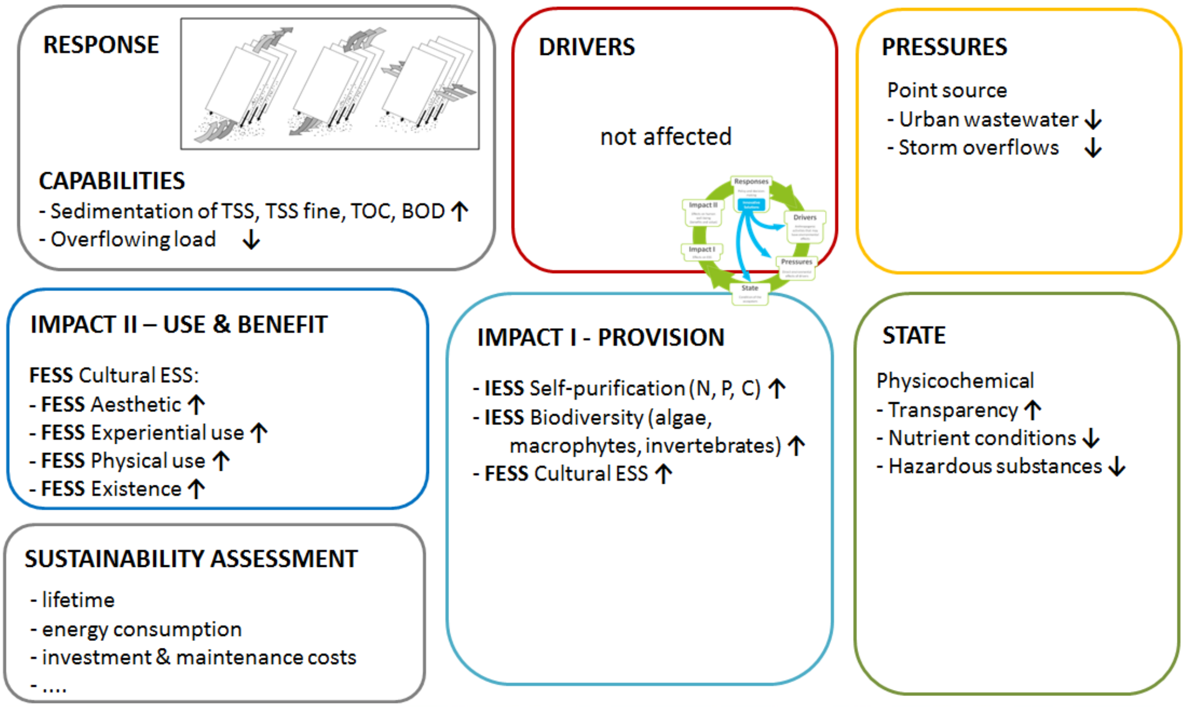


Figure 3 Overview of the ESS and SA of the cross-flow lamella settler.

2.1.2. Using the MIKE Decision-Support Software

The MIKE Info/Workbench ESS Tool was applied in this case study, leading step-by-step through the ESS and SA. The professional MIKE version was not applied, as no water quality model was available for the region, which could have been the basis for deriving time series data or other programmed indicators.

2.1.3. Study description

The system analyzed in this case study is the Emscher basin in Northrhine-Westphalia, North-Western Germany (Figure 4).

Entities providing the information within this case study are: Emschergenossenschaft (EG), University of Duisburg-Essen (UDE), IWW Rheinisch-Westfälisches Institut für Wasser (IWW), Umwelt- und Fluid-Technik Dr. H. Brombach GmbH (UFT), Segno Industrie Automation (SEGNO).

The assessment is conducted with the aim of (i) validating the DESSIN ESS Evaluation Framework and (ii) identifying the benefits resulting from the lamella settler technology, which was tested in the DESSIN demonstration study in the Emscher region.

The target audience is: DESSIN partners, EU, people interested in the lamella settler technology, researchers working on the topic of ESS or lamella settler or other water related technologies.

Entities carrying out the assessment are: EG, UDE, IWW, and UFT.

The entity funding the assessment is the European Commission.

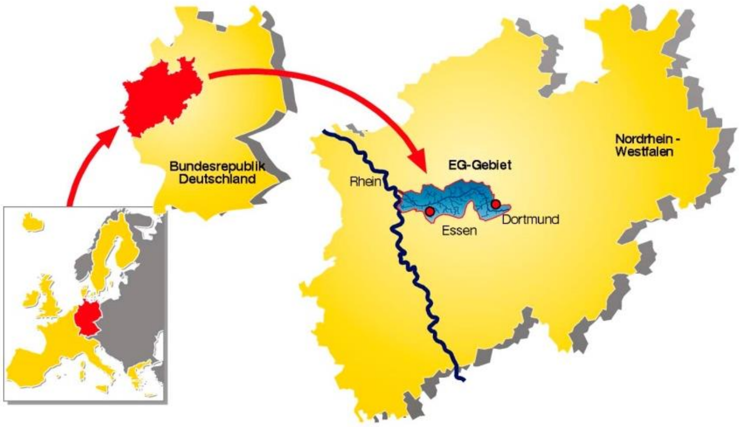


Figure 4 Location of the Emscher catchment within North-Rhine Westphalia, Germany, and Europe.

2.1.4. Response

The lamella settler aims at an increase of sedimentation inside combined sewage storage facilities leading to a reduction of total suspended solids (TSS, TSS fine), total organic carbon (TOC) and the chemical oxygen demand (COD), as shown in the demonstration study. Potential reductions of 37 % (TOC), 17 % (COD), 22 % (TSS fine) and 19 % (TSS) have been observed in the discharge from the lamella settler, *i.e.* after the storage volume has been used, in its current setup (D31.1).

The capabilities of the solution are thus:

- Sedimentation: Enhance sedimentation of TSS, TSS fine, TOC, BOD
- Load: Reduction of overflowing load
- Concentration: Reduction of concentration of TSS, TSS fine, TOC, BOD

Upscaling

Based on these sedimentation efficiencies, upscaling to a large-scale CSO facility was conducted. To this end, the results from the demonstration study were scaled up to the level of an existing CSO facility (CSO "Gartenstraße"), equipped with lamellae in 50 % of its volume. For more detailed information see D31.1. For such a large-scale application, the predicted sedimentation potential corresponds to a load removal of 5.9 % (Q1) to 14.6 % (Median) to 17.2 % (Q3) (Figure 5).

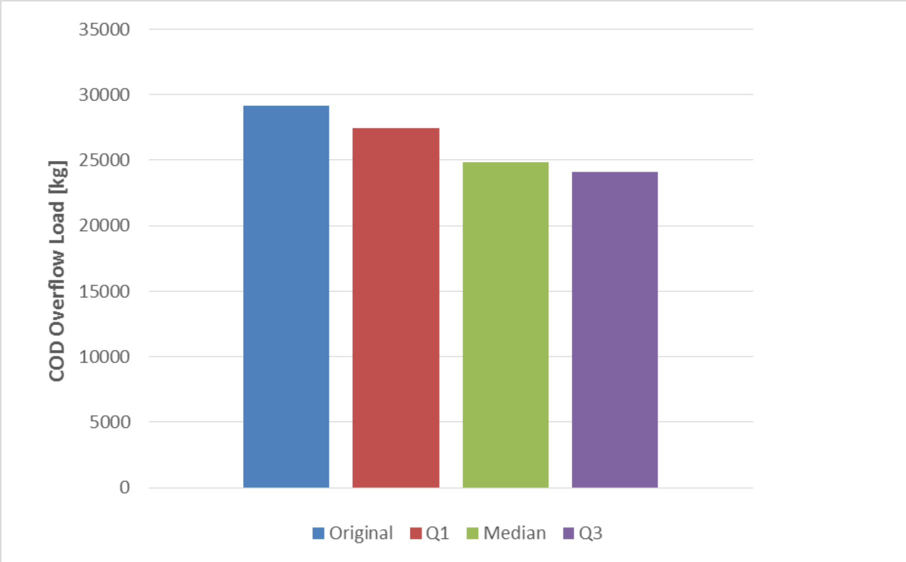


Figure 5 Theoretical COD load in the overflow of CSO "Gartenstraße" in one year (2014). "Original" refers to the overflow without lamellae, "Q1", "Median" and "Q3" represents the overflow with lamellae (storage volume by 50% equipped) modelled with the 25th, 50th and 75th percentile of the efficiencies determined in the container test, respectively.

An enhanced sedimentation inside the storage volume leads to a reduction in the particulate pollutant load discharged to streams during heavy rain events. It, thus, reduces physicochemical stress in the receiving streams. Similarly, discharge of sewage garbage (like toilet paper and sanitary products) will be reduced. Dissolved pollutants and pathogen concentrations will be removed to the extent that they are associated with particles, thus, concentrations within the streams may be reduced.

Uncertainty

The above presented results are only preliminary. The observed variance was too high to reliably report a solid efficiency rate based on the conducted test runs. The results need to be validated in further testing, at different sites and with different particle types, inflow concentrations as well as inflow rates.

Furthermore, the variance in the tests that have been conducted without the lamella modules in the container, *i.e.* only the storage volume, was high as well. For this reason, it is not possible to differentiate the effect of the rectangular storage container itself compared to the lamella modules.

2.1.5. Drivers

The main drivers in the Emscher area are related to the former mining activities (coal mining and steel production), other industrialization and urbanization. These drivers were the reason, why the Emscher and its tributaries were transformed to open wastewater streams. The streams' main task was a safe discharge of wastewater in order to prevent flooding and the spreading of diseases. The open wastewater channels remained in place for over a century and are only now, with the Emscher re-conversion, restored into natural streams. Nowadays, industry (now shifted towards service providers) and urbanization (4.5 mio. inhabitants in the Emscher catchment) are still important drivers but mining activities have ceased. Flood protection is still among the most important drivers. As the Emscher basin now consists of 40 % polder areas, due to land subsidence resulting from the mining period, pumping stations and dikes along the streams are needed and an adequate level of flood protection needs to be guaranteed at any time.

As a result of the strong urbanization, about half of the area in the basin is artificial land cover. This leads to low infiltration of rainwater into the groundwater and high surface run-off during rain events. Thus, large volumes of rainwater are being discharged into the combined sewer network.

Furthermore, transport is still a driver present in the system. A dense network of transport routes through the area shapes the landscape. Many of these routes run alongside the Emscher and its tributaries, including roads, highways, railway routes and an artificial shipping channel (the Rhein-Herne-Kanal).

The basin is one of Europe's most densely populated areas. Due to the high population density and dense urban environment, local recreation is very important for the inhabitants of the Emscher cities.

However, none of the drivers is directly affected by the solution. In general, technical solutions can hardly influence drivers. Drivers can rather be shaped or altered by management solutions. Such management responses, *e.g.* aim at influencing people's behavior or at changing the economic orientation in a city or region (*e.g.* replace mining and heavy industry by service companies).

2.1.6. Pressures

BEFORE

In the Emscher basin, pressures related to the drivers industry, urbanization, transport and flood protection are prevalent. These pressures comprise hydrological and morphological pressures, diffuse and point sources as well as other anthropogenic pressures.

The "capability" of the lamella settler is to reduce point sources. The focus is, thus, on pressures derived from the drivers "industry", "transport" and "urbanization":

- Point source

- Urban wastewater
- Storm overflows (Figure 6)

Figure 6 Exemplary CSO facility Röhrenstraße alongside the upper Emscher/Emscher headwaters (photo: Nadine Gerner)

After completion of the Emscher re-conversion, these point sources will comprise 290 CSO facilities and 4 large-scale WWTPs (Figure 7). The volume of wastewater disposed in the Emscher catchment is 0.6 billion m³/a. Due to the dense population and the high variety of industrial branches, the wastewater consists of diverse substances. Municipal wastewater consists mainly of an organic carbon load as well as nutrients (nitrogen and phosphorus) but also of pharmaceutical residuals, and pesticides/biocides from urban parks and gardens. Industrial wastewater can contain high loads of hydrocarbons and metals. Mining effluents contain hydrocarbons and metals as well as high chloride loads. During rain events, the wastewater is combined with rainwater can be discharged into nearby streams in case the underground storage capacity is exceeded.

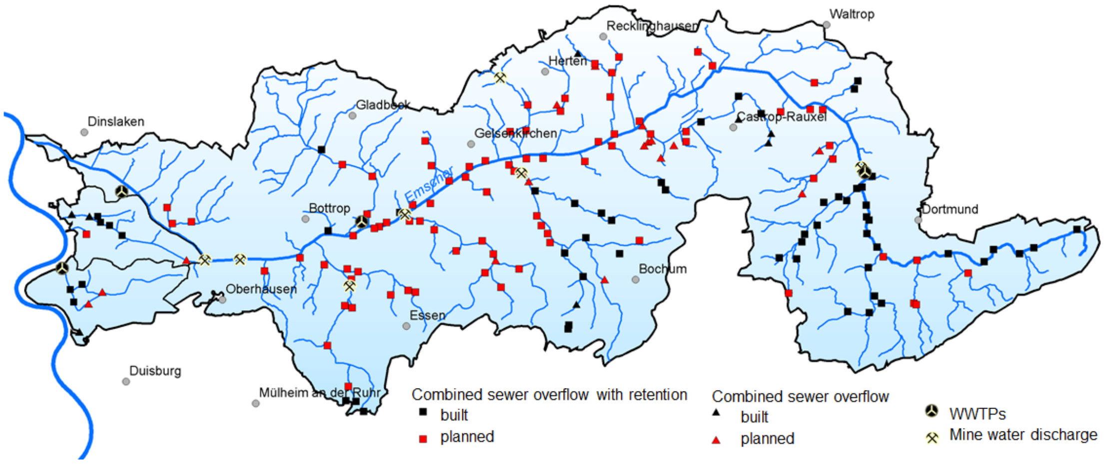


Figure 7 Point sources to the Emscher streams (CSOs and communal WWTPs), status 2008 (Source: Emschergenossenschaft 2009)

When the Emscher restoration will be completed, all streams are generally wastewater free. During heavy rain events, however, discharge of combined sewage into the Emscher streams can occur from these designated point sources (Figure 1). At CSO Ohmstraße in Castrop-Rauxel, for instance, 25 basin filling events and, out of these, 18 overflow events were recorded in the hydrological year 2015 (Emschergenossenschaft 2015). According to Brombach (2012), this number of overflow events is defined as "rare overflow" and is approved by the responsible agencies. Before overflow events occur, the combined sewage is pre-treated through sedimentation in the storage basin. No water is spilled into nearby years without this basic pre-treatment. Still, this point source pressure acts on the ecosystem and its biological communities.

Also run-off during rain events as well as seepage from brownfields and waste deposits causes input of pollutants. Such diffuse sources, however, cannot be reduced via the evaluated solution.

AFTER

The solution alleviates point source pressures originating from CSO via load reduction in the overflowing water. The capabilities of the solution to reduce these point pressures are described in 2.1.4.

2.1.7. State

BEFORE

During rain events, streams are regularly exposed to high water flows combined with high concentrations of solids and garbage (Figure 8), originating from point and diffuse sources.

Figure 8 Garbage deposition at the stream shore downstream of a CSO facility, following a heavy rain event (photo: Laura Rosenboom).

A direct effect of inorganic and organic suspended solids in streams is the simple sedimentation of fine particles on the stream bed. An alteration of the structure and substrate of the water body bed and the water-sediment surface is the result.

This hinders aeration of the stream bed and interstitial areas. Furthermore, it can clog the gills of benthic macroinvertebrate filter feeders and prevent grazers from feeding on biofilm or algal films on stones or other surfaces. Further, if interstices are silted, no refugial spaces for aquatic species are left. The loss of species due to flow peaks during CSO events has been found higher when interstices are silted (Borchardt and Statzner 1990).

The long-term accumulation of fine sediment inside the stream, thus, causes morphodynamic changes. This also reduces the habitat diversity for benthic species. For example, well aerated gravel areas become covered by fine sediment, making this habitat inaccessible for specialized species such as Ephemeroptera, Plecoptera and Trichoptera species (mayflies, stoneflies and caddis flies).

Furthermore, the excess sediment can be remobilized at a later rain event, again bringing eutrophying and oxygen depleting substances as well as adhering toxic pollutants into the water column.

The effects of enhanced loads of nutrients and organic carbon can either be acute or chronic. Acute and chronic toxicity on biofilms, macroinvertebrates and fish can be caused by ammonia (NH^{3+}), nitrite (NO^{2-}), heavy metals and other dissolved or particle bound contaminants. Particle bound contaminants are potentially taken up together with food particles - especially by filter feeders or sediment dwellers.

Excess nutrients can lead to eutrophication, as they trigger excessive algal and macrophyte growth. These produce oxygen during daytime but consume oxygen at night, causing temporary oxygen depletion. Furthermore, secondary oxygen depletion results from the degradation of this excessively growing algal/macrophyte biomass. Thus, another severe acute effect is oxygen depletion due to the oxygen consuming process of degradation of organic matter (*i.e.* hydrocarbons, fats and proteins).

AFTER

The capacity of the lamella settler solution to reduce load discharge into recipient waters is advantageous for the water quality of the receiving streams. Less suspended solids, particle bound nutrients (mainly phosphorous), organic load (*i.e.* TOC and COD) and adhering contaminants enter the streams. This avoids fine particle deposition onto the stream bed and the detrimental effects of organic matter, nutrients and contaminates described above. As a result, aquatic and riparian species are subjected to reduced pressures.

Concluding, the following parameters of State are affected:

- Hydromorphological
  - Morphology
    - Structure and substrate of the water body bed
    - Water-sediment surface
    - Character of the riparian environment and/or floodplain
    - Structure of the water body shoreline (due to sedimentation of particles)
- Physicochemical
  - General
    - Transparency
    - Sound (due to sedimentation of particles)
    - Odor
    - Oxygenation conditions
    - Nutrient conditions
  - Priority hazardous substances
  - Other pollutants
- Biological (here only marginal and indirect effects due to water quality improvement are expected)
  - Aquatic animals
    - Composition and abundance of benthic invertebrate fauna

- Composition and abundance of fish fauna
- Composition and abundance of aquatic plants

- Riparian animals
  - Composition and abundance of invertebrate fauna
  - Composition and abundance of riparian reptile species
  - Composition and abundance of riparian amphibian species

Uncertainty

The effects of lamella settlers on receiving streams depend on a large number of influencing factors and conditions. For this reason, a solid prediction of an expected State of the ecosystem, *i.e.* its hydromorphology, water quality and biology, cannot be made due to a large number of assumptions.

The resulting water quality depends on the frequency and duration of overflow events as well as on the number of CSO facilities along a stream and the distance between them. It further depends on the water volume inside the stream at the point of overflow, which determines the dilution of the overflowing combined sewage by, ideally clean, river water. This means, the effect on the river also depends on its water quantity and quality before receiving the overflowing water. It also has to be noted that the so called first flush at the beginning of rain events usually mobilizes high loads then during the rest of the event. It is decisive if the first flush can be transported to the WWTP or safely stored in a CSO or if it will fully or partly be discharged into a recipient stream. All these conditions and parameters will determine the final in-stream concentration of *e.g.* the total suspended solids. The bioavailable concentrations of particle-bound nutrients (such as phosphorous) or hydrophobic contaminants (such as persistent organic pollutants) adhering to these solids, are furthermore influenced by abiotic parameters such as pH.

A change in the chemical quality class according to the WFD is improbable, as the effect of the lamellae mainly shows during rain events. An expectedly large part of the discharged combined sewage will quickly be diluted and washed away while only the part which settles ins the stream remains present also after the rain event and can eventually be remobilized.

2.1.8. Impact I - Provision

The parameters of State affected by the solution were identified in 2.1.7. These parameters describe the quality of an ecosystem and are decisive for the ecosystem’s ability to provide ESS. The set of ESS related to the identified parameters of State affected by the lamella settler are described in the present section.

