MSc Program
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Implementation of WHO Water Safety Plans for Small Utility Units in the Republic of Moldova

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Affidavit

I, **OLESEA ROŞCA-SCHIRRER**, hereby declare

1. that I am the sole author of the present Master's Thesis, "IMPLEMENTATION OF WHO WATER SAFETY PLANS FOR SMALL UTILITY UNITS IN THE REPUBLIC OF MOLDOVA", 139 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, 20.03.2012

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Signature

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Olesea Roşca-Schirrer

Abstract

This thesis presents preparative studies on the path towards implementing the WHO Water Safety Plans for the city of Teleneşti in the Republic of Moldova.

The WHO Water Safety Plans (WSPs) are a risk-management approach to ensure drinking water quality in a sustainable way. The main focus of the WSPs is to improve the water quality in the long run based on actions at the catchment area, rather than implementing treatment options which might be expensive for some regions of the world.

The technical conditions of the water supply and sanitation systems of Moldova are heavily degraded due to lack of maintenance and investments, so that water utilities cannot reliably provide safe drinking water.

This work specifically investigates the situation of the Teleneşti water supply system. A broad collection of data has been assembled to describe the fundamental parameters and characteristics of the existing utility services and to spot the major risks and the extent and effectiveness of existing control measures. Major issues include a strongly increased ammonium content in the source water and recurring microbial contamination cases. These are presumably caused by organic sewage leaching or waste washout, common use of pit latrines, and widespread livestock keeping, as well as due to the frequent pipe breaks and possibly through unauthorized access and related backflow.

Structured along the modular WSP development process, this thesis analyses and comments on each module, outlines evident risks in the water utility of Teleneşti and gives recommendations to help the course of a future WSP implementation. It thus serves as a viable starting point for WSP pilot studies and could stimulate an active development in water system management in the region.

Contents

Chapter 1

Introduction

1.1 Motivation

In the last decades, drinking water resources receive increased attention as their immense value, but also their vulnerability is increasingly being recognised (UNESCO, 2012a,b,c).

The Republic of Moldova, a country with turbulent history, was annexed to the Soviet Union in World War 2. Its climate and favourable agriculture conditions made it well known for its regional agricultural products and its wine, but the landscape also suffered from large-scale agricultural production methods and shows strong signs of erosion. In the 1990s and early 2000s, after the Soviet Union had collapsed and the Republic of Moldova had become independent, the country went through a severe decline in its economic situation, currently being ranked as poorest country in Europe in terms of GDP. With its low-profile economy directly affecting all layers of society in daily life (the average monthly per-capita income is below EUR 200 (Salary Statistics Moldova, 2010) and annual per-capita GDP (purchasing power parity) is USD 3383 as of 2011 (Int. Monetary Fund, 2011) and significantly lower numbers in rural areas) related problems in drinking water safety pollution of the environment are critical. Lack of regular maintenance works and of infrastructure investments results in a widespread technical degradation of water utilities especially in rural areas, see Fig. 1.1.

The sketched bad technical conditions make the supply and sanitation systems vulnerable, unsafe, and unreliable. This, consequently, endangers the health of the consumers and poses significant risks to the environment. The problems are aggravated by the use of unsafe or disadvantageous alternatives by the population such as shallow-water wells and pit latrines.

This situation is highly complex and cannot be improved or resolved easily. However, working towards sustainable implementations of best-practice solutions

Figure 1.1: *Left*: An artesian well in Teleneşti, Republic of Moldova (Foreground: Unauthorized open dumping of waste). *Right*: Teleneşti wastewater chlorination station lacking regular maintenance.

may lead to robust improvements in the medium- and long-run. One such best-practice approach are the "Water Safety Plans" (WSPs), developed and promoted by the World Health Organization (WHO), see Bartram et al. (2009).

The WSP approach is a comprehensive risk management onset to consistently and continuously identify and counteract risks in water supply and sanitation systems, and to monitor and improve the taken measures. It represents a continuous strategy to efficiently manage water utilities, whereby including all stakeholders' perspectives (particularly those of the population, business units, utility operators, and local political actors).

To shift an existing water system to a WSP-based approach is a major effort and cannot be done by a single person. A dedicated WSP team equipped with varied professional background needs to be set up – this represents the first of 11 modules comprising the WSP development process. In this thesis, first preparatory work towards a potential future implementation of the WSP onset in the city of Teleneşti should be conducted.

1.2 Thesis Contributions

This thesis aims to provide three contributions: Firstly, it gives an overview on the state of the art in drinking water quality standards, research, and specific challenges faced in the Republic of Moldova and provides a selection of methodological tools for the development of the WHO Water Safety Plans for small utility units in the Republic of Moldova, accounting for the special boundary conditions of these.

Secondly, the thesis provides a WSP-specific collection of data and information on the current water supply situation in Moldova and particularly in the city of

Teleneşti. Being a desk study of limited extent, this data collection cannot be complete nor could all found material be fully verified. However, despite the low accessibility of this information and difficulties in its retrieval, the author could gain access to formalized, informal, and implicit knowledge on the system. As a result, the compiled pool of data and the extracted information in this work has not been collected and presented in this extent and form before, which is believed to be a valuable resource and starting point for future related work and research activities.

Finally, the thesis relates the modules comprising the WSP development process to this data set, effectively preparing the future implementation of a WSP for the water supply and sanitation for Teleneşti. The currently evident problems, hazards, and risks are sketched, existing control measures are outlined, and new control measures for yet uncontrolled risks are formulated and proposed. For each module of the WSP development process, specific problems are spotted and recommendations are given by adopting the WSP perspective.

1.3 Thesis Structure

The thesis is structured as follows: Chapter 2 provides an overview on the state of the art in the fields related to drinking water quality standards, the WSP onset, the water quality situation and effects on a global scale as well as specifically for the Republic of Moldova. Chapter 3 follows the modular WSP structure and summarises each WSP module, based on the WSP manual and related sources. Suitable tools and examples are selected, which best fit the specific conditions found in small utilities. Chapter 4 provides information on the water supply situation at the national level for the Republic of Moldova, and Chapter 5 compiles and presents the gathered information on water supply and sanitation in the city of Teleneşti. Chapter 6 relates the WSP implementation modules to the situation in Teleneşti and is intended to prepare the potential implementation of specific WSPs for this city. Finally, a wrap-up of the given recommendations and concluding remarks are given in Chap. 7. The thesis ends with an Appendix (Chap. A) which contains relevant data tables, figures, and various maps of the city of Teleneşti.

Chapter 2

State of the Art

2.1 Drinking Water Quality Standards

International norms on drinking water quality and human health, including quantitative guideline values, are proposed in the WHO Guidelines for Drinking-Water Quality (WHO, 2011). They serve as basis for national regulations and standards in many countries in the world.

In the USA, the main federal law for ensuring safe drinking water quality levels is the Safe Drinking Water Act (SDWA), authorizing the Environmental Protection Agency (EPA) to set water quality standards and protect the water from pollutants.

The European Union realized its drinking water regulations for all member states in form of the European Council Directive 98/83/EC (European Council, 2009). It defines minimal drinking water quality standards and monitoring obligations for the EU member states.

In Bernardini et al. (2011), actions towards setting national target values for water quality actions in the Republic of Moldova are outlined. Moreover, the water quality situation of the country is documented.

2.2 Water Safety Plans

"The quality of drinking water is a powerful environmental determinant of health." (WHO, 2010a) Water is crucial for human life, but it can also be the cause of a number of diseases when not appropriately managed. The problem of endemic and epidemic infections related to unsafe water supplies continues to be a significant global problem. Any nation, being a developing or a developed one, can be exposed to waterborne diseases, and the occurrence of such outbreaks may lead to loss of life, disease and economic burden to individuals and communities. (Davison et al., 2005)

According to the WHO, assurance of safe drinking water is the basis for the prevention and control of waterborne diseases. (WHO, 2010a) The safety of drinking water may be compromised by many factors of microbial, chemical, radiological, or physical origin. The WHO Guidelines for Drinking-Water Quality (GDWQ) set standards for safe drinking water and were developed with the aim to protect human health. The WHO GDWQ propose pro-active efforts to assess and decrease health risks related to drinking water, and the way to achieve this is by adopting a Water Safety Plan (WSP). (WHO, 2011) The WSP is a comprehensive risk assessment and risk management approach which aims "to consistently ensure the safety and acceptability of a drinking-water supply" from catchment to consumer. (WHO, 2011; Bartram et al., 2009) It comprises "a holistic framework for safe drinking water, which encompasses flexible and locally-relevant health based targets, a system of integrated risk assessment and incremental risk management from catchment to consumer"(WHO, 2010a). The main focus of the WSPs is to improve the water quality in the long run based on actions at the catchment area, rather than implementing treatment options which might be expensive for some regions of the world. (WHO, 2010a) Thus, the WSPs are a preventive management-oriented approach, being both cost-effective and realizable for specific settings world-wide. (WSPortal, 2008) Moreover, it is a flexible approach which relies on a supplier's existing practices and organisational habits. (WHO, 2011) Although such an approach might necessitate a longer implementation term, it will eventually be more effective and sustainable than a treatment-focused approach. (WHO, 2010a)

The benefits in implementing the WSPs are numerous. The following points are listed in the WHO GDWQ as the key benefits for water suppliers implementing WSPs (WHO, 2011):

- "demonstration of "due diligence";
- improved compliance;
- rationalizing and documenting existing operational procedures, leading to gains in efficiency, improvement of performance and quicker response to incidents;
- better targeted and justification for long-term capital investments based on risk assessment;

- improved management of existing staff knowledge and identification of critical gaps in skills for staff;

- improved stakeholder relationships."

In the WSP approach, the drinking water supplier must perform the following three actions in order to assure safe drinking water (Bartram et al., 2009; WSPortal, 2008; WHO, 2011):

1. A systems assessment:

    - Assemble a team and establish a methodology by which a WSP will be developed;
    - Identify all the hazardous events that can affect the supply of safe water to consumers, including every point of the drinking water supply: catchment, treatment, and distribution to the consumers' point of use;
    - Assess the risks that may be introduced by each hazard and hazardous event.

2. Effective operational monitoring:

    - Analyse if controls or barriers for each significant risk are existent and are effective;
    - Validate the effectiveness of controls and barriers;
    - Prove that the system is at any point safe.

3. Management:

    - Review the hazards, risks, and controls regularly;
    - Keep detailed records for transparency and for justification of outcomes.

WSPs are different in terms of their complexity, depending on the situation and local environment. Thus, the WSPs should be developed individually for each drinking water system apart. For small utility units, there may be a number of challenges in the process of developing the WSP. Usually these are due to insufficient human, technical, and financial resources. Specifically tailored WSP development for such supplies can help to identify simple and cost-effective methods for their protection and improvement. (WHO, 2011)

This thesis is primarily based on the "Water Safety Plan Manual – Step-by-step risk management for drinking-water suppliers" (Bartram et al., 2009) which provides practical guidelines to facilitate the implementation and development of WSPs. The following texts and tools are interconnected to the WSP manual and are relevant in the WSP development process:

WHO Guidelines on Drinking-Water Quality (WHO, 2011): The WHO Guidelines on Drinking-Water Quality are WHO's international norms on water quality and human health, used as the basis for regulation and standard setting in developing and developed countries world-wide. The Water Safety Plans (WSPs) are incorporated into Chapter 4 of this document (WHO, 2011), where the principles of a WSP approach are described. While the WHO GDWQ (WHO, 2011) gives a broad overview of the purpose and principles of a WSP, their practical application is explained in the WHO "Water Safety Plan Manual – Step-by-step risk management for drinking-water suppliers" (Bartram et al., 2009).

Water Safety Portal (WSPortal, 2008): The "WSPortal" is an online repository that gathers and publishes WSP-related case studies, references and tools, which provide practical guidance to the water suppliers in effectively implementing WSPs. This way, WSPortal contributes to the improvement and maintenance of safe drinking water. (WSPortal, 2008)

WSP Quality Assurance Tool and User Manual (WHO and IWA, 2010a,b): The WSP Quality Assurance Tool (WHO and IWA, 2010a) aims to develop mechanisms to help water suppliers to objectively assess progress in the implementation of WSPs and to ease regular improvement by systematically highlighting the progress areas and opportunities for improvement. Detailed instructions on how to use the WSP Quality Assurance Tool are given in the User Manual (WHO and IWA, 2010b). This tool is relevant in an operational context, but will not be treated further in this thesis.

Water Safety Plans: Managing Drinking-water Quality for Public Health (WHO, 2010b): This is a brief document which clearly and concisely states the benefits of shifting to a WSP approach.

WSPs: resources to support implementation (WHO and IWA, 2010c): This is a briefing note which explains ways to collect WSP-related key information and resources.

2.3 Water Quality: General Statements, Global Effects

A global overview and assessment of the world's water resources are quantitatively given in Shiklomanov (2000). It is identified that the scarcity of water suitable for drinking water supply is likely to increase in the forecast period 2010-2025 worldwide. These findings are in accordance with the key issues emphasized in the most recent World Water Development Report (UNESCO, 2012a,b,c): worldwide, 3.5 million people die yearly due to contaminated water, and 800 million people do not have access to clean drinking water. Drinking water scarcity is expected to aggravate worldwide in the next decades.

In Howard and Bartram (2003), an average of 7.5 $^{\text{liters}}/_{\text{day}}$ of drinking water is proposed as minimum per-capita amount necessary to enable basic hydration, food preparation, and hygiene.

Economic effects of actions to improve water supply and sanitation (WSS) systems are investigated in Hutton and Haller (2004); Hutton et al. (2007). A comparison of four countries, including the Republic of Moldova, in terms of the economics of scale impact of investments in the WSS sector is carried out in Nauges and Van Den Berg (2008). These studies show that investments in under-developed WSS sectors typically lead to large benefits, both financial and immaterial (health, living quality).

2.4 Specific Pollutants

In this thesis, increased ammonium and fluoride contents in drinking water sources are of concern. The health effects of ammonium in drinking water are detailed in WHO (2003). The properties of chloramines and related health risks, which can be formed in the presence of chloride and high ammonium levels, are detailed in WQA (2004). To remove ammonium and other compounds during water treatment, modified activated carbon has been proposed (Lupascu et al., 2006).

Fluoride-related health risks are studied in Fordyce et al. (2007) for Central Europe, identifying an optimal band of fluoride content which minimises adverse health effects.

2.5 Water Quality in the Republic of Moldova

Water quality is an important concern in the Republic of Moldova, which is reflected in various analyses and studies listed in the following.

Opopol (2006) analyses the principal threats related to water management and supply in the Republic of Moldova. He identifies three issues for improvement: the overall poor water resource quality, the low rural supply standards, and the need for watershed protection.

The groundwater and rural drinking water quality in the Republic of Moldova is analysed in Melian et al. (1999) for two pilot regions. The found contaminations of the targeted shallow-well waters are mainly of microbial origin, as well as by nitrates and selenium. Sanitary conditions (wide-spread use of pit latrines in rural areas) are identified as most probable cause.

A drinking water quality analysis for Moldova's capital Chişinău is conducted in Friptuleac et al. (2006). While the water fulfills most hygienic parameters, high levels of nitrate and of total dissolved solids (TDS), as well as high mineral levels are identified, and the necessity of continuous monitoring and of a holistic water quality management approach are recognized.

The largest river flowing into the Republic of Moldova is the Dniester. Sprynskyy et al. (2007) study the phenolic pollution in the Dniester river basin in the Ukraine. They find significantly increased contaminations compared to the natural background levels and attribute these to be caused by the regional oil and gas industry. It is assumed that the river's self-cleaning capacities cannot cope with the phenolic runoff, and chlorination of the river's water for treatment is discouraged due to the danger of chlorophenol formation.

Zubcov et al. (2012) investigate the concentrations of Copper and Zinc in the tissues and organs of freshwater fish from main fishing areas in the Republic of Moldova. A strong dependence of these concentrations on the maturity of the fish (with a peak in the pre-spawning period) is found. Also, the muscular concentrations do not exceed limits for safe human consumption as given by the United Nations Food and Agriculture Organization (UN FAO) but fail to comply with more restrictive standards.

Finally, the impact of various climate change scenarios on the country's aridity and crop yield is studied in Corobov (2002) based on statistical methods. The necessity of actions to adapt to the occurring scenarios is shown. The characteristics of dryness and drought periods in the Republic of Moldova is analysed in Potop and Soukup (2009) from historical data, and a significant increase since the 1980s is found.

Chapter 3

WSP Modules

This chapter is a combined summary of the WSP Manual (Bartram et al., 2009) and of the fourth chapter of the WHO GDWQ (WHO, 2011) on Water Safety Plans, with some additions from other relevant works in this area. This compilation is intended to facilitate the understanding of the WSP development process. The additional sources coming in the following text will be explicitly cited as they appear. The summary was written focusing on the points that fit the specificity of small water supply units.

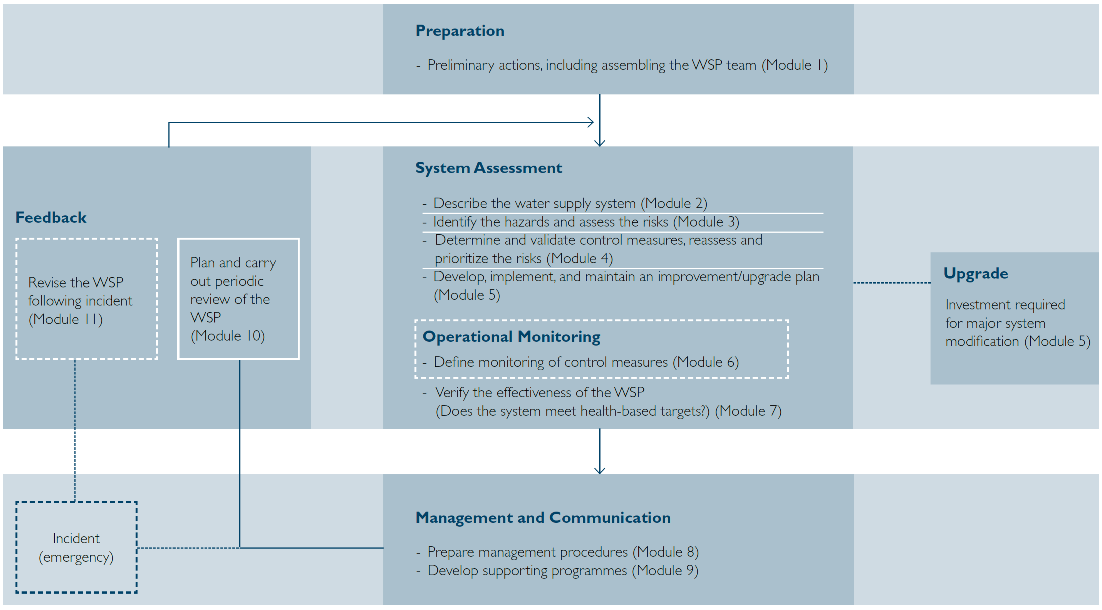


Figure 3.1: Modules of a WSP (taken from Bartram et al. (2009))

The development of a WSP follows a structured process comprised of eleven modules. The WSP's development and implementation modules are represented schematically in the WSP Manual (Bartram et al., 2009), see Fig. 3.1. In the preparation phase (module 1), a well-qualified WSP team needs to be assembled to carry out the development and implementation process, followed by a thorough system assessment. Detailed information is gathered to describe the existing water supply system, its structure, properties, and stakeholders. The next three modules aim to identify hazards, risks, their impacts on water quality and define and assess control measures to counteract these risks. Formalised methods are provided to efficiently improve or upgrade the WSP when needed by addressing uncontrolled risks by priority. Modules 6 and 7 define and develop monitoring of control measures and verification of the effectiveness of the WSP, respectively. Management and communication aspects are addressed in modules 8 (preparing management procedures for standard operation as well as for emergencies) and 9 (development of supporting programmes). Finally, feedback processes in terms of periodic reviews (module 10) and after incidents/exceptional events (module 11) are defined.

The so-called WSP cycle represents the continuous process of managing and ensuring drinking water quality via the WSP approach, see Fig. 3.2.

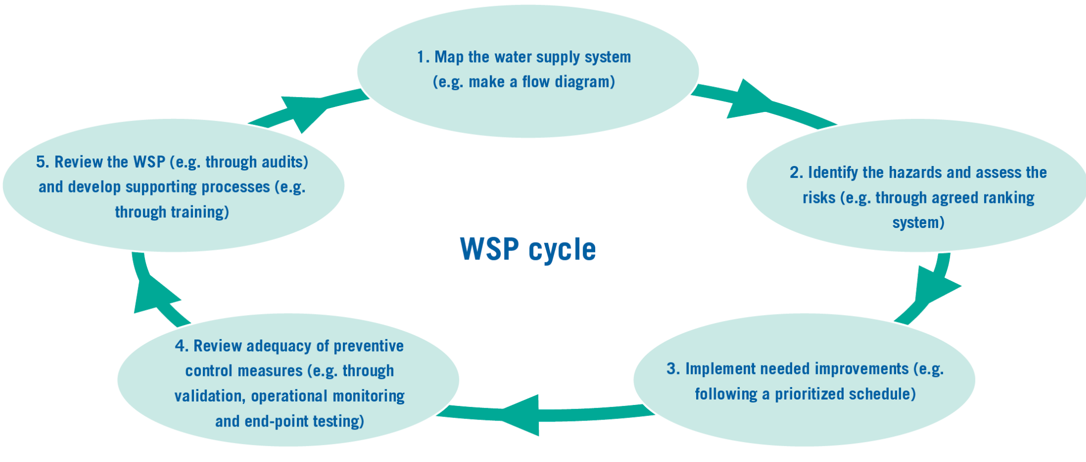


Figure 3.2: The WSP cycle (taken from WHO (2010b))

In the remainder of this chapter, each module is detailed in the following recurrent pattern to help the reader understand the WSP structure:

1. Overview
2. Key Actions
3. Specific Challenges or Limitations: these should be taken into consideration before proceeding to the implementation of the module.
4. Outputs
5. Supporting Tools / Examples: A selection of tools from the WSP Manual (Bartram et al., 2009) which facilitate the process of establishing and

supporting an organised activity of the team is given. Depending on the individual features and the size of the supply systems, necessary tools are chosen and applied.

3.1 Module 1: Assembling a WSP Team

A qualified and dedicated WSP team is a key ingredient in the development, implementation, and maintenance of WSPs. The WSP team should be lead by the drinking water supplier, and all the members of the team need to have sufficient experience and expertise in the field of water supply (water abstraction, treatment and distribution, and hazards that might affect the safety of drinking water throughout the whole water supply system). Usually a WSP team will be composed of members involved at each point of the drinking water supply system, and often representatives of different stakeholders will be included. Teams may be formed differently, depending on the local situation and the size of the drinking water supply. An example of a possible team composition may be seen in Tool 1.2 (p. 15). In case of small utilities, external expertise might be necessary and of significant help. Important responsibilities of the team are to develop, implement, and maintain the WSP, to make the WSP approach understood by everyone involved in the safety of drinking water within or outside the concerned utility, and to prepare the methodology of WSP approach implementation. A key task of the WSP team is to decide on the way the WSP will be implemented for the specific supply system and the methodology that will be used, especially in assessing the risks.

3.1.1 Key Actions

- Engage senior management, secure financial and resource support
  This is important in order to obtain approval in case of changes in work practices, to guarantee sufficient financial resources, and to advance water safety as a goal of the concerned organisation.

- Identify the required expertise and appropriate size of the team
  The WSP team members must be selected to combine vital skills: expertise in identifying hazards to the water safety and associated risks, and a good understanding of measures to control these risks are required. In most cases the team members will not be exclusively committed to the implementation of the WSP only, but will continue their usual activities and duties, which affects the necessary team size.

- Appoint a team leader
  A team leader is necessary to ensure focus and project progression. Moreover, a team leader will seek for external support if the required skills are not available locally.

- Define and record the roles and responsibilities of the individuals in the team
  The responsibilities of the WSP team members need to be set at the start of the WSP development and implementation process. Each member's role needs to be clearly stated and recorded. It is of significant help to create a table where WSP-related activities and responsible persons are appointed (see Tools 1.2 and 1.4).

- Define the time frame to develop the WSP
  The time spent on the WSP development process is significant. Nevertheless, the effort decreases as the WSP is established and the concerned organisation becomes accustomed with the system.

3.1.2 Typical Challenges

- "Finding skilled personnel;
- Organizing the workload of the WSP team to fit in with the existing organizational structure and roles;
- Identifying and engaging external stakeholders;
- Keeping the team together;
- Getting the team to communicate effectively with the rest of the utility and other stakeholders." (Bartram et al., 2009, p. 10)

3.1.3 Outputs

As a result of this module, an experienced, multidisciplinary team, which will be able to understand every component of the system and assess all risks associated to each of these components, will be assembled.

3.1.4 Supporting Tools / Examples

Tool / Example 1.1: Checklist of skills to be considered when identifying the required expertise (see Tool 1.1 in Bartram et al. (2009))

The following example is given for a large WSP team:

- "Technical expertise and operational system-specific experience;
- Capacity and availability to undertake the WSP development, implementation and maintenance;
- Organizational authority to report through to the relevant controlling authorities, such as the executive of an organization, or leaders of a community;
- Understanding of the management systems including emergency procedures;
- Understanding of the processes used to obtain and communicate the results of monitoring and reporting;
- Understanding the water quality targets to be met;
- Appreciation of the water quality needs of the users;
- Understanding of the practical aspects of implementing WSPs in the appropriate operational context;
- Understanding the impact of proposed water quality controls on the environment;
- Familiarity with training and awareness programmes."(Bartram et al., 2009, p. 11)

Tool / Example 1.2: WSP team composition (adopted from Tool 1.2 in Bartram et al. (2009))

The table below is an example of a possible list of the roles for the members of a WSP team, including their affiliation and the expertise each of the members shall have. However, every utility is unique and this tool needs to be adopted to the individual setting and size of the concerned utility.

Job Title	Work Team	Expertise
Team Leader / Senior Engineer	e.g. Water Quality Planning	Water quality engineering
Water Supply Operator	e.g. Water Harvesting Team	Operations (distribution, treatment, plant operations)
Process Support - Service Delivery	...	Water Treatment Specialist
Section Leader Water Treatment	...	Treatment Plant Asset Management
Operations Contractor	...	Water Supply Engineering
Process Engineer	...	Water Supply Engineering
Principal Scientist	...	Microbiology
Section Leader Headworks	...	Catchment Operations
Scientist from Retail Water Company	...	Water Quality Specialist / Chemist
Engineer from Retail Water Company	...	Water Quality Engineering / Distribution
Engineering Manager from Retail Water Company	...	Water Quality Planning

Tool / Example 1.3: Different WSP team building approaches for small systems (adopted from Tool 1.3 in Bartram et al. (2009))

In most cases, small utilities do not possess internal water quality experts. Thus, external experts in health and water quality need to be brought in by the operators and management team of the concerned utility from specialised agencies, such as the department of health, engineering and sanitation or natural resources or consultants in the before-mentioned fields.

Tool / Example 1.4: WSP team details form (adopted from Tool 1.4 in Bartram et al. (2009))

The details on the WSP team and subordinate teams need to be recorded and kept up-to-date. An example of how to document the necessary details is shown below.

Name	Affiliation	Title	Role in Team	Contact Information
...	...	...	...	...

Tool / Example 1.5: WSP resourcing plan form (adopted from Tool 1.5 in Bartram et al. (2009))

Activity	Activity Budget	Aspects Sourced within the Utility	Aspects Sourced from outside the utility	Staff Budget
Establishment of WSP team	EUR / USD	Project management and delivery	Facilitation and review	Full-time equivalents (FTE)
...	...	...	...	...

Outsourcing work should be minimised or avoided in order to strengthen in-house knowledge development for the WSP implementation and water quality.

Tool / Example 1.6: WSP stakeholder identification form (adopted from Tool 1.6 in Bartram et al. (2009))

Stakeholder Name	Relationship to drinking water supply issues	Key point	Point of contact in WSP team	Stakeholder pt. of contact	Interaction mechanism	Ref. to contact details, interaction record
Farming organisation with land adjacent to catchment	Livestock raising and agricultural chemical use	Minimisation of chemical and microbial hazards to catchment	...	...	Meetings (e.g. annual, regular, scheduled, informal)	...
...	...	...	...	...	...	...

Tool / Example 1.7: Understanding the WSP commitment (adopted from Tool 1.7 in Bartram et al. (2009))

The responsibility of a WSP is considerable and needs to be shared between all the employees involved in the process within a water supply organisation. Significant time and resources are necessary in the development and implementation of a WSP. Moreover, for the implementation of a WSP, commitment at all levels within the organisation is required. It is of significant importance to maintain a WSP, and this demands continuous management awareness to support the establishment of a culture of compliance with the requirements of a WSP. Some of the benefits of a WSP may sometimes not be seen immediately after the implementation, but the process leads to efficiencies and better understanding of the water supply system, and, which is of special importance, it leads to the production of water that consistently meets the health-based targets.

