UNITED NATIONS
ECONOMIC COMMISSION FOR EUROPE

WORLD HEALTH ORGANIZATION
REGIONAL OFFICE FOR EUROPE

Meeting of the Parties to the Protocol on Water and Health to the Convention on the Protection and Use of Transboundary Watercourses and International Lakes

Working Group on Water and Health
Geneva, 27–28 May 2010
Item 6 of the provisional agenda

Information paper 7

WATER SUPPLY AND SANITATION IN SHORT-TERM CRITICAL SITUATIONS AND ADAPTATION TO CLIMATE CHANGE

Draft guidance on water supply and sanitation in extreme weather events

Submitted by the Chair of the Task Force on Extreme Weather Events

Background and proposed action by the Working Group

1. This document was prepared pursuant to the decision at the first session of the Meeting of the Parties entrusting the Task Force on Extreme Weather Events, led by the Government of Italy, with the preparation of guidance on water supply and sanitation (see the programme of work for 2007–2009 adopted at the first session of the Meeting of the Parties, ECE/MP.WH/2/Add.5 - EUR/06/5069385/1/Add.5).

2. The process of preparation of the draft guidance involved two meetings of the Task Force on Extreme Weather Events (Rome, 21–22 April 2008, Geneva 27–28 October 2009)**,** two meetings of the *ad hoc* drafting group of experts assisting in the preparation of the guidance (Madrid, October 2008 and Rome, February 2009), and the organization of a workshop on “Climate Change, Water and Health” hosted by the Romanian Ministry of the Environment and Forests (Bucharest, 24–25 November 2009). It also involved intense email exchanges between the experts contributing to the Guidance preparation, the Chair of the Task Force on Extreme Weather Events, Dr. Luciana Sinisi (Italy), and the secretariat (see also document ECE/MP.WH/WG.1/2010/7−EUR/10/56335/VII).

3. The Working Group on Water and Health is expected to comment on the draft guidance, in particular to discuss and decide on the final scope and content of the document, to agree on

ways and means to finalize it and to make arrangements for its submission as an official document to the second session of the Meeting of the Parties.

FOREWORD

THIS PAGE LEFT BLANK FOR A FOREWORD BY THE EXECUTIVE SECRETARY UNECE, THE ITALIAN MINISTER OF ENVIRONMENT, LAND AND SEA, AND THE REGIONAL DIRECTOR FOR EUROPE OF WHO

PREFACE

It is well known that adverse meteorological events such as flash floods, droughts, heat waves, cold spells and wind storms are already affecting the European region more and more, and that adaptation to water cycle variations is the key issue of short- to medium-term strategies under climate change and variability scenarios.

There is a broad consensus and wide awareness of the potential for expensive direct damage to people's health and well being, their assets, and crucial socio-economic activities such as agriculture and tourism. But there is a lack of knowledge on how to assess the environmental and health effects associated with exposure to the often complex chemical and biological contamination of water and soil that can follow extreme weather.

Water supply and sanitation are crucial determinants of health, especially during emergencies, but failing or compromised water and sanitation services may in themselves pose a risk, a sometimes irreversible source of contamination, whose impact goes beyond local and national borders.

Under extreme pressure all the different elements of water utility services like abstraction, treatment, mains supply, sewerage systems, sewage treatment works and effluent discharge all become key environmental health determinants, increasing the risk of chemical and biological contamination of water for human consumption, food and bathing waters, and also the risk of vector-borne diseases and those spread by rodents. Water and soil contamination will result from effluent discharge during floods, water supplied will show higher concentrations of pollutants in a drought, and the ability of natural ecosystems to assimilate wastes will be affected by inadequate water for sanitation. In large cities water scarcity will reduce the self-cleaning capacity of sewers, and flooding will exacerbate storm water overflows and the resulting pollution. Environmental health hazards will be more significant in poor and rural areas where utilities infrastructure is lacking, in a bad state, or where small service suppliers cannot cope with adverse weather conditions.

It will not be simply a problem of finding engineering solutions, but a more complex quest for adaptation measures to improve joint coping capacities. The resilience of water supply and sanitation services under changing weather patterns can be quite challenged, and joint efforts are needed from all sectors involved in the sustainable protection of water resources and the risk management of exposed populations to unhealthy environmental risk factors.

Weather and climate extremes will challenge traditional environmental and health preventative systems such as environmental monitoring and control, disease surveillance, and early warning in all phases of preparedness, response and recovery. They will also impair the costly sustainability policies needed to preserve safe water. But in practice, their organization, planning and resources are generally structured on old patterns and time series of weather and hydrological data, impairing overall coping capacities for protecting water quality and health.

Adaptation policy should focus on strengthening the capacities of environmental monitoring, early warning and disease surveillance and, importantly, promote cooperation with relevant stakeholders in risk management such as utilities managers themselves. This should go beyond compliance with the risks usually identified to include those associated with climate change. There is a need for dynamic, adaptive measures tailored to local conditions that will consider all risk elements and be able to cope with a wide range of scientific disciplines and with other critical drivers of vulnerability such as land use, urban and rural population and assets, overexploitation of resources, and unsafe use of new sources of water.

Once again it is not only a problem of engineering solutions or financial investments, but of building a comprehensive medium- to long-term risk management approach and consensus.

Water quality will be the major end point of the pressure applied by extreme weather events to water supply and sanitation systems and, at the same time, the starting point of an increased risk of water-related disorders. How much attention is given to this in current adaptation policies?

Yet many of them often focus mainly on long-term water resource management or on improving forecasting abilities, sometimes neglecting the management of new risk elements like water supply and sanitation in adverse weather. This sectorial isolation could be a problem: indeed water services[1] managers – and environmental health experts as well - are not usually involved in cooperation and consultation frameworks for medium- to long-term adaptation strategy planning.

With all and more of this in mind, under the framework of the 2007-2009 Work Programme of the Protocol on Water and Health to the UNECE Water Convention, the Ministry of Environment, Land and Sea of Italy took the leadership of the Task Force on Extreme Weather Events (TF EWE) established at the Protocol 1st Meeting of Parties in order to provide ad hoc tools to assist Countries in the implementation of the provisions of the Protocol in adaptation policies under climate change challenges[2]. Task Force main mandate was the development of *Guidance on Water supply and sanitation in extreme weather events.*

This *Guidance* is intended to provide an overview on why and how adaptation policies should consider the vulnerability of and new risk elements for health and environment arising from water services management during adverse weather episodes.

Emerging risk factors in conditions of climate variability will receive special attention, with a focus on the response capacity of the environment and health sectors, the role of the managers of water services managers, and information needs, including public communication strategy, as key elements of health risk reduction. Special emphasis is given to adaptation measures to ensure safe water supply and sanitation using existing infrastructure.

This document addresses a broad audience, including policy makers, environment, health and water resources professionals, and water service managers. An integrated environment and health approach steered the development and discussion of the *Guidance*.

The *Guidance* is not intended to be a manual on water supply and sanitation management in emergencies, neither does it aim to be a comprehensive treatise on environment and health risk management under extreme weather conditions. Its aim is broader: by providing an overview of this complex and critical issue it aims to raise awareness of the need to cope with change that is happening before our eyes - not only climate change, but a new world that plays by new rules, that needs new answers and tools and, above all, needs the motivation to abandon old, ineffective sectorial schemes and approaches.

The multidisciplinary efforts and cooperation that lie behind the *Guidance's* development can perhaps be considered a pilot exercise for a new way of coping with complex problems.

Last but not least, I personally feel strongly the need to express my gratitude to all my colleagues in the editorial group. In every minute of our meetings, 'phone calls and mails I have enjoyed the climate of mutual learning and understanding, the absence of purely sectorial argument or

---

1 Paragraph 28 of the European Union Water Framework Directive defines water services as

> " ...all services which provide, for households, public institutions or any economic activity: (a) abstraction, impoundment, storage, treatment and distribution of surface water or groundwater, (b) waste-water collection and treatment facilities which subsequently discharge into surface water..."

2 The main aim of the Protocol is to protect human health and well being by better water management, including the protection of water ecosystems, and by preventing, controlling and reducing water-related diseases. To meet these goals, its Parties are required to establish national and local targets for the quality of drinking water and the quality of discharges, as well as for the performance of water supply and waste-water treatment. They are also required to reduce outbreaks and the incidence of water-related diseases.

overwhelming attitude, the effort made on building common targets and language. It was a quite outstanding lesson to learn.

I also want to warmly thank all the experts from countries, universities, utility companies, NGOs and international organizations that I have met during my Task Force experience: their contributions were essential to launch and to improve Guidance development. Their encouragement, suggestions and enthusiasm for our tasks were really helpful in dealing with the doubts, hesitations and uncertainties that accompanied this challenging pilot experience.

Luciana Sinisi
Chair
Task Force on Extreme Weather Events

ACKNOWLEDGEMENTS

The preparation of the *Guidance on Water Supply and Sanitation under Extreme Weather Events* covered a period of four years (2007–2010). It is a direct outcome of the decision of the Meeting of the Parties to the Protocol on Water and Health at its first session to establish the Task Force on Extreme Weather Events with a mandate to draft the Guidance.

The Task Force on Extreme Weather Events, chaired by Italy, met on 21 and 22 April 2008 in Rome. The meeting was hosted by the Italian Ministry for the Environment, Land and Sea. Another meeting was held on 27 and 28 October 2009 at the Palais des Nations, in Geneva, Switzerland. A special workshop was organized in cooperation with the European Union Water Initiative in Bucharest on 25 November 2009, aimed at promoting cooperation with Russian-speaking countries. A small drafting group, which met several times, also played a major role in the preparation of the Guidance.

The work was coordinated by Dr. Luciana Sinisi, Chair of the Task Force on Extreme Weather Events, from the Italian Superior Institute for Environmental Protection and Research. Valuable support was provided by members of the joint secretariat: mostly by Mr. Roger Aertgeerts (World Health Organization) as well as by Ms. Francesca Bernardini, Mr. Tomasz Juszczak and Ms. Ella Behlyarova (United Nations Economic Commission for Europe).

The work of the Task Force involved 75 experts from 23 countries who took active part in its meetings, exchanging information and directly interacting with the Chair. In addition, experts from four United Nations specialized agencies, as well as non-governmental and water utilities managers organizations provided significant input.

Special thanks go to Mr. Alex Kirby, who edited the publication, and to Ms. Giorgia Knechtlin, Ms. Lucia Dell'Amura, Ms. Olga Carlos and Ms. Diana Teeder, for their secretarial and administrative support.

The joint secretariat gratefully acknowledges the generous financial and technical support of the Italian Ministry for the Environment, Land and Sea, which made possible the preparation of the Guidance, as well as the important contribution by the Ministry of Transport, Public Works and Water Management of the Netherlands.

The joint secretariat particularly thanks the members of the editorial group who drafted and edited the text of the Guidance:

Ms Emma Anakhasyan, Project Coordinator NGO “Armenian Women for Health and Healthy Environment”, Armenia

Ms Doubravka Nedvedova, Ministry of the Environment, Czech Republic

Mr Gyula Dura, National Institute of Environmental Health, Hungary

Ms Benedetta Dell’Anno, Ministry for the Environment, Land and Sea, Italy

Ms Luciana Sinisi, Chair of Task Force Extreme Weather Events, ISPRA,Superior Institute for Environmental Protection and Research , Italy

Mr James Foster, Drinking-water Inspectorate, United Kingdom

Mr Roger Aertgeerts, Scientist, World Health Organization, Regional Office for Europe

Ms Franziska Matthies, Technical Officer, World Health Organization, Regional Office for Europe

Ms Bettina Menne, Technical Officer, World Health Organization, Regional Office for Europe

Mr Giacomo Teruggi, Programme Officer, World Meteorological Organization

The joint secretariat also wishes to heart fully praise the contributions of the other members of the drafting group that, in addition to the members of the editorial group, was also composed by:

Mr Azer Khanlarov, Ministry of Emergency Situations, Azerbaijan

Ms Lea Kauppi, Finnish Environment Institute, Finland

Mr Ion Shalaru, National Centre for Preventive Medicine, Republic of Moldova

Mr Jos Timmerman, RWS Centre for Water Management, the Netherlands

Mr Bogachan Benli, United Nations Development Programme, Regional Project Coordinator, Turkey

Mr Enzo Funari, Chair Protocol Task Force Health Surveillance, Higher Institute of Public Health, Italy

Ms Luca Lucentini, Higher Institute of Public Health, Italy

Mr Massimo Ottaviani, Higher Institute of Public Health, Italy

Mr Emanuele Ferretti, Higher Institute of Public Health, Italy

Ms Helene Di Maggio, Ministry of Environment, Land and Sea, Italy

Ms Giuliana Gasparrini, Ministry for the Environment, Land and Sea, Italy

Ms Sabrina Rieti, Italian Environment Protection and Technical Services Agency, Italy

Ms Elena Mauro, FEDERUTILITY, Italy

Ms Lorenza Meucci, SMAT Torino, Italy

Mr Marco Pelosi, CAP Gestione Milano, Italy

Mr Osvaldo Conio, IRIDE Genova, Italy

Ms Claudia Lasagna, IRIDE Aqua Gas, Italy

Mr Roberto Celestini, ACEA ATO2 Roma, Itlay

Mr Andrea Critto, Euro-Mediterranean Centre for Climate Change, Italy

Alessia Delle Site, ACEA ATO2 Roma, Italy

The joint secretariat also wish to express gratitude to the following experts who reviewed the Guidance greatly improved it with their comments and contributions. Their technical and professional input is gratefully acknowledged.

Mr Bruce Rhodes, Melbourne Water, Australia

Ms Leylakhanim Taghizade, Republican Centre for Hygiene and Epidemiology, Azerbaijan

Mr Michiel Van Peteghem, Flemish Environment Agency VMM, Belgium

Ms Nana Gabriadze, National Centre for Disease Control and Public Health, Georgia

Mr Alexander Mindorashvili, Ministry of Environment Protection and Natural Resources, Georgia

Mr Dominique Gatel, EUREAU - European federation of national associations of drinking water suppliers and waste water services- Deputy Technical Director/ Institutional Relations
Veolia Water, France

Mr Fabio Conti, Professor University of Insubria, Varese, Italy

Ms Sabrina Sorlini, University of Brescia, Italy

Mr Sandro Teruggi, Ecostudio, Italy

Mr Paul-Cristian Ionescu, Ministry of Health, Romania

Mr P J L Dennis, Wessex Water, United Kingdom

Mr Brian Clarke, University of Surrey, United Kingdom

Mr Bogachan Benli, Regional Project Coordinator, Turkey- UNDP - United Nations Development Programme,

Mr Robert Bos, WHO/PHE/WSH, World Health Organization, Geneva

Mr Chee Keong Chew, WHO/PHE/WSH, World Health Organization, Geneva

Ms Jennifer DeFrance, WHO/PHE/WSH, World Health Organization, Geneva

Mr Bruce Gordon, WHO/PHE/WSH, World Health Organization, Geneva

Ms Sinead Tuite, WHO/PHE/WSH, World Health Organization, Geneva

The joint secretariat also wishes to thanks all participants to Task Force Extreme Weather Events meetings for their comments and contributions to overall process:

Ms Ghazaros Hakobyan, State Hygiene and Anti-epidemic Inspectorate, Armenia

Mr Valery Filonau, Republican Scientific – Practical Centre of Hygiene, Belarus

Mr Boril Zadneprovski, Ministry of Environment and Water, Bulgaria

Mr Erkki Santala, Finnish Environment Institute, Finland

Mr Merab Kandelaki, Statskalkanali, Georgia

Ms Zsuzsanna Engi, West-Transdanubian District Environmental and Water Authority, Hungary

Ms Judith Plutzer, National Institute of Environmental Health, Hungary

Ms Gabriella Ceci, Mediterranean Centre for Climate Change, Italy

Ms Francesca De Maio, Italian Environment Protection and Technical Services Agency, Italy

Ms Jessica Tuscano, Italian Environment Protection and Technical Services Agency, Italy

Ms Aijamal Tleulessova, Balhash-Alacol Basin Water-Economic Board, Kazakhstan

Ms Taisa Neronova, State Agency on Environment Protection and Forestry, Kyrgyzstan

Ms Loreta Asokliene, Ministry of Health, Lithuania

Ms Martina Behanova, Public Health Authority, Slovak Republic

Ms Zdenka Kelnarova, Ministry of the Environment, Slovak Republic

Mr Pierre Studer, Drinking Water regulator, Swiss Federal Office of Public Health, Switzerland

Mr Kemal Dokuyucu, Turkish Meteorological Service, Turkey

Mr Nazmi Kagniciogly, General Directorate of State Hydraulic Works, Turkey

Mr Ayhan Taskin, General Directorate of State Hydraulic Works, Turkey

Mr Viacheslav Manukalo, State Hydrometeorological Service, Ukraine

Ms Svitlana Gariyenchyck, Ministry of Environment Protection, Ukraine

Mr Vladimir Garaba, Environmental Movement, Republic of Moldova

Mr Massimo Cozzone, Ministry for the Environment, Land and Sea, Italy

Mr Ahmad Mamadov, Sukanal Scientific Research Institute, Azerbaijan

Mr. Asif Verdiyev, Head Hydrologist, Ministry of Ecology and Natural Resources, Azerbaijan

Mr. Boril Zadneprovski, Senior Expert, Ministry of Environment and Water, Bulgaria

Mr. Nazmi Kagnicioglu, Civil Engineer, General Directorate of State Hydraulic Works, Turkey

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF CASE STUDIES

TO BE INCLUDED IN THE FINAL VERSION

LIST OF PICTURES

LIST OF ACRONYMS

ADRC	Asian Disaster Reduction Centre, Japan
APFM	Associated Programme on Flood Management
BAT	Best Available Technology
CIMO	Commission for Instruments and Methods for Observation
CRED	Centre for Research on the Epidemiology of Disasters
CSO	Combined Sewer Overflow
DIFD	Department For International Development, United Kingdom
DPSIR	Driving forces, Pressures, State, Impacts, Responses
DTI	Daily Tolerable Intake
DWD	Drinking Water Directive
EEA	European Environment Agency
EECCA	Eastern Europe, , Caucasus and Central Asia
EM-DAT	International Disaster Database (of CRED)
ENHIS	ENvironmental Health Information System
EUREA	European federation of national associations of drinking water suppliers and waste water services
EU	European Union
EUWI	European Union Water Initiative
GAC	Granulated Activated Carbon
GCM	Global Climate Model
GDP	Gross Domestic Product
GIS	Geographic Information System
HAV	Viral hepatitis-A
HVAC	Heating, Ventilation and Air Conditioning
IFM	Integrated Flood Management
IPCC	Intergovernmental Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
ISOP	Incident Situation Operational Procedure
ISPRA	Institute for Environmental Protection and Research (Italy)
IWA	International Water Association
IWRM	Integrated Water Resources Management
IWWTP	Industrial Waste Water Treatment Plant
JRC	Joint Research Centre
MC	Microcystins
NMHS	National MeteoHydrological Services
NOD	Nodularins
NOOA	National Oceanic and Atmospheric Administration (United States)
NSICD	National Snow and Ice Data Centre
OECD	Organisation for Economic Co-operation and Development
OCHA	Office for the Coordination of Humanitarian Affairs (United Nations)
PAHO	Pan-American Health Organization
PESETA	Projection of Economic impacts of climate change in Sectors of the European Union based on bottom-up Analysis
PSP	Paralytic Shellfish Poisoning
RCC	Regional Climate Centre
RCOF	Regional Climate Outlook Forum
RTC	Real Time Control
SLR	Sea Level Rise

SOP	Standard Operating Procedures
TDS	Total Dissolved Solids
TFEWE	Task Force on Extreme Weather Events
UNDAC	United Nations Disaster Assessment and Coordination
UNECE	United Nations Economic Commission for Europe
UNHCR	United Nations High Commission for Refugees
UNHYOGO	United Nations Hyogo Framework for Action 2005 – 2015
USDA	United States Department of Agriculture
UWWTP	Urban Waste Water Treatment Plant
VMM	Vlaamse Milieu Maatschappij – Flemish Environment Agency
WBCSD	World Business Council on Sustainable Development
WMO	World Meteorological Organization
WHO	World Health Organization
WFD	Water Framework Directive
WSP	Water Safety Plan
WSS	Water Supply and Sanitation (systems)
WTW	Water Treatment Works
WWTP	Waste Water Treatment Plants

EXECUTIVE SUMMARY

Without any doubt, water supply and sanitation, together with energy, have contributed to a major change of living conditions in mankind's history.

There is also wide agreement on the importance of water supply and sanitation systems to environmental issues and health problems, social services, poverty alleviation, sustainable water resources management, food production and security, drinking water supply and water-related natural disasters.

When the weather is abnormal or the climate is stressed, water and wastewater services systems stand to lose much of their environment and health benefit, for two main reasons:

- they lose their ability to deliver the services required because of direct infrastructure damage (from floods, windstorms and tide surges) or from lack of water (e.g. when a cold spell turns water to ice);
- they become a significant source of chemical and biological contamination of ecosystems, water bodies and soil by their discharges and polluted overload.

This contamination may sometimes be irreversible, and may also affect areas beyond local and national borders. This transboundary aspect is particularly important in the European Region, where there are more than 150 transboundary rivers whose combined watersheds cover more than 40% of the land surface area of the Region[3].

Then when adverse weather events recur, , or when water cycle variations show patterns that do not match usual meteorological and hydrological sequences, there is a serious threat to sustainable livelihoods and to the health of exposed populations.

Such events have already occurred in the European region in the last 20 years. The average number of annual disastrous weather- and climate-related events in Europe increased by about 65% between 1998 and 2007[4].

In terms of social impacts, the CRED Emergency Events Database (EM-DAT)[5] on the epidemiology of disasters shows that in the past 20 years, about 40 million people required health assistance and basic survival needs such as safe shelter, medical assistance, safe water supply and sanitation: an increase of about 400% compared to the 8 million people affected in the previous two decades (1970-90).

In Europe, overall losses caused by weather- and climate-related events increased during the period 1980–2007 from a decadal average of less than €7.2 billion (1980–1989) to about € 13.7 billion (1998–2007).

According to 2006 World Bank report [6] all Countries of Central Asia and the Caucasus are highly exposed to meteorological and hydrological drought.

A severe and widespread drought in 2000-01 wiped out at least 10-26% of crop and livestock production in Armenia, Georgia, and Tajikistan (three to six percent of overall GDP).

[3] Recent UNECE publication reminded us that there are more than 150 trans-boundary rivers in the European part of the region and their basins cover more than 40 per cent of its surface. "Transboundary Flood Risk Management: Experiences from the UNECE Region", UNECE, 2009;

[4] Impacts of Europe's changing climate - 2008 indicator-based assessment- EEA Report No 4/2008

[5] CRED: Centre for Research on the Epidemiology of Catholic University of Louvain, Belgium. The EM-DAT database is accessible at: http://www.emdat.be/ accessed 5 April 2010

[6] "DROUGHT: Management and Mitigation Assessment for central asia and the caucasus- Regional and Country Profiles and Strategies, World Bank 2006

In the same period the hardest-hit communities of Armenia, Azerbaijan, Georgia, Tajikistan and Uzbekistan required food, drinking water, and agricultural input supply relief costing about $190 million.

Windstorm losses across 29 European countries also show an increase of more than 200% in the past 20 years compared with the 1970-1989 period[7].

These extremes will amplify the existing vulnerabilities of water supply and sanitation systems in the region. Indeed, at the EU level more than 20 million citizens lack safe sanitation and rural areas are still very vulnerable compared to urban populations. Up to 2005 in many countries of the WHO European region the percentage of the population connected to waste water treatment facilities ranged between 15% and less than 50%[8]. The EU Urban Waste Water Directive dates back to 1991 and there are currently no plans to revise it. It is probably the most expensive Directive ever adopted with investment costs of about € 30 billion for the 12 new Member States[9]. Yet, not all Member States (EEA, 2006) [10] are in compliance with all of its provisions.
Environment and health risk management under extremes should cope with a wide range of different science and other information and, also, with the internal vulnerabilities of these services such as pressure on existing networks, quality of performance in critical conditions, implementation of technology development and safe delivery of the service.

Besides resilience, moreover, unsuitable management of the infrastructure may have negative impacts on general water management and may in turn affect healthy water and waste water services.

How much of this will affect the Protocol's tasks and objectives, particularly the protection of human health and well-being by better water management, including the protection of water ecosystems, and the prevention, control and reduction of water-borne outbreaks and water-related diseases?

What could be the added value in addressing water supply and sanitation issues under the conditions likely to prevail during extreme weather events for Protocol goals?

How would the overall UNECE Water Convention adaptation strategies and initiatives benefit of such an exercise[11]?

With these demanding questions in mind the multidisciplinary editorial and drafting group established under the framework of the Protocol Task Force on Extreme Weather Events coped with the challenges of designing, elaborating and drafting this *Guidance on Water Supply and Sanitation in Extreme Weather Events*. They were led by the following overarching considerations:

- In extreme conditions water supply and sanitation are a crucial determinant of health both because of the need for safe services in emergencies and because they are themselves a significant risk factor as potential source of heavy pollution;
- In major adverse weather events such as floods and droughts there is not only direct damage

---

7 J. I. Barredo, JRC Ispra, 2009
8 WHO ENHIS, 2009.
9 Report of the World Water Week Seminar "Europe's Sanitation Problem", 2008
10 1)Effectiveness of urban wastewater treatment policies in selected countries: an EEA pilot study ", EEA, 2005; 2) Analysis of Drinking Water and Wastewater Services in Eight European Capitals : the Sustainable Development Perspective, BIPE, 2006;
11 The Protocol Task Force on Extreme Weather Events cooperate, for health, water and extreme weather related issues to the development of UNECE Guidance on adaptation, water and climate edited by the UNECE Water Convention Task Force Water and Climate

for health and for society at large. Health hazards also derive from the increased risk of chemical and biological contamination of water for human consumption, food production and consumption, bathing waters and of changes in the distribution of disease-carrying vectors and rodents;

- Changes in water quality and quantity can be considered as the major environmental end point of the pressure exerted by extreme events and, at the same time, water cycle changes can be seen as the starting point of unhealthy environmental conditions. The efficiency of water supply and sanitation systems plays a major role in this;
- A focused overall environment and health risk management approach needs at first to cope with a wide range of science (engineering, operational, developmental, financial and management), institutional stakeholders (utilities, land users, water resource managers) and frameworks (IWRM, disaster reduction strategies, sustainable development, flood and drought risk management, early warning and forecasting);
- Elements of the principal infrastructure components required to satisfy water cycle management objectives, (such as network of drinkable water supply, sewage collection, treatment and effluent disposal, stormwater collection, treatment and disposal, as well as reclaimed (recycled) water collection, storage, treatment and re-use or disposal) are affected in different ways. (see

Table 2 Projected climate change impacts);

- The *Guidance* is intended also to address adaptation measures for all these infrastructure components to benefit investment planning;
- Any risk management strategies would benefit from other crucial tools like adequate information tools and communication strategies and the strengthening of the coping capacities of environmental monitoring, early warning and disease surveillance;
- Current challenges experienced by utilities managers derive both from climate- and non-climate-relatedfactors. This requires a more integrated and complex approach.

Many non-climate-related drivers and global changes act together to compound and affect extreme events vulnerabilities such as hydrological systems and ecosystems, and economic and social systems.

Land use changes have a role in the rainfall-runoff relationship. Deforestation, urbanization and the reduction of wetlands impair available water storage capacity and increase the runoff coefficient, leading to a growth in flood amplitude and reduction of the time-to peak. Urbanization has adversely influenced flood hazard by increasing the number of sealed areas and infrastructures. The trend towards growing urbanization is also leading to unplanned slum neighbourhoods with poor or non-existent basic water and waste water services. Unsound dwellings, unsafe water for drinking and hygiene, overcrowding and a lack of basic infrastructure such as sewerage networks characterize many informal settlements.

In some countries market-oriented policies designed to facilitate crop production through huge changes in river basins resulted in impaired drinking water supplies to local population.

The increase in water pricing is leading poor people, especially in small communities and rural areas, to use old, unsafe wells and unsafe new sources such as untreated recycled water.

In the *Guidance* development the *ad hoc* editorial and drafting group faced all the challenges discussed above. Problem analysis, together with the professional experience of countries' and international organizations' experts, and the involvement of utilities managers were crucial to developing the draft of the document.

The design and outlook of the *Guidance* is intended to provide an overview on why and how adaptation policies should consider the new vulnerabilities and risks for health and the environment which arise from water and waste services management in adverse weather events. Major topics addressed include:

- *The overall issue of Extreme weather events and water supply and sanitation in the European region (Chapter 1)* - Together with an overview of current data showing how climate change and variability is already increasingly hitting the Region, an overview of water supply and sanitation management system vulnerabilities in the Region, climate- and non-climate-related, is provided. The principal aim is to raise awareness and foster preparedness among decision-makers and stakeholders to ensure the adequate planning of adaptation measures for water supply and sanitation systems, and to enhance the abilities of all sectors involved in risk management such as early warning and theenvironmental and health sectors. Discussion also stressed the crucial role played by managers of the entire water cycle, the need to involve them in planning adaptation policies, the urgent challenges of climate change for an industry facing the need to invest in technology, new facilities and staff training, and the potential for conflicts with mitigation policies.
- *Basic disaster preparedness and early warning. (Chapter 2)* - The chapter recalls key elements of available information tools needed for monitoring, forecasting and vulnerability

assessment to support risk reduction strategies and disaster preparedness. This chapter also includes a reminder of the role of health services in preventing health risks.

- Communication strategies as an integral part of adaptation and risk prevention: how to properly communicate risk to people, how to build and deliver messages to the public - guidance on this essential topic is given in *Chapter 3: Communication in extreme weather events.*
- The special vulnerability to climate change and extreme events of coastal areas of both inland and marine waters, and the need to devise specific environmental approaches of health relevance to support focused adaptation measures, is addressed in *Chapter 4: Vulnerability of coastal areas and bathing waters in extreme weather events.*
- Water safety plans, and the general risk assessment/risk management approach that ensures the safety of water from resource to tap, are a valid approach to managing risks associated with extreme weather events. This is demonstrated in *Chapter 5: Water Safety Plans: an approach to manage risks associated with extreme weather events*.
- An overview of the health risks and impacts associated with floods, droughts, cold spells and heat waves, and their relationship with water safety and the preparedness challenges for the health, environment and water sectors, is given in *Chapter 6: Adaptation measures for water supply utilities in extreme weather events.*
- *Chapter 7: Adaptation Measures for Water Supply Utilities in Extreme Weather Events,* discusses plans for drainage, sewerage and wastewater treatment.

An integrated environment and health approach steers the overall document. Possible cross-cutting issues such as the role of environment, climate and health sectors in weather extremes, the need for policy dialogue and multi-sector partnership building, the challenge of different settings (urban vs. rural, small vs. centralized large scale suppliers) are addressed in all topics, although they would need a more extensive analysis outside the goals of the *Guidance*.

The *Guidance,* obviously, does not aim to be a complete manual of water supply and sanitation management in emergencies, or a comprehensive guide to environment and health risk management in extremes in the emergency and post-event recovery phase.

The aim is broader: by providing an overview of the complex and critical issues we aimed to raise awareness of the need to use available institutional and technical instruments to cope with change that is taking place before our eyes, not only climate change but a whole new world that plays by new rules, that needs new tools, new answers and, above all, the motivation to abandon old, ineffective sectorial schemes and approaches to preserving healthy waters.

Table 1 : Potential impacts on Feature or System in water supply and sanitation - Level of Risk: High (H), Medium (M), Low (L), Insignificant (I)

Extreme Event	Source Water	Abstraction System	Water Treatment Works (WTW)	Water Supply Network	Usage	Sewerage Network	Sewage Treatment Works (STW)	Receiving Water	Groundwater	Ecosystems	Other
Severe Drought	- Reduced quantities available (H) - Reduced quality of surface water sources available (H)	- Reduced water levels at abstraction point adversely affect abstraction rate (M)	- Influent deterioration causes product quality reduction (M) - Reduced throughput affects performance (H)	- Pressure reductions increase infiltration risk (M) - Quality reduction from low flow and long residence time in mains (H)	- Increase in demand (H) - Possible rationing of demand (H)	- Low water use causes sewage to break down in foul sewers (M) - Solids deposited in combined sewers (H) - Sediments in surface water sewers harden (H)	- Influent quality adversely affects treatment (H)	- Effluents from STW reduce water quality (H)	- Depletion of groundwater aquifer (H)	- Grey water recycling minimises potable water supply demand for irrigation etc (H)	- Shallow well systems run dry (H) - Food irrigation needs in rural areas lead to increased demand (H)
Prolonged & Extremely High Ambient Temperatures	- Raw water temperature rise results in lower DO (H) - Water quality more likely to be worsened by upstream STW effluent (H)	- Abstraction system adversely affected (L)	- Lower DO adversely affects bio-water treatment systems i.e slow sand filters (H) - Associated operational equipment failure (L)	- Operational problems resulting from temperature effects (L) - Increased water temperatures adversely affect bio-water treatment (H)	- Potential for substantial increase in demand (H)	- Associated operational equipment failure (L) - Impact on surface water, combined and foul sewer networks (N)	- Lower DO adversely affects treatment (L) - Significant variations in bio-process performance i.e fixed film processes (M)	- Existing water quality more likely to be worsened by STW effluent, low DO etc (H)	- Associated operational equipment failure (I) - Impact on water quality and quantity (L)	- Increase in potable supply demand increases grey water quantities (H)	- Food crops exert increased irrigation demands (H)

Extensive River Catchment Flooding	- Water quality deterioration (H)	- Associated operational equipment failure (L) - Intake system flooded (H)	- Flooding of essential unit process (H) - Process performance adversely affected by poor raw water quality (H)	- Pumping stations flooded (H) - Service reservoirs polluted (L) - Flooded taps & float valves allow contamination (M)	- Increased demand for emergency supplies from areas adjacent to flooding (L)	- Solids deposited in inundated surface water sewers (M) - Foul water & combined sewers overflowing, floodwaters contaminated (H)	- Flooded STWs contaminate floodwater (H) - Diluted influent adversely affects treatment (H)	- Flooded STWs & sewer overflows contaminate surface water (H) - Water quality deterioration (H)	- Borehole pumping control and treatment installation failure within flooded area (H)	- Black water treatment processes widely spread, some more likely to be vulnerable to local flooding with associated pathogen risks (H)	- Local low technology systems very badly affected by flooding (H)
Continued: **Extreme Event**	**Source Water**	**Abstraction System**	**Water Treatment Works (WTW)**	**Water Supply Network**	**Usage**	**Sewerage Network**	**Sewage Treatment Works (STW)**	**Receiving Water**	**Groundwater**	**Ecosystems**	**Other**
Extreme Storm Event Flooding	- Surface water sewer outfalls contaminate local surface waters (L) - Combined sewer-storm water overflows contaminate local surface waters (M)	- Abstraction system adversely affected (L)	- Local flooding causes short-term WTW failure (M)	- Associated operational problems resulting from local flooding (L) - Physico-chemical and bio-systems both affected by influent quality variation (H)	- Likelihood of impact on local usage patterns (L)	- Local overload leading to surface water & combined sewer surcharge and flooding (H)	- Local STW system adversely affected by severe overload (H) - Associated local STW operational problems or short-term system failure (H)	- Associated short-term water quality deterioration (L)	- Associated short term water-quality deterioration (L)	- Black water treatment processes widely spread, some more likely to be vulnerable to local flooding with associated pathogen risks (H)	- Local low technology systems adversely affected by flooding (H)

Extreme and Prolonged Cold Periods	- Freezing affects downstream base flows and local availability (M)	- Operational failure due to freezing (M)	- Failure of outdoor bio-treatment systems i.e. slow sand filters (H) - Frozen tanks and open water surfaces (H)	- Lower water temperatures cause contraction and related mains failures (M) - Freezing in service reservoirs affects supplies (M)	- Impact on usage patterns (N)	- Associated operational problems in foul water pumping stations etc. (M) - Surface water drains and inlets unable to accept melt water (H)	- Freezing adversely affects fixed film treatment processes (H) - Associated operational problems in sedimentation tanks etc. (M)	- Frozen receiving water, and short-term local water quality deterioration caused by effluent concentration (L)	- Aquifer recharge rates adversely affected (H)	- Adverse impact on grey water treatment processes i.e reed beds (H)	- Frozen wells and open water surfaces (H) - Low technology water-flushed sanitation systems adversely affected (M)
Extreme & Prolonged Snowfall Periods	- Snowmelt waters adversely affect quality (M) - Snowmelt waters cause local flooding (M)	- Operational failure due to snowfall depth (L)	- Operational failure of WTW due to snowfall depth (L)	- Adverse impact on service reservoirs (L) - Impact on maintenance programmes lead to local failures (L)	- Impact on local usage patterns (L)	- Adverse impact on local sewerage systems (L)	- Adverse impact on fixed film treatment processes (L)	- Impact on receiving water (N)	- Impact on aquifer recharge (L)	- Adverse impact on grey water treatment processes i.e reed beds (H)	- Snowfall damage to low technology systems with poor build quality (M)

Source: Centre for Environmental Health Engineering, Faculty of Engineering and Physical Sciences, University of Surrey, United Kingdom

1. EXTREME WEATHER EVENTS AND WATER SUPPLY AND SANITATION IN THE EUROPEAN REGION

1.1. KEY MESSAGES

Extreme weather events are already heavily affecting the European Region with growing frequency in the past 20 years, following the global worldwide trend;

In the Region since 1990 more than 450 floods and more than 300 heavy windstorms were classified as disasters and about 40 million people were in the needs of basic survival needs such as food, water, shelter, sanitation and immediate medical assistance.

