# From the water safety plan to the water cycle safety plan – EPAL's experience

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**Abstract:** With its participation in PREPARED – Enabling Change, EPAL aims to demonstrate the feasibility of the innovative Water Cycle Safety Plan (WCSP) framework approach to climate change related risk management. The demonstration was applied to Lisbon's water supply system and allowed the company to diagnose to what extent EPAL's existing Water Safety Plan can be integrated as a System Safety Plan within the wider range of WCSP. Conclusions were that EPAL benefited from being integrated in the broader WCSP team and from broadening the scope of WSP aims. The main difficulties arose from the need to find a scale of consequences suitable for all the parties involved and from the fact that the upstream stakeholder in the river basin, where major interactions were found to happen, did not participate in the demo. The tools developed in order to support the risk identification, analysis and treatment phases proved to be useful, despite lacking a user-friendly interface. Overall, we can conclude that if the concept of the WCSP is to be fully implemented, it will definitely become a powerful tool to manage shared risks in the water cycle in an integrated manner.

**Keywords:** climate change; PREPARED; risk management; Water Cycle Safety Plan; Water Safety Plan; water utilities.

## Introduction

With 146 years of experience, EPAL is the largest and oldest water utility in Portugal, supplying around three million people in 35 municipalities, including the city of Lisbon. The company is one of the partners[1] in the PREPARED project, which was approved under the scope of the 7$^{th}$ EU Framework Programme. With a duration of four years, PREPARED began in February 2010. It is aimed at demonstrating technological, political and managing options available to the cities, in order to increase their preparedness towards expected climate change impacts, in particular on water supply and sewerage systems. Each participating city is represented by a research institution and a utility. The latter is responsible for demonstrating the outcomes of research carried out by the former. In this case, EPAL is committed to demonstrating the feasibility of the innovative concept of the Water Cycle Safety Plan (Almeida *et al.*, 2013a).

Within the scope of the World Health Organization, WHO, guidelines for drinking water quality (WHO, 2009), EPAL had already developed a Water Safety Plan, WSP

[1] 12 European cities, 1 North American city and 1 Australian city, corresponding to a total of 35 entities (investigation institutions, municipalities, water supply and sewerage companies)

(Carneiro *et al.*, 2014), covering the whole water supply system, in order to reduce the risks to consumers' health. Alternatively, given the interactions of urban water and environmental systems as well as the expected effects of climate change, adaptation measures should address all water cycle components. Thus, all relevant stakeholders should be involved in this kind of planning. Broadening the WSP concept to the wider scope of the urban water cycle resulted in a Water Cycle Safety Plan (WCSP), the respective framework being developed in PREPARED (Almeida *et al.*, 2013a; Almeida *et al.*, 2014) in order to allow systematic identification and prioritisation of climate related risks. In this new approach, EPAL's WSP may be regarded as a System Safety Plan (SSP) to be integrated in the wider range of WCSP.

Therefore, objectives undertaken by EPAL are the following: (i) to test/demonstrate the applicability of the new concept, finding out its benefits and drawbacks; (ii) to learn to what extent EPAL's existing WSP is in line with the proposed framework in terms of the SSP and WCSP; (iii) to ascertain the real benefits to the city of Lisbon, namely in respect of climate change risk management.

Here, we will present the outcomes of EPAL's involvement in this work area of PREPARED, in which we believe that our experience may be useful to other utilities that may also want to implement this approach.

## Material and Methods

As a demo utility in PREPARED, we followed the general WCSP framework (Almeida *et al*., 2014) – Figure 1. Besides the proposal of the methodological steps to be followed, risk identification databases as well as risk reduction databases were provided by the project team (Almeida *et al*., 2013b; Almeida *et al.*, 2013c) to assist demo utilities in carrying out their risk assessment.