3.2 Module 2: Describing the Water Supply System

An accurate description of the drinking water system is of significant importance, as it enhances drinking water supply's assessment and evaluation. The scope of the description of the water supply system is to ensure accuracy of the documentation of the whole system supplying the water of a certain quality, in order to be able to adequately assess and manage risks. Each supply must be assessed in detail on its own, also if it is similar to other supply systems. This means that data should be collected for each particular supply system and all modules of the WSP development process should be elaborated exclusively for the concerned water supply system. The detailed description of a system is necessary in order to identify the vulnerable points of this specific system to hazardous events, relevant types of hazards, and control measures. To ensure accuracy of the description, it is necessary to carry out site visits in order to visually check, analyse, and verify the features of the system on the ground.

3.2.1 Key Actions

The description of the system should present an overview of the whole system from the catchment to the consumer's point of use. The elements of each of the system points should be considered concurrently, and the possible interactions between these elements must be recognised. The WSP Manual lists a number of items which should be included in the description of the water supply system. However, this list is not necessarily complete, nor does every listed point fit all kinds of supply systems:

- relevant water quality standards;
- the source(s) of water including alternative sources in case of incident;
- known or suspected changes in source water quality related to weather or other conditions;
- any interconnectivity of sources and conditions;
- details of the land use in the catchment;
- the abstraction point;
- information relating to the storage of water;

- information relating to the treatment of the water;
- details on how the water is distributed including network, storage, and tankers;
- description of the materials in contact with water;
- identification of the users and uses of the water;
- availability of trained staff;
- documentation of existing procedures.

3.2.2 Typical Challenges

In the process of describing the water supply system the following typical challenges should be taken into consideration:

- "Lack of accurate maps showing distribution systems;
- Lack of knowledge of land use / management in catchments;
- Lack of knowledge of industry and risks;
- Finding all government and local agencies with potential information or a role to play;
- Time required by staff to undertake fieldwork;
- Out-of-date procedures and documentation." (Bartram et al., 2009, p. 20)

3.2.3 Outputs

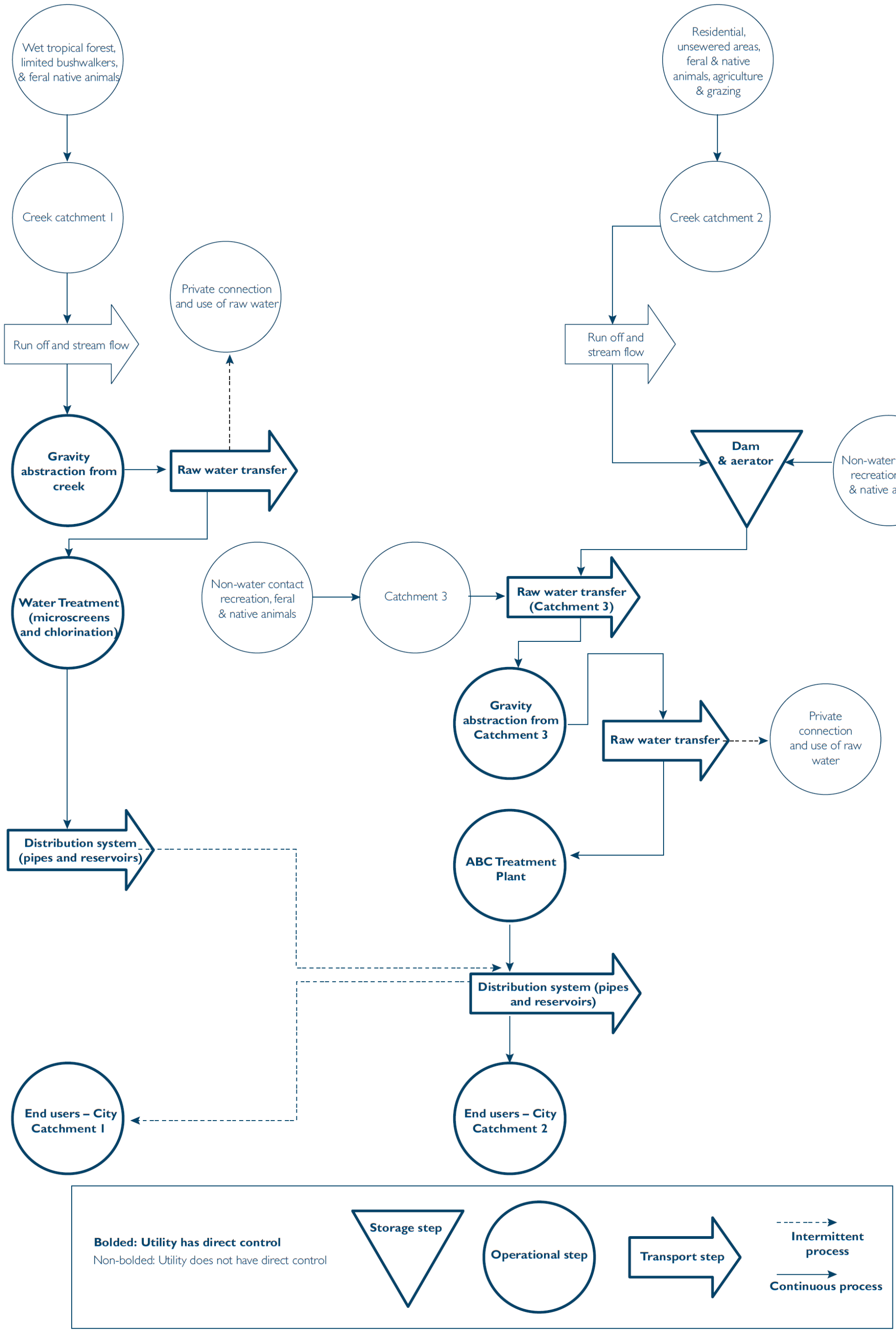
Once this module is completed, a detailed up-to-date description of the water supply system is produced. This also includes a detailed flow diagram. The description of the system contributes to a better understanding of the water quality currently provided by the utility, and it identifies the users and uses of the water.

3.2.4 Supporting Tools / Examples

Tool / Example 2.1: A detailed water system flow diagram (compare Tools 2.3 and 2.5 in Bartram et al. (2009))

It is recommended to elaborate a flow diagram which includes all elements of the water supply system from catchment to point-of-use at a detailed level. A detailed and accurate flow diagram is of great help in the identification of hazards, risks, and current controls. The flow diagram should be verified and validated through on-site field checking and will subsequently be used in the risk assessment process. Other documentation, such as maps showing supply areas, property boundaries, sewage treatment plants, septic tanks, industry, and other sources of potential risk should be checked, referred to, or produced.

In order to keep the flow diagram simple and consistent, standard engineering flow diagram symbols may be used. A flow diagram should include storage, operation, and transportation steps, which are identified with corresponding symbols. Continuous processes should be differentiated from intermittent processes. The following example of a flow diagram is taken from the WSP manual (Tool 2.5 in Bartram et al. (2009)) and includes the above-mentioned details.



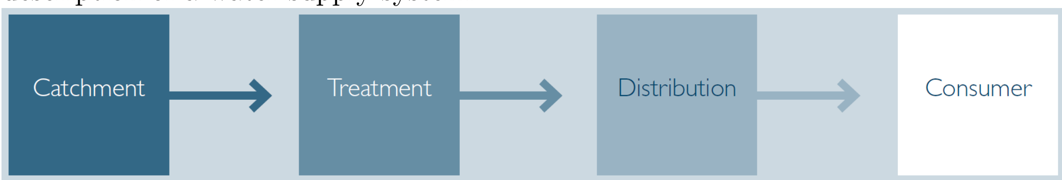
Wet tropical forest, limited bushwalkers, & feral native animals
Creek catchment 1
Run off and stream flow
Private connection and use of raw water
Gravity abstraction from creek
Raw water transfer
Water Treatment (microscreens and chlorination)
Non-water contact recreation, feral & native animals
Catchment 3
Distribution system (pipes and reservoirs)
End users – City Catchment 1
Residential, unsewered areas, feral & native animals, agriculture & grazing
Creek catchment 2
Run off and stream flow
Dam & aerator
Non-water contact recreation, feral & native animals
Raw water transfer (Catchment 3)
Gravity abstraction from Catchment 3
Raw water transfer
Private connection and use of raw water
ABC Treatment Plant
Distribution system (pipes and reservoirs)
End users – City Catchment 2
Bolded: Utility has direct control
Non-bolded: Utility does not have direct control
Storage step
Operational step
Transport step
Intermittent process
Continuous process

Tool / Example 2.2: Considering the basic arrangements of the water supply system to be assessed (adopted from Tool 2.1 in Bartram et al. (2009))

It is important to describe the whole system from the source to the end point of supply in detail, and every subdivision of the system should be covered. This task requires considerable investment of time. This has to be taken into consideration by the responsible staff who implements this module.

Tool / Example 2.3: Basic elements for describing the water supply system (adopted from Tool 2.2 in Bartram et al. (2009))

The following four elements are given by the WSP manual as basic elements for the description of a water supply system.



However, these are just basic and general points to consider, and the description may be detailed by adding other relevant elements in the described water supply system. Some examples may be "more than one source catchment feeding a treatment works; a distribution area receiving water from more than one treatment works; further dividing distribution into trunk main, service reservoir and network elements; and separately considering consumers as industrial and domestic users." (Bartram et al., 2009, p. 21) All inputs and outputs of the system must be documented, even if they do not operate continuously.

Tool / Example 2.4: Intended uses and users of the water (adopted from Tool 2.4 in Bartram et al. (2009))

Some regulations, such as the European Drinking Water Directive (European Council, 2009), specify suitable uses for water. There, water intended for human consumption is defined as water with drinking, cooking, food preparation and food production purposes.

In the process of describing the water supply system, the intended uses of water should be clearly specified, for example general consumption, food preparation, washing, and personal hygiene. The intended users should be also specified, and it should be mentioned whether an extra treatment procedure is necessary for immunocompromised consumers or for some types of industries which require a specific water quality.

3.3 Module 3: Identifying Hazards and Hazardous Events and Assessing the Risks

According to the WSP Manual, "Hazards are defined as: Physical, biological, chemical or radiological agents that can cause harm to public health. Hazardous events are defined as: An event that introduces hazards to, or fails to remove them from, the water supply. For example, heavy rainfall (hazardous event) may promote the introduction of microbial pathogens (hazards) into source water." (Bartram et al., 2009, p. 28)

This module is usually carried out simultaneously with modules 4 (see p. 28) and 5 (see p. 36). Generally, all these three modules deal with water supply system assessment, in which the potential hazards and hazardous events are determined in the whole water supply system, their level of risk is identified, the necessary control measures to prevent the risks are decided, and reaching the standards and targets is confirmed.

During the third module:

- all potential biological, physical and chemical hazards and hazardous events should be identified throughout the whole system; and
- the identified risks should be evaluated.

3.3.1 Key Actions

- Identifying the hazards and hazardous events

  The WSP team needs to assess hazards and hazardous events at every point of the water supply system, for each step of a validated process flow diagram. Identifying hazards involves both desk studies as well as site visits, as in some cases site visits may disclose hazards which would have not been identified by desk studies alone. It also may be necessary to verify historic data, events, and predictive information based on expert knowledge and particular characteristics of the treatment plant and supply system. It is also important to consider factors that are not as obvious, such as the age of the pipes in the distribution system. The team members should be aware of the fact that hazards and hazardous events may appear at any point of the water supply system.

  For an accurate analysis of the catchment it may be necessary to consult public health authorities and other sectors that regulate activities in the catchment, such as land and water use. In order to avoid misses of significant issues and to identify the areas of greatest risk, it is important to adopt a structured approach. An effective management of the catchment area will reduce the necessity for treatment, which will decrease also the operational costs of the supply. Thus, it is important to understand the characteristics of the local catchment and the reasons for raw water quality change, as this is a factor deciding the necessity for treatment and its efficiency, and the health risks associated with the final water quality. The first challenge in drinking water protection is the adequate management of sources and resources. It may be difficult to implement all aspects of source and resource protection from the very beginning. In this case, priority should be given to the management of the catchment.

The distribution system has to be kept in good shape because this is vital for providing high-quality drinking water. Maintaining safe drinking water quality within the distribution system is dependent on the system's design and operation as well as on its maintenance and other procedures to prevent the contamination of the water and to avoid and remove deposits accumulation. In case of pathogen contamination within the distribution system even disinfectant residuals may not be sufficient or adequate to overcome the contamination, thus resulting in high concentrations of the pathogens at the points of use leading to infections and illness. Hazard identification for non-piped community and for household drinking water systems should be ideally accomplished on a case-by-case basis. In practice this is done by relying on general assumptions of hazardous conditions related to existing technologies or system types that may be assigned at national or regional level.

- Assessment of risk
  The risk assessment should be carried out separately and specifically for each drinking water system to account for its unique features. The risks may be described according to the likelihood of their occurrence (e.g. certain, possible, rare). The severity of consequences in case when hazards materialize should be quantified similarly (e.g. insignificant, major, catastrophic). A cut-off point has to be established above which all risks will require actions without delay. The risk assessment may be facilitated by drawing a simple table, in which the potential hazards and hazardous events will be systematically recorded, as well as the estimation of the magnitude of risk. This table eases the task of distinguishing between significant and

less significant risks. It is important to give detailed definitions for the terms used in the description beforehand to avoid subjectivity in the process of risk assessment. Issues to be taken into consideration thereby are impact on human health (most important), aesthetic effects, continuity and adequacy of supplies, as well as utility reputation. By using risk ranking, control measures will be prioritised according to their significance. The ranking depends, to a significant degree, on expert opinion on public health risks associated with the occurrence of hazards and hazardous events.

3.3.2 Typical Challenges

- The possibility of missing new hazards and hazardous events;
  Regular reviews of the risk assessment process are necessary to avoid this issue.

- Uncertainty in assessment of risks;
  This may be caused by "unavailability of data, poor knowledge of activities within the water supply chain and their relative contribution to the risk generated by the hazard or hazardous event." (Bartram et al., 2009, p. 28)

- "Properly defining likelihood and consequence with sufficient detail to avoid subjective assessments and to enable consistency." (Bartram et al., 2009, p. 28)

3.3.3 Outputs

After the implementation of this module, the hazards and hazardous events will be identified, as well as the point in the water supply system they could take place at is identified. The assessed risks will then be clearly expressed, such that they can be interpreted and compared.

3.3.4 Supporting Tools / Examples

The hazards and hazardous events should be identified at every point of the water supply system. Simple tables can be drawn up for each point apart, in which the identified hazards and hazardous events will be listed. The example below, taken from the WSP manual, refers to the hazards and hazardous events which may affect the catchment. Similar tables should be drawn up for each other point in the water supply system, such as treatment, distribution network, or consumer premises. The next steps will be to conclude whether risks are under control, which control measures are used, and if needed, to develop and establish an improvement programme. These tasks are explained in detail in the following modules 4 (see p. 28) and 5 (see p. 36).

Tool / Example 3.1: Typical hazards affecting the catchment (see Tool 3.1 in Bartram et al. (2009))

Hazardous events (sources of hazards)	Associated hazards (and issues to consider)
Meteorology and weather patterns	Flooding and rapid changes in source water quality
Seasonal variations	Changes in source water quality
Geology	Arsenic, fluoride, lead, uranium, radon
	Swallow holes (surface water ingress)
Agriculture	Microbial contamination, pesticides, nitrate
	Slurry and dung spreading
	Disposal of dead animals
Forestry	Pesticides, PAH - polyaromic hydrocarbons (fires)
Industry (including abandoned and formal industrial sites)	Chemical and microbial contamination
	Potential loss of source water due to contamination
Mining (including abandoned mines)	Chemical contamination
Transport - roads	Pesticides, chemicals (road traffic accidents)
Transport - railways	Pesticides
Transport - airports (including abandoned airfields)	Organic chemicals
Development	Run-off
Housing - septic tanks	Microbial contamination
Abattoirs	Organic and microbial contamination
Wildlife	Microbial contamination
Recreational use	Microbial contamination
Competing water uses	Sufficiency
Raw water storage	Algal blooms
	Stratification
Unconfined aquifer	Water quality subject to unexpected change
Well / borehole headworks not watertight	Surface water intrusion
Borehole casing corroded or incomplete	Surface water intrusion
Flooding	Quality and sufficiency of the water

Tool / Example 3.2: Deciding which method of risk assessment is most appropriate (adopted from Tool 3.5 in Bartram et al. (2009))

The risk assessment process may be based on the so-called quantitative, semi-quantitative or on a simplified qualitative approach. The simplified qualitative approach, based on expert judgements of the WSP team, may be sufficient for a small utility of water supply. However, a more complex system may require a quantitative or semi-quantitative risk prioritisation approach, which would comprise an estimation of likelihood / frequency and severity / consequences of hazards and hazardous events. In either case the decision on the choice of risk assessment method must be recorded.

Tool / Example 3.3: Semi-quantitative risk matrix approach (see Tool 3.6 in Bartram et al. (2009) and Deere et al. (2001))

		Severity or Consequence				
		Insignificant or no impact - Rating: 1	Minor compliance impact - Rating: 2	Moderate aesthetic impact - Rating: 3	Major regulatory impact - Rating: 4	Catastrophic public health impact - Rating: 5
Likelihood or frequency	Almost certain / Once a day - Rating: 5	5	10	15	20	25
	Likely / Once a week - Rating: 4	4	8	12	16	20
	Moderate / Once a month - Rating: 3	3	6	9	12	15
	Unlikely / Once a year - Rating: 2	2	4	6	8	10
	Rare / Once every 5 years - Rating: 1	1	2	3	4	5

Risk score	<6	6-9	10-15	>15
Risk rating	Low	Medium	High	Very high

Tool / Example 3.4: How to calculate the risk using the matrix (see Tool 3.7 in Bartram et al. (2009))

Event	Loss of network integrity through illegal connections results in the ingress of pathogens.
Severity of event and basis for score	5 – Public health impact including disease and potentially death.
Likelihood of event and basis of score	2 – Plumbing controls are in place, but are ineffective - at least two outbreaks have occurred from illegal connections in the past 5 years.
Score	5 x 2 = 10 high risk
Outcome	Risk requires prioritizing for action, including reviewing the current controls and whether new control(s) could be implemented (see Module 5).

Tool / Example 3.5: Output of hazard assessment and risk assessment using semi-quantitative approach (see Tool 3.8 in Bartram et al. (2009))

Process step	Hazardous event (source of hazard)	Hazard type	Likeli-hood	Severity	Score	Risk rating (before consideration of controls)	Basis
Source (groundwater)	Cattle defecation in vicinity of unfenced wellhead causing source of potential pathogen ingress in wet weather	Microbial	3	5	15	High	Potential illness from pathogens from cattle, such as *Cryptosporidium*
Source	Cocktail of pesticides from agricultural uses	Chemical	2	4	8	Medium	Potential introduction of toxic chemicals which could lead to concentrations in finished water above national standards and WHO Guideline values
Source	Potential for informal solid waste disposal	Microbial and chemical	1	1	1	Low	Potential for hazardous waste plus rainfall event causing contamination to water supply is low
Storage tank	Unroofed reservoir allows birds to congregate and defecate in treated water	Microbial	2	5	10	High	Potential illness from pathogens such as *Salmonella* and *Campylobacter*
Treatment	No back-up power supply	Microbial and chemical	2	5	10	High	Potential loss of treatment and pumps/pressure
Distribution	Leaks on trunk main and distribution system	Microbial	5	3	15	High	Leaks are a potential source of microbial pathogens and contribute to high % of unaccounted for water

Tool / Example 3.6: Simplified risk assessment based on the expert judgement of the WSP team (adopted from Tool 3.9 in Bartram et al. (2009))

Another option to classify the risks in terms of likelihood and severity of consequences is a simplified risk assessment process based on the team's judgement. Depending on the assessment of the hazards and hazardous events at each step in the process, the risks may be classified as "significant", "uncertain", or "insignificant". Tool 3.7 (see below) gives the definitions to these terms which may be used to identify the events that may demand urgent attention. Urgent attention is needed for "the events of most concern because they happen a lot / or could cause significant illness". (NZ Ministry of Health, 2005)

Tool / Example 3.7: Definition of descriptors for use in simple risk prioritisation (see Tool 3.10 in Bartram et al. (2009))

Descriptor	Meaning	Notes
Significant	Clearly a priority	The risk should be considered further to determine whether additional control measures are required and whether a particular process step should be elevated to a key control point in the system. It is necessary to validate existing control measures before defining whether additional control measures are required.
Uncertain	Unsure if the event is or is not a significant risk	The risk may require further studies to understand if the event is really a significant risk or not.
Insignificant	Clearly not a priority	Note that the risk will be described and documented and will be revisited in future years as part of the WSP rolling review.

Tool / Example 3.8: Prioritising and documenting risks for urgent action or regular review (adopted from Tool 3.11 in Bartram et al. (2009))

In case hazards are classified as of "high", "very high", or "significant" risk, validated controls or mitigation measures are required. An improvement plan is necessary if no suitable controls are in place. Hazards scored as "moderate" or "low risk" need to be documented and frequently reviewed. These risks may also be mitigated by the controls for "high" or "very high" risks.

Tool / Example 3.9: The necessity of working with stakeholders (adopted from Tool 3.12 in Bartram et al. (2009))

> Hazards may occur naturally, as a result of agricultural or industrial activities in the vicinity of the catchment area, or in some cases due to the water supply company. According to the WSP approach, the water utilities should closely work with the other stakeholders to make them familiar with the whole situation of the water supply, with their responsibilities and with the impact of their actions on the water quality, as well as with the ability and reliability of the utility to supply safe drinking water.

3.4 Module 4: Determining and Validating the Control Measures, Reassessing and Prioritising the Risks

According to the WSP Manual (Bartram et al., 2009, p. 39), "[c]ontrol measures (also referred to as 'barriers' or 'mitigation measures') are steps in the drinking-water supply that directly affect drinking-water quality and ensure the water consistently meets water quality targets. They are activities and processes applied to reduce or mitigate risks." Control measures should be planned, implemented, and evaluated so that they guarantee the accomplishment of the health-based targets. Planning and assessing the control measures should be based on hazard identification and risk assessment. Control measures are assessed in the following way:

- existing control measures for each significant hazard and hazardous event are identified at every point of drinking water supply;
- the effectiveness of the control measures is evaluated;
- alternative and control measures are evaluated in case improvement is necessary.

At this module the team should check whether the existing controls are effective. It has to be considered that many control measures may be effective in controlling more than one hazard, whereas for some hazards more than one control measure will be needed to ensure an effective control. The effectiveness of existing controls may be assessed by site inspection, manufacturer's specification, or by monitoring data. Taking into account all existing measures, the risk should be recalculated in terms of likelihood of occurrence and related to the expected consequences. The achieved reduction of risk is to be considered as an indicator of the effectiveness of a specific control measure. In case the effectiveness of a control measure is unknown or unclear at the time of initial risk assessment, the control measure should be considered as not working and the risk calculated respectively. Corrective actions are necessary for any anticipated risks after all control measures have been considered by the WSP team.

3.4.1 Key Actions

- Identifying the controls
  Control measures need to be determined for each of the identified hazards and hazardous events. When the needed controls are not in place to mitigate hazards, they should be clearly documented and addressed. It is recommended to use the multiple-barrier principle in the process of identification and implementation of control measures. This offers the benefit of compensating the failure of one barrier by the effective operation of the remaining barriers.

- Validating the effectiveness of the controls
  Accurate and reliable technical information is of significant importance in the process of anticipating and managing the hazards and hazardous events. "Validation is the process of obtaining evidence on the performance of control measures." (Bartram et al., 2009, p. 39) It should not be mistaken with operational monitoring which demonstrates the continuity of the effectiveness of the validated control.

  The first step of the validation process is to account for already existent data and information. These may include scientific literature, historical data, manufacturer's specification, data from relevant industries, etc. Data used in validation needs to be appropriate to a system's specific conditions, otherwise in some cases the effectiveness of existent control measures may be impaired.

  Validation of the effectiveness of the controls in many cases requires a profound programme of monitoring to demonstrate the controls' performance under normal and exceptional circumstances. This includes a number of different methodologies, such as the use of technical data from scientific literature, or from similar studies at pilot drinking water treatment plants, or catchment sanitary surveys. During operations, it is vital to check the effectiveness of validated controls against pre-determined targets or "critical limits", which may be defined as upper and/or lower limits.

- Reassess risks, taking into account the effectiveness of controls
  Reassessing the risks is the recalculation of risks in terms of likelihood and consequences. In this process the effectiveness of each control should be taken into account. The possibility of control measures to fail or be ineffective for a short duration as well as their long term performance should also be considered. The significant risks where controls are missing need to be highlighted as *remaining significant risks* in the system.

- Prioritising all the identified risks
  The impact that an identified risk may have on the system's capacity to deliver safe water is to be compared and priorities for risk management are to be established and documented. All possible contaminants impacting the quality of drinking water should be considered, however, not all the hazards and hazardous events will cause the same degree of concern. In order to fulfill water quality targets, the system may need corrections or upgrades in case high-priority risks are identified. All uncontrolled and prioritised risks should be addressed in an improvement / upgrade plan in which the responsible persons for the improvements should be selected and the relevant time frame for implementation of these controls should be set. This will be discussed in more detail in module 5 (p. 36).

  The controls may be short-, medium-, or long-term mitigation measures. Examples of short-term mitigation measures are advisory notes/signs, output restrictions or temporary disuse of a specific source. Examples of medium- and long-term mitigation measures are the improvement of community consultation activities, catchment measures, or treatment improvements.

3.4.2 Typical Challenges

- Defining the responsibilities for field work on hazard identification and development of control measures;
- Establishing sustainable and cost-effective controls;
- Risk-prioritisation uncertainty due to lack of data.

3.4.3 Outputs

1. Control identification;
2. Validation of the controls' effectiveness;
3. Identification and prioritisation of risks that are insufficiently controlled.

3.4.4 Supporting Tools / Examples

To identify hazards and hazardous events at every point of the water supply system, and to establish corresponding control measures, simple tables can be drawn up for hazards at each point apart, listing the control measures associated with the identified hazards. The examples below, taken from the WSP manual (Bartram et al., 2009), refer to the control measures associated with catchment-related hazards. Similar tables should then be drawn up for the other points in the water supply system, such as treatment, distribution network, and consumer premises.

Tool / Example 4.1: Typical control measures associated with hazards at a catchment (see Tool 4.1 in Bartram et al. (2009))

Restricted access to catchments
Water utility ownership and control of catchment land
Stock fencing
Moving stock away from river access at calving / lambing times
Codes of practice on agricultural chemical use and slurry spreading
Moving farm operations away from sensitive locations
Planning controls
Agreements and communication with transport organizations
Communication and education of catchment stakeholders
Industrial effluent standards and volume controls
Raw water storage
Ability to close intakes (time of travel information)
River biology – indicator of diffuse or point source contamination
Covering and protecting springs
Ability to use good alternative water sources when hazards affect one source
Continuous monitoring of intake and river
Site inspections
Regular internal inspections of wells and boreholes

Tool / Example 4.2: Critical limits and actions relating to microbial hazards (see Tool 4.5 in Bartram et al. (2009))

Hazards and hazardous events	Examples of control measures	Critical limit target	Critical limit trigger for action
Microbial hazards from contamination of a service reservoir	Ensure inspection covers remain in place Ensure ventilators and cable ducts are secured against vermin entry	Inspection covers locked in place and vermin-proofing intact	Inspection covers not in place or unlocked or damage to vermin-proofing
Microbial hazards from contamination of a source water reservoir	Protection of catchments from stock and human habitation Fencing stock from catchment streams and watercourses	Only permitted development or activity in catchment and stock fencing intact	Any non-permitted development or activity in catchment and any damage to stock fencing
Chemical, microbial and physical hazards overwhelming treatment capability	Cessation of source water abstraction during high contamination periods, e.g. after storms	Rain event, flow rate and turbidity monitoring within normal range	Rain event, flow rate and turbidity monitoring outside of specified range
Chemical cyanotoxin hazards from algal bloom in source water reservoir	Mixing of storages to reduce cyanobacteria	Mixing system operating when required	Failure of mixing system and stratification forming

Tool / Example 4.3: Validation information capture format (adopted from Tool 4.6 in Bartram et al. (2009))

Item validated	Validation	Reference
Chlorine residual critical limit values	...	...
Filtered effluent critical limit values	...	...
Critical limits for underground travel time in riverbank filtration	...	...
Critical limit for turbidity at outlet of each single rapid filtration unit	...	...
...	...	...

Tool / Example 4.4: Validate controls before prioritising risks for mitigation (adopted from Tool 4.7 in Bartram et al. (2009))

Only after the validation of control measures has been completed, the risks can be reassessed and prioritised. Intensive monitoring is one way to carry out the controls' validation, except for controls which proved to be effective over time. An upgrade / improvement plan has to be developed and implemented in case the system proves to be unable to supply the required water quality to consumers.