- IESS Self-purification (N, P, C)
  (CICES nomenclature: “Filtration/sequestration/storage/accumulation by ecosystems”)

In freshwater ecosystems, the self-purification potential of a stream is dependent on the functionality of the biological community and food net (Covich *et al.* 1999). For instance, gammarids (a family of macroinvertebrate crustaceans) shred leaves (Figure 9). Similarly, fish consume, and thus, degrade prey. The broken down organic matter and nutrients can then be taken up by microorganisms in biofilms which grow on surfaces like stones. In this way, the organic matter and nutrients are converted into biomass (for more information on these processes see D13.1). The microorganisms in a biofilm can furthermore conduct denitrification, removing nitrogen from the water column (Niemann 2001, Scholz *et al.* 2012, D13.1). Phosphorous, on the other hand, which is mainly particle-bound in unpolluted natural freshwater waters, is removed from the water column during flooding. It is retained by soil and vegetation in floodplains (Scholz *et al.* 2012).

Figure 9 Macroinvertebrate community consisting of shredders, grazers, filter feeders, etc. sampled at Lake Phoenix (photo: Thomas Korte)

BEFORE

Freshwater ecosystems, therefore, actually require a certain amount of organics and nutrients. To a certain degree, they can also cope with elevated levels of organics and nutrients via the self-purification capacity described above. If concentrations or loads, however, exceed the capacity of a stream to degrade these substances, they cannot be fully removed from the water column.

As described above, self-purification also directly depends on the water-sediment surface

(Borchardt and Wolp 1993). This surface area is reduced through sedimentation of fine particles, decreasing also the area covered by biofilm - an active element in the purification process.

AFTER

With load reduction, the input of fine sediment, organic matter and nutrients as well as toxicants decreases, mitigating the detrimental effects described above.

Uncertainty

A large number of different parameters are involved in these complex ecological interactions. Multiple stressors are present in the system, acting on the biological communities. Due to this complexity, the changes in self-purification are not quantifiable. The above described cause-and-effect chain, however, allows predicting trends.

- IESS Biodiversity (algae, macrophytes, invertebrates, fish)
  (CICES nomenclature: “Maintaining nursery populations and habitats”, “Wild animals and their outputs”)

Biodiversity has an intrinsic value (Science for Environment Policy 2015) and at the same time plays an important role as pre-conditions for ecosystem functioning and the provision of Regulation & Maintenance ESS such as the self-purification potential of streams. Biological communities, furthermore, play an important role for the provision of Cultural ESS, as outlined below (chapter 2.1.9.). Effects on biological communities can, thus, compromise ecological functions and ESS (Covich *et al.* 1999). Specialized species, as for instance the Emscher bullhead (Figure 10), require good water quality. Fish in the Emscher system, however, only have relevance for Regulation & Maintenance and Cultural ESS. No Provisioning ESS of fish for commercial or private use is to be expected. Therefore, the Provisioning ESS “Wild animals and their outputs” might be affected by the response but is not regarded relevant in the study area.

BEFORE

As described in section 2.1.7., biological communities are affected by CSO in various ways. First, losses of habitats may occur due to sedimentation of fine particles. Furthermore, acute or chronic toxic effects - depending on the concentration of these toxicants and possible synergistic effects due to mixture toxicity or multiple stressors - can appear. Eutrophication can cause oxygen depletion and bring biological communities, and thus, the food web out of balance. Furthermore, turbid water decreases light penetration into the water column. If turbidity persists for longer periods of time, animals and especially plants can suffer from the lack of light.

Such stress can cause diverse biocoenoses to be depleted with only tolerant species remaining. Depending on generation times and recolonization potential of the lost species, such depleted communities might be able recover. This success and the time till recovery, however, depend on the frequency and intensity of CSO events.

The ecological status or potential (Döbbelt-Grüne *et al.* 2015) of rivers and streams as assessed by the WFD describes five biological quality elements of freshwater ecosystems (being fish, invertebrates, diatoms, plants and phytoplankton). Achieving the good status/potential can be hindered by periodic stresses such as occasional CSO events.

Figure 10 The Emscher bullhead (*Cottus c.f. rhenanus*) can be found in the upper Emscher/Emscher headwaters (photo: Gunnar Jacobs)

AFTER

A reduction in the load of organic substances, nutrients and toxicants reaching streams can likely reduce the negative effects described above. Improvements in the availability of habitats and biodiversity can, therefore, expected. This again can have positive effects on other Regulating & Maintenance and Cultural ESS, as mentioned above.

Uncertainty

The effects on aquatic communities are determined by even more decisive parameters and conditions. Primarily they depend on the species present in the water body and whether these are sensitive or tolerant species. Species that are sensitive towards turbidity, high organic and nutrient loads and/or low oxygen levels are likely to be more affected by CSOs. Decisive is also the recovery rate of harmed populations after stressful CSO events. This rate depends on the generation time and on the migration and recolonization potential of the affected species.

2.1.9. Impact II - Use & Benefit

- FESS Aesthetic

The Cultural service "Aesthetic" describes the beauty of the land- and riverscape to a person appreciating this land-/riverscape. Partly, the subjective opinion of the beneficiary determines whether a land- and riverscape is considered aesthetic or not (Frank *et al.* 2013). Nevertheless, for the provision of an aesthetic land- and riverscape, several basic requirements exist (Weber and Ringold 2015). Weber and Ringold (2015) identified features of rivers and streams that are important to the public in an US American city. Among these features are indicators such as the appreciation of water clarity, appreciation of the presence of fish, dislike of algae and of odor and garbage. These characteristics or qualities of an ecosystem are important for its appreciation by people. Junker and Buchecker (2007) conducted a study in Switzerland on people's perceptions of the visual attractiveness of restored river sections by using photographic simulations. They found that aesthetic preferences, and thus, also people's valuation of rivers are positively related to eco-morphological quality and are primarily shaped by perceived naturalness (Figure 11).

The importance of biodiversity on Regulation & Maintenance ESS as for instance on the self-purification has been described above. Balvanera and colleagues (2006) have conducted a meta-analysis on the relationship between biodiversity and ecosystem processes. They found a clear evidence that biodiversity has positive effects on most of the ESS assessed in their study. For Cultural services, however, the relationship is less clear and not quantifiable. Fuller *et al.* (2016), nevertheless, showed that psychological benefits increase with the biodiversity in urban greenspaces.

Figure 11 Near-naturally restored upper Emscher/Emscher headwaters in Dortmund (photo: Nadine Gerner)

BEFORE

The above described consequences on hydromorphological and biological conditions by CSO events can severely compromise the aesthetics of land- and riverscapes (Figure 8). Concretely, aesthetic deteriorations originate from the discharge of fine and coarse particulate and dissolved matter, resulting in odor, turbidity and visible pollution of a stream and its shores. After CSO events, odor from faeces and other organic material can occur as well as pollution with toilet paper and similar sewage garbage.

AFTER

A reduced discharge of particulate and dissolved matter to receiving streams and the expectedly enhanced river water quality is, thus, assumed to enhance the provision and use of Cultural ESS.

Upscaling

If all problematic CSO facilities along the Emscher and its tributaries are refitted, an improvement of river water quality might be recognized, resulting in an enhanced provision and use of Cultural ESS in the whole catchment.

Uncertainty

In comparison to the economic impact resulting from the Emscher restoration measures (that was already assessed in the Emscher mature site assessment (D13.1, see S151 and S152)), the improvement via lamella settlers is expected to be rather marginal. As the effects of the lamella settler would not be differentiable from the effects originating from the Emscher restoration, they were not quantified and monetized in this study. However, the tendency is discussed above.

- <u>FESS Experiential use, Physical use, Educational use, Existence</u>

Cultural ESS are final services, as they have direct beneficiaries using them. The provision of the above defined "Aesthetic" service of land- and riverscapes is an important pre-condition for further Cultural ESS such as experiential, physical and educational use or the existence of intact ecosystems or certain species.

BEFORE

In deliverable D13.1, these five services have been assessed for the Emscher mature case: the Emscher re-conversion.

- For the Emscher re-conversion, the "Opportunity for placement of infrastructure in the environment" has been assessed as an example of an experiential use. Here, the value of real estate alongside lakes and streams was quantified and monetized with regard to housing and commercial places (Figure 12).
- Physical use was assessed via "Opportunity for biking and recreational boating" (Figure 12).
- An existence valuation was conducted via the "Knowledge that a restored river area exists, with suitable water quality (*i.e.* GEP)". This existence value was determined as the willingness to pay for a river with a good ecological potential (GEP).
- The educational use in terms of excursions to a lake side and restored streams was quantified as an example of "Opportunities to understand, communicate, and educate". A good example for the improvement of the ESS "Opportunities to understand, communicate, and educate" is also the presence of "blue classrooms" alongside the Emscher and its tributaries (Figure 13).

The Emscher re-conversion with the removal of wastewater from the river bed and the restoration of the stream's structure has been precondition for the creation of places for experiencing the environment and benefitting from it.

However, aesthetic deteriorations originating from CSO can considerably lower riverine aesthetics and recreational and educational services which are dependent on aesthetic land- and riverscapes. For recreational and educational activities with direct water contact, hygienic conditions, and thus, water quality also play an important role. Health effects associated with faecal pollution need to be avoided (WHO 2008).

AFTER

It is also of high importance to have visibly clean water at these places. Pupils, for instance, can then experience the beauty of the restored rivers and understand what intact ecosystems should look like and how they should function.

The lamella settler technology can contribute to avoiding poor water quality by reducing organic matter and garbage input in the water during rain events.

Figure 12 Upper Emscher along Lake Phoenix in Dortmund, a popular place for recreation and housing (photo: Rupert Oberhäuser)

Figure 13 “Blue classroom” alongside one of the Emscher tributaries.

2.2. Application of the Sustainability Assessment

2.2.1. Definition of the assessment and decision case

Scale of the system

Lamella modules can be refitted into existing CSO facilities. Refitting is most feasible into open and rectangular CSO basins. The installation and maintenance effort is much higher - or even impossible - if closed basins are to be refitted. For circular storage channels, the suitability of lamellae is low because the water can bypass the lamellae laterally. Furthermore, lamella modules can lead to blockages of the channel.

Another field of application would be to equip an additional basin behind a CSO facility with lamellae - independent of whether the CSO facility is open/closed or rectangular/round or a circular storage channel. This could be done in case a CSO facility is dimensioned too small or the influent combined sewage concentrations are too high. Problems with undersized CSO facilities are not necessarily related to planning mistakes but can appear due to rising wastewater or rainwater discharge as a result of demographic and climate change, respectively, or rising surface runoff due to growing areas of sealed surface.

For the SA of the lamella settler, we scale all indicators to the level of a full scale CSO facility (with a total storage volume of 2,211 m^3) equipped with lamellae in 50 % of its volume, according to the upscaling calculation done in D31.1. We refer to this as a “middle-sized large scale application”. Based on this upscaling to one full scale CSO facility, we identified 33 storage basins out of the 290 CSO storage facilities in the Emscher catchment, excluding all circular storage channels. Out of these, four rectangular and open CSO storage basins were identified (D31.1), which are most suitable for refitting with lamellae. Thus, the above described upscaling to one real CSO could (very roughly) be multiplied by four to forecast effects on the Emscher basin scale.

Timeframe of assessment

As there will be no alternative solution for decentralized water treatment considered within this SA, only two scenarios have to be compared by the proposed indicator set:

- The situation “BEFORE” is represented by a baseline situation in the Emscher basin. At this baseline, the Emscher re-conversion is assumed to be completed (in 2021). At the present moment (in 2017), part of the Emscher basin is already restored, while part is still under construction. For the discussion of sustainability aspects, we try not to mix up the effects of the Emscher re-conversion and a theoretical/predicted implementation of the lamella settler.
- The assessment and discussion of the sustainability metrics (see below) represents the case

"AFTER" a theoretical/predicted implementation of the lamella settler.

The result of the differences between the BEFORE and the AFTER scenario reveal positive and negative effects of the lamella settler solution over time. The results represent a sustainability check of the solution itself and not a comparison between alternatives.

The SA for the lamella settler is conducted for a one year period. This means, when quantitative assessment was possible, the values are given on an annual basis.

2.2.2. Indicator selection and data collection

For the following assessment, indicators related to water supply systems were neglected since there is no water extracted from the Emscher for drinking water treatment. The remaining list of potential indicators was further checked with special regard to data availability. Due to the lack of modelled data for middle-sized large scale applications, only few indicators have been assessed quantitatively based on measured data and estimates by experts. Expected effects in all other indicator categories are described qualitatively in order to overcome the data gaps. Thus, all five dimensions proposed for SA within the DESSIN ESS Evaluation Framework are adequately addressed in this assessment.

The quantitative assessments as well as further qualitative descriptions to those indicators lacking data for calculations are presented in the following chapter.

2.2.3. Results and discussion

For all relevant SA metrics, a categorization into strong negative to strong positive impact was conducted (Figure 14).

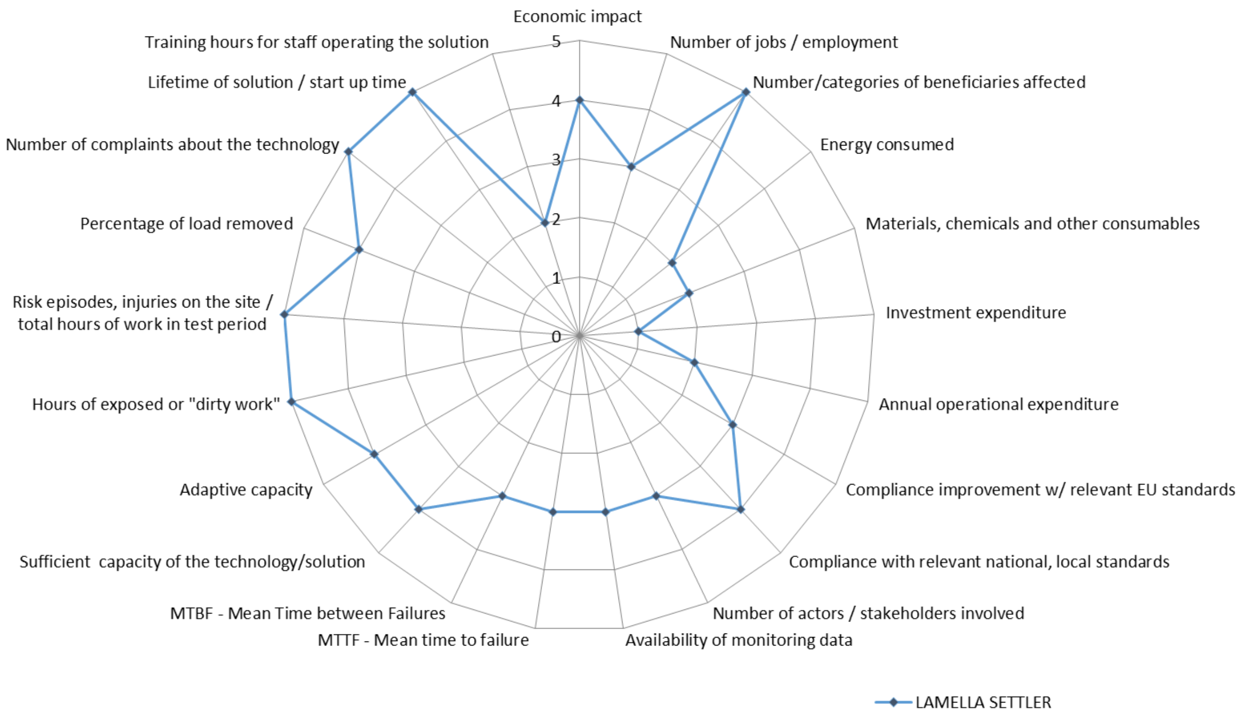


Figure 14 Spider plot showing results of the qualitative SA for decentralized water treatment on a scale from 1 to 5 (strong negative impact – some negative impact – neutral – some positive impact – strong positive impact) - blue points: AFTER.

For a number of SA metrics, a quantitative assessment could be conducted (Table 1).

Table 1 Overview of quantitative data available for the SA of decentralized water treatment.

SA metric/ indicator	DESSIN ESS	unit	before	after	source
S141	Number of beneficiaries affected	[-]	2,210,557	2,210,557	EG
En124	Energy consumed	[kWh/a]	0	788	UFT
En131	Materials, chemicals and other consumables (stainless steel)	[kg]	0	4,000	UFT
F111	Investment expenditure	[€]	0	270,000	UFT
F112	(Additional) Operational expenditure	[€/a]	0	3,308.19	UFT/EG
A221	Lifetime of solution/start up time	[-]	-	118 - 176	UFT
A231	Training hours for staff operating the solution	[h]	-	8	UFT

For all relevant SA metrics, a descriptive assessment is given below.

Social (S) dimension:

S1 Quality of life enhancement

S11 Health and Safety

- S111 Presence of microbial pathogens
- S112 Presence of cyanobacteria and cyanotoxins
- S113 Presence of toxic chemicals

Even after Emscher restoration, during rain events, discharge of CSO can still lead to occasional input of wastewater into the Emscher streams and also run-off during rain events as well as sewage from brownfields and waste deposits causes input of pollutants. The installation of innovative cross-flow lamella settlers in existing stormwater tanks can facilitate a reduction of total suspended solids, total organic carbon and the chemical oxygen demand, as shown in the demonstration study. An effect range between -46.6 % and up to 51.8 % has been observed in the tested setup. For a middle-sized large scale application (as modelled for CSO Gartenstraße) this corresponds to a load removal of 5.9 % (Q1) to 14.6 % (Median) to 17.2 % (Q3). Similarly, there is a potential that sewage garbage (like toilet paper and sanitary products), particles, pollutants and particle-bound pathogens in the overflowing water, and thus, in receiving streams can be reduced.

S12 Economic impact creation

- S121 Economic impact (incl. indirect and induced impacts) derived from initial spending for the solution itself

The improvement of river water quality is assumed to enhance the provision and the use of Cultural ESS in the whole catchment. Nonetheless, this improvement is expected to be rather neglectable in comparison to the economic impact resulting from the Emscher restoration measures that were already assessed within Emscher mature site assessment (D13.1., see S151 and S152). Further economic impacts derived from production effects of the lamella settler (*e.g.* higher level of employment in the installation and operation phase of the technology´s life cycle) are expected to be very low (see also S132).

S13 Job creation

- S131 Number of jobs, amount of employment created by implementation of technology/solution

The implementation of the technology is not expected to have a recognizable effect on the level of employment or number of employees at UFT or EGLV. Maintenance is needed, however, only in the same frequency as for CSO facilities without lamella settler. The extra effort is about 1.5 hours for 2 workers in their monthly maintenance check.

- S132 Number of jobs, amount of employment derived from improved cultural services

Cultural services are expected to be improved through the implementation of lamella settlers in CSO facilities. This improvement can be explained as an indirect effect from the improvement of the water quality in the recipient streams. This will, however, only be recognizable if all problematic CSO facilities along a stream are refitted. Furthermore, the positive effect on Cultural services originating from lamella settlers in CSO facilities can hardly be distinguished from the effect originating from the Emscher restoration.

S14 Equity

- S141 Number of beneficiaries affected

The positive effect on the streams can be appreciated by all inhabitants of the Emscher catchment if they make use of the Cultural ESS provided. These are 2,210,557 inhabitants (engl. Translation: EG annual report 2014/15). However, as mentioned above, the effects of the lamella settler can hardly be distinguished from the effects of the Emscher restoration.

- S142 Categories of beneficiaries affected

As within this assessment only one measure is assessed, neither number nor categories of beneficiaries will vary between scenarios. But as the whole population in the Emscher catchment profits from the measure, there is no exclusion of certain groups to be observed.

S15 Enhance cultural services

- S151 Experiential and physical use of landscapes in different environmental settings
- S152 Intellectual and representative interactions

See S132.

