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1 European stakeholders' visions and needs 2 for stormwater in future urban drainage 3 systems

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21 Abstract:

22 Transitioning from current urban drainage systems to water-smart societies requires the involvement
23 of different disciplines and stakeholders. However, they have different visions and needs on the
24 transitioning process, e.g in terms of financing, policy adaptation and asset management, which
25 additionally vary between regions and countries. Identifying such conflicts between stakeholders is
26 necessary to propose adaptation strategies. Therefore, needs as formulated in policy papers and
27 legislation in seven European countries as well as from the EU funded project Co-UDlabs were collected
28 and individuals involved in the urban drainage community asked about their visions. Results show that
29 whilst there is consensus on the challenges, visions on how to transition are diverse, indicating more
30 interaction between the different stakeholder groups is required to develop consensus. Additionally,
31 organisational and legislative structures often slow down necessary change processes. Roles and
32 responsibilities in the water sector need to be clarified to enable more integrated planning.

33 **Keywords:** SUDS, legislation, adaptation to climate change, stormwater, guidelines, Europe

34 Highlights:

- 35 • Visions on how to transition from urban drainage systems to a water smart society were
36 collected from different stakeholders, policy and legislation documents

- 37 • Formulated needs for such a process were extreme diverse and allowed no limitation to
38 major axes
- 39 • Comparison with visionary documents of NGOs showed that awareness for solutions exists,
40 but implementation of different measures is lags behind.
- 41 • Organisational and legislative structures slow down transitioning processes.

42 Introduction

43 Since the 1990s, a transition from discrete examples of blue-green infrastructure to a holistic approach
44 of integrating stormwater in the urban environment has been ongoing to restore water cycles, to meet
45 major societal and climatic challenges and to make cities more liveable (Bertrand-Krajewski, 2021).
46 These challenges include demographic change, ageing infrastructure, urbanisation, a desire for
47 sustainable infrastructure, and the climate crisis. While the urban drainage sector is not always a major
48 focus for the public domain or policy makers, framework documents on future needs within the water
49 sector have been published by non-governmental organisations (NGOs) such as Water Europe and
50 knowledge generation organisations such as the International Water Association (IWA). The IWA
51 Principles for Water Wise Cities (IWA, 2016) address explicitly urban stakeholders, whereas Water
52 Europe’s three interconnected publications: Multiple Waters for Multiple Purposes and Users (Water
53 Europe, 2016), the Strategy and Research Agenda (Water Europe SIRA, 2016) and Digitalisation and
54 Water (Water Europe, 2021) target more globally the European water sector with a focus on the
55 commercialisation of innovations. In these publications, a future is envisioned in which the “conflicts”
56 generated by these major challenges can be addressed by a “water-smart society” (Water Europe,
57 2016) or, by “water-wise behaviour” (IWA, 2016).

58 IWA and Water Europe use similar concepts to define available water resources in the urban context,
59 and include surface waters, groundwater, polluted water and stormwater. In the IWA nomenclature,
60 these are described as “Sustainable Urban Water”, whereas Water Europe uses the term “Multiple
61 Water”. However, “Multiple Waters” can contain pollutants since brackish and saline water, brines and
62 used water belong to them, while “Sustainable Urban Water” has undergone treatment (“desalinated
63 water”, “recycled water”). The proposed approaches to reach a water-smart society that relies on

64 water-wise behaviour can be summarised as (IWA, 2016; Water Europe, 2016; Water Europe SIRA,
65 2016):

- 66 • Taking the true value of water into account by encouraging a circular economy for water and
67 valorising resources such as nutrients and energy from water. This should also enable
68 development of economically relevant new markets.
- 69 • Encouraging the development of new digital technologies to ensure the most efficient use of
70 all waters.
- 71 • Developing "a hybrid grey and green water infrastructure" (Water Europe SIRA, 2016; Water
72 Europe, 2022) by integrating nature-based solutions (NBS) with traditional infrastructure in
73 centralised and de-centralised solutions while respecting a circular economy approach, to
74 benefit from eco-systemic services.
- 75 • Implementing new governance structures to promote collaboration for better planning by
76 creating cohesion between urban actors (from the expert to the citizen) and interactions
77 between territories to enable synergies.

78 This holistic view of urban hydrology should encourage innovation, research and development of new
79 digital technologies and NBS to move towards a more sustainable and resilient system aligned with
80 current social and societal needs (Water Europe SIRA, 2016).

81 However, the different disciplines and stakeholders involved in this development – academic
82 researchers, industries, small and medium enterprises (SMEs), NGOs and decision-makers in
83 administration and politics, have different visions and needs regarding the future development of
84 urban stormwater infrastructure, which additionally vary between regions and countries.

85 Only if these visions and needs are collected and understood, connections and conflicts between
86 stakeholders can be identified and adaptation strategies proposed in order to support the transition
87 of UDS within the Europe. As e.g. Blumensaat et al. (2019) point out, technological development needs

88 to follow a discussion of its uses and goals if its full potential and value for society should be exploited.
89 Applying a transition theory-based approach, Wihlborg et al. (2019) identified “barriers” and “drivers”
90 of changing from traditional pipe-bound to blue-green infrastructure in structured interviews in two
91 Swedish municipalities. Based on this assessment, suggestions for changes in the local stormwater
92 management were developed.

93 These examples show how important it is to identify the connections and conflicts between
94 stakeholders and to propose adaptation strategies in order to support the transition of UDS within
95 Europe. The aim of this paper is to present the results of an evaluation on the visions of different
96 stakeholders for the future of UDS. This evaluation does not claim to be representative; however, the
97 aim of this work is to identify and examine areas where stakeholders express needs to be fulfilled to
98 enable this transition.

99 **Methods**

100 Collaborative Urban Drainage research labs communities - Co-UDlabs¹ is an EU-funded project aiming
101 to integrate research and innovation activities in the field of Urban Drainage Systems (UDS) to address
102 contemporary public health and flood risks and environmental impacts. It is a transnational research
103 and innovation "starting community", with the aim to influence European regulations and practices to
104 deliver a more sustainable management for UDS in the face of climate change and ageing of grey
105 drainage infrastructure. In order to identify the above-mentioned connections and conflicts between
106 stakeholders and to propose adaptation strategies, three different sources were consulted: (i) public
107 documents from governmental and non-governmental institutions, which define or are related to a
108 “roadmap” towards transitioning to a water smart society; (ii) opinions of the researchers involved in
109 Co-UDlabs, and (iii) opinions from individuals interested in using the RIs as offered by the Co-UDlabs
110 project. The information gathered was used as described below.

¹ <https://co-udlabs.eu/>

111 [Development of an evaluation grid](#)

112 A tabulated evaluation grid based on the themes of interest within the project was developed. This
113 evaluation grid serves to identify the needs in different sections, and therefore contains need-based
114 criteria:

115 (i) Scientific Knowledge,

116 (ii) Techniques and Technologies,

117 (iii) Non-technical Solutions, and

118 (iv) Knowledge Transfer/Training of Practitioners,

119 and categories dealing with

120 (i) Technical Objects with subcategories Performance/ Asset deterioration/ Digital water
121 solutions,

122 (ii) Processes, Impacts and Risks with the subcategories Urban flooding/ Runoff pollution,

123 (iii) Urban Services and Urban Planning – Waterwise Cities, and

124 (iv) Water Cycle with the subcategories Water resources/ Adaptation to climate change.

125 Table S1 (Supplementary material) shows the resulting evaluation grid.

126 [Evaluation of national “roadmaps”](#)

127 The Co-UDlabs consortium comprises of members from seven European countries (Denmark, France,
128 Germany, Spain, the Netherlands, Switzerland and the United Kingdom). For each country, we studied
129 legal and policy documents with respect to the status and future development of UDS. In total, 8 to 25
130 documents per country were assessed regarding information on planned or envisioned future
131 development, as well as description of current shortcomings. Finally, information from X (Denmark), 8
132 (France), 2 (Germany), X (Netherlands), 8 (Spain), 11 (Switzerland) and X (UK) documents were sorted
133 into the different fields of an exemplar of the above-described evaluation grid. Additionally, the
134 relevant governmental and non-governmental structures were described.