Tool / Example 4.5: Maintaining consistency in reassessing and prioritising risks (adopted from Tool 4.8 in Bartram et al. (2009))

- A comprehensive methodology for risk assessment should be developed in advance;
- Hazards must be specifically defined in terms of:
  - Likelihood of their occurrence, considering the effectiveness of controls;
  - Consequences of occurring hazards;
  - Probability to affect the safety of the water supply;
  - Location and time of occurrence.

Tool / Example 4.6: Establishing cut-off points to prioritise risks (adopted from Tool 4.9 in Bartram et al. (2009))

The WSP team has to find a cut-off point beyond which the reassessed risks will demand additional, corrective actions, and below which a regular review will be done. Any risk that is defined as of possible catastrophic consequence, even if of rare likelihood, should be documented and kept under review. Even though the risk classification from "low" to "very high" is partially subjective, the scope is to ease the task of prioritising the most urgent action.

Tool / Example 4.7: Output of hazard assessment and determination and validation of control measures (see Tool 4.10 in Bartram et al. (2009))

Hazardous Event	Hazard Type	Likelihood	Severity	Risk	Control measure	Efficacy of control measure	Basis
Cattle defecation followed by rainfall	Microbial (pathogens)	3	5	15	Filtration of water Boil water advisory if filtration fails (corrective action)	Protozoa controlled by filtration validated by manufacturer's data on pore size and testing for oocysts	Waterborne disease outbreaks seen in similar situations
Etc.							

Tool / Example 4.8: Dealing with uncertainty in scoring of risks (see Tool 4.11 in Bartram et al. (2009))

Supplementary investigations may be added to the WSP in order to address the uncertainty of risks. This is shown in the example below taken from the WSP Manual (Bartram et al., 2009):

Step	Catchment
Event	Leaching from sites such as disused cattle, landfill or contaminated sites and run-off of water soluble compounds (e.g. pesticides) into the source water.
Basis	While the dilution factors are significant, there is no monitoring data available and no barriers in place for this hazard. If pesticides are present in high concentrations, there could be potential health risk.
Possible investigations to reduce uncertainty	1. Undertake a sanitary survey with special focus on pesticide usage and dip site locations, particularly those in the proximity of spray from pesticides. 2. Undertake pesticide monitoring at the source intake during normal and event conditions.
Practicality of investigation	1. High practicality but low cost and could be combined with other studies being undertaken by other stakeholders. 2. High practicality but high cost.
Output	The WSP team recommends which of the above options to undertake, by whom, at what time, and at what cost.

Tool / Example 4.9: Risk prioritisation and reassessment (see Tool 4.12 in Bartram et al. (2009))

Hazard	Hazardous event (source of hazard)	Likelihood	Severity	Score	Risk rating (see table 3.6)	Example control measure	Validation of control measure	Reassessment of risk post-control
Microbial	Inadequate disinfection method	3	4	12	High	Improve disinfection method (longer-term). Minimizing ingress of contamination to system and lengthening reservoir detention times (short-term). Fitting alarms triggered by low disinfectant level.	Alarms effective and demonstration of consistent removal of indicator organisms under range of operating conditions.	Low with appropriate operational monitoring.
Chemical	Formation of disinfection by-products at levels that exceed Guideline values	3	3	9	Medium	Reducing water age through tanks downstream where possible in periods of low water demand.	Consistent reduction in disinfection by-products under range of operating conditions.	Low with appropriate operational monitoring.
Microbial	Less effective disinfection due to elevated turbidity	4	4	16	Very high	Improve clarification and filtration processes (longer-term). Fitting alarms triggered by low disinfectant level.	Alarms effective and demonstration of consistent removal of indicator organisms under range of operating conditions.	Low with appropriate operational monitoring.
Microbial	Major malfunction/ failure of disinfection plant	2	5	10	High	Chlorination plants refitted for equipment and process reliability of 99.5%. Fitting alarms triggered by low disinfectant level.	Alarms effective and demonstration of consistent removal of indicator organisms under range of operating conditions.	Low with appropriate operational monitoring.
Microbial	Reliability of disinfection plant less than target level of 99.5%	3	4	12	High	Defined band widths for chlorine dosing linked to alarms.	Alarms effective and demonstration of consistent removal of indicator organisms under range of operating conditions.	Low with appropriate operational monitoring.
Microbial	Failure of UV disinfection plants	3	4	12	High	Alarms in place for power outages.	Alarms triggered under a range of operating conditions.	Low with appropriate operational monitoring.
Microbial	Low chlorine residual in distribution and reticulation systems	4	4	16	Very high	Set point designed to achieve established target chlorine residual to achieve microbial standards at consumer premises linked to alarms.	Alarms effective and demonstration of consistent removal of indicator organisms under range of operating conditions.	Low with appropriate operational monitoring.
Microbial	Power failure to disinfection plant	2	5	10	High	Dual power source.	Supplies confirmed to come from different generating sources. Automatic switching shown to be triggered under a range of operating conditions.	Low with appropriate operational monitoring.
Physical, chemical, microbial	Contamination of dosing chemicals or wrong chemical supplied and dosed	2	4	8	Medium	On-line monitoring controls. Laboratory analysis certificate from supplier.	Intensive audit of suppliers. Alarms triggered under a range of operating conditions.	Low with appropriate operational monitoring.
Chemical	Over or under dosing from fluoridation plants	3	3	9	Medium	Plants have alarms on high and low levels with dosing cut-offs on high levels.	Alarms triggered under a range of operating conditions.	Low with appropriate operational monitoring.
Chemical, physical	Over or under dosing of lime for pH correction	3	3	9	Medium	Plants have alarms on high and low pH with dosing cut-offs on high pH.	Alarms triggered under a range of operating conditions.	Low with appropriate operational monitoring.
Physical	Failure of pumps	4	3	12	High	Pressure measurement triggering back-up pumps. (Not in place.)	No controls in place.	High - priority for mitigation.
Chemical	Nitrate exceeds compliance standards	3	2	6	Medium	Blending with low-nitrate source from another water supply. (Alternative source itself has rising levels of nitrate and is subject to other demands.)	Unreliable long-term control.	Medium - keep trend under regular review and propose alternative mitigation scheme.

3.5 Module 5: Developing, Implementing and Maintaining an Improvement/Upgrade Plan

If significant risks to the safety of drinking water were found and the existing control measures were found to be ineffective or absent, an improvement/upgrade plan needs to be developed. In this case a person needs to be appointed for the implementation and a target implementation date should be decided.

An improvement/upgrade plan has to be developed with a detailed analysis and careful prioritisation according to the system assessment, as for such plans significant resources may sometimes be necessary. Frequently, however, simply reviewing, documenting and formalising the practices that did not work and addressing the areas where improvements are necessary is sufficient. It is also important to monitor the implementation of an improvement/upgrade plan in order to check whether improvements have occurred and are effective and that the WSP has been updated respectively. New risks caused by establishing new controls should be considered.

3.5.1 Key Actions

- Draw up an improvement/upgrade plan
  Short-, medium-, long-term mitigation or controls for each significant risk should be determined, which can also control other, less significant risks. An example of short-term improvements is the development of community consultation and awareness programmes. Long-term improvements might include covering of water storage or enhanced treatment procedures.

- Implement the improvement/upgrade plan
  The WSP should be updated and risks should be recalculated considering the newly introduced controls. Decisions regarding water-quality improvements should not be made apart from other aspects of the drinking water supply.

3.5.2 Typical Challenges

- Keeping the WSP up-to-date;

- Securing financial resources;

- Lacking human resources, technical expertise, for drafting and implementing the necessary upgrades;

- Ensuring that no new risks are introduced by the improved programme.

3.5.3 Outputs

For each of the major uncontrolled risks, a prioritised improvement / upgrade plan is developed and implemented according to the planned schedule of short-, medium-, or long-term activities.

3.5.4 Supporting Tools / Examples

Tool / Example 5.1: A checklist of issues to be considered when developing an improvement/upgrade plan (see Tool 5.1 in Bartram et al. (2009))

> An improvement / upgrade plan of a drinking water system may involve a range of issues, exemplarily listed in the following:
>
> - "Options for mitigating risks
> - Responsibility for improvement programme (process owner)
> - Financing
> - Capital works
> - Training
> - Enhanced operational procedures
> - Community consultation programmes
> - Research and development
> - Developing incident protocols
> - Communication and reporting" (Bartram et al., 2009, p. 53)

Tool / Example 5.2: Drinking-water quality improvement/upgrade plan actions and accountabilities (see Tool 5.2 in Bartram et al. (2009))

Action	Arising from	Identified specific improvement plan	Accountabilities	Due	Status
Implement measures to control *Cryptosporidium*-related risks.	*Cryptosporidium* has been identified as an uncontrolled risk. Cattle defecation in vicinity of unfenced wellhead is a potential source of pathogen ingress, including *Cryptosporidium*, in wet weather. Currently there is no confidence that these risks are adequately controlled.	Install and validate ultraviolet light treatment. Validation includes comparing theoretical treatment performance against that required to inactivate *Cryptosporidium* infectivity.	e.g. Engineer	e.g. Date the action should be completed by.	e.g. Ongoing, not started, etc.
Implement measures to control risks arising from agricultural pesticides introduced into the water supply.	Risk assessment process has identified a cocktail of pesticides from agricultural uses. Currently there is no confidence that these risks are adequately controlled.	Install ozone and granular activated carbon filtration within the water treatment plant. These controls should be validated through intensive monitoring and shown to continue to work through operational monitoring.	e.g. Engineer	e.g. Date the action should be completed by.	e.g. Ongoing, not started, etc.
Review the need for, and if required, the options for, reducing the risks from viral and protozoan water quality contamination from sewage systems to reduce risks to acceptable levels.	Risk assessment process for pathogens risks arising from sewage systems. Currently there is no confidence that these risks are adequately maintained to acceptable levels by the control measures in place.	Develop additional sewage disinfection and downstream water treatment, including avoidance strategies as warranted.	e.g. Water quality officer	e.g. Date the action should be completed by.	e.g. Ongoing, not started, etc.
Etc.					

3.6 Module 6: Defining Monitoring of the Control Measures

In this module the monitoring of control measures is defined and validated, and procedures are fixed to verify that the controls work. Each control measure is monitored regularly in order to ensure effective system management and achievement of health-based targets. Corrective actions need to be included when the operational targets are not met. All these actions need to be documented in the management procedures.

3.6.1 Key Actions

The number and the type of control measures are determined by the type and frequency of hazards and hazardous events related to the system and depends on specificity of each system. The control points need to be monitored in order to support risk management. This enables the validation of the control measures' effectiveness and that actions will be taken in time to prevent water quality be affected in case of a deviation.

The following list needs to be checked to achieve an effective monitoring:

- “What will be monitored
- How it will be monitored
- The timing or frequency of monitoring
- Where it will be monitored
- Who will do the monitoring
- Who will do the analysis
- Who receives the results for action?” (Bartram et al., 2009, p. 59)

Monitoring data is of great significance in terms of providing the necessary feedback to understand how the system works. Monitoring records should become a routine in the process of WSP development, as they provide the information whether the controls are adequate and the water quality meets the quality targets. Operational monitoring may be carried out by measuring parameters or observational activities. Routine monitoring consists usually of simple observations and tests, such as turbidity and structural integrity.

Operational and critical limits should be determined for control measures. Operational limits are set for each control measures and require timely corrective actions in case of deviations. For some control measures critical limits need to be set, above which the confidence in the safety of the water is lost. Violations of the critical limits demands urgent actions that were defined beforehand and a notification without delay of the local health authority, and in some cases starting the operation of an alternative supply of water set in advance for emergency cases. Monitoring and corrective actions are the steps that ensure that no usage of unsafe drinking water takes place. Corrective actions have to be clear and specific and, if possible, be established in advance to ensure their rapid implementation.

3.6.2 Typical Challenges

- Lacking human resources for monitoring and analysis processes;
- Financial costs due to enhanced monitoring, especially on-line monitoring;
- Inadequate or absent data evaluation;
- Changing the method of monitoring for staff members who are accustomed to do it in another way;

- Ensuring the availability of resources to the operations department for the implementation of corrective actions.

3.6.3 Outputs

By accomplishing this module, the implementation of the control measures at appropriate time intervals is completed and corrective actions are established for deviations that may occur.

3.6.4 Supporting Tools / Examples

Tool / Example 6.1: Checklist of factors to be considered when establishing a monitoring programme for the control measures (see Tool 6.1 in Bartram et al. (2009))

> - “Who will do the monitoring?
> - How frequently will the monitoring be done?
> - Who will analyse the samples?
> - Who will interpret the results?
> - Can the results be easily interpreted at the time of monitoring or observation?
> - Can corrective actions be implemented in response to the detected deviations?
> - Has the list of hazardous events and hazards been checked against monitoring or other appropriate criteria to ensure that all significant risks can be controlled?” (Bartram et al., 2009, p. 61)

Tool / Example 6.2: Corrective actions (adopted from Tool 6.2 in Bartram et al. (2009))

In case the monitoring shows that the critical limit has been exceeded, a corrective action should be established for each control. This will prevent the supply of unsafe drinking water. Events that need immediate intervention and corrective actions may be: "non-compliance with operational monitoring criteria, inadequate performance of a sewage treatment plant discharging to source water, extreme rainfall in a catchment, or spillage of a hazardous substance. Examples of corrective actions include the use of alarms and auto-shutdown mechanisms, or switching to an alternative water source during a period of non-compliance". The use of alternative sources may introduce new risks, thus it is important to identify and address them in advance within the WSP framework.

Tool / Example 6.3: Checklist of issues to consider for devising corrective actions (see Tool 6.3 in Bartram et al. (2009))

- "Have corrective actions been documented properly, including assigning responsibilities for carrying out the actions?
- Are people correctly trained and appropriately authorised to carry out corrective actions?
- How effective are the corrective actions?
- Is there a review process in place for analysing actions to prevent recurrence of the need for a corrective action?" (Bartram et al., 2009, p. 61)

Tool / Example 6.4: Long- and short-term monitoring requirements and corrective actions (adopted from Tool 6.4 in Bartram et al. (2009))

Process step / Control measure	Crit. limit	What	Where	When	How	Who	Corr. action
Long-term monitoring (e.g. control of development in catchment)	...	...	...	...	...	...	...
Short-term monitoring (e.g. chlorination at water treatment plant)	...	...	...	...	...	...	...
etc.	...	...	...	...	...	...	...
Critical limit for turbidity at outlet of each single rapid filtration unit	...	...					

3.7 Module 7: Verifying the Effectiveness of the WSP

Verification is the "final check on the overall performance of the drinking-water supply chain and the safety of drinking-water being supplied to consumers." (WHO, 2011, p. 64) This has to be accomplished by a surveillance agency. The frequency of sampling should correspond to the need to balance the benefits and costs of acquiring additional information. The frequency of sampling usually depends on the served population or on the supplied water volume. It is necessary to develop plans to address the case that test results do not correspond to water quality targets, such as an investigation of the reason, and if necessary corrective actions. In case failures to meet the targets occur repeatedly, it is necessary to review the WSP and develop an improvement / upgrade plan.

Verifying the effectiveness of the WSP implies to undertake the following three activities:

- "Compliance monitoring;
- Internal and external auditing of operational activities;

- Consumer satisfaction."(Bartram et al., 2009, p. 67)

3.7.1 Key Actions

- Compliance monitoring
  A clearly defined monitoring regime has to be established for all control measures. Set limits should be identified against which the effectiveness and monitoring performance will be validated. The results of the verification monitoring should be consistent with the drinking water quality targets. Corrective action plans should be elaborated in such way that the reasons for any unexpected results are understood and actions can be taken to respond to the problem. The monitoring should be done at intervals of planned and unplanned changes in the water supply system.

  Quality assurance and analytical quality control procedures are part of the water quality monitoring programme and should be applied to all activities related to the production of drinking water quality data. The purpose of these procedures is to ensure the *adequate accuracy* (*fit for purpose*) of the produced results. The water quality monitoring programme will comprise a statement about accuracy and precision of the data, and has to clearly define the terms *fit for purpose* or *adequate accuracy*.

- Internal and external auditing of operational activities
  Additional to water quality tests, verification includes WSP audits. Internal and external auditing of operation activities ensure that the quality of water and risks are controlled, thus maintaining the implementation of the WSP. The fulfillment of the following factors are to be verified by the auditing procedure: (WHO, 2011, p. 60)

  - "all significant hazards and hazardous events have been identified;
  - appropriate control measures have been included;
  - appropriate operational monitoring procedures have been established;
  - appropriate operational limits have been defined;
  - corrective actions have been identified;
  - appropriate verification monitoring procedures have been established."

  Audits need to be carried out regularly to be effective. The reviews may be accomplished by regulatory authorities or by qualified independent auditors. The role of auditing can be both of assessment and of checking of compliance.

- Consumer satisfaction
  Checking whether the consumers are satisfied with the water supplied is part of the verification procedure, and it is necessary in order to ensure consumers will not switch to unsafe alternatives.

3.7.2 Typical Challenges

- "Lack of capable external auditors for WSPs;
- Lack of qualified laboratories to process and analyse samples;
- Lack of human and financial resources;
- Lack of knowledge of consumer satisfaction or complaints."(Bartram et al., 2009, p. 68)

3.7.3 Outputs

The accomplishment of this module will confirm that the WSP is complete, effective, and appropriate, and that it is being implemented and accepted in practice. Moreover, it will be confirmed that the water meets the defined water quality targets.

3.7.4 Supporting Tools / Examples

Tool / Example 7.1: Parameters that might be included in routine verification monitoring programmes (adopted from Tool 7.1 in Bartram et al. (2009))

> In most cases, in order to analyse the microbial water quality, indicator organisms are monitored. Most frequently, faecal indicator bacteria *E. coli* or thermotolerant coliforms are monitored at representative points in the water supply system. Sometimes, tools such as heterotrophic plate counts or *Clostridium perfringens* are used for operational and investigative monitoring to understand the water supply system in more detail.
> The indicator verification system is not used for chemical parameters, they are rather determined by direct measurement. Verification for chemical parameters is less frequent than for microbial analysis as they usually occur in non-acute hazardous concentrations. Quantitative and qualitative taste and odour may be also monitored. This is done to check the condition of the distribution network and consumer installations.

Tool / Example 7.2: Checklist of factors to be considered when establishing a routine verification monitoring programme (see Tool 7.2 in Bartram et al. (2009))

- "Where appropriate, draw up a verification monitoring programme in accordance with regulatory requirements;
- Identify appropriate personnel to perform monitoring functions;
- Establish a system of communication between monitoring staff;
- Identify appropriate analysts;
- Ensure appropriate monitoring points are chosen;
- Ensure monitoring frequency is appropriate;
- Ensure results are interpreted and unusual or failing results are investigated;
- Establish a system to ensure the routine reporting of results to the appropriate regulator." (Bartram et al., 2009, p. 69)

Tool / Example 7.3: Auditing the WSP itself and the implementation of the WSP (adopted from Tool 7.3 in Bartram et al. (2009))

Verification involves, apart of the water quality analysis, an audit of the WSP and of the operational practice. This is necessary to confirm WSP's good practice and compliance. It is very important that the auditor has a detailed knowledge of drinking water delivery. The auditor determines where improvements are possible, and has to be present in person when auditing procedures take place, as records may sometimes be factually incorrect and equipment may not be effective in practice.

Tool / Example 7.4: Checklist of factors to consider to ensure all appropriate information is obtained during an audit (see Tool 7.4 in Bartram et al. (2009))

- "All feasible hazards/events are taken into account;
- Appropriate control measures have been identified for each event;
- Appropriate monitoring procedures have been established;
- Critical limits for each control measure are set;
- Corrective actions have been identified;
- A system of verification has been established."(Bartram et al., 2009, p. 70)

Tool / Example 7.5: Operational monitoring and verification monitoring plan (adopted from Tool 7.5 in Bartram et al. (2009): Jinga, Uganda case study)

Unit process	Operational monitoring (see Module 6)			Verification monitoring		
	What	When	Who	What	When	Who
Treatment works	On-line measurement – pH – Chlorine	Daily	Water treatment operators / Analyst	*E. coli*	Weekly	Analyst
				Enterococci	Weekly	
				Record audit	Monthly	
	Jar testing records	Weekly				
	Turbidity	Daily				
	Dosing records	Monthly				
Distribution system	pH	Weekly		*E. coli*	Monthly	
	Turbidity	Weekly				
	Chlorine	Weekly		Turbidity	Monthly	
	Sanitary Inspection	Weekly		Enterococci	Monthly	
Etc.						

Operational and verification monitoring programmes should be developed and documented as part of the WSP. The programmes should include detailed strategies and procedures to undertake in the process of monitoring different features of the drinking water system. The following list contains the points that should be considered in the monitoring plans:

- "parameters to be monitored;
- sampling location and frequency;
- sampling methods and equipment;
- schedules for sampling;
- references to corrective action procedures, including responsibilities;
- qualifications and certification requirements for testing laboratories;
- methods for quality assurance and validation of sampling results;
- requirements for checking and interpreting results;
- responsibilities and necessary qualifications of staff;
- requirements for documentation and management of records, including how monitoring results will be recorded and stored;
- requirements for reporting and communication of results."(WHO, 2011, p. 73)

3.8 Module 8: Preparing Management Procedures

A management plan will mostly describe the necessary measures that are to be taken in order to maintain the optimal operation of the system under normal operating conditions, as well as in case of incidents. Whether Standard Operating Procedures (SOP) in normal operating conditions of the system or corrective actions in case of incident situations, the management procedures should be developed by experienced staff and should be updated respectively, especially in consideration to an improvement / upgrade plan implementation procedure. This will ensure that in case of incidents the situations can be effectively managed. Moreover, it is important to document and report any activity related to the management procedures, especially in case of incidents and emergencies. This is part of a WSP and contributes to assist ownership and implementation of the procedures.

It is part of the WSP to define the management procedures to respond to predictable and unpredictable incidents and to emergency situations. Response plans to incidents may include a variety of alert levels, from minor early warning to emergency actions. Many incidents can be anticipated, and thus response actions related to them can be identified. Examples of response actions may be temporary switching to another source of water (when existent) or enhanced treatment procedures.

Some response actions, however, may be missed out in the incident response plans, either due to unexpected events or because the occurred events were seen as too unlikely to justify the development of an accurate corrective actions plan. Thus, a general incident response plan should be prepared in order to ensure that solutions will be found for various types of possible incidents. It is important to prepare plans for emergency events, in which potential natural disasters, accidents, damage to treatment plants and distribution systems, and human actions are considered. Emergency plans should explicitly designate the responsibilities, include a plan to alert the consumers and a plan to temporarily switch to an emergency supply of drinking water.

3.8.1 Key Actions

The following key actions are essential during this module:

- Documentation of all aspects of the WSP, as well as an efficient, regular review and updating cycle

In order to ensure interconnectivity and engagement between operators and management staff, it is important that the management procedures are kept up-to-date and in place. Moreover, this facilitates the accuracy in the activity of the personnel, provides adequate resources, and ensures that people are willing to provide important information instead of withholding it.

The following procedures should be documented:

  - drinking water system description and assessment, as well as programmes aiming to upgrade and improve the existing water delivery;
  - operational monitoring and verification plan;
  - procedures related to water safety management in normal operational conditions, incidents, and emergency situations;
  - supporting programmes description.

- Development of corrective actions which identify the specific operational response demanded in case of deviations from the set limits
  In case the monitoring discloses a process which operates outside the critical or operational limits, it is necessary to restore the operation by correcting the deviation.

- Following an emergency plan in case of unforeseen events / incidents
  Unforeseen events / incidents or deviations may take place for which corrective actions were not defined. In such case, an emergency plan has to be followed. The emergency plan would include a protocol to assess the situation and determine whether the situation requires the activation of an emergency response plan. The assessment of near misses is of significant importance, as these may signal possible future emergencies.

- Undertaking an investigation following an emergency
  This should involve the participation of all staff members, who will discuss the performance, evaluate the adequacy of current procedures, and address any issues or concerns. The emergency should be properly documented and reported. Amendments to existing protocols may be sometimes necessary.

3.8.2 Typical Challenges

- "Keeping the procedures up to date;

- Ensuring that staff are aware of changes;

- Obtaining information on near misses."(Bartram et al., 2009, p. 76)

3.8.3 Outputs

"Management procedures for normal and incident/emergency conditions which address:

- Response actions;
- Operational monitoring;
- Responsibilities of the utility and other stakeholders;
- Communication protocols and strategies, including notification procedures and staff contact details;
- Responsibilities for coordinating measures to be taken in an emergency;
- A communication plan to alert and inform users of the supply and other stakeholders (e.g. emergency services);
- A programme to review and revise documentation as required;
- Plans for providing and distributing emergency supplies of water."(Bartram et al., 2009, p. 76)

3.8.4 Supporting Tools / Examples

Tool / Example 8.1: Typical Standard Operating Procedures (SOPs) for a water utility (adopted from Tool 8.1 in Bartram et al. (2009))

This tool is a general framework that may be used in the development of a list of typical SOPs for a water utility operation. Due to the varying nature of each water utility and its operation processes, the SOPs list should be created individually. Once documented, the list of SOPs may be extended. The SOP needs to be elaborated in such way that a revision is possible when required.

Category	Sub-category	Standard Operating Procedure
Facility operations overview	General tasks/information	Daily rounds Site security Record keeping Reporting procedures Cross contamination prevention for operators
	Sampling	Sampling procedure
	Emergency response	Power failure
Intake and pre-treatment	Raw water	Valve operation Screening
	Flow measurement	Meter calibration
	Pump operation	Switching duty pump operation Increasing/decreasing pumping operation
Dosing procedure		
Disinfection procedure		
Etc.		

Tool / Example 8.2: Checklist of management procedures (or corrective actions) to deal with incidents (see Tool 8.2 in Bartram et al. (2009))

- "Accountabilities and contact details for key personnel and other stakeholders;
- Clear description of the actions required in the event of a deviation;
- Location and identity of the SOPs and required equipment;
- Location of back-up equipment;
- Relevant logistical and technical information."(Bartram et al., 2009, p. 77)

Tool / Example 8.3: Checklist of characteristics and systems relating to people management which will facilitate ongoing success of the WSP (see Tool 8.3 in Bartram et al. (2009))

- "Choosing meaningful parameters on which to report;
- Having a well-defined and efficient failure reporting system;
- Including higher-level management in reporting so they are involved in events;
- Designing 'respected' audits that target likely areas of complacency that lead to adverse consequences;
- Observing the 'no blame' model where failure is shared by system participants;
- Having a widely accessible mechanism for presenting improvement opportunities, risk analysis and interpretation and for challenging existing practices;
- Ensure that all procedures are signed off at senior level. This is an important part of the continuous improvement mechanism."(Bartram et al., 2009, p. 78)

Tool / Example 8.4: Emergency management procedures (adopted from Tool 8.4 in Bartram et al. (2009))

Solutions in case of emergencies may be either to adjust the treatment of existing sources or temporarily use an alternative water source. The water needs to be disinfected additionally either at the source or during the distribution. All the procedures in case of emergencies have to be documented.

Tool / Example 8.5: Checklist of key areas to be addressed in emergency management procedures (see Tool 8.5 in Bartram et al. (2009))

> - "Response actions, including increased monitoring;
> - Responsibilities and authorities internal and external to the organization;
> - Plans for emergency water supplies;
> - Communication protocols and strategies, including notification procedures (internal, regulatory body, media and public);
> - Mechanisms for increased public health surveillance;
> - Emergency procedure should be practiced regularly." (Bartram et al., 2009, p. 78)

3.9 Module 9: Developing Supporting Programmes

According to the WSP, "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." (Bartram et al., 2009, p. 83) They are not to be confused with corrective actions as they do not directly affect the drinking water quality.

Supporting programmes will mostly consist of already existent aspects that the drinking water supplier will have established as part of ordinary operation. They can be extensive, diverse and involve a great number of people and organisations.

Supporting programmes may involve controlling access to the catchment and reservoirs, land-use control, staff training in all aspects of development and implementation of the WSP, quality control procedures like internal and external analytical control in laboratories, and research and development programmes for long-term solutions support.

3.9.1 Key Actions

- Identifying the supporting programmes necessary for the implementation of the WSP approach (e.g. training, research and development programmes, activities that indirectly support water safety such as improving quality control in a laboratory, continuing education courses, equipment calibration, preventive maintenance, hygiene and sanitation, or legal aspects);

- Reviewing and, if necessary, revising supporting programmes that are already in place;
- Developing supplementary supporting programmes to focus on removing the gaps in staff knowledge or skills that may hinder the implementation of the WSP in time.

3.9.2 Typical Challenges

- "Human resources;
- Equipment;
- Financial resources;
- Support of management;
- Not identifying procedures and processes as part of the WSP."(Bartram et al., 2009, p. 83)

3.9.3 Outputs

Identifying programmes and activities that guarantee that the WSP approach is enclosed in the operations of the water utility.