<u>Environmental (E) dimension:</u>

En1 Efficient use of water, energy and materials

En12 Efficiency in the use of energy

- En123 Green energy usage rate

The energy used for operation and maintenance is taken from the public electricity system. Therefore, the share of green energy usage will be given by the German energy mix. The green energy fraction is, however, not affected by the implementation of the lamella settler solution.

- En124 Energy consumed

The annual energy consumption for the electrical cabinet and the pivoting drive amounts to 2,703 kWh/a, which corresponds to 788.19 €/a.

Further energy consumption incurs in the production process of a middle-sized large scale application, among others for the processing of stainless steel, mechanical manipulation and welding. This energy consumption was, however, not quantified in the present study but would need to be investigated as part of a life-cycle-assessment.

Pumping energy for operation of the lamella settler (pivoting mechanism and pumping of sludge/emptying of the settler volume) was also not included.

En13 Efficiency in the use of materials

- En131 Materials, chemicals and other consumables

A middle-sized large scale application of a lamella settler requires 4,000 tons of steel. With the average EU steel price (Source: www.meps.co.uk/Stainless Price-eu.htm, June 2017) of 2,628.40 €/t the costs amount to 10,513.60 €. The production of the steel is related to energy demand and ecological and social effects during mining and processing as well as during production. Such effects would be assessed in a full life-cycle analysis of the solution.

The lamella settler requires no chemicals in normal operation.

Financial (F) dimension:

F1 Affordability (Ensure liquidity/solvency of the company)

F11 Cost coverage

- F111 Investment expenditure

The investment expenditures for one middle-sized large scale application amount to 270,000 €, consisting of the investment expenditures for an installation into an existing rectangular basin made of concrete (approx. 200,000 €), shipment and installation (approx. 15,000 €) and the expenditures for an electrical switchbox with the necessary controls (approx. 40,000 €).

- F112 Annual operational expenditure

Maintenance will cover the extra work needed for regular inspections, which is, however, needed in the same frequency as for CSO facilities without lamellae. Therefore, not the total inspection expenditures, but only the additional cost is given. Since the cross-flow settler has a self-cleaning pivoting mechanism, it is assumed that no frequent time-consuming manual cleaning (*e.g.* with a firehose) is necessary.

In addition to an overflow basin without lamella settlers, an energy consumption for the electrical cabinet and pivoting drive of approx. 2,703 kWh/a can be expected, which corresponds to approx. 788.19 €/a.

Concerning personnel costs, only the extra time needed during the anyway required monthly CSO maintenance is 1.5 hours for 2 workers per visit, which corresponds to 2,520 €/a.

In total, the additional operational costs for one middle-sized large scale application per year are approx. 3,308.19 €/a.

- F113 Avoided costs and/or additional monetary benefits

As the results on the efficiency assessed in the lamella settler demonstration study are only preliminary and have a high variation, there is a need for further studies before a statement on avoided costs can be made. With a proven efficiency, costs could be avoided for other technologies or additional facilities for decreasing particle and pollutant loads of CSOs. This might potentially become necessary in case of an increasing overflow behavior at CSO facilities due to climatic change (more heavy rain events), demographic change (more inhabitants connected to the sewer network), more stringent regulations or in case of failure to reach the WFD, etc. Similarly, re-fitting lamella modules could prevent from the need to extend the facility in size, saving real estate acquisition and investment costs.

However, until now, the efficiency of the lamella settler measured in DESSIN is not yet validated, and thus, would not yet be accepted for approval by agencies.

Additional monetary benefits resulting from Cultural ESS are expected but cannot be quantified (see 132).

Governance (G) dimension:

G1 Compliance

G11 Compliance with relevant regulations

- G111 Compliance improvement w/ relevant EU standards (WFD, BWD)

As described in chapter 2.1.7. and 2.1.8., the effects of load reduction on the chemical conditions of receiving streams and, subsequently, on their biological quality, depend on a number of factors.
In general, a reduced load discharge into recipient waters is advantageous for the water quality, however, a change in the chemical quality class according to the WFD is improbable.

- G112 Compliance with relevant national, local standards

No worksheet specifically on lamella settlers exists yet but ATV-A 128 (DWA (Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall) 1992) is the currently valid worksheet on the dimensioning of CSOs. If CSO facilities are meant to be dimensioned smaller by the introduction of lamella modules, the equal function and efficiency to a "conventional CSO" needs to be proved according to ATV-A 128.

G12 Stakeholder involvement

- G121 Number of actors/stakeholders involved in planning, implementation, operations, and monitoring

The actors involved were the SME (UFT), the site owner (EG, various departments), the approving agency (District Council Arnsberg).

- G122 Communicative events

For the demonstration case, a short film on the function and advantage of the lamella settler was produced. This would, however, not be conducted in a normal implementation (not research project).

<u>Assets (A) dimension:</u>

A1 Technology/Solution reliability, adequacy, resilience, and safety

A11 Technology / solution reliability, adequacy, resilience and safety

- A111 MTTF - Mean time to failure = 1/[number of observed failure per year]
- A112 MTBF - Mean Time between Failures = cumulative operating time/the observed number of failures by time t

Furthermore failure might incur in case of power outage. This would lead to an outage of the pumps and controlling technology. In Germany, however, power outages occur rarely.

A12 Adequate capacity of the technology/solution

- A121 Sufficient capacity of the technology/solution to the expected use

It is a modular system. However, the hydraulic capacity for one CSO facility is limited by its volume. If the capacity is not sufficient, more units of the solution can, however, be implemented in further CSO facilities (*e.g.* in four additional lamella settlers in the Emscher catchment). Furthermore, the sedimentation capacity of the lamellae might be increased with further research.

A13 Adaptability to changes

- A131 Adaptive capacity as: The probability that the item is able to function at time t (availability at time t) for any given loads

See A121.

A14 Safety and Health of operator/supplier

- A141 [Hours of exposed or "dirty work") on the site/total hours of work per year]*100

The lamella settler operates by itself and no maintenance during or after rain events is needed. Therefore, no dirty work is required. For the monthly maintenance, only an extra effort of approx. 1.5 hours for 2 workers is required.

- A142 Risk episodes, injuries on the site/total hours of work in test period

As in Germany, national accident-prevention directives are very strict and regularly monitored within companies, users of new technologies like lamella settlers will ensure that the requirements of these directives are met. Therefore, increased risks for the staff caused by the lamella settler technology can be excluded.

A15 Efficiency

- A151 percentage of load removed

See reduction rates reported in chapter 2.1.4.

A2 Minimize negative installation effects

A21 Disturbance impact of the technology/solution

- A211 Number of complaints about the technology (due to for instance Noise, Dust, Aesthetics, landscape)/reference time

No additional complaints expected, as the lamellae are inside an already existing combined sewage treatment facility. Odor problems might exist but are not enhanced through the lamellae. Noise by the pivoting mechanisms can be neglected.

A22 Start up time (time from installation to effectiveness)

- A221

The start up time for building and installation by the producer and installer is estimated to be about 2 person months. The lifetime (whole plant) is approx. 20-30 years (VDMA-Einheitsblatt 24657), however, for some parts subject to wear it is only 10-20 years. The lifetime of solution/start up time is, thus, approx. 118-176.

A23 Alignment with existing knowledge

- A231 training hours for staff operating the solution

The required training hours for staff operating the lamellae is approx. 2 hours for 3-4 persons.

Further considerations:

With the application of the lamella settler, the hydraulic pressure on receiving streams remains, though with a reduced load.

3. Real Time Control of sewer network

An innovative solution for Real Time Control (RTC) of sewer systems and CSO facilities was tested in the Emscher region. Figure 15 depicts the system controlled by the ADESBA-RTC. To this end, the RTC has been tested in five CSO facilities in the Emscher basin. These five facilities were located in the sewer network along the upper Emscher and its tributaries in the sub-catchment of the WWTP Dortmund Deusen. Detailed information on the outcome of the testing can be obtained from deliverable D31.1.

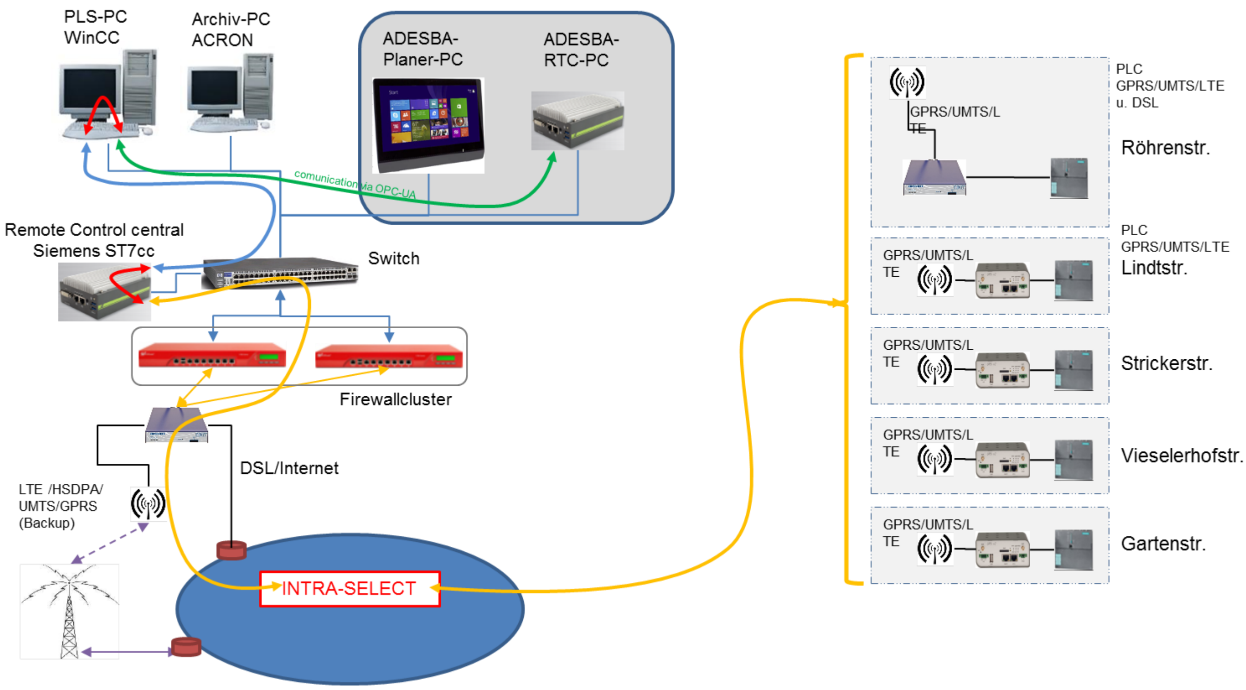


Figure 15 Communication scheme for ADESBA-RTC at the five CSOs (source: SEGNO).

3.1. Application of the DESSIN ESS Evaluation Framework

3.1.1. Overview

An overview of the ESS and SA conducted for the ADESBA-RTC solution is shown in Figure 16.

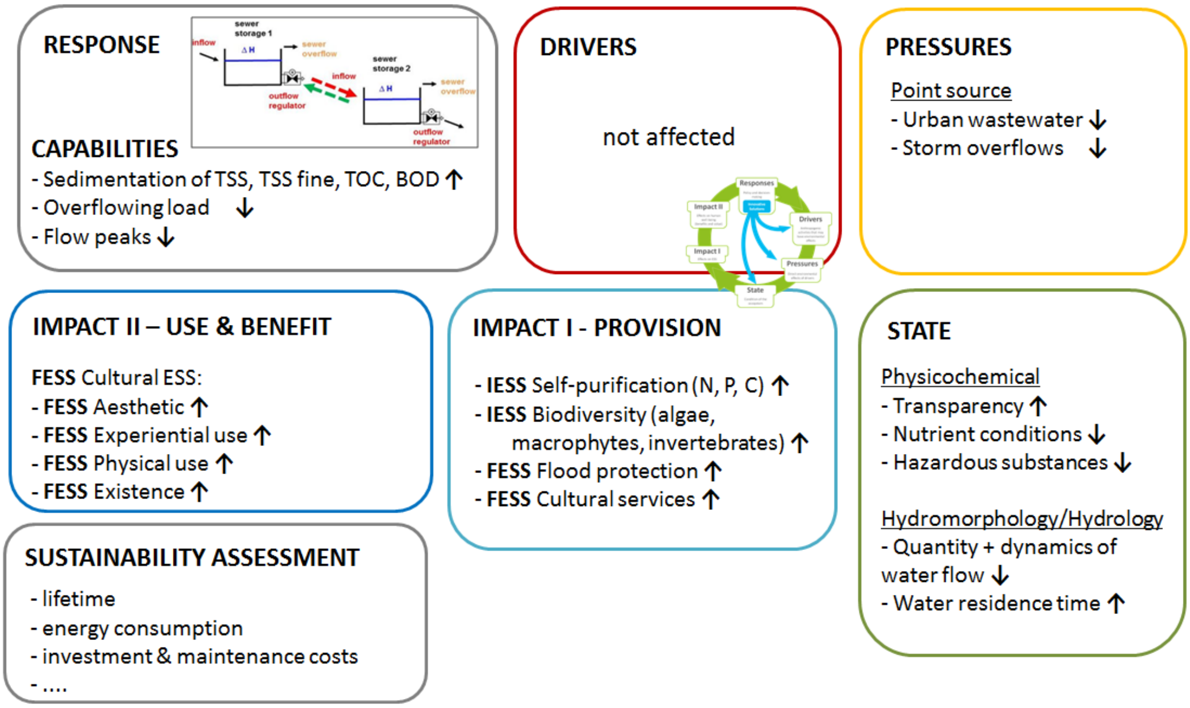


Figure 16 Overview of the ESS and SA of the ADESBA-RTC.

3.1.2. Using the MIKE Decision-Support Software

The MIKE Info/Workbench ESS Tool was applied in this case study, leading through the ESS and SA step-by-step. The professional MIKE version was not applied, as no water quality model was available for the region, which could have been the basis for deriving time series data or other programmed indicators.

3.1.3. Study description

For the RTC, the same study descriptions apply as for the lamella settler, as the assessed system is the same. Thus, see chapter 2.1.3.

3.1.4. Response

The RTC aims at a reduction of overflow frequency and volume. Therefore, it reduces hydraulic stress in the stream. Along with the reduction in volume goes a reduction in overflow load - of both dissolved and particulate pollutants - which represents a reduction of physicochemical stress.

The reduction of the overflow volume into receiving streams was determined in different ways. In an analysis of potential of the five CSO facilities, which were selected for demonstration of the RTC, a potential reduction of 7.8 % was identified. The analysis of success, comparing the testwise operated system including the ADESBA-RTC and the same system without ADESBA, which was simulated in the Simba# model, revealed efficiencies of -16.6 % to 37.3 % reduction in overflow volume.

The capabilities of the solution are, thus:

- Volume: Reduction of overflowing volume
- Peak flow: Reduction of peak flow
- Concentration: Reduction of concentration of TSS, TSS fine, TOC, BOD in the overflowing water
- Load: Reduction of overflowing load

The first two capabilities are not provided by the lamellae (but by the storage volume of the CSO facility), and thus, differentiate the effects of the two solutions. In the case of the RTC, the concentration and load reduction originates from reduced overflow volumes and not from enhanced sedimentation as in the case of the lamella settler.

Upscaling

In DESSIN, the ADESBA-RTC system was tested at only five facilities. To get an impression of the benefit the ADESBA system could provide on a larger scale, the ADESBA algorithm was also tested in a simulation of the whole sub-catchment of the WWTP Dortmund Deusen in the Simba# software. The sub-catchment of the WWTP Dortmund Deusen consists of a combined sewer network, including 36 storage structures, that runs in parallel to the upper Emscher (Figure 17). The CSO facilities, thus, discharge into the upper Emscher or the Emscher tributaries in case of heavy rain events. For the upscaling, the potential overflow reduction by ADESBA was conducted based on these 36 CSOs.

Uncertainty

The results are still preliminary due to the relatively low number of rain events evaluated. Furthermore, uncertainties concerning the accuracy of the measurement and the simulation exist. Nevertheless, the results show the clear tendency that the ADESBA system works as it should, *i.e.* that the overflow volume can be reduced by implementing the ADESBA control.

Figure 17 Impression of the upper Emscher (photo: Daniel Horst)

3.1.5. Drivers

The relevant drivers in the assessed system are the same as for the lamella settler solution, described in chapter 2.1.5.

3.1.6. Pressures

BEFORE

The pressures derived from the relevant drivers are the same as for the lamella settler, as the same study area applies here. For more detailed information, see chapter 2.1.6.

AFTER

The RTC solution is capable of mitigating the same pressures as the lamella settler, *i.e.* to reduce point sources. The focus is, thus, on point source pressures derived from the drivers "industry", "transport" and "urbanization". In contrast to the lamella settler, the RTC additionally reduces hydrological stress, related to the driver "flood protection", by lowering flood peaks (see 3.1.4.)

- Point source
  - Urban wastewater

    - Storm overflows
- Hydrology

A RTC is only effective during events with potential, *i.e.* with remaining storage capacity. During heavy rain events when the entire system is filled, a RTC has no effect. Thus, the RTC is only effective during small to medium events. These, however, are the ones most detrimental for aquatic communities, as they occur quite often. Therefore, a reduction in the total number of overflow events via the ADESBA-RTC is possible. Heavy rain events occur less frequent, and thus, biological communities have the possibility to recover in the meantime.

3.1.7. State

BEFORE

See chapter 2.1.7.

AFTER

The RTC, similar as the lamella settler, affects physicochemical parameters of State via the above described capabilities (see chapter 3.1.4.).

Via the additional capabilities of the RTC (reduction of overflowing volume and of peak flow), hydromorphological and hydrological parameters of State are affected as well. Through a reduction of the discharged CSO, the water flow in the stream during rain events is potentially slightly lower, providing a slight reduction of peak flows. This might reduce shear forces in the stream's bed and shore, and thus, erosion and drift of macroinvertebrates. Borchardt and Statzner (1990) found synergetic effects of the exposure to high flow and sewage, which in combination caused higher population loss of the benthic invertebrate *Gammarus pulex* than individually. The fact that population loss was also depended on the availability of refugial space on the stream bed highlights the importance of the receiving streams' characteristics for the ecological impact of CSOs.

Within DESSIN, a master thesis has been conducted by Horst (2016). Aim of the thesis was to assess the influence of the ADESBA-RTC on an overflow event in the upper Emscher. To this end, a representative overflow event was selected, being the event closest to the median overflow volume and duration of a 25-year simulation dataset. Overflow volume and duration were compared between simulations without and with the ADESBA algorithm in place. Based on overflow volume, the overflow load was calculated, assuming constant nutrient and organic carbon concentrations in the combined sewage. Initial concentrations of nutrients and organic toxicants in the receiving Emscher headwaters have been obtained from monitoring data. Via simple steady-state calculations, final concentrations, emerging after the overflow into the receiving stream has happened, were assessed. The calculations were conducted for low and mean stream flow.

Horst (2016) found a decrease in CSO volume and duration of 31 and 5 %, respectively, for the exemplary overflow event. Resulting in-stream loads were expected to decrease along with the CSO volume (*i.e.* by 31 %), ignoring first flush and dynamic effects. Final in-stream concentrations, however, were only slightly affected (1 to 2 %) by the RTC.

Concluding, the following parameters of State affected by CSO can be influenced by the Response:

- Physicochemical
  - Transparency
  - Nutrient conditions
  - Hazardous substances
- Hydromorphology/Hydrology
  - Quantity and dynamics of water flow
  - Water residence time

Uncertainty

See chapter 2.1.7.

3.1.8. Impact I - Provision

- IESS Self-purification (N, P, C)

The RTC achieves a load reduction of fine sediment, organic matter and nutrients via a reduction of the overflow volume, as described in 3.1.4. The effects of a reduced overflow load on the IESS "Self-purification" are discussed in chapter 2.1.8. and are equally valid for the RTC.