135 After comparing the entries, those with a similar content occurring in different countries were merged.
136 This resulted in a number for countries per field, which represent the number of countries in which
137 needs were identified and assigned to the respective field. The number of entries per field represents
138 the total number of needs identified, and the number of ideas represents the number of needs
139 remaining after merging similar entries. To allow for a comparison, an “agreement rate” was
140 calculated: If all entries in a field expressed the same need and, therefore, resulted in one idea, it
141 corresponds to an agreement rate of 100%; if none of these entries expressed the same need, the
142 agreement rate was 0%. If several entries could be reduced to a lower number of ideas since some of
143 needs the needs expressed were similar, this resulted in:

$$144 \quad \text{agreement rate (\%)} = 1 - \frac{\text{number of ideas}}{\text{number of entries}} \cdot 100$$

145 [Co-UDlabs perspectives](#)

146 In order to assess the visions and needs expressed by the scientists involved in the Co-UDlabs project,
147 two sources were used: the first one was the project proposal, the second one was a public
148 consultation for a revision of the Urban Wastewater Treatment Directive (UWWTD) in 2021.

149 The project proposal was screened according to the criteria and categories of the evaluation grid, and
150 identified needs and visions were recorded as keywords in an evaluation grid dedicated to the Co-
151 UDlabs project visions.

152 Regarding the survey on the revision of the UWWTD, Co-UDlabs project participants from UDC
153 (university, Spain), graie (one individual, non-profit organisation, France), INSA de Lyon (one individual,
154 higher education and research institution, France), EAWAG (expert panel, research institution,
155 Switzerland), Sheffield University (UK) and IKT (non-profit organization, Germany) registered their
156 answers and free comments to the consultation. More details on the respondents are provided in
157 Figure S1 (supplementary materials). From these answers, needs and visions were as well identified
158 and keywords included into the Co-UDlabs evaluation grid (Table S4, supplementary material).

159 A quantitative summary was then performed in an evaluation grid (Table S3, supplementary material).
160 If a topic was treated in the Co-UDlabs proposal, it was counted once irrespective of how many times
161 it was named in the proposal. Responses resulting from the survey on the revision of the UWWTD were
162 counted individually, as well as the number of comments provided on each topic of the same survey.

163 Identification of needs by the users of Research Infrastructure

164 A central role in transitioning to more sustainable urban water management is apparent in the focus
165 group targeted by the Co-UDlabs project due to their potential interest in using the available RI
166 platforms. This group consists of people from SMEs, industry, engineering consultancies, but also
167 academic research groups without their own RI or actors in public service with legal responsibilities in
168 the field of urban drainage. To get their opinions of the future developments in urban drainage, we
169 developed a survey (see Questionnaire, supplementary material) based on the needs and vision
170 assessment from the national roadmaps and the Co-UDlabs participants. Within the survey, the
171 respondents were asked to position themselves in the evaluation grid resulting from the analysis of
172 the national roadmaps and the Co-UDlabs' perspectives, and to express any additional needs. The
173 survey was set online in google forms, and the seven Co-UDlabs partners with RI invited contacts from
174 their networks to participate. Twelve people filled out the survey online; background information can
175 be found in Figure S2, supplementary materials.

176 The survey was also presented during a conference in Rennes, France, in June 2022 ("Carrefour des
177 gestions locales de l'eau de Rennes"), and ~25 participants, mostly from public water utilities and
178 municipalities, were asked to write down their anticipated needs and add it via post-its to a poster
179 presenting the evaluation grid. Approximately 20 participants provided feedback. The needs expressed
180 in the online survey and the post-its from the Rennes workshop were as well transferred into keywords
181 in a combined evaluation grid (Table S5, supplementary material).

182 **Results**

183 **Evaluation of national “roadmaps”**

184 *Denmark*

185 Operation and management of the Danish urban drainage and wastewater systems are divided among
186 many utility companies, with a large diversity in size, age and design of systems and organisation, which
187 are all responsible for providing drinking water, effective drainage and efficient wastewater treatment.
188 On the national level, the Ministry of Environment and Food is responsible for environmental
189 regulation, while the Ministry of Energy, Utilities and Climate regulates utilities and economic issues
190 of the sector. At the local level, 98 municipalities are responsible for water and environment, including
191 production of local water plans and compliance with legislation. They issue permits to the companies
192 that are operating the utilities on a daily basis.

193 In 2007, the Danish parliament decided to introduce new legislation for a more efficient water sector,
194 since it was difficult to separate the economical interactions between utilities and municipalities, and
195 the parliament feared that the total costs of water for the consumer were unreasonably high. Hence,
196 the utilities were legally and economically separated from the municipalities following a new principle
197 that no utility should be able to generate a profit from their activity². Consequently, all utilities undergo
198 benchmarking every year to set a price for water supply – and thereby for activities of wastewater
199 treatment, rainwater management and climate adaptation.

200 The high-level National lines of action are oriented around the UN Sustainable Development Goals
201 (SDGs), focusing on sustainable development of the water sector, with solutions that balance the
202 environmental impact as well as urban and societal developments. The impact of climate change is
203 stressing existing UDS, increasing the risk of flooding and the frequency of combined sewer overflows
204 (CSOs). At the same time, increased public awareness of the environment demands reduction of the
205 adverse impacts from urban areas. It has created a desire to quantify the amount and composition of
206 CSOs on a national scale.

² <https://www.en.kfst.dk/water-regulation/revenue-caps/>

207 In recent years, several water utility companies in Denmark have experienced that stormwater runoff
208 from urban areas has started to vary significantly depending on seasons. The Danish winters have
209 become wetter with more rainfall than previously. Consequently, the soil tends to be more saturated
210 during winter and increases the active stormwater runoff by including semi-permeable and permeable
211 surfaces, where rainfall normally infiltrates. This has generated a focus on methods, measurements
212 and models that can predict location and situation specific runoff.

213 *France*

214 One of the major regulatory difficulties for stormwater management in France is its complexity: many
215 national and local regulations exist, many documents (mostly regulations and guidelines) are available
216 to territorial actors to manage stormwater in a sustainable way, and it is difficult for a non-specialist
217 to get an overview.

218 Spatial planning is a fundamental lever for limiting water-related impacts and risks, and for adapting
219 to climate change. In France a recently enacted law contains the goal of reducing the net land
220 consumption (for housing and economic development) to zero by 2050³ by halving it every decade,
221 while at the same time prioritising the infiltration and evaporation of rainwater.

222 In terms of water policy, in 2015, the NOTRe law⁴ established a new specific competence, the GEPU -
223 Gestion des Eaux Pluviales Urbaines⁵ (Urban Stormwater Management), and helped evolve the
224 distribution of drinking water and sanitation obligations by moving them from single municipalities to
225 groups of municipalities, implying a mutualisation of technical competences. While in 2015, more than
226 33,000 utilities dedicated to drinking water or drainage system management existed⁶, their number
227 decreased to 26,000 in 2020⁷.

³ <https://www.legifrance.gouv.fr/loda/id/JORFTEXT000045197395/> (in French)

⁴ <https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000030985460/> (in French)

⁵ http://www.graie.org/graie/graiedoc/doc_telech/Graie-CompetenceGestionEauxPluvialesUrbaines-OuvragesMissions-mai19.pdf (in French)

⁶ https://www.services.eaufrance.fr/docs/synthese/rapports/Rapport_SISPEA_2015_complet_DEF.pdf

⁷ https://www.services.eaufrance.fr/docs/synthese/rapports/Rapport_Sispea_2020_VF.pdf

228 At the same time, the General Council for the Environment and Sustainable Development (CGEDD),
229 responsible for evaluating public policies and advising ministries, carried out a major national
230 consultation with practitioners and scientists on stormwater management in France. Additionally, in
231 2019, the State led a major consultation with all stakeholders in the framework of the "Assises de l'eau"
232 (water conferences), which also put forward recommendations on stormwater management policy.

233 Regulatory developments are converging towards a strategy at the interface of water management
234 and planning: to promote "integrated stormwater management to make cities sustainable and resilient
235 by encouraging infiltration of rainwater at source" (MTE, 2021), included in an action plan for 2022-
236 2024 by the Ministry of Ecological Transition. It proposes a set of concrete actions reflected in four
237 thematic areas: (i) integrating stormwater into development, (ii) raising awareness of the challenges
238 and benefits of managing rainwater at source, (iii) facilitating urban stormwater governance and
239 policing, and (iv) Improving scientific knowledge. Details on this action plan can be found in
240 Supplementary materials.

241 *Germany*

242 The federal structure of Germany is reflected in "The Federal Water Resources Act" (WHG, 2009),
243 which transposes the requirements of the EU's Water Framework Directive into national law. This act
244 also defines general requirements for wastewater disposal. The water laws and ordinances of the 16
245 federal states supplement and enforce federal water legislation.

246 Water legislation is implemented at the municipal level, which is responsible for wastewater disposal,
247 organised by municipal wastewater utilities or wastewater associations of several municipalities.

248 Due to the decentralised and partly also very localised organisation of German wastewater and
249 stormwater disposal, close cooperation between the stakeholders involved is needed. However,
250 implementing SUDS can be difficult at the municipal level since several departments have to be
251 involved, such as wastewater utilities, spatial planning, road and civil engineering, property owners,
252 and supervisory authorities.