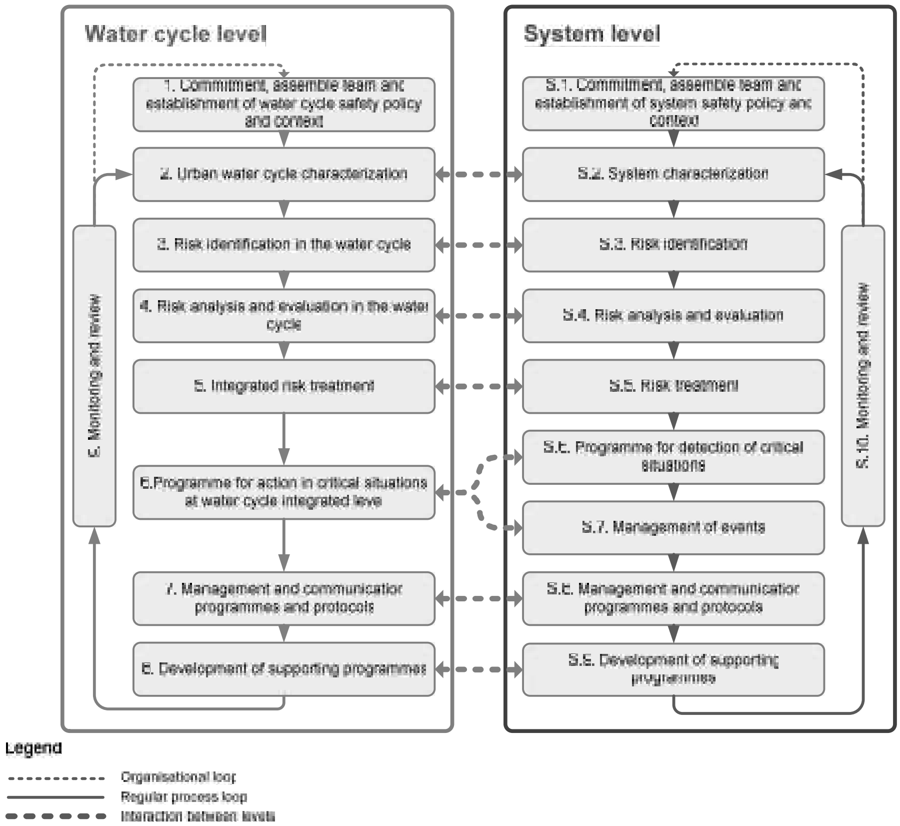


**Figure 1** Methodological approach followed in the demo of the SSP at EPAL (Almeida *et al.*, 2014).

On the other hand, as EPAL had already developed its own WSP (in 2008) to cope with both climate and non-climate related risks, our team also contributed to the definition and completion of the above mentioned framework. Even though all the steps of the SSP have been previously followed in the preparation of the WSP, some modifications had to be made in order to test the WCSP approach.

In respect of the “Assembly of the team” phase, the main difference to point out is the integration of EPAL’s internal team within a larger team at the WCSP level. This included members of the teams responsible for the development of the remaining SSP (Simtejo - wastewater interception and treatment system and CML - wastewater and stormwater collection systems), as well as from the coordination team (LNEC research institute) and from other participants (ERSAR - water and waste services regulator; ARS - National Health Authority; and CML CPFD - Civil Protection Municipal Department). At the integrated level, 13 meetings were held which proved to be excellent opportunities to share visions, information, problems and solutions among the participants.

Given the very different nature of the participants involved in the demo, the “Establishing the context” phase was challenging. A positive aspect is that the WCSP framework led EPAL to broaden its primary aims when compared to the WSP, namely by focusing not only on water quality issues but also on water quality and environmental protection. However, whereas EPAL defined its own criteria for the subsequent phases of risk assessment in the WSP, meeting the general framework of the WCSP meant that a common scale of likelihood and consequences as well as the criteria to analyse risks should be fixed and agreed by all the stakeholders – Figure 2. Although the likelihood of an event affecting different stakeholders in the urban water cycle may be the same for every SSP, the consequences may not be felt equally by all stakeholders. For example, the same percentage of the annual operating budget to quantify the financial consequence of a given event may be perceived as “high” for a certain stakeholder and as “medium” for another one. Similarly, criteria to evaluate risks (i.e., the green-amber-red zones of the risk matrix) depend on the risk tolerance of the organization, which may not be the same for all the stakeholders.

| Classes | Consequence level | Dimensions | |
|---|---|---|---|
| | | Health and safety (public and occupational) | Financial |
| 1 | Insignificant | Minor injuries or health disturbances not requiring medical assistance.<br>No fatalities or life threatening injuries; total recovery. | < 0.1 % AOB* |
| 2 | Low | Injuries requiring hospital treatment; no admissions.<br>No fatalities or life threatening injuries; total recovery. | 0.1-1 % AOB |
| 3 | Moderate | Injuries requiring hospital admissions ≤ 15 days.<br>No fatalities or life threatening injuries; disability ≤ 20%. | 1-5 % AOB |
| 4 | High | Severe injuries requiring hospitalization > 15 days.<br>Up to 2 fatalities or persons with disability > 20%. | 5 - 30 % AOB |
| 5 | Very high | > 2 fatalities or persons with disability > 20%. | > 30 % AOB |

**Figure 2** Example of consequence scale for two dimensions.

The “System characterization phase” was similar to the one developed in the WSP, but interfaces with other stakeholders were identified – Figure 3. It found that the most relevant interactions with EPAL’s water supply system occurred upstream in the system, namely in the catchment area – however, the catchment area authority did not participate in the demo. Little interactions were found to happen with downstream stakeholders.

