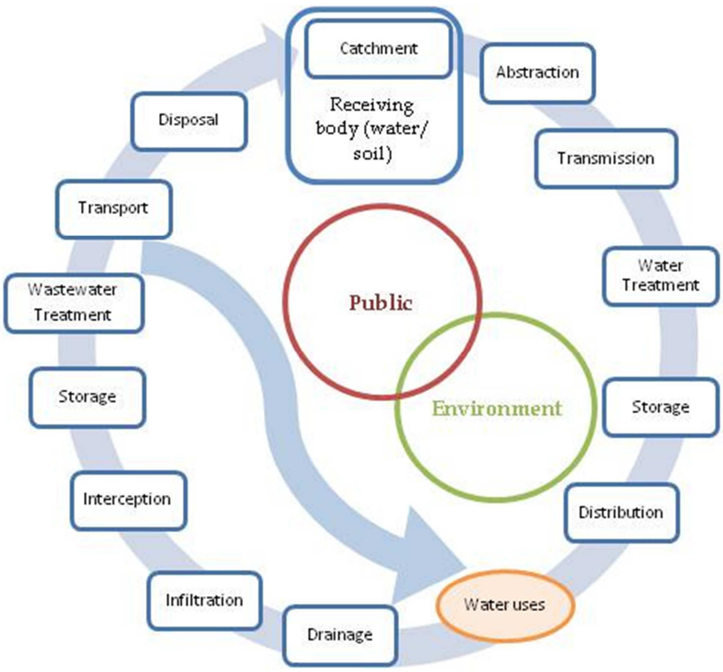
Prepared
enabling change

Risk reduction measures

Supporting document for RRDB structure



SEVENTH FRAMEWORK PROGRAMME

COLOPHON

Title

Risk reduction measures. Supporting document for RRDB structure

Report number
PREPARED 2011.025

Deliverable number

Accompanying document to D 2.4.1.

The deliverable PREPARED 2011.025 D.2.4.1 consists of two parts, a database and an explanatory report. The database is called: *D 2.4.1 Risk reduction measures database (RRDB)*. The explanatory report is called: *D 2.4.1 Risk reduction measures. Supporting document to RRDB structure*

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Document history

Version	Team member	Status	Date update	Comments
0	MC Almeida	Draft	2011-02-01	First proposal of contents
1	MC Almeida	Draft	2011-02-08	First version for consideration by IWW
2	MC Almeida	Draft	2011-03-23	Version + Excel after Skype 22/March2011
3	MCA/CS	Draft	2011-04-06	Updated version
4	LNEC Team	Draft	2011-05-09	Updated version
5	LNEC Team	Draft	2011-09-01	Version to QA
6	All	Final	2011-09-08	Final version incorporating QA

This report is:

PU = Public

Summary

Potential effects of climate dynamics on the urban water cycle can involve the aggravation of existing conditions as well as occurrence of new hazards or risk factors. The risks associated with expected climate changes have to be dealt with by the society in general and by the water utilities and other stakeholders in particular.

The challenges created by climate dynamics require an integrated approach for dealing with existing and expected levels of risk. Given the interactions of urban water and natural systems, adaptation measures should address all water cycle components and their interactions.

The application of the proposed WCSP framework requires a number of tools to facilitate the tasks of working groups involved. One of these tasks is the identification and selection of appropriate risk reduction measures (RRM) to face those risks that were found to be not acceptable.

The database of risk reduction measures (RRDB) is intended to facilitate the systematic identification of RRM for each risk as well as help quantifying the potential for risk reduction.

This document introduces the risk reduction database structure, providing background information, a classification of RRM and presents the adopted database structure as well as the selected criteria to characterise each measure.

The subsequent PREPARED tasks allow testing and improving of this initial proposal of the RRDB as well as feeding the database with data from the selected case studies of the project.

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Acronyms

CSO	Combined sewer overflow
ERP	Emergency response plan
RRM	Risk reduction measure
RIDB	Risk identification database
RRDB	Risk reduction measures database
SOP	Standard operating procedures
SSO	Stormwater sewer overflow
SSP	System safety plan
WCSP	Water cycle safety plan

1 Introduction

1.1 Background

Climate dynamics trends impose important challenges to the urban water sector. Alteration of the range of operation conditions, which may result from atmosphere and sea temperature increase, variation in precipitation quantity and patterns or increase of average sea level, needs to be dealt with proactively by the different stakeholders involved in the urban water cycle.

Potential effects of climate changes on the urban water cycle involve the aggravation of existing conditions as well as occurrence of new hazards or risk factors.

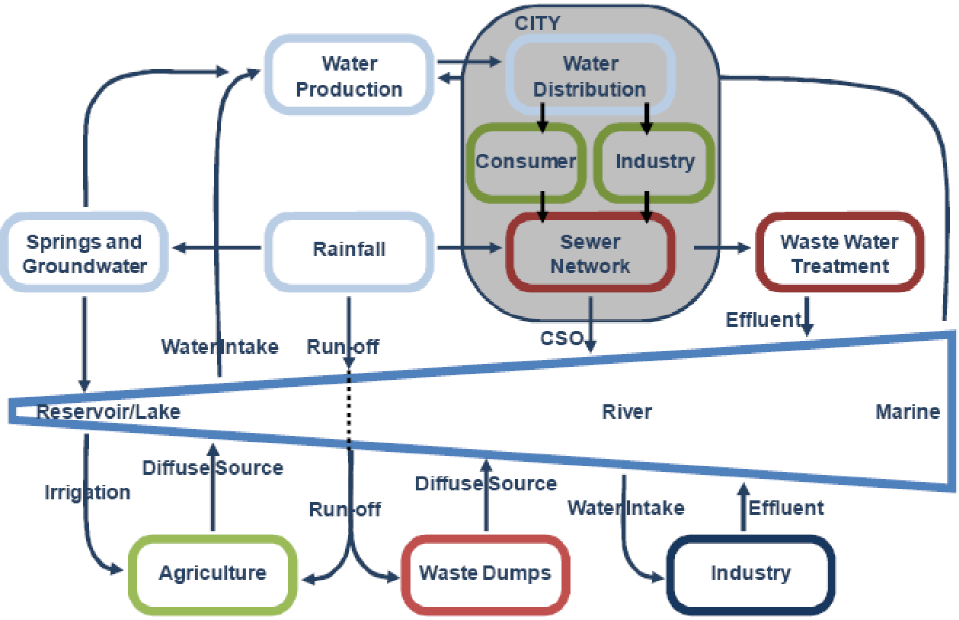


Figure 1 - Water cycle interactions and the city (Extract from PREPARED DoW)

The risks associated with expected climate changes have to be dealt with by the society in general and, in particular, by the water utilities and other stakeholders. It is recognised that these challenges require an integrated approach for dealing with existing and expected levels of risk.