253 In June 2021, a draft version of a National Water Strategy of the Federal Ministry for the Environment,
254 Nature Conservation and Nuclear Safety was published (BMU, 2021). However, this draft is only a basis
255 for further discussions in Germany. Fundamental challenges are the increasing pressure on water as a
256 resource and issues, such as (i) climate change (droughts and heavy rainfall), (ii) changes in
257 environmental policy to reduce pollution of water bodies by nitrate, phosphorus and a multitude of
258 other substances, and (iii) developments such as digitalisation, changes in lifestyle and land use.

259 In general, ten strategic themes are stated for water management: (i) Strengthening awareness of
260 water as a resource; (ii) further developing water infrastructures; (iii) linking water, energy and
261 material cycles; (iv) limiting risks from substance inputs; (v) restoring and managing the natural water
262 balance - preventing conflicting objectives; (vi) implementing water-compatible and climate-adapted
263 land use in urban and rural areas; (vii) further developing sustainable water management; (viii)
264 protecting marine areas (North Sea and Baltic Sea) more intensively against discharges from the land;
265 (ix) strengthening efficient administrations, improving data flows, optimising regulatory frameworks
266 and securing funding; and (x) protecting global water resources sustainably together (BMU, 2021).

267 *Netherlands*

268 In the Netherlands, 21 public waterboards are responsible for managing regional waterbodies. The
269 national directorate for public works and water management “Rijkswaterstaat” has the responsibility
270 for water quantity and quality of Dutch rivers, canals and large waterbodies such as the IJsselmeer.
271 With the expected increase in rainfall peak intensities due to climate change, simply increasing the
272 capacity of existing systems will not ensure sufficient flood protection since a considerable portion of
273 the Netherlands is below sea level, or below acceptable environmental protection levels. Waterboards
274 draft long-term plans on how to cope with these threats.

275 Another important driver for policymaking is the notion of sustainability, in a very broad sense: e.g.,
276 when a municipality plans for new developments, it needs to choose a system for urban drainage that
277 enables (i) the reuse of water, (ii) keeping various ‘streams’ separated resulting in the choice of

278 separate sewer systems unless they are financially or economically not feasible, and (iii) keeping
279 stormwater 'on site' to avoid local drought and subsidence.

280 A very important development is that asset management of UDS has gained more attention over the
281 past 30 years. Regular inspections, rehabilitation and replacement plans are drafted on a regular basis
282 by municipalities.

283 National authorities, waterboards and municipalities need to co-operate to implement the overarching
284 policy as described and work out plans on a detailed level. In the National Water Program (cNWP), the
285 need for knowledge development is identified as a crucial prerequisite to achieve these goals. With
286 new legislation ("omgevingswet"⁸) additional responsibilities are to be given to local authorities
287 (municipalities to implement solutions and the waterboards to enforce local policy) to enable tailor-
288 made locally appropriate solutions. Since the responsibilities are given to local authorities, the national
289 authorities formulated a strategic framework on a high abstract level only.

290 According to the latest progress report, by 2027, it is expected that national waterbodies (e.g. large
291 rivers) will comply with the goals set by the EU WFD, while for regional waterbodies, this compliance
292 accounts only for 35-65% of these waterbodies. Further improving their ecological quality implies,
293 among other measures, reduction of discharge of nutrients sewer networks with a mixture of source
294 control, end-of pipe solutions, and separation of different qualities of water (black, yellow, grey). This
295 may lead to alternative sanitation combined with advanced wastewater treatment methods. In the
296 past 10-15 years, a lot of research has been conducted into these subjects, however, the translation
297 into engineering guidelines and design methods is still largely missing.

298 Given the hydrological situation of the Netherlands in Europe, tuning policymaking and
299 implementation of policies with other European countries (specifically Belgium and Germany) are
300 crucial. The co-operation between these entities needs monitoring for which a rather complex system

⁸ <https://www.rijksoverheid.nl/onderwerpen/omgevingswet>

301 of legislation, policymaking, asset management plans, detailed action plans and long-term agendas are
302 being drafted (cNWP, 2022).

303 *Spain*

304 The current Spanish Water Act has been in force since 1985 and presents the legal framework for water
305 quantity, use, protection, and planning for all Spanish river basins. The current text does not contain
306 any specific aspects on stormwater or urban drainage management.

307 The urban water sector is very fragmented. Water supply, urban drainage and wastewater treatment
308 are managed by the different councils and metropolitan areas according to dozens of regulations at
309 national, regional and municipal level. In some cases, the water services are managed using an
310 integrated approach, especially in large cities and metropolitan areas, but usually, services are divided
311 among several entities and water operators. Regarding wastewater and stormwater transport and
312 treatment, a harmonised governance scheme is missing, and the River Basin District approach as
313 requested by the EU WFD is not applied in most of the large urban agglomerations in which different
314 councils are involved. Design criteria and management practices vary across the country, and even
315 within the same River Basin Districts.

316 Regarding the normative framework, after the transposition of EU UWWTD, the most relevant
317 milestone in Spanish urban drainage was the modification in 2012 of the Regulation of Water Act,
318 which established the permits for spills to water bodies. Since this date, the management of CSOs
319 during rain events is considered in the regulatory framework. The law requires the Ministry of
320 Environment to establish national guidelines defining environmental objectives and technical
321 guidelines to design specific measures and manage stormwater, as well as the promotion of integrated
322 urban drainage planning and CSO monitoring. The guidelines are still in preparation since 2012.

323 In 2016, a modification of the Spanish regulations for the public sector, which introduces urban risk
324 management, states that new industrial and urban developments must implement SUDS to reduce the
325 risk of flooding (Ministerio para la Transición Ecológica, 2019; Andrés-Doménech, 2021). This national
326 framework provides general rules for regional and local governments to develop their own regulations.

327 The main challenges for the water sector are defined in the Spanish Green Book of Governance
328 (Gobierno de España, 2020). These are: (i) adapting the current regulatory framework; (ii)
329 strengthening the organisational and financial structure of the water sector; (iii) improving the
330 coordination and cooperation among the different administration levels; (iv) improving (evidence-
331 based) decision making, water digitalisation and water knowledge; and (v) implementing an integral
332 urban water perspective, ensuring financial resources to assure water quality in a mid- and long-term
333 perspective.

334 According to the analysis of the Green Book, the new governance model for urban water may consider
335 a new way of integrating water services in the city, as well as citizens' opinions. Urban flooding and
336 pollution impacts related to weather events must be included in the analysis of urban water systems.
337 NBS are being promoted. Furthermore, the publication also states the main economy-scale problems,
338 which does not allow small municipalities to provide services at reasonable costs, nor to establish
339 control of sufficient service quality. This has led to the outsourcing of service to private water utilities,
340 which has meant, in most cases the loss of water management information.

341 The "Spanish Urban Agenda" (Ministerio de Fomento, 2018) defines 30 strategic actions aligned with
342 SDGs and 2030 Agenda (UN, 2015), including the main objectives for the field of urban drainage, i.e.
343 to prevent and mitigate climate change impacts, to improve urban resilience, to enhance a sustainable
344 resource management and to favour circular economy.

345 *Switzerland*

346 The Federal Office of the Environment (BAFU) is the most important actor on the federal level in
347 Switzerland, and defines the requirements for water quality. The Water Protection Act specifies the
348 locations where wastewater must be treated and disposed of. The cantons, however, are responsible
349 to ensure that the municipalities develop their own General Drainage Plan (GDP), which is a planning
350 instrument for the strategic development of urban drainage infrastructure, which includes different
351 sections such as flood protection, infiltration/inflow, condition assessment and investment planning.
352 The cantons also guide the development of Regional Drainage Plans for larger interconnected systems.

353 Regarding stormwater pollution, source control in Switzerland is implemented in a similar fashion to
354 remove pollutants from road drainage, as well as heavy metals and pesticides in runoff from “building
355 envelopes”, such as copper roofs and impregnated facades.

356 Urban water management is mostly organised by wastewater associations (“Zweckverbände”). Their
357 goal is to collect and treat domestic, commercial and industrial wastewater produced in their
358 catchment area. Typically, the associations operate a central WWTP on behalf of several municipalities.
359 Often, they operate the main collectors as well, ancillary structures, such as pumping stations or CSO
360 tanks. However, the latter can also be operated by the municipalities.

361 As Switzerland is rather fragmented (the canton of Appenzell Innerrhoden has 16,145 inhabitants and
362 46% of the 26 cantons have less than 200,000 inhabitants) environmental regulatory authorities not
363 only ensure the environmentally sound disposal of wastewater and solid waste, but also organise other
364 tasks, such as the supply of drinking water and protection against flooding. This also means that water
365 issues are dealt with in a wide number of different cantonal laws and ordinances.