Overall losses resulting from weather- and climate-related events have increased clearly during the past 20 years in the EU countries.

In the past decade European countries' major river catchments have experienced several flood episodes, and it was estimated a higher than average rate of global sea level rise (SLR) in the past 15 years, of about 3.1 mm/year.

Drought is heavily affecting Central Asia and the Caucasus. In the 2000-2001 drought period the hardest-hit communities of Armenia, Azerbaijan, Georgia, Tajikistan and Uzbekistan required food, drinking water, and agricultural input supply relief, costing about $190 million

WHO estimates that diarrhoeal disease has caused over 13,500 child deaths in those under 14 years in the eastern European and central Asian countries of the European Region, with a strong association with poor drinking-water quality and hygiene and a lack of sewerage and sanitation

Although there is wide agreement on and awareness of direct damage to societies and people's health, there is a lack of knowledge about assessing environmental concerns and health effects associated with exposure to the complex contamination of water bodies and soil that follows extreme weather events.

Under severe weather conditions water and waste water services are no longer beneficial delivery services, but a significant source of chemical and biological contamination, sometimes irreversible and going beyond local and national borders.

Infrastructure elements of water supply and sanitation (WSS) systems show individual specific vulnerabilities to different types of extremes.

Adaptation and environment and health risk reduction strategies should take into consideration the management of new risk elements for water safety and health hazards associated with bad performance of water supply and sanitation in extremes in the short and medium term period.

1.2. INTRODUCTION

The water cycle is the main mechanism governing our weather and climate. Changes in climate variability and the frequency and patterns of extreme weather events in recent decades across the European Region are clear for us to see. . No-regret adaptation measures, meaning options that would be justified by their benefits even in the absence of any strong link with man-made climate change, are urgently needed to cope with the harm to environmental resources, ecosystems, sustainable livelihoods and people’s health (

Table 2 Projected climate change impacts).

Climate variability is also already observed and it's expected to increase in most locations worldwide.

The term "severe weather" is often used interchangeably with "extreme weather" or "extreme weather events", even though they have distinct meanings: literally, extreme weather events are events that are rare within its statistical reference distribution at a particular place; severe weather instead refers to any dangerous meteorological or hydro-meteorological phenomenon , of varying duration, which risks causing major damage, serious social disruption and loss of human life (WMO).

The IPCC in its fourth assessment report[12] provides scenarios of changes in weather events and an overview of projected impacts on specific sectors. These are summarized below in

[12] Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007 (http://www.ipcc.ch/publications_and_data/ar4/wg2/en/contents.html)

Table 2 Projected climate change impacts.

Extreme events have a number of attributes that make them multifaceted phenomena. These include their rate (frequency), intensity, volatility (shape) and dependence (clustering in space or time). A range of hypotheses exists concerning how extreme events might alter with climate change. These include the "no change", "mean effect" (increase in mean but not variability), "variance effect" (increase in range) and "structural change" (increase in mean and skew of low probability events) hypotheses.

Many international organizations (e.g. World Meteorological Organization WMO, National Oceanic and Atmospheric Administration NOOA), recognize a link between global warming and the increase of extremes.

Table 2 Projected climate change impacts (Source: IPCC, 2007)

Projected Change	**Projected Impacts by Sector**			
	Agriculture, forestry	**Water resources**	**Human health/ mortality**	**Industry/settlement/society**
Warmer/fewer cold days/nights; warmer/more hot days/nights over most land areas.	Increased yields in colder environments; decreased yields in warmer environments;	Effects on water resources relying on snow melt	Reduced human mortality from decreased cold exposure	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced effects of snow, ice etc.
Warm spells/heat waves: frequency increases over most land areas	Reduced yields in warmer regions due to heat stress at key devel.. stages; fire danger increase	Increased water demand; water quality problems, e.g. algal blooms	Increased risk of heat-related mortality	Reduction in quality of life for people in warm areas without air conditioning; impacts on elderly and very young; reduced theral power production efficiency
Heavy precipitation events: frequency increases over most areas	Damage to crops; soil erosion, inability to cultivate land, waterlogging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply	Deaths, injuries, infectious diseases, allergies and dermatitis from floods and landslides	Disruption of settlements, commerce, transport and societies due to flooding; pressures on urban and rural infrastructures
Area affected by drought: increases	Land degradation, lower yields/crop damage and failure; livestock deaths; land degradation	More widespread water stress	Increased risk of food and water shortage and wild fires; increased risk of water- and food-borne diseases	Water shortages for settlements, industry and societies; reduced hydropower generation potential; potential for population migration
Number of intense tropical cyclones: increases	Damage to crops; uprooting of trees	Power outages cause disruption of public water supply	Increased risk of deaths, injuries, water- and food-borne diseases	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers
Incidence of extreme high sea level: increases	Salinisation of irrigation and well water	Decreased freshwater availability due to saltwater intrusion	Increase in deaths by drowning in floods; increase in stress-related disease	Costs of coastal protection versus costs of land-use relocation; also see tropical cyclones above

However the devastating impacts of increasing numbers of extreme weather events worldwide have already promoted several international framework and inter-agencies programmes (e.g. the Hyogo Framework for Action 2005 - 2015) (Anon., 2005) to promote disaster resilience and the introduction of risk reduction strategies into policies of adaptation to climate change. WHO and UNECE themselves were also deeply involved in several initiatives and projects under climate change and extreme events challenges, and many countries launched adaptation strategies.

But in practice many efforts were undertaken to improve integrated water resource management and early warning capacities while neglecting the fact that in extreme conditions water supply and sanitation are a crucial determinant of health, both because of the need for safe services in emergencies and because they are themselves a significant risk factor as potential sources of heavy pollution for water and soil. It is not only any longer a question of engineering or financial solutions. It is also urgent to have an overall assessment of new risks for water safety and health hazards associated with the bad performance of water supply and sanitation in extreme situations.

The aim of this chapter is to briefly review the issue of trends and impacts of extremes in the Region in order to raise the awareness of decision makers and relevant stakeholders about the need to re-tool our capacities to cope with them. The chapter also introduces the topic of the role of water supply and sanitation performance as a major environmental health determinant for water safety.

1.3. EXTREME WEATHER EVENTS: FACTS AND TRENDS

Extreme weather events such as floods or wind storms are the most frequent natural disasters (as defined by the EM-DAT criteria) observed in the last hundred years. But their frequency has shown a striking worldwide increasing trend in the last two decades as well as across the UNECE Region. This is shown below in Figure 1 Number of extreme weather disaster 1980-2008.

Figure 1 Number of extreme weather disaster 1980-2008 – UNECE Region and Global

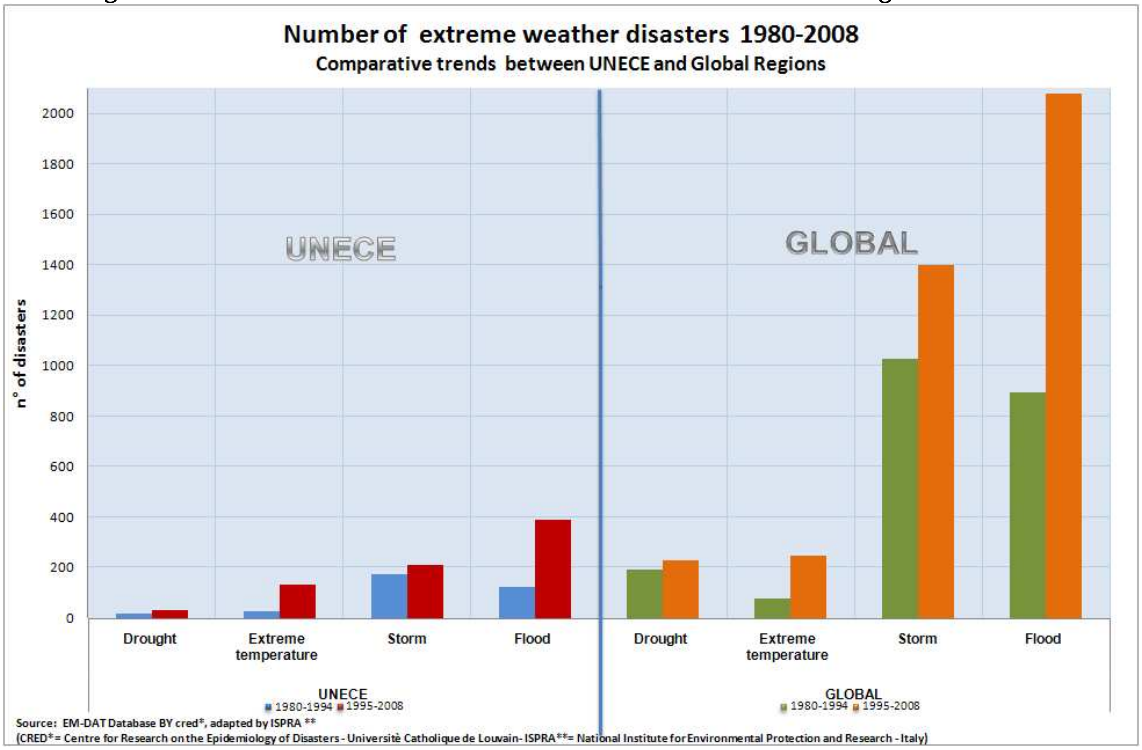


Figure 2 Number of people affected by extreme weather disasters in the Region 1970 - 2008

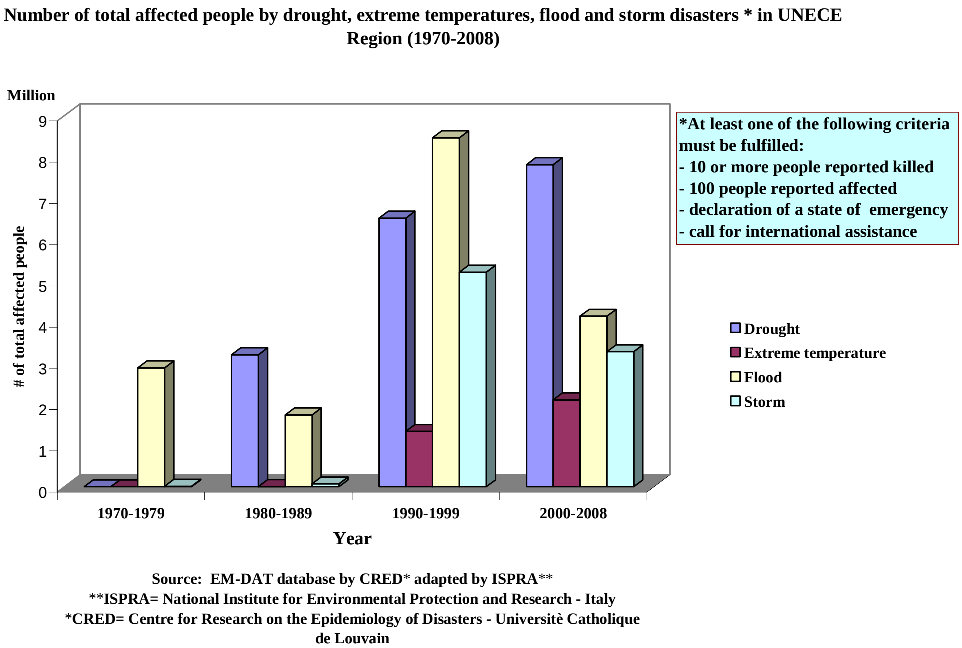


Figure 2 Number of people affected by extreme weather disasters in the Region 1970 - 2008 above shows the number of people affected by disasters, defined as “people requiring immediate assistance during a period of emergency, i.e. requiring basic survival needs such as food, water,

shelter, sanitation and immediate medical assistance". The data show an overall increase by about 400% in the 1970 – 1989 period (38 million vs. 8 million) although a slight decline is noticeable in the last decade, possibly due to improved emergency response systems.

However these numbers describe simply the tip of the iceberg, since they relate *only* to disaster conditions. The Region lacks a comprehensive data base of significant adverse weather events that, even if they do not match EMDAT's disaster criteria, will impose many environment and health impacts and inflict socio-economic damage, including environmental clean-up and recovery costs. They are also liable to damage service and transport infrastructure, houses, economic activities and lead to health system expenditure.

The 2008 EEA report also shows that the average number of annual disastrous weather- and climate-related events in Europe increased by about 65 % between 1998 and 2007..

In terms of financial losses for Central Europe next Figure 3 shows costly floods disasters in the 1990-2006 period and the insured losses.

Figure 3 Central Europe's most costly flood catastrophes since 1990 (Source: Munich Re)

		Overall losses €m	Insured losses €m
1993	Switzerland, France, Italy	1,245	415
	of which northeast Italy	520	
	Switzerland	350	200
1993	Rhine (Germany, France, Netherlands, Belgium, Luxembourg)	1,765	705
	of which Germany	530	160
1994	Northern Italy	7,470	50
1995	Rhine (Netherlands, France, Germany, Belgium, Luxembourg)	2,315	700
	of which Germany	245	105
1997	Oder (Czech Republic, Poland, Germany, Austria, Slovak Republic)	5,400	725
	of which Poland	3,205	410
	Czech Republic	1,660	280
	Germany	330	32
1999	Northern Alps and northern foothills of the Alps (Germany, Switzerland, Austria)	760	290
	of which Germany	410	70
	Switzerland	315	240
2000	Italy, Switzerland	10,000	550
	of which Italy	9,440	355
	Switzerland	390	195
2002	Elbe, Danube	16,825	3,465
	of which Germany	11,830	1,835
	Austria	2,445	410
	Czech Republic	2,445	1,225
2005	Switzerland, Germany, Austria, Hungary, Slovenia	2,690	1,445
	of which Switzerland	1,950	1,300
	Germany	172	40
	Austria	515	110
	Hungary	40	
	Slovenia	4	
2006	Elbe, Danube	390	40
	of which Germany	125	15
	Austria	21	3

* Original values, not adjusted for inflation; converted into € at month-end/year-end exchange rates.

Source: Munich Re's NatCatSERVICE

In Europe, overall losses caused by weather- and climate-related events increased during between 1980 and 2007 from a decadal average of less than €7.2 billion (1980–1989) to about €13.7 billion (1998–2007).

All the countries of Central Asia and the Caucasus are highly vulnerable to meteorological and hydrological drought. A severe and widespread drought in 2000-01 wiped out at least 10-26% of crop and livestock production in Armenia, Georgia, and Tajikistan (three to six percent of overall GDP, Gross Domestic Product) (World Bank, 2006).

In the same period the hardest-hit communities of Armenia, Azerbaijan, Georgia, Tajikistan and Uzbekistan required food, drinking water, and agricultural input supply relief costing about $190 million. The economic impact of agricultural losses and the subsequent relief operations is illustrated below in Table 3 Minimum losses from agricultural drought and relief operations in Central Asia and the Caucasus (Source: World Bank , 2006)

Windstorm losses across 29 countries in Europe show an increase of more than 200% in the past 20 years compared to 1970-1989 (JRC, 2009).

Table 3 Minimum losses from agricultural drought and relief operations in Central Asia and the Caucasus (Source: World Bank , 2006)

Minimum Losses Due to Agricultural Drought and Cost of Relief Operations in Central Asia and the Caucasus, 2000-01				
	Ag Losses (million USD)	% of GDP	% of Ag GDP	Relief Operations (million USD)
Armenia	110-143	2.7	10.1	19.2
Azerbaijan	110	1.0	6.0	n.a.
Georgia	350-460	5.6	25.5	40.9
Tajikistan	100-159	4.8	16.8	104.4
Uzbekistan	130	0.8	2.4	22.9
Total	800	2.0	7.9	187.5

The Figure 4 below shows some details of overall and insured losses from severe windstorms in Central Europe.

Figure 4 Selection of major windstorm catastrophes in central Europe since 1990 (Source: Munich Re)

Year		Event	Country	Overall losses €m*	Insured losses €m*
1990	25–26.1.1990	Winter Storm Daria	Germany	1,000	500
	3–4.2.1990	Winter Storm Herta	Germany	500	250
	25–27.2.1990	Winter Storm Vivian	Germany	1,000	500
			Austria	100	60
			Switzerland	70	50
	28.2.–1.3.1990	Winter Storm Wiebke	Germany	1,000	500
			Austria	100	60
			Switzerland	70	50
			Italy	15	No details
1992	21.7.1992	Severe weather event	Switzerland	85	40
	28.8.1992	Hail	Germany	100	85
1994	4.7.1994	Hail	Germany	420	320
	26–29.1.1994	Winter Storm Lore	Germany	240	200
			Austria	5	No details
			Switzerland	10	No details
1995	21–23.7.1995	Windstorm Emily	Germany	400	300
1999	3–4.12.1999	Winter Storm Anatol	Germany	150	100
	26.12.1999	Winter Storm Lothar	Germany	1,600	650
			Switzerland	1,500	800
			Northern Italy	500	No details
2000	3–4.7.2000	Hail	Austria	160	90
2001	6–7.7.2001	Severe weather event, tornado	Czech Republic	17	6
	7–8.7.2001	Severe weather event, tornado	Northern Italy	200	35
2002	26–27.2.2002	Winter Storm Anna	Germany	570	340
	24.6.2002	Hail	Switzerland	220	170
	5.8.2002	Hail	Northern Italy	80	55
	26–30.10.2002	Winter Storm Jeanett	Germany	1,700	1,200
			Czech Republic	20	10
	16–17.11.2002	Severe weather event, windstorm	Austria	100	70
	25–28.11.2002	Severe weather event, landslides	Switzerland	190	50
2003	2–3.1.2003	Winter Storm Calvann	Germany	250	80
	29–31.8.2003	Severe weather event, landslides	Northern Italy	400	10
2004	9.8.2004	Hail	Slovenia	15	No details
	20.11.2004	Winter storm	Slovak Republic	190	10
2005	7–9.1.2005	Winter Storm Erwin	Germany	210	150
2006	16–17.6.2006	Hail, severe weather event	Austria	80	60
	28–29.6.2006	Hail, severe weather event	Germany	380	230
2007	18–20.1.2007	Winter Storm Kyrill	Germany	3,500	2,400
			Austria	500	200
			Czech Republic	50	30
	20–21.6.2007	Severe weather event	Switzerland	150	75

* Original values, not adjusted for inflation; converted into € at month-end/year-end exchange rates.

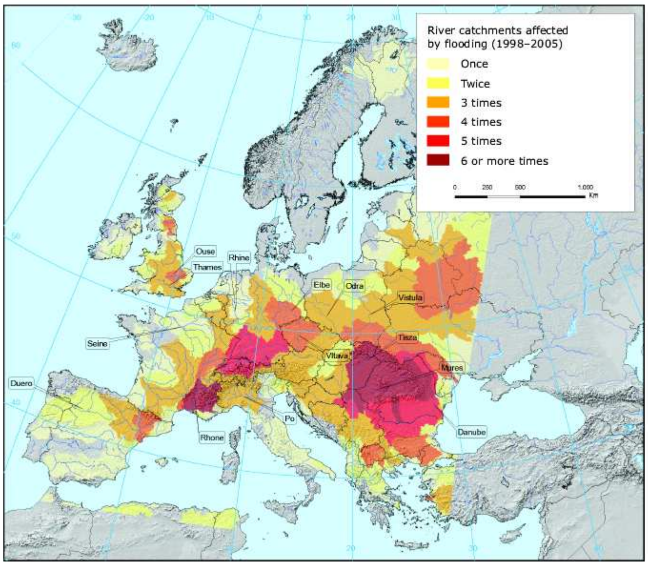
Source: Munich Re's NatCatSERVICE

1.4. EXTREMES ARE NOT ONLY DIRECT DAMAGES

There is a lack of knowledge on medium- and long term impacts on the environment and on the effects of unhealthy environments linked to extreme weather events.

Many data support the goal of a more appropriate assessment of how much effort is needed to address the role of contamination (and of water and waste water services as a source of contamination) in safeguarding healthy water and food consumption and production. Assessment shall also address the issue of how such intense and recurrent episodes will impair the costly environment and health policies in place to prevent water-related diseases.

Figure 5 River catchments affected by flooding 1998 - 2005 (Source: EEA)



In the last 10 years major river catchments of European countries were hit by several flooding episodes.. This is illustrated in Fig. 5 above. In the same EEA assessment, the data showed a higher average rate of global sea level rise (SLR) in the past 15 years of about 3.1 mm/year with an increased risk of impacts on water services infrastructure, tide surges and saline intrusion, and with potential impacts on coastal ecosystems, wetlands and water availability for domestic, agricultural and drinking purposes. All of these represent high vulnerabilities for drinking water availability, the performance of waste water treatment and desalination plants, and the ability of ecosystems to assimilate waste and pollutants.

It is worth recalling that marine and inland aquatic ecosystems are interconnected. Some inland aquatic ecosystems are linked to the ocean ecosystems which they affect, for example through nutrient inflows that cause high productivity in many coastal fisheries, but also negatively by pollutants carried by the water. In addition, a number of marine fishery resources (for instance, fish and shellfish) need inland water ecosystems including estuaries and lagoons to complete their life cycles. The proliferation of harmful phytoplankton in marine ecosystems can cause massive fish kills, contaminate seafood with toxins, affect local and regional economies and upset the ecological balance.

Besides flooding, increasing water scarcity and droughts in many parts of the world may further limit access to water for sanitation, and consequently exacerbate health impacts and limit the ability of natural ecosystems to assimilate wastes. In large cities water scarcity is reducing the self-cleaning capacity of sewers and flooding is exacerbating stormwater overflows and resulting in pollution. Droughts or shortages of water can also affect bathing water quality, because the decreased stream flows do not sufficiently dilute sewage and waste water loads, causing an increase in pathogen numbers and untreated chemicals.

The WHO EURO 2007 Report[13] showed that diarrhoeal disease caused over 13,500 deaths in children aged under 14 years in the eastern European and Central Asian countries of the European Region in 2001, with a strong association with poor drinking-water quality and hygiene and a lack of sewerage and sanitation. In the same period EECCA countries experienced a significant drought.

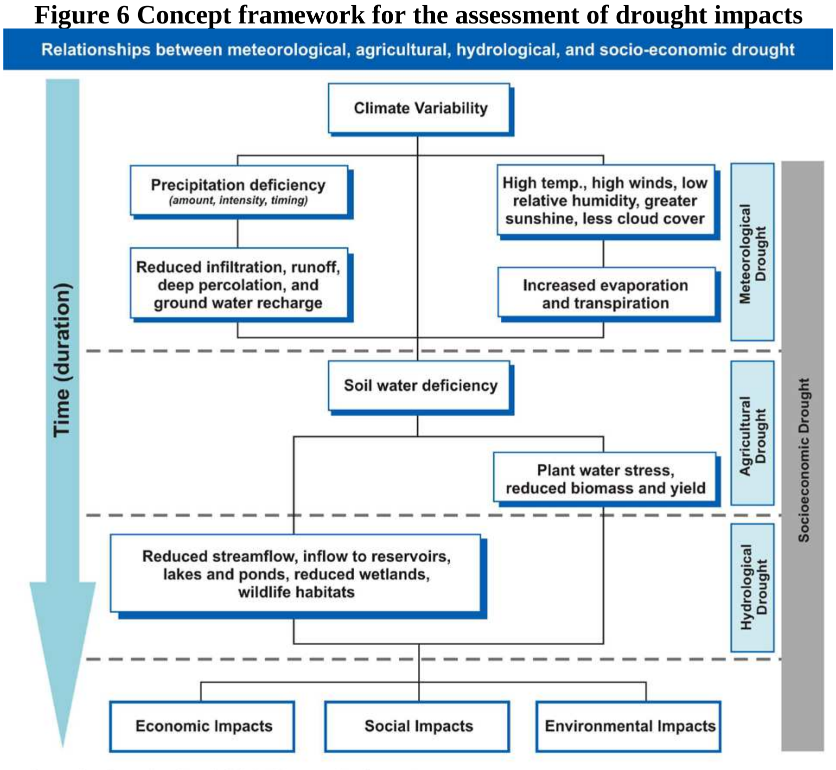
In 2009 in Italy an extraordinary bloom of the cyanobacterium *Planktothrix rubescens* occurred in the Occhito basin, a 13 km^2-wide artificial reservoir with a storage capacity of over 300,000 cubic meters of water. Maximum algal density exceeded 150 million cells/litre and associated microcystin

[13] Children's health and the environment in Europe. A baseline assessment, WHO EURO, 2007

production occurred in raw water used for human consumption in surrounding municipalities (home to about 800,000 inhabitants) (Lucentini L et al.) [14].

There is a growing awareness of the socioeconomic cost of drought, but methodologies to assess its environmental health impacts remain lacking. One approach is shown below in Figure 6 Concept framework for the assessment of drought impacts:

Figure 6 Concept framework for the assessment of drought impacts



Source: http://www.drought.unl.edu/whatis/concept.htm#concept.

In terms of vulnerability assessment it is well know that any climate-related changes will impact on water quality and availability. Examples include:

- ***Increase of lake and river surface water temperatures:*** causing changes like the movement of freshwater species northwards and to higher altitudes, alterations in life-cycle events (earlier blooms of phytoplankton and zooplankton), the increase of harmful cyanobacteria in phytoplankton communities with a consequent raising of threats for lakes' ecological status and of risks for human health;
- ***Reduced water flows*** from shrinking glaciers and longer and more frequent dry seasons; decreased summer precipitation leading to a reduction of stored water in reservoirs fed by seasonal rivers; inter-annual precipitation variability and seasonal shifts in stream flow; reduction in inland groundwater levels; an increase in evapotranspiration as a result of

[14] Reference : Luca Lucentini (a), Massimo Ottaviani (a), Sara Bogialli (a), Emanuele Ferretti (a), Enrico Veschetti (a), Rosa Giovanna (b), Concetta Ladalardo (b), Matteo Cannarozzi De Grazia (b), Nicola Ungaro (c), Rosaria Petruzzelli (c), Gianni Tartari (d), Licia Guzzella (d), Marina Mingazzini (d), Diego Copetti (d)
(a) Department of Environment and Primary Prevention, Italian National Institute of Health, Rome, Italy.
(b) Assessorato alle Politiche della Salute, Regione Puglia, Bari, Italy.
(c) Agenzia Regionale per la Prevenzione e la Protezione dell'Ambiente, Puglia, Bari, Italy.
(d) Water Research Institute, National Research Council, CNR, Brugherio, Monza e Brianza, Italy.

higher air temperatures, the lengthening of the growing season and increased irrigation water usage;

- ***Increased household water demand in the hot season, water scarcity and drought*** will impair raw water sources' reliability as it is altered by changes in the quantity and quality of river flow and groundwater recharge;
- ***Heavy effects on drinking-water quality*** as a consequence of the decrease of pollutant dilution (from increasing water temperatures, and water scarcity/flow). At the same time, increased water flows will displace and transport different components from the soil to the water through fluvial erosion;
- ***Unsuitability of water for drinking and agriculture purposes*** as a consequence of saline intrusion.

Many non-climate-related drivers and global changes also exacerbate some of the vulnerabilities associated with extreme events when they affect, for example, hydrological systems and ecosystems as well as economic and social systems.

Land-use changes have a role in the rainfall-runoff relationship. Deforestation, urbanization and the reduction of wetlands reduce the available water storage capacity and increase the runoff coefficient, leading to growth in flood amplitude and reduction of the time-to-peak. Urbanization has worsened flood hazards by increasing the number of sealed areas and infrastructures. The urbanization trend is leading also to unplanned slums with poor or non-existent, basic water and waste water services.

In some countries market-oriented policies have sought to increase crop production through huge changes in river basins, resulting in impaired drinking water supplies.

The increase of water pricing is leading poor people, especially in small communities and rural areas, to use old, unsafe wells and unsafe new sources such as untreated recycled water.

1.5 EXTREMES AND WATER SUPPLY SANITATION: OLD PROBLEMS, NEW RISKS AND CHALLENGES

The main international and European scientific organizations have pointed out the potential impacts of climate change and extreme weather events on water and wastewater services[15], identifying vulnerable groups and vulnerable sub-regions. Evidence shows that water supply and sanitation utilities, including all infrastructure elements of water abstraction, catchment areas, reservoirs, treatment plants, drinking water pipelines and distribution systems, and sewerage networks are key environmental determinants in these critical conditions.

Improper management of the infrastructure may also have negative impacts on general water management and may in turn affect healthy water and waste water services.

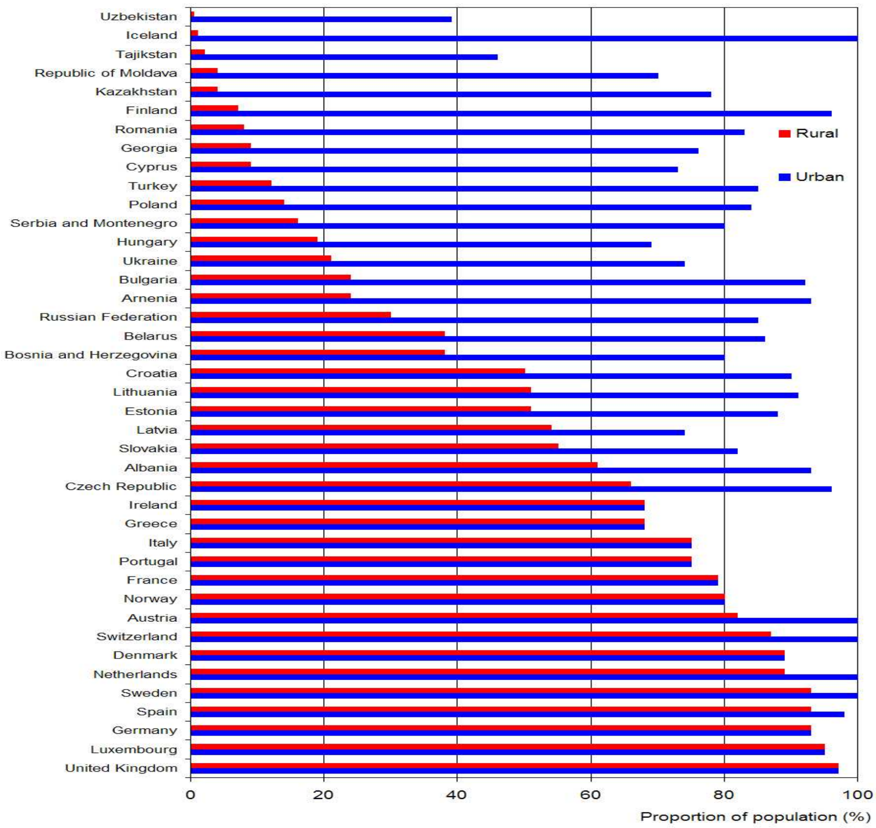
Internal vulnerabilities of these services embrace a wide range of science and information in terms of existing networks, quality of performance in critical conditions, implementation of technology development and safe delivery of the service. Furthermore the potential impacts of the individual

[15] In this paper, the term "water services" is consistent with the definition given in Art 2 § 38 the European Water Framework Directive: " all services which provide, for households, public institutions or any economic activity: (a) abstraction, impoundment, storage, treatment and distribution of surface water or groundwater, (b) waste-water collection and treatment facilities which subsequently discharge into surface water".

"extreme events" can be different given an individual process within each system category of the complex water and waste water services systems (see Table 1).

A quantitative and qualitative analysis of water services in the Region still shows old vulnerabilities. At the EU level more than 20 million citizens lack safe sanitation, and rural areas are still very vulnerable compared with urban populations, as illustrated in **Error! Not a valid bookmark self-reference.**.

Figure 7 Percentage of population with home connection to improved sanitation facilities in urban and rural areas 2006 (Source:WHO EURO ENHIS)



Up to 2005 in many countries of the Region the percentage of the population connected to waste water treatment facilities ranged between 15% and less than 50%.

The EU Urban Waste Water Directive (UWWD)[16] dates back to 1991 and it is probably the most expensive Directive ever adopted, with investment costs of about €30 billion for the 12 new Member States. However, not all Member States (EEA, 2006; BIPE, 2006)[17] are yet in compliance with all its provisions.

In WHO EURO ENHIS Report, 2009 it was stressed that:

> Wastewater from households and industry places a significant pressure on the water environment through the release of organic matter, nutrients, hazardous substances and pathogenic microorganisms. The majority of the European population lives in urban agglomerations (three-quarters in 1999); a significant proportion of urban

[16] Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31991L0271:EN:NOT accessed 5 April 2010

[17] 1) Effectiveness of urban wastewater treatment policies in selected countries: an EEA pilot study ", EEA, 2005; 2) Analysis of Drinking Water and Wastewater Services in Eight European Capitals : the Sustainable Development Perspective, BIPE, 2006;

> wastewater is collected in sewers connected to public wastewater treatment plants. Contamination of aquatic resources by wastewater reduces the possible use of the recipient waters for a variety of applications: treatment to drinking-water standards may become technologically more challenging, while direct use in irrigation may pose specific health risks.

One of the main conclusions of the Conference of EECCA Ministers of Economy/Finance and Environment, “Financing water supply and sanitation in Eastern Europe, Caucasus and Central Asia” (Yerevan, Armenia, November 2005), (OECD, 2005) was:

> In the countries of Eastern Europe, Caucasus and Central Asia (EECCA countries), problems of access to water services are rooted in the history of that region**.** Ambitious investment programmes led to the development of extensive networks of water infrastructure in urban and rural areas. However, these networks were often poorly designed and constructed, and they have not been adequately maintained. As a result, water supply and sanitation infrastructure has seriously deteriorated in most countries in the region and even collapsed in some places, with potentially calamitous consequences for human health, economic activity and the environment.

Improved sanitation or wastewater treatment will improve water availability in several ways. As improved treatment results in waste water that is less polluted, the chance of polluting surface waters or shallow aquifers is reduced. These surface waters and shallow aquifers may therefore be used as a source for the production of drinking water or applied for other uses. Moreover, the ecological quality is less impaired. Also, waste water from treatment plants may be used directly, e.g. tertiary treatment provides waste water that may be suitable for agricultural or industrial use. At the transboundary level, improved waste water treatment reduces conflict potential as the impacts of upstream water use have less impact on downstream use.

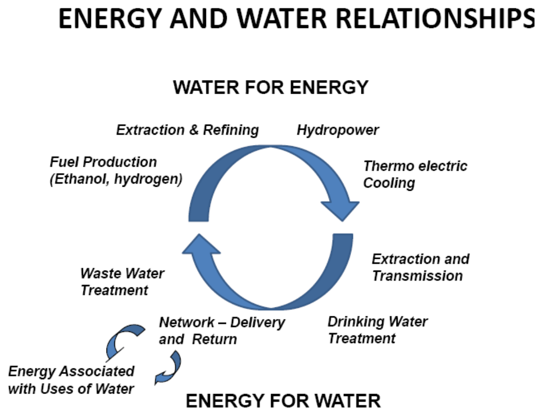
Poor design and maintenance of water and sanitation system infrastructure on the other hand may lead to serious pollution. Increased or intensified precipitation may, for instance, lead to system overflow, in which untreated waste water reaches the surface waters of shallow aquifers. As a result, the use of these waters may have to be excluded for several purposes. Prolonged periods of drought may lead to malfunctioning of the treatment systems and may result in pollution of surface waters or shallow aquifers. Leakage of pipelines and other distribution systems through corrosion, mechanical stress or physical breaking as a result of poor design or insufficient maintenance results in loss of precious drinking water or pollution of shallow aquifers or surface waters. This in turn affects the availability of water of sufficient quality for use as drinking water and for other purposes.

Conflicts exist between energy and water, as illustrated in Figure 8 Energy and water relationships below. Energy production uses water for fuel production processes, and for extraction and refining. Hydropower production alters the natural variability of surface waters and their consequent availability for other uses like agriculture and drinking water. Finally, electrical power plants use water for cooling.

Water services also need energy. Extraction and transport of water, production of drinking water (including desalinization), and delivery and return of water all require energy, as does the treatment of waste water.

Energy production should therefore aim at developing closed systems in which process water is reused, if necessary after treatment. This reduces the need for water as well as the impacts of waste water on surface waters and aquifers. Water services should aim for energy efficiency. Biological treatment, for instance, includes the possibility of producing biogas that in turn can be used for energy to support the treatment process.