Given the interactions of urban water and natural systems and the effects of climate changes affecting the entire water cycle, adaptation measures should address all water cycle components and their interactions. Therefore, a generic framework to tackle the climate change problematic is required. This framework is intended to be systematic and to incorporate uncertainties. Important steps of the framework include identification of risks and opportunities in terms of alternative actions.

While climate changes affect probability and consequences of events, and ultimately originate different events not traditionally experienced in a region, alternatives to address the problems originated by these events are not climate dependent. Hence, classification of interventions or risk reduction measures (RRM) is intrinsically associated with the events resulting in undesired effects.

Within the proposed WCSP framework, two main steps deal with risk treatment (Figure 2). At the integrated level, the risk reduction (RRDB) database is a tool for supporting step 7 - Integrated risk treatment; at system level, for different systems, different sets of risk reduction measures (RRM) need to be identified at step 5.6 depending on the type of system and possible events (Almeida *et al.*, 2010).

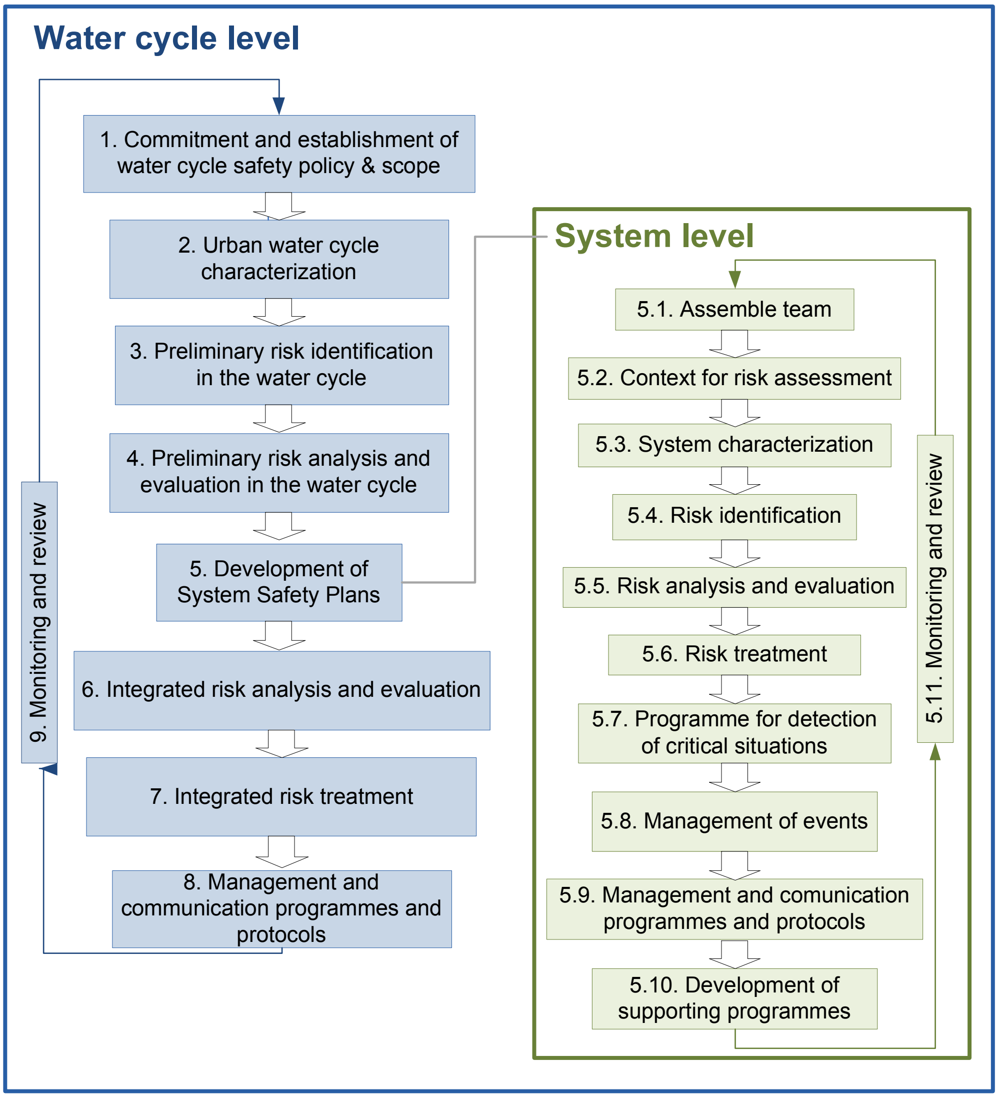


Figure 2 - WCSP framework

The purpose of risk treatment is to modify the previously identified risks that need treatment and involves the selection and evaluation of risk reduction measures. These measures include actions, activities or processes that can be applied at integrated or system level in order to reduce the occurrence and minimize consequences of events. These measures can act on risks in different ways:

- reduce the level of risk either by modifying the likelihood and/or by changing the consequences;

- avoiding the risk by discontinuing the activity that originates the risk;
- removing the risk source;
- sharing the risk with another party.

At both levels of analysis, WCSP key actions include identification, comparison, prioritisation and selection of risk reduction measures. Subsequently, a risk treatment program is developed.

The PREPARED RRDB incorporates information intended to facilitate the application of these steps, especially for identification of risk reduction measures (Table 1).

Table 1– Key actions considered in WCSP risk treatment steps

Integrated level: Step 7.	**Identify risk reduction measures** **Compare, prioritize and select risk reduction measures** **Develop a risk treatment program** **Assess residual risk**
System level: Step 5.6	Identify risk reduction measures Compare, prioritize and select RRM Develop a risk treatment program Assess residual risk

There are numerous factors that determine the level of risk. These **risk factors** can have an effect on the risk level by modifying the **likelihood** or the **consequences** of an event. These risk factors are often causes or causal factors that can be acted upon using risk reduction measures.

At the **water cycle integrated level** issues and interactions are dealt with at a macro scale. Detailed processes analysis is carried out at the **system level**. At the water cycle level it does not make sense to analyse in detail specific processes or component functioning. These should be dealt with at systems level.

At the water cycle level not only treatment measures acting on technical systems are available. For instance, stakeholders other than water systems managers can implement measures to reduce risk, such as measures to control land use or to enforce specific regulations.

Furthermore, measures at the integrated level can complement those at system level, especially when stakeholders other than water utilities are the promoters. For instance, efficient detection and alarm systems are an important way to reduce risk; therefore a program for detection of critical situations at the water cycle level should be developed to complement those existing at system level. Improved communication and the awareness of the effects on elements controlled by other stakeholders will increase the efficacy of responsive actions.