366 An integrated national strategy for urban stormwater management is lacking in Switzerland. However,
367 we identified three major studies, which provide detailed suggestions to address current and future
368 challenges.

369 The synthesis report "Wastewater Management 2025" (EAWAG, 2012) includes "recommendations
370 for action", for which different stakeholders are responsible. They include measures (i) for improving
371 infrastructure management by reducing the heterogeneity and organisational fragmentation; (ii) that
372 improve and promote integrated catchment management actions; (iii) that guarantee the safe and
373 optimal drainage of storm- and wastewater from the settlement area; (iv) to create synergies at supra-
374 regional or national level; and (v) that directly benefit or improve the water quality of surface or
375 groundwater, such as better understanding the impact of wastewater exfiltration on water bodies.

376 “Heat in cities” (BAFU, 2018) emphasises that climate change will lead to more frequent and longer
377 periods of hot weather. The study concludes that urban planning can reduce this urban heat island

378 effect by adapting the design of outside space. Open green spaces must be planned with plenty of
379 shade, and cooling water elements accessible to all. Not only water is important for cooling, but also
380 the supply of fresh air from the surrounding area and air circulation in the city.

381 “Stormwater in settlements” (BAFU, 2022) emphasizes the potential of the “sponge city concept” and
382 concludes that an important factor for success is the transdisciplinary cooperation of the different
383 actors. Those responsible for urban drainage and for flood protection, experts from the fields of urban
384 planning and development, and from architecture and landscape planning, building owners, political
385 actors, etc. must all work together to develop and implement solutions. The study lists specific
386 instruments that are already implemented and allow for a “good handling” of stormwater to ensure a
387 “near-natural” urban water cycle by infiltrating unpolluted rainwater and by discharging mildly
388 polluted rainwater into surface water bodies (AWEL, 2022).

389 To translate the high-level conceptual studies into actionable information and standards, the Swiss
390 association for wastewater professionals (“Verband Schweizerischer Abwasser- und
391 Gewässerschutzfachleute”, VSA) and other professional associations are currently developing several
392 guidelines or recommendations.

393 *United Kingdom*

394 The UK water sector is fragmented with a range of organisations holding different responsibilities in
395 terms of the provision of effective drainage, treatment of wastewater, and the protection of the
396 environment. Water supply, collecting and treating wastewater, and providing “effective” drainage is
397 organised by a small number of catchment-based private water and sewerage companies (WaSCs).
398 However, this applies only in England, while there are different regulatory and political structures in
399 Scotland, Wales and Northern Ireland.

400 The WaSCs resulted from a decision of the UK government in the early 1990s to privatise the public
401 Regional Water Authorities and to issue 25-year licenses to private companies within a designated river
402 basin catchment due to under-investment in water related infrastructure for decades. The private

403 companies were to raise investment funds, resulting in the nine largest UK water companies currently
404 having approx. over £50Bn debt that has funded infrastructure investment since privatisation.

405 Since these companies (with shareholders) are effectively regional monopolies of an essential service,
406 the government created a framework of strict regulation overseen by the Drinking Water
407 Inspectorate⁹, the Water Services Regulation Authority (OFWAT)¹⁰, and the Environment Agency
408 (EA)¹¹. The last two regulators significantly influence the management of UDS. OFWAT's purpose is to
409 ensure water company shareholders get a fair return on their investment and that customer charges
410 are controlled. OFWAT benchmarks companies, so that customer charges are "value for money". The
411 EA as environmental regulator has a duty to ensure that water companies do not cause significant
412 impact on the environment. It regulates the management of CSOs and pollution of groundwater
413 sources, and also has a role in managing river flood risk. All three regulators have oversight from the
414 Department of Food and Rural Affairs (DEFRA) a central government ministry. DEFRA has historically
415 not been pro-active, but recently it has intervened directly, for example requiring the event duration
416 monitoring of practically all storm overflow since 2013s. This open data has generated significant
417 public concern resulting in the recent creation of a Storm Overflow Taskforce. In combination with the
418 recently enacted Environment Act¹², which places significant new obligations on water companies in
419 the field of urban drainage, it has been indicated that there will be much stricter control of pollution
420 impacts of UDS on the receiving waters. The Environment Act forces WaSCs to agree spill reduction
421 targets with the government and also to install upstream and downstream water quality monitoring
422 on all storm sewer overflows operated by WaSCs. The implementation timescale is by the mid-2030s.

⁹ <https://www.dwi.gov.uk/>

¹⁰ <https://www.ofwat.gov.uk/>

¹¹ <https://www.gov.uk/government/organisations/environment-agency>

¹² <https://www.legislation.gov.uk/ukpga/2021/30/contents/enacted>

423 The UK structure has resulted in a number of NGOs that interact with the WaSCs, such as WaterUK¹³
424 and UK Water Industry Research¹⁴ (UKWIR)

425 To add to this complexity, local authorities have a responsibility to investigate flooding incidents and
426 manage flooding in urban areas, which overlaps with responsibilities of the WaSCs to adequately drain
427 their service area and the EA to manage flood risk on main rivers. It has led to a number of initiatives
428 from different parties to develop roadmaps that do not have statutory backing. In addition to the
429 aforementioned Storm Sewer Overflow Taskforce set up by DEFRA, two initiatives will be considered
430 here:

431 1) In 2019 UK Water Industry Research (UKWIR) started a “Big Question” program. This was a
432 series of road mapping projects that examined the 12 big questions facing the UK water sector.
433 These projects involved strong engagement with different players and structured assessment
434 of the different pressures that may emerge over a timescale up to 2050. The UKWIR road
435 mapping projects developed a program of potential R&D projects structured in terms of short-
436 , medium- and long-term needs.

437

438 2) The growing public mistrust in the private WaSCs has led to demands for legislation to obligate
439 collaborate work and higher levels of transparency. Drainage and Wastewater Management
440 Plans (DWMPs) are now a legal requirement under the Environment Act. They aim to provide
441 more consistent long-term planning, to address key risks and make urban drainage and
442 wastewater systems more resilient. DWMPs utilize three groups of tools: (i) capacity
443 assessment frameworks, (ii) storm overflow assessment frameworks, and (iii) wastewater
444 resilience metrics, to better structure wastewater and drainage planning¹⁵.

¹³ <https://www.water.org.uk/>

¹⁴ <https://ukwir.org/>

¹⁵ <https://www.water.org.uk/policy-topics/managing-sewage-and-drainage/drainage-and-wastewater-management-plans/>

445 *Summary of the revised policies*

446 The organisation and legislative structure of stormwater management and treatment in the seven
447 countries represented here is quite different due to historical development, climatic and geographical
448 conditions, as well as economic situation, resulting also in different degrees of private/public
449 involvement. The way national regulations and frameworks have been structured and implemented
450 results in different degrees of competences and interdependences at a local level. In Denmark and the
451 Netherlands, the general responsibilities seem to be well defined between the different actors on the
452 national, regional and local level, whereas the situation in the other five countries is more complex.
453 The management of stormwater and the implementation of SUDS is not always clearly defined.
454 Overlapping responsibilities between municipalities, specific catchment-based organisations
455 (Germany, Switzerland, England, Spain) or municipal clusters (France) and/or undefined allocation of
456 competences lead to conflicts or neglecting of these tasks. Varying legislation in the administrative
457 divisions (e.g., the 16 states in Germany, 17 autonomous communities and two autonomous cities in
458 Spain, 26 cantons in Switzerland, or the four countries of the United Kingdom) add to the overall
459 complexity.

460 However, there is an awareness of a required change towards more sustainable development in the
461 water sector in all countries, although the implementation into the legal framework remains on
462 different levels and is not always clearly defined:

- 463 • Denmark and Spain: national action plans oriented around the SDGs formulate strategic
464 objectives.
- 465 • The Netherlands: draft National Water Program 2022-2027 defines integral long-term goals
466 for the deltas.
- 467 • Germany and France: recognition of the role of land use in future stormwater management;
468 while already implemented into a law in France (NOTRe), currently as draft National Water
469 Strategy in Germany.

- 470 • France and United Kingdom: plans specifically dedicated to sustainable stormwater
471 management and overflow reduction (Action Plan 2022-2024 in France/Storm Sewer
472 Reduction Program in UK).
- 473 • Switzerland: integral national strategy still missing, but the three described reports on
474 wastewater management, heat in cities and extreme events/stormwater management point
475 to the direction such a strategy could take.