Horst (2016) calculated the days and stream kilometers needed for the removal of the excess loads of nutrients and organic carbon by CSO without and with ADESBA-RTC. This was based on the load reductions achieved by RTC as assessed in a first step. Just as the CSO volume decreased, also the days and stream kilometers required for self-purification were estimated to decrease by 31 %.

Uncertainty

The assessment by Horst (2016) includes a number of assumptions and simplifications in order to reduce complexity. For instance, only one representative overflow event was evaluated and the evaluation was based on simulated data. Furthermore, constant combined sewage concentrations were assumed and first flush effects were ignored. Also, simple steady-state calculations were applied, in which the upper Emscher section alongside the five CSOs, at which ADESBA-RTC was implemented, was considered as one steady water body. This was done as no water quality model was available. Additionally, standard self-purification rates from literature (Niemann 2001, Scholz *et* *al.* 2012, D13.1) were applied. This means, the dependency of the purification rate on in-stream concentrations was not taken into account.

- IESS Flood protection

  (CICES classification: "Flood protection", "Buffering and attenuation of mass flows")

As described in 3.1.6., the RTC, in contrast to the lamella settler, has the capacity to reduce the overflow volume and, thus, the water level, flow velocity, and flow peaks in the receiving stream, as discussed in 3.1.7.

BEFORE

In case of very intense rain events and already high water level in the receiving stream by diffuse and upstream point sources, the additional water volume discharged by one or several CSO facilities alongside this stream can further raise the in-stream water level considerably (Figure 18).

AFTER

A reduction of the overflow volume due to the implementation of the RTC can potentially slightly positively affect the IESS "Flood protection". Lowering peaks in water flow and water level can reduce the risks of flooding and dike failure and of river bed and shore erosion and species drift. Thus, also this IESS can have indirect implications on the IESS "Biodiversity". As a consequence, also Cultural ESS, such as riverine aesthetics, recreational and educational services, might be promoted by a RTC. The effects of a RTC via reduced hydraulic and chemical stress on streams and their Cultural ESS are discussed in chapter 3.1.9.

In the overflow event evaluated by Horst (2016), a CSO volume and duration reduction of 31 % and 5 %, respectively, could be detected. Here, it was noticed that CSO volume exceeded the in-stream water volume by up to two orders of magnitude during dry weather conditions. The reason is that the upper Emscher and its headwater is a small stream with a width between 0.5 and 2 m and water levels of only 0.1 to 0.3 m (Horst 2016). The discharge of CSO can, thus, lead to a considerable enhancement of in-stream water level and flow. Such a situation is demonstrated in Figure 18.

Schreer (2008), on the other hand, observed an only moderate reduction of flow peaks by nine different RTC systems evaluated in the catchment of a WWTP in Gießen, Germany.

Figure 18 Overflow event at CSO facility Wörthstraße discharging into the upper Emscher (photo: Jörg Rothholz)

- IESS Biodiversity (algae, macrophytes, invertebrates, fish)

Detrimental effects from CSO discharge of fine particles, toxicants and nutrients on aquatic biological communities, and thus, on the IESS "Biodiversity" as well as on the ecological status/potential as assessed by the WFD, are discussed in chapter 2.1.8. A reduction of these detrimental effects via a reduced overflow load as provided by the lamella settler can similarly be provided by the RTC.

3.1.9. Impact II - Use & Benefit

- FESS Cultural ESS

The FESS "Aesthetic", "Experiential use", "Physical use", "Educational use" and "Existence" can similarly be enhanced by the RTC as discussed in chapter 2.1.9. for the lamella settler.

Uncertainty

As for the lamella settler technology, the improvements on the use of Cultural ESS by the RTC system are expected to be rather marginal in comparison to the economic impact resulting from the Emscher restoration measures (assessed in the Emscher mature site assessment (D13.1, see S151 and S152)). As the effects of the RTC on the use of Cultural ESS would not be differentiable from the effect of the Emscher restoration, Cultural ESS was not quantified and monetized.

3.2. Application of the Sustainability Assessment

3.2.1. Definition of the assessment and decision case

Scale of the system

RTC can be refitted into any existing CSO facilities - whether these are round or rectangular CSO basins or circular storage channels. RTC can either be directly integrated into newly planned facilities or refitted into existing CSO facilities. The latter possibly requires some hardware and software refitting. Refitting of RTC in existing facilities may be valuable if the capacity of a specific CSO facility or the entire sewer network becomes too small. Problems with too small dimensioning can appear due to enhanced wastewater or rainwater discharge as a result of demographic and climate change, respectively, or enhanced surface runoff due to growing areas of sealed surface.

The highest potential of overflow frequency and volume reduction can be expected in those sections of the sewer network where some storage facilities are often not filled entirely during rain events while nearby facilities experience frequent overflows. Strong effects can be expected when storage facilities with large storage volumes are included in the real-time controlled network. Furthermore, a RTC is meaningful in areas where the receiving streams are sensitive and pressure on them needs to be reduced.

For the SA of the ADESBA-RTC, we scale all indicators to the level of a large-scale application of RTC in the sub-catchment of the upper Emscher, according to the upscaling calculation done in D31.1, with the exemplary implementation in 12 CSO facilities and one central office (*i.e.* one ADESBA-PC). We refer to this as a “sub-catchment scale application”.

As 10 sub-catchments exist in the Emscher basin (Emschergenossenschaft 2013), the upscaling done for the sub-catchment of the upper Emscher could be multiplied by 10 to (very roughly) forecast effects on the Emscher basin scale.

Timeframe of assessment

As this SA will not compare an alternative solution to the ADESBA-RTC solution, only two scenarios have to be compared by the proposed indicator set:

- The situation “BEFORE” is represented by a baseline situation in the Emscher basin. At this baseline, the Emscher re-conversion is assumed to be completed (in 2021). At the present moment (in 2017), part of the Emscher basin is already restored, while part is still under construction. For the discussion of sustainability aspects, we try not to mix up the effects of the Emscher re-conversion and a theoretical/predicted implementation of the RTC.
- The assessment and discussion of the sustainability metrics (see below) represents the case “AFTER” a theoretical/predicted implementation of the RTC.

The SA for the RTC is conducted for a one year period. This means, when quantitative assessment was possible, the values are given on an annual basis.

3.2.2. Indicator selection and data collection

For the following assessment, indicators related to water supply systems were neglected since there is no water extracted from the Emscher for drinking water treatment. The remaining list of indicators was further checked with special regard to data availability. Due to the lack of modelled data for a large-scale RTC application, only few indicators have been assessed quantitatively based on measured data and estimates of experts. Expected effects in all other indicator categories are described qualitatively in order to overcome the data gaps. Thus, all five dimensions proposed for SA within the DESSIN ESS Evaluation Framework are adequately addressed in this assessment.

The quantitative assessments as well as further qualitative descriptions to those indicators lacking data for calculations are presented in the following chapter.

3.2.3. Results and discussion

For all relevant SA metrics, a categorization into strong negative to strong positive impact was conducted (Figure 19).

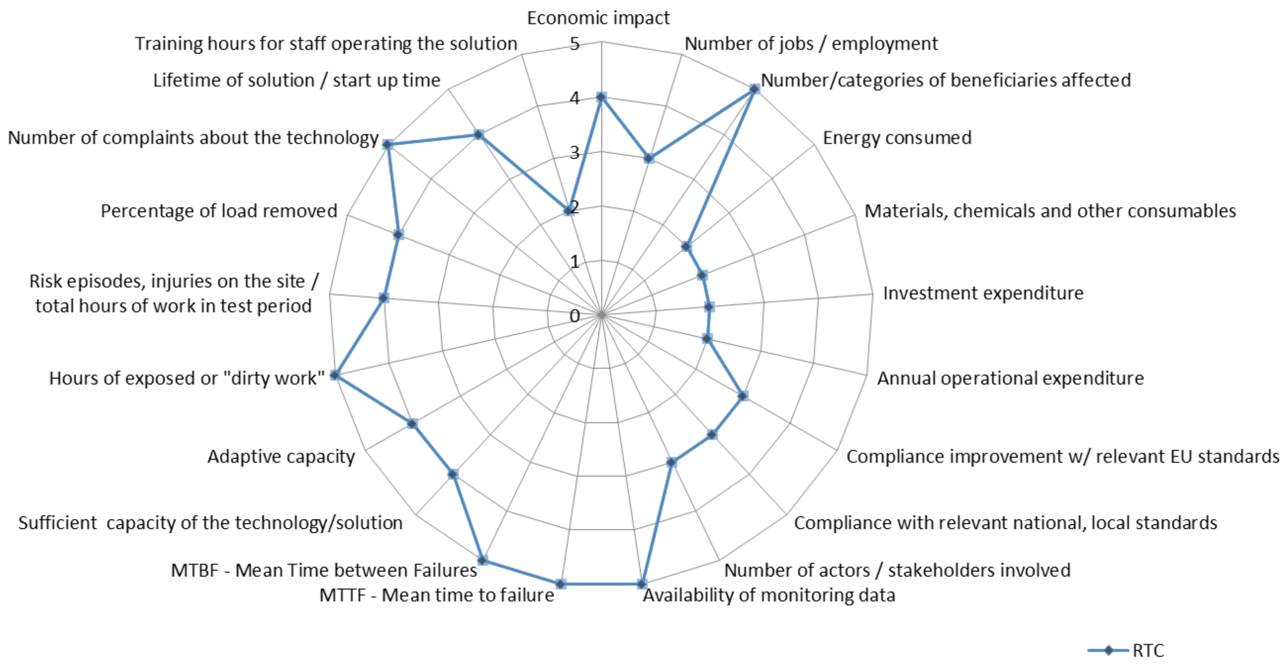


Figure 19 Spider plot showing results of the qualitative SA for the RTC system on a scale from 1 to 5 (strong negative impact – some negative impact – neutral – some positive impact – strong positive impact) - blue points: AFTER.

For a number of SA metrics, a quantitative assessment could be conducted (Table 2).

Table 2 Overview of quantitative data available for the SA of the RTC system.

SA metric/ indicator	DESSIN ESS	unit	before	after	source
S141	Number of beneficiaries affected	[-]	2,210,557	2,210,557	EG
En124	Energy consumed	[kWh/a]	0	5,590	SEGNO
En131	Materials, chemicals and other consumables (rare earth metals)	[g/notebook]	0	80	SEGNO
F111	Investment expenditure	[€]	0	100,000	SEGNO
F112	(Additional) Operational expenditure	[€/a]	0	3,750 - 8,750	SEGNO
A111	(Expected) Unavailability of a managed standard computer	[h/a]	-	87.6	SEGNO
A112	Mean Time between Failures	[h]	-	5,000-10,000	SEGNO
A221	Lifetime of solution/start up time	[-]	-	32 - 60	SEGNO

For all relevant SA metrics, a descriptive assessment is given below.

Social (S) dimension:

S1 Quality of life enhancement

S11 Health and Safety

- S111 Presence of microbial pathogens
- S112 Presence of cyanobacteria and cyanotoxins
- S113 Presence of toxic chemicals

Even after Emscher restoration, during rain events, discharge of CSO can still lead to occasional input of wastewater into the Emscher streams and also run-off during rain events as well as sewage from brownfields and waste deposits causes input of pollutants. Balancing the water level in existing stormwater tanks by a RTC system reduces the entry of pathogens and pollutants in the Emscher streams. Thus, water quality of the the Emscher streams is expected to be increased significantly.

The implementation of a RTC in the sewer network resulted in a reduction of overflow volume by 42.6 %, 38 %, 19.1 % during three rainfall events during demonstration phase. Only during one rainfall event no reduction was observed but an increase by 16.6 % of overflow value. For a large-scale application on the sub-catchment scale (Emscher headwaters), reduction rates of 3.8 % to 7.5 % of the overflow volume could be shown, for 36 and 4 CSOs, respectively. Simplified, the overflow volume is correlated with the overflowing load (when disregarding first flushes and dilution in the later phase of rain events). Thus, a corresponding load removal can be expected. Similarly, garbage (like toilet paper and sanitary products), particles, pollutants and pathogen concentrations within the Emscher streams can be reduced.

S12 Economic impact creation

- S121 Economic impact (incl. indirect and induced impacts) derived from initial spending for the solution itself

The improvement of river water quality is assumed to enhance the provision and the use of Cultural ESS in the whole catchment. Nonetheless, this improvement is expected to be rather negligible in comparison to the economic impact resulting from the Emscher restoration measures that were already assessed within Emscher mature site assessment (D13.1., see S151 and S152). Further economic impacts derived from production effects (*e.g.* higher level of employment in the installation and operation phase of the technology´s life cycle) originating from the RTC are expected to be very low as well (see also S132).

S13 Job creation

- S131 Number of jobs, amount of employment created by implementation of technology/solution

The implementation of the technology is not expected to have a recognizable effect on the level of employment or number of employees at SEGNO or EGLV.

According to the DESSIN DoW, EG had 26 person month in WP31, however, including also the work time for the lamella settler. A rough guess is that 18 person months were spent for the RTC. During the implementation phase of the RTC, the departments operation and telecommunication of EG spent four person months. Additional PM were spent by the project coordination and the water management department. Also the University of Essen contributed considerably.

The implementation of a demonstration study (including the monitoring of success) was, however, for sure more laborious than a future roll-out of the solution.

- S132 Number of jobs, amount of employment derived from improved cultural services

Cultural ESS are expected to be improved through the implementation of RTC in CSO facilities. This improvement can be explained as an indirect effect from the improvement of the water quality in the recipient streams. This will, however, only be recognizable if all problematic CSO facilities along a stream are refitted. Furthermore, the positive effect on Cultural services originating from RTC in CSO facilities can hardly be distinguished from the effect originating from the Emscher restoration.

S14 Equity

- S141 Number of beneficiaries affected

The positive effect on the streams can be appreciated by all inhabitants of the Emscher catchment if they make use of the Cultural ESS provided. These are 2,210,557 inhabitants (EG Geschäftsbericht 2014/15). However, as mentioned above, the effects of the RTC can hardly be distinguished from the effects of the Emscher restoration.

- S142 Categories of beneficiaries affected

As only one measure is assessed, neither number nor categories of beneficiaries will vary between scenarios. But as the whole population in the Emscher catchment profits from the measure, there is no exclusion of certain groups

S15 Enhance cultural services

- S151 Experiential and physical use of landscapes in different environmental settings
- S152 Intellectual and representative interactions

See S132.

Environmental (E) dimension:

En1 Efficient use of water, energy and materials

En12 Efficiency in the use of energy

- En123 Green energy usage rate

The energy used for operation and maintenance is taken from the public electricity system. Therefore, the share of green energy usage will be given by the German energy mix. The green energy fraction is, however, not affected by the implementation of the RTC solution.

- En124 Energy consumed

Energy is required for the computer system, the increased throttle valve activity, the data exchange and the server systems required for data storage. The energy demand of one ADESBA computer per year is 114 W (watts) * 24h * 365d / 1,000 = 1,000 kWh. The energy demand for the server is approximately the same as for the ADESBA computer. Also the energy demand for data exchange is approximately the same as for the ADESBA computer. The energy demand for the throttle valves was estimated as follows: A damper slide DN350 with a motor drive runs with approximately 300 W during a few seconds to minutes (approximated with 1 minute) every 5 minutes (as set now for the ADESBA RTC). With 150 rain days, this results in 1*12*24*150/60 = 720 hours per year. With 300 W, this results in 0.3kW * 720h = 216 kWh per throttle. For 12 throttles, this amounts to 2,592 kWh/a. Disregarded is the energy consumption of the control cabinet (as this is anyway required, even without a RTC).

In total, the annual supplementary energy consumption amounts to approximately 5,590 kWh/a.

Although the energy consumption of the RTC system itself is rather neglectable, an implementation of a RTC on the catchment-scale might have a strong influence of the water volumes that need to be pumped and treated in the WWTP (as more water is progressed to the WWTP instead of being discharged into the next stream). Thus, energy consumption required for pumping and WWTP might be considerable.

En13 Efficiency in the use of materials

- En131 Materials, chemicals and other consumables
  - Amount of specific materials, chemicals or other consumables consumed:

    The total weight of the ADESBA RTC industrial computer with network Ethernet cable is 5 kg.
  - Amount of specific materials, chemicals or other consumables consumed:

    The average amount of rare earth metals is 80 g/notebook (Source: see Annex B.2.).
  - Amount of specific materials, chemicals or other consumables consumed:

    The average price of rare earth metals is 6 $/notebook (Source: see Annex B.2.).

Financial (F) dimension:

F1 Affordability (Ensure liquidity/solvency of the company)

F11 Cost coverage

- F111 Investment expenditure

The investment costs are strongly depending on whether the RTC is implemented right from the start or system is upgraded later on. The investment costs consist of costs for hardware, software, retrofits (damper slides, MID measuring section, latest version of SPS and WinCC, telecommunication) and licenses.
The ADESBA license for installation at 12 CSOs is 54,000 €, the ADESBA-RTC-computer incl. system installation is 6,000 € and the ADESBA engineering, clarification, specification, parameterization, commissioning, documentation, test and trial operation amounts to approx. 40,000 €.
This amounts to a total investment of 100,000 €.

- F112 Annual operational expenditure

Annual operational costs can be estimated with 3,750 € to 8,750 € per year incl. annual costs for energy (incl. 750 €/a energy costs for real-time controlled operation of 12 throttle valves), maintenance and personnel. The latter depend on the time interval defined for maintenance. The maintenance checks of the RTC can expectedly be conducted by trained EG staff. However, an extra effort will incur compared to current maintenance works without RTC.

- F113 Avoided costs and/or additional monetary benefits

A RTC can be implemented in a sewer system where the overflow frequency, volume or load exceeds the thresholds given by regulation and authorizing agencies. Thus, a very cost intensive extension of the sewer network by enlarging channels and CSO facilities can be avoided. In case the RTC is included already during the planning phase, the sewer network and storage basis can possibly be dimensioned smaller than without RTC. This way, costs can be avoided.

RTC can also be implemented where the utilization of the storage volume is not equally distributed over the storage facilities, *i.e.* where some facilities have unused storage volume. Positive effects on stream water quality and, as a result, on stream ecology and biology can, potentially, indirectly facilitate the achievement of the goals of the WFD.

Governance (G) dimension:

G1 Compliance

G11 Compliance with relevant regulations

- G111 Compliance improvement w/ relevant EU standards (WFD, BWD)

As described in chapter 3.1.7. and 3.1.8., the effects of load reduction on the chemical conditions of receiving streams and, subsequently, on their biological quality, depend on a number of factors.
In general, a reduced load discharge into recipient waters is advantageous for the water quality, however, a change in the chemical quality class according to the WFD is improbable.

- G112 Compliance with relevant national, local standards

With ongoing discussions on the digitalization within the frame of "water management 4.0", security issues for critical infrastructure are an important topic. The security recommendations, thus, have to be complied with.

National guidelines exist which give thresholds for the number of overflow events allowed per CSO facility. The authorizing agencies of the respective river basin set the concrete thresholds for the CSO facilities in that basin.

G12 Stakeholder involvement

- G121 Number of actors/stakeholders involved in planning, implementation, operations, and monitoring

The actors involved were the SME (SEGNO), the site owner (EG, various departments), the approving agency (District council Arnsberg).

- G122 Communicative events

For the demonstration case, a short film on the function and advantage of the RTC ADESBA was produced. This would, however, not be conducted in a normal implementation (not research project).

G13 Transparency

- G131 Availability of monitoring data

The RTC allows measuring and visualizing online-data in minute-by-minute intervals, which is new. Furthermore, the implementation of the RTC went along with the programming of a visualization interface and reporting output allowing monitoring the joint filling, overflowing and emptying behavior of various CSOs in the system. In general, this increases transparency of measured data.