The RRDB structure needs to reflect these differences to make the job of the responsible team easier. Thus, specific measures applying to the different levels should be included.

1.2 Scope of the WCSP and RRDB

Widening the scope of safety plans implies consideration of multiple primary aims when looking at the water cycle. Therefore, the envisaged scope of the water cycle safety plans comprises the **protection of public health** but also the **public safety** and the **protection of the environment**. Different exposure modes also need to be considered.

Aspects of water quality as well as water quantity need to be addressed. Numerous examples of interaction between quality and quantity can be given such as the potential effect of water shortages in deterioration of water quality. Insufficient water supply as well as excessive water may cause safety issues (e.g. lack of water for fire fighting, flooding).

The data structure of the RRDB needs to incorporate all these aspects.

1.3 Definitions adopted in this report

A number of definitions used in this report are defined in this section to help communication between different partners. Different terms are often used for the same purpose, or the same term is used with different meanings. Thus, the definitions presented in Table 2 are adopted within the present document and are intended to clarify the meaning as used by the authors. Definitions already presented in reports D 2.1.1 and D 2.2.2 are also considered and not repeated herein.

Table 2 – Definitions adopted in the document

Expression	Definition
Risk reduction measure	Set of actions allowing modification of risk. RRM includes any process, policy, device, practice, or other actions which modify risk and may not always exert the intended or assumed modifying effect.
Risk reduction action	Specific action needed to properly implement the selected RRM. Actions can be of very different nature.

1.4 Structure of the document

The main purpose of this report is to introduce the risk reduction database, providing background information, suggesting a classification of risk reduction measures and criteria to characterise each measure and presenting the proposed database structure.

In this introductory chapter, the background, the relevance of the RRDB for the application of the WCSP framework and specific terminology are presented.

In chapter 2, specifications for each risk reduction measure are presented, including criteria to characterise and define applicability, criteria to assess the potential for risk reduction, actions recommended for implementation and criteria for analysis of viability.

Chapter 3 presents details on aspects to consider in organising risk reduction measures, including the levels and units of analysis.

An overview of the RRDB structure is presented in chapter 4, including the data structure for the RRM catalogue and for the RRM directories. Finally, the main steps to proceed with RRM identification and selection are described.

2 Information requirements on RRM

2.1 General aspects

Information requirements for specifying each risk reduction measure for the purpose of the RRDB cover four main groups:

- Characterisation and applicability;
- Potential for risk reduction;
- Implementation strategy;
- Analysis of viability.

The selected criteria used to describe the four main groups are presented in the following sections. This information allows the user to proceed with a preliminary selection of the RRM having potential to reduce the risk associated with each event for which risk level was found to be not acceptable. A first indication of the potential for risk reduction, of the level of resources involved and actions recommended for the efficient implementation are also of interest to provide a first estimate of the results that might be achieved and effort required.

The criteria should be useful to implement the WCSP framework steps. At different levels of development different detail might be required. In making a first screening of adequate measures, simple and easy to use criteria are preferred but, in later stages, detailed analysis for comparison of measures, more comprehensive criteria might be favoured.

2.2 Criteria to characterise and define applicability of each measure

2.2.1 *Relevant information*

The characterisation and definition of applicability conditions of each measure is essential. The items of information considered relevant for this purpose are:

- description of the measure;
- type of measure to reduce risk;
- contribution to primary aims of WCSP;
- application to level of analysis, system and subsystem;
- type of technical problems addressed;
- appropriate metrics for performance assessment;
- main advantages;
- main disadvantages.

The cost level that might be associated to the measure is not included in this part since it is considered in the criteria for the analysis of viability.

2.2.2 *Description of the RRM*

The description of the measure is a concise explanation of what the measure is about, avoiding repeating information that can be included in the remaining items of this group.

2.2.3 *Type of measure to reduce risk*

Different types of measures are reported by different authors. For instance, for technical systems, Rausand and Høyland (2004) suggest four generic types of measures to reduce risk, namely, the use of barriers, redundancy, personnel training and monitoring, testing and inspections. Others include measures that imply avoidance of a risk, including not initiating or discontinuing an activity (e.g. water reuse for a certain purpose) or a technical process (not using a specific technical process). Some authors classify the type of measure to reduce risk according to major steps, namely, inherently safer design (elimination of hazards), initiating event prevention and accident mitigation (e.g. Kumamoto, 2007). Frequently, types of measures are associated with risk factors, often divided into human, environment and equipment.

Given the reported possibilities and the specificities of the WCSP framework, the following types of measures are considered:

- **Barriers** - any physical impediment or containment method that tends to confine and/or restrict a potentially damaging condition, reducing the probability of events, or containment of event after its occurrence, reducing consequences.
- **Redundancy** - additional, identical and redundant components in a system introduced to decrease the probability of failure of subsystems.
- **Increase components or systems reliability** - substitution of critical elements by more reliable ones, structural modifications of the systems or changes to the safety systems logics (see Cigolini *et al.*, 2009).
- **Increase components or systems effectiveness** - substitution or improvement of system elements by more efficient ones, including upgrading of technology.
- **Prevention of human error** – limiting the effects of a human error, namely by changing human-system interfaces (including changes in automation), changes in procedures (including changing in tasks) or changes in training (Kumamoto, 2007).
- **Maintenance** – adequate preventive or corrective maintenance activities can reduce failure rates and consequently the likelihood of events.
- **Control systems** – detection of failure states, existence of unsafe conditions, by means of monitoring, testing or inspection, and actions to change the state of systems;
- **Accident mitigation** – safe shutdown, continuity in availability of utility's services, adequate confinement integrity and emergency preparedness;
- **Insurance and outsourcing** - the option of risk sharing with another party typically includes insurance and careful contract management, for instance, outsourcing.
- **Avoidance of a risk** – measures that involve deciding not to start or continue with the activity that gives rise to the risk, including not initiating or discontinuing an activity (e.g. water reuse for a certain purpose) or a technical process (not using a specific technical process);

- **Economic and accounting policies** – management practices including water tariffs and reserving money for provisions. Careful establishment of water tariffs is essential as an incentive to not overuse resources. Accounting policies could include e.g. a reserve fund to face events with high consequence but low likelihood available as resource for proper risk management. So a utility would have money ready to pay for instance for alternate water supply services in case of a total breakdown of the water supply system. These measures can be alternatives to making high investments into water supply systems reliability e.g. increasing redundancy. While events do not occur, money is not bound into illiquid assets (as it would be if it has been spend for more system-redundancy) but is still liquid and monetary resources can be spend to face very different contingencies;
- **Adaptation of user and public behaviour** – changes in behaviour of system users or public in general allowing the risk reduction by decreasing the probability or the consequence of an event.