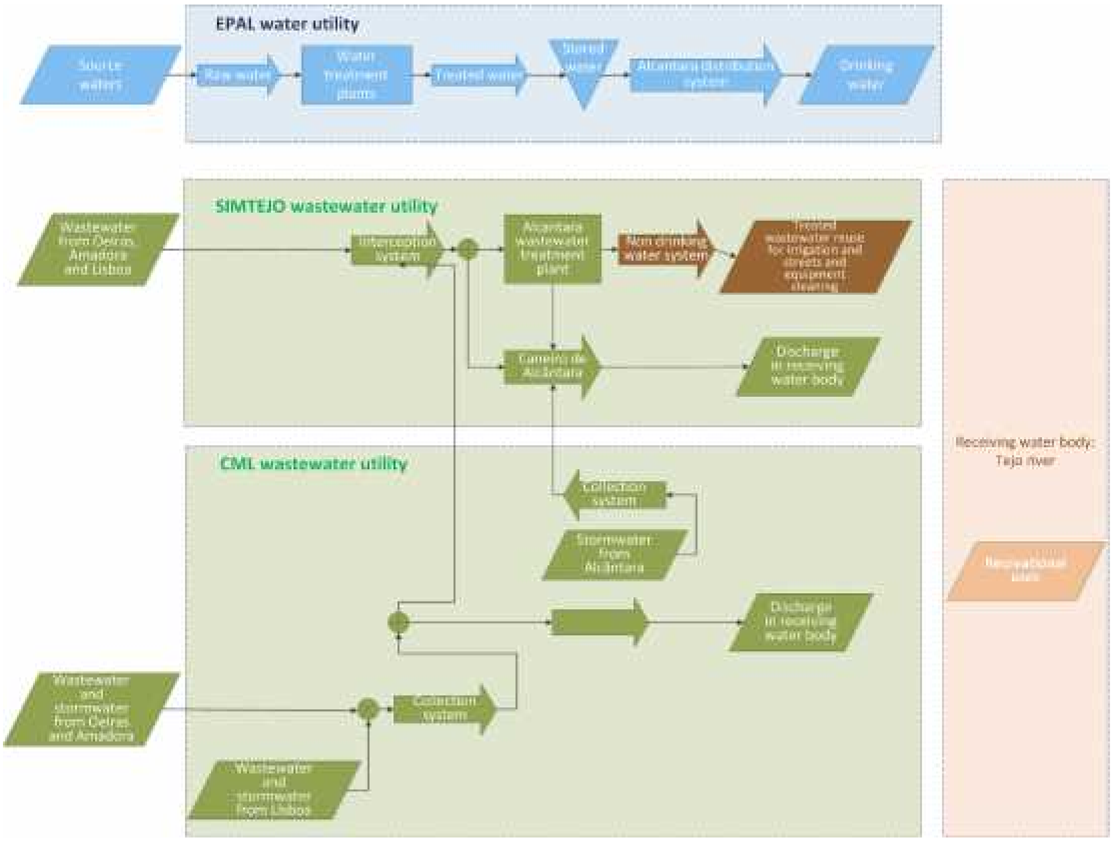

**Figure 3** Identification of water cycle components and interactions.

"Risk identification", "Risk analysis" and "Risk evaluation" phases were carried out with the aid of the following "tools" developed by the coordination / research team (Almeida *et al*., 2013b): list of relevant hazards identified for urban water systems; set of fault trees for hazardous events identified for the water cycle; list of climate related hazards; risk identification database; and risk analysis form. The experience of EPAL gained from the development of the WSP contributed to the enrichment of these tools.

For demonstration purposes, only the following events were considered, taking into account the expected climate change impacts for EPAL's region (Figure 4):

- Presence of chemical contaminants in tap water as a result of contamination of water sources by forest fires;
- Presence of microbial (oxidant resistant) pathogens in tap water in concentrations that might cause illness;
- Extended periods without supply caused by non-availability of surface water due to drought;
- Extended periods without supply caused by failure in the WTP due to flooding of the Treatment Plant.