Assets (A) dimension:

A1 Technology/Solution reliability, adequacy, resilience, and safety

A11 Technology / solution reliability, adequacy, resilience and safety

- A111 "MTTF - Mean time to failure = 1/[number of observed failure per year]"

The ADESBA PC is a managed standard computer. A managed standard computer has an availability of about 99.0 %. This results in an unavailability of 87.6 hours per year.

- A112 "MTBF - Mean Time between Failures = cumulative operating time/the observed number of failures by time t"

ADESBA is a managed standard computer. A managed standard computer has a MTBF of between 5,000 to 10,000 hours, *i.e.* 0.57 to 1.14 years.

A12 Adequate capacity of the technology/solution

- A121 Sufficient capacity of the technology/solution to the expected use

Currently, the thresholds giving the maximum overflow frequency/number and volume are not exceeded. Thus, currently the capacity of the sewer system is sufficient even without RTC. However, with future challenges such as climatic and demographic changes, or enhanced surface runoff due to growing areas of sealed surface, the thresholds might be exceeded, making a RTC necessary and beneficial in terms of staying within the thresholds.

A13 Adaptability to changes

- A131 Adaptive capacity: The probability that the item is able to function at time t (availability at time t) for any given loads

The RTC can progressively be extended by additional CSO facilities, in case the overflow volume reduction is not sufficient anymore. This is rather straight-forward with ADESBA. Only at a certain point, an additional central office (*i.e.* also an additional ADESBA-PC is required). One central office per WWTP catchment is probably a realistic scale.

A14 Safety and Health of operator/supplier

- A141 [Hours of exposed or "dirty work") on the site/total hours of work per year]*100

In general, no additional protective clothing is needed as there is no dirty work except for the regular maintenance work inside the CSO facilities, which is, however, conducted anyway.

- A142 Risk episodes, injuries on the site/total hours of work in test period

In order to prevent any risk during maintenance work inside the CSO facilities, a manual on-off-button was implemented at each CSO facility and in the central office. This prevents that ADESBA starts controlling the throttle valves during maintenance work.

A15 Efficiency

- A151 percentage of load removed

A reduction in the overflow volume by 42.6 %, 38 %, 19.1 % and -16.6 % was shown during four rain events in the demonstration phase. For a large-scale application on the sub-catchment scale (Emscher headwaters), reduction rates of 3.8 % to 7.5 % of the overflow volume could be shown, for 36 and 4 CSOs, respectively. Simplified, the overflow volume is correlated with the overflowing load (when disregarding first flushes and dilution in the later phase of rain events). For more information see chapter 3.1.4.

A2 Minimize negative installation effects

A21 Disturbance impact of the technology/solution

- A211 Number of complaints about the technology (due to for instance Noise, Dust, Aesthetics, landscape)/reference time

No additional complaints expected, as the RTC is part of already existing combined sewage treatment facilities. Odor problems might exist but are not enhanced through the solution.

A22 Start up time (time from installation to effectiveness)

- A221 lifetime of solution/start up time

Start time (time from installation to efficiency) depends on the number of CSO facilities and control offices. Typical for up to 12 facilities is about 3 months for the software implementation, not including the time for potentially required installation of hardware and measurement systems. During DESSIN, the implementation process took considerably longer - 36 months - but included research and gaining experience as well as a lot of re-fitting and trouble-shooting work. In a large-scale roll-out, implementation time is expected to be shorter. The lifetime of the ADESBA solution depends on the quality of the components and the regular maintenance and service. A typical lifetime of about 8 to 15 years can be expected. This results in a lifetime of solution/start up time of 32 to 60.

A23 Alignment with existing knowledge

- A231 training hours for staff operating the solution

A certain effort is required per employee that should use the system. For maintenance of the telecommunication, programming and trouble-shooting, a higher expertise and advanced training is needed.

Further considerations (advantages and disadvantages)

- The overall overflow volume is reduced for the whole real-time controlled system. To achieve this, all CSO facilities need to be equally filled. This means that with the RTC some tanks are filled which would have stayed empty without RTC. As a result, cleaning effort might increase.
- Furthermore, for all - or at least part of - the storage facilities, the overflow frequency increases. As the tanks become equally filled, eventually they all have water levels around the overflow bar. If the rain event continues and the total storage volume of the system is exceeded, overflow will occur at all tanks. Thus, overflow occurs also at tanks which would have stayed empty or less filled without RTC. Plus, during longer rain events, many (though potentially) small overflows can occur when the water level stays around the overflow bar.
- It is, thus, also possible that the first flush gets stored in basins whose outflows are reduced

on demand of the RTC in order to achieve equal filling of all basins and avoid overflow from other basins. If then, the rain exceeds the storage capacity and overflow occurs, the stored first flush might be discharged into the recipient stream.

- A direct consequence of a reduction of the overflow volume is that more combined sewage is transferred to the WWTP. The RTC, thus, directly leads to higher treatment effort and costs as well as higher pumping effort and costs at pumping stations.
- RTC is part of the concepts of „water management 4.0“, and will expectedly be applied more in the near future.
- Increasing flexibility of an infrastructure system with a long lifetime and high fix costs by RTC is an advantage it times when adaptability to future changes is required.
- With the online and remote control, however, the vulnerability and risk of disturbance and cyber-attacks increase, which can disturb the operation of the RTC. Thus, higher demands on security systems arise, resulting in additional costs.
- As ADESBA controls only based on water levels and not on „if-else-commands“, no laborious and complex basin-specific adaptation of the algorithm is required. Also extensions of the systems can be implemented without too much effort.
- It is possible to prioritize sections, where fewer overflows should occur in order to protect vulnerable stream sections of the receiving river.
- Economically, the capacity utilization can be increased; the use of a RTC technology can lead to smarter system utilization. This may help to avoid expensive additional infrastructure investments to reduce the overflow volume to a favoured level.
- Knowledge gain in ICT based sewer network optimization.
- Knowledge gain from simulation models and detailed evaluation of monitored operation.
- Increased personnel capacity will be required during the implementation phase. Investment costs will depend on the ADESBA license fee and the condition of the CSO facilities and their requirements for re-fitting (online telecommunication, controllable throttles, etc.) and, of course, the size of the system to be real-time controlled.
- Although the RTC can minimize overflow volume which has positive effects on the whole system, it has to be assessed, whether the benefits justify additional costs.
- Scheer (2008) has conducted a detailed cost-benefit comparison of various types of RTC with regard to the following categories: combined sewage treatment, water body, WWTP, operation of sewers, implementation and operational costs of system elements. Such an analysis could be conducted complementary to the ESS and sustainability assessment completed in the present deliverable in order to further broaden the knowledge on the consequences of different types of implementation.

4. Uptake of water quality enhancing technologies

4.1. Application of the Manual for Practitioners and Policymakers

The uptake of new technologies is hindered by the willingness to invest (*i.e.* financing issues), regulatory constraints and a lack of trust in novel approaches. To this end, DESSIN has compiled recommendations and options in various documents, outlined below.

4.1.1. Governance & policy implications and novel financing mechanisms

The policy briefs (D12.3) for water managers & policy makers and for technology companies & water utilities give recommendations in order to increase the chances of innovation uptake though governance in terms of good practice.

The briefs recommend, for instance, the development of partnerships between the relevant actors. Such partnerships have been initiated through the DESSIN project, bringing together technology providers and water managers. Similarly, knowledge creation and capacity building has been provided though the project, as also university partners were involved in close collaboration with technology providers and site owners and operators.

The business environment (outside-in) report, deliverable D42.3, has developed a solution package for the Emscher case. The solution package consists of the core solution (*i.e.* cross-flow lamella settler/ ADESBA-RTC/ DESSIN ESS and SA Framework) and support services (such as market analysis, commercialization & capacity building, lobbying with policy makers, etc.).

In D42.3, the following steps were conducted: (1) A product description including the respective solution package and its anticipated impacts on ESS, (2) an initial screening for critical market success factors of the solution, (3) the detailed analysis including the relevant governance framework, an analysis of the market conditions and financial opportunities, (4) barriers and challenges derived from the analysis, and (5) recommendations for SMEs and policy recommendations. Also financing options were screened for the implementation of the two technologies. The re-invest phase in the Emscher region, where facilities that are not up-to-date anymore are renewed, would, for example, be an option for the inclusion of lamella settlers.

4.1.2. Actual implementation processes in the local context

In the Emscher catchment, lamella modules could be refitted quite easily into four rectangular and open storage basins (D31.1). Refitting lamella modules into closed rectangular basins would require higher effort. The meaningfulness/efficiency of refitting in round or circular CSOs is questionable, as a high proportion of the water would pass next to the lamellae.

The RTC technology could be implemented in all CSO facilities in the Emscher region. This would, however, require high investment and maintenance costs. Therefore, it is recommended to conduct an analysis of potential beforehand in order to identify which facilities have excess storage capacity and which facilities have too high overflow rates and volumes.

For actual implementation of the two technologies, approval from the agencies in charge (District Council) needs to be obtained. In Germany, CSO facilities require emission (focus on the discharging system, *i.e.* the CSO facilities) and immission standards (*i.e.* impact on the receiving water bodies) to be assessed and approved. BWK-Merkblatt M3 and M7 offer guidance on conducting a simplified assessment (including a hydraulic and chemical assessment) and a detailed approach (additionally including an ecological assessment). If storage basins are already approved and built, the later implementation of lamella settler or ADESBA-RTC into existing basins is expected to be approved if an enhanced treatment and retention function, respectively, can be demonstrated and any deterioration of these functions can be ruled out.

Deliverable D42.3 also focused on available markets, on the current and future demand, on the status of water bodies and the infrastructure and technological environment, among others.

Furthermore, three short movies have been developed within DESSIN (D41.4) to showcase the two Emscher demonstration cases: One general introductory movie on the Emscher system and on ESS, one movie describing the cross-flow lamella settler and one movie presenting the ADESBA-RTC.

4.2. Conclusion

Borchardt and Statzner (1990) recommend a combination of measures improving stream morphology plus technical solutions for an enhanced overflow treatment instead of large-scale technical projects. The two technologies tested in DESSIN provide the latter aspect and are, in combination with the ecological improvement taking place as part of the Emscher restoration, expected to effectively reduce detrimental effects of CSO events.

In the future, the pressure of CSO will increase further, as predicted for the water bodies in Hamburg (Kuchenbecker *et al.* 2010). Here, overflow volumes are predicted to increase by 42 % (Elbe), 48 % (Bille) and 52 % (Alster) until 2100 due to climate change.

Especially under consideration of climate change, the two technologies offer a high range of flexibility. Thus, such technologies will gain importance in order to adapt the sewer system to these changes.

Highlighting the positive effects of the two technologies on water quality and aquatic ecosystems and the subsequent enhancement of ESS allows demonstrating and communicating the outreaching effects of the technologies on ecosystems and their services.

Assessing further criteria of sustainability, going beyond those examined in the ESS assessment, allows shedding light on additional aspects. This enables a very broad evaluation. Being guided through this assessment by a framework (and a software) helps to consider all these aspects - even though some aspects might not be quantifiable or even described qualitatively. In the latter case, the assessment would also help to identify knowledge gaps, which can then be filled in a target-oriented way.

4.3. Outlook

As described in deliverable D31.1, EG plans to further test both technologies. The contact to the SMEs will, thus, continue also beyond the DESSIN project. Funding options are examined in order to allow also university partners to participate in the ongoing work.

Another short-term aim is to generate a water quality model in order to allow more accurate predictions of the effects of measures. Such measures could also be the lamella settler or RTC.

At EG, a novel sustainability check has been established. From now on, important decisions on projects, measures, events, etc. are only taken after a sustainability check has been conducted. To this end, a rather fast and simple assessment is completed. For technical questions, however, DESSIN's sustainability assessment is available for a more precise evaluation of the broad range of consequences.

Information on ESS is also incorporated into the balanced score card (BSC) as part of the integrated management system at EG. This way, a number of ESS is assessed in annual terms and an improvement is aimed at in the long-term. Furthermore, the enhancement of ESS is an important argument of restoration measures in the Emscher catchment, which is applied for communication and participation purposes and to gain acceptance for costly measures - especially if the effects of those measures only become visible after longer periods of time.

5. References

Balvanera, P., Pfisterer, A. B., Buchmann, N., He, J. S., Nakashizuka, T., Raffaelli, D., Schmid, B., 2006. Quantifying the evidence for biodiversity effects on ecosystem functioning and services. Ecology letters, 9 (10), pp. 1146-1156.

Borchardt, D., Wolp, P., 1993. Labor- und Modelluntersuchungen zur benthischen Nitrifikation in Fließgewässern. Wasserwirtschaft 83 (4), pp. 218-225.

Borchardt, D., Statzner, B., 1990. Ecological impact of urban stormwater runoff studied in experimental flumes: population loss by drift and availability of refugial space. Aquatic Sciences 52 (4).

Brombach, H., 2012. Überwachung und Beurteilung von Entlastungsbauwerken in Kanalisationen. DWA Schönefeld bei Berlin.

Covich, A. P., Palmer, M. A., Crowl, T. A., 1999. The role of benthic invertebrate species in freshwater ecosystems. BioScience 49 (2), pp. 119 - 127.

Döbbelt-Grüne, S., Koenzen, U., Hartmann, C., Hering, D., Birk, S., 2015. Handbuch zur Bewertung und planerischen Bearbeitung von erheblich veränderten (HMWB) und künstlichen Wasserkörpern (AWB), Version 3.0. Erstellt im Auftrag der LAWA. Stand Juli 2015, p. 137.

Emschergenossenschaft, 2009. Flussgebietsplan Emscher.

Emschergenossenschaft, 2013. Fließgewässer im Emscherraum.

Emschergenossenschaft, 2015. RÜB CAS Ohmstraße - Auswertung von Messergebnissen am Regenüberlaufbecken Ohmstraße in Castrop-Rauxel für das WWJ 2015.

Frank, S., Fürst, C., Koschke, L., Witt, A., Makeschin, F., 2013. Assessment of landscape aesthetics - validation of a landscape metrics-based assessment by visual estimation of the scenic beauty. Ecological Indicators, 32, pp. 222-231.

Fuller, R.A., Irvine, K.N., Devine-Wright, P., Warren, P.H., Gaston, K.J., 2007. Psychological benefits of greenspace increase with biodiversity. Biology Letters 3, pp. 390–394.

Horst, D., 2016. Using real-time control of the sewer network to reduce combined sewer overflow - Effects on aquatic ecosystems and their services in the Emscher Headwaters. Master thesis.

Junker, B., Buchecker, M., 2008. Aesthetic preferences versus ecological objectives in river restorations. Landscape and Urban Planning 85, pp. 141–154.

Kuchenbecker, A., Bischoff, G., Ziegler, J., Krieger, K., Verworn, H.-R., 2010. Auswirkungen des Klimawandels auf das Hamburger Kanalnetz.

Niemann, A., 2001. Schädigung des hyporheischen Interstitials kleiner Fließgewässer durch Niederschlagswassereinleitungen. Dissertation, Universität Essen.

Scheer, M., 2008. Ermittlung und Bewertung der Wirkung der Abflusssteuerung für Kanalisationssysteme. PhD thesis.

Science for Environment Policy, 2015. Ecosystem Services and the Environment. In-depth Report 11 produced for the European Commission, DG Environment by the Science Communication Unit, UWE, Bristol. Available at: http://ec.europa.eu/science-environment-policy.

Scholz, M., Mehl, D., Schulz-Zunkel, C., Kasperidus, H. D., Born, W., Henle, K., 2012. Ökosystemfunktionen von Flussauen. Analyse und Bewertung von Hochwasserretention, Nährstoffrückhalt, Kohlenstoffvorrat, Treibhausgasemissionen und Habitatfunktion. In Naturschutz und Biologische Vielfalt 124 (2).

Weber, M. A., Ringold, P. L., 2015. Priority river metrics for residents of an urbanized arid watershed. Landscape and Urban Planning 133, pp. 37-52.

World Health Organization (WHO), 2003. Guidelines for safe recreational water environments. Volume 1, Coastal and fresh waters. Geneva.

ANNEX A: Decentralized water treatment

Annex A.1. Output of MIKE DSS: ESS Evaluation Framework

1. Study Description

1.1. General Information

1 Study Description | 2 Problem Characterization | 3 Responses and Beneficiaries | 4 Impact Evaluation | 5 Sustainability Assessment

1.1 General Information | 1.2 System Boundary | 1.3 Population Data | 1.4 Economic Data | 1.5 Employment Data | 1.6 Overview of Study Area | 1.7 Stakeholders

General Information

Assessment name	Emscher demo case
Objective	The assessment is conducted with the aim of (i) validating the DESSIN ESS Evaluation Framework and (ii) identifying the benefits resulting from the lamella settler/ real time control technology, which was tested in the DESSIN demonstration study in the Emscher region.
Target audience	DESSIN partners, EU, people interested in the lamella settler technology, researchers working on the topic of ESS or lamella settler/ real time control or other water related technologies
Entities carrying out assessment	Emschergenossenschaft (EG), University of Duisburg-Essen (UDE), IWW Rheinisch-Westfälisches Institut für Wasser (IWW), Umwelt- und Fluid-Technik Dr. H. Brombach GmbH (UFT), Segno Industrie Automation (SEGNO).
Entities providing information	Emschergenossenschaft (EG), University of Duisburg-Essen (UDE), IWW Rheinisch-Westfälisches Institut für Wasser (IWW), Umwelt- und Fluid-Technik Dr. H. Brombach GmbH (UFT), Segno Industrie Automation (SEGNO).
Entities funding the assessment	EU

1.6. Overview of Study Area

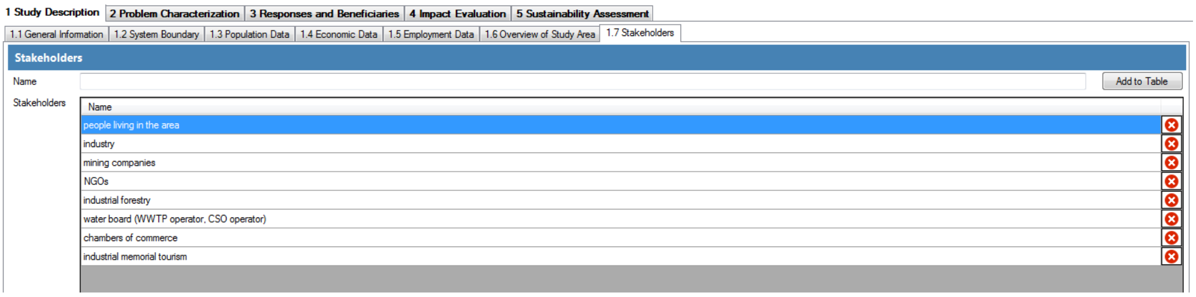
1 Study Description | 2 Problem Characterization | 3 Responses and Beneficiaries | 4 Impact Evaluation | 5 Sustainability Assessment

1.1 General Information | 1.2 System Boundary | 1.3 Population Data | 1.4 Economic Data | 1.5 Employment Data | 1.6 Overview of Study Area | 1.7 Stakeholders