3.9.4 Supporting Tools / Examples

Tool / Example 9.1: Reviewing existing programmes (adopted from Tool 9.1 in Bartram et al. (2009))

> It is not always necessary to develop new programmes when developing supporting programmes. Sometimes, revising the currently existing programmes is sufficient to determine the gaps that need to be addressed. Thus, considering updates of existing programmes is of significant importance. All procedures have to be registered and dated, in order to provide the most recent versions to the staff when necessary.

Tool / Example 9.2: Types of supporting programmes that could be included in the WSP (see Tool 9.2 in Bartram et al. (2009))

Programme	Purpose	Examples
Training and awareness	To ensure organization (and contractor) personnel understand water safety and the influence of their actions.	WSP training Competency requirements Induction training Hygiene procedures
Research and development	To support decisions made to improve or maintain water quality.	Understanding potential hazards Research into better indicators of contamination
Calibration	To ensure that critical limit monitoring is reliable and of acceptable accuracy.	Calibration schedules Self-calibrating equipment
Customer complaint protocol	To ensure that customers are responded to if water quality questions are raised.	Call centre Complaints training
Etc.		

3.10 Module 10: Planning and Carrying out Periodic Reviews of the WSP

Besides the regular reviews of the monitoring process, the WSP team needs to meet and review the whole plan and learn from experiences and new procedures. Planning and carrying out review processes is crucial to the whole process of WSP implementation. It is the basis for carrying out future assessments. In case of an emergency, incident, or near miss, it is necessary to reassess the risks and to include them in the improvement / upgrade plan. In a review round the following items should be considered:

- "data collected as part of monitoring processes;
- changes to water sources and catchments;
- changes to treatment, demand and distribution;
- implementation of improvement and upgrade programmes;
- revised procedures;
- emerging hazards and risks." (WHO, 2011, p. 76)

3.10.1 Key Actions

- Keep the WSP up to date
  An up-to date WSP ensures that new risks that may threaten the production and distribution of safe drinking water are assessed and addressed on

a regular basis. Moreover, an updated and appropriate WSP will help to maintain the confidence of the WSP team and stakeholders in the WSP approach.

The following changes may quickly outdate a WSP:

  - "Catchment, treatment and distribution changes and improvement programmes, which can impact on process diagrams and risk assessments;
  - Revised procedures;
  - Staff changes;
  - Stakeholder contact changes." (Bartram et al., 2009, p. 89)

- Convene regular WSP review meetings
  This is necessary in order to review the entire WSP process to ensure that all aspects are still accurate. Input from the local operator or site visits may be required as part of the review. Situations when the WSP should be additionally reviewed, apart from the regular reviews are: development of a new water source, planning and implementation of major treatment improvements, or following a major water quality incident. The date of the following meeting should be established during the regular review meeting.

3.10.2 Typical Challenges

- "Reconvening the WSP team;
- Ensuring continued support for the WSP process;
- Ensuring that where original staff have left the utility, their duties are maintained by others;
- Keeping records of changes;
- Keeping in contact with stakeholders." (Bartram et al., 2009, p. 89)

3.10.3 Outputs

After accomplishing this module, an updated WSP is established which is suitable for the current needs of the water supply utility and stakeholders.

3.10.4 Supporting Tools / Examples

Tool / Example 10.1: When to review the WSP (adopted from Tool 10.1 in Bartram et al. (2009))

> The review of the WSP should be carried out every time a significant change of circumstances or a problem in the water supply chain arises. Additional reviews of the WSP are necessary apart of the regular ones, especially considering the results of the WSP implementation. All the changes following a review should be documented.

Tool / Example 10.2: Example checklist for WSP review (see Tool 10.2 in Bartram et al. (2009))

> - "Notes of last review meeting;
> - Notes of any interim review;
> - Changes to membership of the WSP team;
> - Changes in catchment, treatment, distribution;
> - Review of operational data trends;
> - Validation of new controls;
> - Review of verification;
> - Internal and external audit reports;
> - Stakeholders communication;
> - Date of next review meeting."(Bartram et al., 2009, p. 90)

Tool / Example 10.3: Changes that can affect the WSP (adopted from Tool 10.3 in Bartram et al. (2009))

> In order to avoid unexpected negative results in case of changes, the WSP team should assess in detail all anticipated risks. An updated and adequate WSP plays an important role in predicting risks and avoiding unpredictability in case of changes or incidents which may affect the distribution of safe drinking water.

3.11 Module 11: Revising the WSP Following an Incident

Periodic reviews carried out by the WSP team are very important from the point of view that it may significantly reduce the number of incidents, emergencies or near misses affecting the water quality, and diminish their severity. In case such events still occur, it is substantial to carry out reviews following every emergency, incident or unforeseen event, as this is a new opportunity to identify areas of improvement. Often it is necessary to involve other stakeholders in the review. The WSP team should be always aware of the circumstances and details of all incidents, emergencies, and near misses. In order to ensure this, it is necessary to include corresponding procedures within the WSP.

3.11.1 Key Actions

- "Review the WSP following an incident, emergency or near miss;
- Determine the cause of the incident, emergency or near miss and sufficiency of the response;
- Revise the WSP as necessary, including updates to supporting programmes."

(Bartram et al., 2009, p. 93)

3.11.2 Typical Challenges

- An open and honest evaluation of the reasons, events, and factors that had an influence on the emergency, incident, or near miss situation;
- Turning attention to and responding to the positive lessons learned, instead of assigning guilt.

3.11.3 Outputs

1. Comprehensive and transparent review of the reasons of the incident's occurrence and a competent response from the utility;
2. Documentation of the lessons learned into the WSP.

3.11.4 Supporting Tools / Examples

Tool / Example 11.1: A checklist of questions to be asked following an emergency, incident or near miss (see Tool 11.1 in Bartram et al. (2009))

- "What was the cause of the problem?
- Was the cause a hazard already identified in the WSP risk assessment?
- How was the problem first identified or recognized?
- What were the most essential actions required and were they carried out?
- If relevant, was appropriate and timely action taken to warn consumers and protect their health?
- What communication problems arose and how were they addressed?
- What were the immediate and longer-term consequences of the emergency?
- How can risk assessment / procedures / training / communications be improved?
- How well did the emergency response plan function?"(Bartram et al., 2009, p. 94)

Tool / Example 11.2: Checklist to revise the WSP following an incident, emergency or near miss (see Tool 11.2 in Bartram et al. (2009))

- "Accountabilities and contact details for key personnel, usually including other stakeholders and individuals, are clearly stated;
- Clear definition of trigger levels for incidents including a scale of alert levels (e.g. when an incident is elevated to a boil water alert);
- Review whether the management procedures were appropriate for the incident and if not, revise accordingly;
- Standard operating procedures and required equipment, including back-up equipment, are readily available, and relevant;
- Relevant logistical and technical information is in hand and up to date;
- Checklists and quick reference guides have been prepared and are up to date;
- Does the risk assessment need revising?
- Do procedures / training / communications need improving?
- Has the incident shown the need for an improvement programme?" (Bartram et al., 2009, p. 94)

Chapter 4

General Situation of the Water Supply System in the Republic of Moldova

4.1 Background Geographic Data

The Republic of Moldova (herein also shortly called Moldova) is located in Eastern Europe, bordered by Romania in the West and by Ukraine in the North, East, and South. Moldova has a total area of $33,851\,\text{km}^2$, with $32,891\,\text{km}^2$ land and $960\,\text{km}^2$ water. The capital of Moldova is Chişinău. (CIA, 2012)

The Republic of Moldova has a moderately continental climate, which is characterised by a long frost-free period, mild winters, and hot summers. Its climate is also characterised by little precipitation, thus Moldova has limited, however sufficient, water resources. The average annual precipitation decreases from North to South with modest precipitation in the North and Centre (between $600 - 650\,\text{mm}$) to low precipitation ($500 - 550\,\text{mm}$) and long dry periods in the South and South-East. (Rep. of Moldova Official Website, 2011)

4.2 Hydrographical Network and Water Quality

The hydrographical network of the Republic of Moldova comprises 3621 rivers and rivulets (WaterWiki.net, 2009, 2008). The main rivers are the Dniester (Nistru), Prut, Răut, Cogâlnic, Bâc, and Botna. There are about 60 natural lakes; the largest are Beleu, Dracele, Rotunda, Fontan, Bâc, and Roşu. About 3000 reservoirs with a water capacity exceeding 30 million m^3 exist in the country. Moreover, Moldova has about 2200 natural water springs (Rep. of Moldova

Official Website, 2011).

In a typical year, the total available aquatic resources are 6.3 billion m^3, in a dry year 4.9 billion m^3, and in a severely dry year only 3.4 billion m^3 (WaterWiki.net, 2009, 2008). However, these resources are even in an extremely dry year sufficient to cover the annual need of water for all national economic sectors and for the supply of drinking water. From the total amount of 3.2 billion m^3 of water needed per year, 2 billion m^3 alone are used by the Moldovan thermal Power Plant, and the remaining 1.2 billion m^3 are used in the following way: 63% for agriculture, 15% for household water supply, 14% for industry and 8% for building, transport and other uses (WaterWiki.net, 2009, 2008). The needed water is supplied from the Dniester river (56%), from the Prut river (8%), from small rivers (8%), and from underground resources (20%). This data does not include the phreatic water sources used in rural areas (WaterWiki.net, 2009, 2008). Thus, Moldova does not face problems of overall water scarcity. However, the problem of water quality is significant and it is continuously aggravating. The degradation of water resources is a great concern for Moldova.

4.2.1 Surface Water Resources

The two biggest rivers of Moldova, Dniester and Prut, represent 90% of the overall surface waters in Moldova. Their catchment areas are located in the Ukrainian Carpathians and their waters, passing through Moldova, discharge into the Danube Delta and Dniester Liman which are located on Romanian and Ukrainian territories and are areas classified as "sensitive environments of European significance" (WaterWiki.net, 2009, 2008). After the Soviet Union had collapsed and after the Republic of Moldova had acquired independence, the Moldovan economic activity slowed down, resulting in a stabilisation of the level of pollution on the territory of the country. (EAP Task Force, 2008) However, even though the quality of waters reaching the territory of Moldova is classified as relatively good, the water quality of the Dniester and the Prut rivers within the country deteriorates to moderately polluted waters, with highly polluted classification in industrial areas (WaterWiki.net, 2009, 2008). As the water in the existing Moldovan lakes is usually highly mineralised with high salinity and shows increased eutrophication levels, the use of surface water resources for drinking water supply is largely limited to the use of water from the Dniester and Prut rivers (EAP Task Force, 2008). In 2002, the water supplied from the Dniester and the Prut rivers represented a third of the total drinking water supply in Moldova, serving mainly the urban population. From this water, up to 20% is used by the food processing industry even though the national Ministry of Health states that

25–50% of the analysed samples from the Dniester and Prut rivers do not comply with the national quality standards for drinking water quality. In both rivers, in 2003, the contents of heavy metals, ammonium, and nitrates exceeded the limits by 5 to 18 times. (WaterWiki.net, 2009, 2008)

4.2.2 Groundwater Resources

Table A.1 (in the Appendix, p. 126) presents the basic characteristics of the main aquifers existing in the Republic of Moldova (EAP Task Force, 2008, p. 24).

Deep Groundwater Resources

Groundwater resources are commonly used for drinking water supply in Moldova. Especially the resources of the Lower Baden Sarmat are being exploited. However, their natural recharge capacity is finite, thus exploitation has to be limited to the natural capacity of recharge to avoid over-exploitation. (EAP Task Force, 2008)

According to EAP Task Force (2008), the use of the groundwater for the purpose of water supply poses the following problems:

- High investment costs connected to the construction of the deep boreholes, and high pumping costs;
- Relatively low yields;
- Treatment requirements, due to the poor water quality;
- The necessity to reduce the over-exploitation of deep aquifers;
- High content of fluoride, which is difficult to be removed. (EAP Task Force, 2008)

Shallow Groundwater Resources

The abstraction of the shallow groundwater is a commonly used method for supplying the needed quantities of water in Moldova, especially in small- to medium-sized towns and rural areas. Shallow groundwater resources can be found all over the country, although not evenly spread, and are fed from the infiltration of precipitation into the ground. The infiltration capacity of precipitation is limited to the recharge capacity of the wells, which depends on the precipitation/evaporation ratio and local conditions. The main water reserves are located in the vicinity of the Dniester and Prut Rivers' underlying aquifers. They yield about $5 - 15\,\mathrm{m^3/h}$, whereas they are being fed by the infiltration of river water and the water from flood plains. The usual recharge potential of shallow groundwater wells all over the country is below 0.5 m^3/h, which in most cases satisfies the needed quantity of water when abstracted via manual methods. (EAP Task Force, 2008)

4.2.3 Groundwater Quality

One of the most important problems in the deep groundwater's quality is the presence of high mineral levels, which in some regions are close to or exceed the maximum admissible concentration levels for drinking water. According to EAP Task Force (2008), "[f]luoride levels often reach $8 - 10$ mg/l, which is many times higher than the WHO guideline limit of 1.5 mg/l". The problem of high fluoride content in drinking water is of significant importance, as it causes serious health issues and it is difficult to be removed. The high levels of fluoride and selenium are rather connected to the soil and its geological characteristics than to human activity. (EAP Task Force, 2008) A study on the Quality of Rural Drinking Water assisted by the World Bank, showed that from 110 shallow-water wells and deep boreholes, "more than 90% had at least one chemical constituent that exceeded the national drinking-water quality standards, and that most wells had at least two chemicals constituents exceeding the standards". The main problems were: hardness (90%), Total Dissolved Solids (TDS) (65%), nitrates and sulphates (55%), selenium (40%), fluoride (15%), and chloride (10%). More than 80% of the tested wells proved to have positive and high concentrations of E. Coli. (EAP Task Force, 2008). The analysis showed a deep relationship between groundwater quality and land-use. Human activity has a great impact on the quality and quantity of the surface and groundwater. Typical main sources of water pollution are urban and rural wastewater, agricultural activity, and spills from inappropriate warehousing and dangerous chemicals, especially fertilisers and pesticides (WaterWiki.net, 2009, 2008). Around residential areas, the water has high concentrations of TDS, nitrates, sulphates, chlorides, and bacteria. The impact of agriculture is not as strong as of residential areas, and there were no considerable amounts of pesticides found in the samples. (EAP Task Force, 2008)

4.2.4 Access of Population to Drinking Water

As stated in Bernardini et al. (2011), the population of Moldova has only limited access to water supplies and sanitations, especially in rural areas. According to data from the National Scientific-Practical Centre of Preventive Medicine, 47% of the Moldavian population had no access to safe drinking water and 54.8%

of the population had no water piped to the household in 2008. The situation concerning the access differs notably by residence and also in territorial profile. 83.7% of population in rural areas compared to 15.3% of that in urban areas had no water pipe in the household. The smallest share of population connected to the water pipe to the household is located in the centre region of Moldova (72.3%). (ApaSan, 2010) As already stated above, the usual source of drinking water for the population lacking water piping to the household are shallow-water wells.

The wastewater sewage systems and treatment facilities in most regions of Moldova are either not existent or in poor, technically degraded conditions (Bernardini et al., 2011). Only urban areas are equipped with wastewater treatment systems. In rural areas mostly pit latrines are installed. Figure 4.1 gives an impression on the water supply and sanitation access in rural areas. (ApaSan, 2010)

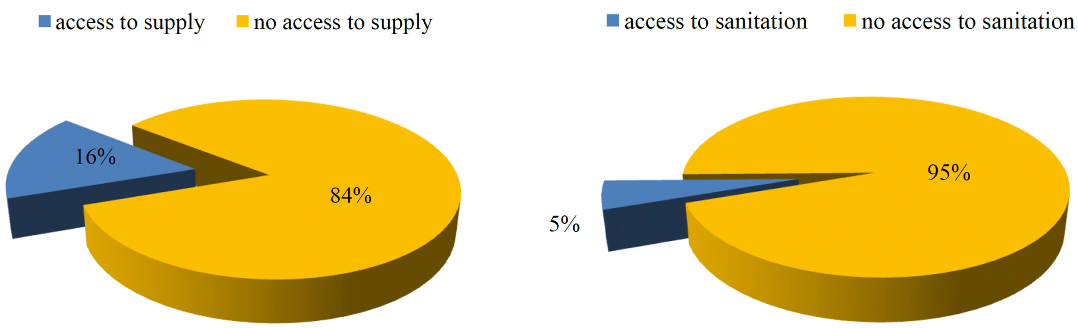


Figure 4.1: Situation in rural areas: Access to water supply (left) and sanitation (right)

4.2.5 Water Infrastructure Projects

Moldova's state budget cannot afford to appropriately cover the water sector's investment needs. Financial allocations meant to improve the infrastructure were insignificant and were often politically biased. However, the situation concerning foreign investments improved in the last years. The Moldovan Government took measures to attract foreign investments and agreements were concluded concerning financial support, with priority given to water-sector related activities. Some of the agreements were signed between the Government of the Republic of Moldova and the European Commission and were part of the European Neighbourhood Policy. Another agreement was signed with the Millennium Challenge Corporation. (ApaSan, 2010)

In the last decade, a number of projects were initiated to improve the Moldovan water sector infrastructure. At the beginning of 2010, a Sector Coordination Council (SCC) was established for the "Environment, Water and Sanitation" sector. "The SCC was meant to be a platform for harmonization and coordination amongst the development partner community and the government, as well as a platform for dialog in reaching consensus on key policy areas within the sector." (Ministry of Environment, 2010a)

According to `apelemoldovei.org` the main donors in the water supply and sanitation (WSS) sector in Moldova are the following (Ministry of Environment, 2010a):

The goals of the agreement signed by the Government of Moldova and the Millennium Challenges Corporation in 2010 are the "improvement of existing irrigation infrastructure, to ensure sustainable access to water resources to facilitate increased agricultural productivity and comprehensive incomes" (Ministry of Environment, 2010a). The allocation amounts 102 million USD (69.5 million EUR[1]).

Another agreement of the Government of Moldova in this area was signed with the European Commission in 2009. The agreement was concluded on the Sector Policy Support Programme and its scope is to enhance the efforts done in the water supply and sewage sector. The total possible amount agreed upon was 45 million EUR. (Ministry of Environment, 2010a)

The World Bank provided Moldova with a loan of 14 million USD (9.5 million EUR[1]) under the National Water Supply and Sanitation Programme, which aims to improve and develop the water supply and sewage systems. The World Bank also contributes to the implementation of other projects in the WSS sectors funded by other donors, such as the Global Environment Fund and European Commission. As part of the Social Investment Fund Project, the World Bank participates in the WSS infrastructure development. (Ministry of Environment, 2010a)

Besides an ongoing project at the "Apă-Canal" Chişinău(Apă-Canal Chişinău) (the municipal company providing the city of Chişinău's residents with water), the European Bank for Reconstruction and Development (EBRD) provided a loan of 10 million EUR to co-finance a WSS infrastructure development programme, alongside the European Investment Bank and the EU's Neighbourhood Investment Facility, each providing a loan of 10 million EUR (thus the total volume of the programme is 30 million EUR). At the end of this project, the beneficiaries will be the residents of six localities. The aim of the project is to improve and

[1]exchange rate: 1 EUR = 1.46777 USD per 7th June 2011, www.xe.com/ucc

extend the water and wastewater systems in these towns, and particularly to regionalise the water services and create regional water companies which would expand their operations in neighbourhood localities. Another important purpose of the programme is to support the participating municipal utilities in providing adequate drinking water and developing wastewater treatment facilities with the scope to improve the state of the Dniester and Prut rivers and ultimately the Black Sea. (EBRD, Projects, 2010; EBRD, News, 2010)

The city of Ciadir-Lunga obtained a grant of 6.56 million USD (4.47 million EUR[1]) allocated by the Turkish Administration for Cooperation and Development (TICA). The grant was given to assist a drinking water supply project. (Ministry of Environment, 2010a)

The Swiss Agency for Development and Cooperation (SDC) started its activity in Moldova in 2000, investing around 1 million EUR every year to develop and improve the WSS infrastructure in a number of localities of the country, especially focusing on rural areas. At present the activity of direct implementation of the projects is taken over by Swiss Resource Centre and Consultancies for Development. The new methods for solving the WSS issues in rural Moldova consist of building Ecosan institutional and domestic sanitation facilities and the Constructed Wetlands for wastewater treatment. (ApaSan, 2010)

The Austrian Development Agency (ADA) accomplished a number of projects jointly with the SDC, as the areas of interest of the two institutions coincide. The ADA made significant efforts in the improvement of the WSS sector of Moldova. (Ministry of Environment, 2010a)

The Kuwait Fund for Arab Economic Development (KFAED) gave a loan of 1.9 million KWD (4.72 million EUR[2]) to six Moldovan regions for the improvement of the water supply systems. (Kuwait Fund)

The Czech Republic has assisted Moldova with around 900 thousand EUR per year in development project aiming to protect the water catchment sources, to construct wastewater treatment plants, and systematically monitoring the quality of water sources. (Ministry of Environment, 2010a)

The OECD/ADA/CzDA/EUWI project was a project on "[s]upporting the Development of an Investment/Action Plan to Help Implement the New Strategy of the Government of Moldova for Water Supply and Sanitation". The project was supported by the Organisation for Economic Cooperation and Development (OECD), ADA, the Czech Republic Development Cooperation, and the EU Water Initiative (EUWI). (Ministry of Environment, 2010b) According to the terms of reference released by the OECD, "[t]he overall objective of this project is to

[2]exchange rate: 1 EUR = 0.402662 KWD per 7th June 2011, www.xe.com/ucc

strengthen the capacity of the Government of Moldova to plan and implement prioritised viable WSS infrastructure investments, to mobilise and effectively allocate financial resources for reaching water-related Millennium Development Goals, while ensuring that WSS services are affordable for the population." (OECD, 2008)

The project was originally planned to be implemented in the period of November 2009 to April 2011 (Ministry of Environment, 2010b). According to the involved consulting agency `publicconsulting.at`, the due date was extended to October 31, 2011. The budget of the project amounted to 160,000 EUR (Wiltschnigg, 2011).

Chapter 5

Water Supply and Sanitation System of the City of Teleneşti

The following chapter focuses on the city of Teleneşti in Moldova. An overview on its geographic and socio-economic features is given, and detailed information on its aquatic resources are collected and presented. This data forms the basis for the next chapter's preparative analysis towards a WSP implementation in the city.

5.1 Introduction to the City of Teleneşti

The city of Teleneşti is situated in the central part of the Republic of Moldova, on the right shore of the Ciuluc Mic rivulet, located 93 km to the North of the capital Chişinău. It occupies land area of steppe and river meadows of the rivers Răut, Ciuluc Mare, and Ciuluc Mic. (Nastas, 2010).

The city is the administrative centre of the Teleneşti district, a small district having 23 surrounding villages and 30 commons under its administration, see Fig. 5.1 (Wikipedia, 2012).

The current official statistic data results of 2011 state that Teleneşti has a population of 8200 (Telenesti Demographic Statistics, 2011). The total surface of the city of Teleneşti within the built-up area is 506.59 ha. The distribution of land is shown in Fig. 5.2 (Nastas, 2010).

Figure A.1 (in the Appendix, p. 127) shows the map of Teleneşti according to functional zones (see Teleneşti City Council (2006)).

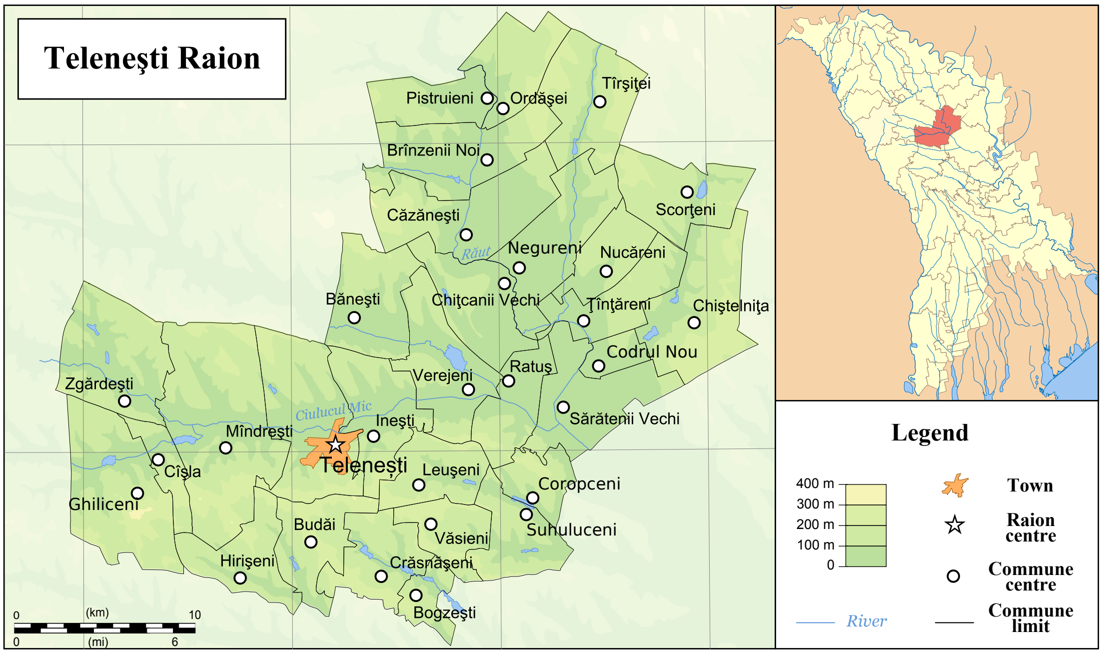


Figure 5.1: Map of Teleneşti district (Wikipedia, 2012)

	Purpose	Surface, ha
1	Residential	272.80
2	Industrial	55.01
3	Transportation and Services	26.83
4	Agricultural use	46.24
5	Streets and Roads	68.52
6	Green	37.19
	Total	506.59

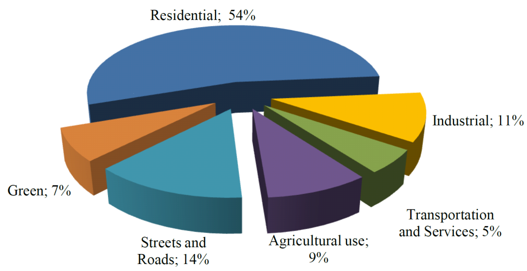


Figure 5.2: Teleneşti land distribution

5.2 Agriculture and Forestry

The total surface of agricultural land associated to the city of Teleneşti is 4693.47 ha, which includes annual plantations (sunflower, corn, grain, potato, etc.), perennial plantations (especially orchards of plum trees and vineyards), as well as grasslands and hay fields, see Fig. 5.3. The agricultural land is located mainly in the South and South-West parts of the town. (Nastas, 2010)

The area of forests belonging to the city of Teleneşti amounts to 10,527 ha and includes natural reservations, green areas, protected areas along the river, protected areas along the streets, and soil-protected areas. (Nastas, 2010)

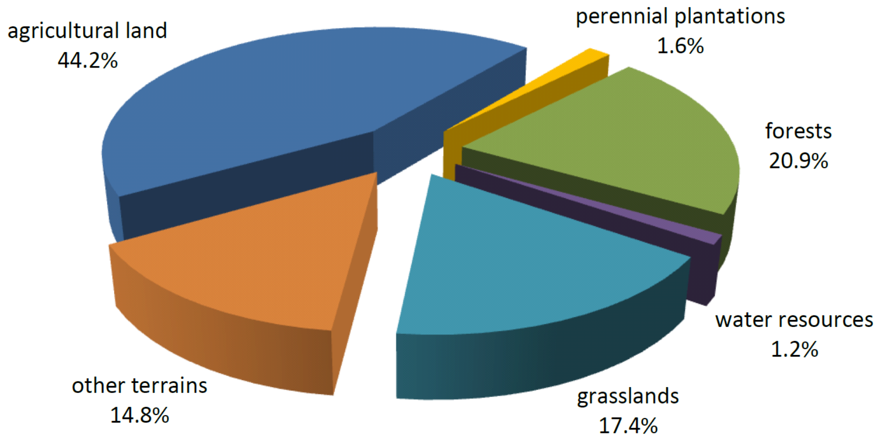


Figure 5.3: Land resources (Nastas, 2010)

5.3 The Socio-Economic Activity

The industrial sector of Teleneşti town is poorly developed, it amounts to only 6% of the total industry of the Teleneşti district. The industrial area of Teleneşti is situated in the North part along the Ciuluc rivulet. The industrial activity is dominated by food production (mills, bakeries, oil mills). (Nastas, 2010)

There are 17 industrial units in the city of Teleneşti from which 15 belong to the food and beverage industry (wineries - 1 unit, processing the agricultural production - 1 unit, mills - 2 units, oil-mills - 2 units, bakeries - 3 units, others - 6 units), and 2 units belong to the light industry (textile, clothing, leather and shoe-industry). (Anton, 2010) Other types of economic / business units are shown in Tab. 5.1 (Anton, 2010). Figure A.2 (in the Appendix, p. 128) presents the map of socio-economic development of Teleneşti.