Figure 8 Energy and water relationships (source: IWA)



Crucially, another factor is an important health determinant and all vulnerabilities mentioned till now are strictly related to it: water pricing.

The costs of providing household, industrial and agricultural water services are increasingly covered through pricing mechanisms. Tariff structures for water supply and waste water treatment have a role in increasing the cost-effectiveness of resource use. Water users like agriculture and industry can strike a balance between their use of water and the income that this will generate. For industry it may lead to increased self-treatment and effluent re-use, the use of cleaner technologies and the reduction of waste generation. Households may become more self-aware in their use of water.

The cost of producing and delivering clean water to urban areas greatly depends on the proximity of raw water sources, the degree of purification needed and the settlement density of the area being served. The cost of providing sewerage and treating wastewater also depends on settlement density, as well as on the characteristics of the influent and the required quality of the effluent.

Water pricing may be achieved in different ways:

- As pollution charges for discharging effluent to natural waters. The charges can be based on volume only, on the effluent’s pollution content, or on the cost of measures to prevent pollution of surface waters.
- As abstraction charges for ground or surface waters (or both). They are typically based on the maximum withdrawal rate permitted by an abstraction licence or on the actual volume withdrawn. They can also be based on the source (ground or surface) or the availability of water in place or time (i.e. seasonal), or the type of user (agricultural or industrial users often benefit from exemptions).
- As service fees for domestic and industrial water services to cover the operational and maintenance cost of operating water facilities. They can be based on volumetric charges or flat rates (based, for instance, on property values). Waste water treatment fees are sometimes calculated as a fixed proportion of the water supply bill or may vary with the volume of water actually supplied.

Costs for water services provision are likely to increase because of the need to meet existing and future drinking water standards, refurbish or replace pipe networks, which are often inadequately maintained, upgrade sewage treatment standards, separate sewage from stormwater networks, and treat urban stormwater and wet-weather sewage overflows.

Social considerations must be included in water pricing, especially in less developed countries. If water is sold at real cost this could represent a large fraction of household budgets and can reduce users' willingness to pay. As a consequence, users may turn to alternative (unsafe) sources of drinking water, which may jeopardise their health, and may seek means to dump waste water, which may affect surface or In this scenario everything should be done to protect health, to overcome inequities and vulnerabilities, and to foster the sustainability of natural resources and ecosystems.

Traditionally water and waste water services were built to protect people from unsafe water, and to protect the environment from dangerous pollution.

Under extreme conditions even gold standard technologies barely manage to meet these goals. Besides, in practice, their performance has to cope as well with all the by now familiar climate- and non-climate-related factors.

Amongst the new challenges for water and waste services, the World Business Council on Sustainable Development (WBCSD) has identified:

- greater demand as a result of increased temperatures and changes in supply;
- need to cope with greater variability in river flow due to changes in temperature and precipitation, with possible damage to water supply infrastructure during heavy rains or droughts;
- salinisation of coastal groundwater reservoirs;
- vulnerability of water services designed for steady conditions under new conditions of higher variability such as floods and droughts;
- water supply and treatment is likely to become increasingly energy- intensive and expensive, while climate change may cause conflicts between mitigation and adaptation policies.

Clearly identified risks also include: potential conflict between industrial water users situated in water-scarce areas for access to diminishing resources of decreasing quality; flooding of water supply works in riparian countries, leading to supply disruption; considerable costs of infrastructure upgrading; and associated damage and/or contamination.

The World Business Council on Sustainable Development (WBCSD, 2008) stated that:

> "Adaptation will not reduce the frequency or magnitude with which climate change events occur, but will protect business and society against events such as drought, hurricanes and flooding."

The European Federation of National Associations of Drinking Water Suppliers and Waste Water Services (EUREAU), which includes both public and private suppliers, and collectively supplies water to around 405 million European citizens, also recognized (EUREAU, 2008):

> "Water, as one of the most important enablers of economic and social development and public health […] needs to be resilient to climate change and shifting weather patterns. There will be increasing pressure on water resources in the coming decades. Climate change represents a key challenge for the water sector in terms of availability of water, flooding in urban areas, and impacts on water and waste water treatment systems and assets."

The resilience of service infrastructure and of any technological adaptation measures including early warning and monitoring systems is also very important, but under such complex scenarios of risks and drivers cannot be simply left to engineering solutions and financial investment.

Science and technology development should also be accompanied by:

- active involvement of relevant stakeholders such as utilities, land users, water resource managers;
- a facilitating mechanism for cooperation frameworks should also be tailored to local needs with the aim of re-tooling local capacities, and enhancing providers' performance, knowledge and awareness of new environment and health risks;
- a multisectoral policy response commitment to cope with changes in adaptation strategies.

The health and policy relevance of this is underlined by the recent WHO HQ initiative (Vision 2030 – the resilience of water supply and sanitation in the face of climate change, WHO, 2010) which clearly states:

> "The ensuing adverse impacts on water and sanitation services constitute a clear and present danger for development and health. New evidence, translated into new advocacy, is needed to raise the awareness in governments, international agencies, nongovernmental organizations and communities about the links between climate change and water and sanitation services, and the consequences for health and development. In a context of relative uncertainty associated with climate change projections, policy responses will have to be formulated based on our current knowledge to address these impacts and consequences."

Appropriate adaptation measures for utilities infrastructure is part of risk management strategies that would benefit other crucial help like adequate information tools for early warning and vulnerability assessment, mass communication strategies, and strengthening the coping capacities of environmental monitoring, early warning and disease surveillance.
All these issues will be addressed in subsequent chapters.

1.6. CONCLUSIONS

Without any doubt, water supply and sanitation, together with energy, define the improvement of living conditions in human history.

There is also a large consensus on the importance of water supply and sanitation for many crucial issues such as environmental and health problems, social services, poverty alleviation, sustainable water resources management, food production and security, drinking water supply and water related natural disasters.

If weather and climate behave in extreme ways, water services systems (water supply, sewerage and waste water treatment) will lose much of their environment and health benefit, becoming instead a significant source of chemical and biological contamination of ecosystems, water bodies and soil. The contamination may sometimes be irreversible, and it may affect areas beyond local and national borders.

Abnormal weather, climate and hydrology can mean a serious threat to sustainable livelihoods and to the health of exposed populations.

This is already happening in the European Region, and has been for the past 20 years: evidence show that floods, windstorms, droughts and extreme temperatures are already severely affecting the Region, in line with the global trend.

We need to strengthen preventative actions to limit direct damage and ensure safe basic survival needs such as water, sanitation and medical assistance in emergencies, and to counteract the health hazards of extreme temperatures, water scarcity, chemical and biological contamination of water and food, and infectious diseases.

There is also an urgent need for a centralized database to monitor the direct socio-economic impacts of extremes in the Region and to help the development of tools to assess the medium- and long-term impact on the environment. We need also to focus efforts on arguing the case for water and waste water services to cope with both climate and non-climate related global and local drivers. There is plenty of data to encourage a more appropriate assessment to address the role of contamination, and of water and waste water services as sources of contamination themselves, , in making possible healthy levels of water and food consumption and production. The data also encourage a new assessment of how intense and recurrent episodes of extreme weather will impair the costly environment and health policies introduced to prevent water-related diseases

Early conclusions suggest that in fostering vulnerabilities assessment and risk management in extremes, many elements still need to be addressed, remembering that the performance of water supply and sanitation is the end point of pressures from extremes, climate and non-climate-related drivers.

Yet vast efforts are needed to bring water supply and sanitation infrastructure to a reasonable level of functioning in extremes.

Several challenges indirectly affect water utilities management:

- increasing costs for ordinary and extraordinary maintenance of systems;
- increasing costs for technology development and tools to cope with recurrent adverse weather events;
- increasing cost for personnel training and early warning/modelling/forecasting;
- decision-making to solve conflicts about water users, for example large and . small companies;
- new regulations on water supply and sanitation;
- communication issues.

All these issues need to be considered within a global context and should be managed within a general framework including transboundary cooperation, public authorities and agencies, all working towards integrated climate change adaptation strategies. What will be needed is a significant modification of strategies, infrastructure, systems and practices. Such approaches are currently being adopted by many water and waste water utilities, but appropriate adaptation measures for utilities infrastructure and overall system ability to cope in situations of extreme weather events should be carefully assessed in view of emerging environmental health risks. Knowledge of these issues should be made available within water utilities companies to facilitate direct involvement in developing adaptation strategies.

2. BASIC DISASTER PREPAREDNESS AND EARLY WARNING

2.1. KEY MESSAGES

- The effectiveness of risk reduction in extreme conditions relies upon a commitment to apply integrated risk management principles in development planning, the existence of well-defined institutional responsibilities, a democratic process of consultation, and an information and awareness campaign. It moves beyond disaster response and reaction, towards risk anticipation and mitigation.
- Preparedness plays an essential role in the whole process, focusing on technology and trained staff needs in terms of procedures and tools necessary to coping effectively with a disaster.
- All information collected by monitoring networks should be made available to all responsible organizations including public health systems, the managers of reservoirs and dams, and water utilities operators who could be affected by the impacts, at both national and transboundary levels.
- Information development should provide adequate support to pre-event vulnerability assessment and post -event assessment of environmental and socio-economic damage.
- Many monitoring , forecasting and management tools are already available for disaster preparedness planning.

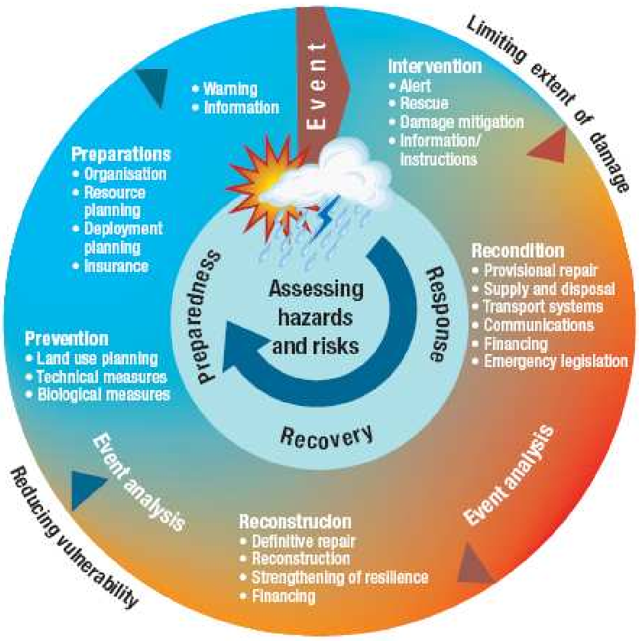
2.2. INTRODUCTION

In its terminology (2004) the United Nations International Strategy for Disaster Reduction (UNISDR) defines disaster risk management as:

> *The systematic process, administrative decisions, organization, operational skills and abilities to implement policies, strategies, and coping capacities of the society and communities to lessen the impacts of natural hazards and related environmental and technological disasters.*

This definition includes measures to avoid (prevention) or to limit (mitigation and preparedness) the adverse effects of hazards. Disaster management provides the means to prevent hazards becoming disasters. The process of disaster management involves a cycle of three phases: preparedness, response, and recovery. This is illustrated in Figure 9 below.

Figure 9 Disaster management process (Source: Swiss civil protection)



Preparedness plays an essential role in the whole process, focusing on technology and trained staff needs in terms of the procedures and tools needed to cope properly with a disaster.

The role of water supply and sanitation utilities in extreme weather conditions is crucial, in preparing and implementing both a preparedness plan and adaptation strategies, since it holds real information and technical capability about the management of water catchments, adduction, storage, treatment, distribution and quality.

Over recent decades there has been a trend towards developing information piecemeal to localize socio-economic activities, high-density populated areas, sensitive sites (hospitals, nuclear power plants, industrial sites, etc), and infrastructures in hazard-prone areas. This has increased the knowledge demand of risk assessment, promoting a "risk culture" which aims to assess, evaluate and reduce the escalation of risk linked to changes in land use and climate variability. International agreements have also sought to include disaster risk reduction strategy in the development process of adaptation strategies to climate change (for example, the UN HYOGO framework).

Risk in general, and in extreme weather conditions in particular, is the result of three factors: the magnitude of the hazard, the degree of exposure to the hazard, and overall socio-economic and environmental vulnerability. This is illustrated below in Figure 10.

Figure 10 Components of risk (Source: ISDR)

2.3. INFORMATION NEEDS: FROM RISK ASSESSMENT TO RISK REDUCTION

The key principle for any development of preparedness and response plans, as for any effective warning system, is to focus on the three different and complex components of risk - hazard, exposure and vulnerability.

There are many tools for risk assessment already available at international and national level. Some of them can present a sectorial approach, in terms of the type of extreme (e.g. flood plans, or heat waves) or of the impact (e.g. environmental, shelter safety, public health); others can provide a more comprehensive assessment approach.

2.3.1. Integration of information needs

Integration of available information is key to dealing with climate proofing. Combining the information listed below (geographical definition of exposed areas, population census, and survey of the economic and sensitive values and assets located in these areas like hospitals, industries, major infrastructure, nuclear power stations, etc.), it is possible to obtain an estimate of vulnerability of the elements at risk. In combination with data about frequency and magnitude of the hazard, different LEVELS of economic losses can be calculated and expressed, e.g. in terms of damage per square meter per year ($/m²/yr) or in damage curves[18].

[18] World Meteorological Organization (WMO), 2007. Economic aspects of Integrated Flood Management. Associated Programme on Flood Management (APFM) Publication (http://www.apfm.info/pdf/ifm_economic_aspects.pdf)

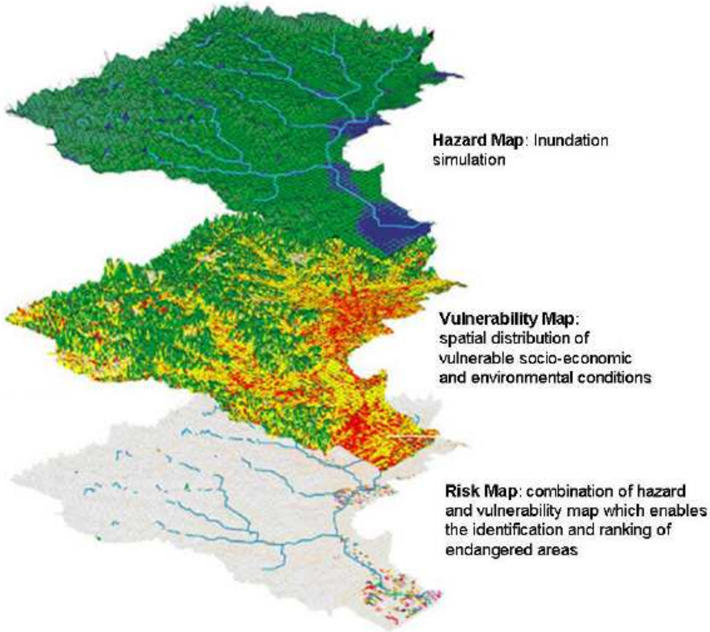
Table 4 Pre-vulnerability assessment

Assessment	**Tools**
Hazard	Hydrometeorological data: • Systematic streamflow measurements • Historical flood data • Annual peaks from rivers in the same region as the river for which hazard assessment is desired • Rainfall frequency data • Curves showing the largest observed floods as a function of drainage area • Temperature data • Evapotranspiration data • Soil moisture data • Groundwater data (including recharge) • Reservoir and lake levels • Seasonal weather forecasts Policies: • Dam operation policy • Reservoir flood-control policy
Exposure	Topographical data: • Specialized geological data • Geomorphological data • Soil studies • Floodable areas • Degree of urbanization • Drainage alteration • Aerial photographs • Satellite images (see Comprehensive Risk Assessment of Natural Hazards – WMO, 1999 [TD 955])[19] Census data: • Geographical distribution of population • Geographical distribution of specific categories of population (e.g. elder people or known cardiopathic/ill people for heat waves) • Surveys • Density of housing • Localization of factories and infrastructures [what does “localisation” mean?] • Economic data
Vulnerability	As vulnerability is a combination of factors that can be physical, economic, social, political, environmental, technical, ideological, cultural, educational, ecological and institutional, these factors are often complex, dynamic and interrelated, mutually reinforcing/amplifying each other. See for example CEH Wallingford Climate Vulnerability Index described in (Sullivan C and J Meigh, 2005; Sullivan C and C Huntingford, 2009)

19 http://www.wmo.int/pages/prog/drr/publications/drrPublications/TD0955_Comprehensive_Assessment_of_Natural_Hazards/WMO_TD0955e.pdf

As an example, integrated flood risk maps help the final users to clearly identify the most endangered areas, infrastructures and utilities. Risk mapping summarizes and presents graphically the outcome of the risk assessment. Other than identifying the risk areas allows users to have an overall and general view of all the components of risk in quantitative terms, identifying those that need to be addressed as a priority, so contributing to planning risk management measures and preparedness. An example of a risk map[20] is shown below in Figure 11 Risk map developed using GIS (Adapted from ADRC)

Figure 11 Risk map developed using GIS (Adapted from ADRC)



Communities and operators of water supply and sanitation utilities should take part in the participatory assessment of risks, vulnerabilities and capacities of supply, distribution and treatment systems linked to action planning by communities, linking them to local development plans.

2.3.2. Post-event assessment of environmental and socio-economic damage

Utilities managers are often pushed by urgent repair works needs and may miss such analysis. Cooperation with other experts/institutions working on the matter may further improve their performance for emergency response and relief coordination.

However, being ready to gather information right after the disaster is another key factor to improve prevention and preparedness. Damage analysis should start before clearing-up operations, while the traces of impacts are still visible. The results of lessons learnt will be useful for improving subsequent risk assessments, including those gauging the effectiveness of rescue operations, and the reconstruction phase.

Keeping this in mind, essential information for the emergency response at this stage would include:

- number of people affected by the malfunctioning of the utility due to the disaster;
- assets that have been damaged, restoration requirements;

20 ADRC http://www.adrc.or.jp/publications/Venten/HP/herath4.jpg

- water quality data;
- assets at risk of being further damaged, based on the status of existing defences and, consequently, number of people at risk of being affected by further malfunctioning;
- status of lifelines (evacuation/access roads, electricity grid, fuel and disinfection product supply), hospitals and shelters;
- current and expected water levels at various locations, as well as weather conditions.

An assessment during the recovery phase is also necessary to understand administrative levels of responsibility for the response, (i.e. local or regional emergency response teams), or whether national or international assistance is required.

Further guidance on this issue is available from various sources, especially national and international bodies working on emergency response and relief coordination. A short list of readily available guidance material includes:

- UNDAC Field Handbook, published by OCHA, providing a rapid assessment methodology on a sectoral basis
- UNHCR Handbook for Emergencies, providing checklists for initial assessments as well as guidance on the provision of safe drinking water
- Community Damage Assessment and Demand Analysis, by the All- India Disaster Mitigation Institute, provides guidance on a staged assessment process for the local level
- Post-Disaster Damage Assessment and Need Analysis, from the Asian Disaster Preparedness Centre, provides ready-made templates for early reporting of damage and needs.

2.3.3. Monitoring and forecasting

Besides hazard assessment, monitoring networks are also the basis of forecasting and early warning systems. Agencies/bodies with responsibilities for monitoring climate and water supply and sanitation usually perform the monitoring but the agencies responsible for collecting, analyzing, and disseminating data and information may vary from one country to another. An analysis of the existing network and its task should be undertaken.

Both in dry and wet periods, a reliable assessment of meteorological variables and of water availability and quality and the outlook for it in the near and long term depends on data listed in Table 5 Data needs for integrated assessment, below:

Table 5 Data needs for integrated assessment

Water quantity	Water quality	Meteorological variables
▪ Precipitation (rain-gauges, low-cost weather radar) ▪ Evapotranspiration ▪ Soil moisture ▪ Ground water (piezometric hydrometers) ▪ Streamflow ▪ Reservoir and lake levels (level meters) ▪ Snowpack	▪ Turbidity ▪ Pathogen analysis ▪ Chemical analysis ▪ Saltwater intrusion in coastal areas[21] Water quality monitoring system should be capable of detecting sudden quality variations in different parts of the supply system (wells, springs, water intakes)	▪ Temperature ▪ Wind speed and direction (anemometers) ▪ Seasonal weather forecasts (climate outlook)
Monitoring should not restrict itself to the hydrometeorological factors, but also include potential impacts e.g. areas subject to landslides or mudflows, glacier and snow melt and the resulting impact on reservoirs		

To be able to integrate in future a local network in the national one, adoption of WMO-recommended or NMHS-adopted standards is necessary. For specific information on how to establish an appropriate hydrometeorological network see WMO Guide to Hydrological Practices (WMO, 2009) or the WMO Guide to Meteorological Instruments and Methods of Observation (CIMO Guide WMO 2008).

All information collected by monitoring networks should be made available to all responsible organizations including public health systems, the managers of reservoirs and dams, and water utilities operators who could be affected by the impacts, at both national and transboundary levels.

For utilities managers, rather than duplicate networks, it is preferable to develop cooperative arrangements serving many purposes. In this respect, big water companies have their own monitoring systems usually linked to the company's remote control system and are technologically equipped to counteract power supply failure in extreme weather conditions. Smaller companies are usually not equipped with these devices/facilities, and connections among suppliers at local and transboundary levels should be properly arranged.

Tables and maps should be available providing details on monitoring locations, parameters, sensors, recorders, telemetry equipment and other related data. In addition, monitoring sites in adjacent basins should be inventoried. In low relief basins, data from those sites could be very useful. Analysis should be performed to identify sub-basins that are hydrologically or meteorologically similar. It may also be the case that information from national monitoring networks is inadequate (architecture, technologies, etc.) for assessment at the local or transboundary level.

[21] Information required for such an assessment would include geology and hydrogeology maps, hydrology and catchment topography data, monitoring data, intake screen depth and stratigraphy, groundwater level variation and groundwater quality, with spatial references for all data

2.4. TOOLS FOR DISASTER PREPAREDNESS PLANNING

2.4.1. Hydrological forecasting tools

Various hydrological tools are available for flood or drought hazard analysis. Hydrological analysis should be compulsory during the planning phase of water supply and sanitation utilities in changing climate conditions. The use of these hydrological tools depends mostly on the availability of adequate data and computation technology. It is however not the purpose of this publication to give a detailed explanation about these techniques, tools and data needs, but to offer a general overview and references. This is illustrated below in Table 6 Hydrological forecasting tools .

Table 6 Hydrological forecasting tools

Frequency analysis	Flood or drought frequency analysis is used to estimate the relation between flood magnitude peak or minimal flow and frequency (WMO, 1989)
Regionalization techniques	To be used for frequency analysis when observed data are available only for short periods or few stations (regional frequency analysis produces results that are more reliable than frequency analysis at a single site - Potter, 1987)
Rainfall/runoff models	If stream flow data is limited, but on the other hand rainfall data is available, another tool that can be used for flood hazard analysis is rainfall/runoff models
Hydrological Modelling	In order to produce a flood forecast for the communities and locations at risk, there must be a hydrological modelling capability that uses meteorological and hydrological data. Hydrological models use real-time precipitation and stream flow data. The models translate observed conditions into future stream conditions
Global Climate Models (and downscaling)	A combination of statistical techniques and regional modelling can be used to downscale climate models and to simulate weather extremes and variability in future climates.

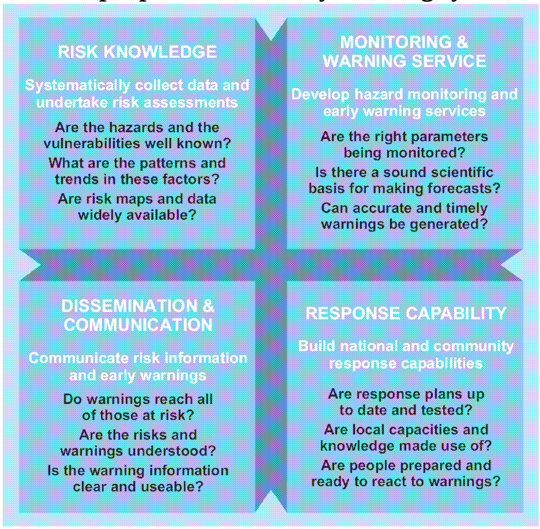
Current hydrological forecast systems are quite affordable and powerful, but effectiveness relies on trained staff. These systems are capable of producing a broad range of forecasts, from stream conditions that will occur in a few hours to seasonal probabilistic outlooks targeted months in advance for larger rivers. Model system selection depends on the amount of data available, complexity of hydrological processes to be modelled, accuracy and reliability required, lead-time required, type and frequency of floods that occur, and user requirements.

With reference to forecasting tools for heat waves, they consist of calibrated models for the definition of meteorological maps; these models are usually fed by a series of parameters measured at ground level such as atmospheric pressure, humidity, wind speed, temperature. Through these maps pressure fields are simulated and/or forecast for definition, through mathematical algorithms, of rain, wind and temperature fields.

2.4.2. Early Warning Systems

A warning means that the hazard is now a reality and that action has to be taken. Early warning is vital for many response activities. The effectiveness of the warning depends on its reliability, the skilled interpretation of the warning signal, exchange and interactive cooperation between different early warning systems (public health, meteorological, environmental, water managers and suppliers) and the ensuing emergency/rescue operations. The longer the lead-time, the more useful the warning, since the number of options for reaction is larger. The four elements of a people-centred early-warning system are shown below in Figure 12 Four elements of people-centred early warning systems (Source: UN/ISDR):

Figure 12 Four elements of people-centred early warning systems (Source: UN/ISDR)



To improve cooperation and avoid conflicts, an open and transparent communication mechanism between the warning manager, the disseminator, the receiver and down to the operators who should take action is a prerequisite. Relevant data and information on hydrometeorological variability and trends, water quality availability and health risks should be made available to water supply and sanitation utilities operators.

The main elements of the early warning chain are:

- Detecting and forecasting impending extreme events to formulate warnings on the basis of scientific knowledge and monitoring, and consideration of factors that affect disaster severity and frequency;
- Disseminating warning information, augmented by information on the possible impacts on people and infrastructure (i.e. vulnerability assessment), to the political authorities for further communication to the threatened population, including appropriate recommendations for urgent action; and
- Responding to warnings, by the operators of the utilities, the population at risk and the local authorities, based on a proper understanding of the information, and subsequent implementation of protective measures.

Communication throughout the early warning chain must be two-way and interactive. Originators, disseminators and end-users must be in continuing contact with one another in order to make the system responsive to people's needs, priorities and decisions. The system has to adjust to users; not the other way around.

2.4.3. Management tools

2.4.3.1. Flood Management Tools

In the framework of Integrated Flood Management (IFM), the Associated Programme on Flood Management (APFM) is making an effort to provide guidance tools for flood managers and various other specialists workingon the subject. . A series of tools has been developed and made freely available for download at http://www.apfm.info/ifm_tools.htm.

These tools are intended to help gain quick access to relevant technical guidance over the Internet. The guidance contained in these tools is intended to clarify the role and context of IFM in applying specific tools. The tools seek to incorporate various relevant materials previously scattered over the Internet and other sources.

2.4.3.2. Regional Climate Outlook Forums

A regional climate outlook forum (RCOF) is a process, pioneered in Africa but still new to Europe, which brings together climate experts, sectorial users and policymakers, to produce regional climate outlooks based on input from National MeteoHydrological Services (NMHSs), regional institutions, regional climate centres (RCCs) and global producers of climate predictions.

RCOFs assess the likely implications of the future climate (particularly droughts, heat waves, etc.) for the most pertinent socio-economic sectors in the given region. RCOFs were originally designed to focus on seasonal prediction, and have significantly contributed to adaptation to climate variability and extreme weather events. The concept can be extended to develop capacities to adapt to climate change, and therefore to its consequences in terms of extreme weather events.

Forums include components ranging from scientific meetings of regional and international climate experts to developing a consensus for the regional climate outlook, typically in a probabilistic form. But probably more relevant for utilities managers is the fact that they involve as well both climate scientists and representatives from the user sectors (agriculture and food security, water resources, energy production and distribution, public health, and other sectors such as tourism, transportation, urban planning, etc.) to identify impacts and implications and formulate response strategies.

RCOFs also review obstacles to the use of climate information, experiences and successful lessons regarding applications of past RCOF products, and enhance sector-specific applications. The development of RCOFs requires good seasonal forecasting skills. These RCOFs then lead to national forums to develop detailed national-scale climate outlooks and risk information, including warnings which can be communicated to decision-makers and the public.

2.4.3.3. Involvement of utility managers in land-use plans

Knowledge of the hazard is a prerequisite for successful impact mitigation. Hazard and risk maps must be established, even if only a residual risk exists. Avoiding exposure to the hazard by keeping hazard zones free of intensive economic use is frequently recommended.

However, water sources and fertile soils encourage intensive human activities (agriculture, industry , and tourist areas) and settlement development, and skilled planning is required in hazard zones. Appropriate building codes and zoning restrictions should be established with the objective, if not of avoiding risk entirely, then at least of minimizing it in these areas.

With a multi-hazard approach in mind, it is also interesting to take into account the positive side-effects of some land uses (e.g. the conservation of perviousssurface areas as farmland will also be effective as evacuation areas for other hazards).The prescription of what constitutes good practice depends very much on the type of hazard.

Safe delivery of water supply and sanitation services in critical conditions should be included in land-use plans and revised regularly (e.g. changes in land-use plans due to socio-economic development).

2.4.4. Hazard proofing

There are several available structural measures which must be adapted case-to-case to the type of hazard. Since total protection is not feasible, a predefined protection target or design standard has to be set. This target varies according to the economic and social values to be protected and according to the economic capacity of the society to protect them. These protection targets often are or become insufficient, either because knowledge of the hazard has improved (e.g. climate change) or due to an increase of the values to be protected (i.e. population development). In all cases prevention measures have to be accompanied by worst-case scenario emergency planning, which forms a key element of preparedness, including regular inspection and maintenance. More details on these measures will be given in the last two chapters of the *Guidance.*

Safe buildings are a key element in reducing vulnerability. Adequate building codes can improve resilience to several risks, including earthquakes, floods, landslides and tornadoes.

Stepping up investments in structural measures is necessary to reach “water security”, i.e. coping with too much, too dirty or too little water. Keeping water supply and sanitation utilities operational during extreme events will contribute to making the community more resilient to hazards. To this end, , building in planned redundancy (e.g. building two access/evacuation routes rather than one, having back-up power generation capacity, a groundwater reservoir etc.) should be promoted.

The involvement of managers of water supply and sanitation utilities is essential, since they should be able to operate continuously while responding to hazards. Therefore they need to be empowered; their management capabilities need to be strengthened; and their participation should be incorporated into disaster mitigation strategies.

In case of emergency, vital facilities, equipment and communications have to be replaced/repaired as soon as possible, even if only temporarily. . In the first instance this includes the ”lifelines” such as water supply, electricity supply, roads and telecommunications, hospitals and sewage systems. In the absence or temporary unavailability of safe water sources and sanitation facilities, utilities should be ready with alternatives. .

It is also important to restore the water supply system if it suffers pollution from flooding events: a chlorine dispenser for disinfecting polluted water to an adequate level should be installed in critical sections of the system.

Other recovery measures may include mobile disinfecting plants or spare pumping stations installed in the same aquifer, exploiting water from a confined (unpolluted) artesian stratum.

2.5. ROLE OF THE HEALTH SYSTEM IN DISASTER PREPAREDNESS AND EARLY WARNING

Development infrastructure that forms the economic and social lifeline of a society, such as communication links, hospitals, etc., should be designed to cope with the most severe natural hazards and should work even in a disaster. . Nor should this infrastructure increase the magnitude of the hazards.

Health systems need therefore to quickly recover their capacity to meet demand for service delivery in extreme weather conditions.

Extreme weather events affect health systems' operations and efficiency in different ways. Health facilities' built-in hazard-prone areas can be damaged, as can the access to them. The increased demand for health care could exceed the local public health capacity (including drugs, stockpiled vaccines, and trained personnel). Spontaneous or organized migration away from the area affected by the extreme events could shift the problem of exceeding the capacity of the health system to other areas. This also increases the potential risk of a critical outbreak of communicable disease, as well as increasing the risk of psychological diseases among the affected population.

Extended periods of drought or heat waves could lead to weakened resistance to various diseases.

The interruption of a health facility's operations after a disaster may be short-term (hours or days), or long-term (months or years). It all depends on the magnitude of the event and its effects on the health sector. The magnitude of an event cannot be controlled; its consequences, however, can be.

When planning a future health facility, the effects of these phenomena can be controlled if site selection is guided by sound information and criteria, and the design, construction, and maintenance can withstand local hazards.

During the 126th session of the Pan American Health Organization (PAHO)'s Executive Committee, it was decided to reduce the impact of emergencies and disasters on health through the following actions:

- planning and executing public health policies and activities covering prevention, mitigation, preparedness, response, and early rehabilitation;
- providing an integrated focus addressing the causes and consequences of all possible emergencies or disasters that can affect a country;
- encouraging the participation of the entire health system, as well as the broadest possible intersectoral and inter-institutional cooperation, in reducing the impact of emergencies and disasters; and
- promoting intersectoral and international cooperation in finding solutions to the health problems caused by emergencies and disasters.

As an example, a comprehensive reference for challenges that have to be met by the public health sector in floods is summarized in Table 7 Health system planning for flood preparedness (Source: Meusel et al., 2004 and WHO, 2005):

Table 7 Health system planning for flood preparedness (Source: Meusel et al., 2004 and WHO, 2005)

Type of activities	Health outcome and preventive measures
Pre-flood activities	▪ Long-term risk management: flood health prevention as part of multipurpose planning ▪ Inter-institutional coordination ▪ Infrastructure flood-proofing ▪ Service planning risk zoning, risk mapping of health care and social care facilities, availability of communication and transport possibilities, emergency medical service preparedness, water and food supply planning for emergencies, evacuation organization, etc.) ▪ Awareness-raising campaigns targeting different groups in areas at risk ▪ Capacity-building and personnel training for emergencies
Health protection during floods	▪ Prevention and treatment of infectious diseases, respiratory problems, injuries, mental health problems and skin and eye diseases - review and prioritize ▪ Possible extra vaccinations for the general population ▪ Communication campaign such as distribution of “boil water” notices, general hygiene advice and information on preventing mould, rodents, snake bites, and electrocution ▪ Outbreak investigation where appropriate ▪ Enhanced epidemiological surveillance of infectious diseases ▪ Risk assessment of major environmental sources of contamination of health relevance ▪ Intensify monitoring of drinking water quality (tap) ▪ Water and food provision ▪
Long-term health protection	▪ Treatment for mould and other pathogenic exposures ▪ Post-flood counselling (for anxiety and depression, for example) ▪ Medical assistance ▪ Enhanced cause-related surveillance ▪ Research for future preparedness and response

Communication and information to the public is also a key role of the health sector to prevent exposure to hazards in extremes (heat waves, cold spells, floods). For more details please refer to the next chapter.

2.6. CONCLUSION

- The effectiveness of risk reduction in extreme conditions relies on a commitment to apply integrated risk management principles in development planning; the existence of well-defined institutional responsibilities; a democratic process of consultation and information; and an awareness campaign. It moves beyond disaster response and reaction, towards risk anticipation and mitigation.
- All key actors such as climate, environment, IT and health professionals should be helped to cooperate to assess and cope with vulnerabilities. In this regard, , utilities managers should be involved in information sharing and preparedness activities, as they are themselves

responsible stakeholders in coping with water and sanitation risks along with increasing demographic pressure, land use, overexploitation of resources, and climate change.

3 COMMUNICATION IN EXTREME WEATHER EVENTS

3.1 KEY MESSAGES

- The communication strategy, based on a multidisciplinary approach, should be part of the risk disaster management and adaptation plans for extreme weather events in order to share knowledge among different actors,
- Specific communication activities should be planned (before, during and after the event) and targeted at different groups at risk (e.g. the elderly, children, rural communities).
- Public authorities must be mainly responsible for elaborating and delivering the messages.
- The media are a key partner in communication.
- Communication should be a long-lasting and institutional process and not only a contingency tool.

3.2. INTRODUCTION: IMPORTANCE OF A COMMUNICATION STRATEGY

People not aware of risks can slow down the emergency operations. Persuading people to evacuate in advance of a predicted threat is very difficult because they tend to discount warnings and it can exacerbate the problem. Appropriate information distribution and sound decision-making before and during weather emergencies are critical to saving lives, reducing injuries and protecting property.

Based on a multidisciplinary approach, a communication strategy can improve the effectiveness of the interventions and so the authorities (water managers) should consider including this strategy in the risk disaster management and adaptation plans designed to cope with extreme weather events. Different types of risk communication strategies should be developed, depending on the type of events (heat waves, cold spells, storms, flooding etc.).
In order to improve the effectiveness of the measures, local authorities play a key role in undertaking work on preparedness and response to extreme events.

The communication strategy should include a plan of specific activities which should start **before** the crisis (pre-events activities) such as specific education programmes at schools, capacity building projects, training of personnel (media staff included) and awareness raising campaigns targeting different groups at risk and focused on vulnerable groups (the elderly, children, etc.).