In the case of microbial pathogens, the risks of contamination have been subdivided according to: (i) their nature (it was decided that E. Coli and enterococcus contamination justify a further breakdown); (ii) the source of contamination resulting from a heavy rainfall event causing discharges to Castelo do Bode reservoir (agriculture runoffs, upstream CSO or animal production industries); and (iii) the role of the treatment system in preventing the problem from reaching the consumers' tap.

In respect of chemical contamination, the primordial source considered has been the occurrence of forest fires with a failure in timely detection and control of contaminants in distributed water. As contributing causes, in all cases, problems with the treatment processes, caused by its failure, insufficiency or inadequacy, were assumed.

For extended periods without supply, the two events considered for the testing were non-availability of surface water due to drought and to failure in the WTP caused by flooding.

| | | | | EVENT CHARACTERISATION | | | |
|---|---|---|---|---|---|---|---|
| Event ID | Short Description | Detailed Description | Hazard | Hazard Description | System/Subsystem where risk source occurs | Component where risk source occurs | System/Subsystem where exposure occurs |
| [illegible] | Microbiological contamination of consumer's tap water with oxidant resistant pathogens | Microbiological contamination (E. coli and enterococci) of consumer's tap water with oxidant resistant pathogens due to discharges to Castelo do Bode Reservoir from upstream CSO caused by heavy rainfall and treatment failure at Asseiceira Water treatment plant due to failure of treatment processes | Presence of microbial pathogens in tap water in such concentration as to cause illness | Presence of E. coli and/or enterococci in tap water | Castelo do Bode subsystem | Castelo do Bode catchment | Plumbing systems in general - tap |
| [illegible] | Microbiological contamination of consumer's tap water with oxidant resistant pathogens | Microbiological contamination of consumer's tap water with oxidant resistant pathogens due to discharges to Castelo do Bode Reservoir from upstream CSO caused by heavy rainfall and treatment failure at Asseiceira Water Treatment plant due to inadequate treatment [illegible] pathogens | Presence of microbial pathogens in tap water in concentrations that might cause illness | Presence of protozoa Cryptosporidium and Giardia | Castelo do Bode subsystem | Castelo do Bode catchment | Plumbing systems in general - tap |
| [illegible] | Microbiological contamination of consumer's tap water with oxidant resistant pathogens | Microbiological contamination of consumer's tap water with oxidant resistant pathogens due to discharges to Castelo do Bode Reservoir from [illegible] and treatment failure at Asseiceira Water treatment plant due to failure of treatment processes | Presence of microbial pathogens in tap water in such concentration as to cause illness | Presence of E. coli and/or enterococci in tap water | Castelo do Bode subsystem | Castelo do Bode catchment | Plumbing systems in general - tap |
| [illegible] | Microbiological contamination of consumer's tap water with oxidant [illegible] | Microbiological contamination of consumer's tap water with oxidant [illegible] | Presence of microbial pathogens in tap water in [illegible] | Presence of protozoa Cryptosporidium and [illegible] | Castelo do Bode subsystem | Castelo do Bode catchment | Plumbing systems |

**Figure 4** Risk identification for selected events.

Given the focus of PREPARED on climate change, the potential effects of climate change trends on the above mentioned risks were analysed, since these may impact on the likelihood or consequence dimensions, resulting in aggravation (-2, -1) or attenuation (+1, +2) of the risks – Figure 5. For example, it was found that microbiological contamination in consumers' tap water with oxidant resistant pathogens may be specially aggravated by the CC indicators and the respective effects "increased frequency of intense precipitation events", "increase in winter storms", "increased water temperature" and "decrease in river flow". This analysis constitutes a distinctive feature from the WSP.