Some overlaps between these types of measures may occur, but are inevitable due to complexity.

2.2.4 *Contribution to WCSP primary aims*

Considering the scope of WCSP, the primary aims of the water cycle safety plans are the **protection of public health and safety** and **protection of the environment** (Table 3).

Table 3 – Definition of the aims of the WCSP

Primary aim	Exposure to hazards	Generic / typical hazards
Protection of public health	Consumer / user	Non-safe water at consumption or use (chemical, microbial characteristics)
	Recreational user	Polluted water when bathing (microbial, chemical contamination)
	Public	Flooding with water contaminated with sewage
Protection of public safety	Consumer / user Public Utility worker*	Infrastructure collapses / bursts Flooding Chemical spillage Release of toxic gases
Protection of environment	Receiving waters (water quality, ecosystems) (Soil) (Air)	Overuse of resources Pollution affecting ecological /chemical status of receiving waters

* In general these issues are dealt with by health and safety legislation, thus not necessarily included in WCSP unless specific conditions occur

For each measure, the potential contribution to one or more primary aims should be identified, as appropriate. When applicable to more than one, the measure should be split in two, since some characteristics may differ. For instance, one measure may apply to reduce risk to public health and to the environment but the results obtained as well as the actions required often differ.

2.2.5 *Application to level of analysis, system and subsystem*

An indication of the level of analysis, system and subsystem to which the measure can be considered facilitates the selection of the measures for specific applications. Herein, subsystem is understood as those parts of the system that provide a specific function, and not necessarily geographically or physically associated parts of a system such as a demand management area in a drinking water system.

As defined in the WCSP framework, analysis can be carried out at integrated (water cycle) level or at system level. In both levels, a measure can be applicable to different systems or subsystems (Table 4). When the measure is not specific to a unit of analysis (and can be used in either level) "general" can be used.

Table 4 – Level of analysis, system and subsystem

Level of analysis	System	Subsystem
1. Integrated	.1. Catchment basin .2. Drinking water .3. Non-drinking water .4. Wastewater .5. Stormwater .6. Receiving waters	(as below for the systems)
2. System	.1. Catchment basin	.1. Surface water catchment .2. Groundwater catchment
	.2. Drinking water	.1. Surface water reservoir .2. Groundwater reserves .3. Abstraction system .4. Groundwater recharge .5. Water treatment .6. Transmission .7. Pumping stations .8. Storage .9. Distribution .10. Plumbing systems
	.3. Non-drinking water	.1. Catchment system .2. Water treatment .3. Advanced wastewater treatment .4. Transmission .5. Pumping stations .6. Storage .7. Distribution .8. Plumbing systems

Table 4 – Level of analysis, system and subsystem (continued)

Level of analysis	System	Subsystem
	.4. Wastewater	.1. Wastewater collection network
		.2. Interceptor system
		.3. Wastewater treatment
		.4. Combined sewer overflows
		.5. Pumping stations
		.6. Storage structures
		.7. Infiltration systems
		.8. Outfalls
	.5. Stormwater	.1. Urban catchments
		.2. Stormwater collection network
		.3. Infiltration systems
		.4. Source controls
		.5. Stormwater treatment
		.6. Stormwater overflows
		.7. Pumping stations
		.8. Storage structures
	.6. Receiving waters	.1. River
		.2. Estuary
		.3. Lake
		.4. Coastal water
3. General	(measure applicable independent of unit of analysis)	

2.2.6 *Type of technical problem addressed*

Different risks and events can have specific technical problems or performance deficiencies associated. Indication of those that can be addressed by the measure is relevant. One RRM can address more than one type of problem.

Most of these technical problems have links with potential climate changes. For sewer systems these problems are systematically presented in the EN 752:2008 and prEN 14 654-2:2010, as well as corresponding sets of measures. Considering all systems, the following types can be considered:

- **Hydraulic** – examples of hydraulic problems in sewer systems include limited or insufficient pipe flow capacity, high peak flows, high flow from illicit connections or sources that should not be directed to sewer, upstream network expansion, flow limited by downstream receiving water level (for instance, subject to tide dynamics) and sedimentation problems. In water supply systems, typical problems are associated with low pressure, undersized pipes, diameter reduction due to incrustations, and increase in water demand.
- **Environmental** – in wastewater and stormwater systems environmental problems include illicit polluted discharges to sewers, untreated discharges from CSO or SSO, exfiltration from sewers, low efficiency in treatment processes.

- **Structural** – in urban water systems structural problems are associated with physical deterioration of component, increasing likelihood of component collapse.
- **Operational** – extensive and expensive operations due to high maintenance, inspection or cleaning requirements, high energy and other resources consumption.
- **Water supply quality** – in water supply systems water quality problems include various possible causes of contamination at abstraction works, low efficiency at treatment works, low velocities causing long retention times and reduction of water quality, poor component condition may deteriorate water quality and poor hydrodynamics in storage tanks may also deteriorate water quality.
- **Water supply scarcity** – causes for water supply interruption can be due to failure of the performance of system components, high demand compared with source availability and water shortages due to low precipitation or contamination of water sources.

The potential impact of the measures in existing technical problems, as presented above, can be expressed in ordinal scales (Table 5), as adequate.

Table 5 – Measure potential for contributing to reduce technical problems

Class	Effect in technical problem
-2	Potential for severe aggravation of the problem
-1	Moderate aggravation of the problem
0	No significant effect
1	Potential for moderate improvement
2	Potential for major improvement

2.2.7 *Indicators or other indexes for performance assessment*

The evaluation of different risk reduction measures may benefit from using specific performance metrics. A minimum set of appropriate indicators or indexes for performance assessment of each specific measure can be provided. The performance metrics can be grounded on IWA performance indicators (Alegre *et al.*, 2006; Matos *et al.*, 2003) or in more specific technical performance measures (Cardoso *et al.*, 2007). For instance, in the case of a sewer system, for an environmental problem, indicators could include CSO number of discharges per year, CSO volume per year, CSO maximum peak flow per year, average concentration of parameter x in CSO discharge.

2.2.8 *Main advantages*

As a complement to the initial description of the measure, the main advantages of the measure, especially linked with climate change effects, can be described here.

2.2.9 *Main disadvantages*

As a complement to the initial description of the measure, the main disadvantages of the measure, especially in terms of potential for side effects (e.g., some RRM may create secondary risks or increase other existing risks), negative impacts on environment or use of resources, and linkage with climate change effects can be described here.