During the event the communication campaign should provide the public with a unique, early and accurate announcement to foster trust in the institutions, to build public flexibility and to guide appropriate public participation to support the rapid control of the crisis. **After** the crisis the lessons learned should be considered in future planning as a useful tool for updating the communication strategy.

3.3. COMMUNICATION ACTIVITIES

Extreme weather events and their impacts on health and environment emphasize the need to keep the community and the general population informed about the associated risks for individuals and the protection measures being taken before, during, and after the event. The first steps are the collection and evaluation of the data. Then the authorities should provide information to the population on how best to protect themselves from extreme weather and climate events in general. The public authorities are the main source responsible for elaborating and delivering the messages and it is advisable to establish a coordinating agency with a leading authority supported by a “risk communication team” consisting of the different actors involved such as water managers, media, non-governmental organizations and other relevant stakeholders.

Awareness-raising campaigns on water and sanitation management and health outcomes should be addressed before the crisis happens. **Education** programmes in schools also play a key role. . **Training** for the identified team should be focused on how to develop timely and effective communication skills to inform the public, partners, and stakeholders about recommendations. During public health emergencies the spokesperson’s image and voice should be familiar to audiences to invite trust. He/she should be trained in how to build up and deliver the messages and should be informed about water and sanitation utilities and public health threats.

Along with increasing awareness and training, the **attitude change of the general public** should be promoted. Communication is a dialogue and requires close interaction between information providers and those who need the information. Beliefs and attitudes can be changed through openly pointing out and explaining the issue. After improving people’s understanding, the receptiveness of climate change messages and creating ownership of the problem, behavioural changes can be promoted. Individuals and groups can be persuaded that they can make a difference in terms of their own lifestyle choices and in mobilizing their communities to reduce their risk of climate-sensitive diseases. In some countries certain groups of the population are more difficult to reach than others, e.g. the elderly, children, immigrants, rural communities and other groups. They need specific attention as well as a specific approach.

Appropriate risk communication procedures foster the trust and confidence that are vital in a crisis. The information should be provided early in a crisis and it should be transparent about what is known and unknown. That helps build **trust and credibility**. The first official announcement will establish the trust and this will guarantee the public acceptance of official guidance and trust **in institutions** and their recommendations.

The announcement should be **accurate, timely, unique, frank and comprehensive**. There is always a complex relationship between providing accurate information and providing it quickly. To wait for complete and verified information before releasing it to the public can generate an information vacuum which can give rise to speculation. Against that, to release information which has not been double-checked or is actually inaccurate runs the risk of misleading the public and undermining the credibility of a spokesperson. Understanding people is also critical to communicating effectively. To change people’s beliefs and their **perceptions** it is necessary to understand what they think and why they act in the way they do. Communicators should develop proper messages to target the public, including information on how they can make themselves safer in a crisis.

Communication with the public and the news media should be planned, taking into account what information it is crucial to pass on in initial messages; what kind of messages should be delivered before, during, and after the event; what are the obstacles to effective communications and how to minimise them for specific audiences. Isolated communities should be identified and special tools developed to reach them.

.

3.4. PARTNERSHIP IN COMMUNICATION

An effective risk communication strategy includes planning, preparation, messaging and working with the media, and the ability to manage the flow of information at each stage.

The **media** play a major role and are the most common channel of communication to the public. The best way to address the challenge is to establish regular briefings with the media and a trained key staff member to deliver, explain and update all information.

Necessary information should be identified and appropriate leaflets, fact sheets and information materials should be developed. Dissemination of information can be achieved by means of the mass media (radio, television, and newspapers), web sites and short message systems via mobile telephones. The general public mostly accepts television advice messages and TV remains the main channel for reaching different population groups.

The **media communication strategy** should be part of the risk communication strategy and it should be planned in advance with the participation of the authorities, non-governmental organizations and other relevant stakeholders. Cooperation with partners as an ongoing process is important if you want the public to take action.In order to deliver targeted and effective messages it is necessary to find out the reporter's needs.

Knowledge and media warnings alone are often not enough to persuade people of the seriousness of a situation. Interpersonal communication is very powerful, so the communicator should take into account **social networks** and develop a long-lasting cooperation with them.

3.5. MONITORING AND EVALUATION OF THE OUTCOMES

Before and during the events the communication strategies and their tools should be tested practically and monitored, while an evaluation of the outcomes should be carried out after the event.

The *ex post* evaluation is crucial to measure the value and effectiveness of the activities, not least in terms of their cost. . It is important to know what changes have happened as a result of communications: the level of awareness of the target audience; actions before/after extreme weather events, and gaps in communications that can be improved. Also, evaluation results are an information source for risk managers, decision makers and the public. It is imperative that after events lessons are learned, including hat did not go well and should be improved.

3.6. CONCLUSIONS

- Appropriate communication and information to the public can reduce injuries and save lives.
- Communication is a key issue to improve the prevention of harm to health as well as the effectiveness of interventions.

4. VULNERABILITY OF COASTAL AREAS AND BATHING WATERS IN EXTREME WEATHER EVENTS

4.1. KEY MESSAGES

Variations in the frequency and intensity of extreme weather events will pose serious challenges to the management of unique coastal ecological and cultural systems.

Vulnerable coastal systems include fisheries, agriculture, tourism, marine and freshwater resources, health infrastructure, and municipal water supply and sanitation systems.

Both major extremes of global climate change can have serious impacts on coastal areas:

- Drying and water scarcity may result in the over-exploitation of groundwater resources, reducing their availability as well as worsening their quality (through contaminant concentrations) with harmful consequences for water supply to the population, agriculture and energy production.
- Extreme rainfall and storms may result in increased runoff, river discharge, more intense erosion and the mobilization of chemical and biological contaminants by surface runoff from urban and agricultural areas.

The highest environmental and health risk stems from the combination of rising sea level and the more intensive coastal storms that would increase the salinisation of water supplies, including aquifers used for drinking-water. The major problem is that in most if not all of the coastal regions groundwater is a key source of water supply; especially of drinking water (more than 2 billion people worldwide depend on groundwater).

Saline water intrusion, accelerated by both the rising sea level and the over-exploitation of groundwater resources in a drying climate, poses both quantitative and qualitative risks to the population. Extreme storm surges combined with rising sea level could result in much higher rates of coastal erosion, which would in turn further increase saline water intrusion. A 5% increase in salt content will rule out many important uses, including drinking water supply and the irrigation of crops, parks and gardens, and will threaten groundwater- dependent ecosystems.

Prevention of saltwater intrusion into coastal aquifers is a key challenge for all human uses and for the protection of groundwater-dependent ecosystems. In developing adaptation strategies the first task is to renew or review the existing water quality standards on the salt content of water resources. Appropriate monitoring systems should also be developed (WHO have not proposed a health-based guideline value for chloride in drinking-water.) A table on salinity levels able to injure irrigated plants is presented in this chapter. Development and regular calibration and verification of hydrological and hydrogeological models (and their combination with climate models?) could increase the chances of developing appropriate adaptation strategies.

One approach to better understanding the vulnerability of coastal areas and recreational water environments to the effects of climate change is to apply the DPSIR framework. This is done below in Table 8 Classification of the climate change impact on the vulnerability of coastal waters according to the DPSIR approach:

Table 8 Classification of the climate change impact on the vulnerability of coastal waters according to the DPSIR approach

Drivers	Natural changes in the climate plus all human actions that (might have) affected the changes
Pressures	Warming of air and water, droughts, rainstorms, flash-floods (with special regard to sea level rise and storm-surges), excessive water abstraction from ground and surface waters. Increasing diffuse-source pollution
State	State of the quality and quantity of available ground and surface fresh water resources in coastal regions
Impacts	Salt-water intrusion into fresh groundwater resources: declining, deteriorating fisheries, agriculture, tourism, marine and freshwater ecosystems, health infrastructure, municipal water supply and sanitation systems, deteriorating freshwater quality.
Responses	Revision of water quality standards, improvement of monitoring systems, development of hydrological and hydrogeological models. Actual strategies that were not mentioned in this chapter but may include: ▪ Finding alternative freshwater resources, storage of river and runoff water, rainwater harvesting; ▪ Development of water desalinating technologies; ▪ Building engineering structures that prevent saltwater intrusion into aquifers; ▪ Securing much more efficient uses of available freshwater by various non-technical, educational, public information, legal-administrative means, etc.

4.2. VULNERABILITY OF INLAND BATHING WATERS

Both extremes of a changing climate (extreme drought and rainstorm runoff), may have serious impacts on the quality of inland bathing waters in rivers and lakes, causing a health risk to people bathing there.

Extreme droughts result in lower river discharges and smaller volumes of standing waters and this will, due to reduced dilution, cause increased concentrations of all types of contaminants discharged into the water. In addition to this, warmer water temperatures will change all temperature-dependent chemical reactions and biological processes, some of which may result in serious deterioration of bathing water quality. A typical example (illustrated briefly below from Lake Balaton, Hungary) is when increased plant nutrient concentrations, warmer water temperatures and lower water levels (allowing better light penetration) can cause the sudden proliferation of algae, among them the bloom of blue greens, which can have an adverse impact on bathers' health via the toxins they contain. Bathing in fresh waters containing toxic cyanobacterial blooms or scum can cause nausea, vomiting, and hay fever-like symptoms, especially in children. The sight and smell of masses of decaying algae would also cause people to avoid the bathing waters.

Drought- and water scarcity-induced migration of people to the north may also result in the re-emergence in bathing waters of viruses and pathogens that have been long extinct in Europe, such as Hepatitis A.

Extreme stormy rainfall runoff may cause sudden and excessive loads of faecal bacteria in bathing waters, especially near urban areas, due to the stormwater overflow of combined sewer systems. Even urban runoff waters arriving via separated sewer systems will cause high loads of many contaminants, including bacteria. Flash storm runoff from agricultural land also sends extra loads of various contaminants into recipient waters and thus to bathing waters via erosion and leaching from rural land, fertilizer- and pesticide-laden agricultural soils, and from various forms of animal husbandry. In Europe the diffuse loads of many contaminants from storm runoff represent the greater part of the total annual load to surface waters (and that was the case even before the onset of the WFD led to rapidly decreasing point-source sewage and waste water loads).

Global warming may encourage the appearance of new pathogens. Examples include *Vibrio* species, *Naegleria* and *Acanthamoeba* species that can better proliferate in the warmer waters. New subtropical/tropical cyanobacterial species can invade European bathing waters. Zoonotic infections may also be changed and amplified due to the changes in migrating animal species, especially those of water fowl.

Adaptation and mitigation measures should first be aimed at achieving joint action and data sharing by all levels of waterrelated authorities, since in most of Europe surface waters belong to both health and water/environmental authorities, which act as separate entities. It is also important to upgrade monitoring systems to include event-based sampling of urban and rural stormwater runoff and the water of the recipient streams and lakes. Data from such monitoring campaigns are practically nonexistent and therefore the actual health risk is not known and reliable counter measures cannot be designed or planned.

Actual adaptation strategies should aimed first at developing/applying urban and rural diffuse load reduction technologies. Among these, the provision of storage of both urban and rural storm runoff water by appropriately designed polishing ponds and wetland systems is the most urgent task. On agricultural land this should be accompanied by the familiar techniques of keeping and storing water in the soil (contour line tillage, terracing, vegetation buffer strips, etc.) thus also removing contaminants and preventing erosion.

More information on the contamination of bathing waters can be found at http://www.strandinformacio.hu/index.php?lang=en. The value of applying the DPSIR approach is shown below in Table 9 Classification of the climate change impact on the vulnerability of inland bathing water according to the DPSIR approach

Table 9 Classification of the climate change impact on the vulnerability of inland bathing water according to the DPSIR approach

Drivers	Natural changes of the climate plus all human actions that (might have) affected the changes of the climate
Pressures	Warming of air and water, drought, rainstorms, flash-floods, Increasing point (end-of-pipe) and diffuse-source pollution
States	State of the quality and quantity of bathing waters of freshwater lakes and streams, including their ecological status.
Impacts	Increasing concentrations of all pollutants due to less dilution by water in drought-affected regions. Excessive growth of algae including blue greens. Warming may cause the appearance of new pathogens. In the case of flash rainstorm runoff sudden and excessive loads of faecal bacteria in bathing waters can be expected, especially near urban areas. High loads of many pollutants from agricultural land caused in this way also adversely affect bathing water quality. Changes in the migration of water fowl may be the source of extra bacterial loads to bathing waters (especially in lakes).
Responses	Health and water/environmental agencies should merge their data bases and harmonize monitoring programmes. The latter must focus on storm/runoff events in both runoff water and in bathing water to provide data for planning adaptation and preventative strategies. Concrete adaptation and control strategies should aim not only at developing and applying urban and rural diffuse load reduction technologies (the BAT, Best Available Technology) but also at developing novel solutions and at the careful regulation of lake water levels (when this is an option).

4.3. SALINE WATER INTRUSION IN AQUIFERS USED FOR THE PRODUCTION OF DRINKING-WATER

Global climate change and extreme weather events (e.g. severe storms, droughts and floods) are expected to have negative effects on the quantity and quality of water resources (EEA, 2007) [22] amplifying the anthropogenic pressures on surface water and groundwater resources (Hiscock and Tanaka, 2006)[23] resulting from the growth in the global population and the demand for potable

[22] European Environmental Agency (EEA), 2007. Climate change and water adaptation issues. Technical Report n.2.

[23] K. Hiscock and Y. Tanaka, 2006. Potential impacts of climate change on groundwater resources: from the high plans of the U.S. to the flatlands of the U.K. National Hydrology Seminar 2006 Water Resources in Ireland and Climate Change. (http://www.opw.ie/hydrology/data/speeches/Hiscock.pdf)

water. Groundwater is a key source of supply, especially of drinking water. In fact, worldwide more than 2 billion people depend on groundwater for their daily consumption (Kemper, 2004)[24].

From a water quality perspective, extreme dry periods may result in a lower dilution capacity and in increased concentration of contaminants in groundwater aquifers, especially in the unconfined ones. In quantitative terms, reduced groundwater recharge during dry periods and increased water abstraction due to warmer temperatures may cause further water stress by reducing groundwater table levels.

Particularly in coastal areas where the pressure on water demand is very high due to population density, agriculture and tourism, the consequences of extreme weather events on freshwater aquifers may be exacerbated by the intrusion of seawater into freshwater aquifers.

Larger storm surges produced by extreme storms, combined with a rising sea level, could result in much higher rates of coastal erosion, which would in turn affect the levels of saline intrusion into coastal freshwater[25].

Coastal freshwater aquifers are strategic resources that provide water for many important uses including town water supply, domestic water supply, irrigation of crops and industrial processes. In addition to the threats posed by extreme events and rising sea levels, saltwater intrusion into groundwater could be exacerbated by human abstraction and over-exploitation.

In general freshwater contamination by seawater of only 5% is usually enough to preclude many important uses including drinking water supply, irrigation of crops, parks and gardens, and the wellbeing of groundwater- dependent ecosystems[26]. So the prevention of saltwater intrusion into coastal aquifers is a key challenge, not only to maintain adequate water quality for human consumption, but also to permit other possible human uses of groundwater, particularly under predicted climate change and extremes.

At international and European level, water quality standards are used to protect human health from the adverse effects of saltwater contamination of drinking water. Limit values of sulphate/chloride/conductivity are useful for estimating seawater intrusion and the intrusion of non-seawater salts into groundwater (EU Groundwater Directive[27]). The Drinking Water Directive[28] (DWD, 98/83/EC) fixed a salinity limit, measured as conductivity, equal to 2500 μS/cm.

According to the World Health Organization (WHO, 2006) no health-based guideline value for chloride in drinking-water was proposed (an excess of 250 mg/litre can give rise to a detectable taste in water). WHO stated in 2006 that the average daily intake of sulphate from drinking water, air and food is approximately 500 mg, food being the major source. The existing data do not identify a level of sulphate in drinking water that is likely to cause adverse human health effects. However, because of the gastrointestinal effects resulting from ingestion of drinking-water containing high sulphate levels, it is recommended that health authorities be notified of sources of drinking water that contain sulphate concentrations in excess of 500 mg/litre.

---

24 Kemper, K.E. 2004. Ground water—From development to management. Hydrogeology Journal 12, no. 1: 3–5.

25 (http://www.ozcoasts.org.au/indicators/saline_intrusion.jsp)

26 (http://www.connectedwaters.unsw.edu.au/resources/articles/coastal_aquifers.html).

27 Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration Available from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:372:0019:0031:EN:PDF Accessed 5 April 2010

28 Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption Accessible from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31998L0083:EN:NOT Accessed 5 April 2010

Important quality standards are also available to set the suitability of groundwater quality for irrigation and protection of plants from saltwater contamination. According to Camberato (2001)[29] irrigation water is classified under four categories based on the salinity hazard, which considers the potential for damaging plants and the accompanying management measures needed for use as an irrigation source. See Table 10 Classification of saline irrigation water (Source: USDA) below:

Table 10 Classification of saline irrigation water (Source: USDA)

Salinity class	Electrical conductivity	Total dissolved salts	Potential injury and accompanying management measures
	µS/cm	(ppm)	
Low	< 250	< 150	Low salinity hazard; generally not a problem; additional management is not needed.
Medium	250 - 750	150 - 500	Damage to salt-sensitive plants may occur. Occasional flushing with low salinity water may be necessary.
High	750 - 2500	500 - 1500	Damage to plants with low tolerance to salinity will likely occur. Plant growth and quality will be improved with excess irrigation for leaching, and/or periodic use of low salinity water and good drainage provided.
Very high	> 2500	> 1500	Damage to plants with high tolerance to salinity may occur. Successful use as an irrigation source requires salt-tolerant plants, good soil drainage, excess irrigation for leaching, and/or periodic utilization of low salinity water.

In addition to water quality standards, groundwater monitoring systems are necessary, particularly in coastal areas where it is important to check saltwater contamination. The implementation of monitoring programmes to protect drinking water quality is an important task. The use of adequately designed monitoring networks can help in optimizing the number of sampling points, including choosing adequate times and suitable sampling positions and constructing an efficient and optimized sampling network (Marangani, 2008). Another tool to help managers in detecting seawater intrusion and monitoring future contamination of coastal aquifers is the application of integrated indexes.

According to Edet and Okerekean (2001), monitoring should be based on an Assessment Index (AI) considering the following indicators of saltwater intrusion: Total Dissolved Solids (TDS), Density (D), Sodium (Na), Chloride (Cl), and Br/Cl ratio. Additionally, , in order to characterize the complexity of salinization and groundwater evolution processes, and to determine the spatial extension of the saltwater contamination, Di Sipio *et al.* (2006)[30] proposed the use of geochemical and isotopic analyses associated with electrical conductivity data.

[29] Camberato, J. 2001. Irrigation Water Quality. Update from the 2001 Carolinas GCSA Annual Meeting, Clemson University Turfgrass Program.

[30] E. Di Sipio, A. Galgaro, G.M. Zuppi (2007). Contaminazione salina nei sistemi acquiferi dell’entroterra meridionale della laguna di Venezia. Giornale di Geologia Applicata 5 (2007) 5-12.

Generally, hydrogeological exploration programmes for the assessment of salt intrusion processes require the use of dedicated monitoring wells and piezometers, the collection of water samples and aquifer performance/water quality tests. The use of multiple-depth monitoring wells including several piezometers installed at different depths can help in monitoring ground-water levels and water quality and determine whether the hydraulic gradient is established from the coast to the pumping wells, indicating possible seawater intrusion (Wesley and Crawford, 2008).

In order to evaluate the potential impacts and risks of seawater intrusion into coastal aquifer systems and to employ appropriate monitoring systems and adaptive measures, especially during extreme weather events, it is essential to characterize both exposure to climatic factors and the sensitivity of groundwater resources to climate variations and extremes (see also chapter 2).

A comprehensive knowledge of the nature of climatic variation in space and time is vital to characterize exposure and therefore climatic stressors that impact on a system. The combination of hydrological and hydrogeological models with climate models gives the opportunity to adjust global climate model (GCM) bias and include improved representations of hydrological processes. Moreover, a combination of statistical techniques and regional modelling can be used to downscale climate models and to simulate weather extremes and variability in future climates.

So regional hydrological and groundwater models integrated with climate and statistical models allow investigators to consider the groundwater balance in the aquifer and to simulate saltwater intrusion under present and future scenarios of climate change. Finally, together with integrated modelling, empirical approaches such as the ”analogue approach” give information that is more specific than that given by the GCMs. By reconstructing past climates (i.e. temperature and precipitation) in a given area these approaches can be used to construct future scenarios by analogy (Dragoni and Sukhija, 2008)[31].

4.4. CONSEQUENCES OF EXTREME WEATHER EVENTS FOR BATHING WATER QUALITY

4.4.1. Vulnerability

Vulnerability has to be taken into account from two perspectives - the susceptibility of i) people and ii) the water source. Personal vulnerability is critical for elderly or immune-compromised people. Also, with respect to diarrhoeal diseases, young children can be considered as a highly susceptible group.

The vulnerability of water sources plays a massive role in changing bathing water quality. Shallow lakes, for example, are more vulnerable to droughts than deep ones. . At lower water levels, or with decreased water volumes, concentrations of all pollutants increase, including plant nutrients, and the water temperature rises more rapidly, resulting in better conditions for emergent tropical and subtropical pathogens to proliferate

In several European countries, especially in the Nordic countries, enteric viruses, mainly Norovirus infections, remain a major waterborne risk (Risebro *et al.* 2007)[32]. It is likely that the risk of disease from these infections elsewhere in Europe is much greater than currently realized. The large

---

[31] Dragoni W, Sukhija BS (2008). Groundwater and climatic changes: a short review. In : Dragoni W, Sukhija BS (eds.) : Climatic Change and Groundwater. *Geological Society of London Special Publication* 288: 1-12.

[32] Risebro HL, Doria MF, Andersson Y, Medema G, Osborn K, Schlosser O, Hunter PR (2007). Fault tree analysis of the causes of waterborne outbreaks. *Journal of Water and Health*, 5(Suppl. 1):1-18.

majority of enteric viral infections is strictly anthropogenic, but climate change impacts could bolster the (re)-emergence of viral infections as a result of poorer quality water because of seasonal drying-out or extreme weather.

In addition to these demographic changes, migration into Europe as a consequence of climate change elsewhere could bring in new viruses and reintroduce those that have declined in importance in the continent. . For example, Hepatitis A infection (HAV) has decreased substantially in most European populations in recent decades as a result of improved sanitation and hygiene.

But immigration into Europe from Africa will lead to an increased incidence of HAV in immigrant populations, and this could lead to an increased risk of re-emergence, including its water-borne spread. Climate change will also affect avian and mammal populations which could bring in new viruses of risk to health. For example, although primarily a respiratory disease, SARS, a zoonotic infection, was shown in one outbreak to spread through waste water.

Case study 1 Consequences of drought in a shallow lake, Lake Balaton, Hungary 2003

Lake Balaton is situated in the western part of Hungary, in Transdanubia. It is the largest shallow lake in Central Europe with a surface area of 593 km^2. The average depth of the lake is 3.14 m and 11,0 m at the deepest point. As a consequence of a series of dry years at the turn of the millennium, the water level of the lake dropped in 2003 to 23 cm below the lowest regulation level, which is 70 cm lower than the multi-annual minimum level. The average annual precipitation into the drainage basin of the lake was 507 mm in these dry years, which is 110 mm lower than the multi-annual mean. Altogether, the depth of the water off the southern flat beaches of the lake turned to as low as 10 to 20 cm along hundreds of meters from the shoreline towards the middle of the lake. As shown by the pictures below, green algal blooms occurred along all the beaches. This algal material concentrated the diatoms into a mass that caused skin irritation by their lance-like structure. A lot of complaints about this were registered during this period. In addition, the sight and smell of algal scum were repulsive, frightening visitors away from the beaches

Picture 1 Algal contamination in Lake Balaton

Mechanical removal of algal beds

Close contact of bathers with algae can pose a direct health risk

4.5. WATER QUALITY CHANGES CAUSED BY EXTREME WEATHER

4.5.1. Stormy rainfalls

Heavy rainstorms causing increased flood runoff, erosion and the washing-off of large amounts of contaminants will have a major impact on the abundance of waterborne pathogens in bathing waters because of increased agricultural soil erosion, the overflow of rural and urban sewage treatment systems, and chiefly because of urban stormwater runoff load. A lot of faecal pathogens will also be washed into bathing waters.

Zoonotic infections may expand as the faeces of wild birds and mammals (notably rodents) on the beaches are washed into the water. Increased erosion from agricultural areas may increase nutrient loads in bathing water, providing better conditions for the proliferation of toxic cyanobacteria. Bathing in fresh water containing toxic cyanobacterial blooms or scum can cause nausea, vomiting and hay fever-like symptoms, especially in children, because they play in shallow water where the blooms can accumulate, The amount of cyanotoxins can reach the DTI (daily tolerable intake), especially in children.

4.5.1.1. Global warming

Warmer air temperature may warm the water and new pathogens or harmful species can appear which are new to the European region. Examples include *Vibrio*, *Naegleria* and *Acanthamoeba* species. . New subtropical/tropical cyanobacterial species can also invade European bathing waters. But the survival rate of some bacteria may be decreased by higher UV irradiation.

4.5.1.2. Droughts and water scarcity

Droughts or water shortages can affect bathing water quality because the decreased stream flows are not sufficient to dilute sewage and waste water loads. This results in an increase in the concentration of pathogens and can cause infections in a greater number. As the Lake Balaton case study shows, the decreased volumes of standing water also result in increased concentrations of contaminants such as plant nutrients, and may lead to several water quality problems. including the increased frequency of cyanobacterial blooms.

4.6. ELEMENTS OF MITIGATION MEASURES FOR BATHING WATERS

4.6.1. Joint information systems and exchange of information

In most of the European member states the database of chemical and ecological water quality is the responsibility of environmental ministries or agencies. But the microbiological data of bathing water quality, including the pathogens’ occurrence, belong to health ministries or networks. In extreme weather situations it is absolutely essential for all agencies to share data and to carry out field measurements together. during such

4.6.2. Prevention of stormwater overflow at sewage treatment plants

In planning and constructing sewage water treatment plants the overflow of untreated sewage must be prevented during heavy rainstorms.

4.6.3. Prevention of erosion and diffuse pollution by appropriate landuse techniques

Erosion of nutrient-rich and fertilized agricultural soils must be prevented, along with the reduction of runoff water that contains high concentrations of nutrients and other contaminants. Similarly diffuse- or non-point source control measures should be carried out in urban and populated rural areas. The techniques available for keeping polluted washoff away from bathing waters vary very much, and several books were published on this subject (e.g. Thornton *et al*. 1999). The best-known techniques for agricultural land include contour line tillage, strip cropping, vegetation buffer strips and terracing.

4.6.4. Monitoring during extreme weather events and risk assessment

Monitoring systems must be upgraded to include the sampling of extreme weather- induced events, both in the runoff water and in the recipient water bodies, by all health and water/environmental agencies involved. Without such event-based measurements a risk assessment of bathing waters cannot be made.

4.6.5. Public awareness and information

One of the main issues to handle in relation to extreme weather events is to inform the public in good time about the dangers and risks of the situation that is expected. It can be done via the Internet and/or by other media.

5. IMPACTS OF CLIMATE CHANGE AND EXTREME EVENTS ON WATER-BORNE DISEASES AND HUMAN HEALTH

5.1. INTRODUCTION

Temperature increases, rainfall fluctuations, periods of drought and heat-waves, as well as sea level rise, have a significant potential to affect freshwater sources, waste water and land related processes as summarized in Table 11.

This chapter describes the potential health effects of intense rainfall, droughts and heat-waves in increasing water-borne diseases, the effects of temperature and runoff on microbiological and chemical contamination of coastal, recreational and surface waters, and some of the direct effects of temperature on the incidence of diarrhoeal and other diseases.

Table 11 Observed and projected changes in climate conditions: potential risks and opportunities (Gatt, 2009)

Climate Change Risks	**Potential Risks and Opportunities**		
	Freshwater resources	Waste water	Land-related processes
Increase in summer temperatures	Increased demand for potable water, increased pressures on groundwater Increased demand on reverse osmosis plants Increased evapotranspiration rates	Increased sewer dry weather flow, increased dry weather treatment volumes Increased treated effluent volumes	Reduction in groundwater recharge, more aggressive regime for agriculture Ground shrinkage
Increasing winter temperatures	Increased demand for potable water, increased pressures on groundwater, increased demand on reverse osmosis plants, increased evapotranspiration rates	Increased sewer dry weather flow, increased dry weather treatment volumes, increased treated effluent volumes	Productive regime for agriculture with opportunities for premium products maturing early
Higher winter rainfall	Increased volumes for recharge, existing water storage volumes might be insufficient, increased storm water runoff	Higher volume of storm water generated which may exceed infrastructure capacity, higher volumes of storm water entering sewers – surcharge events increase, increased volumes of waste water to treat at sewage treatment plants, increased volumes of treated effluent may remain unutilised.	Increased flooding incidence, increased damage to infrastructure, increase in soil erosion
Lower summer rainfall	Lower recharge volumes, increase in demand from agricultural sector,	Lower sewage volumes and consequent treated effluent volumes	Ground shrinkage
Higher intensity of	higher proportion of	Higher peak flows	Increased

rainfall	total rainfall might end up as runoff and not contribute to recharge volumes. higher level of pollutants in stormwater.	in sewers, increased possibility of sewer surcharge and overflows.	incidence of flooding damage to infrastructure, increased soil erosion.
Sea level rise	Reduced volumes of groundwater, increased salinity of groundwater.	Increased seawater infiltration volumes (M) [?], more saline waste water and hence treated effluent.	Loss of land, increased flooding of coastal areas, increased need for flood defences, new methods of construction, insurance premiums may increase.

Overall the relationship between climate change, water-borne diseases and human health is complex. The risk of outbreaks of water-borne diseases increases where standards of water, sanitation and personal hygiene are already low.

5.2. LOWER RAINFALL AND DROUGHT

The IPCC (IPCC, 2007) projections illustrate decreasing water availability and increasing frequency of drought in mid-latitudes and semi-arid low latitudes, with increases in drought frequency for southern and south-eastern Europe, as well as central and south-east Asia. Droughts and severe water stress have major effects on various sectors such as agriculture, forestry and industry. Droughts can damage ecosystems and increase the risk of wildfires. In southern Europe, climate change is projected to worsen conditions (through high temperatures and drought) in a region already vulnerable to climate variability, and to reduce water availability, hydropower potential, summer tourism and, in general, crop productivity (IPCC, 2007)[33].

The impacts on water management and human health are various: decreased river flows with increased concentrations of pathogens; less water for dilution of sewage effluent discharges; intrusion of organic material along the distribution network when system pressure drops significantly; intermittent piped water supply with a risk of introduction of contaminants; reduced water supply; lowering of groundwater table in coastal areas (lower recharge and excessive withdrawals) and increasing seawater intrusion which can lead to salinization of available water resources; and the increased use of waste water in agriculture. (Menne, 2008; Yepes et al., 2000; Senhorst, 2005). Each of these conditions can favour infectious disease outbreaks and worsen water quality, hygiene and sanitation. Droughts can also affect the transmission of some mosquito-borne diseases (Bouma and Dye, 1997; Woodruff et al., 2002; Chase and Knight, 2003, Githeko, A.K. et al., 2000). Drought may exert an influence on cyanobacterial proliferation by increasing nutrient

[33] IPCC - Intergovernmental Panel on Climate Change (2007). Fourth assessment report., http://www.ipcc-wg2.org/

availability (higher concentrations due to surface water evaporation in summer) and reducing water body flow (thus increasing the area of still waters which promote their growth).

The effects of drought on health include, besides these, deaths, malnutrition (under-nutrition, protein-energy malnutrition and/or micronutrient deficiencies), infectious and respiratory diseases (Menne and Bertollini, 2000). Drought and the consequent loss of livelihoods is also a major trigger for population movements, particularly rural-to-urban migration. Population displacement can lead to increases in communicable diseases and poor nutritional status resulting from overcrowding, and a lack of safe water and food (Menne and Bertollini, 2000; del Ninno and Lundberg, 2005).

5.3. HEAT-WAVES

The knowledge of health impacts from extreme temperature and linkages to water supply during periods of very hot and dry weather and possible health effects may imply restrictions and prioritization of water use, control of drinking-water quality, efficiency of sanitation systems and a requirement for collaboration between the health sector and water suppliers.

Episodes of extreme temperature have affected health significantly. For instance, in the summer of 2003, a severe heat-wave struck much of Western Europe. Twelve European countries reported more than 70,000 deaths above the average of the five previous years (Robine *et al.,* 2008). For populations in the EU, mortality has been estimated to increase 1–4% for each degree increase of temperature above a cut-off point (Menne *et al.*, 2008). The PESETA (Projection of Economic impacts of climate change in Sectors of the European Union based on bottom-up Analysis) project (PESETA, 2008) estimates 86,000 extra deaths per year in EU countries with a global mean temperature increase of 3°C in 2071–2100 relative to 1961–1990. Increasing numbers of older adults in the population will increase the proportion of the population at risk. Heat-waves have larger effects on mortality when air pollution is high.

During heat-waves, water as well as electricity consumption/demand increases , sometimes together with a water stress-related decrease of hydropower potential. Hot and dry weather often coincides with lack of water or rainfall, and thus over an extended period of time may also influence water quality as outlined above.

5.4. HIGHER WATER TEMPERATURES

It is interesting that pathogens in the water environment are typically less easily neutralised by lower temperatures: higher temperatures would exert selection towards less temperature-sensitive species, directly promoting the growth of some indigenous bacteria, including pathogenic species (Lipp *et al.* 2002; Kirshner *et al*., 2008). In particular, enteric bacterial pathogens are not able to replicate in the aquatic environment. They are inactivated in the aquatic environment at a rate that increases with temperature. The sensivity to temperature of enteric pathogens varies: cysts of *Giardia* and enteroviruses are less rapidly inactivated compared with oocysts of *Cryptosporidium* (Scijvenand de Rosa Husman, 2005). It is also known that a large variation in temperature susceptibility exists among viruses (Schijven and Hassanizadeh, 2000). For instance, viruses like the hepatitis A virus are fairly temperature-insensitive. Ultraviolet light, too, decreases survival. Increased temperature and increased sunlight will increase the rate of die-off of pathogens in the environment.

5.5. COLD WAVES

Cold weather still threatens the health of many European populations. Most European countries have between 5 and 30% higher death rates in winter than in summer. People with cardiovascular diseases are more at risk, in winter, because of the cold-induced tendency for blood to clot. However, overall winter mortality rates are falling in some European countries. Cold spells may affect water, electricity and heating system availability, with potential impacts on population health and health service delivery. They may also affect transport and therefore slow down access to health services.

Case study 2 Cold spell in Tajikistan 2008

The recent cold wave in Central Asia gives an example of possible health consequences. In 2008, Tajikistan had the coldest winter for 30 years, with electricity generation impaired through frozen inlet streams. Consequently health services and households had no energy for prolonged periods. A rapid health assessment showed a sharp increase in the number of cases of severe burns and frostbite, a 50% increase in hospital admissions from acute respiratory infections, and a doubling of maternal and infant mortality compared with the same period in 2007.

5.6. HIGHER RAINFALL, MORE INTENSE RAINFALL AND FLOODS

Flooding is the most common natural extreme weather event in the European Region (EM-DAT).With climate change, winter floods are likely to increase throughout the Region. Coastal flooding related to increasing frequencies and intensities of storms and sea-level rise is likely to threaten up to 1.6 million additional people annually in the EU alone.

The potential health effects of flooding include (Vasconcelos, 2006):
direct health effects: drowning, injuries (cuts, sprains, lacerations, punctures, electric injuries, etc.), diarrhoeal diseases, vector-borne diseases (including those spread by rodents), respiratory infections, skin and eye infections, and mental health problems; andother effects with health consequences: damage to infrastructure for health care and water and sanitation, crops (and/or disruption of food supply) and property (lack of shelter), disruption of livelihoods, and population displacement.

The limited data available on flood events from a few event-based epidemiological studies s., 2004 show that the greatest burden of mortality is from drowning, heart attacks, hypothermia, trauma and vehicle-related accidents in the immediate term (Meusel et al2004). Studies of the long-term health effects of floods are lacking (WHO Regional Office for Europe, 2005).

Flooding may lead to contamination of water with dangerous chemicals, heavy metals, or other hazardous substances, from storage or from chemicals already in the environment (e.g. pesticides) (Pardue *et al.*, 2005). Unfortunately there is little published evidence demonstrating a causal effect of chemical contamination on the pattern of morbidity and mortality following flooding events (Euripidou and Murray, 2004; Ahern *et al*., 2005). Heavy rainfall/floods can cause over-flooding of sewage treatment plants, run-off of animal dejections and manure with a consequent increase of contamination of surface water and soil. Land use in water catchment and drainage areas will become progressively more important for inclusion in risk assessment and risk management.