476 *Focus of roadmaps with respect to the evaluation grid*

477 The quantitative analysis of the needs identified for the different countries with the evaluation grids
478 described in Methods showed a large heterogeneity of the expressed needs, which is reflected in the
479 summary Table 1, and the detailed entries of the evaluation grid provided in Table S2 (Supplementary
480 material). The only field where more than one country (3 in total) identified the same need (=100%
481 agreement) is 'Technical objects - Assets deterioration / Knowledge transfer'. The need expressed was
482 'to train professionals to improve self-monitoring, knowledge of the state of the works and critical
483 thinking' in the analysed documents of France, Switzerland and the Netherlands. This was also the sub-
484 category with the highest overall agreement. Among eight entries in 'Scientific knowledge', the ideas
485 "Improve the knowledge on pipe deterioration", "Improve the knowledge on NBS medium- to long-
486 term performance" and "Data-driven models to failure of assets" were suggested by two countries
487 each (37.5% agreement), and for 'Techniques and technologies', two out of four entries described
488 "Measuring and data analysis for all infrastructure" (25% agreement). However, common interest was
489 limited with an average of 3.5 countries per criterion (average number of all rows for this column). The
490 sub-category with the maximum number of entries in the revised policies is 'Runoff pollution' within
491 'Processes, impacts, risks' with an average of five countries expressing needs for the different criteria
492 and an agreement of

- 493 • 29% for 'Scientific knowledge': 17 entries resulting in 12 ideas, topics linked to "Monitoring of
494 contaminants and pollution sources" formulated in three national roadmaps, and "Knowledge

495 on emerging contaminants”, “Microbial pollution in surface waters” and “Development of
 496 predictive / detailed models” in two national roadmaps each.

497 • 27% for ‘Techniques and technologies’: 11 entries resulting in 8 ideas, topics linked to
 498 “Metrology: to improve discharge monitoring and data management” formulated in three
 499 national roadmaps, and “(Pollution-based) RTC control” in two.

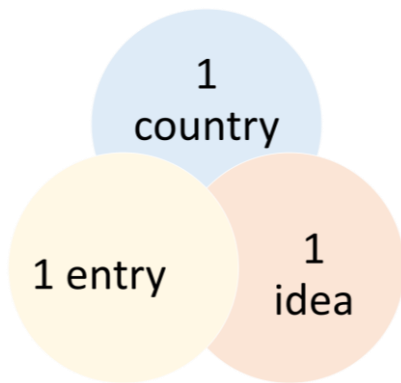
500 • 33% for ‘Non-technical solutions’: 6 entries resulting in 4 ideas, with the topic “Unified taxation
 501 for discharge of nutrients from stormwater outlets and CSO” found in three national
 502 roadmaps.

503

504 *Table 1: Needs expressed in the legislation and policy documents of Denmark, France, Germany, Spain, Switzerland, The*
 505 *Netherlands and United Kingdom, quantitative overview*

Categories \ Criteria		Scientific knowledge	Techniques and technologies	Non-technical solutions	Knowledge transfer – training of practitioners
Technical objects	Performance				
	Assets deterioration				
	Digital water solution				
Processes, impacts, risks	Urban flooding				
	Runoff pollution				
Urban services, urban planning	Waterwise Cities				
Water cycle	Water resources				
	Adaptation to climate change				

506



- The number of countries which expressed a need regarding the specific topic is noted in the top circle.

- The number of entries from all assessed documents is noted in the left circle.

- The number of different ideas in the right circle reflects the

513 total number of needs expressed in all roadmaps.

- The darker the shade of blue, the more countries were concerned; the darker the shade of yellow, the more entries were made; red indicates the amount of different ideas existing.

516 The topic “Runoff pollution” also received overall the highest number of entries, on average 9.25
 517 entries resulting in an average of 6.5 needs expressed per criterion. The second highest global interest
 518 was expressed for ‘Technical objects – Performance’ with an average of 4.25 countries, 8 entries and
 519 6.5 ideas, respectively. Common topics here were for ‘Scientific knowledge’ (10 entries resulting in 6
 520 ideas) “Data driven modelling with AI to develop system knowledge” (3 countries), “Data quality of
 521 available performance monitoring data” and “RTC control / Remote sensing” (2 countries,
 522 respectively).

523 [Evaluation of Co-UDlabs perspectives](#)

524 The Co-UDlabs perspective was obtained from the response of six project participants to the survey
 525 on the revision of the UWWTD and needs formulated in the project proposal. With respect to the
 526 survey, the project partners believe in line with the objectives of Co-UDlabs that the most important
 527 topics of the regulatory review are integrated approaches to better manage stormwater overflows and
 528 urban runoff. All six individuals gave the highest importance to using NBS in urban wastewater
 529 management whenever possible.

530 The majority of the Co-UDlabs respondents found the proposed definition of the problems in urban
 531 wastewater management to be incomplete and insisted on a more global approach, including the

532 effects of global change. They made complementary propositions and remarks in the comment
533 section. With regard to stormwater treatment, these related to:

- 534 • Improved and cost-effective monitoring;
- 535 • Joint and transnational research activities;
- 536 • The inclusion and analysis of spatial data;
- 537 • Paying more attention to CSOs;
- 538 • More flexibility in adapting treatment processes to current technological developments; and
- 539 • Using a more integrative vocabulary with wet weather flow, rather than stormwater.

540 A quantitative overview is presented in Table S3; all weighted answers to the UWWTD survey and the
541 additional comments can be found in Table S4 (Supplementary material).

542 The entries resulting from the Co-UDlabs project description emphasise the column 'Scientific
543 knowledge'. While the responses and comments to the consultation of the UWWTD were strongly
544 guided by the questions asked, it is interesting to see that most of the overall comments were made
545 on the topic of 'Digital water solutions' almost equally distributed to all criteria. This shows that the
546 project participants see a real need to implement new digital technologies and improve their use on
547 all levels, which is also a strong focus of the Co-UDlabs project.

548 The single categories receiving the highest interest were 'Urban services, urban planning – Waterwise
549 Cities' and 'Non-technical solutions' (6 comments). These comments target mostly regulatory issues
550 with a general impact on the water management in a city, e.g.:

- 551 • Enforcing holistic planning by including other disciplines such as urban planners;
- 552 • Including other aspects than technical ones into guidelines, such as socio-economic aspects;
- 553 • Allowing to adapt to technological development more flexibly than in current legislative
554 frameworks; and

555 • Incentives to improve monitoring and data quality.

556 ‘Processes, impacts, risks – Runoff pollution’ received 5 comments for ‘Non-technical solutions’, which
557 also target mostly changes in organisational and legislative aspects, such as reversing the preferential
558 treatment of centralised solutions towards decentralised ones and joining the organisational
559 responsibility for stormwater and wastewater.

560 [Identification of needs by the users of Research Infrastructure](#)

561 In the first part of the survey, the participants were asked whether they agreed with the selected
562 criteria and categories, which was the case for most respondents. The detailed feedback can be found
563 in Supplementary materials (Table S5).

564 In the second part of the survey, the participants were asked to position themselves to the presented
565 evaluation. Three participants criticised that the focus from the national roadmaps as well as from the
566 Co-UDlabs project summarised in Table 1 was too strongly placed on “Technical objects” and
567 “Processes, impacts, risks”, while one participant mentioned that he or she especially agreed with this
568 emphasis.

569 When being asked which specific needs the participants see for the different criteria, there were two
570 types of responses: while one group named the field or criteria they considered most important, the
571 other made concrete suggestions (showed in Table S4, Supplementary material). Overall, the most
572 comments (7) were made concerning ‘Technical Objects – Performance’, with four for the criterion
573 ‘Techniques and technologies’, targeting three different topics: creating structures for stormwater
574 recovery and reuse for events with high return frequencies; promoting pollutant removal; and
575 focussing on infiltration parameters. This criterion also received the most feedback for ‘Digital water
576 solutions’ (6 needs in total for this subcategory) with suggestions for integrated models of urban
577 drainage systems, wastewater treatment plants and receiving waters, models for sewer systems (air
578 and sediments) and life cycle analysis. Also, six entries were made for ‘Processes, impacts, risks –
579 Runoff pollution’ with the majority dedicated to ‘Scientific knowledge’. Here, increased knowledge on

580 dry weather pollution management and accumulation during dry periods, runoff pollution dynamics
581 and polluting effect of infiltrating microplastic materials was requested.