2.3 Criteria to assess the potential for risk reduction

2.3.1 *Relevant information*

Information about potential for risk reduction is undoubtedly relevant to use the RRDB. The items of information considered for this purpose are:

- type of risk reduction potentially achieved with the measure;
- risk reduction effectiveness;
- overall risk reduction cost efficiency.

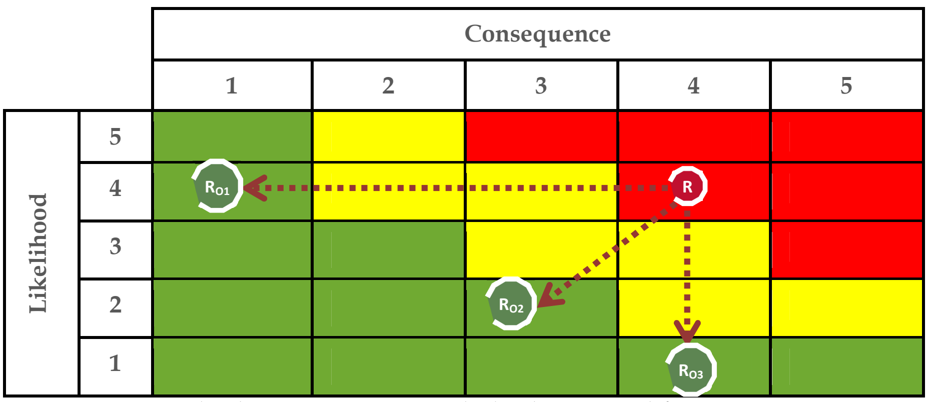
2.3.2 *General types of RRM*

Considering the purpose of risk treatment, in general, RRM comprises all measures with potential to reduce risk. The risk treatment concept, as presented in ISO 31 000:2009, consists in the process of modifying risk. Herein, emphasis of the analysis is only on events with negative consequences, and possibilities consist of:

- **avoiding the risk (A)** by deciding not to start or continue with the activity that gives rise to the risk;
- **reducing the likelihood (L)**, by removing the risk source, acting on relevant risk factors or causes;
- **reducing the consequences (C)**, considering all potential dimensions of the consequence; and
- **sharing the risk (S)** with another party or parties, including contracts and risk financing.

A combination of likelihood and consequence (**LC**) can be obtained with some measures.

Retaining the risk by informed decision is a possible course of action but it can hardly be considered as a risk reduction measure.



Key: R – Estimated risk; R_{01}, R_{02}, R_{03} are residual risks estimated for RR measures 01, 02 and 03, respectively.

Figure 3 – Illustration of objectives of RRM

2.3.3 *Risk reduction effectiveness*

Without specific analysis of specific events and risks it is difficult to determine the estimated effect of a risk reduction measure. Aspects that interest the analyst are the effectiveness of the measure, as an indicator of the achievement of the desired reduction of risk, and the efficiency, understood as the resource consumption for achievement of the desired effect.

Using a scale for the effectiveness can be a first indication based either on experience or expert knowledge. The proposed 3-level scale is thus intended to give a general trend on the effectiveness of the measure. The three levels are associated with the usual risk matrix with three levels of risk.

Table 6 – Measure effectiveness

Class	Risk reduction expected
0	Minor reduction
1	Potential for moderate improvement
2	Potential for major improvement

2.3.4 *Overall risk reduction cost efficiency*

As mentioned in the previous section, together with effectiveness, an indication of the efficiency, understood as resource consumption for achievement of the desired effect, is very useful to support selection of appropriate risk reductions measures in specific applications.

A scale for the expected efficiency can provide a first indication based either on experience or expert knowledge. The proposed scale is thus intended to give a general trend on the overall balance between costs and benefits for the risk reduction achieved.

Table 7 – Measure efficiency as an indicator per risk reduction level

Class	Cost per risk reduction level
0	Doubtful value
1	Justified
2	Highly worthwhile

2.4 Implementation strategy

2.4.1 *Relevant information*

The success of any risk reduction measure strongly depends on the adequacy of the implementation strategy. The strategy needs to clearly include, for each RRM or group of RRM, which type of actions is recommended for the implementation. Co-ordination and involvement of the different stakeholders (water cycle level or system level) should be considered in later stages of application of the WCSP framework.

The main specification included in the RRDB consists of those types of actions that should be considered for adequate implementation and pertinent for cost evaluation.

2.4.2 *Implementation actions*

The types of actions to consider for implementation of measures can be classified into the following categories (Almeida *et al.*, 2004):

- **Design and construction (D&C):** Certain measures involve execution of works or structures, typical phasing is to be considered usually requiring the development of specific design, planning of the works, execution, and other related tasks.
- **Operation and maintenance (O&M):** Tasks of operation and maintenance can be necessary to the measures implementation. For instance, monitoring, testing and inspection, are often essential for providing the information required to potentially reduce the probability, and in some cases the consequences, of undesired events, in conjunction with alarm systems or other corrective actions.
- **Information and education (I&E):** The promotion and dissemination of information on the relevant issues is fundamental for the successful implementation of any measure. Different formats have to be used depending on the target group, which can be the general public or specific groups of professionals, among others.
- **Documentation, training and technical support**: Actions for improvement skills and aptitudes are often essential to increase technical competencies of personnel, without which proper implementation of measures can be compromised. Different formats and means can be used, such as, manuals, guidelines, training courses. Regarding personnel training, courses or other instruction programs allow improvement of knowledge, namely improving procedures and performance under all operation conditions, thus reducing the probability or the consequences of an undesirable event.
- **Regulation, standardisation and legislation (RS&L):** Development of documents regulating different aspects of the activities of water utilities, and of other agents influencing the levels of risk, can result in important benefits for risk reduction. These actions include licensing, banning of products or activities, wastewater discharge permits, and compulsory environmental impacts assessment. Certification of activities, firms and products can also bring improvements in the general performance of associated procedures leading to a safer and more reliable operation of water systems (e.g. ISO 22 000).
- **Economic and financial incentives or penalties (E&F):** The establishment of economic and financial incentives often is the best way to foster the application of a certain measure. However, the introduction of penalties can also be effective in some situations.
- **Research and development (R&D):** Despite existing knowledge and experience, there are open areas that need further research to improve the

applicability, efficacy and viability of certain potential measures as well as development of technological innovations.

- **Social support to the population**: Tailored support actions to the population actions can prove to be very effective and are often disregarded or delayed. These are, especially directed at, but not restricted to, the most vulnerable groups such as elderly, lone parents and long-term sick (see Tapsell *et al.*, 2002, for the case of flooding).

2.5 Criteria for analysis of viability

2.5.1 *Relevant information*

A preliminary indication of the viability of the measure provides useful information. However, only general evaluation is possible since viability strongly depends on local conditions.