Several studies have shown that contamination of fresh water by enteric pathogens is higher during the rainy season (Nchito *et al*., 1998; Kang *et al*., 2001). In a study in the Netherlands (Schjven *et al*., 2005), one of the main conclusions was that increased precipitation in winter and more frequent heavy rain in summer lead to peak concentrations of waterborne pathogens in surface waters that are several orders of magnitude above average levels. These higher pathogen concentrations can affect the quality of drinking and bathing waters, and some foods like vegetables, soft fruits and shellfish. Moreover, the increased load of suspended particles can jeopardize the efficiency of water filtration and treatment systems, worsening the risk of drinking water supply contamination. Beyond that, many water-borne disease outbreaks are related to heavy precipitation events, often linked to water treatment failures (Bates *et al*., 2008; Kistemann *et al*., 2002). For example *Cryptosporidiosis* cases in England and Wales between April and July were positively associated with maximum river flow (Lake *et al*., 2005). In Europe, outbreaks are frequently preceded by heavy rainfall (Atherton et al., 1995; Miettinen et al., 2001). However, it is not feasible to extrapolate the impacts of these events in terms of climate change (McMichael et al., 2004). It is worth noting that heavy rain and floods can increase the nutrient availability of lakes, so inducing cyanobacterial proliferation. Furthermore, increased fresh water inputs into rivers from increased run-off can dilute the estuarine environment and promote blooms of toxic cyanobacteria. For example, a large bloom of *M. aeruginosa* in the upper San Francisco Bay Estuary was widespread throughout 180 km of waterways; microcystins were detected at all stations sampled, and also in zooplankton and clam tissues (Fristachi and Sinclair, 2008).

Overall, the risk of infectious disease following flooding is generally low, although increases in diarrhoeal diseases after floods have been reported (Miettinen *et al*., 2001; Reacher *et al*., 2004;Wade *et al*., 2004; Wolf and Menne, 2007) .

Case study 3 Environmental health aspects of flooded karstic drinking-water resources (Hungary)

The case study describes a large-scale drinking water outbreak. The water supply of a Hungarian city is mainly based on the sensitive karst water springs. An enormous quantity of rain fell on the catchment area of the water source, causing an unusually strong water flow and flooding. Microbiological contamination from several potential sources in the protecting zone of the water was washed into the wells and water mains and caused an outbreak. 3,673 people became ill out of the 60,000 living in the water supply zone, and 161 were admitted to hospital. Public health intervention and hygienic measures were made in line with epidemiological actions, and focused on: i) the protection of the healthy people through providing safe drinking-water supply, ii) the identification of the contamination, and iii) taking measures on risk reduction and preventive actions

5.7. CHANGES IN ECOSYSTEMS

Changes in the phenology (periodic biological phenomena) and the distribution of marine species have been observed, such as earlier seasonal cycles and northward movements which will change marine ecosystems and biodiversity and affect fisheries. Changes in ecosystems will also affect the spread of water-related diseases. Increasing temperatures and changing water quality may create new ecological niches that allow pathogens to invade new areas. Recreational water quality may be degraded by changing natural ecosystems or decline in the quality of waters draining to bathing areas. This may increase the risk of infection for bathers, as well as affecting seafood.

Case study 4 Changes in the marine food web in the European area

Northeast Atlantic Ocean

Projections indicate that warming will extend throughout the water column during the course of the 21st century (Meehl *et al.*, 2007). Sea surface temperature changes have already resulted in an increased duration of the marine growing season and a northward movement of marine zooplankton. Some fish species are shifting their distributions northward in response to increased temperatures.

Baltic Sea

Climate models project a mean increase of 2°-4°C in the sea-surface temperature in the 21st century, and increasing run-off and decreasing frequency of Atlantic inflows, both of which will decrease the salinity of the sea. Consequently, the extent of sea-ice is expected to decrease by 50%-80% over the same period (Meier *et al.*, 2006a) and stratification is expected to become stronger, increasing the probability of a deficiency of oxygen (hypoxia) that kills a lot of marine life in the region. Changes in stratification are expected to affect commercially important regional cod fisheries because stratification appears to be an important parameter for the reproductive success of cod in the Baltic Sea.

Mediterranean Sea

Temperature is projected to increase and run-off to decrease. In contrast to the Baltic Sea, the combination of these two effects is not expected to change stratification conditions greatly because of the compensating effects of increasing temperature and increasing salinity on the density of sea water. The invasion and survival of alien species in the Mediterranean is correlated with the general sea surface temperature increase, resulting in the replacement of local fauna with new species. Such changes affect not only local ecosystems, but also the activities of the international fishing fleet when commercial species are affected (Marine Board Position Paper, 2007).
Source: EEA, 2008

5.8. CHANGES IN SEASONALITY

Water- and food-borne outbreaks commonly follow seasonal patterns, and hence are likely to be affected by changes in climate. For example, illness related to campylobacter and salmonella exhibit a summertime pattern of occurrence (Greer, 2008). *Cryptosporidium* concentrations are highest in waterways in spring during the calving and lambing season.

5.9 CHANGES IN HUMAN BEHAVIOUR

Climate change will also affect people's habits. Warmer temperatures are expected to increase the consumption of fruit, salads, vegetables and drinking water. Warmer, drier conditions will increase recreational water use, potentially increasing the length of the bathing season.

5.10. SEA LEVEL RISE

According to satellite observations, the pace of global mean sea level rise has increased to more than 3 mm/year in the last decade (as compared to a global average in the 20th century of 1.7 mm/year). Because of ocean circulation and gravity effects sea level rise is not uniform but varies across European seas. Sea surface temperature increases have also accelerated in recent decades. For the future, projections suggest European sea level and sea surface temperature will rise more than the global average, with significant impacts on human wellbeing and ecosystems in coastal regions. IPCC (2007) sea level rise estimates are possibly conservative because of the risks of more rapid changes in the Greenland (and Antarctic) ice sheets than assessed so far. Sea level rise can affect human health through coastal degradation, higher tidal surges and coastal flooding.

5.11. CLIMATE CHANGE AND DIARRHOEAL DISEASES

In 2002, there were approximately 205 million cases of diarrhoeal disease in the European Region (Ebi, 2008). This is equivalent to 23 % of the population being affected by episodes of diarrhoea each year, although the rate varied across different zones, from 19 % in Eur-A to 36 % in Eur-B and 20 % in Eur-C. These cases of diarrhoeal disease have a high associated cost in terms of lost working time and health care (Ryan *et al*., 2003). Campbell-Lendrum *et al*. (2003) estimated the number of additional cases of diarrhoea due to temperature increases through to 2030. A dose-response relationship of 5% increase per degree was used for developing countries, but a conservative estimate of 0 % increase per degree was assumed for developed regions. The authors however consider that taking into account the relationship between pathogen behaviour and temperature (e.g. Kovats *et al.*, 2004), it is likely that additional cases of diarrhoeal diseases will be experienced.
Figure 13 gives an idea of the possible increase in cases by 2030.

Figure 13 Projected incident cases under high and low emission scenarios by 2030

Sub-region	Climate	2000		2030	
		Mid	High	Mid	High
Eur-A	S550	0	1,584	0	4,753
	S750	0	1,584	0	4,753
	UE	0	1,584	0	6,338
Eur-B	S550	785	2,355	785	5,496
	S750	785	2,355	785	6,281
	UE	785	2,355	785	7,066
Eur-C	S550	958	1,437	0	3,352
	S750	958	1,437	0	3,352
	UE	958	1,915	0	3,831

5.12. SOME SPECIFIC EXAMPLES OF CLIMATE CHANGE AND WATER-BORNE DISEASES

Pathogenic *Vibrio spp*, such as *Vibrio parahaemolyticus* and *V. vulnificus*, occur in estuarine waters throughout the world and are present in a variety of seafood (Croci et al., 2001; de Sousa et al., 2004; DePaola et al., 1990, 2003). They are part of the natural flora of zooplankton and coastal fish and shellfish. Their number is dependent on the salinity and temperature of the water, and cannot be detected in water with a temperature below 15°C. With the possibility of acquisition of virulence genes by environmental strains and with a changing climate, the geographic range of these pathogens may also change, potentially resulting in increased exposure and risk of infection for humans. Indeed *V. parahaemolyticus and V. vulnificus* are responsible for the majority of the non-viral infections related to shellfish consumption in the United States, Japan and south-east Asia (Wittman & Flick, 1995), and they also occur occasionally in other parts of the world. To date the number of cases which have occurred in Europe is extremely low, but recently a large outbreak (64 cases) was registered in Spain, caused by consumption of *V. parahaemolyticus*-contaminated shellfish harvested in Galicia (Lozano-Leon et al., 2003). The FAO/WHO risk assessment of *V. vulnificus* in raw oysters found a *V. vulnificus*-temperature relationship in oysters at harvest (FAO/WHO, 2005). In the Mediterranean sea the emergence of *V. vulnificus* has been attributed to higher water temperatures, leading to an increased risk from systemic Vibriosis from handling or consuming seafood (Paz *et al*., 2007).

Furthermore, changes in plankton populations and other hosts for which *Vibrio* spp. are commensals or symbionts would similarly alter their ecology. Indeed, an increased production of exudates from algal and cyanobacterial proliferations are expected to further promote the growth of autochthonous pathogens (Lipp et al. 2002; Eiler et al. 2007), and an increased presence of *Vibrio* spp. (including the serotypes of *V. cholerae* O1 and O139, and *V. vulnificus*) has been frequently associated with blooms of cyanobacteria and eukaryotic phytoplankton species (Epstein 1993, Eiler et al. 2007).

Vibrio cholera is considered a model for understanding the potential for climate-induced changes in the transmission of food-borne disease, since peaks of disease are seasonal and associated with higher water temperature and phytoplankton (FAO, 2008d). FAO and WHO have undertaken a risk assessment of choleragenic *V. cholera* O1 and O139 in warm water shrimp for international trade.

Based on the available epidemiological data, it was estimated there was a very small risk of acquiring cholera through consumption of imported warm water shrimp. But further research needs to be conducted to address the existing data gaps (FAO/WHO 2005). The EU Rapid Alert System for Food and Feeds has had several alerts in recent years related to *V. cholera* in imported warm water shrimps from different countries (Rapid Alert System Food and Feed, RASFF, 2007). In

2007, the product category for which the most RASFF alerts were sent was fish, crustaceans and molluscs (21%). These alerts have a consequent socio-economical impact associated with the withdrawal and/or recalls of the seafood products (RASFF, 2007) and consequent risk perception.

Another important group of autochthonous pathogens belongs to the genus *Legionella* which can cause a number of infections of differing severity, generically referred to as legionellosis, ranging from mild febrile illness (Pontiac fever) to a potentially fatal form of pneumonia[34]. The presence of *Legionella* spp. is spread over a wide range of natural environmental conditions, with better performances at temperatures above 35°C and at high phytoplankton concentrations (Fliermans et al., 1981), and the identification of *Legionella* spp. in hot-water tanks or in thermally polluted rivers emphasizes that water temperature is a crucial factor in its colonization of water distribution systems, its proliferation in the environment, and therefore in infection risk. Thermally altered aquatic environments can result in rapid multiplication of *Legionella* spp., which can translate into human disease (Fields et al., 2002). Another important aspect in *Legionella* ecology relates to its nutrient requirements. *Legionella* can proliferate in biofilm, in association with amoebae, protozoa or cyanobacteria (Fields et al. 2002; WHO, 2007). It is commonly found in association with other microorganisms and it has been isolated in cyanobacteria mats, at 45°C over a pH range of 6.9 to 7.6, where it was apparently using algal extracellular products as its carbon and energy sources (Tison *et al*., 1980).

Naegleria fowleri and *Acanthamoeba* spp., possible emergent waterborne pathogens, can proliferate in warmer water columns. Most commonly, the amoebae may be found in bodies of warm fresh water such as lakes, rivers, geothermal (naturally hot) water such as hot springs and drinking water sources, warm water discharges from industrial plants, poorly maintained and minimally-chlorinated or unchlorinated swimming pools, soil (Beheds et al., 2007, Vivesvara et al., 2007, Blair et al., 2008, Jamerson et al,, 2008). Infections with *Naegleria* are very rare and occur mainly during July, August and September, usually when it is hot for prolonged periods, causing higher water temperatures and lower water levels. But it is worth noting that infections can increase during heat wave years. *Acanthamoeba* spp. are microscopic, free-living amoebae that are relatively common in the environment. This amoeba has been isolated from water (including natural and treated water in pools or hot tubs), soil, air (in association with cooling towers, heating, ventilation and air conditioning (HVAC) systems), sewage systems and drinking-water systems (shower heads, taps) (Mubareka *et al*., 2006, Boost *et al*., 2008)[35].

Additionally, *Acanthamoeba* spp. contain several bacterial endosymbionts which can be human pathogens (e.g. *Legionella* spp.), so they are considered to be potential emerging human pathogens (Schmitz-Esser *et al*., 2008).

Cyanobacteria are ubiquitous autotrophic bacteria. Several species produce different toxins that act with different mechanisms and have been associated with acute human intoxications after exposure through drinking and bathing waters (Funari and Testai, 2008). The most investigated group are the hepatotoxins, which include about 80 different congeners of microcystins (MCs), and nodularins (NOD), all inducing acute effects in the liver. Environmental factors can also influence cyanotoxin production, but their role is not fully understood: some studies on MCs showed that the variations

34 *Legionella pneumophila* is the well-known agent of this pneumonia, especially fatal in elderly people. Outbreaks of legionellosis have been reported from all countries in Europe, many of them linked to hotels and other types of holiday accommodation, or to those systems where water temperature is higher than ambient temperature. Legionellosis is indeed caused by aerosols from contaminated potable water distribution systems, cooling towers, building water systems, respiratory therapy equipment and hot tubs, but the presence of *Legionella* spp. in these artificial water systems depends ultimately on the reproductive success of the bacterium in the natural environment (WHO 2007).

35 *Acanthamoeba* is capable of causing several infections in humans like *Acanthamoeba* keratitis, a local infection of the eye that can result in permanent visual impairment or blindness (Anger et al., 2008).

of parameters such as light, culture age, temperature, pH and nutrients give rise to differences in cellular cyanotoxin content (Sivonen and Jones, 1999). Among these parameters, increasing temperature represents an important factor for increased cyanobacterial proliferation (often associated with increase of nutrients and decreased salinity) and a main factor for their poleward movement and possibly their toxicity. The proliferation of cyanobacterial blooms has been described in the majority of European lakes used for drinking water supply and recreational purposes, so that this situation has given rise to concern for human health, which can be affected by consumption of contaminated drinking water or food or by ingesting water during recreational activities. Indeed, some experimental evidence on *Aphanizomenon* spp.-isolated cultured strains have indicated that increasing temperatures up to 28º C caused an approximate two-fold increase in paralytic shellfish (PSP) toxin production (Dias et 2002). *Cylindrospermopsis raciborskii*, known as a species of tropical origin, has been found to occur s with increasing frequency from the mid-1990s in Germany, France, Italy, temperate North American areas, and more recently it has been described as the predominant component of the phytoplankton community of different Portuguese rivers and reservoirs (Saker et al., 2004).

One of the key other water-related health issues is algal blooms. The abundance of toxic HAB-forming[36] dinoflagellates has significantly increased since 1990 in Europe in areas in the North Sea and north east Atlantic (Edwards et al. 2006) and in some marine ecosystems, such as the Grand Banks area of the north west Atlantic (Johns et al., 2003) and Baltic Sea (Wasmund and Uhlig, 2003). This shift in HAB community composition has been linked to increased sea surface temperature. In the Eastern Mediterranean, sudden loads of high nutrient water linked to heavy storms led to an increase in phytoplankton biomass and the dominance of toxic HAB species (Spatharis et al., 2007). Biogeographical boundary shifts in phytoplankton populations made possible by climate change have the potential to lead to the poleward spread of HAB species normally suited to milder waters (Edwards et al., 2006). Norwegian coastal waters of the North Sea have experienced a decrease in salinity related to increased precipitation and increased terrestrial run-off and this has been associated with an increase in abundance of several HAB-forming species (Edwards *et al*., 2006). The impact of HAB on human health could include more cases of human shellfish and reef-fish poisoning (EEA, 2008), as well as impacting the reliability and operating costs of water systems (Bates et al., 2008).

Table 12 Summary table on pathogens and health significance (source: Pond *et al*., in Menne *et al.* (2010))

	Pathogen	**Weather influences**	**Health significance***	**Relative infective dose***	**Infection caused**
Viruses:	Norovirus GGI and GGII Sapovirus Hepatitis A virus Rotavirus Enterovirus Adenovirus Avian influenza virus#	Storms can increase transport from faecal and wastewater sources Survival increases at reduced temperatures and sunlight (ultraviolet) * Changes in	High High High High High High Low	Low Low Low Low Low Low unknown	Gastroenteritis Gastroenteritis Hepatititis Gastroenteritis Gastroenteritis Respiratory&intestinal influenza

[36] HAB: Harmful Algal Blooms

		seasonality			
Bacteria:	Pathogenic *Escherichia coli* *Campylobacter jejuni, C. coli* *Helicobacter pylori* *Legionella pneumophila* *Vibrio cholerae* *Vibrio parahaemolyticus*# *Vibrio vulnificus*# *Vibrio alginolyticus* *Toxic cyanobacteria*	Enhanced zooplankton blooms Salinity and temperature associated with growth in marine environment	High High High High High Medium Low Low Medium	Low Moderate Unknown High High High Low Unknown Moderate	Gastroenteritis Gastroenteritis Stomach&duodenal ulcer Pneumonia Cholera Wound infections, otitis and lethal septicaemia, gastroenteritis, respiratory dysfunctions, allergic reactions
Protozoa:	Cryptosporidium spp. Giardia spp *Naegleria fowleri*# *Acanthamoeba* spp.#	Storms can increase transport from faecal and waste water sources Temperature associated with maturation and infectivity of Cyclospora	High High Low Low	Low Low High Unknown	Gastroenteritis Gastroenteritis Meningoencephalitis Keratitis, blindness

Taxa labelled with # are considered potentially emerging. *according to WHO-report “Emerging Issues in Water and Infectious Disease”, 2003.

Major changes in policy and planning are needed if ongoing and future investments in water supply, sanitation and health are not to be wasted. Technologies capable of adapting to the range of climate change scenarios need to be identified and prioritized. Technologies and planning are needed that can be adapted to cope with multiple threats, including but not exclusively limited to the effects of climate change (WHO, 2009).

6. WATER SAFETY PLANS: AN APPROACH TO MANAGING RISKS ASSOCIATED WITH EXTREME WEATHER EVENTS

6.1. KEY MESSAGES

Water Safety Plans (WSPs) are introduced by WHO's Guidelines for Drinking Water Quality as "…a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchments to consumer". The aim is clear: "to consistently ensure the safety and acceptability of a drinking water supply".

The great advantage of the WSP strategy is that it is dynamic and practical. Therefore it is applicable to improving the safety of water in all types and sizes of water supply system, no matter how simple or complex. Additionally, it is suited to dealing with changes in quantity and quality of water supply expected as a result of extreme weather events. The WSP process provides a mechanism to identify, assess, and reduce the risks to the water supply resulting from extreme weather events. In the following paragraphs, the key steps of a WSP are reviewed on the basis of WHO's "Water Safety Plan Manual: Step-by-step risk management for drinking water suppliers"

6.2. ELEMENTS OF A WATER SAFETY PLAN

6.2.1. WSP team creation and preparatory activities

The WSP team is typically constituted of water supply staff and is a multi-disciplinary team with knowledge and experience of the water supply system, and direct understanding of the hazards to continuity of supply, quality and usage of the final product. The adequate integration of extreme weather events in a WSP approach requires that the team either includes or closely liaises with stakeholders who have knowledge of geohydrological and meteorological characteristics and inputs to the catchment area. The risk assessment should include historic information on past flooding and drought events, as well as detailed projections for future changes in hydrological patterns. Broad stakeholder involvement in the design and implementation of WSPs is essential in predicting extreme weather events, predicting the hazards and risks, developing appropriate contingency plans, and designing effective contingency planning. Health system components such as hospitals, retirement homes etc. may have special requirements for continuity of supply or quality of water which should be taken into account when designing WSPs.

Communication should also be established at an early stage with the national health system to (a) understand better the vulnerability of key components of the health system (hospitals, dispensaries, first aid stations, hospices…); (b) understand the role the health system can play in mitigating and responding to cases of flooding and drought, and how mutual support can be organized; (c) gather information on people with special needs or with restricted self-help capacity (elderly, immune-compromised people, those needing extended home nursing care).

6.2.2. Description of the water supply system

The WSP team needs to describe the water supply system to support the subsequent hazard identification and risk assessment process. This description should include information on the catchment, through treatment and distribution to the point of consumption.

European water services draw on a wide variety of sources (rivers, lakes, wells, mines…); these resources need to be fully identified and registered, including their geohydrological characteristics. This registration must be done with a sufficient level of detail to allow a vulnerability assessment. For example, it is not sufficient to merely register an aquifer and identify its linkages with the overlying surface water. Its vulnerability to pollution originating in the catchment area also needs to be registered and assessed. Information is also needed on abstraction and water uses, quantity and available resources, and how both quantity and quality may be affected by the impacts of climate change.

In coastal areas, not only the feedwater of the aquifer needs to be registered but also the potential intrusion of seawater.

Although by no means exhaustive, the following list illustrates some of the concerns that the WSP team will face at this point of the process:

Linked water services: Interconnections between water services are important to provide aid in case a water service is compromised by an extreme weather event. The physical linkage of water services that operate independently from one another may create additional hazards to service quantity and quality, unless such hazards have been identified prior to the installation of an operational connection. It is therefore important to assess the hazards of emergency inter-connections and take all necessary measures to control them well before any emergency necessitates the operationalization of cross-connections. Links are not limited to piped distribution networks. Experience has shown that water services of major conurbations may be called upon, at very short notice, to take over water supply in rural areas where shallow wells became unproductive during periods of extreme drought. In such cases, connections are done by lorry.

Comprehensive source to tap approach: Within a water supply, there may be various actors and stakeholders that are responsible for different elements of the supply, e..g. source water protection and/or abstraction, water treatment, water distribution and/or storage, and consumer use. It is important to gather information on and understand all the elements of the water supply, regardless of who is responsible. The water supply does not end at the property line and in-house water storage and treatment are important aspects to consider when describing the water supply, and identifying, assessing and mitigating any related risks.

Land use: Detailed information on land use needs to be gathered, identifying potential hazards relating to agriculture, industry and human settlement, infrastructure and treatment failures, sabotage or man-made disasters and natural events. Bear in mind that extreme weather may change or compound the potential risk of a hazard or hazardous event. For example, a historically contaminated site may present no hazard during routine conditions, but intensive rains may create a hazardous event resulting in contamination of the water supply.

Staff capacity. The development of an integrated description of the system may require knowledge beyond that possessed by existing staff. The WSP team may need to partner with other stakeholders, including the public health and environmental sectors, to gather this information.

6.2.3. Identification of hazards and assessment of risks

The role of the WSP is to ask:

what can go wrong at what point in the water supply system in terms of hazards and hazardous events; and how likely is the hazard/hazardous event to occur and how severe would be the consequences if it did. These two activities constitute the risk assessment.

Correct implementation of this step of the WSP requires considerable out-of-the-box thinking capacity. For example, information gathering may have been done on the *composition* of distribution pipes in recognition of plumbo-solvency problems, but pressure fluctuations may have remained unrecognised as a specific hazardous event. This would be an issue in water distribution, but perhaps even more so in sanitation and drainage networks.
Hazard identification and risk assessment inside consumer premises also remains a challenge for many water utilities, and consumers and other stakeholders should be engaged as part of the WSP process.
Table 13 lists some of the hazards and hazardous events typically associated with extreme weather events.

Table 13 Typical hazards associated with extreme weather events

Catchment		Treatment		Distribution	
Hazardous event	*Associated hazards and hazardous events to consider*	*Critical issues to consider in drawing up a WSP*	*Associated hazards and issues to consider*	*Hazardous event*	*Associated hazards and issues to consider*
Meteorology: -Flooding -Droughts	Water quality or quantity change	Power supply	Interruption, loss of treatment, distribution compromised.	Pipe burst	Ingress of contamination
Seasonal variations	Colonization of resource waters by opportunistic invader species	Capacity of treatment works	Hydraulic overload of both drinking water and wastewater treatment plants	Pressure fluctuations	Ingress of contamination
Unconfined aquifer	Water quality subject to unexpected change esp. after long dry spells.	Failure of by-pass facilities (physical collapse or errors in dimensioning)	Inadequate treatment	Intermittent supply	Ingress of contamination
Well/boreholes not watertight	Surface water intrusion	Treatment failure	Untreated water		
Borehole casting corroded or incomplete	Surface water intrusion	Screen / Filter blockage	Inadequate removal of particulate matter		
Flooding	Quality and quantitative sufficiency of raw water, safety of routing floodwaters from critical areas (population, control installations…)	Flooding	Loss or restriction of treatment works		
		Failure of continuous supply of treatment chemicals	Compromised treatment / disinfection		

6.2.4. Determination and validation of control measures and reassessment and prioritization of risks

“Control measures” are activities and processes applied to reduce or mitigate risks. They are determined for each of the identified hazards /hazardous events; missing controls to deal with identified hazardous events need to be documented and addressed.
Control measures must be considered not only for their longer-term average performance, but also in the light of their potential to fail or be ineffective over a short space of time. This is especially important in extreme weather: certain pathogenic organisms and their toxins may, for example, pose a real risk only under conditions of extreme drought.
“Validation” is the process of obtaining evidence of the performance of control measures. Validation is different from operational monitoring of processes which shows that validated controls continue to work effectively. Validation can for example include visual inspection of the catchment area to ensure the absence of cattle, assessment of the underground travel time in river bank filtration, certification of alternative suppliers, testing of alarms for the sudden discontinuation of UV disinfection, etc.
“Risks” need to be recalculated taking into account the effectiveness of each control. All identified risks should then be prioritized.

6.2.5. Development, implementation and maintenance of an improvement plan

For risks that are inadequately controlled, an update or improvement plan should be developed. This plan should consider short, medium and long term options and implementation to control or mitigate the identified risk. In the case of small supplies or resource restrictions, prioritization based on significant risks to human health and a phased implementation approach may need to be considered. Improvement plans are not necessarily limited to work within the water service’s own installations. The WSP approach emphasizes that equal attention is placed on areas outside the direct control of the water supplier, such as the catchment and point of use (consumer). Improvement programmes identified in these areas would require joint action by water services and other stakeholders. Such joint initiatives are usually welcomed by regulators as they are likely to yield, over time, more sustainable results

The development of upgrade plans offers a clear opportunity to explore in depth the links between water and sanitation systems in one area. Well-known risks exist during extreme weather events, such as flooding which may contaminate the resource waters with untreated waste water or from wastewater treatment plants. During extreme drought, contamination may occur from the unsafe use of effluents from under- performing installations. These risks can become much more important in the case of flooding of the wastewater treatment, its partial collapse under increased load factors, or the flooding of sludge drying beds. It is important to review any new hazards that could result from implementation of the improvement programme and recalculate the risks, taking into account the new control measures.

6.2.6. Monitoring control measures

“Operational monitoring” includes defining and validating the monitoring of control measures and establishing procedures to demonstrate that the controls continue to work. For example, in many countries of eastern Europe, leaky pipes and unauthorized connections lead to the ingress of contaminated water. Maintenance of system pressure could be a control measure, and installation of pressure gauges throughout the system an appropriate monitoring measure to ensure that the controls work at all times.

Back-up systems are necessary to ensure continuity of supply if monitoring indicates the failure of a control. For example, if chlorination were to fail and flooding of access roads were to prevent new supplies from reaching the production unit, alternative water sources identified earlier could be allowed access to the distribution network. Of course, risks associated with the use of such alternative sources should be identified and addressed during the initial establishment of the WSP.

6.2.7. Verification of the effectiveness of the WSP

Verification involves three activities which, when undertaken together, provide evidence that the WSP is working effectively. These are:

- ***Compliance monitoring:*** validating effectiveness and monitoring performance against set limits (water quality targets).
- ***Internal and external auditing of operational activities,*** ensuring that water quality is within targeted limits and that risks are controlled.
- ***Consumer satisfaction:*** monitoring this is important to ensure that the water distributed by the utility will indeed be used. Any consumer complaints about taste, colour or smell should raise concern that drinking water may not be safe or acceptable to consumers for consumption.

6.2.8. Preparation of management procedures and supporting programmes

Communication programmes need to be set up to instruct people on safety issues. This may involve reassuring consumers on the continued safety of the water when, for example, temporary discolouration or other organoleptic changes occur due to sudden changes of raw water quality, but it may also mean the management of incidents which compromise the microbial quality of the water. Care should be given to preventing consumers from turning to unsafe water sources if problems do not compromise the safety of the distributed water or are of such a nature that they can easily be controlled by simple in-house treatment.
Standard Operation Procedures (SOPs) need to be prepared for the management of the system under routine conditions. Equally important is the preparation of Incident Situation Operational Procedures (ISOPs) as an integral part of a WSP. ISOPs need to describe in detail the steps to be followed in specific “incident” situations where a loss of control in the system may occur. An efficient, regular review and updating cycle is also important, especially as new information and more refined models of expected impacts of climate change are released almost daily.
Notwithstanding all reasonable efforts to make contingency planning as detailed and comprehensive as possible, it is humanly impossible to foresee all events. Unforeseen events/incidents may, indeed in all likelihood will, occur for which there are no corrective actions in place. In this case, a generic emergency plan should be followed. This would have a protocol for situation assessment and identification of situations that require activation of the emergency response plan.

It is important that impacts of past extreme events, or near misses of service disruption by extreme events, be analyzed, as they could be an indicator of a likely future emergency. It is also important that such lessons be shared as widely as possible within the water utility community through specialized networks, journals etc., and that the WSP be reviewed and updated with the results.
Supporting programmes are activities that support the development of people’s skills and knowledge, commitment to the WSP approach and capacity to manage systems to deliver safe water. Supporting programmes include: research and development; training and capacity building,

equipment calibration programmes, laboratory intercalibration, preventative maintenance, development and installation of customer complaint protocols and their processing, as well as legal training, finance and administrative systems, records management, communications and public education /engagement programmes.
In order to be effective, the WSP needs to be a dynamic and evolving approach that is integrated into the daily management plans and processes of the water supply.

6.2.10 Periodic review

The WSP team should meet periodically to review the overall plan and learn from experiences and new procedures. The review process is critical to the overall implementation of the WSP and provides the basis from which future assessments can be made.
Following an emergency, incident or near miss, risks should be reassessed and may need to be fed into the improvement /upgrade plan.
Also, after substantial capital investment in adapting to climate change, such as the installation of storm water reservoirs, or the installation of PAC (powdered activated carbon) columns, a review of the WSP is indicated to see if SOPs and ISOPs are still adequate or need to be refined and reviewed.
A WSP should also be reviewed following every emergency, incident or unforeseen event, irrespective of whether new hazards were identified, and to ensure that, if possible, the situation does not recur and to see whether the response was sufficient or could have been handled better. The WSP and improvement plan should be updated as a result.
A post-incident review is always likely to identify areas for improvement; in many cases, the greatest benefit will result when other stakeholders are also included in the review.

6.2.11 Integrated water resource management

The advantages of placing water services in the framework of integrated water resources management have been lauded by many authors. Examples of such advantages are: the reduction of negative externalities (for example, cattle grazing in a water catchment area may harm the water quality, but are not usually managed by the water service)that arise from the uncoordinated use of interdependent water and land resources; opportunity costs which arise when production factors are used of low value/benefit costing; and cost savings achieved by widening the range of management options.

A number of countries outside the European Union are making progress towards IWRM through activities in the area of watershed management, clarifying institutional roles and responsibilities, increasing stakeholder participation, and anchoring financing mechanisms in the integrated management concept.

Inside the European Union, the legislative framework has been created for climate adaptation strategies for water services to fit into an IWRM approach. The main elements of this legal strategy are:

- Directive 2000/60/EC of the European Parliament and the Council of 23 October 2000, establishing a framework for Community action in the field of water policy - the Water Framework Directive.
- Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks[37]

[37] The Directive was published in the Official Journal of 6 November 2007; however, at the time of writing it was not yet directly accessible as a URL

Important progress is being made in the provision of guidance on water resource management and climate change by the Parties to the 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes; the guidance documents resulting from these efforts (UNECE. 2009) could be usefully consulted in conjunction with the present volume.

Finally, it needs to be recalled that health issues are frequently neglected or under-estimated in water resource strategies. Health considerations should, however, be incorporated in regional and national stakeholder dialogues on sustainable water resource management, including the use of these resources for water supply and sanitation. Proper screening and scoping exercises will need to be developed to determine the key health issues, and to define the framework in which they are to be considered.

6.3. WSP Checklist

- Functioning WSP team in place
- Methodology by which a WSP is developed and agreed
- On-going commitment and resource support confirmed by senior management of water supply organization
- Water quality targets identified and used as benchmarks to verify adequacy of WSP
- Accurate description of the water supply system from the catchment, through treatment and distribution, to the consumers’ point of use
- Stakeholders directly or indirectly influenced or affected by water safety identified and engaged by WSP team
- Hazards and hazardous events affecting the safety of a water supply identified (based on local knowledge, visual inspections, historical data, and predictive information)
- Risk presented by each hazard and hazardous event assessed and prioritized
- Controls or barriers established or confirmed for each significant risk, with effectiveness validated
- Shorter- and longer-term improvement plans developed
- Operational monitoring continuously carried out along with associated corrective actions when operational targets are not met
- WSP verified as working effectively through compliance monitoring, including end-point testing and auditing
- Accurate records kept, including management procedures maintained for transparency and justification of outcomes.
- Programmes to support WSP implementation executed or planned (e.g. training programmes, calibration of equipment)
- WSP regularly reviewed, including hazards, risks and controls.

7. ADAPTATION MEASURES FOR WATER SUPPLY UTILITIES in EXTREME WEATHER EVENTS

This chapter describes some of the key adaptations that can be made and actions taken by water supply operators in order to continue the supply of safe, clean drinking water during extreme weather events. The focus of the chapter is on drought and flood conditions, but the principles highlighted may be equally applicable to other extreme weather events. Many water suppliers already have in place or are implementing adaptation measures that can mitigate the impacts of extreme weather events. The term “water suppliers” is used here to collectively describe the organisations primarily responsible for the supply of drinking water. This may include private or public water utilities, (local or regional) public authorities or councils, or national/federal organisations. Often it may not be recognised that these measures are also appropriate in mitigating the impacts of climate change or extreme weather events, especially when the original driver was not initially thought of in this context (e.g. population growth).

7.1. VULNERABILITY OF THE WATER CYCLE TO EXTREME WEATHER EVENTS

Climate change and extreme weather events will affect many aspects of the water supply infrastructure, as described in chapter 2. In relation to drinking-water supplies, this will particularly impact on the availability and quality of raw water, which in turn could affect the efficiency of drinking-water treatment processes and the stability of drinking-water in distribution. In general terms water suppliers will need to consider adaptations to deal with greater variation in water quantity (both the availability of raw sources and the demand for suppliers); and greater variability in raw water quality and therefore requirements to ensure the supply of safe drinking water. Therefore in order to ensure a safe and continuous water supply during extreme weather events measures must be taken across all aspects of the water supply system - with regard to water sources (catchments and aquifers); water collection, treatment and distribution, and also in the management of demand and water use on premises.

Particular issues that may affect drinking water supply systems include:

- An increase in the intensity, severity and frequency of extreme weather events
- Reduced availability of water in rivers, reservoirs and aquifers, which also means lower quality in some cases due to reduced dilution of pollutants
- Different treatment of water supplies due to lower quality of water in the environment, which will cost more money and use more energy
- Effects on existing sewerage systems, which were not designed to take climate change into account; more intense rainfall is likely to exceed the capacity of parts of the network and cause local flooding and deterioration of environmental waters
- Water quality problems caused by run-off taking nutrients and pesticides from agricultural land, for example, and transferring them into rivers and lakes
- Effects on the structure and operation of dams and reservoirs, for example from increased siltation and slippage of reservoir walls into the water, contaminating it
- Piped systems for both drinking water supply and sewerage becoming more prone to cracking as climate change leads to greater soil movement as a consequence of wetting and drying cycles
- Increased risk to assets on the coast or in flood plains from flooding, storm damage, coastal erosion and a rise in sea level

- Discolouration and odour problems resulting from higher temperatures and more intense rainfall events
- Likely increased demand for water, particularly at times of reduced availability, exacerbating supply issues
- Financial and economic impacts as well as environmental and social consequences.