Overview of Study Area

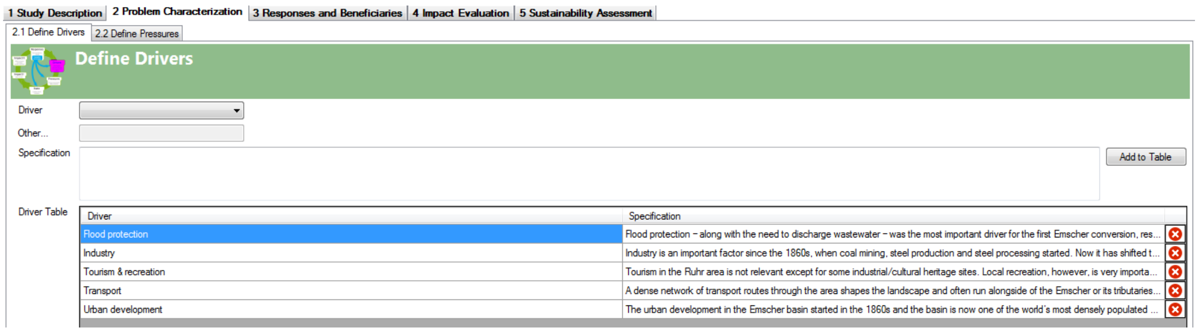
Environmental attributes (e.g. climate type, topography, water quality levels, water availability)	The Emscher catchment is located on the eastern side of the Rhine River in the federal state of North-Rhine Westphalia (NRW). The Emscher catchment basin covers 865 m² and belongs to two geographical regions in the Northern Lowlands: Westphalian Lowlands and Lower Rhine Plain. The highest and lowest elevation in the catchment is 150 m above sea level at the Emscher source in Holzwickede, south east of Dortmund and 25 m at the Emscher mouth in Dinslaken, where it meets the River Rhine. The Emscher River is 85 km long and the total length of the stream network within the basin is 341 km. Mean discharge at Emscher mouth is approximately 16 m³/s. The basin is exposed to temperate seasonal climate with maritime influence. Average annual temperatures range from 8.5 and 10.5 °C with mean annual precipitation of 800 mm. Until 1860, the Emscher River was a slow flowing, meandering river with a length of 109 km from its source in Holzwickede to its discharge into the river Rhine, draining a catchment of approximately 784 km². Mining subsidence in the area resulted in depressions of up to 30 m, causing disturbed river discharge and rising groundwater levels. To restore the water flow, pumping stations were built in the entire catchment and the river mouth was relocated northwards to Dinslaken, increasing the catchment size to 865 km². Continuing mining subsidence precluded the use of culverts for wastewater discharge to avoid leakage due to braking pipes. Wastewater was thus discharged in open aboveground channels. Underground discharge, separated from the natural river bed, was not considered possible because subsidence would have caused underground pipes to break. With ending of the industrial area in the 1960s mining subsidence slowly diminished. By 1990, culverting became feasible again, advancing the planning of the second Emscher conversion or Emscher re-conversion. The aim was to separate the wastewater from the river water, using culverts routing the sewage to wastewater treatment plants (WWTP). Eventually, the original Emscher River and its tributaries should be revitalized. To date, 40% of the Emscher area is depressed due to mining subsidence. This generates a constant need for controlling the water discharge and groundwater level in the catchment, performed by pumping stations.
Economic activities taking place in the area (e.g. land use, land use transitions, comparison of activities by share of GDP)	The former land use in the Emscher basin was mainly urban settling, coal mining, steel production and steel processing. A shipping channel and a network of roads were built for that purpose. With the start of industrialization and a rapid urban growth by 1860, the regular inundation of the extensive Emscher floodplains resulted in frequent flooding of the urban and industrial areas close to the river. In addition, the Emscher River received increasing amounts of waste water originating from industry and settlements. Flooding of the contaminated river lead to the spreading of water-borne diseases and epidemics. Flood defense required coordinated efforts of the municipalities along the Emscher River that founded the Emschergenossenschaft (EG) in 1899, associating individual cities of the Ruhrgebiet, and mining and industrial companies active in the area. The main task of this association was to assure water and waste water discharge and to avoid further flooding, resulting in a straightened and channelized Emscher River. As a result of this first Emscher conversion, the original river length was reduced to 85 km; floodplains were cut off and at the water bodies were lowered by up to 5 m; further actions were channel bed fixation with concrete beds as well as shore embankment. Today's land use is a very densely populated area with 17 cities that form one metropole conglomerate. Agriculture is less prominent in this area then in NRW in average; business has shifted towards service companies. A shipping channel in parallel of the Emscher and a network of highways and roads is present. Artificial land cover (incl. urban settlements, industrial areas and transport infrastructure) amounts to ~ %, agricultural land use ~ 18% (incl. pastures and cropland), natural area (incl. 12.5% of forested area) ~ 22% (Emschergenossenschaft 2009). Making up only 2.5% of the area of NRW, the Emscher region achieves 10.5% of NRW's total annual gross value added (MUNLV NRW 2006).
Socio-economic profile (e.g. population density, average household income, age profile)	About 2.2 M people live and work in the Emscher catchment, the so called "Ruhrgebiet", which is one of the most densely populated areas in Europe. Mean population density is 2,775 inhabitants/km². During industrialization the number of inhabitants in the Ruhr area as increased steeply, however, with high fluctuations. In 2006, 400,000 people less lived in the area compared to 1961. Further decrease in inhabitant number is expected by the Landesamt für Datenverarbeitung und Statistik Nordrhein-Westfalen (LDS NRW) and the Bertelmann-Stiftung (Junkernheinrich et al. 2008).
Socio-cultural aspects (e.g. value systems, role of landscape and land use in identity formation).	The people in the area are used to avoid the streams in the area since 1900, when the streams turned into a system of open wastewater channels. In a densely populated area, places for local recreation are highly demanded. Therefore, one of the main benefits from the Emscher re-conversion is to re-allow the experiencing of the Emscher River and its tributaries and to bring recreation along waterways back to the people.