Criteria considered relevant include general economic criteria, technologic, functional, environmental impact and social acceptance. To all these criteria a qualitative evaluation can be carried out using the codes in Table 8.

Table 8 – Levels of viability

Code	Level of viability
5	High viability
4	Moderate viability
3	Indifferent
2	Tends to be unviable
1	Impracticable

2.5.2 *Economic viability*

Economic viability is strongly dependent on local conditions. While at this step the use of absolute values for cost is not viable for most situations, an alternative indicator of cost magnitude or range can be useful. Therefore, herein only the relative magnitude of required costs in capital expenditure (CAPEX) and expected magnitude of operational expenditure (OPEX) are indicated. Only when carrying out a detailed analysis of the measures the analyst can conclude about the economic viability in specific local conditions and considering relevant economic scenarios. The magnitude of CAPEX and OPEX expected is for an average situation.

CAPEX: Capital expenditures

The capital expenditures include payments for acquiring assets, fixing problems with existing assets, preparing assets to be used in business and costs for property. The sum off all these payments is called CAPEX and is the value which will be capitalized in terms of accounting and will be depreciated over the lifetime of the asset.

The capitalized expenditures will appear in the balance-sheet. But these capitalized expenditures (in sum) are usually no expenses in terms of the income-statement. Hence they do not affect the net-income, since they will not appear in the income-statement as expenses. Only the expenses for depreciation will appear in the income-statement of future periods. Thus, capital expenditures will not affect the net-income of a utility in the period where they are spend, but will affect the net-income of future periods with the depreciation.

Nevertheless, capital expenditures are affecting the statement of cash flows since the CAPEX are payments and therefore influencing the cash flow of investing activities.

OPEX: Operational expenditures

These are the ongoing costs for a project or business. Operational expenditures do include payments for supplies and raw materials, maintenance and repair, administration, insurance, salary and wages, power and electricity and so on.

OPEX are the sum of the project or business operating payments for a period of time, for instance a year. In terms of the income-statement these payments are also affecting the net-income since they will appear under expenses. All direct payments will also influence the cash flow statement and hence the cash flow from operating activities.

Depreciation for the assets used for the project or business is not included here.

Valuation and cost level estimation

Both CAPEX and OPEX need to be regarded in a financial valuation of an investment project, like an investment into redundant water supply system parts to reduce the risk of infrastructure failure.

For the purpose of the RRDB it will be sufficient to give a semi-quantitative estimation of the CAPEX and OPEX associated with the measure. This estimation shall be understood on a relative scale from 1 to 5.

The CAPEX should be estimated in relation to the cash flow from investing activities in the cash flow statement of a utility. So a 5 means the CAPEX has a small value in comparison to a utility cash flow from investing activities. So the CAPEX payments are relatively small for the utility (also means potentially easy to afford).

The OPEX should be estimated in relation to the cash flow from operating activities. Analogue to the scale for CAPEX a 5 means a relatively small value in comparison to the cash flow from operating activities of a utility.

Thus, the general categorization scale can be interpreted for the economic viability as presented in Table 9.

Table 9 – Levels of economic viability

Code	Level of viability
5	High viability. OPEX/CAPEX has a small value in comparison to utilities' cash flow
4	OPEX/CAPEX has a moderate value in comparison to utilities' cash flow
3	OPEX/CAPEX has a medium value in comparison to utilities' cash flow
2	OPEX/CAPEX has a high value in comparison to utilities' cash flow
1	Impracticable OPEX/CAPEX has a very high value in comparison to utilities' cash flow.

2.5.3 *Technologic viability*

Corresponds to availability of technology in the market (e.g. products, equipment, methods required for implementation) or sufficient knowledge for the proposed measure. In some cases, further research or development might be necessary.

2.5.4 *Functional viability*

Corresponds to the evaluation in terms of added requirements for operation and maintenance or, when applicable, performing tasks or uses. When applicable, ease of use should also be considered.

2.5.5 *Environmental viability*

Overall balance between environmental benefits and negative impacts. One measure may have some environmental benefits, for instance, reducing water demand, but implies higher energy consumption, thus the economic viability should consider both benefits and negative impacts.

2.5.6 *Social acceptance*

Overall evaluation of expected acceptance, considering acceptability by stakeholders and the public. Even if in technical terms a measure is very promising, if it is not accepted by stakeholders or the public it will not be as effective as expected.

2.6 Organising RRM

Selection and organisation of the RRM must take into account:

- The use of the RRDB at the two levels of analysis (integrated and system's levels) and the specific systems existing within the water cycle;
- Primary aims of WCSP - protection of public health and safety and protection of the environment. Some measures can contribute to more than one aim. This aspect was already detailed at section 2.2.4;
- The relation with the RIDB structure and events considered.

Database structure needs to be easy to understand and to use when looking for possible alternative RRM to take into account in further analysis leading to the decision for implementation and corresponding planning.

Thus, in order to avoid repeating information, the RRM should be stored in a RRM catalogue, numbered sequentially (unique ID) but organised by level of analysis and per analysis unit. Additionally, some measures can be general, thus applicable to any part of the water cycle.

3 Proposed RRDB structure

3.1 Overview

Typifying RRM is a considerable challenge, considering the complexity of the urban water cycle and the numerous potential alternatives that may have a significant effect in reducing risk, while presenting the necessary information and the necessary links to the risk treatment steps at the two levels.

To face this challenge, the general structure of information was divided in two parts: one includes information about the measures; the other includes information to associate the events with the measures that should be considered to reduce risk for each event under analysis. This structure also intends to avoid repetition of information as much as possible.

Therefore the proposed RRDB consists of two main databases (Figure 4):

1. **RRM catalogue** – where the comprehensive list of measures, numbered sequentially with a unique ID, is stored together with its characteristics and attributes for risk reduction, according to chapter 2.
2. **RRM directory** – consists of a set of six sub-databases relating the possible events with the set of measures that can be considered for reducing the risk associated with that event. One database is tailored to support the risk treatment phase at the integrated water cycle level (Step 7) and the other five to support the risk treatment step at system level (Step 5.6), for each type of system (drinking water system, non-drinking water system, wastewater system, stormwater system, receiving waters). These databases are organised by event type in agreement with types considered in the RIDB.