Table 5.1: Economic / business units in Teleneşti (Anton, 2010)

	Type	Total number	Number
1	Construction enterprises	10	
2	Commerce:	118	
	– stores		96
	– bars, cafés, cafeterias		17
	– fuelling stations		4
3	Trading of plant and animal production		1
4	Services	32	
	– transportation services		8
	– car repair service		6
	– household appliances repair services		2
	– others		7
5	Car technology station	1	
6	Business support infrastructure	9	
	– commercial banks		5
	– savings and loan associations		1
	– consulting and training centres		2
	– Chambers of Commerce and Industry		1

5.4 Aquatic Resources

The average annual precipitations in the city of Teleneşti are 483 mm, from which 101 mm occur in the warm period and 382 mm in the cold period. (Nastas, 2010) The hydrogeological features of the area of Teleneşti are depicted in the map in Fig. A.3 (in the Appendix, p. 129).

The water resources have a surface of more than 54 ha, including 7 lakes and the Ciuluc rivulet. There are 37 artesian wells in the town, from which 4 are exploited by the municipal water supply company DP "Apă-Canal", 14 are either in private possession of economic/business units or are exploited by the population not connected to the central water supply system of "Apă-Canal" (Levcenco, 2011a), and the remaining 19 wells are not used or conserved. Besides the centralised water-supply system the local population is used to abstract water from the local shallow-water wells. The total number of shallow-water wells in the city is 273, from which 263 are used for drinking water purposes (Anton, 2010). Often, these wells are located close to residential areas in the town. In some small outskirts of the city, nearly each household has a shallow-water well in its yard from which water is abstracted for drinking water purposes.

The central water supply and sanitation systems are managed by the municipal water supply company "Apă-Canal". The number of households connected to the water supply system is 1953 (Levcenco, 2012c) out of 2750 households existing in the town. (Anton, 2010) However, only 1383 use the services of "Apă-Canal" due to the reason that the rest of households are currently uninhabited (Levcenco, 2012c).

5.4.1 Artesian Wells' Location and Depth

Out of 37 artesian wells existing in Teleneşti, 15 are in the possession of the municipal water supply company "Apă-Canal" and the remaining 22 belong either to business units or to small outskirts of the city of Teleneşti supplying the local population (Levcenco, 2011b). Only 4 of 15 artesian wells under the possession of "Apă-Canal" are exploited and the other 11 are conserved. The 4 functioning wells provide a sufficient water quantity to supply the population connected to the water supply system as well as business units with the demanded amount of water 24 hours a day, 7 days a week. (Levcenco, 2011a) The 4 exploited wells are labelled by the numbers 1, 2, 14, and 15 (Apă-Canal, 2011) in the available maps and also in this work. Wells 1 and 2 are located in the city centre. Well 14 is located in the South-West, and well 15 is located in the South-East in the Old Teleneşti outskirt. Topographical survey data on the exact locations of the 4 wells is not available. Figure A.4 (in the Appendix, p. 130) presents the map of Teleneşti were the location of the existing wells and the distribution system are shown. Ten of the conserved wells are located in the North part of the city of Teleneşti town in the Ciuluc rivulet valley, and one is in the centre of the city in the vicinity of the Police Office. (Levcenco, 2011a)

The depth of the ten conserved wells placed in the Ciuluc rivulet valley is 80 m. Of the 4 exploited wells, wells 1, 2 and 15 are 103 m deep, well 14 is 125 m deep. (Levcenco, 2011a)

5.4.2 Structure of the Water Supply System

The water supply system consists of the four functioning wells, two reservoirs, and the distribution system. The volume of the two reservoirs is 600 m^3 and 300 m^3, respectively. The two reservoirs are intended to function in shifts or whenever one is dysfunctional. However, at the moment the reservoir with the capacity of 300 m^3 reservoir is out of order and the other is in permanent use. The total length of the water pipeline network is 23.7 km (Levcenco, 2011a) with 30 water distribution pipelines. (Apă-Canal, 2011)

5.4.3 Water Flow

A simplified representation of the water flow is depicted in Fig. 5.4.

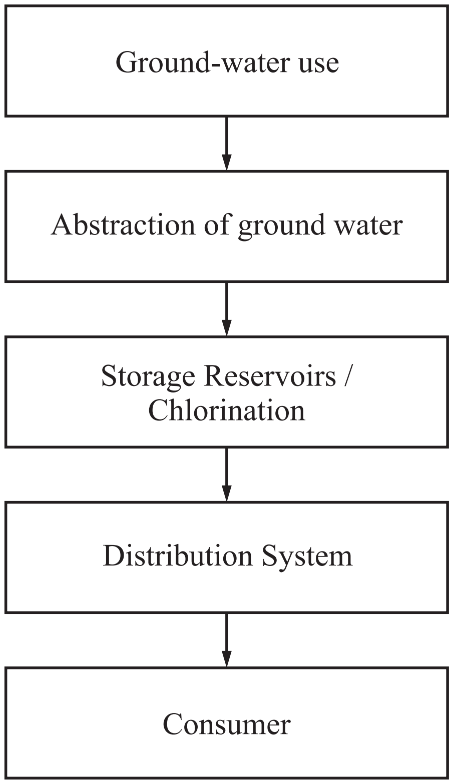


Figure 5.4: Simplified schematic representation of the water flow within the Teleneşti water supply system

The water from the 4 exploited artesian wells is distributed in different ways. Water from wells 1 and 2 is pumped uphill into the 600 m^3 reservoir. There the water is treated by chlorination and flows through the distribution system by gravity to the consumer. Water from wells 14 and 15 is collected in their buffer tanks and flows through the distribution system to the consumers without treatment. (Levcenco, 2012c) In 2012, it is planned to connect the water supply network of the wells 14 and 15 to the water supply network of wells 1 and 2 and to pump the water from wells 14 and 15 to the two existing reservoirs, where the water will be chlorinated before being distributed to the consumers. (Levcenco, 2012d) The maximum water flow rate, if all 15 wells of "Apă-Canal" were to be exploited, would be 2600 $^{m^3}/_{24h}$. The maximum water flow rate from the 4 exploited wells is 1008 $^{m^3}/_{24h}$. However, the quantity of water actually used is only 430 $^{m^3}/_{24h}$. (Levcenco, 2011a)

The total amount of water abstracted in 2011 was 163, 700 m^3, from which 65, 780 m^3 was allocated to the consumers: 52, 700 m^3 to the population, and 13, 080 m^3 to business units, public organisations together with schools and kindergartens. For technical processes done once a year, namely washing the reservoirs and the distribution system, 5002 m^3 water were used. Losses and unregistered or illegal use amounted to 92, 900 m^3 (57%), and "Apă-Canal" suspects unregistered/illegal use be a major constituent of this figure. (Levcenco, 2012c) Partially, however, the losses of water are caused by the overaged distribution system and corresponding supply line losses. In 2010, 100 incidents with loss of water were registered, from which 24 occurred within the central water pipeline of "Apă-Canal", 11 occurred within the pipelines of public organisations and business units, and 65 occurred in household water pipelines. (Levcenco, 2011a)

5.4.4 Bookkeeping and Water Pricing

There are four water meters, one at each of the four functioning wells counting the amount of abstracted water. The data on the amount of abstracted water is collected at the beginning of every month in "Apă-Canal"'s register. The bookkeeping of business units' water use is carried out at a rate of 100% through the installed water meters at each business unit. (Levcenco, 2011a) The total number of water meters at the households' water pipelines is 1350 out of 1953 households connected to the water supply facility. (Levcenco, 2012c)

The water price is 10 MDL/m³ (0.64 EUR/m³)[1] for the population and 35 MDL/m³ (2.24 EUR/m³)[2] for public organisations and business units. The price for sewerage and wastewater treatment is 9.15 MDL/m³ (0.60 EUR/m³)[3] for the population and 26 MDL/m³ (1.66 EUR/m³)[4] for public organisations and business units. The current water tariffs were approved by the City Council at 1st of November 2008. For those households which do not have a water meter installed, certain rules approved by the City Mayoralty apply:

- For water supply and sanitation, 150 l/24h·person are to be charged.
- In case the water is supplied according to a schedule (not all 24 hours), 130 l/24h·person are charged.
- In case the household is connected only to the water supply facility (no sanitation) 120 l/24h are charged.
- If only supply according to a schedule (no sanitation) is performed, 100 l/24h are charged. (Levcenco, 2011a)

[1]http://www.xe.com/ucc/convert/?Amount=10&From=MDL&To=EUR by 21.02.2012
[2]http://www.xe.com/ucc/convert/?Amount=35&From=MDL&To=EUR by 21.02.2012
[3]http://www.xe.com/ucc/convert/?Amount=915&From=MDL&To=EUR by 21.02.2012
[4]http://www.xe.com/ucc/convert/?Amount=26&From=MDL&To=EUR by 21.02.2012

5.4.5 Materials in Contact with Water

The water pipelines (with a total length of 23.7 km) are made of cast iron (1.3 km), steel (3.7 km), and polyethylene (18.7 km). The expected operating life of cast iron pipelines is 40 years, for pipelines made of steel - 15 years, and for those of polyethylene - 18 years. (Levcenco, 2012a) The durability of cast iron water pipelines is very high, leading to practically no failures. Due to their long lifespan, they represent the oldest pipelines in the system: 0.1 km are 50-60 years old, the remaining 1.2 km are 60 years or older. (Levcenco, 2011a)

The length of the water pipelines network made of steel of up to 10 years use is of 1 km, steel of 10 up to 20 years use - 1.4 km, 30 up to 40 years use - 0.7 km, and 50 up to 60 years use - 0.6 km. The condition of the steel water pipeline network aged more than 10 years is unsatisfactory.

The water pipelines network made of polyethylene is younger than 10 years and is 18.7 km long. The condition of the polyethylene water pipeline network is very good. (Levcenco, 2011a)

The two existing reservoirs are made of reinforced concrete and the buffer tanks of wells 14 and 15 are made of steel. (Levcenco, 2011a, 2012a)

5.4.6 The Process of Monitoring the Quality of Water

Water samples of the artesian wells are collected once a year, from the reservoirs once a month, and from the water pipelines 2 times/month (Levcenco, 2012c). The following water quality indicators are tested: odour, taste, transparency, turbidity, hardness, suspended solids, pH value, ammonium (NH_4), nitrite (NO_2), nitrate (NO_3), sulphate (SO_4), chlorides (Cl), copper (Cu), iron (Fe), manganese (Mn), as well as contamination with E. Coli and Enterococci bacteria, see Tables A.2–A.8 (in the Appendix, p. 134–140). (Apă-Canal, 2011)

The quality of water of the whole city of Teleneşti is considered to be rather of technical quality than of drinking water quality. However, nationally it mostly complies with the quality standards of the Republic of Moldova, with the exception of the ammonium (NH_4) amount. (Levcenco, 2011a) The national limit for ammonium is 0.5 mg/dm³, but this value is exceeded by up to 16 times in the four exploited wells. (Apă-Canal, 2011)

Tables A.2–A.8 in the Appendix show the water quality results of the analysis carried out in 2010 and early 2011. The results of the analysis carried out in 2011 show no significant changes. One time the water quality results showed higher values of Enterococci bacteria (5/100ml), and two times levels of 1/100ml of E. Coli bacteria were detected. The values of NH_4 stayed high, namely 5.5 –

6.44 $^{mg}/_{dm^3}$ in the wells, 4.6 − 5.8 $^{mg}/_{dm^3}$ in the reservoirs, and 1.5 − 4.9 $^{mg}/_{dm^3}$ in the distribution system. The microbial values rise presumably in case of damages at the level of the distribution network. (Levcenco, 2012c) Changes in the water quality as a result of weather conditions were not observed in the last 20 years in which 2 floodings have taken place in the town. (Levcenco, 2011b)

5.4.7 Sanitation

The municipal water supply company "Apă-Canal" is also in charge of the sanitation. Out of 2750 households existing in the town (Anton, 2010), 1002 households (36.4%) are connected to the sanitation system of "Apă-Canal". (Levcenco, 2012c) The rest of the households typically have pit latrines installed in the yards which, to the author's knowledge, generally are not constructed in a way to prevent leaching of wastewater into the ground.

Figure A.5 (in the Appendix, p. 131) shows a map of the sanitation system of Teleneşti.

Wastewater Treatment Plant

The capacity of the wastewater treatment plant (see Fig. 5.5) is 3100 $^{m^3}/_{24h}$. For the year 2010 the average volume inflow of wastewater was 230 $^{m^3}/_{24h}$ (83, 100 m^3 for the whole year). The total length of the sewerage pipe network is 7.7 km. (Levcenco, 2011a)

Figure 5.5 is a schematic representation of the infrastructure of the wastewater treatment plant. However, the current technical condition of the wastewater treatment plant is very poor. Thus, the wastewater flow is as follows: The wastewater flows through the sewerage pipelines to the pumping station (not represented in the figure) and from there it is pumped to the inlet chamber (1). From the inlet chamber it flows directly to the anaerobic stabilisation pond (8) where mainly the sedimentation of solids takes place. All other steps in the way are avoided because the installations are dysfunctional. After the anaerobic stabilisation pond, the wastewater flows directly into the Ciuluc rivulet. The only actual treatment consists of minimal oxygen enrichment during the flow of the wastewater to the anaerobic stabilisation pond and from there into the river.

The plan does not show the canals through which the wastewater flows into the Ciuluc mic river, thus the exact location of these canals is not known.

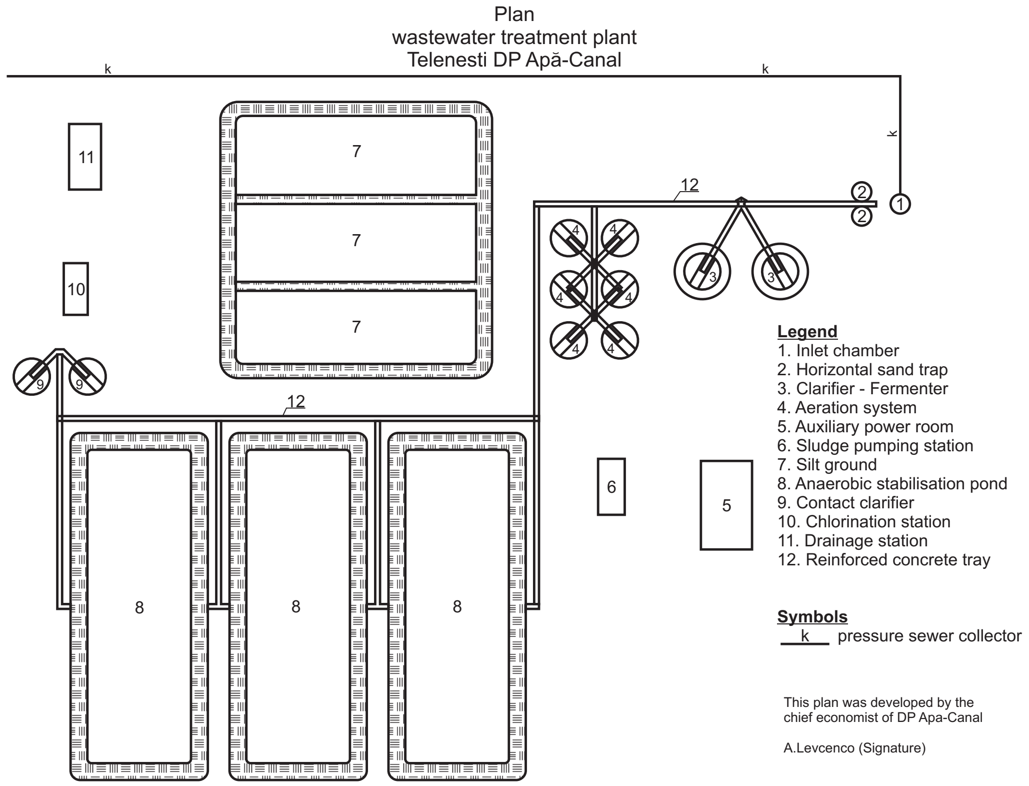


Figure 5.5: Schematic plan of wastewater treatment plant (Levcenco)

5.4.8 DP "Apa Canal" - Structure and Operating Figures

The municipal water supply company "Apă-Canal" employs 30 people. The organisational structure of "Apă-Canal" is listed in Tab. 5.2. (Levcenco, 2011b)

The total revenue for the year 2010 was 1,702,000 MDL (107,536 EUR)[5] and the costs amounted to 1,744,000 MDL (110,180 EUR)[6], yielding losses of 42,000 MDL (2651 EUR)[7]. Water-related revenues were 911,000 MDL (57,493 EUR)[8], opposed to water-related costs of 961,000 MDL (60,648 EUR)[9], so water-related losses of 50,000 MDL (3156 EUR))[10] were incurred. (Levcenco, 2011a)

[5] http://www.xe.com/ucc/convert/?Amount=1702000+&From=MDL&To=EUR
[6] http://www.xe.com/ucc/convert/?Amount=1744000&From=MDL&To=EUR
[7] http://www.xe.com/ucc/convert/?Amount=42000+&From=MDL&To=EUR
[8] http://www.xe.com/ucc/convert/?Amount=911000+&From=MDL&To=EUR
[9] http://www.xe.com/ucc/convert/?Amount=961000+&From=MDL&To=EUR
[10] http://www.xe.com/ucc/convert/?Amount=50000+&From=MDL&To=EUR

Table 5.2: Organisational structure of “Apă-Canal”

Job title	**No. of persons employed**
Director	**1**
Chief engineer	**1**
Chief economist	**1**
Chief accountant	**1**
Accountants	**2**
Master of electrical division	**1**
Electrical engineer	**1**
Master of water supply and sanitation division	**1**
Water supply division	**13**
Control officers	2
Accidents and recovery locksmith	2
Pumping station machinist	1
Electric and gas welder	1
Guardian at the pumping station	1
Guardians at the reservoirs	4
Machinist excavator	1
Tractor driver	1
Sanitation division	**8**
Control officer	1
Accidents and recovery locksmith	1
Pumping station and wastewater rreatment plant machinist	4
Assenisation machine driver	1
Assenisation machine labourer	1
Total	**30**

5.4.9 Potential Sources of Pollution of Water Resources

The potential sources of pollution of water resources in the city of Teleneşti are the 3 petrol filling stations, 1 winery (Roşca, 2010a) which is lacking a wastewater treatment facility (Roşca, 2010b), the asphalt plant SA “Drumuri”, one poultry factory, and the wastewater treatment plant belonging to the municipal water supply company “Apă-Canal”. Other sources of pollution of water resources are leaching content from the landfills, common use of pit latrines, various deposits from livestock farms, widespread livestock keeping, and other active enterprises. (Roşca, 2010a)

Figures A.6 and A.7 (in the Appendix, p. 132 and 133) show the polluted zones and the waste disposal sites of Teleneşti, respectively.

There is only one wastewater treatment plant in the town belonging to the municipal water supply company DP "Apă-Canal" of type BIO 3100 with a capacity of 3100 m^3/day. The station was built in 1974 and is in operation since 1984. Because of its prolonged operation without maintenance and renovation works, the ficility is in a poor technical condition. Thus, the wastewater is insufficiently treated due to the damaged equipment and the sewage flows directly into the Ciuluc river with nearly no prior treatment. (Roşca, 2010a) During 2010, 83, 100 m^3 of insufficiently treated sewage were disposed this way. (Levcenco, 2011a)

5.4.10 Wastewater Monitoring

During 2010 the wastewater monitoring was carried out according to a wastewater monitoring contract and schedule by the *Center of Ecological Investigations Bălţi* (Roşca, 2010a). The results of the laboratory investigations carried out each quarter of the year as well as the annual average results show that the average efficiency of wastewater treatment is unsatisfactory, see Tab. 5.3.

Table 5.3: Wastewater treatment efficiency 2010 (Roşca, 2010a)

Component	**Efficiency of treatment**
Suspended Solids	73.7 %
Chemical Oxygen Demand (COD)	45.2 %
Biochemical Oxygen Demand (BOD5)	71.2 %
Ammonium (NH_4)	41.2 %

The discharge of untreated or insufficiently treated wastewater leads to the contamination of the Ciuluc Mic river and its surroundings with microbial pathogens, which is the cause of frequent acute intestinal infections among the local population. The Ciuluc Mic rivulet has a small water volume and slow flux, thus having a low capacity of self-purification. Therefore, the groundwater resources and especially shallow water sources in its vicinity are of low quality. The groundwater in the protected area of the Ciuluc Mic rivulet shows high concentrations of ammonium and nitrates. Besides the wastewater treatment plant, other sources of these substances are the polluted surface soil, the discharge of the wastewaters from livestock units, and insufficiently secured landfills of industrial and household waste. The lack of river buffer strips is also contributing to intensive pollution of aquatic sources. (Nastas, 2010)

The financial sources allocated for the restoration of the wastewater treatment plant are not sufficient to achieve the local normative parameters of wastewater treatment. To restore the treatment plant to work efficiently, about 17 million MDL (1.13 million EUR) are needed. (Roşca, 2010a)

A new United Nations Development Programme project on the construction of a new wastewater treatment plant is planned to be prepared until the end of 2012, after which investors will have to be found. The cost of the project itself is amounts to 37,000 USD (27,489 EUR)[11]. The new wastewater treatment plant is planned to be constructed in a new place and is intended to provide all necessary facilities for adequate wastewater treatment. The project also includes to connect those households to the sanitation system which do not yet have access. (Levcenco, 2012d)

Today the aquatic sources are less predisposed to pollution from dejections and discharges from livestock units than in the 1980s, because many units ceased their activity. The livestock sector's infrastructure is located in the Northern part of Teleneşti: slaughter-house (North), fish farming (North-West), dairy-products point collection (S.A. Incomlac, North-East). The water quality, however, did not improve significantly in its chemical and microbial pollution parameters since then. It is common for the local population to keep a significant number of poultry and sometimes cattle and swine inside the city, see Tab. 5.4. This is a significant source of water pollution, as the method of keeping the livestock by population does not correspond to the local ecological and sanitation requirements. (Nastas, 2010)

Table 5.4: Livestock kept by population (Anton, 2010)

Type of livestock	**Number**
Cattle	371
Swine	515
Ovine and caprine	1460
Horses	106
Poultry	10620

Furthermore, the common use of pit latrines in some districts of the town, where a significant number of households are not connected to the sanitation system, contribute as well considerably to water pollution. Shallow-water wells are prone to microbial contamination due to pit latrines. (Melian et al., 1999) In 2010, samples of water from 11 selected public shallow-water wells were taken and examined. From these samples, 100% did not comply with the national targets for nitrates, 50% violated hardness limits, and 15% exceeded suspended solids limits. With respect to microbial values, 2 of 11 samples showed contents of E. Coli. As a consequence of these results, 200 of 350 shallow-water wells were disinfected. (Apă-Canal, 2011)

[11] http://www.xe.com/ucc/convert/?Amount=37000&From=USD&To=EUR

Chapter 6

Towards the Application of a WSP in the City of Teleneşti: Modules and Recommendations

For each WSP module (see Chap. 3), a short overview is given, followed by related facts on the situation in the city of Teleneşti. Finally, specific problems are identified and related recommendations are elaborated.

6.1 Module 1: Assembling a WSP team

The goal of this module is to assemble an experienced, multidisciplinary team, which will be able to understand every component of the system and assess all associated risks. (Bartram et al., 2009)

It is recommended that the process of development, implementation and maintenance of a Water Safety Plan is guided by a WSP team formed of members with different professional background. This is important in order to guarantee that the water safety plan will consider technical, financial and social issues. In many cases small utilities do not possess internal water quality experts. Thus, it might be necessary for the operators and management team to bring in external experts in health and water quality from agencies, such as the department of health, engineering and sanitation or natural resources or consultants in these fields. (Bartram et al., 2009)

A list of required skills is of significant use when selecting the WSP team (for an example see Sec. 3.1, Tool / Example 1.1, p. 14). The most important required skills in the qualification of the WSP team members are: sufficient experience and expertise in the field of water supply, such as water abstraction, treatment, distribution, identifying hazards that may affect the quality and safety of water at each point of the water supply system and possessing understanding for the means of controlling them. (Bartram et al., 2009)

6.1.1 Facts

Technical and financial experts for the specific situation of Teleneşti's water supply and sanitation system are available within the municipal water supply company "Apă-Canal", see Tab. 5.2, p. 78. While they could form the core of the WSP team, the social and regional aspects are not yet included.

6.1.2 Problems and Recommendations

- As the Teleneşti's water supply unit is rather a small utility unit, the personnel available may not be enough to cover all the WSP's necessary requirements. Moreover, new competencies introduce new perspectives. According to the WSP approach (Bartram et al., 2009), the team should be as small as possible and as large as necessary. It will, most probably, be necessary to involve external expertise in Teleneşti's WSP team. Experts of health organisations, such as the laboratory of the Preventive Medicine Centre Bălţi are by now already involved in the analysis of the water samples as external experts in the existing "Apă-Canal" municipal organisation. (Levcenco, 2011b) Geological and hydrological competence, as well as expertise in engineering and sanitation are to be considered. However, it has to be decided in the process of assembling the WSP team, whether these experts are to be part of the WSP team or when necessary called in by the operators and management team. In case of external experts, it is important to ensure local acceptance by focusing on the benefit of knowledge transfer to the local experts.

  The structure of a WSP team can take many forms and has to be decided during the initial phase of the development of the WSP. One possible structure of such team for the WSP development in Teleneşti is illustrated in Fig. 6.1.

- The information on the catchment areas and their surroundings as well as information on the existing industry and economic units that may affect the quality of drinking water in the city of Teleneşti is either not existent or misleading. Different sources state different data on functioning and abandoned industry units and the information is not consistent. Thus, identifying the stakeholders at the moment is a challenging.

WSP team

Steering Group
- political authorities (mayor, Ministry of Health)
- health- and environmental protection actors
- financial competence

Task Force
- WSP development coordinator
- leaders, senior engineers, operators of WSS utility
- technical competence

- external experts on water quality aspects (scientists, consultants, laboratories)
- external experts on natural resources (geological and hydrological competences)
- representatives of stakeholders
  - residents / local population
  - drinking-water consumers (private households, industry/business units)
  - waste-water producers (private households, industry/business units)

Figure 6.1: Possible structure of the WSP development team for Teleneşti

Stakeholders need to be identified and their representatives subsequently involved in the process of development, implementation and maintenance of the WSP. For this, it is necessary to gather the necessary information on all the business units or other units that may in a way affect the water quality and make this information consistent. A person responsible for this task may be appointed within the City Council, where a part of the concerned information is already existent.

Table 6.1 below shows the existing economic units and other facilities which may have an influence on the water quality. The information is not complete and therefore it is uncertain if and in which way these units have an influence on the water quality of the four exploited wells. Moreover, their activity should also be considered for other wells existing in the city (and not used at the moment), in case some of these wells may be used as alternative sources at a certain point.

Table 6.1: WSP stakeholder identification form (referred as Tool / Example 1.6 in Sec. 3.1, p. 16), (Anton, 2010; Nastas, 2010)

Stakeholder name	**Relationship to drinking water supply issues**	**Key point**	**Point of contact in WSP team**	**Stakeholder point of contact**	**Interaction mechanism**	**Ref. to contact details, record of interaction**
Mayoralty	Management of landfills, cemeteries	Minimisation of microbial and chemical hazards to catchment / abstraction points			Meetings (e.g. annual, regular, scheduled, informal)	
Bus Terminal	Petrol spills washed by rain water and melting snow	Minimisation of chemical and organic hazards to catchment and abstraction points			Meetings (e.g. annual, regular, scheduled, informal)	
Slaughterhouse	Organic and microbial contamination	Minimisation of organic and microbial contamination to catchment and abstraction points			Meetings (e.g. annual, regular, scheduled, informal)	
Winery (not active)	Chemical and organic contamination	Not clear due to its location and no activity			Meetings (e.g. annual, regular, scheduled, informal)	
Bakery	Organic contamination of waters	Minimisation of organic and chemical (from installations) contamination			Meetings (e.g. annual, regular, scheduled, informal)	
Oil mill	Organic contamination of waters	Minimisation of organic and chemical (from installations) contamination			Meetings (e.g. annual, regular, scheduled, informal)	
Wastewater treatment plant "Apă-Canal"	Organic, microbial and chemical contamination	Affects the overall water quality		"Apă-Canal" representative	Meetings (e.g. annual, regular, scheduled, informal)	

- A problem that may arise in the process of assembling Teleneşti's WSP team is to fit the existing organisational structure and roles with the workload of the WSP team. The existing organisational structure is represented in Tab. 5.2 (p. 78). This corresponds to the existing water supply and sanitation system. It will not be necessary and possible to include the whole personnel of "Apă-Canal" in the WSP team, and on the other hand the WSP team may need other members with competences and backgrounds different than those existing in "Apă-Canal". A precondition to form the WSP team with competences available in "Apă-Canal" is that the water supply organisation itself has to enable and motivate its employees to engage themselves in the WSP development and implementation process. Simple tables including the functions and responsibilities of the WSP team members may be drawn to easier overcome this challenge (see Sec. 3.1, Tool / Example 1.4, p. 15).