Figure 14 Schematic illustration of a river catchment

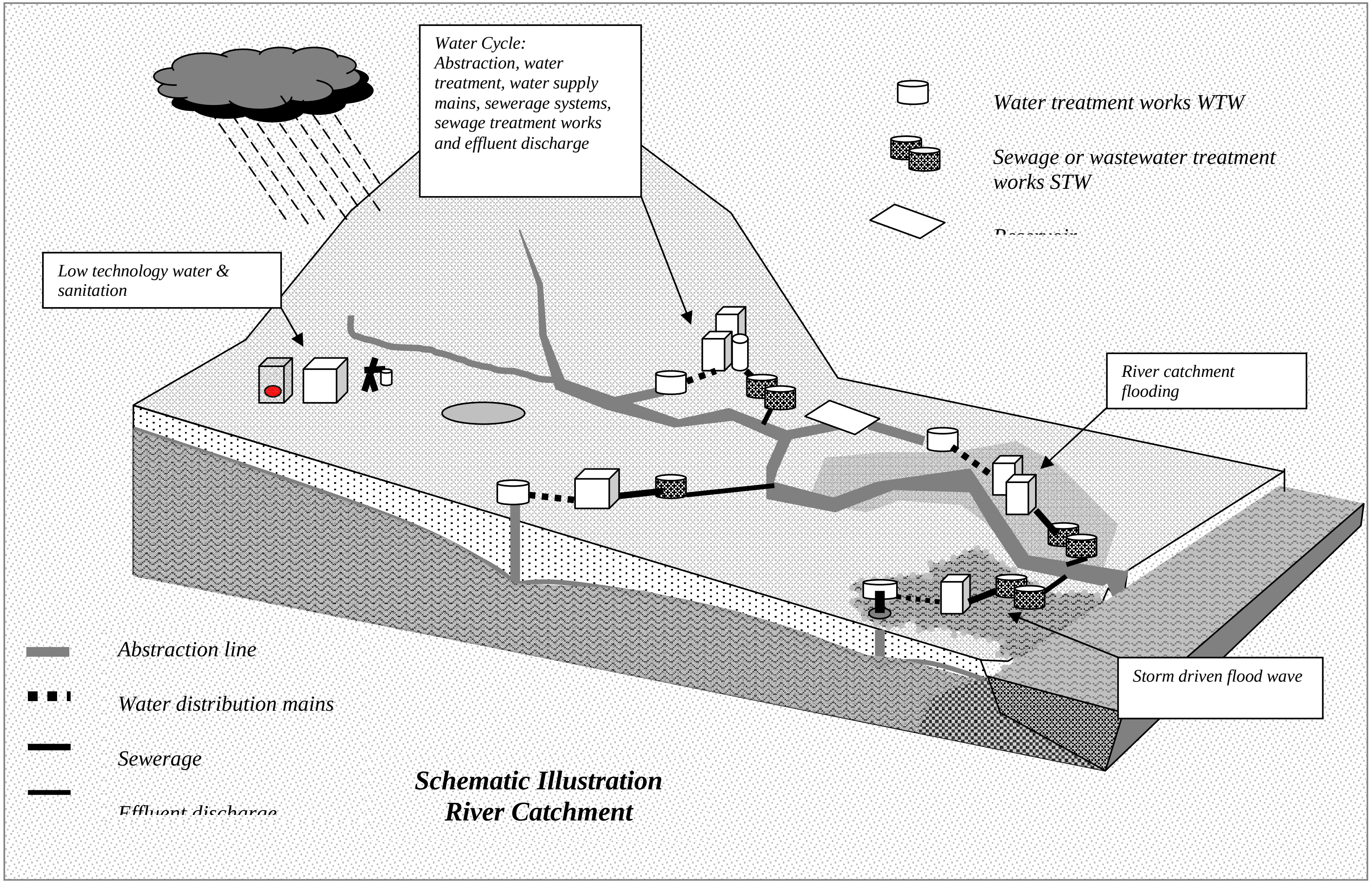


Table 14 Potential impact on Feature or System

Extreme Event	Potential Impact on Feature or System ~ Level of Risk High (H), Medium (M), Low (L) Insignificant (I)										
	Source Water	**Abstraction System**	**Water Treatment Works (WTW)**	**Water Supply Network**	**Usage**	**Sewerage Network**	**Sewage Treatment Works (STW)**	**Receiving Water**	**Groundwater**	**Ecosystems**	**Other**
Severe Drought	- Reduced quantities available (H) - Reduced quality of surface water sources available (H)	- Reduced water levels at abstraction point adversely affect abstraction rate (M)	- Influent deterioration causes product quality reduction (M) - Reduced throughput affects performance (H)	- Pressure reductions increase infiltration risk (M) - Quality reduction from low flow long residence time in mains (H)	- Increase in demand (H) - Possible rationing of demand (H)	- Low water use causes sewage to break down in foul sewers (M) - Solids deposited in combined sewers (H) - Sediments in surface water sewers harden (H)	- Influent quality adversely affects treatment (H)	- Effluents from STW reduce water quality (H)	- Depletion of groundwater aquifer (H)	- Grey water recycling minimises potable water supply/demand for irrigation etc (H)	- Shallow well systems run dry (H) - Food irrigation needs in rural areas lead to increased demand (H)
Prolonged & Extremely High Ambient Temperatures	- Raw water temperature rise results in lower DO (H) - Water quality more likely to be worsened by upstream STW effluent (H)	- Abstraction system adversely affected (L)	- Lower DO adversely affects bio-water treatment systems i.e. slow sand filters (H) - Associated operational equipment failure (L)	- Operational problems resulting from temperature effects (L) - Increased water temperatures adversely affect bio-water treatment (H)	- Potential for substantial increase in demand (H)	- Associated operational equipment failure (L) - Impact on surface water, combined and foul sewer networks (N)	- Lower DO adversely affects treatment (L) - Significant variations in bio-process performance i.e. fixed film processes (M)	- Existing water quality more likely to be worsened by STW effluent, low DO etc (H)	- Associated operational equipment failure (I) - Impact on water quality and quantity (L)	- Increase in potable supply demand increases grey water quantities (H)	- Food crops exert increased irrigation demands (H)
Extensive River Catchment Flooding	- Water quality deterioration (H)	- Associated operational equipment failure (L) - Intake system flooded (H)	- Flooding of essential unit process (H) - Process performance adversely affected by poor raw water quality (H)	- Pumping stations flooded (H) - Service reservoirs polluted (L) - Flooded taps & float valves allow contamination (M)	- Increased demand for emergency supplies from areas adjacent to flooding (L)	- Solids deposited in inundated surface water sewers (M) - Foul water & combined sewers overflowing, floodwaters contaminated (H)	- Flooded STWs contaminate floodwater (H) - Diluted influent adversely affects treatment (H)	- Flooded STWs & sewer overflows contaminate surface water (H) - Water quality deterioration (H)	- Borehole pumping control and treatment installation failure within flooded area (H)	- Black water treatment processes widely spread, some more likely to be vulnerable to local flooding with associated pathogen risks (H)	- Local low technology systems very badly affected by flooding (H)

Continued: Extreme Event	Source Water	Abstraction System	Water Treatment Works (WTW)	Water Supply Network	Usage	Sewerage Network	Sewage Treatment Works (STW)	Receiving Water	Groundwater	Ecosystems	Other
Extreme Storm Event Flooding	- Surface water sewer outfalls contaminate local surface waters (L) - Combined sewer storm water overflows contaminate local surface waters (M)	- Abstraction system adversely affected (L)	- Local flooding causes short term WTW failure (M)	- Associated operational problems resulting from local flooding (L) - Physico-chemical and bio-systems both affected by influent quality variation (H)	- Likelihood of impact on local usage patterns (L)	- Local overload leading to surface water & combined sewer surcharge and flooding (H)	- Local STW system adversely affected by severe overload (H) - Associated local STW operational problems or short term system failure (H)	- Associated short term water quality deterioration (L)	- Associated short term water quality deterioration (L)	- Black water treatment processes widely spread, some more likely to be vulnerable to local flooding with associated pathogen risks (H)	- Local low technology systems adversely affected by flooding (H)
Extreme and Prolonged Cold Periods	- Freezing affects downstream base flows and local availability (M)	- Operational failure due to freezing (M)	- Failure of outdoor bio-treatment systems i.e. slow sand filters (H) - Frozen tanks and open water surfaces (H)	- Lower water temperatures cause contraction-related mains failures (M) - Freezing in service reservoirs affects supplies (M)	- Impact on usage patterns (N)	- Associated operational problems in foul water pumping stations etc. (M) - Surface water drains and inlets unable to accept melt water (H)	- Freezing adversely affects fixed film treatment processes (H) - Associated operational problems in sedimentation tanks etc. (M)	- Frozen receiving water, short term local water quality deterioration caused by effluent concentration (L)	- Aquifer recharge rates adversely affected (H)	- Adverse impact on grey water treatment processes i.e. reed beds (H)	- Frozen wells and open water surfaces (H) - Low technology water-flushed sanitation systems adversely affected (M)

Continued: Extreme Event	Source Water	Abstraction System	Water Treatment Works (WTW)	Water Supply Network	Usage	Sewerage Network	Sewage Treatment Works (STW)	Receiving Water	Groundwater	Ecosystems	Other
Extreme Storm Winds	- High seas and flood waves adversely affect estuary water quality (M) - Storm-driven sea flooding causes saline intrusion into wells and local surface waters (M)	- Operational failure due to storm damage (L)	- Operational failure of WTW due to storm damage (M)	- Operational failure due to storm damage to service reservoir towers etc.(L)	- Impact on local usage patterns (L)	- Impact on local sewerage system infrastructure (L)	- Impact on local STW infrastructure (M) - Wind / water surface interaction compromises settling processes (M)	- Increased mixing and DO levels (H)	- Operational failure due to storm damage (L) - Storm-driven sea flooding causes saline intrusion into wells and local groundwater (M)	- Impact on local sewerage system infrastructure (L)	- Storm damage to low technology systems with poor build quality (H)

- A distinction is made between “Extensive River Catchment Flooding” and “Extreme Storm Event Flooding”.
- “Extensive River Catchment Flooding” is primarily determined by hydrological effects, typically related to excessive snow melt water overloading the river system, or after long periods of heavy rain.
- “Extreme Storm Event Flooding” relates to a single storm event of extremely high intensity, and flooding is likely to be associated with the overloading of the surface water or combined sewerage systems. Impacts are generally experienced as the rain falls for only a short time after the storm has passed.

7.2. ADAPTATION MEASURES FOR DROUGHT EVENTS

Drought is a function of water scarcity. Water scarcity may prevail over long time periods and the distinction between operational water management during times of water scarcity and emergency activity in a drought situation is much less clear than say in the event of a major flooding event. Thus the continued supply of safe drinking water during drought conditions must normally be considered as part of a continuum of operational management during times of water scarcity. So many of the adaptation measures adopted in water-scarce regions are equally relevant during periods of drought (in either water-scarce or other regions).
As with the management of water supplies, it is vitally important to consider the potential impacts (and thus adaptation options) across the whole water supply system, from source to tap. The interrelation of measures across the supply system must also be assessed when considering adaptation measures.

7.2.1. Adaptation measures in advance of an extreme event - drought

7.2.1.1. Source and reservoir management

7.2.1.1.1. Proactive adaptation measures: water sources/resources

The primary impact of drought or water scarcity on drinking water supplies is one of resources or availability. Where possible, adaptation measures to assist in the management of drinking water supplies during such periods should be put in place in anticipation of future drought conditions. These measures are also likely to form part of long term water resources planning and may also contribute to several complementary objectives of the water supplier (e.g. planning for population growth). Table 15 offers some examples of proactive adaptation steps:

Table 15 Examples of adaptation measures

	Adaptation activity	**Examples of adaptation measures**
Water quantity / resources	Strategic water resource planning (25 years +)	• Interconnection of reservoirs between wet/ dry areas (inter-regional transfers) • Variety of sources – might need WTW process capable of dealing with river source at one time of year and stored (reservoir) source at another • Silting of ponds, reservoirs, collection chambers and intake works (due to land degradation and increased erosion) • Improving infrastructure resilience • Resource optimization by supervision systems (telemetry monitoring systems coupled with SCADA & automated control)
	Alternative sources	• Standby sources that are operated regularly to ensure they work when required, and sampled so operators know quality • Small suppliers with no local alternatives • New water sources - risk assessment: reclaimed water, desalination, etc.

The careful management of water resources is fundamental to the supply of adequate safe drinking water during drought conditions. Water suppliers must work with a variety of stakeholders to understand the climatic and meteorological conditions in which they are operating and also with those responsible for environmental protection and the management of water and land-use within catchment areas.

As part of their comprehensive risk assessment and management activities incorporated in a WSP, water suppliers need to identify risks to the availability and quality of resources posed by drought scenarios.

In particular water suppliers need to have in place standing arrangements for communicating with meteorological forecasting units to ensure that long- and short-term forecasts of dry periods can be highlighted and to identify trigger points at which prepared drought management plans can be activated.

Suppliers should work with meteorological and environmental agencies to agree statistical estimates or models of a variety of scenarios. These should typically be based on drought “return periods” or frequencies. Thus scenario details can be created for situations that might be experienced annually, once in every five years, or once every 20 years, for example. Where appropriate, these scenarios can be coordinated with other water resource management activities such as river basin management plans prepared under the European Water Framework Directive. Suppliers should then use these scenarios as planning assumptions to assess the risks to water supply quality and quantity.

In some regions of extreme water scarcity roof-top rain water harvesting offers a reliable source of water, and a minimum quality for safe drinking water can be achieved with moderate effort. Roof-top systems collect and store rainwater from the roofs of houses or large buildings, greenhouses, courtyards and similar impermeable surfaces, including roads. Most of the rain can be collected and stored. How the harvested water will be used depends on the type of surface used and its cleanliness, as well as users’ needs. Modern roofing materials and gutters, for example, allow the collection of clean water suitable for drinking and other domestic uses with limited treatment, especially in rural areas without tap water.

Case study 5 Roof-top rainwater harvesting in a semi-arid climate

A pilot project was launched in a small village in Central Anatolia in Turkey a semi-arid climate, to create awareness about water harvesting technology and to develop a model for replication. The intervention was implemented at thirty houses in the first phase of the project, selected together with the community. Now the pilot site residents enjoy a continuous flow of clean water in their kitchen sinks for the first time in months. In addition to providing clean drinking water in their homes, the rainwater harvesting project has allowed these families to remain in their village.

Case study 6 Impact of climate change on water resources in Azerbaijan

Vulnerability assessment in Azerbaijan suggests a 15-20% decrease in available water resources. Adaptation measures put in place include:

- Reservoirs - construction of new ones, and increasing the efficiency of existing ones ($305million)
- Improvement of water management systems ($12m)
- Reconstruction of existing water and irrigation systems (costs TBC)
- Reducing demand through the use of water-saving technologies ($418m)
- Afforestation ($10m)

These adaptation measures are expected to save 10 billion cubic metres of water to help deal with water scarcity and extreme weather events.

Hydrological extreme events such as droughts and floods, surface run-off, increasing solar UV radiation, temperatures and evaporation, are some of the outcomes of climate change which may seriously impact surface water reservoirs used for drinking water supplies. Indeed, changes in water basin levels, concentrations of nutrients, water chemistry and the growth of toxic phytoplankton directly affect the quantity and quality of raw water as well as treatment practices required for the production of drinking water.

Water quality and safety may also be adversely impacted by drought/water scarcity. These are some of the probable primary impacts:

- there may be a general decrease in raw water quality due to less dilution in source waters
- surface water sources may vary greatly due to reduced flow patterns, draw-down of storage reservoirs, and changes in reservoir limnology
- groundwater may be more susceptible to contamination that was previously caused by changes in hydrogeological flow patterns produced by a changing water table level and the associated impact on saturated soil layers
- an increase in raw and treated water temperatures
- increased temperature and nutrient concentrations in surface waters that may also increase the likelihood and extent of algal blooms (and associated cyanobacteria).

Adaptation measures in themselves may also impact on the safety of water supplies, for example through the need to mix waters with different chemical matrices, or the potential to introduce novel species if large-scale raw water resource transfers are made.
Water suppliers should review the risks to water quality in catchment areas that may result from the above impacts as changes to risk mitigation/control measures may be required.

As with adaptation for water resources, where possible measures to assist in ensuring the continued safety of drinking water supplies should be put in place in anticipation of future drought conditions. Table 16 gives some examples of what can be done.

Table 16 Examples of pro-active measures

	Adaptation activity	**Example of adaptation measures**
Source water quality	Enhanced monitoring to detect deterioration in drought (or when drought conditions are predicted)	Enhanced monitoring of: • Turbidity/physical quality • Indicator organisms (pathogen loading) • Algal species and counts • Broad chemical screens (e.g. GC/MS scan) for emerging contaminants • Limnology – risks of low draw-down, storage reservoir inversion (use of bubblers, forced currents etc.) • Vector-borne diseases (open reservoir management) • Emerging risks – suggested chemicals/pathogens, viruses etc. [link to chapter on emerging health risks]
New sources	Use of	• Knowledge of quality of sources

	alternative/ standby sources	• Pre-event trials/experimentation into impact of mixing water matrices

Case study 7 Unprecedented cyanobacterial bloom and microcystin production in a drinking-water reservoir in the south of Italy

An extraordinary bloom of cyanobacterium *Planktothrix rubescens* was observed in early 2009 in the Occhito basin, a 13 km^2 wide artificial reservoir with a storage capacity of over 270 million cubic meters of water. Maximum algal density exceeded 150 million cells/litre and associated microcystin production occurred in raw water used for production of water for human consumption in surrounding municipalities (serving about 800,000 inhabitants).
Response actions implemented in the first six months were mainly focused on mitigating the risk of toxin presence in distributed drinking water and efficiently communicating risk information to the target population and authorities.
These included:
a) identification and quantification of microcystins in raw, treated and distributed water, showing:
– uncommon, changeable toxin production in raw water samples with dimethyl-MCRR isomers as the main cyanobacterial metabolites (range 5.0-30.5 $\mu g\ l^{-1}$) also together with MC-RR and MC-LR;
– trace of microcystins sporadically detected in distributed water, always below WHO guideline value.
b) specific treatments using granulated activated carbon (GAC) combined with pre-existing treatment practices, *i.e.* pre-oxidation, flocculation, sand filtration and post-disinfection;
c) management of the drinking water supply system in order to reduce the contribution of water from the treatment plant down to about 1,100 litres/second by diluting with water obtained from different sources;
d) risk communication on different media channels, including press communications and a dedicated web site within the Puglia Region Portal.

These activities were integrated with a limnological study of the lake to collect information on the nutrients and algal distribution in the water body during the mixing periods, and the thermal stratification. A FluoroProbe was employed to determine the various algae classes (blue-green algae/cyanobacteria, green algae, diatoms/dinoflagellates/chrysophytae and cryptophytae) and to determine the total chlorophyll in the water. The analyses of dissolved and total nutrients were extended to the main tributaries to evaluate the nutrient loads. Concentrations of macroconstituents both in lake and tributaries were assessed to characterize the matrix of dissolved solutes Levels of trace metals, herbicides and pesticides were also measured in the lake and in the main river waters.

These measures, implemented through intensive cooperation amongst the main stakeholders, were effective in successfully managing the health risk for the affected populations without requiring any limitation of water uses. .
Direct costs relating to the treatment plants can be estimated at about 700,00 Euros for the first emergency actions, which consisted of the removal of a 0.5 meter-high layer of sand from the standard filtration systems and its replacement with a 0.5-meter layer of GAC (granulated active carbon) (about 400 tonnes). Long-term preventative/remediation action is requiring massive investment of about 10 million Euros to implement a specially designed GAC filtration system to remove trihalomethanes (THMs) and microcystins.
Risk management plans for the medium-long term period were implemented in line with the WHO water safety plan approach and involve specific investment for a new flexible treatment system, and investigation of environmental parameters inducing/affecting/regulating bloom formation in the basin related to seasonal changes, specific training activities for local environmental and health authorities.

7.2.1.2. Water treatment works

In order to consider the impact of drought or water scarcity conditions on the operation of water treatment works, suppliers need to consider the original purpose of the works and any treatment processes and the operating performance (both as originally designed and current). Only then can they determine whether adaptation measures are required. For example, suppliers need to review plant and equipment (e.g. chemical dosing equipment) to ensure it remains appropriate for any reduction in flow or change in source water quality. Table 17 suggests some issues to consider.

Table 17 Water treatment works adaptation

Monitoring arrangements	Can monitors detect quality changes which may be more severe or happen more quickly than in "normal operation"? Can monitors detect new risks that might occur due to changes in raw water flows and quality?
Flow controls (weirs, pipes, pumps etc.)	Will these still operate at (significantly) reduced flows? Will these operate under variable flow conditions?
Water losses during treatment	Minimise losses on site through: ▪ audit of all water losses: run sample taps, monitor sample waste, etc.; minimise where possible without compromising quality ▪ optimisation of treatment processes – e.g. optimise filter washing regime to ensure minimal water use but maintain adequate backwash/bed expansion (without compromising water quality)
Delivery of treatment chemicals	What impact does the extreme event have on delivery timescales, quantity, etc.?
Storage of treatment chemicals	▪ Is this affected by the extreme event? ▪ Are the chemicals themselves affected by the event (air temperature, humidity etc) – what alternative storage options are there?
Chemical dosing equipment	▪ What are the critical control parameters for chemical treatment processes in use (pH, temperature, etc.)? ▪ Are variations of these within tolerance levels? ▪ What are the alternatives (e.g. change in chemical change in process, reduction in throughput)?
Disinfection process	▪ Impact of increased water temperature/changed pH on effectiveness of disinfection ▪ How will flow changes affect the effective Ct of disinfection stages?
Power supplies	▪ Is an alternative power supply available in the case of supply restrictions? ▪ Has it been (robustly) tested? ▪ Does using it affect any treatment stages/pumping options?
Staff / Personnel	How might workers (or their access to work) be affected by the extreme event? What are the contingencies?

7.2.1.3. Distribution systems

Variations in the quality and quantity of treated water entering a drinking-water supply distribution system (of whatever size and scale) can introduce new challenges to the operation of that system.

The first step that any water supplier should take to manage the provision of water supplies during an extreme event is the pro-active reduction of leakage from the distribution system. In extreme events, particularly droughts, water resources may well be limited and thus it is important to ensure that as much of the available water reaches consumers as possible. Water suppliers will often determine an acceptable economic level of leakage in conjunction with regulators/local government - the level of leakage at which it is no longer economically viable to make further reductions. However, the assumptions underlying these calculations will need to be reviewed in planning for extreme events where resources will be under greater pressure.

Further possible pro-active adaptation measures for water distribution systems are listed in Table 18:

Table 18 Adaptation of distribution systems

Quantity/ volume related	• Interconnection of distribution networks/resilience; knowledge of key cross-connections, how to operate in emergency situation, water quality implications of operation (is advice to consumers needed?)
	• Manage diurnal flows and levels in service reservoirs - may be necessary to retain water in the reservoirs to meet demand in peak hours (night vs day)
	• Storage tank/service reservoir flow rate monitoring in order to promptly make interventions to reduce water lost through leakages
Quality-related	• Assess need for enhanced monitoring of distribution systems and consumer supplies for physical parameters, chemical parameters (if risk identified) indicator organisms, etc.
	• If flows are restricted then need to consider risks of stagnation in tanks & pipes, minimise “dead ends” in the distribution system in advance to reduce risk of stagnant water
	• Change in operating regime may cause re-suspension of solids (iron etc.) in pipework. Not health issue, but may cause mains water to be rejected leading to consumers seeking an alternative (unsafe) source of drinking water
	• Survey of high risk premises to assess the risk of backflow contamination from premises - localised risk, but need to cover high risk sites such as industrial buildings, chemical works, sewage works, ports etc.

Case study 8 Impact of water supply and usage improvement

A project in the Saray district of Turkey focused on improved access to safe drinking water, along with an awareness campaign on efficient water use.
The Saray municipality is situated on the Cubuk plateau, near Ankara, and has approximately 15,000 inhabitants. The main water supply pipe of the municipality was 25 years old and in disrepair. The old pipe has fractured and leaked frequently, and in 2006 this causes a loss of 50,000 tonnes of water. Furthermore, the material of the pipe (asbestos) was not food-grade nor in line with current food regulations and the water was not treated after it was stored in the main tank. Due to its old age and fragile structure, the pipe fractured and leaked frequently, leaving residents without water and increasing the possibility of contamination.
The Saray municipality, together with the Every Drop Matters regional water partnership project, replaced the ageing pipe with a food-grade ductile pipe, thereby saving significant amounts of water and eliminating the possibility of contamination and other health risks.
In conjunction with the new pipeline, an outreach and awareness campaign centred on the themes of water conservation and efficient use of water was conducted in schools.

7.2.2. MANAGING WATER SUPPLIES DURING EXTREME EVENTS - DROUGHTS

7.2.2.1. Demand management

One of the ways to overcome the issue of water scarcity is through demand management. Technological solutions have their own limitations and so technical improvements are often not enough by themselves. However, it is also necessary to change people's perspective and behaviour patterns and the policies of municipalities, so that they use and manage water resources more efficiently. This can take place over a long time period, for example through pro-active consumer education, but often it forms part of an emergency response during an extreme event.
The role of the water supply utilities should be central in deciding to reduce water consumption at a local level. This can be achieved either by voluntary measures by restricting supplies.
Demand may increase during conditions of water scarcity as those consumers with steady consumption trends (e.g. some industrial users) continue to use water, while others (e.g.farmers using irrigation, or households) increase their consumption in an attempt to maintain their way of life in non-drought conditions. In particular, given the associated weather conditions, consumers may increase their outdoor activities and associated water uses (e.g. swimming pools) and use more treated drinking water to irrigate crops or plants in domestic gardens.
There is a continuum of options, all of which may be implemented through voluntary or mandatory/regulatory means:

Figure 15 Intervention options in extreme events (floods)

Examples of demand management measures that can be taken are shown below in Table 19:

Table 19 Options for demand management

Demand management mechanism	Examples of actions	Issues/risks
Voluntary reductions in use and/or demand	Encouraging increased water efficiency in premises - either through information, short-term incentives, or long-term planning in community building standards. Voluntary reduction in use by large industrial users	Consumers may not participate in voluntary action, leading toinsufficient reduction in demand; localised storage of water may actually increase demand. Impact on economic viability of

		industry
Mandatory restrictions on use (e.g. through local or national legislation)	Not permitting certain uses of treated (mains) drinking-water supply e.g. car washing, garden watering, ornamental pools & fountains etc.	Confusion over restrictions leading to non-compliance; possible reluctance to participate in future voluntary initiatives.
Temporary reduction in flow/pressure	Reducing pressure and/or flows in supply system on temporary basis at suppliers' sites, e.g. by reducing volumes in storage reservoirs or limited pumping.	Increased risk of ingress/ contamination of supply system
Physical restrictions to flow/ pressure	Localised flow restricted to certain premises, locations, supply systems (e.g. "trickle flow" device that provides minimum flow for domestic & sanitary uses).	Increased risk of ingress/ contamination of supply system. Potential impact on public health due to restrictions in drinking-water/sanitation where consumers do not prioritise these needs.
Temporary (rota) cuts in piped supply	Temporary cessation of supply to specific part of a supply system to enable adequate supplies to other areas. This may be achieved by closing of valves in the distribution system, with the affected areas "rotated" to provide supplies to all areas at some point during any given period.	Increased risk of ingress/ contamination of supply system. Potential impact on public health due to restrictions in drinking-water/sanitation where consumers do not prioritise these uses. Encourages consumers to seek alternative (potentially unsafe) supply of drinking-water.
Cessation of piped supply	Piped drinking water supply is stopped at source or to a specific area.	Increased risk of ingress/ contamination of supply system. Impact on public health due to lack of safe drinking-water/sanitation. Encourages consumers to seek alternative (potentially unsafe) supply of drinking-water.

Where pressure or flow reductions are put in place suppliers need to consider the location and needs of vulnerable sectors of the population. For example all premises will need a minimum amount over a certain time period for drinking -water and sanitation. Medical facilities and care homes will need an uninterrupted supply, schools and community buildings may need to be prioritized over other premises, and certain sectors of the population may have specific needs (e.g. for home medical care such as renal dialysis).

If the water supply is not continuous then suppliers will need to carry out a risk assessment of the potential impact on the quality and safety of the supply. This will need to consider the potential contamination risks from ingress (where a pressurized system becomes depressurized) or backflow from contaminated premises in the supply area. Suppliers must ensure that enhanced monitoring of water quality is put in place, in particular for faecal indicators and (where a potential risk is identified) for possible chemical contamination.

Increased health monitoring of the population should also be considered to detect any resulting health/disease burden following changes in drinking-water and/or sanitation arrangements. Water suppliers will need to liaise closely with health professionals to determine the possible risks to consumers and mitigation measures that should be put in place.

Any restrictions on water use will need to be carefully and clearly communicated to consumers so that they are adequately informed of both the resource situation and of actions they can take to assist in resource management. Many examples have shown that where communities are supplied by common or central supplies, then increasing awareness of water scarcity will result in a marked decrease in consumption as individuals take small-scale actions for the collective good. Often suppliers may see demand initially increase in the early stages of any public campaign to raise awareness of water scarcity. as people become aware of possible restrictions and perhaps store stocks of water. But this will generally be more than balanced by subsequent reductions in use.

7.2.2.2. Transboundary water resource management and bulk transportation of water

Where highly drought-stressed areas exist it may be necessary to transfer water in from other regions where resources are more plentiful. Transboundary water transfers can take many forms, varying from small scale intra- or inter-regional transfers (for example between neighbouring water suppliers) to larger-scale transfers or bulk transportation.

Suppliers will need to consider the impacts that introducing a different water source into a supply system will have on existing treatment processes, blending and storage arrangements.

Case study 9 Transboundary transfer of raw water resources in Azerbaijan

The Kura-Araks river system is a principal source of water for industry, agriculture, residential uses and energy in Armenia, Azerbaijan and Georgia, the Islamic Republic of Iran and Turkey. The rivers are important to regional cooperation as they cross and form many of the borders. Both rivers are seriously degraded in places. Water quality is impaired by the disposal of untreated municipal, industrial, medical and agricultural wastes, and by high sedimentation loads resulting from upstream deforestation. Water quantity is constrained by the use of water for agricultural and hydropower purposes, which also affect the river ecosystem in places.

Integrated, inter-country efforts are under way to evaluate the degree of continuing degradation of these river ecosystems and to take action to halt and reverse damaging trends where necessary. The proposed project aims to ensure that the quality and quantity of the water throughout the Kura-Aras river system meets the short- and long-term needs of the ecosystem and the communities relying upon the rivers. Transboundary co-operation is focussing on:

- fostering regional cooperation;
- increasing capacity to address water quality and quantity problems;
- demonstrating water quality/quantity improvements;
- initiating required policy and legal reforms;
- identifying and preparing priority investments, and;
- developing sustainable management and financial arrangements.

Activities already begun include:
- developing a water-sharing agreement between Georgia and Azerbaijan;
- establishing sub-basin management councils;
- in each country, implementing at least one on-the-ground investment to address an urgent cross-border water scarcity or pollution conflict;
- carrying out awareness raising, training, seminars and conferences;
- undertaking the creation of data collection, database preparation, information management systems.

7.3. ADAPTATION MEASURES FOR FLOOD EVENTS

7.3.1. ADAPTATION MEASURES IN ADVANCE OF AN EXTREME EVENT - FLOODING

7.3.1.1. Proactive adaptation measures: water sources/resources

The primary impacts of floods on water supply systems are too much water in the wrong place (i.e. inundation of the water supply infrastructure), or too great a volume of water of an inappropriate quality for use as a source of drinking-water. Where possible adaptation measures to assist in the management of drinking-water supplies during such periods should be put in place in anticipation of extreme events. These measures are also likely to form part of long-term asset management planning and are similar in nature to those for drought scenarios.

Table 20 Examples of pro-active adaptation measures : water sources/resources

	Adaptation activity (floods)	**Example of adaptation measures (floods)**
Water quantity, resources	Strategic water supply system planning	▪ Interconnection of reservoirs in flood-prone and non-flood-prone areas (inter-regional transfers) ▪ Variety of sources – might need WTW process capable of dealing with river source at one time of year and stored (reservoir) source at another ▪ Prevention of silting of ponds, reservoirs, collection chambers and intake works (due to land degradation and increased erosion) ▪ Improving infrastructure resilience ▪ Resource optimization by supervision systems (telemetry monitoring systems coupled with SCADA and automated controm)
	Alternative sources	▪ Standby sources that are operated regularly to ensure they work when required, and sampled to assess quality ▪ Small suppliers with no local alternatives ▪ New water sources – risk assessment: reclaimed water, desalination etc.

As with planning for drought events, water suppliers must work with a variety of stakeholders to understand the climatic and meteorological conditions in which they are operating and also with those responsible for environmental protection, the management of water and land-use within the catchment area.

As part of their comprehensive risk assessment and management activities under the WSP, water suppliers need to identify risks to the availability and quality of water resources, and the impact of flooding on water supply assets.

As with drought scenarios water suppliers need to have in place standing arrangements for communicating with meteorological forecasting units to ensure that long- and short-term forecasts of flooding can be highlighted and should identify both planning assumptions and trigger points at which prepared response plans can be activated.

7.3.1.2. Pro-active adaptation measures – water quality

Water quality and safety may also be adversely impacted by flooding events. The primary impacts are likely to be:

- a general decrease in raw water quality due to greater surface run-off and pollution inputs into source waters;
- surface water quality varying greatly due to extreme flow patterns, and changes in reservoir limnology;
- groundwater becoming more susceptible to contamination that previously due to changes in reservoir limnology;
- an increase in contamination events resulting either from inundation of contaminated land or overflowing of sewerage and drainage systems.

Water suppliers should review the risks to water quality in catchment areas that may result from these impacts as changes to risk mitigation/control measures may be required. As with adaptation for drought events, where possible measures to assist in ensuring the continued safety of drinking water supplies should be put in place in anticipation of future drought conditions. This is shown in Table 21:

Table 21 Adaptation activities (floods)

	Adaptation activity (floods)	Example of adaptation measures (floods)
Source water quality	Enhanced monitoring to detect deterioration in quality associated with peak flows/surges	Enhanced monitoring of ▪ Turbidity/physical quality ▪ Indicator organisms (pathogen loading) ▪ Broad chemical screens (e.g. GC/MS scan) for emerging contaminants ▪ Emerging risks - suggest chemicals/pathogens, viruses etc. ▪ Communication links with sanitation operators to proactively share information on inundation of drainage/sewerage systems
New sources	Use of alternative/standby sources	▪ Knowledge of the quality of sources ▪ Pre-event trials/ experimentation into impact of mixing water matrices
Physical asset protection measures	Flood defences	▪ Identification of key strategic assets (see below)

7.3.1.3. Pro-active adaptation measures – treatment and distribution assets (flood protection)

In many cases water supply assets are located close to water bodies or in floodplain areas. In addition to the potential impacts on treatment process and distribution activities that are outlined above on drought (many of which are equally applicable to flood events), water suppliers need to plan in advance the actions that they would take if a critical site (e.g. treatment plant) or infrastructure were to be unavailable due to an extreme event. In the case of flooding, suppliers should work with environmental protection or federal agencies to identify flood risk areas and estimate the extent and depth of flooding that could be expected in a variety of scenarios.