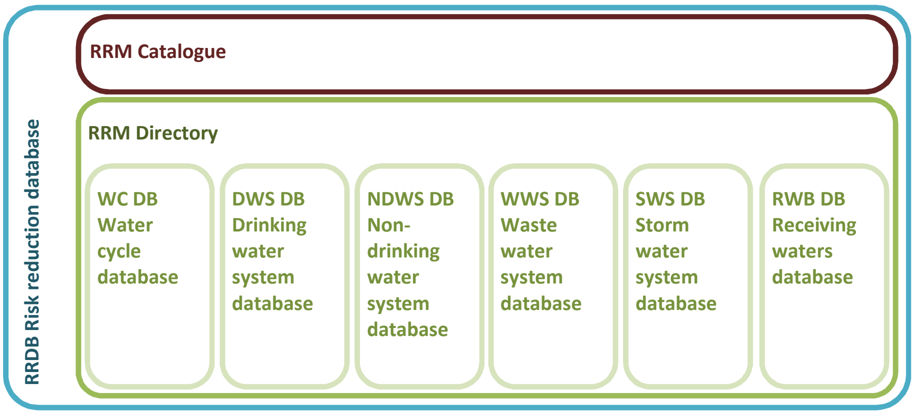


Figure 4 – Main structure of the RRDB

The WCSP and SSP teams may use the databases in the RRM Directory that apply to the respective systems. For instance, in the case of a combined system, both the wastewater and the stormwater RRM databases are useful. From the directory, references are found to the measures that apply to each event; the measures are presented in the RRM Catalogue.

Tables contained in the RRM Catalogue and in the RRM Directory have different structure and contents. The common key between the two databases is the measure ID. The common key between the RRM Directory and the RIDB is the event ID.

In the following sections, details on the structure of each database and respective tables are presented. The first version of the databases is implemented in Microsoft EXCEL.

3.2 Data structure for RRM catalogue

The RRM Catalogue contains four tables: a table with the list of measures (RR Measures), a table with the set of performance indicators that may be considered for the measure (PI Table), a list of performance indicators (PI list) and a table containing the options for each attribute in the RRM table (Options). The attributes of the RR measures table, PI Table and PI list are presented in Table 10 to Table 12, respectively.

Table 10 – Attributes for the RRM Catalogue: RR Measures table

Group	Attribute	Description
Characterisation and applicability	Measure ID	Unique identification reference for the measure
	Description	Summary description of the measure
	Type of measure	Type of measure to reduce risk
	Primary aims	Contribution to primary aims of WCSP
	Application level	Subdivided in three attributes (level of analysis, system and subsystem) where the measure applies
	Technical problem	Type of technical problem addressed (six possibilities can apply)
	Performance metrics	Indicators or indexes for performance assessment (detailed in PI table)
	Advantages	Main advantages
	Disadvantages	Main disadvantages
Potential for risk reduction	RRM type	Type of risk reduction potentially achieved with the measure
	RR effectiveness	Risk reduction effectiveness
	RR cost efficiency	Overall risk reduction cost efficiency
Implementation strategy	Actions	Actions to consider for implementation of measure (six types of actions can be identified)
Analysis of viability	Economic viability	Relative magnitude of CAPEX and OPEX
	Technologic viability	Availability of technology
	Functional viability	Added requirements in operation and maintenance, ease of use
	Environmental viability	Balance between environmental benefits and negative impacts
	Social acceptance	Evaluation of expected social acceptance

The options follow the description presented in chapter 2.

The list of measures is initially organised by technical problem addressed, but database functions should allow queries and filters to provide purpose made views. This organisation is only to facilitate compilation of the list of measures.

Table 11 – Attributes for the RRM Catalogue: PI table

Attribute	Description
Measure ID	Unique identification reference for the measure (as in RR Measures table)
PI ID	Identification reference for the performance indicator (as in PI list or PI reference)
PI name	PI name as in PI table or PI reference
PI reference	Bibliographic reference for further information on the PI

Table 12 – Attributes for the RRM Catalogue: PI list

Attribute	Description
PI ID	Identification reference for the performance indicator
PI name	Performance indicator name
PI expression	Formula for calculating the PI
PI variables description	Variables explained including recommended units
PI reference	Bibliographic reference for further information on the PI

3.3 Data structure for RRM directory

3.3.1 *Sub-databases and tables in the RRM directory*

The organisation of the RRM Directory is by level of analysis, system and subsystem. This option follows the TECHNEAU project databases (http://www.techneau.org/), with minor differences but extending the concept to the whole water cycle. The adoption of this structure is grounded on the idea that an indication of the level of analysis, system and subsystem to which the measure can be considered, facilitates the selection of the measures for specific applications.

As illustrated in Figure 4, the RRM directory combines a set of six main databases relating the possible events with the set of measures that can be considered for reducing the risk associated with that event. Each database has a number of tables corresponding to subsystems.

The six databases that compose the RRM Directory contain two tables per system (WC database) or subsystem (remaining five sub-databases) as presented in Table 13. Within each table, events are grouped per type (as in RIDB).

Table 13 – Tables in sub-databases

Database	Two tables for
Water cycle DB	Catchment basin (including surface and groundwater catchments) Drinking water Non-drinking water Wastewater Stormwater Receiving waters
Drinking water system DB	Surface water reservoir Groundwater reserves Abstraction system Groundwater recharge Water treatment Pumping stations Transmission Storage Distribution Plumbing systems
Non-drinking water system DB	Catchment system Water treatment Advanced water treatment Transmission Pumping stations Storage Distribution Plumbing systems
Wastewater system DB	Wastewater collection network Interceptor system Wastewater treatment Combined sewer overflows Pumping stations Storage structures Infiltration systems Outfalls
Stormwater system DB	Urban catchments Stormwater collection network Infiltration systems Source controls Stormwater treatment Stormwater overflows Pumping stations Storage structures
Receiving waters DB	River Estuary Lake Coastal water

The structure of the two tables is given in Table 14 and Table 15. The first table details the measures recommended for reducing risk for each event; the second table details the actions for each measure and event.

For each event, the set of measures that apply is included using the measure ID from the RRM Catalogue. An implementation priority level is assigned to each measure (Priority 1 means higher priority, so these measures should be considered first for implementation).

Table 14 – Attributes for the tables specifying the RRM for each event

Attribute	Description
Object of analysis	Indication, as appropriate, of system, subsystem or component
Event ID	Event identification number as in RIDB
Event description	Event description as in RIDB
Measure ID	Measure ID as in RRM Catalogue
Measure description	Measure description as in RRM Catalogue
Typical priority	Implementation priority for the measure applied to that event in a typical situation
Potential reduction in consequence dimensions	Typical reduction in consequences associated with the event expected when implementing this measure. Expression in the seven dimensions, namely, health and safety, financial, environmental impacts, functional, service and business continuity, reputation and image or project development. A scale of three levels to be used as presented in Table 6

Table 15 – Attributes for the tables specifying the actions for each RRM and event

Attribute	Description
Event ID	Event identification number as in RIDB
Measure ID	Measure ID as in RRM Catalogue
Action ID	Action identification number
Action type	Considering the options given in chapter 2
General description of the action	Specific information on the action intended to promote the adequate implementation of the measure for reducing risk for the specific event.