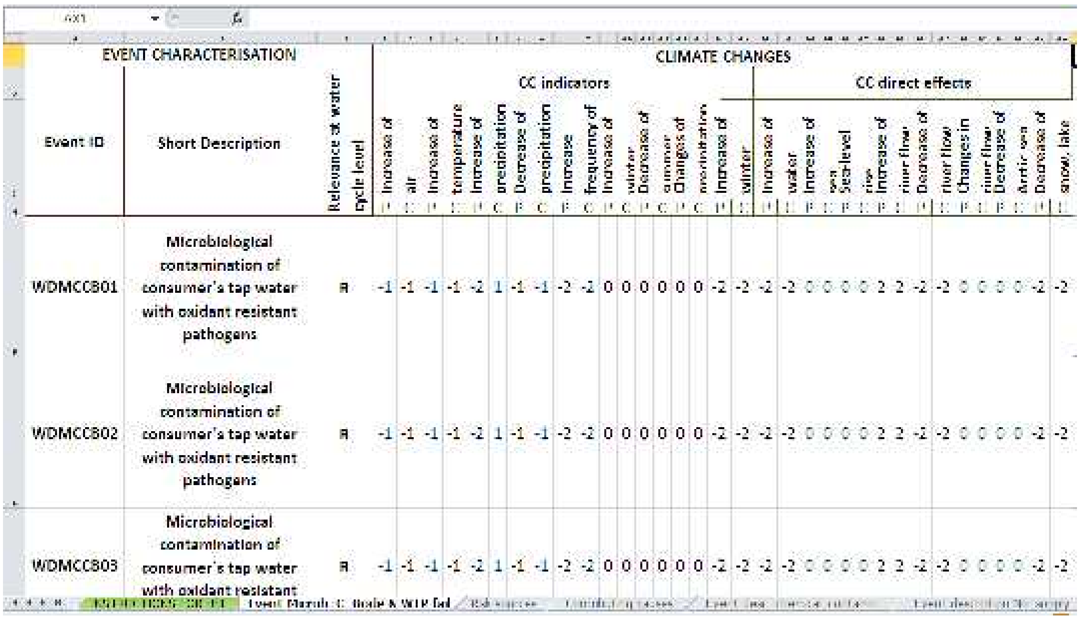

**Figure 5** Potential effects of climate change on risks.

Although it becomes useful to have pre-established concepts as well as pre-defined databases for risk identification and risk reduction measures, the available tools could benefit from some improvements in the interface to become more user friendly. Contrasting with the WSP approach in EPAL, the WCSP framework requires detailed supporting information, as well as an even more structured and formalised process. However, the time involved in the analysis required in the WCSP is significantly higher and somehow, the way the information is displayed makes it difficult to interpret the results.

The "Risk treatment" and subsequent phases in the methodology for developing SSP have only been tested on a theoretical basis, since EPAL is already addressing these issues in the WSP context. Therefore, for each of the selected events, a set of possible risk reduction measures with the ability to reduce either likelihood or consequences (or both) has been chosen from the "portfolio" provided in the PREPARED risk reduction measures database (Almeida *et al.*, 2013c). A total of 60 measures were identified for the water supply system, many of them to be implemented by the catchment area authority, thus being beyond the company's responsibility. Real measures already implemented by EPAL include improvement in treatment processes, installation of monitoring systems, creation of redundancies in the infrastructures and a water loss reduction programme that has placed Lisbon amongst the most efficient cities in the world.

## Results and Conclusions

The results and conclusions of the demonstration of the WCSP framework by EPAL are as follows (Luís *et al.*, 2014; Cardoso *et al.*, 2013):

- Assembly of the team – EPAL's integration into the WCSP team: we consider this to be one of the best outcomes of the project, which created an excellent opportunity to allow the relevant stakeholders of the urban water cycle to gather and to discuss common concerns. This networking has prevailed even beyond PREPARED.

- Context for risk management – SSP led EPAL to broaden its primary aims when compared to WSP, namely water quality versus water quality and environmental protection. However, establishment of common consequence scales to meet all the different stakeholders' specifics proved to be difficult.
- System characterization – interfaces with high-level river basin management were discovered as being highly relevant for EPAL's mission. In contrast, interface with the "downstream" stakeholder – waste water utilities – was found to be of little importance.
- Risk identification, analysis and treatment – although it becomes useful to have pre-established concepts as well as pre-defined databases for risk identification and risk reduction measures, the available tool could benefit from some improvements in the interface to become more user friendly. Also, despite the relevance of all intermediate steps, the amount of supporting information is so great that, in some way, it masks the final results.
- Subsequent phases – handling the identified risks is being done under the WSP process at EPAL.

The company is confident that this innovative approach will enable cities to better manage the risks associated with climate change. In fact, the systemic nature of these risks makes them likely to be addressed in an integrated way by the various stakeholders. The limitations identified can be regarded as inputs to enhance it, thus making it an even better tool for cities to improve their resilience.

If the concept of WCSP is to be fully implemented, a challenge yet to be addressed is who – or what institution – shall guarantee the coordination of the process among the different stakeholders of the Urban Water Cycle. Nevertheless, and overall, we can conclude that it will definitely become a powerful tool to manage shared risks in the water cycle in an integrated manner.

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