1.7. Stakeholders

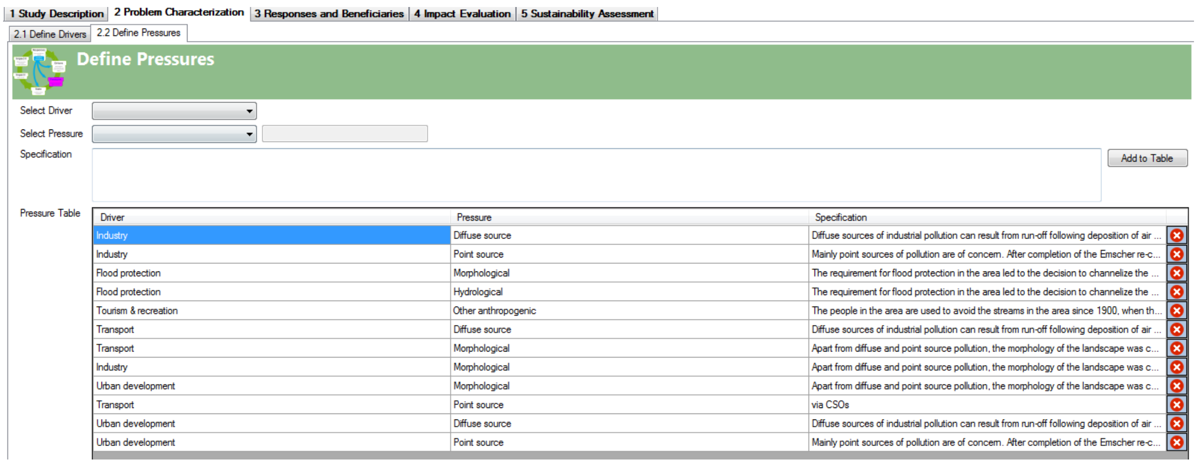


2. Problem Characterization

2.1. Define Drivers

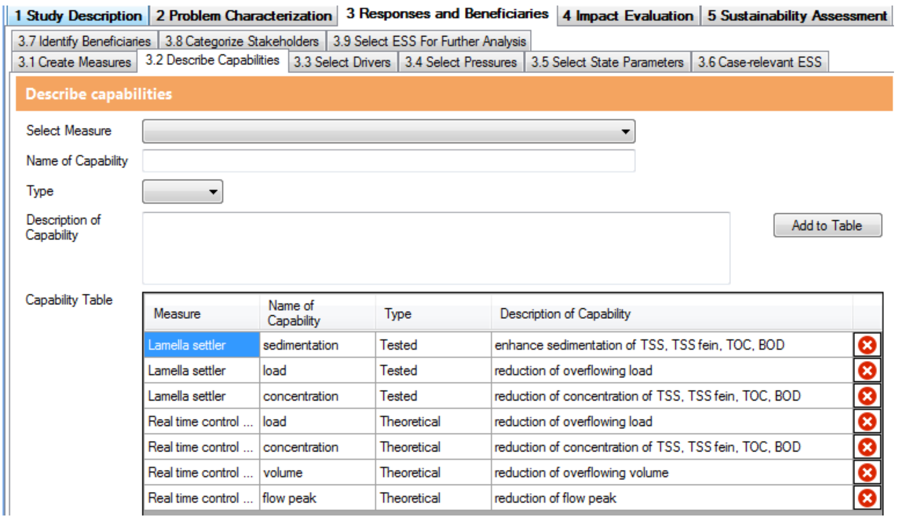


2.2. Define Pressures

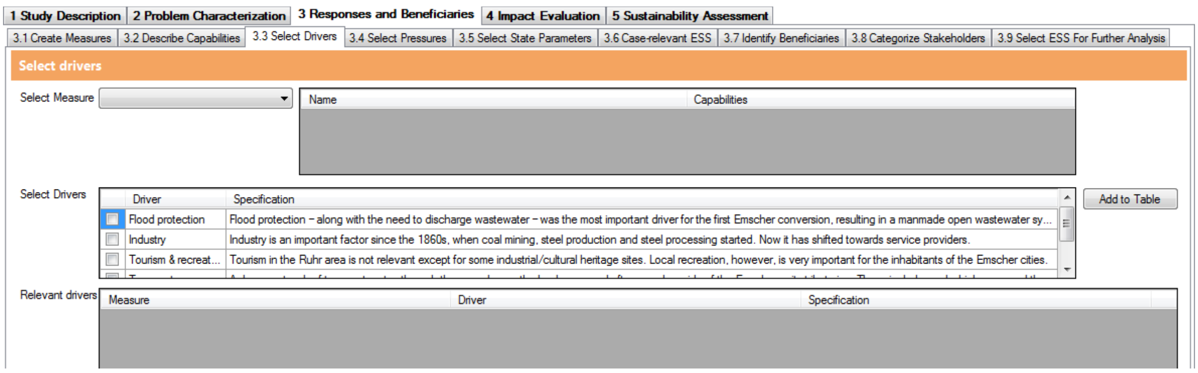


3. Responses and Beneficiaries

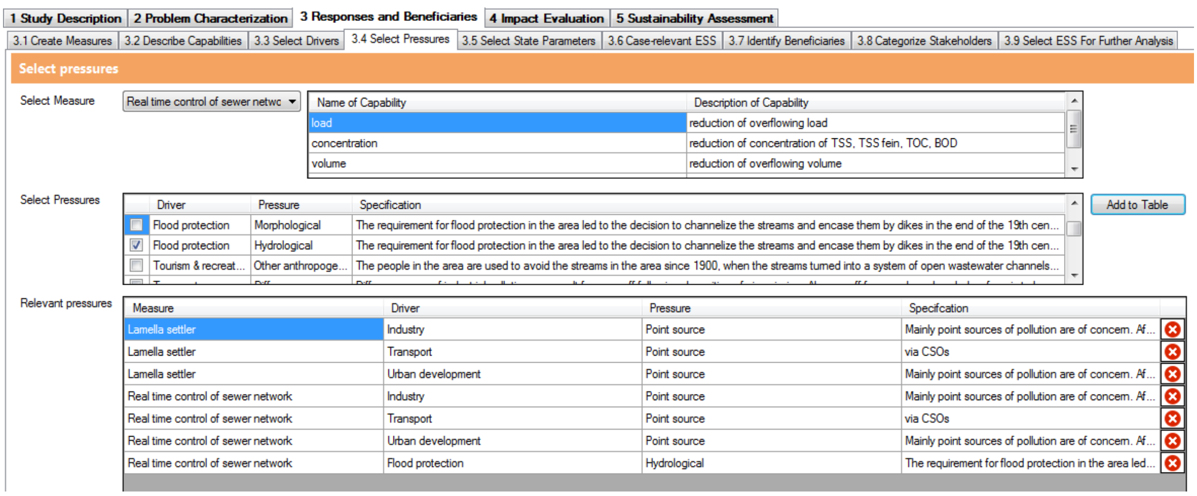
3.2. Describe Capabilities



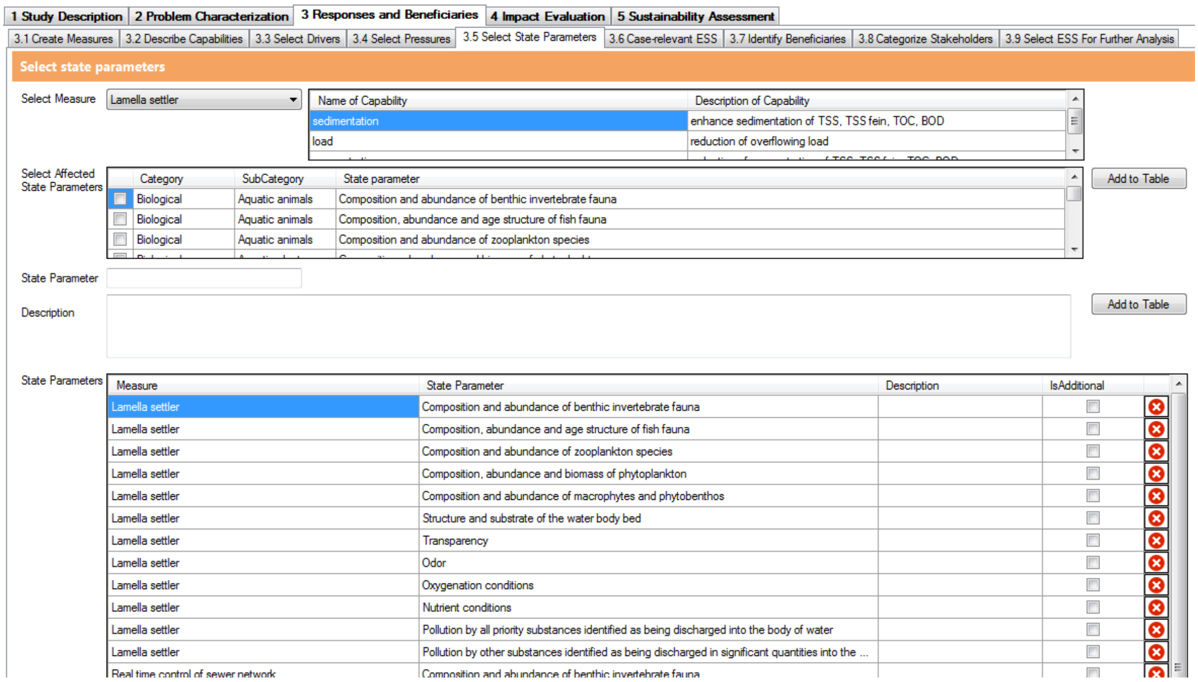
3.3. Select Drivers



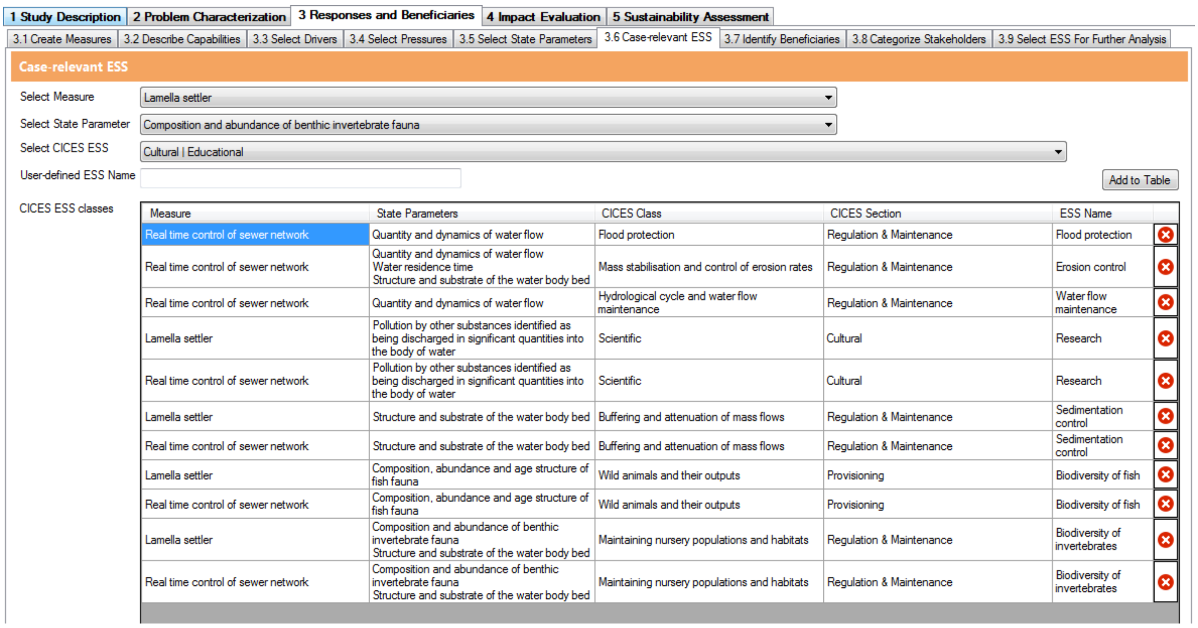
3.4. Select Pressures



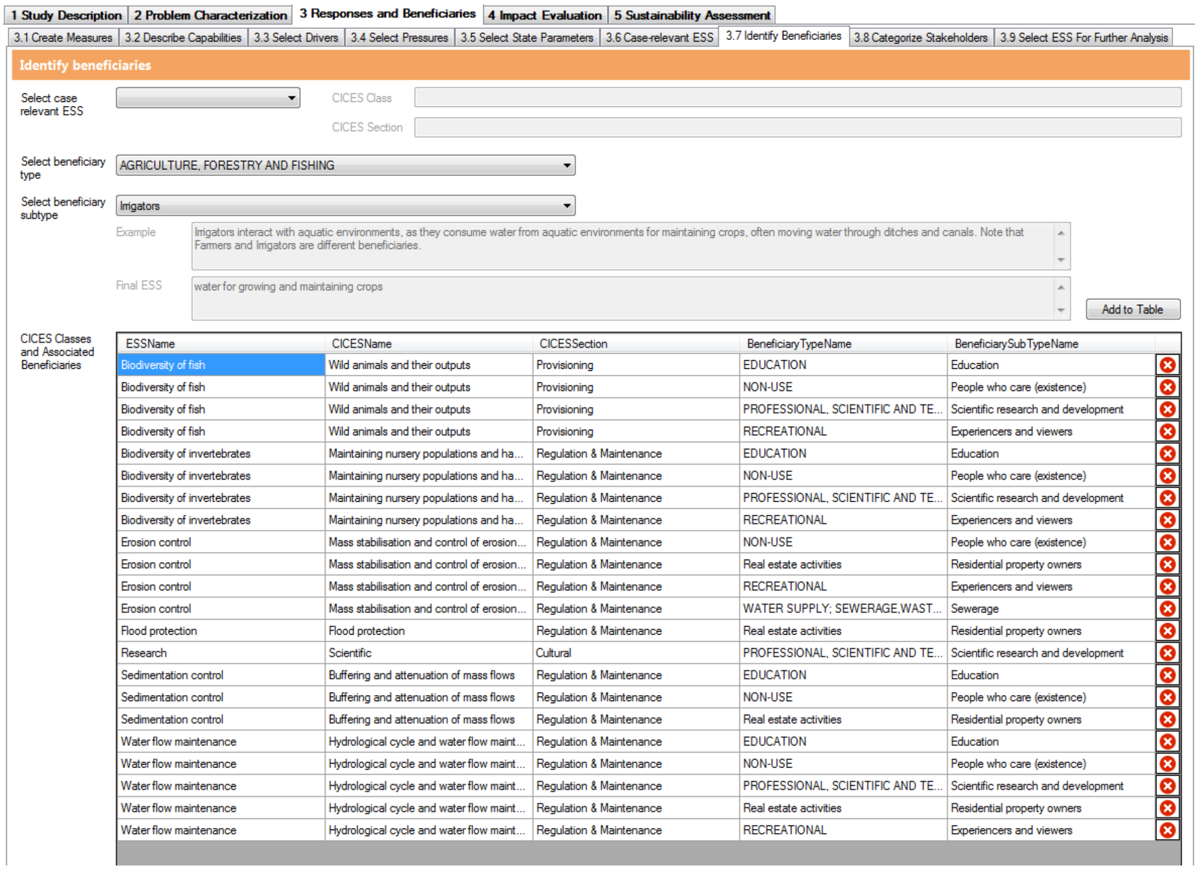
3.5. Select State Parameters



3.6. Case-relevant ESS

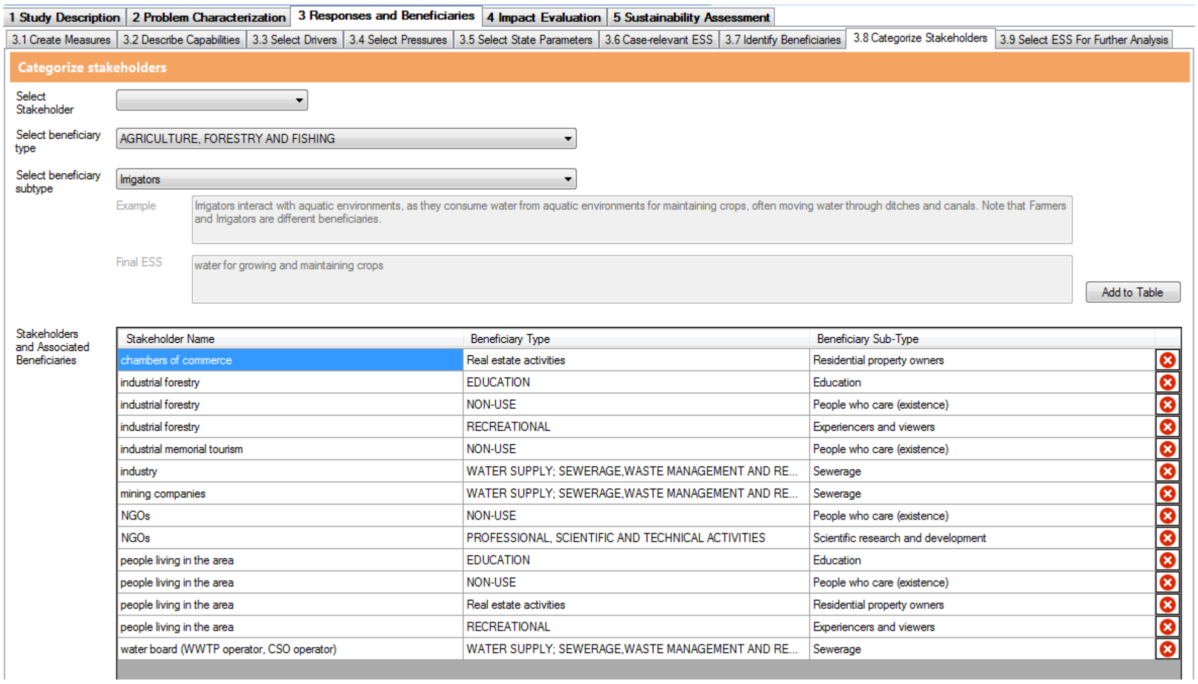


3.7. Identify Beneficiaries



ESSName	CICESName	CICESSection	BeneficiaryTypeName	BeneficiarySubTypeName
Biodiversity of fish	Wild animals and their outputs	Provisioning	EDUCATION	Education
Biodiversity of fish	Wild animals and their outputs	Provisioning	NON-USE	People who care (existence)
Biodiversity of fish	Wild animals and their outputs	Provisioning	PROFESSIONAL, SCIENTIFIC AND TE...	Scientific research and development
Biodiversity of fish	Wild animals and their outputs	Provisioning	RECREATIONAL	Experiencers and viewers
Biodiversity of invertebrates	Maintaining nursery populations and ha...	Regulation & Maintenance	EDUCATION	Education
Biodiversity of invertebrates	Maintaining nursery populations and ha...	Regulation & Maintenance	NON-USE	People who care (existence)
Biodiversity of invertebrates	Maintaining nursery populations and ha...	Regulation & Maintenance	PROFESSIONAL, SCIENTIFIC AND TE...	Scientific research and development
Biodiversity of invertebrates	Maintaining nursery populations and ha...	Regulation & Maintenance	RECREATIONAL	Experiencers and viewers
Erosion control	Mass stabilisation and control of erosion...	Regulation & Maintenance	NON-USE	People who care (existence)
Erosion control	Mass stabilisation and control of erosion...	Regulation & Maintenance	Real estate activities	Residential property owners
Erosion control	Mass stabilisation and control of erosion...	Regulation & Maintenance	RECREATIONAL	Experiencers and viewers
Erosion control	Mass stabilisation and control of erosion...	Regulation & Maintenance	WATER SUPPLY; SEWERAGE,WAST...	Sewerage
Flood protection	Flood protection	Regulation & Maintenance	Real estate activities	Residential property owners
Research	Scientific	Cultural	PROFESSIONAL, SCIENTIFIC AND TE...	Scientific research and development
Sedimentation control	Buffering and attenuation of mass flows	Regulation & Maintenance	EDUCATION	Education
Sedimentation control	Buffering and attenuation of mass flows	Regulation & Maintenance	NON-USE	People who care (existence)
Sedimentation control	Buffering and attenuation of mass flows	Regulation & Maintenance	Real estate activities	Residential property owners
Water flow maintenance	Hydrological cycle and water flow maint...	Regulation & Maintenance	EDUCATION	Education
Water flow maintenance	Hydrological cycle and water flow maint...	Regulation & Maintenance	NON-USE	People who care (existence)
Water flow maintenance	Hydrological cycle and water flow maint...	Regulation & Maintenance	PROFESSIONAL, SCIENTIFIC AND TE...	Scientific research and development
Water flow maintenance	Hydrological cycle and water flow maint...	Regulation & Maintenance	Real estate activities	Residential property owners
Water flow maintenance	Hydrological cycle and water flow maint...	Regulation & Maintenance	RECREATIONAL	Experiencers and viewers

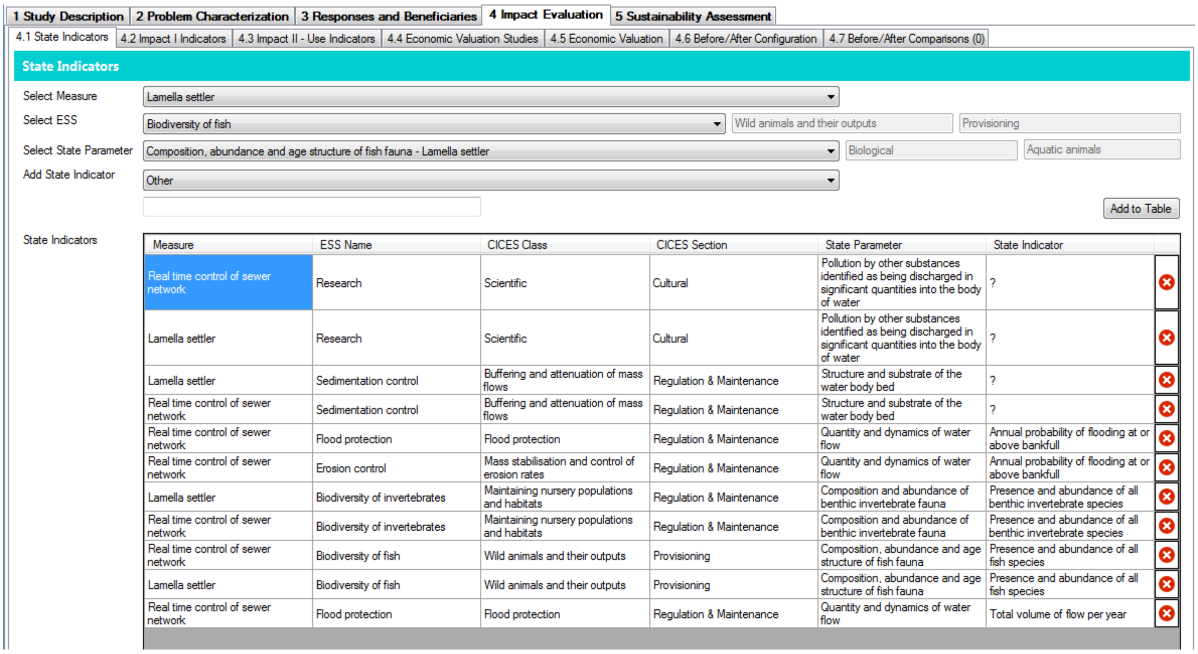
3.8. Categorize Stakeholders



Stakeholder Name	Beneficiary Type	Beneficiary Sub-Type
chambers of commerce	Real estate activities	Residential property owners
industrial forestry	EDUCATION	Education
industrial forestry	NON-USE	People who care (existence)
industrial forestry	RECREATIONAL	Experiencers and viewers
industrial memorial tourism	NON-USE	People who care (existence)
industry	WATER SUPPLY; SEWERAGE,WASTE MANAGEMENT AND RE...	Sewerage
mining companies	WATER SUPPLY; SEWERAGE,WASTE MANAGEMENT AND RE...	Sewerage
NGOs	NON-USE	People who care (existence)
NGOs	PROFESSIONAL, SCIENTIFIC AND TECHNICAL ACTIVITIES	Scientific research and development
people living in the area	EDUCATION	Education
people living in the area	NON-USE	People who care (existence)
people living in the area	Real estate activities	Residential property owners
people living in the area	RECREATIONAL	Experiencers and viewers
water board (WWTP operator, CSO operator)	WATER SUPPLY; SEWERAGE,WASTE MANAGEMENT AND RE...	Sewerage

4. Impact Evaluation

4.1. State Indicators



1 Study Description | 2 Problem Characterization | 3 Responses and Beneficiaries | 4 Impact Evaluation | 5 Sustainability Assessment

4.1 State Indicators | 4.2 Impact I Indicators | 4.3 Impact II - Use Indicators | 4.4 Economic Valuation Studies | 4.5 Economic Valuation | 4.6 Before/After Configuration | 4.7 Before/After Comparisons (0)

State Indicators

Select Measure: Lamella settler

Select ESS: Biodiversity of fish | Wild animals and their outputs | Provisioning

Select State Parameter: Composition, abundance and age structure of fish fauna - Lamella settler | Biological | Aquatic animals

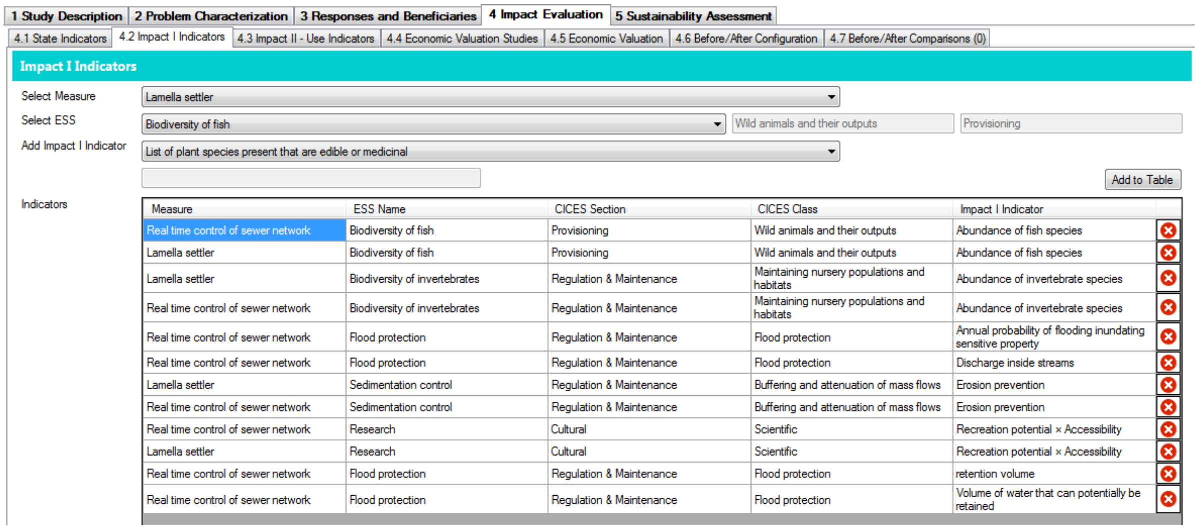
Add State Indicator: Other

Add to Table

State Indicators

Measure	ESS Name	CICES Class	CICES Section	State Parameter	State Indicator
Real time control of sewer network	Research	Scientific	Cultural	Pollution by other substances identified as being discharged in significant quantities into the body of water	?
Lamella settler	Research	Scientific	Cultural	Pollution by other substances identified as being discharged in significant quantities into the body of water	?
Lamella settler	Sedimentation control	Buffering and attenuation of mass flows	Regulation & Maintenance	Structure and substrate of the water body bed	?
Real time control of sewer network	Sedimentation control	Buffering and attenuation of mass flows	Regulation & Maintenance	Structure and substrate of the water body bed	?
Real time control of sewer network	Flood protection	Flood protection	Regulation & Maintenance	Quantity and dynamics of water flow	Annual probability of flooding at or above bankfull
Real time control of sewer network	Erosion control	Mass stabilisation and control of erosion rates	Regulation & Maintenance	Quantity and dynamics of water flow	Annual probability of flooding at or above bankfull
Lamella settler	Biodiversity of invertebrates	Maintaining nursery populations and habitats	Regulation & Maintenance	Composition and abundance of benthic invertebrate fauna	Presence and abundance of all benthic invertebrate species
Real time control of sewer network	Biodiversity of invertebrates	Maintaining nursery populations and habitats	Regulation & Maintenance	Composition and abundance of benthic invertebrate fauna	Presence and abundance of all benthic invertebrate species
Real time control of sewer network	Biodiversity of fish	Wild animals and their outputs	Provisioning	Composition, abundance and age structure of fish fauna	Presence and abundance of all fish species
Lamella settler	Biodiversity of fish	Wild animals and their outputs	Provisioning	Composition, abundance and age structure of fish fauna	Presence and abundance of all fish species
Real time control of sewer network	Flood protection	Flood protection	Regulation & Maintenance	Quantity and dynamics of water flow	Total volume of flow per year

4.2. Impact I Indicators



1 Study Description | 2 Problem Characterization | 3 Responses and Beneficiaries | 4 Impact Evaluation | 5 Sustainability Assessment

4.1 State Indicators | 4.2 Impact I Indicators | 4.3 Impact II - Use Indicators | 4.4 Economic Valuation Studies | 4.5 Economic Valuation | 4.6 Before/After Configuration | 4.7 Before/After Comparisons (0)

Impact I Indicators

Select Measure: Lamella settler

Select ESS: Biodiversity of fish | Wild animals and their outputs | Provisioning

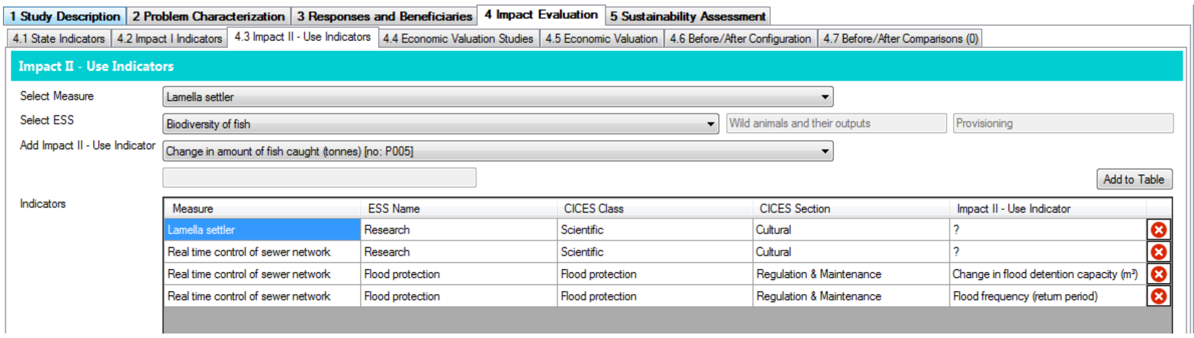
Add Impact I Indicator: List of plant species present that are edible or medicinal

Add to Table

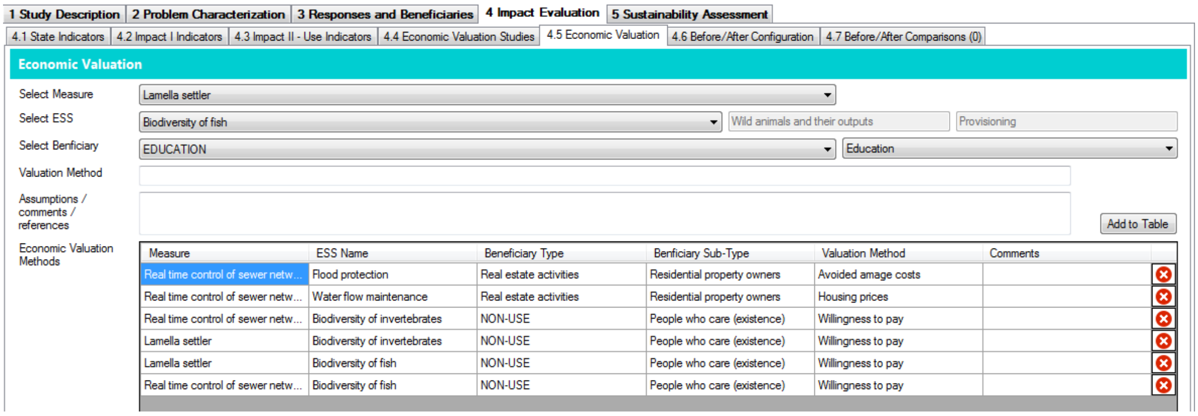
Indicators

Measure	ESS Name	CICES Section	CICES Class	Impact I Indicator
Real time control of sewer network	Biodiversity of fish	Provisioning	Wild animals and their outputs	Abundance of fish species
Lamella settler	Biodiversity of fish	Provisioning	Wild animals and their outputs	Abundance of fish species
Lamella settler	Biodiversity of invertebrates	Regulation & Maintenance	Maintaining nursery populations and habitats	Abundance of invertebrate species
Real time control of sewer network	Biodiversity of invertebrates	Regulation & Maintenance	Maintaining nursery populations and habitats	Abundance of invertebrate species
Real time control of sewer network	Flood protection	Regulation & Maintenance	Flood protection	Annual probability of flooding inundating sensitive property
Real time control of sewer network	Flood protection	Regulation & Maintenance	Flood protection	Discharge inside streams
Lamella settler	Sedimentation control	Regulation & Maintenance	Buffering and attenuation of mass flows	Erosion prevention
Real time control of sewer network	Sedimentation control	Regulation & Maintenance	Buffering and attenuation of mass flows	Erosion prevention
Real time control of sewer network	Research	Cultural	Scientific	Recreation potential × Accessibility
Lamella settler	Research	Cultural	Scientific	Recreation potential × Accessibility
Real time control of sewer network	Flood protection	Regulation & Maintenance	Flood protection	retention volume
Real time control of sewer network	Flood protection	Regulation & Maintenance	Flood protection	Volume of water that can potentially be retained