4 Methodology to populate the RRM catalogue

The methodology to identify and select measures to populate the catalogue consists of the following steps:

- systematisation of measures reported in the literature, allowing to compile a first list, to be verified in subsequent steps of the project. The result corresponds to the deliverable D 2.4.1;
- possible selection of additional measures when developing other project packages (WP 2.2, WA4, WA5);
- identification of additional measures, or validation of those included in the database, during application of WCSP framework to cities (WP 1.4: Eindhoven, Lisbon, Oslo and Simferopol), together with suggestions from other project partners. Applications are also extremely valuable for validation not only of the measures but also the assigned options of the RRM Catalogue attributes;
- final set of RRDB.

An important issue to take into consideration, when selecting the RRM, is the level of control on certain aspects influencing risk. For instance, while controlling cyanobacteria blooms could be feasible; controlling climate variables such as temperature is out of reach.

Additionally, the completion of both the RRM Catalogue and Directories will certainly benefit from the work of completion of the RIDB, especially the later that are in fact depending on the events to be completed.

The first version of the RRM Catalogue (D 2.4.1), containing almost 200 measures, was completed with a first set of measures from literature review. The reference list is given in the annex. The link with WP 2.2 is based on the events included in the preliminary RIDB (D 2.2.3).

The databases should be subject to continuous improvement and verification, as well as completion as described above, throughout the project in work packages related with the WCSP framework (WA1 and WA2).

5 Bibliography

Alegre H., Melo Baptista J., Cabrera Jr E., Cubillo F., Duarte P., Hirner W., Merkel W., Parena R. (2006). *Performance indicators for water supply services*. 2nd edition. Manual of Best Practices Series. IWA Publishing, London. ISBN 1843390515.

Almeida, M.C., Baptista, J.M., Vieira, P., Ribeiro, R., Silva, A.M. (2004). Efficient use of water in Portugal: a national program. *4th IWA World Water Congress*, Marraquexe, Marrocos, 19-24 de Setembro (p. 8).

Almeida, M.C., Vieira, P., Smeets, P. (2010). *Water cycle safety plan framework proposal*. Report D 2.1.1. PREPARED Project.

Cardoso, A., Coelho, S. T., Matos, J. S. (2009). Proposal for a methodology to assess the technical performance of urban sewer systems. In: *Strategic Asset Management of Water Supply and Wastewater Infrastructures*, Ed. Helena Alegre and Maria do Céu Almeida, IWA Publishing, ISBN: 1843391864.

CEN (2008). *EN 752:2008 Drain and sewer systems outside buildings*. European Committee for Standardization.

CEN (2010). *prEN 14 654-2:2010 Management and control of cleaning operations in drains and sewers – Part 2: Rehabilitation*. European Committee for Standardization.

Cigolini, R.D., Fedele, L., Deshmukh, A.V., McComb, S.A. (2009). *Recent advances in maintenance and infrastructure management.* Springer-Verlag, London.

Kumamoto, H. (2007). *Satisfying safety goals by probabilistic risk assessment.* Springer-Verlag, London.

Matos R., Cardoso A., Ashley R., Duarte P., Molinari A. Schulz A. (2003). *Performance indicators for wastewater services*. Manual of Best Practices Series. IWA Publishing, London. ISBN 19002229006.

Rausand, M., Høyland, A. (2004). *System reliability theory. Models, statistical methods, and applications*. Wiley Interscience. USA.

Rosén, L., Hokstad, P., Lindhe, A., Sklet, S., Røstum, J. (2009). *Generic Framework and methods for integrated risk management in Water Safety Plans*. Techneau Report.

Tapsell, S.M., Pennig-Rowsell, E.C., Tunstall, S.M., Wilson, T.L. (2002). Vulnerability to flooding: health and social dimensions. *Phil. Trans. R. Soc. Lond. A* 2002 **360**, 1511-1525.

Annex ▶ Reference list for identification of RRM

Almeida, M. C., P. Vieira, Ribeiro, R. (2006). Efficient use of water in the urban sector (in Portuguese). Technical Guide n. 8, IRAR, Lisbon

Åström, A. and T. Pettersson (2010). Technical efficiency of existing risk Ball, T., Kiefer, J., Sturm, S. and Vieten, B. (2010). Technical efficiency of existing risk reduction options in groundwater systems (D4.3.4). Techneau.

CEN (2010). prEN 14654-2 :2010 Management and control of cleaning operations in drains and sewers - Part 2: Rehabilitation. European Committee for Standardization.

ISO (2009a). ISO 31 000:2009 Risk management. Principles and guidelines. International Standards Organization.

ISO (2009c). ISO Guide 73:2009 Risk management. Vocabulary. International Standards Organization.

Charles, K., Pond, K., Pedley, S. (2009). Vision 2030 - The resilience of water supply and sanitation in the face of climate change, WHO / DFID.

Elliot, M., Armstrong, A., Lobuglio, J. and Bartram, J. (2011). Technologies for Climate Change Adaptation—The Water Sector. T. De Lopez (Ed.). Roskilde: UNEP Risoe Centre.

DCLG (2006). Planning Policy Statement 25: Development and flood risk. Department for Communities and Local Government. Crown, UK.

DCLG (2008). Planning Policy Statement 25: Development and flood risk. Practice guide. Department for Communities and Local Government. Crown, UK.

Kundzewicz, Z. W., Budhakooncharoen, S., Bronstert, A., Hoff, H., Lettenmaier, D., Menzel, L., and Schulze, R. (2002). "Coping with variability and change: Floods and droughts." Natural Resources Forum 26(4): 263–274.

Lindhe, A., Rosen, L., Norerg and T. Bergstedt, O. (2011). Cost-effectiveness analysis of risk-reduction measures to reach wwater safety targets. *Water Research* 45 (2011), 241-253.

Lozán, J. L. , Graßl, H., Hupfer, P., Menzel, L. and Schönwiese, C. D. (2008). GLOBAL CHANGE: Enough Water for all? Hamburg.

McBain, W., D. Wilkes and Retter, M. (2010). Flood resilience and resistance for critical infrastructure. CIRIA Report C688, London.

Menaia, J., R. Beuken and Danciu, D. (2010). Technical efficiency of existing risk reduction options for distribution of drinking water (D4.3.6). Techneau Report.

Niewersch, C. and J. Burgess (2010). Technical efficiency of some existing risk reduction options in treatment systems (D4.3.5). Techneau Report.

Sinisi, L. and Aertgeerts, R. (Eds) (2010). Guidance on water supply and sanitation in extreme weather events. WHO /UNEC for Europe, Denmark.