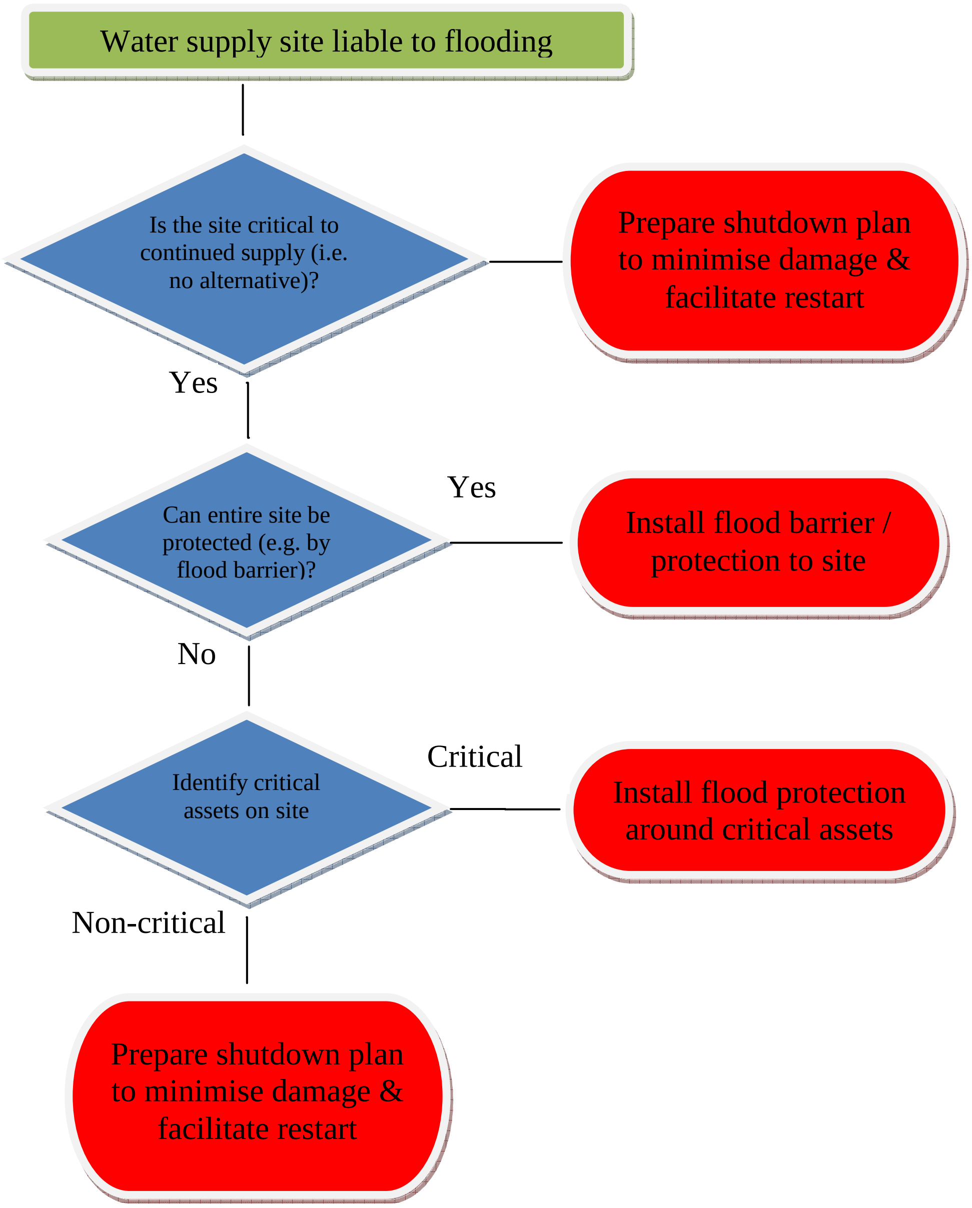
Suppliers should have in place a site-specific plan that identifies not only safe actions and escape routes for staff, but also actions that can be taken to minimise the impact of floodwater on operational equipment. The actions taken will depend on how critical the water supply asset is. If there is no option of alternative supplies and continued operation is required. then physical flood protection will be necessary, for example the installation of physical flood barriers to preventreduce the impact of rising flood waters. If alternatives are available then actions will be required to minimise damage to ensure that if possible the asset can be restarted after a flood with minimal remedial action and impacts on supplies.

Where flooding of plant or equipment does occur then the risks of operating this equipment should be assessed before use. If electrical systems can be powered down before inundation occurs then damage can be significantly limited. In situations such as this the key action is identifying the electrical components to be dried (either *in situ* or off-site), and once flooding has subsided, or equipment relocated, reinstalled and restarted.

Sites where flooding of electrical components is possible should have simple, easy to understand signs/labels warning operators of the risks of operating flooded equipment. This is especially important for community water supplies, for example “WARNING – DO NOT TURN THE PUMP ON. There is a danger of electrical shock and damage to your well or pump if they have been flooded”.

The order of intervention is shown below in Figure 16 Flood protection - order of intervention

Figure 16 Flood protection - order of intervention



Pre-event adaptations might involve the installation of whole-site flood protection, the fitting of flood protection measures to individual buildings, assets (e.g. intake structures/well heads, power supply buildings) or drainage systems (to prevent surcharging). The scale of flood protection measures will be a balance between the expected severity and likelihood of flooding, and the costs associated with physical protection measures. Typical measures may include:

- where possible making buildings water-tight (e.g. temporary flood gates on doors/openings; enabling closure of external drains (to prevent backflow into the building), etc.;
- increasing flood-resistance of buildings/assets by raising critical equipment and points of potential ingress above the maximum expected flood level;
- installating physical flood barriers (around site or specific asset);
- raising boundary walls at intake sites;
- raising the level of borehole headworks (and ensuring headworks are sealed against surface water ingress).

Suppliers should also note that for alluvial flooding, flood protection measures can often be some distance from the water supply site itself - allowing them, for example, to identify sacrificial floodplain areas to flood in preference to the location of the water supply asset – so there is a need for drinking water suppliers to work closely with agencies responsible for planning and flood protection on a basin-wide approach.

Flood preparation measures can also involve actions that staff are required to take to minimize damage in the event of a flood, such as checking seals on borehole headworks to prevent ingress, and isolating process streams or electrical equipment. Companies should approach this in a systematic manner to identify risks and how these might be mitigated. Examples of some of the actions that may be taken in advance of a flood are:

- relocation of critical stores;
- relocation of treatment chemical stores;
- closure of unused (non-critical) drainage and overflow valves to reduce risk of backflow;
- isolation of all electrical equipment once flood water reaches a certain trigger level (so as to minimise necessary recovery measures and aid the reinstatement of supplies).

Extreme events, likely to be more common under climate change scenarios, require a rethink of the assumptions made in the preparation of flood adaptation measures. In particular, recent extreme events have shown the need for water suppliers to rethink and review their vulnerability assessments, to rely less on historical forecasts and to plan for more extreme circumstances outside previous assumptions.

7.4. REGAINING DRINKING WATER SUPPLY SYSTEMS

7.4.1. Following Drought

When replenishing raw water storage reservoirs, reservoir managers should ensure that this is done in a controlled manner, so as not to impact adversely on the quality of water being abtracted for treatment. For example this may involve only allowing the reservoir to replenish at a certain rate to avoid the disturbance of excessive sediment,, or ensuring adequate dilution of a poor quality source.

Suppliers should also consider the impact on the aquatic system downstream of the reservoir, and the needs of other downstream abstractors, as well as possible environmental/ecological impacts. But priority should always be given to the safety and security of drinking water supplies.

Suppliers should also be aware that some deterioration in raw water quality may be seen several months or years later as a result of changes during a drought period. For example, colouration of water from upland catchments containing peat soils (due to naturally occurring humic acids) has been seen to increase markedly in summers following a previous drought period. Thus ongoing assessment of risks from catchment areas, informed by local knowledge of catchment hazards, remains important in the post-recovery period.

7.4.2. Following flooding

When regaining drinking water supplies after a flood it is critical that water suppliers work closely with community leaders and local health professionals/health departments, especially with regard to any precautionary measures that must be taken prior to consumption of water that is supplied (e.g. boiling it before use).

As a general principle, where possible water suppliers should prioritise the use of groundwater/well water where these are well protected (i.e. where they come from a confined or well protected aquifer) in preference to using water taken from rivers or lakes (surface water). This is because the contamination impact on surface water will probably be very much greater. However this will vary with local circumstances, and a risk assessment, based on local knowledge of source waters, should be used to prioritise their use for treatment and supply as drinking water.
Before restarting, flooded treatment works and distribution network disinfection will require a number of planned actions that need to be taken and tailored for centralized, decentralized and community-based production utilities.

Key principles of recovery are summarized in Table 22 Key principles in recovering a water supply system (summary table):

Table 22 Key principles in recovering a water supply system (summary table)

Regaining wells & boreholes	Start with most usedcritical supply first **Assess damage**: check pump, check borehole casings/void (using clean steel rod or dip tube) **Rehabilitate**: clear borehole with compressed air, ensure headworks are above ground level and re-sealed, repair pump & ancillary equipment. **Test pump output**: pump out at least 2x borehole volumes, check clarity and basic quality. If not acceptable then re-assess and rehabilitate again (or if repeated, then consider abandoning). Check pump output with required demand/pre-event output. **Disinfect**: ENSURE NOBODY CAN USE DURING DISINFECTION. Check pH is between 6 and 8, and turbidity <5NTU. Add at least 1 litre of 0.2% chlorine solution for every 100 litres of water volume in the borehole and allow to stand for as long as possible. Flush until residual chlorine is <0.5mg/l. **Sample:** Sample for indicator bacteria (evidence of pathogens). If possible ensure satisfactory samples from two seperate sampling exercises are obtained prior to supply to consumers.
Regaining water treatment works	Use skilled, experienced personnel (where possible who have a working knowledge of the particular WTW). Reinstatement priorities should be as follows (<u>complete all prior to supply to consumers</u>): – Ensure source protection as far as possible – Reinstate physical treatment – Reinstate disinfection – Reinstate chemical treatment stages – Reinstate non-critical treatment (in short term) stages Follow same model as above: **Assess/rehabilitate/test/disinfect/sample.**

7.4.3. Disinfecting and restarting domestic distribution systems (house connections and public buildings)

Supplies should prioritise premises where vulnerable consumers may use the water supply (e.g. hospitals, health care centres etc.), and public buildings to ensure that risks to the general population are reduced. Remediation of domestic premises may be complex and will require clear communication with consumers/householders.

It may involve using a dedicated workforce with knowledge of domestic plumbing arrangements to work alongside the population of an affected area in assessing risks and putting into place actions to remediate the domestic pipework.

Where the potential for contamination by pathogens is identified by the risk assessment then the domestic system should also be disinfected. The most effective way to do this is one unit, such as a length of pipe, at a time: ensure the supply is not consumed for a set period, introduce a high strength chlorine-based solution into the distribution pipework (e.g. at the entrance meter or tank), allow to stand for several hours (typically 2.0mg/l chlorine for at least 8 hours) and then flush the system until a low chlorine residual is obtained (typically 0.2 – 0.5 mg/l).

If chemical contamination is suspected then remediation will depend on the nature of the contaminant but may vary from flushing of pipework, treatment with specific removal chemicals (and then flushing), through to complete removal and replacement of domestic pipework. Water suppliers should work with both building owners and health professionals who understand the human toxicological profile of the substance concerned to determine an appropriate remediation strategy.

Case study 10 Recovering a water supply system after floods (England, 2007)

WEATHER EVENT:
Wettest May -July period since records began (250 yrs)
4 times the average rainfall
1 month's rainfall in a 24 hr. period

IMPACTS
13 people died
Major disruption to essential services
>50,000 premises flooded
Several billion pounds in damage
Sewerage systems overwhelmed in many areas
300 sewage treatment works flooded
6 water treatment works shut down
Mythe WTW (Gloucestershire) shut down due to site flooding
No piped water supply to 340,000 consumers

EMERGENCY SUPPLY and RECOVERY
Alternative supplies provided by tankers, temporary tanks (bowsers) and bottled water
Full recovery of the supply system took 16 days
Extreme rainfall following a prolonged wet period led to unprecedented flooding in parts of England and Wales in June and July 2007. This caused significant disruption to essential services – transport, electricity supplies and the provision of water and sanitation services. Floodwater levels were considerably higher than had previously been experienced and in many cases exceeded the levels that had been planned for.

Over 300 sewage treatment works were flooded and 6 water treatment works were shutdown due to flooding, including Mythe WTW which is the only source of piped drinking water to 340,000 consumers in Gloucestershire. Alternative water supplies were provided via mobile tankers, temporary tanks (bowsers) in the streets and bottled water. Full recovery of the piped water supply took 16 days.

Although there were no direct health effects reported as a result of the water supply interruption, the importance of a holistic (water safety plan) approach to managing risks throughout the water supply system was demonstrated. Existing plans to shut down the WTW during flood events assisted in the restoration of WTW operations; and existing regulations to prevent major contamination of depressurised water mains was effective in reducing risks to consumers when water supplies were re-instated

However the recovery of the piped water supply was delayed by a lack of understanding of the role and responsibilities of water suppliers on the part of other agencies responding to the incident. In addition, inappropriate advice about water consumption was initially provided to consumers due to a lack of understanding of risk management in water supply operations.

Knowledge and understanding of the roles and responsibilities of responding organisations is therefore highlighted as a key learning point from this incident. Although a flood plan was in place at the site, the events of summer 2007 were more severe than the water supplier had planned for. The need to re-think vulnerability assessments to take account of more extreme events is also highlighted was a key learning point.

7.5. EMERGENCY PLANNING & INSTITUTIONAL CAPACITY ISSUES

7.5.1. Emergency planning & preparedness

Water suppliers should ensure that they have a clear understanding of local and regional resilience and emergency response arrangements. These will vary widely and may even change within a supplier's operational area. Suppliers should ensure that they are aware of the key agencies involved, who is responsible for the co-ordination of response and recovery actions (e.g. area police chief, the local mayor's office, etc.) and what is expected of their own organisation. Taking into account appropriate security and confidentiality issues, emergency planners should share information about each other's equipment and capabilities to enable a co-ordinated response to be planned. This may allow a much larger event to be successfully managed without the need for large stockpiles of equipment or materials.

Critical issues to consider are:

- Catchments
  - rethink vunerability assessments
  - don't rely on history: forecasts are short-term
  - plan for more extreme events – rethink assumptions
  - monitor rainfall levels, flood levels, deterioration in raw water quality

- Treatment works
  - assess local risks and have a plan in place

- Distribution
  - assess risks and mitigation measures, e.g. access to service reservoirs
  - provide? check? controls to prevent contamination by "backflow"

- Consumers
  - assess risks in and from buildings in advance
  - understand human behaviour in extreme events
  - prepare clear information and advice.

Suppliers should ensure that formal emergency plans and arrangements are put in place with all agencies and that these are exercised in a variety of conditions. Emergency plans should include key actions to be taken by each organisation and contact details for health authorities/ professionals, state, regional and local agencies, key operational control centres (e.g. of ministries/bureaus of environment protection departments etc.), and emergency services. These contact details and associated protocols should be tested on a periodic basis in conjunction with the partner agency.

Emergency exercises should cover both the crisis phase and the recovery phase, as the restoration and reintroduction of assets is critical. Recovery plans should include planning of measures to ensure that the drinking water supply is safe for consumption (or appropriate advice is given to consumers).

Water supplier emergency plans should contain clear definitions of roles in an incident including a description of the role of each organisation and of individuals/teams who will contribute to the incident response. If emergency plans rely on bringing in additional resources it needs to be clear before they arrive what they are there to achieve.

7.5.2. Emergency distribution of alternative water supplies

Where the normal water supply arrangements are disrupted by an extreme event, then suppliers and/or agencies need to provide an alternative supply to at least meet the drinking and sanitary requirements of the population.

The amount of water required by consumers will depend on the priority of need that you are addressing. This is easily summarised in the diagram below, which gives an estimated volume required per person for different uses. It should be remembered that water of different qualities will be required for different uses, as shown in Figure 17:

Figure 17 Differentiated water quality requirements (Source: WHO, 2005)

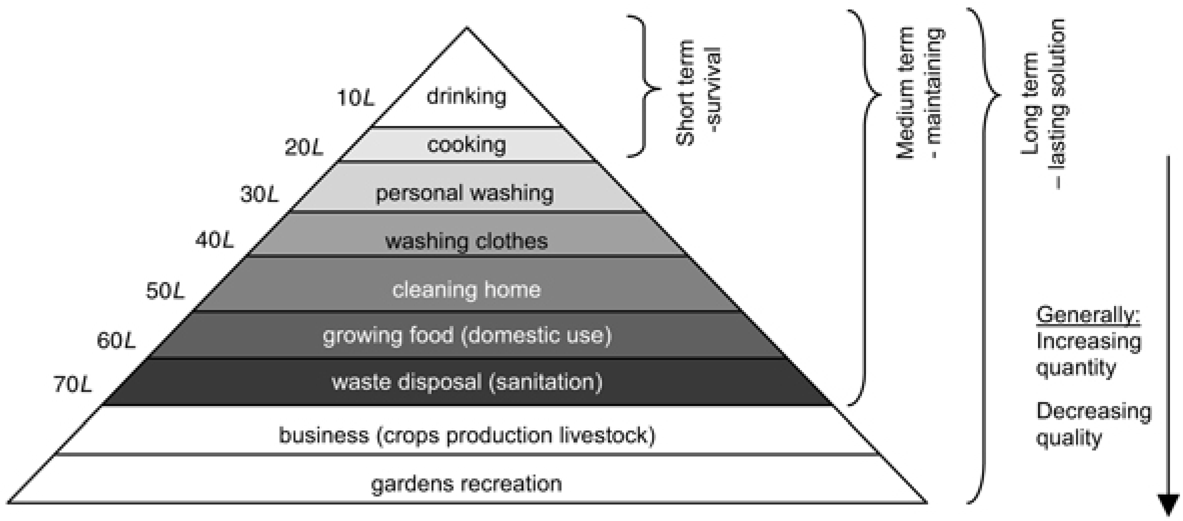


Figure 17. [From: WHO – Technical Notes for Emergencies Technical Note No. 9 Draft revised: 7.1.05]

Where water is supplied via an existing safe piped system, it is NOT recommended that this system should be used to provide untreated water. The recovery of such a system to a standard where safe drinking water can once again be delivered will take a substantial period of time, during which public health may be compromised. Equally, consumers who are expected to do something different from normal - e.g. boiling water before drinking it where they do not normally do this, or using it only for non-consumption purposes - should be informed clearly by the supplier what they must do [link to communication chapter this needs to be specified]. Very careful consideration should be given to the method of providing these volumes of water, and the quality requirements of different uses.

Where consumers are normally supplied with their drinking water via a piped system (be it centralised or a community water supply) and this is no longer available (or its use is restricted by an extreme event), then drinking water must be supplied to the community. An effective way to distribute water in the absence of "normal" piped water supplies is via the use of mobile water tanks or storage units. These can be in various forms:

- road tankers/trailer tanks
- pillow tanks/bags–large plastic water holders placed on the ground or back of a vehicle
- bowsers/portable tanks (usually towed behind a vehicle to a static location)
- bottled water

Where possible use tanks and tankers reserved for drinking water. They should be constructed of a material that will not be detrimental to the quality of drinking water held within it. Even where dedicated tankers are used, then these should be disinfected prior to use (see below). Where suitable quality control measures are in place they may be disinfected prior to an event and stored ready for easy dispersal in an emergency. This must include suitable storage conditions (the tank must not be contaminated, and satisfactory test samples should be obtained from stored tanks on a regular basis).

Where containers are not dedicated for drinking water, then they should be cleaned, flushed and disinfected prior to use. The internal surface of the tank, together with internal surfaces of any fixtures or fittings (taps, pipework etc.) should be cleaned with clean water and detergent, then flushed with potable water (if possible via a pressurised supply/pipe), ensuring safe disposal of the flushing water.

Box: Water supply tanks disinfection :

Alternative water supply tanks should be disinfected internally by the addition of a chlorine solution for 24 hrs (for example 14% sodium hypochlorite solution), and then rinsed (with safe, potable water), and refilled with a safe water supply. After approximately 30 minutes standing time a sample of the tank contents should be taken to ensure it is safe to supply to consumers. The water should meet all local drinking water quality requirements applicable to the manner in which it is supplied (and advice given to consumers).

Suppliers should ensure that consumers are adequately informed about the purpose of the water supplied and what are appropriate uses and precautions to take. Suppliers should take into account that where consumers have to transport drinking water from a distribution point or temporary tank/bowser/tanker, then the receptacle used do do this will introduce a risk to safety). . Even where the drinking water stored in the temporary tank is safe, consumers should be advised to boil (and cool) the water before consuming it, to mitigate the risks of contamination during carriage to their premises.

7.5.3. Institutional capacity / Mutual aid

Resources to help in dealing with an extreme event can be shared across a particular sector or group of affected sectors. Water suppliers may put in place "mutual aid" arrangements where collective agreements are made to share a proportion of each other's equipment or resource. For example a water supplier may arrange to share road tankers, static water tanks, pumps, laboratory services or other operational assets from a water supplier who is not affected by an event in their area. It is important that such arrangements are planned for and agreed in advance (based on predictions of what may happen) so that they can be put in place without delay in a major incident. It is good practice to have in place an agreed list of equipment and capabilities that suppliers are willing to share in advance of any event, , together with an agreement in principle on the minimum and maximum levels of aid that may be available on a voluntary or commercial basis.

In additional to mutual aid from other water suppliers, aid can be sought and obtained from existing partners and contractors, civil emergency organisations (who may hold strategic equipment stores), national agencies and in many cases the military. Again, it is important to document in advance what aid is available (and how much), where it is located (or delivery lead times), and the processes that need to be followed in order to initiate the provisionof this aid (including tried and tested communication arrangements/contact numbers).

7.5.4. INTERDEPENDENCIES / BUSINESS CONTINUITY

To ensure continuity of a water supply, one needs to be aware of the nterdependency that exists between people, chemical supplies, laboratory facilities, electricity supplies and other factors. A holistic rather than a series of individual approaches is needed to resolve problems.In the event of an extreme event (particularly flooding or adverse weather), access to water supply sites may be affected, as may the provision of services from other suppliers and utility providers.

Water suppliers should ensure that their operational arrangements are extended to consider the impacts of extreme weather events. For example, they may need to consider the issues raised in Table 23:

Table 23 Impacts and mitigation measures

Impact	Mitigation measure(s)
Access restrictions unavailability of staff	Shut-down of asset Remote operation Resident staff Increasing chemical stocks & strategic spares
Failure of support services (other utilities, laboratory services, etc.)	Alternative power supplies (see below) Increased use of on-site water quality testing

Electrical power supplies are critical to the continued operation of the water supply system. Water suppliers should put in place arrangements with local electricity companies to restore power supplies to key water supply assets as an essential service. It is helpful for suppliers to identify key strategic assets that are critical to the continued supply of treated drinking water. Service Level Agreements should be put in place with electricity companies which specify agreed standards of service. Such agreements may include resolutions on the provision of multiple electricity feeds to a site, or a minimum “down time” period, within which mains electricity supplies are restored. Where multiple feeds are in place, a full failure analysis should be conducted to see if there are common points in the electricity distribution system that may cause all independent feeds to fail simultaneously. It may also be appropriate for co-funded projects to be put in place to improve the resilience of power supplies to a particular location or asset. An assessment of the reliability of a power supply should be combined with an assessment of the need for alternative power sources.

Water suppliers should consider the need for either fixed or portable equipment to provide an alternative power supply. Where generators are used, care should be taken to ensure that these are appropriately sized for the site at which they are (or may be) used. This should take into account the continued operation of all key processes, pumps, monitoring and alarms, and also the additional loads placed on the supply by operating changes (for example the starting of pumps). Generators should be regularly maintained and tested to ensure they operate when required. This regular testing should ideally be conducted “on-load” - that is with a typical electrical power demand on the system - to simulate real conditions in the event of a power failure. Consideration should also be given to the mode of changeover between mains power supplies and the alternative source. This may necessitate manual intervention by operators, although various automated change-over options are possible to minimise the impact on the water supply processes.

Case study 11 Water supply problems in the case of power cuts caused by extreme weather conditions

In the west Transdanubia region of Hungary a Mediterranean cyclone resulted in a considerable amount of precipitation in the form of snow on 27th January 2009. A great quantity of snow froze on (mainly medium voltage) network cables, which were damaged by its weight and by the accompanying strong wind, thereby causing an extensive power cut. The power cut affected 34 settlements and 89,000 consumers. Due to the interruption of the power supply, the electrically driven pumps and equipment of both the water utilities and the waste water treatment plants ceased working as there was a shortage of emergency power generators with the required capacity. The pressure in the water supply systems fell and varied significantly. The greatest cause for concern in regard to public health considerations was not so much the stagnant water in the piped distribution systems as the possibility of ground water and waste water feeding back into the water pipes. In compliance with the provisions of Government Decree 201/2001 (X. 25.) on the quality requirements of drinking water and the associated control procedures, the municipality and the water supply company notified the population that, on the recommendation of the National Public Health Service (NPHMOS) any water intended to be used for drinking or cooking should be boiled until the time when the water pressure had been fully stabilised. In several settlements water tankers had to be used to ensure sufficient water supply, which proved difficult under the snowy conditions. . The measure remained effective until the achievement of a negative bacteriology result in the water samples taken after the stabilisation of the water pressure confirmed the restoration of water supply. Under the difficult ground conditions the restoration operation took more than 72 hours.

Both water supply and waste water treatment are of key importance for public health, as the lack of them may constitute a considerable health risk, and therefore the provision of an adequate back-up power supply based on a satisfactory number and capacity of emergency generators, to cover for the eventuality of power cuts caused by extreme weather conditions, is an important factor in the vulnerability assessment.

7.6. SUMMARY

Climate change is likely to affect the availability and quality of raw water, which in turn could affect the efficiency of drinking water treatment processes and the stability of drinking water in distribution. More frequent extreme rainfall could lead to increased surface water turbidity and higher numbers of pathogens (and their indicators). This would result in a greater challenge for water treatment works, particularly surface water sites. Changes in rainfall may cause more frequent or intense periods of water scarcity and/or drought. This will result in a decrease in available resources and may also increase the chances of resource contamination.

Water suppliers can adapt to prepare for extreme events to minimise their impact on consumers by, for instance, improving the resilience and interconnectivity of supplies, assessing risks to supply systems and treatment processes in advance, and, where possible, putting in place controls to minimise these risks.

8 ADAPTATION MEASURES FOR DRAINAGE, SEWERAGE AND WASTE WATER TREATMENT

8.1. KEY MESSAGES

- To assess the risk level of potential impacts of weather events on drainage/sewer systems and WWTPs a punctual analysis should be performed for each element of the systems and under different circumstances of floods and intense rain, drought and prolonged water scarcity, increased temperatures and heat waves.
- Generally speaking, extremely intense rainfall and river flooding are characterized by a primary risk for public safety, while heat waves or extended droughts generally imply a delayed secondary effect on drainage and waste water systems, specially in urban areas.
- Weather-sensitive design criteria are the primary means for climate proofing in new drainage networks.
- In designing adaptation measures for sanitation systems in extreme weather events it is also necessary to know that every extreme hydrological situation causes fluctuations in pollutant concentrations in wastewater inflow to the WWTPs and thus affects the efficiency of the treatment process. The differences in biochemical load cause problems in different technological sections and related treatment processes.
- In existing networks, the highest hydraulic capacity should be assured by undertaking periodical maintenance and cleaning of the most significant nodes of the network.
- Extended drought periods normally have a much less critical effect on drainage and sewerage systems, but persistent droughts may have an environmental impact if intense rainfall events occur directly afterwards and exceed combined sewer capacity.
- With small networks and limited budgets, decentralized systems face different constraints to climate proofing management and they should have close links with the main environmental authorities and even agreements with centralized systems' managements for emergency interventions.
- The precondition of a well-handled emergency is skilled staff able to recognise the danger, analyse the risk and respond properly. Staff should be properly trained and the system regularly tested for emergencies. Another important priority is good communication among everyone involved - system operators, owners, state administration, river basin authorities, the management of official rescue systems and all other stakeholders.

8.2. CLIMATE CHANGE IMPACTS ON DRAINAGE SYSTEMS, SEWER SYSTEMS AND WASTE WATER TREATMENT PLANTS

Climate change inevitably leads to changes in weather conditions in affected regions. Increases in average temperature can be expected, and a consequent decrease in both the amount of precipitation and its seasonal distribution. So, for instance, there may be long periods without precipitation followed by extraordinarily strong flash rains.
When speaking about the impact of climate change on the drainage/sewer systems and waste water treatment plants (WWTPs) it is important to consider changes in quantity and timing of precipitations (rainfall intensification, flash floods, long dry periods), air temperature, sea level, and a higher frequency of extreme weather (decrease in return period of extreme events).

Storms, heavy rainfall events and a higher frequency of flood events require:

- quality protection of drainage systems, sewer systems and WWTPs against high peaks of hydraulic load;
- additional storm water storage in retention reservoirs and storm water tanks;
- treatment of the first flash storm water containing high concentrations of pollutants.

Prolonged periods without any rainfall lead to:

- a lower waste water discharge and the consequent accumulation of solid waste sediments and encrustation in sewers that can clog them ;
- a decrease in waste water flow and unpleasant odour from water rotting in the system;
- an increasing population of rodents associated with increased quantities of sediments and solid waste in pipelines;
- a growing risk of disease dissemination;
- salt water intrusion, especially in coastal agricultural areas, causing the degradation of sewers and affecting the quality of waste water.

Increasing air temperature affects the processes of wastewater treatment, , especially because:

- lower oxygen solubility in water can lower the efficiency of active sludge compartment,which leads to higher consumption of compressed air in biological treatment processes for the same treatment effect;
- higher dust concentrations raise the costs of air filtration;
- faster biological processes (activated sludge process, digestion) are faster because of the higher air temperature, and sludge dewatering processes are also more efficient;
- the costs of heating up anaerobic digesting facilities falls.

One of the first steps improving knowledge of the impacts of weather events on drainage/sewer systems and WWTPs is the assessment of the risk levels related to the different events. In particular, such events as extremely intense rainfall and river flooding are characterized by a primary risk for public safety, while heat waves or extended droughts generally imply a delayed secondary effect on drainage and waste water systems.

The decreasing dilution capacity of the receiving water bodies is an important aspect of climate change because the longer droughts to be expected would lead to a significant decrease in river flow. Yet the pollution load of waste water will be higher because users will have saved water during dry periods, or because of high pollution concentrations in the first flash storm water after the dry period. So careful monitoring of water quality in waste water discharges and in recipient bodies isessential during droughts. . Higher concentrations of pollutants in the waste water together with the decreased dilution capacity of the recipient bodies would require an increased purification effect from the WWTPs and might even prompt the imposition of stricter limits for discharges in order to keep the current quality level of surface waters.

When designing measures for the adaptation of sanitation systems to extreme weather events it is also necessary to remember that every extreme in hydrology causes fluctuations in pollutant concentrations in waste water inflow to the WWTPs and thus affects the efficiency of the treatment process. The differences in biochemical load cause problems in different technological sections and related treatment processes.

8.3. ADAPTATION MEASURES TO URBAN WASTE WATER TREATMENT PLANTS BEFORE AND DURING DROUGHTS

From the point of view of the drainage of urbanised areas, in contrast with extreme rain and river floods, (primarily a risk for the people's safety of the inhabitants)extreme droughts endanger the environment in particular and have a lower immediate impact than other extreme weather events. However, the necessary management, maintenance and operational measures for the mitigation of the adverse effects of extreme drought on sewer systems and urban wastewater treatment plants (UWWTPs) should be mentioned. The following may be regarded as the main consequences of an extremely dry period:

- reduction of the ability of sewage to pass through the pipe because of encrustation and sediments, and lengthening of the time of stay of wastewater in the system caused by partial or full blocking of pipeline;
- deterioration of water organoleptic properties - bad smell from the sewage system, as well as from the first section of the treatment plant;
- increased occurrence of rodents and other vermin in and around the sewage system;
- possibility of infection spread.

Preventative measures must be organised in time, and planned as a part of standard plant operation and maintenance linked to average rain-free periods in the region. Cooperation with other organisations involved in city cleaning is advisable, as is communication with stakeholders.

8.3.1. Maintenance of sewer systems during an extremely long dry period

During a long drought, periodic checking and cleaning of electro-mechanical equipment and of sewage system pipelines and accumulation tanks should be carried out, to ensure their full hydraulic capacity and to prevent the accumulation of solids. In the case of big combined sewer systems, regular and frequent cleaning of roads and pavements (in urban areas), and sewer system inlets and manholes is also important. During long dry periods, it is recommended that the sewer system pipelines should be rinsed with service water (water treated in the biological stage of UWWTP, to avoid wasting water treated to public supply standards). For rinsing urban surfaces, completely safe disinfected water has to be used, according to public health regulations.

The availability of simultaneous models used to identify the most critical points when considering sedimentation and hydraulic capacity is increasing. Extensive monitoring and measurements are necessary for calibrating these systems. It is also necessary to remember that mathematical models illustrating the rate of flow through sewage systems are less accurate in establishing minimum flow rates. In some cases sufficient information on possible sediment formation during extremely low rates of flow may be obtained only through monitoring the current statusof pipelines. As a general criterion – criteria is plural] , it is best to verify that the flow speed of the waste water is >0.5 m/s to ensure the sewers retain a self-cleaning capability.

All usual as well as exceptional maintenance procedures should be defined in the operational maintenance, crisis and emergency plans, and part of those should include a description of communication with stakeholders. For example, the use of domestic grinders for disposal of moist domestic waste should be restricted in such conditions. Appropriate staff training is also necessary so they can identify risk, and respond to it. In the case of extensive city sewage systems, maintenance of roads and sewer and drainage networks is usually carried out by several companies, and so a joint maintenance plan valid for all participating companies must be drawn up.

In coastal areas it is necessary to prevent infiltration of sea water into the sanitation system, which could be endangered by the salt. . So the pipelines should be waterproof and regularly checked.

8.3.2. Operation of UWWTPs during extremely long dry periods - changes in hydraulic and pollution load

UWWTPs designed to ensure a sufficient level of wastewater treatment from combined sewer systems are usually designed to be able to maintain high efficiency even during marked fluctuations of rate of flow and pollution. In period of longer drought, and in subsequent periods of torrential rain, these fluctuations are even higher. Differences between the level of the UWWTPs' pollution load in workday peaks, or during washing out of sediments from the sewage system, and the level of their pollution load overnight in the rain-free period, are extreme. A treatment plant's technological equipment should be designed taking into account this fluctuation of pollution as well as hydraulic load.

An important part of a UWWTP`s technological adaptation for periods of extreme drought should be the possibility of regulating the amount of dissolved oxygen in activation tanks (the amount of air pumped into them ), in order to ensure that conditions of operation of the UWWTP`s biological section during an extreme pollution load are similar to those during normal operation. On-line oxygen-measuring sensors would consequently help the regulation of the process.

8.4. ADAPTATION MEASURES BEFORE AND DURING FLOODS

The knowledge of weather change indicators and provision of information on current weather conditions in the relevant area are fundamental aspects of strategies for protecting sanitation systems against flash rains and floods. This enables an appropriate response by the UWWTP`s management to local extreme weather changes, showing increased rains or decreased periods between flash rains, and prevents overloading of sanitary systems.

The potential vulnerability of the system during heavy rains and floods is related to the spatial variability of changes in hydrological conditions, type of drainage and sewer system (combined or separate sewerage system, pipeline location above the ground in more temperate countries, type of technological process used in waste water treatment (biological, physico-chemical), and also to the structure of the drained area (centralised systems, or decentralised local systems). Adaptation measures should be defined and implemented specifically according to the weak spots of the network.

8.4.1. Centralized drainage/sewerage systems and urban waste water treatment plants – preventative measures

Centralized systems are often characterized by a large drained area with a high share of built-up area, served by one central main UWWTP with a dominant role and possibly several smaller facilities in the city outskirts. The vulnerability of centralized systems can be seen in the function of the central UWWTP. When an emergency occurs and the central UWWTP is out of order, all the waste water from the area is discharged into the receiving water body in one spot without any treatment. This could have a significant impact on surface water quality.

Centralized urban sewer networks were often built step by step as the cities grew. Rainwater from built-up areas (roads, pavements etc.) was drained together with the wast water from households and industries. This type of combined system worked satisfactorily until a heavy rainfall occurred, when the capacity of the system was insufficient. Because of high concentrations of pollution in the first flushed water, combined sewer overflows can be potential sources of pollution for the receiving surface waters. The problem can be overcome by installing retention tanks for the storage of extra flush water, which can be treated in the UWWTP when the storm is over.

In modern housing developments or in rural areas where no sewerage system existed before, separate drainage systems used to be installed. Separate drainage systems have two pipelines (branches), one for sanitary waste water, which carries its content to the UWWTP, and one for surface water (rainwater), ending directly in the receiving water body. This type of sewer system is effective in controlling flows to the UWWTP. Problems could arise with misdirected connections and also with high pollution of surface water from the first flush. In many European countries the water volume collected during the first two or three hours of a precipitation event is redirected from the drainage system to primary treatment in order to reduce the content of sediments washed out from the surface of roads and roofs. The primary sedimentation in the highly polluted first flush water can be improved by chemical-physical treatment (coagualtion-flocculation)

In adapting to climate change, experienced as increased rains or flash floods, the preparedness and immediate feedback from the managers of sewers and UWWTPs play a key role in preventing the systems flooding. The age of urban facilities can be a significant limitation. The structure of the network may be too poor to allow it to be adapted to changed hydraulic and chemical loads without problems. The adjustment of the whole hydraulic capacity of the system can be economically impossible. . In these cases the risk of flooding of the system can be mitigated but not fully eliminated.

The highest possible hydraulic capacity of existing sanitation systems can be achieved mainly by periodic routine maintenance of the system and its important nodes, including precise cleaning of drainage/sewer pipelines and fittings, and other parts of the system to avoid overfilling or congestion. The pipelines must be kept waterproof and impermeable to prevent the infiltration of waste water to groundwater as well as to prevent the penetration of water from outside to the sewers during flooding. Mechanical and electric parts of pumping stations should be regularly checked and maintained. Apart from ordinary electromechanical equipment, aspare flood pumps should also be available for emergencies. Alternative electricity sources should be also prepared because power failures can often occur during floods as well as in other weather extremes.