4.3. Impact II - Use Indicators



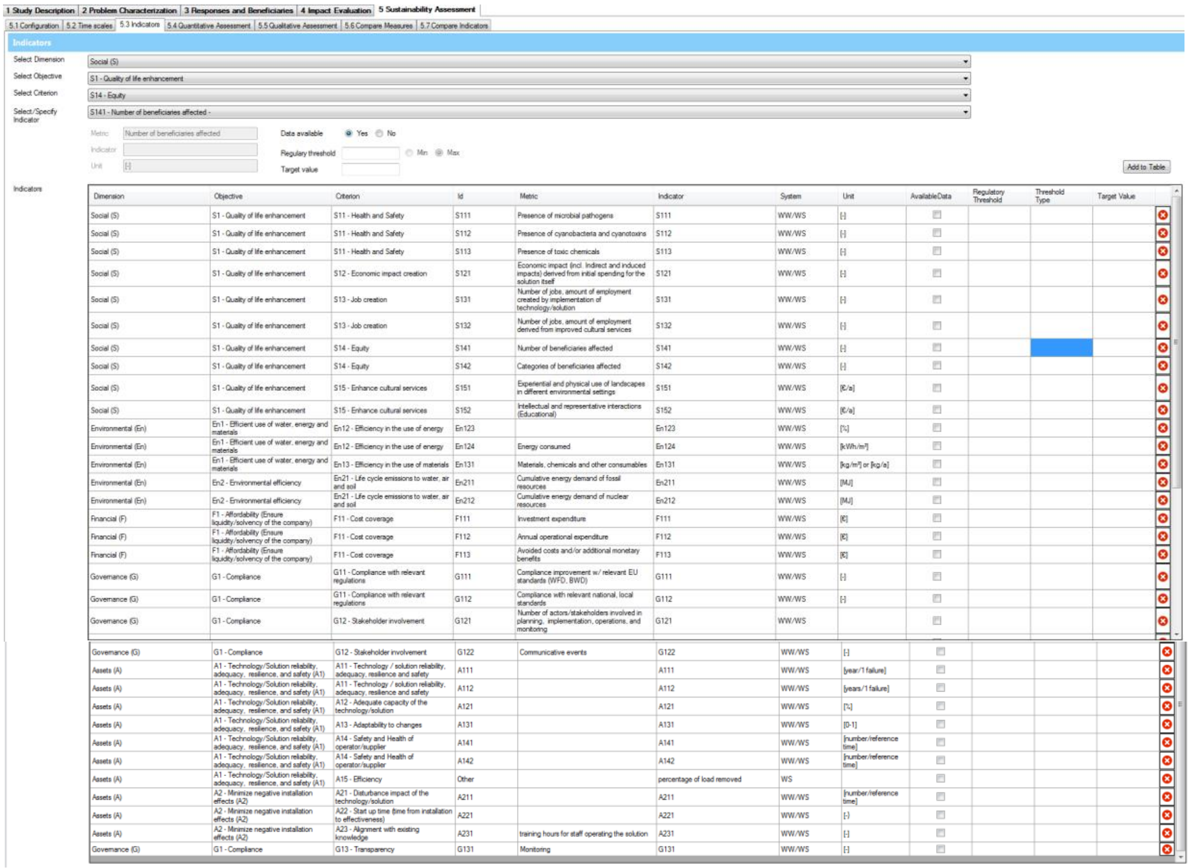
4.5. Economic Valuation



Annex A.2. Output of MIKE DSS: Sustainability Assessment

5. Sustainability Assessment

5.3. Indicators



Dimension	Objective	Criterion	Id	Metric	Indicator	System	Unit	AvailableData	Regulatory Threshold	Threshold Type	Target Value
Social (S)	S1 - Quality of life enhancement	S11 - Health and Safety	S111	Presence of microbial pathogens	S111	WW/WS	[-]				
Social (S)	S1 - Quality of life enhancement	S11 - Health and Safety	S112	Presence of cyanobacteria and cyanotoxins	S112	WW/WS	[-]				
Social (S)	S1 - Quality of life enhancement	S11 - Health and Safety	S113	Presence of toxic chemicals	S113	WW/WS	[-]				
Social (S)	S1 - Quality of life enhancement	S12 - Economic impact creation	S121	Economic impact (incl. Indirect and induced impacts) derived from initial spending for the solution itself	S121	WW/WS	[-]				
Social (S)	S1 - Quality of life enhancement	S13 - Job creation	S131	Number of jobs, amount of employment created by implementation of technology/solution	S131	WW/WS	[-]				
Social (S)	S1 - Quality of life enhancement	S13 - Job creation	S132	Number of jobs, amount of employment derived from improved cultural services	S132	WW/WS	[-]				
Social (S)	S1 - Quality of life enhancement	S14 - Equity	S141	Number of beneficiaries affected	S141	WW/WS	[-]				
Social (S)	S1 - Quality of life enhancement	S14 - Equity	S142	Categories of beneficiaries affected	S142	WW/WS	[-]				
Social (S)	S1 - Quality of life enhancement	S15 - Enhance cultural services	S151	Experiential and physical use of landscapes in different environmental settings	S151	WW/WS	[€/a]				
Social (S)	S1 - Quality of life enhancement	S15 - Enhance cultural services	S152	Intellectual and representative interactions (Educational)	S152	WW/WS	[€/a]				
Environmental (En)	En1 - Efficient use of water, energy and materials	En12 - Efficiency in the use of energy	En123		En123	WW/WS	[%]				
Environmental (En)	En1 - Efficient use of water, energy and materials	En12 - Efficiency in the use of energy	En124	Energy consumed	En124	WW/WS	[kWh/m³]				
Environmental (En)	En1 - Efficient use of water, energy and materials	En13 - Efficiency in the use of materials	En131	Materials, chemicals and other consumables	En131	WW/WS	[kg/m³] or [kg/a]				
Environmental (En)	En2 - Environmental efficiency	En21 - Life cycle emissions to water, air and soil	En211	Cumulative energy demand of fossil resources	En211	WW/WS	[MJ]				
Environmental (En)	En2 - Environmental efficiency	En21 - Life cycle emissions to water, air and soil	En212	Cumulative energy demand of nuclear resources	En212	WW/WS	[MJ]				
Financial (F)	F1 - Affordability (Ensure liquidity/solvency of the company)	F11 - Cost coverage	F111	Investment expenditure	F111	WW/WS	[€]				
Financial (F)	F1 - Affordability (Ensure liquidity/solvency of the company)	F11 - Cost coverage	F112	Annual operational expenditure	F112	WW/WS	[€]				
Financial (F)	F1 - Affordability (Ensure liquidity/solvency of the company)	F11 - Cost coverage	F113	Avoided costs and/or additional monetary benefits	F113	WW/WS	[€]				
Governance (G)	G1 - Compliance	G11 - Compliance with relevant regulations	G111	Compliance improvement w/ relevant EU standards (WFD, BWD)	G111	WW/WS	[-]				
Governance (G)	G1 - Compliance	G11 - Compliance with relevant regulations	G112	Compliance with relevant national, local standards	G112	WW/WS	[-]				
Governance (G)	G1 - Compliance	G12 - Stakeholder involvement	G121	Number of actors/stakeholders involved in planning, implementation, operations, and monitoring	G121	WW/WS					
Governance (G)	G1 - Compliance	G12 - Stakeholder involvement	G122	Communicative events	G122	WW/WS	[-]				
Assets (A)	A1 - Technology/Solution reliability, adequacy, resilience, and safety (A1)	A11 - Technology / solution reliability, adequacy, resilience and safety	A111		A111	WW/WS	[year/1 failure]				
Assets (A)	A1 - Technology/Solution reliability, adequacy, resilience, and safety (A1)	A11 - Technology / solution reliability, adequacy, resilience and safety	A112		A112	WW/WS	[years/1 failure]				
Assets (A)	A1 - Technology/Solution reliability, adequacy, resilience, and safety (A1)	A12 - Adequate capacity of the technology/solution	A121		A121	WW/WS	[%]				
Assets (A)	A1 - Technology/Solution reliability, adequacy, resilience, and safety (A1)	A13 - Adaptability to changes	A131		A131	WW/WS	[0-1]				
Assets (A)	A1 - Technology/Solution reliability, adequacy, resilience, and safety (A1)	A14 - Safety and Health of operator/supplier	A141		A141	WW/WS	[number/reference time]				
Assets (A)	A1 - Technology/Solution reliability, adequacy, resilience, and safety (A1)	A14 - Safety and Health of operator/supplier	A142		A142	WW/WS	[number/reference time]				
Assets (A)	A1 - Technology/Solution reliability, adequacy, resilience, and safety (A1)	A15 - Efficiency	Other		percentage of load removed	WS					
Assets (A)	A2 - Minimize negative installation effects (A2)	A21 - Disturbance impact of the technology/solution	A211		A211	WW/WS	[number/reference time]				
Assets (A)	A2 - Minimize negative installation effects (A2)	A22 - Start up time (time from installation to effectiveness)	A221		A221	WW/WS	[-]				
Assets (A)	A2 - Minimize negative installation effects (A2)	A23 - Alignment with existing knowledge	A231	training hours for staff operating the solution	A231	WW/WS	[-]				
Governance (G)	G1 - Compliance	G13 - Transparency	G131	Monitoring	G131	WW/WS	[-]				

5.5. Qualitative Assessment

1 Study Description | 2 Problem Characterization | 3 Responses and Beneficiaries | 4 Impact Evaluation | 5 Sustainability Assessment

5.1 Configuration | 5.2 Time scales | 5.3 Indicators | 5.4 Quantitative Assessment | 5.5 Qualitative Assessment | 5.6 Compare Measures | 5.7 Compare Indicators

Qualitative Assessment

Indicator	Description	Baseline	Lamella settler (1 years)	Real time control of sewer network (1 years)
A111 - - A111		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 0 StrongPositive: 100
A112 - - A112		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 0 StrongPositive: 100
A121 - - A121		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0
A131 - - A131		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0
A141 - - A141		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 0 StrongPositive: 100	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 0 StrongPositive: 100
A142 - - A142		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 0 StrongPositive: 100	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0
A211 - - A211		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 0 StrongPositive: 100	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 0 StrongPositive: 100
A221 - - A221		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 0 StrongPositive: 100	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0
A231 - training hours for staff operating the solution - A231		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 100 Neutral: 0 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 100 Neutral: 0 Positive: 0 StrongPositive: 0
En123 - - En123		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0
En124 - Energy consumed - En124		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 100 Neutral: 0 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 100 Neutral: 0 Positive: 0 StrongPositive: 0
En131 - Materials, chemicals and other consumables - En131		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 100 Neutral: 0 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 100 Neutral: 0 Positive: 0 StrongPositive: 0
En211 - Cumulative energy demand of fossil resources -		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0	StrongNegative: 0 Negative: 100 Neutral: 0 Positive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0
En212 - Cumulative energy demand of nuclear resources - En212		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0
F111 - Investment expenditure - F111		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 100 Negative: 0 Neutral: 0 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 100 Neutral: 0 Positive: 0 StrongPositive: 0
F112 - Annual operational expenditure - F112		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 100 Neutral: 0 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 100 Neutral: 0 Positive: 0 StrongPositive: 0
F113 - Avoided costs and/or additional monetary benefits - F113		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 0 StrongPositive: 100	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0
G111 - Compliance improvement w/ relevant EU standards (WFD, BWD) - G111		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0
G112 - Compliance with relevant national, local standards - G112		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0
G121 - Number of actors/stakeholders involved in planning, implementation, operations, and monitoring - G121		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0
G122 - Communicative events - G122		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0
G131 - Monitoring - G131		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 0 StrongPositive: 100

5.5. Qualitative Assessment (continued)

Indicator	Description	Baseline	Lamella settler (1 years)	Real time control of sewer network (1 years)
Other - - percentage of load removed		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0
S111 - Presence of microbial pathogens - S111		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0
S112 - Presence of cyanobacteria and cyanotoxins - S112		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0
S113 - Presence of toxic chemicals - S113		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0
S121 - Economic impact (incl. Indirect and induced impacts) derived from initial spending for the solution itself - S121		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0
S131 - Number of jobs, amount of employment created by implementation of technology/solution - S131		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0
S132 - Number of jobs, amount of employment derived from improved cultural services - S132		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 100 StrongPositive: 0
S141 - Number of beneficiaries affected - S141		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 0 StrongPositive: 100	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 0 StrongPositive: 100
S142 - Categories of beneficiaries affected - S142		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 0 StrongPositive: 100	StrongNegative: 0 Negative: 0 Neutral: 0 Positive: 0 StrongPositive: 100
S151 - Experiential and physical use of landscapes in different environmental settings - S151		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0
S152 - Intellectual and representative interactions (Educational) - S152		StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0	StrongNegative: 0 Negative: 0 Neutral: 100 Positive: 0 StrongPositive: 0

ANNEX B: Real Time Control of sewer network

Annex B.1. Output of MIKE DSS: ESS Evaluation Framework

1. Study Description

1.1. General Information:

equivalent to Annex A.1

1.6. Overview of Study Area:

equivalent to Annex A.1

1.7. Stakeholders:

equivalent to Annex A.1

2. Problem Characterization

2.1. Define Drivers:

equivalent to Annex A.1

2.3. Define Pressures:

equivalent to Annex A.1

3. Responses and Beneficiaries

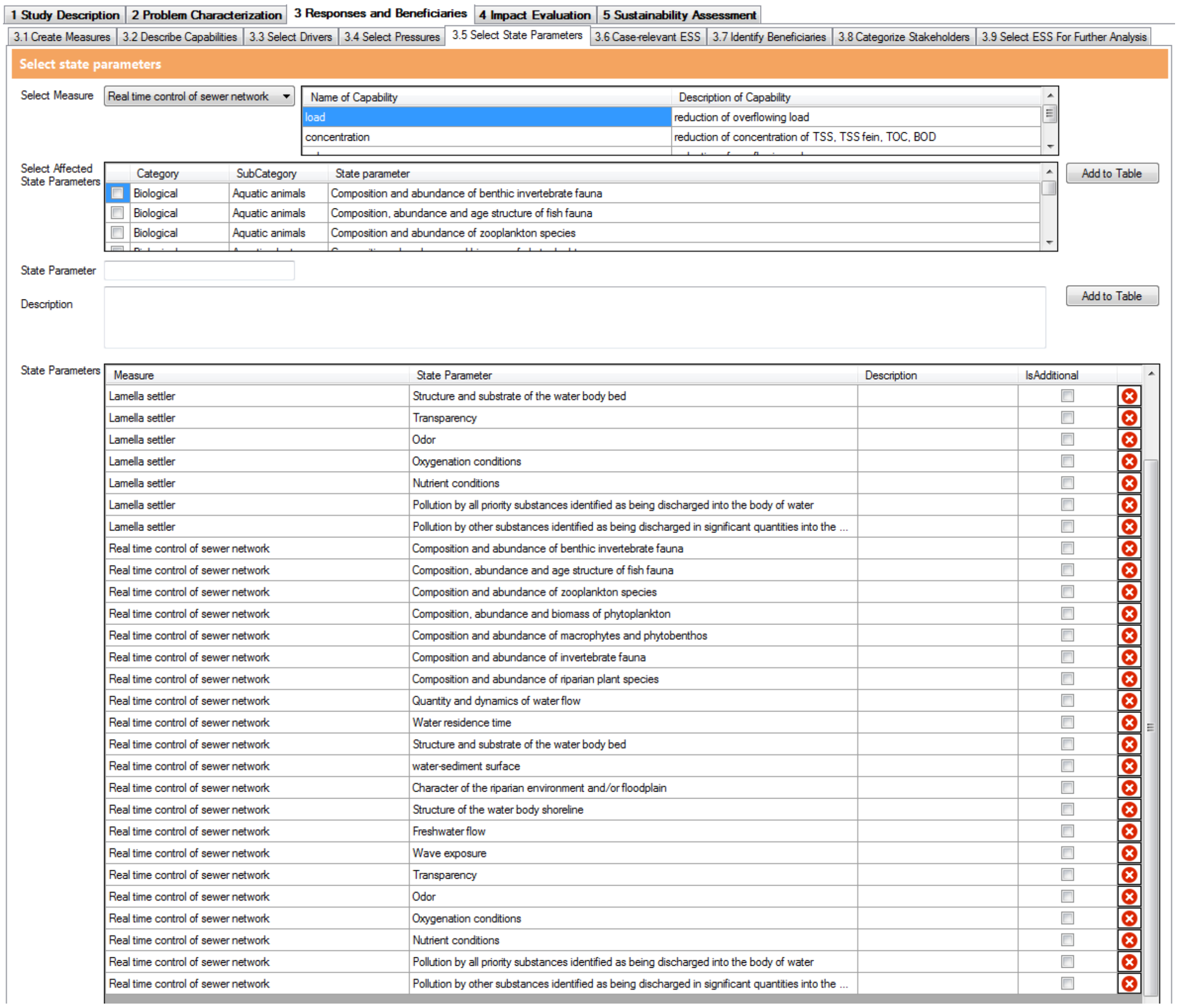
3.2. Describe Capabilities:

see Annex A.1

3.4. Select Pressures:

see Annex A.1

3.5. Select State Parameters



1 Study Description | 2 Problem Characterization | 3 Responses and Beneficiaries | 4 Impact Evaluation | 5 Sustainability Assessment

3.1 Create Measures | 3.2 Describe Capabilities | 3.3 Select Drivers | 3.4 Select Pressures | 3.5 Select State Parameters | 3.6 Case-relevant ESS | 3.7 Identify Beneficiaries | 3.8 Categorize Stakeholders | 3.9 Select ESS For Further Analysis

Select state parameters

Select Measure: Real time control of sewer network

Name of Capability	Description of Capability
load	reduction of overflowing load
concentration	reduction of concentration of TSS, TSS fein, TOC, BOD

Select Affected State Parameters

Category	SubCategory	State parameter
Biological	Aquatic animals	Composition and abundance of benthic invertebrate fauna
Biological	Aquatic animals	Composition, abundance and age structure of fish fauna
Biological	Aquatic animals	Composition and abundance of zooplankton species

Add to Table

State Parameter

Description

Add to Table

State Parameters

Measure	State Parameter	Description	IsAdditional
Lamella settler	Structure and substrate of the water body bed		
Lamella settler	Transparency		
Lamella settler	Odor		
Lamella settler	Oxygenation conditions		
Lamella settler	Nutrient conditions		
Lamella settler	Pollution by all priority substances identified as being discharged into the body of water		
Lamella settler	Pollution by other substances identified as being discharged in significant quantities into the ...		
Real time control of sewer network	Composition and abundance of benthic invertebrate fauna		
Real time control of sewer network	Composition, abundance and age structure of fish fauna		
Real time control of sewer network	Composition and abundance of zooplankton species		
Real time control of sewer network	Composition, abundance and biomass of phytoplankton		
Real time control of sewer network	Composition and abundance of macrophytes and phytobenthos		
Real time control of sewer network	Composition and abundance of invertebrate fauna		
Real time control of sewer network	Composition and abundance of riparian plant species		
Real time control of sewer network	Quantity and dynamics of water flow		
Real time control of sewer network	Water residence time		
Real time control of sewer network	Structure and substrate of the water body bed		
Real time control of sewer network	water-sediment surface		
Real time control of sewer network	Character of the riparian environment and/or floodplain		
Real time control of sewer network	Structure of the water body shoreline		
Real time control of sewer network	Freshwater flow		
Real time control of sewer network	Wave exposure		
Real time control of sewer network	Transparency		
Real time control of sewer network	Odor		
Real time control of sewer network	Oxygenation conditions		
Real time control of sewer network	Nutrient conditions		
Real time control of sewer network	Pollution by all priority substances identified as being discharged into the body of water		
Real time control of sewer network	Pollution by other substances identified as being discharged in significant quantities into the ...		

3.6. Case-relevant ESS: *see Annex A.1*

3.7. Identify Beneficiaries: *see Annex A.1*

3.8. Categorize Stakeholders: *see Annex A.1*

4. Impact Evaluation

4.1. State Indicators: *see Annex A.1*

4.2. Impact I Indicators: *see Annex A.1*

4.3. Impact II - Use Indicators: *see Annex A.1*

4.5. Economic Valuation: *see Annex A.1*

Annex B.2. Output of MIKE DSS: Sustainability Assessment

see Annex A.2

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