- Problems to effectively communicate within a team may occur in any team at any time. Lacking the necessary information, as currently is the case in Teleneşti, makes the communication even more difficult.

  A person skilled in communication, mediation, and management is of significant importance. Regular meetings within the utility and with the stakeholders should be scheduled according to their agendas and be communicated well in advance. Representatives of each stakeholder should be appointed at the beginning of the WSP development process. It is of significant importance that all representatives are present at each meeting in order to enable an effective communication and balanced decisions.

6.2 Module 2: Describing the Water Supply System

The goal of this module is to describe the water supply system in detail, which helps to identify the points of the system vulnerable to hazardous events, relevant types of hazards, and to establish control measures for these hazards. (Bartram et al., 2009; WHO, 2011)

A detailed description of every point of the water supply system from catchment to consumer point of use facilitates accurate documentation, which enables an adequate assessment, evaluation and management of the risks. As each supply system is unique, the necessary data is to be collected for each system apart, also in case of similarities with other systems. A desk study is not sufficient for an accurate description of a water supply system. Thus, site visits are necessary to be carried out as part of the WSP. The description of the water supply system includes defining the intended uses of the water supplied (general consumption, food preparation, washing, and personal hygiene) as well as the intended users. (Bartram et al., 2009; WHO, 2011)

6.2.1 Facts

The description of the main features of Teleneşti's water supply system is given below (inspired by the list given in the WSP Manual). For a more detailed description see Chap. 5 (p. 68).

- Relevant water quality standards are stipulated in Moldova's Government Decision 934 of 15th Aug. 2007 on the Establishment of the Automated Information System "State register of natural mineral water, drinking water, and bottled soft drinks" (Government of the Republic of Moldova, 2007). These lay down standards comparable to those defined by the European Council Directive 98/83/EC (European Council, 2009).

- Sources of water:
  The water supply is fed by four artesian wells which currently supply different parts of the city. Only the water of two wells is subject to chlorination treatment, while the water of the other two is not treated before distribution. The average water demand is significantly lower than the wells' recharge capacity, so the total quantity of water is sufficient even if single wells are out of order. (Levcenco, 2011a) The four wells are currently not mutually connected, so during repairs or cleaning works, the respective part of the city is not supplied with water for a certain period of time. Currently, the only alternative sources for the population of the affected parts of the city are generally unsafe shallow-water wells.

- Changes in water quality related to weather conditions have not been experienced as a considerable issue in the past. Other factors, such as the bad condition of the distribution system, are held responsible for random deterioration in water quality (increased microbial values in the distribution system) (Levcenco, 2011b), but also chemical pollutants from household and industrial origin pose a significant problem.

- The abstraction point and catchment area:
  Wells 1 and 2 are located in the centre of the city in a residential area (89 m above sea level). In this area, many houses are not connected to the

sanitation system and make use of pit latrines. Well 14 is located at the city edge next to the storage reservoirs at 127 m above sea level, however it is not connected to them. Well 15 is located far outside the urban area of Teleneşti at 110 m above sea level. All wells and storage areas are located outside of relevant pollution zones (see map in Fig. A.6 in the Appendix, p. 132), whereby a landfill is located at 205 m above sea level in only about 1000 m distance of wells 14 (and the storage reservoirs) and 15. (Google Earth Teleneşti, 2012; Levcenco, 2011a)

- Information relating to the storage of water:
  The water from wells 1 and 2 is pumped and stored in one of the two existing reservoirs. Wells 14 and 15 are equipped with buffer tanks and the water is not stored for a long period of time: it is directly fed into the distribution system. In case of incidents at the storage facility, there is no other storage capacity as one of the reservoirs is currently out of order.

- Information relating to the treatment of the water:
  The water of wells 1 and 2 is chlorinated after it is pumped into the reservoir. The substance used for chlorination is chlorinated lime with 16% active chlorine (Cl). Other treatment methods are not used to date.

- Details of how the water is distributed including network, storage and tankers:
  After being pumped to the reservoir and after the treatment, the water of the wells 1 and 2 flows by gravity through the distribution system to the consumers. The other two wells (14 and 15) are not connected to the reservoir. The water is collected in their buffer tanks from which it flows by gravity through their separate branches of the distribution system to the respective consumers.

- Description of the materials in contact with water:
  Storage reservoirs: reinforced concrete;
  Buffer tanks: steel
  Distribution system: cast iron, steel, polyethylene.

- Identification of the users and uses of the water:
  The consumers are the local population, public organisations including schools and kindergartens, and economic units. The water is currently used for general consumption.

- Availability of trained staff:

Technical and financial competence is available within the existing water supply organisation "Apă-Canal". (Levcenco, 2011b) However, social and regional aspects are not in place yet.

- Documentation of existing procedures:
  It is a challenge to collect the necessary information because it is often spread amongst different organisations without coherent structure of the data. A frequent observation is that inconsistent data exists among different organisations.

6.2.2 Problems and Recommendations

- Information quality
  A description of the Teleneşti water supply system is given in more detail in Chap. 5. However, this information is not complete. The data is spread amongst different organisations and is often misleading. The existing maps showing the entire water supply system are of limited accuracy, low resolution, or manually drawn. It may be difficult to find all the local agencies possessing the necessary information for a detailed description of Teleneşti's water supply system.

  To fully identify all system aspects, vulnerabilities, and risks, an established WSP team must verify, extend, and deepen the collection of information and finally describe existing control measures. Only then a comprehensive risk management process can be developed and implemented. Keeping close, informal contacts within the community may ease the task of gathering the relevant information.

- The knowledge of the land use in the catchment areas, as well as the knowledge on the existing industry and economic units are limited. This hinders the identification of the potential pollution sources of water in the four exploited wells and the identification of stakeholders that may be necessary to be involved in the WSP development and implementation.

  The information on the surroundings of catchment areas and on the existing industrial and economic units needs to be extended and documented. More information on the use and the sealing of the landfills and their influence on the groundwater quality has to be collected based on site investigations.

- Microbial contamination
  The microbial values in the distribution system are randomly increased. In 2010, there were four cases of increased concentrations of E.Coli of more

than 1/100 ml, reaching one time 8/100 ml (see Tab. A.4, Tab. A.5, Tab. A.7, and Tab. A.8, pages 136–140 (Apă-Canal, 2011)). The reason for these changes is not clear to "Apă-Canal", but it is supposed to be connected to pipe breakage and with that ingress of contamination into the distribution system.

It is of significant importance to find the exact reason for the increased microbial values in order to avoid recurrent cases and cases of illness among local population.

- High ammonium levels
  From Tab. A.2 (in the Appendix, p. 134) (Apă-Canal, 2011) it can be seen that the ammonium (NH_4) content in the wells is very high, reaching up to 8.1 $^{mg}/_{dm^3}$, which is 16.2 times the limit value defined in national health standards of 0.5 $^{mg}/_{dm^3}$. (Government of the Republic of Moldova, 2007) Typical point sources of increased ammonium concentration in the groundwater are sanitation facilities (leaching from pit latrines) and waste disposal sites. Other diffuse sources are slurry spreading on agricultural fields or animal faeces. (Thompson et al., 2007)

  Ammonium is toxic to the human body only at very high doses which cannot be expected to occur in drinking water (WHO, 2003). However, increased levels of ammonium can decrease chlorination efficiency, can produce chloramines and can, under certain conditions, result in elevated nitrite formation (WHO, 2003). The reasons for the high content of NH_4 in the four exploited wells of Teleneşti city are not known exactly but potential sources can be spotted:

  - the landfills of the city;
  - two former livestock factories;
  - the livestock kept by the population inside the city;
  - the significant number of pit latrines inside the city;
  - possible damaged sealing of deep boreholes and related ingress of contaminated surface water.

  The reason for such high levels of ammonium is of significant importance and has to be identified. Geological aspects have to be investigated, as the considered wells are 103 to 125 m deep (Levcenco, 2011a), thus a high content of NH_4 is rather unusual. Close monitoring of nitrite and nitrate and of chloramines in the distribution system and at selected consumer end points are essential to gain a comprehensive understanding of the reasons. Potential hazards connected to the ammonium content in the water are discussed in Module 3 (p. 92).

- Flow diagram

  The information on the whole infrastructure of the Teleneşti water supply system is assumably existent, but it was only possible to collect it in an incomplete form in the process of writing this work. It is thus difficult at present to develop an accurate flow diagram which would represent the whole existing infrastructure of the water supply system.

  Figure 6.2 represents a potential flow diagram of the Teleneşti water supply and sanitation system. It was developed based on the information gathered in the process of writing this work. However, as the information at some points is incomplete, it has to be verified by a formed WSP team, as advised in the WSP Manual, with on-site visits and additional information. An accurate flow diagram is of great help in identifying the hazards, risks and corresponding controls. (Bartram et al., 2009)

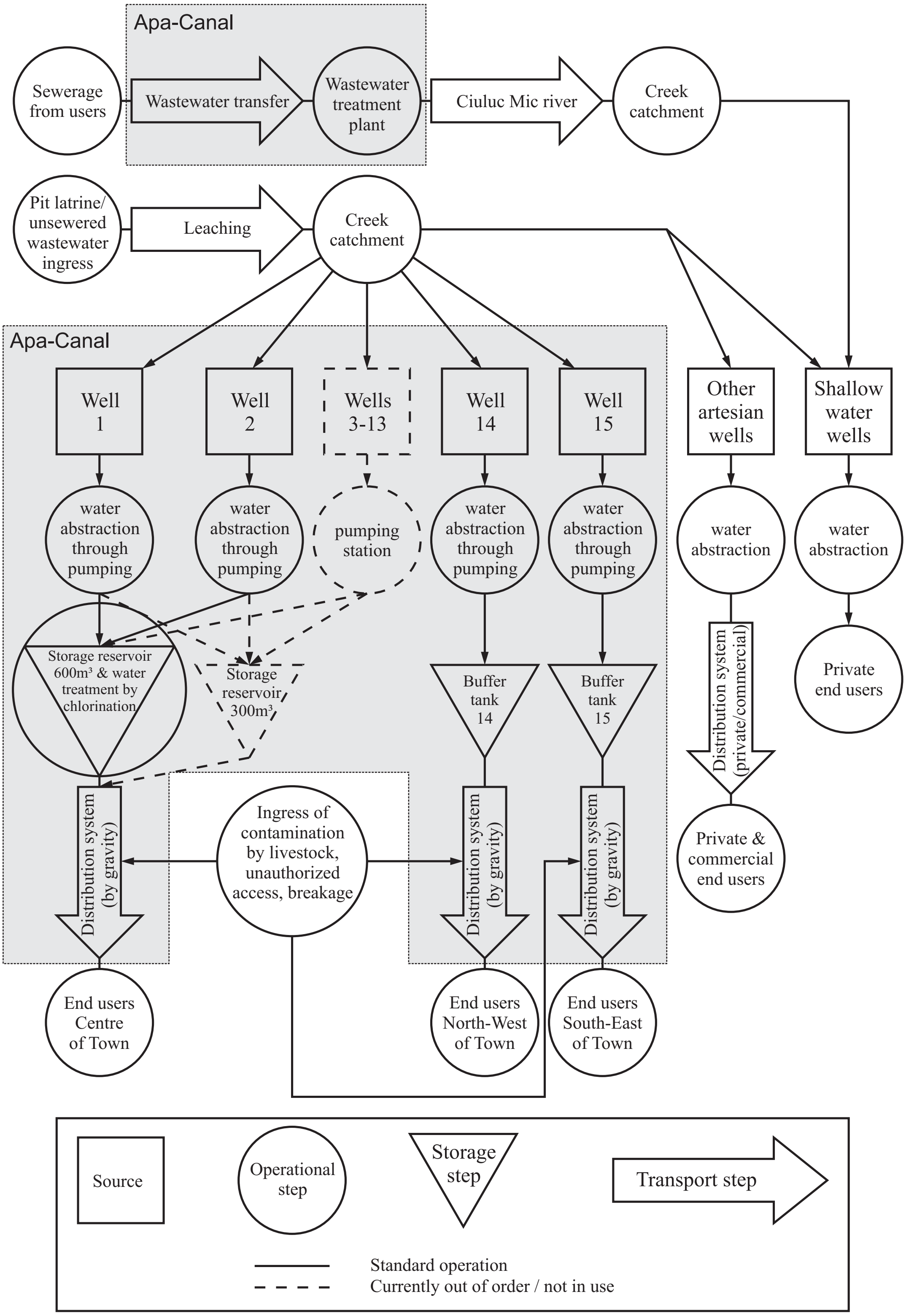


Figure 6.2: Flow diagram of the Teleneşti water supply and sanitation system

6.3 Module 3: Identifying Hazards and Hazardous Events and Assessing the Risks

The goal of this module is to identify all the potential biological, physical and chemical hazards and hazardous events that may affect the water quality at each point of the water supply system and to evaluate the identified risks. This module is usually carried out at the same time with modules 4 and 5. Taken together, these three stages relate to the assessment of the water supply system:

- the potential hazards and hazardous events are identified;
- their level of risk is determined;
- the control measures for controlling the risks are decided;
- achieving the standards and targets is proven.

For more details see Sec. 3.3, p. 22.

6.3.1 Facts

- Figure A.6 (in the Appendix, p. 132) shows potential water pollution factors in the city of Teleneşti. These are in the first place the landfill situated on a high point outside the city, two cemeteries which are in use, one closed cementary, the slaughterhouse, the wastewater treatment plant, and several economic and industrial units (oil-mill, bus terminal, winery, brick factory). However, the map does not show the two former big livestock factories as well as the existing poultry factory which are also significant sources of groundwater pollution. (Teleneşti City Council, 2006)

- The distribution system is made of cast iron, steel, and polyethylene. Although the age of the cast iron pipes is up to 60 years, their durability is very high and leads to almost no failures. The condition of the steel pipelines is unsatisfactory from 10 years of use and older, and the age of these pipelines ranges from 10 up to 60 years. The water pipelines made of polyethylene, all in use for less than 10 years are in very good conditions.

6.3.2 Problems and Recommendations

- The information on the use of the former waste disposal site and its influence on the groundwater of Teleneşti city is not known. Although recently closed, it will serve as source of pollution for more decades to follow. All types of waste collected within Teleneşti city and a village nearby were disposed at this landfill. The single protection layer to the groundwater is the natural barrier of clay. The landfill is situated on a high point of the city at about 200 m above the sea level, whereas the 4 wells used as sources of drinking water are at about 120 or less meters above the sea level and situated just about 1 to 1.5 km away from the landfill (Google Earth Teleneşti, 2012). The flow direction of leaching waters of the landfill is believed to point away from the city, meaning that it should not have significant influence on the 4 existing wells' water quality (Google Earth Teleneşti, 2012). However, this information is not verified geologically.

The closed landfill may represent one reason for the high amount of ammonium found in the groundwater of the four exploited wells. Thus thorough investigations of the site and its surroundings have to be carried out. Geological investigations may provide the necessary information relating to the influence of the landfill on the water quality.

- An unauthorised waste disposal site exists in the North of the city in the region of the Ciuluc Mic rivulet valley. It is located in the direct vicinity of an artesian well. The well is not under the possession of Teleneşti's water supply system, however Izvoraş outskirt's population in the North of Teleneşti is supplied with water from this well. This landfill was already cleaned several times, however the local population continues to dispose waste on this area. (Roşca, 2012b)

  Measures to remove this waste disposal site have to be taken. For this, it is necessary to involve the mayoralty of Teleneşti. Finding other uses for the territory may solve the problem. Education programmes may raise the awareness in the population on the impact of waste on the groundwater.

- Until the mid-1990s, two big livestock breeding factories (swine and cattle) were located at two city edges. The numbers reached 36,000 heads per year of swine and 4000 heads per year of cattle (Roşca, 2012b). Although both factories ceased their activity about 15 years ago, they may still be responsible for the high concentrations of NH_4 in the groundwater due to inappropriate facilities for residual waters and manures / livestock faeces, which penetrated the soil deeply and reached the groundwater. The sites still exist, however they are abandoned or used for different purposes: the swine breeding factory is overtaken partly by a poultry factory (with improved facilities and almost no residual waters) and is partly used since 2010 as site for depositing the waste of 7 localities including Teleneşti. The waste is disposed in the former manure depositing sites which were constructed with a base layer of clay covered with liner. The buildup of the new landfill site is still an ongoing project which is planned to be further improved. More detailed information on the new landfill is not available. The cattle breeding factory was divided and sold distributed to subsequent land owners which mostly did no longer use the existing structures and demolished the facilities. Only two compartments are still used as a small livestock factory of swine and cattle (not more than 100 heads / year). (Roşca, 2012b)

Detailed site investigations of both former factories are necessary to identify current hazards for the quality of the groundwater. It may be necessary to call in scientists to interpret all the results and assess the risks associated to them.

- The livestock kept by the population inside the city is likely a significant source of groundwater pollution and represents another potential reason for the high concentration of NH_4 in the groundwater. The number of livestock is significant (see Tab. 5.4), and the methods of keeping these animals do not correspond to the national ecologic and hygienic requirements. (Nastas, 2010)

  The problem of the widespread livestock keeping within the city is of significant importance as it is difficult to eliminate. Due to the economic situation, the livestock breeding at household level is a significant source of food for the local population and it is a well-accepted and adopted habit. Thus, big efforts will be necessary in order to improve the situation in this regard. Education programmes for the local population to raise awareness of the influence of livestock faeces on the groundwater and a decision at municipality level specifying hygienic requirements may be a start in the process of improving the situation. Innovative solutions to reduce the livestock-related contamination ingress into groundwater should be sought in the community.

- Pit latrines and the wastewater treatment plant:

  - Pit latrines may be another factor for the high amount of NH_4 in the groundwater. A significant number of households are not yet connected to the sanitation system (1748 out of 2750 (Anton, 2010; Levcenco, 2012c)). To the author's knowledge, in some outskirts of the city no sewerage network exists. Thus, pit latrines are installed at each household without sewerage connection. The usual pit latrines in the city have no soil protection layers, thus their contents easily penetrate to the groundwaters. Especially the shallow-water wells are prone to microbial and chemical contamination originating from the leaking content of pit latrines. (Apă-Canal, 2011; Melian et al., 1999)

  - The wastewater treatment plant poses a risk for bad quality water in the entire region, especially downstream along the Ciuluc Mic rivulet (e.g. the neighbouring village of Ineşti). The treatment plant is largely dysfunctional and the wastewater from the households and industry flows practically untreated into the Ciuluc Mic rivulet. Ciuluc Mic rivulet has a slow flow and therefore has a low self-purification capacity. (Nastas, 2010)

  A project in cooperation with the United Nations Development Programme (UNDP) on improving the sanitation system is currently being developed and is planned to be finished in 2012. The project plans comprise the construction of a new wastewater treatment plant and the extension of the connection of households to the sewerage network. However, it will still take some years until the project can be implemented, as at this stage there is no financial support found. (Roşca, 2012a)

- The number of households connected to the water supply system is 1953 out of 2750 existing in the town (Levcenco, 2012c; Anton, 2010). This means that 797 households use unsafe water sources. Shallow-water wells are common sources of drinking water for the local population. However, the water in these wells is of poor quality. Samples taken in 2010 of 11 selected shallow-water wells within the city showed increased values of microbial contamination and high nitrate content (Apă-Canal, 2011).

  Measures have to be taken in order to avoid that the local population recurs to the shallow-water wells as drinking water sources. The infrastructure of the water supply system has to be improved in the long term: the distribution system has to be extended, so that the entire population has access to safe drinking water. Education programmes are of significant importance in this context too, as they raise awareness regarding the water quality of such sources as well as the people's responsibility in reducing pollution.

- Losses and unregistered or illegal use were 57% of the total amount of water abstracted in 2011. (Levcenco, 2012c) Although the unregistered and illegal use is considered as a significant problem for the Teleneşti water supply system, no data exists on the amount of water loss versus the amount of illegally abstracted water. Unauthorised connections may lead to back-siphonage and the ingress of contaminants into the distribution system (Breach, 2009a,b), however, also pipe breakages enable the ingress of contamination.

Countering the illegal use is difficult especially given the local economic situation. However, a programme of local community education could highlight the risks, and also increased network inspections could identify some of the points at which regular illegal use occurs. (Breach, 2009b)

Finally, public abstraction points could provide safe drinking water without the risk back-siphonage and thus may be of positive effect for the population (free availability, safe drinking water) and for the system as a whole (less illegal use, less back-siphonage).

- The distribution system is made of cast iron, steel and polyethylene pipes. The entire line of the distribution system made of steel is poor which leads to frequent incidents (Levcenco, 2011a). Besides being unreliable and inefficient in its management, this may be the cause of random increased microbial values in the distribution system.

  Maintenance and repair works are to be carried out, eventually replacing all steel pipelines, starting with those in a critical condition.

- Ingress of contamination by no/insufficient/inappropriate cleaning (washing-through) of the water supply system.

  According to the document used within "Apă-Canal" (Fedorova, 1985), the whole water supply system has to be washed through regularly for hygienic and technical reasons. However, due to insufficient financial resources, these measures are not carried out. (Levcenco, 2012a) These measures are used against microbial contamination, thus they have to be carried out to ensure safe drinking water.

Table 6.2 lists the currently evident potential hazardous events (or sources of hazards) and the associated hazards that may affect the water quality at all points of Teleneşti's water supply system. However, this list has to be verified, improved, and completed in the process of development and implementation of the WSP when the related information is improved:

Table 6.2: List of hazardous events and associated hazards that may affect the water supply system

Hazardous events (source of hazards)	**Associated hazards (and issues to consider)**
Waste disposal sites	Microbial and chemical and organic contamination
Technological degradation of distribution network	Risk of pipe breakage Ingress of microbial contamination
Insufficient / inappropriate cleaning of water supply system	Ingress / buildup of microbial contamination
Agriculture	Microbial contamination, pesticides, nitrate Slurry and dung spreading Disposal of dead animals
Industry (including abandoned and formal industrial sites)	Chemical and microbial contamination Potential loss of source water due to contamination
Pit latrines	Microbial contamination
Slaughter house	Organic and microbial contamination
Livestock keeping, former and present livestock factories	Microbial contamination, ingress of ammonium/nitrite/nitrate into groundwater
Geology	Fluoride, selenium
Capacity of treatment works	Overloading treatment
Disinfection	Reliability Disinfection by-products
Treatment failure	Untreated water
Mains burst	Ingress of contamination
Intermittent supply	Ingress of contamination
Unauthorized connections	Contamination by backflow

6.4 Module 4: Determining and Validating the Control Measures, Reassessing and Prioritising the Risks

The goal of this module is to identify the controls, validate their effectiveness, and identify and prioritise the risks that are insufficiently controlled. At this stage the effectiveness of the existing controls should be verified. Some control measures may be effective in controlling more than one hazard, whereas for some hazards more than one control measure will be necessary to ensure an effective control. Site inspection, manufacturer's specification, or monitoring data may prove the effectiveness of the existing controls. After all control measures have been taken into account, it is necessary to develop corrective actions. The planning and assessment of control measures should be based on hazard identification and risk assessment and should guarantee the accomplishment of the health-based targets (see Sec. 3.4, p. 28).

6.4.1 Facts

The following control measures are already in place:

- The wells are sealed and hermetically covered against surface water intrusion and contaminations with other surface substances or suspended solids that may influence the water quality of the wells;
- Protection zones of 30 m diameter around the wells are respected;
- The territory where the two reservoirs are located is fenced;
- Regular reservoir inspections take place;
- Reservoirs are covered.

6.4.2 Problems and Recommendations

The following is a list of possible control measures to be defined for Teleneşti's water supply system:

- Maintenance and repair works:
  There were no complete renovation works in the whole water supply system for 20 years. The steel distribution system was partly exchanged when the quality of pipelines was in poor conditions. Maintenance works are not done

due to insufficient financial resources. (Levcenco, 2012a) This makes the distribution system prone to frequent breakages and thus potentially leads to the ingress of microbial contamination. Microbial contamination occurs only at the distribution system level. Thus improvement and maintenance of the distribution network may be an effective control measure against microbial contamination. Maintenance works every few months or once a year may reduce the costs of frequent repair works.

- Disinfection works in case of incidents:
  In case of incidents the valves on both ends of the broken pipe are closed and the broken pipe is being repaired or exchanged. Due to the lack of financial resources, no disinfection is done. Only in extreme situations, the repaired part of the system is washed through with chlorinated water.

  It is necessary to find a modality to carry out disinfections in case of incident in order to avoid microbial contamination at the distribution level. (Fedorova, 1985)

- Communication and education of catchment stakeholders
  One integral aspect of the WSP development is to closely work with the stakeholders that may have an influence on the water quality (Bartram et al., 2009). For this, first of all detailed information on existing stakeholders that may affect the water quality should be collected and documented.

- Ability to use good alternative source when hazards affect existing sources:
  No alternative water sources for the pipe supply network exist currently. The four artesian wells supplying the population with water are not mutually connected. Wells 1 and 2 supply the central region of the city, well 14 supplies the North-West outskirt, and well 15 the South-East outskirt. In case of dysfunction of one of the wells or repair works the affected part of the city cannot be supplied with water until the works are completed. There are 33 artesian wells apart from the four wells exploited by "Apă-Canal". Eleven of them are in the possession of "Apă-Canal" but are not used at the moment, because the four exploited wells can cover the water demand entirely. The other wells are either in private or commercial possession. The quality of the 33 artesian wells is not known. Only in case of interest from owners of the wells, samples of the wells may be taken and examined. However, this means the owner has to pay for the water analysis, which is an expensive service for the local population. (Levcenco, 2011b)

  The information on the water quality of the 33 artesian wells is of significant importance, as it may be useful for the identification of alternative sources and in gaining an understanding of the groundwater quality throughout the city. Thus, it is necessary to carry out investigations on the quality of water of all artesian wells existing in the city.

- Site inspections

  Except for the reservoirs, currently no site inspections are done. The quality of the pipelines is assessed in case of incidents at the point of the distribution system where the breakage took place. (Levcenco, 2012a) The information that could be collected as a result of site inspections is of great importance, as it could reveal necessary data about the sensitive points of the water supply system and avoid repetitive incidents, which may directly lead to direct contamination of the water supply with pathogens. Sediments may also form in reservoirs and tanks, which makes it difficult to maintain desired disinfectant residual levels. (Vitanage et al., 2004)

  Table 6.3 lists points in the water supply system were inspections should be done.

Table 6.3: Inspections, adopted from (Vitanage et al., 2004)

Items	**Check**
Grounds and banks	Trees and bushes close to reservoir; localized luxuriant growth of grass may indicate leakage; wet patches; animal damage; cracks and signs of ground movement
Roof cover	Cracks, animal damage or ponding may indicate poor drainage
Hatches	Damage to cover, lock, built-in ventilators and seals
Disinfection system	Security of housing and operation of the equipment
Pipework	corrosion, fixings, outlet screens and outlet blockages
Roof, walls and floor	Roof to wall joints, locations where installations pass through the roof, indications of leakage such as stains and deposits, root intrusion and cracks
Distribution network	pipelines (especially steel pipelines), valves, points on the distribution system where microbial contaminations are likely due to the surroundings
Consumers end point	Pipelines in the basements of buildings

- Up-to-date network maps

  The existing maps showing the entire water supply system are of limited accuracy, low resolution, or manually drawn. This makes it difficult to easily pass the needed maps to the people involved in the WSP implementation or to quickly respond to incidents. A Cadastral Office exists in the city, where the required expertise is bundled. The competence available in the Cadastral Office may be involved in improving the maps of the entire water supply and sanitation system. A future transition to using a Geographic Information System (GIS) can, if managed well, ease data access for all relevant actors and shorten the incident response time.

- Consumer education
  Education programmes for raising the awareness of the local population about the quality of water and the actions to be taken in case of incidents and the implied water quality changes may be also an indirect control measure. The education programmes could be developed as part of supporting programmes (see Sec. 6.9 for more supporting programmes).

- Inform the local population in case of incidents and related water quality changes.
  Currently there is no possibility to inform the population in case of incidents or changes in drinking water quality (Levcenco, 2012a). An improvement regarding this is necessary. Call centres, local radio/TV broadcasts, or loudspeaker announcements may be involved in case there are significant changes in the quality of water which may have a negative effect on the health of the local population. Advice to boil / not use water in case of increased microbial values should be adopted as a common practice of the utility.

6.5 Module 5: Developing, Implementing and Maintaining an Improvement/Upgrade Plan

The goal of this module is to develop and implement an improvement / upgrade plan for all major uncontrolled risks. This has to be done based on a planned schedule of short-, medium-, or long-term activities.