It is advisable that treatment plants’ managements develop and regularly update maintenance, crisis and emergency plans for sanitation systems for both floods and droughts which provide operators with management rules and levels of critical indicators, enabling them to recognize the potential threat and to be able to respond on time and correctly to the potential emergency. Especially in the case of large systems, draining extensive urban areas where different parts of the system are managed by different operators, common maintenance and emergency plans are desirable to secure lasting clarity about the whole system.

The fundamental assumption of a well-prepared crisis and emergency plan is intimate knowledge and detailed mapping of the system. The best way would be to use an easily available detailed plan in GIS form. The modelling of a hydrological regime of adjacent surface water bodies in emergency situations necessary for effective emergency planning can be performed by the UWTTP operators, but what is more effective is cooperation with other specialised bodies such as forecasting agencies, river basin authorities etc.

Doing your own hydraulic modelling of the sanitation system in emergency situations for current and expected weather conditions is highly recommended. It allows UWWTP operators to define weak spots in the system and to propose effective measures in planning procedures. The use of simulation models of storm water runoff in complex networks has recently increased due to their better accessibility and reliability. The accuracy of simulated scenarios primarily depends on a deep knowledge of the network and precise model calibrations based on measured data. It is necessary not only to develop a mathematical model of a sanitation system, but also to calibrate the model under a certain set of meteorological conditions and link it to the real-time meteorological data collection system. The operators can use the results of this model to prepare the sanitation sytem and UWWTP for the flow and load fluctuations to minimise the impact on the system and the recipient.

The precondition of a well-handled emergency situation is skilled staff able to recognise the danger, analyse the risk and respond properly. The staff of the facility should be appropriately trained and the system regularly tested for emergencies. Another important aspect is good communication among all actors, system operators, owners, state administrations, river basin authorities, managers of official rescue systems, and all other stakeholders.

8.4.2. Decentralized and community-based sanitation systems – preventative measures

Some issues concerning centralized sanitation systems mentioned above can be taken into account also when considering decentralized and community-based systems. But the situation in this case remains different:

- decentralized systems are characterized by small networks and facilities with limited budgets;
- in countries with warm winters the sewage systems of small settlements used to be located above the ground This makes them more vulnerable to extreme weather;
- the equipment of small networks and facilities is usually not at the highest technological level, so during emergencies it is less effective;
- the use of simulation models and telemetry systems may not be affordable, so experience and knowledge of the network as well as of all its equipment and of its reaction to past critical events becomes more important (periodic surveys, a register of critical situations during extreme events, etc.);
- extreme weather events do not very often concentrate their effects on a smaller area, although when it happens it can hit a major part of the system. Response to the impact is therefore less flexible in terms of operational, hydraulic and treatment capacity.

The impact of stormwater on decentralised systems can significantly increase water flow fluctuation during rainfall events, so the adoption of measures mitigating the water inflow to the UWWTP is highly recommended, e.g. support of safe infiltration of rain water directly on to the surface, or separation between sewer and rain water drainage networks. This measure is useful also in the case of massive snow falls when the anti-cryogenic chemicals are being used on the roads. These chemicals can harm purification processes in very small UWWTPs with a low content of water and sludge. The separation of drainage and sewers is possible only if suitable natural receiving bodies for direct water discharges are available. In the case of a combined sewer system the amount of anti-cryogenic chemicals should be controlled by a special regulation.

Where the sewage pipelines are located above the ground it is recommended that they should be secured against damage caused by storm water where necessary, e.g. in hilly areas, and against landslides.

Operators of decentralized systems should closely cooperate with the state environmental authorities and with operators of the main centralized sanitation systems to use their experience and equipment (it is advisable to sign agreements on cooperation in emergencies).

For those systems cost-benefit analysis could be employed to decide whether some way of connecting to a neighbouring large centralized system can lead to greater overall efficiency.

Many rural settlements are not equipped with sewers and treatment plants. . Waste water disposal from households is achieved by small home WWTPs, and septic tanks or simple cesspools are used for biological waste. When small home WWTPs are being designed for wastewater disposal it is necessary to take into account the location of remote houses in flood prone rural areas.

8.4.3. Centralized drainage/sewerage systems and UWWTPs - protective measures during floods

Even if weather forecasts are nowadays detailed and precise, the assessment of the extent of a flash storm and its impact on the sanitation system is unpredictable. This is valid especially for extensive combined sewer systems. Flooding does not only mean a temporary increased level of river or other surface waters during which the area in the proximity of the riverbed is flooded. The damage can be caused also by the water not being able to flow naturally away from any area, or by the volume of rainwater exceeding the capacity of the drainage system for a longer time.

In long highly fluctuating rivers, flood waves generated by intense rainfall can propagate quite rapidly, with potentially dangerous effects on sanitation systems along the river as well as downstream in areas not directly affected by storm events. During floods surface water from the river can enter the sewer system through hydraulic connections between the river and the sewer, e.g. combined sewer overflows, weirs, outlets, and leaky sewage conduits. UWWTPs can also be flooded directly from the river or from backwater in the surrounding area.

Reasons leading to the flooding of UWWTPs can be insufficient flood protection, failure in the system or the magnitude of the flood wave. Damage can be caused also by human factors if duties assigned in an emergency plan are neglected. Good management of a sanitation system therefore requires deep knowledge of the hydrological regime of adjacent surface water bodies. The operators should have good communication with river authorities, dam and sluice operators, and flood protection bodies along the river and should be prepared to immediately install components of a flood mitigation and protection system (mobile flood protection walls, pumping devices etc.).

Floods always affect all the hydraulic capacity of a drainage system. Natural gravitational discharge from the drainage system or from a UWWTP is gradually disabled, and it is necessary to start operating reserve pumping stations. That is why full operability of ordinary as well as emergency electro-mechanical equipment (flood pumps) should be secured. Electric generators should also be on stand-by and their connection to the key facilities of the plant (pumping stations, recirculation, mixing and aeration) should be available as break-outs are frequent. The skilled staff should be ready to assume all the responsibilities which the crisis and emergency plan demand. The vulnerability of the system is then strongly influenced by the number of pumping stations available to pump the excessive water back to the receiving water body. UWWTPs located on flat land are more vulnerable than those connected to a gravitation sewer.

The full functioning of UWWTPs and pumping stations should be ensured for as long as possible by continual checking/maintenance of electro-mechanical facilities as well as of the structural components of the system. Fundamental maintenance activities within the system are solid waste disposal and cleaning of sewer conduits, storm water tanks and other objects to maintain the maximum hydraulic capacity of the system.

For large systems, a central operational unit should be in charge of supervising the response of the whole network, directing special maintenance teams and alerting public and other stakeholders involved in the case of risk to public safety (sewer back-flooding of urban areas, possible contamination of sensitive areas with waste water, pollution of water bodies and groundwater sources, etc.).

Simulated hydraulic models can be used to define appropriate ways of working during the extreme event in real time. The epicentre of extreme rainfall events is usually confined to a small area, so it could be possible to use the residual hydraulic capacity of drainage/sewer networks by regulating the flow or redistributing storm water towards branches facing less demand. This kind of measure requires interconnections between different parts of the sewerage network, installation and proper maintenance of automatic control system elements within the system, and a well-calibrated centralized system of real time control (RTC).

The protection of the UWWTP must be based on the assessment of the real level of risk so that its operation will be maintained and the flooding of vital equipment and pollution of the surface water prevented. There are several pieces of practical advice on how to protect a UWWTP against flooding:

- the building of a flood protection embankment around the UWWTP and sewerage facilities, and the possible construction of mobile flood protection walls;
- closing anti-backflow devices (valves, gates, sluices…) and using pumping stations to protect the systems against the back wave from the recipient water body;
- locating essential UWWTP compartments above the level of the flood with long return period (operation of this solution is more costly, because the whole inlet has to be pumped up even during dry periods);
- using the principle of “containment” - crucial technology and electro-technical equipment is placed in one protective steel container or concrete structure, ensuring the safe operation of the facilities inside during the flood;
- removing and storing dismountable equipment from the UWWTP and the sewer facilities to prevent damage;
- removing all chemicals and other potentially dangerous contaminants from the area of the UWWTP and sewer facilities to prevent additional pollution of surface and ground water.

During the flood the UWWTP should be kept in operation as long as possible even if most of the waste water is treated only partially. A high dilution capacity of the receiving water body during flooding makes it possible to keep an acceptable quality of water, even if only part of the incoming waste water, for which the UWWTP is designed, is treated completely.

If flood protection is overwhelmed and the situation does not allow operation of the UWWTP any more, electrical devices (pumps, compressors, and other electrical devices needed for the restoration of the treatment plant) should be removed first to avoid any damage caused by rising water.

Case study 12 Scenarios of water entering UWWTP areas during the 2002 flood (Czech Republic)

These are some examples of problems faced by UWWTPs in Czech Republic in 2002:

- overflowing of flood protection embankments because of rising water level in the river (central UWWTP in Prague);
- inundation of waste water treatment plant area by surrounding floodwaters because of insufficient protection upstream (UWWTP in České Budějovice);
- flooding of WWTP because of over-large inlet of water from the river which entered drainage and sewer systems through insufficient anti-back flow devices (UWWTP in Teplice, UWWTP in Ústí nad Labem);
- flooding from back-flow water coming from downstream.

8.4.4. Decentralized and community-based sanitation systems - protective measures during floods

Very often the operators of decentralized sanitation systems are not well enough prepared to handle emergencies without the help of professionals, mostly because of a lack of reserve equipment (pumps, tanker trucks etc.) and sometimes also because of insufficient expertise among the staff. Good cooperation during the emergency with the state administration and with operators of central UWWTPs or other organisations owning the necessary equipment can help to overcome this problem.
Activities that have to be undertaken during and after the flood (until total restoration of the system) are:

- to avoid the release of contaminated water and especially contaminated sludge from cesspools and septic tanks into surface and ground water;
- to protect drinking water resources, wells and boreholes from contamination by polluted flood water;
- to keep the sanitation system working as long as possible;
- if necessary to remove all electrical devices from pumping stations and small domestic WWTPs endangered by flooding so that they can be used for a smooth re-start of the system after the flood;
- after the flood to remove all sludge from cesspools and septic tanks, to have it treated in the nearest UWWTP and to start to operate it as soon as possible;
- to rinse flooded sewers with high-pressure water if needed and reset the operation of the local sewer system and UWWTP as soon as possible.

In rural areas it is very important to observe basic hygiene requirements: to prevent a mass escape of dangerous bacteria to surface and ground water, and to keep the sanitary system operating as long as feasible, or in a state that allows it to be restored as rapidly as possible to an operational condition.

8.5. REGAINING STORATION OF THE SEWAGE SYSTEM AND UWWTP

Once the extreme weather event is over, damage assessment is the fundamental part of the restoration process. It must be carried out as quickly and thoroughly as possible. It is necessary to identify the most affected areas, and to define priorities and the help that is needed, in order that management of the restoration is logical and methodical, not chaotic. Further, it is necessary to carry out a first analysis of what actually happened during the flood, and to roughly assess its impacts and direct causes (i.e. in particular to identify inadequate flood protection measures in order to improve them in the future). Later on it will be necessary to draw up a more comprehensive estimate of risks and an analysis of the individual aspects of the event and its effects. For this secondary process, it is important, in particular, to:

- specify all critical elements in the system, in relation to the flood;
- develop an expert analysis on the basis of newly collected data;
- design new measures;
- improve infrastructure for any possible future extreme event.

8.5.1. Regaining and restart of drainage/sewer network operation

In particular the following activities need underlining as basic operations ensuring the restoration of functions of the drainage/sewer system after the extreme event:

- restart normal operation - through a special service team, working uninterruptedly 24 hours a day, ensuring free passage through conduits and checking and restoring the main pumping station collectors in the sewer network
- perform uninterrupted centralised monitoring of the functions of the drainage and sewer system main junctions, accumulation tanks, pumping stations etc.

The long-term impacts of possible service failures on the local inhabitants should be mitigated. In this critical period, it is necessary not to neglect relations with the public and stakeholders, which can be encouraged through prompt provision of information and dealing quickly with all complaints.

8.5.2. Regaining and restart of the UWWTP operation

Just as with the restoration of sewer network function, the restoration of UWWTP operation after a flood has to be started immediately after the danger has passed. The procedure for the start of UWWTP operation is as follows:

- General primary measures:
  - making all areas of the UWWTP accessible and documenting damage;
  - gradual removal of dirt, disinfection and cleaning of buildings and technological equipment (if necessary);
  - drawing up a plan for the restart procedure;
  - assessing the stability of buildings and structural compartments.
- Technological measures:
  - ensuring the electrical energy supply;
  - making waste water distribution systems and the bypass systems of the UWWTP passable;
- Technological start of the UWWTP operation:
  - start of pre-treatment (cleaning grating, grit chamber, grease trap) operation, for the present bypassing the sedimentation and biological stages;
  - start of sludge management operation (at least storage reservoirs) - this is the necessary precondition for the start of primary sedimentation (due to the usual high content of solids in the treated water, it is necessary to protect the existing pumps by drawing away most of the sediments) ;
  - start of operation of mechanical treatment stage, and chemical precipitation in sedimentation tanks (the preconditions for this are functional pre-treatment and sufficient capacity for sludge storage);
  - removal of solids from activation basins. If this is not possible, mobile mixing in activation basins is necessary;
  - start of operation of the aeration system, and subsequently gradual putting into operation of the biological stage (its precondition is functional primary sedimentation);
  - gradual putting into operation of automated management systems, preceded by manual dispatcher control.

The most difficult part of the procedure is gradually putting the biological treatment stage into operation. During the flood, activated sludge is usually washed away from the tanks, or its decay takes place (a similar situation occurs by anaerobic sludge stabilisation in sludge digestion tanks). It can be done by:

- inoculation with sludge from another UWWTP;
- "cultivating" new active sludge without inoculation;
- using the original sludge(although decayed) which has not been washed away, thanks to the sedimentation in the biological stage tanks after aeration switch-off and before the inflow of flood water (the best method).

According to experience from the Czech Republic in 2002, reaching performance of the biological stage which is comparable with the original standard takes several months, regardless of the memthod used for putting the activation tanks into operation. In southern countries, where warm weather prevails, the process could be shorter.

To speed up the process of returning a UWWTP to work after a flood, it should be modified according to the level to which the UWWTP was affected, and also according to how it was shut down before the flood. For example, if the electrical equipment was protected by means of dismantling, cleaning it will not be part of the process, but re-assembling it will be. If some of the UWWTP’s stages were not affected thanks to the success of flood protection measures, the procedure of putting it back into operation is shorter and less complicated. However, the sequence of putting the individualstages into operation always has to be kept.

8.6. SPECIFIC ISSUES OF INDUSTRIAL WASTE WATER TREATMENT PLANTS

The functioning of industrial waste water treatment plants (IWWTPs) and of solid urban waste plants (especially for the waste’s highly decayed organic part which produces leaking fluids) can be especially threatened during floods. Flooded and washed-out IWWTPs can represent enormous danger for people and for the environment because of the possible presence of hazardous substances.

As industrial facilities use different technologies for waste water treatment according to the quality of treated waste water and the techniques chosen, the flood protection strategies and damage recovery in IWWTPs will require specific approaches. Besides the basic principles applied by UWWTPs, the protection of IWWTPs against floods will require specific crisis and emergency plans, including accident emergency warning systems connected to the national one, and individual detailed analyses of technology/technique, equipment, and chemicals used and discharged. Industrial wastewater, sludge and chemicals stored and used in the process have often to be treated as hazardous and so regulations on hazardous substances have to be scrupulously respected. Special training for staff is essential.

Flood protection measures in IWWTPs and restoration activities should take into account special technologies used as a part of industrial treatment processes, which require special approaches not normally needed in UWWTPs. Beside the protection of special electrical equipment (e.g. for electro-flotation), safe intermediate storage of contaminated wastewater, sludge and other chemicals should be designed (for example safe tanks, flood-protected industrial lagoons for liquid hazardous wastes, etc.).

During a flood an emergency can develop not only as a threat to surface or ground water, but also to other parts of the environment (through contamination of soil, toxic gas emissions, etc.), so operators should be trained and prepared to respond to these situations as well.

During the flood it is advisable to:

- ensure the good operation of pumping stations, in order to make sure they keep working so as to avoid releases of untreated industrial waste water into surface or ground water;
- protect each compartment of an IWWTP against flooding, including temporary toxic sludge storage;
- install (temporarily or permanently) mobile units for waste water treatment – these can operate above the level of flood water to avoid untreated water being released into surface or ground water;
- keep the internal warning system which monitors defects in the IWWTP in operation even during the flood;
- be prepared to clean all contaminated equipment and dispose of hazardous toxic waste water and sludge. For this purpose a recovery plan drawing on experience to date can be developed. Waste water or sludge with hazardous substances should never be released into surface or ground water.

The guidelines for restoring IWWTPs after flood are basically the same as for large UWWTPs – the accessibility of the area, a damage assessment, the re-establishment of electrical power, cleaning sewer conduits and step-by-step restoration of all treatment processes (from preliminary treatment to automatic control systems). Obviously, if some of the processes were operating during the flood, the restoration process will be much faster.

Case study 13 Damage caused by the 2002 flood to the IWWTP in Rozoky (Czech Republic)

This IWWTP has an anaerobic mechanical-biological treatment process. The purification is completed in a UWWTP. The waste water treatment plant can treat 72 000 P.E. and the inlet is 840 m^3/day. During 2002'2 extreme flood it was totally inundated. The water level in the receiving river overtopped a 6 m-high flood protection embankment with a 1.4 m-thick overflowing jet. The floodwater pressure even lifted the gas tank in the basement, the building housing the engine room was damaged, the tank for chemical injection floated 100 m away and other tanks remained in place tethered only by the pipeline fittings. All electro-motors and control systems were destroyed. The total restoration costs reached 29% of the budget for the previous reconstruction in 2000. Yet the waste water treatment plant was operating again after just three months.

After the experience gained from the 1997 and 2002 floods in the Czech Republic, flood protection measures on IWWTPs should be an important part of crisis and emergency plan, which is dealt with when the administrative permission for IWWTP is being issued according to the Czech regulations.

8.7. SUMMARY

Climate-proofing of centralized middle to large drainage and sewerage networks consists of a wide range of preventative measures with both direct and indirect effects on the impact of extreme weather events. For both centralized and decentralized system managements, the editing and the diffusion of a fully comprehensive emergency plan is fundamental to prepare operating staff to recognize and react to defined risk levels. In particular, a warning system may be useful in case of inefficiency that can cause safety risks.

Furthermore, weather-sensitive design criteria are the primary means for climate-proofing in new drainage networks. Their dynamic adaptation to local extreme weather changes, such as rainfall intensification, or the reduction of extreme events' return time, is fundamental to avoiding frequent saturation of the drainage network. However, metropolitan drainage and sewerage systems can be very old and an adjustment of the whole hydraulic capacity to fast climate modifications is often economically unsustainable. The risk of floods in urban areas can therefore be reduced, not eliminated.

In existing networks, the highest hydraulic capacity should be assured by undertaking periodic maintenance and cleaning of the most significant nodes of the network. In the case of large systems where road drains, drainage and combined sewerage may be managed by different companies, coordinated maintenance plans are recommended.

The full service of treatment plants and pumping stations should be ensured by periodic maintenance of the structures and the electro-mechanical components and by providing the stations with emergency electrical generators, as one consequence of extreme rain is often a local electricity breakdown. Before this comes the acquisition of detailed and widespread knowledge of the whole network which, especially in large and old drainage systems, often requires long and expensive surveys completed by the preparation of a geographical information system (GIS) in order to make the information easily accessible by different users.

In recent years, hydrodynamic models to simulate the effects of rain events on large combined sewer networks have become more and more accessible. Careful calibration of models under certain sets of meteorological conditions and their links to a real-time meteorological data collection system allow the operator to predict the most critical nodes of the network depending on the focus and intensity of a storm, and thus to control an emergency operation in advance. RTC methods based on a centralized telemetry structure are nowadays fundamental means for the management of complex drainage and sewerage systems.

Prolonged floods can also be considered extreme events for all the drainage and sewerage systems characterized by hydraulic connections with water bodies such as combined sewer overflows (CSOs), discharge channels or permeable sewers within flood areas. In long, highly variable rivers, in particular, flood waves generated by intense rainfall can propagate quite rapidly, with potentially dangerous effects on downstream drainage systems not directly affected by storm events. Good management of a drainage system closely linked to main water bodies could therefore require: a deep knowledge of their hydrological regime; a close relationship with river authorities and entities managing any dams or locks upstream or downstream of the relevant area; the installation of flow-regulating organs wherever water bodies can interfere with the drainage network capacity (anti-backflow valves, movable CSO weirs, RTC-regulated pumps, etc.)

Extended drought periods normally have a much less critical effect on drainage and sewerage systems. Encrustations, unpleasant odours and, in the worst case. disease diffusion could result from an extremely long dry period in combined sewers in a densely populated area; although this is not a major issue for well-designed covered sewers.

Persistent droughts can also have an environmental impact if intense rainfall events occur directly after them and exceed the combined sewer capacity. The first storm water spilled by CSOs has been proved to have a significant polluting impact on receiving bodies, with immediate local effects on their quality, for which reason the main treatment plants should have first storm treatment compartments (although a potential reduction in biological treatment efficiency due to storm water should be taken into account). In fact, as concerns wastewater treatment, extreme weather events impacts affect the purge capacity of the plants since the waste water input pollution load changes, causing problems for the subsequent sections and processes of the entire treatment system.

Being generally characterized by small networks and limited budgets, decentralized systems are subject to different constraints to climate-proofing management, such as:

- the intensity of the events: extreme weather events reach their peak less often on a small area, although when emergencies do happen they can involve a major portion of the system, whose response to the impact is therefore less flexible; ;the use of simulation models and telemetry systems may not be economically sustainable, while the knowledge of the network and of its reaction to past critical events becomes more important (requiring periodic surveys, registers of extreme events’ criticalities, etc.);
- the impact of stormwater on rural systems can significantly increase flow variability during rainfall events, so that separation between sewerage and drainage networks is highly recommended (especially if many natural receiving water bodies are available for stormwater discharges);
- with houses in flooded rural areas, it is necessary to make a careful plan and management scheme for domestic treatment plants.

In general, decentralized systems should have close relations with the main environmental authorities and even agreements with centralized systems’ managements for emergency interventions.

Case study 14 Sewerage network and sanitation planning, management and recovery in case of extreme events

CASE STUDY: Flemish Environment Agency: sewerage network and sanitation planning, management and restoration in case of extreme events

Planning of waste water infrastructure for extreme events

In the Flemish Region, the use of hydrodynamic models to simulate the effects of rain events on the sewer networks has for many years been widely integrated and applied in the processes of planning, designing and construction of new sewer networks, as well as in making best use of the existing sewer networks.

Extensive drought periods do not occur in our region in a way that has a critical effect on the drainage and sewerage systems. However they can have an environmental impact when followed by intense rainfall events, since in the Region the majority of the sewer networks consist of combined sewerage systems.

Therefore the collecting systems are constructed following these standards:

- allowing extensive volumes (at least six times the volume of the dry weather flow) of a mixture of waste water and rainwater to be transported towards the centralised treatment facilities;
- limiting the pollution of receiving waters from storm water overflows to a maximum of seven days of overflow/year.

In addition, the construction of sewer networks has over the last decade and more evolved into separated systems. This aims at preventing the rainwater from flowing into the sewer networks and at keeping the rainwater where it falls in order for it to infiltrate back into the ground. This enlarges the existing hydraulic capacity of the sewer systems for events of extreme rainfall.

Management of waste water infrastructure for extreme events

As for management, sewer systems need to be big enough to prevent untreated waste water from overflowing into the rivers, and treatment plants need to treat sufficiently high volumes of a mixture of waste water and rainwater when there is intense rainfall. For several decades it has beenn standard practice in the Region to secure biological treatment of a volume equal to three times the dry weather flow (3Q14, in else more than 5Q24 “in else” makes no sense. Should it be “or else”?]) and to provide a primary treatment on an equal supplementary volume. About ten years ago, a study of Aquafin, the public limited company responsible for the construction and management of the treatment plants and large collecting systems of the Region, showed that the entire volume collected towards the treatment plants (thus 6Q14, in else more than 10Q24) can be treated biologically (in secondary and in most cases tertiary treatment, to remove nitrogen and phosphorus) without substantial costs. All renovated and new treatment plants and/or those where this could be implemented without excessive cost now have these treatment facilities. Aquafin also continuously monitors the functionality of the systems of all treatment plants and crucial pumping stations of the sewerage network to prevent ecological damage. This continuous monitoring, with a linked alarm system, enables a quick response in case of extreme events. Since 2008 the Region has been implementing a supplementary control system for the good management of the treatment facilities by monitoring different indicators, such as the continuous functionality of the treatment plants and the pumping stations and their adequate reactions in case of dysfunction.

Restarting wastewater treatment plants after flooding (restoration)

In the Flemish Region, the functionality of wastewater treatment plants is rarely affected by flooding events. The recovery activities were limited to the restarting of the installations due to power cut-offs.

Monitoring of waste water infrastructure: storm overflows

The Flemish Environment Agency (VMM) is responsible for the ecological supervision of the waste water treatment infrastructure. Since 2002, VMM has elaborated a network of measuring stations to monitor the effects of storm overflows on the surface water quality. This storm overflow network consists of 250 measuring stations running on solar energy which monitor overflow infrastructures 24/7 with level sensors and quality sensors (for turbidity, conductivity and temperature).

After a few years of measuring expertise, the following conclusions can be drawn:

the expected maximum duration of overflows working, namely 2% on a yearly base, was an underestimate. An average of 3.4% has been measured;

the data from the measuring stations have revealed several bottlenecks, resulting in local adaptations to the infrastructure and further optimisation of investments in the sewer system;

the monitoring network is used as an instrument to support grants or refusals for companies to connect to the public sewer system.

Since 2008 VMM has redirected the measuring stations to critical points like certain treatment plants and pump stations. These will also be monitored by the wastewater treatment plants and local/municipal authorities by means of additional flow measurements in order to improve waste water collection, transportation and final treatment.

As a result, better co-ordination of the (critical) pump stations should minimize overflows, with positive effects on the surface water quality.

8.8. CHECKLIST

Table 24 Checklist for adaptation measures for drainage and sewerage systems

General preventative and maintenance measures for urban sanitation systems to be prepared for extreme weather events (drought, flood, storm):	***Adaptation measures for urban sanitation systems in the case of drought*** Extreme droughts don't have an immediate impact on the sanitation system. Besides measures included in part 1, specific measures for drought periods are recommended to prevent clogging of the system and allowing the treatment of highly polluted waste water as well.	***Preventative, protective and restoration measures for urban sanitation systems in the case of storms and heavy rains (floods)*** Floods represent primarily an immediate risk for inhabitants and property. Besides measures included in part 1, specific measures for protection against flood and mitigation of their impact are recommended	***Preventative, protective and recovery measures for industrial waste water treatment plants in the case of storms and heavy rains (floods)*** Basic principles applied to UWWTPs are valid also for IWWTPs. It should be borne in mind that an emergency in an industrial plant can affect not only water and its environment, but also other components of the environment.
▪ have a reliable forecast on meteorological and hydrological conditions as well as information on current weather conditions; ▪ detailed mapping of the system should be available, preferably in the GIS form; ▪ use of simulated hydrological models of water runoff based on precise measurements and calibration increase knowledge of vulnerability of the system related to changes in the surrounding	*Measures to avoid input of solid waste to pipelines to prevent their clogging:*	*Preventative measures against floods:*	*Specific issues of IWWTPs:*
	▪ regularly rinse adjacent pavements and roads (with hygienic safe water); ▪ if necessary ban the use of domestic grinders on the moist fraction of waste; ▪ carry out careful measurement and monitoring for calibration of the models, which are less accurate in areas of minimum rate of flow.	▪ construction of separate drainage for rainwater where possible; ▪ construction of protective measures against floods (permanent yet mobile walls); ▪ installation of retention tanks for superfluous flash water (especially in the case of combined sewers); ▪ having spare flood pumps available for emergencies ; ▪ having alternative electricity	• flood protection measures must reflect the fact that each industrial plant uses different techniques and technologies as well as raw materials (e.g.. chemicals); • each industrial facility should have its own Crisis and Emergency Plan, including an internal emergency warning system connected to the public one, and a detailed analysis of techniques,

<table>
<tr>
<td rowspan="3">hydrological conditions;
▪ use of mathematical models to illustrate the hydraulic characteristics of the sanitation system helps to identify its most critical points;
▪ for large systems the central operational unit can be in charge to steer and supervise the response of the network;
▪ maintain the system and its important nodes periodically (clean and wash pipelines and tanks to prevent aggregation of sediments, perform regular maintenance of machines, pumping stations and their electric parts);
▪ develop and regularly update maintenance, crisis and emergency plans based on cooperation of all actors (facilities owners, operators, municipal authorities, road management, river basin authorities, flood authorities, flood forecasting authorities, stakeholders, etc.);
▪ train the staff for the</td>
<td></td>
<td>sources prepared as a power failure may occur during flood or storm.</td>
<td>technologies, equipment and chemicals used, as well as basic principles of IWWTP recovery;
• regulations valid for hazardous substances have to be respected - safe intermediate storage of contaminated water, sludge and chemicals should be used, permitting their consequent safe disposal;
• special training of staff covering all possibilities is essential.</td>
</tr>
<tr>
<td>Efficient operation of UWWTP:</td>
<td>Protective and operational measures for urban sanitation systems in the case of floods:</td>
<td></td>
</tr>
<tr>
<td>▪ the UWWTP must be constructed to be able to maintain high efficiency in the case of increased pollution loads
▪ adapt the amount of dissolved oxygen in the activation tanks to higher demand during extreme pollution load (if possible by means of automatic regulation)</td>
<td>▪ the system should be kept in operation as long as possible;
▪ good communication among UWWTP operators, river basin authorities, dam operators, flood protection bodies, hydrological and hydrometeorological monitoring and forecasting institutions based on the maintenance, risis and mergency lans should be standard ;
Technical measures:</td>
<td></td>
</tr>
</table>

emergency (drought, flood, storm, wind etc.); ▪ involve and inform public; test theemergency system regularly.		▪ on the basis of warning from the forecasting institution or flood protection body, immediately install flood mitigation and protective technical components (flood protection walls, pumping devices etc.); ▪ location of the most essential UWWTP compartments above the flood level or in tanks is an advantage; ▪ close anti-backflow devices and use pumps to protect system against back wave from recipient water; • all the time, maintain the maximum hydraulic capacity of the system, and prevent solid sedimentation; • bring electric generators to the stand-by position and use them when necessary; • if needed and possible, remove all endangered dismountable equipment to present its damage; • store all chemicals and other contaminants in a safe place.	
		Protective measures in rural areas	

		during floods:	
		▪ in the case of abundant snowfall restrict the use of anti-cryogenic chemicals, which can damage the treatment process in small UWWTPs; ▪ avoid release of contaminated sludge from septic tanks and cesspools to the water; ▪ protect the sources of drinking water (e.g. wells) from contamination; • after the flood, remove all sludge from cesspools and septic tanks to transport it to the nearest UWWTP.	
		Restoration of sanitation system after the flood:	
		▪ restart the system as soon as possible; ▪ assess the stability of buildings and structural compartments; ▪ clean and disinfect the affected UWWTP area, including buildings and technological equipment; ▪ verify, restore and monitor cleanness of conduits and pumping stations; ▪ draw up a plan of recovery	

		on the basis of thorough damage analysis. *Technical measures:* ▪ ensure electric supply; ▪ clear waste water distribution and bypass systems; ▪ start pre-treatment (bar screen, grease trap), with bypass of sedimentation and biological treatment; ▪ start sludge management operation (at least sludge storage reservoirs), which is a precondition for the start of primary sedimentation; ▪ start the operation of mechanical treatment and possible chemical precipitation in primary sedimentation tanks (a precondition is the functioning of pre-treatment and sufficient capacity for sludge storage); ▪ start the operation of the aeration system and gradually put the biological stage into operation (a precondition is the functioning of primary	

		sedimentation); • gradually put the automatic management system into operation.	

Annex 1

BIBLIOGRAPHY

1.1. Supporting documents

(2009) Transboundary Flood Risk Management: Experiences from the UNECE Region. UNECE Geneva

(2008) Impacts of Europe's changing climate – 2008 indicator-based assessment. EEA Report No4/2008. EEA

(2006) DROUGHT: Management and Mitigation Assessment for Central Asia and the Caucasus-Regional and Country Profiles and Strategies, World Bank

UNECE (2009) Guidance on Water and Adaptation to Climate Change. United Nations New York and Geneva Available from: http://www.unece.org/env/water/publications/documents/Guidance_water_climate.pdf Accessed 5 April 2010

1.2. Cited references

(2005) Effectiveness of urban wastewater treatment policies in selected countries: an EEA pilot study EEA

(2005) Financing water supply and sanitation in eastern Europe, Caucasus and Central Asia – Proceedings from a conference of EECCA Ministers of Economy/Finance and Environment and their Partners (Yerevan, Armenia, 17 – 18 November 2005) OECD. Available from: http://www.oecd.org/dataoecd/29/46/36388760.pdf Accessed 5 April 2010

(2005) Final Report of the World Conference on Disaster Reduction United Nations New York ref A/CONF.206/6 available from: http://www.unisdr.org/eng/hfa/docs/Final-report-conference.pdf A

(2005) Hyogo Framework for Action 2005 – 2015 : Building the Resilience of Nations and Communities to Disasters UNISDR available from: http://www.unisdr.org/wcdr/intergover/official-doc/L-docs/Hyogo-framework-for-action-english.pdf Accessed 5 April 2010

(2005) Minimum water quantity needed for domestic use in emergency WHO Geneva Accessible from: http://www.who.int/water_sanitation_health/hygiene/envsan/minimumquantity.pdf Accessed 5 April 2010

(2006) DROUGHT: Management and Mitigation Assessment - FOR CENTRAL ASIA AND THE CAUCASUS. World Bank

(2006) Analysis of Drinking Water and Wastewater Services in Eight European Capitals: the Sustainable Development Perspective EEA

(2008) Progress and Prospects on Water: For a Clean and Healthy World with Special Focus on Water and Sanitation. SIWI. Available from: http://www.siwi.org/documents/Resources/Synthesis/Synthesis_full_version_08.pdf accessed 5 April 2010

(2008) Adaptation, an issue brief for business WBCSD Geneva. Available from: http://www.wbcsd.org/DocRoot/iMn5EtG4bkjxQNLfU9UZ/Adaptation.pdf Accessed 5 April 2010

(2008) EUREAU Position Paper "Climate change and Water and Waste Water Services" EUREAU Accessible from: http://www.eureau.org/page.php?id=6 Accessed 5 November 2008

(2008) WMO Guide to Meteorological Instruments and Methods of Observation WMO no 8 of 6 August 2008 Accessible from: http://www.wmo.int/pages/prog/www/IMOP/publications/CIMO-Guide/CIMO_Guide-7th_Edition-2008.html Accessed 5 April 2010

(2009) Highs and lows :Weather risks in central Europe. Munich Re 2009

(2009) Guide to Hydrological Practices Sixth Edition Vol I Hydrology – From Measurement to Hydrological Information; Vol II Management of Water Resources and Application of Hydrological Practices. WHO

(2009) Wastewater treatment and access to improved sanitation ENHIS available from: http://enhiscms.rivm.nl/object_document/o4730n27386.html Accessed 5 April 2010

(2010) Vision 2030 – The resilience of water supply and sanitation in the face of climate change WHO Geneva / DFID Available from: http://www.who.int/water_sanitation_health/publications/9789241598422_cdrom/en/index.html Accessed 5 April 2010

Barredo, J., personal communication, 2009

Bartram J et al., (2009) "Water Safety Plan Manual: Step-by-step risk management for Drinking-water Suppliers" WHO Geneva / IWA Available from: http://www.who.int/water_sanitation_health/publication_9789241562638/en/index.html Accessed 5 April 2010

Buitenkamp M and Stintzing A R (2008) Europe's Sanitation Problem WECF p 7 available from: http://www.waterlink-international.com/download/whitepaper_uploadfile_7.pdf Accessed 5 April 2010

Sullivan C and J Meigh Targeting attention on local vulnerabilities using an integrated index approach: the example of the climate vulnerability index Water Sci Technol. 2005;51(5):69-71 Abstract available at http://www.ncbi.nlm.nih.gov/pubmed/15918360 Accessed 5 April 2010

Sullivan C.A. and C. Huntingford (2009) Water resources, climate change and human vulnerability Proceedings of the 18th World IMACS/MODSIM Congress, Cairns, Australia, 13 – 17 July 2009 Available from: http://www.mssanz.org.au/modsim09/I13/sullivan_ca.pdf Accessed 5 April 2010

Thornton J. A.; Rast W., Holland M.M., Jolánkai G., Ryding S.O. (editors) (1999): Assessment and Control of Non-point Source Pollution of Aquatic Systems;- A Practical Approach. Man and the Biosphere Series Volume 23. UNESCO, Paris and Parthenon Publishing, Carnforth. p. 466