582 *Common needs and visions*

583 All three sources used for the needs assessment – national roadmaps, input of Co-UDlabs participants
584 and potential RI users -, resulted in various needs being pointed out for each category analysed in the
585 proposed framework. However, looking at the different propositions some can be summarised. Table
586 2 gives an overview of the different sources per topic. A need had to be mentioned at least twice by
587 different initiators to be included. The following topics were identified:

588 *“Technical objects”*

589 For the subcategory ‘Performances’, more ‘Scientific knowledge’ by far the most interest was
590 requested on data collection, data quality and the use of data in modelling. Three common other topics
591 resulted from the analysis were related with (i) the evaluation of maintenance and long-term evolution
592 of urban drainage assets; the (ii) standardisation of the assessment of UDS performances; and (iii) the
593 treatment of highly variable wastewater flows impacted by stormwater.

594 For all other criteria of this subcategory, a variety of suggestions with only few overlaps were made.
595 To be named here are for ‘Techniques and technologies’ the identification of sewer infiltration,
596 adaption of sewer systems and soil infiltration; and for ‘Non-technical solutions’, integrated
597 stormwater management and multi-stakeholder governance. Standardisation of guidelines and
598 planning materials as well as network creation were addressed at least twice in ‘Knowledge transfer
599 and training of practitioners’.

600 The entries for ‘Assets deterioration’ subcategory resulted for ‘Scientific knowledge’ in three main
601 groups, (i) research on sewer processes leading to corrosion; (ii) long-term performance and resilience
602 of UDS and NBS; and (iii) the use of “big data”, especially for modelling.

603 Data collection and analysis was highlighted in the ‘Techniques and technologies’ criterion. Even more
604 interest was expressed for ‘Non-technical solutions’ around the management of assets and questions

605 of costs and investment strategies. For 'Knowledge transfer', training of professionals to improve self-
606 monitoring, knowledge of installations and critical thinking was identified as a consistent need.

607 In "Digital water solutions", three topics were commonly named for both 'Scientific knowledge' and
608 'Techniques and technologies' across all sources. These are (i) Advanced monitoring, such as the use
609 of interconnected smart monitoring techniques; (ii) improved data management and evaluation, e.g.,
610 through data harmonisation and sharing; and (iii) modelling, e.g., integrated models for parts of the
611 sewer infrastructure as well as holistic models for the sewer, WWTP and surface waters.

612 Citizen involvement and public access to collected data is the most considered aspect for 'Non-
613 technical solutions'. Other widely named aspects are around organisational issues, e.g., for data
614 management questions and agreements on data requirements. In 'Knowledge transfer and training of
615 practitioners', the major issue is training for new monitoring devices and development of strategies
616 for their use. There are various other needs named, but uniquely once per topic and source.

617 *"Processes, impacts, risks"*

618 The subcategory 'Urban flooding' is uniquely covered by the national "roadmaps". 'Scientific
619 knowledge' and 'Techniques and technologies' are mainly requested for predictive models and risk
620 maps, which are also referred to under 'Non-technical solutions' (e.g., support of their creation). For
621 'Knowledge transfer', the national "roadmaps" suggest several means, e.g., case studies and
622 demonstration-scale projects, and 'Training of professionals' in the design and operation of existing
623 networks for preventative flood management, among other suggestions.

624 For the sub-category of "Runoff pollution", by far the most needs were formulated, which can be found
625 in all three sources used for this assessment. For example, more 'Scientific knowledge' is requested for
626 (i) monitoring of contaminants, and pollutant sources, especially with regard to the quality of the
627 obtained data; (ii) the impact of pollutants on the environment, e.g., on surface waters, groundwater
628 or the soil used for infiltration; (iii) the dynamics of pollutant accumulation and transport; and (iv)
629 modelling around runoff events.

630 Data collection and model development as well as runoff management especially with NBS were the
631 two consistent topics in 'Techniques and technologies'.

632 According to this assessment, 'Non-technical solutions' should mainly focus on (i) financial aspects: for
633 example, unified taxation for nutrient discharge from stormwater outlets and CSOs and better
634 application of the "polluter pays" principle; and (iii) developing an integrated planning for stormwater.
635 Lastly, training on metrology was the only common point named for 'Knowledge transfer and training
636 of practitioners'.

637 *Urban Services, urban planning - Waterwise cities*

638 The needs pointed out for 'Scientific knowledge' showed no agreement; five out of the seven different
639 entries can be found in the various national "roadmaps" (Table S.3). Development of design
640 approaches and strategies for urban planning, including the evolution of standards for the building
641 industry was the most addressed topic in 'Techniques and technologies'.

642 'Non-technical solutions' was the criteria that receiving the most entries, with three identified topics:
643 (i) governance structure on different levels: necessity of implementing clear structures between the
644 different stakeholders and holistic planning in urban planning by establishing frameworks and open
645 policies; (ii) local responsibilities: allow local operators to develop their own action plans, e.g., by also
646 strengthening inter-municipal cooperation; and (iii) boosting innovation: accelerate the adoption of
647 innovation, e.g., by explicitly opening the inclusion of new technologies in regulatory frameworks.

648 The entries for 'Knowledge transfer and training of practitioners' identified three topics: (i) develop
649 tailored training activities, especially on stormwater management, for different stakeholders; (ii)
650 create an overview of available research infrastructures and enable access and network creation; and
651 (iii) provide information for the public.

652 *Water cycle*

653 In the subcategory "Water Resources", the entries for developing 'Scientific knowledge' resulted in
654 two main groups, which were (i) the impact of wet weather discharges on receiving water; and (ii) the
655 prevention and restoration of surface waters;

656 The development of predictive models was the most common point for the criterion ‘Techniques and
657 technologies’; and Adaptation of legislation to an integrated resources management for ‘Non-technical
658 solutions’.

659 Only two criteria resulted in corresponding needs for “Adaptation to climate change”, which were for
660 ‘Scientific knowledge’ developing of integrated and holistic models as well as anticipating the effects
661 of global change on existing sewer systems; and to make technical choices and connected regulations
662 climate-proof (‘Techniques and technologies’).

663 *Table 2: Guiding topics derived from the expressed needs in the three evaluated sources, which require (near)*
664 *future activity*

Criteria		Scientific knowledge	Techniques and technologies	Non-technical solutions	Knowledge transfer – training of practitioners				
Categories									
Technical Objects	Performances	Data collection and quality		Sewer infiltration		Integrated stormwater management		Standardisation	
		Maintenance and long-term evolution		Adaption of sewer systems		Multi-stakeholder governance		Network creation	
		Standardise assessment		Soil infiltration					
		Treatment of highly variable flows							
	Assets deterioration	Sewer processes		Data collection and analysis		Management of assets		Training of professionals	
		Performance and resilience				Costs and investment			
		Big data							
	Digital water solution	Advanced monitoring		Advanced monitoring		Citizen involvement		Training for monitoring devices	
		Data management and modelling		Data management		Organisational issues			
				Modelling					
Processes, impacts, risks	Urban flooding	Predictive models and risk maps		Predictive models and risk maps		Predictive models and risk maps (support)		Case-studies and demonstration-scale projects	
								Preventative flood management	
	Runoff pollution	Monitoring of contaminants		Data collection and model development		Financial aspects		Training on metrology	
		Impact of pollutants		Runoff management		Sustainable stormwater solutions			
		Pollutant dynamics				Integrated planning			
		Modelling							
Urban services, urban planning	Waterwise Cities	<i>No common topic could be identified.</i>	Design approaches and strategies		Governance structure		Tailored training activities		
					Local responsibilities		Available research infrastructures		
					Boosting innovation		Information for the public		
Water cycle	Water resources	Impact of wet weather dischargers on receiving waters		Predictive models		Adaptation of legislation to an integrated water resources management		<i>No common topic could be identified</i>	
		Prevention and restoration of surface waters							
	Adaptation to climate change	Integrated and holistic models		Make technical choices and regulations climate-proof				<i>No common topic could be identified.</i>	
		Anticipating the effects of global change on existing sewer systems				<i>No common topic could be identified.</i>			

number of needs found in the national "roadmaps" referring to this topic
 number of needs named by different Co-UDlabs participants or in the proposal
 number of needs named by (potential) RI users

665

666 Discussion and conclusions

667 Overall, the evaluation shows that the particular needs for UDS identified by the different stakeholders
 668 are quite diverse, and cannot be limited to major axes. The fact that numerous needs were identified
 669 indicates what efforts still needs to be made for transitioning to sustainable urban drainage systems

670 to be achieved and that whilst there is consensus on the challenges there is no clear agreement on the
671 exact transition pathway to follow.