As in some instances an improvement / upgrade plan requires significant investments of resources, it has to be developed with a detailed analysis and careful prioritisation according to the system assessment. However, often for a new improvement / upgrade plan it is sufficient to simply review, document and formalise the practices that failed and address the areas where improvements are necessary. The monitoring of such plans is a necessary procedure in order to ensure that improvements have occurred and are effective and that the WSP has been updated respectively. It should also be considered that new risks may be introduced by the establishment of new controls. For more details see Sec. 3.5, p. 36.

6.5.1 Facts

From the general situation of Teleneşti's water system, it is evident that many of the found problems can be countered by new investments into its infrastructure. However, not all issues can be satisfactorily resolved with a reasonable level of funding, and, even more importantly, a sustainable approach must be realized to maintain these improved conditions.

The WSP approach provides these features: it does not focus on monetary issues, but rather on the efficient management of hazards and risks, and it promotes this task to be carried out in a continuous and sustainable way.

6.5.2 Problems and Recommendations

After having identified and prioritised the risks and hazards, a selected set of the most important problems should be addressed.

The most striking encountered problems are the pit latrines, the open livestock keeping, and the quality of the distribution system. In the past, these problems have not been addressed effectively, and corresponding control measures are missing.

The task of solving these problems is large and complex and needs to be planned in short-, medium-, and long-term perspectives. Setting and achieving milestone targets every few years for long-term development, e.g. to gradually and consistently decrease the use of pit latrines and to reduce unauthorized waste disposal, represents one potential approach within this improvement process. Exemplary onsets are listed in Tab. 6.4.

Given the local situation of Teleneşti (and, similarly, of the Republic of Moldova as a whole), domestic investments are low and funding is hard to raise. To ensure successful implementation, special attention to these constraints has to be paid in the development of improvement measures and an upgrade plan.

Table 6.4: Drinking water quality improvement/upgrade plan actions and accountabilities

Action	Arising from	Identified specific improvement plan	Accountabilities	Due date	Current status
Implement measures to control high values of ammonium	Ammonium values consistently exceed limits by far and are identified as an uncontrolled risk. Potential sources may be pit latrines, livestock keeping, waste disposal sites, 2 former livestock factories. Currently no adequate control measure exists.	Long-term multi-modal approach: Gradually improve and expand sanitation system and remove pit latrines, develop and implement local hygienic regulations for livestock keeping, launch education and awareness programmes for water safety	WSP team as a whole	Milestones to be reached by specified times (years)	Not started
Implement measures to control risks of microbial contamination	E. Coli values randomly exceed limits which could be caused by pipe breakage or backflow and poses an uncontrolled risk. Currently no adequate control measure exists.	Medium-term approach: Replace steel pipes, ensure regular maintenance	WSP Team / Task Force	Milestones to be reached by specified times (months, years)	Not started

6.6 Module 6: Defining Monitoring of the Control Measures

The goal of this module is to complete the implementation of the control measures at appropriate time intervals and establish corrective actions for deviations that may occur.

To demonstrate that the controls work, the monitoring of control measures has to be defined and validated and procedures fixed. In order to ensure effective system management and achievement of health-based targets, each control measure has to be monitored regularly. In case the operational targets are not met, corrective actions need to be included. All these actions need to be documented in the management procedures, for more details see Sec. 3.6, p. 38.

6.6.1 Facts

The information on an existing national law regarding procedures of monitoring is not available. The document Government of the Republic of Moldova (2007), the water supply company "Apă-Canal" Teleneşti refers to, stipulates the water quality standards and the monitoring requirements for water quality.

6.6.2 Problems and Recommendations

- Currently there is no monitoring programme for control measures established by "Apă-Canal" Teleneşti. The following is a list of questions to be considered in the process of establishing a monitoring programme (Bartram et al., 2009):
  - What will be monitored?
  - Control measures may be derived from Sec. 6.4, p. 98, or may be complementary to the ones listed there
  - How it will be monitored?
  - When and how often should the monitoring take place?
  - Where will it be monitored?
  - Who will carry out the monitoring?
  - Who will do the analysis?
  - Who will take action?

- Ensure frequent monitoring of the water quality after the treatment procedures took place.
  Currently, the quality of the water is monitored the following way (Levcenco, 2012c)

  - Sources (4 artesian wells): 1 time / year,
  - Reservoirs: 1 time / month
  - Distribution network: 2 times / month.

  This frequency of monitoring may be not enough to ensure safe drinking water to the local population. In high-quality water supply systems, daily control of easily retrieved parameters (e.g., pH, turbidity) and weekly/bi-weekly control of all other relevant parameters are practiced. (Bartram et al., 2009)

- Establish a plan to use alternative sources and immediately inform the customers in case of incidents.
  The water quality of the other existing wells is currently not known, thus it is difficult to establish alternative sources in case of emergencies.

  Currently the 4 wells used for drinking water purposes are not connected. Wells 1 and 2 are connected to the 2 existing reservoirs. Wells 14 and 15 do not have a connection to the reservoirs. The water from wells 1 and 2 is pumped into one reservoir (the second is out of order), chlorinated, and from there the water flows by gravity through the distribution system to consumer. The water from wells 14 and 15 is accumulated in their buffer tanks and from there flows by gravity through the distribution system to the consumer without treatment. (Levcenco, 2012c) Thus in case of incidents at any of these wells or repair works the part of the city supplied with water from the dysfunctional well is without water for a certain time. The alternative source of water for the population in such cases is to resort to using water from shallow-water wells or other unsafe sources.

  A plan to connect the four wells is being developed in 2012. According to the plan the water from the four wells would be pumped into the two existing reservoirs, chlorinated and then distributed to the entire city. This way, in case one well will have to be disconnected, the entire city will still have access to water. (Levcenco, 2012a) The information concerning the stage at which this plan is developed is not available.

6.7 Module 7: Verifying the Effectiveness of the WSP

The goal of this module is to confirm that the WSP is complete, effective, and appropriate, and that it is being implemented in practice, meaning that the water meets the defined water quality targets. The verification has to be accomplished by a surveillance agency. In case the test results do not correspond to water quality targets, plans to address the issue need to be developed and if necessary corrective actions should be established. An improvement / upgrade plan is necessary in case failures to meet the targets occur repeatedly. Besides the water quality analysis, verification involves also an audit of the WSP and of the operational practice. For more details see Sec. 3.7, p. 42.

6.7.1 Facts

At the moment the water quality is tested the following way: Samples from the four artesian wells are collected 1 time/year, from the reservoirs 1 time/month, and from the distribution system 2 times/month. The tested water quality aspects are: odour, taste, transparency, turbidity, hardness, suspended solids, pH value, ammonium (NH_4), nitrite (NO_2), nitrate (NO_3), sulphate (SO_4), chlorides (Cl), copper (Cu), iron (Fe), Manganese (Mn), as well as contamination with E. Coli and Enterococci bacteria (see Tab. A.2–Tab. A.8 in the Appendix). The water quality results show high values of NH4 in the water of the four exploited wells, sometimes exceeding the national limit of 0.5 $^{mg}/_{dm^3}$ by 16 times (Apă-Canal, 2011). Although not extremely high, increased microbial values are also randomly observed.

6.7.2 Problems and Recommendations

The verification of WSP's effectiveness requires its practical implementation, thus the following information has to be examined in detail and adapted to the situation after the implementation of the WSP for Teleneşti. This has to be carried out in regard to Teleneşti WSP's goals. Following the implementation, the verification process should answer the questions related to the problems hindering to ensure safe drinking water. Some of the questions to be considered are listed below; however this list will have to be extended fitting the specificity of the WSP to be carried out in Teleneşti:

- Is it possible to provide safe drinking water?

- Are all health standards consistently met by the provided water?
- Is the problem of the shallow-water wells addressed and solved?
- Are all the pit latrines removed?
- Could the main problems relating the water quality (high NH_4 values in the wells' water, microbial contamination) be solved in a sustainable way?
- Are the sanitation and distribution systems extended and brought into a reliable, maintained condition?
- Is the problem of unregistered or illegal use of water addressed and solved?
- Is the problem of insufficient and inconsistent data solved?
- Are the sites that impact the water quality identified and removed or improved?

It is evident that all these problems cannot be solved within a short period of time, not only due to the current economic situation, but in the first place because of their complexity and persistency. However, with a good management which is supported by the WSP, the improvement of the difficult water supply and sanitation situation of Teleneşti city is realisable.

6.8 Module 8: Preparing Management Procedures

The goal of this module is to prepare a management plan which will include the necessary measures to be taken to maintain the optimal operation of the system under normal operating conditions (Standard Operating Procedures (SOP)), along with measures in case of incidents - corrective actions.

Management procedures to respond to predictable and unpredictable incidents and to emergency situations have to be defined as part of the WSP and a general incident response plan should be prepared. This is important in order to ensure appropriate solutions for various types of incidents that could occur. The plans should include an explicit list of responsibilities, a consumer alert plan, and a plan to switch to alternative sources in case of emergencies. For more details see Sec. 3.8, p. 48.

6.8.1 Facts

Currently no comprehensive emergency action plan exists for Teleneşti. In case of incidents, the existing water supply company "Apă-Canal" conducts repairs of the particular damage of the water supply system. Due to lack of financial resources, these works are carried out only in case of incidents and only at the point where the incident took place. No maintenance work is carried out and no general repair has been done for 20 years. Also, no reliable communication process is established and customers are not informed of incidents. (Levcenco, 2012a)

The government decision Government of the Republic of Moldova (2007) requires suppliers to regularly report the water quality as well as changes in water quality to the affected public.

6.8.2 Problems and Recommendations

- No WSP-related responsibilities are defined.
  Currently, responsibilities are only defined within "Apă-Canal" in a technical scope. However, additional or different responsibilities are needed within the WSP framework, and means are required to ensure that these responsibilities are taken.

  Clear definitions of an extended set of responsibilities need to be laid down, including the WSP development process, standard operating procedures, emergency plans and information/communication procedures for standard and exceptional operations, and WSP team members need to be assigned to and made responsible for these items. Training measures for all involved team members, including the utility employees, enhance their understanding and identification with the WSP goals. Including close communication ties to the customers ensures that risks can effectively be reduced also in emergency events and also raises the people's trust into the utility service.

- No emergency action and information plans exist.
  Currently, no information flow exists from the utility to the customers. This bears uncontrolled risks in case of system failures and lowers confidence in the provided utility service.

  An emergency response plan needs to be developed and implemented (as outlined in module 4), and an effective consumer information procedure needs to be installed.

- No alternative sources are available.

  As part of a short-term emergency response plan, switching to alternative sources can be helpful if the original sources affected by an incident cannot provide water of sufficient quality. (Bernardini et al., 2011) Even though many other artesian wells exist in Teleneşti and could at least partially be activated quickly, their water quality is unknown and not monitored.

  This data could be obtained with low additional effort and can provide useful information on potential alternative sources with different, possibly better water quality characteristics. A systematic scheme to evaluate and select alternative water sources should be created and implemented, see module 4.

The following procedures should be developed and documented:

- drinking water system description and assessment, as well as programmes aiming to upgrade and improve the existing water delivery;
- operational monitoring and verification plan;
- procedures related to water safety management in normal operational conditions, incidents, and emergency situations;
- supporting programmes description.

6.9 Module 9: Developing Supporting Programmes

The goal of this module is to identify programmes and activities which guarantee that the WSP approach is enclosed in the operations of the water utility.

Supporting programmes will mostly consist of already existent aspects that the drinking water supplier will have as part of ordinary operation. They can be extensive, diverse and involve a great number of people and organisations. In the process of developing supporting programmes, also the existing programmes have to be considered. Sometimes, these can be utilized without changes, or directly be augmented by addressing evident problems. For more details see Sec. 3.9, p. 53.

6.9.1 Facts

In the Soviet Union, dedicated training centres for the technical staff have been operating with free training offers. Today, these training courses are charged for, and due to financial constraints the employees of “Apă-Canal” cannot attend them. Consequently, employee training is often performed based on theory self-study and on-the-job practical experience and concluded by an internal examination and a subsequent raise in the employee's qualification level. (Levcenco, 2012b)

6.9.2 Problems and Recommendations

Supporting programmes relating to Teleneşti's water supply and sanitation systems may involve:

- More effective control on the access to the catchment and reservoirs;
- Improvement and extension of protection zones around abstraction points;
- Land-use control:
  - for example at the site of the unauthorised waste disposal in the region of Izvoraş,
  - appropriate management of the site of the former slaughterhouse,
- Continuous staff training in all aspects of WSP development and implementation;
- Research and development programmes for long-term solutions support, such as for the:
  - reduction of NH_4 content in the drinking water,
  - preventing microbial contamination,
  - removing the pit latrines,
  - removing the shallow-water wells as sources for drinking water,
  - examining in detail geological aspects of the land for detailed water quality results and reasons in their changes.
- Preventive and regular maintenance works at each point of the water supply and sanitation systems;
- Creating the structures to inform the population in case of emergencies;
- Education programmes for raising the awareness of people concerning:
  - water quality in the city of Teleneşti,

- actions to be taken in case of incidents and their impact on water quality,
- increased microbial values due to illegal use of water,
- the effect of unauthorised waste disposal sites,
- the importance of safe drinking water and appropriate sanitation,
- the water quality of shallow-water wells,
- the effect on the water quality of widespread livestock keeping inside the city without appropriate hygienic facilities.

6.10 Module 10: Planning and Carrying out Periodic Reviews of the WSP

The goal of this module is to establish an updated WSP by periodic reviews and adaptation to new circumstances and risks. It is important to consider that experiences and new procedures provide new knowledge. Fundamental changes in the water system (changes in the network structure, staff- or stakeholder changes, etc.) can naturally outdate a WSP quickly, but typically gradual changes occur over extended durations. For more details see Sec. 3.10 (p. 55).

6.10.1 Facts

No evidence on recurrent reviews or audits on the established working routines was found specifically for Teleneşti.

6.10.2 Problems and Recommendations

A certain time should be allowed to pass for changes to take place. As a guideline, WSP reviews are usually organised every 6 years under normal circumstances. However, each time significant changes take place, the review of the WSP process has to be carried out in order to identify new or newly introduced risks.

An important organisational challenge to master is to maintain contacts within the WSP team as well as to stakeholders over the years between reviews. This can be supported by a strategy to conduct regular information events, for example annual workshops and networking events. Also, it is essential to clearly document the relevant changes made and decisions taken in these reviews for later use and reference.

6.11 Module 11: Revising the WSP Following an Incident

The goal of this module is to carry out comprehensive and transparent review after each relevant incident or emergency with the goal of finding its reason. These situations provide opportunities to identify areas of improvement. Also, communication is vital – both during the incident response and in a post-incidence review. The WSP team needs to be aware of the circumstances and details of all incidents, emergencies, and near misses. For more details see Sec. 3.11.

6.11.1 Facts

The infrastructure of Teleneşti's water supply is unmaintained and overaged, thus prone to frequent incidents.

6.11.2 Problems and Recommendations

- Many incidents occur (avg. 5 pipe breaks per year and km in Moldova (Bernardini et al., 2011)), and random microbial contamination occurred (see Tab. A.4 and Tab. A.8). These issues are related to the conditions of the distribution system.

- Inappropriate or insufficient actions are taken which do not address a sustainable solution but only consist of partial repairs because no funding for maintenance or for infrastructure investments is available.

If, after the other WSP modules have been implemented, such incidences occur again, a post-incidence review needs to be carried out and the effectiveness of existing control measures, or the existence of new risks has to be identified. Structured incidence response plans as well as appropriate control measures should be updated or created, so that the witnessed incident can effectively be mitigated or dealt with better in the future.

For incidents occurring after corrective actions have been taken, it is important to analyze and document the lessons learned and if necessary to come up with an improvement / upgrade plan.

Chapter 7

Summary, Conclusions, and Outlook

This thesis presents preparative studies on the path towards implementing the WHO Water Safety Plans (WSPs) for the city of Teleneşti in the Republic of Moldova. The technical conditions of the water supply and sanitation systems of the country are heavily degraded due to lacking maintenance and investments. The same situation is found in Teleneşti. This work provides three main contributions to address this situation: First, an overview on relevant drinking water quality standards, water quality studies, and specific challenges faced in Moldova is given. The WHO Water Safety Plan (WSP) onset is presented and its advantages are highlighted. The modular WSP development process is explained based on a compilation of related sources and formulated specifically for small utility units. The second contribution is a comprehensive collection of information on the current water supply situation in the city of Teleneşti. The compiled pool of data and the extracted information in this work has not been collected and presented in this extent and form before, which is believed to be a valuable resource and starting point for future related work and research activities. Third, the WSP development modules are related to the specific situation in Teleneşti using the collected information. The currently evident problems, hazards, and risks are sketched, existing control measures are outlined, and new control measures for yet uncontrolled risks are formulated and proposed. The goal of these contributions is to effectively prepare the future implementation of a WSP for the water supply and sanitation system of Teleneşti.

Drinking water is recognised worldwide as one of the most important natural resources. Ensuring safe drinking water supply enables the prevention and control of waterborne diseases. WHO guidelines and national and international regulations define widely accepted standards on drinking water quality. To develop and operate water supply and sanitation systems efficiently and to ensure high resulting water quality, considerable complexity and a wide range of risks need to be managed. The WSP onset provides a comprehensive best-practices risk assessment and risk management approach which aims to consistently ensure safe drinking water supply from catchment to consumer. It focuses on a preventive, long-term, catchment-oriented onset which has proven to be cost-effective and realizable in many different settings worldwide.

The modular WSP development process is comprised of 11 modules: first, a well-qualified WSP team needs to be assembled to carry out the development and implementation process, followed by a thorough system assessment. Detailed information is gathered to describe the existing water supply system, its structure, properties, and stakeholders. The next three modules aim to identify hazards, risks, their impacts on water quality and define and assess control measures to counteract these risks. Formalised methods are provided to efficiently improve or upgrade the WSP when needed by addressing uncontrolled risks by priority. Modules 6 and 7 define and develop monitoring of control measures and verification of the effectiveness of the WSP, respectively. Management and communication aspects are addressed in modules 8 (preparing management procedures for standard operation as well as for emergencies) and 9 (development of supporting programmes). Finally, feedback processes in terms of periodic reviews (module 10) and after incidents/exceptional events (module 11) are defined.

In this work a broad collection of data has been collected to describe the fundamental parameters and characteristics of the existing utility services and to spot the major risks and the extent and effectiveness of existing control measures. This data was documented based on the data structures recommended and used by the WSP manual and extended where necessary to detail the specific situation.

The water supply system of Teleneşti is generally technically degraded due to lacking maintenance or renovation. Water is abstracted from four exploited artesian wells. Two of these wells are connected to a central storage reservoir where the water is chlorinated and distributed to large parts of the city, whereas the other wells currently serve separate distribution branches without any pretreatment. The distribution system is partially comprised of old steel pipes prone to frequent breakage.

Major issues include a strongly increased ammonium content in the source water, presumably caused by leaching from landfills and/or widespread livestock keeping within the city, as well as recurring microbial contamination of the distribution systems, presumably due to the frequent pipe breaks and possibly through unauthorized access and related backflow.

Being a desk study of limited extent, this work can only be of preparative character. Despite good efforts, the provided data collection could only partially be verified. During the WSP implementation process, this data pool needs to be extended, deepened, and verified by thorough research as well as site visits.

Based on this information, recommendations with regards to each module of the WSP development process have been formulated specifically for Teleneşti's water supply system. Selected recommendations are:

- In the process of collecting the information it became evident that information is often spread amongst different organisations, without coherent structure, incomplete, or inconsistent. Also, it is often present as implicit knowledge only, but not in written or easily accessible form. This results in increased efforts in reliable information retrieval and evaluation. Potential solutions to increase accessibility and consistency is a transition to the active use of GIS and other database systems.

- The system description is based on the collected data, however additional investigations and information updating needs to be carried out by a formed WSP team. This is especially important in terms of the found problematic water quality parameters: the reasons for the high ammonium concentrations and microbial contamination need to be investigated in detail.

- When assembling the WSP team, all relevant competencies should be included, and all stakeholders should be accounted for. An exemplary structure is given for the case of the small utility unit of Teleneşti (see Fig. 6.1, p. 83).

- In dealing with the widespread open livestock keeping, the use of pit latrines, and unprotected or unauthorized landfills, the population has to be incorporated and made aware of the relations to water quality. Also the quality of shallow-water wells should be tested and public awareness to associated risks should be generated. Training/awareness programmes, but also other participatory and educational offers could raise the response and involvement of the local population and generate identification with the goals of a sustainable, holistic management of water resources.

- In case of incidents such as pipe breakage and related increased microbial values, no information flow from the water utility to the consumers is currently established. Installing efficient communication procedures to quickly inform the affected population of service interruptions or contaminations is mandatory to protect people's health and can also improve their confidence in the utility.

- Currently, no alternative sources are defined, and no data on the water quality of other existing wells is available. To ensure safe drinking water supply also in case of incidents or emergencies, it is necessary to find safe alternative sources.

- To address these complex, difficult issues under the given financial constraints, a strategic medium- or long-term plan has to be followed with the aim to continuously reduce the major risks by gradually shifting to new management and operating practices.

- Finally, new investments and adhering to a regular maintenance plan will be necessary to secure and maintain high-quality drinking water supply. It should be attempted to acquire further international funding if national resources cannot provide a sufficient financial support for the needed works.

Concluding, this work has set a first step towards the potential development and implementation of the WSP approach in Teleneşti. However, the scope of this study is naturally limited: being a desk study, although considerable efforts have been made to verify and secure the collected information, their integrity and correctness cannot be guaranteed without actual site inspections and local investigations. Thus, the present study should be understood as a guideline showing and analysing the most evident characteristics. In the author's opinion this work now represents a viable starting point for WSP pilot studies and it is the author's hope to having contributed to an ongoing and active development in water system management in the region.

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Appendix A

Tables and Maps

This appendix collects tables, illustrations, and maps for direct reference.

Table A.1: Characteristics of Moldova's main aquifers (adapted from EAP Task Force (2008))

Formation	Period	Thickness (m)	Avg. depth of wells (m)	Range of yield (m^3/h)	Main contaminants	Lithology / comments
Gruntovi	Quarternary	2-20	10-15	0.05-0.12	NO_3, SO_4, Hardness, Microbiology TDS	Sand and sandstone. Most private wells draw from this aquifer
Middle Sarmat	Neogene	20-30	100-300	2-10	Turbidity, sand, iron	Sand, standstone with some clay horizons.
Lower Baden-Sarmat	Neogene	30-50	NM = 50, CM = 100-200, SM = 200-260	2-5	NO_3, SO_4, F, TDS, Hardness	Limestone with some sand horizons. Moldova's main aquifer containing 70% of groundwater resources.
Mel	Gretaceous Silurian	30-50	NM=50-100, CM = 150-200	2-100	F,TDS	Mainly sandstone with some limestone. Exists in Northern Moldova only.
Upper Sarmat	Neogene	10	Generally 100, but 250 in Prut valley	3-10	Fine sand	Clay with sand lenses. Local aquifer in southern Moldova.
Pont	Neogene		Ditto	5-10	Fine sand	Sand with limestone horizons. Local aquifer in southern Moldova.

Legend: NM - Northern Moldova, CM - Central Moldova, SM - Southern Moldova, NCM - North-Central Moldova

Figure A.1: Map of Teleneşti: Functional Zones (Teleneşti City Council, 2006)

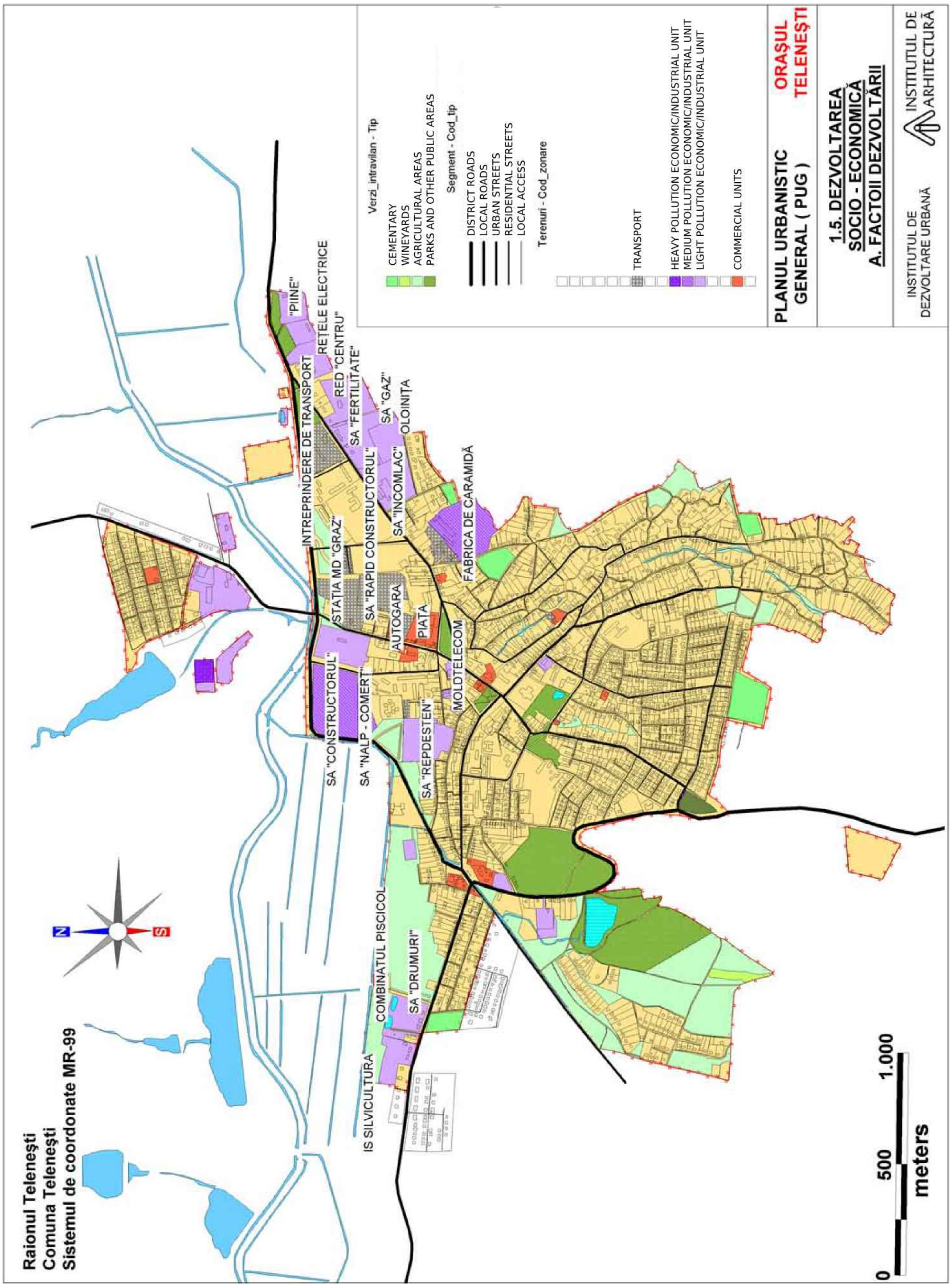

Figure A.2: Map of Teleneşti: Socio-economic development (Teleneşti City Council, 2006)

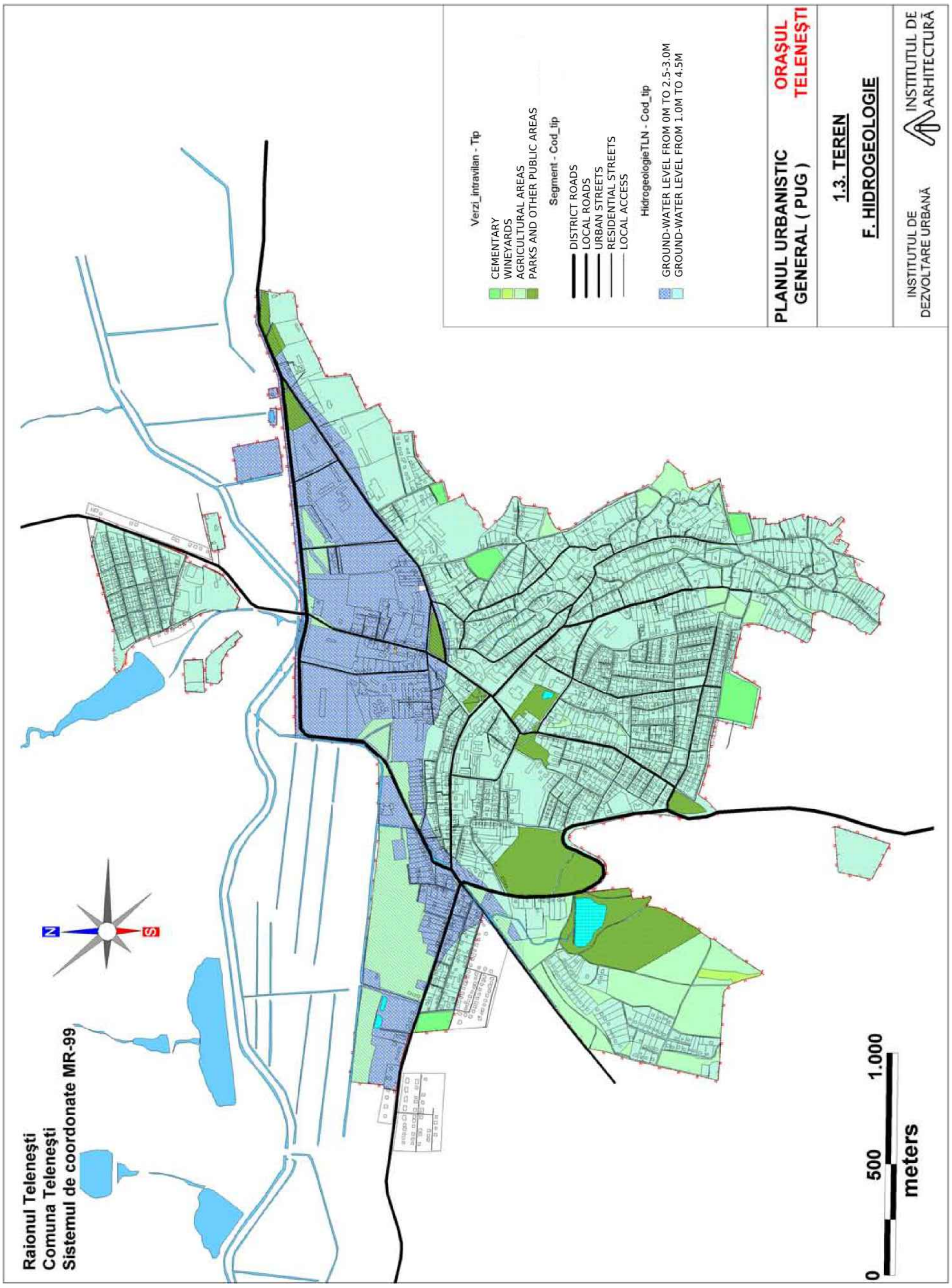

Figure A.3: Map of Teleneşti: Hydrogeology (Teleneşti City Council, 2006)

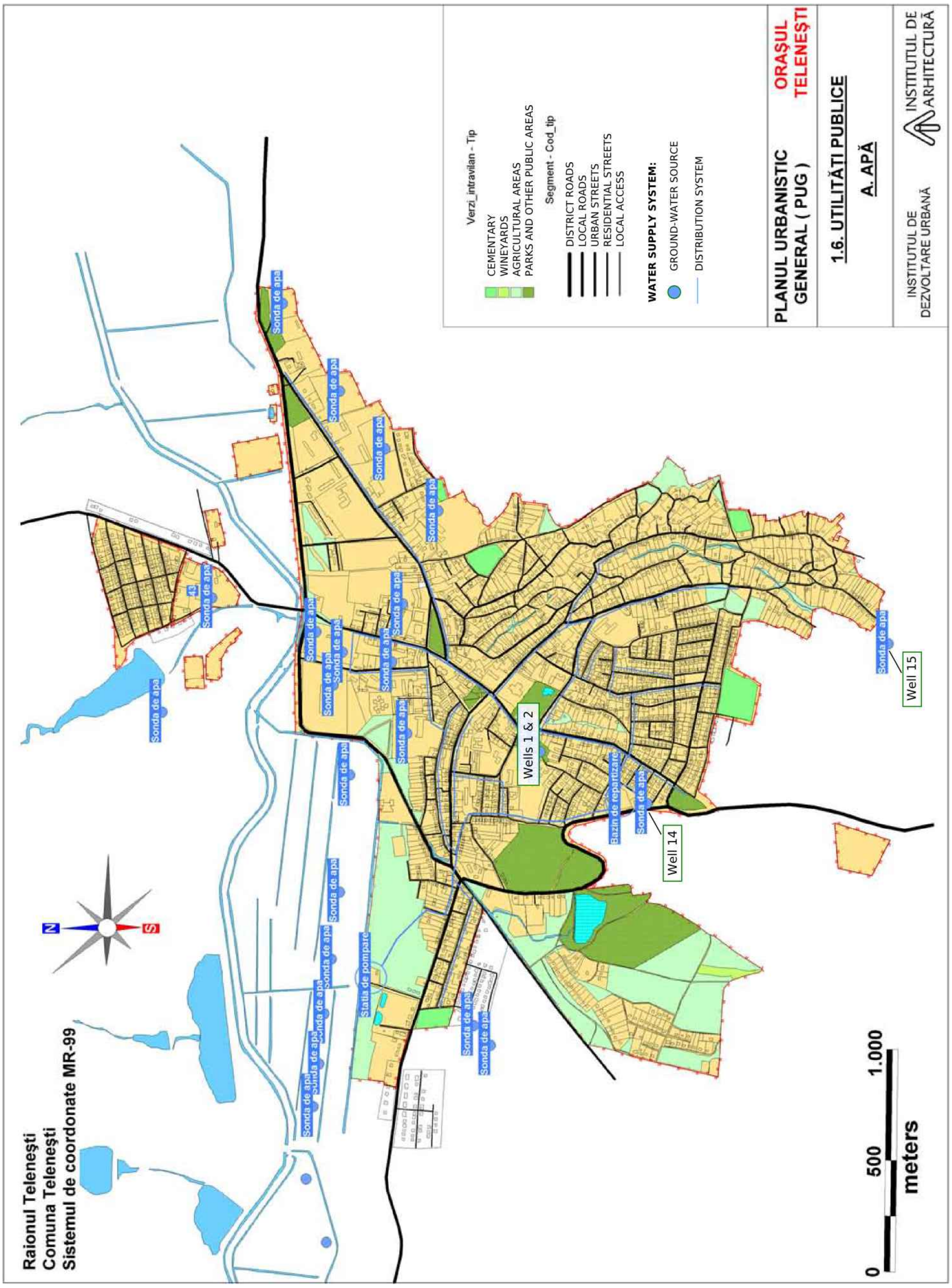

Figure A.4: Map of Teleneşti: Public Use: Water (Teleneşti City Council, 2006)

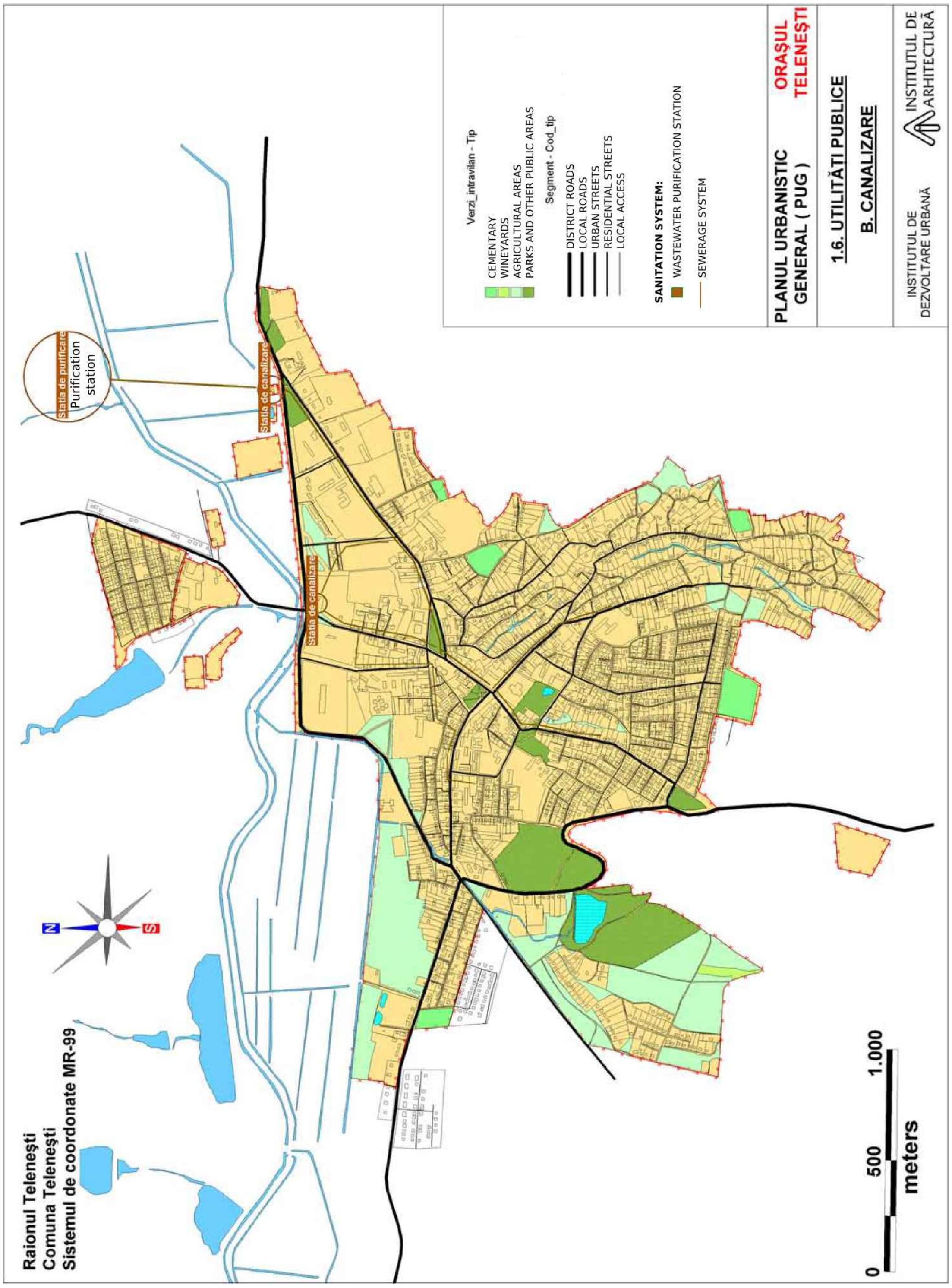

Figure A.5: Map of Teleneşti: Public Use: Sanitation (Teleneşti City Council, 2006)

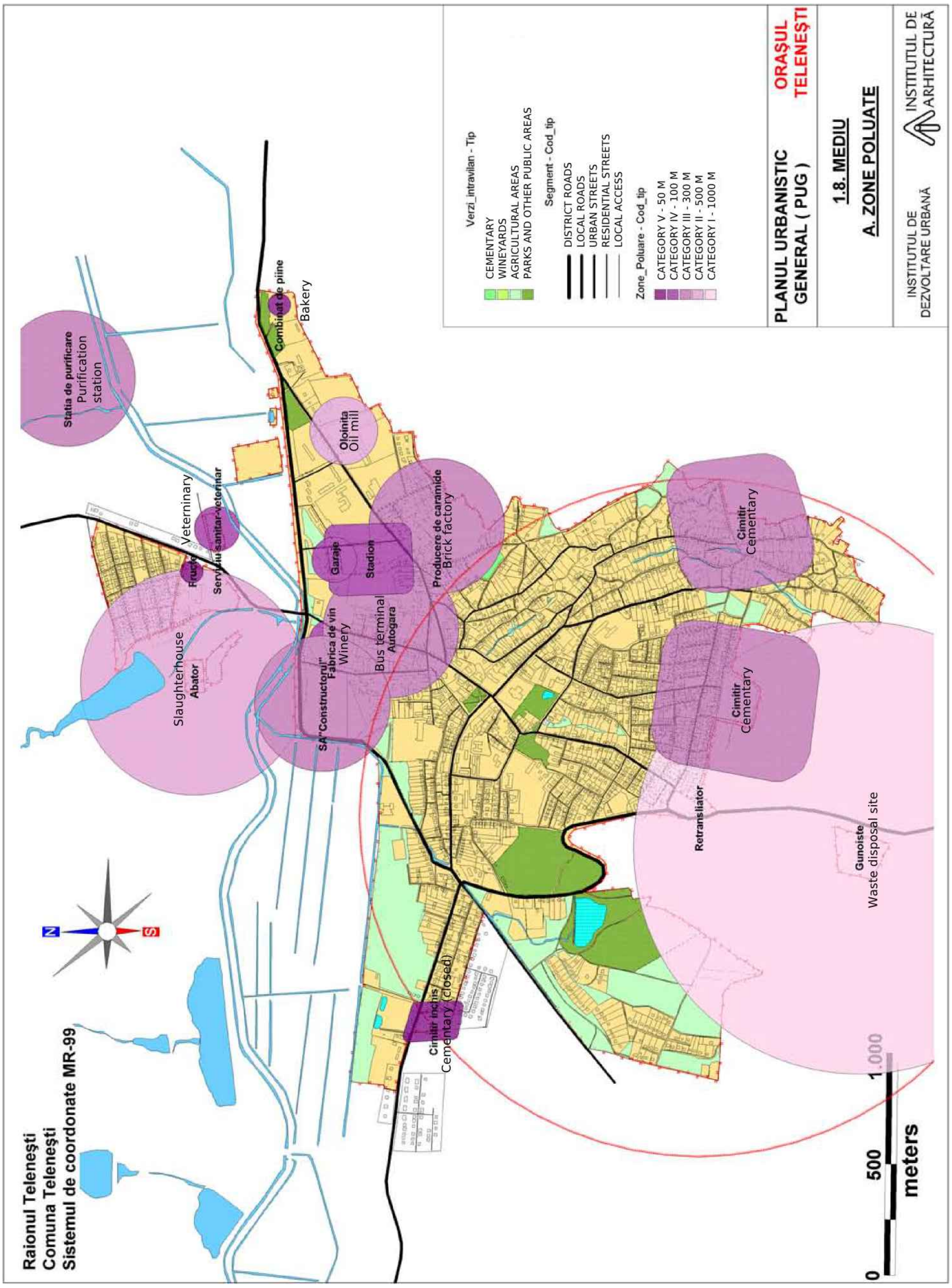

Figure A.6: Map of Teleneşti: Environment: Pollution (Teleneşti City Council, 2006)

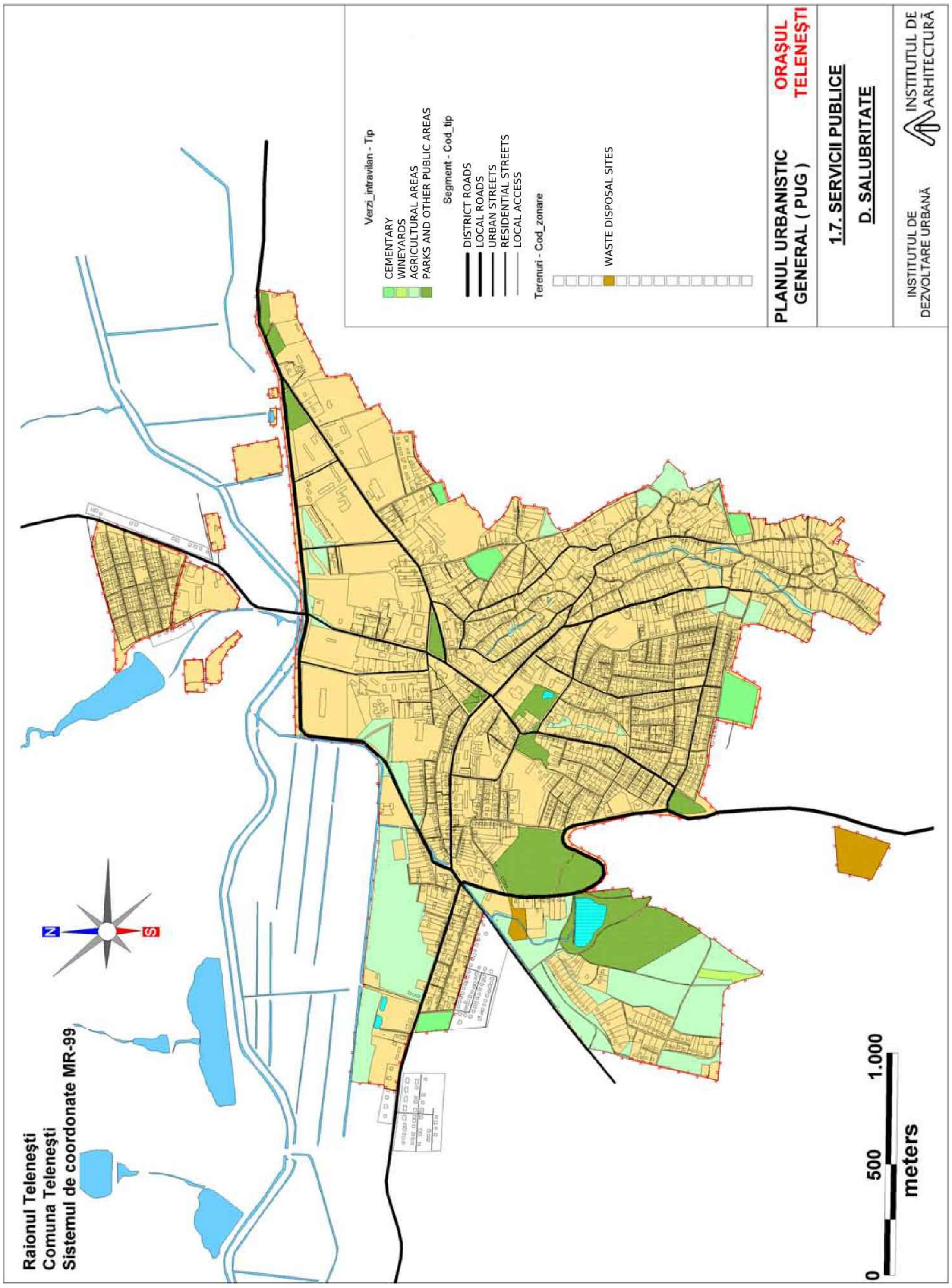

Figure A.7: Map of Teleneşti: Public Use: Waste Management (Teleneşti City Council, 2006)

Table A.2: Water quality results: Artesian wells, 2010 (Apă-Canal, 2011)

Water quality aspects	**Base unit**	**Tolerable value based on national health standards**	**Council Directive 98/83/EC value**	**Source no. 1**		**Source no. 2**		**Source no. 14**		**Source no. 15**	
				Sample date		**Sample date**		**Sample date**		**Sample date**	
				21.07.	12.07.	21.07.		21.07.		29.04.	
Odour	Acceptable	Acceptable	Acceptable	0		0		0		0	
Taste	Acceptable	Acceptable	Acceptable	0		0		0		0	
Transparency	/m	6		6		6		6		6	
Turbidity	mg/dm³	1	Acceptable	1		1		1		1	
Hardness	° dH	5		1.6-4.4		1.8-5.0		1.8-5		1.5-4.2	
Suspended Solids	mg/dm³	1500		1673	827	1499.5		1523.5		1112	
pH	-	6.5-9.5	6.5-9.5		7.56						
Ammonium (NH_4)	mg/dm³	0.5	0.5	7.3		7.5		8.1		4.8	
Nitrite (NO_2)	mg/dm³	0.5	0.5	0		0		0		0.06	
Nitrate (NO_3)	mg/dm³	50	50	0.1	0.67	0.1		0.1		0.1	
Sulphate (SO_4)	mg/dm³	250	250	246.5	262.2	254		258		248	
Chlorides (Cl)	mg/dm³	250	250	42.5	49.6	46		45.5		38	
Copper (Cu)	mg/dm³	1	2	0.03	0.02	0.03		0.03			
Iron (Fe)	mg/dm³	0.3	0.2	0.3	0.15	0.24		0.27			
Manganese (Mn)	mg/dm³	0.05	0.05	0.01	0.01	0.01		0.01			
E. Coli	no./100 ml	0	0								
Enterococci	no./100 ml	0	0								

Table A.3: Water quality results: Reservoirs, 2010 (Apă-Canal, 2011)

Water quality aspects	**Base unit**	**Tolerable value based on national health standards**	**Council Directive 98/83/EC value**	**Water quality results / Sample date**							
				29.01.	25.02.	17.03.	29.04.	31.05.	07.06.	21.07.	30.09.
Odour	Acceptable	Acceptable	Acceptable	0		0	0		0	0	0
Taste	Acceptable	Acceptable	Acceptable	0		0	0		0	0	0
Transparency	$/m$	6		6.1		6	6		6	6	6.1
Turbidity	mg/dm^3	1	Acceptable	1		1	1		1	1	1
Hardness	° dH	5					2.9-8.1				
Suspended Solids	mg/dm^3	1500					864				
pH	-	6.5-9.5	6.5-9.5								
Ammonium (NH_4)	mg/dm^3	0.5	0.5	4.05		5.2	6.9		7.5	7.3	5.6
Nitrite (NO_2)	mg/dm^3	0.5	0.5	0.08		0.08	0.06		0.07	0	0.06
Nitrate (NO_3)	mg/dm^3	50	50	0.1		0.1	0.1		0.1	0.1	< 0.1
Sulphate (SO_4)	mg/dm^3	250	250				258.5				
Chlorides (Cl)	mg/dm^3	250	250				43.5				
Copper (Cu)	mg/dm^3	1	2								
Iron (Fe)	mg/dm^3	0.3	0.2								
Manganese (Mn)	mg/dm^3	0.05	0.05								
E. Coli	no./100 ml	0	0	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Enterococci	no./100 ml	0	0	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

Table A.4: Water quality results: Distribution system - Renaşterii street, 2010 (Apă-Canal, 2011)

Water quality aspects	**Base unit**	**Tolerable value based on national health standards**	**Council Directive 98/83/EC value**	**Water quality results / Sample date**							
				29.01.	25.02.	17.03.	31.05.	07.06.	21.07.	30.09.	28.10.
Odour	Acceptable	Acceptable	Acceptable	0		0	0		0	0	0
Taste	Acceptable	Acceptable	Acceptable	0		0	0		0	0	0
Transparency	/m	6		6.1		6		6.1	12	6.1	6.1
Turbidity	mg/dm³	1	Acceptable	1		1		1	2	1	1
Hardness	° dH	5									
Suspended Solids	mg/dm³	1500									
pH	-	6.5-9.5	6.5-9.5								
Ammonium (NH_4)	mg/dm³	0.5	0.5	2.85		3.6		4.5	4.8	1.4	1.95
Nitrite (NO_2)	mg/dm³	0.5	0.5	0.11		0.14		0.07	0.08	0.07	0
Nitrate (NO_3)	mg/dm³	50	50	0.1		0.1		0.1	0.1	0.1	< 0.1
Sulphate (SO_4)	mg/dm³	250	250								
Chlorides (Cl)	mg/dm³	250	250								
Copper (Cu)	mg/dm³	1	2								
Iron (Fe)	mg/dm³	0.3	0.2								
Manganese (Mn)	mg/dm³	0.05	0.05								
E. Coli	no./100 ml	0	0	< 1	< 1	1.3	< 1	< 1	< 1	< 1	< 1
Enterococci	no./100 ml	0	0	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

Table A.5: Water quality results: Distribution system - Ştefan cel Mare street, 2010 (Apă-Canal, 2011)

Water quality aspects	**Base unit**	**Tolerable value based on national health standards**	**Council Directive 98/83/EC value**	**Water quality results / Sample date**							
				29.01.	25.02.	17.03.	29.04.	31.05.	07.06.	21.07.	30.09.
Odour	Acceptable	Acceptable	Acceptable	0		0			0	0	0
Taste	Acceptable	Acceptable	Acceptable	0		0			0	0	0
Transparency	/m	6		6.1		6			6.1	12	6.1
Turbidity	mg/dm³	1	Acceptable	1		1			1	2	1
Hardness	° dH	5									
Suspended Solids	mg/dm³	1500									
pH	-	6.5-9.5	6.5-9.5								
Ammonium (NH_4)	mg/dm³	0.5	0.5	2.7		0.75			4.05	4.2	1.65
Nitrite (NO_2)	mg/dm³	0.5	0.5	0.13		0.05			0.11	0.1	0.09
Nitrate (NO_3)	mg/dm³	50	50	0.1		0.1		0.1	0.1	0.1	< 0.1
Sulphate (SO_4)	mg/dm³	250	250								
Chlorides (Cl)	mg/dm³	250	250								
Copper (Cu)	mg/dm³	1	2								
Iron (Fe)	mg/dm³	0.3	0.2								
Manganese (Mn)	mg/dm³	0.05	0.05								
E. Coli	no./100 ml	0	0	< 1	< 1	< 1	< 1	< 1	< 1	1	< 1
Enterococci	no./100 ml	0	0	< 1	< 1	< 1	< 1	< 1	< 1	1	< 1

Table A.6: Water quality results: Reservoirs, 2010-2011 (Apă-Canal, 2011)

Water quality aspects	**Base unit**	**Tolerable value based on national health standards**	**Council Directive 98/83/EC value**	**Water quality results / Sample date**					
				28.10.	30.11.	10.12.	31.01.	23.02.	09.03.
Odour	Acceptable	Acceptable	Acceptable	0	0	0	0	0	0
Taste	Acceptable	Acceptable	Acceptable	0	0	0	0	0	0
Transparency	$/m$	6		6.1	6.1	6.1	6.1	6.1	6.1
Turbidity	mg/dm^3	1	Acceptable	1	1	1	1	1	1
Hardness	$^\circ dH$	5							
Suspended Solids	mg/dm^3	1500							
pH	-	6.5-9.5	6.5-9.5						
Ammonium (NH_4)	mg/dm^3	0.5	0.5	2.7	1.65	2.85	5.8	5.25	5.2
Nitrite (NO_2)	mg/dm^3	0.5	0.5	< 0.003	0.09	0.08	0	0.06	< 0.003
Nitrate (NO_3)	mg/dm^3	50	50	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Sulphate (SO_4)	mg/dm^3	250	250						
Chlorides (Cl)	mg/dm^3	250	250						
Copper (Cu)	mg/dm^3	1	2						
Iron (Fe)	mg/dm^3	0.3	0.2						
Manganese (Mn)	mg/dm^3	0.05	0.05						
E. Coli	no./100 ml	0	0	< 1	< 1	< 1	< 1	< 1	< 1
Enterococci	no./100 ml	0	0	< 1	< 1	< 1	< 1	< 1	< 1

Table A.7: Water quality results: Distribution system - Renaşterii street, 2010-2011 (Apă-Canal, 2011)

Water quality aspects	**Base unit**	**Tolerable value based on national health standards**	**Council Directive 98/83/EC value**	**Water quality results / Sample date**				
				30.11.	08.12.	31.01.	23.02.	09.03.
Odour	Acceptable	Acceptable	Acceptable	0		0		0
Taste	Acceptable	Acceptable	Acceptable	0		0		0
Transparency	/m	6		6.1		6.1	6.1	12.1
Turbidity	mg/dm³	1	Acceptable	1	1	1	1	1
Hardness	° dH	5						
Suspended Solids	mg/dm³	1500						
pH	-	6.5-9.5	6.5-9.5					
Ammonium (NH_4)	mg/dm³	0.5	0.5	1.05	3	1.05	3.7	0.75
Nitrite (NO_2)	mg/dm³	0.5	0.5	0.06	0.11	0.09	0.09	0.19
Nitrate (NO_3)	mg/dm³	50	50	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Sulphate (SO_4)	mg/dm³	250	250					
Chlorides (Cl)	mg/dm³	250	250					
Copper (Cu)	mg/dm³	1	2					
Iron (Fe)	mg/dm³	0.3	0.2					
Manganese (Mn)	mg/dm³	0.05	0.05					
E. Coli	no./100 ml	0	0	< 1	1	< 1	< 1	< 1
Enterococci	no./100 ml	0	0	< 1	< 1	< 1	< 1	< 1

Table A.8: Water quality results: Distribution system - Ştefan cel Mare street, 2010-2011 (Apă-Canal, 2011)

Water quality aspects	**Base unit**	**Tolerable value based on national health standards**	**Council Directive 98/83/EC value**	**Water quality results / Sample date**					
				28.10.	30.11.	08.12.	31.01.	23.02.	09.03.
Odour	Acceptable	Acceptable	Acceptable	0	0	0	0	0	0
Taste	Acceptable	Acceptable	Acceptable	0	0	0	0	0	0
Transparency	/m	6		6.1	6.1	6.1	6.1	6.1	12.1
Turbidity	mg/dm^3	1	Acceptable	1	1	1	1	1	1
Hardness	° dH	5							
Suspended Solids	mg/dm^3	1500							
pH	-	6.5-9.5	6.5-9.5						
Ammonium (NH_4)	mg/dm^3	0.5	0.5	1.3	1.65	2.7	2.7	4.5	2.85
Nitrite (NO_2)	mg/dm^3	0.5	0.5	< 0.003	0.09	0.09	0.09	0.07	0.07
Nitrate (NO_3)	mg/dm^3	50	50	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Sulphate (SO_4)	mg/dm^3	250	250						
Chlorides (Cl)	mg/dm^3	250	250						
Copper (Cu)	mg/dm^3	1	2						
Iron (Fe)	mg/dm^3	0.3	0.2						
Manganese (Mn)	mg/dm^3	0.05	0.05						
E. Coli	no./100 ml	0	0	< 1	8	< 1	< 1	< 1	< 1
Enterococci	no./100 ml	0	0	< 1	< 1	< 1	< 1	< 1	< 1