672 Only a small number of the needs were identified by the three sources – i.e. national roadmaps, Co-
673 UDlabs participants and (potential) RI users (Table 2). While this is also due to the limited number of
674 responses from the RI users, it also could indicate that more interaction between the different
675 stakeholder groups is necessary to develop consensus, but the sample size in our study is too limited
676 for a definite conclusion. In a review article by Qiao et al. (2018), the authors tried to identify the
677 challenges linked to the implementation of urban sustainable stormwater management. Unclear
678 leadership and responsibilities, governance arrangements and a lack of private stakeholder
679 participation (in the sense of participation of individual households) were considered to slow down
680 such a transition. While other than the private stakeholders in the review, the RI-users included in the
681 Co-UDlabs project are well informed of the necessary changes in the stormwater sector, transversal
682 communication between the different involved groups does not seem to be sufficient at this point. In
683 a study in Sweden (Bohman et al., 2020), where workshops between urban planners, government
684 officials and water utilities were held to identify the major problems hindering sustainable stormwater
685 management in urban planning, it was pointed out that a real collaboration between the different
686 involved stakeholders is often lacking, which slows down the development of a common vision.

687 Shortcomings of maintenance and assessment of UDS performance has been critically discussed in the
688 urban drainage community over the last two decades (Langeveld et al., 2022); that it is a topic in our
689 evaluation shows that transfer into practise is not yet satisfactory.

690 Some of the identified needs are quite in line with the visionary documents of IWA and Water Europe
691 summarised in the Introduction. It is interesting to see that all questions around (real-time) big data
692 management and advanced monitoring and training in these technologies were mentioned in the
693 different sources. Water Europe proposed these aspects in their Strategic Innovation and Research
694 Agenda (SIRA) as “shorter to medium impact measures” for the years 2017-2021 as the first stage of a

695 three-stage program to shift the European Water System (Water Europe SIRA, 2016). This shows that
696 while awareness of the importance of these topics is developing in different stakeholders, concrete
697 actions in many cases still need to follow.

698 Qiao et al. (2018) identified also a lack of funding as an influencing factor for the rate of transition,
699 which might slow down the overall process. High initial investments were also named as hindrance in
700 a study of Forrest et al. (2020) on transferring from classical sewer to sustainable urban water solutions
701 by upscaling a local pilot project to three major cities.

702 Blumensaat et al. (2019) assessed future trends associated with ubiquitous sensing in the water sector
703 in a horizontal scanning process. Elements of the ten identified most emerging topics were addressed
704 in “Technical Objects - Digital water solutions”, especially by naming advanced monitoring.
705 Additionally, one of these trends was coherent with a topic identified for “Processes, impacts, risks -
706 Runoff pollution”: linking aquatic ecology to emissions, i.e. mitigating the impact of pollutants on the
707 environment by new monitoring techniques, integral data sets and harmonised indicator metrics.
708 These topics were identified as highly novel and important, but less familiar (Blumensaat et al., 2019),
709 and the fact that they were named by different parties in our study shows a common awareness of
710 them.

711 The evaluation of the organisation and legislative structure in the countries represented in our study
712 also can be a source of slowing down innovation in the urban drainage sector; this phenomenon was
713 mentioned in Qiao et al. (2018). The evidence collected in this study shows a high degree of agreement
714 in the challenges and constraints that are faced in the area of stormwater management and that more
715 collaborative and coordinated approaches are needed. Forrest et al. (2020) name existing regulations
716 or policies as prohibitive or restrictive in terms of implementing sustainable solutions, including
717 rainwater harvesting and greywater reclamation. The analysis of the documents and responses in our
718 study did show that the regulatory and organizational structures put in place to manage stormwater
719 varied considerably, from country to country and even within some countries, e.g. Spain. Some

720 countries manage stormwater at a single municipality level whilst others at a larger scale integrating
721 urban and surrounding rural areas. Confusion on responsibility for stormwater management was
722 mentioned in several countries.

723 This diversity in approach has happened even with several well-established European directives, such
724 as the Water Framework Directive and the Urban Wastewater Treatment Directive, which are widely
725 thought to be effective. It is clear that many countries have tried to integrate stormwater management
726 into existing governmental structures with a range of success in terms of effective flood risk reduction.
727 Changes in the legislation and organisation of stormwater management are occurring or are proposed
728 in all countries studied; however, it is clear that an “ideal” approach has not yet been identified. This
729 period of changes offers significant opportunity for comparative studies as new organisational and
730 regulatory structures are introduced. However, more integrated planning of the water sector, which
731 was one of the points mentioned for different criteria and categories, as well as clarifying roles and
732 responsibilities of all actors need to be more strongly implemented.

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742 [Disclosure statement](#)

743 The authors declare that they have no known competing financial interests or personal relationships
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745 **References**

- 746 Andrés-Domenech, I., Anta, J., Perales-Monpaler, S., Rodríguez-Hernández, J. (2021) Sustainable Urban
747 Drainage Systems in Spain: A Diagnosis. *Sustainability* 13, 2791.
748 <https://doi.org/10.3390/su13052791>.
- 749 ARE (2022) Umgang mit dem Klimawandel im kantonalen Richtplan. Bundesamt für Raumentwicklung
750 (eds.). [https://www.are.admin.ch/are/de/home/medien-und-](https://www.are.admin.ch/are/de/home/medien-und-publikationen/publikationen/strategie-und-planung/umgang-mit-dem-klimawandel-im-kantonalen-richtplan.html)
751 [publikationen/publikationen/strategie-und-planung/umgang-mit-dem-klimawandel-im-](https://www.are.admin.ch/are/de/home/medien-und-publikationen/publikationen/strategie-und-planung/umgang-mit-dem-klimawandel-im-kantonalen-richtplan.html)
752 [kantonalen-richtplan.html](https://www.are.admin.ch/are/de/home/medien-und-publikationen/publikationen/strategie-und-planung/umgang-mit-dem-klimawandel-im-kantonalen-richtplan.html) (accessed 23/11/2022). In German.
- 753 AWEL (2022) Richtlinie und Praxishilfe Regenwasserbewirtschaftung.
754 [https://www.zh.ch/content/dam/zhweb/bilder-dokumente/themen/planen-](https://www.zh.ch/content/dam/zhweb/bilder-dokumente/themen/planen-bauen/bauvorschriften/bauvorschriften-zu-abwasser-versickerung/versickerung/richtlinie-und-praxishilfe-regenwasserbewirtschaftung-awel-2022.pdf)
755 [bauen/bauvorschriften/bauvorschriften-zu-abwasser-](https://www.zh.ch/content/dam/zhweb/bilder-dokumente/themen/planen-bauen/bauvorschriften/bauvorschriften-zu-abwasser-versickerung/versickerung/richtlinie-und-praxishilfe-regenwasserbewirtschaftung-awel-2022.pdf)
756 [versickerung/versickerung/richtlinie und praxishilfe regenwasserbewirtschaftung awel 202](https://www.zh.ch/content/dam/zhweb/bilder-dokumente/themen/planen-bauen/bauvorschriften/bauvorschriften-zu-abwasser-versickerung/versickerung/richtlinie-und-praxishilfe-regenwasserbewirtschaftung-awel-2022.pdf)
757 [2.pdf](https://www.zh.ch/content/dam/zhweb/bilder-dokumente/themen/planen-bauen/bauvorschriften/bauvorschriften-zu-abwasser-versickerung/versickerung/richtlinie-und-praxishilfe-regenwasserbewirtschaftung-awel-2022.pdf) (accessed 23/11/2022). In German.
- 758 BAFU (2018) Hitze in Städten. Grundlage für eine klimaangepasste Siedlungsentwicklung (Heat in cities.
759 Basic principles for an urban development adapted to climate). Bundesamt für Umwelt, Bern.
760 Umwelt-Wissen, Nr. 1812.
761 [https://www.bafu.admin.ch/bafu/de/home/themen/klima/publikationen-](https://www.bafu.admin.ch/bafu/de/home/themen/klima/publikationen-studien/publikationen/hitze-in-staedten.html)
762 [studien/publikationen/hitze-in-staedten.html](https://www.bafu.admin.ch/bafu/de/home/themen/klima/publikationen-studien/publikationen/hitze-in-staedten.html) (accessed 22/06/2022). In German.
- 763 BAFU (2022) Regenwasser im Siedlungsraum - Starkniederschlag und Regenwasserbewirtschaftung in
764 der klimaangepassten Siedlungsentwicklung (Stormwater in settlements – extreme
765 precipitation in climate-adapted settlements). Bundesamt für Umwelt (BAFU); Bundesamt für
766 Raumentwicklung (ARE). Umwelt-Wissen Nr. 2201. In German.
- 767 Bertrand-Krajewski, J.-L. (2021) Integrated urban stormwater management: Evolution and
768 multidisciplinary perspective. *Journal of Hydro-environment Research* 38, 72-83,
769 <https://doi.org/10.1016/j.jher.2020.11.003>.
- 770 Blumensaat, F., Leitão, J.P., Ort, C., Rieckermann, J., Scheidegger, A., Vanrolleghem, P.A., Villez, K.
771 (2019) How urban storm- and wastewater management prepares for emerging opportunities
772 and threats: digital transformation, ubiquitous sensing, new data sources, and beyond – a
773 horizon scan. *Environmental Science and Technology*, 53(15), 8488-8498.
774 <https://doi.org/10.1021/acs.est.8b06481>.
- 775 BMU (2021) National Water Strategy, Draft of the Federal Ministry of Environment.
776 Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit, Bonn.
777 <https://www.bmu.de/en/download/national-water-strategy> (accessed 20/04/2022).
- 778 Bohman, A., Glaas, E., Karlson, M. (2020) Integrating Sustainable Stormwater Management in Urban
779 Planning: Ways Forward towards Institutional Change and Collaborative Action. *Water MDPI*
780 12(1), 203. <https://doi.org/10.3390/w12010203>.
- 781 cNWP (2022) Nationaal Water Programma 2022-2027 (National Water Program 2022-2027).
782 Ministerie van Infrastructuur en Waterstaat, Ministerie van Landbouw, Natuur en
783 Voedselkwaliteit, Ministerie van Binnenlandse Zaken en Koninkrijksrelaties.
784 [https://www.helpdeskwater.nl/onderwerpen/wetgeving-beleid/nationaal/nationaal-water-](https://www.helpdeskwater.nl/onderwerpen/wetgeving-beleid/nationaal/nationaal-water-programma-2022-2027/)
785 [programma-2022-2027/](https://www.helpdeskwater.nl/onderwerpen/wetgeving-beleid/nationaal/nationaal-water-programma-2022-2027/) (accessed 21/04/2022). In Dutch.
- 786 Eawag (2012) Abwasserentsorgung 2025 in der Schweiz. (Wastewater management 2025 in
787 Switzerland). Schriftenreihe der Eawag Nr. 21. [https://www.lib4ri.ch/institutional-](https://www.lib4ri.ch/institutional-bibliography/eawag/schriftenreihe-der-eawag.html)
788 [bibliography/eawag/schriftenreihe-der-eawag.html](https://www.lib4ri.ch/institutional-bibliography/eawag/schriftenreihe-der-eawag.html) (accessed 22/06/2022). In German.
- 789 Forrest, N., Stein, Z., Wiek, A. (2020) Transferability and scalability of sustainable urban water solutions
790 – A case study from the Colorado River Basin. *Resources, Conservation & Recycling* 157, 104790.
791 <https://doi.org/10.1016/j.resconrec.2020.104790>.

792 Gobierno de España (2020) Libro Verde de la Gobernanza del Agua en España (Spanish Green Book on
793 Water Governance). [https://www.miteco.gob.es/es/agua/temas/sistema-espaniol-gestion-](https://www.miteco.gob.es/es/agua/temas/sistema-espaniol-gestion-agua/Libro-Verde-de-la-Gobernanza-del-Agua.aspx)
794 [agua/Libro-Verde-de-la-Gobernanza-del-Agua.aspx](https://www.miteco.gob.es/es/agua/temas/sistema-espaniol-gestion-agua/Libro-Verde-de-la-Gobernanza-del-Agua.aspx) (accessed 20/04/2022). In Spanish.

795 IWA (2016) The IWA Principles for Water Wise Cities (2nd edition). International Water Association
796 (ed.), London, United Kingdom. [https://iwa-network.org/wp-](https://iwa-network.org/wp-content/uploads/2016/10/IWA_Brochure_Water_Wise_Communities_SCREEN-1.pdf)
797 [content/uploads/2016/10/IWA_Brochure_Water_Wise_Communities_SCREEN-1.pdf](https://iwa-network.org/wp-content/uploads/2016/10/IWA_Brochure_Water_Wise_Communities_SCREEN-1.pdf) (accessed
798 06/04/2022).

799 Langeveld, J.G., Cherqui, F., Tscheikner-Gratl, F., Muthanna, T.M., Fernandez-Delgado Juarez, M.,
800 Leitão, J.P., Roghani, B., Kerres, K., Almeida, M.C., Werey, C., Rulleau, B. (2022) Asset
801 management for blue-green infrastructures: a scoping review. *Blue-Green Systems* 4(2), 272–
802 290. <https://doi.org/10.2166/bgs.2022.019>.

803 Ministerio para la Transición Ecológica (2019) Guías de adaptación al riesgo de inundación. Sistemas
804 Urbanos de Drenaje Sostenible (Flood risk adaptation guidelines. Sustainable Urban Drainage
805 Systems). Spanish Ministry for Ecological Transition.
806 [https://www.miteco.gob.es/es/agua/temas/gestion-de-los-riesgos-de-inundacion/guia-](https://www.miteco.gob.es/es/agua/temas/gestion-de-los-riesgos-de-inundacion/guia-adaptacion-riesgo-inundacion-sistemas-urbano-drenaje-sostenible_tcm30-503726.pdf)
807 [adaptacion-riesgo-inundacion-sistemas-urbano-drenaje-sostenible_tcm30-503726.pdf](https://www.miteco.gob.es/es/agua/temas/gestion-de-los-riesgos-de-inundacion/guia-adaptacion-riesgo-inundacion-sistemas-urbano-drenaje-sostenible_tcm30-503726.pdf)
808 (accessed 20/04/2022). In Spanish.

809 Ministerio de Fomento (2018) Spanish Urban Agenda. Spanish Ministry of Development.
810 <https://www.aue.gob.es> (accessed 20/04/2022).

811 MTE (2021) Gestion durable des eaux pluviales : le plan d'action. (Sustainable managing of stormwater:
812 action plan). Ministry of Ecological Transition.
813 [https://www.ecologie.gouv.fr/sites/default/files/Gestion_durable_des_eaux_pluviales_le_pla-](https://www.ecologie.gouv.fr/sites/default/files/Gestion_durable_des_eaux_pluviales_le_plan_daction.pdf)
814 [n_daction.pdf](https://www.ecologie.gouv.fr/sites/default/files/Gestion_durable_des_eaux_pluviales_le_plan_daction.pdf) (accessed 22/06/2022). In French.

815 Qiao, X.-J., Kristoffersson, A., Randrup, T.B. (2018) Challenges to implement urban sustainable
816 stormwater management from a governance perspective: A literature review. *Journal of Cleaner*
817 *Production* 196, 943-952.

818 Schweizerische Eidgenossenschaft (2020) Anpassung an den Klimawandel in der Schweiz - Aktionsplan
819 2020-2025 (Adapation to Climate Change – Action Plan 2020 – 2025). Bundesamt für Umwelt
820 (ed.). Bern, 164 p. <http://www.bafu.admin.ch/ui-2022-d> (accessed 15/09/2022). In German.

821 UN (2015) Transforming our world: The 2030 Agenda for Sustainable Development. United Nations.
822 [https://www.un.org/ohrrls/sites/www.un.org.ohrrls/files/2030_agenda_for_sustainable_devel-](https://www.un.org/ohrrls/sites/www.un.org.ohrrls/files/2030_agenda_for_sustainable_development_web.pdf)
823 [opment_web.pdf](https://www.un.org/ohrrls/sites/www.un.org.ohrrls/files/2030_agenda_for_sustainable_development_web.pdf) (accessed 19/09/2022)

824 Water Europe (2016) The Value of Water. Multiple Waters for Multiple Purposes and Users. Water
825 Europe, Brussels, Belgium, ISBN: 9789028362130.

826 Water Europe (2021) Digitalization & Water. Start with digital water and end with a water-smart digital
827 sector. Water Europe, Brussels, Belgium. [https://watereurope.eu/wp-content/uploads/WE-](https://watereurope.eu/wp-content/uploads/WE-Position-Paper-Digitalization-and-Water.pdf)
828 [Position-Paper-Digitalization-and-Water.pdf](https://watereurope.eu/wp-content/uploads/WE-Position-Paper-Digitalization-and-Water.pdf) (accessed 11/04/2022).

829 Water Europe (2022) Opportunities for Hybrid Grey and Green Infrastructure in Water Management:
830 Challenges and ways forward. Water Europe, Brussels, Belgium, ISBN 9789464003086

831 Water Europe SIRA (2016) Water Europe Strategic Innovation and Research Agenda (Water Europe
832 SIRA) 2030. Water Europe, Brussels, Belgium, ISBN 9789028362161.

833 Wihlborg, M., Sörensen, J., Olsson, A. (2019) Assessment of barriers and drivers for implementation of
834 blue-green solutions in Swedish municipalities. *Journal of Environmental Management* 233, 706-
835 718. <https://doi.org/10.1016/j.jenvman.2018.12.018>.